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Harbor Committee Comments on January 2004 Calibration Report for Savannah Harbor Model by ATM

Draft; March 1, 2004; Larry Neal

CBOD Loadings and Decay Rates

1. Long-term BOD tests were conducted on effluent samples and river samples. Aged river water was used to dilute effluent samples for these tests.
2. The decay-rate analysis for the instream and marsh transect long-term BOD sampling was not found in the report (only lab reports in Appendix, no decay-rate analysis).
3. The largest NPDES point source to the harbor is the IP discharge which averaged about 8,000 lbs/day BOD5 during the August 1- October 15 period of 1999 (Law 2000, Figure 3-43). The CBOD decay rate for all three IP long-term BOD effluent samples was 0.02 /day (base e, 20 degree basis).
4. A CBOD decay rate of 0.02 per day corresponds to an f-ratio (UCBOD-to-5-day CBOD ratio) of 10.5. An f-ratio of 10.5 converts the average 8,000 lbs/day BOD5 load from IP to a UCBOD load (which the model uses) of 84,000 lbs/day.
5. In contrast to the 0.02/day measured CBOD decay rate for the IP discharge, the CBOD decay rate used in the river model decays all CBOD (including the IP discharge) at an assumed rate of 0.09 /day. A CBOD decay rate of 0.09 corresponds to an f-ratio of 2.8 compared to the 10.5 f-ratio associated with the IP discharge..
6. An f-ratio of 2.8 converts an 8,000 lbs/day BOD5 load to a UCBOD load of only 22,400 lbs/day rather than the 84,000 lbs/day based on the time series BOD tests; a 275 % difference in BOD loading.
7. 84,000 lbs of CBOD decayed at a rate of 0.02 /day consumes 1663 lbs of river DO in the first day after discharge compared to 7,229 lbs of DO consumed for a decay rate of 0.09 /day; a 335% difference in DO consumed. In 30 days time, the DO consumed from the river by 84,000 lbs of UCBOD at the measured rate

of 0.02 /day would be 20,154 lbs compared to 60,173 lbs of DO consumed for a decay rate of 0.09 /day; a 193 % difference in river DO consumed.

8. The largest municipal NPDES point source discharge to the harbor is the City of Savannah's President Street plant. This discharge averaged about 1,100 lbs/day of CBOD5 during the August 1 – October 15 period of 1999 (Law, 2000, Figure 3-38). The measured CBOD decay rate for three President Street effluent samples averaged 0.06 /day which corresponds to an f-ratio of 4.0. This f-ratio converts the CBOD5 of 1,100 lbs/day to a UCBOD of 4,400 lbs/day. In contrast, a decay rate of 0.09, as used in the model, corresponds to an f-ratio of 2.8 that would convert 1,100 lbs/day of CBOD5 to only 3,080 lbs/day UCBOD; a 43 % difference in CBOD loading.
9. The average CBOD decay rate for the 12 long-term BOD samples from the river at the Ft. Jackson (RM 10.6) and Corps Dock (RM 16.6) stations range from 0.030 to 0.082 /day with an average of 0.056 /day.
10. A series of long-term BOD tests (Law, 2000) using various dilutions of IP effluent, President Street effluent, and aged Savannah River water found that the individual source BOD curves were additive in the mixture and that the individual source decay rates were thereby retained in the mixtures. This means that use of a single CBOD decay rate in a model is an oversimplification when there are substantial differences in decay rates among the significant sources. Such an oversimplification is the case in Savannah harbor where the single largest point source decays at a measured CBOD decay rate of only 0.02 /day, the average measured instream decay rate is 0.056, and the decay rate selected for use in the model calibration is 0.09 /day.
11. The CBOD decay rate used in the model is too high on average by a factor of about 1.6 (0.09 / 0.056 = 1.6). This significant overstatement of CBOD decay thereby overstates DO demand from BOD sources and requires too high a reaeration rate and added BOD (ocean boundary) in attempting to match calculated DO against measured DO.
12. The UCBOD loadings to the model are based on measured CBOD decay rates and their associated f-ratios. If the agencies choose to accept the use of a much higher CBOD decay rate of 0.09 /day for the model (1.6 times the average measured river-sample decay rate and 4.5 times the measured decay rate for the largest point source), the basis for the UCBOD model loadings for point sources should be reconsidered and recalculated using the lower f-ratio corresponding to the assumed instream rate of 0.09 / day. Otherwise, the point source oxygen demand rate is substantially overstated in the DO model.
13. A discussion or explanation of CBOD (or NBOD) calibration could not be found in the calibration report. A discussion and rationale for assuming the ocean boundary UCBOD at 3.3 mg/l was not found in the calibration report. This assumed ocean boundary UCBOD concentration is greater than most of the UCBOD concentrations measured in the harbor near the major point sources and is equal to the high-tide average UCBOD measured at Ft. Pulaski. In retrospect, it should not be surprising that it was necessary to assume a high

UCBOD concentration in the ocean boundary in order to offset the selection of a CBOD decay rate in the model that is too high by a factor of about 1.6.

14. The sensitivity testing of the model to the ocean boundary UCBOD assumption and the ocean-boundary percent saturation for DO could not be found in the calibration report.

Reaeration Rate Coefficients

15. More discussion and explanation of how the O'Connor Dobbins equation for reaeration is being applied would be helpful (i.e., What "mean depth of flow" term is applied? What "mean velocity" term is applied?). What are the reaeration rate coefficients calculated in the model compared to reaeration rate coefficients from studies of other large tidal rivers and estuaries? What, if any, use was made of the USEPA gas dome measurements in estimating or adjusting reaeration rates? On page 3-5, what is the rationale behind dividing the surface exchange coefficient by the depth of the model surface layer? Is it logical that as the model uses a smaller thickness for the surface layer that the surface exchange increases?
16. The reported DO calibration effort required (1) a substantial increase in the CBOD decay rate over measured rates, (2) an assumption that the ocean boundary UCBOD concentrations (3.3 mg/l) were about the same or greater than measured harbor UCBOD concentrations, and (3) an assumed ocean boundary DO concentration of only 75 % of DO saturation. All of these adjustments and assumptions were apparently made because the model was calculating higher DO concentrations than the measured concentrations. The calibration adjustments made were made to either increase DO consumption by BOD (increased decay rate and assumed ocean boundary CBOD) or to reduce the available DO from the ocean boundary. Instead of increasing DO demand and reducing the ocean boundary DO to calibrate the model, was due consideration given to the possibility that the way in which the O'Connor Dobbins empirical equation is being adapted might be overdriving DO income from atmospheric reaeration?
17. The report gives reaeration values calculated in the model ranging from 0.35 to 1.60 /day (page 5-11). However, reaeration rates reported from other studies of tidal rivers and estuaries (USEPA, 1978, after Hydroscience 1971) range from only 0.08 to 0.4 /day...a 4-fold difference. Why is reaeration so much higher in this application?
18. Aside from the way the reaeration rate coefficient is calculated, what DO deficit in the model is being multiplied by the calculated reaeration rate coefficient to derive reaeration income at the surface? It should be the DO deficit at the water surface where the driving force for reaeration (DO deficit) is physically expressed. Using a DO deficit that is greater than the actual surface DO deficit will also overdrive calculated DO income, even if the reaeration rate coefficient is otherwise correct.
19. Given that BOD decay rates and SOD rates were directly measured for this study and given that the light-limited effects of photosynthesis and respiration

are considered insignificant in the DO balance, the main factors needed for calculating the DO balance have been measured...except for reaeration. The problem is that there are no measurements for reaeration, only empirical formulation, and the calculated reaeration seems too high by a possible factor of 4 when compared to other tidal systems.

20. Would it not be more prudent to first try the classic "indirect calculation" method for determining reaeration rates before adjusting measured results for BOD decay and assuming an elevated offshore BOD source with reduced DO saturation? In the indirect method, reaeration rates are essentially back calculated by measuring or accounting for everything else in the DO balance equation except reaeration and then selecting reaeration rate coefficients to best match the observed DO data. This would seem here to be a more logical approach to DO model calibration than first assuming CBOD must be decaying faster than the measured CBOD decay rates while simultaneously assuming that the ocean boundary must be a significant source of CBOD to the harbor.
21. The basic O'Connor Dobbins empirical model for reaeration states that the reaeration rate coefficient increases proportionally with the square root of the mean water velocity while decreasing proportionally with the mean water depth raised to the 1.5 power. The indirect calculation of reaeration rates in certain segments where data are more robust might also be used to calibrate the empirical equation to fit this particular application. Adding a term to account for reaeration enhancement as wind speed increases above some threshold (e.g., say 2 mph) might also prove helpful because the O'Connor Dobbins equation otherwise only considers water velocity and depth as drivers for the reaeration rate coefficient.
22. Beyond the DO modeling application, simply looking at the effects of increasing depth and decreasing velocity on empirical-formula reaeration rate coefficients might also be a useful way to estimate the effect of channel deepening on atmospheric reaeration rates and related DO deficits. Overall, the maximum DO deficit should increase proportionally as the reaeration rate decreases (recall that $K1L = K2D$ at the DO sag point). Reaeration rates would logically decrease as a function of increasing depth and decreasing velocity. For example, according to the O'Connor Dobbins empirical equation, a mean depth increase from say 40 to 44 feet reduces the calculated reaeration rate coefficient by about 13 percent if velocity remains unchanged. Similarly, if mean velocity is decreased from say 2 fps to 1.8 fps and the depth remains unchanged then the calculated reaeration rate is decreased by about 5 percent. It isn't necessary to model DO to know that a deeper slower-moving flow will have a lower reaeration rate.
23. If any DO model is calibrated with too much reaeration income, it is axiomatic that counteracting errors must be made in other DO balance parameters or boundary conditions. In this case it appears that overestimation of oxygen demands in the model may be the unwitting result of too much reaeration calculated in the model.

Conclusion

The DO/BOD calibration needs further work and reconsideration before the DO results are usable for decision-making purposes where accurate DO projections are of significant importance.