Evaluation of the Sensitivity of the Falls Lake Nutrient Response Model

UNRBA Monitoring Program Development and Implementation

E213006400

Cardno ENTRIX

Shaping the Future

Executive Summary

The existing Falls Lake Nutrient Response model developed by the North Carolina Division of Water Resources (NCDWR) includes tributary inputs from 17 locations around Falls Lake. Cardno ENTRIX used the existing model to perform sensitivity analyses to determine the relative importance of each of the tributaries (i.e., is the model more sensitive to a particular lower lake tributary that would indicate that additional monitoring is needed in that area). It should be noted that the NCDWR model was used as calibrated and set up by the Division of Water Resources for the development of the Falls Lake requirements. The existing model was used as a tool to evaluate future monitoring needs for an updated model. This evaluation doesn't attempt to make adjustments to the existing model to improve its sensitivity or recalibrate the model. The model is being used for reference purposes to determine the most critical model inputs to guide future monitoring objectives.

The sensitivity analyses described in this TM were developed to identify whether any specific tributary, or tributaries, have a particularly strong influence on lake water quality. A key question of the monitoring program is where to focus monitoring resources, so determining if particular tributaries are more influential than others will help the UNRBA allocate limited monitoring resources. This sensitivity analysis was conducted assuming 50 percent increases in tributary nutrient loading for two reasons. First, past sensitivity analyses evaluated the influence of reductions in nutrient and chlorophyll inputs on Falls Lake Nutrient Response model water quality model predictions (Cardno ENTRIX 2013a, Framework for a Re-examination of Stage II of the Falls Nutrient Strategy). The results of these simulated reductions in nutrients and chlorophyll *a* are presented again in this TM. Second, some of the tributaries have very low nutrient loads relative to the upper lake tributaries in the current version of the model. Testing the sensitivity of the model to reduced nutrient loads from one of these tributaries would be difficult to detect because the effects of their loads are already overwhelmed by the loading from the larger tributaries. The impacts from large nutrient increases on overall lake water quality are easier to detect in the model output.

Additional model sensitivity analyses on in-lake modeling parameters were outside of the scope of work for this project. However, in preparation for planning of future special studies to address issues such as benthic nutrient flux rates, sediment inflow partitioning, and algal growth rates which influence model predictions, the Fiscal Year 2015 Monitoring Program scope of work will include resources to refine this need and will look at modeling sensitivity prior to moving forward with special studies. For now, Cardno ENTRIX has identified specific monitoring studies for incorporation into the monitoring plan that will provide, as appropriate, the collection of data needed to refine the model inputs of these parameters. These will be described in more detail in the draft Monitoring Optimization TM.

For the most part, the sensitivity analyses (using both the State's model and an empirical model developed by Cardno ENTRIX (2013a)) indicate that the lake is most responsive to changes in loading that occur from the five upper tributaries which drain the largest watershed areas, contribute the largest flow volumes, and receive discharges from the largest wastewater treatment plants in the basin. Based on the existing model, none of the tributaries in the middle or lower part of the watershed disproportionally impacted water quality in the vicinity of Highway 50 or the Raleigh water supply intake relative to any other tributary.

A separate set of analyses were conducted to determine how sensitive the Falls Lake Nutrient Response model (also referred to as Environmental Fluid Dynamics Code or EFDC model) was to the various methods available to generate daily tributary nutrient concentration input values for the model. The State's method for developing EFDC model inputs uses interpolation between grab samples. The USGS has developed a series of regression models that estimate loads by correlating observed water quality

concentrations with flow data. Cardno ENTRIX tested the sensitivity of the EFDC model to changes in input loading methods. These sensitivity analyses compare the baseline EFDC model inputs developed by NCDWR (using the linear interpolation method) to LOADEST inputs based on pairing water quality samples with either daily average flows or 15-minute flows, both of which are reported by USGS for the upper lake tributaries. While the LOADEST model performed better on Ellerbe Creek when 15-minute flows were used to develop the regressions, the LOADEST models developed for the other four upper lake tributaries were not very sensitive to the time increment of the flow measurements (Section 2).

The EFDC model was very sensitive to how the daily nutrient concentration and flow model inputs were calculated, particularly in the Ellerbe Creek arm of the lake (Section 3.4). The different LOADEST models and variations in flow estimation totals produce very different nutrient loading patterns to the lake, which have a strong effect on simulated lake water quality. These analyses indicate that when the UNRBA begins to revise the State's EFDC model based on the collection of new monitoring data, that the choice of tributary nutrient input estimation method will have a strong effect on the model's response. Targeted storm event monitoring with post storm event monitoring for 2 to 3 days afterward can be used to provide the data needed to determine which method most accurately estimates actual loading. This monitoring would need to be conducted during the UNRBA monitoring program period and prior to the time that the Falls Lake Nutrient Response model revisions are initiated.

In addition to these sensitivity analyses, Cardno ENTRIX (2013c) previously evaluated the EFDC model sensitivity to tributary chlorophyll *a* concentrations. The results of those analyses were presented in the Task 4 TM (from 2012 UNRBA project, Support of Long Term Planning and Regulatory Nutrient Activities in the Falls Lake Watershed, TM4 located at http://unrba.org/sites/default/files/Task4TM_FINALJune18.pdf), and are repeated in this TM (Section 3.1) to present all of the existing model sensitivity analyses in one document. On the basis of this previous work the concentration level tributary inputs of chlorophyll *a* to Falls Lake likely affect the sensitivity of the model to changes in nutrient loads. During some times of the year, the model appears to be more sensitive to this assumption for tributary chlorophyll *a* inputs than to the methodology used to determine the flow and nutrient input relationships (Section 3.4). The monitoring program is being designed to collect chlorophyll *a* samples within the tributaries so that actual data can replace the use of assumed chlorophyll *a* concentrations.

Overall, the EFDC model water quality predictions make sense in general terms; chlorophyll *a* and nutrient concentrations within the lake increase along with increased nutrient inputs from the tributaries. Decreases in chlorophyll *a* and nutrient loading from the tributaries produce reductions in predicted chlorophyll a and nutrient concentrations throughout the lake. Also, the tributaries with the largest flows and wastewater treatment plants influence lake nutrient concentrations more than tributaries that contribute lower volumes of flow. Although the model predictions make sense, the model is not as responsive to changes in inputs as experience would lead us to expect. This may be due in part to the model's calibration that was based on chlorophyll *a* inputs from the tributaries that reflected values found in the tributary's arm instead of from the free-flowing section. The relatively small lake response to changes in nutrient inputs may have influenced the setting of the Stage II nutrient reduction targets. Therefore, therefore the accurate measurement of tributary input levels are values, particularly for chlorophyll *a,* is a high priority for the monitoring program.

General conclusions related to future UNRBA actions that result from this TM include:

> The UNRBA monitoring program should include collection of chlorophyll *a* data within the tributaries to allow future model inputs to reflect actual tributary conditions.

> Since the tributaries with the largest flows have the most influence on lake water quality, it is important that the loading from these tributaries be estimated as accurately as possible.

> We recommend that the UNRBA monitoring program includes regular water quality monitoring at tributary loading stations from the largest 5 tributaries and supports at least one USGS flow gage on

each of these tributaries. Monitoring should also occur at the mouths of the other smaller tributaries in the middle and lower lake, but this monitoring could occur less frequently.

> Water quality monitoring stations will also be established at jurisdictional boundaries.

> Monitoring frequency at all water quality monitoring locations will be determined using statistical assessments to identify the number of samples needed to characterize water quality with an agreed upon level of certainty. The appropriate level of certainty will be discussed with the UNRBA and described in the Water Quality Estimation Technical Memorandum (TM).

> Flow estimation models, described in the Flow Estimation TM will be used to estimate flows at most jurisdictional boundaries. Appropriate monitoring in the watersheds that reflect jurisdictional loading will also be undertaken in the final monitoring plan. However, for this TM monitoring recommendations relate to direct inputs to the lake response modeling.

> Cardno ENTRIX has proposed that the UNRBA use the USGS LOADEST program to generate daily nutrient concentrations for running the EFDC model.

> The USGS LOADEST model can be used to generate loadings at most tributary loading locations using a daily flow estimate paired with monthly water quality sampling. Daily loading estimates for some tributaries, particularly Ellerbe Creek and possibly Knap of Reeds Creek may be generated by pairing water quality measurements with 15-minute or hourly flow data.

> The UNRBA should request that the NCDWR provide the source code associated with the existing Falls Lake Nutrient Response model. Once this code is obtained the model file size limitations can be modified so that the model can be run on a less than daily timestep for a sufficient amount of time to predict annual or growing season conditions within Falls Lake.