Modeling Workgroup October Quarterly Review

Minutes

Day 1 – January 7, 2025

9:00 AM – 3:30 PM

Event webpage: Link

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

9:05 Conowingo Model Development – Earl Hayter, Jodi Ryder, CoE-ERDC and Matt Rowe, MDE

Description: Progress in the development of the Conowingo Model will be presented.

Early Hayter: We're developing a hydrodynamic, nutrient, water quality, and sediment transport modeling system for the Conowingo Reservoir. Once developed and calibrated, we will apply it to two key model applications: dredging scenarios and extreme events. One important aspect is the changing hydrodynamics from reservoir sediment infill from upstream and material removal via dredging. The modeling system is dynamically linked—hydrodynamic and sediment transport models are run simultaneously. For the simulation period from 1991 to 2000, every change in sediment transport, whether deposition or erosion, updates the hydrodynamics at each time step in every grid cell. Water quality and biogeochemistry models are also dynamically linked within EFDC+ (Environmental Fluid Dynamics Code), an open-source model. We'll particularly focus on variations in nitrogen (N) and phosphorus (P) and the chemical changes within the reservoir. Additionally, we'll predict changes in sediment diagenesis and the chemistry in the sediment bed, along with the flux between bed and water column. Physical changes will also be predicted, and data collection is scheduled for mid-to-late March. The data will be analyzed at the Sediment Research Lab at US Army Engineer Research and Development Center (ERDC) in Vicksburg, Mississippi (MS), and used for simulating dredging and climate change scenarios.

In the first quarter of FY25, we focused on acquiring existing data (slide 10). We've received significant datasets from the Environmental Protection Agency (EPA) Bay Program, thanks to Lew and Gopal, as well as from Maryland Department of the Environment (MDE) and the University of Maryland. The types of data include hydrodynamics, sediment, nutrients, and bathymetry. For the hydrodynamic model's first version, we're using bathymetry data from MDE dated around 2014.

The hydrodynamic model for Conowingo Reservoir Modeling System (CRMS, slide 11) will be fully developed and validated by the end of Q2 FY25. We're also starting development of the sediment transport and nutrient water quality models this quarter, as they will take longer to complete. The team selected EFDC+, an enhanced version of EFDC originally developed by John Hamrick in the late 1980s and refined by Dynamic Solutions in Edmonds, WA. The code is open source and available for download. EFDC uses a curvilinear, structured grid. EFDC+ is a fully coupled model for hydrodynamics, sediment, water quality, and contaminant transport—though we won't use the contaminant transport part for this study. Dynamic Solutions also developed a sophisticated GUI for EFDC, which requires a license but offers strong pre-processing and post-processing capabilities. We will use this GUI throughout the study, and in future meetings, we'll present early model results using it. It's called the EE Modeling System.

The initial model is three-dimensional. Major inflows include data from the Phase 6 model: Holtwood Dam, direct watershed runoff, Muddy Run Power Reservoir, and Conowingo Dam. Additional inflows are from Muddy Creek and Broad Creek (west side of the reservoir). Outflows are modeled, and atmospheric inputs such as pressure, winds, rainfall, and evaporation are also considered. Slide 12 shows the model grid for the Conowingo Reservoir. The multicolored contour shows bottom elevation in meters. The upstream end starts at Holtwood Dam, with the downstream end at Conowingo Dam. This version uses the 2014 bathymetry from MDE. For the first version, I tend to overrefine the grid to run longer simulations and analyze spatial-temporal variations in velocity—both horizontal and vertical. This helps identify areas with significant velocity gradients during normal and high-flow events. The final operational model will have fewer cells, but with refined areas where strong gradients occur, ensuring accurate sediment transport predictions.

Each grid cell uses 10 vertical sigma layers, whether in deep or shallow water, providing vertical resolution crucial for sediment and water quality modeling. Accurately representing velocity gradients is essential—sediment transport depends heavily on bed shear stress, which is proportional to velocity squared, and erosion rates often relate to the shear stress raised to the second or third power. Ensuring accurate hydrodynamics is key, as erosion and resuspension rates rely on velocity to the fourth power.

- ***Comment:*** *Lew Linker:* The bathymetry we're seeing here—this is relative to sea level, bottom elevation and not depth. The blue areas represent the deeper portions at the base of the reservoir near the dams and the red areas represent the shallow regions. The depth in the red regions, particularly in the northern region is shallow (around 1 meter). The upper portion would have relatively high velocities and a lot of sediment movement toward the main body of the reservoir. Along the sides, it looks like there are shallow regions where quiescent waters might allow sediment to accumulate

- ***Q:*** *Lew Linker:* where would Peach Bottom Nuclear Plant be located on this bathymetry? Somewhere along the western shore, correct?
  - ***A:*** *Earl Hayter:* Peach Bottom is on the western shore, about in the middle of the reservoir's length. It's somewhere in that vicinity.
  - ***Response:*** *Lew Linker:* Got it, in the middle along the western shore. There's also an electricity backup line to the nuclear plant running from Conowingo to Peach Bottom. So, dredging can't disturb that area. Any potential dredging work would need to happen on the eastern side.

On slide 13, we have the very fine grid we developed. You can see down at the dam itself, in the lower portion of the image, each of those small gray shapes is a grid cell. They're not perfect squares; most are rectangles, quadrilaterals, because it's a curvilinear grid, meaning angles aren't all exactly 90 degrees. To give you an idea of the grid cell size, the dark dot you see there shows a grid cell that's approximately 27 meters by 24 meters. That's just to illustrate the scale. However, many of these grid cells will be coarsened and enlarged in the final version. Slide 14, provides a zoomed-in view of the upper portion of the model domain.

Now, focusing on sediment transport modeling (slide 15). We've already started setting up the sediment transport model using data we've received from MDE and previous studies conducted by Maryland and others. I've begun preparing input files for the cohesive sediment transport model used in EFDC+. So, development has started, but we're also awaiting sediment data collection, scheduled before the end of March. Subsequent analysis of that data is crucial, but since the data won't be collected until late in the second quarter, we likely won't have it until the third quarter.

Jodi Ryder: I'll highlight a few things that have happened since our last meeting. One major focus has been determining how we'll assess the different fractions of material in the sediment. We've held several meetings to develop the sampling plan. We met with Constellation to understand what information they have, followed by a meeting with the sampling team and ERDC to discuss where and when we might collect samples. We've also identified the lab that will handle the sediment carbon analysis.

We now have a clear pathway to conduct the sediment carbon assessment. Sample collection is likely to occur in March, depending on weather conditions at that time. We also had a meeting at MDE where we discussed potential scenarios to run in the model. Although we didn't finalize all the details, we developed a matrix of ideas outlining the key factors for scenario selection. some specifics we concluded on include the calibration period. We'll use hydrology from 1991 to 2000. We also identified sets of dredging scenarios and storm events for the model runs. The hydrology will come from different scenarios run through the watershed model. Since we're using 2014 bathymetry, 2010 serves as our pre-event baseline, allowing us to examine future impacts.

The specific years aren't critical—the key is having near-future and long-term output dates to assess, like 2035 and 2055. For dredging scenarios, we'll start with a baseline without dredging and consider variations involving specific locations or amounts of material removed. Further discussions, including input from Constellation and MDE, will help refine those details. Their insights, especially regarding previous pilot dredging experiments, have been helpful.

Regarding storm events, we didn't focus on specific historical storms but rather on timing and magnitude variations. We're considering early and late-season hurricanes, something like a Hurricane Lee-type event, as well as very high-magnitude events and more regularly recurring but still significant storm events. The goal is to outline the scenario framework and fit specifics to it once the baseline model is operational.

9:30 Discussion of the Conowingo Model Development and Application

Q: *Richard Tian:* you mentioned a "limiter" in the model. What did you mean by that?

- ***A:*** *Jodi Ryder:* Yes, in EFDC+, you can define as many algae groups as needed. Each group is defined by its specific growth, respiration, and decay rates. The code is capable of handling that, though it's not necessarily something we'll implement in this study. It was more a general comment on the model's capability.

Q: *Gary Shenk:* This is a really great modeling plan. What I'm trying to think about is how this integrates into the Bay Program's modeling suite. One of the key takeaways for me from the in-person meeting we had in Baltimore a few months ago was that this model has a runtime of about a week. I understand why—that level of spatial detail is necessary, especially to properly investigate the different dredging scenarios. But that also means it can't be part of the regular scenario runs directly. We discussed developing an emulator for this model to integrate it into the watershed-to-Conowingo-to-Bay model framework. Is that still under consideration?

- ***A:*** *Earl Hayter:* I believe so. Jenny and I need to connect to talk more about it. Part of what we need to address is whether developing that emulator fits under our current agreement with MDE and the associated funding. It's not explicitly in the work plan, so we'll need to have further discussion to see if it's feasible within this scope.
- ***Response:*** *Gary Shenk:* That makes sense. In that earlier meeting, we also talked about the fact that climate change scenario development was part of the work plan. The idea, at the time, was that the Bay Program and Gopal could supply the climate change scenarios, and that could possibly offset the effort needed to develop the emulator. Of course, I don't have insight into your budget, so that's something to revisit later.
- ***Comment:*** *Lew Linker:* That's a good point, Gary, we want to use the climate change estimates being developed for the Bay Program to keep this study aligned with the broader body of work. I think we'll need to continue that conversation offline to determine whether the emulator is viable, possibly with some trade-offs.
- ***Q:*** *Richard Tian:* I have a question related to Gary's comment about the model runtime being around a week. You mentioned earlier that the current grid has nearly 50,000 cells, but you're planning to reduce that number. I'm wondering—if the grid becomes small enough, could the runtime be significantly reduced? Is that possible?
    - ***A:*** *Earl Hayter:* Yes, the production model will definitely have fewer cells, as I mentioned earlier. The runtime will also depend on how many sediment size classes we decide to model. For example, my initial setup includes six different sediment size classes to represent the range and distribution throughout the reservoir. Additionally, the number of constituents modeled in the nutrient and water quality components will influence the runtime. Once we finalize the hydrodynamic model with fewer cells, we'll have a much clearer estimate of the runtime. But overall, the primary factors are the number of sediment classes, nutrient constituents, and grid cell count. One more thing to add—the model runtime is also influenced by the time step required for stability. In sediment transport modeling, especially when simulating both suspended and bed load transport, a very small time step may be necessary. That will be determined as we proceed.

9:40 [Phase 7 Watershed Model Overview](#) – Gary Shenk, USGS-CBPO

Description: Gary will provide an updated timeline for completion of the Phase 7 Model in time for the 2026 partnership review. Implementation of the WQGIT-approved application of HUC12 segmentation for Phase 7 Watershed Model river-segments will be discussed.

Today, we are presenting a setup for how the MWG will be organized in 2025 with a final model that is ready for review. The key topics covered today include the scale of CAST, the connection plans between the various parts of the watershed model, and the MWG timeline.

The core values of the MWG that was adopted about ten years ago (the four "I's") are:

- *Integration:* Ensuring we use the most recent science.
- *Independence:* Considering the best available evidence for everything we do.
- *Innovation:* Always striving for improvements.
- *Inclusiveness:* Making sure the entire partnership is involved.

The Watershed Phase Seven (P7) Plan. The watershed model consists of three main parts.

1. *CAST:* This is the watershed model. It's the tool we use for decision-making and for tracking BMPs (Best Management Practices) toward the WIPs (Watershed Implementation Plans). Once we finalize this by the end of the year, we'll be running thousands of scenarios over the next several years.

2. *CalCAST:* Isabella Bertani leads this tool, which finds the parameters that best match observations. These observations include loads and trends in loads. To ensure CAST is a reliable model, we need the best parameters for watershed delivery and load changes versus inputs. CalCAST is essentially a statistical version of CAST, designed to provide the most accurate parameters. Once P7 is finalized and documented, CalCAST will still be used for other projects but not directly for scenarios. Its primary purpose is ensuring the best parameters are in place.

3. *Dynamic Model:* Gopal Bhatt leads this part, which takes the loads estimated through CAST and loads them into the estuary model. This allows comparison against in-stream monitoring observations. The dynamic model is not used for every management scenario but is essential when collaborating with partners for specific projects.

In short, CalCAST informs CAST, and CAST constrains the dynamic model to ensure consistent answers over the long term.

Today's presentations (Day 1 of the MWG Quarterly Review) will cover:

- *Scale*: the Water Quality Goal Implementation Team (WQ GIT) has made a decision regarding the scale of CAST river segments. Slide 7 shows the difference between a land segment, a river segment, and an NHD catchment. A land segment generally represents a county. Some counties are split into two or three parts due to varying rainfall. A river segment is a section where a river is simulated, with about 10 segments per county in Phase Six. An NHD catchment refers to smaller watersheds.

- *Watershed Model Scales*: For CalCAST, Isabella uses national and regional datasets available at the NHD 100K scale. The dynamic model also uses this scale, which is essential for driving the estuary model. For P7 CAST, we're doubling the number of watersheds compared to P6.
- *Multiple Scales*: Input data like fertilizer, manure, and atmospheric deposition are available at the county level, while BMPs and land management details are at the Land River Segment scale. We downscale from the county level and upscale from the NHD scale to run everything at the Land River Segment level, following the same process as in P6.

Our specific Plans for our efforts are to:

1. *Annual Flow Normalized Data:* We aim to use annual flow-normalized data for nutrients and average annual data for flow. This approach aligns with the management questions CAST is designed to answer, specifically trends in anthropogenic loads.
2. *Passing Through CAST:* During scenarios, we won't have CalCAST. Therefore, we must follow the same path during calibration to ensure consistency.
3. *Dynamic Model Calibration:* While CalCAST provides global parameter estimates, localized calibration through the dynamic model is necessary to achieve higher accuracy. This process mirrors what we did in P6.
4. *Automation:* In Quarter 1 and Quarter 2, we will use P6 data. By Quarter 3, we'll incorporate final land use data, WQGIT decisions, and other updates. To handle this efficiently, we need to automate the entire process from CalCAST to CAST and the dynamic model. This will ensure we can quickly rerun analyses with new data.

9:55 Discussion of the Phase 7 Model Overview

Comment: *Lew Linker:* as the watersheds increase in river order, riverine processes become more important. Your strategies allow the best approach for the HSPF simulations for the instream processes like sorption, scour, etc. While CalCAST gives us watershed perspectives. Your strategies give us best of both approaches moving forward.

- ***Response:*** *Gary Shenk:* these process models can hit the mark, and it is capturing more processes than the statistical models but applying it to CC scenarios because we don't have those processes 100% modeled. A conversation we have to have is how to calibrate the model to these scenarios.

- ***Q:*** *Jeniffer Olszewski:* is the idea that the calibration will be a reiterative process or just one calibration and done?

    - ***A:*** *Gary Shenk:* Just one and done. To your point, we are doing some iterations right now. For example, as Gopal encounters calibration challenges, he has discussions with Isabella, and that informs how she's calibrating CalCAST. So that back-and-forth is happening at this stage, but once we get to the point shown on this slide, it's intended to be one calibration finalized.

- ***Response:*** *Jenny Olszewski:* you mentioned climate change—it might be interesting to keep that iterative calibration alive for a few more rounds, especially as you begin climate change scenarios.

10:05 Update on CalCAST Development – Isabella Bertani, UMCES-CBPO

Description: Isabella will describe the progress made in improving CalCAST for phosphorus and sediment. The different approaches that have been tried will be reviewed.

Isabella Bertani: This quarter's focus in CalCAST development centered on improving total phosphorus (TP) and sediment modeling. While past efforts have more heavily emphasized nitrogen, the team has now prioritized refining the TP and sediment components. CalCAST is a statistical version of CAST that retains the same structural framework but calibrates certain parameters statistically. The model calculates average annual loading rates for over 40 load sources, adjusting those rates at the catchment scale using local inputs and sensitivities. For now, those sensitivities are based on P6, but future updates may incorporate new values from Joseph Delesantro's research. Key phosphorus-related inputs include fertilizer, soil phosphorus, sediment loss, storm flow, and several direct loads like wastewater and atmospheric deposition.

A major area of refinement has been the land-to-water factors, which influence how much of a pollutant actually reaches water bodies. By testing different combinations of catchment characteristics, the team increased the model's explanatory power for TP from 35% to around 76%. Variables that significantly improved performance included soil erodibility (K factor), maximum one-day rainfall, stream and pond density, and baseflow index. These predictors are supported by regional literature and align with physical processes affecting phosphorus transport. While the model now performs well globally, it still shows bias at several River Input Monitoring (RIM) stations—locations that feed directly into the estuary model and are critical for load delivery. The team continues to refine these calibrations, particularly for outliers like Conowingo, where a customized reservoir attenuation parameter improved performance without overgeneralizing across other sites.

For sediment, the modeling framework is similar, relying heavily on RUSLE-based estimates and adjusted by BMPs and interconnectivity metrics. However, sediment performance still lags behind phosphorus. Initial models explained only 5% of sediment yield variability, though recent enhancements have increased this to 55%. Despite this improvement, bias at key monitoring stations remains too high for the results to be usable in estuary modeling. Additional testing of catchment variables, sensitivity factors, and stream delivery formulations is planned to bring sediment modeling up to acceptable standards.

Flow-normalized models have also been built for phosphorus, nitrogen, and sediment. These models help examine long-term trends independent of annual weather variability. Initial findings suggest the same catchment parameters used in average annual models also work well in annual models, though spatial variability continues to drive model calibration. Performance comparisons at individual stations vary, with some matching the WRTDS observational trends well, while others show notable discrepancies. These insights guide ongoing refinements and highlight areas where further adjustments are needed.

Looking ahead, the team plans to finalize CalCAST by July. While TP and nitrogen are close to completion, sediment and annual modeling need further refinement. Priorities include incorporating Joseph's sensitivity data, improving land-to-water and stream delivery formulations, exploring lagged response formulations, and ensuring consistent, accurate load delivery to the estuary model. The ultimate goal is to provide the estuary modeling team with high-quality, spatially consistent load estimates for use in the Chesapeake Bay modeling framework.

10:25 Discussion of CalCAST Development

Q: *Lew:* Sediment is probably the one parameter that is dictated by storage and movement in river channels and lag time. It's not surprising that sediment is the parameter with the most difficulty. Generally, the HSPF should perform well for sediments. So, your work continues to bring us to a good position. But the interface with the refinements of the CalCAST and the Dynamic Model – do we have a place for the Dynamic watershed Model and what is happening in the watersheds and the rivers?

- ***A:*** *Isabella:* Actually, we do incorporate their data into the model. Greg developed a very useful dataset using a random forest model, which includes stream bed and bank loading rates as well as floodplain deposition rates for each NHDPlus catchment. His model is based on his floodplain observations and results in catchment-specific loading rates, which makes them naturally easy to incorporate into CalCAST. So yes, we are using his data directly in the model.

10:35 Progress in Phase 7 WSM Development – Gopal Bhatt, Penn State-CBPO

Description: A key theme of the last quarter has been the linkage of the Dynamic Watershed Model (DWSM) and Main Bay Model (MBM). The initial linkage and plans for future improvements leading to an automatic NetCDF transfer of calibration and scenario files will be discussed. In addition, work to provide atmospheric deposition loads to the MBM coastal water domain and general progress in the DWSM will be described.

Gopal Bhatt: Over the past quarter, a major focus has been on strengthening the connection between the Dynamic Watershed Model (DWSM), the airshed model, and the SCHISM-based estuary model developed by VIMS and partners. The DWSM serves three main purposes: it provides essential inputs to both the main Bay model (MBM) and tributary models; it is calibrated using monitoring data for nitrogen, phosphorus, and sediment; and it supports collaborative research. This model is now guided by statistical

CalCAST outputs and uses average annual loads and parameters for various constituents. The team has made iterative improvements to segmentation and simulations—especially for small streams—ensuring feasible runtimes while enhancing the model's utility for estuary modeling and Phase 7 load delivery.

One of the most notable changes from P6 to P7 is increased spatial specificity. In P6, all river segments were modeled with HSPF, while tidal areas received direct discharges without river routing. P7 introduces a mixed approach: small streams use non-iterative routing models, and larger rivers still use HSPF. This change reduces the tidal-only discharge areas while expanding the modeled non-tidal and terminal segments, allowing finer resolution and more accurate load delivery. Compared to P6's 64 river segments and 535 tidal discharge zones, P7 includes many more simulated streams and rivers, improving spatial representation and model performance.

Over the past few months, three improved versions of the DWSM dataset were developed. The October version laid the groundwork. The November 2024 beta version added refinements like point source integration at the NHD scale and subroutine bug fixes. The December version incorporated the latest CalCAST parameters and showed clear improvements, particularly in nitrogen load estimation. Comparisons across nine RIM stations and tidal segments revealed that while the P7 October version under-accounted for point sources, corrections made in later versions significantly improved agreement with observed data and previous model estimates. By December, differences in nitrogen loads had narrowed, though further refinements are still needed.

Robust QA/QC efforts between CBPO and VIMS played a key role in improving the model linkage. This included identifying and removing redundant tidal catchments, and resolving unrealistic water temperatures generated during low-flow periods. An error related to the version of the P6 watershed model used in the estuary model was also discovered and addressed. These adjustments underscore the importance of detailed model vetting in linking watershed and estuary systems.

Looking ahead, a key advancement involves converting the output file format from text to NetCDF to align with the needs of the SCHISM estuary model, tributary models, and the Chesapeake Global Collaboratory. This change will replace over 200,000 text files with a single, efficient, portable NetCDF file. It will streamline model linkage, reduce storage demands and errors, and eliminate manual steps. The team is also working with VIMS to ensure tributary load data are correctly aligned with SCHISM grid cells, including updated geospatial attributes in the new output. Testing of this system is planned for the coming quarter, which will enhance consistency, efficiency, and inter-model compatibility.

- ***Q:*** *Lew Linker:* It's clear that P7 needs to resemble P6 more closely—especially when it comes to representing WRTDS estimates at the RIM stations (slide 13). For the next data delivery to the MBM and multiple tributary models (MTM), I wonder if we should consider continuing to use P6 loads for the RIM stations. However, for non-RIM areas—particularly the Coastal Plain—Phase 7 loads might now be demonstrably better than what was essentially a rough estimate in P6. In P6, coastal plain loads were derived by transferring attributes from RIM segments, which may have oversimplified things. What do you think of using P6 loads for RIM stations and P7 loads for non-RIM areas?

- ***A:*** *Gopal Bhatt:* I may have spoken from the perspective of watershed calibration, which differs slightly from how we link loads to the estuary model. So, there's still work to do. As Gary laid out, we can expect continued refinements, not just from CalCAST—possibly with adjustments to inputs and sensitivities—but also from additional adjustments on the DWSM side. These refinements will help bring model outputs at the RIM stations and elsewhere into better agreement. I think this coming quarter will be crucial for us to develop and implement a concrete plan, so the estuary modelers have reliable loads to work with. Until now, we've essentially been telling them to wait for improvements, but it's time to deliver. So, yes, I think we have some homework ahead of us, and I'd echo what Gary outlined earlier in terms of next steps.
- ***Q:*** *Dave Montali:* As you work to improve RIM station performance, wouldn't that indirectly change the modeling results for the terminal and tidal segments as well? For example, if model performance improves at RIM stations—presumably meaning loads are adjusted upward to better match WRTDS—wouldn't we also expect to see increased loads in the terminal (red) and tidal (green) segments in future P7 versions?
- ***A:*** *Gopal Bhatt:* That's a good point. You're right. Many of the adjustments we make will affect not just RIM stations but also several terminal stations where we have monitoring data. So, we should indeed expect changes in both the terminal (red) and non-RIM (blue) areas. However, the tidal areas (green) may not change as much, since they're unmonitored and rely heavily on CalCAST outputs rather than dynamic model calibration.
- ***Comment:*** *Gary Shenk:* Agreed. If part of the load updates comes from changes to CalCAST, that will affect the non-tidal loads as well. But if refinements are only applied within the dynamic model, it won't affect the tidal loads—except, as Gopal mentioned, where there is downstream monitoring below the RIM stations.

Gopal Bhatt: A key component of improving model linkage involves integrating airshed loads into the estuary model. While the current focus is on the estuary, this work will eventually extend to the watershed model as well. With support from Jesse Bash, the team has received updated data from CMAQ version 5.3.3.2, which includes wet and dry deposition data for both oxidized and reduced nitrogen, at a 12-kilometer resolution. This dataset spans 2002 to 2019 and covers both the watershed and estuary domains. However, to support model calibration across short- and long-term timelines, data from 1985 to at least 2024 is needed. The team is exploring a hybrid approach that combines historic P6 CBP airshed model data with the new CMAQ data to bridge this temporal gap.

Another critical advancement involves expanding the spatial domain. Earlier estuary models only covered the Chesapeake Bay proper, but the SCHISM model now extends into the coastal ocean. This matters because significant nutrient inputs—up to 35% for nitrogen and 65% for phosphorus—may come from ocean sources, including atmospheric deposition. To address this, the team is using CMAQ data to estimate deposition in coastal ocean areas and determine its relationship to Bay-level deposition. By analyzing 54 grid cells covering the Bay and 311 cells for the coastal ocean, they found that nitrogen deposition in the coastal ocean is, on average, 84% of that in the Bay.

Further breakdowns revealed that coastal ocean oxidized nitrogen deposition was 82% of Bay levels, and reduced nitrogen was 88%. When separating wet and dry deposition, the analysis showed that dry deposition was significantly lower in the coastal ocean, while wet deposition remained similar at about 95% of Bay levels. A spatial gradient was also noted—nitrogen deposition increases from north to south in the coastal ocean. However, prevailing southward ocean currents and warmer Gulf Stream patterns indicate that southern coastal deposition is unlikely to influence Bay water quality, helping refine which oceanic regions to focus on in model development.

Deposition trends from 2002 to 2019 were consistent across the Bay and coastal ocean, supporting the idea that Bay trends can be used to estimate historical trends in the coastal ocean. This provides a potential path for recreating long-term deposition datasets using a consistent methodology. While early findings show only minor differences, ongoing analysis will fine-tune these relationships and determine their implications for model inputs.

In summary, progress continues on integrating atmospheric deposition into estuary and watershed modeling. Future efforts will refine the dynamic watershed model further by incorporating the latest CalCAST and CMAQ data, while working closely with the Main Bay modeling team to adopt NetCDF formats and standardized variable conversions. These advancements will ensure consistency, reduce errors, and strengthen the connection between airshed, watershed, and estuary models.

11:15 Discussion of Phase 7 WSM Development Progress

Comment: *Lew:* The coastal ocean is an important part of the system—it's closely linked to nitrogen loads, and the inputs there are comparable to what we receive from the watershed, including both point and nonpoint sources. So, the exchange at the ocean boundary is crucial. In P5 and P6, we accounted for this by decrementing the ocean boundary load based on atmospheric deposition reductions. This was an estimate informed by a Horwith paper describing coastal ocean inputs. But now, for the first time, with the CMAQ model domain extending over the coastal ocean, we have an opportunity to refine those estimates. So, reductions in atmospheric NOx emissions will reduce coastal ocean deposition. Consequently, the ocean boundary load will decrease, and this reduction will now be directly quantified within the MBM. This is significant—likely on the order of a few million pounds of total nitrogen (TN), and a similar amount of dissolved nitrogen (DN). It's a big step toward improving our overall assessment of total nitrogen loads entering the Bay.

Q: Zhengui: I have a question about the CMAQ grid coverage for the Chesapeake Bay. Slide 21 shows the CMAQ grid for the Chesapeake Bay—specifically, the grid cells you're planning to use for the MBM linkage. I noticed that the current grid focuses on water areas, but wouldn't it be better for us, in the main Bay model, to have a CMAQ grid that also covers all the tributaries within the Bay? That way, interpolation would be much easier for our model.

- ***A:*** *Gopal:* Yes, Zhengui, excellent question—and we will definitely get there. This focus on water-only grid cells was intentional for the purposes of this particular analysis. Deposition behaves differently over water-dominant areas compared to areas where there's an intersection with land, so for this trend and spatial analysis, we limited it to pixels entirely over water. However, when we eventually generate atmospheric deposition loads for both Bay waters and coastal ocean waters, the data will have full spatial coverage across the entire SCHISM domain—including all tributaries and land-water interfaces. This is consistent with what we did in P6, where we extrapolated deposition spatially to cover the full domain. In fact, there may now be better tools available for handling land-use-specific deposition, which we can leverage moving forward. So yes, you're right to raise that point, and we're definitely tracking that as part of our ongoing work.

11:25 **Development of Efficient Multi-Objective Optimization Procedures – Kalyan Deb, Pouyan Nejadhashemi, Gregorio Toscano, Ritam Guha, and Hoda Razavi, MSU**
Description: Progress on the integration of web-user and decision-making interfaces, and tasks for multi-state implementation using machine learning and parallel computing platforms will be presented. The upcoming webinar on application of the optimization tool will be discussed.

Ritam Guha: This presentation will discuss what has been developed so far and how we're building a system to help optimize best watershed management practices (BMPs) for the Chesapeake Bay area from an analytical perspective. Moving on to the timeline, we are currently in Quarter 1 of 2025, focusing primarily on Task 4: interactive optimization and decision-making using a user-friendly dashboard. It's divided into four sub-parts:

1. Developing a user-friendly optimization framework through a dashboard so users can optimize watershed management practices intuitively.
2. Implementing surrogate-assisted optimization to speed up evaluations. Right now, evaluating solutions requires using the CAST system, which takes time. Surrogate models—machine learning models—will predict solution quality and reduce evaluation time.
3. Adding robust optimization, ensuring the solutions we provide are resilient to uncertainties and variations in real-world scenarios.

4. Focusing on sustainable watershed management practices, the ultimate goal of this project.

Right now, our focus is on the first sub-part: building the user-friendly dashboard. Here's an overview of the optimization workflow:

- At MSU, we've developed a system that uses an optimization algorithm to suggest BMP solutions.
- These solutions are evaluated by sending them to the CAST processor, which returns pollution load estimates. In addition, we calculate the cost of each BMP solution.
- The optimization algorithm uses both cost and pollution load as objectives and iteratively improves the solution set over several iterations. There are two main parts here: one internal to MSU (where optimization occurs) and one external—the CAST processor (hosted elsewhere).

Previously, a key downside of the system was that users and developers shared the same platform. So, when developers added new features or performed maintenance, users had to wait due to system downtime. To resolve this, we made several adjustments. We migrated the implementation code to a robust, scalable, and secure system housed at MSU's COIN Lab (established in 2012). This lab is dedicated to optimization research, equipped with 13 PCs, two MSU-maintained servers, NVIDIA GPU stacks, and 24/7 facility support. The system is secure and scalable, with access currently limited to me but expandable as needed.

We've now separated the user and developer environments: Users access the system via coinlab.chesapeakebay.app; Developers work on a separate copy via devdash.coinlab.chesapeakebay.app. This separation ensures uninterrupted access for users while allowing developers to test and integrate new features without affecting user operations. Previously, the architecture had users sending requests to a single external development system, which communicated with CAST servers, creating downtime risks and limited scalability. Now, by moving to COIN Lab servers, users and developers interact with independent systems, reducing downtime and improving maintainability.

Here are three key improvements made to the Dashboard over the last quarter:

1. Updated Progress Data: We've imported the latest 2023 CAST progress data. Users can now run optimizations using up-to-date information.
2. Separate User & Developer Interfaces: We've implemented two distinct portals—coinlab.chesapeakebay.app for users and devdash.coinlab.chesapeakebay.app for developers—allowing for stable user access even during development.
3. Enhanced Reduction Target Options: Users can now set reduction targets for all three pollutants—nitrogen, phosphorus, and sediments—rather than just nitrogen, adding flexibility and control over their optimization scenarios.

On the dashboard, users can:

- Create a new optimization scenario (*a live example was given for Richmond County*).
- Select the appropriate dataset (e.g., 2023 progress data).
- Set reduction targets for nitrogen, phosphorus, or sediments.
- Select or deselect specific BMPs to include in the optimization.

Run the optimization process, which outputs:

- Multiple solutions balancing cost and pollution reduction.
- Downloadable files detailing BMP configurations and outcomes.

There are several upcoming improvements coming, including:

- Status Column: Adding a status indicator for each scenario (e.g., initializing, optimizing, completed) to inform users of progress.
- Email Updates: Sending automatic email notifications when optimizations start and finish.
- Advanced Cost Settings: Allowing users to customize BMP costs if they have better local data.
- Result Sharing: Adding functionality for users to share optimization results with others for collaborative analysis.
- Scenario Deletion: Enabling users to delete unneeded scenarios directly.
- Uniform Solution Distribution: Improving the optimization algorithm to provide a more uniform spread of solutions, minimizing gaps between feasible options in terms of cost and pollutant load.

Kalyan Deb: Given these developments, we've already started discussions and formally requested a no-cost extension for the project—an additional year. Originally, the project was set to conclude in March 2026. Considering the personnel changes, platform transitions, and anticipated enhancements, we believe extending the project to March 2027 will allow us the necessary time to complete everything properly.

Looking ahead, our immediate priority is to finalize the optimization code so that the system is fully operational and we can move forward with scheduling the webinar. Once that's done, we'll shift focus to the remaining objectives for the project period, including:

- Extending optimization capabilities to multiple counties, rather than just single-county scenarios.
- Incorporating the "Innovization" concept—something we've discussed previously. This approach helps extract useful rules and patterns from optimization results, which can then be used to streamline future runs and improve efficiency.
- Parallel CAST evaluations: Currently, solution evaluations are done sequentially, one at a time. Gregorio has already explored parallelization, so we plan to leverage multiple threads to allow several solutions to be evaluated simultaneously, significantly speeding up the process.

- Implementing surrogate-assisted and robust optimization: This will further enhance both the speed and reliability of the solutions.

Some of these improvements are focused on advancing the optimization algorithm itself, while others are more interface-related—making the system more intuitive and accessible for users. With all these tasks planned, we believe the requested one-year extension will give us sufficient time to complete the project at a high standard.

11:50 Optimization Discussion

Q: *Lew Linker:* A webinar is a really exciting idea and the work presented today with Richmond as your example demonstrates how useful of a tool your optimization is. We should find an informational webinar, like today, with an extended invitation to multiple jurisdictions would be advantageous. Do you think the Coin lab transfer to CBP would be pose any challenges? More generally, how transferrable is this to other regions?

- ***A:*** *Ritam:* I don't see any issues at all. We would just need to identify a place and computer, we can demonstrate how it works – alongside some maintenance – anyone anywhere can use this tool.
- ***Response:*** Pouyan Nejadhashemi: In terms of code transfer and operational readiness—yes, that's very doable. But I want to add a word of caution. You mentioned other watersheds like Long Island Sound, or the Great Lakes. In those regions, they may not have a core CAST system running. Our current optimization system is tightly coupled with CAST—specifically with the elements and variables within it. The process of connecting optimization to any watershed model is technically feasible. We've done similar work integrating optimization with models like HSPF and SWAT. However, input variables and characteristics would differ based on the watershed model used in other regions. For scalability, as you recall from our work in West Virginia, we've developed strategies using machine learning to enable scalability. But again, the inputs from CAST play a crucial role. So while the framework and methods are transferable, adjustments would be needed depending on the model and data availability in those areas.
- ***Comment:*** Lew Linker: I'm thinking of this in phases: starting in 2025, we could hold introductory webinars focused specifically on Chesapeake Bay Program optimization—explaining what it is and demonstrating its utility. Moving into late 2025 and 2026, we could then start the technology transfer process, preparing it for broader application. By the first quarter of 2027, as we approach project closure, there are national forums and webinars where it would be very beneficial to present this tool to a wider audience. It's a perfect opportunity to showcase what's been applied in the Chesapeake Bay and explore how it could be adapted for other coastal systems, lakes, or rivers. That long-term thinking about broader applications is exactly what we need.
- ***Response:*** *Pouyan Nejadhashemi:* In fact, as you might recall from our last quarterly, we've already made several national presentations—around six—highlighting this work to different audiences. I personally chaired the

Environmental Modeling Software Conference last year, where we showcased it prominently. We have more presentations planned this year as well.

- ***Comment:*** *Ritam Guha:* Yes, just to briefly add—the actual transfer process is quite straightforward. The core code transfer is easy. The key requirement is having the CAST system running because our optimization process interacts directly with CAST to evaluate solutions. In addition, the cost information for BMP implementation is crucial. Currently, we compute this within our system, so as long as we have the necessary cost data and CAST evaluations available in any new location, the optimization tool can be applied there without issue. It's primarily about feeding the right data into the system.

12:00 LUNCH

12:45 Future Climate Impacts of CBP BMP Efficiencies – Maya Struzak, David Rounce, and Sarah Fakhreddine, Carnegie Mellon University

Description: Progress will be presented on application of APEX and SWMM, well-documented, open source, and public domain watershed and stormwater models, under different future climate hydrologic conditions to determine relative pollutant removal efficiency change of current CBP-approved NPS and stormwater management BMPs.

Maya Struzak: This project focuses on assessing how climate change may impact the effectiveness of Best Management Practices (BMPs) in reducing pollution in the Chesapeake Bay. The team is conducting a modeling sensitivity study using two modeling tools—APEX for agricultural BMPs and SWMM for urban BMPs. The goal is to evaluate the pollutant removal efficiencies of sediment, phosphorus, and nitrogen under current climate conditions as well as projected future scenarios.

The modeling framework includes four physiographic regions and four land uses (row crops, hay lands, pasture, and forest). BMP selection was informed by the Chesapeake Bay Program's top 20 most implemented and most effective BMPs. These were filtered through a feasibility analysis to identify practices that could realistically be simulated in APEX without requiring land use changes. The current shortlist consists of five BMPs, though most apply only to row crops, and the team is open to additional suggestions.

To simulate BMP performance, the team is building and managing six categories of input files within APEX, ranging from site characteristics to agricultural operation schedules. Given the large number of scenarios (a minimum of 48 * N), automation has been critical. Python scripts were developed to streamline the creation and combination of input files across land uses, BMPs, climate scenarios, and regions. Each simulation includes both general baseline data and BMP-specific operations, overlaid with climate data to assess effectiveness under varying conditions.

Initial test runs have been conducted using a simplified cornfield model. These early simulations, which excluded BMPs, revealed issues with sediment outputs and the model's ability to fully process hourly weather data. While output values for flow, nitrogen, and phosphorus appeared usable, sediment data is currently being investigated.

Runtimes for these simulations were fast, but may be underestimated if the model isn't fully reading hourly inputs.

Next steps include resolving the sediment issue—potentially linked to wind data—and verifying that the hourly data is being correctly ingested by APEX. The team will also continue refining the input data, distinguishing between what must be based on real-world observations versus what can be generalized. Finally, actual BMP simulations will begin, starting with cover crops, which are expected to provide relatively simple and informative results.

1:15 Discussion of Stormwater Management in a Changing Climate SWM & AG BMPs

Q: *Lew:* I had a question about the data inputs. We want to represent, for example, the 1991–2000 period. I assume we're using weather data from PRISM, as used in Phase 6 and provided by Gopal, along with the climate change scenarios from Phase 6. The advantage is that it takes a lot of work off your team and allows for broader application. I just wanted to confirm we're using those inputs?

- ***A:*** *Maya Struzak:* We are using the NASA data as it seemed easy enough but what you're stating makes a lot of sense. I will use that moving forward.
- ***Q:*** Lew Linker: Regarding the physiographic regions—are we modeling a representative area within each region, like the coastal plain? Or are we doing an average or sampling within the region? I can't recall how we decided to handle that.
- ***A:*** Maya Struzak: That's something I'm still working through. Part of it involves assessing how sensitive the model is to different settings. For now, I've just been using a flat plot of land, but eventually we could adjust slopes, soil types, and other parameters for each physiographic region. Right now, I'm keeping things basic just to get the model functioning correctly.
- ***Q:*** Lew Linker: Exactly, and that's where we should be right now. But as we move forward, it would be useful to be strategic in how we populate user-supplied data for APEX or SWMM. In earlier phases, like P2, we spent a lot of time determining things like when to plant and harvest row crops, and these operations varied by model segment. Are we planning to use those historical assumptions as a reference? They might be valuable as a starting point, if not used directly.
- ***A:*** Maya Struzak: Yes, I think that would be a good idea. We're still in communication with folks who have access to agricultural operations data, so that's something in progress.
- ***Response:*** Lew Linker: Right. We might need to reconcile the assumptions made by the BMP expert groups with what's being used in modeling. A lot of time was spent working with conservation districts and others to determine, for example, when side dressing is applied or how much fertilizer is used in initial applications in different segments of the Chesapeake Bay. That could be a valuable foundation, adjusted as needed based on expert input.
- ***Comment:*** Dave Montali: I think there's a better resource than referring Maya to expert panels. Jess or Olivia might have more direct information. The real question is: if you need to make an assumption about planting dates, what's used in CAST? There's likely a more efficient way to get that data than digging

through expert panel reports. We should ask how this was handled in P6—that would be more effective.

Q: *Clifton Bell:* Are the models you're using focused solely on hydrologic processes, or do they also include biological or ecological processes that could be affected by climate change? At last summer's STAC Climate Change Modeling Workshop, we heard about the greening effect of higher CO_2 levels, including potential increases in nutrient uptake by vegetation. This could partially offset some hydrologic impacts. So my question is: can your models account for those effects, directly or indirectly? And are you planning to include that in your analysis?

- ***A:*** *Sarah Fahkreddine:* That topic has come up in prior discussions with Lou, Gary, and Gopal. The model does have the capability to include CO_2 effects if we input future CO_2 concentrations. We could run some preliminary sensitivity tests to determine the significance. Initially, we scoped the project to focus only on hydrology and temperature changes, excluding CO_2. But if it turns out to be important, we can include it. The model supports that functionality.
- ***Comment:*** *Lew Linker:* We should look into that. So far, CO_2 has had only a modest influence in our modeling, but Clifton raises a good point. It's a bit of a black box—higher CO_2 and temperatures, maybe more precipitation, would theoretically encourage plant growth and thus nutrient uptake. But warmer, wetter conditions could also speed up decay of organic material in soils. It's unclear if the net effect is more or less nutrient export. It's worth scoping and quantifying to determine if it's important enough to include, or if it simply helps complete the overall picture.
- ***Q:*** *Gary Shenk:* I remember a conversation we had in a smaller group. While Maya is currently using NASA's climate inputs, we had discussed using our own data. But if I remember correctly, we agreed the point wasn't to model a specific year like 2035 or 2050. The goal is to understand how BMP effectiveness changes in response to specific climate variables—say, increased precipitation or temperature. So, any climate dataset could work for this purpose, but our inputs might be more convenient because we've already prepared many climate scenarios. The key is not the year itself but the sensitivity relationship.
- ***Response:*** *Lew Linker:* Right, that's a good point. This becomes an operational question—what's easiest to use? While there's no strong reason to use the P7 scenarios specifically, they do offer three advantages: they'll be vetted by the Bay Program, thoroughly documented, and potentially easier to apply. But as you said, there are other valid approaches. The main thing is that we can analyze the functional relationship between variables like temperature, moisture, and CO_2 and their relative effects.

1:25 **Updating and Improving Loading Sensitivity to Inputs and Phosphorous Loading Processes – Joseph Delesantro, ORISE-CBPO**
Description: Joseph will follow-up from his last Quarterly presentation on agricultural sensitivities and crop uptake and expand on the possibility of using proposed refined sensitivities. In addition, progress in the sanitary exfiltration loads will be described

including the approach to apply it systematically everywhere in the Chesapeake watershed in a generalized fashion that will be consistent with the available data on gravity sewer systems.

Joseph Delesantro: CAST defines sensitivity as the change in export load per unit change in input load (delta). This concept helps capture how land use and management practices affect nutrient runoff into streams and fields. In P6, many land uses lacked sensitivity values, meaning export loads were assumed constant across time and space. As the team prepares for P7, they are revisiting these values to ensure alignment with current science and improving accuracy through literature reviews and field data. A key tool in this process is CalCAST, which can use expert knowledge and literature values as priors to calibrate sensitivities more precisely.

Much of the work has focused on phosphorus and nitrogen, particularly from manure and fertilizer sources. Over 80 relevant studies and models have been reviewed, including SPARROW and SWAT watershed models. A normalization approach was introduced to account for differences in land use representation between study types, specifically adjusting for high-intensity agriculture. This helps align diverse datasets with CAST's modeling framework. The literature values for fertilizer nitrogen and phosphorus show reasonable consistency with P6 estimates and are being used to inform CalCAST calibrations. However, some complexities remain, particularly with phosphorus partitioning and differences in model assumptions.

Urban sensitivity modeling has encountered challenges due to the high variability and uncertainty of input data in urban environments. Most literature focuses on loading rates rather than input-output sensitivity. While some studies provide quantifiable input data, their limited number and variability in urban structure make it difficult to generalize findings for CAST. Additional guidance will be sought from the Urban Nutrient Management Panel. Related efforts are also underway to improve sensitivities tied to nutrient uptake and atmospheric deposition in forests, though these are still in early stages.

Efforts are also being made to incorporate previously overlooked phosphorus loading controls—particularly hydrologic connectivity and in-stream biogeochemical processes. These factors significantly influence how phosphorus moves through the landscape, especially under rapid surface runoff. The team is collaborating to integrate land-to-water factors and assess available data on stream pH, conductivity, and temperature to reflect these processes more accurately within the model.

Another key area of progress is modeling sanitary sewer exfiltration. Gravity-fed pipes often leak, not just due to failure but by design, and this leakage introduces highly nutrient-rich wastewater into the environment. Although the overall Bay-wide nitrogen contribution may be small, local urban impacts can be significant. A preliminary modeling structure has been developed, using exfiltration as a percentage of treated volume and adjusted for system type, geology, and rehabilitation history. Testing is underway in VA and MD, with plans to refine and expand the model ahead of a full workgroup review in March.

1:55 Discussion of Updating and Improving Loading Sensitivity to Inputs, Phosphorous Loading Processes, and Related Activity Update

Q: *Lew Linker:* I know you're coordinating with other workgroups that will ultimately make decisions on this, and we appreciate that you're deeply engaged in the literature and model findings. I suppose the key question at this point is, based on where we are and the status of the Bay Program workgroups, do we anticipate changes in fertilizer and manure sensitivities? Are those changes likely or unlikely? What's your sense?

- ***A:*** *Joseph Delesantro:* As I understand it, the decision on sensitivities falls within this group's scope. My hope is that the fertilizer and manure literature value distributions can be used as prior inputs for Isabella's CalCAST model. We'll wait to see how the calibration performs before making any final decisions. That's the plan for now. Of course, Tom and Jess are actively addressing fertilizer and manure inputs through the Ag Modeling Workgroup. Thinking about Gary's "blue arrow" framework, those inputs are obviously a major factor in the resulting output values, which are influenced by the sensitivities.
- ***Response:*** *Lew Linker:* So, the literature values can serve as priors for CalCAST, and CalCAST can help inform the Modeling Workgroup's decisions. Meanwhile, input data is being addressed on the other side of the equation. So we can anticipate potential changes, even if they're not yet confirmed. Very useful context. With regard to forest and other natural lands like wetlands, the sensitivity to atmospheric deposition is still in early stages, but we're looking forward to it. The P6 sensitivities appear to be low based on the literature we've seen so far. We're hoping to see an update on that—possibly by April. Also, nutrient uptake is a significant topic. When nutrients are applied to land, they largely go into crops. So even small changes in uptake could have a major effect on nutrient export. That's going to be a big one.
- ***Comment:*** *Joseph Delesantro:* In the past, I thought about uptake in the context of nutrient use efficiency. But after some recent discussions, I'm reconsidering that approach. It may not align well with how inputs and uptake are separately parameterized. So I'm now focusing on models that directly parameterize uptake—such as SWAT, where this can be done, although it isn't always. APEX can also handle this, along with a few other models. I'm exploring this alternative direction to see what we can learn.
- ***Response:*** *Lew Linker:* APEX is progressing, although it's still early. It may not align with the P7 timeline, but it could be a useful source of information—particularly since APEX is expected to become a Bay Program, open-source, public-domain model. It might be more applicable in Phase 8. Eventually, it could help us understand the impact of input changes across different physiographic regions. A useful tool, even if not available for immediate decisions.

Q: *Dave Montali:* I don't believe the Wastewater Treatment Workgroup has met in a while, and perhaps these issues are better addressed there. But earlier, you mentioned that sanitary sewer exfiltration is expressed as a percentage of wastewater treated. I was curious—if we consider variations in annual treatment volumes, which are often influenced by wet weather, does increased precipitation necessarily increase exfiltration? Or, in your opinion, would dry weather flow be a more accurate metric to base exfiltration rates on?

- ***A:*** *Joseph Delesantro:* I would prefer to use dry weather flow. There are potential issues with relying on total treatment volume, especially since not all facilities report dry weather flow separately. The science clearly supports using dry weather flow as a more accurate indicator of exfiltration. There's also some inconsistency in how exfiltration is reported in the literature. As we finalize our methodology, we may choose to subset the literature values to include only those that define exfiltration as a percentage of dry weather flow. Where dry weather data isn't available, we may be able to make reasonable assumptions to estimate it, and I've already begun working on that.

Q: *Dave Montali:* One other point: the last factor you mentioned, the fraction of sewer systems that are new or rehabilitated, has some overlap with BMP implementation. It raises a policy question: if you factor that into what comes out of the facility, can utilities still get credit for rehabilitation work done to reduce infiltration and inflow (I&I)? It's a sequencing issue—are we representing the load first, and then applying mitigation BMPs? If you pre-emptively reduce the load based on rehab work, others might not be able to get credit for doing the same thing later. Maybe doing an I&I rehab should be treated as a BMP that offsets exfiltration, in line with how we manage credits elsewhere.

- A: Joseph Delesantro: How this is integrated into the model—especially the order of operations and how it affects crediting—is something I'll need to defer to you, Gary, and others to help navigate. It's a critical policy question that goes beyond my direct role, but definitely something we need to resolve.
- ***Comment:*** *Lew Linker:* your technical approach is very well thought out. It strikes a great balance between data availability, applicability across the watershed, and findings from literature, including your own work in North Carolina. As you mentioned—possibly on slide 24—this exfiltration load could represent about 3% to 11% of urban nitrogen load in the Chesapeake Bay watershed. Since this will likely shift load allocation between septic systems and nonpoint urban sources, it becomes a useful tool for decision-makers. Septic loads are harder to manage since they rely on individual homeowners. But in major metro areas like D.C., Baltimore, and Richmond—where there are resources and technical expertise—it makes a lot of sense to rehabilitate systems to reduce I&I and improve flow. This effort helps support more effective urban wastewater management and contributes to a more informed and resource-driven modeling approach. Your work on this is a valuable contribution to P7.

Comment: *Lew Linker:* In the Western Branch—where coal mining activity has significantly altered pH levels from 1955 to the present. That shift could influence phosphorus fate in streams and rivers. As waters become more naturally alkaline, we may see more phosphorus being absorbed by sediments. So while we may not be reducing the overall load reaching the Bay, we could be altering the timing of delivery. Instead of rapid phosphorus transport under acidic conditions, we may now see phosphorus being retained and slowly released over decades.

2:05 Key Airshed Model Scenarios for Phase 7 – Jesse Bash, Chris Nolte, and Dan Loughlin, EPA-ORD

Description: Progress on the completion of the Phase 7 library of CMAQ Airshed Model scenarios this month will be presented. Scenarios include the 2002-2019 Base, 2016 Base Scenario, 2035 Inflation Reduction Act (IRA) Scenario, 2035 IRA and State Targets Scenario, 2035 Net Zero Carbon Scenario, 2050 IRA Scenario, 2050 IRA and State Targets Scenario, and 2050 Net Zero Carbon Scenario.

Jesse Bash: The presentation focused on the impact of decarbonization scenarios on atmospheric nitrogen deposition to the Chesapeake Bay, summarizing research conducted with colleagues and recently delivered to the Bay Program. Retrospective CMAQ simulations from 2002 to 2019 were used to assess emission trends, using EPA's EQUATES project data and the 2017 National Emissions Inventory (NEI) methodology. The team observed a greater than 50% reduction in NOx emissions, largely due to mobile sources and electric generating units (EGUs), reflecting improvements from the Clean Air Act.

Simulations for future years (2016, 2035, and 2050) were conducted using CMAQ version 5.4 and linked with projections from the Global Change Analysis Model (GCAM). GCAM scenarios, based on IPCC assumptions, model the interaction between greenhouse gas emissions and policy decisions. The GLIMPSE tool translated these emissions into sector-specific air pollutant reductions, enabling analysis of how policies like vehicle electrification can drive co-benefits in air quality.

Two primary future scenarios were modeled: the Inflation Reduction Act (IRA)/Limited Mitigation scenario and a more ambitious Net Zero scenario. While both scenarios show declining CO_2 and NOx emissions through 2050, the Net Zero case projects deeper and more sustained reductions, particularly in urban areas due to electrification. Ammonia emissions, primarily from mobile sources, also decrease, though agriculture—excluded from mitigation strategies—remains a steady source.

Nitrogen deposition in the Chesapeake Bay watershed is projected to decline by approximately 20% under the IRA scenario by 2035, with slightly diminished benefits by 2050 due to economic and population growth. The Net Zero scenario achieves an additional 4% reduction in deposition by 2050. However, as combustion-related sources decline, agriculture's share of total nitrogen deposition rises, reaching over 60%, highlighting the need for future attention to agricultural practices.

In conclusion, while decarbonization through energy and transportation policy effectively reduces nitrogen deposition, the relative contribution from agriculture is increasing. Future strategies will need to address agricultural emissions to continue improving air quality and watershed health. The results underscore the importance of integrated, cross-sector approaches to meet long-term environmental goals.

2:20 Discussion of Key Airshed Scenarios for Phase 7

Q: *Lew Linker:* That's a good update from the October quarterly. As I recall, the urban sources of ammonia are estimated to decrease—probably due to fewer mobile source emissions from catalytic converters and reduced slip emissions from selective catalytic reduction systems. So, with agricultural sources increasing, that becomes the key story. They are now the majority of sources. But at least for urban areas, you showed ammonia going down—if I understood that correctly?

- ***A:*** *Jesse Bash:* Yes, that's correct. If you compare the IRA and Net Zero cases, you see larger reductions in urban areas. Much of that is due to electrification of the mobile sector. We also observe large reductions in NOx emissions in urban areas for the same reason.
- ***Q:*** *Dave Montali:* It's not that agricultural emissions are rising significantly—it's that ag is making up a larger share of a smaller total load. Am I understanding that correctly? Are agricultural emissions going up dramatically, or are they just not declining like the urban and combustion sources?
- ***A:*** *Jesse Bash:* They're not going down in these scenarios. So it's becoming a larger fraction of the overall emissions—essentially a bigger slice of a smaller pie. The transport changes slightly, but probably not significantly at the scale of the Chesapeake Bay watershed. Ammonia emissions, when combined with SO_2 or NOx, can form aerosols that travel farther. This means more local ammonia deposition, but that doesn't show up clearly at the scale I'm presenting.

Q: Lew Linker: Can we look at the histogram slide showing the NOx and ammonia levels (slide 7)? I thought the ammonia increased slightly in the IRA plus Limited Mitigation scenario. Maybe I'm misremembering.

- ***A:*** *Jesse Bash:* If you look closely at the 2050 IRA case, there's a slight increase in ammonia, likely due to population and economic growth, particularly from mobile and industrial sectors. We didn't change ammonia emissions in the scenarios because there wasn't a policy driver for that. The 20% reduction shown is almost entirely due to reduced combustion emissions. In 2016, there was a decrease in wet deposition because aerosols are more effectively scrubbed from the atmosphere by rain. With fewer ammonium aerosols, there's less wet deposition and a slight increase in dry deposition as remaining ammonia deposits more locally on soil, vegetation, or water.
- ***Response:*** *Lew Linker:* We should make a note for future modeling—maybe not in the next few months, but within the next few years. We could run some agricultural

scoping scenarios using GCAM, the watershed model, and the Bay model. That could include strategies like manure incorporation or more efficient fertilizer use.

Q: *Richard Tian:* between the 2035 Net Zero and the 2050 Net Zero scenarios, is population growth held constant or does it increase?

- ***A:*** *Jesse Bash:* Population does grow in those scenarios. There are built-in assumptions about population growth. We based those on IPCC scenarios, specifically the "middle of the road" projection.

2:30 Application of ISAM for CBP Nitrogen Emission Reductions – Gary Shenk, USGS-CBPO and Gopal Bhatt, Penn State-CBPO

Description: A presentation of how ISAM output can be used to distribute credit for nitrogen (ammonia and NOx) emission reductions will describe tables of the final ratio between emission and delivery to tidal waters. Additional tables for NOx and ammonia delivered to the watershed, from the watershed, and direct to the Bay will also be presented. The Modeling Workgroup will decide if ISAM should be used in both Phase 6 and Phase 7 or will be applied for Phase 7 only.

Gary Shenk: I will provide an update on modeling efforts related to atmospheric nitrogen deposition, noting that much of the work was led by Jesse, Sarah, and Gopal. The focus of the presentation is on how to account for air emissions reductions at the state level, beyond those already assumed from national policies, in Chesapeake Bay watershed planning models. Historically, reductions from national policies have been "pre-baked" into planning targets. However, when states go further with emissions reductions not captured by national laws, a more refined method is needed to properly credit those efforts.

An earlier solution developed in Phase 6 was based on 2013 CMAQ source attribution data and estimated the delivery of oxidized nitrogen by state. For example, emissions in Delaware were credited at a rate of 1.83 pounds delivered to the Bay per 100 pounds emitted (slide 4). Reduced nitrogen was not modeled at the time, and values were estimated based on assumptions about its transport behavior. The updated approach uses the Integrated Source Apportionment Method (ISAM) within CMAQ, allowing for a more sophisticated linkage between emissions and deposition by both region and source type.

To enhance regional resolution, the watershed was divided into smaller zones, especially near the Bay, ensuring that emissions from outside the watershed (e.g., in New York) could still be credited appropriately. For each region, multiple emission source types were modeled, including EGUs, mobile sources, poultry, manure, and commercial marine vessels. Fertilizer emissions were not modeled regionally due to platform limitations but were approximated using a weighted average of poultry and manure since they share spatial characteristics.

Results from the model show that geography and source type both significantly influence how much nitrogen deposition reaches the Bay. For example, only 0.55% of on-road mobile emissions from the Northeast region return to the Bay, compared to over 2% from similar sources in the Central Piedmont (slide 9 & 10). Commercial marine emissions in the same region show even higher return rates (nearly 4%) highlighting that emissions closer to the Bay and from certain sectors have a greater impact.

When comparing this new approach to older models, the overall sensitivity to oxidized nitrogen emissions remains relatively consistent, though there are regional shifts. Delaware shows a slight increase in delivery estimates, while Maryland and Virginia show decreased sensitivity. For ammonia (reduced nitrogen), the new modeling shows that previous methods likely overestimated its impact, with current results showing about half the sensitivity previously assumed.

In conclusion, while the CMAQ ISAM runs are complete and published, final delivery values still require integration with the Phase 7 watershed model. The MWG is tasked with approving the method (not the values yet), and once Phase 7 is finalized, they can proceed with delivering updated sensitivity values. If approved, the Water Quality Goal Implementation Team (WQGIT) will decide whether to apply these new values in current management efforts, including Phase 6 planning models.

2:50 Discussion of Applying ISAM for CBP Nitrogen Emission Reductions

Comment: *Lew:* This is much better than what we previously had in P5, especially in regard to ammonia. I hope we can rapidly come to a decision.

Q: *William Keeling:* What exactly is the decision that I am expected to approve?

- ***A:*** *Gary:* The method we're asking to approve is independent of Jesse's earlier presentation. It specifically refers to how we calculate credit for emission reductions that go beyond what's covered under state implementation plans. It uses the updated ISAM model to go from emissions to deposition, and then through the watershed model to determine loading reductions. It's the same approach approved in P5 and P6, just updated with new modeling tools. The majority of deposition is already included in planning targets; this method only applies to those rare, additional reductions beyond national laws, like what occurred in Virginia's Hopewell case.
- ***Response:*** *Dave:* This is about quantifying credit beyond what national laws already provide. For P7, this methodology appears to be the most scientifically sound approach to assess additional reductions. I think we should approve it unless there are strong objections.

Q: *Samuel:* On slide 12 & 13, do we average the bars to the states since they are now broken down into regions? For West Virginia, where you now show two regions, should we average those bars to compare to P5, which considered the whole state as one unit?

- ***A:*** *Gary:* Not exactly. You'd look at the regions individually. For example, the central part of West Virginia aligns with previous estimates, while the southern part shows about half the sensitivity. So comparisons aren't directly apples-to-apples; the data is more granular now, which changes how we interpret the results.
- ***Response:*** *Dave:* So, a state would need to make a case showing how it implemented reductions above federal requirements, specifying the reduction amounts in each region. What we're approving today are the factors to apply to those reductions.

Comment: *Scott Heidel:* It would be super helpful to have a clear messaging of decisional elements in certain meetings so that it can be all hands at the meetings.

*****Decision**: we will hold on making a decision on use of ISAM until **Wednesday, January 15th**. No responses will be considered as a "yes/approve". ***

3:00 Agricultural Modeling Team Progress – Tom Butler, EPA-CBPO

Description: Tom will outline progress being made by the Agricultural Modeling Team (AMT). In addition, previous limitations in the Phase 6 pasture and hay nutrient application rates will be summarized along with proposed changes to the hay/pasture land cover class and their associated nutrient application curve groupings now being considered by the AMT will be briefly discussed.

Tom Butler: As we prepare for P7, our focus is on agricultural inputs and how best to represent them in the model. One key topic that has come up recently is manure application. I want to provide some context on how we're thinking about this and where we're headed.

Currently, manure is applied in CAST based on land use types that group together similar crops. These applications are county-specific and structured around three priority groups, with Group 1 containing high-value crops like grains, and Group 3 including nitrogen-fixing crops, which typically receive less manure. The idea behind this structure is to direct nutrients toward more commercially important crops. However, the Agricultural Modeling Team (AMT) has been discussing whether these groupings truly reflect how manure is applied in practice—and the consensus is that the existing groupings may not be accurately aligned with real-world practices.

In particular, concerns have been raised around how hay and pasture land uses are treated. These land uses represent a large portion of agricultural acreage across the Bay watershed and are particularly important for certain states like Virginia. Representatives from Virginia pointed out that the current application assumptions for hay and pasture are unrealistic. In response, Virginia proposed a new approach that distinguishes between managed and unmanaged hay and pasture, creating two new land use categories that better reflect actual management practices. This approach received broad support from the partnership.

The proposal involves prioritizing managed hay and managed pasture alongside other high-priority crops like row crops, while placing unmanaged hay and pasture in a lower-priority group. The goal is to align nutrient application more accurately with how land is

used and managed. We've now separated out these new land uses, rerun CAST, and are preparing to present comparisons between the current version and the version with the proposed updates. These comparisons will help inform upcoming decisions.
We plan to present this updated analysis at the AMT meeting this Friday (link to meeting webpage). The agenda has been released, and the slides and data will be shared ahead of time. This discussion will be an action item, and the team will be asked to make a decision on it. Beyond manure application, the AMT is also exploring topics like inorganic fertilizer use, crop yields, and potential integration of industry data, aiming to continuously improve model accuracy.

3:15 Discussion of Potential New Pasture and Hay Land Uses

Q: *Dave:* How did you determine the amount of land to classify as managed for hay and pasture? Was it based on reported nutrient management?

- ***A:*** *Tom:* For the test run, we used fixed percentages: 25% for hay and 10% for pasture as managed. This approach was informed by discussions with the Virginia representatives, who have strong data on this. It's just a test setup for now and subject to change.

Q: *Lew:* What does managed pasture look like in comparison to the regular pasture?

- ***A:*** *William Keeling:* The main difference is that previous versions of the model allowed us to credit nutrient management on hay and pasture. In many cases—especially where biosolids or organic materials are used—nutrient management plans are both implemented and beneficial. This led us to recognize that not all pasture acreage is the same. Some is completely unmanaged, while some is highly managed and includes various BMPs. So, the idea is to carve out a subset of acres that are managed and eligible for nutrient management credit, which would better represent the diversity of hay and pastureland across the watershed.

3:25 ADJOURN

Modeling Workgroup October Quarterly Review

Day 2 – January 8, 2025

10:00 AM – 2:45 PM

Event webpage: Link

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

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Day 2 – January 8th, 2025.

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

10:05 Preparing for Linkage of Phase 7 and CBP Habitat Models – Ryan Woodland, Victoria Coles, Xiaoxu Guo, and Raleigh Hood, UMCES
Description: Development of Phase 6 scenario NetCDF files of key water quality scenarios for development and support of ancillary living resource models of oysters, white perch, crabs, and blue catfish will be presented. The Phase 6 NetCDF library of base, WIP, climate change, and all-forest scenarios will be made to be freely available to all requesters as part of a new initiative at UMCES called Chesapeake Global

Collaboratory (CGC). CGC will leverage preexisting water quality predictions from the previous Phase 6 CH3D-ICM hydrodynamic-water quality model as input for CB living resource/habitat models. Predictor variables include temperature, salinity, and DO (for white perch) and they simulate things like respiration, metabolism, etc. Ultimately, Net CDF links between the Phase 7 SCHISM-ICM and CB living resource/habitat models will be made.

Ryan Woodland: The project uses existing outputs from the P6 Chesapeake Bay TMDL models and combines them with previously published metabolic and bioenergetic models for selected species. The goal is to evaluate how changes in environmental conditions—such as temperature, dissolved oxygen, and salinity—affect species like Eastern oysters, blue crabs, white perch, and blue catfish.

The project's approach focuses on linking water quality to higher trophic levels, which are relevant to fisheries management, cultural interests, and ecosystem health. Researchers are using spatially and depth-resolved model data in netCDF format to calculate species-specific metabolic responses, such as growth rate, under various scenarios. These scenarios include baseline conditions, TMDL implementation, BMP adoption, and climate change projections for 2025 and 2055. White perch was used as the initial test species due to the availability of detailed lab-based metabolic data for juvenile growth, respiration, and feeding under variable environmental conditions.

Victoria Coles: I want to provide a brief highlight of the technical work of converting the CBP model output—originally in unformatted Fortran binary—into the more user-friendly netCDF format. This conversion, led by data scientist Xiaoxu Gao, enables easier analysis using tools in Python, R, and MATLAB. Additional tools were developed to compare model output with observed monitoring data and to visualize model layers and variables, such as growth rate and oxygen levels, across depth and time. These tools and tutorials are publicly available via GitHub, although large data storage and sharing remain challenges.

Ryan Woodland: Preliminary results demonstrate how this metabolic modeling approach can highlight spatial trade-offs across the Bay. For instance, some regions may experience increased productivity under nutrient reduction scenarios, while others may show declines due to the loss of fertilization effects. These spatially explicit outputs will help managers identify areas of concern or opportunity and better understand the ecological implications of policy decisions. The team is also planning a public-facing platform for broader access to results.

Next steps for the project include refining habitat constraints (e.g., masking out unsuitable high-salinity zones for white perch), expanding the approach to other species, and finalizing which CBP scenarios to include. The project demonstrates how combining advanced data science with ecological modeling can support informed management decisions in the Chesapeake Bay and potentially serve as a model for other regions.

10:20 Discussion of Phase 7 and CBP Habitat Models

Q: *Lew Linker:* On slide 3 there is a range of scenarios being used but I think CC2025 and CC2055 could use the Conowingo. I think this would be important to include those load reductions for the Conowingo inflow.

- ***A:*** *Ryan Woodland:* That's a great observation and one thing that is great about this tool is that it is very flexible and adaptable.

Comment: *Dave Montali:* When you compare the 1990s to the TMDL, an introspective thought we can easily ask ourselves what did we do to put us where we are now. In other words, what if we don't go further—what happens then? Being able to show living resource improvements from completing the TMDL could be very impactful.

- ***A:*** *Ryan Woodland:* as long as the output is in netCDF format, we can apply our metabolic modeling approach. So, if we have a model fitted and calibrated to the most recent data from the last 20 years, we could apply these methods to see how species have responded over that time.

Q: *Richard Tian:* At one point, you mentioned integrating across different zones. For management, we operate segment by segment—currently 104 segments, previously 92. I wonder if your results could be aggregated by segment, which would be more useful for Chesapeake Bay management. Secondly, you mentioned possible future work on SAV. That would be valuable, as SAV is a management goal with defined criteria. It's currently a challenge to assess SAV across scenarios, and your work could help advance that. Just my personal comment—thank you.

- ***A:*** *Victoria Coles:* We've looked at criteria related to light attenuation in a separate project focused on vibrio habitat, which also depends on water clarity. I think modeling SAV habitat using simple models with the KD parameter from the Bay Program model is quite feasible. We've already developed some bias correction tools to account for non-linear response functions. If you could share the grid conversion files that map model output to management-relevant segments, that would help us provide results at the appropriate scale.

Comment: *Lew Linker:* My sense is that we'll be using this analysis to paint in broad strokes. It won't be down to the level of saying a specific BMP like conservation tillage or nutrient management will change habitat in a given creek. But it will allow us to explore the broader picture—like what happens under future climate change with or without TMDL implementation. Another broad brush we might want to add is a "no action" scenario—what if we did nothing beyond Clean Water Act requirements like secondary treatment? That could help tell a powerful story, especially when contrasted with a worst-case scenario like all forest combined with climate change.

- ***Response:*** *Ryan Woodland:* That's a great point. Based on Victoria and Raleigh's work, climate change is expected to negatively affect many aspects of living resources, while TMDLs are projected to provide a net positive effect even in the face of climate change. Your suggested comparisons—like no action vs. TMDL—could really help illustrate the story. This approach is valuable not for predicting outcomes in specific creeks, but for highlighting where we might see relative gains or losses. Summarizing results at scales like segments, tributaries, or salinity zones—as Richard suggested—will likely provide the most meaningful insights into net effects.

Comment: *Gary:* We have always known that we need to get into living resources and have made some attempts but we couldn't really get all the way there. What you presented here is something that can get us there.

10:30 **Update on Main Bay Model (MBM) Progress – Zhengui Wang, Joseph Zhang, and Jian Shen, VIMS**

Description: Ongoing progress on the MBM water quality (ICM) living resource modules of oysters, SAV, and tidal marsh will be presented. Sensitivity scenario comparisons between Phase 6 and Phase 7 living resource modules and shoreline erosion inputs will be reviewed and progress in the linkage of the Phase 7 Dynamic Watershed Model (DWSM) and MBM will be presented.

Zhengui Wang provided a comprehensive update on the P7 MBM, emphasizing recent advancements in the oyster module and the integration of watershed loading data. The team has significantly refined how the model simulates oyster growth and biomass, especially for reef oysters. Improved calibration of biological processes, such as filtration rates, has resulted in more realistic spatial and temporal distributions of oyster biomass across the Chesapeake Bay. Observational comparisons from MD and VA confirmed the model's accuracy in capturing seasonal and annual trends, marking a substantial improvement over earlier model versions.

In addition to reef oysters, the model now incorporates other species, including freshwater and estuarine oysters. Although not yet validated with field data, their modeled distributions—freshwater species in the Upper Bay and tidal rivers, estuarine species in shallow Middle Bay areas—appear reasonable. The model also introduces variable oyster coverage per grid cell, allowing for a more accurate Bay-wide estimate of total biomass. These enhancements set the stage for future refinements and broader ecosystem applications.

To evaluate ecosystem benefits, the team assessed the oyster module's impact on water quality. They observed modest improvements in particulate organic carbon and DO concentrations, especially in shallow and riverine zones. Sensitivity simulations, which modeled 10- and 30-fold increases in oyster biomass, suggested even greater benefits, including improved DO levels. These results indicate that historically abundant oyster populations likely played a critical role in maintaining water quality in the Bay.

Much of the recent work has focused on integrating preliminary P7 watershed loading data into the model. The team processed over 200,000 files and developed automated workflows to reorganize and combine them into a central database. This facilitated efficient data access and allowed flow and nutrient values to be accurately distributed across the model grid. The process required detailed knowledge of segment attributes and geometries to ensure robust, realistic mapping of input sources to the Bay model.

To allocate watershed loading to the Bay model grid, the team used a combination of interpolation methods and attribute-based matching. This was especially important for watersheds that didn't directly intersect with the model grid. Special handling was also applied to nine RIM rivers to ensure flow entered at river heads. Comparisons with P6 showed similar flow trends overall, but P7's higher resolution improved accuracy in local areas—correcting errors such as reverse flow in Upper York.

Preliminary results from the updated hydrodynamic model are promising. Simulations showed strong agreement with observed tidal signals across the Bay, with correlation coefficients up to 0.98. Temperature and salinity calibrations also showed improvement. Surface and bottom temperatures saw reduced root mean square errors (RMSE), especially in rivers and shallow areas, while salinity accuracy improved in the Middle and Lower Bay. Some local degradation remains in a few river locations, indicating a need for further calibration. Overall, the integration of P7 loading has enhanced model performance and laid a solid foundation for future ecosystem assessments.

11:15 Discussion of the Main Bay Model (MBM) Progress

Comment: *Lew:* I appreciate the efforts from both the MBM team and the watershed model team to ensure that this exchange is as effective as possible. One of our top priorities is to get the best calibration from the DWSM into the MBM so the team can begin working with a settled and reliable calibration. We have a meeting scheduled on the 13th with the MBM team, and that would be a good opportunity to discuss the next tranche of P7 data. With each quarterly, a new tranche from the watershed model is delivered to the MBM team and MTM. We need to consider how to make this process more efficient and deliver a stable calibration set quickly. That way, we can begin sensitivity analyses—exploring impacts from climate change or the WIPs. With Isabella's updates on coastal plain loading, we should consider whether blending P6 RIM station data with P7 coastal plain data would provide a more stable and representative calibration. While future improvements may be incremental, that blend might offer a practical solution.

Comment: *Carl:* It is surprising to me to hear that there is no data for particular species. These species had a substantial impact on Chl-a concentrations. I think it is important to compare what is coming out of this model to what has been collected previously, especially how certain tributaries are sensitive to this.

- ***A:*** *Zhengui:* Unfortunately, we couldn't find those data but if you could help with obtaining that, we would appreciate it. If we can get that data, we can support the impact oysters have on water quality. I have only received reef oyster.

Q: *Lew:* On slide 12, there are islands that are blank spaces on SCHISM and we are getting new land uses that will apply tidal wetland attenuators on those islands. How bad would it be to place tidal wetlands as attenuators on those islands? It may have some influence on the shallow waters.

- ***A:*** *Zhengui:* I think this should not be a problem as long as we receive those loadings.

11:25 **New Approaches in Model Criteria Assessment – Richard Tian, UMCES-CBPO**
Description: The criteria assessment for the period for 2021-2023 is being developed with the addition of continuous data in the Main Bay and in shallow water and with the shallow water data flow observations. Progress in the development of this new approach incorporating all the available data will be presented.

Richard Tian: The presentation is more of a guided discussion on the potential use of high-frequency, sensor-based data—such as dataflow and continuous monitoring (Conmon) datasets—for water quality criteria assessment in the Chesapeake Bay. These data offer significant spatial and temporal resolution, capturing parameters like temperature, salinity, DO, and pH at fine time intervals (e.g., every 15 minutes or even every few seconds). The dataflow surveys, primarily conducted in the Maryland portion of the Bay, have covered entire segments over consecutive three-year periods and were specifically designed to align with rolling three-year criteria assessment cycles. Conmon stations, managed largely by MD DNR, add another layer of vertical and temporal detail, with some deployments including multiple sensors throughout the water column.

VA has also contributed high-resolution data through rotational stations and dataflow efforts, although current deployments are more limited. The overall availability of high-frequency data is substantial, with millions of data points collected across decades, posing both opportunities and challenges for integration into existing assessment frameworks. While this data could significantly enhance the resolution and accuracy of interpolations, it introduces concerns around data management, consistency, and computational limitations. For instance, incorporating the full dataset could exceed memory capacity, necessitating sub-sampling strategies to make the data usable in existing systems.

One question for the group: should high-frequency sensor data be integrated into the existing 3D interpolator or wait for the upcoming 4D interpolator tool being developed by the monitoring team? The 4D tool, still under development, aims to predict daily water quality conditions using statistical modeling and could potentially account for sub-hourly variability. However, integrating this new tool would require decisions on how model results are used in regulatory and management contexts, especially since current TMDL allocations and nutrient reduction strategies are based on long-term, 3D interpolated datasets.

One suggestion is a dual assessment strategy—one based on long-term monitoring data for consistency with existing methodologies, and another using high-frequency sensor data to conduct short-term, high-resolution evaluations when data are available. This would allow for leveraging detailed snapshots of Bay conditions without disrupting established management processes. In summary, the general conversation emphasized the need for further discussion on technical feasibility, data representativeness, and potential regulatory implications, and welcomed comments and suggestions from the group.

11:40 Discussion of New Approaches in Model Criteria Assessment.

Comment: *Tish:* From our experience with the James River chlorophyll modeling, we took the dataflow cruise tracks and aggregated them by interpolator grid cells. For chlorophyll, we calculated a median for each grid cell where the data points fell, and then we applied scenario modifications to those medians. That approach seemed like a reasonable way to handle the dense data without needing to modify each individual point. I haven't yet considered the continuous monitoring data, but I'm sure there are ways to subsample it to ease computational demands. I'm certainly happy to explore different options.

- ***Response:*** *Gary:* We had started talking with MDE about how to handle the Fishing Creek data but didn't land on a good method for the dataflow data. I really like your idea. What we proposed to Maryland for the Conmon was based on a 2017 method. In some of our conversations, you were considering using 2017 for conmon, and I went back to that section and it describes evaluating each station to see if there are two capture days where 10% of observations are below the criterion. I think that's what we're going to propose, just following that 2017 publication. Still, it's a good question, Richard, how we deal with that in both monitoring and modeling scenarios when it arises.
- ***Response:*** *Lew:* When we look at shallow water data, like 1-2 m, we're measuring temperature, salinity, turbidity, chlorophyll, and DO. For Bay-wide water quality in deep channels or open water, that data is less directly applicable. Shallow water Conmon data is very relevant for living resources and habitat, but perhaps less so for current Bay water quality assessments. One way to address this is to tailor the data product to its purpose. The idea of a 4D interpolator is beautiful, but it's not available for Phase 7. It might be developed afterward and be more useful for Phase 8. In James River chlorophyll assessments, where chlorophyll is central, a 3D or 4D interpolator might be entirely appropriate. For the broader Chesapeake Bay TMDL, we might stick with the current assessment methods for water quality but apply the new approach to habitat and shallow water modeling.
- ***Comment:*** *Gary*: The idea is that the 4D interpolator will be available for decisions. Not entirely sure of the timeframe but it should be available for all the criteria in 2028. We are going to give it a shot.

Q: *Lew:* would it be fair to say that this exploratory work is contributing to what could eventually become the 4D interpolator?

- ***Response:*** *Gary:* I think this can be considered more of as a backup plan. We're working with MDE and Virginia. Everyone wants to use the data, and we're all approaching it differently. We'll come together in the CAP Workgroup and figure it out. Plan A is the 4D interpolator, but if that's not ready, we want solid backups. Maryland and Virginia both want to start using Plan B even before Plan A becomes available.

11:50 Initial Assessment of Decarbonization on Chesapeake Airshed, Watershed, and Tidal Bay Loads – Richard Tian, UMCES-CBPO; Jesse Bash, EPA-ORD; and Gopal Bhatt, Penn State-CBPO

Description: The decarbonization sensitivity scenarios developed on GLIMPSE-GCAM-CMAQ by Jesse Bash, Chris Nolte, and Dan Loughlin, (EPA-ORD) were run on the Phase 6 Watershed and Estuary Models to understand the influence of reduced atmospheric nitrogen loads on tidal water quality.

Richard: While climate change poses significant challenges to Bay restoration, there are two key groups of people making a difference: those actively working to reduce emissions (e.g., through electrification policies) and those assessing the potential environmental benefits of these efforts. We modeled three scenarios using the water quality model: a reference scenario based on projected 2030 air conditions, a 2035 scenario reflecting state-led electrification efforts, and a more ambitious 2050 net-zero emissions scenario.

The 2030 reference scenario already includes significant reductions due to existing air quality regulations. The 2035 scenario reflects initiatives like California's plan to electrify medium- and heavy-duty vehicles and achieve 30% emissions reductions by 2030. The 2050 scenario, though hypothetical, illustrates the potential of net-zero policies. Across these scenarios, most states in the Chesapeake Bay watershed are engaged to some degree, whether through statutory mandates or voluntary targets, suggesting broad regional alignment with emission reduction goals.

Data shows that under the 2035 and 2050 scenarios, nitrogen deposition in the Bay region is projected to decrease significantly, up to 2 million pounds under the 2035 scenario alone. These reductions are comparable to or greater than the benefits achieved through direct climate mitigation efforts. For example, nitrogen load reductions from air quality improvements were equivalent to more than half the estimated benefits of climate change response efforts modeled separately. Nitrate, ammonium, and organic nitrogen contributions would all decline under these cleaner air scenarios.

In terms of water quality improvements, the models showed a 4% reduction in hypoxic volume under the 2035 scenario and a 2.5% reduction under the 2050 scenario for deep-channel zones. Open water areas showed even more promising results—up to a 6% improvement in dissolved oxygen attainment. Segment-level analysis revealed that areas like CB4 and the York River experienced relative attainment improvements exceeding 20–30%. While some segments showed no change, others displayed measurable gains, confirming that air quality policy has a significant and beneficial impact on Chesapeake Bay health.

12:05 Discussion of Initial Decarbonization Sensitivity Scenarios

Q: *Lew:* Can you remind us what the base conditions are for 2030 air? Specifically, what loading assumptions are we applying? Are we using the WIP assumptions?

- ***A:*** *Richard:* My understanding is that this is essentially the WIP scenario, but without climate change considerations. The 2030 air numbers differ from earlier WIP versions like 2020 or 2025. Also, climate-related elements such as Conowingo reductions were not included in this analysis.
- ***A:*** *Gopal:* Exactly. To directly answer the question, this is a Phase 3 WIP scenario that does not include climate change mitigation or the Conowingo reductions. So, it's a partial version of the P3 WIP but with 2030 air conditions layered on. Climate dynamics are not included in this scenario.

12:15 LUNCH

12:45 Final Documentation of Algal Temperature Correction for Algal Growth – Carl Cerco, Arlluk

Description: Carl will review the final documentation of algal temperature correction for algal growth for Model Workgroup decision.

Carl: We've been exploring the relationship between algae production and temperature, specifically for use in climate change scenarios. This is particularly relevant as we begin to see maximum temperatures in the Bay occasionally approach 30°C, and in climate projections, potentially reach 32°C or higher. Most of our work has focused on observations within the Bay, especially in shallow tributaries where temperatures run higher. We've used a lot of the data Richard presented earlier, including from VECOS and conmon, and we also reviewed literature and other modeling efforts to understand observed responses in different systems.

A key takeaway is that observations suggest chlorophyll concentrations tend to decline once temperatures exceed approximately 32°C. That means we can't use a traditional exponential growth function for algal production that increases indefinitely with temperature. Instead, we need a function that levels off around 32°C, or even declines at higher temperatures. We've developed temperature–growth relationships accordingly and provided them to the MBM team. I'm not sure if they've been fully integrated yet, but the documentation is available on the Chesapeake Bay Program website. This work is preserved in a formal report (link below).

The recommended function reflects what we see in the Bay—temperature increases up to about 32°C are associated with increasing chlorophyll levels, but beyond that point, the relationship weakens and eventually reverses. In extreme scenarios like 40°C, growth would clearly decline. However, most of our data and projections lie within the 30–32°C range, where things begin to flatten out. It's important to avoid relying on individual stations to justify conclusions. Instead, we reviewed about 20 stations with large datasets from sources like Conmon and VECOS. Temperatures at some of these stations reached up to 35°C, but most hovered around 32°C. Tish conducted a quantile regression analysis on this data, examining both the 50th and 90th percentiles to emphasize extreme values rather than average trends.

Her analysis split the data into two groups—below and above 32°C. Below that threshold, about 80% of stations showed a significant positive relationship between temperature and chlorophyll. However, above 32°C, the trend reversed: approximately 80% of stations showed a significant negative relationship or no relationship at all. This provides strong evidence that chlorophyll levels do not universally increase with temperature. Instead, once temperatures exceed 32°C, chlorophyll concentration typically flattens or declines. This directly supports the relationship we're proposing for use in the Bay models.

In conclusion, this analysis confirms that algal growth does not continue to rise with increasing temperature beyond a critical threshold. The appropriate modeling approach is to incorporate a growth function that plateaus or drops after 32°C. This reflects both observational data and sound scientific reasoning.

Here is the final documentation found on the MWG Publications webpage.

12:55 Discussion of Algal Temperature Correction for Algal Growth

Comment: Lew: What we now have is an algal response curve that behaves realistically under climate change scenarios. It shows either continued increase or levels off as temperatures approach the mid-30s °C. We don't expect to see much above that range even with projected climate scenarios. Based on the weight of the evidence, we're recommending use of the algal temperature-growth curve described by Carl. The MBM team has provided flexibility to allow sensitivity testing, so while user-defined curves are possible, Plan A is to use the scientifically supported relationship documented in the report.

Q: *Dave:* Is this different from what we have used in the past?

- ***A:*** *Lew:* Yes, the diatom curve, which applies to cold-water algal species, remains unchanged. This new curve applies specifically to the green algae group. The blue-green algal curve is also unchanged, as it was previously determined to be appropriate.
- ***Response:*** *Zhengui:* This curve has not made any impacts on our findings and we will continue to use this in our work.

Comment: *Clifton Bell*: I really appreciate the thorough investigation and write-up from Carl and Tish. We played a role in initiating this discussion, and I'm glad to see it reach a scientifically defensible conclusion. I sent Carl an email just yesterday, and I wanted to express that I think choosing 32°C as the optimum is a conservative and reasonable choice. The data shows a plateau between 29°C and 32°C, and when Tish and I were discussing quantile regressions, we tried running them using 30°C and 31°C thresholds, with similar results. The top of the curve is so flat that results are not highly sensitive to the exact cutoff. Importantly, this doesn't contradict the Eppley curve—it still shows increasing growth over most of the relevant range, with the exceptions occurring under rare, extreme heat. While we expect some adaptation in algal communities, this curve represents a practical approach for typical conditions.

Q: *Raleigh Hood:* I've expressed concerns about this approach before, and I won't repeat them here, but I do want to make one important point. Chlorophyll biomass and algal growth rate are not synonymous. Chlorophyll is a result of both growth and grazing, so even if growth increases, higher grazing rates could cause biomass to decline. Ideally, this analysis would be based on actual growth rates or carbon uptake, not chlorophyll alone. Chlorophyll is only a proxy, and not a perfect one. Still, I'll leave it at that.

- ***A:*** *Carl:* Thanks, Raleigh. Just to address your point, I've been thinking about how to represent this. The blue curve on this slide is the traditional Eppley curve, and the red curve is one I derived by subtracting a respiration function from the Eppley growth curve, essentially a difference of two exponentials. This gave a shape that matches observed chlorophyll behavior, growth increasing with temperature, then leveling off or declining at higher temperatures. But it's incredibly difficult to calibrate a model using this difference-of-exponentials approach, it's mathematically complex and not practical. Plus, there is physiological evidence suggesting that some cellular production processes do max out at high temperatures. So, using a growth curve that mimics observed chlorophyll trends is the most practical solution for our modeling needs.

****Decision:** we approve this report and proceed with this curve as our standard as our calibration approach.*

1:05 Progress with the Patapsco-Back MTM – Harry Wang, VIMS and Jeremy Testa, UMCES

Description: The Patapsco-Back MTM Team, one of the three MTMs supported by a five-year grant, will describe progress on the MTM.

Harry: We've modified the Chesapeake Bay model to treat the C&D Canal as an open boundary, rather than assigning fixed flow rates as was done previously. This approach allows us to better represent its influence on Upper Bay dynamics. NOAA data from Reedy Point (at the canal's terminus) provided continuous records of water level, temperature, air temperature, and specific conductance, which we converted to salinity. Despite minor data gaps, we interpolated a complete time series for use in the model. Comparing open vs. closed boundary simulations, we found that opening the boundary allows fresher Reedy Point water to enter, producing subtle but measurable salinity differences of 0.5–1 PSU in the Upper Bay, particularly near CB 1.1 and CB 2.1.

In addition, we included freshwater inflows from small tributaries like Gwynns Falls, Jones Falls, and the Patapsco River. Though small, these are urbanized watersheds with highly impervious surfaces, leading to intense, short-duration runoff events. We constructed long-term discharge time series using baseflow-preserving, low-pass filtering techniques and adjusted peak flows based on watershed area. Adding these tributaries to the model led to local reductions in salinity at WT 5.1—approximately 0.2–0.3 PSU. While these contributions don't drastically change the entire harbor's salinity and temperature, they do cause meaningful local variability.

We also revisited persistent salinity underpredictions at WT 5.1, which previously showed errors of 3–5 PSU. After October's presentation, we streamlined the model grid by replacing triangular elements with a uniform quadrilateral mesh and adjusted the channel depth to a uniform 17 meters (55 feet) to reflect a more realistic bathymetry. While these changes resulted in approximately 0.5 PSU improvement, the salinity bias remained. Further analysis of CB 3.3W revealed strong mixing behavior, in contrast to more stratified regions nearby. This suggests insufficient salinity exchange between Upper Bay and Baltimore Harbor.

The root cause appeared to be geometric skewness in the nudging zone at the model's open boundary. The deeper portion of the channel was misaligned, causing asymmetric flow transitions. To address this, we deepened the nudging zone uniformly and removed the skew. Preliminary model results show a noticeable improvement: surface salinity at WT 5.1 increased by approximately 2 PSU, even during the spin-up period, with similar trends at the bottom layer. While the simulation is still running, early results are promising, and we anticipate further salinity improvement with continued model spin-up. I plan to present the complete results next Monday.

In summary, this quarter's work focused on model calibration and verification, emphasizing salinity and temperature. We successfully incorporated new freshwater sources and opened the C&D Canal boundary. While their impacts are localized, they improved our representation of urban hydrology. The broader Upper Bay is now well-calibrated, but WT 5.1 remains a challenge. Channel grid refinements and nudging zone corrections have already improved the simulation, and ongoing adjustments show additional promise.

1:35 Discussion of Patapsco MTM Progress.

Q: *Lew:* It's great to see the C&D Canal now represented with an open boundary rather than a fixed constant value. The improvements observed at CB1 and CB2 stations are promising. With this now being an open boundary, we'll eventually need to consider how sea level rise will affect the C&D Canal, just as we do at the ocean boundary. As we project sea level rise, we'll need to plan accordingly for this region. I'm not asking for answers today, but it's an important future consideration. Another related point: given the synergy between the MBM and the MTM, particularly with improvements at CB1 and CB2, should we consider implementing an open boundary at the C&D Canal within the main Bay model as well?

- ***Comment****: Joseph:* I share your concerns about scenario simulations and their complexity. Harry, you've done excellent work. After your last presentation, we reviewed the WT 5.1 issue and made some changes near the Baltimore Harbor in our model. We found that regrading the access channel helped address the problem, but your results suggest another important insight: there appears to be a significant difference in behavior between the East and West sides of the harbor. That likely has a simple explanation—differences in bathymetry and dynamic sediment processes. When analyzing vertical salinity differences in 3D, we need to ensure that the model station depth matches the actual location. I suspect our current DEM might not reflect the true channel position. We may need to shift the station location slightly into the actual channel.

- ***Response:*** *Zhengui:* Yes, we've observed improvements in the latest simulation at WT 5.1. The root mean square error for the bottom layer has improved—from about 6.6 previously down to approximately 3.8. While there's still some bias, it's much better than before. Surface salinity has also improved: previous bias was around -1.7 PSU, but now it's reduced to about -0.5 PSU.

Comment: *Carl:* With the open boundary now implemented at Reedy Point, I noticed a significant salinity change at CB 2.1. I can think of two possible reasons why salinity may have increased at CB 2.1. First, the Delaware Bay is saltier than the Chesapeake, so we could be importing salt through the C&D Canal. Second, increased upstream circulation in the Chesapeake could be pushing more salt northward and out through the canal. Either mechanism could lead to higher salinity at CB 2.1. I'm curious which of these is responsible. Looking ahead, while it's relatively straightforward to implement a salinity boundary condition at Reedy Point, we would eventually need a 10-year time series for parameters like chlorophyll, organic nitrogen, or organic carbon. If those are coming in from the Delaware Bay, it could pose significant challenges. I don't currently understand why the salinity increased at CB 2.1, but further investigation could provide valuable insight into the system and its long-term water quality implications.

- ***Response:*** *Harry:* My understanding is that we're in a hydrodynamic modeling phase, and I was curious about how the system would respond. From what I can tell, the effect is mostly limited to stations CB 2.1 and CB 2.2. Operationally, we opened the boundary at Reedy Point, but for full water quality modeling, we would need many more parameters. I don't believe Reedy Point offers long-term data beyond salinity. The reason we have salinity data is because of concerns about saltwater intrusion near Philadelphia's drinking water intake, so they've maintained long-term monitoring there. We were fortunate to have that, but I don't believe other water quality parameters are available at that location. So, the water quality team will need to consider how to handle that moving forward.
- ***Comment:*** *Lew:* A note for our future planning: we're seeing increasing vessel sizes and draft depths across marine shipping. While we don't know exactly when this will affect our region, it's likely to happen. I appreciated the attention to detail in modeling the shipping channels in the Baltimore Harbor. Once we have our Patapsco-Back model ready for scenario applications, we might want to run sensitivity scenarios focused on increasing channel depths. Would deeper channels drive greater circulation? Would that produce measurable water quality benefits? It's something worth considering in scenario planning.
- ***Comment:*** *Larry:* another possibility to consider with the open boundary at Reedy Point is the loss of freshwater from the Chesapeake into the Delaware Bay.

That could allow more saltwater intrusion from the south, further up the Bay. So, in addition to salt being imported from Delaware Bay, we may also be facilitating salt intrusion from within the Chesapeake itself. I agree a simple test comparing salt flux through the canal, open versus closed, would help clarify this. Beyond that, I want to emphasize that there's a great deal of interest in using this model beyond the Bay Program, especially for Baltimore Harbor. That increases the importance of getting salt intrusion right. For example, I had a student recently analyze a fish kill event in Baltimore Harbor last summer. One of the key questions was whether the kill was caused by local mixing or the intrusion of high-salinity, low-dissolved-oxygen water through the shipping channel. Unless we accurately simulate salt intrusion variability into the inner harbor, we won't be able to answer that. So, this modeling effort has wide relevance.

- ***Q:*** *Raleigh:* Is it possible to use different boundary configurations for physics and water quality? For example, could the physical model use a dynamic open boundary while the water quality model uses a simpler, closed boundary with constant or time-varying values?
- ***A:*** *Carl:* You can assign any water quality boundary conditions you want, including constant values for 10 years. The question is how realistic that would be, and what the impact would be on results. It's something we need to think through. It wouldn't be feasible to run two separate models, one with an open boundary for hydrodynamics and one with a closed boundary for water quality. That would be too complex to manage. I'm not dismissing the idea, but we need to investigate it carefully and decide what makes the most sense.

1:45 **Progress on the Rappahannock MTM & P7 Linkage – Qubin Qin, East Carolina University and Jian Shen, Zhengui Wang, Pierre St-Laurent, VIMS**

Description: Progress on the Rappahannock MTM will be reviewed by the Rappahannock MTM Team.

Pierre: Here we will present on unpublished findings from an estuarine circulation study focused on the Rappahannock River, placing it in the context of five Chesapeake Bay tributaries: the James, York, Rappahannock, Potomac, and Susquehanna. While a formal update on the Rappahannock is pending, this analysis offers insight into how these systems differ in terms of circulation strength, freshwater input, and salinity dynamics. Using geographical boundaries based on salinity intrusion and estuarine extent, the study highlights that although all five tributaries are partially mixed and have similar bathymetric features at their mouths, they vary significantly in tidal range, salinity of inflow water, and especially in freshwater discharge from the land.

To assess circulation, we applied a simplified two-layer estuarine model using output from a 3D numerical model sampled every 30 minutes over eight years. The core metric of interest was the volume of estuarine inflow and outflow (Q_{in}, Q_{out}), paired with the salinities of those flows (S_{in} and S_{out}). A key finding was that across all tributaries, the mixing of freshwater with incoming saline water follows a common pattern: high mixing efficiency upstream that plateaus near the mouth due to diminishing salinity gradients.

Despite differences in watershed size and hydrology, the ratio of S_{out} to S_{in} consistently ranged between 0.8 and 0.9, indicating a natural limit to how fully freshwater mixes with saline inflow.

The Rappahannock stood out for its relatively complete mixing (around 0.89), due to its low freshwater discharge and moderate estuarine area. A regression analysis using tributary area and freshwater inflow as predictors produced a strong correlation (R^2 = 0.73) with mixing completeness across the five systems. This allowed us to predict estuarine circulation strength using only watershed discharge, estuarine area, and inflow salinity. Most of the differences in circulation strength across tributaries were attributable to differences in river discharge, with Susquehanna at the high end due to its large watershed.

Temporal analysis revealed that drivers of estuarine circulation vary by timescale. On annual timescales, freshwater discharge was the dominant driver. However, at weekly and monthly scales, correlations with freshwater input weakened significantly. Instead, wind stress, particularly winds blowing down-estuary toward the southeast, emerged as the primary driver of short-term variability. This result aligns with previous studies, such as work in the York River, which found that down-estuary winds enhance vertical stratification and circulation by lowering vertical viscosity.

In summary, this study found that estuarine circulation across major Chesapeake Bay tributaries is governed largely by freshwater discharge at long time scales, while wind becomes more influential over shorter periods. The mixing efficiency of freshwater with saline inflow appears to converge near a common upper threshold, regardless of tributary, due to physical limits on salinity gradients.

2:05 Discussion of Rappahannock MTM Progress

Q: Joseph: First, regarding your use of Parker's analysis—it's a two-layer exchange approach, right? As far as I know, that approach, along with similar scaling methods, typically integrates over the full depth of the estuary. The mixing coefficient and diffusivity equations you're using are based on horizontal gradients, not vertical. That's something to consider because vertical structure plays a big role in exchange flow dynamics. Using horizontal diffusivity to represent vertical circulation strength may not be ideal. Also, how exactly do you determine S_{in} and S_{out}? You mentioned S_{in} can be inferred from proximity to the continental shelf, but is that really valid, especially since bottom salinity is highly dynamic in these systems?

- ***A:*** *Pierre:* The inference about S_{in} is based on long-term averages. Over eight years, the inflow salinity isn't random—you can clearly observe systematic differences. The James consistently has the highest salinity, followed by the York and others in a roughly monotonic order. The Susquehanna is an exception because of its deep channel, which allows saltier water to penetrate farther in.

Q: *Richard:* Since salinity is a conservative property, it doesn't go anywhere—it remains within the estuary. Over long time scales, like the eight-year period you analyzed, the salt coming in and going out should balance. So how do you justify having a salinity ratio?

- ***A:*** *Pierre:* Over the long term, the transport of salt in and out must be equal, yes. But in my analysis, they are not fluxes; however, they're the flux-averaged salinities of the inflow and outflow, measured in PSU. So I'm not comparing salt flux directly, just the average salinity values associated with those fluxes. Another way to think about it is to compare bottom and surface salinity—they can be quite different.

Q: *Lew:* Given projected increases in freshwater inflow and sea level rise in the Rappahannock due to climate change, we might expect more saline inflow as well. Do you think your analysis could help us anticipate changes in residence time or provide insight into future water quality impacts?

- ***A:*** *Pierre:* Any increase in freshwater inflow could offset some of the salinity increases due to sea level rise. It's hard to predict which effect will dominate - it's not straightforward.
- ***Comment:*** *Jian:* In our study, we found that residence time is roughly the estuary volume divided by the outflow. With sea level rise, even a 1-meter increase can significantly change the estuary's volume. But circulation itself may not change much if the horizontal salinity gradient remains relatively stable. In general, volume increases more significantly than the salinity change at the boundary. One issue we've had with the Rappahannock model is that we can get salinity right in the middle of the river, but we struggle with nutrients and DO. The middle section behaves strangely—somewhere around LE-3 or 4. We're not exactly sure why. It might be interesting to revisit your cross sections and see if that middle portion behaves differently from the upstream and downstream segments.

2:15 **Progress on the Choptank MTM – Jian Zhao, William Nardin, Elizabeth North, Larry Sanford, Jeremy Testa, UMCES and Jiabi Du, Texas A&M**
Description: Progress on the Choptank MTM and P7 linkage will be described by the Choptank MTM Team.

Jiabi: Here we present our efforts to resolve a persistent issue in the hydrodynamic model for the Choptank River and specifically, the underestimation of salt intrusion at the upper estuary monitoring station ET5.1. Observations show salinity spikes during the latter half of the year, which the model fails to replicate. To address this, we tested a variety of potential solutions, including extending the model grid upstream, refining grid resolution, and adding water bodies to better represent tidal basins. While the model already performed well in the lower and middle estuary regions, the upper estuary remained problematic.

A promising improvement came from converting the model grid to a fully triangular mesh, which leveraged a higher-order transport scheme to reduce numerical diffusion. This slightly improved salt intrusion simulation, though it still fell short of observed values. We also examined the influence of river discharge using watershed model data and adjusted freshwater inputs to better align with observed seasonal patterns. However, this had minimal impact, suggesting the root cause may not be in the grid or flow data.

We speculate that unresolved issues could stem from outdated bathymetry or inadequate wind data. Sedimentation over the past 30 years may have altered estuary depths, affecting salt transport, while using a single wind station for the entire river likely oversimplifies wind-driven dynamics. Although more testing is needed to verify these hypotheses, the team decided to move forward concurrently with biogeochemical modeling (ICM) to maintain project momentum.

We implemented a fully coupled hydro-biogeochemical model using nutrient loading from the watershed model and boundary conditions from the MBM. Initial results showed good agreement in the lower estuary for temperature, salinity, and DO, but significantly underestimated dissolved organic carbon (DOC) in the mid-estuary, an important zone for assessing model performance. To address this, we adopted updated parameters from the MBM, including enhanced phytoplankton metabolism and sediment flux modules, which yielded substantial improvements in both DOC and DO predictions.

Despite these gains, some nutrient concentrations, particularly nitrogen, remained inaccurate. We plan to continue calibrating the model and will focus heavily on refining nutrient dynamics and phytoplankton growth throughout the year. Additionally, we intend to correct open boundary and point source conditions to reduce error propagation into mid-estuary stations. Overall, there remains the need for parallel progress on both hydrodynamic and biogeochemical fronts to better simulate system dynamics and support water quality management in the Choptank River.

2:35 Discussion of Choptank MTM Progress

Comment*: Lew:* One thing we should consider is whether the latest work by Zhengui, particularly related to tidal wetlands, oysters, and sediment inputs, is included. Additionally, the newest inputs from the dynamic watershed model should be available soon and may provide improved data for water quality modeling in the Choptank. I think we're in a good place. Updating inputs could give us an even better starting point before making changes to half-saturation concentrations for major nutrients. We prefer to keep those values consistent across our tributary models unless there's a compelling reason to change them. Eventually, we may integrate the MBM and MTM, and consistency is important to avoid introducing artifacts. Do you have the latest living resource model inputs that Zhengui has been developing?

- ***Response:*** *Jiabi:* We understand that some issues take a long time to resolve, which is why we want to keep moving forward. Regarding the watershed inputs, we have not yet implemented the latest version. We're still using older data, but as mentioned in the presentation, we believe the newer model inputs will yield better results for both hydrodynamics and biogeochemical simulations. Yes, we agree it's a good idea to keep everything consistent with the MBM. That's why we adopted the parameter setup used there.

Comment: *Joseph:* Regarding the DOC, as Jian often says, it could be coming from tidal marshes or wetlands. These aren't currently accounted for in the watershed loading. Maybe we can consider including this in the future. Eventually, we might need to discuss whether the model group should introduce a separate species for DOC—specifically refractory DOC, which is non-reactive and originates from wetlands or upstream rivers.

- ***Comment:*** *Larry:* The turbidity maximum zone, where sedimentation is highest, is not dredged in the upper Choptank and lies between the two stations where one looks good and the other doesn't. Over 30 years, it's possible that 30 to 40 centimeters of sediment have accumulated there. It would be interesting to artificially remove that sediment and deepen the channel through that area to see how it affects the model results.
- ***Response:*** *Jiabi:* Yes, that's exactly what I'd like to do. I checked the NOAA navigational chart, and it allows you to zoom in and examine that area in detail. I'd like to test the impact of artificially dredging the channel. I think it could help. One question, though, is whether we can obtain bathymetry data going back to the 1990s. That would be valuable in understanding the historical changes.

2:45 ADJOURN