UNRBA Monitoring Program Interim Report

UNRBA Monitoring FY 2017

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Executive Summary

This 2016 Interim Report provides a status update for the UNRBA Monitoring Program for data collected through June 2016. From August 2014 through June 2016 routine monthly water quality sampling occurred twice a month on the five largest tributaries and monthly at the 13 other Lake Loading Stations. These sites are monitored for nutrients (various species of nitrogen and phosphorus), total and volatile suspended solids, total and dissolved organic carbon, and chlorophyll a concentrations from the tributaries to provide data that was not available when DWR developed the model in support of the Falls Lake Nutrient Management Strategy. Routine data are also collected monthly from 18 jurisdictional monitoring stations located close to jurisdictional boundaries. These stations are monitored for nutrients, chlorophyll a, and total organic carbon. The UNRBA also collaborates with NCDEQ on the collection of monitoring data from Falls Lake. The State monitors most water quality parameters in the lake monthly at twelve locations and collects extra sample bottles for analysis by the UNRBA contract laboratory for specialized parameters such as UV absorbance. In addition the UNRBA conducts several Special Studies that address questions about model inputs and assumptions or provide data for use during model calibration.

So far during the UNRBA monitoring period, rainfall patterns and lake elevations have been relatively normal. Overall the annual rainfall in 2014 and 2015 has been higher than the 30 year average of 43 inches, but within the middle 50 percent of observations since 1985. As a result, lake levels have been at or above median values in contrast to the drought years on which the Falls Lake Nutrient Management Strategy were based (2005 through 2007).

The majority of water quality observations from the UNRBA Monitoring Program are compliant with NC water quality standards. For example, North Carolina water quality standards specify that dissolved oxygen (DO) concentrations should be no less than 4 mg/L. Of 930 total DO measurements, approximately 93 percent were above the standard and 7 percent fell below 4 mg/L. The water quality standard for pH specifies values between 6 and 9. Field measured values of pH at the Jurisdictional and Lake Loading stations showed approximately 99 percent compliance with the standard. For chlorophyll a, the water quality standard is 40 µg/L. Of 526 chlorophyll a values measured at the lake loading stations, 504 (96 percent) were below the 40 µg/L water quality standard, and median values were near or below 10 µg/L. These chlorophyll a data are being collected to fill a critical gap in the State's modeling that assumed concentrations in tributaries flowing into the lake were equivalent to concentrations measured in the lake.

All analytical data collected through the UNRBA monitoring program (both from Routine Monitoring and from Special Studies) are evaluated for compliance with the quality objectives outlined in the UNRBA Quality Assurance Project Plan (QAPP). Data accuracy, precision, and completeness reviews are performed following each monitoring event and reviews of field and laboratory practices are performed on a routine basis to ensure that the representativeness, accuracy and precision of data collection efforts meet the criteria set forth in the UNRBA's QAPP. The UNRBA Routine Monitoring program was designed to collect data from representative sites in the Falls Lake basin and at regular time intervals in order to capture data during conditions representing the entire monitoring period. All efforts are made to adhere to this sampling plan; however some samples are understandably missed due to factors such as dry stream conditions, extreme weather, site access limitations, equipment malfunction, or staffing issues.

From August 2014 to June 2016, the UNRBA collected about 92 percent of the samples and data points anticipated in the monitoring plan. Most of the missed data collection (~ 75%) has been attributable to dry conditions which prevented sample collection from some sites. This was typically because of dry streambeds or the presence of only a disconnected pool at the sampling location. In some instances, the water was too shallow across the entire channel to obtain a clean sample uncontaminated by sediment material. Ice storms in February 2015 accounted for eleven percent of the missed samples, despite multiple collection attempts. Site access issues, typically from construction efforts, were the cause of the remaining missed samples.

Accuracy and precision of measurements are continually assessed through the review of field, trip, and bottle blank concentrations, field and laboratory duplicate samples, and matrix spike recoveries. As discussed in the QAPP, accuracy can be assessed through a variety of measurements including blank samples, laboratory control samples, and matrix spike samples. There have been no issues with laboratory control samples and only a few occurrences of matrix spike recoveries outside of the QAPP criteria (<5%). Cardno will continue to monitor and log accuracy through matrix spike recoveries; per EPA guidance, matrix spike recoveries outside of the designated recovery range do not indicate a systemic problem as long as laboratory control samples are otherwise in control.

Routine Monitoring continues to produce a large volume of useful data to support the goals of the UNRBA, with more than two full years of data collection now completed. Several Special Studies have also been completed, and others are still ongoing to provide additional information to support one or more of the goals. Updated versions of the Monitoring Program guidance document and the associated Quality Assurance Project Plan have been prepared and submitted to the North Carolina Division of Water Resources.

No changes are recommended to the Monitoring Program at this time. Several adjustments to the program were implemented at the beginning of FY2017 for reasons discussed in the 2016 Annual Report (Cardno 2016). The 2017 Annual Report will explore whether any additional changes to the Monitoring Program are recommended for implementation in FY2018 (July 2017 through June 2018).

1 Purpose of the UNRBA Monitoring Program

1.1 Introduction

The Upper Neuse River Basin Association (UNRBA) Monitoring Program is primarily composed of two categories of water quality monitoring. The first category is Routine Monitoring, which is the repeated testing of water quality variables at fixed locations over many months. Routine Monitoring provides insight into the seasonal and annual variation of nitrogen, phosphorus, chlorophyll and other parameters over time. UNRBA Routine Monitoring began in August 2014. The second category, Special Studies, is a series of focused evaluations conducted within a limited timeframe. Most Special Studies are intended to inform water quality model development and calibration so that baseline and management scenarios can be more accurately simulated. Special Studies are also used to assist the UNRBA in its efforts to explore and examine water quality and nutrient management programs, policies and regulations. Each Special Study is evaluated at the end of each monitoring year to determine whether it should be continued, modified, suspended, or replaced with another effort in the subsequent year.

In 2014, the UNRBA initiated the Monitoring Plan that described the locations, parameters, frequencies, and duration program (Cardno 2014b; http://www.unrba.org/monitoring-program). The Monitoring Plan is maintained and updated to reflect changes in the program over time. As established in Section 5 (f) of the Falls Lake Nutrient Management Strategy (http://portal.ncdenr.org/web/fallslake/home), the UNRBA Monitoring Plan was initially approved by DWR on July 16, 2014. An updated monitoring plan document was submitted to DWR in September 2016. The UNRBA Monitoring Quality Assurance Project Plan (QAPP) was developed specifically for the program to ensure that data are reliable and suitable for consideration for regulatory purposes. The QAPP describes the protocols and methodologies to be followed by field and laboratory staff to ensure data precision and accuracy. It was initially approved by the North Carolina Department of Environmental Quality (NCDEQ) Division of Water Resources (DWR) on July 30, 2014; an updated version was submitted to DWR in October 2016.

An Interim progress report of the monitoring results is prepared each fall, and Annual Reports are prepared each year in the spring. The Monitoring Program scope and budget coincide with the UNRBA's Fiscal Year, which runs from July 1 through June 30.

This Interim Report provides a status review of the UNRBA Monitoring Program from January through June 2016. Additionally, this report presents results of 2016 data along with data from Years 1 and 2 (2014 and 2015) of the program. While the Annual Reports also provide results and interpretation of data collection efforts by other entities, Interim Reports generally only address the results of data collection funded by the UNRBA. Thus, Interim Reports do not include data collected by local jurisdictions or DWR within Falls Lake and its watershed.

1.2 Regulatory Background

The North Carolina Environmental Management Commission (EMC) passed the Falls Lake Nutrient Management Strategy ("the Rules"), requiring two stages of nutrient reductions within the Falls of the Neuse Reservoir watershed (N.C. Rules Review Commission 2010). Stage I is described in 15NCAC 02B .0275 (4) (a), and Stage II is described in 15NCAC 02B .0275 (4) (b). The Rules recognize there is uncertainty associated with the water quality modeling performed by DWR used to establish the Stage II requirements, and therefore, allow for re-examination of the Stage II nutrient loading reduction requirements after additional data collection, as specified in Section 5(f) of the Rules. The UNRBA Monitoring Program was specifically designed to reduce the uncertainty and to re-examine the scientific assessment and modeling predictions used by DWR to support these rules.

1.3 UNRBA Re-examination Strategy

In 2011, the UNRBA began a re-examination process of the regulatory framework for Stage II of the Rules. Full implementation of the nutrient reduction strategy, which is more stringent than any other nutrient strategy implemented in the State, will require extremely costly actions on the part of UNRBA member governments and other regulated parties, and there is uncertainty as to the practical ability to achieve the mandated reductions. In light of this uncertainty and the potential financial impact of these rules and the importance of Falls Lake as a resource, the UNRBA began examination of the technical basis and regulatory framework for Stage II of the Falls Lake Strategy. Local governments within the UNRBA agree that protecting Falls Lake as a water supply and public resource is paramount, but they want to ensure that the rules applied to the watershed sufficiently reflect the Lake's uses and that regulatory and management requirements are reasonable, fiscally responsible, and efficaciously improve the water quality of the resource. Based on a review conducted by Cardno (2013), the Stage II Rules are not technically, logistically, or financially feasible. Given the high cost of implementing Stage II (approximately $945 million (NCDWQ 2010)) and the uncertainty of whether the prescribed nutrient reduction would yield the targeted chlorophyll *a* concentration, the scientific re-examination process relies on additional data collection and new modeling efforts to support revised lake response modeling, as well as evaluation of various regulatory options.

The Rules require that NCDEQ issue a status update for the Falls Lake Nutrient Management Strategy every five years, beginning in 2016. The most recent version of that update report was issued in March 2016 and is available on the NCDEQ website (http://portal.ncdenr.org/web/fallslake/rules-implementation-information). The report summarizes progress toward implementation of the Rules and describes changes in nutrient loading to the lake and lake water quality. The 2016 status report highlights the improvements (reductions) in chlorophyll *a* concentrations observed throughout the lake. The report recognizes the UNRBA as a collaborative partner to further the science with respect to reducing the uncertainty associated with the lake modeling, expanding the "toolbox" of best management practices that may be used for compliance, and employing conventional and innovative nutrient control measures to improve water quality in the lake (NCDEQ 2016).

1.4 Objectives of the UNRBA Monitoring Program

The UNRBA Monitoring Program is designed to support the UNRBA's three main goals, as prioritized by the UNRBA Path Forward Committee:

1. Revise lake response modeling,
2. Support alternative regulatory options as needed, and
3. Allocate loads to sources and jurisdictions.

The sections below provide an overview of the current components of the monitoring program and of the data obtained under the program through June 2016.

2 Overview of UNRBA Monitoring Program

This Interim Report addresses monitoring efforts from January 2016 through June 2016 within the context of the results of the entire monitoring program since August 2014. During the six-month period since the previous Annual Report, the UNRBA Monitoring Program focused on Routine Monitoring and a series of Special Studies. Additional information about the general nature of the Routine Monitoring and Special Studies efforts are provided in the Monitoring Plan and in the Plan of Study for each individual Special Study (https://unrba.org/monitoring-program).

2.1 Routine Monitoring

The Routine Monitoring Program was established to characterize the spatial and temporal variability of water quality in the Falls Lake Watershed. It includes Lake Loading stations and Jurisdictional stations located on tributaries to the lake. Data collection is managed by Cardno. The Monitoring Program contract and initiation of any major changes to the program are synchronized with the UNRBA fiscal year (FY) from July through June. The Routine Monitoring efforts on the tributaries are outlined in Table 2-1, and the tributary stations and associated monitoring frequencies are provided in Table 2-2. Routine Monitoring also includes coordination with DWR, which conducts monthly monitoring at long-term stations located within the Falls Lake Reservoir.

2.1.1 Lake Loading Stations on Tributaries in the Falls Lake Watershed

To characterize the tributary inputs to Falls Lake, and to support lake response modeling, flow and water quality data are needed from locations as near as possible to the mouth (point of entry) for each of the lake's 18 tributaries. Water quality and USGS flow gage locations are shown on Figure 2-1. The USGS maintains ten flow gages and one stage gage in the watershed. Site characteristics for these gages are provided in the Flow Estimation Technical Memorandum (Cardno 2014a) available at http://www.unrba.org/monitoring-program.

From August 2014 through June 2016 routine water quality sampling occurred twice a month on the five largest tributaries and monthly at the 13 other Lake Loading stations. Beginning in July 2016, routine sampling occurs monthly at all 18 stations with additional sampling during high flow conditions. High flow sampling is important because water and nutrient contributions from the watershed drives much of the lake's chlorophyll response. The program also includes collection of total and volatile suspended solids, total and dissolved organic carbon, and chlorophyll a concentrations from the tributaries to provide data that was not available when DWR developed the model in support of the Rules.

The parameters selected for routine monitoring at Lake Loading stations were generally based on the input from the UNRBA member organizations and the requirements of the Environment Fluid Dynamics Code (EFDC) model originally used by DWR for Falls Lake. The UNRBA Monitoring Program is reviewed annually and may be revised to modify parameter coverage, frequencies, and sampling locations to optimize data collection for the UNRBA's needs.

2.1.2 Jurisdictional Boundary Stations on Tributaries in the Falls Lake Watershed

The Rules specify that loading from the various governmental jurisdictions in the Falls Lake watershed must be reduced. Establishment of water quality monitoring stations between the jurisdictions and at key loading points such as the outlets of major tributaries within a jurisdiction can be used to 1) provide water quality data from multiple areas for all member jurisdictions, 2) prioritize best management practice (BMP) implementation in areas with the highest nutrient loading, 3) calibrate watershed models and, 4) potentially assess changes in loading over time.

Twenty stations (Figure 2-1) were identified based on input from the UNRBA Path Forward Committee (PFC) and are being monitored monthly to characterize water quality near jurisdictional boundaries between the UNRBA member governments. As with the Lake Loading stations, data collection efforts at Jurisdictional stations may be modified in the future to optimize data value for the UNRBA.

Table 2-1 Overview of Routine Monitoring Components of the UNRBA Monitoring Program from August 2014 through June 2016.

Parameter	Start Date	End Date	Stations
Field Measurements:			
Air temperature	Aug, 2014	**Aug, 2015**	All
Water temperature	Aug, 2014	Ongoing	All
Specific conductance	Aug, 2014	Ongoing	All
Dissolved Oxygen	Aug, 2014	Ongoing	All
pH	Aug, 2014	Ongoing	All
Reference-point tape-down	**Jan, 2015**	Ongoing	All
Dye velocity	**Jan, 2015**	Ongoing	All
Laboratory Analyses:			
Total Kjeldahl nitrogen	Aug, 2014	Ongoing	All
Soluble Kjeldahl nitrogen	Aug, 2014	Ongoing	Lake Loading
Nitrate + nitrite	Aug, 2014	Ongoing	All
Ammonia	Aug, 2014	Ongoing	All
Total phosphorus	Aug, 2014	Ongoing	All
Total soluble phosphorus	Aug, 2014	Ongoing	Lake Loading
Orthophosphate	Aug, 2014	Ongoing	Lake Loading
Total organic carbon	Aug, 2014	Ongoing	All
Dissolved organic carbon	Aug, 2014	**Jun, 2016**	Lake Loading
Chlorophyll *a*	Aug, 2014	Ongoing	Lake Loading
Total suspended solids	Aug, 2014	Ongoing	All
Volatile suspended solids	**Jul, 2015**	Ongoing	Lake Loading
Color (platinum cobalt)	Aug, 2014	**Jun, 2016**	Lake Loading
Visible absorbance at 440nm	Aug, 2014	Ongoing	Lake Loading
UV absorbance at 254nm	Aug, 2014	Ongoing	Lake Loading
5-day carbonaceous biochemical oxygen demand	Aug, 2014	**Jun, 2016**	Lake Loading

Table 2-2 UNRBA Tributary Stations and Sampling Frequency through June 2016

Name[1] (Station Type[2])	Subwatershed	Stream Name	County	Drainage Area (mi^2)	Sampling Frequency
NFR-41 (JB)[3]	Flat	North Flat	Person	12.7	Monthly
NFR-37(JB)	Flat	North Flat	Person	15.8	discontinued
NFR-32(JB)	Flat	North Flat	Person	32.8	Monthly
SFR-30(JB)	Flat	South Flat	Person	54.4	Monthly
FLR-25(JB)	Flat	Flat	Person	102	Monthly
DPC-23(JB)	Flat	Deep	Person	32.1	Monthly
FLR-5.0(LL)	Flat	Flat	Durham	169	Twice Monthly[5]
NLR-27(JB)	Little	North Fork Little	Orange	21.9	Monthly
SLR-22(JB)	Little	South Fork Little	Durham	37.4	Monthly
LTR-16(JB)	Little	Little	Durham	78.3	Monthly
LTR-1.9(LL)	Little	Little	Durham	104	Twice Monthly[5]
ENR-49(JB)	Eno	Eno	Orange	60.5	Monthly
ENR-41(JB)	Eno	Eno	Orange	73.2	Monthly
ENR-23(JB)	Eno	Eno	Durham	121	Monthly
ENR-8.3(LL)	Eno	Eno	Durham	149	Twice Monthly[5]
CMP-23(JB)	Knap of Reeds	Camp	Durham	1.99	Monthly
KRC-4.5(LL)	Knap of Reeds	Knap of Reeds	Granville	41.9	Twice Monthly[5]
ELC-3.1(LL)	Ellerbe	Ellerbe	Durham	21.9	Twice Monthly[5]
UNT-0.7(LL)	Unnamed	Unnamed	Granville	3.43	Monthly
PAC-4.0(LL)	Panther	Panther	Durham	3.24	Monthly
LLC-1.8(LL)	Little Lick	Little Lick	Durham	13.8	Monthly
LLG-0.9(JB)	Little Ledge	Little Ledge	Granville	3.74	Monthly
LGE-17(JB)	Ledge	Ledge	Granville	1.79	Monthly
LGE-13(JB)	Ledge	Ledge	Granville	3.49	Monthly
LGE-5.1(LL)	Ledge	Ledge	Granville	20.3	Monthly
LKC-2.0(LL)	Lick	Lick	Durham	10.8	Monthly
ROB-7.2(JB)	Robertson	Robertson	Granville	4.43	Monthly
ROB-2.8(LL)	Robertson	Robertson	Granville	12.0	Monthly
BDC-2.0(LL)	Beaverdam	Beaverdam	Granville	12.7	Monthly
SMC-6.2(LL)	Smith	Smith	Granville	6.3	Monthly
BUC-3.6(JB)	New Light	Buckhorn	Granville	1.21	Monthly
NLC-3.8(JB)	New Light	New Light	Wake	9.90	Monthly
NLC-2.3(LL)	New Light	New Light	Wake	12.3	Monthly
UBC-1.4 (LL)	Upper Barton	Upper Barton	Wake	8.26	Monthly
LBC-2.1 (LL)	Lower Barton	Lower Barton	Wake	10.4	Monthly
HSE-11(JB)	Horse	Horse	Franklin	3.88	Monthly
HSE-7.3(JB)	Horse	Horse	Wake	7.11	Monthly
HSE-5.7 (JB)[4]	Horse	Horse	Wake	9.60	alternate site
HSE-1.7(LL)	Horse	Horse	Wake	11.9	Monthly
HCC-2.9(LL)	Honeycutt	Honeycutt	Wake	2.76	Monthly

[1]Name combines an abbreviation for the stream with the approximate distance from the station to Falls Lake (km).

[2]JB refers to a Jurisdictional Boundary station and LL refers to a Lake Loading station.

[3] NFR-41 was added in July, 2015 to replace site NFR-37 due to concerns about safety and accessibility at NFR-37.

[4] HSE-5.7 was used as an alternate for HSE-7.3 in May-June, 2015 while HSE-7.3 was inaccessible due to construction.

[5] As of July 1, 2016, these samples are being collected monthly rather than twice monthly.

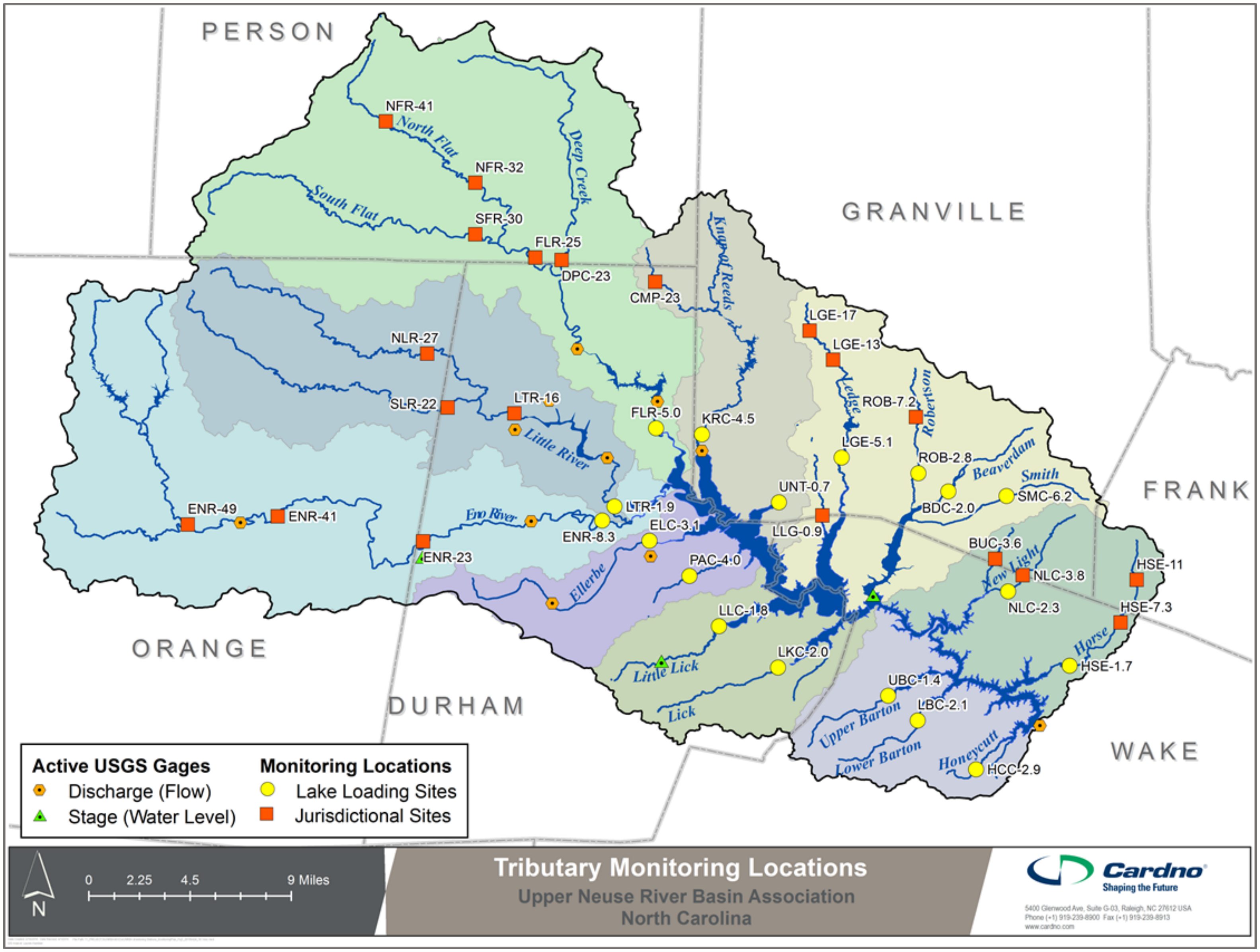

Figure 2-1 UNRBA Lake Loading and Jurisdictional Monitoring Locations (see Table 2-2 for station details) and Existing USGS Gages

2.1.3 Falls Lake Monitoring

Monitoring of the Falls Lake Reservoir provides data on ambient water quality conditions, as well as for calibration and validation of updated lake models. Ongoing monitoring by DWR, local governments (City of Raleigh and City of Durham), and North Carolina State University's Center for Applied Aquatic Ecology (NCSU CAAE) provides data that may be used (Figure 2-2). Data are obtained from these sources on an annual basis and therefore are not included in this FY 2017 Interim Report. A summary of data-collecting agencies and the parameters they monitor is provided in the UNRBA's Monitoring Plan.

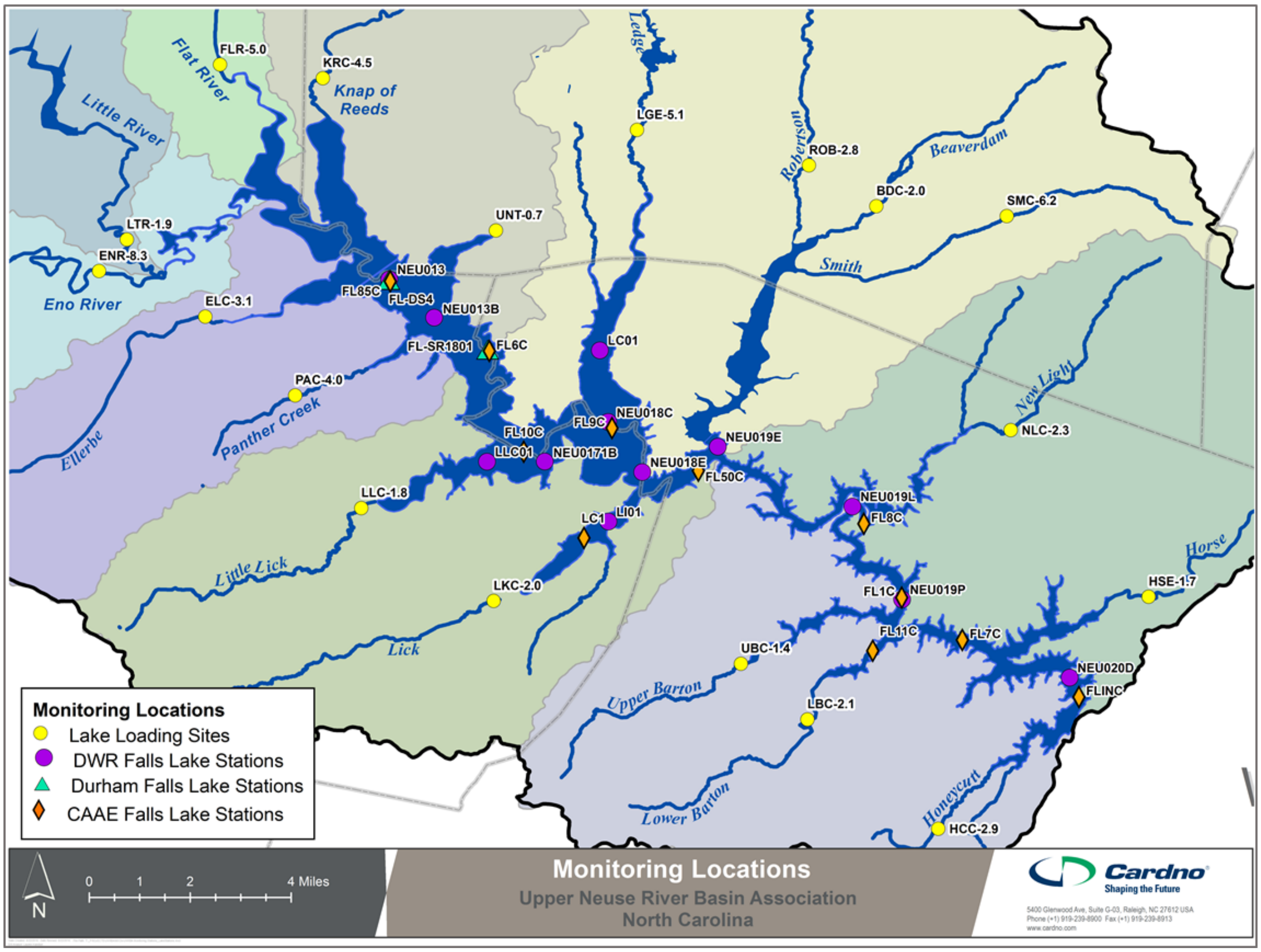

Figure 2-2 Falls Lake DWR, City of Durham, and CAAE Monitoring Locations, along with UNRBA Lake Loading Stations

2.1.4 Modifications to Routine Monitoring Since 2016 Annual Report

No changes to the Routine Monitoring program were implemented during the FY2016 monitoring year (July 2015 through June 2016) and therefore no modifications are relevant to the data presented in this mid-year report. The FY2017 monitoring year includes a few changes to parameters being monitored and monitoring frequency; these changes are described in the Monitoring Plan.

2.2 Special Studies

The UNRBA Monitoring Program includes Special Studies designed to address specific questions. This section briefly summarizes the Special Studies which have been implemented as a part of the UNRBA's Monitoring Program (Table 2-3). Each Special Study is guided by a Study Plan developed by Cardno and approved by the UNRBA Executive Director. These plans include details on sampling methods and quality assurance protocols and are available on the UNRBA website (http://unrba.org/monitoring-program). Special Studies results obtained since the previous Annual Report are presented in Section 4.

2.2.1 Storm Event Sampling

Storm Event Sampling is focused on obtaining additional water quality data from major tributaries to Falls Lake under varying streamflow conditions over time. In contrast to the twice monthly grab samples taken under the Routine Monitoring process, this data collection effort employs automated sampling equipment to collect multiple discrete samples as stream flows rise and then fall during and following a storm event. Such data allow for a better understanding of the contribution of nutrients and related parameters across the entire hydrograph of associated storm events. Data from this study will be used to better inform model development and calibration for simulating water quality conditions in Falls Lake. Updated results, which include data from the May and February 2016 storm events, are provided in Section 4.1. This special study is not continued in the FY 2017 UNRBA Monitoring Plan.

2.2.2 High-Flow Sampling

This Special Study is used to obtain supplementary water quality grab samples from select tributaries to Falls Lake under high flow conditions which may be under-represented by routine monitoring. High flow conditions are periods when stream flow increases markedly above normal flows in response to a rain event. This supplemental effort helps to ensure that data are available for locations expected to reflect substantially different pollutant loading during periods of high flows. Data from this study will help to inform the Falls Lake modeling.

Modifications to this special study were initiated in July 2016 to provide more frequent data collection from the largest tributaries under high flow conditions, as outlined in the FY2017 Monitoring Plan and the High-Flow Study Plan.

Table 2-3 Summary of UNRBA Special Studies Status

Monitoring Program Component	Purpose
Storm Event Sampling (initiated in Fiscal Year 2015) (concluded in Fiscal Year 2016)	Obtain water quality data with automated samplers throughout the elevated flow period associated with storms to improve loading estimates to Falls Lake. These data will be used to help verify the accuracy of methods used to develop tributary loading input files for modeling efforts.
High Flow Sampling (initiated in Fiscal Year 2015)	Obtain additional water quality grab samples when there is elevated flow at select Lake Loading stations. These data will be used to determine if water quality in these areas is different when flows are elevated and thus conveying more water and loading to the lake. These data will be used to ensure that loading estimates from these tributaries are representative of delivered loads.
Falls Lake Sediment Sampling (initiated in Fiscal Year 2015)	Evaluate nutrient concentrations in Falls Lake sediments to improve estimates of internal loading of nutrients from the lake sediments. These data will be used to evaluate sediment models that may be used to estimate nutrient loading and to provide information to facilitate planning for a potential EPA study of in situ sediment nutrient releases.
Support Development of Alternative Regulatory Options (funded in Fiscal Year 2015)	Meetings with regulators (DEQ and EPA) to discuss alternative regulatory strategies for Stage II of the Falls Lake Nutrient Management Strategy. These meetings will be used to identify their study expectations for support of alternate regulatory approaches and to be sure the UNRBA monitoring program collects or has access to this information.
Falls Lake Constriction Point Flux Assessment (initiated in Fiscal Year 2016)	Obtain water quality and velocity measurements through primary constriction points within Falls Lake to 1) provide data at a finer temporal scale than the routine DWR monitoring, 2) quantify how material moves from one lake segment to the next, and 3) provide data for future model calibration to ensure that the model is accurately representing changing conditions at time steps that match short-term lake response.
Light Extinction Data Collection (initiated in Fiscal Year 2016) (concluded in Fiscal Year 2016)	Evaluate historic light extinction data 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 help determine how well Secchi depth data can fulfill the data requirements for future updates to and calibration of the EFDC lake response model and other data analysis approaches.
Basic Evaluation of Model Performance (initiated in Fiscal Year 2016) (concluded in Fiscal Year 2016)	Use the existing models (EFDC, BATHUB, and the Falls Lake Framework Tool) and the conceptual empirical/probabilistic model to support the ongoing evaluation of and potential adaptations to the Monitoring Program by helping to ensure that data collected through the Program is appropriate and sufficient for future modeling efforts.
Recreational Use Assessment (initiated in Fiscal Year 2016) (concluded in Fiscal Year 2016)	Compile available recreational data for Falls Lake and conduct background research on recreational use evaluations on other lakes and reservoirs in the Southeastern U.S. and elsewhere to 1) assess the current status of the recreational use of Falls Lake and 2) support discussions with NCDWR and EPA on the need for additional recreational studies.

2.2.3 Lake Sediment Evaluation

The Lake Sediment special study examines the nutrient and organic carbon content of sediment samples from Falls Lake. These data will support a more precise understanding of the spatial variability of sediment characteristics, bottom water and pore water nutrient concentrations, and benthic nutrient flux rates in Falls Lake. This evaluation provides information to simulate spatial variability in benthic nutrient flux. The existing version of the Falls Lake Nutrient Response Model assumed uniform nutrient flux conditions throughout the lake. Information from this study will help develop a better understanding of the importance of internal nutrient loads to the waters of Falls Lake. Data collection for this special study was conducted in June 2015 and preliminary results of this study can be found in the Fiscal Year 2016 Annual Report (Cardno 2016). Final results on this study will be released in FY2017.

2.2.4 Support Development of Alternative Regulatory Options

This Special Study is intended to help identify and define information and approaches needed for supporting alternative regulatory approaches for Falls Lake. For this Special Study, Cardno is available to the UNRBA to respond to various regulatory issues as they arise and to assist preparing a strategy and presentation materials for meetings and discussions with regulators (EPA and DWR). The goal of these meetings will be to discuss agency positions concerning alternative regulatory approaches and to help identify the kinds of data that may be needed to support such approaches.

2.2.5 Constriction Point Study

Water quality in Falls Lake may be driven by processes that occur at relatively short time steps. NCDWR samples water quality in Falls Lake at 12 locations monthly, but these data do not provide insight to inlake dynamics during rapidly changing conditions such as following a large storm event.

The Constriction Point Special Study was developed to characterize conditions as water is moving at greater than usual rates between partially isolated portions of the reservoir. Because the lake is segmented by several bridge causeways (i.e., constrictions), it is beneficial to understand how material moves from one segment to the next. The bridge constrictions are points of concentrated flow and are an efficient location to monitor the downstream transport of water and material.

Collecting velocity and water quality data at these locations over multiday periods when flows are changing in response to storm events can provide enhanced understanding for model calibration as part of the re-examination strategy. Two data collection events were provided for in the FY2016 budget. The first took place in January 2016 and the second event will be conducted when suitable conditions occur. Results from the initial data collection event were presented in the FY2016 Annual Report (Cardno 2016).

2.2.6 Light Extinction Data

This Special Study comprised a minor effort to analyze available historical data on light extinction from Falls Lake and to determine the strength of the relationship between actual light extinction measurements and Secchi depth. This evaluation can help to identify the degree of modeling uncertainty resulting from using Secchi depth data as a proxy for light extinction measurements. The results of this study were presented in the Fiscal Year 2016 Annual Report (Cardno 2016).

2.2.7 Basic Evaluation of Model Performance

This Special Study was added to help evaluate models for the re-examination of the Falls Lake Nutrient Management Strategy and whether or not the Monitoring Program design was sufficient or required revisions to address modeling needs. This study focused on modeling approaches the UNRBA may use for the re-examination and potential alternative regulatory approaches. A technical memorandum summarizing the study results was released in August 2016.

2.2.8 Recreational Use Evaluation

This Special Study evaluated recreational uses that may relate to the attainment of water quality standards. Falls Lake is classified, in part, to protect recreational uses, which includes consideration of fishing, fish consumption, wildlife, and secondary recreation, defined as "wading, boating and other uses involving human body contact with water where such activities take place in an infrequent, unorganized or incidental manner."

Findings from this evaluation may help inform the re-evaluation process with respect to aligning nutrient management efforts with maintenance of designated recreational uses. The evaluation can also support discussions of alternative regulatory approaches where attainment of recreational uses is considered among the targets for adjusting water quality criteria or standards.

The results of this evaluation were presented in the Fiscal Year 2016 Annual Report (Cardno 2016).

3 Results and Discussion of Routine Monitoring Through June 2016

This section presents and discusses the Routine Monitoring data collected through the end of June 2016.

Data Available Online:
This report does not include raw data. The complete UNRBA database can be accessed online after setting up a user account at http://unrba-wqp.cardno.com/index.php. Users can review raw data, generate summary statistics, and obtain detailed station information.

3.1 Overview of Hydrologic Conditions

The UNRBA Monitoring Program does not provide for any direct collection of flow data. The brief analysis in this section uses data from public sources to provide hydrologic context for the overall Monitoring Program. To illustrate the overall hydrologic conditions for the monitoring period precipitation patterns in the Falls Lake watershed and Falls Lake water levels were compared to historical information.

Precipitation data was obtained from available National Climatic Data Center (NCDC) rain gages and USGS rain gages in the Upper Neuse Basin. Annual and monthly precipitation totals were calculated for each gage with a complete data set available and results compared among gages to identify the spatial variability and comparisons to the 30-year normal values for the region. Depending on the data completeness for each year, between four and six NCDC gages and six USGS gages were used for this summary.

Total rainfall in both 2014 and 2015 was similar to the 30-year annual average for the region of 43 inches. Total precipitation in 2014 ranged from 41 to 62 inches across the watershed with a mean of 49 inches. In 2015, total precipitation ranged from 38 to 58 inches with a mean of 48 inches. Though slightly wetter than average, both years' values fall within the middle 50% of historical annual totals since 1985. The total rainfall between January and June of 2016 ranged from 17 to 29 inches among gages with an average rainfall of 23 inches. The 30-year average for the January through June period is 22 inches.

In addition to total precipitation, timing of rainfall can also be important. For example, particularly wet springs can deliver large amounts of nutrients which then can fuel algae blooms throughout the summer. In 2006, which was selected as the baseline year to develop the Falls Lake Nutrient Management Strategy, drought conditions were present for much of the year, but two storm events late in the year brought the annual precipitation back up to the typical range. Extreme patterns such as these affect water quality much differently than if the same amount of rain were delivered evenly over the course of a year.

To assess whether monthly rainfall patterns were different from typical values over the past 30 years, Precipitation totals by month were examined to identify months or seasons which were unusual. Figure 3-1 shows how the monthly precipitation from rain gages differs from the 30-year average for the watershed. In this figure, zero represents the 30-year average. Values above zero show periods with more rain than average and values below zero indicate drier periods. The darker shaded region shows the range of the middle 50% of precipitation values over the last 30 years and can be considered as a reference range for typical precipitation amounts (i.e. the shaded band can be qualitatively viewed as representing "normal" conditions). Precipitation is not uniform over the watershed and the spatial variation in total precipitation for each month is shown by the orange boxes in Figure 3-1. The boxes show the 25th, 50th, and 75th percentiles of precipitation over the region with whiskers extending to the full range of values observed at the various rain gauges. Measurements which are considered statistical outliers are shown as black dots.

In general, the monitoring period appears to have been fairly normal in terms of precipitation. However, in 2015 the months of May and August were notably drier than normal while the months of November and December were wetter than normal. In 2016, January was drier than normal (though it followed an unusually wet December) while June had more rain than normal at most of the gaged locations.

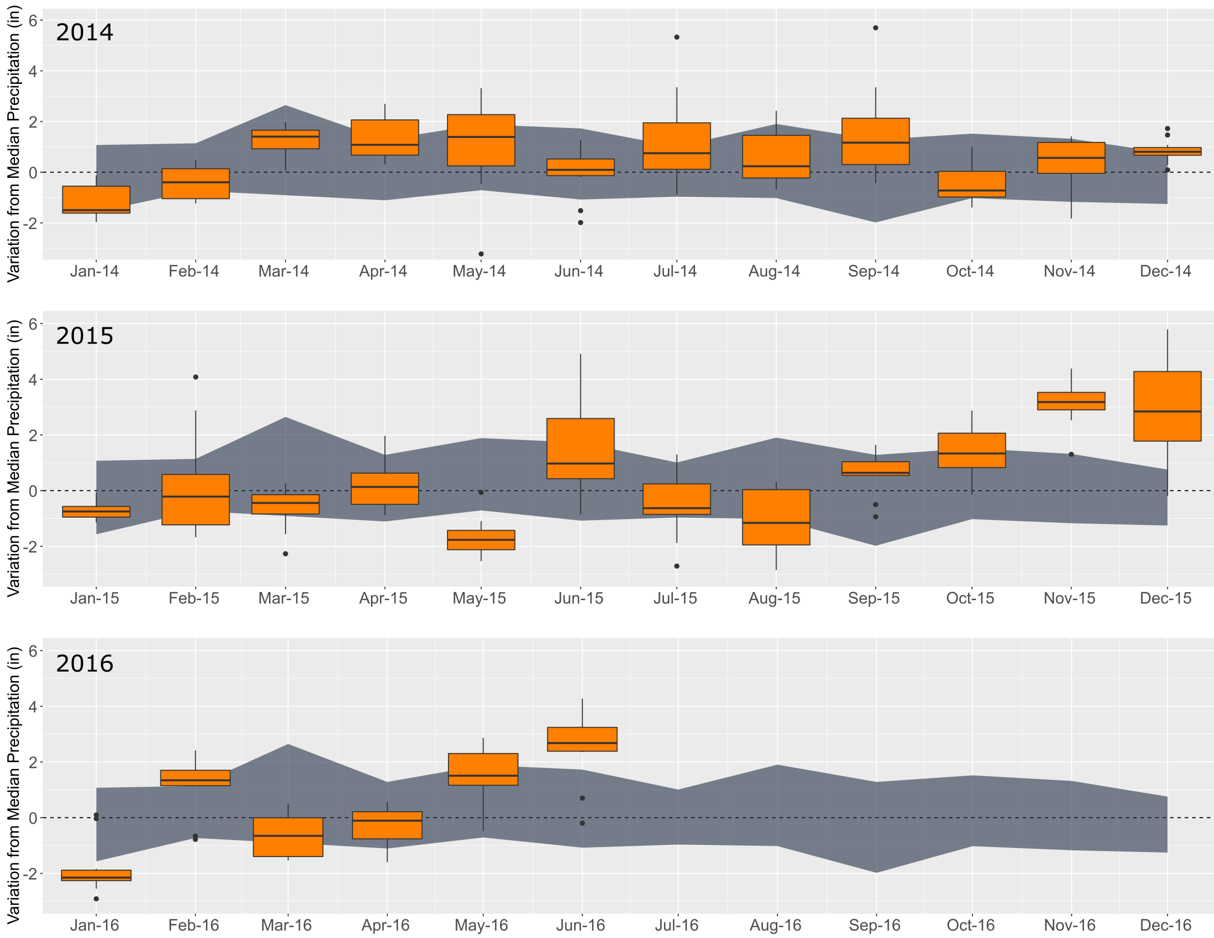

Figure 3-1 **Variation from 30-Year Normal Monthly Precipitation in the Falls Lake Watershed.** Orange boxes display the 75th (top), median (horizontal line), and 25th percentiles (bottom) of precipitation among 10 to 12 gages within the Falls Lake watershed. Whiskers extend to the range of observed values; statistical outliers[1] are displayed as black circles. The darker shaded region contains the 25th to 75th percentile range of monthly precipitation over the preceding 30 years. Actual long-term median monthly rainfall totals range from 2.9 (February) to 4.4 (July) inches, with 10 months of the year having long-term median rainfall between 3.0 and 4.0 inches.

[1] By convention, statistical outliers for these plots are values that fall below the 25th percentile (lower quartile) or above the 75th percentile (upper quartile) by more than 1.5 times the difference between the upper and lower quartile values.

A related analysis was conducted on the Falls Lake daily water level data collected by the USACE (Figure 3-2). For this analysis, median values (dashed line) are based on data reported from 1987 to present. From January 2014 to March 2015, the observed stage (orange line) in Falls Lake was generally higher than normal (above the 75th percentile much of the time). From April 2015 to October 2015, lake levels were very close to the median value. From October 2015 through January 2016, lake levels were relatively high (generally above the 75th percentile for most of this time and exceeding the 95th percentile towards the end of December 2015 and January 2016). Between February and June of 2016, lake levels remained at or above median lake levels for the period.

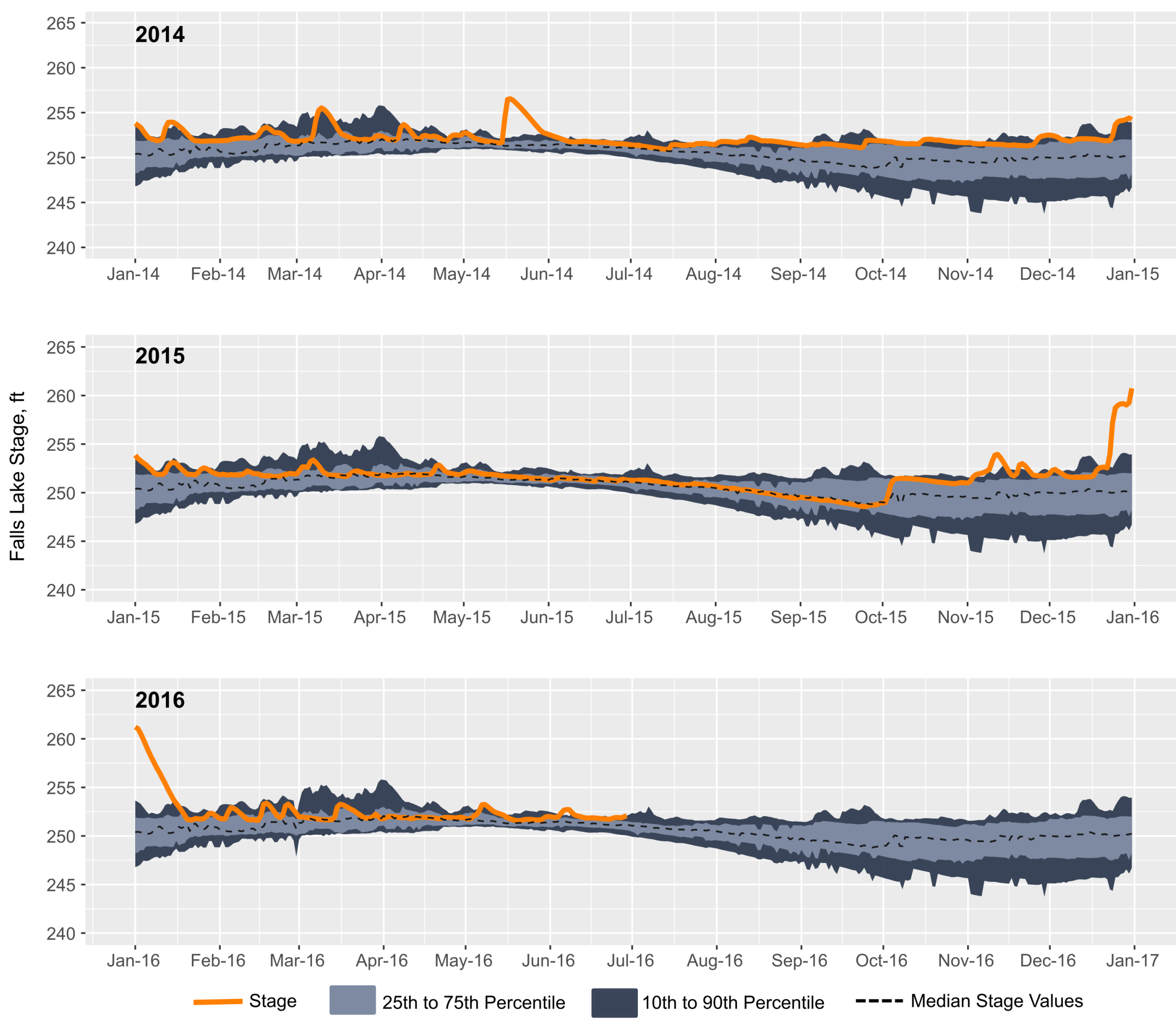

Figure 3-2 **Falls Lake Elevation from January 2014 through June 2016**
Median values (dashed line) and percentiles are based on data from 1987 to present.

In contrast to the lake levels of the current monitoring period (2014-2016), lake levels during the modeling period which the Falls Lake Rules were developed from (March 2005 through September 2007) were influenced by significant dry periods (Figure 3-3). The region was experiencing a relatively severe drought during the modeling period, and lake levels were at or below median values from March 2005 through May 2006 and from May 2007 through December 2007. A small number of large storms, including Tropical Storm Alberto in June 2006, brought the lake levels up from June 2006 through April 2007. Because lake levels preceding these events were relatively low, much of the nutrient loading delivered to the lake from these storms was stored for long periods of time and likely contributed to some of the highest chlorophyll *a* concentrations measured in the lake over the past two decades. When lake levels are at or above normal, as with the more recent monitoring period, the residence time in the lake is generally shorter and algal concentrations tend to be lower.

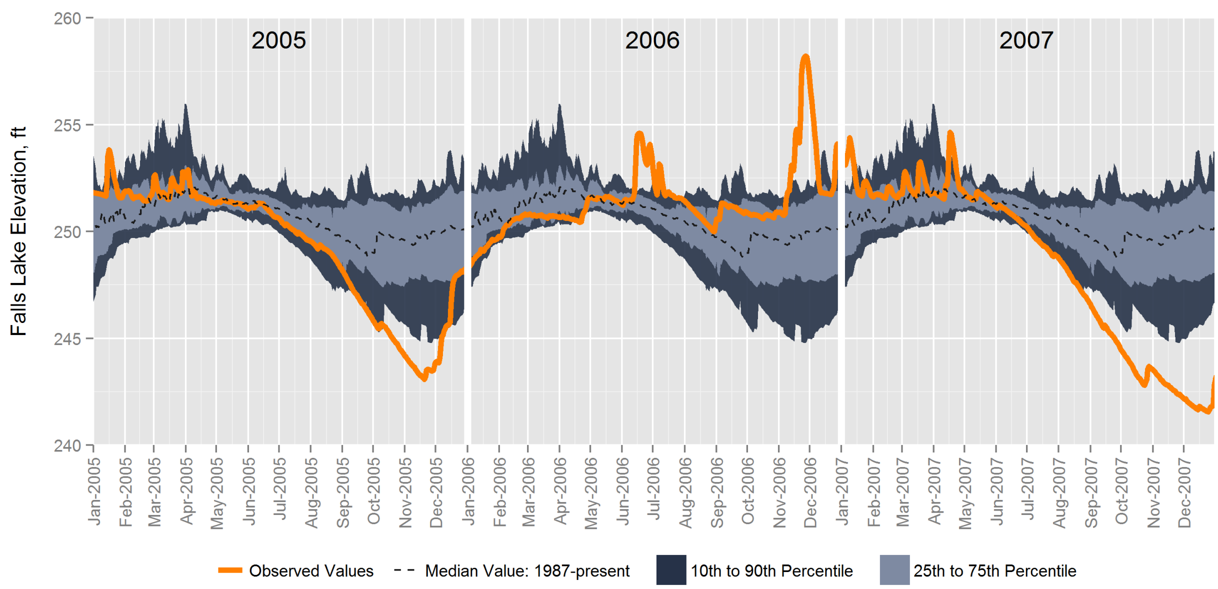

Figure 3-3 **Falls Lake Elevation (stage) in Feet Above Mean Sea Level for the Period of DWR's EFDC Model Years 2005 through 2007 (Orange Line).** The historical median (dashed line) and reference ranges (shaded regions) for each day of the year are shown for 1987 through 2015.

3.2 Overview of Routine Monitoring Data

This section presents data collected by the UNRBA's Monitoring Program for Jurisdictional and Lake Loading stations. Lake data from DWR and other monitoring organizations are obtained on an annual basis and are therefore not included in this FY2017 Interim Report.

The graphics and comments offered below are intended to provide a general understanding of the water quality parameters and their context based on data observations from August 2014 through June 2016. Box and whisker figures are shown to present a statistical summary of the data, but each data point is also superimposed to indicate the full distribution of the data. To highlight data collected since the previous Annual Report was released, samples collected between January and June of 2016 are shown as yellow circles. Data collected in 2016 are typically within the ranges of values seen in prior months. However these values primarily represent winter and spring conditions and therefore, because of seasonal patterns in some parameters, the 2016 data are not expected to have distributions that exactly match those from the entire prior monitoring period. As a guide for interpreting the box and whisker figures, an example box and whisker figure is shown below (Figure 3-4) with the meanings of each component labeled.

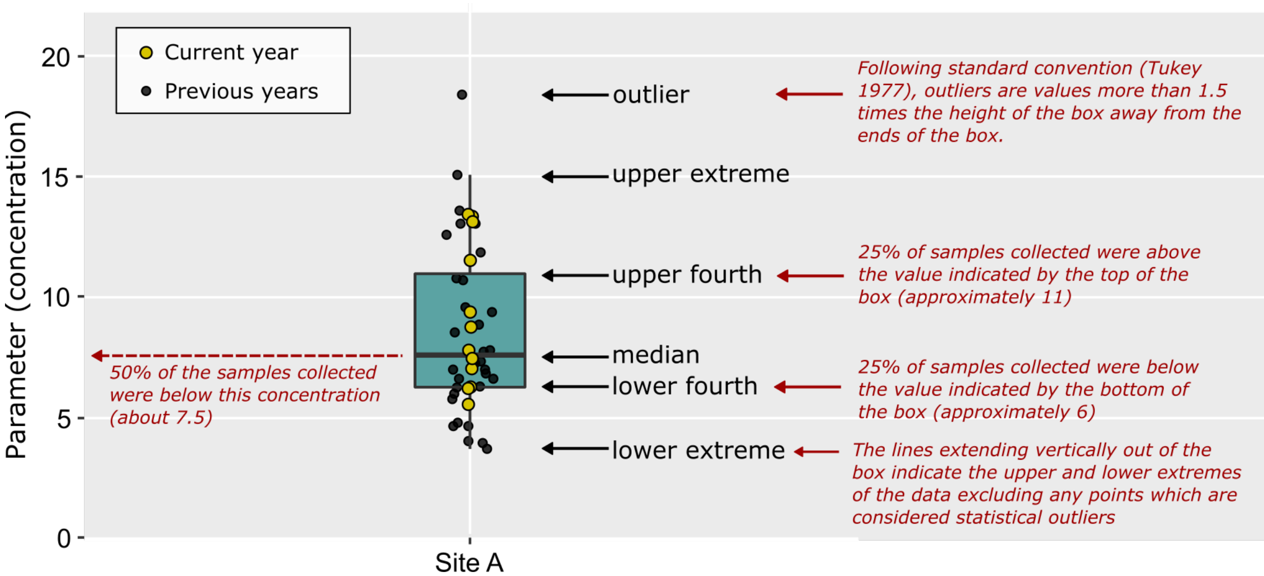

Figure 3-4. An example box and whisker figure as used in this report and the meanings of figure components. Data points (black and yellow circles) are spread horizontally to better show points which would otherwise overlap.

Within each figure data are grouped by subwatershed. Within each group, stations on the same tributary are displayed from the most upstream to the most downstream location. This arrangement allows quick inspection of whether spatial patterns are present. Jurisdictional Boundary stations are shown with a light shading and labels including “(JB)”, while Lake Loading stations are shown with a dark shading and labels including “(LL)”. Table 2-2 (Section 2.1.3) provides a list of all tributary stations using the same station identifiers.

For some figures in this report, a log-scale is used to improve the visual display of the observations. When observed concentration values have a skewed distribution (where the range of observations covers several orders of magnitude with only a few elevated values), a standard linear axis typically obscures the interesting variability at low concentrations so that the few elevated values can be shown on the same figure. In these cases, a log scale is used for the vertical axis to better display the variation among values at low concentrations. On a log scale, distances represent multiples rather than linear increments; on the figure, the distance between 1 and 10 is the same as the distance between 10 and 100 since both are increases by a factor of 10. Thus, absolute differences between numbers a given distance apart at the low end of the axis are much less than the absolute differences between numbers that are the same distance apart higher on the axis.

In addition to displaying figures of individual water quality measurements, preliminary comparisons of water quality related to compliance with water quality standards are also provided. Three parameters monitored by the UNRBA have numeric water quality standards (dissolved oxygen, pH, and Chlorophyll *a*). Graphs and tables for these parameters show the level(s) of the applicable state standards for each parameter.

> <u>Dissolved oxygen</u> (DO) - Field measurements of DO are provided in Figure 3-5. DO concentrations tend to be lower at locations with slow-moving or stagnant water, or large wetland complexes, including Beaverdam Creek, Robertson Creek, Unnamed Tributary, and Panther Creek. North Carolina water quality standards specify that DO is to be no less than 4 mg/L. Of 930 total DO measurements, approximately 93 percent were above the standard and 7 percent fell below 4 mg/L, with all of those occurring at 14 of the monitored stations, as listed in Table 3-1.
>
> These stations tend to be in areas with low slopes and stagnant flows, and many are within wetland-dominated areas. North Carolina water quality standards include a provision that DO levels in “swamp waters, lake coves or backwaters, and lake bottom waters may have lower values if caused by natural conditions,” and further provide that “water quality standards will not be considered violated when values outside the normal range are caused by natural conditions” (15A NCAC 02B .0205).

Table 3-1 Stations with dissolved oxygen measurements below the NC state standard (August 2014 to June 2016)

Subwatershed	Station ID	Number of DO Values Measured	Number of Values Reported Below 4 mg/L	Percent of Values Below 4 mg/L
Beaverdam Creek	BDC-2.0 (LL)	24	7	29
Camp Creek	CMP-23 (JB)	19	1	5
Flat River	FLR-5.0 (LL)	44	10	23
Ledge Creek	LGE-13 (JB)	15	1	7
Ledge Creek	LGE-5.1 (LL)	23	4	17
Lick Creek	LKC-2.0 (LL)	22	2	9
Little Lick Creek	LLC-1.8 (LL)	24	3	13
Little Ledge Creek	LLG-0.9 (JB)	22	9	41
Little River	LTR-1.9 (LL)	46	5	11
North Flat River	NFR-41 (JB)	12	2	17
Panther Creek	PAC-4.0 (LL)	23	6	26
Robertson Creek	ROB-7.2 (JB)	17	2	12
Robertson Creek	ROB-2.8 (LL)	24	7	29
Unnamed	UNT-0.7 (LL)	24	7	29
All Monitored Stations		**930**	**66**	**7**

> pH - The North Carolina water quality standard applicable to the Falls Lake watershed requires that pH be between 6 and 9. Field measured values of pH at the Jurisdictional and Lake Loading stations are almost always within this range, with most values falling between 6.5 and 7.5 (Figure 3-6). Data collected from August 2014 through June 2016 showed approximately 99 percent compliance with the standard. Ten stations had one or two pH values below 6; only one station had a single value greater than 9 (Table 3-2). North Carolina water quality standards include a provision that pH levels in "swamp waters may have a pH as low as 4.3 if it is the result of natural conditions" (15A NCAC 02B .0211(14)), and further provide that "water quality standards will not be considered violated when values outside the normal range are caused by natural conditions" (15A NCAC 02B .0205).

Table 3-2 Stations with pH observed below the NC state standard (August 2014 to June 2016)

Subwatershed	Station ID	Number of pH Values Measured	pH Values Reported below 6.0 or above 9.0	Percent of Values below 6.0 or above 9.0
Beaverdam Creek	BDC-2.0 (LL)	24	1	4
Buckhorn Creek	BUC-3.6 (JB)	21	1	5
Camp Creek	CMP-23 (JB)	19	2	11
Horse Creek	HSE-11 (JB)	22	1	5
Horse Creek	HSE-5.7 (JB)	2	1	50
Knap of Reeds Creek	KRC-4.5 (LL)	43	2	5
Ledge Creek	LGE-13 (JB)	15	2	13
Ledge Creek	LGE-17 (JB)	17	1	6
New Light Creek	NLC-3.8 (JB)	23	1	4
Robertson Creek	ROB-7.2 (JB)	17	1	6
All Monitoring Stations		**930**	**12**	**1**

> Temperature - Most variability associated with this parameter is due to seasonal changes rather than location in the watershed. Temperatures at the Jurisdictional and Lake Loading stations are generally similar though some of the sampling locations with smaller drainage areas tend to have cooler temperatures (Figure 3-7). This may be because these locations do not always have sufficient water to sample, and when data are collected it occurs following precipitation events, as opposed to other sites where water may be present and exposed to solar radiation for longer periods. In addition, narrower streams may have more shading from shoreline vegetation.

> Specific conductance - Field-measured specific conductance values at the Jurisdictional and Lake Loading stations are generally consistent throughout the watershed. The higher ranges of values tend to occur downstream of major wastewater treatment plants and small package plants (Figure 3-8).

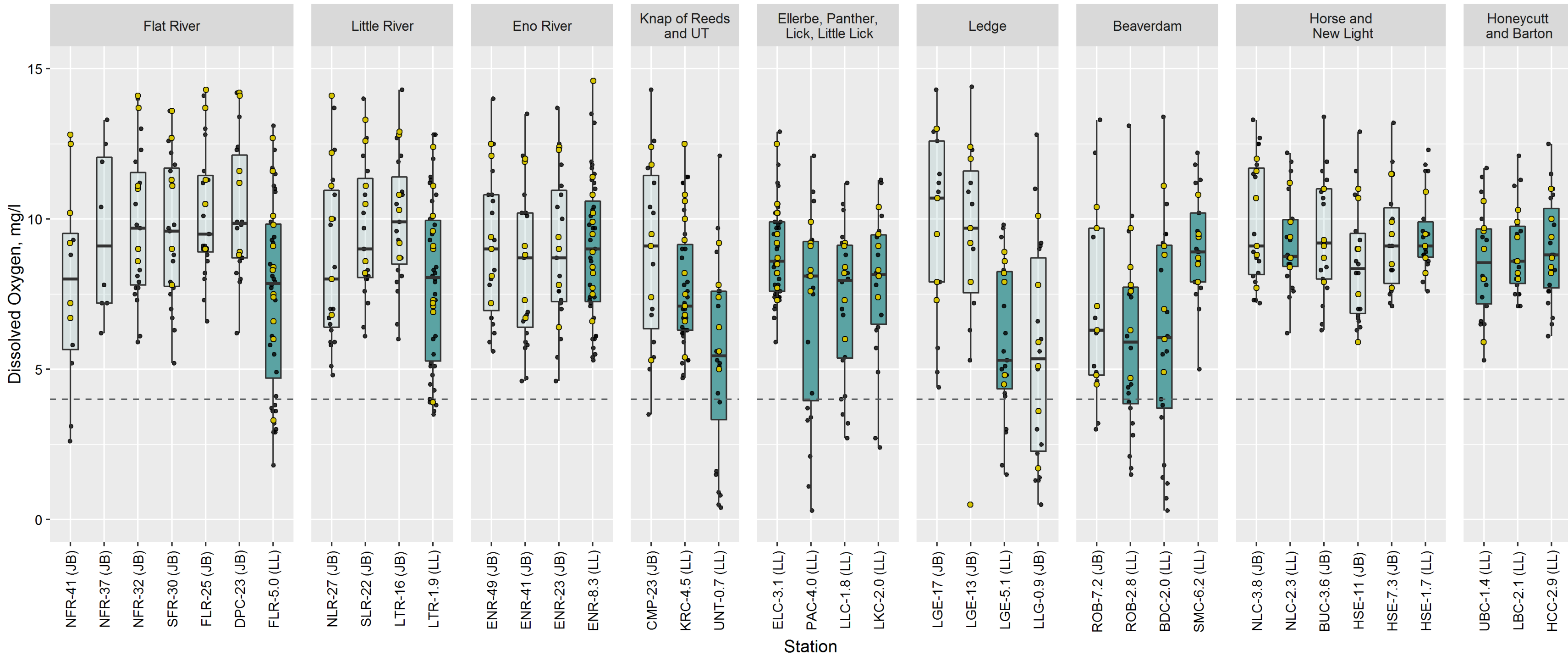

Figure 3-5 **Dissolved Oxygen in Jurisdictional Boundary and Lake Loading Samples from August 2014 to June 2016.** The State's instantaneous dissolved oxygen standard of 4 mg/L is shown as a horizontal dashed line. Jurisdictional Boundary stations are displayed with a light shading and Lake Loading stations are displayed with dark shading. Data collected between January and June of 2016 are highlighted as yellow circles.

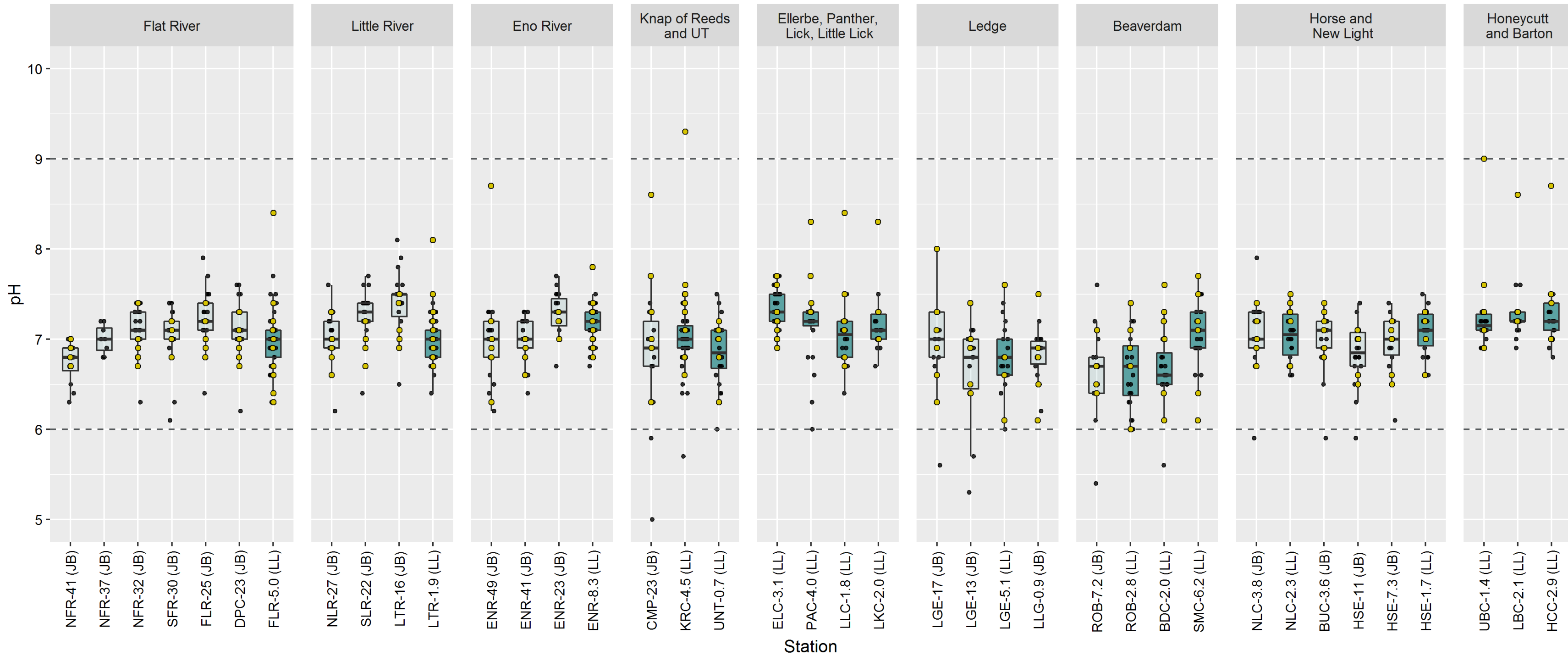

Figure 3-6 pH in Jurisdictional Boundary and Lake Loading Samples from August 2014 to June 2016. The State's upper and lower pH standards are shown as horizontal dashed lines at values of 9 and 6. Jurisdictional Boundary stations are displayed with a light shading and Lake Loading stations are displayed with dark shading. Data collected between January and June of 2016 are highlighted as yellow circles.

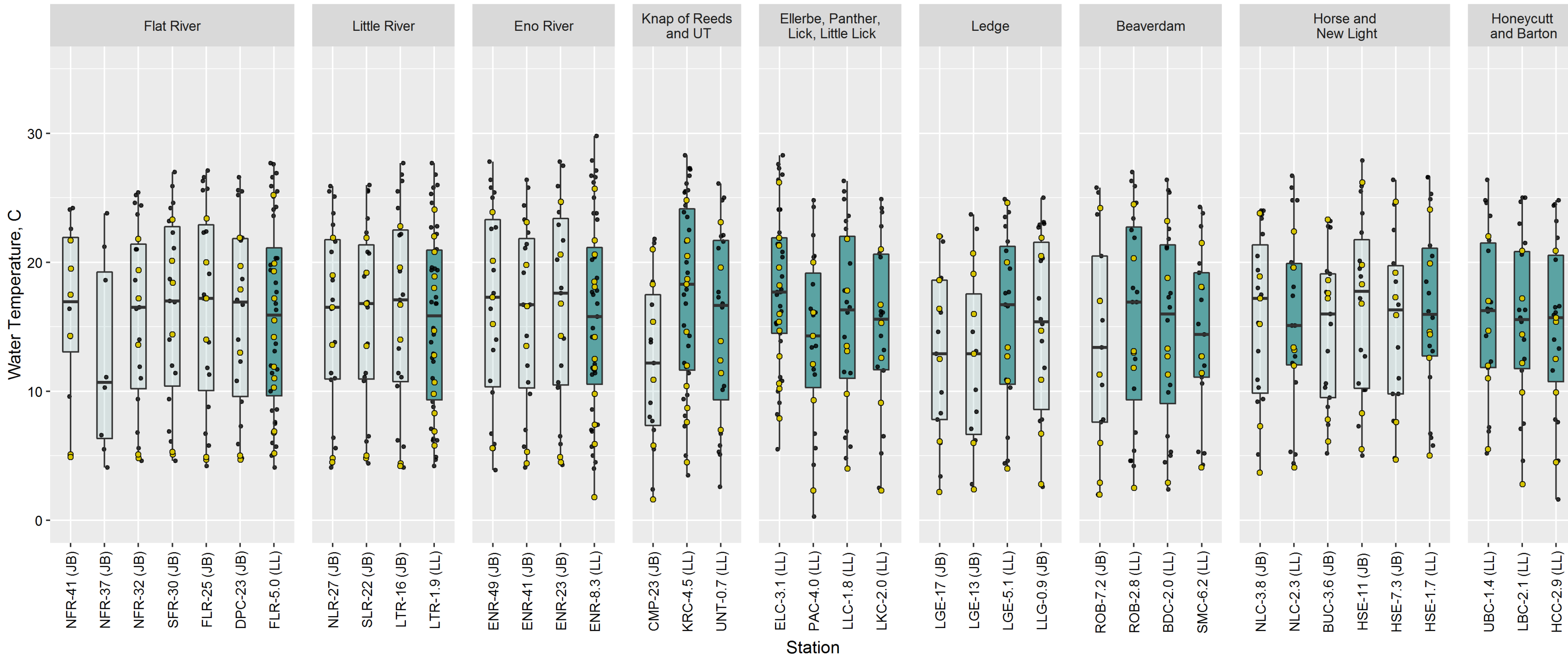

Figure 3-7 Temperature in Jurisdictional Boundary and Lake Loading Samples from August 2014 to June 2016. Jurisdictional Boundary stations are displayed with a light shading and Lake Loading stations are displayed with dark shading. Data collected between January and June of 2016 are highlighted as yellow circles.

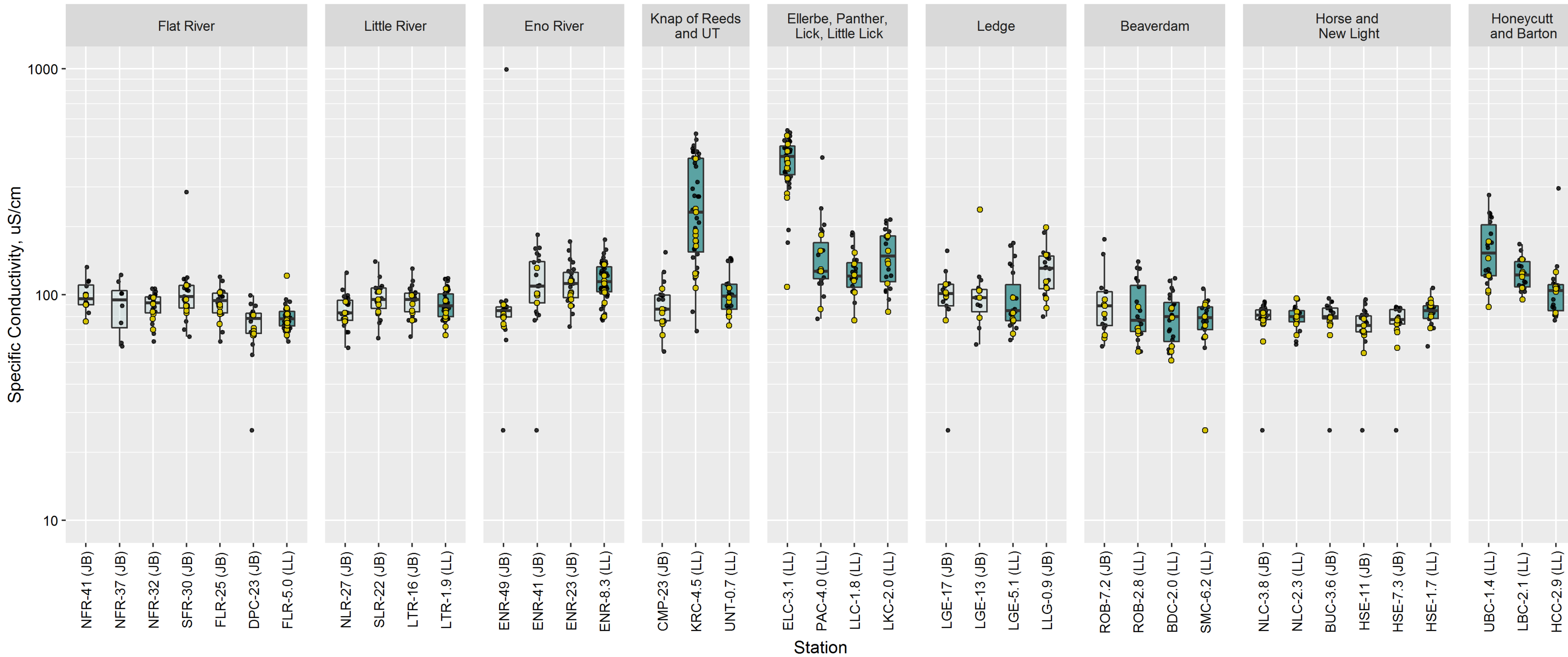

Figure 3-8 Specific Conductance in Jurisdictional Boundary and Lake Loading Samples from August 2014 to June 2016. Jurisdictional Boundary stations are displayed with a light shading and Lake Loading stations are displayed with dark shading. Data collected between January and June of 2016 are highlighted as yellow circles.

> Chlorophyll *a* is a green pigment in algae that allows them to use energy from the sun to build living tissue through photosynthesis. Chlorophyll *a* content is an indication of how much algae is present in the water. While algae is an important component of healthy aquatic ecosystems, too much algae can cause problems with treatability for drinking water, taste and odor problems, or drastic fluctuations in dissolved oxygen and/or pH that can cause problems for aquatic organisms.

Chlorophyll *a* is a key parameter for the reassessment of the Falls Lake Nutrient Management Strategy because the required nutrient reductions were adopted due to exceedances of the state water quality standard in the 2008 and 2010 assessment periods (data from 2006 to 2008). Furthermore, because of a lack of chlorophyll *a* data from the tributaries, the model used by the State of North Carolina assumed input concentrations of chlorophyll *a* were equal to the concentrations observed in the lake. Subsequent analyses have shown that the model is sensitive to that assumption, and the data collected by the Monitoring Program through June 2016 show tributary chlorophyll *a* concentrations are typically much less than the concentrations observed in the lake. In fact, 85% of all tributary measurements were below 10 µg/L, which is a quarter of the state standard, and 96% of all measurements were below the State's 40 µg/L standard.

Chlorophyll *a* data collected at Lake Loading stations are shown in Figure 3-9. All tributary chlorophyll measurements since the previous Annual Report (January through June 2016) were below the state standard of 40 µg/L. Over the entire monitoring period, concentrations in the tributaries have typically been much lower than the state standard, with the exception of some elevated concentrations observed in sluggish, wetland areas. Of 526 chlorophyll *a* values measured at the lake loading stations, 504 (96 percent) were below the 40 µg/L water quality standard and all stations had median values of less than 11 µg/L. Only 22 observations from the watershed exceeded 40 µg/L, representing only seven of the monitored tributary stations, as listed in Table 3-3, and the majority of these elevated values occurred during times of below average streamflow. Despite having occasional elevated values, the median values for each of these sites is 10 µg /L or lower. For Unnamed Tributary and Beaverdam, Ledge, Panther, and Robertson Creeks, all observed chlorophyll concentrations above 40 µg/L occurred during times when surface velocities estimated by dye addition were less than 0.01 feet per second (dye moved less than a foot over two minutes) and discharge estimates based on basin proration of nearby USGS gages were less than 3 cfs. Algal proliferation is not unexpected in shallow, sluggish water bodies, including wetlands. North Carolina water quality standards include a provision that "Water quality standards will not be considered violated when values outside the normal range are caused by natural conditions" (15A NCAC 02B .0205).

Table 3-3 Stations with Chlorophyll *a* Measured above the NC State Standard (August 2014 to June 2016)

Subwatershed	Station ID	Number of Chl *a* Values Measured	Number (and percent) of Chl *a* Values Reported above 40 µg/L	Median Value	90th Percentile Value
Beaverdam Creek	BDC-2.0 (LL)	24	4 (17%)	2.6	150
Eno River	ENR-8.3 (LL)	47	1 (2%)	1.9	8.6
Flat River	FLR-5.0 (LL)	44	4 (9%)	10	25
Ledge Creek	LGE-5.1 (LL)	23	2 (9%)	8.9	32
Panther Creek	PAC-4.0 (LL)	23	1 (4%)	7.0	24
Robertson Creek	ROB-2.8 (LL)	24	5 (21%)	6.0	60
Unnamed	UNT-0.7 (LL)	24	5 (21 %)	4.3	75
All Stations		**526**	**22 (4%)**	**10**	**15**

> Total nitrogen measured at tributary stations is presented in Figure 3-10, nitrate + nitrite is in Figure 3-11, ammonia is in Figure 3-12, and organic nitrogen is in Figure 3-13. The higher ranges of values of nitrate + nitrite and total nitrogen tend to occur downstream of major wastewater treatment plants and small package plants; higher values of ammonia and organic nitrogen occur downstream of these facilities and in areas dominated by slow-moving, wetland conditions.

> Total phosphorus in the watershed (Figure 3-14) tends be higher downstream of major wastewater treatment plants and in areas dominated by slow-moving or wetland conditions. The highest concentrations have been observed downstream of the SGWASA WWTP; part of the distribution for site KRC-4.5, including the maximum value (3.8 mg/L) and 75th percentile value (0.625 mg/L), has been cutoff of the figure to scale the axes. SGWASA has been undergoing WWTP upgrades and have experienced some operational disruptions that resulted in relatively high concentrations. Following upgrades at the North Durham Water Reclamation Facility, which discharges to Ellerbe Creek, values at station ELC-3.1 are similar to other stations in the watershed. It is anticipated that as the SGWASA WWTP stabilizes following operational changes and upgrades, that concentrations at this location will decline relative to what was observed during this monitoring period.

> Total suspended solids (TSS) levels are generally consistent among the Jurisdictional and Lake Loading stations in a subwatershed (Figure 3-15). Stations draining relatively small watersheds and those located in slow-moving areas tend to have higher concentrations of TSS.

> Total organic carbon (TOC) data collected in tributaries of Falls Lake (Figure 3-16) indicate the highest concentrations often occur in areas dominated by slow-moving conditions and wetland complexes, where plants and other organic materials tend to accumulate and decompose.

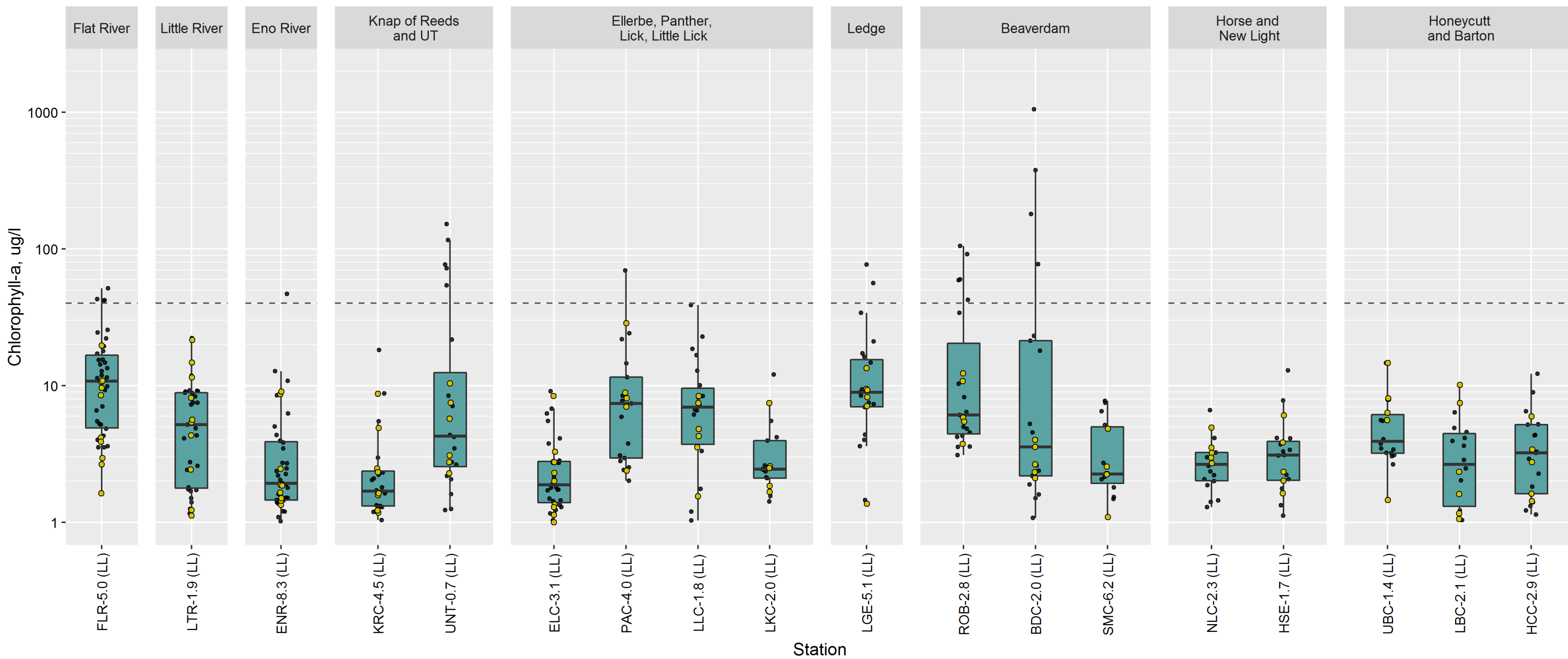

Figure 3-9 Chlorophyll a in Lake Loading Samples from August 2014 to June 2016. The State's standard of 40 µg/L is shown as a horizontal dashed line. Data collected between January and June of 2016 are highlighted as yellow circles.

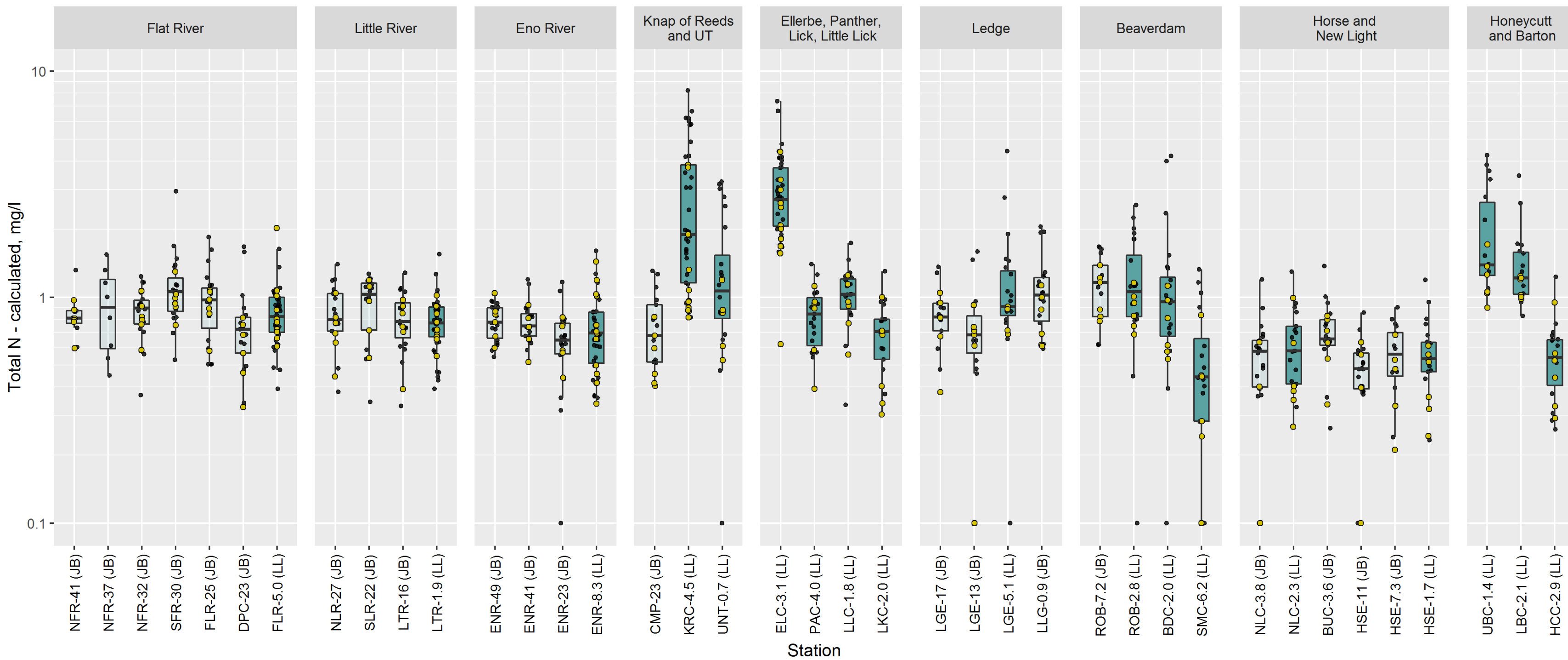

Figure 3-10 Total Nitrogen in Jurisdictional Boundary and Lake Loading Samples from August 2014 to June 2016. Jurisdictional Boundary stations are displayed with a light shading and Lake Loading stations are displayed with dark shading. Data collected between January and June of 2016 are highlighted as yellow circles.

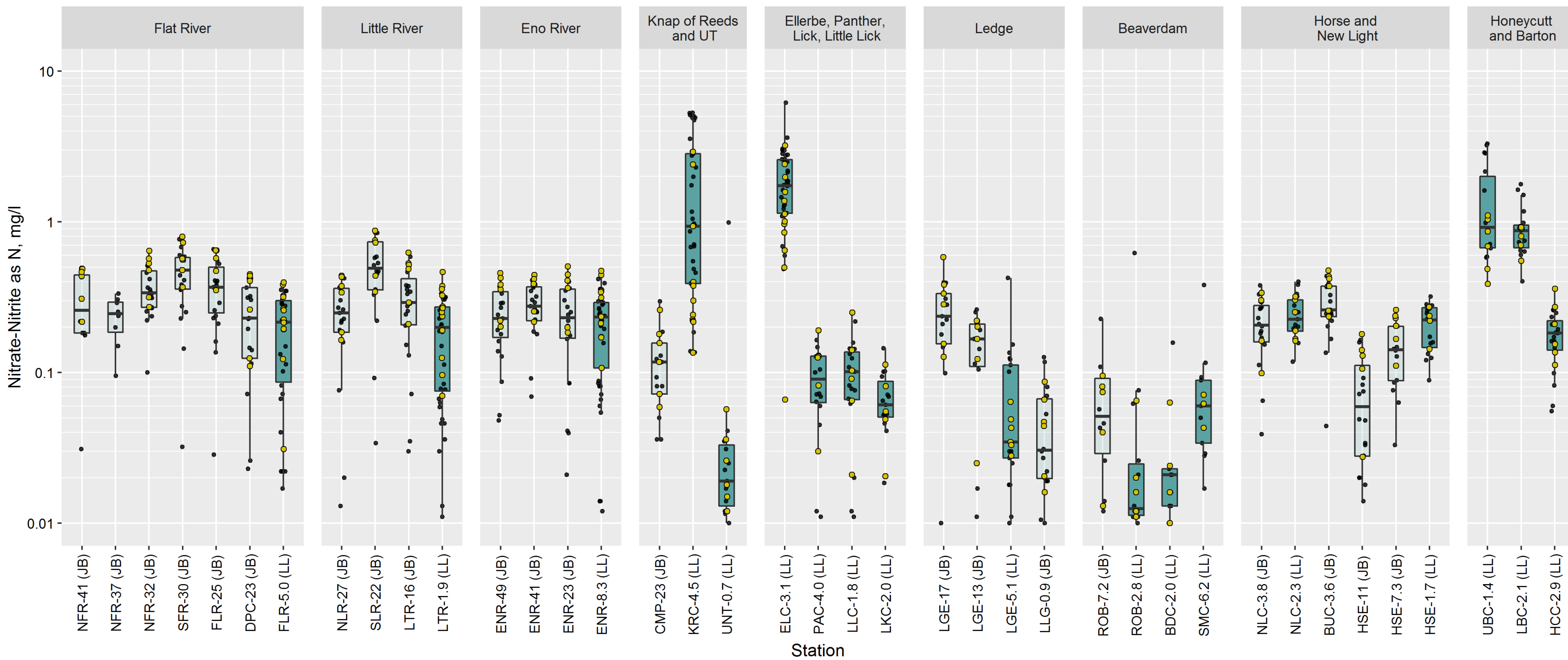

Figure 3-11 **Nitrate plus Nitrite in Jurisdictional Boundary and Lake Loading Samples from August 2014 to June 2016.** Jurisdictional Boundary stations are displayed with a light shading and Lake Loading stations are displayed with dark shading. Data collected between January and June of 2016 are highlighted as yellow circles.

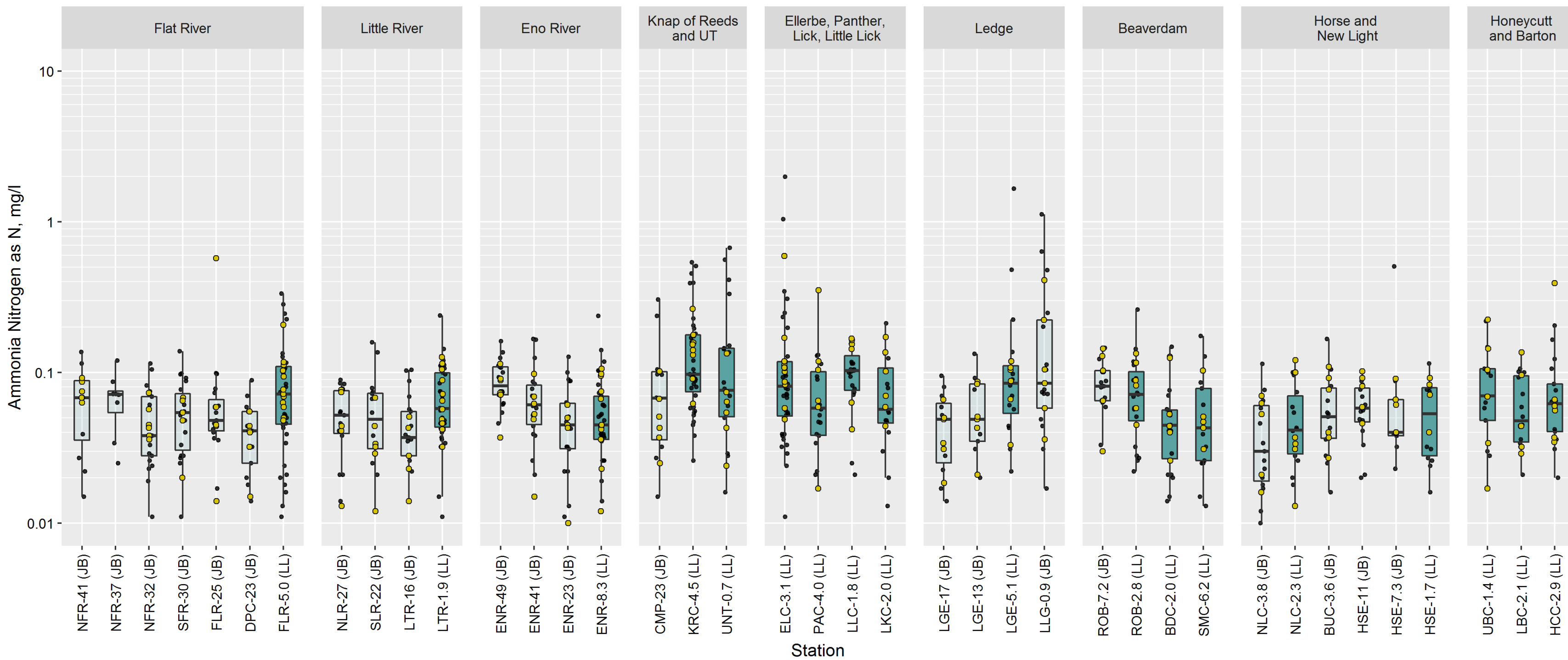

Figure 3-12 Ammonia in Jurisdictional Boundary and Lake Loading Samples from August 2014 to June 2016. Jurisdictional Boundary stations are displayed with a light shading and Lake Loading stations are displayed with dark shading. Data collected between January and June of 2016 are highlighted as yellow circles.

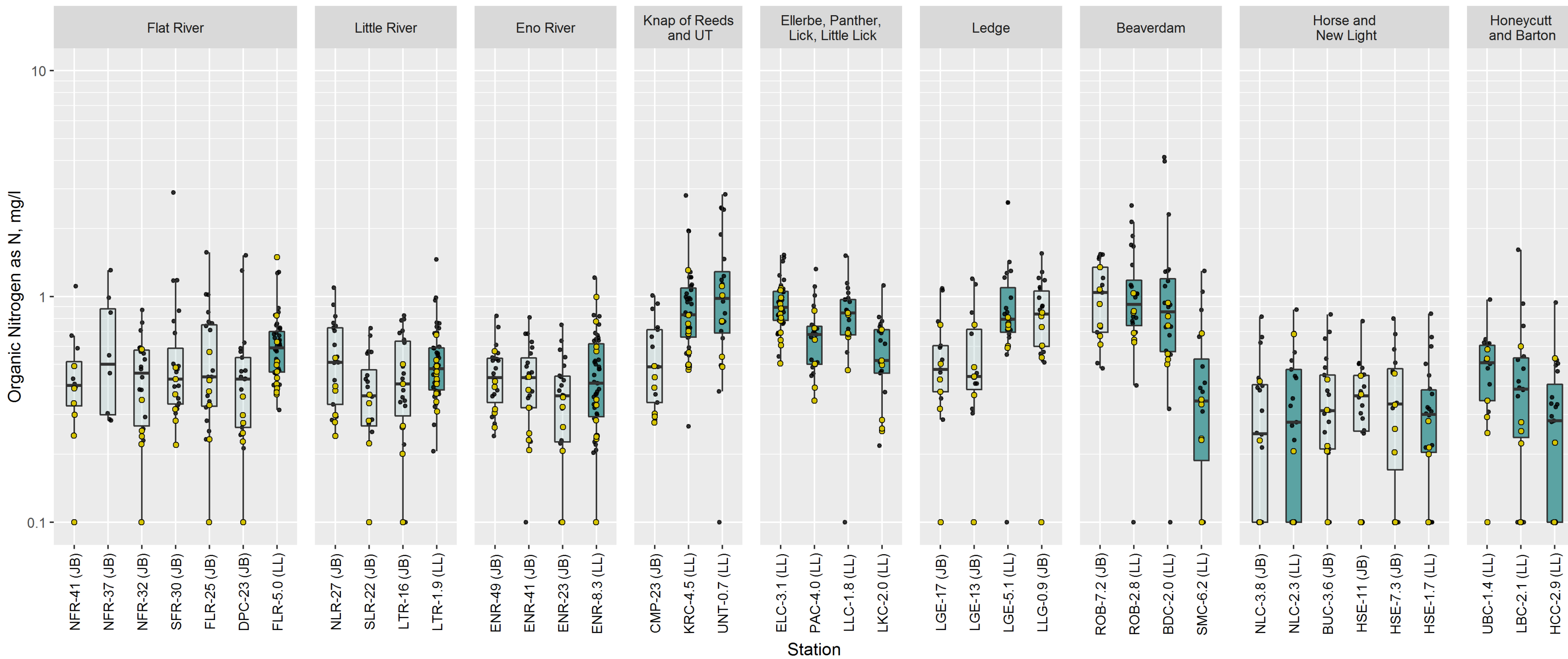

Figure 3-13 **Organic Nitrogen in Jurisdictional Boundary and Lake Loading Samples from August 2014 to June 2016.** Jurisdictional Boundary stations are displayed with a light shading and Lake Loading stations are displayed with dark shading. Data collected between January and June of 2016 are highlighted as yellow circles.

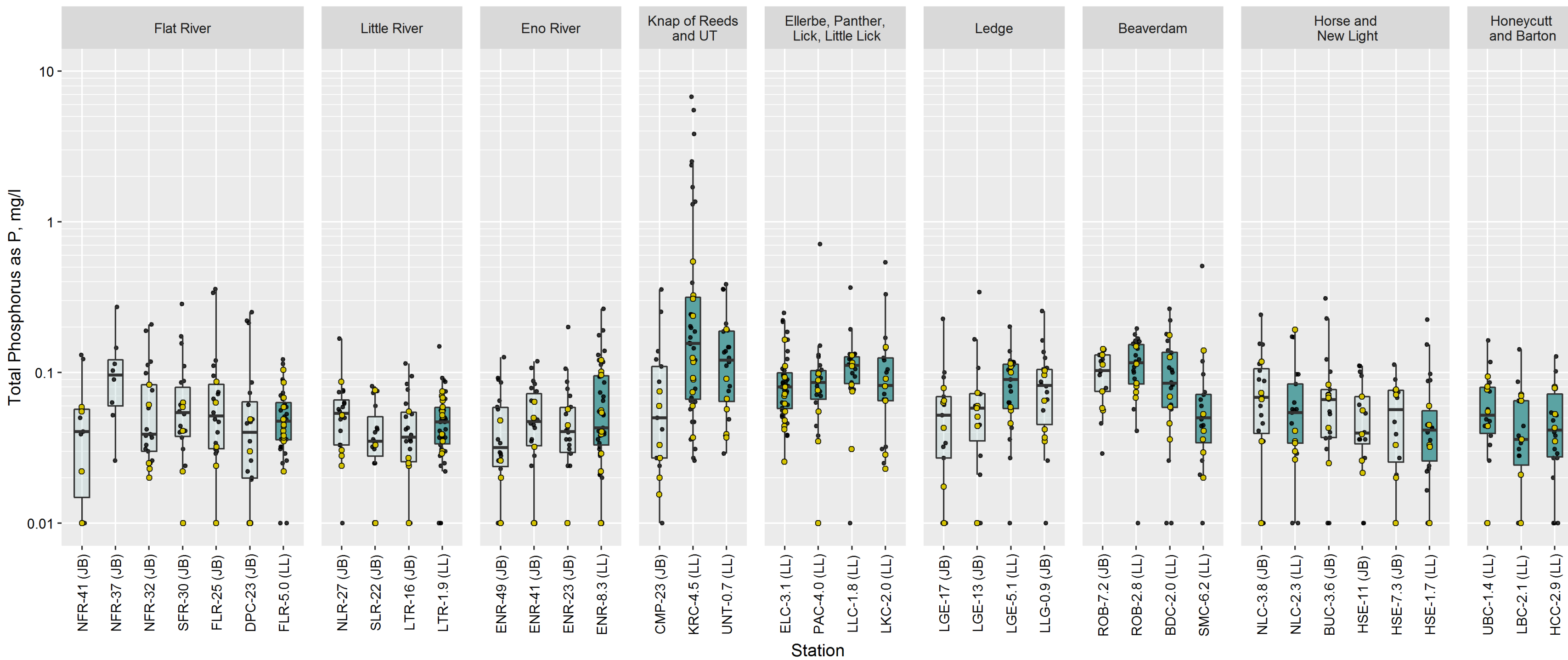

Figure 3-14 Total Phosphorus (TP) in Jurisdictional Boundary and Lake Loading Samples from August 2014 to June 2016. Jurisdictional stations are displayed with a light shading and Lake Loading stations are displayed with dark shading. Data collected between January and June of 2016 are highlighted as yellow circles. May samples from the Jurisdictional sites and June samples from the Lake Loading sites were analyzed outside of accepted hold-times but are included in this visual representation of the data and have been qualified in the database.

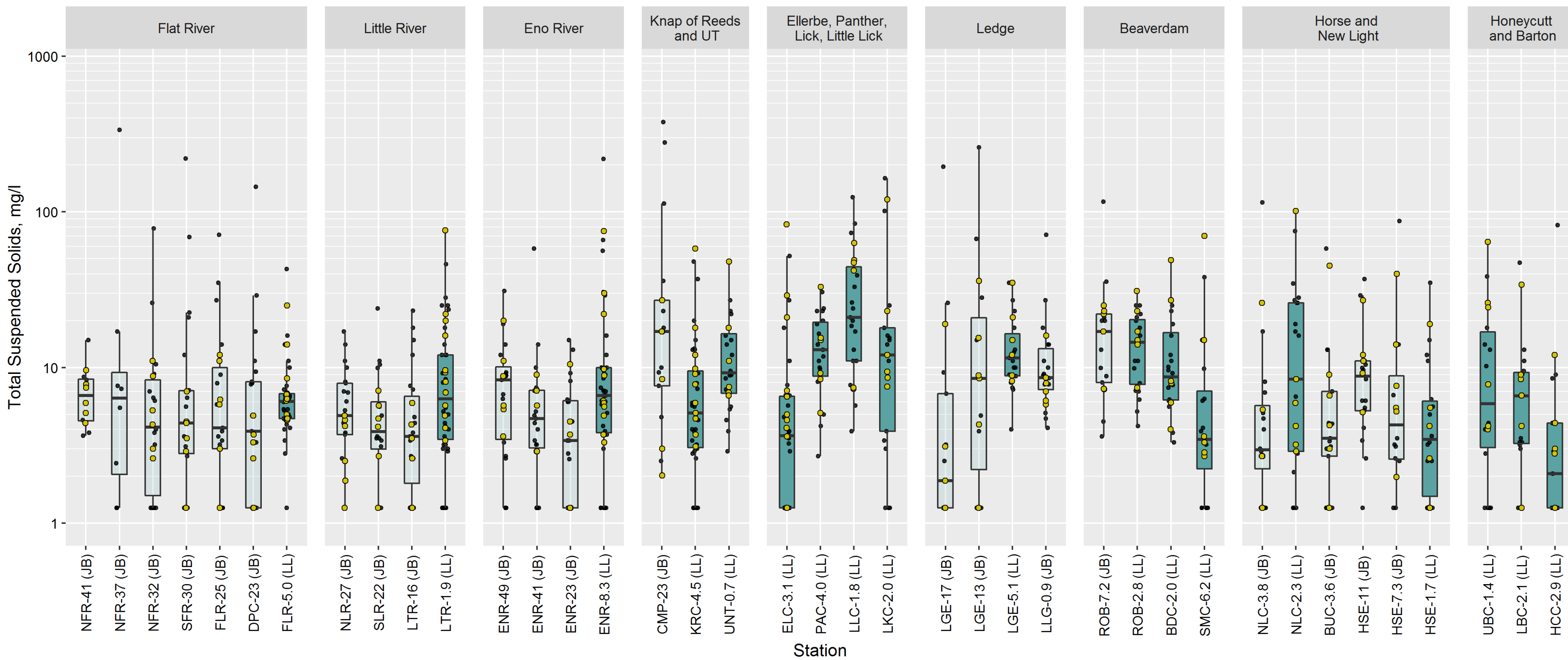

Figure 3-15 Total suspended solids (TSS) in Jurisdictional Boundary and Lake Loading Samples from August 2014 to June 2016. Jurisdictional Boundary stations are displayed with a light shading and Lake Loading stations are displayed with dark shading. Data collected between January and June of 2016 are highlighted as yellow circles.

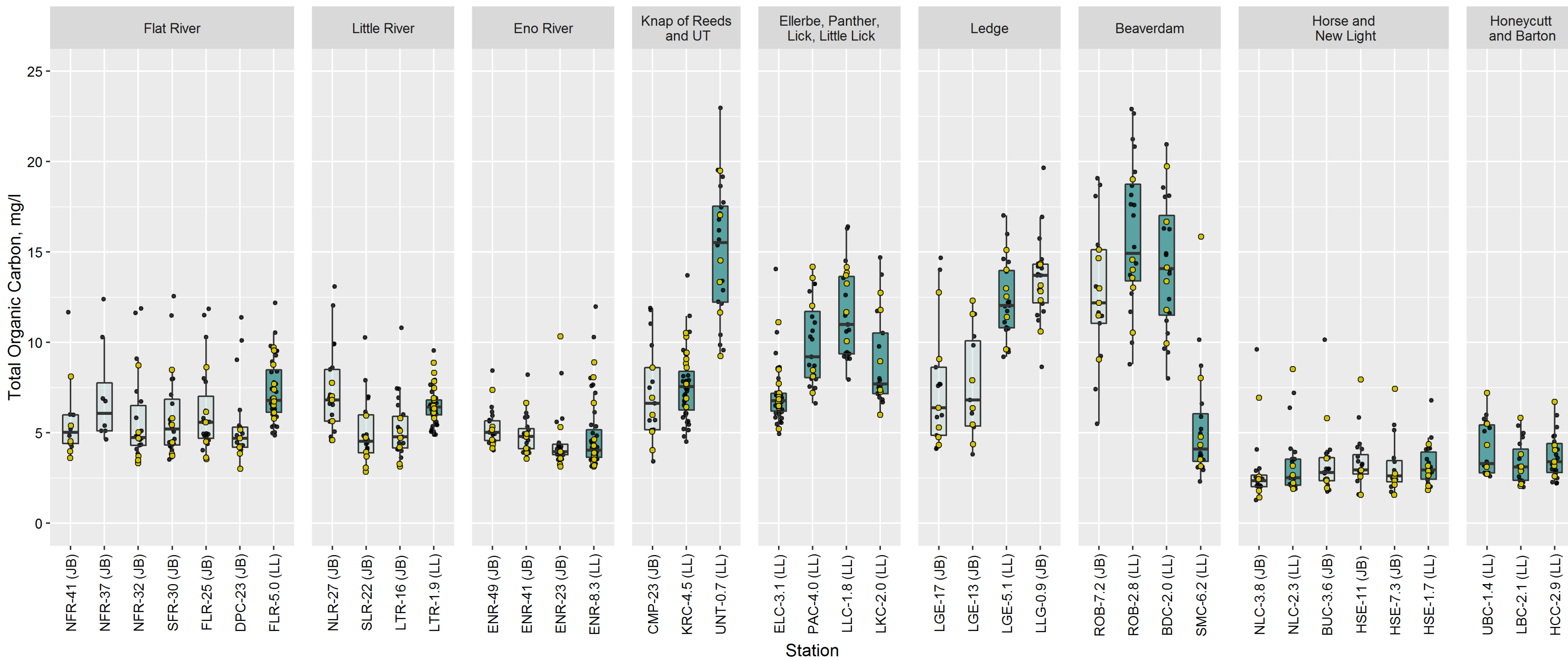

Figure 3-16 Total Organic Carbon (TOC) in Jurisdiction Boundary and Lake Loading Samples from August 2014 to June 2016. Jurisdictional Boundary stations are displayed with a light shading and Lake Loading stations are displayed with dark shading. Data collected between January and June of 2016 are highlighted as yellow circles.

3.3 Quality Assurance Considerations

All analytical data collected through the UNRBA monitoring program (both from Routine Monitoring and from Special Studies) are evaluated for compliance with the quality objectives outlined in the UNRBA Quality Assurance Project Plan (QAPP). Data accuracy, precision, and completeness reviews are performed following each monitoring event and reviews of field and laboratory practices are performed on a routine basis to ensure that the representativeness, accuracy and precision of data collection efforts meet the criteria set forth in the UNRBA's QAPP.

3.3.1 Representativeness and Completeness

The UNRBA Routine Monitoring program was designed to collect data from representative sites in the Falls Lake basin and at regular time intervals in order to capture data during conditions representing the entire monitoring period. All efforts are made to adhere to this sampling plan; however some samples are understandably missed due to factors such as dry stream conditions, extreme weather, site access limitations, equipment malfunction, or staffing issues.

From August 2014 to June 2016, the UNRBA collected about 92 percent of the samples and data points anticipated in the monitoring plan. Most of the missed data collection (~ 75%) has been attributable to dry conditions which prevented sample collection from some sites. This was typically because of dry streambeds or the presence of only a disconnected pool at the sampling location. In some instances, the water was too shallow across the entire channel to obtain a clean sample uncontaminated by sediment material. Ice storms in February 2015 accounted for eleven percent of the missed samples, despite multiple collection attempts. Site access issues, typically from construction efforts, were the cause of the remaining missed samples.

Due to isolated analytical equipment failures at the laboratory, several total phosphorus samples collected at the end of May and beginning of June 2016 were analyzed outside of recommended sample hold times: total P samples collected from the 18 Lake Loading sites in June 2016 were analyzed between 12-14 days past the 28-day hold time specified in the QAPP, and samples from all Jurisdictional sites in May 2016 and 8 Jurisdictional sites collected in June 2016 were analyzed between 5 and 30 days past hold-time limits. These data are reported in the UNRBA database with the appropriate qualifier code indicating they were analyzed outside of approved hold-times.

3.3.2 Accuracy and Precision

Accuracy and precision of measurements are continually assessed through the review of field, trip, and bottle blank concentrations, field and laboratory duplicate samples, and matrix spike recoveries. As discussed in the QAPP, accuracy can be assessed through a variety of measurements including blank samples, laboratory control samples, and matrix spike samples. There have been no issues with laboratory control samples and only a few occurrences of matrix spike recoveries outside of the QAPP criteria (<5%). Cardno will continue to monitor and log accuracy through matrix spike recoveries; per EPA guidance, matrix spike recoveries outside of the designated recovery range do not indicate a systemic problem as long as laboratory control samples are otherwise in control.

In 2014, concerns were noted with elevated field blanks for some nutrient parameters (ammonia, nitrate + nitrite, total Kjeldahl nitrogen, and total phosphorus). These concerns were resolved with the laboratory. Since November 2014, there have been zero blank exceedances for nitrate plus nitrite and total Kjeldahl nitrogen. Additional procedures were put into place with the laboratory in July and August 2015 to resolve continuing concerns with ammonia and total phosphorus field blanks above reporting levels. These measures have reduced the number of blank exceedances from 14% to 5% for TP and from 26% to 12% for ammonia-N.

Precision describes the reproducibility of measurements and is assessed through field and laboratory duplicate samples. The UNRBA QAPP specifies specific criteria for the precision of laboratory measurements as determined by the relative percent difference (RPD) between matrix spike or laboratory duplicate samples. These precision criteria have consistently been met for all parameters. The QAPP additionally sets RPD precision criteria for field duplicate samples. Differences between field duplicate results incorporate both lab errors as well as inherent variability between duplicate samples collected in the field. Field duplicates generally meet targets for field precision, however in some cases applying a relative percent difference (RPD) criteria to samples with low concentrations of analyte have resulted in RPD values above the specified targets.

Cardno evaluates and logs both relative and absolute differences between field duplicate samples and matrix spike duplicate samples in order to quantify and track the degree of uncertainty associated with field measurements for each parameter throughout the monitoring program. This will ultimately provide the end user with the information needed to quantify the uncertainty associated with field measurements.

4 Special Studies Results

This section provides results from the automatic sample collection performed for the Storm Event Special Study. This is the only special study for which additional data have been collected since the May 2016 Annual Monitoring Report. The status of all special studies including those which have been completed as well as those which are ongoing are presented in Section 2, above.

4.1 Storm Event Sampling

Storm Event Sampling efforts were conducted in February and May of 2016 on Ellerbe Creek and Eno River, capturing two distinct storm peaks for each tributary. Figure 4-1 and Figure 4-2 show the hydrographs at these monitoring locations and the distribution of water quality samples for each storm event sampled. Parameter concentrations measured in the samples are presented in relation to synoptically gaged flows in Figure 4-3 for Ellerbe Creek and Figure 4-4 for Eno River.

Earlier results of the Storm Event Sampling Special Study were presented in the previous Annual Report (Cardno 2016) and the model performance evaluation technical memorandum. The relationships between flow and concentrations of measured parameters for the spring 2016 sampling event fall within the ranges of values seen with the previous storm events (Figure 4-3 and Figure 4-4).

In the Eno River, most of the parameters show a pattern of increasing concentration with river flow, except for nitrate plus nitrite which remains relatively stable once flows exceed 200 cubic feet per second. For ammonia, the relationship with flow was relatively strong during the fall events (September and October) but weaker during the spring events (April). In Ellerbe Creek, there is much more variability in parameter concentrations, particularly at low flows when the WWTP discharge comprises a greater portion of the flow. At higher flows, much of the observed variability with discharge is attributable to higher concentrations on the rising portions of the hydrograph than on the falling portions. For this tributary, accurate predictive loading models will likely need to consider both stream flow and discharge monitoring data reported by the facility.

Patterns observed clearly demonstrate the variability in parameter concentrations associated with changes in flow. Of particular value is knowledge that the upper range of flows generally is associated with different water quality characteristics than the lower flows. These results led to the recommendation and inclusion of additional sampling under high flow conditions in the FY2017 Monitoring Plan. This effort will benefit future modeling work and increase confidence in nutrient loading estimates when flows are elevated.

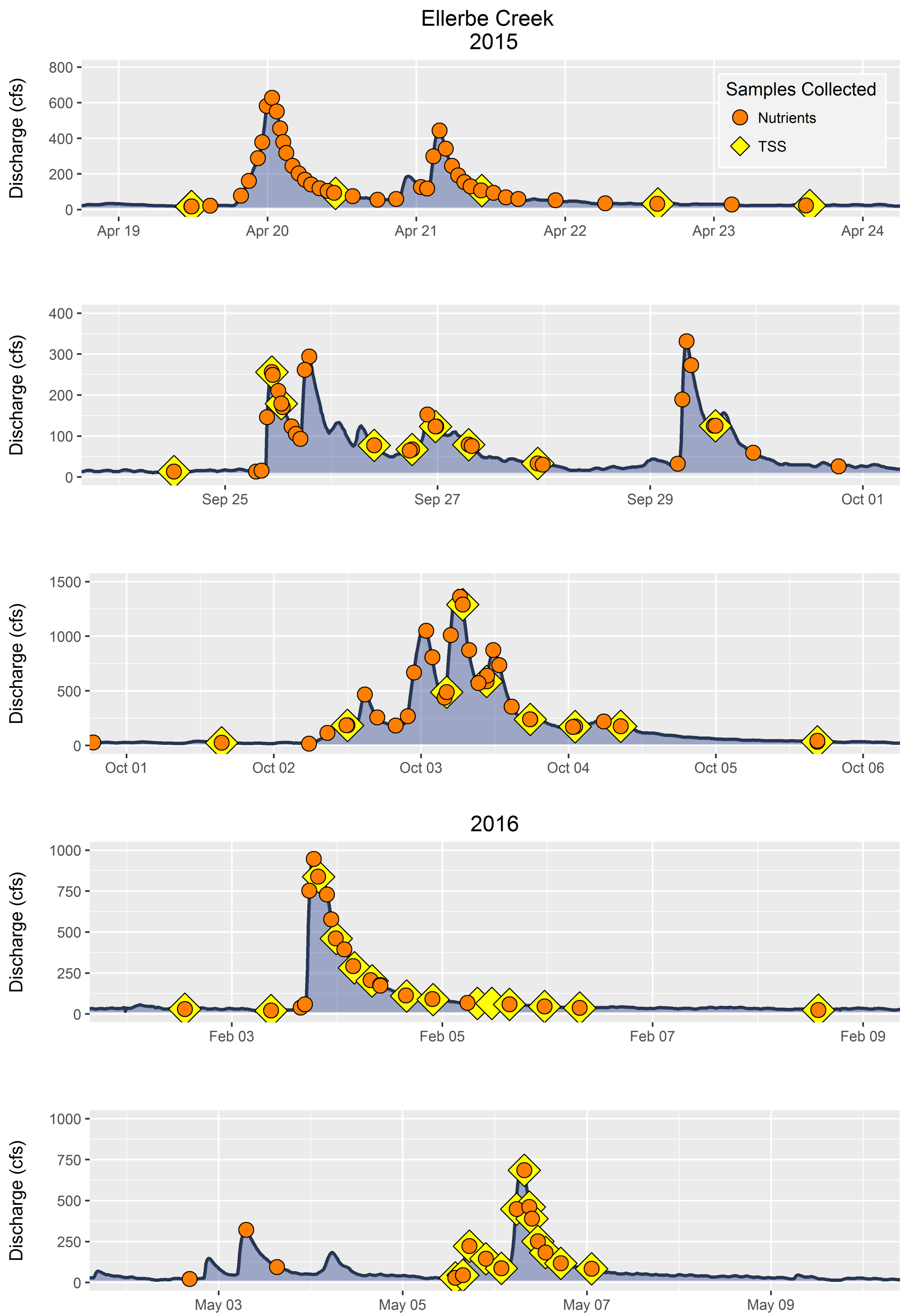

Figure 4-1 Hydrographs and Water Quality Samples Collected from Ellerbe Creek during the 2015 and 2016 Storm Events (symbols for Samples Collected only reflect the time of sample collection and not the magnitude of chemical analysis results)

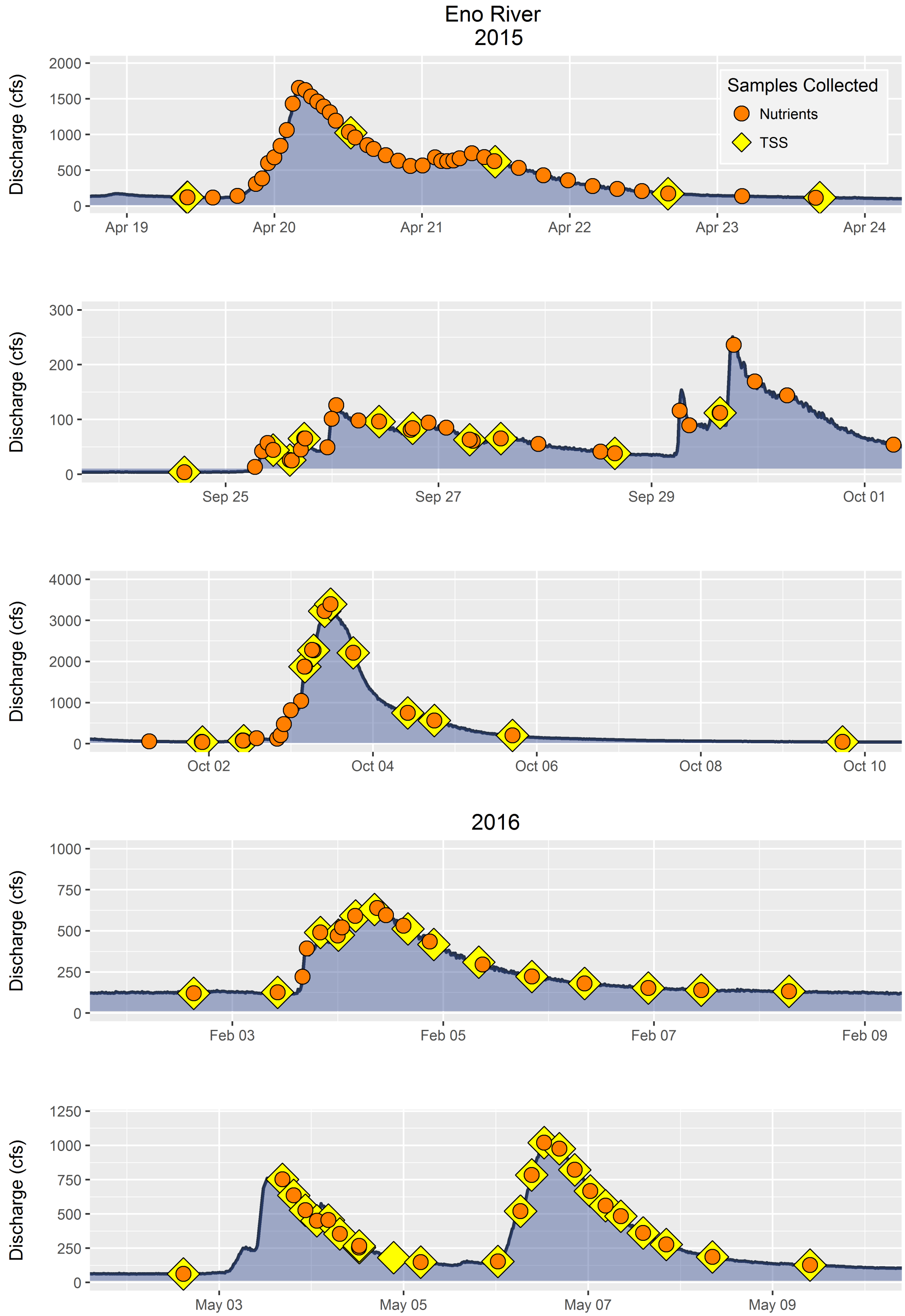

Figure 4-2 Hydrographs and Water Quality Samples Collected from Eno River during the 2015 and 2016 Storm Events (symbols for Samples Collected only reflect the time of sample collection and not the magnitude of chemical analysis results)

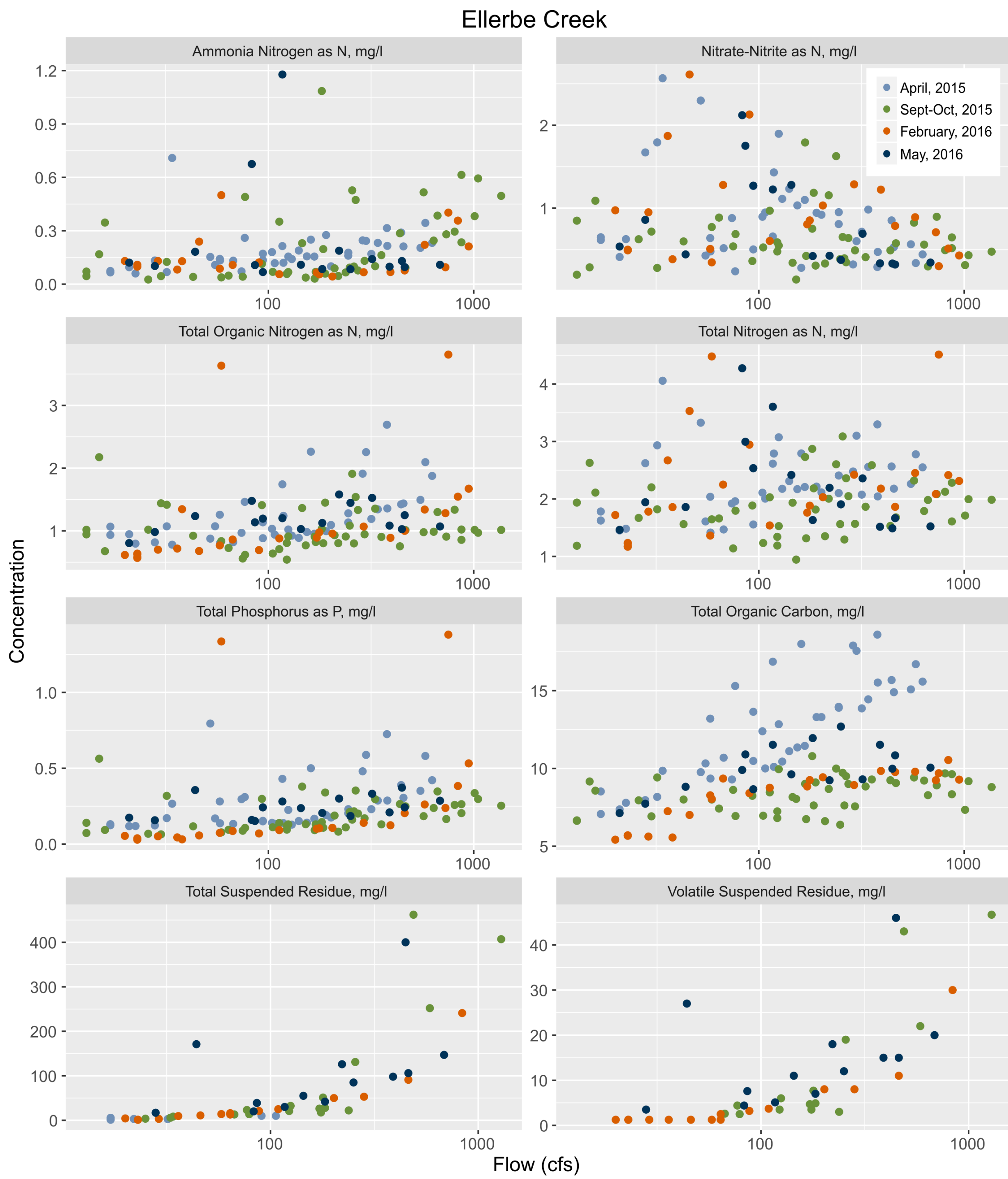

Figure 4-3 Water Quality Concentrations versus Flow Observed in Ellerbe Creek during the 2015-2016 Storm Events. Because flow values cover multiple orders of magnitude, note the horizontal axes use a log scale.

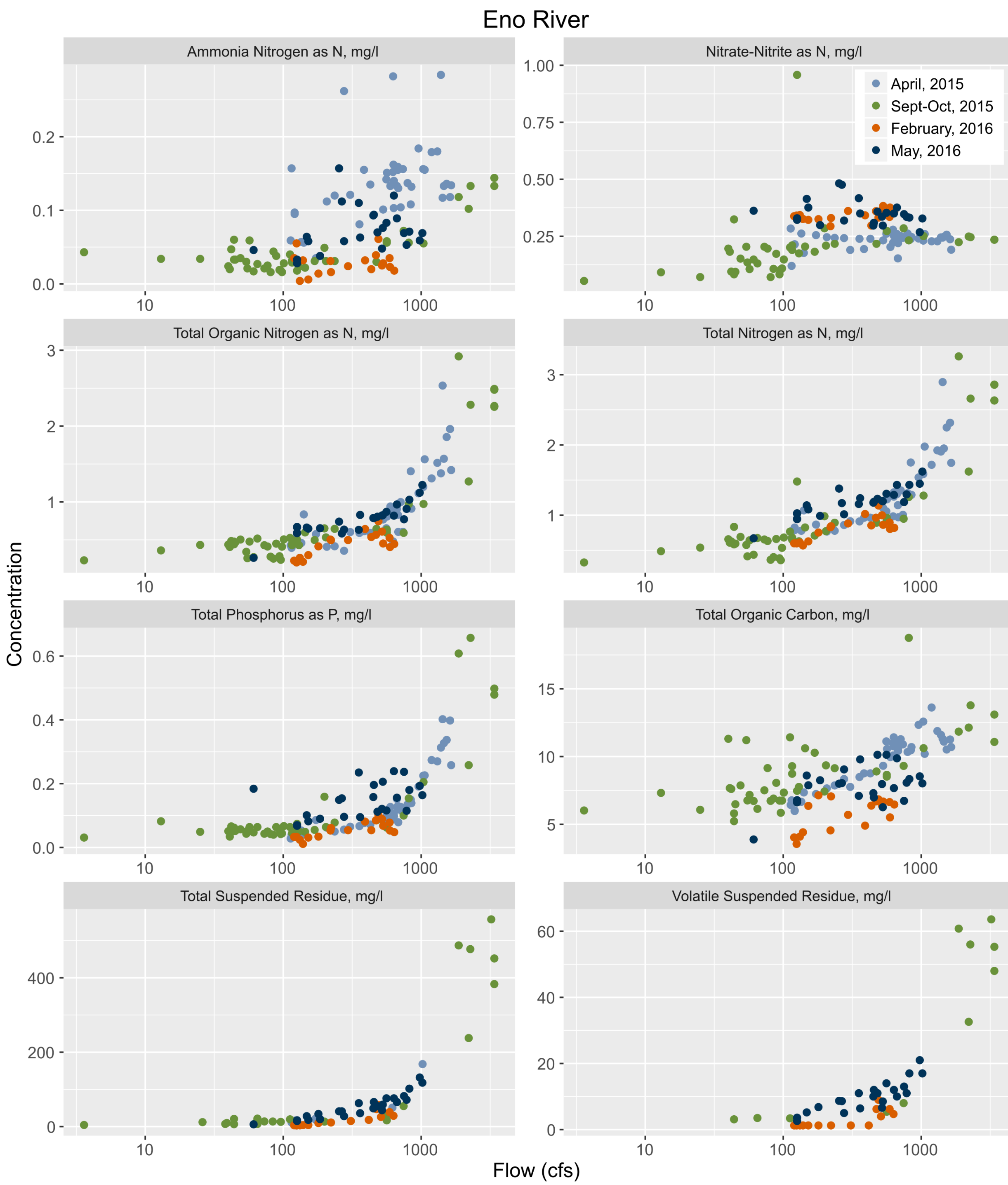

Figure 4-4 Water Quality Concentrations versus Flow Observed in Eno River during the 2015-2016 Storm Events. Because flow values cover multiple orders of magnitude, note the horizontal axes use a log scale.

5 Conclusion

Routine Monitoring continues to produce a large volume of useful data to support the goals of the UNRBA, with more than two full years of data collection now completed. Several Special Studies have also been completed, and others are still ongoing to provide additional information to support one or more of the goals. Updated versions of the Monitoring Program guidance document and the associated Quality Assurance Project Plan have been prepared and submitted to the North Carolina Division of Water Resources.

No changes are recommended to the Monitoring Program at this time. Several adjustments to the program were implemented at the beginning of FY2017 for reasons discussed in the 2016 Annual Report (Cardno 2016). The 2017 Annual Report will explore whether any additional changes to the Monitoring Program are recommended for implementation in FY2018 (July 2017 through June 2018).

6 List of References

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