Phase 6 Climate Change Model Initial Findings: Hot, Wet, and Crowded

Modeling Workgroup
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Key Points in Assessment of 2025 Climate Change Risk

- The PSC's December 2017 and July 2018 decisions were, "No change in the target loads set by the PSC until 2025, or unless PSC decides to do otherwise." We have our decision model.
- The PSC also said to adjust the 2022-2023 milestones with an accounting of the climate change risk to water quality standard achievement.
- The PSC may change the load target to account for estimated climate change risk, may keep the current (December 2017) estimated climate change target, or change the timing of target achievement to something other than 2025.

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Key Points in Assessment of 2025 Climate Change Risk

- The new 2019 climate change assessment confirms the December 2017 climate change findings with a better model, providing better understanding of underlying processes, more specific findings on nutrient speciation, CSOs, wet deposition of nitrogen, etc.
- Loads have decreased by about 10% from the December 2017 estimates of the load required to respond to climate risks and achieve 2025 water quality standards. Now the additional load reduction estimated to respond to climate change risk are 8M lb TN (before was 9M lb TN) and 0.43 M lb TP (before was 0.49M lb).

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Key Points in Assessment of 2025 Climate Change Risk

- We have one CBP decisional model which was finalized in July 2018 and then used to generate target loads for the CBP partnership which are now fixed until 2025 (unless adjusted by PSC).
- We have one climate change analysis model that the CBP partnership will review over the next two years for technical sufficiency and policy application to adjust the decisional model to address climate change risk in the 2022-2023 Milestones as directed by the PSC.

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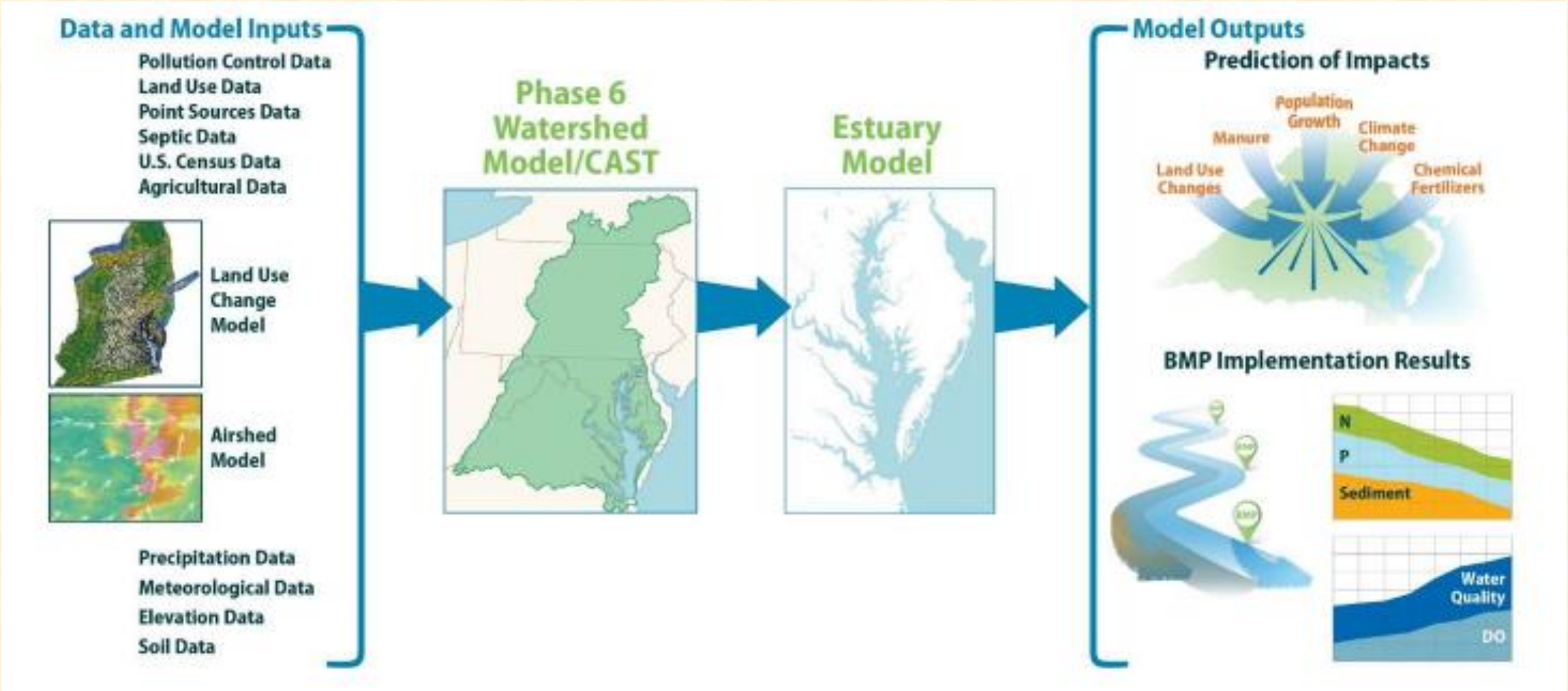
Assessment of 2025 Climate Change in the Airshed

Airshed Key Finding: Increased wet deposition N loads under increased precipitation.



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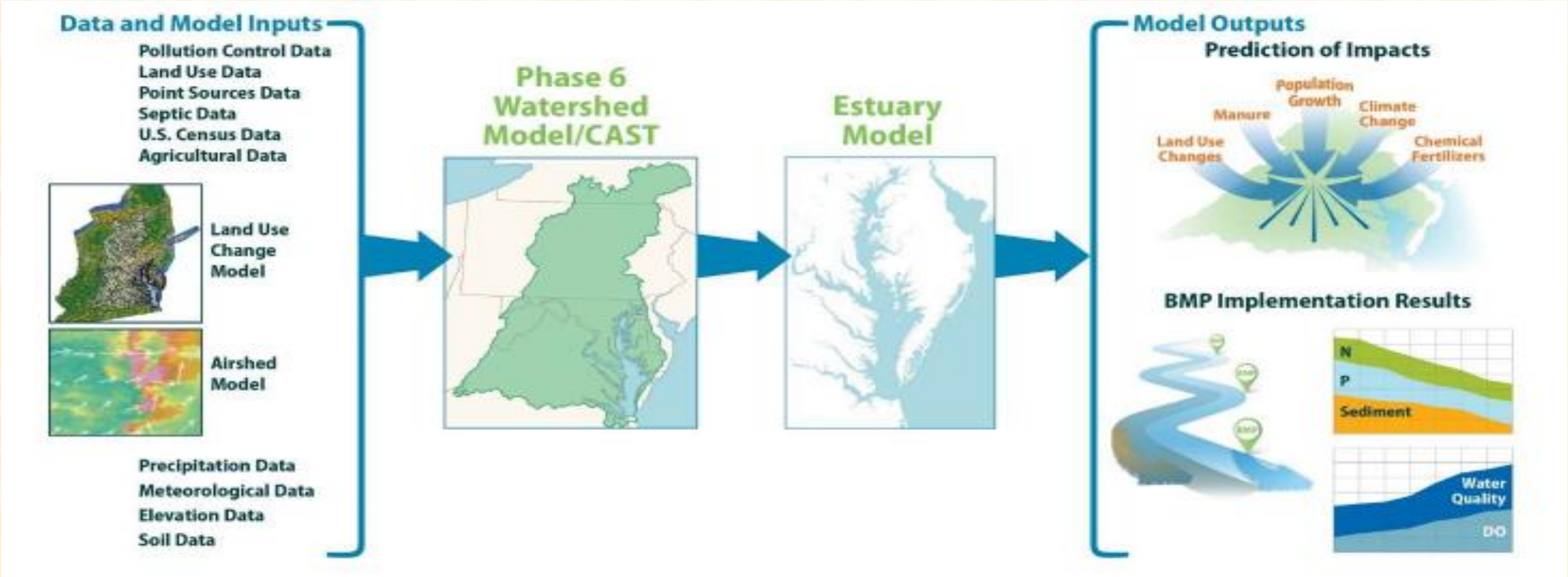
Assessment of 2025 Climate Change in the Watershed

Watershed Key Findings: Increased precipitation volume, precipitation intensity, and evapotranspiration are major determinates of changes in loads due to climate change. (Land use change beyond 2025 also increases nutrient and sediment loads.)



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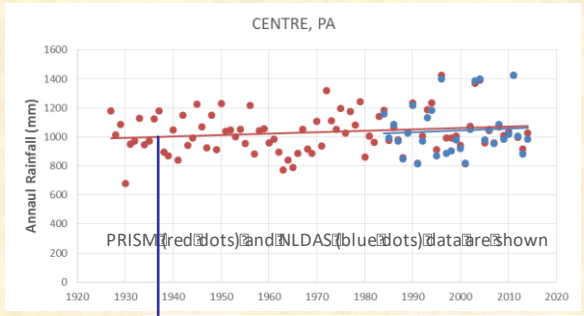
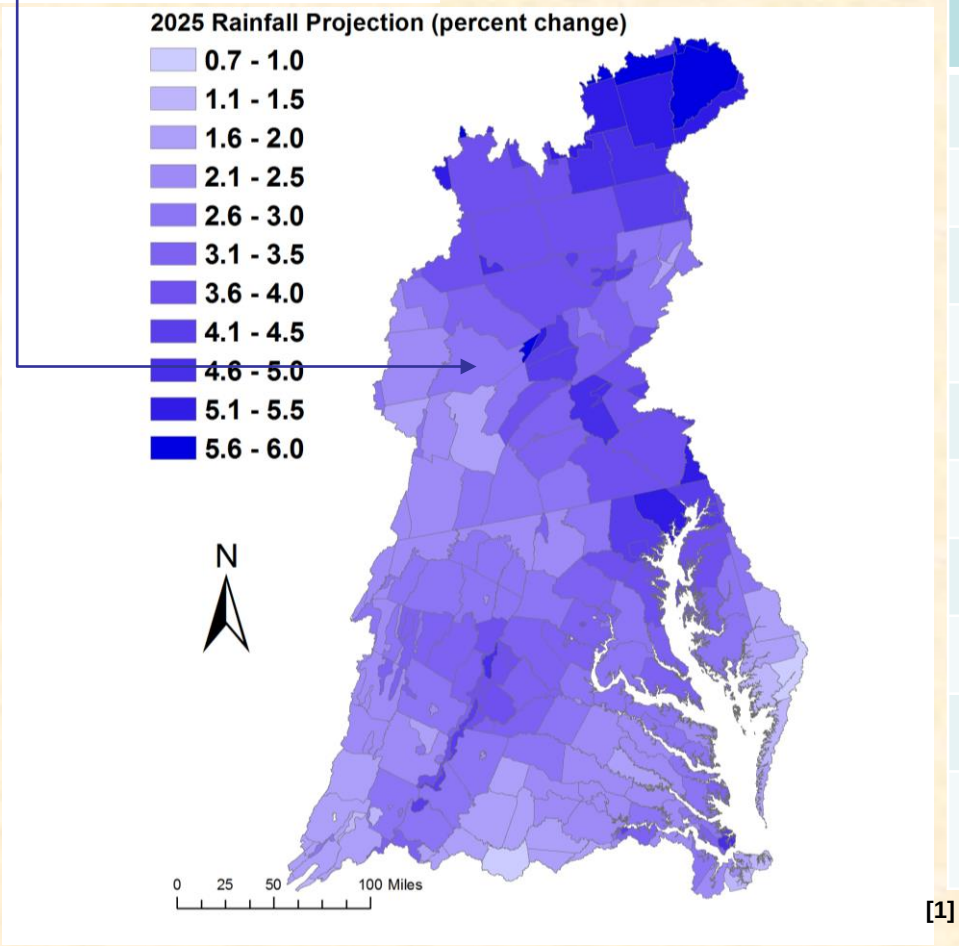
Precipitation Volume Increasing



Projections of rainfall increase using trend in 88-years of annual PRISM[1] data



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%**

[1] Parameter-elevation Relationships on Independent Slopes Model

The 1991 – 2000 period of hydrology & nutrient loads is the basis of decisions in the Chesapeake TMDL.

There are 30 years between 1995 and 2025.

Long term mean precipitation increased 3.1% and temperature by 1° C.

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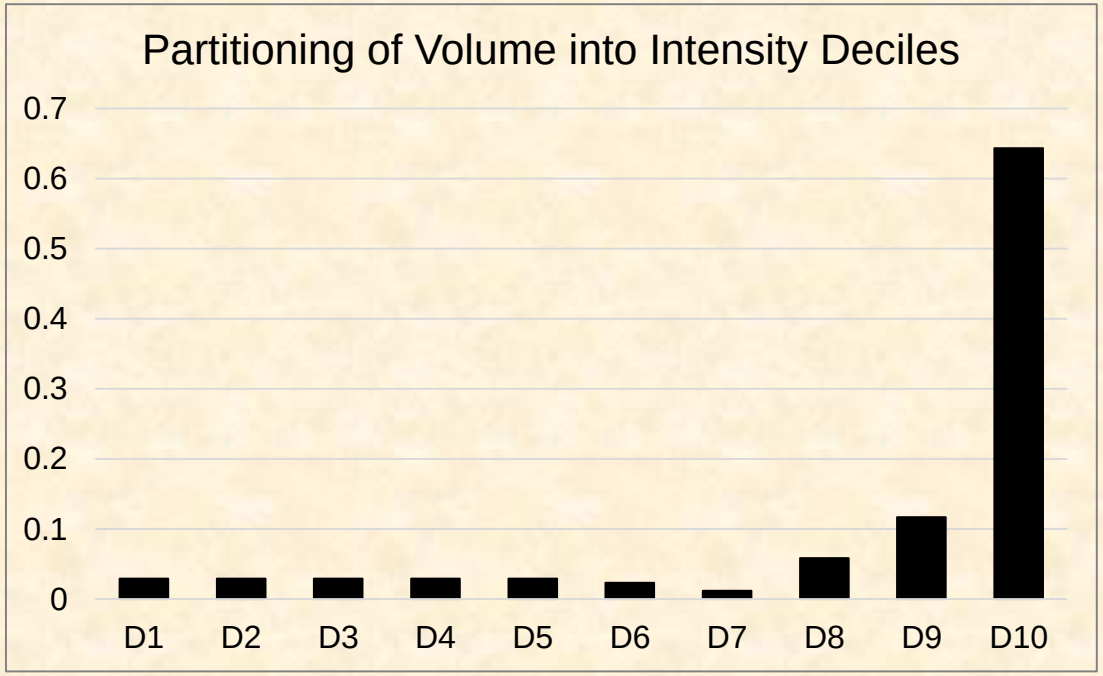
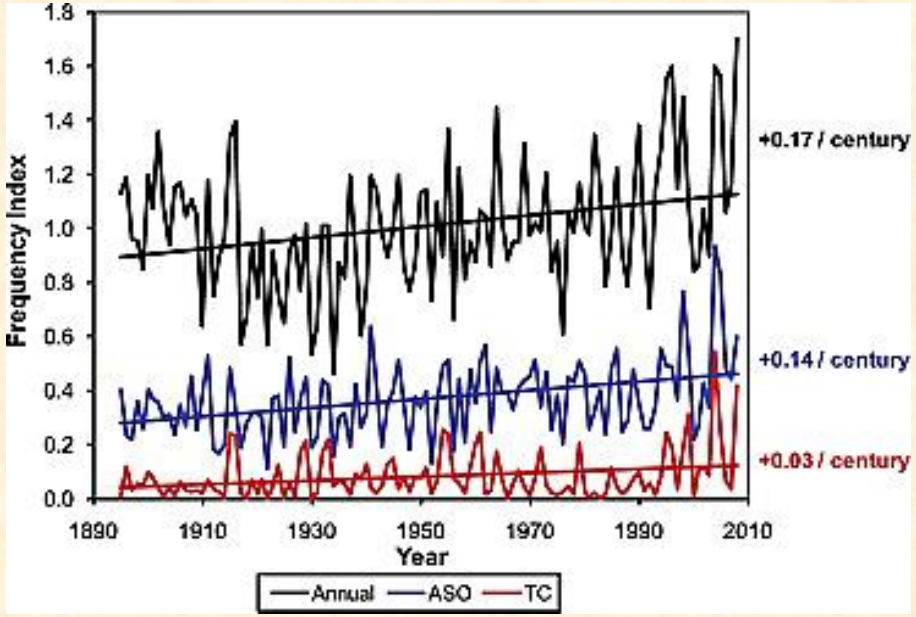
Rainfall Intensity Increasing

Observed trend of more precipitation volume in higher intensity events based on a century of observations.



Source: Groisman et al., 2004



National average heavy precipitation event index (HPEI) for the entire year (annual, black), for August through October (ASO, blue), and for heavy events associated with tropical cyclones (TC, red). [Kunkel et al., 2010]

Summary of Changes in Nutrient Species Delivery

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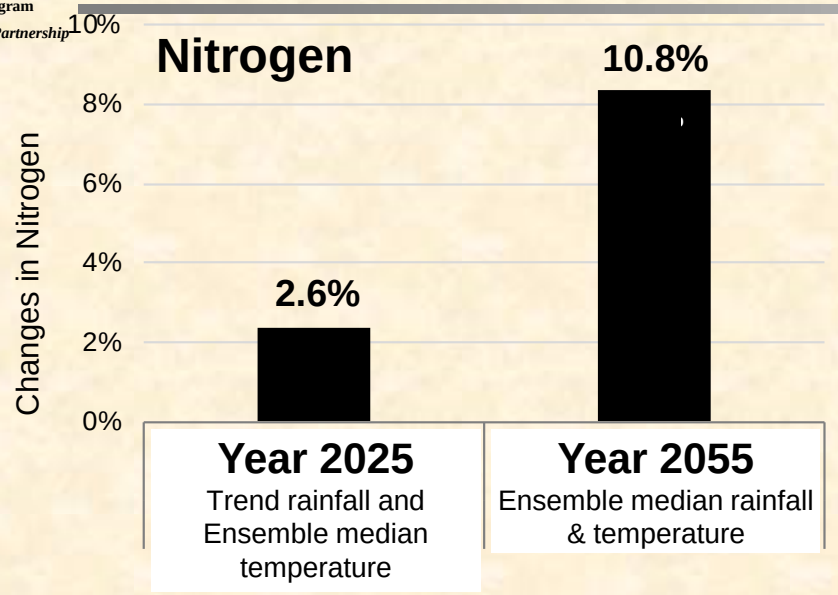
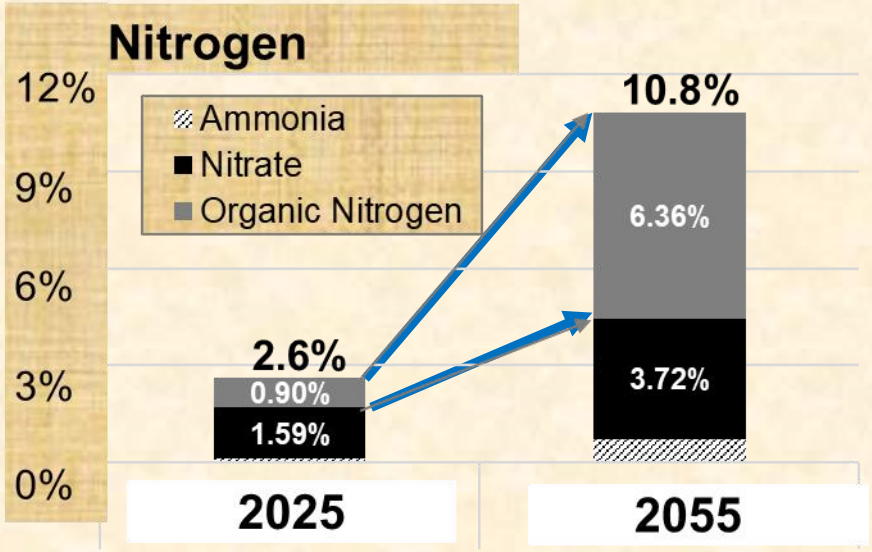
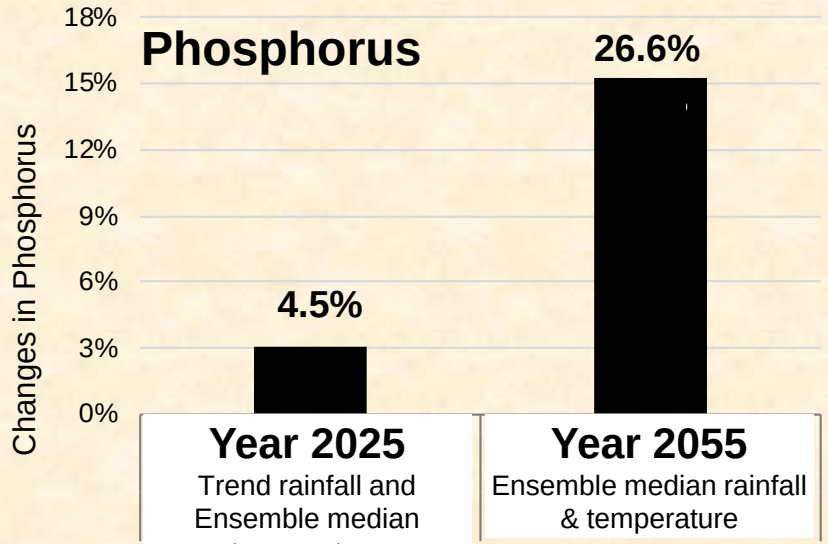
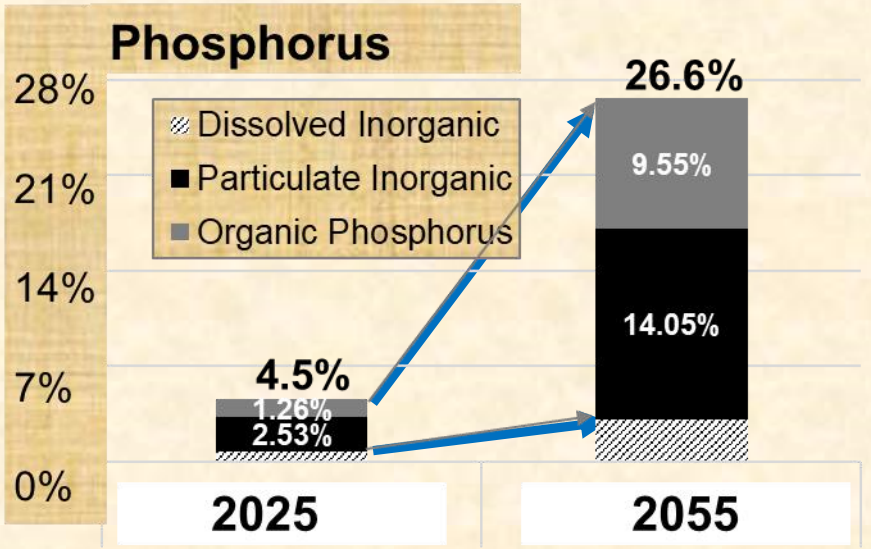




Arrows show relatively more increase in organic N & P or PIP compared to DIN or DIP.





The TN & TP loads are steadily increasing from 2025 to 2055 under climate change but there is a greater proportion of refractory N and P in the total N & P going forward.

***Trend**: projection of extrapolation of long-term trends*
***Ensemble**: 31-member ensemble of RCP4.5 GCMs*

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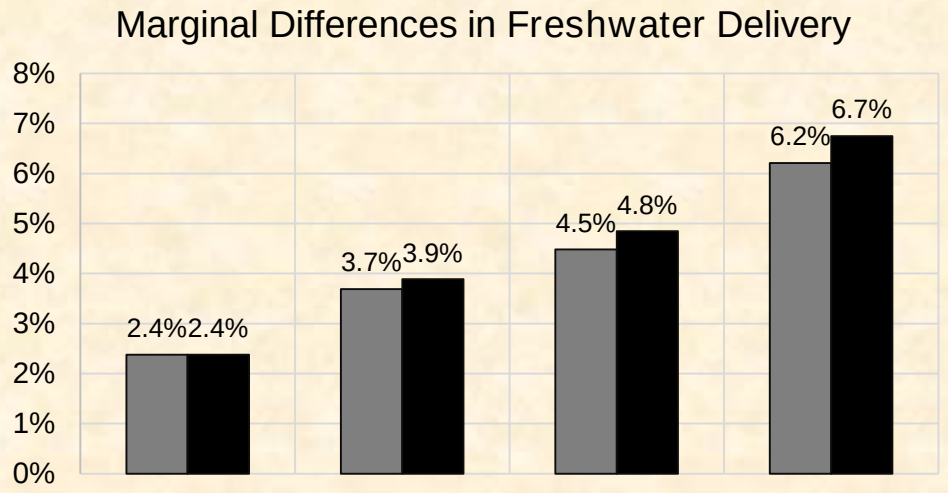
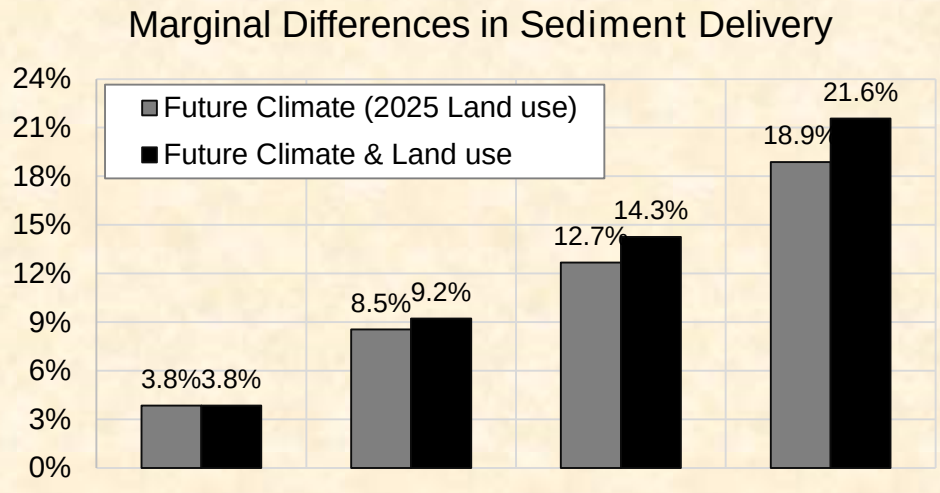
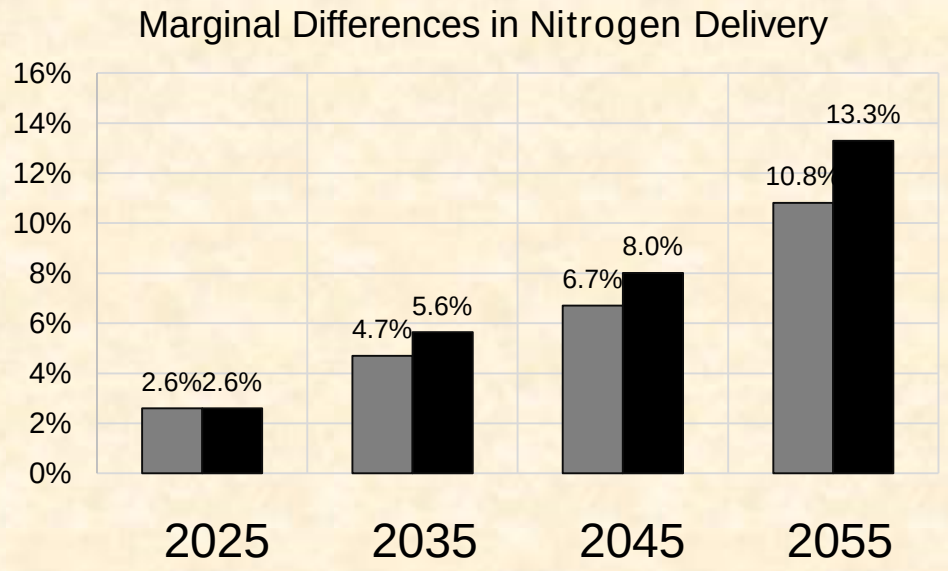
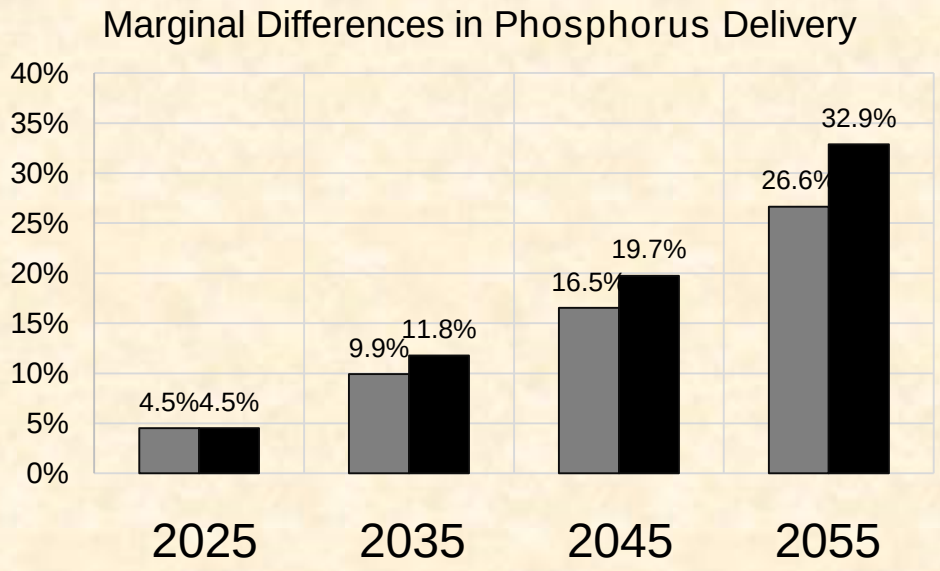
Estimates of Climate Only and Climate and Land Use









Grey bar = climate only Black bar = Climate and Land Use

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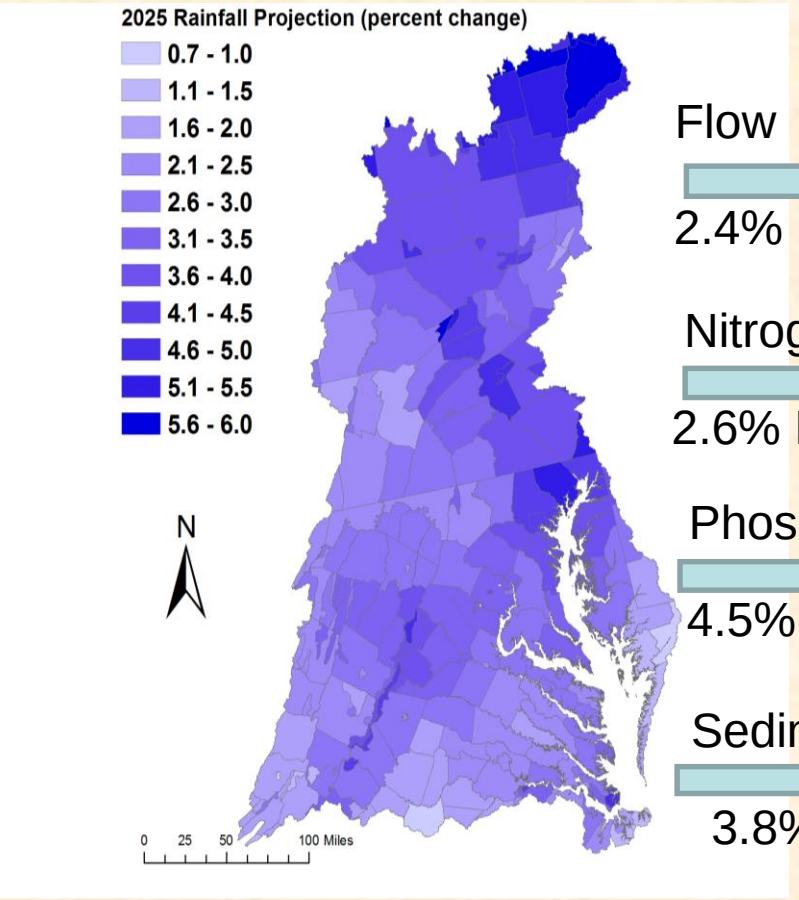
Elements of 2025 Climate Change in the Estuary



Model: CH3D-ICM 400m-1km Resolution

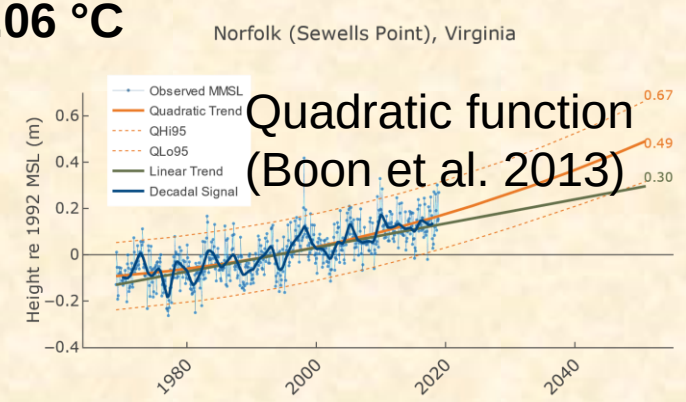
Flow
2.4% Increase

Nitrogen Load
2.6% Increase

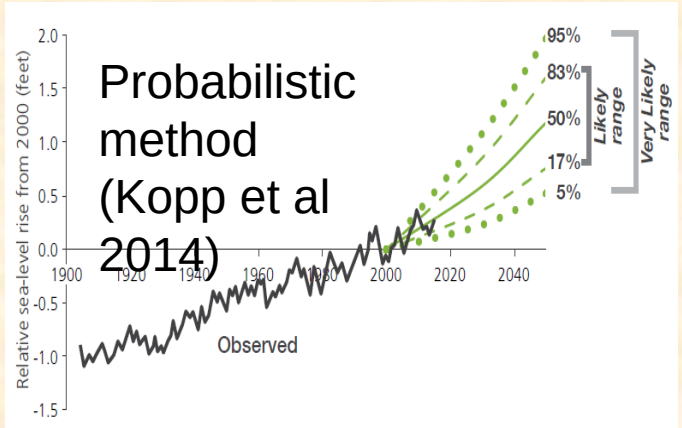
Phosphorus Load
4.5% Increase

Sediment Load
3.8% Increase

Air-temperature increase: 1.06 °C



Quadratic function (Boon et al. 2013)



Probabilistic method (Kopp et al 2014)

2025 Sea Level Rise: 0.22m

Open boundary T: + 0.95 °C; S: + 0.18 psu (Thomas et al., 2017)

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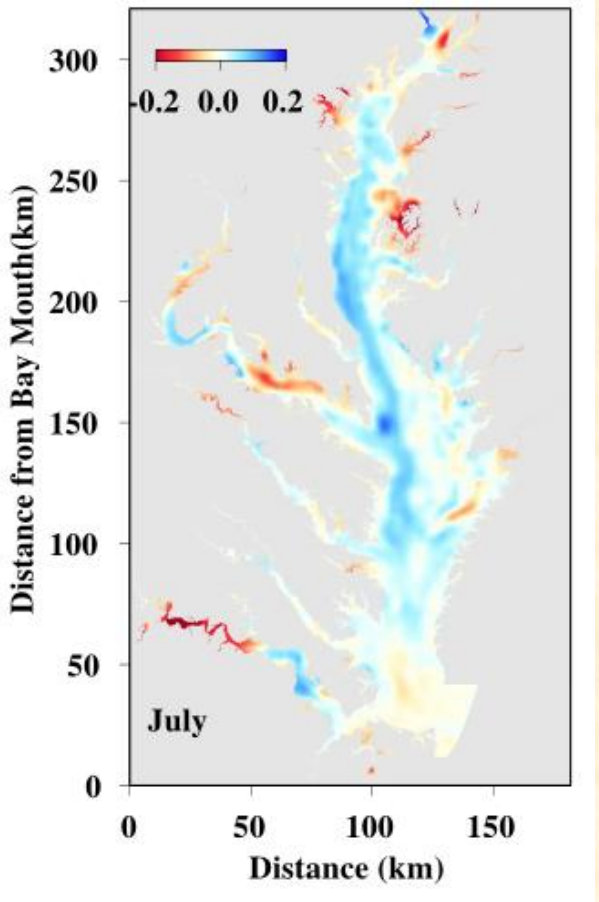
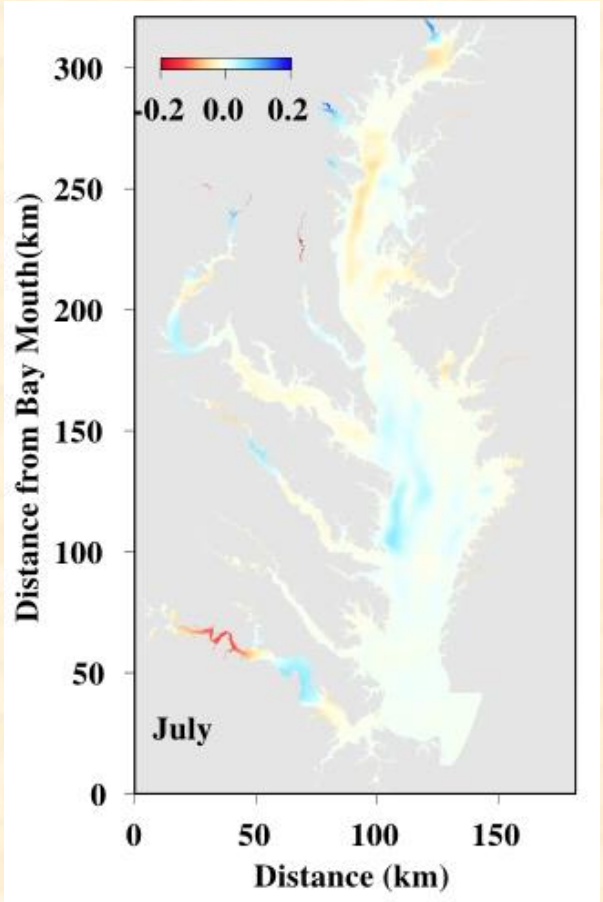
Bottom DO Change: 1995 to 2025

Keeping all other factors constant, sea level rise and increased watershed flow reduce hypoxia in the Bay, but the predominant influence are the negative impacts of increased water column temperature.

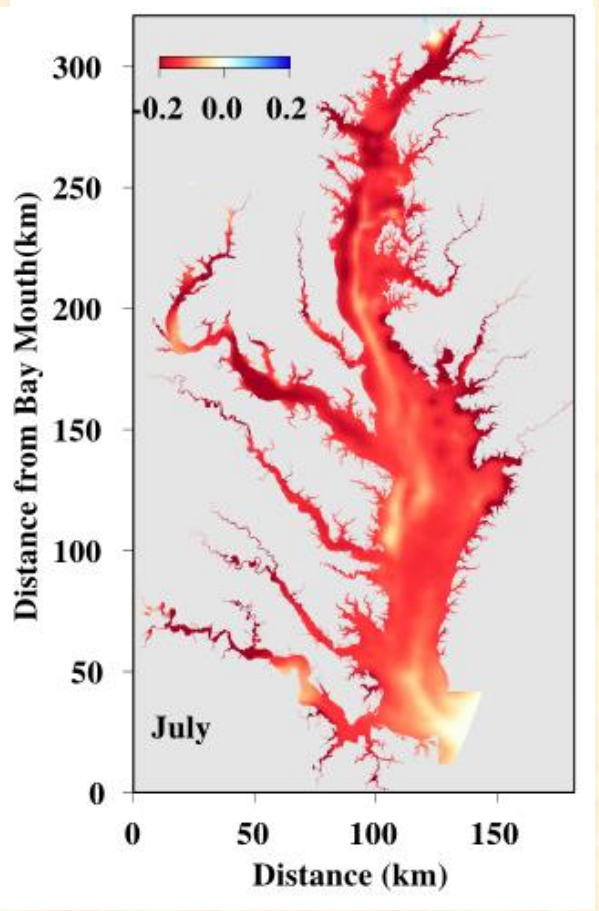
Sea Level Rise



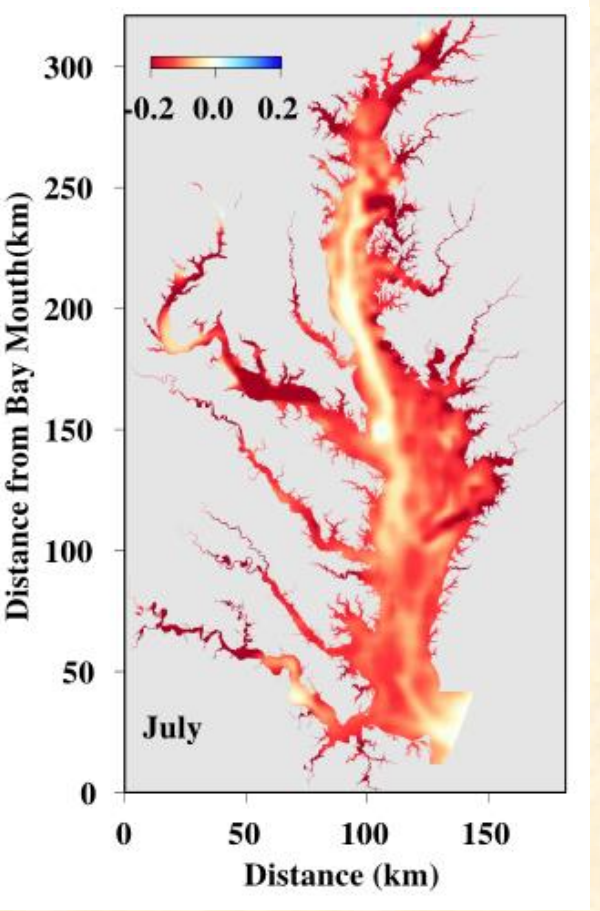
Watershed Flow



Increased Temp.



All Factors



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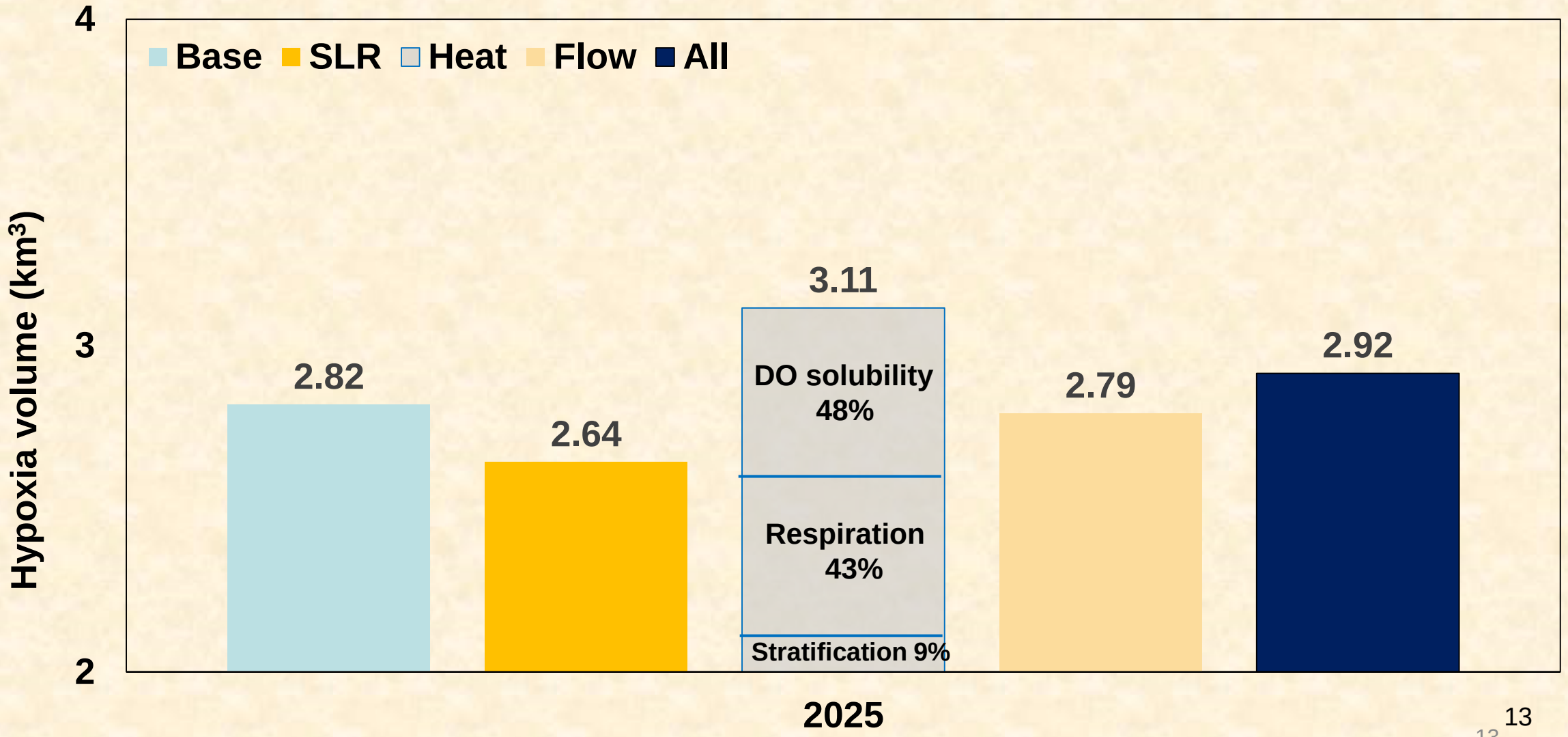
Summer (Jun.-Sep.) Hypoxia Volume (<1 mg/l) 1991-2000 In the Whole Bay



13

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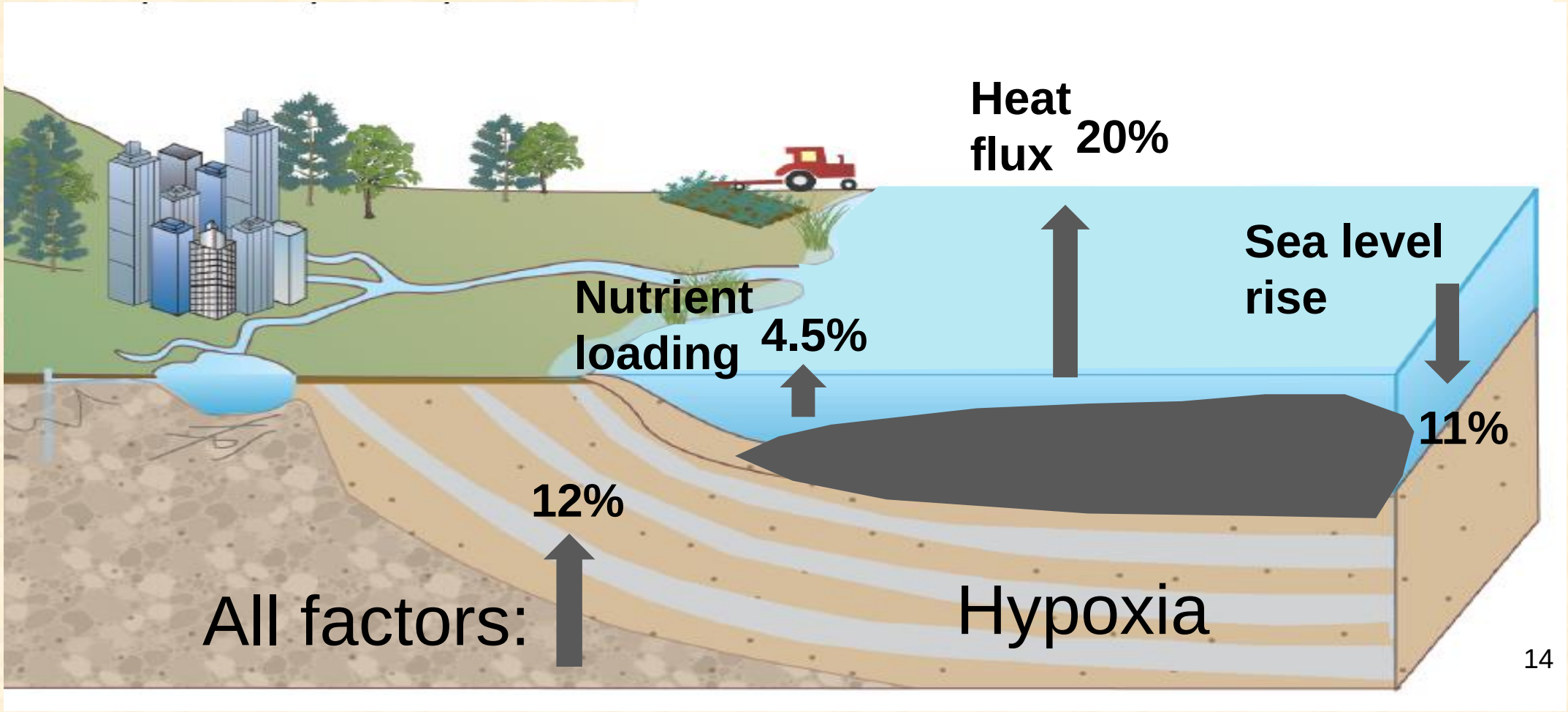
Elements of Hypoxia Volume Change: 1995 - 2025

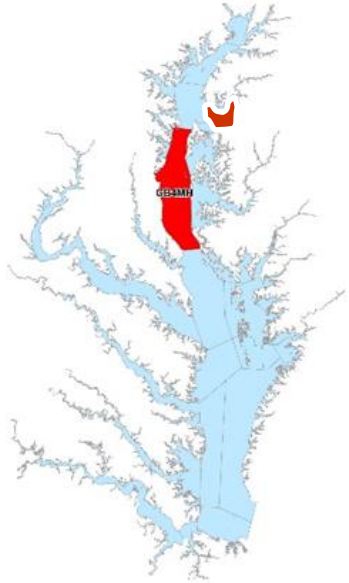


Summary
Hypoxia volume change by 2025

The CBP Climate Change Assessment

Achievement of **Deep Channel DO** water quality standard expressed as a incremental increase over the PSC agreed to (December 2017; July 2018) 2025 nutrient targets for growth and Conowingo Infill

CB Segment	State	2025 Climate 2025 Land Use 204TN 14.0TP 1993-1995 DO Deep Channel	2035 Climate 2025 Land Use 208TN 14.6TP 1993-1995 DO Deep Channel	2035 Climate 2035 Land Use 209TN 14.7TP 1993-1995 DO Deep Channel	2045 Climate 2025 Land Use 212TN 15.4TP 1993-1995 DO Deep Channel	2045 Climate 2045 Land Use 213TN 15.7TP 1993-1995 DO Deep Channel	2055 Climate 2025 Land Use 220TN 16.7TP 1993-1995 DO Deep Channel	2055 Climate 2055 Land Use 222TN 17.1TP 1993-1995 DO Deep Channel
CB3MH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CB4MH	MD	**1.4%**	**2.9%**	**3.1%**	**4.5%**	**5.2%**	**6.9%**	**8.2%**
CB5MH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CB5MH	VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
POTMH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RPPMH	VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ELIPH	VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CHSMH	MD	**1.1%**	**1.6%**	**1.6%**	**2.2%**	**2.2%**	**3.3%**	**3.3%**



Achievement of Deep Water DO Water Quality Standard

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Achievement of **Deep Water DO** water quality standard expressed as a incremental increase over the PSC agreed to (December 2017; July 2018) 2025 nutrient targets for growth and Conowingo infill

CB Segment	State	2025 Climate 2025 Land Use 204TN 14.0TP 1993-1995 DO Deep Water	2035 Climate 2025 Land Use 208TN 14.6TP 1993-1995 DO Deep Water	2035 Climate 2035 Land Use 209TN 14.7TP 1993-1995 DO Deep Water	2045 Climate 2025 Land Use 212TN 15.4TP 1993-1995 DO Deep Water	2045 Climate 2045 Land Use 213TN 15.7TP 1993-1995 DO Deep Water	2055 Climate 2025 Land Use 220TN 16.7TP 1993-1995 DO Deep Water	2055 Climate 2055 Land Use 222TN 17.1TP 1993-1995 DO Deep Water
CB3MH	MD	0.1%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
CB4MH	MD	**1.0%**	**1.6%**	**1.6%**	**2.0%**	**2.1%**	**2.6%**	**2.9%**
CB5MH	MD	**0.5%**	**0.9%**	**1.0%**	**1.3%**	**1.3%**	**1.6%**	**1.6%**
CB5MH	VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CB6PH	VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CB7PH	VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PATMH	MD	0.0%	**0.7%**	**0.7%**	**2.0%**	**2.2%**	**3.0%**	**3.0%**
MAGMH	MD	0.0%	0.0%	0.0%	0.2%	0.2%	-0.2%	0.4%
SOUMH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SEVMH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PAXMH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%
POTMH	MD	0.1%	0.3%	0.4%	0.7%	0.7%	0.9%	1.0%
RPPMH	VA	0.2%	**1.2%**	**1.4%**	**1.7%**	**1.8%**	**1.9%**	**1.9%**
YRKPH	VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ELIPH	VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SBEMH	VA	0.0%	0.0%	0.0%	0.5%	**0.6%**	**3.3%**	**4.0%**
CHSMH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
EASMH	MD	0.1%	0.2%	0.2%	0.4%	0.5%	0.5%	0.5%

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Achievement of Open Water DO Water Quality Standard

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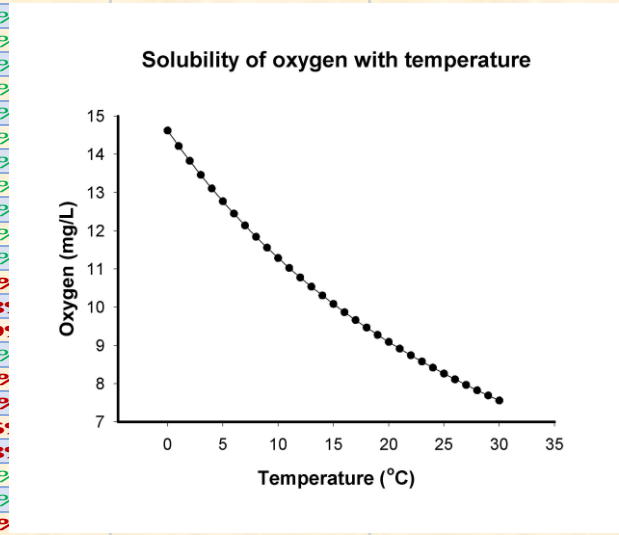
CB Segment	State	2025 Climate 2025 Land Use 204TN 14.0TP 1993-1995 DO Open Water	2035 Climate 2025 Land Use 208TN 14.6TP 1993-1995 DO Open Water	2035 Climate 2035 Land Use 209TN 14.7TP 1993-1995 DO Open Water	2045 Climate 2025 Land Use 212TN 15.4TP 1993-1995 DO Open Water	2045 Climate 2045 Land Use 213TN 15.7TP 1993-1995 DO Open Water	2055 Climate 2025 Land Use 220TN 16.7TP 1993-1995 DO Open Water	2055 Climate 2055 Land Use 222TN 17.1TP 1993-1995 DO Open Water
CB1TF	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CB2OH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CB3MH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CB4MH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CB5MH_MD	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CB5MH_VA	VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CB6PH	VA	0.4%	0.7%	0.8%	1.0%	1.1%	1.3%	1.4%
CB7PH	VA	1.1%	1.8%	1.9%	2.8%	2.9%	4.0%	4.1%
CB8PH	VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
BSHOH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
GUNOH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
MIDOH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
BACOH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
PATMH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
MAGMH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
SEVMH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
SOUMH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
RHDMH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
WSTMH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
PAXTF	MD	3.3%	3.4%	3.3%	4.3%	4.3%	5.1%	
WBRTF	MD	21.3%	28.6%	21.3%	43.6%	51.2%	58.8%	
PAXOH	MD	6.1%	9.5%	11.0%	10.7%	12.0%	12.9%	
PAXMH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	
POTTF_DC	DC	1.8%	2.6%	2.7%	3.0%	3.2%	3.9%	
POTTF_MD	MD	0.5%	0.6%	0.7%	2.0%	2.3%	2.9%	
ANATF_DC	DC	5.1%	6.0%	6.4%	8.6%	9.2%	10.6%	
ANATF_MD	MD	10.6%	16.4%	16.8%	24.7%	25.7%	29.8%	
PISTF	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
MATTF	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
POTOH1_M	MD	0.3%	0.5%	0.5%	0.9%	0.9%	1.4%	
POTMH_MI	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RPPTF	VA	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	3.7%
RPPOH	VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RPPMH	VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CRRMH	VA	4.2%	5.6%	5.6%	7.1%	7.1%	8.9%	9.7%
PIAMH	VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
MPNTF	VA	16.6%	18.5%	18.1%	15.7%	16.2%	10.0%	11.0%
MPNOH	VA	3.6%	0.3%	9.8%	0.0%	0.0%	0.0%	0.0%
PMKTF	VA	8.9%	14.6%	10.0%	10.2%	10.2%	2.8%	3.3%
PMKOH	VA	2.9%	1.8%	5.3%	-2.6%	-2.6%	-3.3%	-3.3%
YRKMH	VA	2.3%	1.8%	4.5%	2.5%	3.2%	4.3%	5.3%
YRKPH	VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
MOBPH	VA	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%	0.2%
JMSTFL	VA	0.0%	0.6%	0.5%	1.1%	1.2%	1.2%	1.4%



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Achievement of Open Water DO Water Quality Standard

CB Segment	State	2025 Climate 2025 Land Use 204TN 14.0TP 1993-1995 DO Open Water	2035 Climate 2025 Land Use 208TN 14.6TP 1993-1995 DO Open Water	2035 Climate 2035 Land Use 209TN 14.7TP 1993-1995 DO Open Water	2045 Climate 2025 Land Use 212TN 15.4TP 1993-1995 DO Open Water	2045 Climate 2045 Land Use 213TN 15.7TP 1993-1995 DO Open Water	2055 Climate 2025 Land Use 220TN 16.7TP 1993-1995 DO Open Water	2055 Climate 2055 Land Use 222TN 17.1TP 1993-1995 DO Open Water
JMSTFU	VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
APPTF	VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
JMSOH	VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CHKOH	VA	4.6%	7.2%	7.2%	7.8%	11.4%	7.8%	7.8%
JMSMH	VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
JMSPH	VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WBEMH	VA	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
SBEMH	VA	5.6%	13.7%	7.7%	22.2%	23.2%	25.3%	25.6%
EBEMH	VA	4.9%	7.9%	7.9%	7.9%	7.9%	9.4%	9.4%
ELIPH	VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
NORTF	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
C&Dcanal	MD/DE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BOHOH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ELKOH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SASOH	MD	0.0%	1.7%	2.2%	2.2%	2.2%	0.4%	0.4%
CHSTF	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CHSOH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CHSMH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
EASMH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CHOTF	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CHOOH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CHOMH2	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
CHOMH1	MD	0.0%	0.1%	0.1%	0.2%	0.2%	0.3%	0.3%
LCHMH	MD	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%
FSBMH	MD	29.9%	-14.0%	37.8%	-28.3%	-28.3%	-28.3%	-28.3%
NANTF_DE	DE	0.0%	0.2%	0.2%	0.0%	0.0%	0.0%	0.0%
NANTF_MD	MD	0.7%	4.7%	4.3%	0.7%	2.2%	0.0%	0.0%
NANOH	MD	0.4%	1.6%	1.2%	0.0%	0.4%	0.0%	0.0%
NANMH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WICMH	MD	7.6%	7.8%	7.6%	17.6%	17.6%	24.2%	24.2%
MANMH	MD	4.0%	4.0%	4.0%	0.0%	0.0%	-0.6%	-0.6%
BIGMH	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
POCTF	MD	0.0%	7.7%	0.0%	7.7%	7.7%	7.7%	7.7%
POCOH_MD	MD	0.0%	7.7%	0.0%	7.7%	7.7%	7.7%	7.7%
POCOH_VA	VA	0.0%	7.7%	0.0%	7.7%	7.7%	7.7%	7.7%
POCMH_MD	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
POCMH_VA	VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TANMH_MD	MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TANMH_VA	VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%

Chesapeake Partnership Accountability Framework

- December 2017 and updated July 2018 decisional model for tracking targets to 2025.
- 2019 CC Model for adjustment of July 2018 decisional model for CB watershed and Bay climate change risk.
- 7 Watershed Implementation Plans (WIPs) describe what amount, how, where, and when for **all implementation required to achieve water quality standards by 2025.**
  - Phase I in 2010
  - Phase II in 2012
  - **Phase III in 2019**
- 2-Year Milestones ensure short term progress

By the 2022-2023 milestones there will be quantifiable reductions needed to defend water quality standards from future climate risk.

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The CBP Climate Change Assessment

- The CBP has developed the tools to quantify the effects of climate change on watershed flows and loads, storm intensity, increased estuarine temperatures, sea level rise, and ecosystem influences including loss of tidal wetland attenuation with sea level rise.
- Future climate change analyses on estimated on a 2025 (short term), 2035, 2045, (moderate term), and 2055 (long term) conditions for CBP management decisions.
- Additional load reductions to address future climate risk will be incorporated into the 2022-2023 Milestone Assessment.

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