

High Rock Lake Model Review #2

Response to Comments

Comments submitted to DWR from Yadkin Riverkeeper and YPDRBA/NC DOT

October 27, 2016

Background

An initial draft of the High Rock Lake modeling report and accompanying model files were provided to the High Rock Lake Technical Advisory Committee (TAC) members for a 60-day review and comment period in September 2012. A subgroup of TAC members (NC Department of Transportation (DOT) and the Yadkin Pee Dee River Basin Association (YPDRBA)) contracted with a third party, LimnoTech, Inc (LTI), to perform the review on their behalf. Comments were also submitted by the Yadkin Riverkeeper, Alcoa Power Generating, Inc. (APGI), and the Piedmont Triad Regional Council (PTRC). Responses to comments and descriptions of resulting model revisions are described in the supplemental document titled "[High Rock Lake Technical Advisory Committee Draft Lake Response Models Review Comments and Responses, March, 2013](#)" (Tetra Tech, 2013).

Following the TAC review, EPA modified the WASP model to address the comments and applied the modified advanced eutrophication module to High Rock Lake to account for multiple algal groups. The revised model was provided to TAC on May 5, 2015.

LTI then reviewed the revised model on behalf of TAC members DOT and YPDRBA, and submitted further comments to DWR on November 30, 2015. The Yadkin-Pee Dee Riverkeeper also contracted Drs. Scott Wells and Chris Berger of Portland State University and provided their comments on the revised model on November 30, 2015.

Upon receiving the second round of model review comments, EPA further revised the model. DWR then further revised the model in October 2016 to correct errors in the WASP model input files and updated the draft report originally prepared by Tetra Tech to incorporate results of the final model. Responses to comments and descriptions of resulting model revisions are described here.

Yadkin Riverkeeper (only comments identified by reviewer as significant included for response here)

1. Model Grid - Figure 2-3 indicates there are only 5 vertical layers near dam. This is too coarse simulate vertical temperature and concentration differences near the dam where layer thicknesses are likely greater than 3 m.

As stated in the report in Section 2.2.5, the "spatial scale of the whole lake model is such that the model represents the average depth of the forebay, rather than the maximum depth immediately adjacent to the turbine intake." A model should be able to represent the actual maximum depth near the dam rather than use average conditions of the forebay. The model report stated that "the reservoir has an average depth of 17 feet and a maximum depth of 62 feet." The cell at the dam has a bottom elevation of 175.16 m (from the file dxdy.inp) and a depth of 13.98 m or an initial water surface of 189.14 m at the model start date. This would make the depth at the dam at normal full pool only 15 m or about 49 ft deep at its maximum,

much less than the reported maximum depth of 62 ft. The model must represent the physical system as close as possible.

Response: *The five-vertical-layer model set up is a tradeoff between computational costs (e.g. computational time, memory usage) and close representation of lake bathymetry. The model was developed for the purpose of predicting chlorophyll-a responses to different nutrient loadings from the watershed. Since the State assesses chlorophyll a standard at water surface (photic zone), model simulation of bottom water dynamics was not set as priority. We acknowledge that this version of High Rock Lake Nutrient Response Model is not designed for simulating bottom water temperature or water quality concentrations.*

2. Model grid – no wetting/drying - On p. 2-3, the model report stated that EFDC was run without wetting and drying of the grid. The report states that “model grid does not represent lateral expansion of the lake surface into low-lying nearshore areas when the water surface elevation exceeds normal pool elevation of 190.2 m.” To not model wetting and drying especially during flood events, biases the model results during these events and any lingering consequences of the flood on water quality.

As mentioned in Tetra Tech (2015b), the WASP model does not allow for wetting and drying of model segments leading to mass balance errors. This is another limitation of the chosen model framework.

On page 4 of the comment response report (Tetra Tech, 2015b), it is stated that “as noted in Section 3.2.2, the model grid does not represent lateral expansion of the lake surface into low-lying nearshore areas when the water surface elevation exceeds the normal pool elevation, leading to spurious discrepancies in the WSE fit. This is a standard approach in grid-based models.” This is not standard approach in grid-based models. Standard approach is to develop the grid above normal pool elevation in order to adequately model the higher water levels.

Response: *The decision was made at an early stage of model development to not include wetting-drying calculation to save computational costs for a model of this scale (1525 segments in total). Not including wetting-drying calculations primarily impacts cells close to the shore. Since model results are calibrated and used for management purpose at the monitoring stations which are located in the channels, the impact of not including wetting/drying is rather minimal.*

3. Model grid – volume and area vs elevation - Fig. 2-5 shows the storage vs volume for the model and the lake. It is unclear why there is an error of between 20-25% or higher for the deeper elevations (below 600 ft) and what bias this introduces into the model results. Perhaps this is a result of not regarding the full depth of the reservoir (see comment #1 above)?

Also, since the model was run without wetting and drying of the grid, Fig 2-5 should be represented by the following graph (see added red line) since above normal pool, elevation 623.9 ft, the model does not spread out into neighboring segments.

Response: *Please refer to responses to comments 1 and 2.*

4. Selective withdrawal for dam outflow - The EFDC model does not have a selective withdrawal mechanism for outflows. In stratified reservoirs, the volume withdrawn from reservoir outlets

usually includes water from multiple vertical layers. As mentioned in the model documentation (Tetra Tech, 2002, 2007), “the constant flowrate source and sinks are distributed uniformly over the vertical layers, while the time series specification of source and sink flows allows arbitrary distribution over the vertical layers.” In modeling stratified reservoirs, this is an inappropriate assumption. Selective withdrawal theory, as used in the model CE-QUAL-W2, is an important part of properly modeling outflow hydraulics and their impact on vertical stratification.

Another limitation of EFDC is stated in the report in Section 2.2.8 that “because the EFDC model uses a sigma vertical grid, the depth associated with individual layers stretches or shrinks with water surface elevation and layers do not correspond to fixed elevations.”

Response: *DWR and EPA worked with APGI, the operators of the dam, to ensure dam operations were represented accurately in the model design.*

5. Temperature modeling and coupling of EFDC and WASP - EFDC computes the temperature (density) field and this information is used in the WASP water quality model. Unfortunately, there is no linkage or feedback of the WASP model to the EFDC model to account for processes which interfere with light penetration such as turbidity and algae growth which are primary water quality parameters of concern in High Rock Lake. This is a weakness in the model framework that can affect the ability of the model to account for these important feedback processes.

As an example, the light extinction coefficient in the WASP model is dynamic, computing light extinction based on suspended solids (inorganic, organic and algae) but the EFDC model uses a fixed value of light extinction that is ‘calibrated’. The model report states that a static value of 1.7 1/m was used for light extinction in EFDC whereas field data of light extinction show that the average was about 2.3 1/m and varied dynamically from 0.7 to 6.9 1/m. This shows the severe limitation of this modeling framework in representing the thermal profile in the lake.

Response: *As with any other model, the model package of EFDC/WASP has its own limitations. As the commenter pointed out, the linkage between EFDC and WASP is currently a one-way linkage rather than a two-way coupling.*

6. Meteorological Data - Page 2-9 states that “temperature from Winston-Salem Reynolds Airport, located approximately 30 miles north-northeast of High Rock Lake, is not fully appropriate to conditions at the lake surface, particularly during hot summer weather when lake evaporation results in temperatures that are cooler than over land. This microclimate effect was approximated by a small reduction in summer air temperatures: specifically, summer temperatures greater than 22 degrees C were multiplied by a factor of 0.93, which was determined through model calibration.” There is no doubt that meteorological conditions at Winston-Salem are probably different than over High Rock Lake. This air temperature reduction factor though seems arbitrary and may mask model errors in the temperature calibration. Were there temperatures recorded locally in the vicinity that could be used to test the above microclimate hypothesis? Were there other meteorological conditions other than air temperature, such as wind, which were perhaps different than the meteorological data used in the model? Also, if air temperature was reduced, why was dew point temperature not also reduced holding relative humidity constant?

Comparing weather conditions at Winston-Salem to conditions at the lake, Weather Underground provided air temperature data that is shown below for June 29, 2015.

As shown above, maximum air temperature at High Rock Lake on this day was almost 10°F warmer than the maximum air temperature at Winston-Salem. This may be an anomaly for this one site and day, but comparing Lexington to Winston–Salem one finds that the site closer to High Rock Lake (Lexington) has higher average daily high temperatures in the summer than Winston-Salem, not cooler air temperatures. If on-site air temperature data are available, then they should be used rather than arbitrarily using a calibration adjustment to air temperature.

Response: *All available meteorological data were used in development of the model.*

7. Water mass balance correction - The report states that “the flow correction was applied as an additional outflow located at the dam forebay. The average flow correction value is equivalent to about 15 percent of the reported dam outflow.” While a water mass balance correction is necessary, the 15% of the dam outflow is high since most gage errors are less than 10% range. Hence, applying this flow correction all at the dam outflow is probably not correct unless there was both substantial leakage and flow inaccuracies at the dam. According to Tetra Tech (2015b), the flow inaccuracies were on the order of 5% and leakage was minimal. Such a large flow correction at the dam would have affected vertical stratification dynamics. Since this approach shows inaccuracies in accounting for water inflows, outflows, evaporation, etc., could it have been a flow correction to the inflows rather than the outflow and how sensitive is the model to this? In most cases where there is vertical stratification, this does affect model stratification dynamics.

Response: *Uncertainties with regards to flow estimation have been addressed in previous model review comments as well as through additional language added to the model report.*

8. Water quality – dissolved oxygen - The validation results for dissolved oxygen (DO) show that the error statistics show a significant bias with RE in Table 3-18 typically from -10% to -20% and a large RMSE above 2 mg/l. If the validation has systematic bias with dissolved oxygen, then the model should be re-calibrated to eliminate this bias. The bias implies that applying this model to other situations could also result in a systematic error in DO.

On page 22 of the comment response report (Tetra Tech, 2015b) it was stated: “The scope of work for this project did not specify DO as a priority parameter for calibration; thus, calibration statistics were not presented and DO should not have been included in Table 3-1. However, DWQ recognizes the coupling between oxygen levels and various other eutrophication related processes and endeavored to ensure that the DO simulation was qualitatively reasonable. Dissolved oxygen will be further evaluated during the model revision and results will be included in the resulting model report.” It is not possible to model eutrophication and algae growth adequately if DO is not a calibration parameter. DO affects nutrient availability and thus algae growth. DO is a critical state variable for predicting sediment release of nutrients. If DO is not modeled, then the model cannot be considered able to represent sediment anoxic release which is often an important nutrient input. This point is actually mentioned in the watershed modeling report (Tetra Tech, 2012) on page 5-24: “A reasonable simulation of DO is, however, needed as the occurrence of hypoxia affects a variety of stream nutrient transformation processes.”

Page 3-43 of the lake modeling report states: “Dissolved oxygen observations were collected at different depths of monitoring stations. Model predicted DO concentrations at the surface layer of the model cell are used to compare with the observations within one meter from water surface at each monitoring station.” Why were only surface layers used to compare model predictions and observed data? Given the availability of data beneath the surface the surface layer and the importance of DO concentrations on nutrient release, predictions of DO and data should have been compared at multiple depths by plotting vertical profiles. Figures 3-26 and 3-27 show observed DO concentrations near the surface of approximately 4 mg/l or less, which are alarmingly low for water near the surface. Such low values near the surface suggest anoxic conditions are possible deeper in the water column.

Response: *Dissolved oxygen was not a primary calibration target for the nutrient response model.*

9. Water quality – algae - Page 3-20. Algae growth rate of 2.8 is outside the range given in the table even though the range in the table seems incorrect. If the value is indeed above the range, why was this high value used? If not, correct the Wool et al. (2001) reference with correct values. A high algae growth rate may have been used to help compensate for the over prediction of nitrogen and phosphorus limitation that reduces algae growth.

The report states that “bluegreens dominate (at or above 75% in unit density) during warm seasons, while diatoms and green algae are the main algal groups during winter and spring.” Since the model is capable of simulating 3 algae groups, it was not clear why only 2 groups were used in the model, warm and cold water algae.

Also, it was unclear why it was not practical to have a varying algae percentage ratio between the 2 species at the lake boundaries. As stated in the report, “ideally, the percentage of individual algal groups at lake boundaries should be a function of time or water temperature, but time-varying ratio for algae partition is not practical in WASP.” Even though sensitivity studies showed that the partitioning of the one algae group into 2 groups was not sensitive to lake dynamics, why was the 75%/25% constant ratio used at the boundary? Fig 2-6 shows that the 75% cyanobacteria percentage may be reasonable only between July-October, but not at other times.

In Table 3-8, it is unclear how the cold water algal group varied its growth by temperature since there is just an optimal temperature for growth of 10oC which is in contrast to the cyanobacteria group.

Response: *The reference for algae growth rate has been corrected in the report. For partitioning algae input at the boundary, due to limitations of WASP input, a constant partition is used which typifies the data pattern observed during critical period of July-October. In addition, since the model is not sensitive to such input, and during other non-critical months the boundary algae is very low, we believe this approach is reasonable. The temperature dependence of algae growth rate is captured with the “Temperature Coefficient” and assuming 20°C as the optimal temperature for warm-water algal group 1. For cold-water algal group 2, a different method is used to capture temperature effect, which involves specifying an optimal temperature.*

10. Water Quality –benthic flux of nutrients - The report states that “the observed average phosphorus benthic flux was assumed to apply only from April 1 through October 31 (the period in which bottom hypoxia is most likely). The average measured ammonia flux was applied from April 1 through October 31 and was reduced to 60 percent during other days.” Most modeling approaches use a predictive model for dissolved oxygen that can then model anoxic release. Prescribing a fixed flux during set periods of time is not predictive and the model cannot be used for alternatives to investigate nutrient reduction strategies without a fully predictive water column dissolved oxygen model that can initiate anoxic processes.

Response: *This is limited by available data. A fully functioning and calibrated sediment diagenesis model would be required to capture dynamics in sediments. However, not enough data is available to develop such a model for High Rock Lake.*

11. Water Quality – nitrogen - There is a distinct bias for the model to under-predict total nitrogen and nitrite-nitrate nitrogen for most stations. Table 3-11 shows that REs for Total N were typically -20%, while in Table 3-13, REs for nitrate-nitrite were often up to -40%! This suggests that the model’s boundary conditions or internal loadings do not account for a large fraction of the nitrogen sources in the model.

Model results indicate nitrogen is a limiting nutrient, but is this actually occurring in the lake or is this just the result of the model under-predicting nitrogen concentrations?

Response: *EPA revised the model to address this concern of under-prediction of nitrogen. As the model currently stands, nitrite-nitrate prediction is improved. Some under-prediction of total nitrogen still exists during the model calibration period, however, during validation period, we see more balanced results of REs among different stations in High Rock Lake. A list of revisions to model parameterization is provided in the end of this document.*

12. Water Quality – phosphorus - The report states that “similar to the calibration results, the model validation statistics confirms that the model represents annual and seasonal averages well but not the short-term temporal variability among individual observations.” Any model with inputs in the ranges of the data should be able to capture average ranges. Can this be improved and if so how?

For dissolved PO₄-P, the report states that “the model simulation results represent the observed average phosphate concentrations and the range of its variability well, however, model representation of individual events are often inaccurate in this dynamic system.” If the model does not respond to dynamic events properly, how can this be improved?

Also, how can the conclusion of the report state that “model provides valuable insights into the dynamics of nutrient and algal response in High Rock Lake” when earlier statements show that nutrients “are often inaccurate in this dynamic system”?

There is a large negative bias of predicted phosphorus concentrations in the lake indicating significant loading sources have been left out. Relative error for the calibration year ranges from -10% to -30%.

Response: EPA revised the model to address this concern of under-prediction of phosphorus. The REs for TP prediction from current model vary between negative and positive values during both calibration and validation periods, suggesting no systematic bias exists. A list of revisions to model parameterization is provided in the end of this document.

13. Water Quality – calibration - On page 5-1, the modeling report states: “For nutrients and algae, the model has a low amount of bias and meets most targets for a “good” quality simulation in terms of relative error and coefficient of variation.” Error statistics for total nitrogen and nitrite-nitrate indicate a significant negative bias for nitrogen. Since the model under-predicts nitrogen and also predicts nitrogen limitation, TMDL scenarios might over predict the reduction in algae that would actually occur if loadings in nitrogen were reduced. Algae that the model predicts is nitrogen limited could be phosphorus limited instead, or not limited by nitrogen or phosphorus and limited by light instead.

Response: Please see responses to comments 11 and 12.

14. Sediment oxygen demand used in the model was not what was mentioned in the model report (Tetra Tech 2015). This would significantly affect the oxygen balance in the reservoir and aerobic and anaerobic processes. A scaling factor of 0.5 appears to have been applied to the average measured SOD of $-1.595 \text{ g/m}^2/\text{d}$, resulting in the much lower than measured model SOD. Note that Tetra Tech (2015) stated that “[t]he average measured flux rates were selected as initial values for the model application and applied to all lake bottom segments.” The report does not mention that the SOD flux rates used in the model were half of what were measured.

Response: The scaling factor has been corrected in the revised model.

15. Since the model uses prescribed fluxes of nutrients not based on anoxic conditions, the model cannot predict the impact on nutrient recycling in the lake as a result of anoxic processes.

Response: Please refer to response to comment 10.

16. Even though clarification is required for how the N and P fluxes from the sediment were handled, the output from the model shows 0 N and P fluxes from many model segments. This needs clarification since the report mentions that there were N and P fluxes set to average sampling values. This can affect the nutrient balance in the lake.

Response: There was an error with the output variable in the version of WASP that was used. Sediment fluxes were being used.

17. It is unusual not to have temperature limitation for an algal group. By not having temperature limitation, the warm-water group could grow at all times at the same rate. Growth rate limitation of algae is standard modeling practice. This is non-standard modeling practice and would affect all algae processes of the warm-water algae

Response: Based on analysis of the existing data, temperature limitation for warm-water algae was not a concern in High Rock Lake.

18. This is an issue with the EFDC model not being consistent with the WASP model where TSS varied over time. This would affect light transparency affecting currents and temperature stratification

Response: *A dynamic TSS transport model is not invoked in EFDC, we expect its impact on the flow and temperature field is very limited. The addition of sediment transport would have added additional computational time and no effect on the overall water quality.*

19. Clarification is needed to assess whether CBOD total in WASP includes all possible CBOD including dissolved and particulate. POM values ranged to as high as over 10 mg/l while Total CBOD was close to zero. Perhaps the WASP model does not account for particulate organic matter as part of CBOD. Generally, POM of about 10 mg/l would be close to 14 mg/l O₂ or CBOD. Clarification is needed to assess whether CBOD only includes dissolved organic matter or treats it independently

Response: *CBOD simulation is corrected in the revised model. WASP does include particulate organic matter and the accumulation and cycling of detritus. These materials are cycled back to CBOD through a mineralization and dissolution process.*

20. Settling rates can affect algae predictions significantly. Algae predictions then affect nutrient and oxygen dynamics in the lake. Setting zero settling velocities for algae is not standard modeling practice

Response: *The reviewer used a different method to get the settling of phytoplankton from the water column. WASP is settling the phytoplankton using the Solids Transport Fields instead of the segment parameter fields.*

YPDRBA/NC DOT

1. **Figures 4-1 – 4-3**

While the majority of the 2015 model calibration report (NCDWR 2015) was focused on the comparison of target output parameters with corresponding observed data, Figures 4-1 through 4-3 in the 2015 report also showed calibrated model output for the limiting factors on algal growth. LimnoTech did find some apparent differences with our model output, when compared with those shown in the report (example of discrepancies shown in Figure 3 below). It is unclear how the models could differ in these limitation parameters, while producing the same results for nutrients and chlorophyll a. We would request that NCDWR check the plots in the report relative to those LimnoTech produced with their output and explain the differences if possible.

Response: *The figures have been corrected.*

2. **Solids and Settling**

WASP7 allows for the use of up to three classes of solids to be parameterized individually. Each of the model state variables has a transport/settling field that is defined by assigning a solids class. Solids Class 1 is assigned for the larger and heavier particulate variables, such as inorganic solids. The inorganic phosphorus state variable is also assigned to this transport field. The settling rate for these variables is set to 1 m/d for the vast majority of the model grid. Approximately five model cells in the Yadkin River use a much higher settling rate of 8 m/d.

Solids Class 2 is assigned a uniform settling rate for the entire system of 0.57 m/d, representing organic nutrients and detritus. The cold-water algal group is also assigned to this transport field. The modeling report (NCDWR 2015) indicates that this group is intended to represent a mix of diatoms and chlorophytes; however, this settling rate is too high for chlorophytes, and is more suitable for diatoms.

Solids Class 3 is assigned a much smaller settling rate of 0.06 m/d, with the exception of about 15 cells in Abbots Creek that have a settling rate of 0.28 m/d. These transport properties are also assigned for ammonia and nitrate. The vast majority of nitrate is assigned to the dissolved phase (discussed below) so very little will settle in model applications. However, approximately 15% of the ammonia is set to the particulate fraction, so this portion of the nutrient will settle in the model. This is an unrealistic representation for ammonia.

Finally, the Solids Class 3 transport field is also used by the summer algal group. The modeling report (NCDWR 2015) indicates that this group is intended to represent blue-green algae, which can take advantage of buoyancy to improve conditions for light and nutrient uptake at the water surface. LimnoTech feels that this settling rate is too high for blue-green algae, and this algal class should be assigned a buoyant (zero) settling rate or even a negative settling rate.

Response: *A single vertical layer in High Rock Lake model is up to around 3 m in depth, especially at the deeper region, particles with 0.06 m/d settling velocity will need up to 50 days to settle out from one layer to the layer beneath it. Therefore, we disagree that this settling rate is too high.*

3. Algal Functional Group Parameterization

The advanced eutrophication module in WASP7 allows the user to individually parameterize three distinct algal groups, for example diatoms, green, and blue-green (i.e., nuisance) algae. The revised model only utilized two functional groups, corresponding to warm-water and cold-water groupings. Due to this simplification, broad assumptions had to be made on how to specify growth kinetics and physical transport properties for each group.

The 2015 modeling report (NCDWR 2015) justifies using two functional groups by showing the percentage of blue-green, green, and diatom algae as determined by unit density (Figure 2-6, 2015 report). This figure shows that during the summer months, blue-greens represent over 80% of the unit density, while diatoms and greens are approximately equal in the winter months, with very low blue-green density. NCDWR used Figure 2-6 (2015 report) as justification for configuring the warmwater group to represent blue-greens and the cold-water group to represent a mix of greens and diatoms. However, unit density distribution is a poor indicator of biomass distribution. Comparing the distribution of biovolume (mm³/m³) is a more direct comparison to the phytoplankton biomass state variables used in WASP7, and therefore should have been the basis for determining how to differentiate algal groups in the model. LimnoTech re-created a distribution similar to the one shown in report Figure 2-6 (NCDWR 2015) using biovolume instead of unit density (Figure 4 below). (Note that biovolume was reported in the phytoplankton class distribution dataset along with unit density.) From this plot it is clear that greens and other types (such as chrysophytes, cryptomonads, dinoflagellates, euglenoids) of algae make up a significant portion of the algal biovolume in both the summer and the winter. Both diatoms and greens are closer to equal components of the winter biovolume, although greens may be slightly more dominant.

Based on the functional group distribution shown in Figure 4 above, no single functional group comprises the vast majority of biomass during any season, and so the most appropriate modeling approach would be to include three algal groups representing 1) blue-greens, 2) greens and others, and 3) diatoms. By using only two groupings, the warm-water class must represent a mix of bluegreen and green kinetic parameters, and the cold-water class must represent a mix of greens and others and diatom kinetics. Such pairings are troublesome due to significantly different responses to physical and biological drivers between the functional groups. In our opinion, this is a serious failing of the model formulation and associated calibration.

NCDWR's representation of the cold-water group was intended to represent a mix of greens (and other algae) and diatoms; however, the optimal temperature of 10°C is not consistent with literature values for green algae (this value is much more suitable for diatoms). This further illustrates the critique that a distinct class representing greens and other algae should have been implemented in the model.

Similarly, an optimal temperature was not specified for the growth of the warm-water algal class, which was intended to represent blue-greens. By not specifying a value, WASP7 applies a default value of 20°C for the optimal growth rate. Again, this value is inappropriate for blue-greens, which thrive at 24°C or even warmer water temperatures.

Other functional group specific parameters, such as maximum growth rate, nutrient half-saturation constants, settling rates, optimum light saturation, and carbon-chlorophyll a ratios can vary across the three functional groups represented above in Figure 4, and this is common in many eutrophication models.

Response: *DWR's phyecologist recommended the use of unit density instead of biovolume in our analysis since biovolume is estimated from unit density and hence some substantial extra amount of data uncertainty will be included if biovolume is used. The different parameters for algal dynamics used in the model are based on EPA's analysis to current available data in High Rock Lake.*

4. Dissolved Fractionation

The modeling report (NCDWR 2015) states that the dissolved fractions of nutrients were varied spatially in the domain: "Values were set to be generally consistent with the ratio of dissolved to total nutrient concentrations observed from in-lake monitoring data. For example, the observed mean dissolved fraction of total phosphorus increases from 50 percent at HRL051, the most upstream mainstem station, to 63 percent at YAD169F, at the dam forebay." Several segments in the model input table have values specified for the dissolved fraction that differ from the ranges and values shown in Table 2-6 in the report. For example, there are segments with a dissolved orthophosphate component set to greater than 75%, although the report states the values range from 50 to 60%. It is unclear from the report if these values were adjusted as calibration parameters. Additionally, most of the values are not round numbers, so it is unclear if some interpolation was applied.

As mentioned in the discussion on settling, a portion of the ammonia state variable is defined as particulate (approximately 15%), and it is allowed to settle according to the Solids Class transport field. This may result in an unrealistic loss of the nutrient. The report (NCDWR 2015) does not show any data demonstrating that a portion of ammonia was measured to be

particulate. This is potentially a loss process for ammonia that is not really occurring in the lake and therefore should not be included in the ammonia cycling dynamics represented in the model.

Response: *The values reported in Table 2-6 are typical values used in the model. The text has been revised accordingly in the updated model report.*

5. Light Extinction

The modeling report (NCDWR 2015) states that:

“...the background light extinction function was used to represent the typical light extinction within different areas of the lake, with incremental contributions from simulated inorganic solids and chlorophyll a concentrations. Specifically, the background light extinction rate was set equal to the observed light extinction after backing out contributions from algae and suspended inorganic sediment as simulated by the model. The model output was checked to ensure that simulated light extinction time series were consistent with the range obtained from observed Secchi depth and PAR measurements.”

This methodology is confusing and not well documented. It appears that the light extinction function was varied spatially based on model-simulated sediment and algal biomass, however, no values or figures are presented demonstrating this. Additionally, the report (NCDWR 2015) mentions that the simulated light extinction values were consistent with observations; however, no evidence is presented to support this claim. LimnoTech visually compared the model-calculated light extinction coefficient with those calculated from Secchi depth data for several stations. In the most upstream stations (e.g., HRL051), the model consistently over-predicted light extinction (Figure 5); however the model did a better job of matching observations further downstream (Figure 6). Figure 5 (as well as model input) indicates that the background light extinction coefficient was set to 3.4 m⁻¹ for the region of the model grid near station HRL051. However, the 2015 modeling report (Table 2-11) states that the Secchi depth-based observed total light extinction at this station was 3.08 m⁻¹. The Secchi-depth based light extinction value includes the contributions from inorganic solids and algae, and therefore it is unreasonable to expect that the background light extinction (excluding inorganic and organic solids) would be higher. It is unclear if the specified background values were simply used as calibration parameters.

Response: *The background light extinction coefficient was used as one of the calibration parameters, with those calculated from Secchi depth data providing general guidance.*

6. Other Inputs

LimnoTech notes that there appears to be a discrepancy in the atmospheric nitrate deposition rate. The modeling report (NCDWR 2015) states that a rate of 0.802 mg/m²/d was used in the model; however, the input value is set to 0.12 mg/m²/d. LimnoTech performed a sensitivity model run using the value specified in the report, and the model showed little sensitivity to this correction.

Response: *The model has been corrected to reflect the measured rate of 0.802 mg/m²/d.*

Summary of WASP - High Rock Lake Model Revisions October 2016

Model Report

- p. 2-17: changed “range” to “typical values” in the text for values of dissolved nutrient fractions.
- p. 3-19: updated model parameters
- p. 3-20: corrected reference values for maximum algal growth rate.
- P. 3-20: updated model parameters
- Table 3-5 to 3-18: updated model calibration and validation statistics
- Figures 3-11 to 4-3: updated figures using revised model results

Model Parameterization

- The value for oxidized N deposition rate used in the model was corrected according to the text on Model Report p. 2-16 (changed from 0.12 to 0.802).
- k12c – Nitrification rate at 20°C, per day: changed from 0.12 to 0.2
- k71c – Mineralization rate of dissolved organic nitrogen (per day): changed from 0.075 to 0.15
- Death Rate Constant for algal group 1: changed from to 0.02 to 0.08
- CBOD2 was added to represent POM/detritus recycled to CBOD.

Further revisions were made by the Division of Water Resources after errors were found in the linkage between HSPF and WASP.

- Model input of boundary conditions were corrected to exactly reflect the descriptions in the model report. These include:
 - Organic nitrogen/phosphorus concentrations that converted from CBOD of corresponding tributaries were corrected.
 - Solid phase of ammonium and phosphate were added.
 - TSS concentrations from several small tributaries were corrected.
 - Nutrient concentrations averaged from two reaches (144 and 145), both feeding into Flat Swamp Creek, were used for its boundary condition.