Review of: HDR Consultants, April 2017, *Hydrodynamic and Sediment Transport Analyses for Conowingo Pond,* Report for Exelon Energy Corp. Report downloaded 1 May 2017.

Review by: Peter Wilcock, Ph.D. 30 May 2017

Review Comments

HDR has developed a coupled hydrodynamic, sediment transport, and nutrient model, the Conowingo Pond Mass Balance Model (CPMBM) for the purpose of simulating sediment and nutrient loads. This report describes the development and performance of the hydrodynamic and sediment portions of the model. The model uses sediment inputs estimated by a HEC-RAS model of Lake Clarke and Lake Aldred developed by WEST consultants in 2016.

The hydrodynamic simulations appear to work well. The choice of model parameters (roughness, in particular) is in a reasonable range. It is, of course, much easier to accurately estimate water surface elevation than it is to estimate sediment transport and bed elevation changes. It would be surprising if the hydrodynamics worked poorly.

At the heart of the sediment transport model is a balance between rates of sediment erosion and sediment deposition. Deposition rates are based on standard fall velocities. Erosion rates are much harder to estimate for a bed containing a mixture of cohesive and cohesionless grains. The model apparently uses two different methods for estimating the boundary stress for initiating erosion (τ_{ce}) and uses a constant rate of erosion when $\tau > \tau_{ce}$. Thus, the bed in each cell erodes at a constant rate for as long as the stress exceed the critical. Although the erosion rate is surely not constant in all cells and for all flows, this assumption is simple and consistent with the available information from the SEDFLUME experiments. One might hope that a more detailed erosion rate model might be possible after effort has been made to sample and test the reservoir sediment, but I concur that this is not the case. It is preferable to have a simple model that falls within a reasonable range than to have a detailed model that provides no better (and possibly worse) estimates.

The report is generally well written and documented. The model development, calibration, and results are presented clearly, although some points of clarification would be useful.

p. 27: "Erosion thresholds were calibrated so that computed bed elevation changes over the course of the simulation were in rough agreement with spatial and temporal pattern and pond-wide average bed elevation change determined from interpolated bathymetric survey results."
prw: More detail is needed here. Is this calibration for the entire model run or only for the initial time steps? What values of erosion threshold were selected in the end? Are these values different from those determined from Equations 2-16 and 3-1? In what cases?

p. 28: "Dimensionless diameters and critical shear stress values for each particle type were then determined based on effective diameter using Equations 2-15, 2-16, and 2-19."
prw: I believe this should be Equations 2-16, 2-17, and 2-20. It is also not clear when 2-16 is used and when Equation 3-1 is used. Is it 2-16 always for *in-situ* material and 3-1 only for material deposited during the simulation?

p. 33: "Consequently, erosion thresholds for initial bed layers at the start of simulations were adjusted during sediment transport model calibration."
Is this applied only to the surface layer, or to the full bed? What were the adjusted values for erosion thresholds? Are they in a reasonable range?

Equations 3-1 and 3-2. These relations are used to estimate τ_{ce}, at least in some cases. First, the relation between % clay and plasticity index is rather poor (Figure 7), as may be expected for cohesive sediments. Second, it is not clear when this relation is used to estimate τ_{ce}. Is it only for sediment that is deposited during the simulation? Is it also used when there is scour? Also, the reference for Jacobs et al. (2011) is not given.

p. 27: "The erosion rate used for simulations was assigned as **0.002 cm/s** (0.236 feet/hour) …"
p. 33: "Whenever the shear stress acting on the bed exceeded the critical shear stress for erosion, sediments were assumed to erode at a rate of 1.18 feet/hour (**0.01 cm/s**), which is within the range of USACE (2014) SEDFLUME results."
These two sentences indicate two different values of erosion rate. Please reconcile.

The behavior of the sediment bed under scour conditions remains poorly known. This is a problem with available input rather than the model, although this problem necessarily limits the possible fidelity of any model. In the long simulation (1997-2014), 18 of the model grid cells show scour greater than 30 cm (Figure 66), which exceeds the depth of any characterization of bed behavior. In the 2008 to 2014 comparison of surveyed and simulated elevation change (Figure 69), 25 of the cells in the simulation and 56 of the cells in the observed (about one-fifth of the cells) show scour greater than 30 cm.

Response to Review Questions

1. Is the modeling approach reasonable and credible to satisfy the goals defined in the *Proposal for Lower Susquehanna River Reservoir System Model Enhancements in Support of the 2017 Chesapeake Bay TMDL Midpoint Assessment*?

The calibrated model is useful for the purposes defined in the *Proposal for Lower Susquehanna River Reservoir System Model Enhancements in Support of the 2017 Chesapeake Bay TMDL Midpoint Assessment*. The hydrodynamic and sediment transport models selected are appropriate and current; the specific model developed made effective use of the available data.

2. Does the Conowingo Pond Mass Balance Model (CPMBM) provide added value to the information available to the EPA Chesapeake Bay Program and the State of Maryland? Does it inform and advance the current science and understanding of the Lower Susquehanna River Reservoir System?

The model is clearly an advance over previous efforts. Previous models were limited in their dimensionality. Additional information has become available that allows for a more accurate model. This model comes much closer to matching observed changes in reservoir bed elevation than any previous model.

3. Given the data which were available to the modelers, evaluate the model results, input parameters, and modeling assumptions made to determine if the models perform reasonably.

Beyond uncertainty in the estimates of the critical stress for sediment erosion, the choice of input parameters was clear and credible. The simulated sediment load at Conowingo Dam matches the USGS observations remarkably well.

4. Are the modeling outputs developed under this study appropriate to help inform or guide the suite of Chesapeake Bay Program models (i.e. the Watershed Model and Water Quality and Sediment Transport Model)?

These model results are close to the best one can hope for in terms of informing the CBP models. The simulated water and sediment flux is consistent with observations using a credible, appropriately formulated model. There will remain considerable uncertainty in the modeled results, but a better answer will not be available without extensive and long term further monitoring covering a wide range of different flow conditions.

5. While keeping the goals of the study in mind, could the models and outputs be improved? If possible, please identify specific areas of potential improvement (e.g., model input datasets/parameters, modeling assumptions, process description, other modeling systems or programs, etc.).

Estimating sediment entrainment. There is a need to be clearer about how values of τ_{ce} were calculated and which value of erosion rate was used. Beyond that, there is a broader need to understand how model results may be sensitive to the choice of τ_{ce} and erosion rate.
(i) a report of values of τ_{ce} and erosion rate used in the final simulation is needed, including an assessment of whether all values used are reasonable and consistent. Were the values used and the rules applied consistent across the reservoir? Did they change with time?
(ii) some estimate of the sensitivity of model results to the choice of τ_{ce} and erosion rate would be useful.

Grain Size. The model uses four grain sizes (clay, silt, sand, gravel) as well as a nominal grain size for coal. It would be useful to compare simulated *vs.* observed grain size of the sediment load at Conowingo Dam. This provides a separate basis for evaluating model performance. Similarly, it would be useful to compare the beginning and ending grain size of the reservoir bed. If the transport of different grain sizes is off, progressive sorting of the bed should show that effect clearly.

Uncertainty. The report notes that "uncertainties in flows at Holtwood contribute to uncertainties in sediment load estimates" and the "Uncertainties in SSC estimates contribute to uncertainties in sediment load estimates". It would be useful to explore how uncertainties in the upstream boundary condition, as well as uncertainties in the bottom boundary condition for sediment erosion, may contribute to uncertainties in the simulated loads at Conowingo Dam. It would be informative to propagate uncertainty in the upstream *and* bottom boundary conditions into uncertainty in the CPMBM predictions.

End of Review

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