2021 Status Report

Falls Lake Nutrient Strategy

View of Falls Lake from Forest Ridge Park in Raleigh

For July 8, 2021 Meeting
of the N.C. Environmental Management Commission

Developed by the N.C. Division of Water Resources
Nonpoint Source Planning Branch

NORTH CAROLINA
Department of Environmental Quality

The Nonpoint Source Planning staff gratefully acknowledges the input and recommendations offered by the following individuals and organizations during various stages of this report:

Adugna Kebede, N.C. Division of Water Resources
Alix Matos, Brown & Caldwell
Andy McDaniel, NC Department of Transportation
Andy Painter, N.C. Division of Water Resources
Annette Lucas, N.C. Division of Energy, Mineral and Land Resources
Charles Weaver, N.C. Division of Water Resources
Cody Norwood, South Granville Sewer and Water Authority
Craig Caldwell, N.C. Division of Water Resources
Forrest Westall, Upper Neuse River Basin Association
Haywood Phthisic, Neuse River Compliance Association
Jeanette Powell, N.C. Division of Energy, Mineral and Land Resources
Jeff Mahagan, Hillsborough Wastewater Treatment Plant
Jim Hawhee, N.C. Division of Water Resources
Joey Hester, N.C. Department of Agriculture and Consumer Services
John Dodson, North Durham Water Reclamation Facility
Katie Merritt, N.C. Division of Water Resources
Kelly Williams, N.C. Division of Mitigation Services
Kristen Slodysko, N.C. Division of Water Resources
Local governments of the Upper Neuse River Basin Association
Mike Templeton, N.C. Division of Water Resources
Nathaniel Thornburg, N.C. Division of Water Resources
Niki Maher, N.C. Division of Water Resources
Pam Behm, N.C. Division of Water Resources
Reginald Hicks, Durham Department of Water Management
Sandra Wilbur, City of Durham Public Works Department
Scott Schroyer, South Granville Sewer and Water Authority
Steve Wall, UNC Institute of the Environment
Sushama Pradhan, N.C. Department of Health and Human Services
Trish D'Arconte, N.C. Division of Water Resources
Vicki Westbrook, Durham Department of Water Management

Questions or comments regarding this report may be directed to:

N.C. Division of Water Resources
Nonpoint Source Planning Branch
1617 Mail Service Center
Raleigh, NC 27699-1617

Recommended citation:

Division of Water Resources Nonpoint Source Planning Branch (2021). 2021 Status Report: Falls Lake Nutrient Strategy. N.C. Department of Environmental Quality. Raleigh, NC.

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Executive Summary

Purpose of Report: The Falls Lake Nutrient Management Strategy, also referred to as the Falls rules, is a comprehensive set of rules enacted in January 2011 to reduce nitrogen and phosphorus inputs to Falls Lake to address exceedances of North Carolina's chlorophyll *a* standard of 40 µg/L. The chlorophyll *a* standard helps to protect the designated uses of Falls Lake - water supply, fish and wildlife propagation, flood control, and recreational uses – from impacts caused by an overabundance of algae.

Now in their tenth year of implementation, the Falls rules were precedent-setting in both the magnitude of nutrient reductions required – 40 percent nitrogen and 77 percent phosphorus - and the length of time provided to recover the chlorophyll *a* standard – 30 years. In light of these sizable commitments, and to inform potential adaptive management planning, the rules required the Division to report to the Environmental Management Commission (EMC) on specific aspects of progress in the Falls Lake watershed beginning in January 2016 and every five years thereafter. This is the second five-year report under that requirement.

More specifically, per requirements of the Falls Purpose and Scope rule, 15A NCAC 2B .0275, this report provides an update on implementation of the rules, an assessment of nutrient loading to the lake, details on watershed activities relative to the rules, assessments of progress towards achieving the chlorophyll-*a* water quality standard, it characterizes advances in scientific understanding and control and accounting technologies, and it identifies future research and data needs.

The Falls Lake Nutrient Management Strategy rules are available on the DWR website at: [https://deq.nc.gov/about/divisions/water-resources/water-planning/nonpoint-source-planning/falls-lake-nutrient-strategy.](https://deq.nc.gov/about/divisions/water-resources/water-planning/nonpoint-source-planning/falls-lake-nutrient-strategy)

Changes to Implementation Requirements: Certain changes to rules implementation have occurred since adoption, and additional changes are anticipated during readoption. The Falls rules include a staged, adaptive implementation process spanning 30 years. As originally adopted, Stage I implementation was 10 years in length, through 2020, with the objective of meeting the chlorophyll-*a* standard in the lower lake (downstream of Highway 50) by meeting intermediate loading targets. However, through the passage of S.L. 2016-94 and S.L. 2018-5, the General Assembly extended the end of Stage I until such time as the Falls Lake Rules are readopted, and it required readoption to commence by December 2024.

Stage II of the rules as adopted calls for additional reductions in the upper watershed to achieve the nitrogen and phosphorus targets of 40 and 77 percent, respectively, and for meeting the chlorophyll *a* standard throughout the lake by 2041. These unprecedented control targets were derived from water quality models that necessarily involved scientific uncertainty. At the time modeling was conducted, the available water quality data was not as robust as would be ideal. Given this combination of factors – magnitude of reduction needs, long implementation timeframes, and stakeholders' desire for more robust modeling, the Falls Purpose and Scope rule included acknowledgement of the uncertainty associated with modeling, and it allowed for the development of supplemental models that could be used as a basis for future revisions to the restoration strategy. In turn following rules adoption, the Upper Neuse River Basin Association (UNRBA) launched a monitoring and remodeling initiative, described below, that will greatly inform readoption of the rules. Thus, it is expected that the character of the Stage II requirements will be reconsidered through the rules readoption process.

Sources of Data for this Report: This second 5-year report benefits from data collected and analyzed not only by the Division, but also from an extensive, 4-year data collection effort conducted by the UNRBA to support a full remodeling of the watershed and lake, as well as early results of a three-year UNC Collaboratory study of the lake and the Falls nutrient strategy.

DWR used its ambient monitoring data from the five major tributaries in the upper watershed to estimate changes in nutrient loading to the lake. Staff also used DWR lake monitoring data, and data submitted by the NCSU Center for Applied Aquatic Ecology, to evaluate changes in lake chlorophyll *a* levels since the Falls rules were adopted.

Additional data collected through ongoing research efforts of the UNC Collaboratory is being coordinated with the UNRBA's re-examination effort and will help inform the UNRBA's remodeling of Falls Lake. Recommendations from both these efforts will also inform the content of the Division's next 5-year report and the EMC's readoption of the Falls Lake Nutrient Management Strategy.

Each of these efforts is summarized in the following sections.

DWR Water Quality Analyses – Loading: The Division evaluated nitrogen and phosphorus loading to the lake using two different methods. The USGS LOADEST method was used to estimate the total or "raw" tributary nutrient loads delivered to the lake. This method characterizes the total amount of nutrients being delivered by tributary inputs by year, which varies year-to-year, sometimes greatly, due to changes in annual rainfall and resulting stream flows. The second analysis is designed to neutralize the influence of flow variability by calculating flow-normalized tributary loads and concentrations using the USGS Weighted Regressions on Time, Discharge, and Season (WRTDS) method. Removing the effects of annual flow variations, is useful for observing changes or trends in nutrient loads that may be attributable to nutrient management actions. Loading estimates for both methods used 2006-2019 water quality and flow data collected from the upper five subwatersheds, which represent all of the inflow to the upper end of the lake and three-quarters of the flow to the entire lake.

As expected, the LOADEST analysis documented large variations in stream flow and resulting load inputs to the lake between years. While rainfall patterns for the period were such that flow happened to increase by 100 percent between the 2006 baseline year and 2019, nitrogen loading increased only 37 percent while phosphorus loading actually decreased by an estimated 17 percent. These raw load results are promising and suggest a positive influence from watershed management actions.

To improve the loading analysis by removing this year-to-year flow variability, the Division performed a second analysis using the WRTDS method. The resulting flow-normalized estimates indicated a 20 percent reduction in nitrogen and 52 percent reduction in phosphorus in the combined 5-tributary load between baseline and 2019.

While loading analyses are inherently less definitive than water quality standard assessments, for the upper five flow-gauged tributaries evaluated by DWR, the analyses that best gauge the degree to which Stage I loading targets have likely been met with weather-driven variability factored out – the flow-normalized loading comparisons – show mixed results. Not surprisingly, the more wastewater-dominated the stream, the more successfully these loading goals appear to be met. Specifically, Ellerbe and Knap-of-Reeds Creeks both meet or exceed the nitrogen target and strikingly over-achieve the phosphorus target. Meanwhile, Eno River, the other upper tributary with a major domestic wastewater facility, has a much larger watershed and nonpoint source component. Predictably it has achieved less– approximately half of the Stage I 20 percent nitrogen target, but has just about reached the 40 percent phosphorus target. The two remaining gauged upper tributaries are the nonpoint source-dominated Little and Flat Rivers. They have shown increases of ten to twenty percent nitrogen, and either no change in phosphorus (Flat) or roughly a surprising forty percent decrease in phosphorus (Little). Overall, it appears that nonpoint source progress has not been so clear to date.

While it may be too soon to tell just how big a role the Falls rules played in these reductions, the management actions by wastewater treatment plants likely played a key role, while agriculture and new development likely also contributed.

DWR Water Quality Analysis – Chlorophyll a. In 2010, the Division initiated a Study Plan for the Ongoing Assessment of Falls of the Neuse Reservoir. This plan involved monthly lake monitoring at twelve locations to track changes in chlorophyll *a* concentrations with implementation of the Falls rules. Staff conducted three different analyses of the chlorophyll data as described here.

First, the status of attainment of the chlorophyll *a* water quality standard in the lake, as reported biennially in 303(d) lists to EPA under the Clean Water Act Integrated Report process, is compiled from the Division's 2008 through 2018 Integrated Reports. Attainment of the chlorophyll *a* standard is the ultimate metric for gauging strategy progress. At the same time, a number of procedural factors outlined in the body of this report have resulted in status shifts on certain segments from one Integrated Report to another, underscoring the importance of taking a longer view of this metric. A longer-view summary is that most of the lower lake is meeting the chlorophyll *a* standard in data timeframes that roughly correspond to implementation of Stage I of the Falls rules. Since then, including over the last two biennial Integrated Reports, there has been little meaningful change in the lake's status of standards attainment, with the upper lake remaining mostly in exceedance of the standard.

The second analysis compares over time the percent of chlorophyll samples exceeding the standard, station by station. Results echo the greater status of standards attainment pattern, and this method also adds some nuance. For each time period evaluated, exceedance rates of the chlorophyll *a* standard are higher in the upper end of the lake and gradually decrease moving downstream to the dam. There is little change in the rates of exceedances in 2015-2019 compared to 2011-2014. Between the two time periods, chlorophyll *a* exceedance rates decreased in the Ledge Creek and Little Lick Creek arms in the upper lake and at one mid-lake at station. In contrast, there was a slight increase in the chlorophyll *a* exceedance rate just downstream of highway NC-50. The added nuance is the ability to see reduced rates of exceedance in the upper lake post-rules that are not apparent using the simpler metric of meeting criteria vs. not meeting criteria.

The current period of 2015-2019 shows improved (lower) rates of standard exceedance lake-wide relative to the baseline period, but shows little change from the data period of 2011-2014. The added nuance is the ability to see gradations in the frequency of standard exceedance. While this comparison reveals reduced rates of exceedance in the upper lake post-rules, this result is considered more a reflection of different sampling regimes between baseline and current, where baseline sampling was more intensive during productive summer months than current monitoring efforts.

The Division added a third chlorophyll analysis for this report, temporal comparison of *magnitudes* of standard exceedance station by station. Only the last two, post-rules data periods used in the exceedance frequency analysis were evaluated here. Similar to the frequency analysis, changes were minor across these two periods. This analysis was experimental and may provide further insights in a future 5-year report.

UNRBA Monitoring/Modeling Project and UNC Collaboratory Study: The UNRBA launched major efforts over the past ten years to address the scientific uncertainty of the Falls nutrient strategy and its underpinning water quality models. They collected additional water quality data at least monthly between August 2014 and October 2018 from 38 tributary stations in the Falls watershed as part of a $3.5 million member-funded Monitoring Project. This project was designed to support their remodeling of the lake and watershed, development of alternative regulatory targets as appropriate, and to inform re-examination of Stage II of the Falls Lake Rules.

As part of this project, the Association contracted targeted special studies to address specific modeling questions and data gaps such as the contributions of nutrient loading from lake sediments and loading to the lake during storm events. They used results to gain more detailed understanding of the lake's physical, chemical, biological, and geological characteristics. Their results are presented in a 2019 Final Monitoring Report. Their supplemental modeling project is currently underway and scheduled to be completed in 2023.

Meanwhile in 2016, the General Assembly created the Policy Collaboratory at the University of North Carolina at Chapel Hill, and Session Law 2016-94 directed the organization to oversee the funding of studies of the Jordan and Falls nutrient management strategies, and to provide recommendations to the EMC to guide further rulemaking. Subsequent session law revised the due dates for the final Collaboratory Falls study to December 2023 and extended the deadline for formally beginning the Falls rules readoption process to December 31, 2024.

Through the Collaboratory, researchers began conducting Falls Lake and watershed studies in 2019. The intent is a comprehensive approach to understanding the current nutrient issues and potential solutions for the lake. This collection of ongoing research projects synthesizes interdisciplinary analysis of Falls Lake's nutrient content and fluctuation, the factors that affect it, mitigation strategies and their effectiveness, and financial implications of proposed processes. The following topics are currently being studied by the Collaboratory:

- Quantifying Sediment Nutrient Processing
- Study of High and Low Flow Conditions
- Cyanotoxin Presence and Year-Round Dynamics
- Balance Between Cyanobacterial N Fixation & Denitrification
- Estimating Onsite Wastewater Treatment Systems on Nutrient Loading
- Importance of Lake Ecosystems to Global Organic Carbon Cycling
- Green Street & Wet Pond Retrofit Guidance
- Paying for Nutrient Management

From the beginning, the UNRBA has coordinated closely with the Collaboratory on study needs and continues to coordinate as they work to incorporate researchers' study results into their modeling and reexamination efforts. The Collaboratory is also providing third-party review of the UNRBA's water quality models. While the Collaboratory projects are in progress, results of the UNRBA's monitoring data analyses are summarized here. Final results for both will be included in the next five-year report.

UNRBA Water Quality Analyses: The UNRBA's loading analyses expand on DWR's efforts by including atmospheric and lake sediment sources of loading in addition to tributaries, and they reach back before the baseline time period to analyze historical data collected by others as far back as the initial impoundment of Falls Lake. The UNRBA's loading analyses overlap DWR's to some extent, however differences in monitoring time periods, stations and methods are such that their results provide somewhat different and also useful insights on lake condition.

The first UNRBA analysis provides a more holistic 'total loading' analysis of nutrient inputs to the lake since baseline by quantifying inputs from all 18 lake tributaries, atmospheric deposition and internal loading from lake sediments. For this study, the DWR Falls Lake Environmental Fluid Dynamics Code (EFDC) model was used to provide loading estimates for the smaller tributaries in 2006 and compared against their recent, 2015-2018 monitoring-based LOADEST estimates of these tributary loads. Results show that from 2006 to 2017, total nitrogen and total phosphorus loads to the Lake have decreased by 13 percent and 15 percent, respectively. While these results understandably differ somewhat from DWR's for the upper five tributaries, more instructive is the fact that the lower nutrient load of 2017 contrasted against higher chlorophyll *a* levels that year, illustrating how current-year total annual loading, even fully accounted-for, is not the only driver of algal growth in the lake. Other potential factors could include timing and magnitudes of flows and loads, as well as precipitation and other weather patterns, during the course of the year. In any case, these uncertainties underscore the need to take a longer view of the lake's response to hopefully discern management-driven patterns over the noise of sources of inherent variability.

The UNRBA also developed a retrospective analysis using a generalized additive model (GAM) to estimate tributary nutrient loading for three major tributaries to Falls Lake - Eno River, Ellerbe Creek, and Knap of Reeds Creek. These three tributaries each receive discharge from a major wastewater treatment plant and have been monitored monthly near their outlet to the lake since the 1980s when the reservoir was created. The GAM method can handle a larger dataset than LOADEST, enabling use of the entire historical dataset, starting back in the 1980's, to compare early post-impoundment loading to more recent estimates.

Results of this analysis through 2018 show that total nitrogen loads from these three tributaries decreased by approximately 60 percent and total phosphorus loads decreased by approximately 90 percent. At the same time, total discharge from these three tributaries was approximately 50 percent higher in 2018 compared to 1983 due to higher rainfall totals in 2018 as a result of several winter storms and Tropical Storms Florence and Michael. The increase in flow but large decrease in overall nutrient load strongly suggests that the reductions were driven by significant wastewater treatment plant improvements along with implementation of the 1988 phosphate detergent ban in the early 1990s.

Status of Falls Nutrient Management Strategy Implementation: The Falls rules are now in their tenth year of implementation. Aside from a delay to Existing Development rule implementation discussed below, all rules are being implemented as originally required and each source is meeting or exceeding its Stage I reduction goals. Implementation of Stage I, including Existing Development, will continue until the rules reexamination is completed and the rules are readopted in approximately the 2026-2027 timeframe. A summary of implementation status is provided below:

Wastewater: Point sources in the Falls watershed were required to achieve a 20 percent nitrogen reduction and 40 percent phosphorus reduction by 2016. As noted in the previous 5-year report, all three major wastewater dischargers met their Stage I reduction goals in 2014. For this report, as of 2019, the three facilities have achieved strong additional reductions totaling 57 percent nitrogen and 73 percent phosphorus collectively. These impressive reductions are in fact even below Stage II nitrogen allocations and just shy of the Stage II phosphorus allocations. Maintaining these high levels of performance into the future will likely become operationally and economically challenging with continued growth, but these large loading reductions are no doubt providing distinct ongoing benefits to the lake's condition into the foreseeable future.

New Development Stormwater: Beginning in mid-2012, local governments implemented new development stormwater ordinances that require developers to meet nutrient export targets on a project basis that embody the strategy reduction goals relative to average pre-development loading. Depending on project type and size, development projects are required to meet at least 30 percent to 50 percent of their nutrient load reduction requirements onsite, while the rest can be met with offsets. Through December 2020, 114,930 pounds of nitrogen and 16,408 pounds of phosphorus offset credits were purchased as part of meeting new development requirements.

Agriculture: The agriculture community is required to submit progress reports to the Division annually. The 2019 crop-year report estimates reductions in agricultural nitrogen loss of 77 percent and 36 percent from croplands and pastureland, respectively, relative to baseline estimates. A large portion of these reductions are the result of agricultural land going out of production and being developed, but there have also been significant reductions in fertilization rates on hay land along with modest investments in agricultural best management practices to reduce nutrient loads as well.

Existing Development: Under the original rule, local governments were required to reduce nutrient loading from lands developed between 2006 and 2012 back to baseline levels by 2021. However, the process of expanding the “toolbox” of creditable nutrient reduction practices required additional time. With approval from the Commission, implementation of the rule was delayed while the Division, DEMLR Stormwater staff and the UNRBA worked closely together over the course of eight years to identify, prioritize, and develop credit accounting and design specifications for a good number of additional SCMs and other practices to add to the toolbox. In January 2021, the Commission approved a revised model program, and affected parties have until July 2021 to submit and begin implementing their local programs or a joint compliance program.

While approval of additional nutrient practices continues, to address concerns over the Existing Development rule limiting compliance credit to use of only approved nutrient practices, UNRBA, with collaborative input from other stakeholders and DWR, developed a compliance option for Stage I known as the Interim Alternative Implementation Approach (IAIA). The innovative IAIA is an investment-based approach that instead relies on minimum annual funding commitment levels by participating jurisdictions toward a broader suite of beneficial, eligible practices. It requires implementation within the watershed of either approved nutrient practices or those that provide broader water quality benefits and likely nutrient value. Rule compliance is assured based on joint accounting with high-performing Association dischargers.

All twelve of the UNRBA member local governments have confirmed their intent to participate in the IAIA. It is anticipated that this concept will be considered for existing development during the rules readoption process.

Strategy-Wide Activities: In 2020, the Division worked with stakeholders to develop a “Catalog of Nutrient Reduction Practices” to provide a single, comprehensive listing of all currently approved nutrient reducing practices available for use across the range of nutrient strategy rules. The Catalog includes stormwater SCMs as well as agricultural, wastewater, and ecosystem practices and identifies the rules under which each practice is applicable. It also includes references to the practice design standards and credit accounting methods and outlines a streamlined process for proposing and approving additional candidate practices in the future. The Catalog was approved by the Division Director in April 2021.

Summary and Looking Ahead: As discussed above, chlorophyll *a* analyses conducted by DWR show that the Stage I water quality goal established in the Purpose and Scope rule of attaining nutrient-related standards in the lower lake has largely been met. As of the 2018 303d list, the lower lake is meeting the chlorophyll *a* standard with the exception of two arms rated “inconclusive”, which means they do not meet the requirements for exceeding criteria, but also do not meet requirements for meeting criteria either, and the frequency of exceedance analysis shows reduced frequencies of chlorophyll *a* exceedance in the Ledge and Little Lick Creek arms in the upper lake post-rules. That said, it should also be noted that most of the lake’s response progress occurred in the first five-year post-rules period and there has been little change in chlorophyll *a* status between that period and the current reporting period. Meanwhile, status of the secondary Stage I goal of improvement in the upper lake is less clear due to differences in monitoring regimes between the two periods.

The Stage I loading targets that support the Stage I water quality goals are 20 and 40 percent reductions in nitrogen and phosphorus, respectively, from baseline. The degree to which Stage I loading targets have likely been met with weather-driven variability factored out – the flow-normalized loading comparisons – show mixed results. Point source-dominated streams over-achieved phosphorus load reduction goals and appear reasonably close to the nitrogen goals. Meanwhile, it appears that nonpoint source-dominated streams have shown mixed results.

It should also be noted that the post-rules period has experienced almost uniformly wetter years than the baseline and pre-rules period, and as a result, the total or “raw” loading has not shown the improvements described based on flow-normalized loading. It will require longer-term observation to see whether a changing climate tends toward wetter overall, which would present distinct challenges to nutrient management, or only yields greater rainfall variability, which itself would likely still present significantly increased loading challenges.

The UNRBA’s monitoring efforts and special studies conducted over the past five years have helped demonstrate that there are many factors influencing primary production in Falls Lake beyond tributary total annual nutrient loading amounts. Internal nutrient loading, large storm events and other weather variability, changes in retention time, variations in lake depth, and morphology all play varying, but important roles in the pattern of chlorophyll *a* concentrations in Falls Lake.

Over the next three years, the UNC Collaboratory Falls Lake Study and the UNRBA Modeling and Regulatory Support Project will be central to establishing the foundation for future recommendations that will inform the EMC’s rules readoption process set to begin in 2024. The Collaboratory is scheduled to complete and report their findings and recommendations from the Falls Lake Study by 2023. In the meantime, the UNRBA modeling team continues to coordinate closely with the Collaboratory as they work to incorporate the results of these ongoing studies into their modeling efforts, which are scheduled for completion in the next 24 months.

The methodology for assessing water quality and efficacy of the chlorophyll-*a* standard and its connection to designated uses and ecological integrity of the lake remains an important question for the UNRBA. The UNRBA’s remodeling effort is anticipated to result in recommendations on these topics in addition to recommendations for changes to the Stage II rules that may result in requirements that differ in character from the current rules.

As implementation continues, it remains important that the ongoing collaboration between the Division and the UNRBA extends to re-examining the long-term strategy for Falls and builds upon an improved understanding of the lake’s processes and how it reacts to different management approaches.

Introduction

Scope of Report

Pursuant to Sub-Item (5)(b) of the Falls Lake Nutrient Management Strategy's Purpose and Scope rule (15A NCAC 02B .0275), the Division is charged with providing the Commission an update every five years on water quality progress in the lake and advances being made in supporting science, control technologies, management practices and accounting systems.

(5)(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"

The first report was provided to the Commission in 2016. This is the second five-year report. The next progress report in 2025 will include additional information and analysis to help inform any future modifications to Stage II of the management strategy.

(5)(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 rules revisions based on the information reported pursuant to Sub-Items (b) and (c) of this Rule;"

There continues to be an extensive amount of monitoring and research conducted in the Falls watershed since the rules were originally adopted. The additional analysis called for in the 2025 report will be greatly informed by the results of this work. The results of the watershed and lake remodeling work currently underway by the Upper Neuse River Basin Association will be particularly informative to this process. Recommendations from the UNC Collaboratory Falls Lake Study will also be available by the end of 2024 and included in the next progress report.

Item (6)(e) of the Rule calls for the Division to work in collaboration with and include information provided by local governments and other interested parties in developing these reports.

(6)(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;"

Staff identified in the acknowledgements section of this report their appreciation for the stakeholder input provided. Comments were solicited from stakeholders during various stages of the development of this report and the draft report was provided for a two-week informal public comment period in March 2021.

The remainder of this report is presented in five sections. After a general overview, the status of implementation is provided rule by rule. This is followed by an updated assessment of water quality metrics regarding the lake's response to implementation. The report continues, with updates regarding advances on a broad array of watershed restoration sciences, ranging from atmospheric deposition of nitrogen to groundwater nutrient studies, control technologies, management practices, and compliance accounting systems. Finally, the Division offers some brief parting thoughts regarding the continuing implementation of the Falls Lake strategy moving forward.

About Falls Lake

Characterization of Lake and Watershed

Falls of the Neuse Reservoir, also known as Falls Lake, is an impoundment that covers 12,400 acres in Wake and Durham Counties. The lake is located in the upper Neuse River Basin, which drains a mixture of forested, agricultural, and urbanized lands (Table 1). Approximately 60 percent of the watershed is forested. The Lake serves as the primary drinking water source for Raleigh and surrounding communities including Garner, Rolesville, Wake Forest, Knightdale, Wendell, and Zebulon. The City of Raleigh's E.M. Johnson Water Treatment Plant receives water directly from lower Falls Lake, presently drawing approximately 41 million gallons per day.

Falls Lake is also a premier recreation destination for residents of North Carolina and visitors from afar. Falls Lake State Recreation Area, one of 42 units in North Carolina's State Parks system, encompasses more than 5,000 acres and hosts approximately one million visitors annually. Water-dependent uses include five swim beaches as well as expansive boating and fishing opportunities. Other parks bordering Falls Lake include the 236 acre Blue Jay Point (Wake) County Park and Penny's Bend Nature Preserve, home to more than 460 plant species.

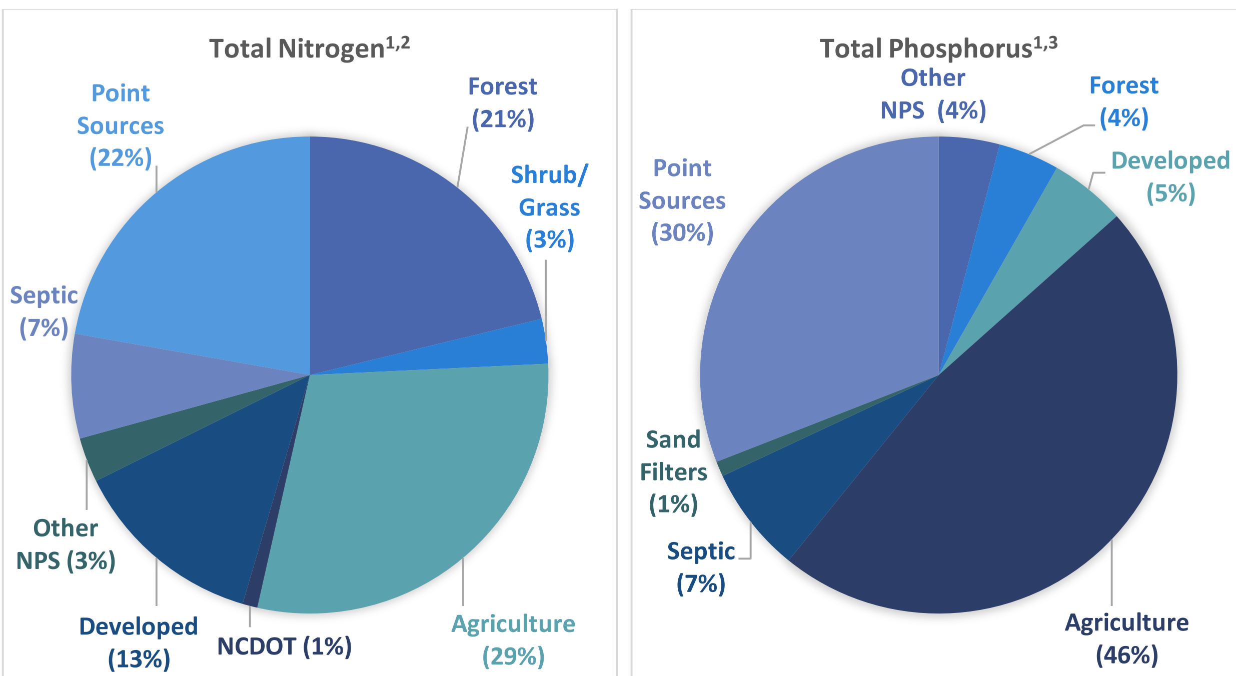
The watershed draining to Falls Lake covers 770 square miles across six counties, including portions of Raleigh and Durham. Over 90,000 people reside there. According to the 2019 U.S. Census Bureau population estimates, the annual population growth rate in the Raleigh metropolitan area is 2.0 percent with an overall percentage growth of 23 percent from 2010 to 2019, which rates among the top ten metropolitan areas in percentage growth in the country. Falls Lake serves as the water supply reservoir for over 600,000 people in Wake County and its watershed includes 8 smaller reservoirs.

TABLE 1. SUMMARY OF LAND COVER IN FALLS LAKE WATERSHED (2001 AND 2016 NATIONAL LAND COVER DATASET)

Aggregated Land Cover Type	2001 (acres)	Percent of watershed	2016 (acres)	Percent of watershed	Change (acres)	Percent change
Forest	297,965	60%	293,337	59%	-4,628	-2%
Agriculture	82,045	17%	78,086	16%	-3,959	-5%
Developed	66,984	14%	75,633	15%	8,648	13%
Grassland/Shrub	18,470	4%	18,017	4%	-453	-2%
Open Water	15,475	3%	16,771	3%	1,296	-8%
Wetland	12,223	2%	11,380	2%	-842	-7%
Barren Land	588	< 1%	526	< 1%	-63	-11%

In 2009, the Division developed a Falls Lake watershed model and nutrient response model to aid in the development of the nutrient management strategy for the lake (Division of Water Quality Modeling/TMDL Unit, 2009a). The Watershed Analysis Risk Management Framework (WARMF) model was selected by the Division for this purpose because of its capability to assess the impact of point and nonpoint sources in a large watershed with varying land cover and management conditions. The Falls WARMF model estimated the proportion of total nitrogen and total phosphorus loads to Falls Lake from a variety of different sources and land use types in the upper Falls watersheds, relative to the baseline year of 2006. Based on this analysis, agriculture and point sources were the two most significant sources of both nitrogen and phosphorus to the lake (Figure 1).

FIGURE 1. ESTIMATED PROPORTIONS OF NITROGEN AND PHOSPHORUS LOADING SOURCES FROM UPPER FALLS WATERSHED TO FALLS LAKE (2006).



[1] Due to rounding, totals do not equal 100%
[2] Other sources that contribute less than 1% of nitrogen loading include wetlands, sand filters, sanitary sewer overflows, and air deposition.
[3] Other sources that contribute less than 1% of phosphorus loading include shrub/grass, NCDOT, wetlands, and sanitary sewer overflows.

Water Quality History

The Army Corps of Engineers recommended Falls Lake for construction in 1963, and it was approved for construction by Congress in 1965. Primary benefits of the lake included control of persistent riverine flooding downstream and enhancement of a drinking water source. Other projected advantages included the protection of downstream water quality, fish and wildlife conservation, and recreation. Pre-construction assessments of the project conducted by the US Army Corps of Engineers (USACE 1974) and the State of North Carolina Department of Natural and Economic Resources Office of Water and Air

Resources (1973) predicted that algal blooms would occur in the upper part of Falls Lake, and that this part of the lake would likely not meet water quality standards. The assessments concluded that the benefits of the lake would outweigh the risks associated with algal blooms.

Falls Dam construction was completed in 1981. In 1983 the Environmental Management Commission gave Falls Lake the Nutrient Sensitive Waters designation. Point source restrictions on nutrient dischargers in the watershed began in the 1990s, and in 1996, the Upper Neuse River Basin Association (UNRBA) was formed.

In the early 2000's, approximately 20 years after the Falls Lake impoundment reached full pool level, the UNRBA published The Upper Neuse Watershed Management Plan covering the entire Falls Lake watershed. The Division also began enhanced monitoring to assess whether the lake was meeting water quality standards. In 2005, the General Assembly required the Commission to adopt a nutrient strategy for Falls Lake. Subsequent legislation resulted in the development and implementation of the Falls Lake strategy by January 2011.

Based on water quality data collected between 2002 and 2006, Falls Lake was listed for chlorophyll *a* on North Carolina's 2008 biennial listing of waters not meeting criteria, which are waters that have not attained all water quality standards, as required under Section 303(d) of the federal Clean Water Act. The green pigment chlorophyll *a* is an indicator of algal productivity. In North Carolina, non-trout waters have a chlorophyll *a* standard not to exceed 40 µg/L. The 303(d) list is a list of waters that are not meeting water quality standards and require a Total Maximum Daily Load or an alternate strategy to bring waters into compliance with water quality standards. The portion of the lake above interstate I-85 was also listed for turbidity.

Falls Lake Nutrient Strategy

Implementation History

The Falls Lake Nutrient Management Strategy has been in place and implemented for just over ten years. In 2014, the North Carolina General Assembly passed HB 74 which requires the periodic readoption of all the Department's rules every ten years. This was followed by S.L. 2016-94 in 2016 calling for an evaluation of the Falls and Jordan nutrient strategies and separating these rules from the rest of the periodic rules readoption process, setting later rulemaking timelines for these two watersheds. This legislation directed the University of North Carolina at Chapel Hill to oversee studies of the Jordan and Falls strategies and to provide recommendations to the Commission to guide further rulemaking. S.L. 2018-5 later revised the due dates for the final UNC Falls study to December 2023 and extended the deadline for formally beginning the Falls rules readoption process to December 31, 2024. The UNC Collaboratory's Falls Lake Study is currently underway with interim reports due to the Commission in 2021 and 2022.

In addition to the work by the UNC Collaboratory, the UNRBA has been conducting a "re-examination" process of the Falls Lake nutrient management strategy that included collecting additional water quality monitoring data from the Falls Lake watershed between August 2014 and October 2018. The UNRBA also conducted several special studies in the lake and watershed to fill data gaps. This additional data along with DWR's lake monitoring data is being used by the UNRBA to conduct enhanced water quality modeling of the lake to provide a more sophisticated analyses in support of the re-examination of Stage II of the Falls Lake Rules. More recently, stemming from its additional monitoring and analysis, the UNRBA has made clear that it intends to recommend some form of site-specific water quality standard related to the trophic conditions and uses of Falls Lake at the conclusion of its study guided by the draft proposal from DWR for site specific chlorophyll-a standard for High Rock Lake. The UNRBA's ongoing re-evaluation effort is scheduled to be completed in 2023. The results of this re-examination effort will be made available for consideration by the UNC Collaboratory to help guide their recommendations put forth in a final UNC Falls Lake Study Report and will inform the Division's readoption of the Falls Lake nutrient management strategy.

Strategy Content Overview

The Falls Lake strategy is a comprehensive set of rules designed to address excess nutrient inputs to Falls Lake. The rules require major sources of nutrients to reduce their nitrogen and phosphorus loads from a 2006 baseline load by 40 and 77 percent, respectively. Intermediate goals have also been established. DWR modeling has projected that these reductions will achieve the chlorophyll *a* water quality standard.

The Falls Lake strategy is significantly more challenging than other regional nutrient strategies in at least two respects. First, modeling suggests an unprecedented degree of nutrient reduction to meet the chlorophyll *a* standard. Additionally, some nutrient reduction measures have already been implemented within Falls watershed because of the larger, overlapping, Neuse River Basin strategy that was in place for 15 years before the adoption of the Falls Lake strategy.

Considering these and other issues, the Falls Lake strategy was designed as a phased, adaptive approach. Stage I is designed to meet the chlorophyll *a* standard in the lower lake. To do so, it requires obtaining approximately half of the full reduction targets, 20 and 40 percent nitrogen and phosphorus, respectively, by both point and nonpoint sources. Existing Development Stormwater is given a Stage I target of reducing nutrient loads back to Baseline (2006) levels. Stage II calls for reductions of 40 percent nitrogen and 77 percent phosphorus, from the upper watershed area, with the overall goal of achieving all reductions and meeting chlorophyll *a* standards throughout the lake by 2041 to allow the lake time for the nutrient load reductions achieved during Stage II.

Nutrient sources addressed by the rules include agriculture, fertilizer application, wastewater discharges, and stormwater runoff from both new development and existing developed lands. A trading rule was also enacted, promoting the use of cost-effective management options to meet strategy goals. Table 2 lists the eight rules that make up the Falls Nutrient Strategy.

The adaptive aspect of the Falls Lake strategy allows for continuous evaluation during implementation to inform needed adjustments, which would require additional rulemaking. The rules allow for supplemental data and modeling to be submitted by affected parties to inform reconsideration of the regulatory requirements. It also ensures that Stage II is not undertaken without an evaluation of technological and implementation progress and a better understanding of the Falls Lake limnology including any uncontrollable constraints that may influence the attainment of the chlorophyll *a* standard. Additional topics for investigation include the lake's response to Stage I implementation, the feasibility and cost of Stage II strategies, and the regulatory alternatives for protecting the lake.

The Division is charged to report to the Commission every five years regarding strategy implementation, load reductions, and lake response. Furthermore, the Division is tasked with evaluating the state of scientific, technical and accounting advancement across a range of challenging nutrient management issues. This document is the second such report. A reevaluation report is also mandated in 2025 to assess the results of stage I implementation and their implications for Stage II.

TABLE 2. FALLS LAKE NUTRIENT STRATEGY RULES

15A NCAC 02B Rule	Rule Title
.0275	Purpose & Scope
.0276	Definitions
.0277	Stormwater Management for New Development
.0278	Stormwater Management for Existing Development
.0279	Wastewater Discharge Requirements
.0280	Agriculture
.0281	Stormwater Requirements for State & Federal Entities
.0282	Options for Offsetting Nutrient Loads

Implementation of the Falls Lake Strategy

Stage I of the Falls Nutrient Management Strategy rules is now in its tenth year of implementation. Nearly all of the rules are being fully implemented at this time and each of the regulated sources under those rules are either meeting or exceeding their Stage I reduction goals; implementation of a joint compliance approach for Stage I existing development rules is set to begin in July 2021. The following is a summary of implementation progress to date of each rule of the management strategy.

Wastewater Rule

The Falls wastewater rule aims to reduce point source nutrient loads by establishing (1) annual mass limits on nitrogen and phosphorus for the three existing publicly owned wastewater treatment dischargers in the upper watershed and (2) concentration limits for the two smaller private domestic plants in the lower watershed. In the upper watershed, Stage I establishes mass limits based on a 20 percent reduction from baseline in total nitrogen (TN) and 40 percent reduction in total phosphorus (TP), both achieved by 2016. Stage II establishes mass limits based on a 40 percent reduction from baseline in TN and 77 percent reduction in TP, both to be achieved by 2036. Limits for the two private plants in the lower watershed will also contribute to the point source reduction efforts. As in the Neuse River Basin nutrient strategy, the wastewater rule includes provisions for new and expanding discharges, for a group compliance option, and for in-lieu fee payments to offset exceedance of the annual loading caps. The rule also provides for the transfer of allocation among individual dischargers.

In reviewing the wastewater dischargers reduction progress, it is important to keep in mind that due to recent legislation the implementation of the Stage II requirements is delayed until after the strategy reexamination and rules readoption process is completed. This means that it is currently unclear how stringent the Stage II requirements will be relative to the current rule until that process is completed and the readopted rules in place.

The three major dischargers in the upper watershed are the municipal wastewater treatment plants for South Granville Water & Sewer Authority (SGWASA), North Durham, and Hillsborough. All three dischargers have optimized their performance and implemented nutrient controls to meet their Stage I allocations by 2016. In fact, by 2014 the three facilities collectively reduced their collective nitrogen and phosphorus loads by 20 and 57 percent respectively from the 2006 baseline. As of 2019 the three facilities have made even further reductions and reduced their collective nitrogen and phosphorus loads by 57 percent (Figure 2) and 73 percent (Figure 3) respectively from the 2006 baseline. While these current reductions are below even their Stage II allocations, it will become increasing challenging to maintain those levels of reduction as the facilities approach their full permitted flow where this level of reduction will no longer be economically achievable with current biological nutrient treatment technology.

FIGURE 2. WASTEWATER TN DISCHARGE LOADS, FALLS LAKE WATERSHED

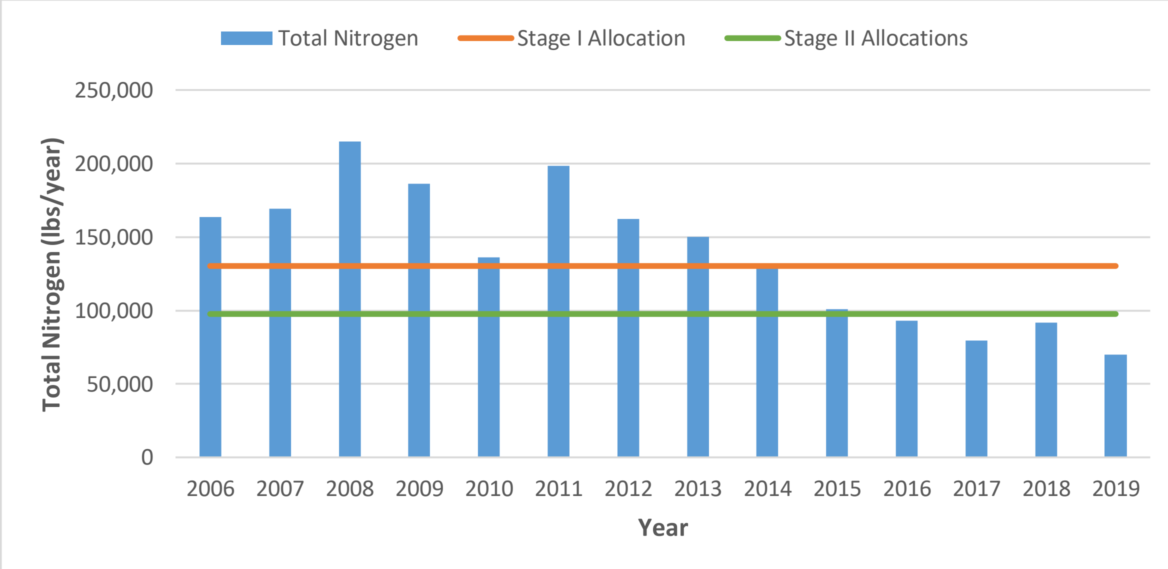
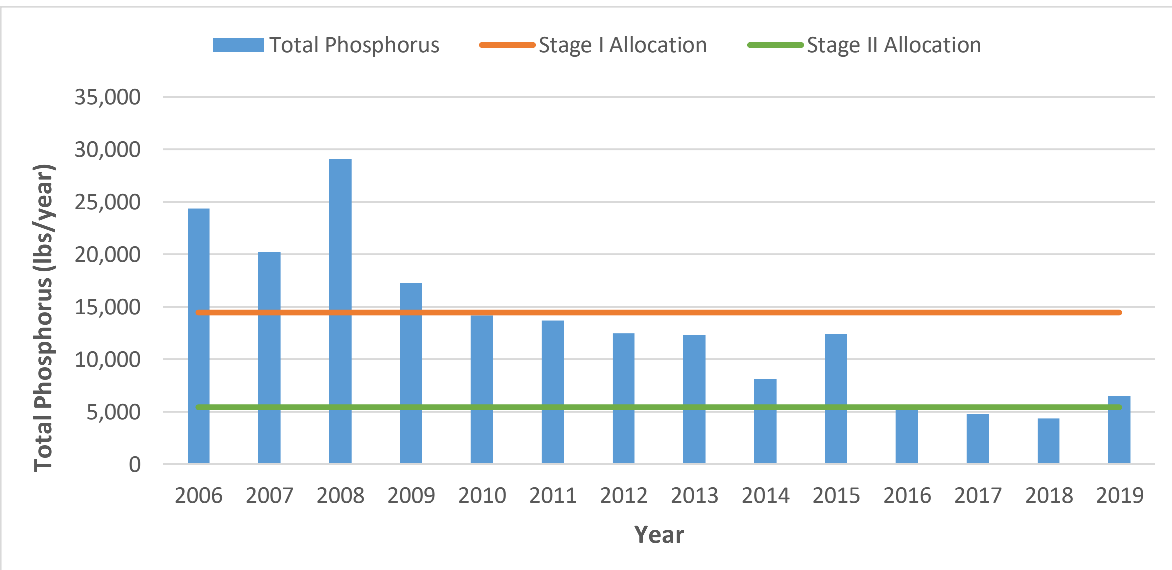


FIGURE 3. WASTEWATER TP DISCHARGE LOADS, FALLS LAKE WATERSHED



Agriculture Rule

The Agriculture Rule uses a collective strategy for farmers to meet nitrogen loss reduction goals in two stages. The Stage I goal is 20 percent nitrogen loss reduction and 40 percent phosphorus reduction by 2020. Stage II goals are 40 and 77 percent for nitrogen and phosphorus, respectively, by 2035. A Watershed Oversight Committee (WOC) administers the rule, and state and local Soil and Water staff assist farmers with implementation. The WOC developed accounting methods for tracking nitrogen and phosphorus loss, which were approved by the Commission in March 2012. The WOC submitted an initial accounting report to the Commission in March 2013 followed by annual reports in 2014 and 2015.

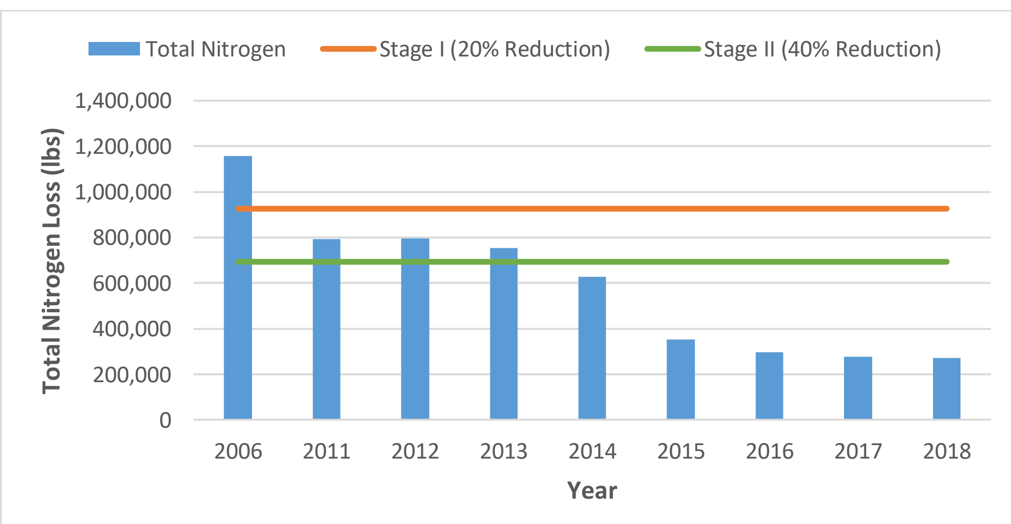
In the 2020 annual report, which covers agriculture activities through crop year 2018, the agriculture sector estimates that they are exceeding the collective Stage I nitrogen loss reduction goal with a 77 percent reduction in nitrogen loss from croplands and 36 percent pastureland nitrogen reduction in the watershed (Figure 4). Agriculture accounting methods do not estimate changes in phosphorus loss.

Qualitative phosphorus indicators used to infer relative changes in phosphorus loss suggest that phosphorus loss has not increased in the watershed. Phosphorus indicators show a 22 and 12 percent decrease in animal waste phosphorus production and tobacco acreage, respectively, and a 38 percent increase in cropland conversion to grass and trees since the 2006 baseline, all of which signal decreases in phosphorus loss.

Reductions in nitrogen have been achieved through an overall decrease in cropland acres under production, a decrease in nitrogen application rates, and an increase in best management practices (BMPs) such as 20 and 50-foot riparian buffers. Since the 2006 baseline, cropland decreased in the watershed by an estimated 31,807 acres of which were permanently lost to development.

Agriculture is also required to account for pasture-based livestock operations that potentially affect nutrient loading. This was previously done through the use of a pasture point accounting system that quantifies changes in the extent of livestock-related nutrient controlling BMPs. In August 2016, the Falls WOC accepted the recommendation of the Pasture Points Committee to revise the pasture accounting method. The "pasture point" method was replaced with a system that utilizes NLEW to estimate reductions in nitrogen loss over time. Pasture nitrogen loss accounting relies on USDA-NASS data which is gathered via the Census of Agriculture every five years. The most recent Ag census was published in 2017. The next update to the Census of Agriculture will be in 2022. Using the most recent information available from 2017, the counties in the Falls Lake Watershed reported a 36 percent nitrogen loss reduction from pastureland relative to the baseline, which exceeds the rule-mandated 20 percent goal.

FIGURE 4. ESTIMATED N LOSS FROM CROPLAND AGRICULTURE, FALLS LAKE WATERSHED



New Development Rule

This rule requires all local governments in the Falls Lake watershed to develop and implement stormwater programs for new development activities. Under these programs, development projects must be designed to meet nutrient loading rate targets of 2.2 lbs./acre/year TN and 0.33 lbs./acre/year TP. These targets represent the strategy percentage goals applied to average undeveloped loading conditions. Developers are required to achieve between 30 percent and 50 percent of the needed reduction onsite, depending on whether they disturb less than or more than one acre for their project. They can then meet the remaining reduction needs through offsite measures including purchase of reduction credits from private banks or payment to the Division of Mitigation Services nutrient offset in-lieu fee program.

All local governments in the Falls watershed adopted and began implementing local stormwater programs in July 2012. Reports documenting their development activity and load reductions are submitted to the Division annually. As of December 2020, there have been 114,930 pounds of nitrogen and 16,408 pounds of phosphorus nutrient offsets purchased for new development projects. Additional discussion about the utilization of nutrient offsets, factors that may impact their future use and projected program changes is provided in the state of knowledge section of this report.

Existing Development Rule

The Falls Lake Existing Development Rule requires local governments to develop and implement load reduction programs to reduce nutrient loading from existing developed lands under their control in the watershed. Implementation is divided into two stages, with Stage I calling for reductions in loading back to 2006 baseline levels, and additional reductions called for in Stage II that require all major sources of nutrients in the watershed to reduce their nitrogen and phosphorus loads by 40 and 77 percent from baseline levels, respectively.

In 2013, in preparation for implementation of their Stage I load reduction programs, local governments developed inventories and characterized load reduction potential of various nutrient reducing activities. During that same year, the Division developed a preliminary draft model program to assist local governments with developing their local load reduction programs. This model program was presented to the Commission in July 2013, at which time the Division requested more time to work with affected parties to continue developing credit accounting for additional nutrient reducing practices.

Development of Nutrient-Reducing Practices

Existing Development requirements are a relatively recent regulatory innovation in North Carolina and nationwide. To this point, they have relied primarily on implementing relatively costly stormwater BMP retrofits in developed landscapes. Local governments have expressed the desire to have the broadest set of creditable practices and a high degree of flexibility for implementation of the requirements of the rule. To address this need, the Division has been working closely with the UNRBA and other affected parties over the past eight years to identify, prioritize and develop credit accounting for several additional practices to add to the ‘toolbox’ of nutrient reducing measures. The Division, with significant support from the UNRBA and other agencies and organizations, has assembled all of the current creditable practices in one place by developing a “Catalog of Nutrient Reduction Practices” to provide a single, comprehensive listing of all currently approved nutrient practices including references to their design standards and nutrient reduction credit accounting.

The Division and the UNRBA have invested a considerable amount of time and resource and sought the input of numerous subject matter experts to develop credit accounting for additional nutrient reducing practices that can be used to comply with the Existing Development rule. In 2014, the Department granted funds to the UNRBA to add to $310K invested by its member governments for an association contract to support development of credit for these additional practices. Through this joint effort between the Division and the UNRBA, credit has been established for six new, state-approved nutrient reducing practices and design variants for several existing SCMs that can now be used towards meeting the Rule requirements. The six new additional practices that have been approved for credit by the Division over the past five years are soil improvement, storm drain cleanout, street sweeping, remedying discharging sand filters, remedying illicit discharges and the practice of cattle exclusion.

Credit guidance documents for these practices were reviewed by the legislatively established Nutrient Scientific Advisory Board, or NSAB, which includes Jordan and Falls Lake local government stormwater professionals, to improve their utility. Details of the nutrient credits and design standards for these practices and any additional practices developed by DWR or by a third party to be vetted by the Nonpoint Source Planning Program and approved by the Division Director are located in the Division’s Nutrient Catalog discussed in more detail in the stormwater “State of Knowledge” section of this report.

Existing Development Stage I Model Program

In 2020, the Division completed the development of a revised model program that affected parties could use to guide development of their mandated load reduction programs. This model program was developed with input from the regulated community and approved by the Commission at its January 2021 meeting. It provides an organizing structure for affected parties to use as a guide to develop their local load reducing programs by identifying the minimum elements they are required by rule to include in their Stage I program submittals. The model includes the option to comply with the requirements of the Existing Development Rule through either implementation of a local load reduction program, or by working together to collectively meet their reduction objectives through a joint compliance approach. The UNRBA and its membership have spent the past two years collaborating with stakeholders to develop a joint compliance approach for meeting the Stage I existing development rule requirements. This initiative was completed and approved by the UNRBA Board of Directors in March 2021, as further described in the “IAIA” section below.

Now that the Model Program has been approved by the Commission, affected parties have until July 2021 to submit and begin implementing their local programs or joint compliance program. The Division will work with those choosing to implement individual load reduction programs in order to finalize their Stage I load reduction need calculations and their program plans.

Stage I Interim Alternative Implementation Approach

The Upper Neuse River Basin Association, with collaborative input from the Division and other stakeholders, has developed a combined compliance option for Stage I known as the Interim Alternative

Implementation Approach (IAIA). This approach recognizes that the major wastewater treatment plants in the Falls Lake watershed have, as of 2019, exceeded their required Stage I nutrient load reductions by approximately 50,000 pounds of nitrogen per year and 10,000 pounds of phosphorus per year. When compared to preliminary estimates of Stage I existing development load reduction requirements, the Stage I credits at the wastewater treatment plants exceed total Stage I existing development nitrogen load reduction requirements by close to a factor of 10, and their phosphorus requirements by significantly more.

The IAIA is an investment-based approach that relies on minimum annual funding commitment levels by participating jurisdictions that are put toward eligible practices. It requires implementation of such practices to further offset nutrient loading impacts from existing development or that provide broader water quality benefits within the watershed and Falls Lake. This integrated watershed approach includes a broad set of actions that expand the state's existing set of approved nutrient reduction practices. The eligible practices have been identified and included in the IAIA Program Document in consultation with DWR and other stakeholders, including environmental advocacy groups, to ensure their implementation will result in nutrient reductions or broader water quality benefits. The eligible practices under the IAIA expands the list of practices provided in the Rule to add actions that have a known water quality benefit but for which nutrient calculation methods have not been approved. Examples include land conservation in high priority areas, repair and replacement of leaky wastewater infrastructure, septic system inspection and pump out programs, fertilizer application education programs, pet waste education and pick-up stations.

Participants in the IAIA will develop projects through their own jurisdictional authority, under an interlocal agreement where two or more jurisdictions collaborate on a project, or through local organizations such as Soil and Water Conservation Districts, County Health Departments, conservation trusts, etc. (as specified in the IAIA program guidelines). Nutrient offset credits can also be obtained from private nutrient offset banks or the Division of Mitigation Services. The costs for acquisition of these credits would also apply to the participating jurisdiction's financial commitment under the IAIA.

State & Federal Rule

This rule establishes stormwater requirements for state and federal entities analogous to local government new and existing development stormwater rules. The N.C. Department of Transportation (NCDOT) is treated differently than other state/federal entities based on the unique character of its activities. NCDOT's program to address their nutrient reduction requirements in Falls, referred to as the Guided Reduction of Excess Environmental Nutrients (GREEN), was approved by the Commission on January 9, 2014. This program describes NCDOT's plan for addressing nutrient load reduction requirements associated with new and widening roads, new non-road development and existing road and non-road development. To meet their existing stormwater requirements in Falls NCDOT must install at least six stormwater retrofits per year. Non-road NCDOT projects must meet the Falls new development rate targets and new NCDOT road projects are deemed compliant if they meet buffer protection rule requirements.

Since the GREEN program was implemented in 2014, NCDOT has not completed any new projects in the Falls watershed that would be subject to the non-road development requirements. To meet their Existing Development Rule requirements NCDOT has performed retrofit feasibility assessments of 5 interchanges in Lower Falls Lake Watershed and 20 interchanges in Upper Falls Lake Watershed. They have installed a total of 23 retrofits as of 2019. These retrofits involved converting concrete-lined ditches to grassed swales and vegetated areas with enhanced bio-filtration as well as construction of dry detention basins.

NCDOT currently has eight additional retrofit projects in the design phase with a target construction date of 2022. The timeline for construction has been adjusted in order to distribute construction costs over the next several years in response to significant reductions to NCDOT's budget in 2020.

Summaries of NCDOTs annual retrofit activities and associated nutrient load reductions are included in NCDOT's annual reports available online https://connect.ncdot.gov/resources/hydro/Pages/Highway-Stormwater-Program.aspx

Non-NCDOT state and federal entities are required to implement their stormwater requirements on the same timeline as local governments. Of the approximately 46,000 acres of state and federally owned land in the watershed, three quarters is either forested parkland or developed campuses associated with the national guard, universities and state-owned hospitals and correctional facilities. With the approval of the Falls Existing Development Model Program, staff are currently in the process of coordinating with these facilities to assist them in developing their Stage I local programs for complying with their existing development stormwater requirements.

Lake and Watershed Trends

Changes in Loading to the Lake

Evaluating changes in nutrient loading to Falls Lake is a useful evaluation because it provides a measurement of what the lake is experiencing in terms of pounds of nitrogen and phosphorus delivered to the lake. However, it is important to recognize that the loading changes presented in this report are estimates that are heavily influenced by hydrologic conditions. Loading estimates vary year by year based on differences in annual rainfall and corresponding increases and decreases in flow. As such, the loading estimates provided in this section demonstrate how highly variable loading can be and are not presented as an indicator of how well the regulated community have complied with the reductions requirements of the Falls Lake Nutrient Management Strategy.

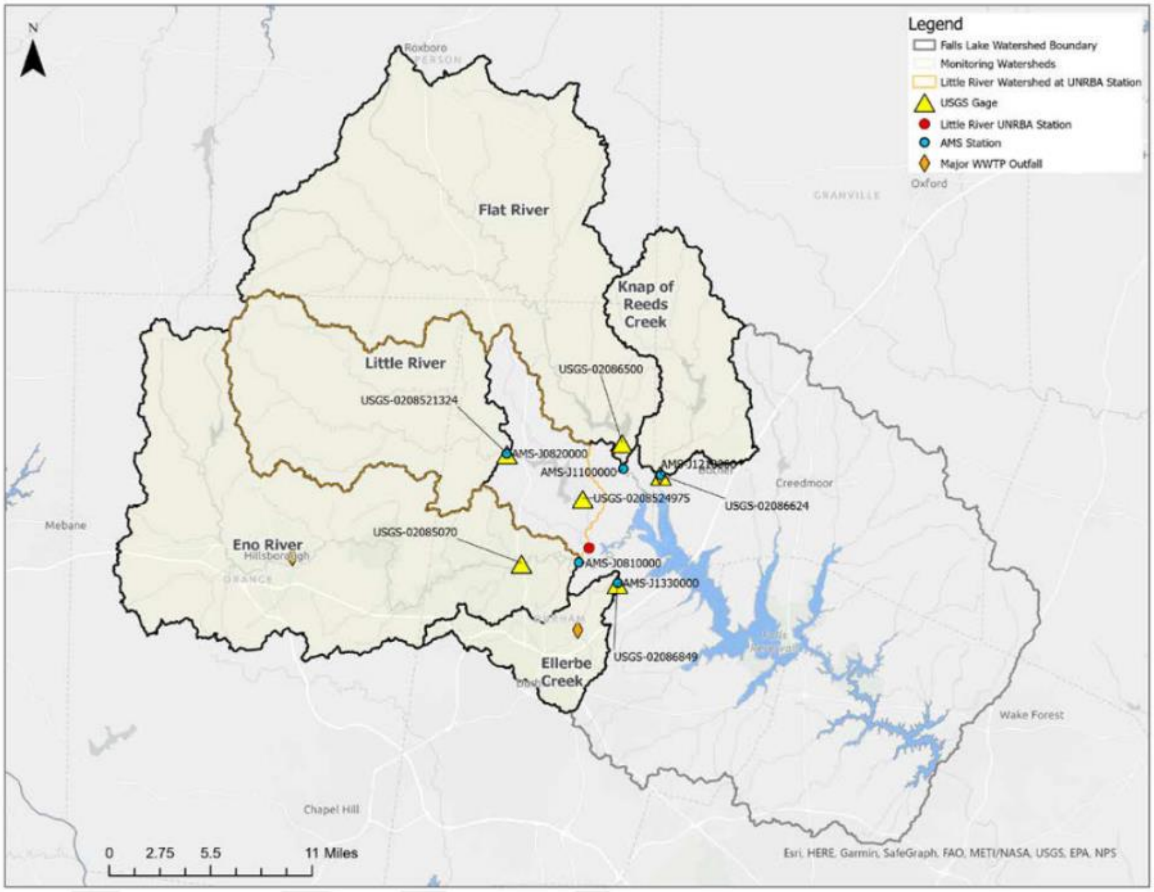
For this report, DWR analyzed monitoring data from 2006 to 2019 to estimate annual nutrient loading to the lake and evaluate changes in this loading and flow for all the streams that had flow gauging pre and post strategy implementation, which are the upper five major tributaries to Falls Lake. The upper five major tributaries are the Eno, Little, and Flat Rivers, and Knap of Reeds and Ellerbe Creeks. These five tributaries are the source of more than 75 percent of the combined flow delivered to the entire lake and were used for developing the 2006 baseline loading estimated in the Division's 2009 watershed model. The location of the DWR monitoring stations and USGS flow gauges are provided in Figure 5.

Load Estimation Process

Nutrient loads were calculated using two methods; the first uses the USGS LOADEST method. LOADEST creates a regression model based on stream flow, concentration, and time to develop mean load estimates with 95 percent confidence intervals on a monthly basis (Runkel et al. 2015). This regression equation can then be used to predict raw loading estimates by filling in the monitoring gaps where paired observations for flow and water quality are not available. This method is best used to understand the total amount of nutrients being delivered by tributary inputs, which can vary greatly year-to-year due to changes in annual rainfall and resulting flows. For this analysis DWR used the model setting of "0", which allows LOADEST to automatically select the best regression model to use which varies by parameter.

The second method used addresses the influence of flow variability by calculating flow-normalized tributary loads and concentrations using the USGS Weighted Regressions on Time, Discharge, and Season (WRTDS) method. This method removes the effects of annual flow variations and is useful for observing changes in nutrient loads that occur as a result of management activities. The WRTDS method is a recently developed exploratory data analysis approach that provides insight about the characteristics of water quality data and can be used to evaluate changes in nutrient concentration and loads (Hirsch and De Cicco, 2015; Hirsch et al., 2010).

FIGURE 5. LOCATIONS OF USGS GAGE STATIONS AND DIVISION AMS IN FALLS LAKE WATERSHED



DWR LOADEST Nutrient Loading Estimates

Tables 3 and 4 provide the resulting annual nitrogen and phosphorus load contributions from the five major tributaries to Falls Lake from 2006 to 2019. Higher stream flows over the last seven years have largely driven higher loading estimates for total nitrogen for the combined tributaries. As a result, the combined tributary LOADEST estimated loading to Falls Lake in recent years has not decreased compared to the 2006 baseline. The estimated loads for 2007, 2011, and 2012 are lower than the baseline year load as a result of relatively lower stream flows during these years.

Total nitrogen and phosphorus annual loading contribution and total flow from each tributary is shown in Figures 6 and 7. Notably the Ellerbe and Knap of Reeds Creeks have seen the largest reduction in estimated nitrogen loading. These reductions are most likely driven by improvements in wastewater treatment facilities that discharge to those waterways. The Flat and Eno Rivers, which do not have wastewater discharges have slightly increased nitrogen loading during the study period. These increases in loads in watershed dominated by nonpoint sources suggest that flows resulting from increased rainfall in recent years is the main reason behind load increases. However, determining the exact reason behind changes in loading is challenging because it changes from year to year due to changes in hydrologic conditions. Use of flow-normalized loading analysis is one way to attempt to tease out the factors that influence loads.

TABLE 3. COMBINED TRIBUTARY LOADEST ANNUAL NITROGEN LOAD ESTIMATE

YEAR	Combined Tributary Total Nitrogen Annual Load Estimate (lbs.)	Total Annual Tributary Flow (Cubic Feet Per Year)
2006	954,745	9,017,595,489
2007	685,399	7,339,437,562
2008	1,144,064	9,854,252,251
2009	1,466,426	16,190,869,205
2010	1,054,032	11,272,422,413
2011	449,328	4,277,925,230
2012	465,534	4,898,111,558
2013	1,038,631	12,835,033,070
2014	1,129,615	14,292,405,590
2015	1,171,854	15,121,981,066
2016	1,139,275	14,654,135,866
2017	1,060,060	11,671,222,151
2018	1,806,557	23,243,318,582
2019	1,311,452	18,099,995,832

* Calculated as the sum of annual averages of the daily mean flow from the five major tributaries.

FIGURE 6. COMBINED LOADEST NITROGEN LOADING AND ANNUAL FLOW WITH STACKED TRIBUTARY CONDITIONS

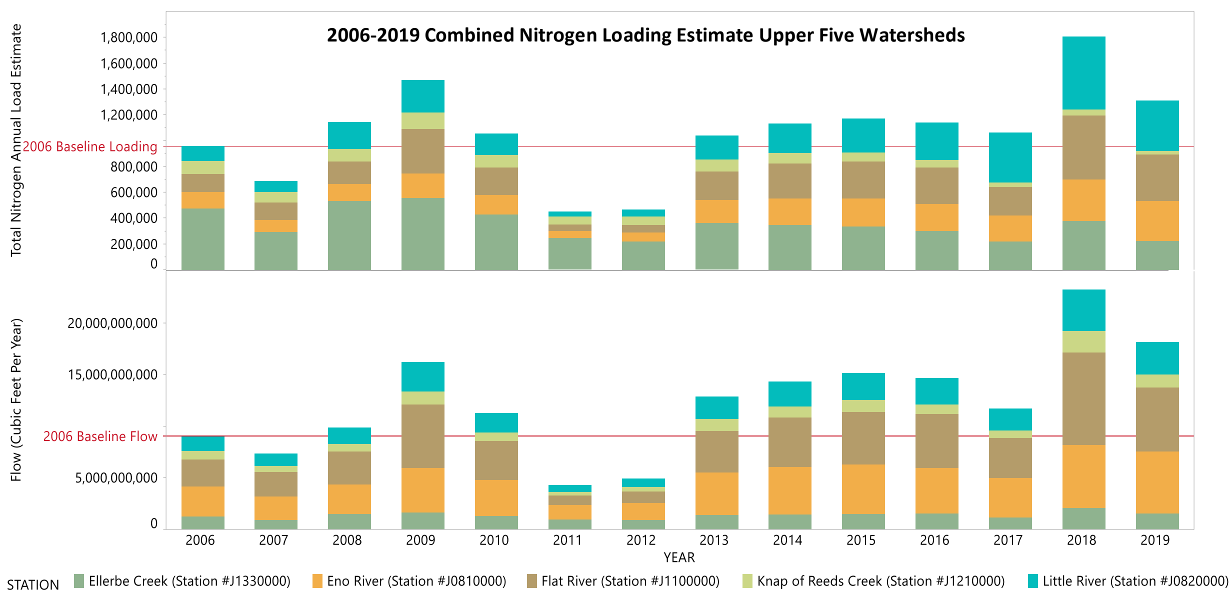
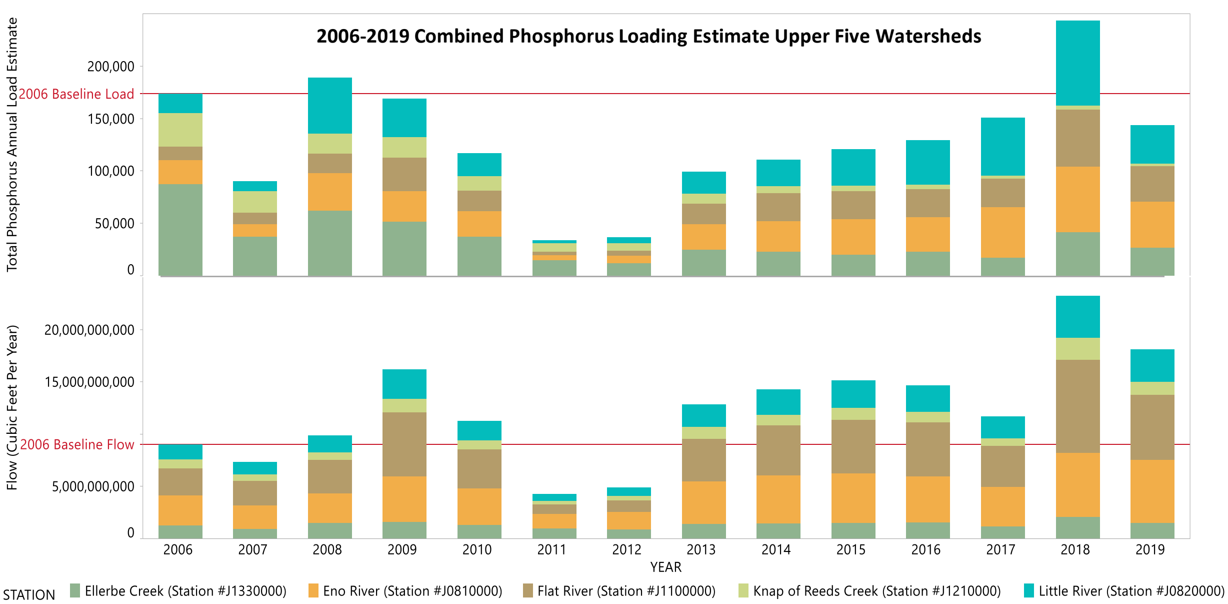


TABLE 4. COMBINED TRIBUTARY LOADEST ANNUAL PHOSPHORUS LOAD ESTIMATE

YEAR	Combined Tributary Total Phosphorus Annual Load Estimate (lbs.)	Total Annual Tributary Flow (Cubic Feet Per Year)
2006	173,613	9,017,595,489
2007	90,403	7,339,437,562
2008	189,189	9,854,252,251
2009	168,960	16,190,869,205
2010	116,605	11,272,422,413
2011	34,010	4,277,925,230
2012	36,565	4,898,111,558
2013	99,387	12,835,033,070
2014	110,658	14,292,405,590
2015	120,502	15,121,981,066
2016	129,568	14,654,135,866
2017	150,788	11,671,222,151
2018	243,621	23,243,318,582
2019	143,732	18,099,995,832

FIGURE 7. COMBINED LOADEST PHOSPHORUS LOADING AND ANNUAL FLOW WITH STACKED TRIBUTARY CONTRIBUTION



The results of DWR's LOADEST loading analysis indicate that annual delivered total nitrogen load from the upper five subwatersheds in 2019 represents an increase of approximately 37 percent relative to the 2006 baseline. They also show that annual delivered total phosphorus loads have decreased 17 percent over the same time period. The increases in nitrogen correlate with wet years, suggesting that the increased precipitation, as indicated in Tables 3 and 4 with the over 100 percent increase in flow in 2019 relative to the baseline, resulted in additional inputs from nonpoint source runoff.

Phosphorus loading decreased despite the increase in flow and while nitrogen loading did increase, it was less than half of the percent increase in flow, suggesting management activities in the watershed have had some impact on loads. The reductions in phosphorus loading to the lake are largely attributable to reductions by the three major municipal wastewater treatment plants located in the upper Falls watershed. Reductions from agriculture and new development may have also supported these trends to some degree.

These results are not surprising given that despite nutrient reductions from both point and nonpoint sources in the watershed, nutrient loads and the lake response are driven primarily by hydrological conditions. Higher flow tends to be associated with higher nutrient loads to the lake and more discharge downstream from the dam when lake levels are high. This scenario then leads to shorter residence time in the lake and less time for algal growth and nutrient uptake to occur. When higher flows and nutrients loads enter the lake when water levels are low, the lake acts more as a storage basin and the residence time, and subsequently algal growth, can be relatively high. Therefore, depending on the preceding hydrologic conditions, higher flows and nutrient loads can either enhance or impede algal growth in the lake. This weighting of loads in light of flow points to the need for an analysis that statistically factors out the variability of flow.

Combined Tributary Flow-Normalized Nutrient Loading Trends

To improve the loading analysis by removing this year-to-year flow variability, the Division performed a second analysis using the WRTDS method. By eliminating the influence of flow, this approach provides the ability to observe signs that factors other than changes in rainfall may have impacted loading in the watershed. Table 5 shows the combined tributary flow-normalized nutrient loading from the five major tributaries to Falls Lake for the 2006-2019.

This method is a recently developed exploratory data analysis approach that provides insight about the characteristics of water quality data and can be used to evaluate changes in nutrient concentration and loads. The method employs the use of weighted regressions of concentrations on time, discharge, and season. It is useful for observing nutrient reduction progress (or lack thereof) by reducing effects of year-to-year variability in discharge on the record of trend in water quality.

WRTDS uses probability distributions of daily streamflow to reduce or eliminate the influence of random, year-to-year streamflow variability on estimates of trends in concentration and load while preserving the influence of long-term trends in streamflow. This approach also has the ability to identify non-monotonic trend patterns and the ability to differentiate between trends in concentration versus trends in flux.

Once the Flow-normalized loads and concentrations are estimated for each ambient monitoring stations, annual load reductions relative to the 2006 baseline year and five-year average load reductions relative to the 2006-2010 were computed. The recently developed WRTDS Bootstrap Test (WBT) was employed to determine the uncertainty of trend results in flow-normalized load including the 90% confidence intervals for the magnitude of trend, hypothesis tests for trend in flow-normalized concentration and flow-normalized load (α =0.1) and the likelihood that the direction of trend is correct (Choquette et al., 2019, Hirsch et al., 2015). For the selected Falls Lake watershed stations, the likelihood of an upward or downward trend for the annual (from 2006 to 2019) and multi-year (from 2006-2010 to 2011-2019) loads and concentrations were estimated

During this period, the combined annual tributary flow-normalized TN, TP, NOx-N, and TKN loads decreased by 20%, 52%, 37%, and 2%, respectively (Table 5). In addition to the change from 2006 to 2019, the percent change from the 2006-2010 average (Pre management Strategy Period) to the 2011-2019 average (Post Management Strategy Period) was calculated. These percent changes for TN, TP, NOx-N, and TK were reductions of 11%, 34%, 22%, and 1%, respectively (Table 6).

Additional supporting figures showing the combined annual flow-normalized average concentrations and total loads for total nitrogen and total phosphorus along with the 90 percent confidence intervals for each of the five upper tributaries are provided in Figures 27 through 30 for reference in Appendix 5.

Table 5. Combined tributary flow-normalized annual nutrient load estimates and percent change from baseline year of 2006

	Flow-normalized load in Pounds per Year						Percent Change
Parameter (lbs./year)	2006	2006 LCL	2006 UCL	2019	2019 LCL	2019 UCL	From 2006
TN	1,024,488	877,297	1,158,094	821,222	709,358	914,072	-20%
TP	152,736	118,445	199,642	72,863	56,147	93,700	-52%
Nitrate-N	553,140	393,526	698,047	350,094	262,051	454,367	-37%
TKN	527,125	441,351	608,356	516,984	418,316	594,867	-2%

LCL = 90% Lower Confidence Limit
UCL = 90% Upper confidence Limit

Table 6. Combined tributary flow-normalized annual nutrient load estimates and percent change from 2006-2010 average (Pre-Management Strategy Period)

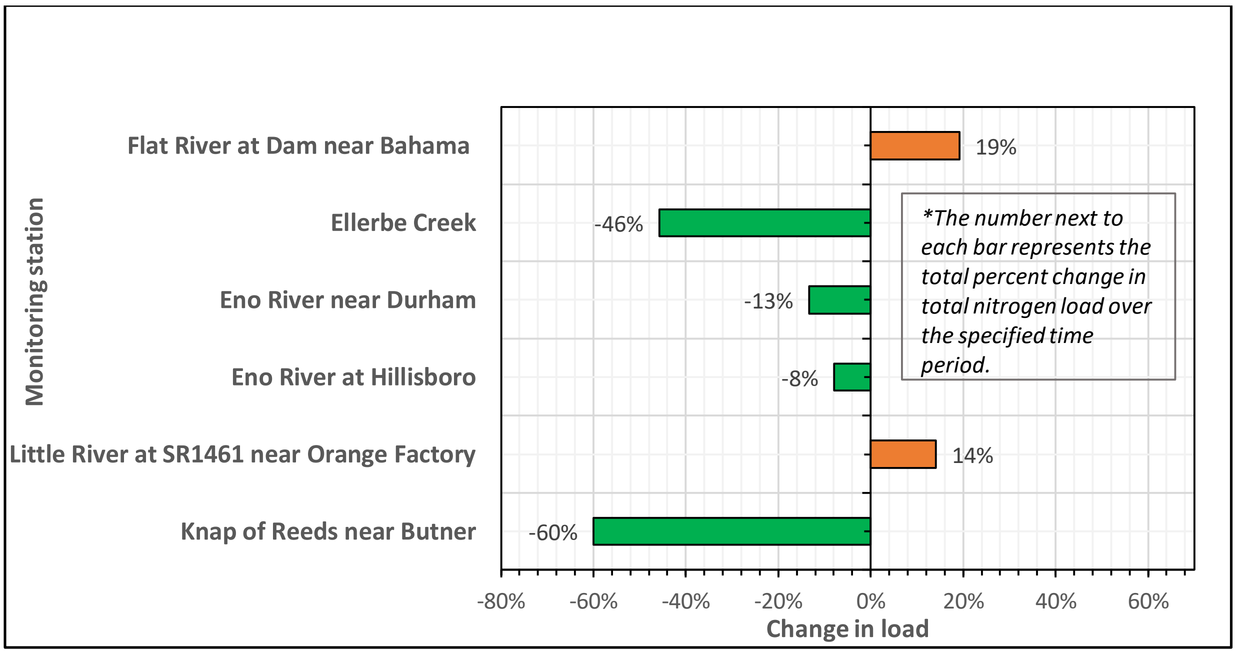
	Flow-normalized load in Pounds per Year						Percent Change
Parameter (lbs./year	2006-2010	2006-2010 LCL	2006-2010 UCL	2011-2019	2011-2019 LCL	2011-2019 UCL	From 2006-2010
TN	986,040	861,378	1,104,290	875,480	773,766	965,362	-11%
TP	130,302	103,318	167,047	85,691	67,666	108,136	-34%
Nitrate-N	505,401	375,338	624759	393,542	307,568	490,986	-22%
TKN	529,374	449,179	607,857	524,382	438,154	593,700	-1%

LCL = 90% Lower Confidence Limit
UCL = 90% Upper confidence Limit

Individual Tributaries Flow-Normalized Nutrient Loading Trends, 2006-2019

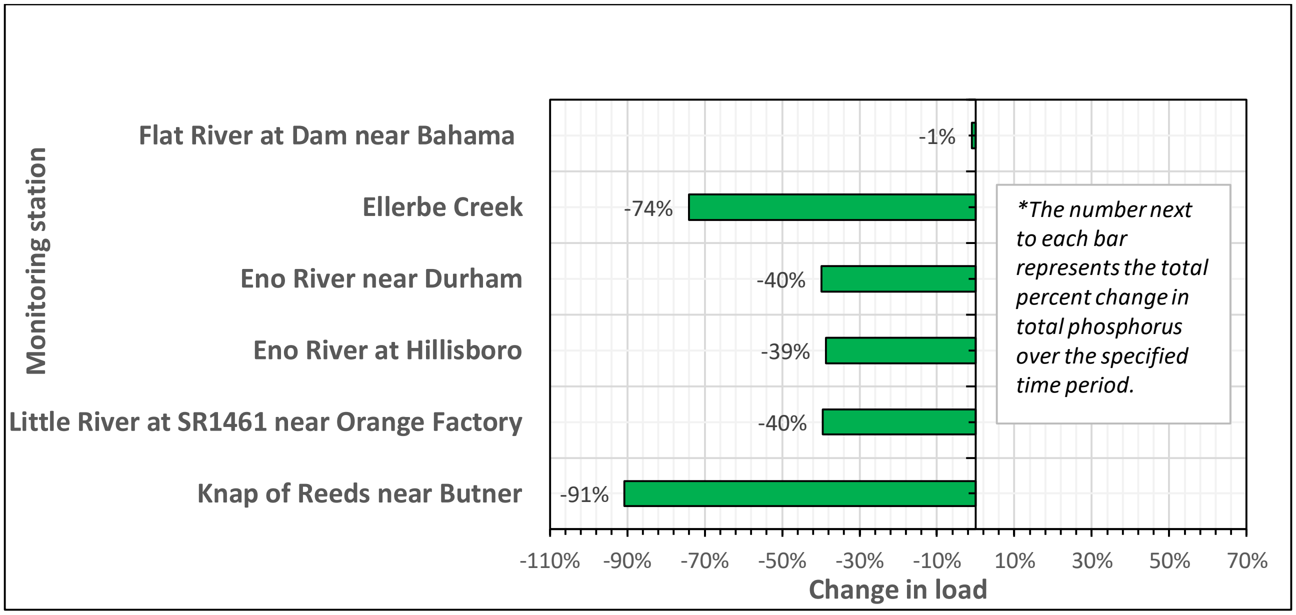
Figures 8 and 9 show the summary of the reductions in flow-normalized loads for TN and TP from the five upper tributaries during the 2006-2019 period. A statistically significant downward trend was observed at the Knap of Reeds creek, Ellerbe Creek and Eno River near Durham sites. The decreases in flow-normalized total nitrogen load (FNTN) at these sites may be related to wastewater treatment plant improvements and reductions. The Flat River near Bahama and the Little River near Orange Factory site exhibited slight increases in flow-normalized total nitrogen load. The increases in FNTN at the Flat River and The Little River sites likely reflect the increase in contribution of nonpoint source loads during this period. DWR's monitoring station on the Little River is above the Little River Reservoir and does not account for nutrient processing that takes place in the impoundment before eventually being delivered to Falls Lake.

FIGURE 8. CHANGE IN FLOW-NORMALIZED TOTAL NITROGEN LOADS DURING THE PERIOD, 2006-2019, FOR SELECTED FLOW-GAUGED FALLS LAKE WATERSHED MONITORING STATIONS



During the 2006-2019 period, with the exception of the Flat River, all other tributaries show substantial decreases in total phosphorus load (Figure 11). The likelihood of the trend in flow-normalized total phosphorus load at these sites is statistically highly likely downward. The likelihood of the trend in flow-normalized total phosphorus load for the Flat River site is uncertain (upward/ downward trend as likely as not). The largest reductions in FN total phosphorus loading in Ellerbe and Knap of Reeds Creeks suggest reduction in contribution of point sources and improvements in wastewater treatment facilities.

FIGURE 9. CHANGE IN FLOW-NORMALIZED TOTAL PHOSPHORUS LOADS DURING THE PERIOD, 2006-2019, FOR SELECTED FLOW-GAUGED FALLS LAKE WATERSHED MONITORING STATIONS



Multi-Year Flow-Normalized Nutrient Loading Trends

In addition to the annual changes in flow-normalized load, the change from the 2006-2010 to 2011-2019 time periods was computed. Figure 10 shows the summary of the reductions in flow-normalized total nitrogen loads from the five upper tributaries during the 2006-2010 and 2011-2019 period. During this period, the Ellerbe Creek and the Knap of Reeds sites show substantial decreases in FNTN loads while the Eno River site near Durham shows a smaller decrease. A highly like downward trend was observed at the three sites. The decreases in FNTN at these sites may be related to wastewater treatment plant improvements and reductions. The Flat River near Bahama and the Little Rivers near Orange Factory site exhibited increases in FNTN. The trend at the Flat River site was highly likely upward and that of the Little River site was very likely upward.

FIGURE 10. CHANGE IN TOTAL NITROGEN LOADS DURING PERIOD, 2006-2010 TO 2011-2019, FOR SELECTED FALLS LAKE WATERSHED MONITORING STATIONS

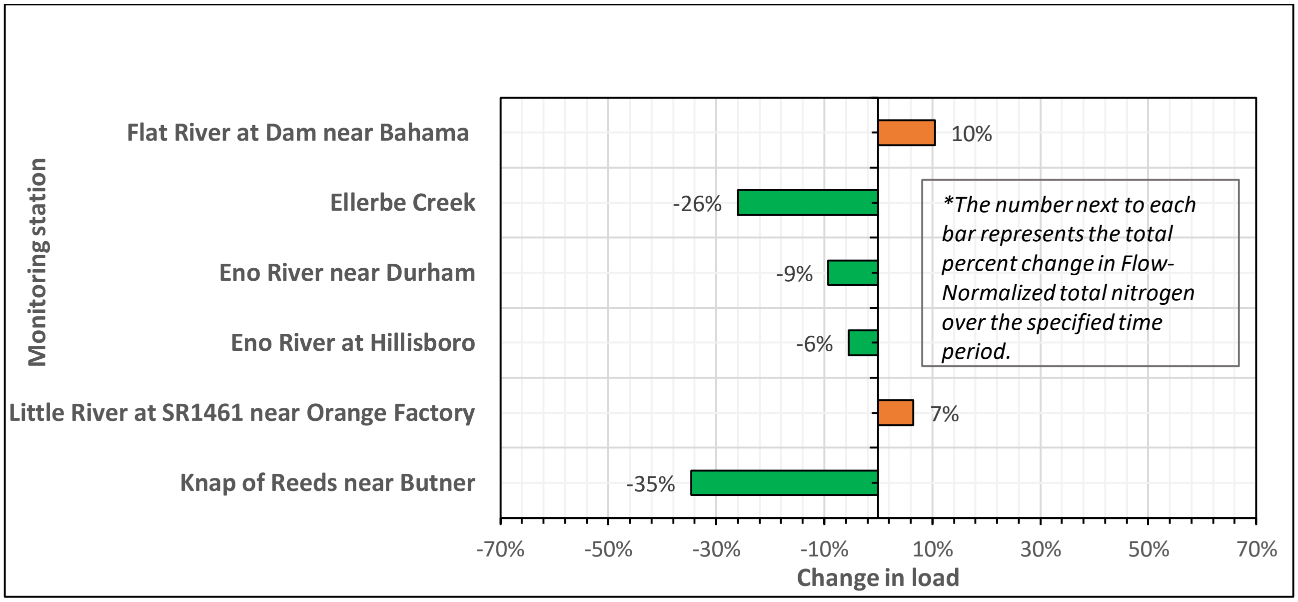
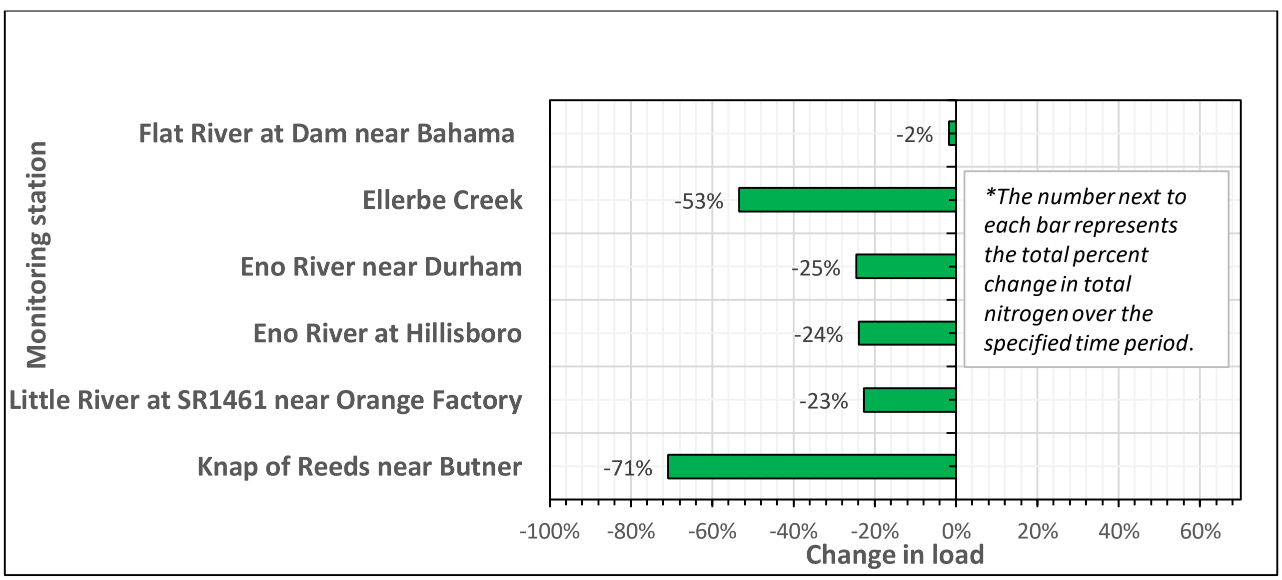


Figure 11 shows the summary of the reductions in flow-normalized total phosphorus loads during the 2006-2019 to 2011-2019 period. During this period, the Ellerbe Creek, the Knap of Reeds, the Eno River site near Durham, the Eno River near Hillsborough, and the Little Rivers near Orange Factory sites show substantial decreases in FN total phosphorus load. The likelihood of the trend in flow-normalized total phosphorus load at these sites is highly likely downward. The likelihood of the trend in flow-normalized total phosphorus concentration for the Flat River site is uncertain (upward/ downward trend as likely as not).

FIGURE 11. CHANGE IN TOTAL PHOSPHORUS LOADS DURING THE PERIOD, 2006-2010 TO 2011-2019, FOR SELECTED FALLS LAKE WATERSHED MONITORING STATIONS



Lake Chlorophyll *a* Concentrations

In addition to evaluating changes in nutrient loading, the Division conducted an assessment of changes in chlorophyll *a* concentrations in Falls Lake before and after the strategy became effective in January 2011. The following is a summary of in-lake chlorophyll *a* concentrations (water quality standard 40 ug/L) pre and post strategy implementation.

Two different analyses were performed with the chlorophyll *a* data. The first is a percent exceedance analysis by station, that is the fraction of each station's samples exceeding the standard for given time periods. The second is a magnitude of exceedance analysis by station, characterizing the extent to which concentration values at a station ranged above the 40 ug/l standard. Three chlorophyll *a* datasets are included in the percent exceedance analysis. The first is for the time period of 2005-2007, prior to adoption of the strategy. The second is for the time period of 2011-2014, during which many of the strategy components were implemented. This portion of the analysis was provided in the first five-year report. This report adds another five-year period, 2015-2019. Figures 12 through 14 illustrate the spatial distribution of chlorophyll *a* standard percent exceedance rates for the three time periods. DWR ambient lake data were used for this analysis. Table 7 summarizes the results by station. Due to budget limitations Falls lake was not monitored from October 2007 through 2010, hence the gap in time periods. Since that time, the Division has conducted monthly sampling of the lake.

FIGURE 12. PERCENT OF SAMPLES EXCEEDING CHLOROPHYLL A STANDARD OF 40 µG/L FROM 2005 – 2007

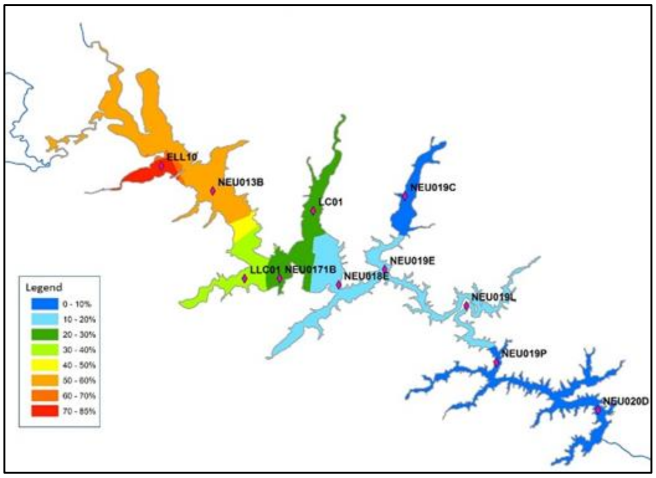


FIGURE 13. PERCENT OF SAMPLES EXCEEDING CHLOROPHYLL A STANDARD OF 40 µG/L FROM 2011 – 2014

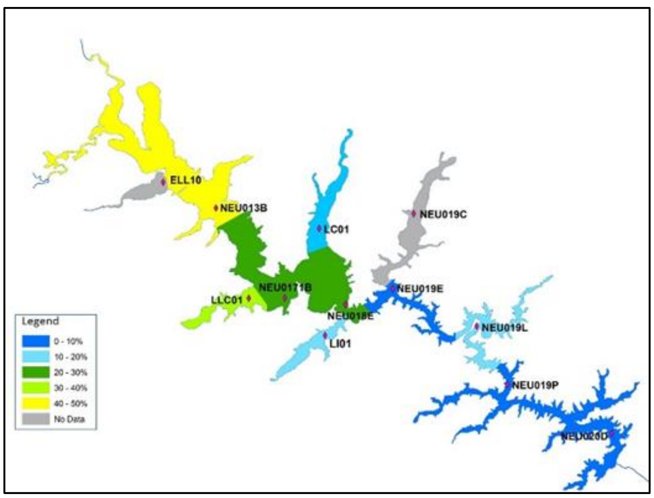


FIGURE 14. PERCENT OF SAMPLES EXCEEDING CHLOROPHYLL A STANDARD OF 40 µG/L FROM 2015 – 2019

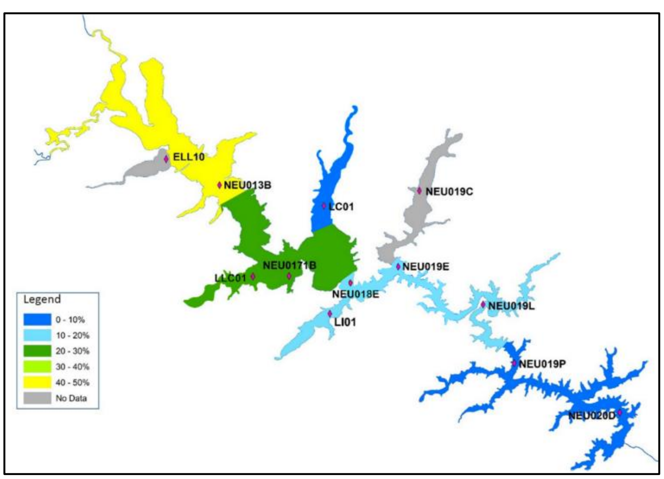


TABLE 7. TEMPORAL COMPARISON, PERCENT OF SAMPLES EXCEEDING THE CHLOROPHYLL A STANDARD OF 40 µG/L

Station	2005-2007 (3 years)		Post-Strategy 2011-2014 (4 years)		Post-Strategy 2015-2019 (5 years)	
	n	Percent over 40 µg/L	n	Percent over 40 µg/L	n	Percent over 40 µg/L
Mainstem						
NEU013B	50	53%	47	45%	57	40%
NEU0171B	51	25%	47	28%	58	24%
NEU018E	51	16%	47	21%	58	17%
NEU019C	51	4%	not sampled		not sampled (except for summer 2016)	
NEU019E	51	16%	48	8%	58	10%
NEU019L	51	12%	48	10%	57	12%
NEU019P	51	10%	47	6%	58	9%
NEU020D	51	10%	46	4%	58	3%
Arms						
ELL10	38	84%	station dropped		station dropped	
LC01	38	21%	46	17%	59	8%
LLC01	38	39%	46	33%	58	24%
LI01	0	n/a	44	14%	58	17%

For each time period evaluated, exceedance rates of the chlorophyll *a* standard are higher in the upper end of the lake and gradually decrease moving downstream to the dam. There is little change in the rates of exceedances in 2015-2019 compared to 2011-2014. Between the two time periods, chlorophyll *a* exceedance rates decreased in the Ledge Creek and Little Lick Creek arms (LC01 and LLC01, respectively) and mid-lake at station NEU018E. In contrast, there was a slight increase in the chlorophyll *a* exceedance rate just downstream at station NEU019E.

For the second part of the chlorophyll analysis, the magnitude of chlorophyll *a* concentrations were also evaluated for the time periods of 2011-2014 and 2015-2019. The distributions of chlorophyll *a* concentrations by station are provided in Figures 15 and 16 below. Blues and greens on the charts represent samples meeting the chlorophyll *a* standard of 40 ug/L. Yellows, oranges, and reds represent increasing magnitudes of exceedances of the standard. Visual comparison of the two figures suggests that there is not much change across the two time periods with regards to the distribution of magnitudes of chlorophll *a* concentration. In general, there are higher magnitude exceedances of the standard upstream (starting with NEU013B) versus downstream near the dam (NEU020D).

FIGURE 15. DISTRIBUTION OF CHLOROPHYLL A CONCENTRATIONS (UG/L) BY STATION FROM 2011 – 2014

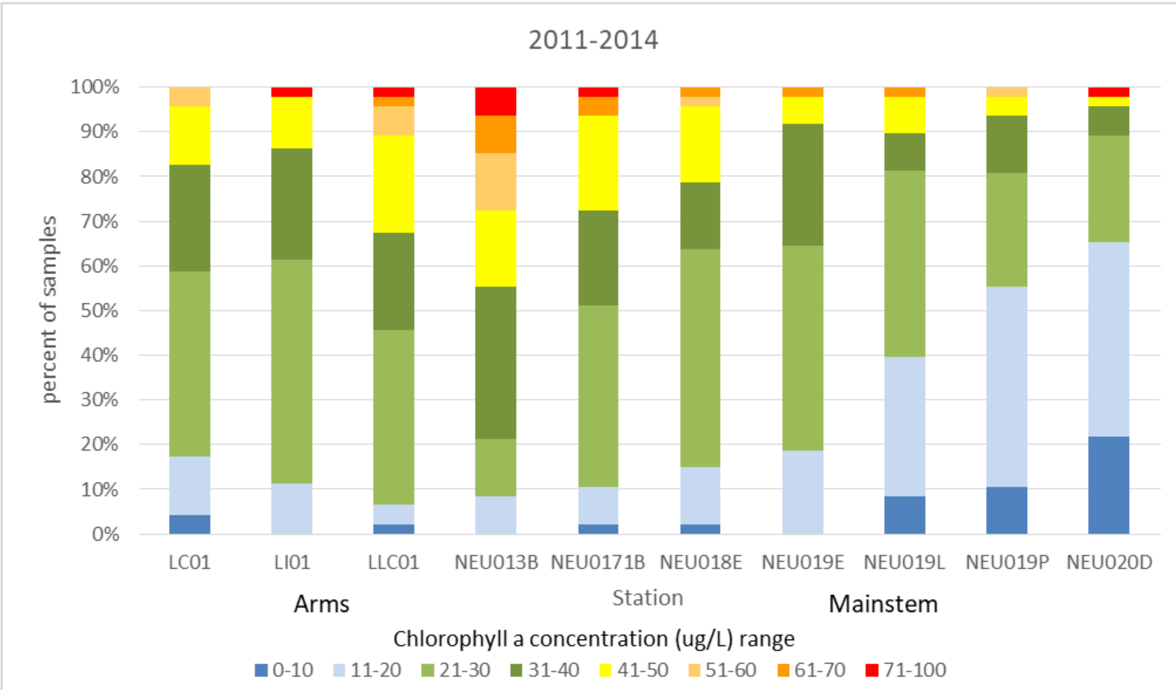
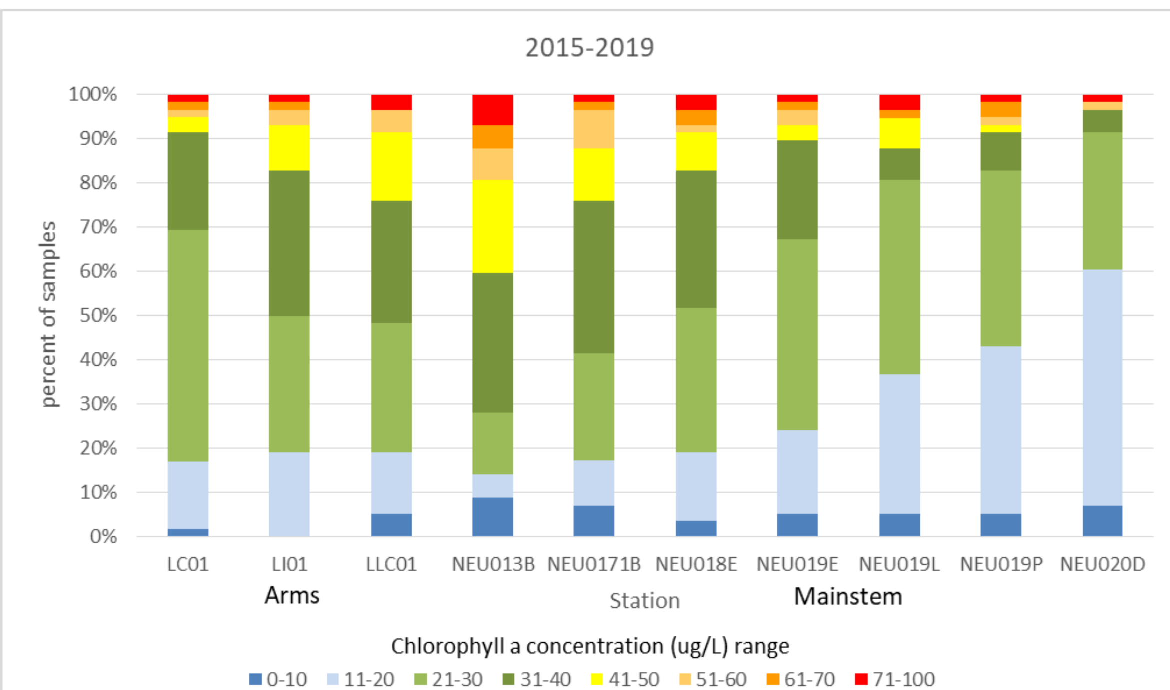


FIGURE 16. DISTRIBUTION OF CHLOROPHYLL A CONCENTRATIONS (UG/L) BY STATION FROM 2015 – 2019



Integrated Report Summary

The Division performs water quality monitoring in Falls Lake and performs biannual Integrated Report assessments as required by the Clean Water Act to evaluate compliance with meeting the strategy goal of achieving the chlorophyll *a* water quality standard throughout the lake. Each Integrated Report offers a five-year data assessment window of water quality standards attainment in the lake. This assessment is the ultimate administrative metric for compliance with the Clean Water Act.

Estimating changes in lake water quality through comparison of biannual Integrated Reports is not recommended for several reasons. First, in North Carolina, assessment methodologies have changed from one Integrated Report to the next, which can and does impact assessment decisions. Second, each subsequent Integrated Report evaluates a five-year data window by adding two new years and dropping two old years from the data window. This leaves three years of the same data included in the subsequent assessment. For example, the 2014 Integrated Report evaluates years 2008 through 2012. The 2016 Integrated Report dropped 2008 and 2009, kept 2010 through 2012, and added 2013 and 2014. Finally, there are cases where third party data is submitted that had not been submitted for prior Integrated Reports, which can lead to segment changes.

For the 2008, 2010, and 2012 water quality standards assessments, the assessment methodology required a greater than 10 percent exceedance rate to be considered not meeting criteria (i.e. non-attainment of the standard). The results of these three assessments indicated non-attainment of the chlorophyll *a* standard in both the upper and lower segments of Falls Lake.

For the 2014, 2016, and 2018 water quality standards assessments, the Environmental Management Commission adopted changes to the State's assessment methodology to require a standard exceedance decision to be based on a greater than 10 percent exceedance rate with 90 percent statistical confidence. Also of note, the 2016 and 2018 water quality assessments included third-party data submitted by NC State's Center for Applied Aquatic Ecology (CAAE) that the state was able to use to better define potential areas of concern within the lake. The Division is in the process of analyzing data and finalizing the assessment for the 2020 Integrated Report.

Table 8 below summarizes the nutrient related listings signifying waters not meeting criteria since the lake's initial listing in 2008. For more information on the State's Integrated Report program, including more details regarding changes in assessment methodology, please visit: https://deq.nc.gov/about/divisions/water-resources/planning/modeling-assessment/water-quality-data-assessment/integrated-report-files.

TABLE 8. CHANGES IN WATERS NOT MEETING CRITERIA FROM INTEGRATED REPORT ASSESSMENTS SINCE 2008

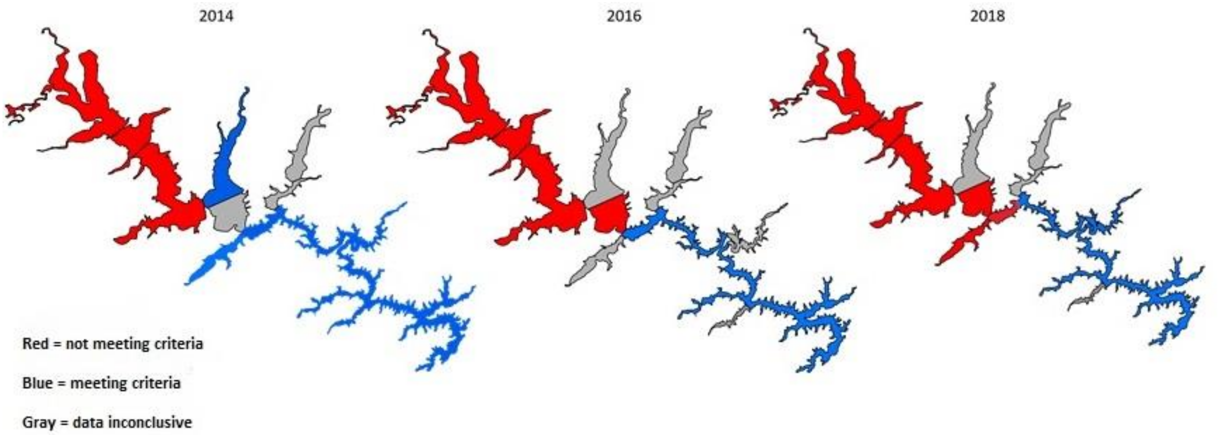
Assessment Unit ID	Description	Parameter Not Meeting Criteria
2008 Integrated Report Assessments		
27-(1)	From source (confluence of Eno River Arm of Falls Lake and Flat River Arm of Falls Lake) to I-85 bridge	turbidity, chlorophyll *a*
27-(5.5)	From I-85 bridge to Falls Dam	chlorophyll *a*
2010 Integrated Report Assessments		
27-(1)	From source (confluence of Eno River Arm of Falls Lake and Flat River Arm of Falls Lake) to I-85 bridge	turbidity, chlorophyll *a*
27-(5.5)a	From I-85 bridge to Panther Creek	turbidity, chlorophyll *a*
27-(5.5)b	From Panther Creek to Falls Dam	chlorophyll *a*
2012 Integrated Report Assessments		
27-(1)	From source (confluence of Eno River Arm of Falls Lake and Flat River Arm of Falls Lake) to I-85 bridge	turbidity, chlorophyll *a*
27-(5.5)a	From I-85 bridge to Panther Creek	turbidity, chlorophyll *a*
27-(5.5)b	From Panther Creek to Falls Dam	chlorophyll *a*
2014 Integrated Report Assessments		
27-(1)	From source (confluence of Eno River Arm of Falls Lake and Flat River Arm of Falls Lake) to I-85 bridge	turbidity, chlorophyll *a*
27-(5.5)a	From I-85 bridge to Panther Creek	turbidity, chlorophyll *a*
27-(5.5)b1	From Panther Creek to Ledge Creek Arm	chlorophyll *a*
27-(5.5)b2	Ledge Creek Arm	None
27-(5.5)b3	From Ledge Creek Arm to Lick Creek Arm	None
27-(5.5)b4	From Lick Creek Arm to Falls Dam	None
2016 Integrated Report Assessments		
27-(1)	From source (confluence of Eno River Arm of Falls Lake and Flat River Arm of Falls Lake) to I-85 bridge	turbidity, chlorophyll *a*
27-(5.5)a	From I-85 bridge to Panther Creek	turbidity, chlorophyll *a*
27-(5.5)b1	From Panther Creek to Ledge Creek Arm	chlorophyll *a*
27-(5.5)b2	Ledge Creek Arm	None
27-(5.5)b3	From Ledge Creek Arm to Lick Creek Arm	chlorophyll *a*
27-(5.5)b4a	Lick Creek Arm	None

27-(5.5)b4b	From Lick Creek Arm to New Light Creek Segment	None
27-(5.5)b4c	New Light Creek Segment	None
27-(5.5)b4d	From New Light Creek Segment to Falls Dam	None
27-(5.5)b4e	Lower Barton Creek Arm	None
2018 Integrated Report Assessments		
27-(1)	From source (confluence of Eno River Arm of Falls Lake and Flat River Arm of Falls Lake) to I-85 bridge	turbidity, chlorophyll *a*
27-(5.5)a	From I-85 bridge to Panther Creek	turbidity, chlorophyll *a*
27-(5.5)b1	From Panther Creek to Ledge Creek Arm	chlorophyll *a*
27-(5.5)b2	Ledge Creek Arm	None
27-(5.5)b3	From Ledge Creek Arm to Lick Creek Arm	chlorophyll *a*
27-(5.5)b4a	Lick Creek Arm	chlorophyll *a*
27-(5.5)b4b1	From Lick Creek Arm to Hwy 50 Bridge	chlorophyll *a*
27-(5.5)b4b2	From Hwy 50 Bridge to New Light Creek Segment	None
27-(5.5)b4c	New Light Creek Segment	None
27-(5.5)b4d	From New Light Creek Segment to Falls Dam	None
27-(5.5)b4e	Lower Barton Creek Arm	None

The Falls Lake rules established under Section 15A NCAC 02B .0275 (5) (viii) provide that when a segment of the lake demonstrates compliance with the state's chlorophyll *a* water quality standard for at least two consecutive use-support assessments, further load reductions will not be required. In the 2014 Integrated Report assessment, the lower portion of the lake met criteria for chlorophyll *a.* However, while the 2016 and 2018 Integrated Report assessments did not indicate any nutrient-related standard exceedances in the lower lake, portions of the lower lake were shown to be not in compliance with the chlorophyll *a* standard either and had results of "data inconclusive." This is demonstrated in Figure 17 below.

It is important to note that inconclusive results in the lower lake do not necessarily indicate degradation in water quality occurred. The changes between 2014 and 2016 are due to the inclusion of third party data (as discussed above) that increased the spatial coverage of monitoring data. This third party data allowed the state to better delineate the lake into assessment units that reflect similar water quality conditions with regards to chlorophyll *a*.

FIGURE 17. COMPARISON OF CHLOROPHYLL *A* STANDARD ASSESSMENTS FROM 2104, 2016 AND 2018 INTEGRATED REPORTS



In-Lake Chlorophyll a Evaluation Summary

Chlorophyll *a* concentrations in Falls Lake were evaluated three different ways. First, percent exceedances of the standard provided information on relative changes within the lake (e.g. upper lake versus lower lake) over time. Second, bar charts of the magnitude of chlorophyll *a* concentrations for each station added information on potential changes in the scale of exceedances per station. Finally, evaluation of the Integrated Report assessments provided summarizes of status of standards attainment decisions over time. The last analysis informs Section 15A NCAC 02B .0275 (5) (viii) of the Falls rules, which provides that when a segment of the lake demonstrates compliance with the state's the chlorophyll *a* water quality standard for at least two consecutive use-support assessments, further load reductions will not be required.

The analysis shows exceedance rates are higher in the upper shallower end of the lake and gradually decrease as the lake narrows and becomes deeper moving downstream towards the dam. Changes in the magnitude of chlorophyll *a* concentrations between the two post-implementation time periods were minimal, suggesting that there has been little change in chlorophyll *a* since the rules went into effect. This is not entirely unexpected, as it will take considerable time for the lake to respond to reductions in nutrient loading from nonpoint sources. Nutrient reductions are being implemented but will take considerable time to attain the standard.

In addition to this time-lag, the results of the UNRBA's monitoring efforts and analysis, discussed in the next section, point to many controlling and constraining factors impacting the lake's water quality beyond tributary nutrient loading. Other factors likely influencing chlorophyll-*a* concentrations include internal nutrient loading, temperature, changes in retention time, variations in lake depth, morphology, and dam releases. Attaining compliance with the water quality standards in Falls Lake will be greatly informed by the future findings from the UNRBA re-examination process and the recommendations of the UNC Collaboratory.

Summary of Upper Neuse River Basin Association Monitoring Project

At the time the original Falls Lake modeling effort was conducted, the data available to develop and calibrate the models was limited, and DWR did not have the resources or the time to conduct studies that would address key data gaps. To address these data gaps, and ultimately comprehensively remodel both the watershed and the lake, the UNRBA and its member local governments have carried out a detailed multi-year monitoring project of the Falls watershed. While the Association's modeling efforts based on this additional monitoring are currently ongoing, their array of monitoring projects and subsequent data analyses have provided a valuable set of additional insights on the lake's behavior.

During the UNRBA's monitoring project, which ran from 2014 to 2018, the membership invested approximately $3.5 million in additional monitoring and analysis to fill data gaps and address uncertainties associated with the original watershed and lake modeling used to develop the Falls Lake strategy. This monitoring data was also collected to support the UNRBA's reexamination of the Stage II rules in accordance with the procedures and requirements outlined in the adaptive management section of the Falls Purpose and Scope Rule, 15A NCAC 02B .0275. This additional water quality data will also be used by the Division to supplement the assessment of water quality in the lake and tributaries throughout the watershed and help inform future management decisions.

The UNRBA Monitoring Program was specifically designed to build upon the scientific assessment and modeling predictions used by the state to support the Falls Lake Nutrient Management Strategy with the purpose of supporting the remodeling of the lake and watershed, development of alternate regulatory options as needed, and more precisely allocate loads to sources and jurisdictions. The program was comprised of two major components: routine monitoring of tributaries at fixed stations, and special studies that were conducted to provide a detailed understanding of the functions of the lake's physical, chemical, biological, and geological characteristics.

In 2019, the UNRBA developed a final comprehensive monitoring report that summarizes the data collected during their monitoring project. The report focuses primarily on data collection by the UNRBA, NCSU Center for Applied Aquatic Ecology, and DWR. The report also looks at historical data collected by others as far back as the initial impoundment of Falls Lake. The report provides both loading summaries and analysis in addition to characteristics of the lake potentially impacting water quality. This information will assist the UNRBA modeling team to develop updated models for the re-examination process. These models will be used to evaluate options for managing nutrients in the watershed to improve water quality in Falls Lake as well as the evaluation of potential regulatory options like site specific criteria to ensure existing uses in the lake continue to be met.

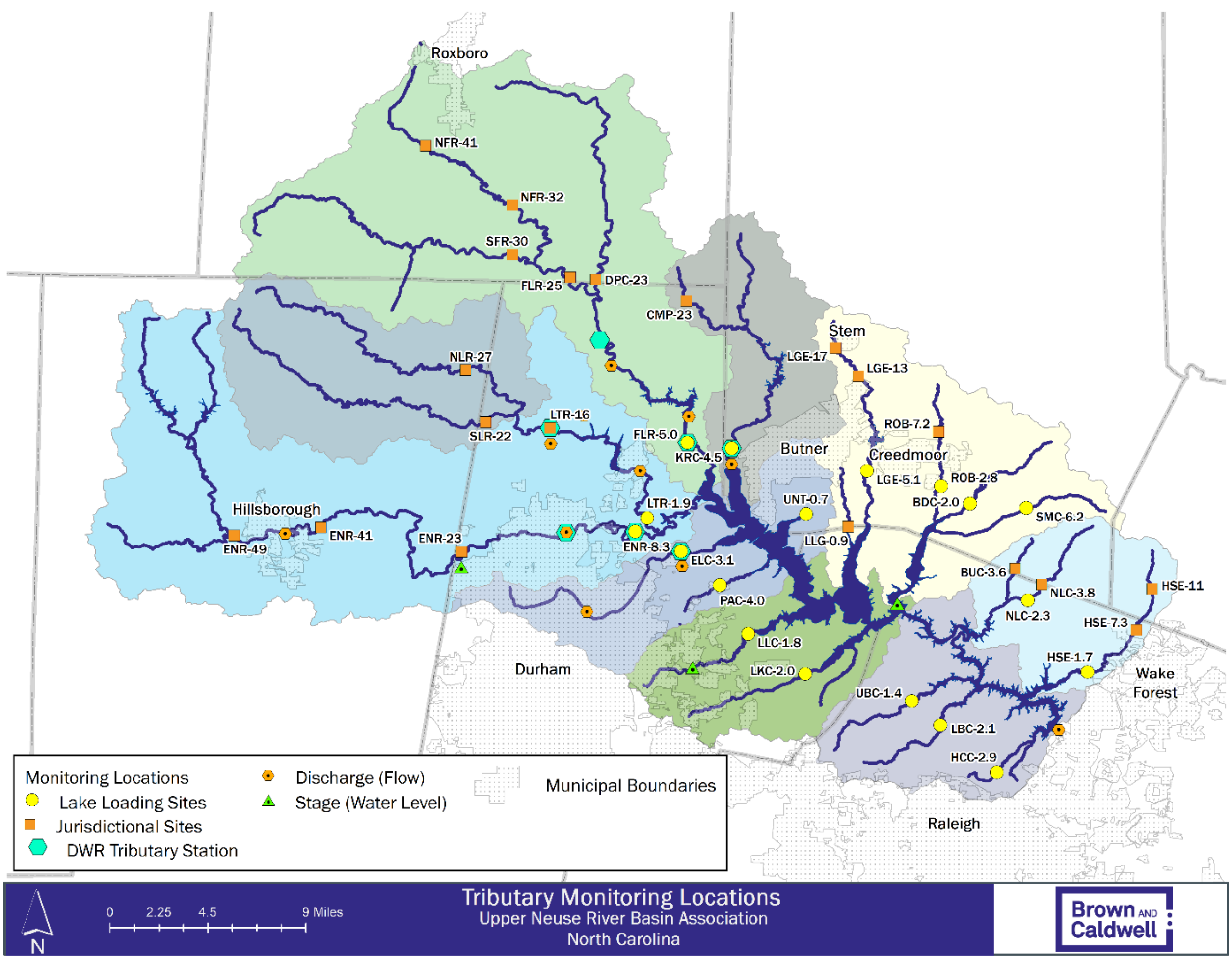
An overview of the UNRBA's routine monitoring program and lake loading estimates is provided below. Summaries of the special studies conducted and the insights they provide are included in the state of knowledge section of this report. The Final 2019 UNRBA Monitoring Report with additional details about the methods used and a full analysis of their findings is available on the UNRBA website here at http://www.unrba.org/monitoring-program

UNRBA Routine Monitoring Program

The UNRBA Routine Monitoring Program began in August 2014, continued through October 2018, and measured nutrients, sediment, carbon, chlorophyll *a* and sixteen other water quality parameters from 38 tributary stations in the watershed on a monthly basis for 51 months resulting in more than 38,000 measurements. Beginning in November 2018, a much-reduced "Transition Monitoring" effort continued obtaining data from a smaller set of stations.

Eighteen lake loading stations were located on the major tributaries to Falls Lake (Figure 18). The five largest tributaries that enter the upper end of the lake were monitored twice-monthly for the first two years then monthly for the remainder of the study; the remaining 13 stations were monitored once per month throughout the duration of the project. An additional 20 jurisdictional monitoring stations were located further upstream on these tributaries and sampled monthly. Data from these stations was collected to help characterize water quality near boundaries between jurisdictions. Each of these stations was monitored monthly.

FIGURE 18. UNRBA LAKE LOADING AND JURISDICTIONAL MONITORING LOCATIONS



Source: UNRBA 2019 Final Monitoring Report

UNRBA Loading Evaluation

The UNRBA's analyses expand on DWR's efforts by combining both tributary loads and other sources of nutrient inputs to the lake such as atmospheric deposition and lake sediments. They looked beyond recent data and analyzed historical water quality data collected by others as far back as the initial impoundment of Falls Lake.

The UNRBA developed two statistical models to estimate loading to Falls Lake. They used the USGS LOADEST model to estimate tributary loads during the pre-strategy sampling period conducted by DWR between 2005 and 2007 to compare to post-strategy estimated loads from UNRBA's monitoring period of 2014 to 2018. A second model known as a generalized additive model (GAM), was used to evaluate the entire dataset of historical monitoring results from 2018 all the way back to the 1980s to allow for comparison of the post-impoundment loading to the UNRBA's recent monitoring period for these same four tributaries.

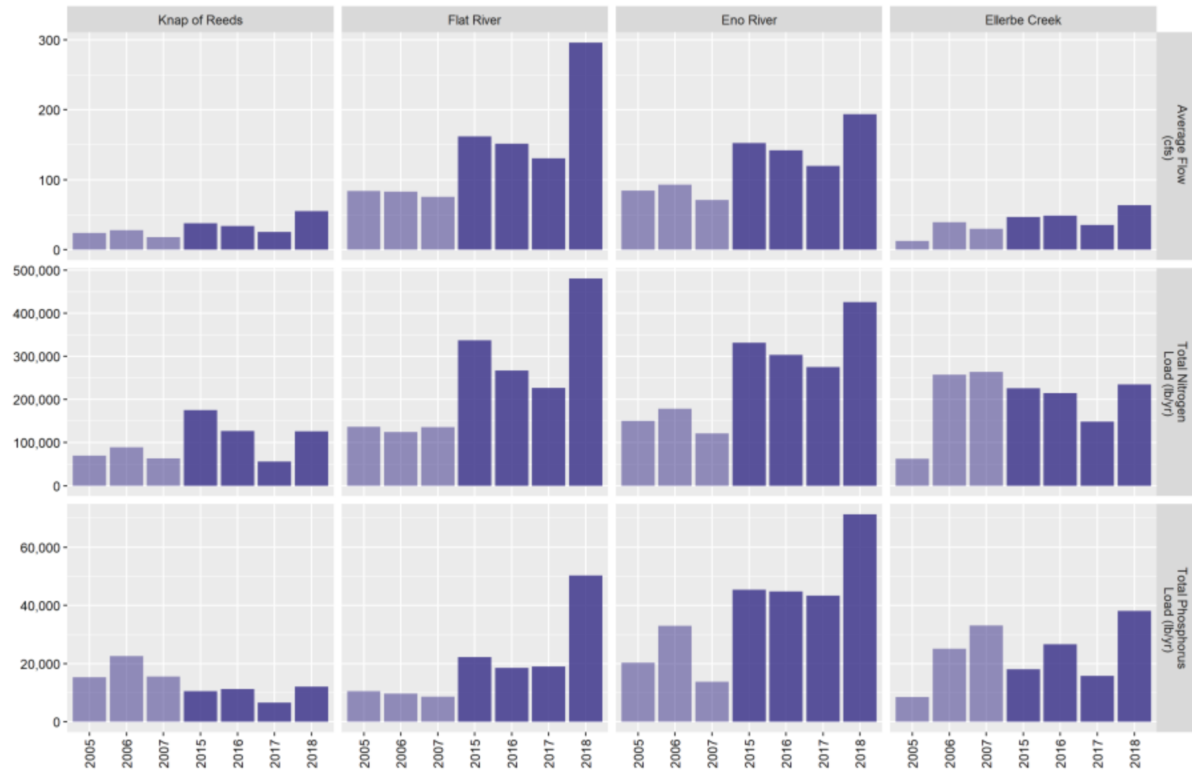
While UNRBA's loading analyses overlap DWR's to some extent, differences in monitoring time periods, stations and methods are such that their results, while also useful, cannot be directly compared to DWR's

UNRBA Estimated Loading Changes Since Baseline

The first UNRBA first analysis provides a holistic view of nutrient inputs to the lake by evaluating changes in nutrient availability inlake since the 2006 baseline. This analysis expands on DWR's LOADEST analysis of the upper five tributaries by capturing the combined effects of all 18 lake tributaries. For this comparison, the DWR Falls Lake Environmental Fluid Dynamics Code (EFDC) model was used to provide estimates of loading from all tributaries in 2006 and compared against LOADEST estimates of tributary loads for the UNRBA's recent monitoring period (2015-2018). Other sources of loading to the lake such as atmospheric deposition and internal loading from lake sediments were also included.

Results from this analysis show that from 2006 to 2017, total nitrogen and total phosphorus loads to the Lake have decreased by 13 percent and 15 percent, respectively (Figure 19). Interestingly, the lower nutrient load of 2017 contrasted against the higher chlorophyll *a* levels that year which suggests that current loading is not the only driver of algal growth in the lake. These results highlight that tributary loading is only one aspect of loading experienced by the lake and these other nutrient inputs will need to be considered as the management strategy is revisited through the rules reexamination process.

FIGURE 19. ANNUAL FLOWS AND LOADS FOR BOTH BASELINE AND UNRBA MONITORING PERIOD



Source: UNRBA 2019 Final Monitoring Report

UNRBA Estimated Nutrient Loading Changes Since Lake Impoundment

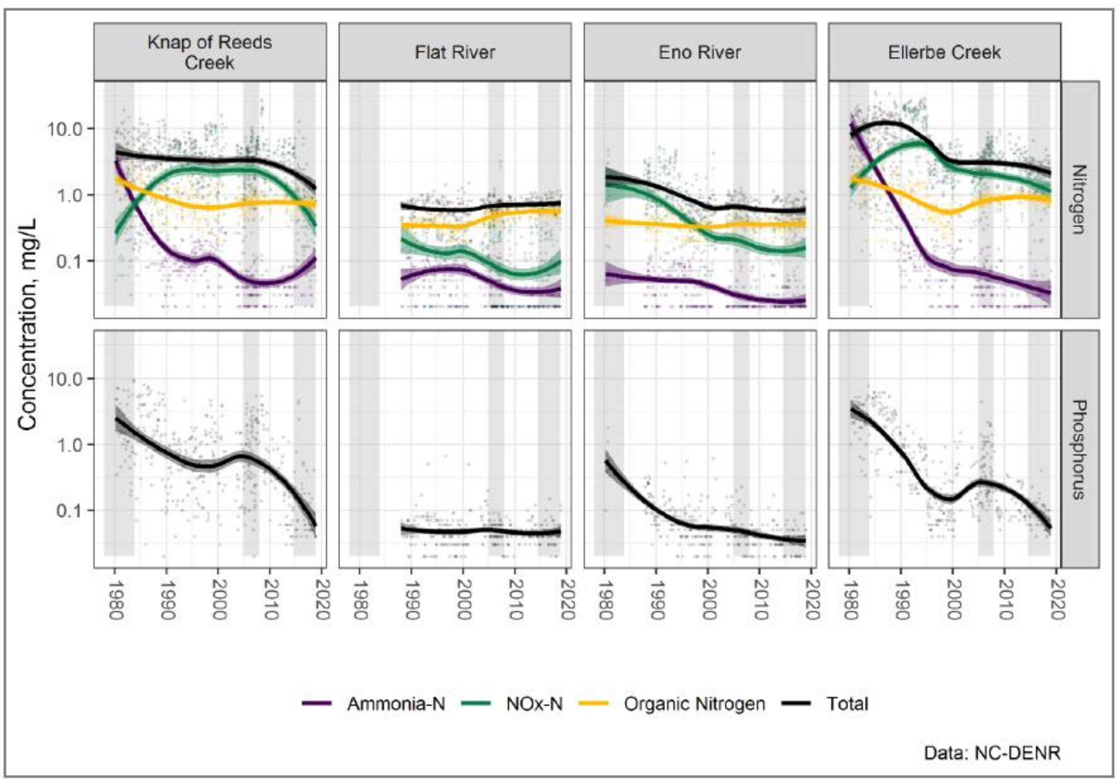
The UNRBA also developed a retrospective analysis using a generalized additive model (GAM) to estimate tributary nutrient loading for three tributaries to Falls Lake (Eno River, Ellerbe Creek, and Knap of Reeds Creek). These three tributaries each receive discharge from a major wastewater treatment plant and have been monitored monthly near their outlet to the lake since the 1980s when the reservoir was created. Unlike the LOADEST method used by both DWR and the UNRBA, the GAM method can handle a larger dataset allowing the entire historical dataset, starting back in the 1980's, to allow for comparison of the post-impoundment loading experienced when the lake was first filled to the more recent monitoring period.

Results of this analysis show that between the lake being filled in the early 1980's and 2018, total nitrogen loads from these three tributaries decreased by approximately 60 percent and total phosphorus loads decreased by approximately 90 percent. While at the same time total discharge from these three tributaries was approximately 50 percent higher in 2018 compared to 1983 due to higher rainfall totals is 2018 as a result of several winter storms and Tropical Storms Florence and Michael. The increase in flow but decrease in overall nutrient load strongly suggests the reductions driven by wastewater treatment plant improvements and implementation of the phosphate detergent ban in the mid-1990s. This is further supported by the results that indicated the year-to-year variation of tributary loads was primarily the result of differences in how much water was moving through the tributary (UNRBA, 2019).

Results also showed significant decreases in nitrogen and phosphorus concentrations in Knap of Reeds Creek and Ellerbe Creek since the lake was impounded in the early 1980's (Figure 20). Ammonia concentrations have also decreased substantially in both Knap of Reeds and Ellerbe Creeks, while nitrate plus nitrite has fluctuated over time.

Nutrient concentrations in the Flat and Eno Rivers show less change over time, which is not all that surprising given the higher stream flows in recent years since these two watershed are dominated by nonpoint sources while the reductions in nitrogen and phosphorus concentrations in Knap of Reeds and Ellerbe Creeks are likely a reflection of the major nutrient reductions achieved by the wastewater treatment plants located in those two watersheds.

FIGURE 20. NITROGEN AND PHOSPHORUS CONCENTRATIONS (1980 THROUGH 2018)



Source: UNRBA 2019 Final Monitoring Report

UNRBA Transition Monitoring

The UNRBA Transition Monitoring Program began in November 2018 following completion of the full UNRBA Monitoring Program. This scaled-back monitoring program continued monthly sample collection at 12 stations in the watershed through June 2020 to track water quality conditions on tributaries that are not monitored by other organizations. The data collected through this effort will be used to aid the adaptive management and improve understanding of how weather events affect loading and lake response. Based on the samples collected between 2018 and 2020, water quality conditions in the watershed did not appear significantly different than the conditions observed during the UNRBA's routine monitoring period of 2015 to 2018.

State of Knowledge

In addition to lake loading progress, 5-year Falls reports are to address advances in various nutrient management disciplines, technologies, and accounting processes pertinent to the Falls Lake strategy. The results of staff's inquiries are provided below. For orientation purposes, at the start of each topic, excerpts of the guiding rule text are provided, with the preface for each charge provided in Sub-Item (5)(b) of the rule and understood to be that the report shall address the stated subject. The entire segment of the Purpose and Scope rule establishing the scope of the report is provided in Appendix I.

This section of the report also includes summaries or relevant studies and evaluations either completed or ongoing by the UNC Collaboratory as part of their Falls Lake Study as well as Special Studies conducted by the UNRBA for their ongoing Stage II re-examination process.

Wastewater Improvements Made and Technology Outlook

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

This section provides a summary of the technology that was employed by each of the three major wastewater treatment plants in the upper Falls watershed to meet their Stage I allocations by 2016. It also provides an overview of new technologies and waste management options they may need to explore in order to meet Stage II allocations by 2036, and the current outlook for those options. Stage I mass limits for the Upper Falls dischargers are equivalent on average to 3.09 mg/L TN and 0.34 mg/L TP at 110 percent of current flows (an allowance selected for 2016 flows). These are currently achievable using biological nutrient removal technology at current daily flow conditions. The Stage 2 mass limits, on the other hand, are the most stringent the Division has ever proposed, equivalent to approximately 1.1 mg/L TN and 0.06 mg/L TP at the facilities' full permitted flows. At full flow, these limits are beyond the reach of economically achievable biological nutrient treatment technology.

For the sake of comparison, treatment levels for best available technology (BAT) are commonly cited as 3.0-3.5 mg/L TN and 0.05-0.5 mg/L TP in southern climates. Thus, Falls Lake dischargers using current treatment technologies would not meet the Stage 2 mass limits for nitrogen, at least not when the facilities reach their full permitted flows (mass = flow x concentration). However, it is still reasonable to expect that, with more experience in the operation of nutrient treatment processes and with further improvements in treatment technologies, performance will move closer to the Stage 2 limits. In fact, we have already seen progress in the ten years since the strategy was first adopted:

- Several facilities in the lower Neuse River basin have achieved an annual average TN less than 2.0 mg/L in recent years,
- Operations-based approaches are achieving significant reductions and forestalling major upgrades across the country, and
- At least one promising new technology (the anammox process) has emerged and that is now employed at both the North and South Durham WWTP.

It remains to be seen what advances can be realized in the next ten years. The Division will continue to monitor these developments and provide further updates on advances in treatment technology in the next report in 2025.

Before the Falls Lake rules went into effect in 2011, dischargers in the upper Falls watershed were already subject to nitrogen limits under the existing Neuse nutrient strategy that, at permitted flows, require moderate biological nutrient removal (5.5 mg/L TN at full permitted flows). Each of the facilities also had in place a land application program to dispose of wastewater residuals and biosolids. Chemical addition and gravity settling have been used to remove phosphorus.

Since the Falls rules went into effect, each of the upper Falls facilities has taken significant steps towards reducing the nutrient loads and continue to discharge nitrogen and phosphorus well below their Stage I allocations through a combination of optimized system management and treatment technology upgrades.

Current Wastewater Treatment Technology

Nitrogen removal technology for municipal wastewater discharges has existed for decades but was used only rarely until the mid-1990s. Performance continues to improve as the technology evolves and operators and consultants become more experienced with the new systems. The accepted limits of biological nutrient removal technology have decreased from 6-8 mg/L TN in the late 1980s and early 1990s to 3.5 mg/L in the late 1990s, then to 3.0 mg/L in the last decade. Today it appears that 2.0 mg/L or less total nitrogen is potentially attainable, about a third as much as considered attainable less than 20 years ago (DWR, 2010).

Phosphorus removal from wastewater can be achieved through either chemical removal or biological treatment or a combination of both. Chemical phosphorus removal typically involves precipitating influent phosphorus by adding an iron or aluminum salt to the treatment process. Some of the disadvantages of chemical phosphorus removal are increased storage requirements and sludge production increases. Biological phosphorus removal is achieved by processing influent wastewater through an anaerobic and aerobic sequence where polyphosphate accumulating organisms take up excess phosphorus. The main advantages of biological phosphorus removal are reduced costs and less sludge production compared to chemical precipitation.

The following is a brief summary of recent upgrades and current nitrogen and phosphorus treatment technologies used at each wastewater facility in the upper watershed.

North Durham Water Reclamation Facility (WRF)

The North Durham WRF has a permitted capacity of 20 million gallons per day (MGD) and discharges an average 10.5 MGD into Ellerbe Creek. The facility currently uses a 12.5 MGD flow train, including flow equalization, a 5-stage biological phosphorus-nitrogen removal activated sludge process, deep-bed effluent filters and a supplemental carbon and alum feed building. The 5-stage biological nutrient removal flow train was designed and constructed in 1995. A supplemental carbon and alum feed building was completed in 2014, resulting in significant decreases in phosphorus discharge. A bulk water reuse station was also brought online in 2016. Ongoing optimization of these existing processes has reduced nitrogen discharges well below the Stage I permit requirements.

A master plan for future phased expansion and attainment of more stringent effluent standards was completed in 2012. This planning effort covers the next 20 years of operation and addresses a number of improvements to meet the Falls wastewater rule requirements. Phase 1 of the North Durham Water Reclamation Facility (NDWRF) Process Improvements Project began construction in early 2018. This represents the first phase of major plant improvements recommended in the 2012 WRF Master Plan. These improvements are expected to be complete by June 2021. The construction costs of these improvements is approximately $30M, and includes the following related to nutrient reduction:

- Aeration basin diffuser replacement
- New aeration basin influent and effluent channel mixers
- Two new secondary clarifiers
- Equalization for new ANITA™ Mox sidestream facility
- Reclaimed water distribution line to the new Water Management administration facility

The optimization of existing processes at the North Durham plant has reduced nitrogen discharges well below the Stage I permit requirements with average nitrogen discharge concentrations ranging between 1.90 to 2.90 mg/L over the past five years. Future process improvement projects currently in the design stage include new aeration basins, construction of the ANITA™ Mox sidestream facility and effluent filter media replacements that will provide the ability to denitrify in the filters.

The North Durham Plant has used a number of strategies to reduce phosphorus in the discharge. They currently use their 5-stage Biological Nutrient Removal Process (BNR) process and alum addition to maintain a phosphorus discharge that is consistently 50 percent or more below their allowed phosphorus allocation. Average phosphorus discharge concentrations from the North Durham Plant over the past five years have ranged between 0.08 to 0.18mg/L.

Current ongoing projects at the facility will add side stream equalization to balance the nutrient load throughout the day. Future projects under consideration include repurposing phosphorous removed from the waste stream into fertilizer pellets.

South Granville Sewer & Water Authority (SGWASA)

The 5.5 MGD South Granville Water and Sewer Authority (SGWASA) Water Treatment Facility currently discharges at an average of 2.0 MGD. The facility completed a $30 million upgrade in 2017 that improved the overall system performance and continues to fully meet its Stage 1 discharge requirements.

The facility upgrades consisted of numerous improvements to different treatment processes, including the construction of a new pretreatment area with dual mechanical step screens including a manual bar screen and grit removal system. The upgraded pretreatment area also includes a new influent pump station with seven vertical turbine pump and two 2.5 MG Equalization Tanks (E.Q.) to help control flows through the facility.

After passing through the pretreatment area, wastewater is then treated through anaerobic and anoxic zones followed by oxidation basins where the denitrification and nitrification process is accomplished. This is followed by secondary clarification. These treatment processes combine to make up the 5-stage Bardenpho Biological Nutrient Removal (BNR) process. Clarified effluent is pumped to the denitrification filter system where filtration and denitrification continues where there is a carbon source fed chemical (Glycerin). A new chemical feed system was installed for other chemicals used at the plant. Waste activated sludge is pumped to aerobic digesters for digestion, digested sludge is dewatered using a screw press where it is stored under a covered solids facility pad, dewatered and thickened sludge is then land applied as biosolids.

The upgrades to the facility also included a new Supervisory Control and Data Acquisition (SCADA) program that communicates with most of the infrastructure onsite. With the new technology included in the facility upgrade SGWASA has been able to obtain average nitrogen discharge concentrations ranging between 1.70 to 2.67 mg/L over the past five years.

Phosphorus reductions at SGWASA are also achieved through treatment using their phosphorus biologically in their five-stage BNR process and through chemical removal by feeding some aluminum sulfate into the process. Average phosphorus discharge concentrations from SGWASA over the past five years have ranged between 0.10 to 0.34 mg/L.

Hillsborough Wastewater Treatment Plant

The Hillsborough treatment plant has the capacity to treat up to 3 MGD and is currently operating at slightly under half capacity. A $19 million expansion and upgrade of the plant was completed in 2014. The facility's 2 stage activated sludge treatment process was upgraded to a 5-stage biological nutrient removal process which included installation of new denitrification filters, new clarifiers, and solids processing. Treated water is discharged to the Eno River. Stabilized waste solids are reused as a soil amendment/fertilizer on several neighboring agricultural fields or transported to a composting facility. Over the past five years the Hillsborough plant has maintained average nitrogen discharge concentrations ranging between 1.45 to 1.94 mg/L.

The tertiary treatment system at Hillsborough is already set-up to meet its phosphorus Stage II limits. The process uses a flash mixer with flocculation which allows them to utilize a coagulant followed by polymer before filtration. The current average phosphorus discharge concentrations from the Hillsborough treatment plant over the past five years have ranged between 0.16 to 0.77 mg/L. It is anticipated that the current process can be optimized in the future to achieve the Stage II treatment needed to achieve annual total-phosphorus concentrations below 0.1 mg/L.

Advanced & Improved Wastewater Treatment Technology Options

Depending on how quickly their flows increase, the upper Falls facilities may have to apply more advanced treatment technologies to continue meeting their Stage I nutrient limits. They will certainly have to do so to meet their final Stage II limits, which under the current rules are required to be met by calendar year 2036. The upper Falls dischargers currently rely on conventional biological nutrient removal processes to remove as much nitrogen as possible and more advanced technologies to achieve further reductions. Phosphorus removal is currently being achieved at each facility through a combination of both chemical and biological processes. All three of the upper Falls dischargers have evaluated available technologies and concluded that presently reverse osmosis systems are the most likely approach to effectively meet the proposed Stage II nitrogen limits. The Stage II phosphorus limits will require additional optimization of their current chemical and biological removal processes and likely require some sort of advanced side stream treatment.

The advance phosphorus treatment process needed to meet the required Stage II limits would greatly increase operational costs, but is considered to be achievable. By comparison, the nitrogen reductions needed to achieve the Stage II nitrogen concentrations needed will be much more difficult and exponentially more expensive to achieve.

Reverse Osmosis – Nitrogen Removal

Reverse osmosis or ion exchange may be able to reduce nitrogen concentrations to 1 mg/L or lower. Reverse osmosis systems work by concentrating pollutants and other materials found in wastewater, separating it into a high-quality effluent stream (approximately 75 percent of the total flow) and a ‘reject’ stream (25 percent). Cost estimates for reverse osmosis units vary based on the amount of reject water produced. Even when used in series, this form of treatment could result in a total volume of reject water that exceeds 500,000 gallons per day. There is considerable uncertainty about how to properly manage this reject stream, which casts doubt on the feasibility of relying entirely on reverse osmosis for nutrient removal.

Reverse osmosis systems are rarely used to treat municipal wastewater on this scale, thus experience is limited and actual performance and true costs are uncertain. Also, impacts on the rest of the plant’s operations are uncertain. Questions remain regarding how the reverse osmosis process will affect solids handling and disposal, side-stream management, and general operations.

Capital costs for reverse osmosis are high, perhaps $16-18 per gallon of treatment capacity compared to $1-3 per gallon for biological nutrient removal upgrades. These high costs result in part because extensive pretreatment such as membrane filtration is necessary to maximize the service life of the reverse osmosis units. Membrane filtration and reverse osmosis units are also energy-intensive, so their operating costs are high and potentially volatile as well.

Sidestream Enhanced Biological Phosphorus Removal

Sidestream enhanced biological phosphorus removal (S2EBPR) is an emerging alternative process to address common challenges with conventional biological treatment of phosphorus. Biological phosphorus removal has been used for decades, but requires expensive standby chemical to achieve reliable and consistent performance. Advancements in the understanding of the activated sludge process over the past 10 years have shown that diverting a portion of the biomass from the sludge generated from conventional treatment to a “sidestream” reactor creates fermentative conditions. These conditions produce a more diverse microbe population that increases phosphorus removal performance and stability (Downing, 2020)

According to an ongoing project funded through the Water Research Foundation (WRF) and lead by researchers at Black & Veatch and Cornell University, facilities in North America have experimented with S2EBPR over the past several years. However, there is no standard approach to its application.

One of the main drivers for this project is to capture treatment data generated by these facilities and existing studies to consolidate the information and develop definitive recommendations for design of this advanced biological phosphorus removal process. Nineteen facilities ranging between 1 MGD and 350 MGD are participating in this research project which is expected to be completed within the next two years.

Source Controls

Source controls refers to the process of reducing nutrient contributions at the sources. Where dischargers to the municipal system are industries with significant nutrient levels, this can be an effective means of reducing a treatment plant's nutrient discharge. This approach has limited utility in the Falls watershed, as none of the municipal plants has industrial users that are major nutrient sources.

Other Emerging Wastewater Treatment Technologies

In March 2013 the EPA published *"Emerging Technologies for Wastewater Treatment and In-Plant Wet Weather Management,"* which provides an overview of recent innovative and emerging wastewater treatment technologies. One promising treatment technology included in this guidance document is the use of Anammox bacteria in a biological nitrogen removal process. The process can save up to 63 percent of the oxygen demand (energy) compared to conventional nitrification/denitrification. It can achieve up to 95 percent ammonia removal and produces much less biosolids in comparison to existing processes (Tetra Tech, 2013a). Wastewater researchers and designers are still exploring the nature of this new treatment process, the range of applications and conditions for which it well suited, appropriate design and operating parameters, and actual performance in full scale applications. The City of Durham's Anita™ Mox process for side-stream treatment was placed into service at the South Durham Water Reclamation Facility in November 2015. This site, which discharges into the Upper New Hope Arm of Jordan Lake, is the first installation in North Carolina and second in the United States. Currently, the process is meeting removal projections of 60 percent in both reactors. Based on the results of the pilot process at the South Durham facility, the City of Durham also started using this process at their the North Durham WRF in 2016.

Outlook for Falls Dischargers

While emerging technologies like those discussed above will be available as the Falls strategy enters Stage II, the overall economic feasibility of using those technologies may be a determing factor in whether they can be implemented. In the meantime, it appears likely that point source dischargers in the upper Falls watershed will ultimately rely on a combination of advanced treatment technology and wastewater reuse to meet their final nutrient limits. While large-scale reuse has not been seen as a cost-effective option in the past, it may become more desirable when compared with far more expensive advanced treatment alternatives.

Current and Projected Extent of Reuse & Land Application

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

Land application is considered a reasonably effective means of dealing with the sludge generated by wastewater treatment processes when done according to state permits. In most cases, residuals application is limited based on agronomic rates to meet plant needs, such that they displace the use of commercial fertilizer that would presumably otherwise be applied to fields. Under this logic, nutrient loading rates to the environment are not increased as a result. However, residuals application generally has raised concerns among various interests based more on other constituents of the waste stream that are concentrated in this process bi-product.

The North Durham Water Reclamation Facility (NDWRF) and South Granville Water and Sewer Association (SGWASA) have active permits to land apply residual solids originating from their wastewater treatment facilities. Since the 2006 baseline year, land application of these residuals have remained fairly stable in terms of volumes applied, with no discernable trend apparent (Table 9). Hillsborough discontinued its land application activities in 2013 in favor of offsite composting for its residuals.

TABLE 9. LAND APPLICATION OF WWTP RESIDUALS IN FALLS LAKE WATERSHED (DRY TONS)

Year	SGWASA	Hillsborough	Durham	Total WWTP Residuals
2006	0	281	4,532	4,813
2007	378	216	5,751	6,345
2008	235	263	4,347	4,845
2009	273	238	3,845	4,356
2010	283	335	5,161	5,779
2011	308	294	3,583	4,185
2012	238	228	4,070	4,536
2013	357	0	3,306	3,663
2014	339	0	4,850	5,189
2015	304	0	5,009	5,313
2016	282	0	6,620	6,902
2017	226	0	5,600	5,826
2018	307	0	3,929	4,236
2019	453	0	5,245	5,698

Wastewater Reuse

Wastewater reuse programs can be an effective means of reducing a facility's nutrient loads by reducing its discharge flows, providing another tool to help a facility stay within its allocation as growth occurs. In reuse, a portion of the treated effluent is diverted from discharge and either applied to land or reclaimed for beneficial uses like irrigation, cooling water supply, or process uses. Opportunities for land application or irrigation in the Falls watershed are limited due to unfavorable soil conditions and topography. Suitable sites also tend to be relatively small and fragmented, making it more difficult and expensive to establish distribution lines to those sites.

None of the three major dischargers in the Falls watershed have a formal reuse program, but in 2016 NDWRF did add a bulk water reuse station that is used for toilet flushing in their new Water Management administration facility.

Stormwater Treatment Technology

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

Significant and ongoing improvements to stormwater treatment technologies have continued to be developed over the past five years. These improvements include the addition of several nutrient-reducing stormwater control measures, development of credit for design variants of existing practices and significant updates to the DEMLR Stormwater Program's rules and guidance documentation to codify practice design criteria in rule to comply with recent legislative mandates. These updates have applicability in both new development and existing development settings in the Falls watershed and are summarized below.

Updated Stormwater Design Manual

In 2017, NCDEMLR updated their Stormwater Design Manual (SDM) to include updated practice-by-practice information on SCM maintenance, inspection and repair requirements. The Manual now also provides more detailed design specifications for SCMs to meet the Minimum Design Criteria (MDC) that are codified in the readopted state stormwater rules (02H .1001 through 02H .1062), which went into effect on January 1, 2017. The Design Manual and state stormwater rules can be downloaded from the NCDEMLR website at https://deq.nc.gov/sw-bmp-manual.

The Manual also sets out the process for approval of new SCMs. An internal-external stakeholder workgroup is currently revising this process, including an expansion to establish a predictable framework for periodically revising nutrient credits and associated credit accounting methods for existing SCMs. This stakeholder group is currently considering moving the processes for both approving new SCMs and for revising credit for existing ones, to the DEMLR SCM Credit Document, as discussed below, in addition to providing detailed recommendation on process improvements.

SCM Credit Document

A new SCM Credit Document was developed in 2018 through a joint effort between NCDEMLR, DWR, stormwater researchers, and the SCM Crediting Team stakeholders. In addition, the UNRBA with the support of their consultant, Brown & Caldwell, assisted in establishing nutrient credits for design variants for bioretention cells and level spreader-filter strips that are reflected in the SCM Credit Document. The Credit Document provides a first full listing of nutrient-reducing SCMs and their many design variants available for use in new development post-construction settings as well as for retrofitting into existing developed landscapes. The Credit Document was coordinated with DWR's completion of, and reflected the content of, the Stormwater Nitrogen and Phosphorus (SNAP) Accounting Tool, which provided the ability to account for the nutrient loading benefits of this expanded set of SCMs. A fuller discussion of the SNAP Tool is provided in the Accounting Tools section below. The SCM Credit Document provides a summary table of all the DEMLR-approved SCMs and variants with their primary or secondary rating, hydrologic fates of influent, and nutrient effluent concentrations. A second table provides qualitative ratings on other SCM benefits for all of the approved SCMs. These tables are useful for facilitating comparisons between SCMs. Individual chapters detail the technical basis for credit assignments as well as under- and oversizing and design variant options. The current SCM Credit Document is available on the NCDEMLR website at https://deq.nc.gov/sw-bmp-manual.

There are also a number of proprietary SCMs and design variants that are currently under development by the private sector that have the potential to be added to the Credit Document in the next few years. This includes proprietary devices such as StormFilter, Bayfilter as well as Isolator Row.

Meanwhile, NCSU researchers continue to evaluate the effectiveness of several other evolving public domain stormwater technologies like Subsurface Gravel Wetlands and regenerative stormwater conveyance. They are also researching the nutrient removal capabilities of a popular type of "green street" retrofit known as suspended pavement street systems and developing wet pond retrofit guidance as part of the UNC Collaboratory Falls Lake Study. A brief summary of their initial findings is provided in the Collaboratory update provided later in this section. In addition, NCSU is currently winding down a study focusing on the nutrient performance of the Sand Filter stormwater SCM in order to add current, region-specific nutrient performance data to the existing credit basis for this longstanding stormwater practice.

As noted in the Stormwater Design Manual description above, it appears likely that an expanded SCM approval and credit revision process will be added to this document and include instruction on data submittal requirements for new stormwater technologies as well as guidance on how the Crediting Team will review and calculate data submitted for evaluation of nutrient reductions.

Catalog of Nutrient Reduction Practices

In 2020, the Division created a Catalog of Nutrient Reduction Practices to serve as a single reference resource with the most up to date list of eligible nutrient-reducing practices of all types, including stormwater SCMs as well as agricultural, wastewater, and ecosystem practices. For most practices to date, design standards reside with the originating program, such as DEMLR's Stormwater Program, and the Catalog provides reference information to those sources. The Catalog also outlines a streamlined process for approving design standards and associated credit for future candidate types of nutrient load-reducing practices. For candidate new or revised stormwater SCMs, it recognizes NCDEMLR's lead role and approval process, described in the Stormwater Design Manual and Credit Document sections above, for use in new development settings. A draft of the Nutrient Catalog was completed and provided to stakeholders for public comment in November 2020. The catalog was approved by the Division Director in March 2021 and is available on the DWR's Nonpoint Source Planning Branch website at the following url: https://deq.nc.gov/about/divisions/water-resources/planning/nonpoint-source-management/nutrient-offset-information#approved-nutrient-reduction-practices

New (and Existing) Development Stormwater Treatment Practices

Table 10 lists the core set of nutrient-reducing SCMs suitable for both new development post-construction treatment and for retrofitting into existing developed settings, as listed in the Catalog of Nutrient Reduction Practices. As described above, DEMLR's SCM Credit Document provides a full listing of all variants of each practice type along with key nutrient and pollutant performance characteristics for each.

TABLE 10. STATE –APPROVED NUTRIENT REDUCING SCMS

Practice Name	Design Specifications	Credit Method
Infiltration System	SDM / MDC	SNAP
Bioretention Cell	SDM / MDC	SNAP
Wet Pond	SDM / MDC	SNAP
Wet Pond w/ Floating Wetland	SDM / MDC	SNAP
Stormwater Wetland	SDM / MDC	SNAP
Permeable Pavement	SDM / MDC	SNAP
Sand Filter	SDM / MDC	SNAP
Rainwater Harvesting	SDM / MDC	SNAP
Green Roof	SDM / MDC	SNAP
Disconnecting Impervious Surface	SDM / MDC	SNAP
Level Spreader Filter Strip	SDM / MDC	SNAP
Pollutant Removal Swale	SDM / MDC	SNAP
Dry Pond	SDM / MDC	SNAP
Proprietary Stormwater Control Measures		
Silva Cell Suspended Pavement w/ Bioretention	SDM / MDC	SNAP
Filterra	SDM / MDC	SNAP[2]

[1] SDM/MDC – Stormwater Design Manual / Minimum Design Criteria

[2] SNAP – Stormwater Nitrogen and Phosphorus Tool

Municipal Separate Stormwater Sewer Program Updates

Between 2018 and 2019, DEMLR staff restructured the Municipal Separate Storm Sewer System (MS4) Permitting Program to address numerous issues identified by EPA, DEMLR and permittees in recent years. The updates included creating a balanced and sustainable workload for staff, improved technical assistance and program support for permittees, and a clear and consistent permitting process for MS4s.

Numerous tools and training were developed to assist staff and permittees in implementing a compliant program. Tools developed included a suite of standard MS4 templates, an improved web site, and routine outreach to permittees. Training activities included five MS4 workshops statewide to educate permittees on the new MS4 tools and processes, a workshop to train DEMLR staff to perform consistent MS4 audits, and presentations at numerous trade organizations and events. DEMLR staff also attended

EPA inspector training. Once training on the restructured MS4 program was completed, DEMLR staff began performing compliance inspections in accordance with EPA program delegation requirements.

Existing Development-Only Stormwater Treatment Practices

Table 11 provides the current list of DWR Director-approved practices developed by DWR or by a third party as recognized in the North Carolina Nutrient Catalog discussed above. The first five practices listed in Table 11 were all approved during the past five-year reporting period by going through the practice approval process described in the Catalog, which includes working with subject matter experts, vetting by the NSAB and a public comment period before receiving approval from the Division Director. A sixth practice, Cattle Exclusion, was also developed, but its use is contingent upon the completion of a trading framework currently under development by the Division.

Several of these practices were proposed, developed and/or reviewed by organizations that have worked in close partnership with the Division to expand the toolbox of creditable nutrient-reducing practices. Credit development partners that have engaged with DWR to date include the UNRBA, NC Division of Energy, Mineral, and Land Resources (NCDEMLR), the NSAB, and the Agriculture Watershed Oversight Committees (WOCs) in the Falls and Jordan Watersheds.

TABLE 11. STATE –APPROVED NUTRIENT REDUCING EXISTING DEVELOPMENT PRACTICES

Practice Name	Design Specifications	Credit Method
Developed Land Activities		
Remedying Discharging Sand Filters	DWR Practice	DWR Practice
Remedying Illicit Discharges	DWR Practice	DWR Practice
Soil Improvement	DWR Practice	DWR Practice
Storm Drain Cleaning	DWR Practice	DWR Practice
Street Sweeping	DWR Practice	DWR Practice
Other Development Site Activities		
Treatment of Redevelopment	n/a	SNAP
Overtreatment of New Development	n/a	SNAP
Impervious Surface Conversion	n/a	SNAP
Reforestation of Developed Land	n/a	SNAP
Upfitting Existing SCMS	SDM / MDC	SNAP
Wastewater Activities		
Creation of Surplus Allocation	15A 2B .0279	15A 2B .0279
Surplus Allocation via Regionalization	15A 2B .0279	15A 2B .0279

Development of Credit Accounting for Additional Practices

Several additional practices are currently under development and will be added to the Catalog once their credit accounting methods and design specifications have been either updated or completed and successfully gone through the approval process described in the Catalog. The current status of each of these pending practices is provided below. As they are completed, these practices will be added to the

Catalog and be available to affected parties for implementation towards meeting their rule requirements.

Design specifications and nutrient crediting for remedying malfunctioning septic systems is currently under development and is expected to utilize results of additional watershed modeling being conducted by the Upper Neuse River Basin Association in the Falls watershed, which will provide updated data on the nutrient loading from and expanded range of onsite wastewater systems.

Credit accounting for riparian revegetation is currently limited to the practice of restoring riparian forested buffers on agricultural lands. However, the Division is in the process of developing design standards and crediting for the practice of improving riparian zones in urban landscapes. Like the remedying malfunctioning septic systems practice above, a considerable amount of work has already been invested in developing this practice, including a draft practice proposal submitted by the UNRBA. Given the complexity of this practice, the Division plans to reengage subject matter experts for input on this practice over the course of the next year and is also contracting with NCSU to conduct additional research on nutrient exports from pervious covers. The findings from this research will help inform the urban buffer credit method as well as revisions to the SNAP accounting tool.

Stream restoration is another restoration practice currently being evaluated for credit. It is arguably the most challenging and complex credit determination of all the optional practices. The Division has conducted significant evaluation of this practice, starting with the Chesapeake crediting approach. Based in part on the findings of this research, staff are still exploring the best approach for developing design specifications and credit accounting for the multiple components of this practice. Given the complex nature of this practice the Division plans to engage relevant subject matter experts and the NSAB to assist in the development and approval of by the end of 2021. Other practices under development to note are rural buffer restoration and cropland conversion. As discussed in the nutrient offsets section of this report, the Division is considering a transition away from providing static, pre-set literature-based nutrient credits on a per-acre basis for rural buffers. The process for revisiting the credit method for this practice will likely involve multiple subject matter experts and extensive stakeholder input. Work on establishing an approved credit method for cropland conversion has not yet begun, but is anticipated within the next year.

Affected parties may also propose using other practices beyond those they are required to evaluate per the Rule if they can provide accounting methods acceptable to the Division. The Division approval process for such practices is detailed in the Catalog***.*** The Catalog also provides guidance on establishing credit for novel practice installations where a practice's nutrient reduction performance may be insufficiently studied to provide a basis for assigning presumptive credit.

Programmatic Measures Implemented by Local Governments

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

An area of interest during the Falls rulemaking for its potential nutrient credit value was that of programmatic management activities conducted by local governments. Programmatic practices under discussion at the time included street sweeping improvements, illicit discharges to the storm sewer system, fertilizer ordinances, and pet waste ordinances.

Over the past five years, the Division and the UNRBA have continued to collaborate on establishing nutrient reduction credit for programmatic measures to expand the number of cost-effective tools available to assist local governments to address their existing development load reduction requirements. In 2017, the UNRBA successfully developed the nutrient practice document for remedying illicit dischargers to stormwater systems. This was followed by the Street Sweeping and Storm Drain Practice documents, which were completed and approved by DWR in 2019. All three of these programmatic practices are included in the Divisions Nutrient Credit Catalog and are eligible for credit towards meeting the existing development stormwater rule requirements.

For this report, the Division reached out to the local governments in the watershed in late 2020 to collect updated information about any programmatic practices they are currently implementing and whether they are conducting instream monitoring to determine benefits of implementing these practices. Based on the responses, it appears many local governments in the watershed continue to implement, at a minimum, some form of street sweeping and illicit discharge and elimination (IDDE) program. Others have additional measures in place such as programs or ordinances addressing pet waste and fertilizer application on lands managed by the city of county. Programmatic measures currently implemented by local governments in the Falls watershed are summarized below in Table 12.

TABLE 12. PROGRAMMATIC PRACTICES IMPLEMENTED BY FALLS LOCAL GOVERNMENTS

Local Government	Programmatic Practice
Butner	IDDE Program
Creedmoor	Improved Street Sweeping, Pet Waste Ordinance, IDDE Program, Fertilizer Ordinance for City Property, Yard Debris / Storm drain Ordinance
Durham	Public Education on Sanitary Sewer Overflows, Street Sweeping, Stormwater system cleaning (Vactor trucks), Pet Waste Program, Dry Weather Outfall Screening Program, Collection System Inspections, IDDE Program, Yard Waste Program, Land Conservation, Comprehensive Watershed Planning for Retrofit Project Identification, Residential Retrofits Program
Hillsborough	Collection System Inspections , Leaf Collection, Street Sweeping
Raleigh	Public Education Programs, Sanitary Sewer Overflows Prevention and Abatement, Collection System Inspections, Stormwater Systems Inspections and Maintenance, Leaf and Yard Waste Collection, IDDE Program, Street Sweeping, Land Conservation, Sediment and Erosions Control for Projects Disturbing > 12,000 SF, Require Natural Resource Buffers on Watercourses which Exceed NC Buffer Rule Standards.
Roxboro	Pet Waste Ordinance, Collection System Inspections, Street Sweeping, Leaf Collection, Smoke Testing and Video Inspections of Stormwater System (2019)
Stem	None reported
Wake Forest	Public education fertilizer application, Street Sweeping, Leaf and Yard Waste Collection, Anti-Litter Campaign.
Durham County	Voluntary Citizen Fertilizer Reduction
Franklin County	Illicit discharge detection & elimination
Granville County	Increased Septic Inspections Programs
Orange County	IDDE Program, Collection System Inspections
Person County	Septic Remediation Grant Program
Wake County	IDDE Program

Stormwater Retrofitting of Existing Developed Areas

In addition to implementation of programmatic measures already in place, a few Falls communities have already begun actively planning retrofit projects and other nutrient-reducing practices that can be credited towards their existing development requirements either under a local program or a part of the joint compliance IAIA. Projects are in various stages of development (land acquisition, preliminary design, funding). The city of Creedmoor and Durham have indicated they are both planning regional wetlands and wet ponds to treat substantial areas. In recent years, the City of Durham in particular has been implementing a number of pilot projects and grant projects to implement practices that reduce stormwater volume and/or reduce nutrient concentration. The following is an overview of the projects the City of Durham has implemented in the watershed since the Falls Lake Rules have been adopted:

- Rain gardens and cisterns in residential areas continue to be installed through community partnerships with watershed groups, schools, Durham Soil and Water District.
- Two filtration boxes (Silva Cells) were installed with NC State as part of a research opportunity.

- Two Bioretention Cells were installed with Ellerbe Creek Watershed Association and other partners.
- Two existing wet ponds were retrofitted with floating treatment wetlands, with monitoring by NCSU to assess the reductions in TSS, nitrogen and phosphorous (Hillandale Golf Course and NC Museum of Life & Science).
- Installation of a green roof and bioretention cell at the West Village redevelopment of an old cigarette factory.
- Funding of third-party installation of rain gardens (Ellerbe Creek Watershed Association and Durham Soil and Water Conservation District).
- A bioretention area was constructed in Central Park as part of a stream restoration on a tributary of South Ellerbe Creek.
- Several pocket wetlands were constructed in Northgate Park treating runoff entering Ellerbe Creek as part of a stream restoration project.
- Three additional stream restoration projects: Goose Creek (Long Meadow Park and Eastway Elementary School), Ellerbe Creek (ECWA 17), and Lick Creek (SWCD Olive Branch Rd.)

Looking ahead, Durham is continuing its construction of the South Ellerbe Wetland restoration project. Phase 1 which involved the demolition of the existing building has been completed. Phase 2 will be under way shortly to reuse the soils that are to be removed from the site. Phase 3 which is the construction of the wetland will start after Phase 2 has been completed. The City also has a grant project and interlocal agreement to install more residential green infrastructure projects.

Since 2016, the City of Durham has continued its efforts to evaluate Algal Turf Scrubber technology. This technology removes nutrients from fresh water, like Falls Lake, by pumping water through a facility to grow algae. The algae is then harvested and the treated water is returned to its source. Durham completed an Algal Turf Scrubber pilot study in 2017. Data from the pilot study was evaluated and showed that Algal Turf Scrubber technology was a cost-effective way to provide nutrient treatment. Durham has subsequently completed a project in 2020 to identify potential locations for the construction of a full-scale facility. This project looked at factors including water availability, nutrient removal, site development features, construction costs, and permitting considerations.

A map of all of Durham's retrofit and restoration projects treating existing development stormwater is provided in Appendix 5 of this report.

Assessment of Instream Benefits of Programmatic Measures

While there has been extensive monitoring within the Falls watershed over the past five years performed by both the UNRBA and local governments like the City of Durham to track trends in nutrient loading, there have been no watershed-specific studies that specifically tailored to quantify the instream nutrient reduction benefits from implementing programmatic management measures. Lacking targeted studies on this issue, the ongoing evaluation of practice creditability and development of credit estimates is proceeding based on the availability of research findings and accounting methods from similar physiographic regions elsewhere, particularly the Chesapeake watershed.

Updates to Accounting Tools

"(xi) Updates to nutrient loading accounting tools;"

Rule compliance accounting is accomplished through the use of different accounting tools for each source type. Wastewater loading estimates rely on actual end-of-pipe monitoring combined with relatively simple assumptions and mathematical calculations, providing the most certain source loading estimates. Wastewater accounting and annual reporting is in place and no significant improvements are considered necessary. Nonpoint source load estimates inherently involve more uncertainty, and nonpoint management science and accounting tools are evolving. For the regulated Falls nonpoint sources, tools are in place and being used for agriculture, new development stormwater, and existing development stormwater. At the same time, improvements are being completed to the current site-level stormwater tool, a potential replacement tool is in the planning stages, and a watershed-scale practice crediting and tracking tool is also under development. The following is an overview of these accounting tools and a brief summary of recent and anticipated developments.

Stormwater Nitrogen and Phosphorus Accounting Tool (SNAP)

When the Falls New Development Stormwater Rule was adopted in 2011 the Jordan/Falls Stormwater Tool was the site-level runoff load estimator used by developers to determine site load reduction needs and demonstrate compliance with the New Development rule nutrient export targets. The tool was also designed to be applied to existing development to calculate reduction credit for stormwater BMP retrofits. Improvements to the tool were initiated in 2013. In 2018 significant updates were made to the tool and it was renamed the Stormwater Nitrogen and Phosphorus (SNAP) tool.

Like its predecessor, the SNAP tool moves away from the fixed percent nutrient removal efficiencies used in most stormwater tools. It instead assumes fixed effluent concentrations specific to individual BMPs regardless of influent concentration, an approach that more accurately represents stormwater treatment processes as determined by substantial research in-state corroborated by findings nationally and internationally. This methodological change better reflects the greater treatment efficiencies seen on sites with higher runoff nutrient concentrations. A second advancement incorporated into the design of the tool is adding explicit estimation of and accounting for the infiltration and evapotranspiration that occurs as stormwater passes through a BMP, crediting this loss of volume toward nutrient load reduction.

The most notable updates made to the SNAP tool in 2018 are the improved ability to estimate credit for an oversized or undersized practice, which is especially useful for existing development retrofits, and the addition of several BMPs capturing advances in design and performance science including a custom BMP option that allows user specification and credit estimation for emerging and future creditable practices. In addition, refinements have been made to concentration values for several land covers and BMPs, and numerous user-friendliness improvements were made along with the development of a greatly expanded and revised user manual for the tool.

Future updates planned for the tool in the next two years include developing a SNAP-compatible worksheet to convert from lot sizes to land cover amounts and from dwelling units to land cover amounts. The tool will also be updated for use in the Neuse and Tar-Pamlico basin to show compliance with their revised stormwater rules which were readopted in 2020.

Storm EZ-Tool

Storm-EZ is another site-level runoff estimator that currently focuses entirely on hydrology and can be used by developers to demonstrate compliance with Low Impact Development criteria. Use of Storm-EZ is voluntary. In May 2014 Falls Lake local governments were notified that the Division would accept the results of the Storm-EZ tool with some adjustments for nutrient compliance on developments that meet LID criteria. The Division is currently in discussions with DEMLR concerning a merger of the SNAP Tool and Storm-EZ into a single combined tool for all stormwater programs to improve efficiency and utility to the development community and local governments for both new and existing development. This process is currently in the data-collection and evaluation phase.

The Storm-EZ tool is based on the Natural Resources Conservation Service discrete curve number method and current research on stormwater control measures. Designers enter data about the site plan and the stormwater control measures that will be used. The tool then reports how closely the project matches the pre-development runoff volumes. Storm-EZ can also be used to judge compliance with the "basic treatment" approach (85 percent TSS removal) or a hybrid approach of low impact development practices used in conjunction with basic treatment. There have been no additional updates made to the Storm-EZ Tool since it was first made available in 2014.

UNRBA Credit Tool

The UNRBA Credit Tool is based off a modified version of the Watershed Treatment Model (WTM) developed by the Center for Watershed Protection, Inc. It is a spreadsheet-based tool developed by the UNRBA to facilitate existing development rule compliance under individual local programs. It accepts the BMP credit outputs of site-level stormwater tools and adds the ability to estimate credit for watershed-scale programmatic practices and non-urban practices as well as estimate delivered load reductions to Falls Lake. It provides for tracking and reporting all practices. Development of the modified WTM was completed in 2016. While most of the local governments in Falls have indicated their intent to meet the existing development rule Stage 1 requirements using the investment based IAIA Program, the UNRBA Credit tool remains an available option to them for tracking nutrient reductions where applicable. A separate reporting tool for the IAIA is under development by the UNRBA.

Agriculture Nitrogen Loss Estimation Worksheet Tool

The agricultural sector uses the Nitrogen Loss Estimation Worksheet (NLEW) to track progress towards achieving the required nitrogen reductions under the collective compliance approach provided in the Falls Lake agriculture rule. NLEW is an empirical spreadsheet-based estimator of N loss from edge-of-field that captures changes in loss from changed application rates, changes to crop acres and BMP implementation. For rule compliance a county-scale version is run annually and results compared to baseline values. In 2016 the N.C. Division of Soil and Water Conservation secured funding to make several updates to the tool during the winter of 2016. These updates to the NLEW tool were completed in 2017 and included:

- Updated realistic yield expectations (RYE) for current crops
- Updated soil management groups
- Development method for adding RYE for new crops in future years
- Simplification and automation of data import and export
- Synchronization of data sources across NLEW and Nutrient Management Software
- Upgrades for obsolete software according to C+ programming language
- Maintenance of software code on N.C. Department of Agriculture and Consumer Services servers (currently stored on CD-ROM and N.C. State University servers)

In the summer of 2016, the Falls WOC also made changes to the pasture accounting method used for compliance with the agriculture rule. The old "pasture point" system that assigned points for pasture BMP's was replaced with a system that utilizes the NLEW Tool to estimate reductions in nitrogen loss from pasture over time. Pasture nitrogen loss accounting relies on USDA-NASS data which is gathered via the Census of Agriculture every five years.

Utilization of Nutrient Offsets & Upcoming Program Changes

"(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;"

In the Falls Lake watershed, a developer must meet nutrient loading rate targets of 2.2 lbs. N/acre/year and 0.33 lbs. P/acre/year for stormwater exiting the property. The developer's nutrient load is calculated using the development plan and the SNAP stormwater accounting tool. Most developments exceed the rate targets absent any stormwater treatment practices. The Falls New Development Stormwater rule requires 30 to 50 percent of the total load reduction needs to be met onsite using such stormwater practices. Once that obligation is met, the developer may pay an in-lieu fee to purchase the remainder of their nutrient loads as credit from an offsite reduction activity to meet the loading rate targets, a process referred to as nutrient offset.

The nutrient offset rule, NCAC 02B .0703, generally establishes standards for the creation of nutrient offset credits by the Division of Mitigation Services and private nutrient offset providers. These credits are purchased by regulated parties to earn nutrient credit away from their project site when it provides a more cost-effective compliance option. The regulatory objective of this rule is to lower the costs of rule compliance while achieving equivalent nutrient reductions elsewhere. To meet this objective and ensure the integrity of the trading market, credited nutrient reductions must be equivalent in magnitude and certainty with the excess nutrient loading increases allowed by their use.

Nutrient offset has evolved over time through a series of session laws into a 2-option system; private offset banks and the N.C. Division of Mitigation Services (DMS) in-lieu fee program. While there are multiple options for obtaining offsets, the purchase of third-party offsets from private banks is the most popular. This is because most local government entities and all private developers seeking third-party nutrient offsets must do so through a state-approved private nutrient bank within the watershed where the development project is located (G.S. §143-214.26). When credit from approved private banks is not available, seekers of nutrient offsets are then eligible to participate in the DMS Nutrient Offset Program. Some local governments and state and federal entities are exempt from this requirement and may choose to use either a private bank or the In-Lieu Fee program. There is also at least one local governments in the Falls watershed that is exploring developing their own nutrient bank to offset future impacts within their jurisdiction.

The trend in North Carolina over the past decade has been toward using the least cost alternative for offset credits, despite the preference of local governments to have offsets implemented closer to the impacts. Because of their relative low cost, the predominant practice used by nutrient credit providers is restoration and enhancement of farmed riparian areas into protected forested buffers that reduce nutrients by filtering farm runoff. Presently these practices are credited at a rate of 75.77 lbs. N/acre/year nitrogen and 4.88 lbs. P/acre/year. Assuming a life expectancy of 30 years, riparian buffers have a lifetime credit value of 2,273 lbs. N/acre and 146.4 lbs. P/acre. While an increasing number of other practices described in preceding sections are eligible to generate nutrient reduction credit for sale, they have not typically been as cost-effective as the reforestation of riparian areas.

Nutrient Offset Utilization Trends

There are currently seven private banks established in the Falls Lake watershed for the purpose of providing of nutrient offset credits. Six of these banks are in the upper Falls watershed. Three of the seven banks were approved in past three years. Additionally, DMS has two nutrient offset projects in the upper watershed. As of December 30, 2020, all of the private banks and DMS projects have completed in-ground restoration at their respective sites. An overview of all nutrient transactions from the banks and DMS projects is provided in Table 13.

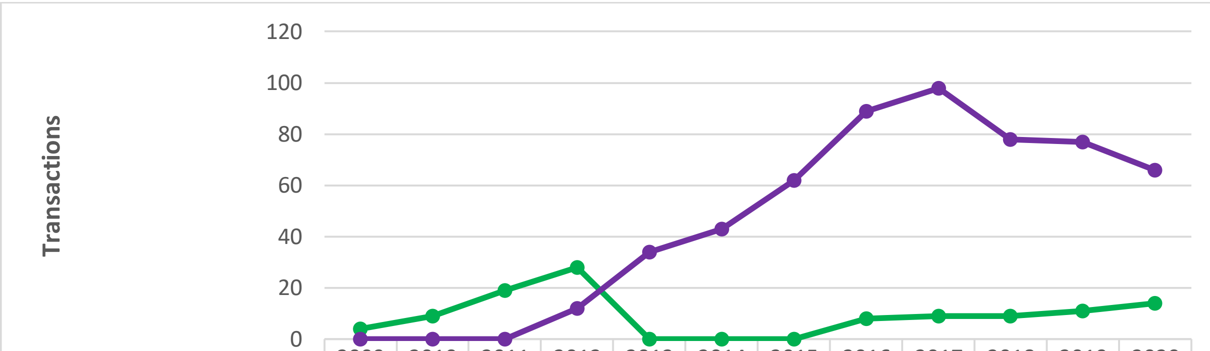
TABLE 13. THIRD-PARTY OFFSITE LAKE WATERSHED NUTRIENT TRANSACTIONS THROUGH 2020

	Nitrogen	Phosphorus
Private bank transactions	295	264
Private bank credits sold (lbs.)	99,594	11,999
DMS transactions	46	65
DMS credits sold (lbs.)	15,336	4,409
All transactions	107	68
Total credits (lbs.)	114,930	16,408

Nutrient credits were available in the Falls Lake watershed as early as 2009 to facilitate compliance with the Neuse nutrient strategy stormwater rule, with DMS responsible for the bulk of these transactions through 2012. However, with the legislative establishment of a preference for private bank credits and the approval of the seven private mitigation banks, between 2012 and 2016 virtually all nutrient offset payments were made to private banks. Since then, DMS has accepted nutrient offset payments when private bank credits have not been available for purchase.

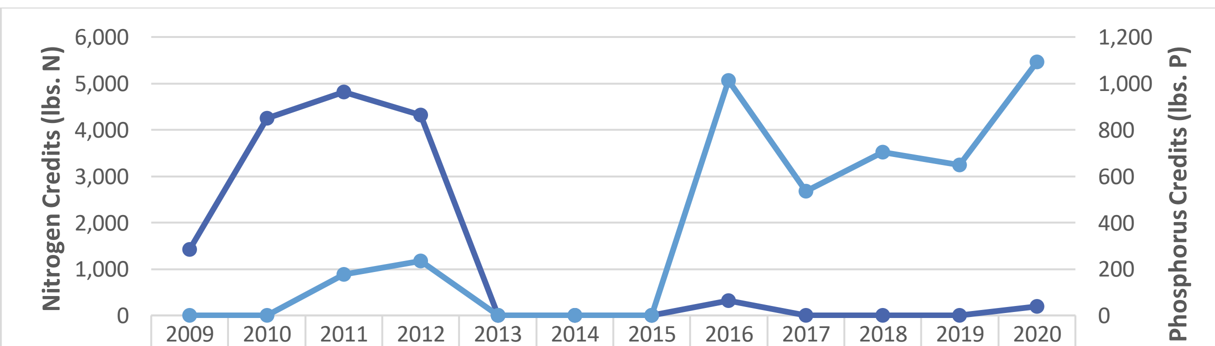
The rate of nutrient offset credit transactions and number of credits sold appears to be generally increasing in the watershed largely precipitated by implementation of the Falls new development rule (Figures 21 and 22). The number of nutrient offset credit transactions and credits sold annually between 2016 and 2020 has increased compared to the previous five-year period, but remains fairly stable year to year with a slight dip in activity in 2020 that is likely related to a slowdown in construction projects due to the COVID pandemic.

FIGURE 21. NUTRIENT OFFSET TRANSACTIONS IN THE FALLS LAKE WATERSHED



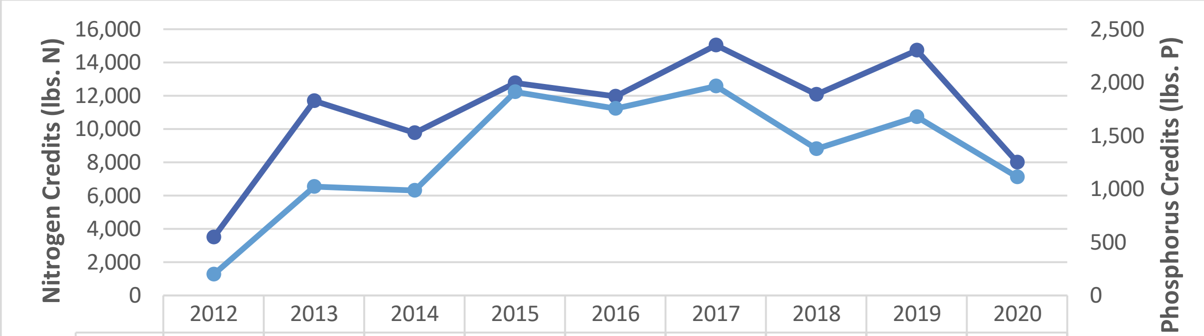
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
DMS (N & P)	4	9	19	28	0	0	0	8	9	9	11	14
Private Banks (N & P)	0	0	0	12	34	43	62	89	98	78	77	66

FIGURE 22. DMS IN-LIEU FEE NUTRIENT OFFSET CREDITS SOLD IN THE FALLS LAKE WATERSHED



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
N	1,419	4,259	4,818	4,322	0	0	0	320	0	0	0	198
P	0	0	178	236	0	0	0	1,014	535	703	648	1,094

FIGURE 23. PRIVATE BANK NUTRIENT CREDITS SOLD IN THE FALLS LAKE WATERSHED

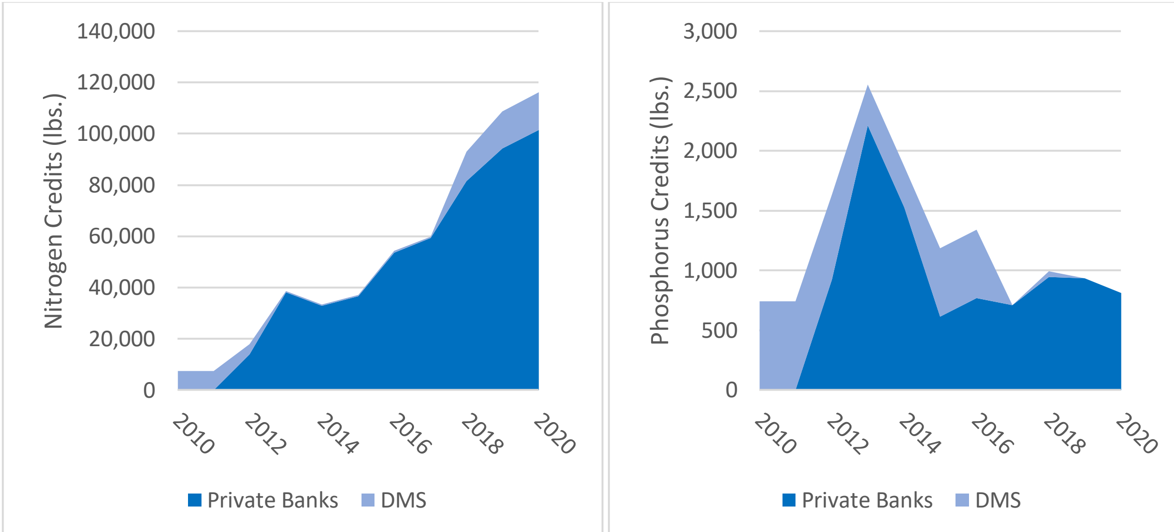


	2012	2013	2014	2015	2016	2017	2018	2019	2020
N	3,501	11,708	9,763	12,757	11,974	15,053	12,085	14,740	8,013
P	198	1,023	983	1,910	1,755	1,965	1,377	1,677	1,111

These graphics illustrate the course that the current 2-option system has taken to date in the Falls watershed. This trend, however, is not necessarily a good predictor of the future. Development activity may continue to be sufficient to support the development of both private banks and DMS in-lieu fee nutrient offset projects in the future.

Figures 21 and 22 above clearly demonstrate that the nutrient offset market in the Falls remains active enough to support multiple providers in the watershed. Credit from private banks is likely to remain available as long as there is a demand and it remains profitable. One potential disadvantage of private banks in general is that they may find the credit demand rate in low-activity watersheds to be insufficient to merit the gamble on profitability, and may thus may not be established where developers need an offset option. In those cases, the DMS nutrient offset program fills an important role as an offset option where bank credits are not available. Offset credit availability for both nitrogen and phosphorus in Falls watershed is provided in Figure 24 below.

FIGURE 24. NITROGEN AND PHOSPHORUS CREDIT AVAILABILITY IN THE FALLS LAKE WATERSHED



Projected Changes to Nutrient Offsets

Regarding projected utilization of offset credits, two primary factors are likely to affect future demand for credits in the Falls Lake watershed: development trends and the emergence of cost-effective alternatives to offsets. Though detailed projections have not been developed for this report, it is anticipated that the current development trend in the watershed will continue. Regarding the second factor, the only potential alternative to offsets would be achieving greater reductions on site. Some advancements in on-site options may emerge in the coming years associated with the efforts described in preceding sections to expand the toolbox of practices and improve accounting. Specifically, practices under development include variants to conventional SCMs that will accommodate varying site constraints by allowing variations in practice design specifications and tying those variations to nutrient reduction performance. While this is being driven by existing development site constraints, it will also allow for oversizing a practice where feasible on a new development for extra credit. This may allow for greater levels of compliance on site.

Another factor that could increase the attractiveness of on-site alternatives is if the cost-effectiveness of the current default practice of buffer restoration were to be reduced. One recommendation under consideration by the Division is a transition away from providing static, pre-set literature-based nutrient credits that are calculated on a per-acre basis for riparian buffer restoration. This potential change is motivated by the accumulation of additional science that suggests the need for a more site-specific approach that would still provide predictability based on a defined method.

Among its benefits, this change has the potential to encourage innovation and incentivize the restoration of high-quality buffers by mitigation providers. However, this transition is projected to lower the number of nutrient credits currently granted for buffer restoration projects. This could result in an increase in offset credit rates or a reduction in the number of riparian buffer restoration projects implemented. Such an increase has the potential to make other nutrient-reducing practices, including SCMs, more financially competitive with buffer restoration. One potential benefit of SCMs being viewed as more financially viable is that it may promote more reductions being achieved on site or at the very least closer to the impact which is something several local governments have shown support for in the past.

Regarding potential changes to the nature of offsets, while revised buffer restoration crediting may diminish its value somewhat, other offsite practices or buffer restoration variants currently being evaluated for nutrient credit may affect outcomes. These include credit for livestock exclusion from streams and credit for hydrologic restoration of buffer function. Other offsite practices under development such as stream restoration and cropland conversion to trees are perhaps less likely to compete with buffer restoration from a nutrient cost-effectiveness and availability standpoint.

Altogether, expanded on-site options and potentially less attractive offsite options may combine to damp a generally increasing trend in offset needs tied to the improving economy. This discussion has also highlighted potential changes to the nature of offsets via diversification in practices driven by, and likely more useful for, existing development but having some potential utility in new development settings as well.

Forest Preservation

Regarding the second report subject area tied to nutrient offset, *“an assessment of any load reduction value derived from preservation of existing forested land cover,”* use of a forest preservation practice for nutrient reduction credit was a topic of discussion between Division staff and stakeholders in 2018 and 2019. By definition nutrient loading to streams and Falls Lake cannot be reduced by preserving existing uses, including forest preservation. However, forest preservation reduces the amount of land that may ultimately be developed otherwise, and push development to convert greater proportions of higher loading farmland instead. The result would be some amount of extra load reduction through that development being held to rule-established loading rates that were based on assumptions of less development of higher loading lands. The significance of this potential credit is currently being evaluated.

A policy analysis was conducted by NCSU researchers an included in the UNC Collaboratory’s Jordan Lake Final Report to the Commission in 2019. This analysis was performed to verify and discuss the merits or shortcomings of forest conservation as a nutrient reduction strategy. The findings shared in this analysis concluded that forest preservation needs a coordinated watershed-wide effort to hedge against nutrient load increases and that the co-benefits of this practice fall in environmental, social, and economic categories, and also include health benefits. It also recommended the development of incentives that would promote the conservation of high priority land, the reforestation of agriculture land, and coordination of planning and development to optimize the benefits of the practice (UNC, 2019).

Land conservation is included as an eligible practice under the UNRBA’s investment based IAIA program for meeting the Falls existing development requirements jointly as that program expands the list of practices to include those that have a known water quality benefit but for which nutrient calculation methods have not been approved.

Atmospheric Deposition Trends

"(vii) 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;"

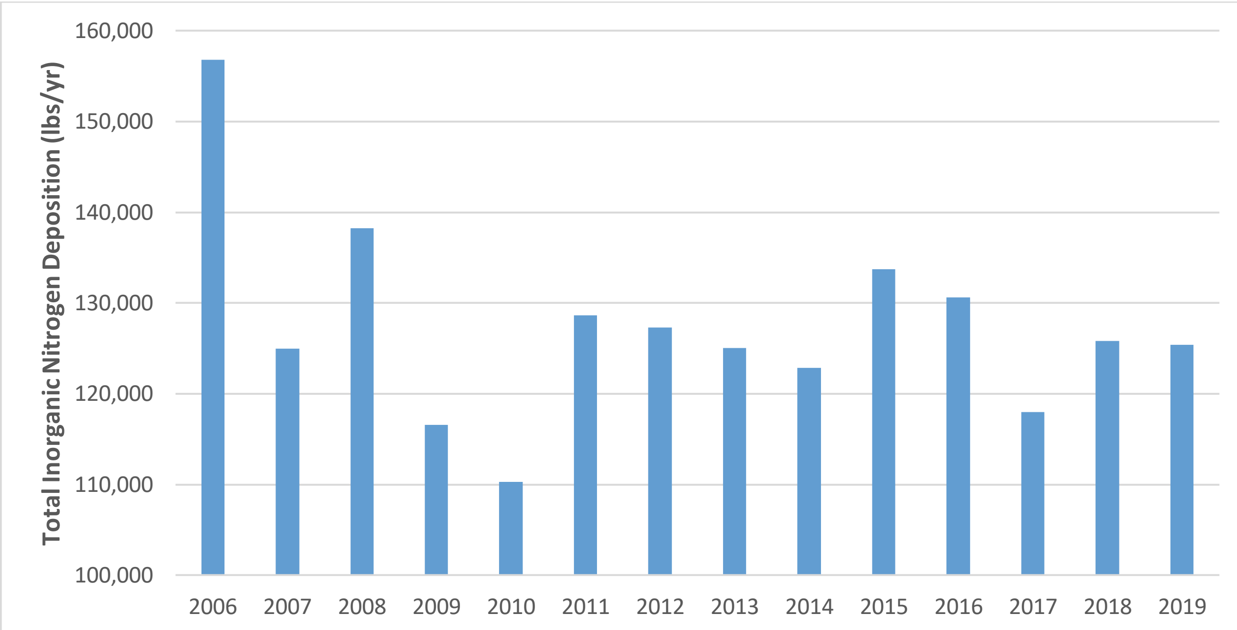
Atmospheric deposition of nitrogen was a nutrient source input included in the development of both the Falls watershed loading and Falls Lake response models developed by DWR; this source will also be included in the UNRBA models. Since the DWR lake response model was used to set strategy reduction goals, a decrease in atmospheric deposition could potentially lessen the magnitude of other source reductions needed to recover the lake. Atmospheric nitrogen is delivered in two ways, wet and dry deposition. The net effects of atmospheric deposition in the watershed is already indirectly accounted for in water quality sampling which accounts for pollutants from all sources. The analysis here is an evaluation of the atmospheric deposition that occurs directly to the surface of Falls Lake which has a surface area of approximately 12,000 acres at normal pool level.

The the UNRBA's 2019 Monitoring Report includes an evaluation of atmospheric deposittion of nitrogen to the surface of Falls Lake that extensd through 2017. This data was collected to provide a comparison of this loading source over time, particulalry to the baseline period. DWR has expanded on this previous work for this report by adding data through 2019.

A 2012 study conducted by the City of Durham that evaluated the contribution of organic Nitrogen to the total nitrogen load from atmospheric sources found that more than 95 percent of nitrogen deposited from the atmsphere is inorganic. (AMEC, 2012). With this in mind, deposition data from the EPA Clean Air Status and Trends Network (CASTNET) simulation of wet and dry inorganic deposition rates for the CASNET site located in the Research Triangle Park was used for this analysis.

As with the UNRBA's analysis, the results indicate a promising downward trend in recent atmospheric nitrogen deposition in the Falls watershed with an estimated decrease in inorganic nitrogen deposition to the lake surface by approximately 31,422 lbs/year, representing a 20 percent decline in the watershed since the 2006 baseline (Figure 25). Looking forward, the expected maturation of prior air emissions regulatory initiatives and new ones in progress together suggest further reductions are likely. The Division will continue to download the annual deposition data for this site for comparison in future reports to track changes in atmospheric deposition in the Falls watershed.

FIGURE 25. ANNUAL TOTAL INORGANIC NITROGEN ATMOSPHERIC DEPOSITION TO THE SURFACE OF FALLS LAKE BASED ON RATES SIMULATED IN CASTNET



Regulatory Drivers and Outlook

Nitrate deposition reductions are likely due to several state and federal air quality initiatives with overall decrease in inorganic nitrogen deposition attributable to regional and global reductions in emissions from vehicles and stationary sources like power plants.

Atmospheric NO_x contributes to elevated ozone levels, which have adverse human health effects. NO_x is emitted from the combustion of fossil fuels, including in electric utilities and motor vehicles, and is also a byproduct of natural lightning strikes and burning of biomass. While NO_x reductions can be attributed to many factors, the N.C. Clean Smokestacks Act is particularly notable for its requirement, now met and exceeded, for coal-fired power plants to reduce NO_x emissions by 77 percent by 2009 (North Carolina Department of Environment and Natural Resources, 2015).

Looking forward, other regulatory initiatives designed to curb motor vehicle and interstate power plant emissions are likely to further reduce nitrate deposition in the Falls watershed as their requirements continue to be implemented. In addition, a recently settled lawsuit between North Carolina and the Tennessee Valley Authority resulted in the reduction and capping of NO_x sources by 2018 and installation of modern pollution controls for TVA's facilities (North Carolina Department of Environment and Natural Resources, 2015).

In contrast, funding for maintenance of existing air quality monitoring stations is often uncertain and establishment of new air quality monitoring stations is rare, particularly in support of watershed management. The quality of monitoring information available to inform Falls Lake approaches, or those in North Carolina's nutrient strategy watersheds generally, is unlikely to improve absent additional investment.

Summary of Studies Evaluating Nutrients from Groundwater

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

Groundwater discharge to surface water is potentially one of the largest nutrient fluxes in the environment (Robert W. Howarth, Boyer, Pabich, & Galloway, 2002). Reviews of nitrate contamination in the United States have found a relationship between regional nitrogen loads to groundwater and nitrogen loads in corresponding surface water discharges (R. W. Howarth et al., 1996; Smith, Schwarz, & Alexander, 1997).

Pollutants delivered through groundwater flow, such as nitrate, are generally delivered at much slower rates than those in surface water but can be major contributors to a basin's overall loading. For example, the Scientific and Technical Advisory Committee of the Chesapeake Research Consortium estimated in 2005 that 40 percent of all nitrogen reaching the Chesapeake Bay had travelled through groundwater before reaching the bay.

Concentrations of nutrients in groundwater can vary greatly with respect to land use, fertilizer and residuals application rates, and nutrient management practices within a watershed. Nutrient inputs to groundwater systems can be grouped into five general categories: precipitation, point-source discharges, crop-fixed nitrogen, commercial fertilizer, and animal waste (G. McMahon & Lloyd, 1995). Generally in North Carolina basins, nitrate concentrations are highest in groundwater near the surface in areas where contamination sources are present in higher densities, particularly in agricultural and urban areas (Harned, McMahon, Spruill, & Woodside, 1995).

Recent studies have used new scientific methods to age-date nitrogen found in groundwater discharging to surface water systems. They indicate that nitrogen pollution entering surface water through base-flow can vary greatly in its age, with lag times between recharge and discharge on the scale of decades. A recent study by Kennedy et al. (2009) in the North Carolina coastal plain used chlorofluorocarbons and dissolved gas modeling to date nitrogen-laden groundwater contributing to the Bear Creek watershed. Results indicated that groundwater discharge ranged in age from 10 to 60 years old. This lag time suggests that in areas where reductions in nutrient application have been prioritized, resulting improvements in surface water quality should be expected to occur over the course of decades. Oenema et al. (2005) found that reductions in excess agricultural nitrogen and phosphorous through chemical fertilizer applications resulted in limited immediate improvement in surface water quality due to the presence of other contaminant sources and the discharge of nutrient rich groundwater predating the reductions.

Kennedy et al (2009) also showed a 50 percent reduction of nitrate concentrations in groundwater before discharge as a result of denitrification within the aquifer and in the riparian zone. Similar results were found by McMahon et al. (1996) in the South Platte River (Colorado), where denitrifying activity in the floodplain and in sediments reduced base-flow nitrate loading by 70 percent compared to predictions based on median concentrations within the aquifer. Ultimately groundwater was found to contribute 18 percent of the river's nitrate load, significantly less than would be expected in the absence of denitrification within the aquifer.

Spruill et al. (2005) characterized the fate and transport of nitrogen from a concentrated animal feeding operation to surface waters in the Neuse River basin. This study used chlorofluorocarbons, tritium, and silica to estimate residence times and date groundwater within the system. Groundwater within the system was up to 30 years old, but age varied significantly based on the geophysical characteristics of each site sampled. Groundwater less than 10 years old contained elevated dissolved oxygen and nitrate concentrations, while groundwater dated between 10 and 30 years old had low dissolved oxygen and low nitrate. Nitrate from a shallow surficial aquifer was heavily denitrified once entering the riparian zone, contributing little to total stream nitrogen loading. Conversely, shallow groundwater intersecting a tile drainage system significantly contributed to instream nitrogen concentrations, accounting for approximately 30 percent of the increase in nitrate flux observed along the given reach. This difference emphasizes the spatial heterogeneity of potential groundwater influences on surface water quality depending on both nutrient management practices and physical landscape characteristics.

These studies and others like them (Böhlke, Harvey, & Voytek, 2004; Burns, 1998; Chestnut & McDowell, 2000) suggest that geophysical and chemical properties of the aquifer, groundwater residence time, and the presence of a riparian buffer affect the nutrient composition and water quality of baseflow entering a surface water system. While these results provide some insights, they were largely conducted in the coastal plain or in other geographic areas outside of the Falls lake watershed. Further research is needed to assess this flux in the piedmont to better understand loading to Falls Lake.

A recent study by Messier et al. (2014) developed a land use regression (LUR) - Bayesian Maximum Entropy (BME) model to predict point level groundwater nitrate concentrations in North Carolina using data from private drinking well and groundwater monitoring wells. The model derived from monitoring well data predicted groundwater nitrate concentrations in the Falls Lake watershed ranging from 0.04 mg/L to 114.8 mg/L with a mean predicted concentration of 0.66 mg/L. These results can be combined with the USGS base-flow index grid for the contiguous United States and USGS National Water Information System historical discharge data to estimate potential nitrate contribution to the Falls Lake watershed via groundwater discharge.

A recent study by Johnson and Stets (2020) from the U. S. Geological Survey of legacy groundwater quality found that the lack of significant decreases in nitrate loads in some US rivers and streams, despite significant efforts, may be due to the continued slow release of nitrogen during surface water low-flow conditions. Stored nitrogen in groundwater flowing into surface waters from past agricultural practices and treated effluent from wastewater facilities may be increasing nitrogen concentrations during periods of diminished surface water flow. This legacy nitrogen would not reflect current reduction efforts and may contribute to upward nitrogen concentration trends in watersheds with high levels of groundwater discharge. Thus stream discharge and nitrate concentration can be used to predict the contribution of legacy or current practices. Neuse and Eno River water samples were used in this study but Falls Lake water quality was not addressed.

The Falls Lake watershed has a mean base-flow index of 0.295, meaning that 29.5 percent of total watershed discharge is estimated to be contributed by groundwater discharge to surface water. From 1983 to 2014, the Neuse River at the Falls Lake dam had a mean yearly discharge of 527 million m^3/year. With a predicted mean groundwater nitrate concentration of 0.65mg/L, approximately 760,000 lbs/year of nitrate could be contributed by groundwater to surface waters within the watershed. However, this estimate does not account for denitrification processes within groundwater system, which have been shown by the aforementioned studies to significantly reduce nitrate concentrations before discharge to surface waters. Because these processes are dependent on several unquantified factors, additional research is needed to more accurately assess groundwater nutrient loading in the Falls Lake watershed. However, these figures can provide an order-of-magnitude estimate of groundwater nutrient contributions affecting surface water quality, perhaps partially explaining unquantified nutrient sources within the watershed and lag times observed between nutrient loading reductions and increases in surface water quality.

Summary of Studies Evaluating Nutrients from Septic Systems

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

Nutrient load estimates for onsite wastewater systems (OWS), commonly known as septic systems, have been made using large-scale water quality models with wide-ranging transport assumption. Relevant field research to support nutrient transport assessments in the Piedmont has been minimal (Berkowitz, 2014). The DWR Falls Lake watershed model suggests that residential onsite wastewater systems, both conventional septic systems and discharging sand filters, are potential sources of nutrients in the Falls Lake watershed.

Although malfunctioning septic systems have the potential to deliver higher loads of nitrogen and phosphorus to surface waters than functioning septic systems, the magnitude of the delivered load varies and is dependent on factors including the type of malfunction and characteristics of the soil, land, and hydrology between the systems and receiving water (Tetra Tech, 2013b).

In 2019, the Division completed the development of the practice document for remedying discharging sand filters relying heavily on the supporting technical information provided by a 2013 Tetra Tech Report developed for the Nutrient Scientific Advisory Board (NSAB). Design specifications and nutrient crediting for remedying malfunctioning septic systems is currently under development and is expected to utilize results from the UNC Collaboratory Falls Lake Study as well as additional watershed modeling being conducted by the Upper Neuse River Basin Association in the Falls watershed, which will provide updated data on the nutrient loading from these systems.

The following is a brief updated summary of six relevant works that evaluate nutrient loads from these sources and serve as the basis for our current understanding of their impact in the Falls watershed. In some cases, like the work performed by Tetra Tech and Hazen & Sawyer, the efforts described below encompass extensive literature reviews that capture the results of numerous studies specific to North

Carolina and beyond.

Estimating the Influence of Onsite Wastewater Treatment Systems (2019-Ongoing)

This ongoing study as part of the UNC Collaboratory Falls Lake Study will help determine the extent to which onsite wastewater treatment systems cause elevated nutrient concentrations in streams draining to Falls Lake. It will also help approximate how much nitrogen and phosphorus from onsite wastewater treatment systems drains to tributaries in the Falls Lake watershed.

These research questions will be addressed using multiple lines of evidence obtained from a literature review, GIS analysis, and field monitoring of tributaries in the watershed. The literature review of onsite wastewater nutrient loading was focused on research conducted in the North Carolina Piedmont, and Piedmont regions in other southeastern states. Published studies that focused on wastewater and wastewater treatment in similar settings with clay to loam soils were also considered for conventional septic systems in addition to sand filter systems, TS-II systems, and proprietary treatment systems. Field sampling locations were selected based on watershed and septic system characteristics of watersheds draining to the lake.

Initial findings suggest that sub-watersheds that rely on onsite wastewater systems are more likely to have elevated nitrogen concentrations compared to sub-watersheds that rely on municipal wastewater treatment. However, results also indicate that while onsite wastewater nutrient can be translated to streams, the influence may vary depending on a range of factors such as system type, density, soil, and in-stream attenuation.

Onsite wastewater nitrogen loading from subwatersheds ranged from 0.15 to 5.9 lbs/N/person/yr. Potential phosphorus loading was found to be considerably lower ranging from 0 to 0.41 lbs/P/person/yr. The data and literature review suggests approximately 74-100 percent of nitrogen and 90-100 percent of phosphorus are attenuated between conventional onsite systems and streams. A future aspect of this work will focus on identifying tributaries in the watershed with elevated nutrient concentrations associated with onsite wastewater and develop best management approaches for nutrient attenuation.

In 2019 the Division coordinated with the UNRBA and the researchers involved with this study to provide additional funding through the EPA 319 grant program to fund additional work that will result in producing updated nutrient export values for up to a dozen different types of onsite systems. This updated export information will be added to the model code of the WARMF model the UNRBA is developing as part of the reexamination process.

Nutrient Exports from watersheds with varying septic system densities in the North Carolina Piedmont (2018)

The goal of this study was to determine if significant differences in nutrient concentrations and exports exists between piedmont watersheds with different densities of septic systems. The study areas consisted of watersheds with high density septic, low density septic, sand filter, a sewered watershed, and a forested watershed. Samples were collected from January 2015 through December 2016. Results indicated that septic system density was a significant factor in the delivery of septic-derived nutrients to these nutrient sensitive, water supply watersheds of the North Carolina Piedmont.

Field Evaluation of Nitrogen Treatment by Conventional and Single-Pass Sand Filter Onsite Wastewater Systems in the North Carolina Piedmont (2016)

The goal of this study was to gain a better understanding of nutrient treatment efficiency of OWS installed in the clayey soils of the NC Piedmont (Wake and Durham County). Researchers monitored four sites with piezometers installed in the flow path of the wastewater plume to monitor the groundwater adjacent to the drainfield and at various distances downgradient from the systems. Two conventional, and two single-pass sand filter OWS were studied. The septic tank effluent, sand filter effluent, groundwater from piezometers and adjacent surface waters were sampled 5 times during 2015. Treatment efficiency of each OWS was determined by comparing concentrations of nutrient in septic effluent to nutrient concentrations in GW down-gradient from the OWS and in sand filter effluent. Total dissolved nitrogen (TDN) concentrations and masses reduced by 98 and 70 percent respectively 35 meters down-gradient from conventional OWS relative to septic tank effluent. The sand filter OWS reduced concentrations by 80 percent and mass by 50 percent.

Phosphate Treatment by Onsite Wastewater Systems in Nutrient Sensitive Watershed of North Carolina's Piedmont (2016)

The purpose of this study was to gain a better understanding of phosphate treatment efficiency of OWS installed in the clayey soils of the NC Piedmont (Wake and Durham County). The Study included four sites with piezometers monitoring GW near the systems. The Conventional and Sand Filter OWS reduced phosphate concentrations by an average of 99 and 90 percent respectively, before discharge to surface waters. Mass load reductions were greater for conventional systems at 95 percent relative to sand filter systems that removed 83 percent. Additional treatment of sand filter effluent using a reactive media or slag material is recommended. This is a companion study to the one listed above based on measurements at identical sites.

Chesapeake Bay Program. Recommendation of the On-Site Wastewater Treatment Systems Nitrogen Reduction Technology Expert Review Panel (2014)

The Chesapeake Bay Program Office On-Site Wastewater Treatment Systems Nitrogen Reduction Technology Expert Review Panel was formed to recommend on-site wastewater treatment technologies and best management practices for existing and new wastewater treatment systems. The panel reviewed existing scientific research and provided recommendations for TN reduction credits for specific technologies and system modifications. The panel concluded that 11 lbs. TN/person/year could be reasonably estimated as the nitrogen loading associated with the septic tank effluent from a conventional septic tank system. The panel agreed with the current CBPO assumption that an average TN reduction of 20 percent occurs within a conventional gravity flow drainfield. Based on these assumptions, the panel concluded that the edge-of-drainfield TN load can be estimated at 8.8 lbs.

TN/person/year (Adler et al., 2014).

Tetra Tech. North Carolina Piedmont Nutrient Load Reducing Measures Technical Report. Prepared for NCDWR (2013)

The Division contracted with Tetra Tech in 2012 to characterize nutrient load reduction performance associated with remedying discharging sand filters and malfunctioning septic systems (Tetra Tech, 2013b). The work included an analysis of available local data and published literature on effluent concentrations from these types of systems. The findings suggest that properly functioning conventional septic systems effectively reduce nutrients prior to surface water delivery. However, malfunctioning septic and discharging sand filter systems were determined to be potential sources of nutrients and could be replaced or remedied to earn nutrient reduction credits for existing development rule requirements.

Under the programmatic approach Tetra Tech proposed for addressing conventional septic systems, jurisdictions would be awarded credit for malfunctioning systems addressed in a given year. However, the credits are adjusted and reduced to account for the nutrient load that new unremedied malfunctions deliver. The documented improvement in malfunction rate between successive years is multiplied by the total number of septic systems in the jurisdiction to determine the annual net reduction credit. The first year's malfunction rate serves as the baseline against which succeeding years will be measured.

Table 14 below summarizes the nitrogen credit Tetra Tech proposed to be awarded for each of three proposed remedial alternatives for addressing malfunctioning septic systems. Phosphorus load reduction credits are 1.8 lbs./cap/year for remedying a direct septic tank effluent discharge, 0.88 lbs./cap/year for remedying a direct greywater discharge, and 0.54 lbs./cap/year for remedying a drainfield malfunction.

TABLE 14. TN LOAD REDUCTION CREDIT FOR REMEDYING MALFUNCTIONING SEPTIC (LBS./CAP/YEAR)

Malfunction	Repair with properly functioning septic	Connection to major NPDES system	Replace with subsurface TS-II	Replace with discharging TS-II
Direct septic tank effluent discharge	10.67	11.0	10.87	6.6
Direct greywater discharge	0.37	0.70	0.57	--
Drainfield malfunction	3.27	3.60	3.47	--

The report also provided nutrient credit recommendations for replacing discharging sand filter systems (DSFs). These systems differ from conventional onsite treatment in that they are residential wastewater treatment systems that use some form of pretreatment beyond the primary treatment a septic tank provides and are permitted to discharge to surface waters, ditches or the ground surface. There are four major types of DSFs and three possible remedies to address nutrient loading concerns.

Recommended remedies include upgrade of single-pass filters to advanced nutrient-reducing treatment systems, connection to major NPDES system, replacement with properly functioning septic system, and replacement with an advanced on-site subsurface discharging system. Credits for remedies to discharging sand filters are similar for the septic, advanced on-site, and major NPDES options, while the upgrade from a single-pass filter to advanced treatment warrants modest TN reduction credits. Recommended nutrient load reductions for remedying DSFs are summarized in Tables 15 and 16 for TN and TP, respectively.

TABLE 15. TN LOAD REDUCTION CREDIT FOR REPLACING DISCHARGING SAND FILTERS

System	DSF loading rate	Upgrade to discharging TS-II equivalent	TS-II with subsurface soil dispersal	Connection to major NPDES system*
	(lbs./cap/year)	(lbs./cap/year)	(lbs./cap/year)	(lbs./cap/year)
Remedy loading rate		4.4	.13	--
Types of DSFs		Remedy load reduction credit (lbs./cap/year)		
Single-pass with regular discharges	7.4	3.0	7.3	7.4
Single-pass with no or infrequent discharges	7.4	3.0	7.3	7.4
Recirculating filters and other advanced discharging systems	4.4	--	4.3	4.4
Malfunctioning discharging systems	7.4	3.0	7.3	7.4

** Assumes all load transferred to major NPDES sector*

TABLE 16. TP LOAD REDUCTION CREDIT FOR REPLACING DISCHARGING SAND FILTERS

System	DSF loading rate	Upgrade to discharging TS-II equivalent	TS-II with subsurface soil dispersal	Connection to major NPDES system*
	(lbs./cap/year)	(lbs./cap/year)	(lbs./cap/year)	(lbs./cap/year)
Remedy loading rate		1.8	0	--
Types of DSFs		Remedy load reduction credit (lbs./cap/year)		
Single-pass with regular discharges	1.8	--	1.8	1.8
Single-pass with no or infrequent discharges	0.9	(-0.9)	0.9	0.9
Recirculating filters and other advanced discharging systems	1.8	--	1.8	1.8
Malfunctioning discharging systems	1.8	--	1.8	1.8

** Assumes all load transferred to major NPDES sector*

Hazen and Sawyer. A Review of Onsite Wastewater System Performance and Nutrient Trading Policy to Support Falls Lake Nutrient Strategy Development. City of Raleigh Public Utilities Department. January 2013.

In 2013 the City of Raleigh contracted with Hazen & Sawyer to conduct a review of onsite wastewater system performance (Sadler, Waldroup, McLawhorn, & Buchan, 2013). This work resulted in a comprehensive literature review of studies related to onsite wastewater treatment technologies, effluent quality, and treatment performance. The study resulted in a summary of effluent quality from various onsite treatment technologies and prompted discussions concerning nutrient attenuation in soil and nutrient and groundwater movement to receiving streams. It also summarized approaches, including watershed models and spreadsheet-based tools, to assess nutrient load contributions from these systems.

The report details the fate and transport of nutrients from onsite wastewater treatment system in the Falls Lake watershed. Phosphorus and nitrogen attenuation in soils is discussed, and 77 percent and 79 percent of phosphorus and nitrogen loads were attenuated in their watershed model for properly functioning septic systems. Average effluent data from sand filters is reported from 10 site visits in 2008 as 21.1 mg/L TN and 16.1 mg/L TP. The report provides a summary of minimum, average, and maximum effluent quality concentrations from on-site wastewater treatment systems and details septic system nutrient loads delivered to the downstream waters. The Hazen & Sawyer report also contains a comprehensive summary of effluent quality data for onsite wastewater treatment systems.

State of Knowledge: UNRBA Special Studies

As part of the UNRBA's Monitoring Program they conducted eight special studies in order to better understand the nutrient dynamics of Falls Lake including factors that are likely to influence water quality in the lake beyond changes in nutrient loads. The information gathered through these special studies along with the results of the UNRBA's extensive routine monitoring project will also be used to address previous data gaps and provide valuable insights in the model development process and inform the ongoing Stage II rules re-examination process.

The special studies briefly summarized below will also help support the development of alternative regulatory options for Stage II of the Falls Lake Nutrient Management Strategy. Additional details about the methods and findings of each of these evaluations can be found in the UNRBA's 2019 Final Monitoring Report posted online at https://www.unrba.org/monitoring-program.

High Flow Sampling

High flow conditions are periods when stream flow increases markedly above normal flows in response to a rain event (UNRBA, 2019). The DWR ambient monitoring program data used for the original watershed and lake modeling efforts did not specifically target high flow conditions. However, flow data collected by the UNRBA indicates that approximately 20 percent of the water delivered to the lake comes from flows occurring 1 percent of the time, and 40 percent of the water coming into the lake comes during 5 percent of the time.

High flow conditions are typically under-represented by routine monitoring schedules and having supplemental data during these high hydraulic loading events captures a broader spectrum of inflow conditions to the lake which will improve the calibration of the watershed model and inform more accurate timing of loading in the lake response models. To address this, the UNRBA collected supplemental water quality grab samples from the five upper tributaries to Falls under high flow conditions between 2015 and 2018.

The results of this additional sampling helped to provide a better representation of water quality conditions across a range of hydrologic and seasonal conditions and served to improve the UNRBA's statistical loading estimates to better represent nutrient loads being delivered to the lake.

The UNRBA also plans to use the data collected from this high flow sampling study during their re-examination modeling effort to further evaluate the degree to which nutrient loads can be managed by SCMs measures designed to treat the first inch of runoff.

Storm Event Sampling

This special study measured nutrients and carbon on a sub-daily time scale to characterize how water quality changes throughout the elevated flow period associated with storms and how storm events affect tributary contributions of nutrients and related parameters. Storm event sampling occurred two to four times per year on two tributaries. These data were used to help to compare loading patters during different seasons and will also help inform the calibration of the UNRBA's watershed model for high precipitation conditions.

Lake Sediment Quality and Internal Nutrient Loading Evaluation

This special study examined the nutrient and organic carbon content of sediment samples from Falls Lake at 20 locations. DWR's 2009 Falls Lake Nutrient Response EFDC Model assumed uniform nutrient flux conditions throughout Falls Lake. The results of this study evaluated this assumption and helped develop a better understanding of the importance of internal nutrient loads in the lake.

Constriction Point Assessment

This study measured the flow and the movement of nutrients, sediment, carbon, and chlorophyll *a* from one segment of Falls Lake to the next over a range of flow conditions at specified bridge causeways (I-85, Fish Dam Road, and Highway 50). The idea being that such crossings may have physical influence on the lake's behavior by altering or restricting the movement of water. Velocity and water quality data was collected at these constriction points over two over multiday periods in 2016 when flows were influenced by storm events to provide enhanced understanding of how water was moving from one area of the lake to the next.

The results of this study provided data to aid model calibration and to characterize how the lake's shape and the presence of bridge causeways affects the flow and processing of nutrients in different parts of the lake. This data can also be used to ensure that the model is accurately representing changing conditions at smaller time steps than those represented by monthly lake sampling.

Light Extinction Data Collection

The UNRBA also evaluated historic light extinction data from the mid-1980's to early 1990's collected in Falls Lake to determine the relationship between actual light extinction measurements and Secchi depth. Light penetration is an important parameter for estimating algal production and this evaluation will aid in the development of uncertainty estimates and calibration of the lake models.

A simple linear regression model was developed to assess whether Secchi depth was a good approximation of depth of light attenuation. Results indicated the relationship between Secchi depth and light extinction measurements was sufficiently strong to meet the needs of mechanistic modeling.

Basic Evaluation of Model Performance

This study evaluated the different modeling approaches the UNRBA planned to use for the re-examination process to ensure that data collected through the Monitoring Program is appropriate and sufficient for future modeling efforts. Based on this evaluation, the monitoring plan was updated in 2017 to include more high flow sampling and measurements of CBOD5 were ended after two years of data collection. Overall goal of these refinements is to improve the development and calibration of the UNRBA lake models.

Recreational Use Evaluation

For this study the UNRBA compiled available recreational data for Falls Lake summarizing recreational facilities associated with the lake, types of activities undertaken, and estimates of annual recreational visits. They also conducted background research on recreational use evaluations on other lakes and reservoirs in the Southeastern U.S. and elsewhere to assess the current status of the recreational use of Falls Lake.

Prior data compiled by the UNRBA found no linkage between visitor counts to the lake and the lakes water quality conditions. This work was followed up with a review of social media posts and reviews posted to publicly available websites as an indicator of positive recreational use of the lake the public continues to enjoy. This information can also be used to inform discussions with NCDWR and EPA on the need for additional recreational studies.

This evaluation also summarizes other sources of information. For example, according to the USACE (2013), all types of recreational uses for Falls Lake are being met and are not limited by water quality; rather, limitations on the number of visits are due to the carrying capacity of Falls Lake and its facilities. Online reviews of Falls Lake by approximately 230 users of TripAdvisor show that more than 90 percent of the reviewers ranked their experience as “Excellent” or “Very Good” across a broad range of recreational activities (BC 2019). Recreational and sport fishing are popular on Falls Lake. The Major League Fishing Pro Bass Tour, which held three of its six tournament rounds on Falls Lake in late March 30, 2019 with 80 professional anglers.

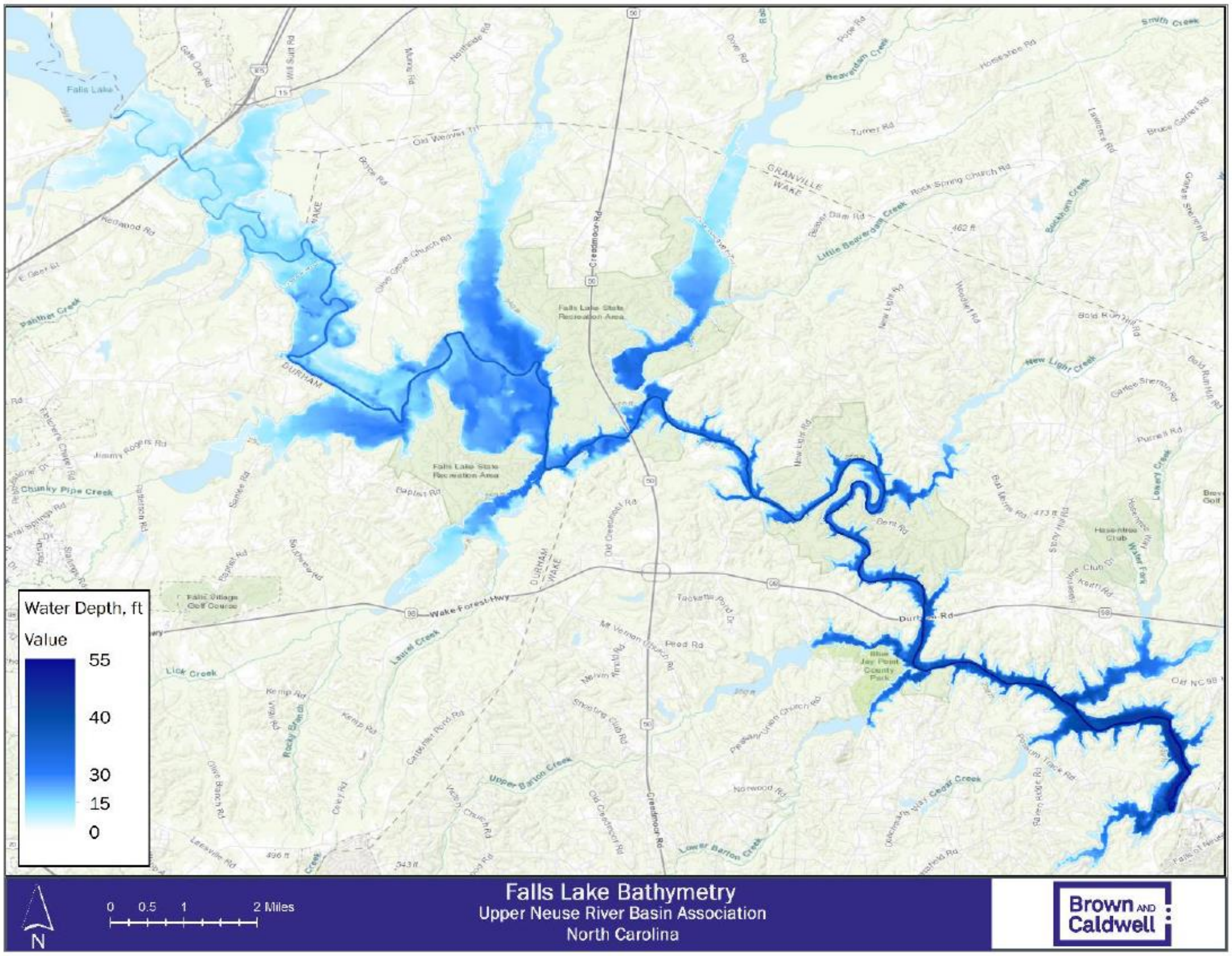
Reservoir Bathymetry and Sediment Mapping

Underwater topography (bathymetry) influences the retention and movement of water and as a result can influence biological processing of nutrients that can affect the growth of algae. The primary goal of this study was to enhance the bathymetric data to build a more robust hydrodynamic model for the lake by collecting depth data on transects averaging every tenth of a mile throughout the lake. For this analysis, over four million depth-sounding samples were collected throughout the lake using a boat mounted dual-frequency echosounder over the course of two weeks in the spring of 2017.

Having an accurate representation of the underwater topography is important for understanding the volume of water each segment of the lake contains and to refine the EFDC lake model grid. In general, Falls Lake is characterized as having broad, shallow areas in the upper lake (above Highway 50) and narrow, deep areas in the lower lake. Figure 26 below shows the water depths throughout Falls Lake based on the data collected through this study.

This data was also used to estimate the thickness of the sediment layer along the bottom of the lake allowing for estimates of sediment nutrient flux throughout the lake using the sediment quality data described earlier. An empirical model was also developed as part of this work to estimate nutrient flux from the sediment to evaluate the transfer of nutrients from sediments to the overlying water. The estimated internal loading from the lake sediments were estimated to be roughly 14 percent and 9 percent of the total estimated nitrogen and phosphorus loads to the lake, respectively, and the current level of nitrogen stored in the lake sediments could be released over several decades with no additional inputs into the lake.

FIGURE 26. WATER DEPTHS OF FALLS LAKE



SOURCE: UNRBA 2019 FINAL MONITORING REPORT

State of Knowledge: UNC Collaboratory Falls Lake Study

In 2016, the NC General Assembly approved legislation that directs UNC-Chapel Hill to oversee a study of nutrient management strategies and create a comprehensive analysis of existing water quality data for both Jordan and Falls Lakes. The legislation provides $500K annually over six years beginning in FY 2016-2017 with progress reports on the study required each year. The first three years of study were focused on Jordan Lake, culminating in the final legislative report submitted in December 2019. In the fall of 2019, the UNC research team transitioned from Jordan Lake to focusing on Falls Lake. A 2018 budget bill extended the deadline for the Falls project requiring study results by the end of 2023, with interim updates in advance of the final report.

Over the course of 2019 and 2020 researchers from UNC, East Carolina University, and NC State University have been conducting a number of research projects focused on Falls Lake. This collection of research projects synthesizes interdisciplinary analysis of Falls Lake's nutrient content and fluctuation, the factors that affect it, mitigation strategies and their effectiveness, and financial implications of proposed processes.

The research underway at Falls Lake and in the watershed represents a comprehensive approach to understanding the current nutrient issues and potential solutions for policy makers. The initial findings summarized below represent issues of significance to local governments and resource managers in the Falls Lake watershed. They will be explored further through the continuing research before the final UNC Collaboratory Study Report is completed in 2023 and will play a significant role in informing the Falls Lake rules readoption process.

Quantifying Sediment Nutrient Processing

This study collected sediment cores from the bottom of Falls Lake in an effort to determine nitrogen fluxes, sediment oxygen demand, and to help describe nutrient changes in order to inform research-based policy management. Sediment cores and bottom water were collected from six sites along the main stem on Falls Lake and incubations were run with bottom water in an environmental chamber matching in situ temperatures of the lake.

Results showing low dissolved nitrogen concentrations demonstrated that denitrification rates in the lake are limited by nitrogen availability. Although the lake was not found to be thermally stratified, nitrogen concentrations were observed to be lower in bottom water. Extrapolation of the mean denitrification rates at the ambient nitrate concentrations showed an estimated 16 percent of total nitrogen reaching the lake could be removed via denitrification when compared to the modeled delivered load to the lake reported in DWR's 2009 Falls Watershed Model. This demonstrates considerable potential for lake sediments to remove nitrate. Additional measures of denitrification through the spring and summer seasons will provide a more complete assessment of this removal pathway from Falls Lake.

In Situ Observational Study: A Look at High and Low Flow Conditions

The purpose of this study is to determine how the nutrient levels in Falls change during high and low flow conditions and how water movement over hourly timescales differ from water movement over seasonal scales and how it affects nutrient levels in the Lake. Acoustic Doppler Current Profilers were used at four locations along the lake to measure water velocity with downriver moorings used to measure temperature, irradiance, conductivity and water depth. Measurements were recorded in three minute averages every 10 minutes from Nov 2019 through June 2020.

Results of this study show high levels of freshwater input at the top of the lake were reflected in conductivity levels as quick increases followed by longer lasting reductions in conductivity. Conductivity measurements from sites further down lake do not show rapid rise and associated freshwater inputs suggesting outflow from the dam may significantly control advancement of freshwater input. The study also showed that majority of sediment influx associated with high river flows enters the system uplake and that the shallower upper lake sections cool more quickly than the deeper lower lake sections resulting in increased density of cooler water which can lead to long-lake density driven currents.

Cyanotoxin Presence and Year-Round Dynamics

This study is being done to answer the question as to whether year-round patterns of cyanobacterial abundance (chlorophyll-a) in Falls Lake are associated with toxin presence for microcystin (MCY), cylindrospermopsim (CYN), anatoxin (ANA), saxitoxin (STX), and or beta-Methylamino-L-alanin (BMAA). And whether specific environmental factors are associated with algal abundance and/or toxin concentrations in Falls Lake. Monthly surveys were conducted to collect whole lake water at 11 stations to determine particulate and dissolved toxin levels and chlorophyll-*a* concentrations.

Results showed chlorophyll-a concentrations averaged slightly higher within the upper, wider portion of the lake compared to the narrower, lower portions of lake. Chlorophyll-*a* levels remained relatively high throughout late fall and early winter months. Low MCY and CYL concentrations were primarily detected in dissolved phase indicating that sampling may not have coincided with peak bloom conditions when toxins were expected to be mostly bound inside cells. Overall, multiple stations tested positive for up to 4 of the toxins throughout the surveys. However, none of the concentrations exceeded regulatory guidelines or criteria.

These results indicate a potential risk from chronic low-level exposure to multiple toxins which could pose a risk when fish caught in the lake are consumed by humans. Additional toxin monitoring is needed to assess water quality and ecosystem health for the Lake and will help create a baseline for cyanotoxin dynamics in Falls and inform future evaluations of food web impacts and public health exposure risks.

Defining Balance Between Cyanobacterial N Fixation & Denitrification

This project is using direct measurements of planktonic N_2 fixation and a mass balance approach to calculate a lake-wide rate of denitrification to address uncertainties of past modeling efforts in order to help create a more accurate nutrient response model for Falls. Samples were collected from the photic zones at six stations in the lake to measure N_2 fixation using acetylene reduction assays. N2 fixation rates were compared to light availability at each depth level and to the nutrient concentration of each sample. Annual stream loads of total nitrogen and phosphorus into and out of Falls lake were calculated using the weighted regressions on time, discharge and season (WRTDS) model based on gaged stream flows and monthly concentration data. Whole lake denitrification rates were estimated based on the ratio of N:P retention and mass ratio of surface sediments that were determined by a previous study (Alperin, 2019).

Result indicate the denitrification removes about 20 percent of the tributary loads to the lake. An observable but statistically insignificant relationship was observed between N2 fixation and light availability and negative relationship between ammonium and N_2 fixation. Future work will refine the estimate by considering variation with depth, light availability, and volume represented by each layer in the lake.

Importance of Lake and Impoundment Ecosystems to Global Organic Carbon Cycling

The objective of this study is to better understand sediment fluxes associated with Falls Lake, ranging from rates of sediment inputs to the fate or particulate materials within the lake on time scales from seasonal to decadal. Four tributaries (Ellerbe, Eno, Flat, Little) were sampled every two weeks for eight months colleting 1-2 liters of water that were then filtered to collect suspended matter. Samples were dried and reweighed to determine particulate mass accumulated.

Results indicate that the sediment input from each of the four tributaries are similar in character. At three of the sites, carbon to nitrogen ratio ranges indicate that the most likely sources of organic matter discharge comes from soil organic matter while Ellerbe creek discharge was influenced by fertilizer, septic and sewage.

Paying for Nutrient Management

The main objective of this project is to develop a cost and revenue inventory, and a 'revenueshed' tool. A revenueshed tool will show flow of current and potential revenue that may be used for nutrient reduction.

The UNC Environmental Finance Center will continue its work in the next two years to examine these costs, receive input from stakeholders and decision makers, and ultimately produce a set of recommendations for how local governments can meet the costs of a nutrient management strategy under the rules. To support this, they will complete the development of the revenueshed tool and use the model to demonstrate a set of scenarios for how revenue may be generated under existing or modified revenue generation frameworks. The research will include a deeper dive into expanding the Raleigh Watershed Protection Fee and implementing a revenue generation mechanism associated with recreation. Finally, they will address the affordability implications for watershed residents associated with each revenue generation technique that we model in the revenueshed tool.

Green Street Retrofits & Wet Pond Retrofit Guidance

This research examined the nutrient removal capabilities of a popular type of "green street" retrofit, suspended pavement street systems. The goal was to determine the potential impact of scaling green street retrofits on water quality in Falls Lake. "Green streets" are transportation corridors in which low impact development is employed as a design principle by using a variety of green stormwater infrastructure (GSI) practices to treat direct transportation surface drainage in the right-of-way" (Shaneyfelt et al., 2017). Suspended pavement street systems utilize un-compacted native soil or engineered soil media underneath sidewalks to treat stormwater runoff and include full-canopy trees to provide evapotranspiration and nutrient uptake. Reductions in pollutants are attributed to filtration, sedimentation, and the system's internal water storage (IWS). Silvia Cells® are a type of suspended pavement system approved by NCDEMLR to manage stormwater runoff.

North Carolina State University (NCSU) researchers and the City of Durham monitored two undersized Silva Cell systems (North and South) for water quality and hydrologic improvement from May 2019 to June 2020. They collected 16 and 5 effluent water quality samples from the North and South systems, respectively. The project site's target TN and TP loading rates were calculated using the NCDEQ Stormwater Nitrogen and Phosphorus Tool (SNAP)

Results showed the annual TN and TP loading rates from North and South systems were well below the site's target rates and indicate undersized Silva Cells have the potential to mitigate the environmental impacts associated with development.

This project also built upon previous literature review on floating wetland islands that can be added to existing stormwater ponds to improve their nutrient reduction performance. Using currently available data and recommendation from the Jordan Lake Study, design guidance was developed to aid the development community in implementation of FWI and other available wet pond retrofits.

UNRBA Model Review

There are four types of models being developed by the UNRBA to support the re-examination of Stage II. The first is a WARMF watershed model to estimate sources of nutrients from the watershed to the Lake. The second model, WARMF Lake, will be used to receive direct input from the watershed model to quickly evaluate the impacts of nutrient loading scenarios on lake water quality. The third model is a hydro-dynamic water quality model using the Environmental Fluid Dynamics Code (EFDC) to simulate concentrations of nutrients, carbon, and algae in that result from hydrologic and loading inputs from the watershed. The UNRBA also plans to develop a fourth model, a statistical model, to evaluate how designated uses are affected by lake water quality.

Dan Obenour Associate Professor at NCSU, will analyze the UNRBA watershed and water quality models in comparison to scientific literature on model development and biophysical rate estimates. This study will further focus on the representation of nutrient sourcing, transport, and fate within the watershed. The UNRBA will receive literature review, model assessment, and list of recommendations identifying each model's strength, limitation, and suggestion for future improvements.

Researchers at NCSU will collaborate with the UNRBA to analyze their watershed and water quality models being developed as part of the Stage II reexamination process and compare the models against existing scientific literature addressing nutrient sourcing, and fate and transport within a watershed to help identify each models strengths limitations and make suggestions for improvements to the final UNRBA model products.

Next Steps

This five-year report provides a snapshot of the current state of rule implementation activities in the watershed as well as changes in tributary loading and lake water quality. It highlights both the challenges in achieving the water quality goals of the nutrient management strategy and the need for additional information to inform the adaptive management of the lake and ongoing rules reexamination process. All the while, the regulated community continues to work constructively and collaboratively with the Division to improve water quality in Falls Lake. The partnership between DWR and stakeholders has been essential and invaluable in addressing the formidable challenges inherent in sustaining the resources and designated uses the lake.

As detailed in this report, major efforts have been underway over the past ten years through initiatives by the UNRBA to address the scientific uncertainty of the Falls nutrient management strategy and its underpinning water quality models. Looking ahead, it remains important that the ongoing collaboration between the Division and the UNRBA extends to re-examining the long-term strategy for Falls and builds upon an improved understanding of how the lake reacts to different management approaches.

Over the next three years, the UNC Collaboratory Falls Lake Study and the UNRBA Modeling and Regulatory Support Project will be central to establishing the foundation for future recommendations that will inform the EMC's rules readoption process set to begin in 2024. The Collaboratory is scheduled to complete and report their findings and recommendations from the Falls Lake Study by 2023. In the meantime, the UNRBA modeling team continues to coordinate closely with the Collaboratory as they work to incorporate the results of these ongoing studies into their modeling efforts which are scheduled for completion in the next 24 months.

The methodology for assessing water quality and efficacy of the chlorophyll-a standard and it connection to designated uses and ecological integrity of the lake remains an important question for the regulated community in the watershed. The UNRBA's remodeling effort is anticipated to result in recommendations on these topics, in addition to recommendations for changes to the Stage II rules that will likely result in result in requirements that differ in the character from the current rules.

Looking ahead, it remains important that the ongoing collaboration between the Division and the UNRBA extends to re-examining the long-term strategy for Falls and builds upon an improved understanding of how the lake's physical, chemical, biological, and geological characteristics and how it reacts to different management approaches.

Appendices

Appendix 1: Falls Lake Chronology of Events, Past and Projected

Year	Event
1930s	State of North Carolina requests a study for creating Falls Reservoir
1959	Neuse River from mouth of Little Creek to Wake Finishing Plant (encompassing present Falls Lake) receives water supply classification (A-II).
1963	Army Corps of Engineers recommends Falls Lake for construction
1965	Congress authorizes construction of Falls Lake with Flood Control Act of 1965
1973	N.C. Department of Natural and Economic Resources Office of Water and Air Resources releases its Special Analysis of the Falls of the Neuse Project
1974	Army Corps of Engineers releases its Final Environmental Impact Statement (Revised) Falls Lake Neuse River Basin North Carolina
1978	Falls Lake construction begins
1979	Statewide chlorophyll *a* standard adopted
1981	Falls Lake construction complete
1983	Falls Lake water levels reach present day normal levels
1983	Falls Lake designated as Nutrient Sensitive Waters (NSW), water supply designations expanded to include Falls Lake.
1989	Water supply protections mandated in North Carolina, S.L. 1989-426
1992	Falls Lake classified as a water supply watershed
1997	S.L. 1997-458 caps nitrogen and phosphorus wastewater outputs into NSW
2004	Division monitoring and modeling studies of the lake begin
2005	S.L 2005-190 requires EMC to adopt a nutrient strategy for Falls Lake
2005	Falls Lake Technical Advisory Committee forms
2007	Falls Lake field study completed
2008	Falls Lake named to federal 303(d) list for chlorophyll *a* and turbidity standard exceedances
2009	Session Law 2009-486 directs Commission to adopt a nutrient strategy for Falls Lake by January 15, 2011.
2009	Nutrient Scientific Advisory Board created through Session Law 2009-216
2009	Falls Lake model complete
2010	Falls Lake nutrient strategy is adopted
2011	Stage I of Falls Lake nutrient strategy is initiated
2011	Watershed Oversight Committee appointed to guide oversight of Falls Agriculture Rule.
2014	UNRBA Begins Additional Monitoring for Stage II Re-examination
2016	Falls Lake Nutrient Strategy Interim Report and every 5 years thereafter
2016	Planned attainment of chlorophyll *a* standards downstream of NC-98
2018	Legislation Calls For UNC j8 & Extends Stage I until Rules Readopted
2018	UNRBA Monitoring Project Completed / Remodeling Project Begins
2019	UNC Collaboratory Falls Lake Study Begins
2021	Original rules – End Stage I, attainment of chlorophyll *a* standards in Lower Falls Lake, commence Stage II implementation (*delayed through legislation*)
	Projected Timeline
2023	UNRBA Falls remodeling scheduled to be Completed
2023	UNC Collaboratory Final Report & Recommendations to EMC
2024	EMC Begins Falls Nutrient Strategy Rules Readoption Process
2025	DWR Falls Lake Nutrient Strategy Reevaluation Report Due to EMC
~2027	Anticipated Effective Date for Readopted Rules & Start of Revised Stage II
2041	Original rules - planned attainment of chlorophyll *a* standard throughout Falls Lake

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Figure 27. Combined Average Flow-Normalized Tributary Nitrogen Concentration for Long-Term Flow Conditions for the Upper Five Major Tributaries of Falls Lake

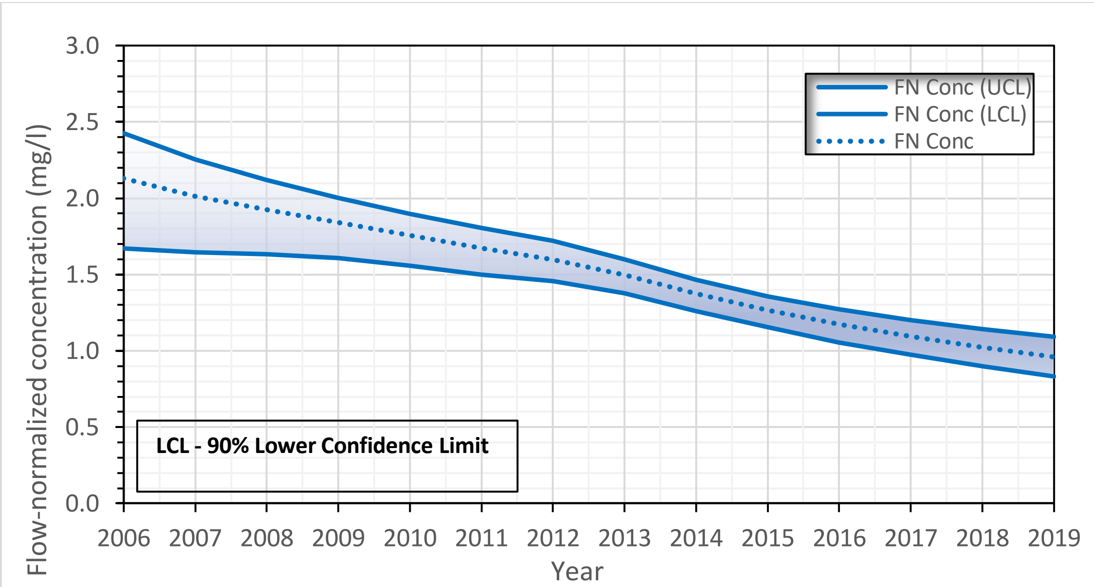


Figure 28. Combined Flow-Normalized Tributary Nitrogen Load For Long-Term Flow Conditions for the Upper Five Major Tributaries of Falls Lake

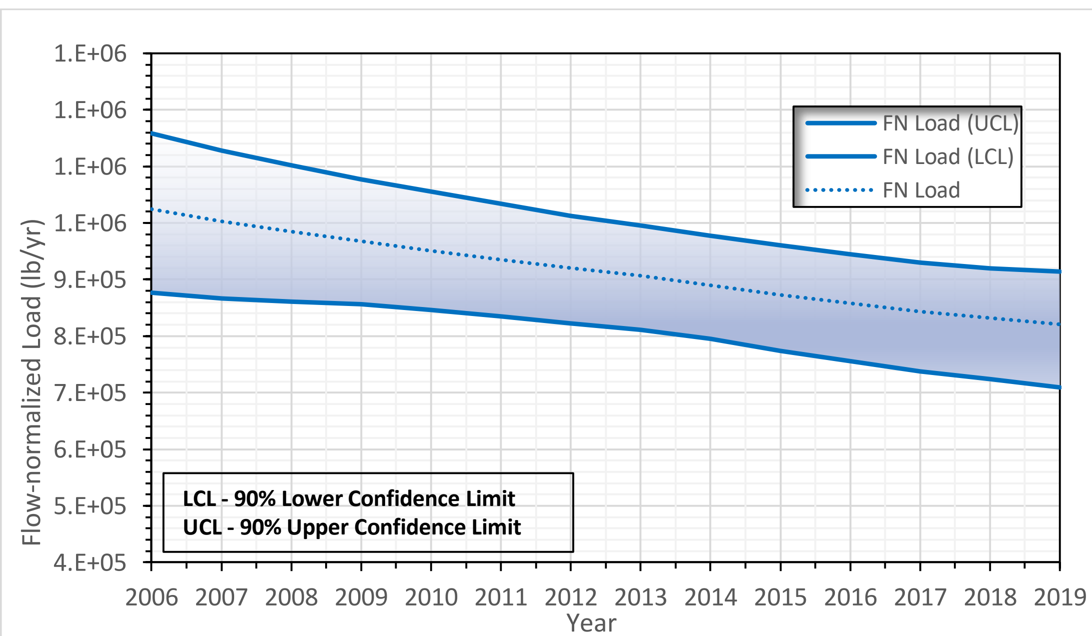


FIGURE 29. COMBINED AVERAGE FLOW-NORMALIZED TOTAL PHOSPHORUS CONCENTRATION FOR LONG-TERM FLOW CONDITIONS FOR THE UPPER FIVE MAJOR TRIBUTARIES OF FALLS LAKE

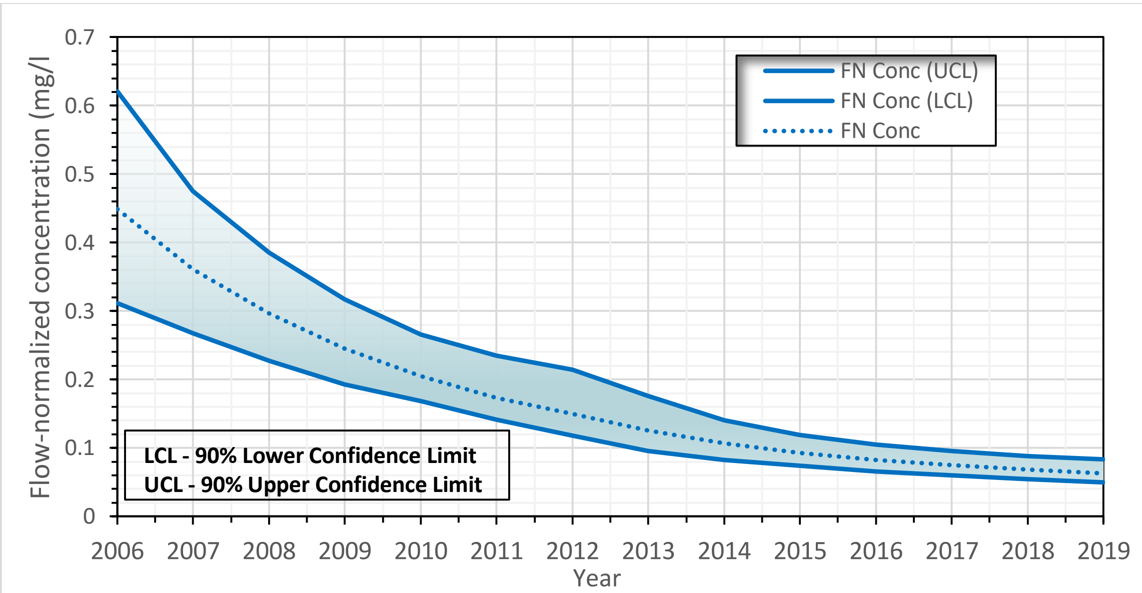
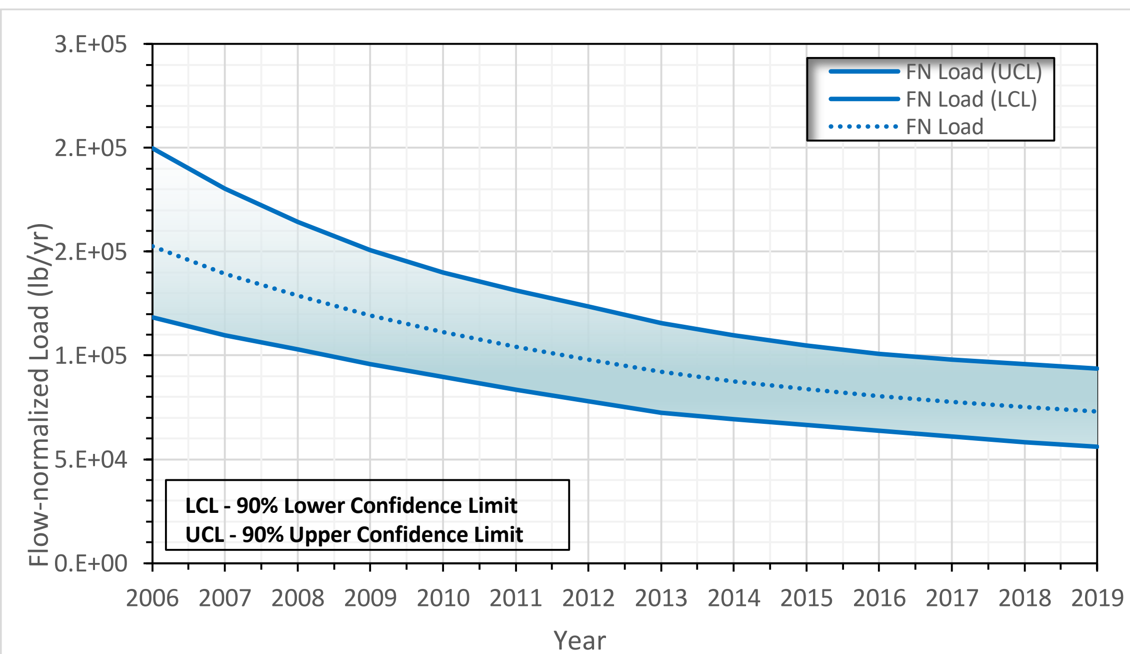
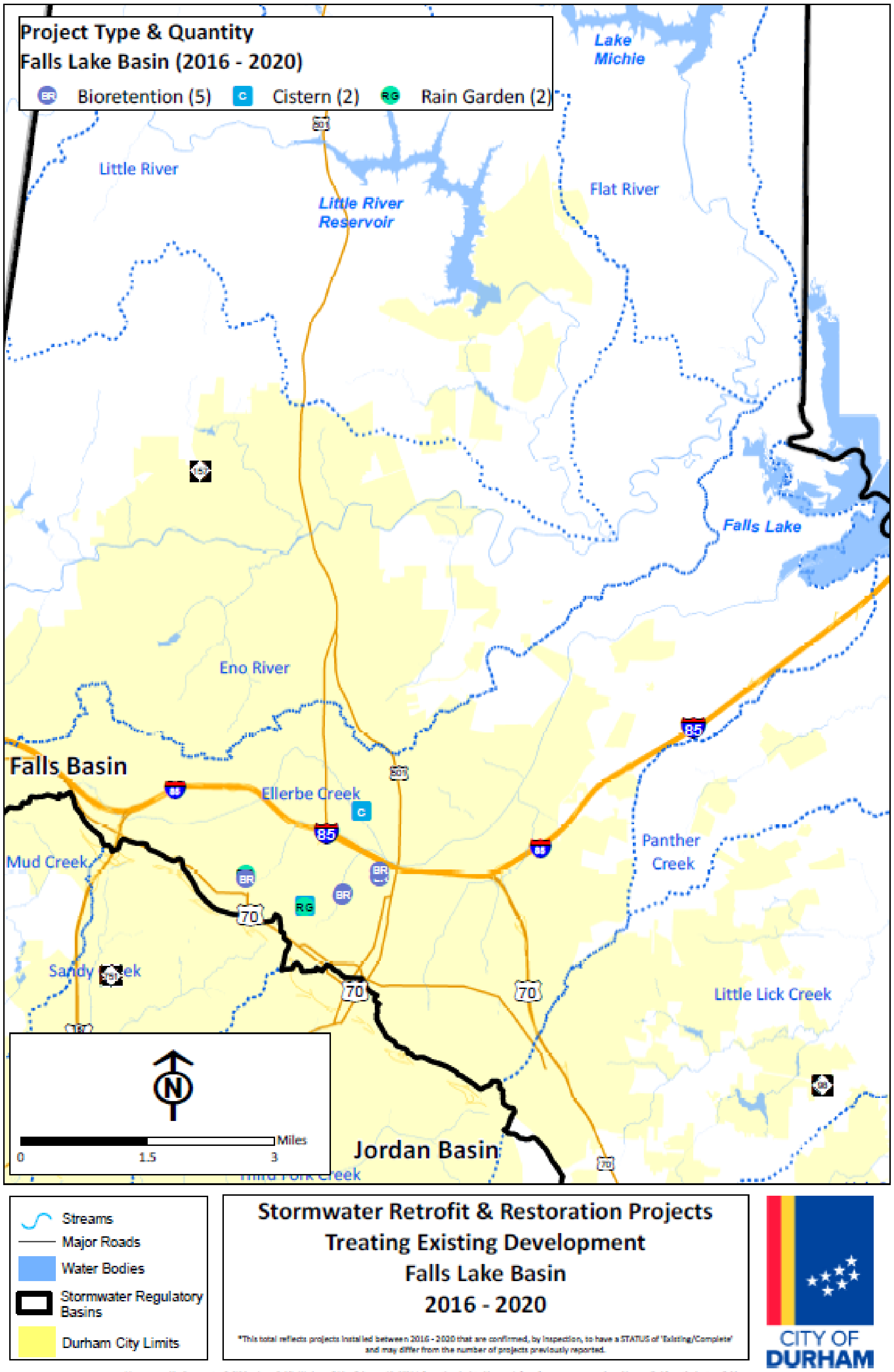


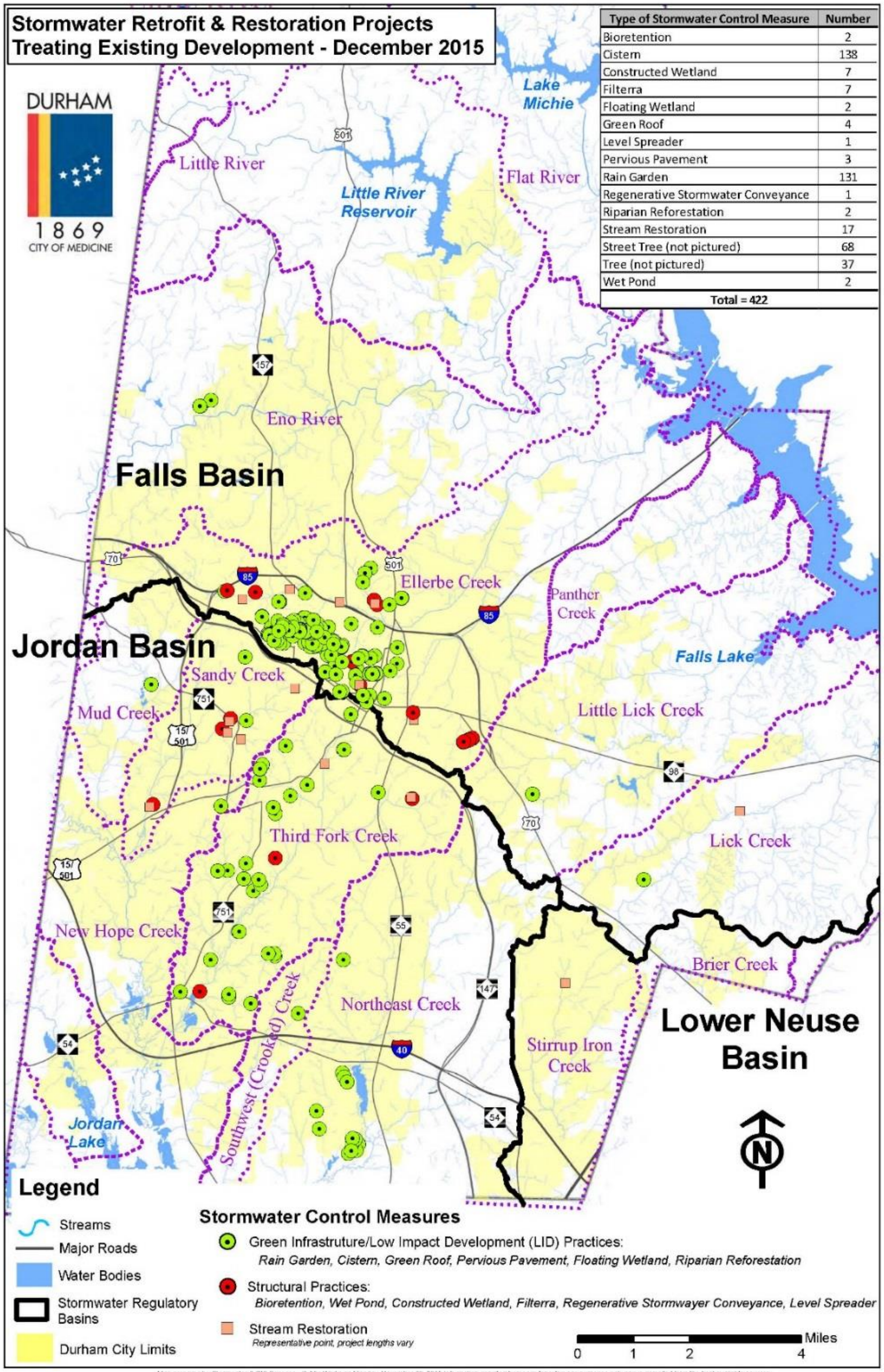
FIGURE 30. COMBINED FLOW-NORMALIZED TRIBUTARY PHOSPHORUS LOAD FOR LONG-TERM FLOW CONDITIONS FOR THE UPPER FIVE MAJOR TRIBUTARIES OF FALLS LAKE



Appendix 5: Maps Showing of City of Durham Storm water Retrofit & Restoration Projects



Map prepared by Stormwater & GIS Services - Public Works on Friday, February 19, 2021 Information depicted hereon is for reference purposes only and is compiled from the best available sources. The City of Durham/Durham County assumes no responsibility for errors arising from use or misuse of this map.



Map prepared by Stormwater & GIS Services - Public Works on Monday, November 30, 2015. Information depicted hereon is for reference purposes only and is compiled from the best available sources. The City of Durham/Durham County assumes no responsibility for errors arising from use or misuse of this map.

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