Addendum to B. Everett Jordan Reservoir TMDL for High pH and Turbidity Impairments

March 6, 2014
EPA APPROVAL ON: April 3, 2014

[Waterbody IDs: High pH and Turbidity: 16-(37.3), 16-(37.5)a, 16-(37.5)b, 16-41-2-(9.5)
Turbidity: 16-41-1-(14)]

Cape Fear River Basin

Submitted by:
NC Department of Environment and Natural Resources
Division of Water Resources (DWR)
1611 Mail Service Center
Raleigh NC 27699-1611

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Introduction

The North Carolina Division of Water Quality (DWQ, now Division of Water Resources) developed a Total Daily Maximum Load (TMDL) for the B. Everett Jordan Reservoir (Jordan Lake) to address chlorophyll-*a* impairments. EPA Region 4 approved the TMDL on September 20, 2007 (DWQ, 2007). Nutrient controls are the most common focus of management schemes for reducing excessive algal growth and chlorophyll-*a* concentrations. Therefore, the Jordan Lake TMDL was written to address total nitrogen (TN) and total phosphorus (TP) loads to the lake.

Jordan Lake is also listed for high pH and turbidity impairments in the 2002 303(d) list. This addendum to the original TMDL addresses high pH and turbidity impairments within Jordan Lake. The impaired waters and associated assessment units (AUs) are listed below:

Impairments	Area	AU
pH	Haw River*	16-(37.3), 16-(37.5)a, 16-(37.5)b
	Morgan Creek**	16-41-2-(9.5)
Turbidity	Haw River*	16-(37.3), 16-(37.5)a, 16-(37.5)b
	Morgan Creek**	16-41-2-(9.5)
	New Hope Creek***	16-41-1-(14)

*include Jordan Lake below normal pool elevation; **include Morgan Creek Arm of Jordan Lake; ***includes New Hope River Arm of Jordan Lake.

Impairment Description

Haw River arm and Morgan Creek arm of Jordan Lake are on the 2012 303(d) list for both high pH and turbidity. The New Hope Creek Arm is listed for turbidity impairment. Figure 1 shows the locations of the sampling stations and high pH and turbidity impairments.

The three parts of Jordan Lake that are listed in Category 5 - 303(d) list for high pH and turbidity impairments are also impaired for chlorophyll-*a* but are in Category 4t due to the Jordan Lake TMDL described above.

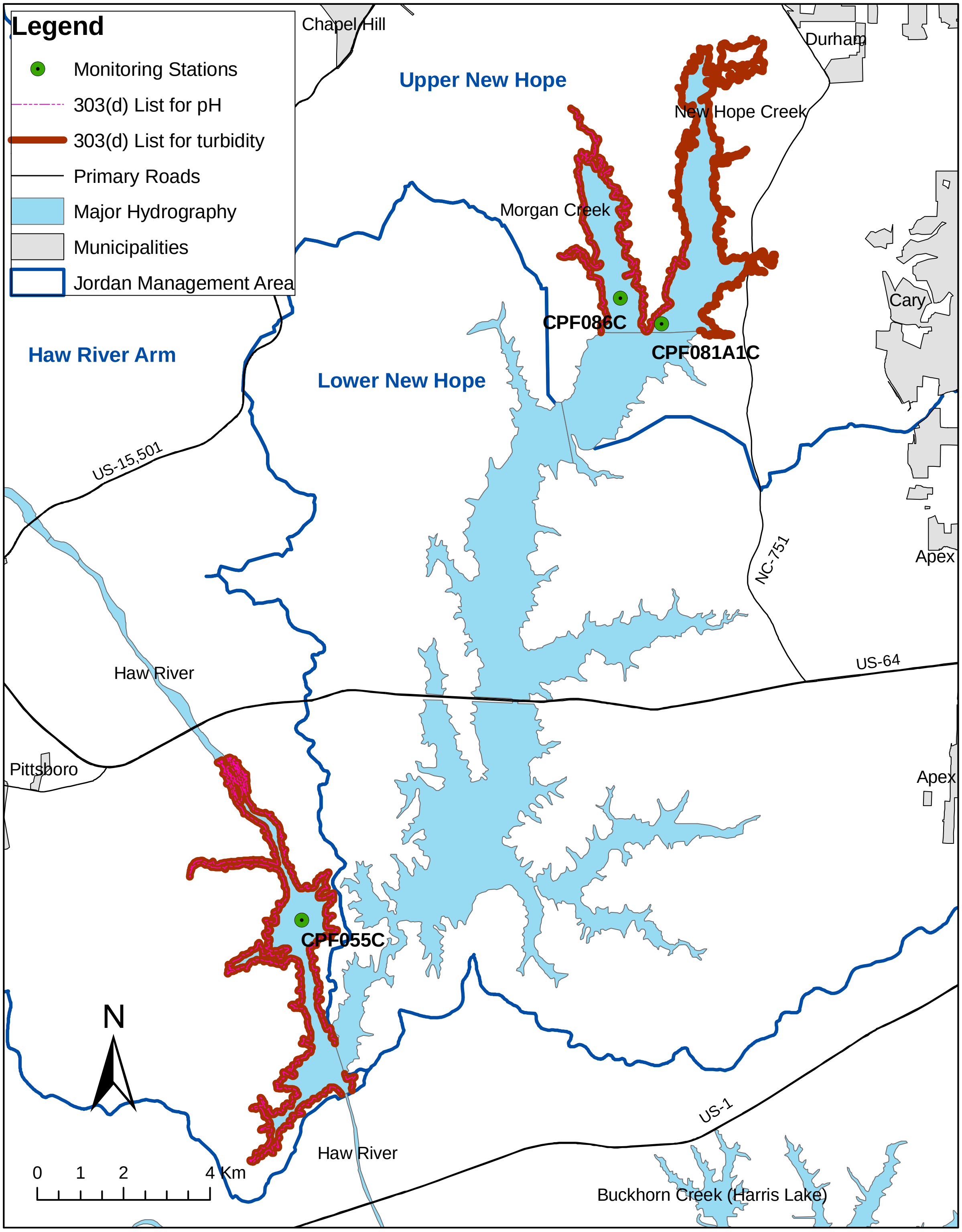

Figure 1. Locations of monitoring stations and impaired segments for high pH and turbidity in Jordan Lake.

Water Quality Target

The North Carolina fresh water quality criteria for pH and turbidity in Class C waters state the following:

pH: shall be normal for the waters in the area, which generally shall range between 6.0 and 9.0 except that swamp waters may have a pH as low as 4.3 if it is the result of natural conditions;

Turbidity: the turbidity in the receiving water shall not exceed 50 Nephelometric Turbidity Units (NTU) in streams not designated as trout waters and 10 NTU in streams, lakes or reservoirs designated as trout waters; for lakes and reservoirs not designated as trout waters, the turbidity shall not exceed 25 NTU; if turbidity exceeds these levels due to natural background conditions, the existing turbidity level shall not be increased.

Monitoring Data

Jordan Lake has been monitored extensively since it was impounded in 1982. A detailed description of data available is included in Tetra Tech (2001), which is available online. For this study, depth profiles of pH and photic zone data of turbidity and chlorophyll *a* were obtained at the three stations shown in Figure 1. The data used are from 1990 through August 2013, which covers the baseline period of 1997 to 2001 in the original Jordan Lake TMDL. Each station was generally sampled on the same day, Figure 2 shows the sampling frequency.

In Jordan Lake, pH and other physical parameters were measured at the surface (0.1 m below surface), at every meter below the surface and near the bottom of each station. In order to investigate relationships between pH and other water quality parameters (e.g. chlorophyll *a*) which were collected as photic-zone composite samples, mean photic-zone pH values were calculated in this study as the average of measurements between the surface and two times the Secchi depth.

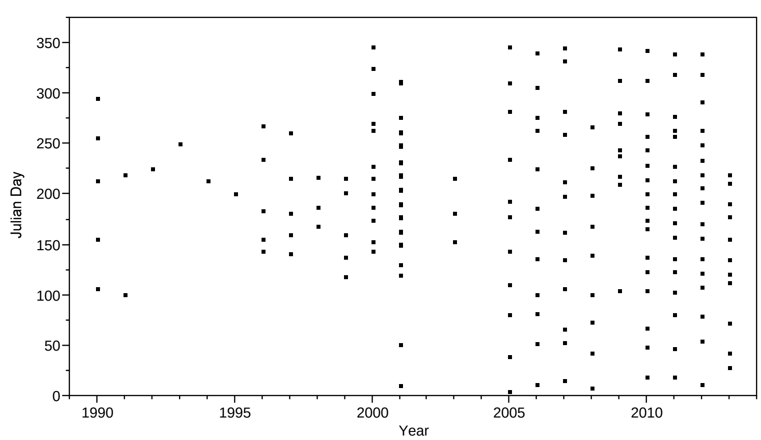

Figure 2. Sampling date distribution.

pH – nutrient relationship

pH is a measure of the hydrogen ion activity in a solution. In natural water systems, pH tends to remain within a narrow band of "neutral" conditions due to the buffering capabilities of inorganic carbon species. The inorganic carbon buffering system is influenced greatly by a number of heterogeneous reactions including atmospheric exchange of carbon dioxide, dissolution/precipitation of carbonate minerals such as calcium carbonate, and photosynthesis / respiration (Chapra, 1997). pH values vary as a result of all the above processes.

Depth profiles of pH are presented in Figures 3-5, together with water temperature (Temp) and dissolved oxygen (DO) for different seasons. Results from station CPF081A1C are presented here as a reference since New Hope Creek is not impaired for pH. Similar to Temp and DO, pH tends to be higher at the surface and lower near the bottom of the water column. Vertical stratifications appear to be more significant during summer for all the three variables. Figure 6 suggests that photic-zone pH normally peaks during May to August at station CPF055C and during July to October at stations CPF081A1C and CPF086C. Similar seasonal patterns were also observed for chlorophyll *a* concentrations.

Correlation coefficients between pH, temperature and DO are presented in Table 1. The restricted maximum likelihood method in JMP was used to calculate the values. As temperature rises, pH and DO normally decrease in pure water. These relationships often show up in Jordan Lake (indicated by the negative correlations) during cold seasons when biological activities are low. However, biological activities occurring in lake surface waters may drive such relationship into opposite direction. For example, higher water temperature promotes algal growth, which produces more DO and consumes carbon dioxide and in turn increases pH during the day. In addition, as temperature rises, the solubility of carbon dioxide is reduced, likely leading to higher pH. When such processes dominate, positive correlations show up between water temperature and pH and also between temperature and DO. The stronger positive correlations between pH and temperature during warmer seasons indicate that highly elevated pH is most likely resulted from biological activities such as excess algal growth.

Table 1. Correlations between pH, water temperature and DO.

		pH vs. Temp	pH vs. DO	DO vs. Temp
CPF055C	Spring	0.6010	0.3269	-0.0723
	Summer	0.6518	0.7609	0.4870
	Fall	0.1878	0.6184	-0.4242
	Winter	-0.0321	0.1370	-0.5798
CPF081A1C	Spring	0.0389	0.4407	-0.4901
	Summer	0.5096	0.4734	0.0640
	Fall	-0.0797	0.7169	-0.5237
	Winter	0.0983	0.5810	-0.3241
CPF086C	Spring	-0.0056	0.5311	-0.3977
	Summer	0.4914	0.5766	0.0891
	Fall	-0.1446	0.6544	-0.5875
	Winter	0.1128	0.4538	-0.4092

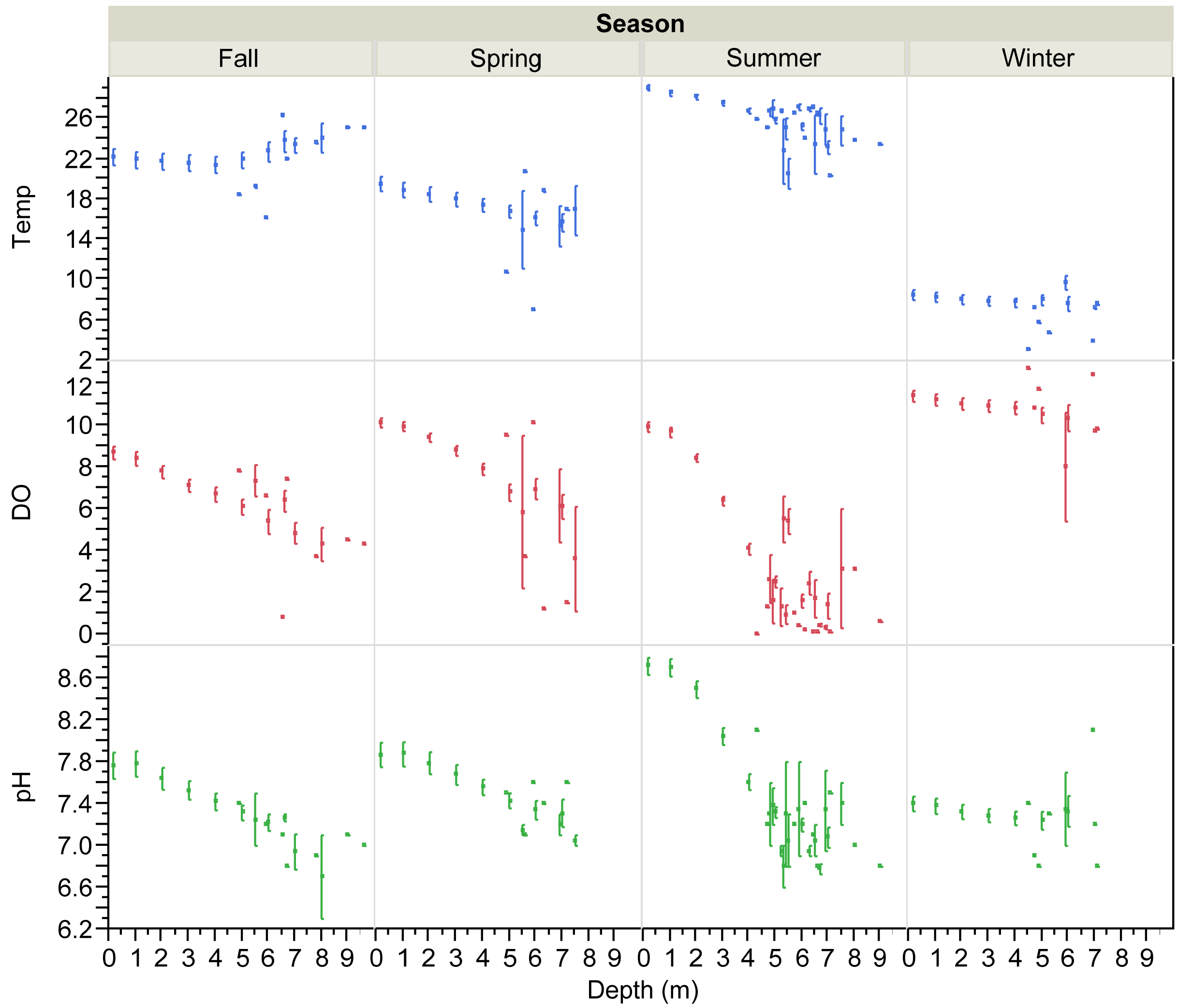

Figure 3. Mean water temperature (Temp) (in °C), DO (in mg/l) and pH at different depth of the water column at CPF055C. Error bars indicate one Standard Error from the mean.

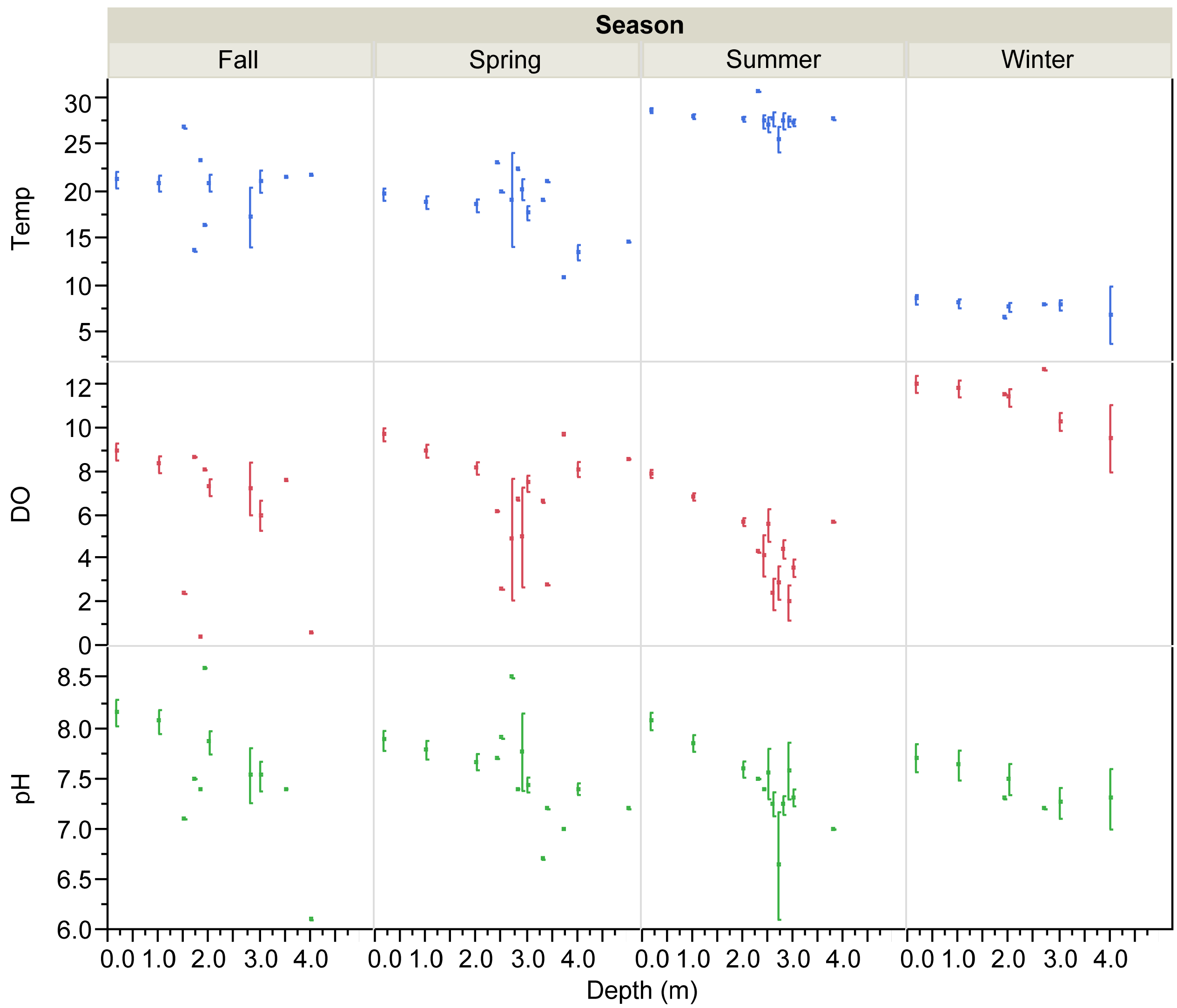

Figure 4. Mean water temperature (Temp) (in °C), DO (in mg/l) and pH at different depth of the water column at CPF081A1C. Error bars indicate one Standard Error from the mean.

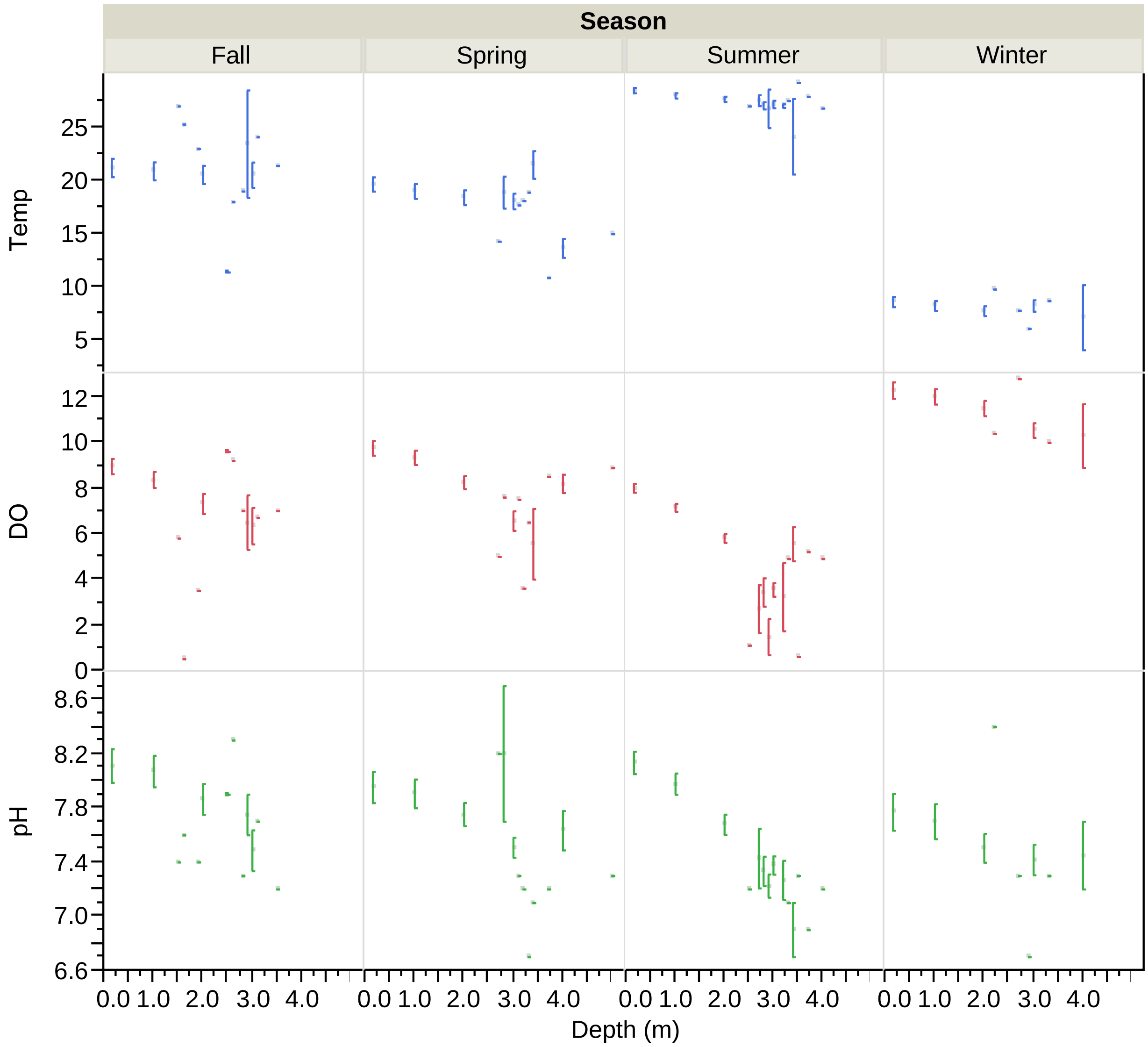

Figure 5. Mean water temperature (Temp) (in °C), DO (in mg/l) and pH at different depth of the water column at CPF086C. Error bars indicate one Standard Error from the mean.

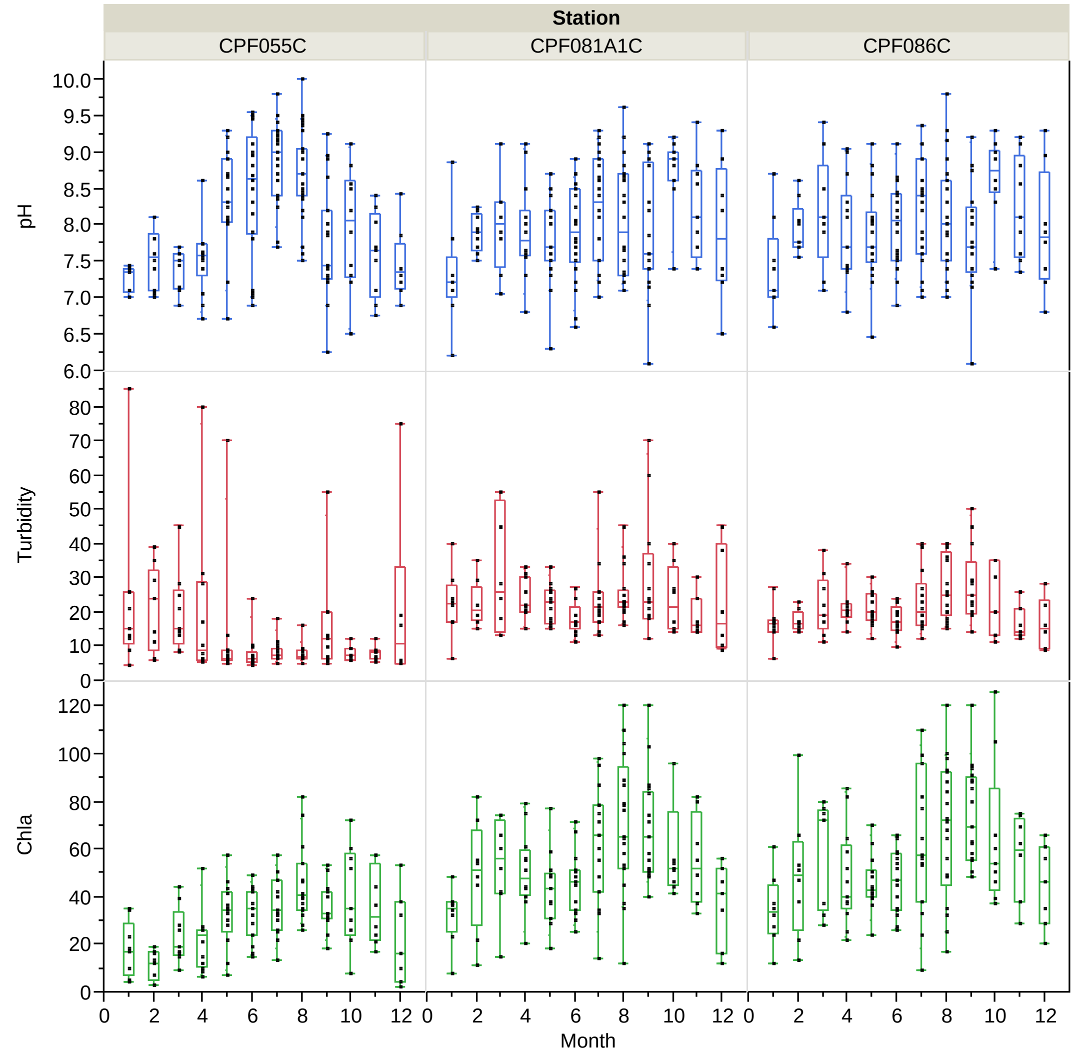

Figure 6. Quantile plot of photic-zone pH, turbidity (NTU) and chlorophyll *a* concentrations (µg/l) at different months.

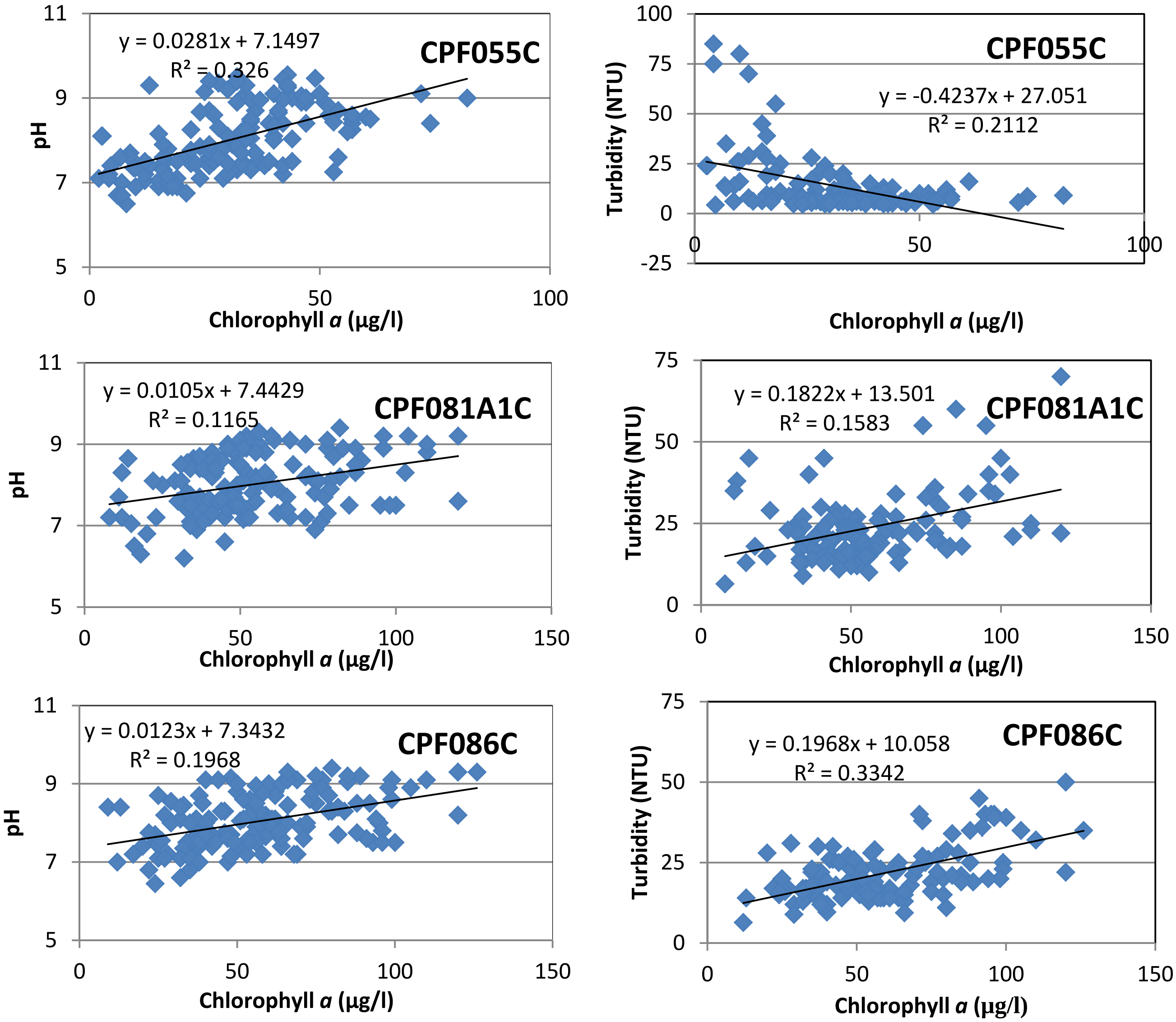

Figure 7. Scatter plots of pH vs. chlorophyll a concentrations and turbidity vs. chlorophyll a concentrations at the three Jordan Lake stations.

Chlorophyll *a* has long been used as an index of the productivity and trophic condition of surface waters. (Steele, 1962). High concentrations of chlorophyll *a* indicate algal blooms that respond to excessive nutrient inputs. Algal blooms have dramatic effects on water chemistry, including pH. When algae remove carbon dioxide during photosynthesis they raise the pH by increasing the level of hydroxide. The opposite reaction occurs during respiration when carbon dioxide is produced, lowering hydroxide and lowering the pH. Therefore, high pH is often associated with high chlorophyll *a* concentrations. This can be seen in Figure 7.

Turbidity – nutrient relationship

Turbidity in water is a measure of how cloudy or murky the water is. It is normally caused by particles suspended or dissolved in water that scatter light and hence make the water appear cloudy or murky. Particulate matter can include sediment, fine organic and inorganic matter, soluble colored organic compounds, algae, and other microscopic organisms. The sources of turbidity in lakes could be in-situ production (e.g., algae or bank erosion) or runoff from the watershed.

Turbidity data at the three stations in Jordan Lake are available starting from June 2003. Seasonal patterns of turbidity are not very clear (Figure 6); however, turbidity and chlorophyll *a* are linearly correlated at stations CPF081A1C and CPF086C (Figure 7), suggesting algae contribution to turbidity at the Morgan Creek and Upper New Hope arms of the lake. Such positive correlation does not exist at station CPF055C. By contrast, at station CPF055C, turbidity appears to be driven by flow from its drainage basin. In addition, at all the three stations, turbidity is closely correlated with total phosphorus concentrations (Figure 8).

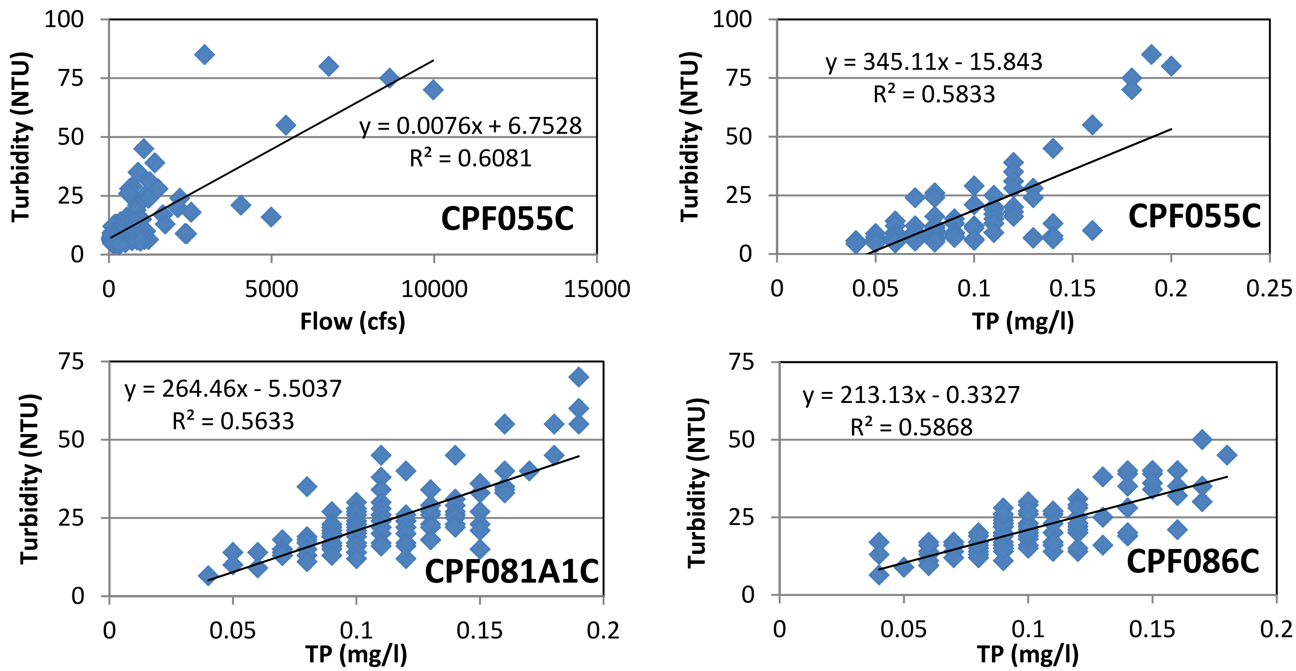

Figure 8. Turbidity vs. flow and total phosphorus (TP) in Jordan Lake.

Jordan Lake TMDL and Nutrient Management Strategy

The Jordan Lake TMDL assigned separate loading reduction targets to the major arms of the reservoir for both total nitrogen and total phosphorus. Nutrient load reductions targets from 1997-2001 baseline loading are shown in Figure 9 for each arm.

In addition to the TMDL, North Carolina adopted mandatory Jordan Lake Rules in 2009 to reduce the amount of nutrient pollution entering Jordan Lake. Full text of the rules can be found at www.jordanlake.org. The rules require:

- Stormwater management programs for new and existing development.
- Protection of existing vegetated riparian buffers.
- Reductions of nutrient loading from point source discharges.
- Reductions of nutrient runoff from agriculture.
- Sound fertilizer management.

The required watershed reductions specified in the Jordan Lake TMDL are expected to reduce nutrient loading as well as sediment runoff to the lake. As a result, the chlorophyll *a* standard in the lake is expected to be met after full implementation. Due to close relationships between pH and chlorophyll *a* at all three stations in Jordan Lake, the pH standard is expected to be met as well. High turbidity in the Morgan Creek and Upper New Hope arms of the lake is at least partially caused by in-situ algal growth. High turbidity in the lower portion of Jordan Lake below the conjunction of Haw River is closely associated with runoff and phosphorus. As sediment and phosphorus runoff, and in-situ algal growth are reduced, the turbidity standard in Jordan Lake is expected to be met.

Regular monitoring will continue throughout implementation to ensure that standards are attained. DWR may reevaluate the need for individual TMDLs for pH and/or turbidity in Jordan Lake if the required reductions are determined to be insufficient.

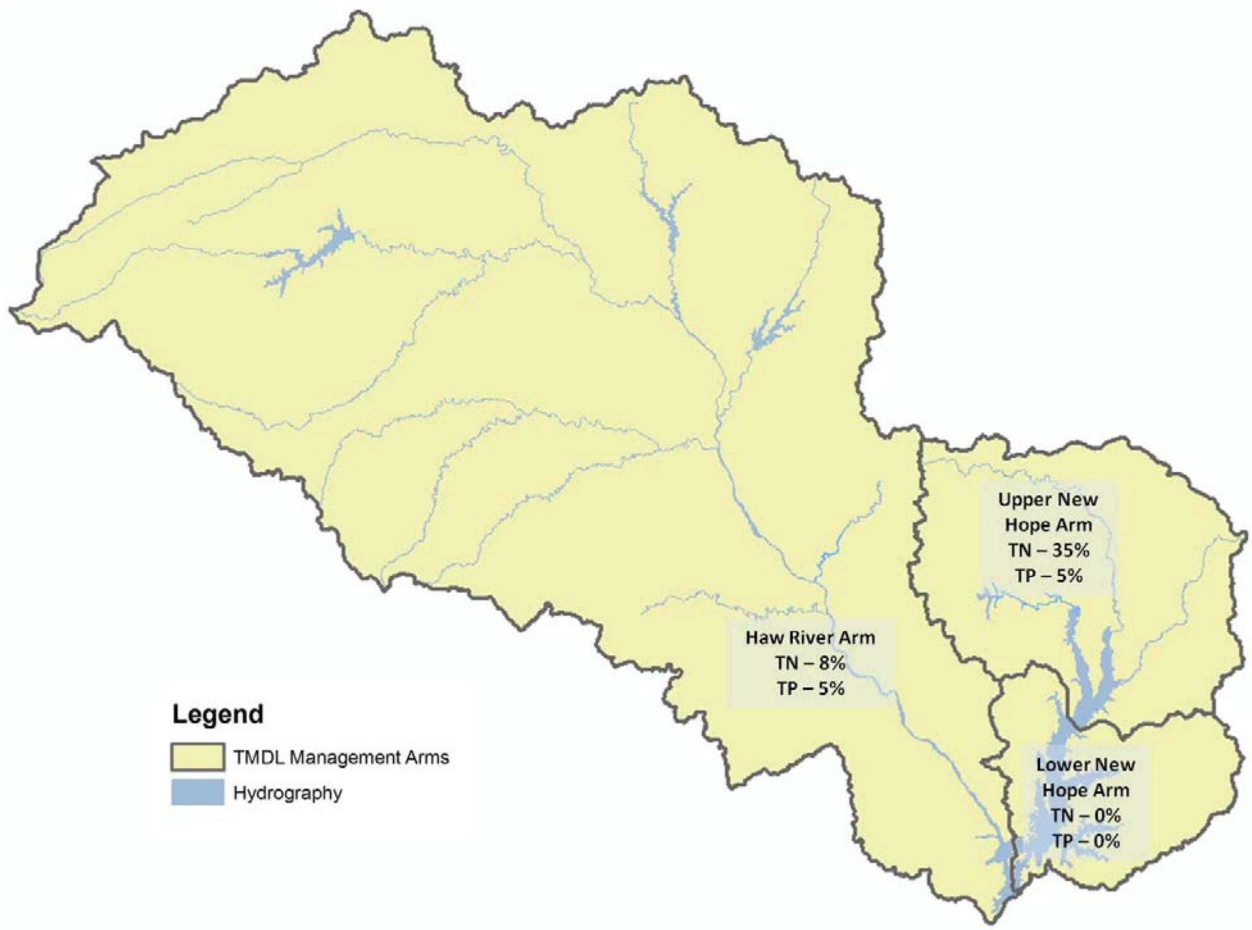

Figure 9. Nutrient load percent reduction targets from 1997-2001 baseline. Note that there is no loading reduction target for the Lower New Hope Arm; the TMDL provides a loading cap equal to 1997-2001 baseline nutrient loads. There is no 303(d) listing for high pH and turbidity for the Lower New Hope Arm.

Public Participation

DWQ staff, the Triangle J Council of Governments, and the Piedmont Triad Council of Governments initialized an extensive stakeholder process in 2003 to receive stakeholder input on the Jordan Lake nutrient reduction strategy. A total of 21 stakeholder meetings were held between May 2003 and December 2004 to discuss TMDL development, modeling issues, target setting, and nutrient management strategy development.

The Jordan Lake TMDL was public noticed in the relevant counties on April 1, 2007 in four local newspapers (the Durham Herald-Sun, the Winston-Salem Journal, the Greensboro News & Record, and the Raleigh News & Observer). The TMDL was also public noticed through the North Carolina Water Resources Research Institute email list serve. Finally, the TMDL was available on DWQ's website during the comment period.

A draft of this addendum to the Jordan Lake TMDL was publicly noticed through various means, including electronic notification of the draft addendum to known interested parties. The addendum to the Jordan Lake TMDL was available on the DWR's website at http://portal.ncdenr.org/web/wq/ps/mtu/tmdl/tmdls during the comment period. The public comment period lasted from January 16 through February 17, 2014. Copies of the public notices are included in Appendix A.

DWR received three sets of public comments on the addendum to the Jordan Lake TMDL. Summaries of the comments and DWR responses are included in Appendix B.

Reference

Chapra, S.C., 1997, Surface Water Quality Modeling, McGraw-Hill Companies Inc., 844p.

Steele, J.H., 1962, Environmental control of photosynthesis in the sea. Limnol. Oceanog., 7: 137-150.

Tetra Tech, 2001, Jordan Lake Nutrient Response Modeling Project: Existing Data Memorandum http://portal.ncdenr.org/c/document_library/get_file?uuid=1130e42e-b843-4455-bf96-4acf79153420&groupId=38364

DWQ, 2007, B. Everett Jordan Reservoir, North Carolina Phase I Total Maximum Daily Load, NC Department of Environment and Natural Resources, Division of Water Quality http://portal.ncdenr.org/c/document_library/get_file?uuid=bc043b19-0787-466f-aa7b-779717e55201&groupId=38364

Appendix A. Public Notice of Addendum to Jordan TMDL to Address High pH and Turbidity

The TMDL public comment period was announced on both the NC DWR Modeling and Assessment Branch's website and the Water Resources Research Institute of the University of North Carolina (WRRI) email listserv on January 16, 2014.

- Notice on the Modeling and Assessment Branch's Website: http://portal.ncdenr.org/web/wq/ps/mtu

1/16/14 The Draft Addendum to the Jordan Lake TMDL for High pH and Turbidity Impairment is available for public comment. Comment submittal instructions are available with the above link.

- WRRI listserv email received regarding public comment period:

From: Lin, Jing
Sent: Thursday, January 16, 2014 12:12 PM
To: 'wrri-news@lists.ncsu.edu'
Subject: DRAFT Addendum to B. Everett Jordan Reservoir TMDL to Address High pH and Turbidity Impairments Now Available for Public Comment

North Carolina Department of Environment and Natural Resources
Division of Water Resources

January 16, 2014

Now Available for Public Comment

DRAFT Addendum to B. Everett Jordan Reservoir TMDL to Address High pH and Turbidity Impairments

The Addendum proposes that pH and turbidity standards are expected to be met within Jordan Lake as a result of full implementation of the existing required nutrient load reductions specified in the original Jordan Lake TMDL. No additional load reductions or other requirements are proposed.

The Addendum document can be found at http://portal.ncdenr.org/c/document_library/get_file?uuid=b3089f81-40a2-4031-b7e4-0fbef93f8406&groupId=38364. The draft Addendum was developed to meet requirements of Section 303(d) of the Federal Water Pollution Control Act. It is subject to approval by EPA.

Interested parties are invited to comment on the draft Addendum by February 17th, 2014. Comments should be directed to Jing Lin at Jing.Lin@ncdenr.gov.

The document may be modified based on the comments received. Comments and responses on the Addendum will be included in the TMDL package to be submitted to EPA.

Jing Lin
Modeling and Assessment Branch
NC DWR-Water Planning
Email: Jing.lin@ncdenr.gov
Phone: 919-807-6410

Appendix B. Public Comments Responsiveness Summary

The public comment period extended from January 16 through February 17, 2014. Comments were received from six organizations jointly (American Rivers, Cape Fear River Watch, Haw River Assembly, NC Conservation Network, Southern Environmental Law Center, WakeUp Wake County), NC Department of Transportation, and the City of Durham. These comments with the NC Division of Water Resources' responses are provided below.

1) One comment expressed support for this Addendum to address pH and turbidity impairment in Jordan Lake.

   Response: DWR appreciates the stated support.

2) One comment expressed concern about using total nitrogen and total phosphorus as surrogates for pH and turbidity impairments in Jordan Lake.

   Response: Although the Jordan Lake TMDL and Rules were not designed to achieve pH or turbidity compliance in the Lake, the required watershed reductions specified in the Jordan Lake TMDL are expected to reduce nutrient loading as well as sediment runoff to the lake. As a result, the chlorophyll a standard in the lake is expected to be met after full implementation. Due to close relationships between pH and chlorophyll a at all three stations in Jordan Lake, the pH standard is expected to be met as well. High turbidity in the Morgan Creek and Upper New Hope arms of the lake is at least partially caused by in-situ algal growth. High turbidity in the lower portion of Jordan Lake below the conjunction of Haw River is closely associated with runoff and phosphorus. As sediment and phosphorus runoff, and in-situ algal growth are reduced, the turbidity standard in Jordan Lake is expected to be met.

3) One comment mentioned that some AUs covered in this Addendum are not listed under Category 5 in the draft 2014 NC Water Quality Assessment suggesting improving water quality and that pH and turbidity are parameters which are not well suited for direct load calculations, and thus the TMDL management approach. Has the Division considered a Category 4b approach for these two parameters?

   Response: The draft 2014 NC 303(d) list is subject to EPA approval. TMDLs are developed for waters on the most current approved 303(d) list, i.e., 2012. Category 4b would be more appropriate for waters without an existing approved TMDL.

4) Two comments asked for more information about the data used for the analysis.

   Response: Figure 2 and additional text were added to the Addendum to explain the time period and frequency of data collection that was used in the analysis (p.5, under section Monitoring Data). Some text was also reorganized to avoid confusion about the calculation of photic-zone pH.

5) One comment asked to include a significance test for Figures 6 and 7 and a regression equation added to the turbidity vs. chlorophyll *a* graph for station CPF055C in Figure 6.

   Response: The intent of this analysis was to explore the relationships between the variables and was not designed to conduct statistical significance test. However, we conducted Analysis of Variance in response to the comment and found that all linear relations presented in Figures 6 and 7 are strongly statistically significant. In addition, a regression equation was added to the graph as recommended by the comment.

6) One comment recommended that "the amended TMDL must explicitly acknowledge the point source character of MS4 stormwater."

   Response: As stated in the original Jordan Lake TMDL, "No attempt was made to separate permitted (WLA-SW) and nonpermitted (LA) loading associated with nonpoint sources. EPA requires that loads allocated to NPDES permitted stormwater be placed in the wasteload allocation, which had previously been reserved for continuous point source loads (EPA 2002). Since the WLA allocation associated with NPDES permitted stormwater was not separated in a formal manner, the percent reduction associated with the management area (i.e. Upper New Hope Arm, Lower New Hope Arm, and Haw River Arm) will apply. According to the Phase II rules, MS4 permittees are responsible for reducing the loads associated with stormwater outfalls for which it owns or otherwise has responsible control." (p.49). The point source nature of MS4 stormwater was recognized in the original TMDL, although formal separation (from non-permitted stormwater) in loading was not quantified.

7) One comment recommended that "the addendum must acknowledge the need to implement load reductions upstream" and that "in light of the state's failure to curb the ongoing growth of loading into the lake, and the prospect of substantive revisions during the process of rules readoption, the Jordan rules cannot be said by themselves to provide reasonable assurance that TMDL reductions will be achieved. The addendum should assert that the load reductions required by the TMDL will at a minimum be realized for point sources through their NPDES permits."

   Response: TP limits added to the large dischargers' permits went into effect in 2010. At least eight out of fourteen large dischargers (>0.1 MGD, collectively accounting for 99.4% of the total permitted flow) in Jordan watershed have either upgraded or plan to upgrade their treatment systems. We anticipate that the wasteload reductions required by the TMDL will be realized for point sources through their NPDES permits.

8) One comment suggested to "include a statement describing the impaired uses that have resulted in a Category 5 listings for pH and turbidity."

   Response: As stated in the original Jordan Lake TMDL (p.7) "Surface water classifications are designations applied to surface water bodies that define the best uses to be protected within these waters (e.g., swimming, fishing, and drinking water supply) and carry with them an associated set of water quality standards to protect those uses. The New Hope Creek Arm of Jordan Reservoir is classified as a WS-IV B NSW CA. The Haw River Arm of Jordan Reservoir is *classified as WS-IV NSW CA. Combined, the waters of the reservoir are protected for water supply, primary and secondary recreation, fishing, wildlife, fish and aquatic life propagation and survival, agriculture and other uses suitable for Class C. Jordan Reservoir was designated as a Nutrient Sensitive Water (NSW) in 1983." The best uses for Jordan Lake were not repeated in this Addendum. The corresponding water quality criteria for pH and turbidity were included in this Addendum in page 5.*

9) One comment suggested that New Hope Creek is not impaired for pH and analyses using CPF081A1C should be removed from the section titled "pH – nutrient relationship".

   Response: A statement was added to the Addendum (p.5) that results from station CPF081A1C was presented as a reference since New Hope Creek is not impaired for pH.

10) One comment suggested that the "turbidity – nutrient relationship" sections should be revisited to include quantitative support of the relationship and discussion on sediment sources of turbidity.

    Response: The multiple sources of turbidity were discussed in the 1st paragraph under Section Turbidity – Nutrient Relationship. Sediment as a source of turbidity was acknowledged. However, this Addendum is not intended to forecast turbidity as a function of algae and/or sediment, rather to show that the original Jordan TMDL and the associated management strategy, which will reduce algae production in the lake and sediment loading to the lake, would also reduce turbidity and result in turbidity meeting criteria in the lake. The Addendum also states that "Regular monitoring will continue throughout implementation to ensure that standards are attained. DWR may reevaluate the need for individual TMDLs for pH and/or turbidity in Jordan Lake if the required reductions are determined to be insufficient."

11) One comment recommended to include a discussion of other turbidity impairments upstream of the lake segments. It states: "Third Fork Creek and Northeast Creek are currently in the 303(d) List for turbidity; a TMDL exists for Third Fork Creek. These creeks are major tributaries to the Upper New Hope Arm of Jordan Lake. The City of Durham has recently completed extensive work on a Northeast Creek water quality model, which indicated that in-stream erosion was a significant contributor to sediment and turbidity in Northeast Creek. It is unclear how management of sediment and turbidity in Northeast Creek is related to this TMDL for Jordan Lake."

    Response: The Addendum is not intended to address impairment in tributaries. We appreciate the work that Durham has done to provide more information on turbidity in Northeast Creek.

12) One comment suggested that the turbidity-chlorophyll a relationship be evaluated by season. The comment questioned the increase of turbidity in the winter.

    Response: High turbidity in winter months was noted at station CPF055C, as suggested by the comment that "it is related to in-stream erosion related to higher seasonal stream flow." This relationship was recognized in the Addendum (e.g. Figure 8 turbidity vs. flow at CPF055C). In *addition, turbidity data were available only after June 2003 (p. 12). Separating the analysis into four seasons would much reduce the sample size and affect the quality of the analysis.*

13) One comment suggested that the Jordan Lake TMDL and Nutrient Management Strategy section should accurately reflect the implementation of the strategy. The third sentence in the first paragraph states that the same percent reduction was applied to “all sources” throughout the watershed, which is incorrect.

Response: The statement was removed from the Addendum.