Upper Neuse River Basin Association
Special Study Plan
Date Issued: November 24, 2015

Special Study Name, ID# and Origination:

Constriction Point Study, SS.LR.5

This Special Study was added to the Cardno FY 2016 monitoring contract to provide data on movement of water, nutrients, chlorophyll, and suspended sediment through certain constriction points (bridge crossings) that partially separate segments of the lake.

Responsible Contractor(s):

Cardno – responsible for study planning, general management and oversight, lake sampling, and data analysis.

Environment 1 – responsible for water quality laboratory analyses according to the UNRBA QAPP.

This Special Study supports the following objectives of the UNRBA Monitoring Program:

- Lake response modeling
- Support of regulatory options

Purpose of Study:

This study is designed to provide data on the movement of water quality constituents through Falls Lake associated with periods of higher flows through the lake. This effort is different from the routine lake monitoring in that it (a) focuses on periods of above-normal water movement through the lake, (b) measures not just *concentrations* of water quality parameters but also the *mass* of material moving through the lake via synoptic flow measurements, and (c) provides data on short-term variability in water quality which is not obtained through routine monthly sampling. This effort will provide data to enhance calibration and validation of the EFDC model which was not available for the existing 2005-2007 model years.

Water quality in Falls Lake is influenced by processes occurring over a variety of time scales (e.g., quickly changing sunlight, cloud cover, and wind velocity; weather patterns operating over hours or days; seasonal changes in temperature or precipitation; and changes in land use occurring over years to decades). The existing Falls Lake EFDC model operates on a very short time step in order to be able to capture quickly changing processes such as hydrodynamics and algal response to sunlight as well as the more slowly changing drivers such as seasonal temperature shifts. The short-term hydrodynamics and productivity processes in the model have important implications for model predictions. However, actual in-lake measurements representing these short time scales, which can be used to calibrate and validate the model, are currently lacking. Monthly water quality data (as collected by NCDWR) can be used for characterizing the overall condition of the lake, for assessment purposes, and as general calibration targets, but cannot generally be used directly to assess model performance across a range of hydrologic conditions such as those following a large storm event.

This study is designed to collect flow and water quality data over relatively short time periods (e.g., days versus weeks) as flow conditions through the lake are changing. The data can then be used in conjunction with monthly monitoring data in model calibration and validation to confirm that the model is accurately representing the long term trends (compared to monthly data) and the short term responses (compared to data collected up to daily during changing hydrologic conditions).

Sampling will occur at constriction points within the lake to maximize the efficiency of data collection. The earthen causeways associated with bridge crossings focus flow through relatively narrow conveyances where discharge and water quality can be more easily measured. These constriction points also contain the historic channel of the Neuse River, which is substantially deeper than the lake bottom on the adjacent sides of the channel.

In addition to simplifying the measurement of material fluxes, the partial separation of the lake into segments separated by bridge causeways controls the way materials such as nutrients, sediment, algae, and carbon move downstream from one basin to the next, and this can have important management and regulatory implications. During times of low flow, these constrictions limit the mixing between the lake segments. Data from this study will document how material moves from one segment of the lake to the next during different flow conditions and will allow the model to be calibrated to correctly account for these dynamics. Thus, this study may also inform the development of alternative regulatory options since it will better characterize the water quality relationships between the major segments of Falls Lake, including consideration of how they might be regulated independently of one another.

Summary of Study Methods:

Sampling Locations and Timing

Discharge and water quality data will be measured at selected constriction points. In fiscal year 2016 (FY2016), sampling will occur at the I-85 crossing and the Hwy 50 crossing. If time allows during the suitable sampling window, data will also be collected at the Fish Dam Road crossing which lies between I-85 and Hwy 50. These points were selected because the roadway causeways partition the lake into major segments: I-85 separates the uppermost segment (which receives water from over 65% of the Falls Lake drainage area) from the rest of the lake. Highway 50 is typically viewed as the boundary between the “upper lake” (shallower and wider) and the “lower lake” (deeper and more riverine). Other minor constrictions are present in the lake downstream of Highway 50 (e.g., New Light Road and Highway 98) but this study focuses on portions of the lake where the largest upstream to downstream variability in water quality has typically been observed.

Two sampling events are planned for FY2016 in an attempt to capture a broader set of conditions and to help ensure that the model is more robust and not calibrated to fit one event with a high degree of accuracy at the expense of misrepresenting conditions outside of that period. To maximize the benefit of this intensive data collection effort, sampling events will be conducted around times when flow through the constriction is expected to be high. Up to five data collection trips will be spaced across a number of days to characterize elevated water velocities and their decline toward normal flows.

Based on an analysis of rainfall data and modelled flows (derived from 2006 baseline model outputs) it was determined that rainfall ranging from 1 inches to 3 inches over 1 to 2 days will result in measureable current speeds through the constriction if water is also being released from the dam. A storm of this magnitude can result in elevated velocities for one to two weeks. The duration of such velocities depends on inflow rates from the tributaries and outflow rates from the dam. After large rain events, the USACE manages releases from the dam to maintain target lake levels as well as downstream flows. Cardno will monitor the lake levels, inflow rates, and outflow rates prior to initiating and throughout the sampling period to predict the likely duration of elevated flows, and adapt the sampling frequency accordingly.

Based on a review of historical reservoir data, the most likely time period for suitable sampling conditions will be late fall through spring. The first event is planned for late fall or winter. Data obtained during the first event can be used to refine the study design for the second event planned for Spring 2016.

Discharge Measurements

A SonTek RiverSurveryor M9 Acoustic Doppler Current Profiler (ADCP) will be used to measure water current and flow discharge across a transect at each constriction point. This unit will be used as a downward-looking ADCP which is towed across the water surface from shore to shore to obtain a complete three-dimensional profile of water velocities. Several passes across each transect are made to obtain an average discharge and an estimate of variability from measurement to measurement. Boat velocity and location along each transect (both necessary for calculating discharge) are tracked via two methods which provide some degree of redundancy: an integrated GPS and using ADCP bottom tracking. Bottom tracking does not work if the reservoir sediment bed is moving downstream due to elevated water velocity. Tests for these moving bed conditions will be completed prior to sampling using the USGS-preferred loop test method (Mueller and others, 2013). If moving bed conditions are present, GPS measurements will be used to calculate discharge instead of bottom tracking.

Water velocity measurements will be used to calculate discharge through the constriction points using the SonTek River Surveyor Live software according to manufacturer protocols. Because boat velocity is tracked both by bottom tracking methods and by GPS, these data are evaluated to determine the most reliable data set for use in calculating discharge following manufacturer and USGS guidance. Temperature profiles will be collected in conjunction with ADCP measurements to identify whether temperature correction of velocities is required prior to calculating discharge.

Water Quality

Sample locations. Grab samples will be collected at three locations across each constriction point conveyance area: (1) at 1 meter below the surface over the deepest portion of the historic river channel, (2) at 1 meter above the bottom at the deepest portion of the river channel, and (3) at 1 meter below the surface midway between the river channel and the shoreline (see Figure 1). These sampling locations were selected based on information obtained from a reconnaissance visit to the constriction at Highway 50 in August 2015. Samples collected during that visit showed very similar water quality at 1-meter depth (relative percent difference of less than 1%), but distinctly different quality near the bottom of the channel.

Parameters. The following parameters will be measured at each constriction point, coincident with the ADCP transects: total phosphorus, total Kjeldahl nitrogen, ammonia, nitrate plus nitrite, total organic carbon, total and volatile suspended solids, chlorophyll *a*, Secchi depth, and temperature profiles. Dissolved nutrient species will not be collected because of the time intensive procedures field required to process these samples. Analysis of the dissolved constituents based on the DWR ambient monitoring data indicates that these are a relatively small fraction of the total concentrations, and so the resources needed to acquire this data would not result in a proportional value of information. All water samples will be collected as discrete samples using a van Dorn sampler.

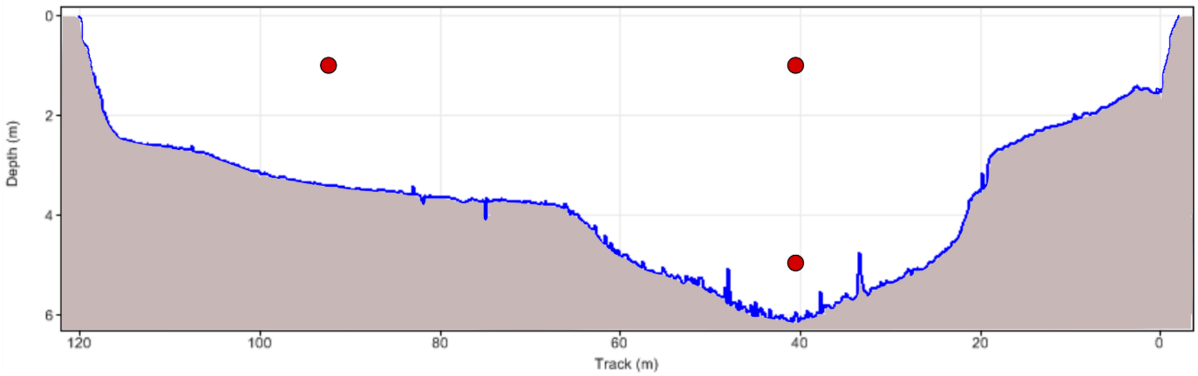

Figure 1. Bathymetry and water quality sampling locations for an example transect (across the Hwy 50 crossing). The blue line shows the water depth along the transect and the red circles are locations where water samples will be collected. Three-dimensional velocities will be measured over the entire transect to create a complete current profile of the lake cross-section. Note that the depth axis is exaggerated relative to the horizontal position.

Estimating the Movement of Material through the Constrictions

For each water quality parameter measured, estimates of the mass of material moving through the constriction (for example, grams of nitrogen per hour) will be developed for each transect and sampling day using the water quality results and velocity data collected. These estimates will be paired with uncertainty ranges which include the variability among repeated discharge measurements, the specified accuracy of the ADCP instrument, and the variability observed among the three water quality measurements and reasonable assumptions about gradients between the measured values.

Quality Assurance/Quality Control:

ADCP measurements and discharge calculations will be made following established manufacturer and USGS protocols (Mueller 2013) including proper compass calibration, moving bed loop tests, review of data as it is being collected for common sources of error such as loss of GPS signal, air entrainment under the sensor, and compass interference, and post-processing of data. Lake water quality data will be collected, preserved, handled, stored, analyzed and reviewed for quality control as specified in the UNRBA QAPP. Data will be analyzed to derive discharge estimates using the SonTek River Surveyor Live software following the procedures outlined in the manufacturer protocols. Estimates of the amount of material passing through the constrictions during a specific time (e.g., mass of nitrogen per hour) will be derived by multiplying the discharge measurements, water quality concentrations, and appropriate conversion factors; estimates of uncertainty will be included as part of this analysis.

Reporting/Deliverables:

Cardno will communicate with the UNRBA Executive Director on a regular basis on the progress of this Special Study. Status updates will be provided to the UNRBA Path Forward Committee and the Board of Directors at their regular meetings during Cardno's status updates on the overall Monitoring Program.

Information generated by this Special Study will largely be used to inform future modeling efforts. The results of this study will be provided in the FY 2016 Annual Report. In the event data collection, laboratory analysis and analytical review are not complete by the April deadline for the FY 2016 Annual Report, they will be provided in a supplemental technical memorandum or the FY2017 Interim Report.

The data collected under this Special Study will be provided electronically through the UNRBA online data portal.

References

Mueller, D.S., C.R. Wagner, M.S. Rehmel, K.A.Oberg, and F. Rainville. 2013. Measuring Discharge with Acoustic Doppler Current Profilers from a Moving Boat. Techniques and Methods 3-A22. Chapter 22 of Book 3, Section A. Version 2.0. in Techniques of Water-Resources Investigations of the U.S. Geological Survey.