CBP Modeling and Climate Resiliency Workgroups Response to PSC Requests for Further Documentation and 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 water quality the following actions were directed:

- 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.

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 future plans for additional analyses in order to fulfill the PSC decision of preparing draft Phase III WIP planning targets in response to climate change within the 2022-2023 milestones.

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

Water Quality and Sediment Transport Model (WQSTM) of the tidal Bay.[1] Sea level rise and the appropriate distribution of temperature in the Bay's water column were the most important components of the climate change estimates in the tidal Bay, with loss of tidal wetland estimated to be increasingly important after 2050.

There were two primary changes in the summer of 2017. The first was a change in estimated sea level rise for 2025 and the second was a finer appreciation of the types of nutrients estimated to the observed increase in precipitation in the watershed.

A Change in Sea Level Rise Estimates for 2025 to Better Represent 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 Climate Resiliency Workgroup (CRWG) on regional sea level rise was based upon global tide gauge rates and regional land subsidence rates. Specifically, the CRWG recommended that a range of sea level rise projections of 0.2 meters to 0.4 meters[2] for 2025 and 0.3 meters to 0.8 meters[3] for 2050 be applied in the Bay 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.[4][5] Upon reviewing these new projections, it was recognized that regional adjustments to global tide gauges were insufficient to estimate sea level rise in the Chesapeake. Observations at the mouth of the Chesapeake indicated a trend from the historical records of the tidal gauge at Sewells Point, VA of 17 centimeters (6.7 inches). Accordingly, since July 2017 the more appropriate estimate of 17 centimeters (6.7 inches), based on observations in the Chesapeake, was applied for the 2025 estimates of sea level rise and the influence climate change has on Chesapeake water quality.

What Was The Impact?

The influence of changing sea level rise estimates for 2025 was significant. As sea level rises the Bay becomes more open to the ocean and estuarine circulation delivers more oxygenated waters to the deep waters of the Chesapeake. Model estimates were of a 13 percent decrease in hypoxia in the deepest waters of the Chesapeake[6] due to a sea level rise of 30 centimeters (1 foot) which was enough to accommodate the increased flow and loads from the watershed, resulting in little overall change to the attainment of DO water quality standards.

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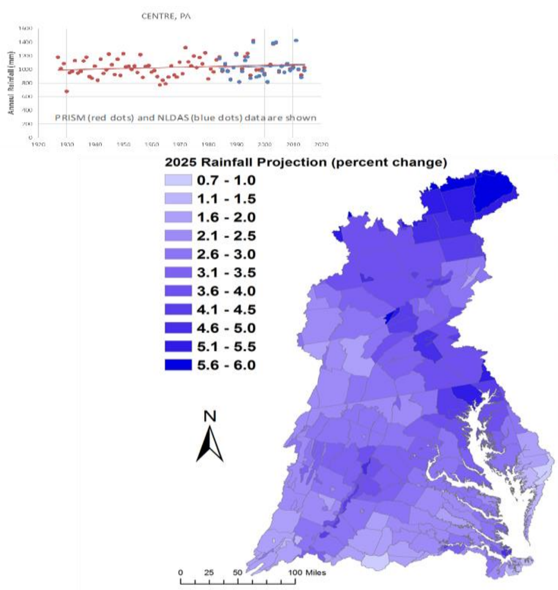
[1] Cerco and Noel, 2017
[2] (8 inches to 1 foot 4 inches)
[3] (1 foot to 1 foot 8 inches)
[4] Sweet, W.V., R.E. Kopp, C.P. Weaver, J. Obeysekera, R.M. Horton, E.R. Thieler, and C. Zervas, 2017: *Global and Regional Sea Level Rise Scenarios for the United States*. NOAA Technical Report NOS CO-OPS 083. NOAA/NOS Center for Operational Oceanographic Products and Services.
[5] See: http://www.vims.edu/newsandevents/topstories/slr_scenarios.php
[6] Segment CB4MH

With the decreased sea level rise estimate of 17 centimeters (6.7 inches) the positive influence of increasing the openness of the Bay to the ocean was halved. The decreased sea level rise estimate was insufficient to overcome the 7 percent increase in hypoxia due to the two primary components of increased temperature in the Bay waters (a 5 percent increase in hypoxia) and increased watershed loads (a 2 percent increase in hypoxia).

A Consideration of the Nutrient Types that Make Up Total Nitrogen and Phosphorus

Inputs to the 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 watershed. Long term (1940-2014) streamflow trends based on observed flow in Chesapeake watershed rivers corroborated the changes in increased precipitation over the last 30 years.



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 mobilized dissolved nutrients[7]. In addition, with the anticipated increases in larger precipitation events[8] 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 WSM 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

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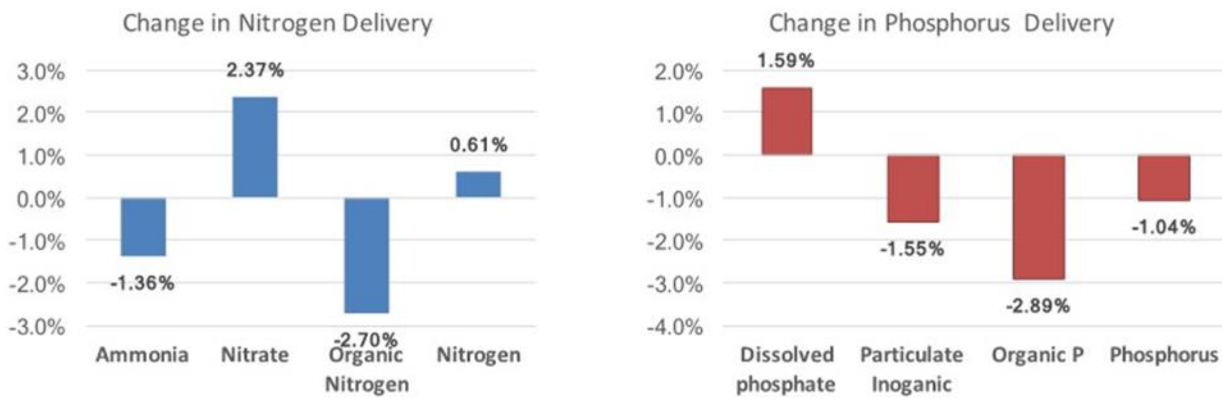
[7] Dissolved nitrate and ortho-phosphorus

[8] 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.

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.

The percentage changes for each nutrient type comprising total nitrogen (blue) and for phosphorus (red) are shown in the figure below. In summary, inorganic nutrients increase with climate change; and particulate organic nutrients are decreased. This is significant because the dissolved inorganic nutrients of nitrate and phosphate have a higher influence on the development and maintenance of low dissolved oxygen waters in the Chesapeake.

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



What Was The Impact?

The low estimated total nitrogen (1.2 million pounds) and total phosphorus loads (-100,000 pounds) masked the importance of the different nutrient components that made up the load. Increases in estimated dissolved nitrate and phosphate are particularly effective in generating hypoxia in the Chesapeake compared to the decreased estimated organic and particulate nutrients that were simulated.

Unfortunately, there are no management practices that reduce only dissolved nitrate and phosphate. Therefore, the increased dissolved nutrient loads needed to be translated into the overall loads that are controlled by current management practices in the watershed. Accordingly, the estimated increased loads of dissolved nutrients from the effects of climate change in the watershed were replaced with the equivalent loads of 9 million pounds nitrogen and 0.5 million pounds phosphorus to represent the load reductions of a mix of dissolved, particulate, and organic nutrient types controlled by current management practices.

Why Do We Have Confidence In The Current Estimates For 2025?

The 2025 climate change estimate were extensively based on long term historical records of observations. The historical records provide the tends that project the 30 year change between the 1991-2000 ten-year average flow basis of the 2010 TMDL, and all subsequent target loads, to the 2025 year. This is needed to update the flows and loads of the CBP ten-year average hydrology to the current flows and loads in the Chesapeake. Observed historical records used include precipitation volume, precipitation intensity, long term observed flows in the Chesapeake watershed, carbon dioxide concentrations, sea level rise from tide gages, observed salt intrusion, and tidal wetland loss. Further, the 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 future trends in flows, loads, and the Bay's response to climate change.

The 2025 estimates are the current state of science based on expert guidance from STAC scientists and the Climate Resiliency Workgroup. The model design for climate change analysis and the data sets used are based on STAC guidance[9]. Additional guidance comes from extensive peer reviews of the CBP models and their findings[10,11,12]. Overall, the current estimates of the 2025 climate change influence on Chesapeake water quality are the best that can be developed today with the currently available 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 Modeling and Climate Resiliency Workgroups, working with other key Chesapeake Bay Program groups, will develop and implement a complete and fully operational model of climate change assessment by 2019. In 2020 the CBP partners will complete a technical review and process for approval of the new refined model and its findings. In 2021, the policy implications for including targets adjusted for the influence of climate change into the 2022-2023 milestones will be considered by the partnership, and by 2022 the refined findings on climate change will be implemented in the milestones.

Activities to support the partnership's deeper assessment of climate change in the watershed and Bay 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 will 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. Supporting this work, a STAC workshop is proposed for the summer of 2018 that will directly support the PSC intention to refine and improve, to the extent possible, the climate change estimates by 2019. Further support comes from a Chesapeake Community Modeling Program symposium in June 2018 where sessions on improving the assessment of climate change in the Chesapeake are planned.

9 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.*

10 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.

11 STAC Peer Review of WQSTM (In preparation for 2018 publication)

12 STAC Peer Review of Climate Change Findings (In preparation for 2018 publication)