Proposal for Lower Susquehanna River Reservoir System Model Enhancements in Support of the 2017 Chesapeake Bay TMDL Midpoint Assessment

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Exelon Generation Company, LLC (Exelon) submits this proposal for Lower Susquehanna River Reservoir System model enhancements in support of the 2017 Chesapeake Bay Total Maximum Daily Load Midpoint Assessment. Proposal sections found below include:

1.0 BACKGROUND

The Chesapeake Bay Total Maximum Daily Load (Bay TMDL), developed in 2010, calls for a 2017 Midpoint Assessment to review the progress made toward meeting the goal of sediment and nutrient load reductions to the Chesapeake Bay (the Bay). According to the Chesapeake Bay Program (CBP) website (https://www.chesapeakebay.net/about/programs/tmdl/mpa), the primary objectives of this Midpoint Assessment are:

1. Gather input from the Partnership on issues and priorities to be addressed in order to help meet the goal of all practices in place by 2025 to meet water quality standards
2. Based on these priorities, review the latest science, data, tools, and BMPs, incorporate as appropriate into the decision-support tools that guide implementation, and consider lessons learned
3. Help jurisdictions prepare Phase III WIPs, which will guide milestones and implementation from 2018 to 2025.

One of the priorities identified by the CBP to be addressed during the Midpoint Assessment was to develop a better understanding of the potential impact, if any, sediment and nutrient transport from the Lower Susquehanna River Reservoir system has on Bay water quality. In the early 2010's a two phase approach was implemented to address this, including: Phase 1) enhanced modeling via Phase 6 of HSPF and WQSTM, and Phase 2) implementation of a Lower Susquehanna River Integrated Sediment and Nutrient Monitoring Program.

The Lower Susquehanna River Integrated Sediment and Nutrient Monitoring Program (Integrated Monitoring Program) is a multi-year field study, started in 2014, in cooperation with Exelon, Maryland Department of Natural Resources (MDNR), Maryland Department of the Environment (MDE), University of Maryland Center for Environmental Science (UMCES), U.S. Geological Survey (USGS), U.S. Army Corps of Engineers (the Corps), and the U.S. Environmental Protection Agency (USEPA) Chesapeake Bay Program. The primary goals of this Program are to:

1. Determine the impact, if any, of storm events between 100,000 and 400,000 cfs on sediment and associated nutrient loads entering the Lower Susquehanna River from upstream sources (including Conowingo Pond), and
2. Determine the potential resulting impacts of storm events, if any, on Bay water quality from sediment and nutrients entering Conowingo Pond from upstream sources, scouring from sediment behind Conowingo Dam and passing through the Dam.

The study was to target up to six storm events with flows equaling or exceeding 100,000 cfs. At the conclusion of all field efforts, the results of the Integrated Monitoring Program were to be used to update the suite of Bay Watershed and Water Quality models for use in the 2017 TMDL Midpoint Assessment. As of the date of this proposal (January 2016), two official sampling events have occurred, both of which had peak flows less than 182,000 cfs.[1] In late 2015, due to a lack of storm events in the target flow range and the lack of corresponding empirical data which Program partners had hoped would have been available by now, Program partners began discussing alternative approaches that could be implemented in early 2016 to supplement the modeling efforts associated with the Midpoint Assessment.

From these conversations, Exelon developed a two phased-modeling approach that would enhance and complement the existing Phase 6 HSPF Watershed Model (HSPF) as well as the inputs to the Bay Water Quality and Sediment Transport Model (WQSTM). The two phased modeling approach includes developing:

1. An enhanced one-dimensional HEC-RAS model of Lake Clarke and Lake Aldred, similar in nature to the one developed by the USGS as part of the Lower Susquehanna River Watershed Assessment (LSRWA). Enhancements in the new model will include a longer calibration and verification period based on 2013 and 2015 bathymetry that were not previously available to the LSRWA modelers, modeling of suspended sediment load plus estimates of bed load, individual cohesive soil properties for each soil group, and true unsteady flow. The output from this model will result in improved sediment loads from Lake Clarke and Lake Aldred, which can then be used to re-parameterize HSPF and improve the sediment loads entering Conowingo Pond (the Pond); and
2. A coupled hydrodynamic, sediment transport, sediment nutrient flux and water quality mass balance model for Conowingo Pond – the Conowingo Pond Mass Balance Model (CPMBM). This model will allow for an improved evaluation of the extent to which changes in sediment storage and nutrient bioreactivity within the Pond affect sediment and nutrient delivery to the Bay. The output from this model combined with the results of the UMCES biogeochemical experiments

[1] Sampling Event No. 1 occurred April 6-14, 2015 with peak flows of 146,000 and 182,000 cfs. Sampling Event No. 2 occurred April 22-25, 2015 with a peak flow of 125,000 cfs.

being conducted as part of the Integrated Monitoring Program will allow for improved inputs to the WQSTM.

The proposed approach is presented below in greater detail.

2.0 APPROACH

The HSPF model (and its many sub-models) is the primary tool used by the CBP to model the Chesapeake Bay watershed including the Lower Susquehanna River Reservoir system. The Lower Susquehanna River Reservoir System is defined as the reach of river from Marietta, PA to Conowingo Dam and includes Lake Clarke (Marietta to Safe Harbor Dam), Lake Aldred (Safe Harbor Dam to Holtwood Dam), and Conowingo Pond (Holtwood Dam to Conowingo Dam).

Although the three reservoirs found in this reach are each modeled using separate sub-basins for each reservoir, inflow and outflow data are based on observed measurements recorded at Marietta, PA (upstream of Lake Clarke) and Conowingo Dam. As such, the reservoirs found in this system are modeled as a mixed reach using a lumped parameter approach within the constraints of HSPF. Given this, the accuracy of HSPF in any particular reservoir is a source of uncertainty. Finally, levels of critical flow (critical shear stress) are set individually for both scour and deposition of silt, clay, and sand.

Given this, it appears that HSPF parameterization could be improved by a more detailed analysis of the physics associated with sediment transport in each impoundment as well as by a more site specific analysis of the biogeochemical processes in Conowingo Pond. Integral in this latter analysis, for Conowingo Pond, is the need to improve the compatibility between various bioreactivity constituents (G1, G2, G3) from HSPF to WQSTM.

In order to enhance the Phase 6 HSPF model and address some of these potential limitations, Exelon proposes to implement a two phased modeling approach of the Lower Susquehanna River Reservoir System. Phase I of this approach is to develop a HEC-RAS model to evaluate sediment transport through Lake Clarke and Lake Aldred. The HEC-RAS model will update and improve sediment loading predictions from the upper two reservoirs to Conowingo Pond compared to those based on the work summarized in the Langland and Koerkle, 2014 report *"Calibration of a One-Dimensional Hydraulic Model (HEC-RAS) for Simulating Sediment Transport through Three Reservoirs in the Lower Susquehanna River Basin, 2008-2011."* The output from the HEC-RAS model will be used to develop sediment vs. flow rating curves at Safe Harbor and Holtwood Dams which will then be used to re-parameterize HSPF. The re-parameterized HSPF output will then be used as input for Phase II – the Conowingo Pond Mass Balance Model. Recognizing that sediment dynamics and hydraulics in the Lower Susquehanna River Reservoir System are currently represented within HSPF at a somewhat simplified level, due to model limitations, the proposed modeling approach whereby sediment rating curves will be used to estimate sediment influx will provide an improved understanding of the system and its complexities by more explicitly addressing the physics of sediment transport.

Phase II of the proposed approach will consist of developing a coupled hydrodynamic, sediment transport, sediment nutrient flux and water quality mass balance model for Conowingo Pond (CPMBM). This model will provide detailed representations of processes that affect sediment and nutrient transport through the Pond by simulating sediment loads, nutrient loads, and nutrient bioreactivity. The output from this model will be used to enhance the input parameters for WQSTM to aid in the Bay TMDL reassessment efforts.

Although this is proposed as a two phased modeling approach, due to the tight scheduling requirements of the Midpoint Assessment, work on each model will occur simultaneously. Once the new HEC-RAS model has been calibrated and completed, the re-parameterized HSPF model will be used as the final sediment loading input dataset.

The methodology and schedule for each modeling effort are discussed below.

2.1 Lake Clarke and Lake Aldred HEC-RAS Modeling

WEST Consultants, Inc. (WEST), on behalf of Exelon, will develop a HEC-RAS model of Lake Clarke and Lake Aldred using HEC-RAS 5.0 (Beta). WEST has extensive experience in sediment transport modeling and are also contractors to the Hydrologic Engineering Center of the Corps. The enhanced HEC-RAS model will be used to update and improve sediment loading predictions from the upper two reservoirs to Conowingo Pond compared to those based on the work summarized in Langland and Koerkle, 2014. Table 1 provides a side-by-side comparison of the HEC-RAS model version used in Langland and Koerkle, 2014 as compared to the HEC-RAS model version to be used for this effort.

Table 1 – HEC-RAS Model Comparison, 2014 vs. 2016

Item	USGS *(Langland & Koerkle, 2014)*	Exelon
Model	HEC-RAS 4.2 Beta	HEC-RAS 5.0 Beta
Hydrographs	Quasi-unsteady flow	True unsteady flow
Calibration Period	2008-2011	2008-2013[2]
Verification Period	N/A	2013-2015
Simulations	Separate models for erosion and deposition	If possible, single model
Cohesive Soil Properties	One set for all soil groups	Individual set for each soil group
Inflowing Sediment	Suspended load only	Suspended load plus estimate of bed load

The upstream model boundary will be at the Susquehanna River at Marietta, PA USGS gage while the downstream boundary will be at Holtwood Dam. Digital terrain data from 1996/2008 (USGS), 2013 (Exelon) and 2015 (Exelon) will be reviewed and processed for model calibration and validation. Hydrologic data will be processed into the correct format to be used as model input, as will sedimentation data. The Langland and Koerkle, 2014 HEC-RAS model will be reviewed and elements of it used as applicable. The model will be created using 1996/2008 bathymetric data and the hydraulics will be verified for different steady flow rates.

[2] The Exelon modeling team has had preliminary conversations with MDNR, MDE, and CBP regarding expansion of this time period back to 1996. At this time the Exelon modeling team is still examining the feasibility of such an adjustment.

The downstream boundary condition will be stage at Holtwood Dam where a rating curve will be developed relating flow and stage at that location. Later, the model geometry will be modified as necessary to accommodate unsteady flow modeling. The upstream boundary condition will be changed from steady flow to a flow hydrograph in order to switch from steady flow to unsteady flow modeling. The initial hydrograph for debugging will be a steady flow rate but this will later be changed to the discharge as measured at USGS Gage 01576000, Susquehanna River at Marietta, PA.

After the model is running satisfactorily for fixed bed conditions, emphasis will be placed on modeling mobile bed conditions (i.e., sediment transport modeling). Sediment gradations will be input from existing information including both the Langland and Koerkle, 2014 model and core samples collected by the USGS in 2000. Sediment rating curves (amount of inflowing sediment for given flow rates) will be developed for the upstream boundary at Marietta using USGS suspended sediment information and estimating an additional bedload component.[3] Inflowing sediment loads for the Conestoga Creek and Pequea Creek tributaries will also be developed based on USGS gage information. Contributions from other tributaries are unquantified but are expected to be minor and therefore will not be modeled.[4] Shear stress parameters needed for cohesive sediment modeling will be developed based on the SedFlume data derived from samples at Conowingo Pond. Analysis of these samples critical shear stresses and their variation as a function of gradation and density will be used to assign parameters to bed sediments at Lake Clarke and Lake Aldred with similar characteristics.

The model will be run with unsteady sediment transport for the period 2008-2013. Model calibration will consist of adjusting input parameters such that the computed scour or deposition within the period reasonably matches the computed volume change based on bathymetry measurements at the beginning and end of the same period. Afterwards, a verification period simulation will be performed from 2013 until 2015 and again, the computed change in volume from scour and/or deposition will be compared with similar volume change estimated from measured bathymetries. Based on the calibrated and verified models, a sediment rating curve (sediment flow by grain size class versus flow rate) will be developed at Holtwood Dam.

The sediment rating curve will be provided to the CBP from which the HSPF model can be re-parameterized based on the sediment loads predicted from the HEC-RAS model. Outputs from the re-parameterized HSPF model at Holtwood Dam will be used as the input parameters for the CPMBM. WEST will coordinate with HDR and fine-tune the model, if necessary, to obtain better calibration with estimated sediment outflows at Conowingo Dam based on measurements there.

As discussed in Section 2.2 below, HDR will perform a series of up to nine (9) storm-event model simulations. WEST will prepare production run models to estimate sediment outflow from Holtwood Dam for inclusion in the HDR model (either directly or via re-parameterization of the HSPF model, if time allows). At this time, it is anticipated that production runs will be executed for storm-events of three (3)

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[3] The Exelon modeling team will review the following datasets to determine which is the best input dataset for the model: 1) HSPF inputs at Marietta, 2) WRTDS inputs at Marietta, or 3) sediment rating curve based on USGS measurements at Marietta.

[4] The Exelon modeling team will review HSPF tributary loads for tributaries which are included in the Watershed Model to determine if their inclusion in the HEC-RAS model is warranted.

magnitudes of flow: 400,000 cfs, 700,000 cfs, and 1,000,000 cfs. Additionally, WEST will coordinate with HDR and fine-tune the model if necessary such that the WEST model sediment outflows from Holtwood Dam will allow the HDR model to obtain better calibration with estimated sediment outflows at the Conowingo Dam.

2.2 Conowingo Pond Mass Balance Modeling

HDR, on behalf of Exelon, will develop a coupled hydrodynamic, sediment transport, sediment nutrient flux and water quality mass balance model for Conowingo Pond. This model (the Conowingo Pond Mass Balance Model or CPMBM) will allow for an improved evaluation of the extent to which storm related scour and associated nutrient loads from within the Pond affect sediment and nutrient delivery to the Bay. This modeling effort would also provide information to help the CBP TMDL team refine its evaluation of water quality impacts in the Bay. In particular, output from the model will help inform HSPF concerning the magnitude of solids and nutrients, as well as the bioreactivity of those nutrients, that deposit during low flow periods and potentially re-suspend or erode from the Pond during high flow (>400,000 cfs) events on the Susquehanna River.

Hydrodynamic and sediment transport components of the overall model will be constructed using the Estuarine, Coastal, and Ocean Model (ECOM) (hydrodynamics) and its Sediment Transport Ziegler, Lick, and Jones (SEDZLJ) module (sediment transport) ("ECOM/SEDZLJ" hereafter). ECOM/SEDZLJ is used to simulate water velocities, depths, and shear stresses within the water column and on the sediment bed. In combination with information detailing grain size distributions and erosional characteristics of bed sediment, SEDZLJ uses hydrodynamic velocities and shear stresses to simulate erosion and depositional processes, bed consolidation, and transport through the water column for a wide mixture of particle types. As a function of particles size and shear stresses, sediments can be transported as suspended load or bed load. SEDZLJ uses SEDflume data to characterize erosion characteristics.

Water quality components of the overall model will be constructed using the Row, Column, and Advanced Ecological Simulation Program (RCA) water quality model and its integrated sediment flux sub-model ("RCA/SFM" hereafter). Nutrients and dissolved and particulate organic matter transported through the water column will also interact with the sediment bed. RCA/SFM can be used to simulate the full suite of nutrients and organic matter to assess water quality in terms of eutrophication and sediment diagenesis. This includes state-variables to describe carbon (C), nitrogen (N) and phosphorus (P) cycles. Decomposition or diagenesis of particulate organic matter (C, N, and P) in the sediment bed is a primary factor that drives biogeochemical cycling of nutrients in the bed of the Pond. In RCA/SFM, organic matter is divided into three pools of differing reactivity: (1) labile (highly reactive, time scales of several weeks) (G1); (2) refractory (much less reactive, time scales of several months) (G2); and (3) effectively inert (largely non-reactive) (G3). The "G" notation is based on a RCA/ SFM that also considers sorption of dissolved inorganic phosphorus and ammonium to bed solids and additionally represents enhanced sorption of dissolved inorganic phosphorus to iron oxides in the aerobic layer of the sediment bed.

RCA/SFM also considers nitrification of ammonium to nitrate in the aerobic layer of the bed and denitrification of nitrate to nitrogen gas in the anaerobic layer of the bed, as well as fluxes to the overlying water column and burial of sorbed ammonium to the deep sediment bed. The nitrification/denitrification process can represent a significant loss mechanism of deposited particulate organic nitrogen from the system. Inorganic phosphorus on the other hand has no loss pathways other than burial to the deep sediment bed or diffusive flux to the overlying water column. Finally, RCA/SFM considers production of H_2S and CH_4 as the result of the diagenesis of organic carbon in the absence of oxygen and depletion of porewater nitrate and sulfate due to oxidation/reduction processes.

GRID DESIGN

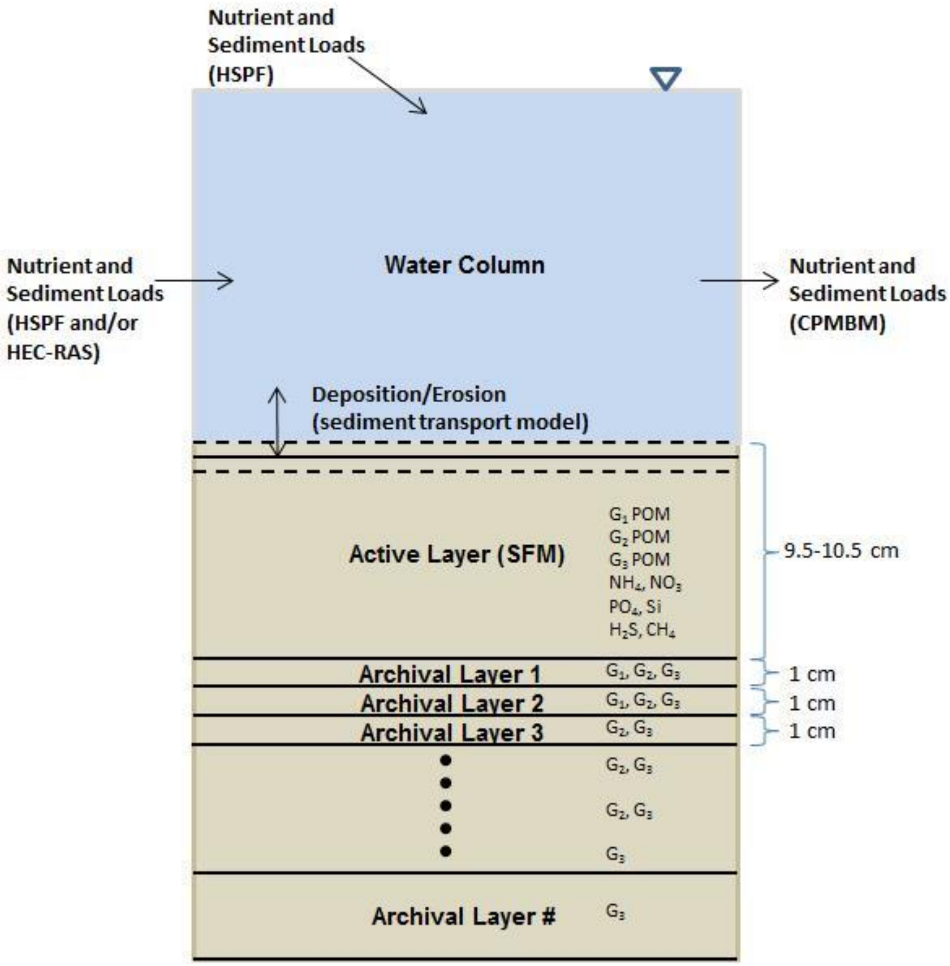
A curvilinear, orthogonal grid will be developed to resolve hydrodynamic and sediment transport features of the Pond, such as velocity gradients and erosion or deposition zones along the bed. The model domain will extend approximately 15 miles (24 kilometers), from Holtwood Dam upstream to Conowingo Dam downstream. Pond widths vary between approximately 2,100 meters (6,900 feet; 1.3 miles) to approximately 480 meters (2,600 feet; 0.5 miles). Mid-channel water depths throughout the Pond vary from approximately 6 meters (20 feet) to 30 meters (100 feet).

Cell lengths and widths will vary in the curvilinear grid. In general the pond will be segmented into approximately 50 to 75 rows of cells from upstream to downstream and have approximately 10 to 20 columns of cells across the Pond (with fewer in narrow areas and more in wider areas). HDR assumes that three-dimensional hydrodynamic calculations will be performed and that the grid will have five to ten vertical sigma layers to represent the water column. With 10 sigma layers, and assuming an equal depth distribution of the sigma layers, each layer represents 10 percent of the total water depth at each location. To reduce computation effort, HDR will also explore use of 5 sigma layers. Initial data review suggests that use of fewer sigma layers may be reasonable given the general absence of thermal stratification.

There is a tradeoff between grid cell size and computational effort to perform model simulations. Smaller grid cell sizes provide greater spatial resolution but require greater computational effort (i.e., longer model run times) because the maximum timestep that can be used for numerical integration will be smaller. Model timesteps are controlled by the volume of the smallest grid cell and the maximum velocity through that cell. For planning purposes, a grid with these approximate dimensions (420 meters long, 115 meters wide, and 9 meters deep) would require a timestep of approximately 1-2 seconds for velocities that could occur during a very high flow event of 1.13 million cfs (32,000 cms), which is approximately the flow rate that occurred during Hurricane Agnes. The goal is to generate a model grid that provides sufficient spatial detail while allowing hydrodynamic and sediment calibration simulations to be completed in fewer hours of computer time.

The RCA/SFM water quality model and sediment flux model will be coupled to the hydrodynamic and sediment transport model, using information for water elevations, flows and mixing coefficients, and temperature from the hydrodynamic model and settling rates, deposition and resuspension rates, and changes in bed elevation and composition from the sediment transport model. RCA/SFM will use the same grid resolution as employed in ECOM/SEDZLJ for the water column. In the sediment bed, the SFM portion of the model will be vertically segmented and will use a 10-cm thick active surface layer where biogeochemical reactions and bioturbation occurs and a “archival stack” of approximately 300 1-cm thick slices (3 meters) (Figure 1) that will store a record of G1, G2, and G3 pools and corresponding concentrations of ammonium, nitrate, and inorganic phosphorus and H_2S and CH_4. Organic matter and nutrients are “pushed” or moved down into the archival stack during depositional events or periods and moved up from the archival stack into the active layer and the overlying water column during erosion events. In this manner, the SFM builds a sequence of conditions for the bed that are coupled with corresponding changes of sediment bed elevations that occur in the sediment transport model.

Figure 1 – Vertical Segmentation of Sediment Bed in the SFM Model



STATE-VARIABLES

The hydrodynamic model state-variables are water depth, temperature and velocity, as determined by governing equations for continuity (conservation of mass) and momentum. For the planning purposes of this proposal, the sediment transport model will have four state-variables to express concentrations of coarser sand, finer sand, silt, and clay. State-variables in the sediment transport model will be subject to refinement as particle size data are reviewed and further consideration is given to cohesive characteristics of sediment transport. The water quality model will have a series of state-variables to express different organic and inorganic forms of nitrogen, phosphorus, and carbon and transformation rates between different forms of each constituent within the sediment bed. With these state-variables, the coupled hydrodynamics, sediment transport, sediment nutrient flux and water quality mass balance model will simulate sediment and nutrient loads and the relative reactivity of organic matter (C, N, P) transported out of the Pond.

State-variables in the coupled ECOM/SEDZLJ – RCA/SFM framework are generally consistent with those used by WQSTM. This will provide a more consistent basis to parameterize sediment and nutrient loadings to WQSTM and will reduce or eliminate assumptions regarding processes within the Pond that are presently embedded in the coupling between HSPF and WQSTM. However, HSPF state variables differ from those in ECOM/SEDZLJ – RCA/SFM (and WQSTM). Upstream loads and boundary conditions described in terms of HSPF state variables will need to be mapped to those used in ECOM/SEDZLJ – RCA/SFM. If due to logistics, schedule, or other factors, complete Phase 6 watershed model outputs are not available to the Exelon team, loads for the CPMBM would be specified from the enhanced HEC-RAS model for sediment and the HSPF watershed model for nutrients.

BOUNDARY CONDITIONS, FORCING FUNCTIONS AND OTHER DATA

The proposed model will use upstream flows, solids loads, and nutrient loads at Holtwood Dam and from the tributaries that discharge directly to the Pond as estimated by the re-parameterized HSPF watershed model. In concept, HSPF is calibrated to measurements at the Marietta, PA monitoring station and at other points in the watershed and accounts for differences in transport between Marietta and the upstream limit of Conowingo Pond. However, additional data analysis will be needed to specify factors needed to completely determine model boundary conditions and forcing because the state-variables in HSPF do not have a one-to-one correspondence to state-variables in the proposed model for the Pond.

Upstream solids loads (i.e., loads at the face of Holtwood Dam at the upstream limit of the Conowingo Pond model) from HSPF will be fractionated into loads for each solids size class in the sediment transport model based on data collected at Marietta and tributaries, including grain size measurements for the period May 2014 through April 2015. Upstream nutrient and carbon loads would be based on values from HSPF and separated into loads for each state-variable in the water quality model based on analysis of data collected at Marietta. For example, recent data at Marietta include measurements for unfiltered and filtered forms of nitrogen (nitrate + nitrite + ammonia + organic-N) (dissolved, particulate) and similar measurements for phosphorus and organic carbon. Similarly, solids loads for the surrounding watershed would be fractionated into loads for each solids size class in the sediment transport model based on data for Conestoga and Pequea Creeks. Additional inferences regarding grain size distributions for upstream and watershed loads may be drawn from sediment cores collected from the Pond.

For the hydrodynamic model, downstream boundary conditions will also need to be specified. In particular, it will be necessary to specify flow leaving Conowingo Pond via hydropower generation (i.e., withdrawals through the turbines) and rating curves to represent spill over the dam as controlled by gates along the dam headworks or from other available data sources.

Other information to define conditions in the sediment bed will be determined from a number of other sources. For the sediment transport model, particle size distributions, erosion characteristics, and other bed properties will be defined based on SEDflume data presented in Attachment B-2 of Appendix B of the LSRWA report (Scott and Sharp, 2014). The assessment of bed properties may be iteratively refined during calibration by mapping spatial distributions of bed properties in conjunction with patterns of bottom shear stresses calculated by the hydrodynamic model.

Settling speeds for each solids class in the sediment transport model will calculated based on sand particle sizes using standard equations for non-cohesive particles (Cheng, 1997)[5], other literature

[5] Cheng, N. S. 1997. Simplified Settling Velocity Formula for Sediment Particle, Journal of Hydraulic Engineering, American Society of Civil Engineers, 123(2):149-152.

sources for any finer, cohesive size classes, and settling tube tests being conducted by UMCES as part of the ongoing Integrated Monitoring Program.

CALIBRATION PROCESS AND SIMULATION PERIODS

The primary calibration variable for the hydrodynamic model is the coefficient of drag, which expresses frictional resistance (drag) exerted on a parcel of water as flow occurs. The balance between gravity and drag forces along the flow path determines the velocity and depth of flow. Drag coefficients are determined using a logarithmic velocity profile to describe how velocities change near a boundary. A minimum drag condition exists because some energy is lost to friction during flow regardless of water depth. As part of the hydrodynamic model calibration the minimum coefficient of drag ($C_{d,min}$) is set within a physically meaningful range to minimize differences between measured and simulated water depths (and velocities).

For the sediment transport model, calibration generally occurs by selecting erosion parameters (e.g., critical shear stress for erosion, erosion rates, etc.) from within ranges defined by SEDflume data and selecting effective particle diameters to define deposition parameters corresponding to the broad size classes used as model state-variables (e.g., coarse sand, fine sand, etc.). Values for these sediment transport parameters will be set within ranges defined by measurements (or literature) to minimize differences between measured and simulated suspended solids concentrations and to capture trends, magnitudes, and spatial patterns of net sedimentation along the sediment bed as defined from bathymetric surveys over time.

A similar calibration process will be followed for the nutrient transport and sediment flux models. The key information will come from the hydrodynamic/sediment transport model, which will determine deposition and erosion of organic matter and sorbed nutrients and corresponding burial within the sediment bed. Calibration or model skill will consist of comparison of model computed sediments and nutrients against observed sediments and nutrients discharged from the Pond through the powerhouse and spill gates. In addition, comparisons of model computations against observed flux data and pore water and solid-phase chemistry from cores collected and analyzed as part of the ongoing UMCES research project will be made.

Initial model calibration (diagnostic simulations) will be performed for the period 2008-2013/2014. This period includes bathymetric surveys and data for more parameters required by the model than any other period for which measurements are reported. Although measurements exist for 2014 and 2015, these data may not be directly used for calibration purposes because the CBP will be running the HSPF watershed model only through 2014. Selection of the ending date will be determined by the end-date used in the HSPF modeling effort. In either case, these most recent data will be used to help guide development of model inputs (e.g., rating curves for suspended sediment grain size) and for qualitative calibration purposes.

Longer-term model simulations (prognostic simulations) will be performed for the longest period practical to provide a more reliable basis estimate of the proportion of particles, nutrients, and organic matter associated with the G1, G2, and G3 pools in the sediment bed. If practical from the perspective of model calibration and the computational effort required, the ideal case would be to perform long-term simulations for the 1990's through 2013 period to confirm the long-term (decade+) behavior of the sediment transport model.

Because of the different rates at which different processes occur and the timeframes over which they can be measured, it may be necessary to adjust model parameterizations determined for the calibration period to better reflect long-term processes that cannot be well-defined during short-term simulations. For example, model performance for net sedimentation patterns within the Pond may be more realistically evaluated over the course of a long-term (e.g., decadal) simulation rather than a shorter period. As such, longer-term simulations will provide a check on model performance beyond evaluations based on a short-term calibration. Any adjustments to parameters will ensure that model results are consistent with measurements and yield meaningful long-term results.

MODEL RUNS

To assist in evaluating the potential resulting impacts of storm events, if any, on Bay water quality from sediment and nutrients entering Conowingo Pond from upstream sources, scouring from sediment behind Conowingo Dam and passing through the Dam the Exelon team envisions conducting the following model runs in collaboration with CBP and Corps modelers:

1. Base case model calibration/confirmation run for the period of record – 1984-2014 using Phase 6 HSPF with the CPMBM included. This run will be analogous to run LSRWA_4 as noted in Appendix C of the LSRWA. Output from this run will be provided to the WQSTM;
2. Phase 6 HSPF 2010 TMDL loads with the CPMBM included for the period 1991-2000. This run will be analogous to run LSRWA_3 as noted in Appendix C of the LSRWA. Output from this run will be provided to the WQSTM
3. Phase 6 HSPF 2010 TMDL loads with the CPMBM included for the period 1991-2000 but with Conowingo Pond in a no scour condition. Output from this run will be provided to the WQSTM; and.
4. Phase 6 HSPF 2010 TMDL loads with the CPMBM included for the period 1991-2000 but with Conowingo Pond in a no scour and no deposition condition. Output from this run will be provided to the WQSTM

In addition to the four (4) model runs listed above, HDR will also perform a series of up to nine (9) management simulations for combinations of storm event flow and loading conditions. At this time, it is anticipated that the storm-events will include three (3) magnitudes of flow: 400,000 cfs, 700,000 cfs, and 1,000,000 cfs. The final determination on the magnitude of flows to be examined will be determined at a later date in cooperation with MDNR, MDE, and CBP. For each storm-event flow case, HDR will run for up to three (3) different sediment and nutrient loading scenarios. The range in nutrient loading conditions will be made in consultation with the CBP. Results from these runs will be provided to the CBP and the Corps for use in the WQSTM. For the CBP's use in other modeling efforts, additional runs may be performed as part of the Midpoint Assessment.

3.0 SCHEDULE & REVIEW

Exelon's proposed modeling enhancements were presented at the January 13-14, 2016 STAC Workshop and again at the January 20, 2016 CBP Modeling Workgroup Quarterly Meeting. This work plan was then circulated to STAC and the CBP Modeling Workgroup for review and comment.

The Exelon team anticipates having a completed HEC-RAS model by the second week of February. The draft report will then be finalized and submitted for review by the CBP, MDNR, MDE, Exelon, and an independent peer review. Following review of all comments the final HEC-RAS model will be available by the end of February 2016 (depending on the significance of the comments) with the final HEC-RAS report available by early March 2016.

The CPMBM approach and methodology will be presented by the Exelon team at the STAC Workshop January 13-14, 2016. In order to meet the scheduling milestones associated with the 2017 TMDL Midpoint Assessment, a fully calibrated model and all production runs will be completed by the end of the first quarter 2016. The Exelon team will prepare a final report detailing model development, parameterization, simulation results, and skill assessments (i.e., comparisons of measurements and model results). Results of data analysis efforts will also be incorporated into the report, as appropriate, to characterize model performance. The final report will be available in early April 2016.

The Exelon team will work closely with the CBP Modeling Workgroup and Corps modelers throughout this process to ensure that all parties are in agreement on the methods used, deliverables provided, and implementation of results into the suite of CBP models (specifically Phase 6 CBP Watershed Model and WQSTM). In addition, all modeling efforts and reports will be subject to review by an independent modeling evaluation group. The proposed model evaluation group will be selected and agreed upon by MDNR, MDE, CBP, and Exelon. The modeling evaluation group will review the modeling methods, results, and reports and provide feedback and comments as appropriate. All comments provided by the evaluators will be taken under advisement by the Exelon team. In addition, the Lower Susquehanna River Reservoir System modeling enhancements proposed herein will also be subject to a separate STAC peer review.