# Presentation of Updated Phase 6 Modeling Results for Climate Change Impacts

Water Quality Goal Implementation Team
February 10, 2020

Lew Linker, EPA; Gary Shenk, USGS; Gopal Bhatt, Penn State;
Richard Tian, UMCES; and the CBP Modeling Team
*llinker@chesapeakebay.net*

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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

- 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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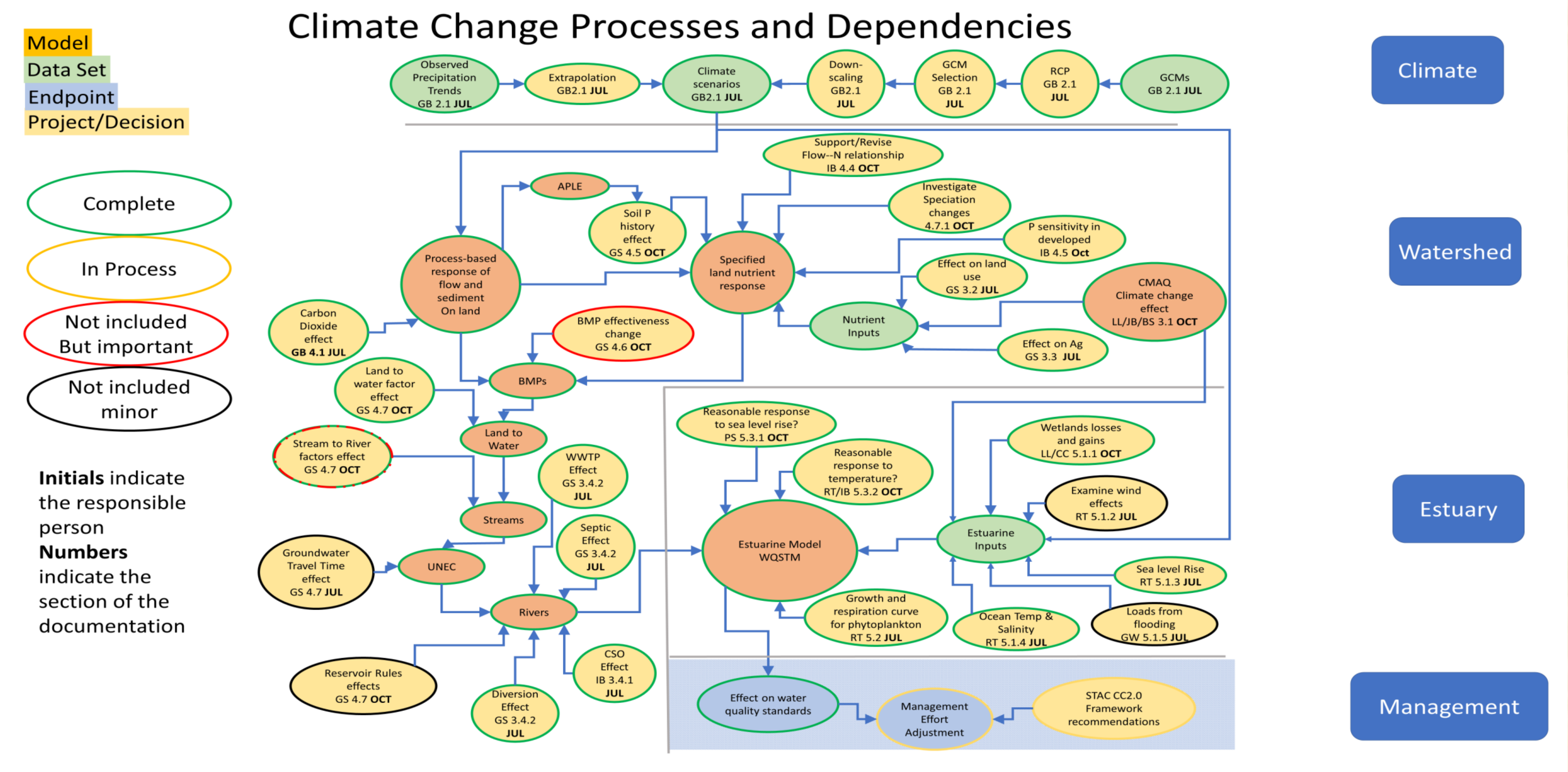
# Elements of Chesapeake Water Quality Climate Risk Assessment



# 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.
- There has been a consistent estimate of CB4MH Deep Channel and Deep Water DO nonattainment from the December 2017 PSC meeting to today of about 1.5% and 1%, respectively, even though we've expanded our climate change analysis to reexamine everything and to make many assessment refinements.

# Assessment of 2025 Climate Change in the Airshed

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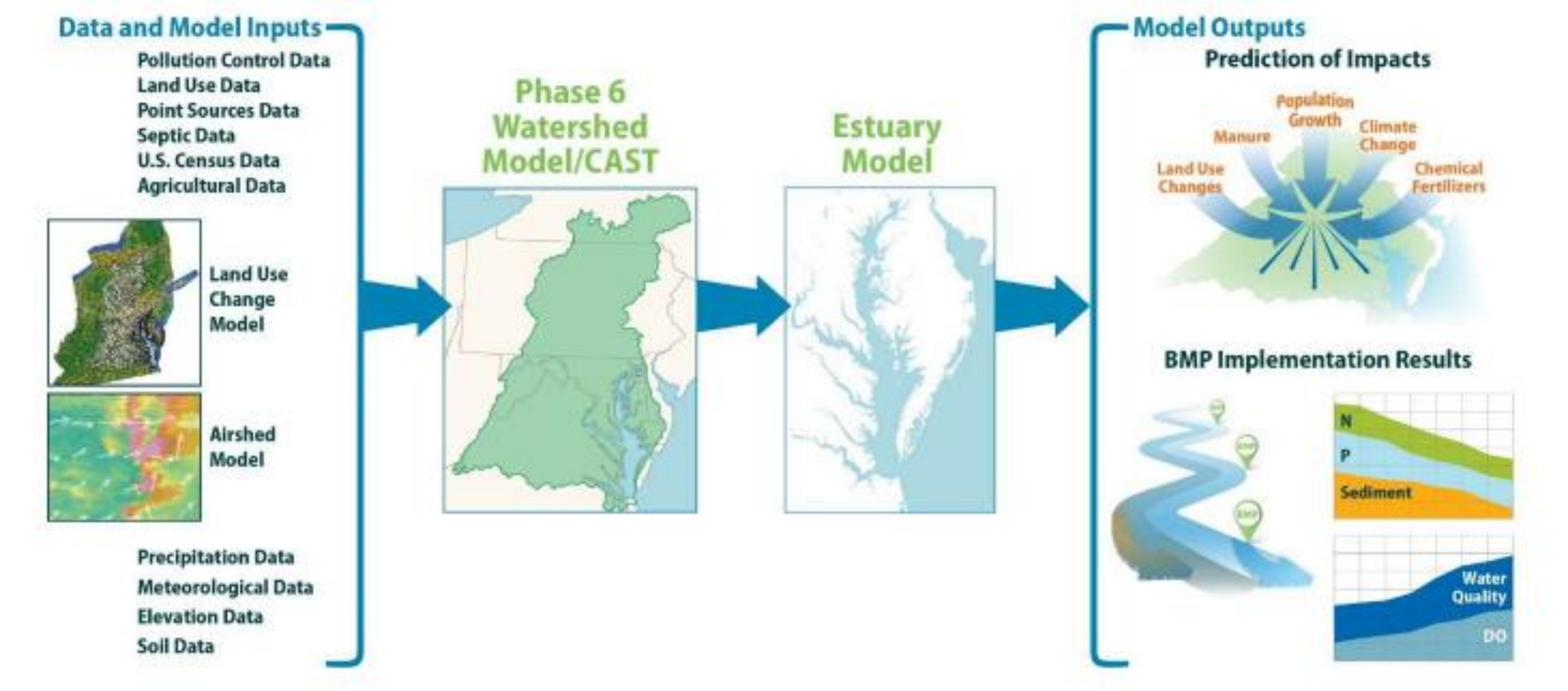
## Airshed Key Finding: Increased wet deposition N loads under increased precipitation.



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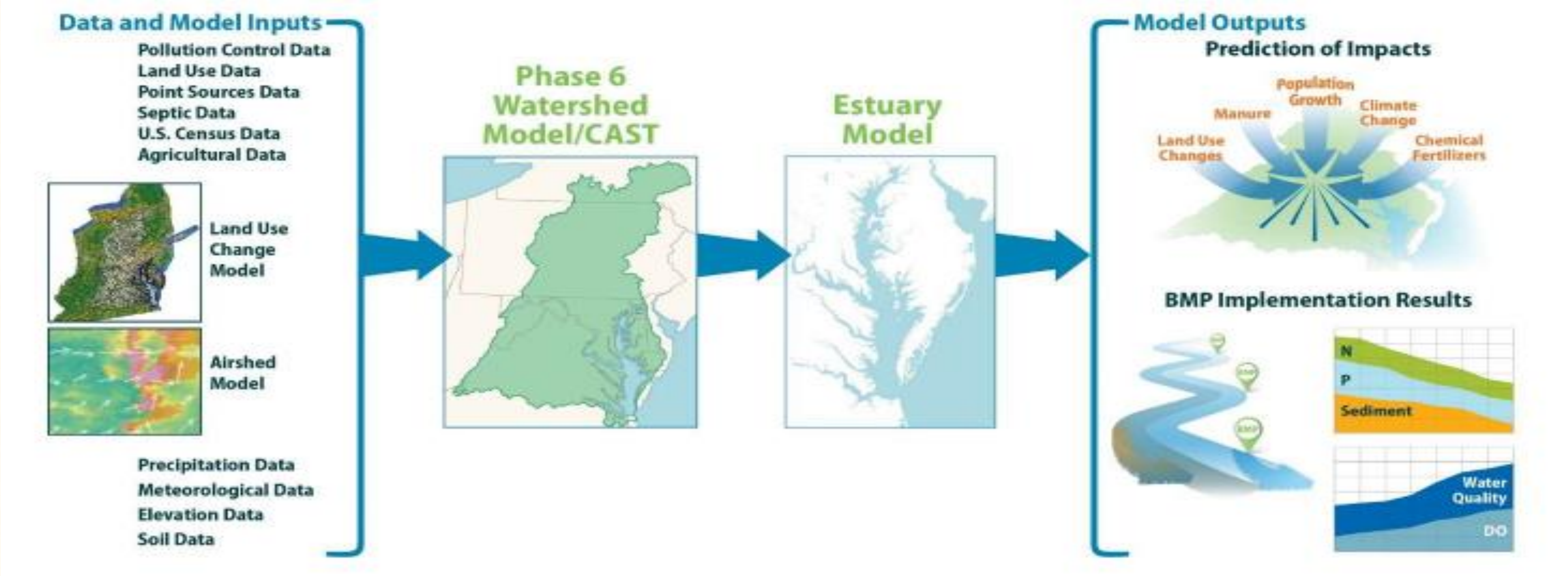
# Assessment of 2025 Climate Change in the Watershed

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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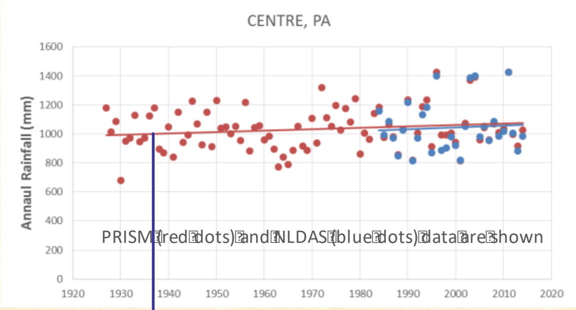
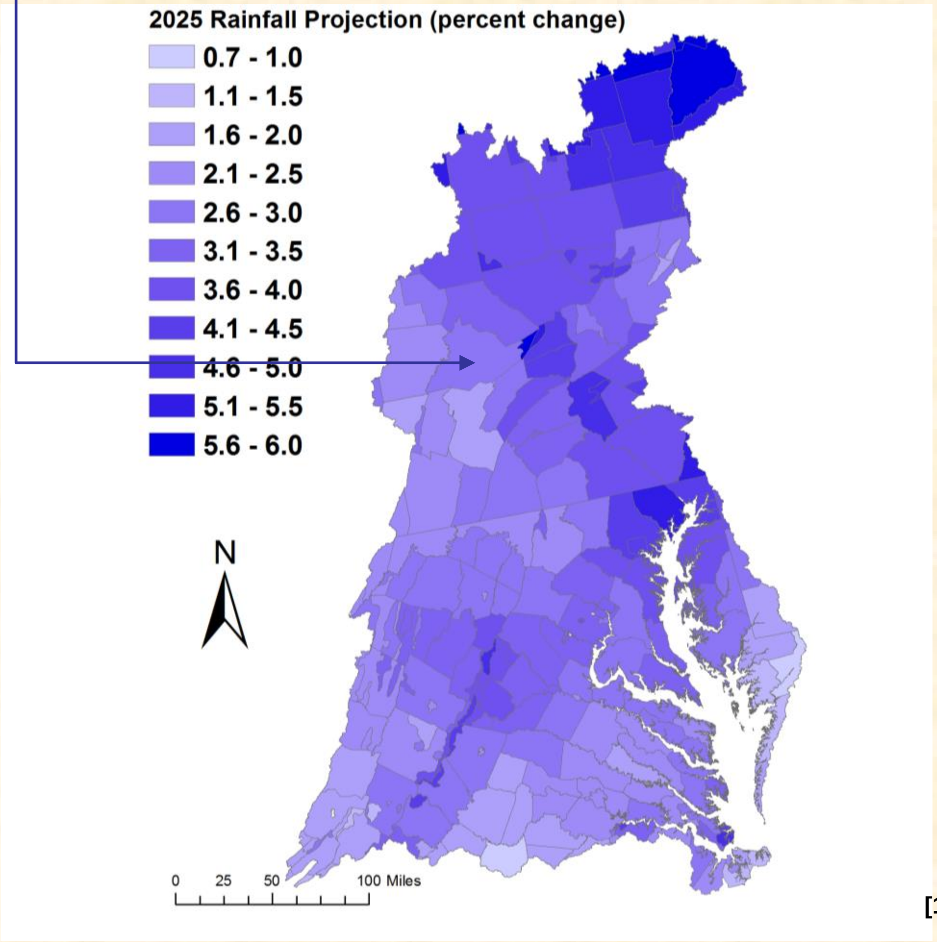
# Precipitation Volume Increasing




## 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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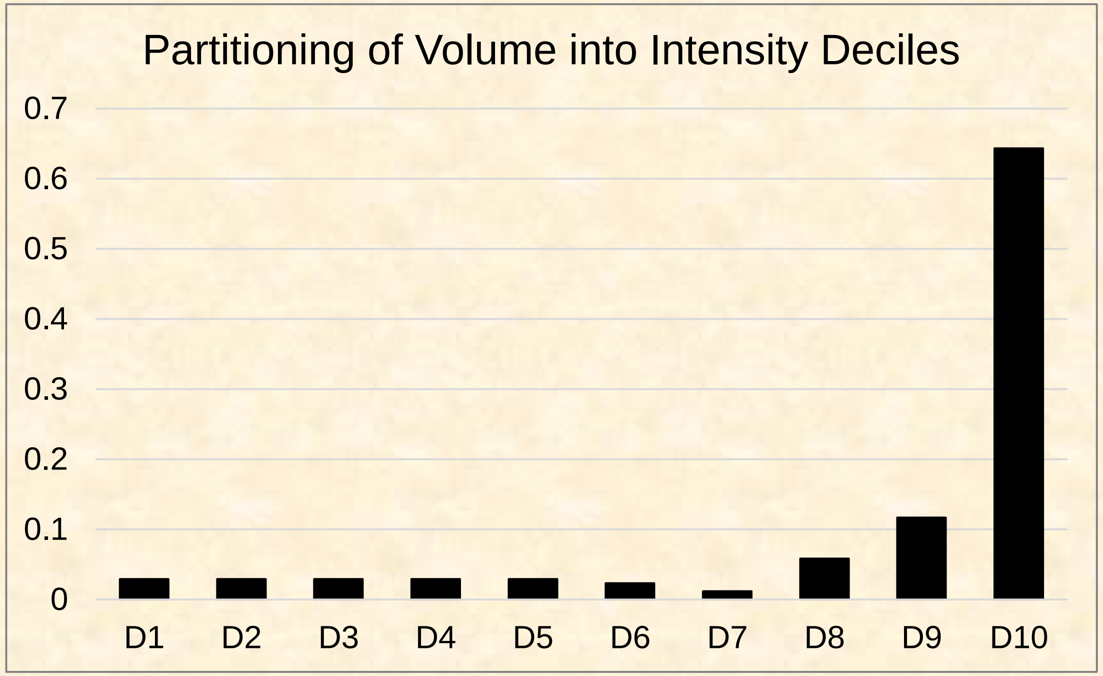
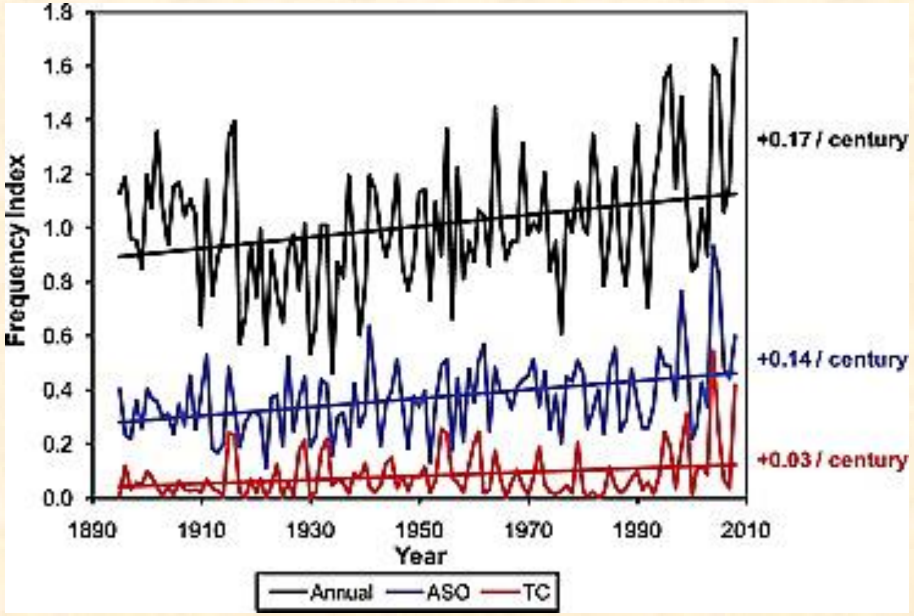
# Rainfall Intensity Increasing

*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]

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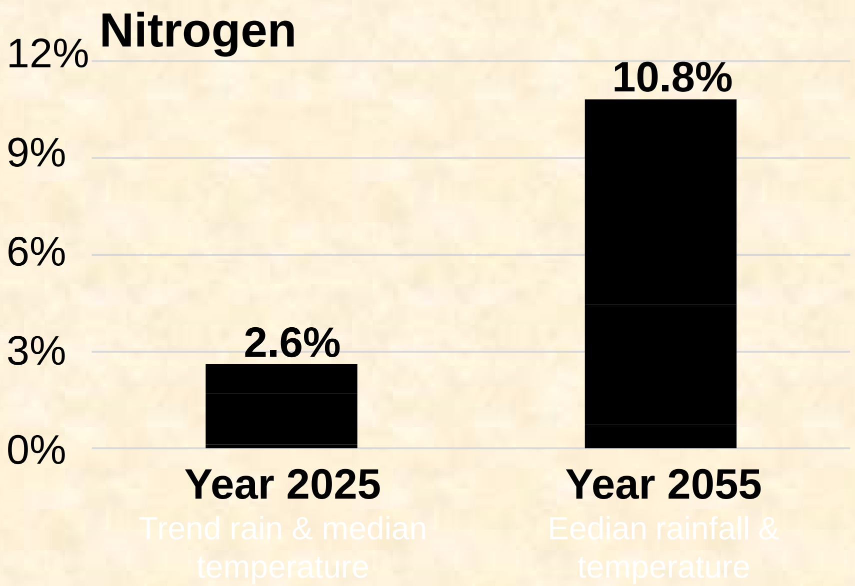
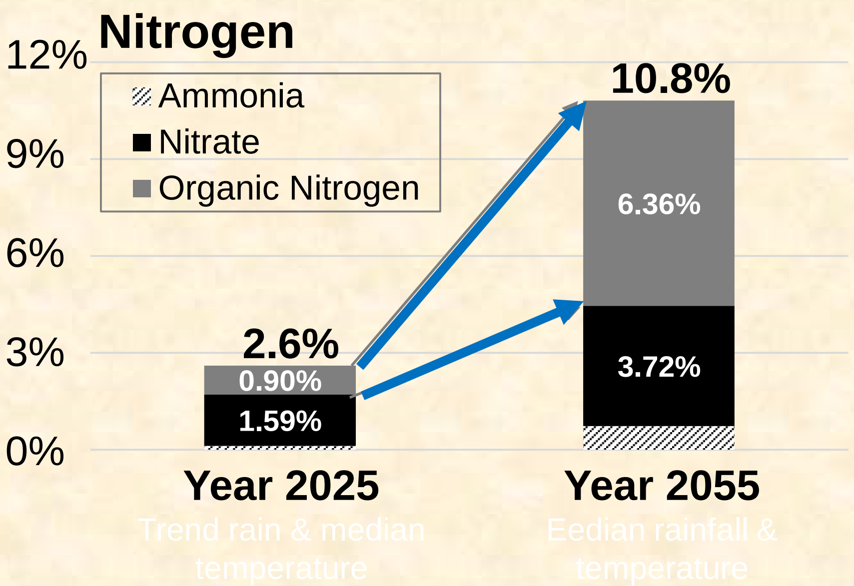
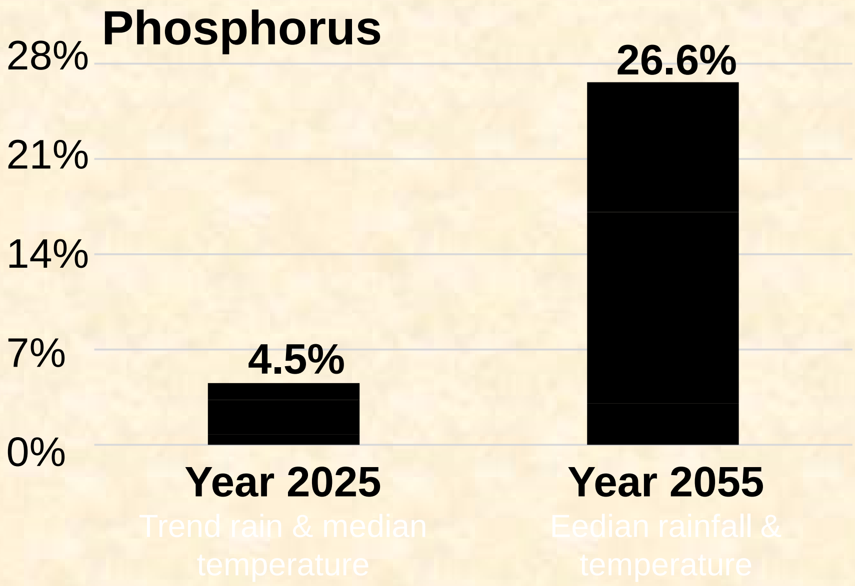
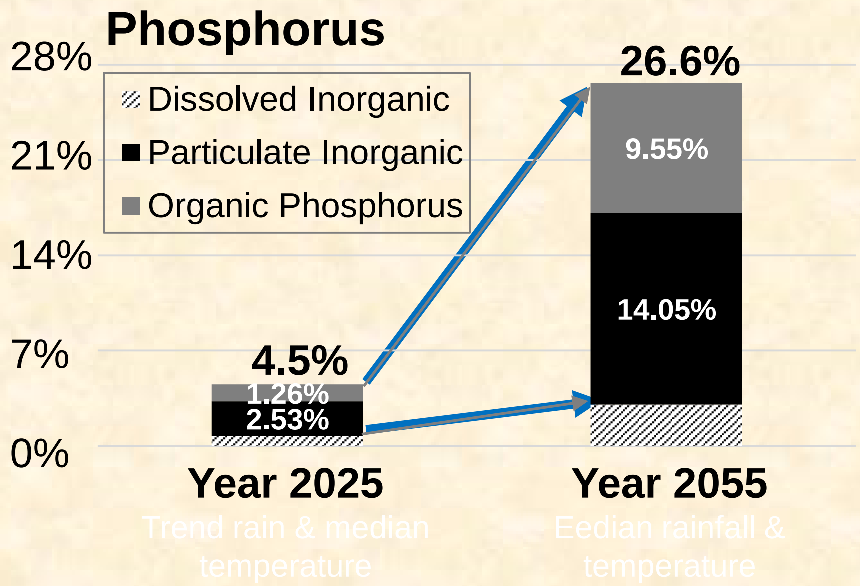
# Summary of Changes in Nutrient Species Delivery




**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.**

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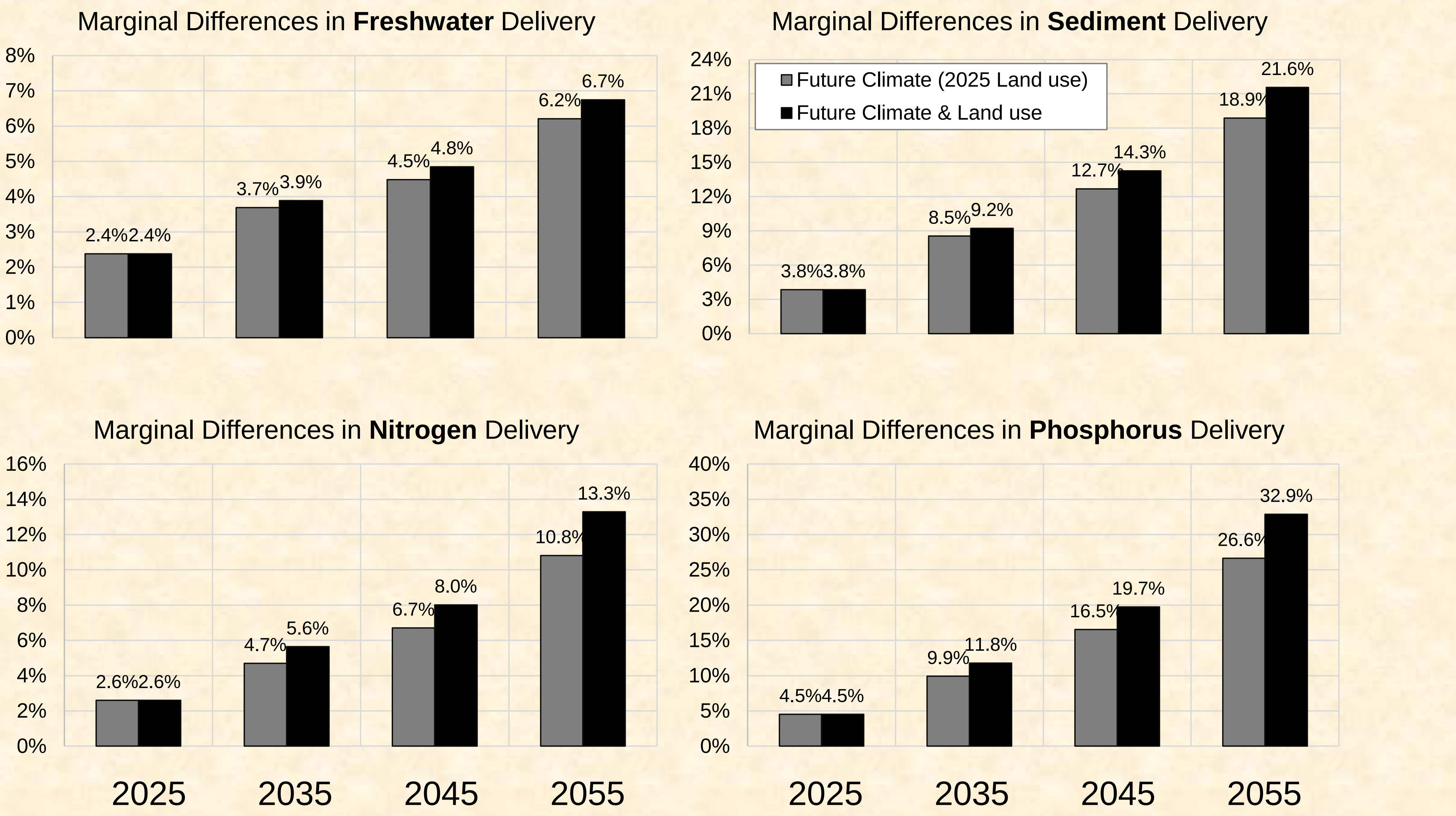
# Estimates of Climate Only and Climate and Land Use




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

# Elements of 2025 Climate Change in the Estuary

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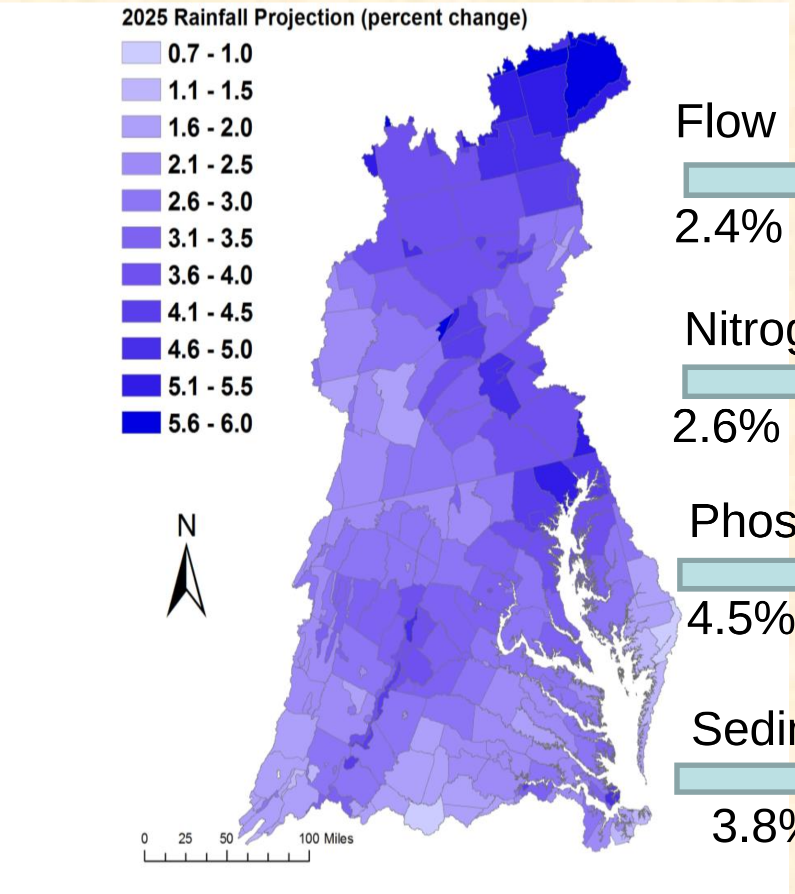
**Air-temperature increase: 1.06 °C**




**Phase 6 Watershed Model**

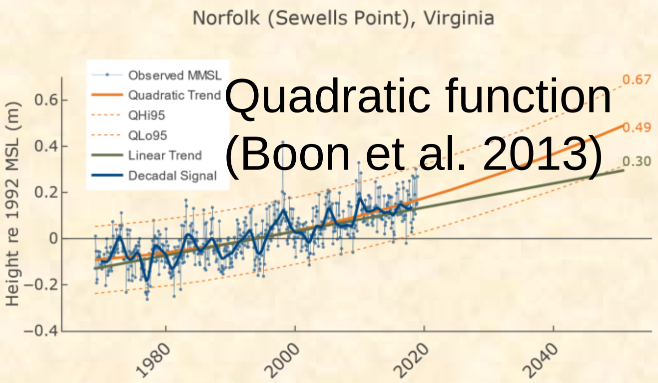
Flow
2.4% Increase

Nitrogen Load
2.6% Increase

Phosphorus Load
4.5% Increase

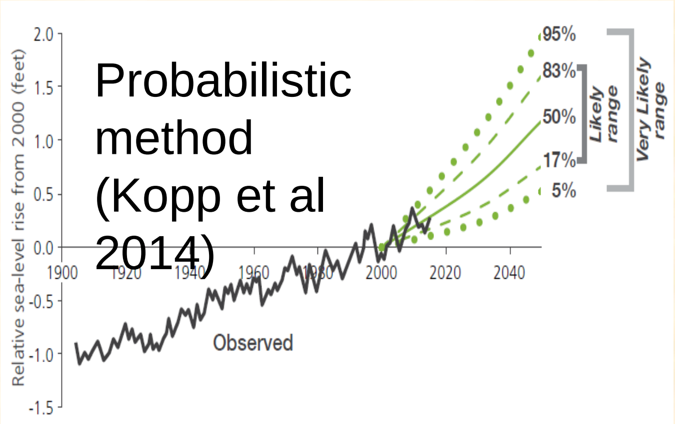
Sediment Load
3.8% Increase

**Model: CH3D-ICM**
**400m-1km Resolution**




Quadratic function (Boon et al. 2013)

**2025 Sea Level Rise: 0.22m**




Probabilistic method (Kopp et al 2014)

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

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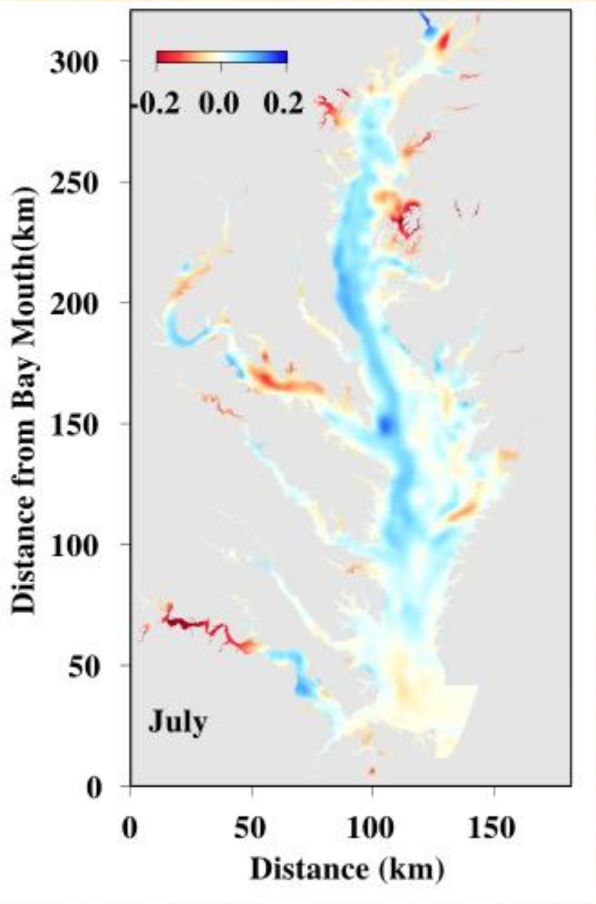
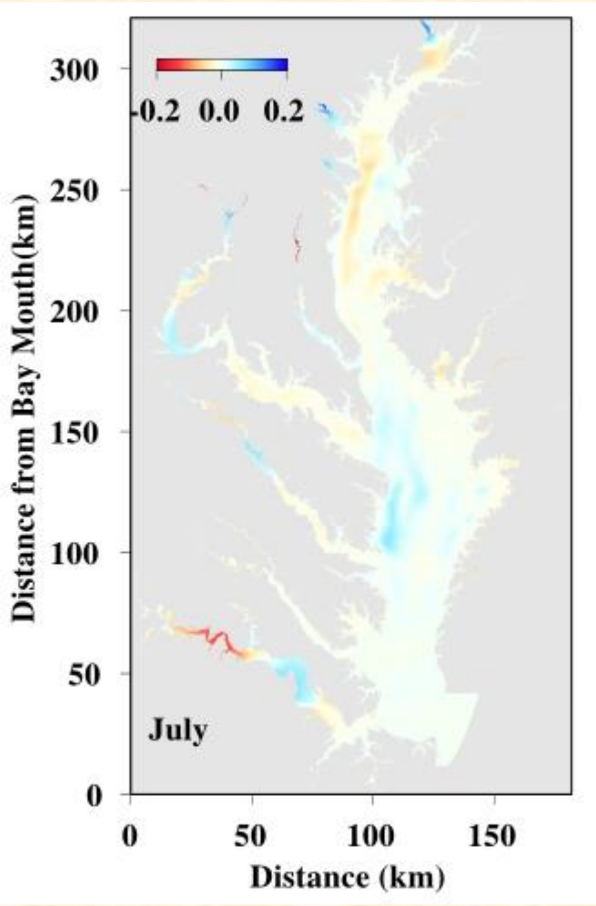
# Bottom DO Change: 1995 to 2025

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.

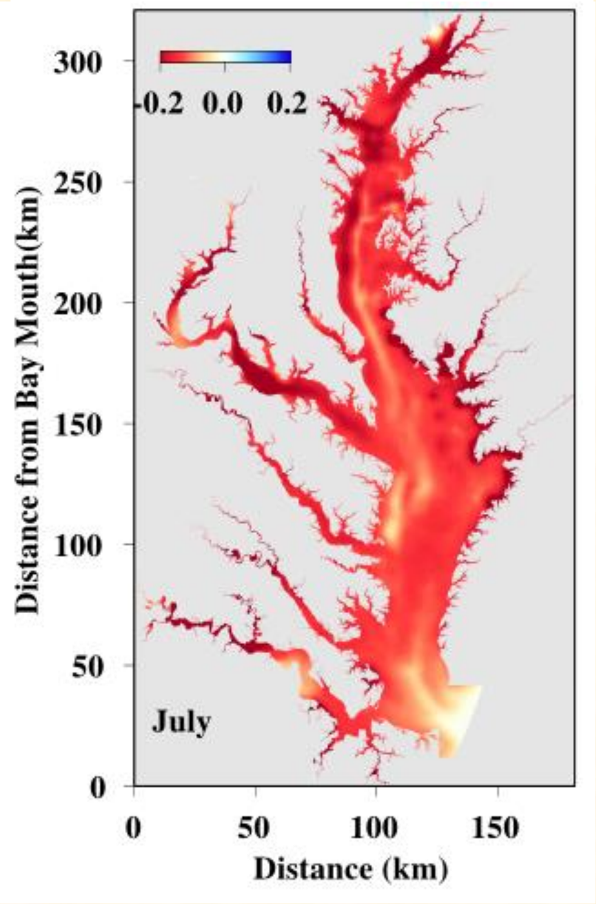
**Sea Level Rise**



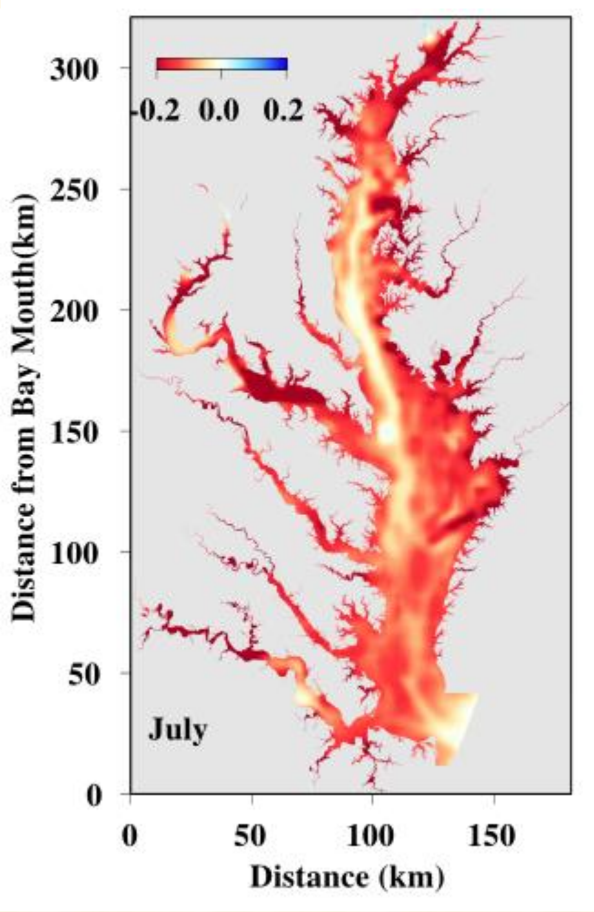

**Watershed Flow**



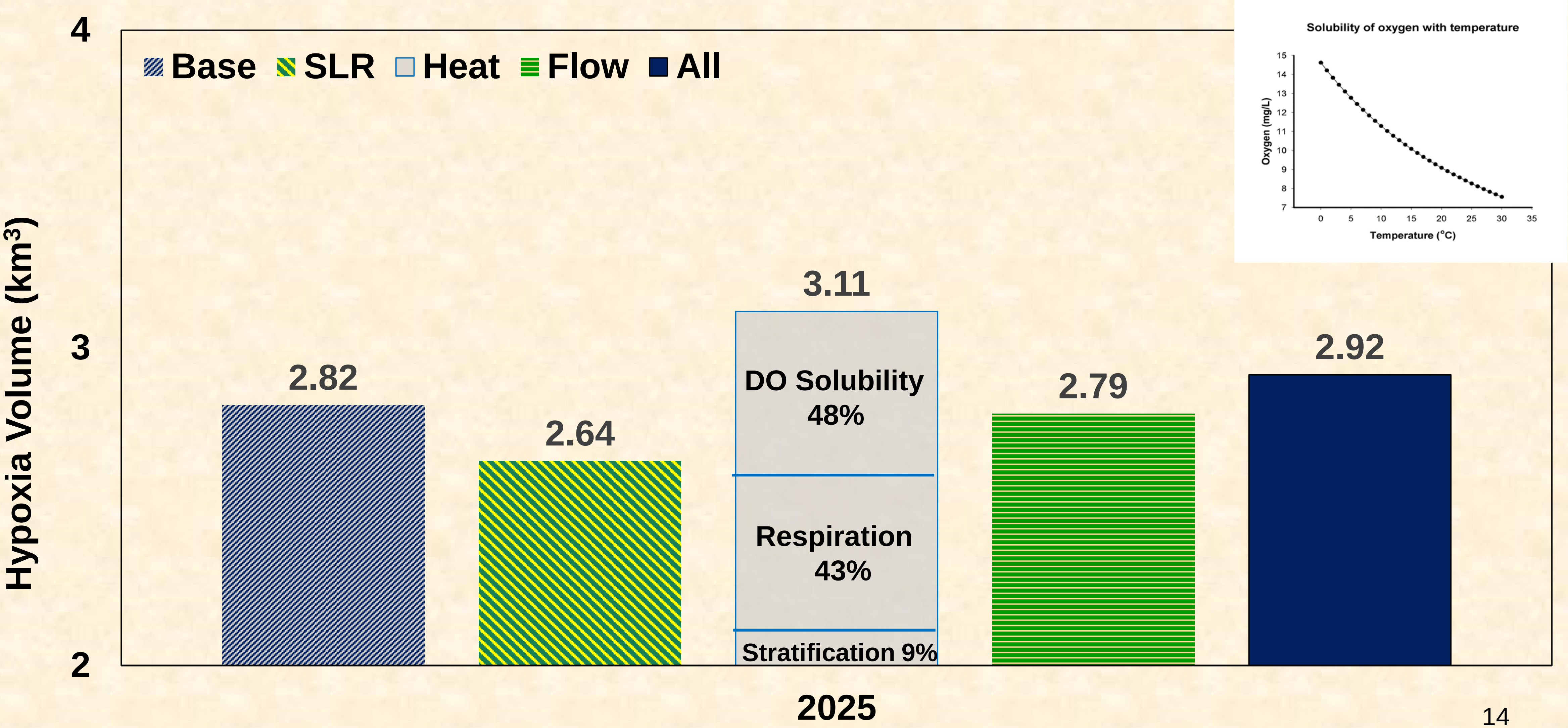

**Increased Temp.**




**All Factors**



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



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# Current Climate Change Only Scenarios

***Air-temperature increase: 1.06 °C***

***Sea Level Rise: 0.22m***

Flow

+2.4% est. 2025

TN

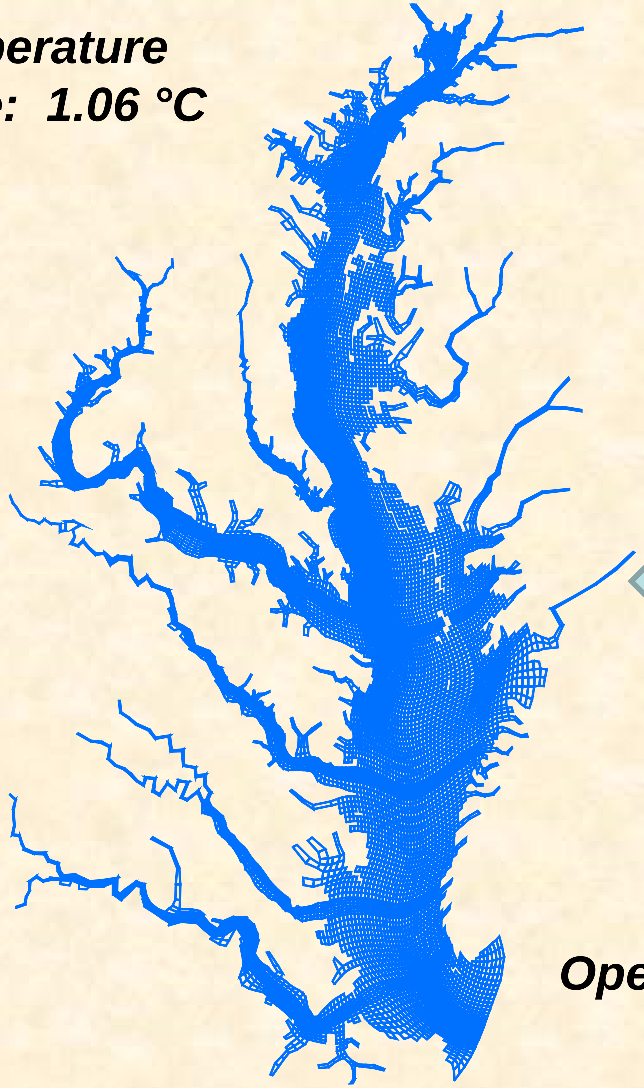
+2.6% est. 2025

TP

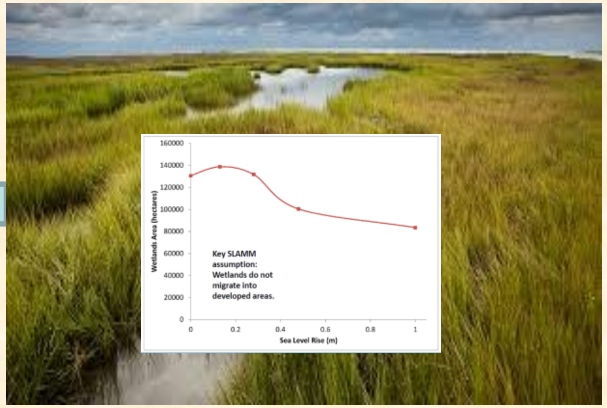
+4.5% est. 2025

Sediment

+3.8 est. 2025



**Tidal wetland change**



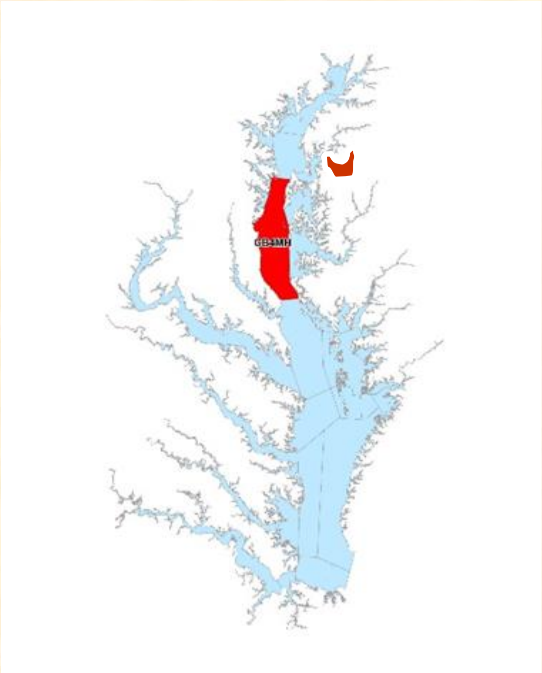

***Open boundary delta T: + 0.95 °C; delta S: + 0.18 psu***

(Thomas et al., 2017)

# △Achievement of Deep Channel DO Water Quality Standard

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

| CB Segment | State | 2025 Climate<br>2025 Land Use<br>204TN<br>14.0TP<br>1993-1995<br>DO Deep Channel | 2035 Climate<br>2025 Land Use<br>208TN<br>14.6TP<br>1993-1995<br>DO Deep Channel | 2045 Climate<br>2025 Land Use<br>212TN<br>15.4TP<br>1993-1995<br>DO Deep Channel | 2055 Climate<br>2025 Land Use<br>220TN<br>16.7TP<br>1993-1995<br>DO Deep Channel |
|---|---|---|---|---|---|
| CB3MH | MD | 0.00% | 0.00% | 0.00% | 0.00% |
| CB4MH | MD | 1.47% | 3.15% | 4.62% | 7.31% |
| CB5MH | MD | 0.00% | 0.00% | 0.00% | 0.00% |
| CB5MH | VA | 0.00% | 0.00% | 0.00% | 0.00% |
| POTMH | MD | 0.00% | 0.00% | 0.00% | 0.00% |
| RPPMH | VA | 0.00% | 0.00% | 0.00% | 0.00% |
| ELIPH | VA | 0.00% | 0.00% | 0.00% | 0.00% |
| CHSMH | MD | 0.01% | 0.92% | 1.08% | 2.34% |



# ΔAchievement of Deep Water DO Water Quality Standard

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Achievement of **Deep Water DO** water quality standard expressed as ***an 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 | 2045 Climate 2025 Land Use 212TN, 15.4TP 1993-1995 DO Deep Water | 2055 Climate 2025 Land Use 220TN, 16.7TP 1993-1995 DO Deep Water |
|---|---|---|---|---|---|
| CB3MH | MD | 0.01% | 0.15% | 0.16% | 0.21% |
| CB4MH | MD | 0.94% | 1.61% | 2.00% | 2.66% |
| CB5MH | MD | 0.52% | 1.01% | 1.32% | 1.66% |
| CB5MH | VA | 0.00% | 0.00% | 0.00% | 0.00% |
| CB6PH | VA | 0.00% | 0.00% | 0.00% | 0.00% |
| CB7PH | VA | 0.00% | 0.00% | 0.00% | 0.00% |
| PATMH | MD | 0.01% | 0.02% | 0.42% | 2.66% |
| MAGMH | MD | 1.66% | 1.66% | 1.91% | 1.91% |
| SOUMH | MD | 0.00% | 0.00% | 0.00% | 0.00% |
| SEVMH | MD | 0.00% | 0.00% | 0.00% | 0.00% |
| PAXMH | MD | 0.00% | 0.00% | 0.00% | 0.00% |
| POTMH | MD | 0.03% | 0.15% | 0.56% | 0.81% |
| RPPMH | VA | 0.00% | 0.24% | 1.48% | 1.85% |
| YRKPH | VA | 0.00% | 0.00% | 0.00% | 0.00% |
| ELIPH | VA | 0.00% | 0.00% | 0.00% | 0.00% |
| SBEMH | VA | 0.00% | 0.00% | 0.44% | 3.12% |
| CHSMH | MD | 0.00% | 0.00% | 0.00% | 0.00% |

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# △Achievement of Tidal Fresh Open Water DO Water Quality Standard

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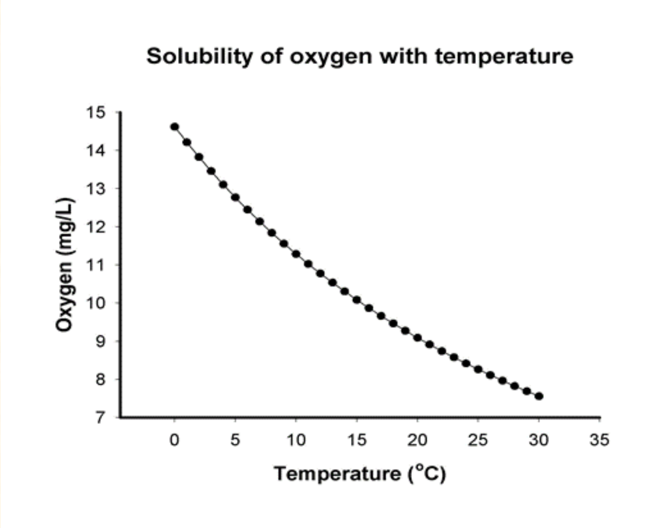
Estimating substantial increases in Open Water DO nonattainment under increased (1ºC) 2025 temperature in shallow waters.




| | | 1995 Climate | 2025 Climate | 2035 Climate | 2045 Climate | 2055 Climate |
|---|---|---|---|---|---|---|
| PAXTF | MD | 2.81% | 11.93% | 11.95% | 12.37% | 13.35% |
| WBRTF | MD | 0.00% | 32.27% | 32.27% | 39.65% | 54.64% |
| PISTF | MD | 4.63% | 4.65% | 4.65% | 4.65% | 4.65% |
| MATTF | MD | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| RPPTF | VA | 0.00% | 0.00% | 0.00% | 0.00% | 1.65% |
| MPNTF | VA | 1.31% | 27.03% | 36.88% | 41.21% | 35.67% |
| PMKTF | VA | 6.90% | 71.26% | 81.54% | 74.44% | 69.83% |
| JMSTFL | VA | 0.00% | 0.00% | 0.38% | 0.96% | 1.02% |
| JMSTFU | VA | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| APPTF | VA | 4.59% | 0.00% | 0.00% | 0.00% | 4.59% |
| NORTF | MD | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| CHSTF | MD | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| CHOTF | MD | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| NANTF_MD | MD | 0.00% | 0.73% | 4.70% | 0.73% | 0.00% |
| POCTF | MD | 0.00% | 69.83% | 77.48% | 77.48% | 77.48% |

# Open Water (OW) DO Nonattainment Investigated Using Observed Data, Research, and Modeling Tools

- One avenue of OW DO examination is through what we see in the observed trends. We'll be examining the observed trends in Open Water, Deep Water, and Deep Channel DO and temperature along with due consideration of the role salinity/sea level rise could play in OW DO. Following the above, the WQSTM will be examined to ensure that it is capturing the observed trends found in OW, DW, & DC.
- We'll also work in coordination with Jeremy Testa and his team in the work they are doing for STAC's shallow tidal water Climate Change Technical Synthesis and work to apply an examination of what multiple models tell us about OW DO nonattainment.

# △Achievement of Polyhaline Open Water DO Water Quality Standard

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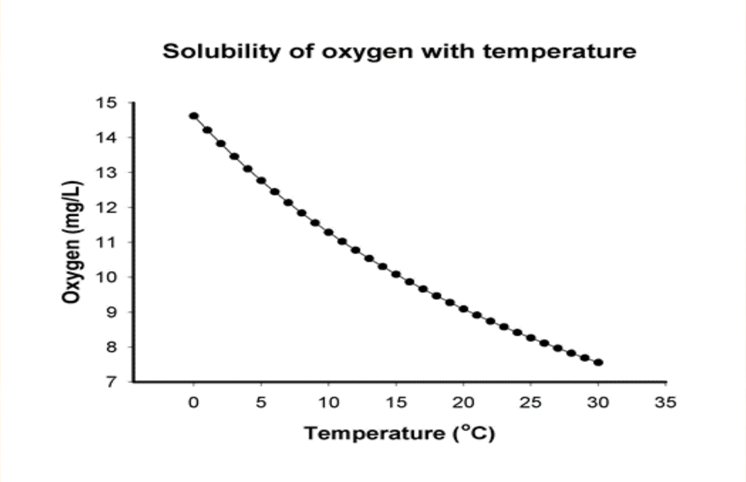
| | | 1995 Climate | 2025 Climate | 2035 Climate | 2045 Climate | 2055 Climate |
|---|---|---|---|---|---|---|
| CB6PH | VA | 0.13% | 0.49% | 0.81% | 1.09% | 1.39% |
| YRKPH | VA | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| MOBPH | VA | 0.00% | 0.00% | 0.01% | 0.11% | 0.16% |
| JMSPH | VA | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |

In deeper CB segments with Open Water designated uses somewhat removed from shallow water areas water quality attainment is more widespread…..



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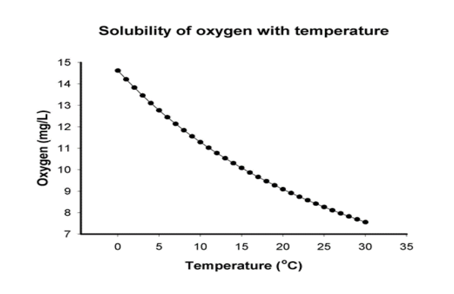
# △Achievement of Main Bay Open Water DO Water Quality Standard

| | | 1995 | 2025 | 2035 | 2045 | 2055 |
|---|---|---|---|---|---|---|
| CB1TF | MD | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| CB2OH | MD | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| CB3MH | MD | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| CB4MH | MD | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| CB5MH_MI | MD | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| CB5MH_VA | VA | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| CB6PH | VA | 0.13% | 0.49% | 0.81% | 1.09% | 1.39% |
| CB7PH | VA | 0.64% | 1.74% | 2.43% | 3.34% | 4.51% |
| CB8PH | VA | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |

In deeper CB segments with Open Water designated uses somewhat removed from shallow water areas water quality attainment is more widespread…in most cases.



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# 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.**

# 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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- Future climate change analyses 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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# Key Points in Assessment of 2025 Climate Change Risk



From a better climate change assessment model the 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. With the improved model the additional load reduction estimated to respond to climate change risk are 8.0 M lb TN (Dec. 2017 was 9.1 M lb TN) and 0.43 M lb TP (Dec, 2017 was 0.49 M lb TP).

# Key Points in Assessment of 2025 Climate Change Risk

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Based on the recommendations of the January 2020 Modeling Quarterly Review, better methods to estimate allocations based on equating what is required to remove DO nonattainment volume in the Chesapeake have further reduced estimated loads to address climate risk in the 2022-2023 Milestones. With the improved allocation method the estimated range of additional load reductions are between 5.0 – 6.7 million pounds TN and 0.35 – 0.47 million pounds TP depending on the approach/ methods recommended by the WQGIT.

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# Conclusions on Open Water DO Nonattainment:

- Open Water (OW) DO nonattainment in shallow water is being investigated from a number of avenues using observed data, research, and modeling tools.
- Air temp/water temperature increase is a real climate effect that makes OW DO attainment difficult in some areas.
- OW is impacted by climate change and the CBP Partnership could consider it in estimating climate change risks to OW DO standards.
- However, we ultimately need a better shallow water model to include all the OW DO data and better understand the climate effects in those areas that are closest to where people experience the Bay.
- Addressing OW DO nonattainment is usually addressed as a local issue. Nevertheless, OW DO nonattainment in the main Bay (CB7PH) could be used in global (watershed wide) climate allocations if the CBP Partnership chooses to do so.