CBP Modeling and Climate Resiliency Workgroups Response to PSC Requests for Further Documentation on the Assessment of Climate Change Impacts to Chesapeake Water Quality

Briefing Paper for the Principals' Staff Committee in Preparation for their March 2, 2018 Meeting

Background

At its December 19-20, 2017 meeting, the Chesapeake Bay Program Partnership's Principals' Staff Committee (PSC) directed the consideration of climate change in the Phase III WIPs through a narrative strategy that describes the state and local jurisdictions' current action plans and strategies to address climate change, as well as the jurisdiction-specific nutrient and sediment pollution loadings due to 2025 climate change conditions. Further, in order to better communicate and apply the underlying science in the assessment of climate change impacts to Chesapeake Bay water quality, the following actions were directed by the PSC:

- Address the uncertainty by documenting the current understanding of the science and identifying research gaps and needs.
- Develop an estimate of pollutant load changes (nitrogen, phosphorus, and sediment) due to 2025 climate change conditions.
- Develop a better understanding of BMP responses, including new or other emerging BMPs, to climate change conditions.
- In 2021, the Partnership will consider results of updated methods, techniques, and studies and revisit existing estimated loads due to climate change to determine if any updates to those load estimates are needed.
- Jurisdictions will be expected to account for additional nutrient and sediment pollutant loads due to 2025 climate change conditions in a Phase III WIP addendum and/or 2-year milestones beginning in 2022.[1]

As a start to the above direction from the PSC, the Chesapeake Bay Program Partnership's Modeling Workgroup, in coordination with the Climate Resiliency Workgroup, developed this documentation of recent analyses of climate change influences on Chesapeake water quality. The briefing document also describes the proposed future plans, pending PSC review and approval, for additional analyses in order to fulfill the PSC decision to account for additional nutrient and sediment pollutant loads due to climate change within the 2022-2023 milestones.

[1] [1] The Chesapeake Bay Program Partnership Principals' Staff Committee December 19-20, 2017 meeting summary of decisions and actions accessible at: https://www.chesapeakebay.net/what/event/principals_staff_committee_meeting_december_2017.

What Changed in the Climate Change Analysis in the Six Months Prior to the December 2017 PSC Meeting and Why?

For the analysis of climate change in the Chesapeake watershed, the primary variables considered were precipitation volume, precipitation intensity, temperature, evapotranspiration, and carbon dioxide concentrations. Of these, the most important were those controlling runoff including precipitation volume and evapotranspiration. For the estuary, the influence of sea level rise, increased temperature of tidal waters, and tidal wetland loss were incorporated into the Partnership's Chesapeake Bay Water Quality and Sediment Transport Model.[2] Accounting for sea level rise and the appropriate distribution of changes in temperature in the Bay's water column were the most important components of the climate change estimates in assessing effects the Bay water quality conditions, with loss of tidal wetland estimated to be increasingly important after 2050.

There were two primary changes in Partnership's assessment of the effects of climate change on Bay water quality condition which occurred in the summer and fall of 2017. The first was a change in estimated sea level rise for 2025. The second was a much better understanding of the types of nutrients estimated to increase in loads to the Bay with increased the projected increases in precipitation in the watershed and the resultant management implications.

Change in Sea Level Rise Estimates for 2025 to Better Represent Long Term Observations

The primary change in the climate change estimates in the second half of 2017 was the change in estimated sea level rise from 30 centimeters (1 foot) to 17 centimeters (6.7 inches). Initially, guidance from the Partnership's Climate Resiliency Workgroup on regional sea level rise was based upon global tide gauge rates and regional land subsidence rates. Specifically, the Workgroup recommended that a range of sea level rise projections of 0.2 meters to 0.4 meters[3] for 2025 and 0.3 meters to 0.8 meters[4] for 2050 be applied in the Partnership's Chesapeake Bay Water Quality Sediment Transport Model. The medians of these ranges, 0.3 meters (1 foot) for 2025 and 0.5 meters (1 foot 8 inches) for 2050, were used for the Bay model simulations of sea level rise until the summer of 2017.

In early 2017, both the National Oceanic and Atmospheric Administration (NOAA) and the Virginia Institute of Marine Science, released updated sea level rise projections.[5][6] Upon reviewing these new projections, the Partnership's Climate Resiliency Workgroup and the Modeling Workgroup recognized that regional adjustments to global tide gauges were insufficient to estimate sea level rise in the Chesapeake. Observations at the mouth of Chesapeake Bay indicated a sea level rise of 17 centimeters (6.7 inches) by 2025 based on the long term trend from the historical records of the tidal gauge at Sewells Point, Virginia. Accordingly, since July 2017 the more appropriate estimate of 17 centimeters (6.7 inches), based

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[2] Cerco and Noel, 2017.
[3] 8 inches to 1 foot 4 inches.
[4] 1 foot to 1 foot 8 inches.
[5] Sweet, W.V., R.E. Kopp, C.P. Weaver, J. Obeysekera, R.M. Horton, E.R. Thieler, and C. Zervas, 2017: *Global and Regional Sea Level Rise Scenarios for the United States*. NOAA Technical Report NOS CO-OPS 083. NOAA/NOS Center for Operational Oceanographic Products and Services.
[6] See: http://www.vims.edu/newsandevents/topstories/slr_scenarios.php

on long term observations in Chesapeake Bay, was applied by the Climate Resiliency Workgroup and the Modeling Workgroup for developing the 2025 estimates of sea level rise and the influence climate change has on Chesapeake Bay water quality.

What Was the Projected Impact on Chesapeake Bay Water Quality?

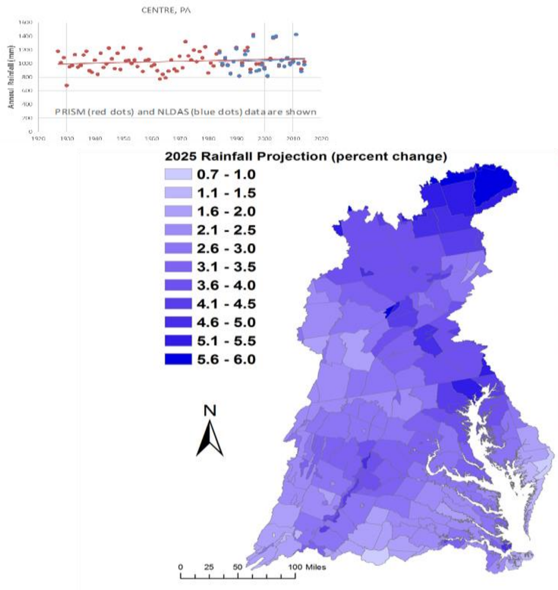
The influence on the projected Chesapeake Bay water quality response to changing sea level rise estimates for 2025 was significant. As sea level rises, Chesapeake Bay becomes more open to the ocean and the estuarine circulation within the Bay delivers colder, more oxygenated ocean waters to the deep waters of Chesapeake Bay. Earlier in 2017, model estimates were of a 13 percent decrease in hypoxia in the deepest waters of Chesapeake Bay[7] due to a sea level rise of 30 centimeters (1 foot). This sea level rise was high enough to accommodate and essentially counteract the increased river flow and increased nutrient loads from the Chesapeake Bay's watershed, resulting in little overall change to the model predicted 2025 attainment of the Delaware, the District, Maryland and Virginia's Chesapeake Bay dissolved oxygen water quality standards.

With the decreased sea level rise estimate of 17 centimeters (6.7 inches) adopted by the Climate Resiliency Workgroup and applied by the Modeling Workgroup starting in the summer of 2017, the positive influence of increasing the openness of the Bay to the ocean was essentially cut in half. The decreased sea level rise estimate was insufficient to provide for the additional influx of enough colder, more oxygen-rich ocean water to counteract the 7 percent increase in hypoxic conditions. These increased low dissolved oxygen conditions were due to two primary components: 1) increased temperature in the Bay waters causing those waters to hold less oxygen, allowing less oxygen to get to the bottom waters, and increasing the biological community's consumption of oxygen (yielding a 5 percent increase in hypoxia); and 2) increased watershed loads (resulting in a 2 percent increase in hypoxia).

Consideration of the Nutrient Types that Made Up Nitrogen and Phosphorus Loads

Inputs to the Partnership's Phase 6 Chesapeake Bay Watershed Model to simulate climate change included an estimated 3.1 percent increase in precipitation volume based on trends in 87 years of historical precipitation in the Chesapeake Bay watershed (see graphic, figure and table below). Long term (1940-2014) streamflow trends based on observed flow in the Chesapeake Bay watershed's rivers corroborated the changes in increased precipitation over the last 30 years.

[7] Maryland's Chesapeake Bay segment, CB4MH, located between the Chesapeake Bay Bridge and the mouth of the Patuxent River.



Change in Rainfall Volume
2021-2030 vs. 1991-2000

Major Basins	PRISM Trend
Youghiogheny River	2.1%
Patuxent River Basin	3.3%
Western Shore	4.1%
Rappahannock River Basin	3.2%
York River Basin	2.6%
Eastern Shore	2.5%
James River Basin	2.2%
Potomac River Basin	2.8%
Susquehanna River Basin	3.7%
Chesapeake Bay Watershed	**3.1%**

The increased precipitation mobilizes dissolved nutrients[8]. In addition, with the anticipated increases in larger precipitation events,[9] the volumes of precipitation were distributed throughout each year but weighed heavily to the highest precipitation events. Following Groisman et al. (2004), the final estimates of future climate scenarios in the Partnership's Chesapeake Bay Watershed Model assumed that almost the entire increase in estimated precipitation volume due to climate change was placed in the highest decile (90% to100%) of intensity. Consistent with this approach, precipitation intensity at lower levels were decreased. This had the influence of increasing the particulate nutrients in the highest intensity rainfall events, but decreasing overall runoff of particulate nutrients overall.

Overall, inorganic nutrients increase with climate change; and organic nutrients are decreased. This is significant because the dissolved inorganic nutrients of nitrate and phosphate have a much higher influence on the development and maintenance of low dissolved oxygen waters in Chesapeake Bay as these forms of dissolved inorganic nutrients are the preferred 'food' for algae, leading to algal blooms at higher concentrations.

Estimated Changes in Watershed and Bay Loads by 2025 Due to Climate Change

What Was the Impact?

The low estimated change in Chesapeake Bay watershed loadings of total nitrogen and total phosphorus loads masked the importance of the different nutrient components that made up these watershed-based nutrient load. This is because the watershed loads of nutrients due to the effect

[8] Dissolved nitrate and ortho-phosphorus.

[9] Groisman, Pavel Ya, R.W. Knight, T.R. Karl, D.R. Easterling, B. Sun, J.H. Lawrimore, 2004. "Contemporary changes of the hydrological cycle over the contiguous United States: Trends derived from in situ observations." *Journal of hydrometeorology* 5:1 pp 64-85.
Groisman, Pavel Ya, Richard W. Knight, and Thomas R. Karl, 2001. "Heavy precipitation and high streamflow in the contiguous United States: Trends in the twentieth century." *Bulletin of the American Meteorological Society* 82:2 pp 219-246.

of increased precipitation projected under continued climate change were almost entirely composed of dissolved nitrate and phosphate. Pound for pound, these dissolved inorganic forms of nutrients are much more effective at causing low dissolved oxygen conditions in Chesapeake Bay compared to the more normal mix of organic and inorganic, dissolved and particulate nutrients that are loaded into Chesapeake Bay under more average, less intensive rainstorms. That is because these forms of dissolved inorganic nutrients are the preferred 'food' for algae, leading to algal blooms at higher concentrations, which when they die they are decomposed by bacteria which consume oxygen from the Bay's waters.

Unfortunately, there are no management practices that reduce only nitrate and phosphate. Therefore, the increased dissolved inorganic nutrient loads needed to be translated into the mix of overall organic and inorganic, dissolved and particulate nutrient loads that are controlled by current management practices in the watershed. Accordingly, significant load reductions of a typical mix of dissolved, particulate, and organic nutrient types controlled by current management practices are required to make up for increases in inorganic dissolved nutrients.

Why Do We Have Confidence in the Current Estimates for 2025?

The estimated 2025 climate change conditions were extensively based on long term historical records of observations. Observed historical records used by the Partnership to project out to 2025 include precipitation volume, precipitation intensity, long term observed river flows in the Chesapeake Bay watershed, carbon dioxide concentrations, sea level rise from tide gages, observed salt intrusion, and tidal wetland loss. Further, these long term historical observations are corroborated with regional climate change models which substantiate both data sources and allow confidence in the extension of model based estimates to years beyond 2025 in order to examine even longer term future trends in flows, loads, and the Chesapeake Bay's response to climate change.

The 2025 estimates are the current state of science based on expert guidance from the Partnership's Scientific and Technical Advisory Committee (STAC) scientists and the members and leadership of the Climate Resiliency Workgroup. The model-based approaches to the Partnership's climate change analyses and the data sets used were based on extensive STAC guidance[10]. Additional guidance comes from STAC sponsored independent scientific peer reviews of each of the Partnership's models and the climate change assessment procedures and protocols[11,12,13]. Overall, the estimates of the 2025 climate change influence on Chesapeake Bay

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[10] STAC Workshop on Guidance for Climate Change Modeling: Johnson, Z., M. Bennett, L. Linker, S. Julius, R. Najjar, M. Mitchell, D. Montali, R. Dixon. (2016). *The Development of Climate Projections for Use in Chesapeake Bay Program Assessments.*

[11] STAC Peer Review of Watershed Model: Easton, Z., D. Scavia, R. Alexander, L. Band, K. Boomer, P. Kleinman, J. Martin, A. Miller, J. Pizzuto, D. Smith, C. Welty. (2017). Scientific and Technical Advisory Committee Review of the Phase 6 Chesapeake Bay Watershed Model. STAC.

[12] STAC Peer Review of Chesapeake Bay Water Quality Sediment Transport Model (in preparation for February 2018 publication)

[13] STAC Peer Review of Climate Change Climate Change Assessment Framework and Programmatic Integration and Response Efforts (in preparation for March 2018 publication)

water quality presented at the December 19-20, 2017 PSC meeting were reflective of the best available scientific observations, analysis tools, models, research, and data.

What Are the Plans to Increase Confidence in Estimating 2025 Climate Change Conditions for a Phase III WIP Addendum and/or 2-Year Milestones Beginning In 2022?

Following the direction of the PSC, the Partnership's Modeling and Climate Resiliency Workgroups, working with other key Chesapeake Bay Program groups, propose, pending PSC review and approval, developing and implementing a complete and fully operational climate change modeling and assessment system by 2019. In 2020 the CBP partners would complete a technical review and process for approval of the new refined modeling and assessment system and its scientific and technical findings. In 2021, the policy implications for including targets adjusted for the influence of climate change into the 2022-2023 milestones would be considered by the partnership, and by 2022 the refined findings on climate change would be implemented in the milestones.

Activities to support the Partnership's deeper assessment of climate change effects on Chesapeake Bay and its watershed are proposed to include the reexamination of all inputs used in the climate change analysis. In addition, a detailed examination of each major land use type in all major basins would be done to ensure the simulated loads are consistent with the science and to increase confidence that the changes in loads from the land are being correctly computed.

In addition, a STAC workshop is proposed for the summer of 2018 that will directly support the PSC's charge to refine and improve, to the extent possible, the climate change estimates by 2019. Further support from the Chesapeake Bay's scientific community comes from a Chesapeake Community Modeling Program symposium in June 2018 where sessions on improving the assessment of climate change in the Chesapeake Bay and its watershed are planned.