UNRBA Annual Monitoring Report – 2014 Data

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1 Purpose of the UNRBA Monitoring Program

1.1 Regulatory Background

In 2010 the North Carolina Environmental Management Commission (EMC) passed the Falls Lake Nutrient Management Strategy ("The Rules"), requiring two stages of nutrient reductions (N.C. Rules Review Commission 2010); http://portal.ncdenr.org/web/fallslake/home. The Rules establish a Nutrient Management Strategy for Falls of the Neuse Reservoir to be implemented in two stages: 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 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).

1.2 UNRBA Re-examination Strategy

In 2011, the Upper Neuse River Basin Association (UNRBA) began a reexamination process of the regulatory framework for The Rules. Implementation of the nutrient reduction strategy, which is more stringent than any others implemented in the State, requires extremely costly actions on the part of UNRBA member governments and other regulated parties. In light of the potential financial impact of these rules and the importance of Falls Lake as a resource, the UNRBA began examination of the technical bases and regulatory framework for The Rules, particularly Stage II. Local governments agree that protecting Falls Lake as a water supply is paramount, but they want to ensure that the standards applied to the watershed sufficiently reflect the Lake's uses and that control requirements are reasonable, cost effective, and effective in improving the water quality of this resource.

In January 2012, the UNRBA contracted Cardno to conduct the technical and regulatory review of the Falls Lake Nutrient Management Strategy. 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 levels, Cardno (2013a) recommended a multi-part approach for moving forward with the re-examination process. The overall process relies on additional data collection and new modeling efforts to provide a scientific basis for the reexamination. These efforts will support revised lake response modeling, as well as evaluations of the various regulatory options that comprise the overall plan for the re-examination process. The state of North Carolina used the Environmental Fluid Dynamics Code (EFDC) water quality and hydrodynamic model to develop its nutrient reduction targets, and it is anticipated that the same model will be required in the re-examination process.

In 2014, the UNRBA and Cardno developed a Monitoring Plan to describe the locations, parameters, frequencies, and duration of the Monitoring Program (Cardno 2014b; http://www.unrba.org/monitoring-program). As established in Section 5 (f) of the Falls Lake Nutrient Management Strategy, the UNRBA submitted the Monitoring Plan to the North Carolina Division of Water Resources (DWR) for their review and approval. On July 16, 2014, DWR issued a memorandum approving the UNRBA Monitoring Plan. The UNRBA and Cardno also developed the UNRBA Monitoring Quality Assurance Project Plan (QAPP) which describes the protocols and methodologies to be followed by field and laboratory staff to ensure that a high degree of data precision and accuracy is maintained. The UNRBA Monitoring QAPP was approved by DWR on July 30, 2014 and subsequently signed by representatives of the UNRBA, Cardno, Environment 1 Inc. (analytical laboratory), and DWR.

1.3 Objectives of the UNRBA Monitoring Program

The UNRBA Monitoring Program includes routine monitoring (in addition to ongoing data collection efforts by DWR and other entities), along with special studies 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.

Table 1 outlines the routing monitoring to support Objectives 1 and 2. Table 2 describes the UNRBA Special Studies underway in 2014 that can be used to support all three objectives. Additional details about these studies are described in the Monitoring Plan (Cardno 2014b; http://www.unrba.org/monitoring-program).

Table 1. Overview of Routine Components of the UNRBA Monitoring Program

Monitoring Program Component	Data Use	UNRBA Objectives Supported	Years 1 and 2	Years 3, 4 and 5 (optional)
Lake Loading at 18 tributary stations	To quantify lake loading inputs to Falls Lake Environmental Fluid Dynamics Code (EFDC) model	Revised Lake response modeling	**Twice a month** Ellerbe, Eno, Little, Flat, and Knap of Reeds; **Monthly** all other locations.	**Twice a month** Ellerbe, Eno, Little, Flat, and Knap of Reeds; **Monthly** Little Lick, Lick, Ledge, New Light, and Upper Barton; **Monthly – Quarterly** frequency to be determined for specific locations following statistical analyses.
20 jurisdictional boundary tributary stations	Demonstrate water quality at multiple locations for all UNRBA member organizations	Source allocation and estimation of jurisdictional loading	**Monthly** all locations	**Monthly – Quarterly** frequency to be determined for specific locations following statistical analyses

Table 2. UNRBA Special Studies under Way in FY 2015

Monitoring Program Component	Purpose
High Flow Monitoring at Eight Tributary Stations	Obtain water quality data when there is flow at stations that are often stagnant
Storm Event Sampling on Eno River and Ellerbe Creek	Obtain water quality data throughout the elevated flow period associated with storms – to improve loading estimates to Falls Lake with updated modeling
Falls Lake Sediment Sampling	Evaluate nutrient concentrations in Falls Lake sediments – to improve estimates of sediment nutrient dynamics in updated modeling, and to provide information to facilitate potential U.S. EPA study of *in situ* sediment nutrient dynamics in the lake.

2 Overview of UNRBA Monitoring Data for 2014

Following approval of the UNRBA Monitoring Plan and QAPP by DWR, routine monitoring began in August 2014. Under the services contract with the UNRBA, Cardno is required to produce an Annual Report to inform the UNRBA of the nature of the monitoring results, and to assist the UNRBA in setting the scope and budget for the following monitoring year. Cardno's contract and budget coincide with the UNRBA fiscal calendar, running from July 1 of the current year through June 30 of the following year. Annual Reports are prepared in the spring and provide a summary of the data collected during the preceding calendar year, and in future years, the report will make reference to data collected in previous years. An abbreviated interim report is also prepared in the fall of each year to document monitoring results through the end of the fiscal year.

This initial annual report addresses five months of data, from the beginning of the monitoring program in August, through December 2014. During this period, the UNRBA Monitoring Program focused on Routine Monitoring. Detailed site descriptions and a full list of sampling parameters are provided in the Monitoring Plan (Cardno 2014b; http://www.unrba.org/monitoring-program).

2.1 Lake Loading Sites on Tributaries in the Falls Lake Watershed

To characterize tributary loading inputs to support lake modeling, flow and water quality are needed at the lake entry point of each of the lake's 18 tributaries. These locations are shown on Figure 1. Sampling occurred twice a month at the five upper lake tributaries which, based on previous information, generally contribute roughly 75 percent of the nutrient loading to Falls Lake. It is important to have high confidence in nutrient load estimates for these tributaries because water and nutrient contributions from the trigutaries to the lake drive much of the lake's response. These inputs also reflect watershed contributions and these represent the regulatory control target of the Rules.

Parameters for routine monitoring were based on the requirements of the EFDC model, along with input from UNRBA member organizations. In addition to the standard field parameters and lab analyses for nutrients, several additional parameters were collected as noted in Section 3. In subsequent monitoring years, the UNRBA Monitoring Program may be revised to modify parameter coverage, frequencies, and sampling locations to optimize data collection for the UNRBA's needs.

2.2 Jurisdictional Sites 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 within 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 1) were identified based on input from the UNRBA Path Forward Committee and are being monitored monthly to characterize water quality at jurisdictional boundaries (excluding those covered under the lake loading stations). Similar to the other monitoring components, in subsequent monitoring years, the data collection efforts at jurisdictional sites may be revised to optimize data value for the UNRBA.

2.3 Falls Lake Monitoring

Monitoring of Falls Lake provides data that can be used for calibration and validation of a revised Falls Lake water quality model (e.g. concentrations of chlorophyll *a*, nutrients, and carbon) as well as data on additional physical, chemical and biological processes to improve the model's performance.

Data collected under a State-approved QAPP can be included in the database for agency consideration and model development. Ongoing monitoring by DWR (under its established QAPP), Center for Applied Aquatic Ecology (CAAE), and local governments potentially provides data that can be considered for these efforts. At UNRBA's request, DWR added a monitoring station and several parameters to their routine lake monitoring beginning in October 2014. Figure 2 shows the DWR monitoring stations on Falls Lake. Data summaries for the parameters that DWR analyzes may be accessed through the DWR website (http://portal.ncdenr.org/web/wq/fallsjordan).

Figure 1. UNRBA Lake Loading and Jurisdictional Monitoring Locations (see Table 3 for station details) and Existing USGS Gages

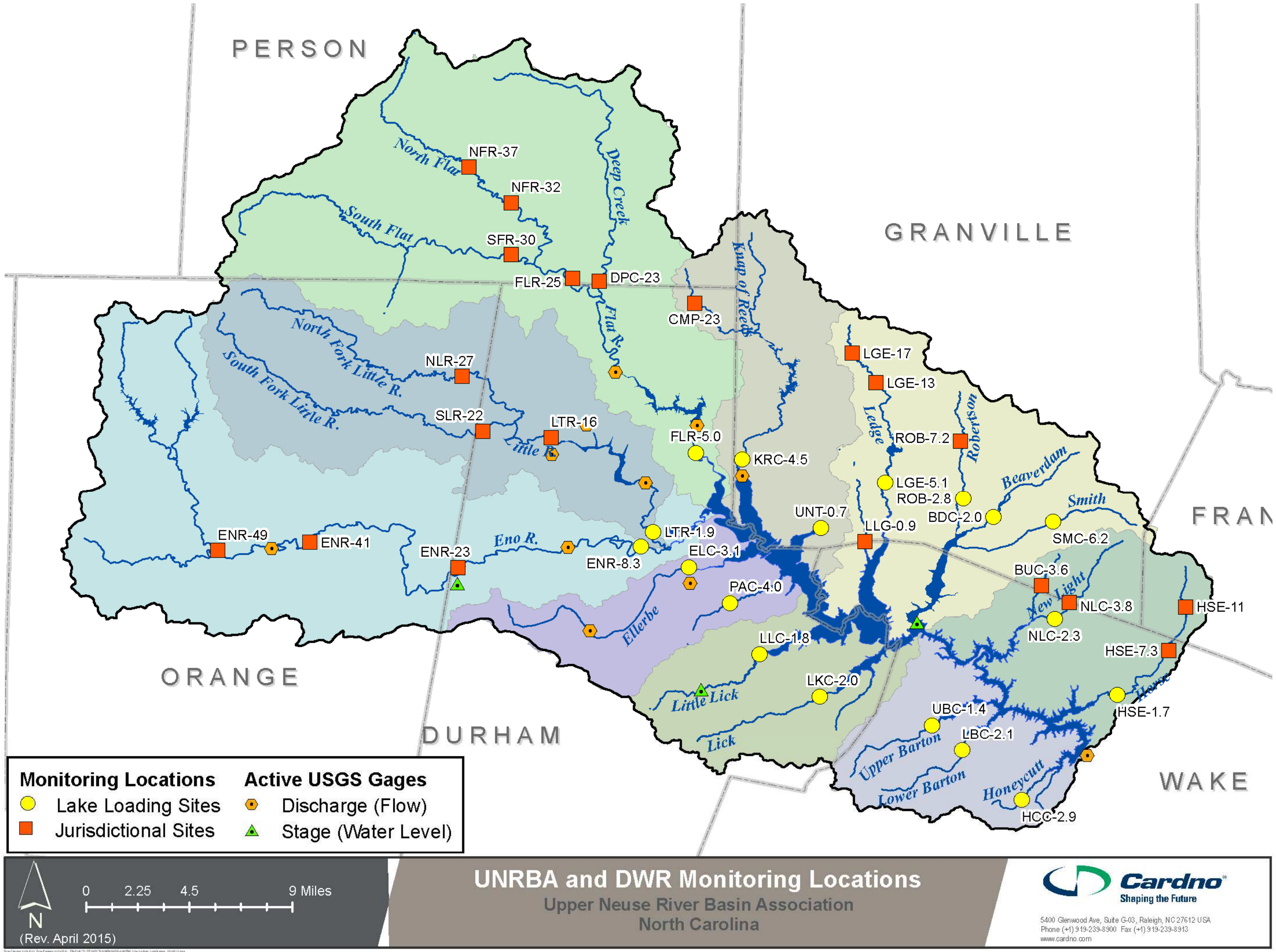
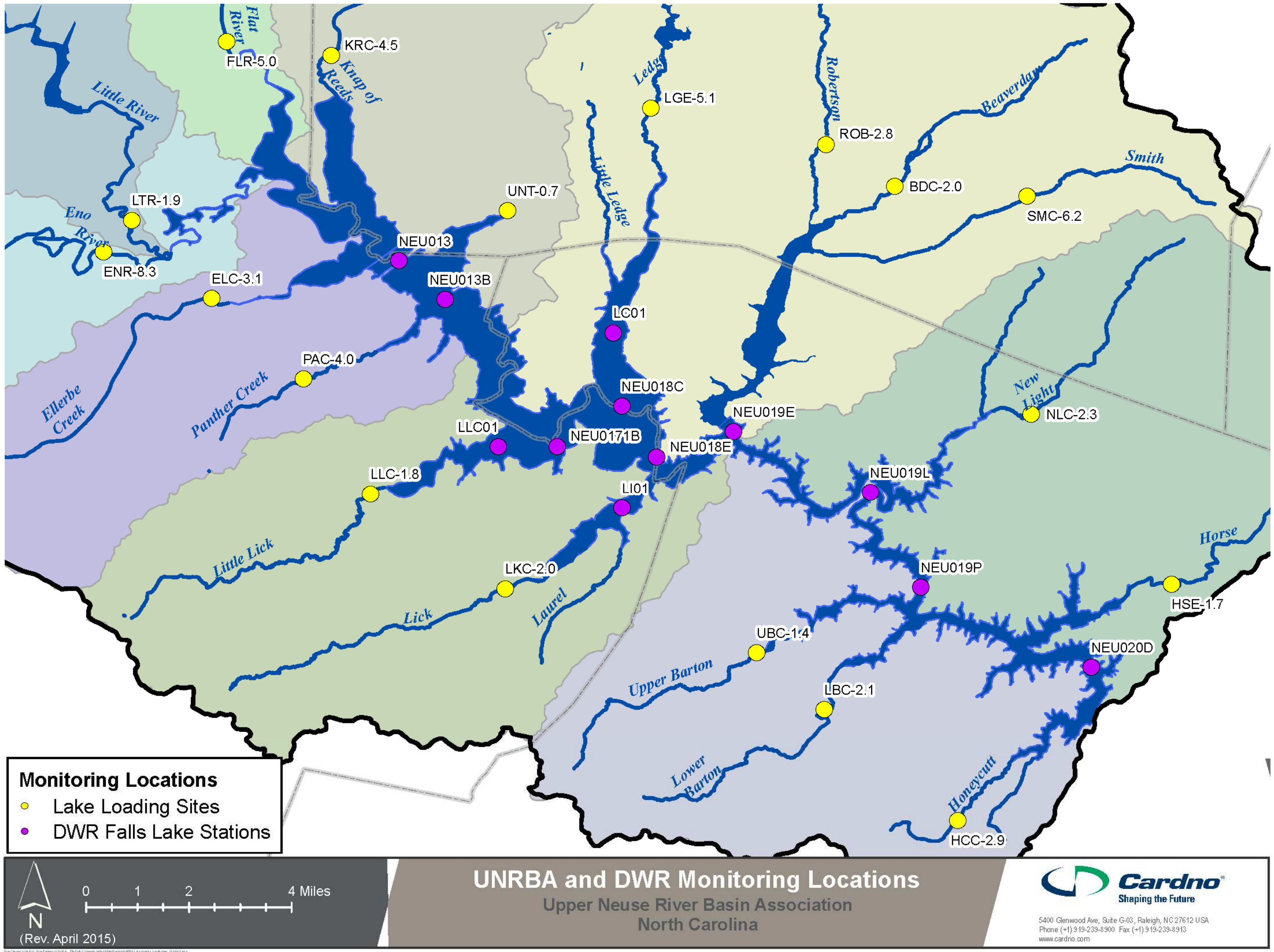


Figure 2. Falls Lake DWR Monitoring Locations shown with UNRBA Lake Loading Stations



3 Summary of Data Collected in 2014

Data Available Online!

Rather than providing more than 3,000 raw data points here in static tables that use additional paper when printed, the entire data set from the routine monitoring discussed in this report is available in an online database provided by the UNRBA..

To access the data, please visit http://unrba-wqp.cardno.com/index.php

The UNRBA Monitoring Program began in August 2014 following DWR approval of the Monitoring Plan and Monitoring QAPP as described in Section 1. This Annual Report summarizes the data collected through December 2014. Approximately 3,000 water quality data values have been generated from the lake loading, jurisdictional boundary, and Falls Lake stations during this period. The total number of data values collected through December 2014 is not a large amount of data but it does provide important initial information for the reexamination process. However, five months of data are not sufficient to warrant substantial statistical analysis. In subsequent reports when more data are available, the annual report will include more statistical descriptions and interpretation of the data. This report presents measured values for these key parameters: total nitrogen, total phosphorus, chlorophyll a and total organic carbon. The complete UNRBA database, including data for other monitored parameters, can be accessed online after setting up a user account at http://unrba-wqp.cardno.com/index.php. With a UNRBA database account users can review raw data, generate summary statistics, and obtain detailed station information.

The majority of the data values from samples analyzed by the UNRBA contract laboratory are reported as concentrations. Concentrations represent the amount of a substance present in a specific volume of water at the time the sample was collected. Concentrations are expressed as milligrams per liter (mg/L – one thousandth of a gram) or micrograms per liter (µg/L – one millionth of a gram).

Figure 3 shows the daily precipitation that occurred during this monitoring period.

Graphical representations of data for the four key parameters noted above are provided in Figures 4 through 7. Each individual plot presents the measured values for a particular parameter within one subwatershed (tributary) system. Grouping by subwatershed provides spatial context, using a unique three letter code to refer to each stream. Stations within a subwatershed plot are ordered from upstream to downstream, and the numeric part of the station code refers to the distance upstream from Falls Lake. Stations labels with “(LL)” indicate a lake loading station, and stations labeled with “(JB)” indicate a jurisdictional boundary station. For example, FLR-5.0(LL) refers to the lake loading site on the Flat River that is 5 miles upstream of Falls Lake. Table 4 provides a list of all tributary stations. Data values displayed as triangles indicated that ¼ inch or more of precipitation occurred in the preceding 48 hours.

Figure 3. Daily Precipitation Observed in Durham, NC from August to December 2014

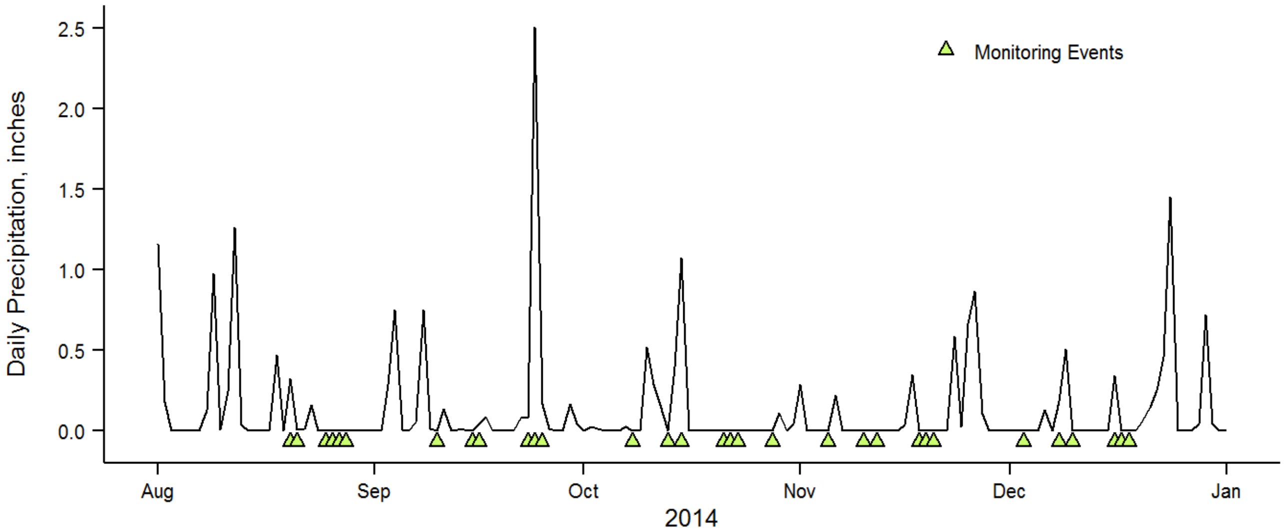


Table 3. UNRBA Routine Tributary Monitoring Locations and Sampling Frequency for 2014

Name[1] (Station Type[2])	Subwatershed	Stream Name	County	Distance Upstream (mi)	Drainage Area (mi^2)	Sampling Frequency
NFR-37(JB)	Flat	North Flat	Person	37	15.8	Monthly
NFR-32(JB)	Flat	North Flat	Person	32	32.8	Monthly
SFR-30(JB)	Flat	South Flat	Person	30	54.4	Monthly
FLR-25(JB)	Flat	Flat	Person	25	102	Monthly
DPC-23(JB)	Flat	Deep	Person	23	32.1	Monthly
FLR-5.0(LL)	Flat	Flat	Durham	5	169	Twice monthly
NLR-27(JB)	Little	North Fork Little	Orange	27	21.9	Monthly
SLR-22(JB)	Little	South Fork Little	Durham	22	37.4	Monthly
LTR-16(JB)	Little	Little	Durham	16	78.3	Monthly
LTR-1.9(LL)	Little	Little	Durham	1.9	104	Twice monthly
ENR-49(JB)	Eno	Eno	Orange	49	60.5	Monthly
ENR-41(JB)	Eno	Eno	Orange	41	73.2	Monthly
ENR-23(JB)	Eno	Eno	Durham	23	121	Monthly
ENR-8.3(LL)	Eno	Eno	Durham	8.3	149	Twice monthly
CMP-23(JB)	Knap of Reeds	Camp	Durham	23	1.99	Monthly
KRC-4.5(LL)	Knap of Reeds	Knap of Reeds	Granville	4.5	41.9	Twice monthly
UNT-0.7(LL)	Unnamed	Unnamed	Granville	0.7	3.43	Monthly
ELC-3.1(LL)	Ellerbe	Ellerbe	Durham	3.1	21.9	Twice monthly
LKC-2.0(LL)	Lick	Lick	Durham	2	10.8	Monthly
LLC-1.8(LL)	Little Lick	Little Lick	Durham	1.8	13.8	Monthly
PAC-4.0(LL)	Panther	Panther	Durham	4	3.24	Monthly
LGE-17(JB)	Ledge	Ledge	Granville	17	1.79	Monthly
LGE-13(JB)	Ledge	Ledge	Granville	13	3.49	Monthly
LGE-5.1(LL)	Ledge	Ledge	Granville	5.1	20.3	Monthly
LLG-0.9(JB)	Little Ledge	Little Ledge	Granville	0.9	3.74	Monthly
BDC-2.0(LL)	Beaverdam	Beaverdam	Granville	2	12.7	Monthly
ROB-7.2(JB)	Robertson	Robertson	Granville	7.2	4.43	Monthly
ROB-2.8(LL)	Robertson	Robertson	Granville	2.8	12	Monthly
SMC-6.2(LL)	Smith	Smith	Granville	6.2	6.3	Monthly
HSE-11(JB)	Horse	Horse	Franklin	11	3.88	Monthly
HSE-7.3(JB)	Horse	Horse	Wake	7.3	7.11	Monthly
HSE-1.7(LL)	Horse	Horse	Wake	1.7	11.9	Monthly
NLC-3.8(JB)	New Light	New Light	Wake	3.8	9.9	Monthly
BUC-3.6(JB)	New Light	Buckhorn	Granville	3.6	1.21	Monthly
NLC-2.3(LL)	New Light	New Light	Wake	2.3	12.3	Monthly
HCC-2.9(LL)	Honeycutt	Honeycutt	Wake	2.9	2.76	Monthly

[1]Name combines an abbreviation for the stream with the approximate distance from the station to Falls Lake.
[2]JB refers to a jurisdictional station and LL refers to a lake loading station.

Figure 4. Total Nitrogen Concentrations in Tributary Samples from August to December 2014

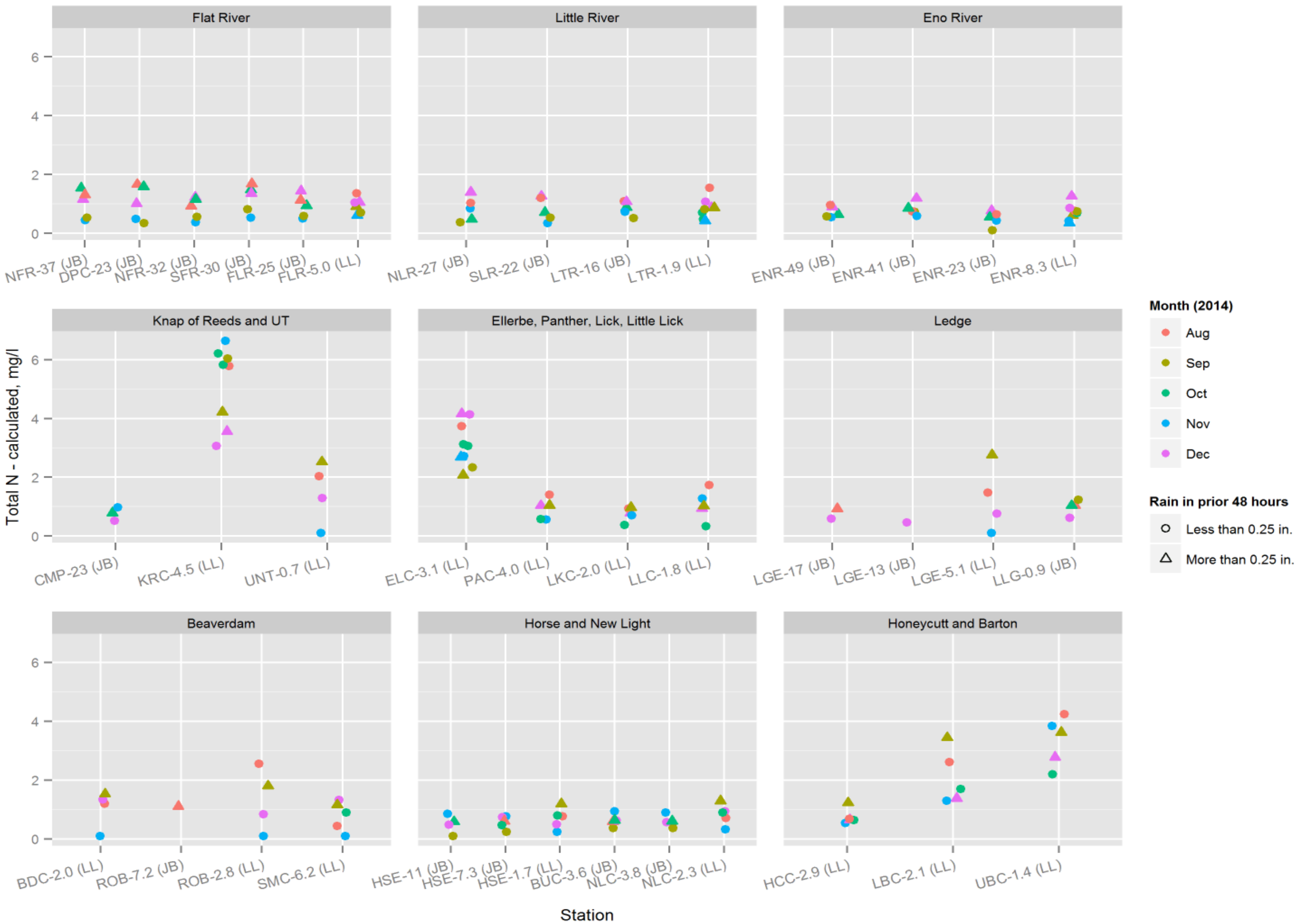


Figure 5. Total Phosphorus Concentrations in Tributary Samples from August to December 2014

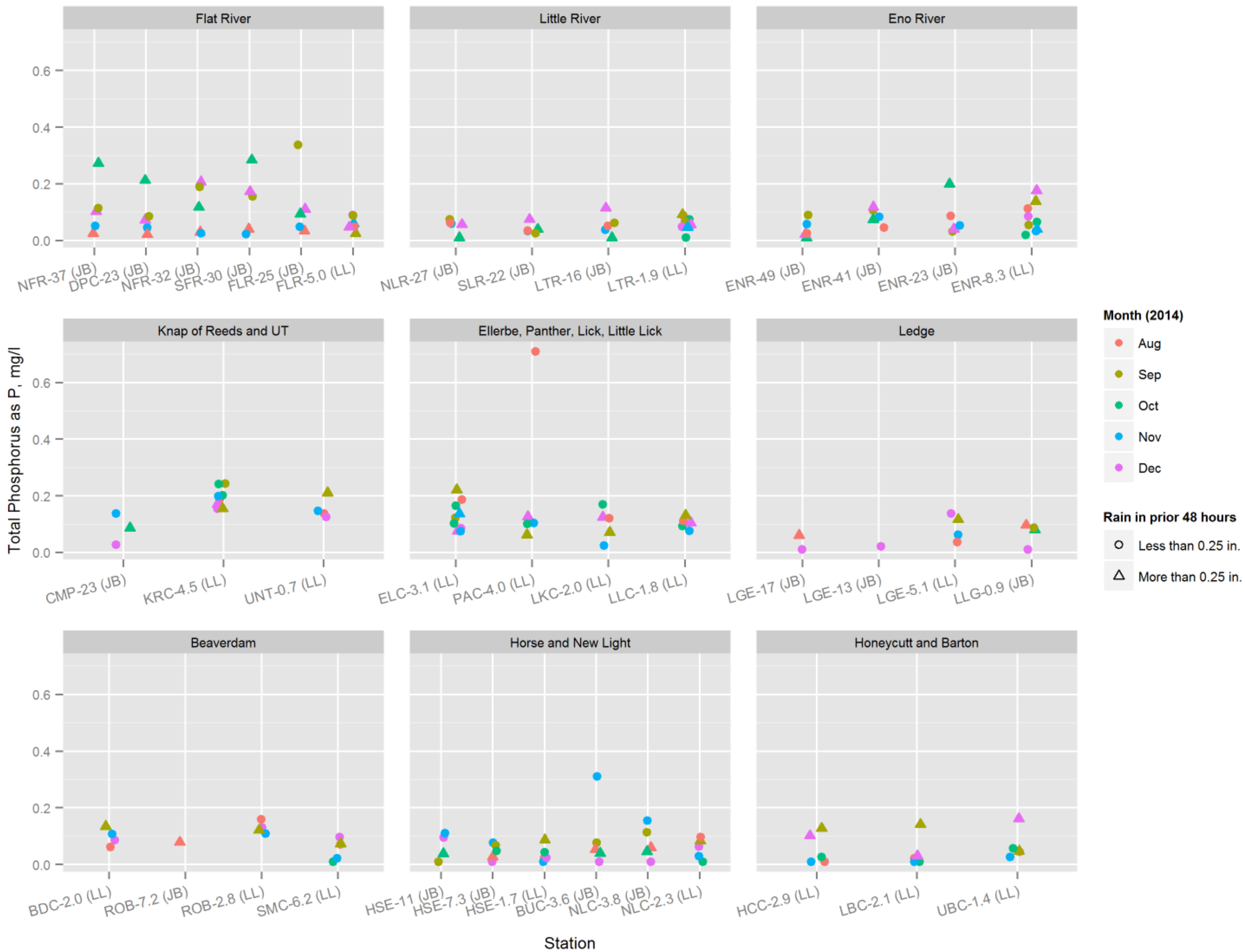


Figure 6. Total Organic Carbon Concentrations in Tributary Samples from August to December 2014

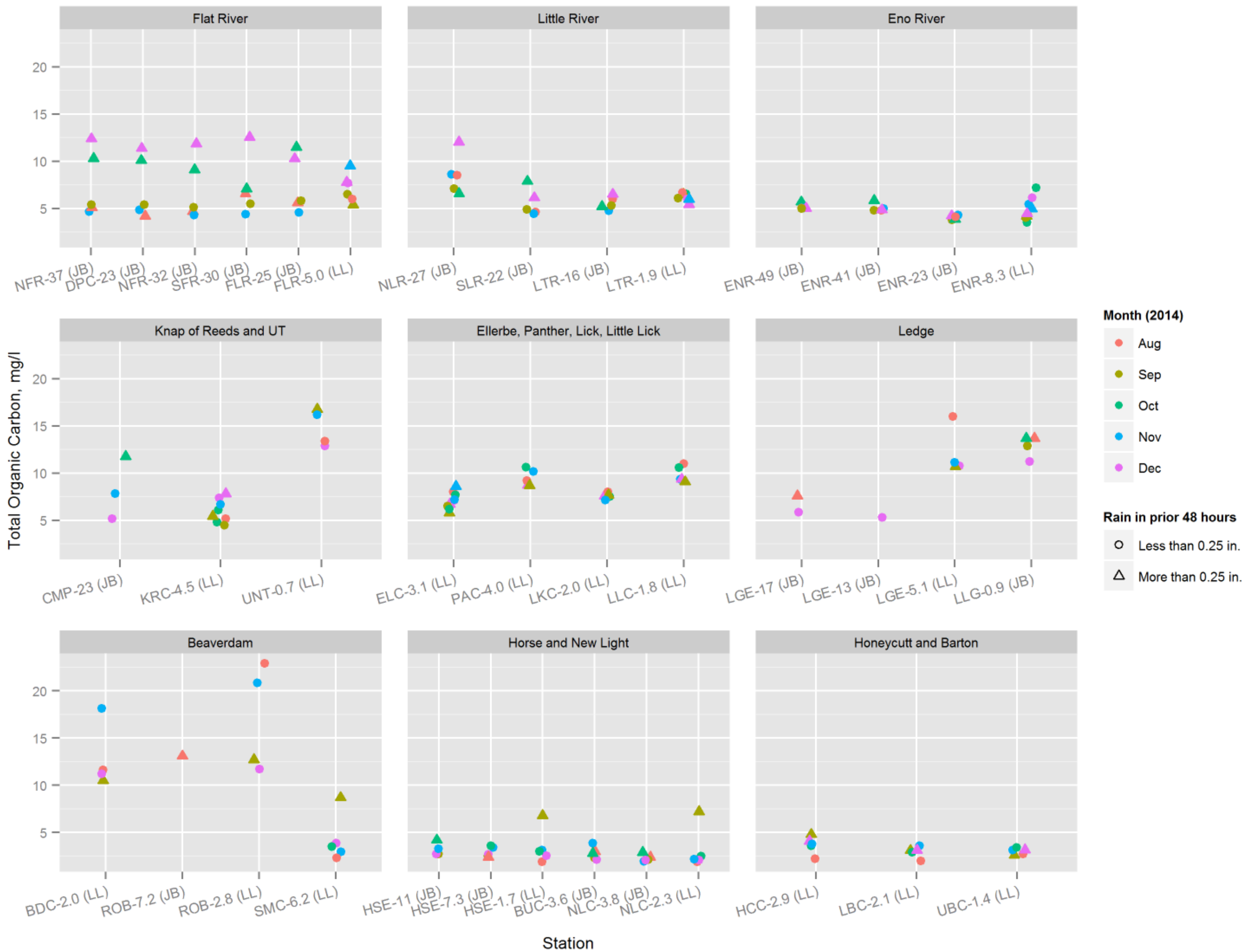
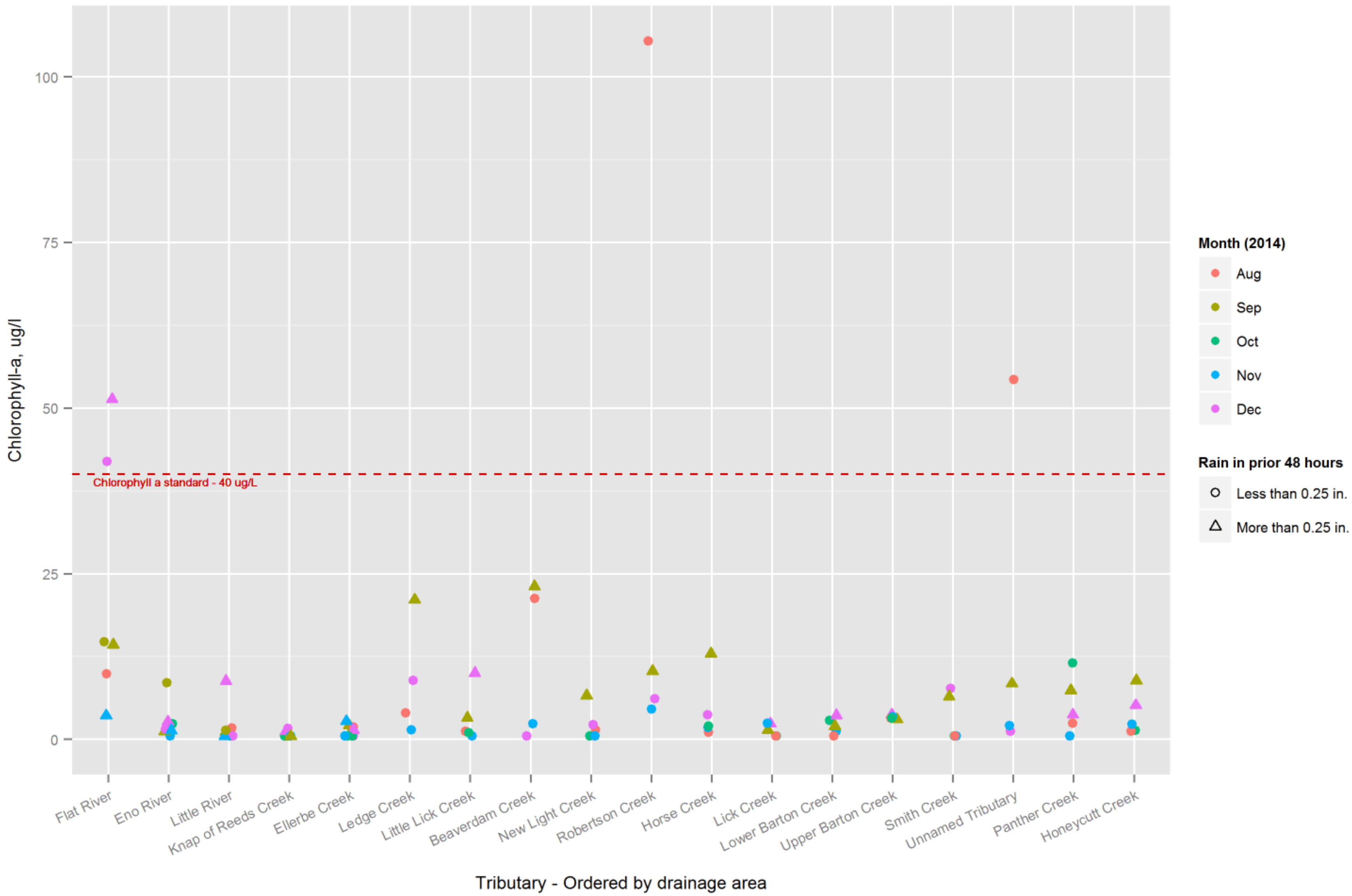


Figure 7. Chlorophyll a Concentrations in Tributary Samples from August to December 2014



As stated above, with only five months of data, it is premature to draw extensive conclusions. The statements offered below are intended to provide a general understanding of the water quality parameters and their context based on initial observations. The majority of the DWR 2014 lake water quality data has already been summarized in its 2014 report, therefore the observations below refer to tributary monitoring at lake loading and jurisdictional locations; the link to the DWR data is http://portal.ncdenr.org/web/wq/fallsjordan.

> Nitrogen is an essential nutrient for all forms of life and our atmosphere is about 80 percent nitrogen. Nitrogen in watersheds generally comes from sources such as atmospheric deposition, surface runoff of rainwater, shallow groundwater, discharge from wastewater treatment plants or onsite disposal systems, residential or agricultural fertilizer, and manure. Total nitrogen, as reflected in the graphics above, is calculated as the sum of several different forms of nitrogen found in the environment. In the Falls Lake watershed, total nitrogen concentrations tend to be higher downstream of major wastewater treatment plants (e.g., Knap of Reeds Creek and Ellerbe Creek), downstream of package wastewater treatment plants (Upper and Lower Barton Creek), and in large wetland complexes (Beaverdam Creek, Robertson Creek, Unnamed Tributary).

> Phosphorus, also an essential nutrient, often enters water bodies in association with soil, because phosphorus tends to bind with certain types of soil particles (particularly with clay soils common in the Piedmont). It is also a component of stormwater surface runoff, shallow groundwater, discharge from wastewater treatment plants or onsite disposal systems, fertilizers, and manure. Total phosphorus includes organic and inorganic forms. Ortho-phosphate represents the inorganic fraction of phosphorus that is not tied up in organic matter such as algae or decaying plant material. In the Falls Lake watershed, phosphorus concentrations tend to be higher downstream of major wastewater treatment plants (e.g., Knap of Reeds Creek and Ellerbe Creek) and in large wetland complexes (Beaverdam Creek, Robertson Creek, Unnamed Tributary).

> Carbon is considered the primary building block of all living things. Total organic carbon (TOC) is the amount of carbon bound in an organic compound, and it is often used as a non-specific indicator of water quality. Total organic carbon in a water sample may include algae or other microorganisms, small fragments of decaying animal or plant material, and animal waste. In the Falls Lake watershed, TOC measurements tend to be higher in wetland complexes such as Ledge Creek, Beaverdam Creek, Robertson Creek, and Unnamed Tributary.

> Chlorophyll a is a green pigment in plants and algae that allows them to use energy from the sun to build living tissue through photosynthesis. Water samples for Chlorophyll a are an indication of how much algae is in the water. While algae is an important component of aquatic ecosystems, too much algae can cause problems with water treatability for drinking water, taste and odor problems, or drastic fluctuations in dissolved oxygen and/or pH that can cause problems for aquatic organisms. Under North Carolina water quality standards, the Falls Lake watershed should have chlorophyll a levels no greater than 40 µg/L. In the Falls Lake watershed, concentrations of chlorophyll a tend to be higher in areas with stagnant water or large wetland complexes such Flat River, Ledge Creek, Beaverdam Creek, Robertson Creek, and Unnamed Tributary. Concentrations in free flowing waters have been generally low during the first five months of tributary monitoring. Of 107 chlorophyll a values measured, 103 (96 percent) were below the 40 ug/L water quality standard. Only 4 observations exceeded 40 µg/L, representing only three of the monitored tributary stations, as listed in Table 5.

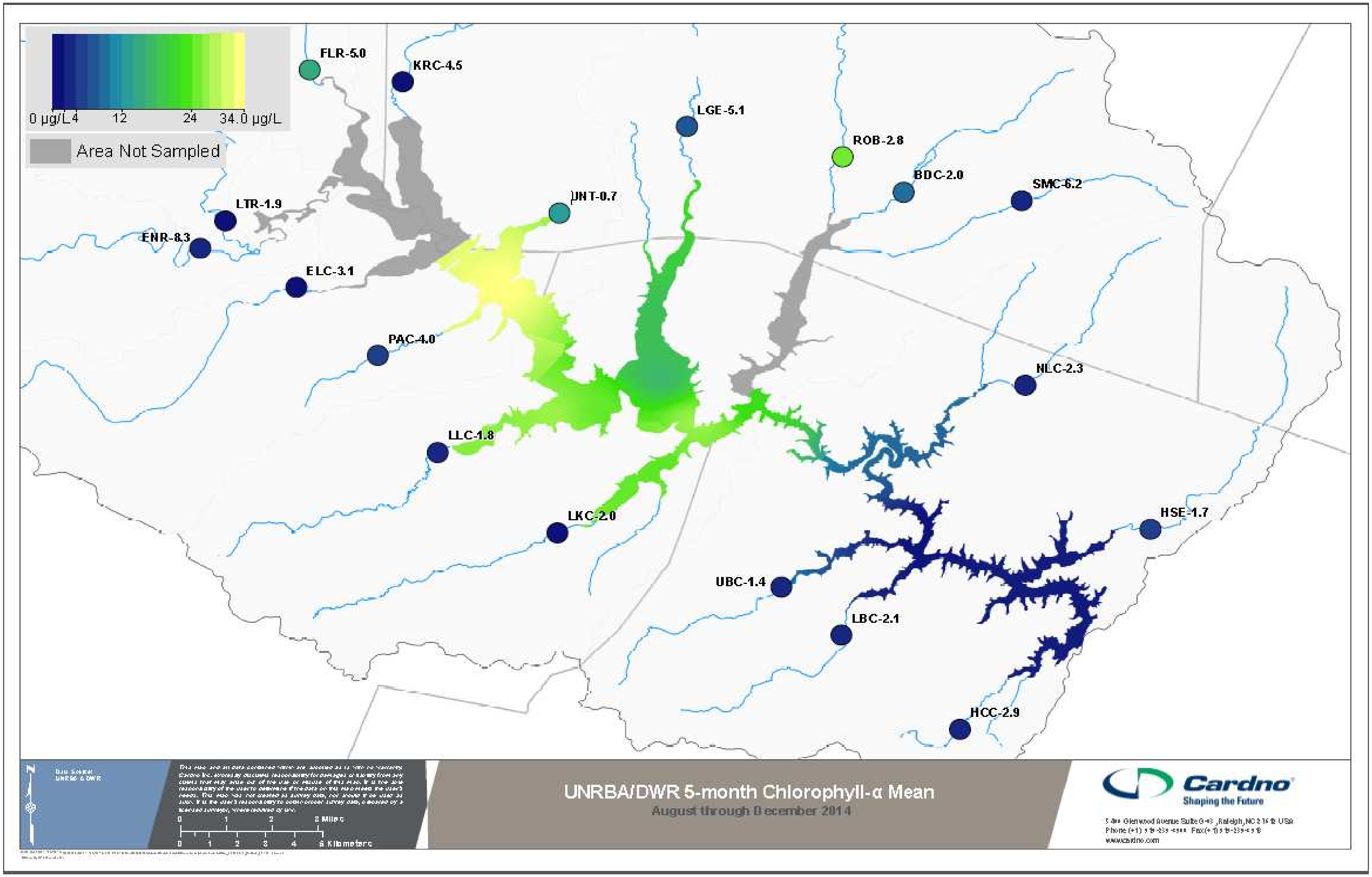
Table 4. Stations with Chlorophyll *a* Measured above the NC State Standard

Subwatershed	Station ID	Chlorophyll a > 40 ug/L
Flat River	FLR-5.0(LL)	2/6 (33%)
Robertson Creek	ROB-2.8(LL)	1/4 (25%)
Unnamed	UNT-0.7(LL)	1/4 (25%)
	All Sites	**4/107 (5%)**

* Values shown are: Number of measured values below the standard / Total Number Measurements, and (Percent of measurements below the standard)

> Chlorophyll a data collected on the Falls Lake tributaries through the UNRBA Monitoring Program will provide input data for the Falls Lake water quality model which were not collected when DWR initially developed the model. At the time DWR assumed that the chlorophyll concentrations entering Falls Lake from the tributaries were the same as those measured at the nearest lake station. This DWR modeling assumption may not have been entirely accurate. The data collected in 2014 under the UNRBA Monitoring Program and the 2014 DWR lake sampling for chlorophyll-a suggest that tributary concentrations are lower than those observed at the nearest lake station. Figure 8 shows the average concentration (from August 2014 to December 2014) at each lake loading station compared to a spatial interpolation of data collected in 2014 by DWR in Falls Lake.

Figure 8. Average Chlorophyll a Concentrations Observed in the Falls Lake Watershed Compared to Observations in Falls Lake from August 2014 to December 2014



> Dissolved oxygen (DO) is commonly measured in water resource monitoring, and represents the amount of oxygen in the water and available for respiration by many aquatic organisms. North Carolina water quality standards applicable to the Falls Lake watershed specify that DO is to be no less than 4 mg/L at any time. In the Falls Lake watershed, dissolved oxygen concentrations tend to be lower in monitored locations with slow-moving or stagnant water, or large wetland complexes, including Beaverdam Creek, Robertson Creek, Unnamed Tributary, and Panther Creek. Of 186 total DO measurements, approximately 90 percent were above the standard and 10 percent fell below 4 mg/L, with all of those occurring at just eight of the monitored stations, as listed in Table 6.

Table 5. Stations with Dissolved Oxygen Observed below the NC State Standard

Subwatershed	Station ID	DO < 4 mg/L*
Beaverdam Creek	BDC-2.0(LL)	3/4 (75%)
Flat River	FLR-5.0(LL)	3/6 (50%)
Ledge Creek	LGE-5.1(LL)	1/4 (25%)
Little Lick Creek	LLC-1.8(LL)	2/5 (40%)
Little Ledge Creek	LLG-0.9(JB)	3/4 (75%)
Panther Creek	PAC-4.0(LL)	2/5 (40%)
Robertson Creek	ROB-2.8(LL)	2/4 (50%)
Unnamed	UNT-0.7(LL)	2/4 (50%)
	All Sites	**18/186 (10%)**

* Values shown are: Number of measured values below the standard / Total Number Measurements, and (Percent of measurements below the standard).

> A measure of acidity or alkalinity is pH, using a scale of 0 to 14, and pH can affect various metabolic functions of aquatic organisms, as well as biogeochemical processes and the chemical behavior of certain metals. Most water bodies have pH levels near the middle of the pH scale (7), and the North Carolina water quality standard applicable to the Falls Lake watershed requires that pH be between 6 and 9. Data collected from August to December 2014 showed 100 percent compliance with this standard. Stations in large wetland complexes on Beaverdam Creek, Robertson Creek, and Unnamed Tributary often had pH values lower than the other stations, but no pH measurements less than 6 were observed during this period.

4 Monitoring Program Revisions

An important component of the UNRBA Monitoring Program is the ability to adapt as new information is accumulated. Revisions to the plan could be a direct result of the data collected under this program or information learned from other organizations studying the lake and watershed. Any changes to the monitoring program must balance cost with the purpose and value of information gained or lost by the revision. Potential changes to routine monitoring may include adjustments in locations, parameters, or sampling frequency.

Because monitoring began in August 2014, and the currently available information spans a period of only five months, this Annual Report does not include recommendations for substantive changes to the UNRBA Monitoring Program. It is recommended that a minimum of 12 months of data be collected and analyzed before major programmatic changes to locations, parameters, or sampling frequencies are made. Even after 12 months of data are collected, programmatic revisions may be implemented conservatively, recognizing that a full range of hydrologic conditions may not have occurred. However, monitoring program revisions for FY 2016 may be recommended/made based on input from the PFC to address general monitoring objectives or to expand coverage within any specific component area of the monitoring program.

While programmatic revisions are not recommended at this time, there are some issues that Cardno continues to track, and which may lead to revisions in the future. Examples include:

- Changes to station locations (e.g., due to bridge construction)
- Altered monitoring protocols for stagnant wetland dominated sampling stations
- Issues associated with low dissolved oxygen and high chlorophyll a at stagnant locations that could misrepresent or bias larger-scale averages for the lake
- Parameters that are routinely at or below detection limit that could be eliminated or sampling frequency reduced to provide cost savings (e.g., 5-day carbonaceous biochemical oxygen demand)
- Parameters that are highly correlated where individual analyses may not be providing additional valuable information (e.g., collection of both dissolved and total organic carbon)
- Revisions to the QAPP to address quality assurance issues that may arise
- Inclusion of supplemental data collection within Falls Lake proper, to supplement DWR’s data collection for enhanced modeling accuracy
- Adjustment of monitoring frequency at stations that consistently show low variability (indicating less frequent sampling may be appropriate) or high variability (indicating more frequent sampling may be desirable).

5 List of References

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