Modeling Workgroup (MWG) Quarterly Review

October 17, 2023

Event webpage: Link

This meeting was recorded for internal use only to assure the accuracy of meeting notes.

ACTION ITEMS

- **Gary Shenk will email Jeremy Hanson and CC Bryant Thomas to raise the topic of how to prioritize which uncertainties to address with the tools available. Gary and Bryant will ask Jeremy for time at the WQGIT to discuss which categories of uncertainty are most important to decisionmakers, so there is ample time to inform the calibration and application of uncertainty quantification in tools like CalCAST.**
  - **Status: In progress. Small group meeting scheduled.**
- **When completed, Isabella Bertani will share the list of stations and relevant criteria identified in the Water Quality Data Portal processing methodology with state monitoring agencies and other monitoring organizations. Monitoring agencies and organizations will be asked to review the criteria and list of stations. Monitoring agencies and organizations should let Isabella know if any qualifying stations are missing from the list.**
  - **Status: Not yet ready to begin.**
- **The optimization team will work with Lew Linker and Dave Montali to develop and roll out their 2024 optimization webinars.**
  - **Status: TBD.**
- **Carl Cerco, with the help of Tish Robertson and Vamsi Sridharan, will explore two more analyses of the data Carl has presented on the algal growth curve topic. Then an interim decision on the temperature optimum for the summer blue-green algal group will be decided at the January 2024 MWG quarterly, which will stand until STAC can evaluate that decision in May 2024 at the Climate Change 3.0 Workshop.**
  - **Status: Analysis complete. Review in progress.**
- **Lew Linker will initiate a conversation with Gary and Gopal about how to ensure managers can move forward with a wave power-based shoreline erosion rate.**
  - **Status: Complete.**
- **Larry Sanford will send Richard Tian the list of locations with data for shoreline erosion.**
  - **Status: Richard has reached out to Jeff Halka about the protected shoreline data.**
- **Richard Tian will bring the operational questions pertinent to shoreline erosion to the MBM monthly team meeting.**
  - **Status: Complete.**
- **Lew Linker will ask Guido Yactayo and Dinorah Dalmasy about MDE's data on SSOs, with the purpose of informing the Patapsco MTM development.**
  - **Status: Complete.**

- **Nicole will set up a small group with Richard, Carl, and Lew to discuss next steps for the sensitivity runs of benthos bioturbation parameters.**
    - **Status: Unknown.**

10:00 Announcements and Amendments to the Agenda – Mark Bennett, USGS and Dave Montali, Tetra Tech

Summary

Dave and Lew reiterated the importance of having hybrid meetings going forward.

10:05 Introduction to AI within Watershed Management – Isabella Bertani and Qian Zhang, UMCES-CBPO and Mike Evans, Chesapeake Conservancy

This is a reprise from the recent STAC Quarterly on potential and actual application of artificial intelligence (AI) for watershed management. Among the specific applications discussed was the Chesapeake Conservancy's work on mapping wetlands and large solar arrays throughout the Chesapeake watershed.

Summary of Isabella Bertani's Presentation

Isabella's presentation focused on a broad introduction to artificial intelligence, machine learning, and deep learning. Isabella defined common AI terms (slides 3-6), categories of machine learning algorithms (slides 7-11), and what distinguishes deep learning (slides 12-14).

Summary of Qian Zhang's Presentation

Qian's presentation focused on a few illustrative examples of machine learning and deep learning methods present in the literature. Qian began with two examples of using supervised learning for regression analyses to predict salinity and chlorophyll-a, respectively (slides 4-5). Qian also provided three examples of using supervised learning for categorical predictions of biological condition, nutrient limitation and regional patterns and drivers of total nitrogen (TN) trends in the Chesapeake Bay watershed, respectively (slides 6-7, 9). Qian concluded with an example of unsupervised learning, which used clustering to identify regional patterns and drivers of TN trends in the Chesapeake Bay watershed (slide 8).

Summary of Mike Evans' Presentation

Mike's presentation was more narrowly focused on how the Chesapeake Conservancy has leveraged deep learning to utilize remotely sensing imagery to address environmental challenges. Mike provided a brief overview of remote sensing, and how deep learning convolutional neural networks, within the field of computer vision, has facilitated implementation of image segmentation techniques to classify pixels on the landscape. These developments have allowed the Chesapeake Conservancy to map solar arrays, quantify land use transitions over time, and predict future trends in solar arrays in the Chesapeake Bay watershed. Another application of these techniques has been using a long short-term memory (LSTM) model to map non-tidal wetlands across the entire

Chesapeake Bay watershed, greatly improving existing National Wetland Inventory maps.

10:45 Discussion of AI Applications for Watershed Analysis and Management

Summary

Lew said these are appropriate methods and tools for addressing CBP priorities.

Regarding the solar array application, Lew asked if we see this approach adopted in other parts of the country. Mike said other groups have put out similar models in different regions. Lew asked if a similar approach can be applied to wind energy development. Mike said with sufficient training data and time, nearly any land use transitions can be tracked across the landscape if it is a community priority, like solar in this case. Lew also asked if these land use transitions can be projected out to key management years, like 2035, 2045, etc. Mike said they utilized a Bayesian statistical model to analyze past trends to project out to future years, which can be utilized for specific target years.

Dave said on slide 14, the results for West Virginia had not identified any solar. Mike said this is notable, and as far as they can tell by confirming with the Energy Information Administration, no utility scale ground mounted solar arrays were in place in West Virginia as of 2021. Mike caveated that rooftop solar was not within the scope of this mapping effort.

Julie said the Climate Resiliency Workgroup (CRWG) and Land Use Workgroup (LUWG) are interested in tracking tidal wetlands over time. Julie asked if the wetland mapping also includes tidal wetlands. Mike said given the outdated data for nontidal wetlands, the GIT funded project has prioritized nontidal wetlands. However, the long-term goal of this work is to track tidal wetlands also. Julie said that is good news since the CRWG is interested in sea level rise and marsh migration, and these data products could be useful in creating an indicator for the climate adaptation outcome to identify current wetlands and then compare them to sea level rise projections. Mike said the team at Chesapeake Conservancy would like to utilize these methods for real time monitoring, but it depends on the temporal needs of these models. For example, there was a desire to use National Aerial Imagery Program (NAIP) data to map these wetlands, and that only comes out every 3-4 years. Mike said depending on resources and staff time, it could be feasible to update the marsh maps annually. Julie replied that an annual update would be excellent. Lew said the temporal component is a critical question for the MWG since the Sea Level Affecting Marshes Model (SLAMM) is essentially a bathtub model and it will be important to augment that with enhanced observations of current extent.

Kristin Saunders asked if we could train the model to find the best places to place solar that will also help protect vulnerabilities (for instance, direct solar growth toward already impervious surface and away from prime agricultural lands and forest areas, as an example). Mike replied that seems to be the question on everyone's mind. Mike is not sure that deep learning or AI would be the best approach to an intentional siting question because his understanding is that there are known 'rules' or practices that might decide

where we want to guide siting, in which case one would want to directly parameterize a spatial model to find those locations.

Scott Heidel said he is curious if buffers, cover crops, conservation tillage, etc. could also be detected for reporting purposes of BMP implementation. Mike replied that conceptually, finding those features is possible. It will depend on how many examples you have to train a model on, and how large they are. At some point, we lose the ability to distinguish very small features, even in 1 m resolution imagery.

George Onyullo said in the District of Columbia, it would be interesting to see what the model projects for future wetland extent given the rapid loss that has been observed. Mike said the team is not yet ready to project future conditions of wetlands, because they are still focused on mapping wetlands reliably and quickly. However, projecting future extent of wetlands is a long-term goal.

11:05 Phase 7 Watershed Model Overview – Gary Shenk, CBPO

Gary provided an overall summary of progress.

Summary

Gary began with a broad overview of the major components of Phase 7 Model development and the schedule, which can be tracked here. Last month, the modeling team brought on Joseph Delesantro as an EPA ORISE fellow to focus on inputs and sensitivity and Joseph has hit the ground running and is on track to make substantial improvements to the Phase 7 Watershed Model. Gary then gave a preview of watershed model presentations taking place later in the meeting.

11:15 Discussion of the Phase 7 Model Overview

Summary

Bryant Thomas asked Gary to describe how we will evaluate model uncertainty with Phase 7 development. This may be more of a question for the estuarine model, but it does apply to the entirety of the model applications. Gary replied that having a simple model gave us the opportunity to address uncertainty. Gary said in some ways we will be able to assess spatial uncertainty in CalCAST, but over the next few years we need to discuss what the managers want to do with that uncertainty so we can tailor our uncertainty calculations appropriately. We are developing the tools to measure uncertainty, but we need to understand the management application to hone the tools. Dave said this seems to be a reoccurring question. Gary said CalCAST will get to that spatial variability, but we need to make that connection to management applications. Bryant asked if an action item should be to go to the Water Quality Goal Implementation Team (WQGIT) to ask about questions of uncertainty to get started on this topic earlier. Gary said ideally this would be a joint action item between the CBP and a state partner. Gary will write an email to Jeremy Hanson to start the conversation and will include Bryant. Lew said Gary has been dealing with this question for most of his career at the CBP. There is an aggregate uncertainty problem across the suite of models, so it is critical to determine which questions of uncertainty are most relevant for managers.

Harry Wang said in the Patapsco, the main nonpoint nutrient loading source is urban stormwater. Harry asked if they have metropolitan city stormwater pipe loading. Gary said yes, they have estimates for stormwater and two separate ways of dealing with the source. If it is in a combined sewer, they are estimating all the loads coming from the combined sewer, some overflow, and some wastewater treatment. If it is not in a combined sewer, we have estimates of stormwater runoff from those areas. This is a part of Phase 6 and will be part of Phase 7 Watershed model too. Lew said Joseph Delesantro has experience with research in urban watersheds and the MWG is happy to have him on board. Joseph introduced himself and said in his first month, he has been learning about the program and focused on inputs and sensitivities for agricultural watersheds and will also look at urban watersheds.

11:25 Update on CalCAST Development – Isabella Bertani, UMCES-CBPO

Isabella provided an update on the development of a reproducible workflow to process water quality data in order to update and expand the calibration dataset for CalCAST and the dynamic watershed model.

Summary

Isabella began with a brief recap of the motivations for developing a reproducible workflow for processing water quality to serve as calibration data (slides 2-3). There are three major purposes for working on the water quality portal database: dynamic watershed model calibration and verification, CalCAST calibration, and other future applications like the machine learning request for proposals.

Isabella then explained in detail each step of the workflow for creating the reproducible water quality portal, which relied on standards established in the literature. This involved raw water quality data portal data processing and clean up (slides 7-8), raw USGS streamflow data processing and clean up (slides 10-11), USGS Streamflow gage matching for load estimation with water quality portal stations (slides 13-15), and the application of screening criteria for load estimation (slides 17-20).

Isabella provided some quick updates on CalCAST average annual TN predictions at current calibration stations (slides 21-22) and concluded with next steps (slide 23).

11:40 Discussion of CalCAST development

Summary

To clarify, Bryant asked if Isabella is using state-collected water concentration data to help with model calibration which would include the CBPs nontidal network, but also many additional regularly sampled stations. Gary confirmed this is correct. Bryant replied, “That's very good to hear.” Bryant asked if there is a list of the stations being used for calibration and verification. Bryant would like to see the list and share with his colleagues at VA DEQ, especially field staff. They will be glad to hear there is an additional use of the data being collected. Bryant said the trends monitoring stations may have use in the Bay model calibration or otherwise, which can be identified as a great co-benefit. Isabella said once this work is completed, the list will be distributed to

monitoring agencies so they are informed of which stations are being used and can let the modeling team know if any stations were missed.

Qian said this is impressive and important work on data compilation. For the example on streamflow data processing/cleanup (station 01488500), only the period that meets all the pre-established criteria is retained. Qian noted that station has only one or two years of gap. For the purpose of retaining as much information as possible, an alternative approach would be to keep the entire record, run WRTDS, and exclude load estimates for the few years around the gap where flow information is missing. Qian does not know how many "new stations" fall into this category. It may not matter much for eventual model calibration. Isabella replied it's definitely a good idea to retain as much data as possible for model estimation and then just remove estimates in years around gaps. It may not affect the number of stations substantially, but it may improve model estimates at individual stations if more data is used.

Dave said there is a lot of sampling going on in areas without flow data, so if that precludes the use of that data, we should say it up front to our partners. Norm Goulet agreed with this point. Isabella said yes, they will provide monitoring organizations with this information and other parameters up front when it comes to calibrating load concentration; however, the modeling team does not want to disincentivize the collection of monitoring data that might be useful for other purposes. Bryant said at this point it is probably too late to change monitoring stations for Phase 7, but it will be good to know.

Vamsi Sridharan asked if there is interest in expanding the calibration data curation to include guidance on how each curated dataset should be used? Based on experience developing hundreds of hydrologic, hydrodynamic and TMDL models, we may be able to contribute to such a process and would love to have an opportunity to work with you. Isabella said she is open to collaboration on this question and agreed to continue this conversation offline.

Mike Evans said this is fantastic and incredibly useful work! Mike asked if Isabella is planning to make her scripts available through GitHub or as an R package. Mike said cleaning data from the water quality portal is a major limiting step in a bunch of contexts and he imagines the tools Isabella developed would be of use to many. Isabella said she will make her R scripts available but does not currently have plans to make them into an R package.

Qian suggested once the data compilation is completed, a data release (like the USGS data releases) may be considered in order to make the data available to a larger pool of users. Robert Sabo and Lew endorsed this idea, saying it will be widely used and would be helpful as a citable reference.

Lew said this is a worthwhile project and Isabella has created a great product by leading this effort.

11:55 Progress in Phase 7 WSM Development – Gopal Bhatt, Penn State-CBPO

The NHDplus 100K scale Phase 7 Dynamic Watershed Model (DWM) prototype with simulations of hydrology, sediment, nutrients, water temperature, DO, and phytoplankton

is now operational for the entire watershed. The DWM is using a nested model segmentation of streams and rivers with a hybrid structure for the simulation of water quality processes using HSPF and Simple Routing models. During this quarter, progress was made on the implementation and testing of a simplified hydraulic routing scheme for the small NHDplus streams. Gopal surveyed the progress and results from the simple routing for hydrology and described activities upcoming in the next quarter.

Summary

Gopal began with an overview of the DWM, including its framework and purpose, which is to provide inputs for the estuarine models, facilitate watershed model calibration and scenario applications, and support research and collaboration activities.

Gopal then provided a summary of progress in prior model development (slides 5-7). Gopal paid particular attention to hydraulic routing for small streams, specifically channel hydraulic properties, conceptual model and simplifications, and model testing and verification (slides 8-18).

Gopal concluded with a brief summary of progress and the next steps for the Phase 7 DWM (slide 19).

12:25 Discussion of Phase 7 WSM Development Progress

Summary

Vamsi said Gopal may be already familiar with implicit time stepping schemes, but these can help tremendously with managing stable solutions for large timesteps with courant number greater than 1. Vamsi said with implicit time stepping (a variation of leapfrog), his team was able to achieve very large timesteps with courant number going into 7-10 range, and still keep solutions stable in this paper: "Sridharan, V. K., & Hein, A. M. (2019). Analytical solution of advection-dispersion boundary value processes in environmental flows. *Water Resources Research*, 55(12), 10130-10143." Gopal replied he has a copy of that paper and has read it. In the implementation of our non-iterative routing scheme, we started with something really easy and simple to see how it worked, and in that process what kind of assumptions were necessary, and tradeoffs in terms of numerical simplifications. We really hope to look into implicit schemes to see how it impacts run time and improvements gained by it. Gopal will follow up with Vamsi to discuss this further.

Joseph Zhang said besides implicit method, semi-Langrangian method can also bypass Courant condition. Vamsi said yes, semi-Langrangian could also help with ephemeral streams. Gopal replied they have not considered the semi-Langrangian method yet, but they will explore this going forward.

Guido asked if the geomorphon approach being used to derive the channel geometry has been compared with traditional methods to delineate a watershed using an elevation model. Gopal said there has been a number of field campaigns in different physiographic regions to collect different datasets for comparison, but he is not aware of comparing these methods. One method that has been used is the regression method, so Gopal said

this would be of interest to him and Peter Claggett. The MWG may be of help here because we have estimated these properties for these small streams, so hopefully this leads to some sort of evaluation. Gopal said he is very impressed by the quality of the data, especially the presence of data on ephemeral streams.

Guido asked about the computational time required to run Hydrological Simulation Program – Fortran (HSPF) in the traditional setting vs the simplified approach. Guido asked because HSPF is a very valuable product jurisdictions benefit from, and he wants to understand the resolution and running time. Gopal said the new simple routing is much faster than HSPF because it does not require iterative components to converge on a solution. Simple routing is about 3-4x faster than HSPF.

Lew asked about next steps for the DWM, specifically the representation in a generalized network. Lew said the hydrology is excellent and nitrogen will likely be straightforward, but it will likely be more challenging for sediment and phosphorus because they change their concentration by orders of magnitude depending on flow. Lew asked if simplified scour deposition approaches may be utilized. Gopal said some his early thinking is that machine learning will be useful in adding the needed information. DWM will be constrained by CalCAST, but the variability associated with flow is necessary. This will be a watershed model team discussion.

12:30 LUNCH

1:00 Development of Efficient Multi-Objective Optimization Procedures - Gregorio Toscano Pulido, Kalyan Deb, Pouyan Nejadhashemi, and Hoda Razavi, MSU

Progress since the June Quarterly in the development of efficient multi-objective (MO) optimization procedures including replicating the study with the rest of the BMPs was presented.

Summary

Pouyan began with an overview and timeline of the project. Pouyan walked through the team's efforts to validate the re-optimization of West Virginia, before moving to an exploration of innovization strategies beyond West Virginia, specifically looking at Virginia data. Pouyan provided the framework of multi-criteria decision-making to organize this approach. Pouyan concluded with next steps for the optimization team, which includes the development and release of the 2024 optimization webinars.

1:20 Optimization Discussion

Summary

Regarding the inefficiency of manure transport of TN, Dave asked if a similar relationship would also hold for phosphorus in communities with an excess of manure. Pouyan said that in Nelson County, there is not a lot of manure developed and the neighboring counties have an excess of manure. In the CAST system you see more nitrogen in the system because of this. Dave agreed with this for nitrogen, but there are different conditions for phosphorus. Kalyan said these are the kind of questions we are

interested in now, so if there is a different state where manure will play a bigger role, we should explore that. The results presented today were optimized for nitrogen, so while many of the BMPs also had benefits for phosphorus and sediment, there were some minor tradeoffs. We will run separate optimizations for phosphorus and sediment too.

Dave asked how the optimization team categorized the forest buffer, fence pasture, and grassland buffers in the land use. Pouyan said they have a dedicated table that organizes the 206 efficiency BMPs and the remaining 90 are split into three categories. Olivia said the BMPs Dave talked about have two components: land use change and efficiency, but one cannot be implemented without the other for the examples Dave gave.

Olivia asked was the step checking land conversion vs. efficiency based on land use or across land uses. This question was not answered.

Lew said because of computational limitations, the optimization effort is split into multiple steps, which innovization represents. Lew asked for clarification on how this approach is implemented. Pouyan said innovization is about learning from optimization. In the first round, the hypothesis was that BMPs were going to be very different in urban vs. agricultural areas. The two top counties in urban and agriculture were compared on a pareto front with different ranking strategies. If one wants to pick the top ten BMPs, they can look at the highest implementation area, the maximum allowable BMPs, ot the cost of nitrogen. There are 990,000 combinations for optimization, so AI is needed to evaluate the combinations and understand universal applications. We looked at Nelson County to determine if we can group counties based on the combination of load sources using cluster analysis. These leads to four different methods to optimize the results. No other environmental optimization efforts are comparable in scope, so we are still building the plane while flying it.

Robert Sabo said he has some concerns about the take home message for manure transport, given the low numbers of animals in Nelson County. Robert said in terms of uncertainty, would it be possible to include error bars on those plots since those BMPs are attempting to attenuate and are essentially a roll of the dice. That is compared to reducing nutrient inputs directly via a nutrient management plan or manure transport. Pouyan said one next step is incorporating the uncertainty into optimization. CAST does not generate an uncertainty output, but we can add that by running 11 scenarios to determine an uncertainty band. You can take the median of simulations. Kalyan said uncertainty handling is critical in optimization. We need to understand the source of uncertainty. If core-CAST can provide uncertainty we can leverage that, but if not, we can look for uncertainty in implementation of BMPs, which can be handled with probability distributions. We would need to use a Monte Carlo simulation to get a sense of the variance by calling core-CAST many times. These are some of our next steps. Pouyan showed a figure plotting the uncertainty of the optimization algorithm with cost and load, which utilizes a stochastic model. This means with less run time, there is more variance.

Bill Keeling said manure is not managed at a county scale but at the farm scale. Bill does not understand the logic of applying animal and manure BMPs in a county that is animal and manure poor. Pouyan said he will respond to this comment offline.

Lew said we have 2024 and 2025 to bring the CBP up to speed on the optimization approach, and 2026 to make the CBP competent in using the optimization tools. The webinars will be essential to do this.

1:30 **Integrated Source Apportionment Method Analysis of Atmospheric N-Deposition – Gopal Bhatt, Penn State-CBPO; Jesse Bash, ORD-EPA; and Gary Shenk, CBPO**

Sarah Benish, Jesse Bash, et al. developed estimates of emission source contributions to N deposition for the Chesapeake Bay airshed using Community Multiscale Air Quality (CMAQ) model v5.3.2 with Integrated Source Apportionment Method (ISAM). CBPO has been reanalyzing that data in conjunction with CAST data for its potential management applications. The presentation surveyed the progress on this integrated analysis along with a few example applications using plausible *what-if* scenarios.

Summary

Gopal began with an overview of the CMAQ-ISAM domain used to estimate nitrogen deposition to the Chesapeake Bay airshed based on sources and the receiving geographic regions.

Before comparing ISAM results with CAST, Gopal reviewed the results of CAST-19 for TN inputs and delivery to the Chesapeake Bay watershed. Gopal then presented an integrated analysis of CMAQ/ISAM and CAST budget for the atmospheric nitrogen emission/deposition/delivery. Gopal broke out ammonia deposition to the Chesapeake Bay watershed by source and region. In a series of bar and pie charts, Gopal identified the total delivered pounds by sector to the watershed and tidal areas, in addition to deposition, for the northeast, central, and Chesapeake Bay airshed regions.

Gopal walked through a few what-if scenarios, such as if the on-road nitrogen emissions were cut in half or the electrical generating unit nitrogen emissions were cut in half (slides 12-13). Gopal concluded by comparing these what if scenarios on slide 14.

1:50 **Discussion of ISAM Analysis**

Summary

Lew shared that the modeling team is already involved in talks with energy-environment modelers to build on this work. The results on slide 14 also show the promise of these reductions, which should be very helpful in the year of review (2026).

Robert Sabo said he is not particularly familiar with the Electrical Generating Unit (EGU) reduction scenarios, but in Illinois the large majority of the corn crop is grown with enhanced efficiency fertilizers, which have a mixed effect on ammonia emissions. Robert asked if Gopal has considered exploring these questions, in terms of the agricultural ammonia emissions reduction. Gopal replied that fertilizer emissions of ammonia and manure related emissions will definitely have an impact on delivery. These scenarios have not yet been run, but they will have a tangible impact on deposition and delivery. Gopal said what interests him is that these models are being put together for potential management application with respect to climate, so it is important to consider

additional factors like this. Robert replied it seems like there is potential to run a scenario, but it seems like it will have a substantial effect based on this data.

Gary Shenk said the scenarios presented are very much of interest, especially to managers. Gary said the MWG is charged with determining sensitivities for the Phase 7 models. This is not decisional right now, but Gary wanted to point out that sensitivities to emissions, delivery to the watershed, and delivery to tidal waters are what the MWG will put in the model.

Robert said Gopal might not being able to answer this question, but certain Bay states have pegged themselves to California emission standards and electric vehicle only sales mandate. Robert asked would states get credit for emission and nitrogen loading loss reductions or would this fall under federal responsibility? Lew replied the MWG will be directed on how to apply these policies by the WQGIT, so stay tuned for more information.

2:00 SWAT-C: A Watershed Scale Carbon Cycling Model - Xuesong Zhang, USDA-ARS, Hydrology and Remote Sensing Laboratory

Integrating field experiments, remote sensing, and process-based modeling to improve understanding and quantification of watershed scale carbon cycling.

Summary

Xuesong began with some rationale for this project, specifically the significance of agriculture-based greenhouse gas (GHG) emissions mitigation. Negative emissions technologies (NETs) are needed to scale up the capture and storage of carbon, but many existing efforts and models have an incomplete accounting of terrestrial-aquatic carbon fluxes since it neglects lateral carbon fluxes. The Chesapeake Bay is an ideal location to investigate this project's research aims given the ongoing restoration efforts, data availability, and opportunity to build in carbon considerations into the CBP's suite of models.

This model will be part of the Soil and Water Assessment Tool - Carbon (SWAT-C), which is well used. Xuesong walked through the terrestrial carbon module, cropland carbon fluxes, and soil organic carbon simulations. Xuesong explained they have used continuous measurements of particulate organic carbon and dissolved organic carbon in the Tuckahoe watershed to being exploring this question of terrestrial and aquatic carbon modeling, in addition to building on previous research in New York. Working with the MWG, the research team will scale up to entire Chesapeake Bay watershed using remote sensing.

2:20 Discussion of Chesapeake SWAT-C modeling

Summary

Lew said in some findings there is evidence of increased diagenesis and mineralization because of higher temperatures. Lew asked Xuesong to speculate on how forest carbon might change in consideration of higher temperatures and CO_2 leading to greater productivity but also greater diagenesis. Xuesong replied this topic is the cutting-edge

challenge of carbon cycling studies. Xuesong's strategy is to incorporate new data into the SWAT-C model to improve model fidelity. Xuesong stressed the need to collaborate with partners to ensure the model results are being utilized appropriately.

Gary commented that in a previous STAC workshop, it was requested that the MWG include carbon in its suite of models. Gary said how this work will be applied has not yet been determined in Phase 7, but it will likely involve a simplified version of C-SWAT. Kristin Saunders said the carbon sequestration information is important to several of the goal teams (habitat, fisheries, and climate for instance) and having a stronger nexus in CAST would be appealing to them as well as they try to get jurisdictions to focus on co-benefits implementation for multiple outcomes. Gary said there may be many paths to measuring these co-benefits.

Vamsi asked if the SWAT-C application have the capacity to incorporate wetland and SAV interception of nutrients and carbon? What, if any, is the mechanism for this? Xuesong responded they have a simplified version of wetland volume and are trying to incorporate the NASA Wet-Carbon Modeling Group's model into C-SWAT, but this depends on future funding availability. In terms of SAV, Xuesong said they are trying to do more with SAV, besides the benthic algae they currently have in the model. Xuesong said this is not his area of expertise.

2:30 **STAC Workshop Report *Using Local Monitoring Results to Inform the Chesapeake Bay Program's Watershed Model* – Gary Shenk, CBPO**

Gary described the recently approved STAC workshop report *Using Local Monitoring Results to Inform the Chesapeake Bay Program's Watershed Model*.

Summary

Gary began with a review of the three uses of monitoring data in the CBP watershed model: calibration, comparison with trends, and knowledge generation. Gary walked through the recommendations for the CBP to consider:

- Include local data in model calibration.
  - Look for other established data sets.
- Compare with TMDL expectations.
  - Discuss policy changes to incorporate monitoring.
- Include as generalized knowledge, specifically new urban load sources.

There were also four recommendations for local networks to consider: design for BMP effectiveness, identify new statistical tools, expand existing programs, and consider climate change.

The overall conclusions were to:

1. Direct use of more monitoring data in calibration.
2. Perform a more meaningful comparison of output.
3. Ensure better design and methods for watershed studies to produce generalizable knowledge.

2:45 Discussion of STAC workshop report

Summary

Lew said the workshop was robust and there was consensus on the findings.

Norm Goulet and KC Filippino thanked Gary for presenting and said they are looking forward to the final report coming out. They also expressed their interest in how this new data will be used in the Phase 7 suite of models.

2:55 Introducing the Patapsco MTM Team – Lew Linker EPA-CBPO, Harry Wang, VIMS and Jeremy Testa, UMCES

The Patapsco/Back MTM Team, one of the three MTMs supported by a five-year grant, was presented and the work plan was discussed. The CBPO will also support two in-house MTM teams for the James and Potomac.

Summary

Lew provided a bit of background on why the Patapsco/Back Rivers were selected for a MTM, explaining that the watershed is highly populated, and the tributary is a major contributor of nutrient loading to the Bay when considering its relative flow.

Harry started the presentation by providing context on the current conditions and factors affecting water quality in the Patapsco/Back. This included physical characteristics of the watershed, typical loading sources, and the status and trends of water quality parameters.

Harry then walked through the model domain and structure, including the locations of monitoring stations. Harry said a major challenge that requires coordination will be linking the estuary model with the stormwater network of a major urban area.

Harry outlined the approach and tasks the Patapsco/Back MTM team will undertake (slide 11), before walking through tasks 3 and 4 in more detail.

3:10 Discussion of Patapsco/Back MTM

Summary

Lew said in terms of the river outputs, Jones Fall and Herring Run are well understood, as are all of the point sources. Urban stormwater will be more uncertain, as will be how to represent features such as the Inner Harbor artificial islands. Lew said overall, this work is well positioned to advance the science.

Dave said he believes there is an issue in Baltimore Harbor and this watershed with sanitary sewer overflows, and that this might be a confounding factor. Kristin Saunders said she thinks Dave is correct. There were issues coming in Jones Falls, Herring Run and Gwynns Falls as recently as 2018 and more recently. They are operating under a consent order extended to 2030 right now.

Lew said we do not have CSOs in this watershed, but SSOs are present. Gary said his recollection in loading all of the MTMs and the MBM is that Gopal will provide one output for every NHD catchment (roughly one square mile), and then each team will divide this output by the number of cells receiving those outputs. Gary said the

partnership decided back in 2009 not to include SSOs in the model. Lew explained this was because SSOs are considered to be illegal and episodic, so they did not want to include them in the model because there would not be an allocation for these loads. Gary said if there is partnership push back to this decision, this conversation can be revisited, which it looks like it will.

Bill Keeling said any SSOs loads are going to be considered nonpoint sources and therefore will not be treated by the BMPs. Norm confirmed this is correct and said the issue of SSOs has been around for a long time and was not included originally because of pushback on SSOs being illegal. KC Filippino said SSOs occur more frequently with increased precipitation. The Wastewater Treatment Workgroup (WWTWG) is looking for at-large members and will be up and running early next year she thinks.

Lew said it might be useful for MDE to consider allowing SSO allocations for the Patapsco/Back MTM.

Pete von Loewe and Vamsi have developed sediment transport modeling for looking at future climate impacts on toxics TMDLs in the Anacostia River, which was presented on the second day of this meeting. Pete is also developing additional sediment transport modeling for contamination remediation in the Potomac and Anacostia Rivers. Additionally, Vamsi and Pete will soon begin developing a DC Bacteria TMDL model, where will include such sources of sewer pollution. Vamsi said he looks forward to ways in which we may collaborate if possible.

3:20 ADJOURN

Participants: Alex Gunnerson, Alisha Mulkey, Anna Kasko, Arianna Johns, Ashley Hullinger, Bill Keeling, Breck Sullivan, Bryant Thomas, Carlington Wallace, Cassie Davis, Dave Montali, Doug Bell, Dylan Burgevin, Gary Shenk, George Onyullo, Gopal Bhatt, Gregorio Toscano Pulido, Guido Yactayo, Harry Wang, Helen Golimowski, Hassan Mirsajadi, Hoda Razavi, Isabella Bertani, Jeremy Testa, Jesse Bash, Jian Shen, Jian Zhao, Jonathan Leiman, Joseph Delesantro, Joseph Zhang, Julie Reichert-Nguyen, Kalyanmoy Deb, Karinna Nunez, Karl Blankenship, Katie Walker, KC Filippino, Kristin Saunders, Lew Linker, Mukhtar Ibrahim, Mike Evans, Nicole Cai, Norm Goulet, Olivia Devereux, Peter Tango, Pouyan Nejadhashemi, Qian Zhang, Rebecca Murphy, Robert Burgholzer, Robert Sabo, Richard Tian, Sam Merrill, Samuel Canfield, Scott Heidel, Sophia Grossweiler, Vahid Raiei, Vamsi Krishna Sridharan, Xuesong Zhang, Zhengui Wang.

MWG Quarterly Review

October 18, 2023

Event webpage: Link

This meeting was recorded for internal use only to assure the accuracy of meeting notes.

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9:00 Announcements and Amendments to the Agenda – Dave Montali, Tetra Tech, and Mark Bennett, USGS

Summary

Lew Linker provided a reminder of the upcoming CERF, NCER, and Chesapeake Community Research Symposium conferences.

9:05 Update on Main Bay Model (MBM) Progress – Zhengui Wang and Joseph Zhang, VIMS

Progress in the MBM development was presented.

Summary

Zhengui began with an overview of progress on developing the MBM, which detailed the issues resolved during model calibration. Zhengui then walked through the MBM set-up, specifically the physical, biological, and watershed loading components, plus the dissolved oxygen (DO) issue in the lower Bay.

Zhengui spent most of the presentation describing preliminary water quality results of the MBM (slides 7-25). This included examining common water quality parameters (salinity, temperature, DO, chlorophyll-a, dissolved inorganic nutrients, dissolved organic matter, and particulate organic matter) at both the surface and the bottom of the water column for multiple stations. The results from the new Semi-implicit Cross-scale Hydroscience Integrated System Model (SCHISM) framework were compared with the older Curvilinear-grid Hydrodynamics 3D Model (CH3D) framework.

Zhengui concluded with a progress report and next steps for the MBM team.

9:35 Discussion of the Main Bay Model (MBM) Progress

Summary

Lew Linker asked if the plots on slide 16 are showing all of the data or just the summer period. Zhengui replied the plots represent the entire data period. Values for just the summer are available on slide 15.

Lew said this presentation lays the groundwork for showing how this new Phase 7 MBM is as good or better compared to the Phase 6 MBM. Lew emphasized this model is the result of a large, collaborative team. Lew said as part of the next steps to be taken it will be important to include the atmospheric deposition loads for both Chesapeake Bay and the coastal ocean.

Carl Cerco asked about bottom temperature, noting how it is not accurate, and asked why it was attributed to water type. Joseph said it is related to light attenuation and heat transfer. Carl said it is hard for him to believe light attenuation is a driver of this. Carl said instead, it is likely the boundary condition is off by 2-3 degrees Celsius, and those discrepancies are propagating throughout the Bay, as demonstrated by the longitudinal plots. Joseph agreed and said the team will investigate this discrepancy. Lew and Carl asked if there were similar boundary condition issues with salinity. Joseph said he does not believe there is an issue with salinity and noted that the temperature and salinity boundary conditions come from different data sources.

Jiabi Du said there is an overestimate of surface DO and asked for the reason behind this. Joseph and Zhengui said this issue is on their radar and the team will be investigating this question. Carl suggested looking at how the team is calculating DO saturation to explore this further.

Richard asked about the temporal outputs of the MBM. Zhengui said they have both one-hour (station) and six-hour outputs (3-D space) for SCHISM. Richard asked which output is being used to calculate the statistics. Zhengui said the statistics depend on the methods being used. The observations data is bi-weekly, so Zhengui uses a two-day window of the nearest observations (temporally). Richard said the six-hour output is instantaneous.

Richard asked about the loading for the model. Zhengui said they use the watershed mapping polygons explained on slide 27.

Richard said a potential challenge down the line may be rerunning the physics to account for changes in sediment loading, with respect to SAV. Joseph said this is a great comment and suggestions from others indicate the sediment needs to be added in both the physics and biological steps. Joseph said it is not a perfect solution, but adding sediment into both steps will help.

Vamsi asked what the model resolution is compared to ICM, especially in the middle Bay, and along the Bay coasts. Joseph said SCHISM is finer than CH3D in both horizontal and vertical. SCHISM is unstructured so it varies across the channel. In important tributaries it is similar to the main channel, but in less important areas it is coarser. Lew asked if it would be fair to say SCHISM is an order of magnitude finer. Richard said the SCHISM grid is about five times finer than CH3D, in his estimation.

Vamsi asked if the MBM team has a way to disaggregate (at least get the sub-grid statistics) of the water quality parameters along the coastal cells. Vamsi asked because several fine scale projects such as marsh restoration and SAV replanting, rely on high resolution WQ data, and it would be nice to extract some sub-grid info from the model. Joseph said yes this is important and it is on the to-do list.

Harry Wang asked about the carbon levels on dissolved organic matter (slide 24). Harry said he was impressed by Xuesong's presentation the day before and recommended considering dissolved organic matter in a similar manner. Lew said in Phase 6 there was an organic carbon input from the Watershed Model, but it was based on observed organic nitrogen because organic carbon observations are rare in the watershed. Lew agreed much can be improved and the team will consider Xuesong's research.

Richard said the atmospheric deposition of nutrients is significant. Once it is added to the model, it can change the results. Richard suggested adding atmospheric deposition soon, even if it is a simplified value. Joseph said this is very high on the to-do list and it will be done next. Lew said Richard is right, atmospheric deposition comes in as nitrate and ammonia, so is very biologically active and has an annual loading rate of about 16 million pounds TN.

Dave asked if an updated MBM calibration will be presented in January 2024. Joseph said yes, an updated calibration will be presented then.

9:55 **Refinement of the Temperature Dependence of Algal Growth Rates in the MBM and Multiple Tributary Models (MTMs) – Carl Cerco, Arlluk Technology Solutions, LLC**

Carl wrapped up his examination of the shallow water monitoring data of continuous temperature and chlorophyll observations and other data sources for the purpose of refining the algal growth response to temperature in the MBMs and MTMs. The Modeling Workgroup was asked to decide how to apply the current understanding of how temperature effects algal growth rates in the Phase 7 MBM.

Summary

Carl began by describing the purpose of this exercise, which is to examine existing chlorophyll and temperature data for indications of temperature dependence. Carl, with the help of Isabella Bertani and Richard Tian, used three datasets (two continuous, one discrete; one from MD, one from VA, one from the CBP) totaling 27 stations to investigate the trends in chlorophyll *a* concentrations over warming water temperatures.

Carl noted that using scatterplots and box and whisker plots, chlorophyll *a* concentrations mostly drop off when the temperatures are in the 30-32 degree Celsius range, but there are few observations at these temperatures, so it is difficult to interpret.

Carl concluded with some recommendations (slide 29) and caveats (slide 31).

10:20 **Discussion of the Refinement of the Temperature Dependence of Algal Growth Rates**

Summary

Dave asked how the MWG will decide on this question. Lew emphasized that the MWG will follow the data. Lew said this will not be a definitive decision right now, but we do need guidance for our modelers because temperatures in the shallows will get to those low 30-degree Celsius levels. Lew reiterated the importance of providing guidance on this question to the MBM and MTM teams as they continue with their model development.

Tish Robertson said the continuous data plots make me think quantile regression might sus out some interesting patterns. Looks like the conditional 90th percentile distribution might "respond" a lot differently to temperature than the conditional 50th percentile distribution.

Vamsi wondered if a simple multiple linear or logistic regression with interaction terms for each location along the bay transect will tell you if there is an effect of other variables on chlorophyll *a* than temperature. This may also help figure out what the effect of temperature alone is likely to be everywhere.

Carl said he will write a memo to summarize the results of this work and will present it to the upcoming STAC Climate Change 3.0 workshop where they will provide feedback.

Lew asked if anyone thinks there is compelling evidence for ever increasing algal growth curves. Looking at the Bush River box and whisker plot on slide 16, it the growth rate appears to level off. Dave said he does not, but he has heard the argument that new species will replace currently existing species. Clifton Bell said we are not refuting the Eppley Curve here or the idea that species might be able to adapt, but instead we are saying that these new unusually high temperatures will not be adapted for algal species. Clifton said we need to pick one value for all the scenarios due to operational model reasons.

Lew asked if anyone would object with proceeding with Carl's temperature optimum of 32 C, essentially asymptotic, for summer blue-green algae (slide 30). Dave asked if it would decrease or flatline after 32 C. Norm asked if it would make a difference if it decreased or flatlined. Lew said no, it does not matter and operationally it would not change the result. Carl added it would bring us back to where we were originally. Clifton said for regulatory reasons, if it really does go down, it should be represented that way. Carl said it does seem to flatten out from 30-35 C, only in the true extremes above 35 C is there a diminishing point. Larry Sanford said this past summer, the Gulf Coast of Florida saw consistent temperatures in 37-38 degree C range and those harmful algal bloom phytoplankton species (not the ones being looked at today) were fried and saw large die-offs. Lew said operationally we see flattening out or dying out slightly.

Jian Shen said in the James River, there is nutrient limitation upstream during high temperatures. Results are very similar when he has tested sensitivity for flat vs continual climate adjustment growth in the tidal fresh of the James River, but he does not know about implications for the MBM.

Lew asked if anyone would object to taking the recommendations from Carl (temperature optimum of 32 C for the blue-green algal group) and using them operationally until it is evaluated at the STAC Climate Change 3.0 workshop in May 2024. Vamsi suggested exploring some of the suggestions he and Tish made before going with a value. Lew asked if Carl would be able to review those suggestions, try those methods out, and present them in January 2024. Carl said he will need some help, potentially from Vamsi and Tish. Vamsi and Tish agreed to help.

Carl Cerco, with the help of Tish Robertson and Vamsi Sridharan, will explore two more analyses of the data Carl has presented on for the chlorophyll-a. Then a decision on the interim temperature optimum for summer blue-green algal group will be decided at the January 2024 MWG quarterly, which will stand until STAC can evaluate that decision in May 2024 at the Climate Change 3.0 Workshop.

10:45 Introducing the Choptank MTM Team – Lew Linker EPA-CBPO, Jian Zhao, UMCES, Jiabi Du, Texas A&M, and Larry Sanford, Jeremy Testa, Elizabeth North, and William Nardin, UMCES

The Choptank MTM Team, one of the three MTMs supported by a five-year grant, was presented and the work plan was discussed.

Summary

Jian Zhao began with a review of the setting in the Choptank, including current living resource and water quality interests in the tributary. Jian then outlined the tasks for the Choptank MTM team (slide 8), specifically developing the Choptank Grid and identifying the observations for model validation.

10:55 Discussion of Choptank MTM

Summary

Lew asked Jian where the boundary conditions for the Choptank should be placed. Jian said the northern boundary should be near the Bay Bridge and the southern boundary should be south of the Honga river to include exchanges and the impacts of sea level rise. Lew said the CBP modeling team stands ready to help with providing inputs or other information.

Carl said he is not sure how the team should deal with the quick erosion of Blackwater National Wildlife Refuge, but he perceives it as a major challenge which must be addressed. Jian said the team needs to discuss the physics and calibration for water quality and sediment. Jiabi said it will depend on how the model works and the purpose of the model. If the focus of the model is water quality, then it will likely not need to be part of the grid. Lew said Carl is not suggesting having a grid in blackwater, this is the choice of practitioners, but instead that Blackwater must be an input of organics. Lew said this will be important because the inputs were carefully considered in Phase 6 as refractory.

Lew said the calibration period must first be 1991-2000 (first priority), but after that it can include more recent calibration data, such as the continuous DO data from the hypoxia profilers.

11:05 Progress on the Rappahannock MTM – Qubin Qin, East Carolina University and Nicole Cai, ORISE-CBPO

Initial work on the Rappahannock MTM was described.

Summary

Qubin Qin began with a review of the objectives and tasks of the Rappahannock MTM. Regarding the first task, Qubin documented refinements to the Rappahannock grid and boundary conditions. Qubin then walked through a study to apply a participle tracking model to analyze impacts of water intake on ichthyoplankton mortality in the tidal freshwater region of the Rappahannock River (slides 7-30). This section included a

description of the grid near the intake area, the calibration data, the particle tracking model, and the results of 34 particle tracking model scenarios.

11:20 Discussion of Rappahannock MTM Progress

Summary

Lew said it was interesting that this model was including the water intake components in the Rappahannock. Qubin replied this is an advantage of finer resolution. Lew said if there were interest in the future of intakes under climate change, he would recommend contacting Richard Tian about getting access to the Phase 6 forcing.

Richard Tian asked if there is a random walk component of particle tracking. Joseph said it was considered, but Qubin did not use that component because he was able to utilize the finer grid. Richard said he thought it was present in the horizontal turbulence, which might lead to difficulties with reproducibility. Qubin said another consideration of including random walk is that it would not be possible to track the center of the cell groupings. Richard said he understands the tradeoffs of the random walk approach and has referred to it as a super particle in the past when performing particle tracking modeling for sea scallops. Vamsi said he thinks random walk diffusion should not be included in most locations, but maybe it could be useful in understanding the turbulence around the intake, thus informing sensitivity.

Vamsi said he had a paper a few years ago where they looked at the effect of number of particles on statistical robustness among other things: Sridharan, V. K., Monismith, S. G., Fong, D. A., & Hench, J. L. (2018). One-dimensional particle tracking with streamline preserving junctions for flows in channel networks. Journal of Hydraulic Engineering, 144(2), 04017063. Qubin said he will look into this paper.

Robert Burgholzer said 0.15% daily trapping against a natural 20% rate is roughly 1%. So, 1% increase, but a couple questions:

1. Can we speculate that 10 intakes of this magnitude might amount to 10% increase in mortality?
    a. Qubin replied that in a different project in the James River, they are exploring the accumulation effect of the impacts. Qubin said he will a more robust answer later, but where it is cumulative in a linear sense or there is feedback from the intake, he would expect mortality to increase.
    b. Robert said a 10 % increase in the mortality rate could lead to a 20% increase in mortality.
2. How does the 20% daily "natural" mortality rate accumulate? That is, for how many days is the natural daily rate occurring, for 12 days, we would have an effective total mortality of 94% (maybe reasonable given what Robert has heard around the watershed from fisheries folks).
    a. Qubin replied if there is accumulation of the daily mortality rate, the 20% is an average for observed values for different species (the range is 1-99%). Qubin said fisheries specialists would be better positioned to answer this question.
    b. Robert said knowing the team is leveraging the high-resolution grid to explore questions of mortality is great to hear.

11:30 **Estimated Nutrient Exchanges Among Coastal Estuaries in Restoration** – **Nicole Cai, ORISE-CBPO**

Nicole delved into the examination of the benthos database and the benthic role in sediment resuspension. This work involved categorizing more than 2,000 species documented in the Chesapeake Bay into various functional groups, which will subsequently be integrated into the MBM and MTMs to account for their impacts on the sulfide release and nutrient cycling. Furthermore, Nicole provided an overview of the initial advancements made in creating a comprehensive regional model spanning from Long Island Sound to Florida. These efforts will serve as a foundation for a tracer study designed to assess connectivity among East Coast water bodies. The study will be invaluable not only for understanding general water flow patterns but also for specific investigations, such as tracking the movement of debris.

Summary

Nicole Cai began by revisiting the over-estimation of lower Bay DO for multiple models. Nicole explored model results and the literature to answer the question "Where does oxygen consumption come from?" Nicole investigated two hypotheses: one on resuspension-drive convection and another on benthos driven convection. Nicole provided examples of results from both hypotheses.

Nicole then presented an update of her work in testing the remote influence and nutrient exchange from other coastal water bodies along the US East Coast. Nicole focused on improvements to the model grid near Cape Cod and Boston Harbor, before turning to the results of simulations for load sources from Long Island Sound. Nicole concluded with next steps for this project, such as model validation and calibration and statistic and machine learning analysis.

11:45 **Discussion of Inclusion of Benthos in MBM and MTMs and Estimated Nutrient Exchanges Among Coastal Estuaries**

Summary

Lew said the visualization of sources from Long Island Sound is very helpful in tracking beyond our mid-1990s calibration. The initial understanding how much these systems influence Chesapeake Bay is very informative.

Dave asked if these influences are measurable or are they more theoretical. Lew said these influences are guessable. There was a paper by Howarth that said boundary conditions in the mid-Atlantic are one-third pelagic, one-third coastal, and one-third atmospheric deposition. In the past, Phase 6 boundary conditions were adjusted for atmospheric deposition. Even though these concentration differences are infinitesimal, it shows up in the mass given the large amounts of water being exchanged at the mouth of the Bay.

Richard Tian asked what the initial condition of sulfide in the sediment is. Is it entirely from diagenesis/atmospheric deposition to the sediment or is there already storage in the sediment? Nicole said there is an initial condition in the form of iron sulfide, which has a

larger settling rate. The sources of the sulfides are primarily driven by diagenesis in the sediment when there is low DO and saltwater. There is a distribution of dissolved and solid sulfides in the sediment. Richard asked for the larger domain, how will the model handle the physical currents (like the Gulf Stream). Nicole said she is working on that now. Nicole is going to do the model evaluation based on the NOAA and USGS station data, and then the sea surface temperature using satellite data. For the salinity calibration, she will refer to the data availability from the CBP and NOAA coastal stations. Nicole said she and her collaborators will investigate a heat budget assessment as well. Joseph said he can send Richard the NOAA forecast and calibration values.

Lew said this is an impressive result in terms of the resuspension of hydrogen sulfide. Lew asked how to preserve mass balance here. Nicole said mass balance is conserved because the sources of hydrogen sulfide is from the settled PON oxidation when there is no oxygen available in the sediment, but the sulfate is there is oxidize them. When released from the sediment to water column, the oxygen is consumed. Lew replied that if we are preserving mass balance and the physical chemistry and we get this result, this is a real win. It has been a longstanding problem for bottom DO in the lower Bay.

Lew said in Phase 5 MBM, there were modules looking at benthic infauna and filter feeders. The explicitly simulated findings were that infauna was largely reworking the sediment column such that fresher top layers were mixed with lower layers, but it did not have much effect on water quality. This stands in contrast to the results for filter feeders, which did have a result. Lew said these reports can be unearthed if needed. Carl said in the diagenesis model Dominic Ditoro created for the CBP, bioturbation was parameterized, and it was surprisingly sensitive. Carl said we need to go back to the original model to do some sensitivity runs for the bioturbation parameter. We did not simulate benthos because in the model they were not linked to anything, but if they were dynamically linked to sediment processes to understand the connection to water quality, that would be great, but it is a big job. Lew suggested having a small group discussion on this topic, with people like Nicole and Carl. Nicole said she is familiar with the sensitivity of the mixing and coefficient parameters from this model. Nicole said this is why she is not trying to incorporate a dynamic benthos module because the CBP does not have the temporal data. The CBP data is yearly, and only has the range, distribution, and annual distribution of the benthic biomass. Nicole said her first hypothesis makes more sense looking at the data, so the bioturbation consumption may not influence the bottom DO calculations. Nicole said she will look into the bioturbation sensitivities. Lew asked if Nicole could look at what we want to discuss, like setting up the conversation, pace, and when to meet with the goal of helping Nicole.

Harry Wang said he is glad Nicole is considering the resuspension of the material. Harry said convection is usually used for air, but this is considered to be resuspension or erosion. Harry said in the lower Bay, one of the previously discussed mechanisms is the wave influence from the coast up to the Potomac River. Nicole clarified the solute material in the poor water from the unconfined groundwater is what is being subjected to convection, not the resuspended solids themselves. Harry asked if it is poor water subject to convection into the water column, because then it will be in the form of bubble, strictly

speaking. Harry asked if Nicole could use the hydrostatic model to handle the rising of the bubble?

12:05 LUNCH

1:00 Shoreline Erosion Testbeds of Corsica and Choptank Rivers – Richard Tian, UMCES-CBPO

Progress in assessing the efficacy of a dynamic input of shoreline sediment and associated nutrients using fine scale models of the Corsica and Choptank Rivers was presented. To do a dynamic input of shoreline loads we'd need 1) wave power (f wave speed, wave energy, and depth), 2) shoreline height, 3) protected shoreline, 4) bulk density, 5) sand, silt, clay classes, 6) eroded shoreline TN & TP species.

Summary

Richard began by comparing how shoreline erosion was treated in Phase 6 compared with the recommendation for how it will be treated in Phase 7. The significance of shoreline erosion is that it is particularly a challenge under climate change and sea level rise. Additionally, there is new best available science which should be incorporated into the model.

Richard then compared wave height simulated by SCHISM and CH3D with observed values at locations in the lower, middle, and upper Bay. Richard also walked through the temporal and spatial distribution of the observed and simulated shoreline erosion by model. Richard used the Choptank and the Corsica as an example to explore these results by comparing simulated outputs at each monitoring stations. Richard also demonstrated some early calibration results with CH3D.

Richard concluded with the following take home points:

- The wave model functioned properly.
- Wave-driven shoreline erosion reproduced the measured erosion.
- Wave power redistributed shoreline erosion in space and time.

Richard asked if this work should:

- Be applied Bay-wide?
    - Richard said technically, it should be doable.
- Include interannual variability?

1:20 Discussion of Shoreline Erosion Testbeds

Summary

Lew said on slide 10, his understanding is that Phase 6 there were three cells for the Corsica with a rate of shoreline erosion estimated for each cell coming from observed recession rates. This served as a forcing function for associating erosion with rainfall. The applied recession rate is applied differently in space and time because of the wave

power variability across the Corsica. Lew said this appears to be a demonstrably superior approach to Phase 6.

Lew asked if Richard has the cosign of wave energy everywhere with SCHISM. Richard said yes, at each timestep the direction of the wave is recorded. Lew asked if on slide 10, the red areas exist because of the wind and the fetch from the Chester into the Corsica. Richard said that is what he believes.

Lew asked if there would be a technical challenge to applying this to the entire Bay. Richard said if we do the entire Bay, we can distribute that number to all tributary teams. Richard said Zhengui has set up a test case with the wave model, but Richard is not sure to what extent it is calibrated. Richard said if the wave model is set up and he has shoreline erosion, it can be applied to the entire Bay. Lew said as long as there are not computational or input challenges, it would be nice to have this data for every year.

Raleigh Hood said at the last quarterly Richard had asked about shoreline hardening in the Choptank. Raleigh asked if these results assume everything is erodible or if shoreline erosion is taken into account. Richard said he is using Karinna Nunez's VIMS shoreline layer, which includes hardened shorelines as of 2000. However, there may be new installations since 2000 which may have been missed. Lew replied that previously there was a large, generalized shoreline recession rate modified by shoreline protection, which was rolled up into the 3-D model cells. The other limitation was a constant bank height. However, with Richard's analysis we can have refinement with variable bank height and protected shoreline. Dave asked if we are able to represent protected shorelines Bay-wide if we try to apply shoreline erosion Bay-wide. Lew said this is a spatial resolution difference. The Phase 6 CH3D model in the Choptank should have this represented but aggregated up. With the finer resolution in Phase 7, we can work with variable bank height and have a more specific input of shoreline erosion, as well as the power function. Carl added that even protected shorelines can still have erosion. For example, at the base of the sea wall there will be erosion on the seaside, which one might call sub-surface erosion. Richard said in Phase 6 CH3D, when the shoreline is not protected, 2/3 happened above the surface (bank erosion) and 1/3 happened at sub-tidal erosion.

Carl said the data represented here are from long-term datasets. We do not want to compare any single year to the observed data; instead, we want the longest term run possible from the model compared to the dataset.

Carl provided context as to why shoreline erosion was previously matched with hydrology in CH3D, which was to help managers more easily assess the load alongside non-point sources. Carl said if you move forward with the proportioned wave energy approach for shoreline erosion, you first need to make sure this works with managers. Lew said he would check with Gary and Gopal on this but said we can use it the same ways as shoreline erosion rate. Gary agreed with Carl that this is an important consideration for the partnership to review. Gary said we want an estimate of the long-term rate that is based on some state of management. Then this long-term rate can be temporally disaggregated at the longest time step possible based on wave power in the estuarine model where it will vary only based on the implementation of management practices.

Larry Sanford said in terms of model comparison, this is very good, but there are other locations in the Bay (York River, Todd's point in the Choptank - 2002) where we have observed data. Before we move forward, it would behoove us to compare with observed data. Richard asked Larry to send a list of this data. Larry said he would, but also recommended contacting the nearshore team at VIMS and Scott Hardaway. Lew said this is a good idea and something the team will do.

Richard asked if the wave model has been calibrated yet or not. Zhengui said it has been calibrated somewhat with the wave observation data. Jiabi Du gave a presentation on this topic previously.

Lew asked if operationally it would be untenable to take the Phase 6 inputs and develop them everywhere in the Bay, and then revisiting with the variable bank heights and protected shorelines. What are the tradeoffs? Richard said the wave model in CH3D has wave height but not the direction, which is very important in this case. In terms of bank height, the height currently available is not very precise. Lew suggested taking this topic to a future MBM team meeting to discuss the tradeoffs and making an operational decision on how to proceed.

1:30 Comparison of P6 Bay Model and CESR Estimated Hypoxia – Richard Tian, UMCES-CBPO

In order to have a fair comparison between the model prediction and observation of water quality attainment in the Comprehensive Evaluation of System Response (CESR) report, a long-term run of the CH3D-ICM was carried out and the outputs were analyzed in the save way of the reported observation result. The presentation detailed the methodology and outcomes from this effort.

Summary

Richard began by reviewing how the figure of interest (4.9) was calculated in the CESR report and the two major challenges (slide 3). Richard explained why this not a direct comparison and then described his efforts to improve the comparison of the model and observed results. Richard compared results from deep water, deep channel, and open water. Richard included estimation of model bias and how it was handled.

Richard concluded with the following messages:

- The model tends to overestimate DO in the deep channel and underestimate DO in the open water, but the bias was corrected to certain extent by using the delta approach.
- The model predicted water quality attainment is less contrast to observation than we thought.
- Continue the effort to manage nutrient loads and better days are ahead.

1:50 Discussion of Comparison of Phase 6 Bay Model and CESR Estimated Hypoxia

Summary

Gary said Lew may be correct about the spin up and the instantaneous load reduction being the reasons why the CESR plot does not compare correctly, but Gary said the CESR figure (on the right) on slide 11 is comparing two separate things. The blue dots are essentially weather, and the orange dots are more reflective of the management applications. As we get the Phase 7 models together, we need to evaluate them for the management decision, which is really what we are focused on. CESR has challenges us to do that. Dave said we should do our due diligence in Phase 7 to see what we can improve, especially for phosphorus in the watershed, but he is concerned by misconceptions around CESR that nutrient reductions are not important. Dave said we also need to improve our communication of model differences. Lew said in a world of soundbites, it is difficult because we have a binary metric. Looking at the literature and observations, we do see improvements in DO, but we do not see widespread attainment. This is a difficult message to convey. Richard said it is important to include margin of error as well.

Lew so I think unless we hear otherwise, we should hold steady, develop Phase 7, and that would be our path forward. Does this describe what you are saying Gary. Gary said slide 11 shows that our model is not exactly on, but it is not as bad as CESR is indicating. Additionally, we need to keep in mind the warning of CESR, which is that we need to predict phenomena relevant to management applications.

2:30 **Anacostia Toxics Assessment and Future 2035 and 2055 Climate Change Assessment – Peter von Loewe and Vamsi Sridharan, Tetra Tech**

Peter described recent work done in the Anacostia River on estimating toxics fate and transport under current and future climate conditions.

Summary

Peter began with an overview of the project and the modeling need, before going into the details of model development. Peter presented the model results for toxic contaminants, and then walked through the climate change scenario updates and how those scenarios impact toxics.

2:50 **Discussion of Anacostia Toxics Assessment and Future 2035 and 2055 Climate Change Assessment**

Summary

Lew asked about the status of the TMDL. Vamsi said they are not sure. George said the stakeholders requested an extension on the comment period, which was accepted. No additional comments have been received yet, but DC DOEE still does expect comments by the end of October 23rd. George said DC DOEE has a policy of including climate change in their TMDLs which are in alignment with the CBP's approach to climate change. This allows for both local and regional planning. Lew said this is a sound approach and shows that environmental management is not static. Vamsi said the team decided to use the CBP CRWG projections because it was important to have consensus regionally on those methods. The reason Vamsi did not talk about attenuation in the presentation is that natural attenuation would require 5-6 decades.

Dave said the bottom line is that in general, the climate effects of sea level rise and precipitation shorten the attenuation time for these toxic contaminants. Vamsi said very marginally yes, but only a few years in the scope of 5-6 decades. George added that one of the publications on this topic noted that not all pollutants were impacted equally by climate change.

3:00 ADJOURN

Participants: Alex Gunnerson, Angie Wei, Arianna Johns, Ashley Hullinger, Bill Keeling, Bryant Thomas, Carlington Wallace, Carl Cerco, Clifton Bell, Doug Austin, Dave Montali, Doug Bell, Dylan Burgevin, Elizabeth North, Gary Shenk, George Onyullo, Gopal Bhatt, Gregorio Toscano Pulido, Harry Wang, Hassan Mirsajadi, Isabella Bertani, Jiabi Du, Jian Zhao, Jonathan Leiman, Joseph Delesantro, Joseph Zhang, Karinna Nunez, Karl Blankenship, KC Filippino, Kimberly Dagen, Larry Sanford, Lew Linker, Marjy Friedrichs, Mukhtar Ibrahim, Mike McMahon, Nicole Cai, Norm Goulet, Peter von Loewe, Pierre St. Laurent, Qian Zhang, Qubin Qin, Raleigh Hood, Rebecca Murphy, Robert Burgholzer, Richard Tian, Sam Merrill, Samuel Canfield, Scott Heidel, Jian Shen, Tish Robertson, Vahid Rafaei, Vamsi Krishna Sridharan, Xuesong Zhang, Zhengui Wang.