Challenges of the 2017 Midpoint Assessment To Be Addressed by the Water Quality and Sediment transport Model (WQSTM)

Water Quality and Sediment Transport Model (WQSTM)
Peer Review Meeting

June 5, 2017

Chesapeake Bay Program
Science, Restoration, Partnership

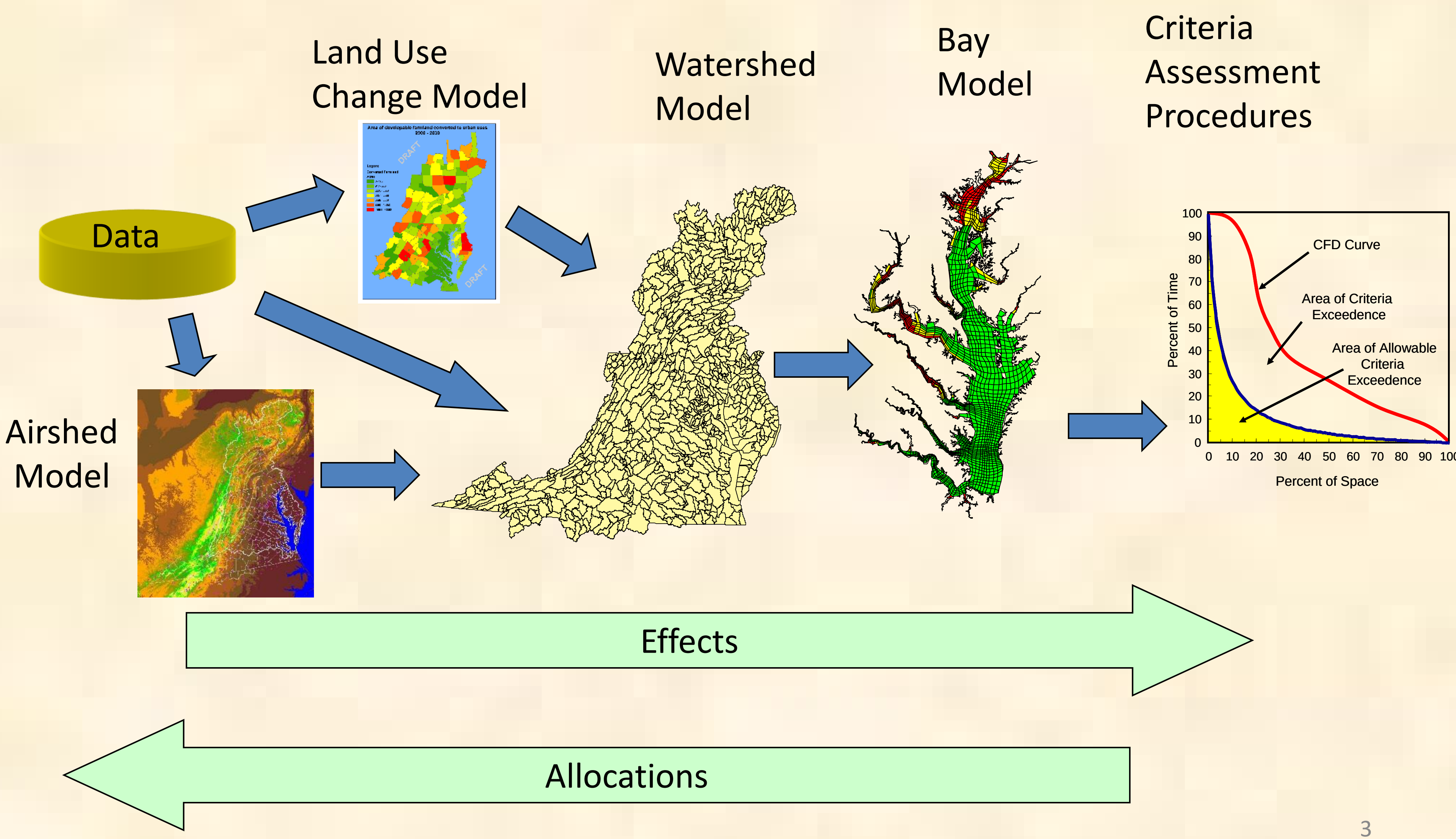
2017 Water Quality Sediment Transport Model Raison D'être

- Providing an assessment of tidal water quality attainment to guide development of the Phase 3 Watershed Implementation Plans (WIPs) for the period 2018 to 2025, as well as to provide information to CBP decision makers on other aspects of the 2017 Midpoint Assessment management decisions, such as the influence the expansion of oyster aquaculture and sanctuaries has on Chesapeake water quality.

- Understanding how the ‘dynamic equilibrium’ of Conowingo infill influences nutrient loads from the Lower Susquehanna and provide insights on economically efficient approaches to offset the increased nutrient loads in order to fully attain water quality standards.

- Estimating the influence of increased temperature, precipitation, tidal wetland loss, sea level rise, and other climate factors have on tidal water quality.

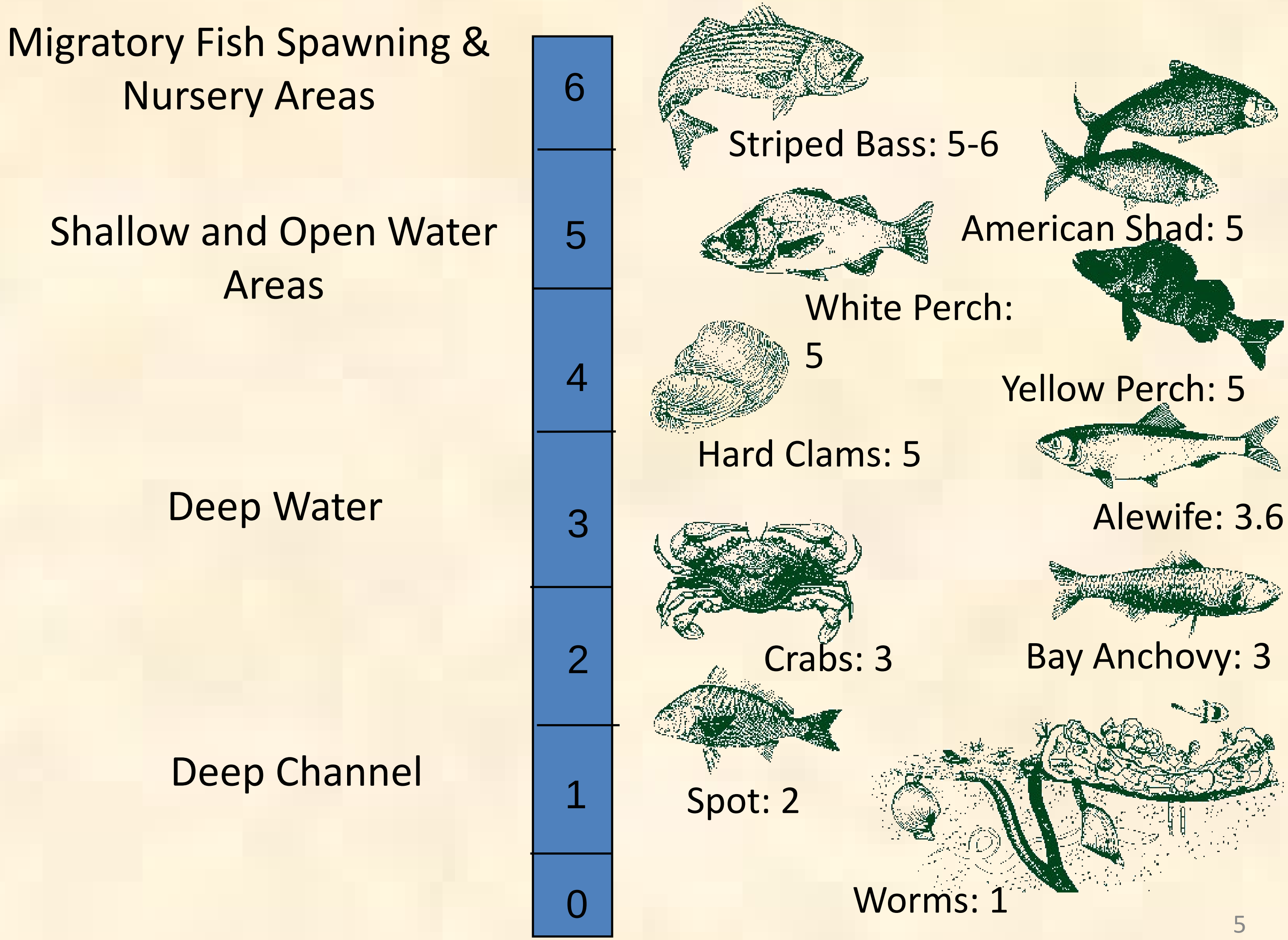
Decision Support System



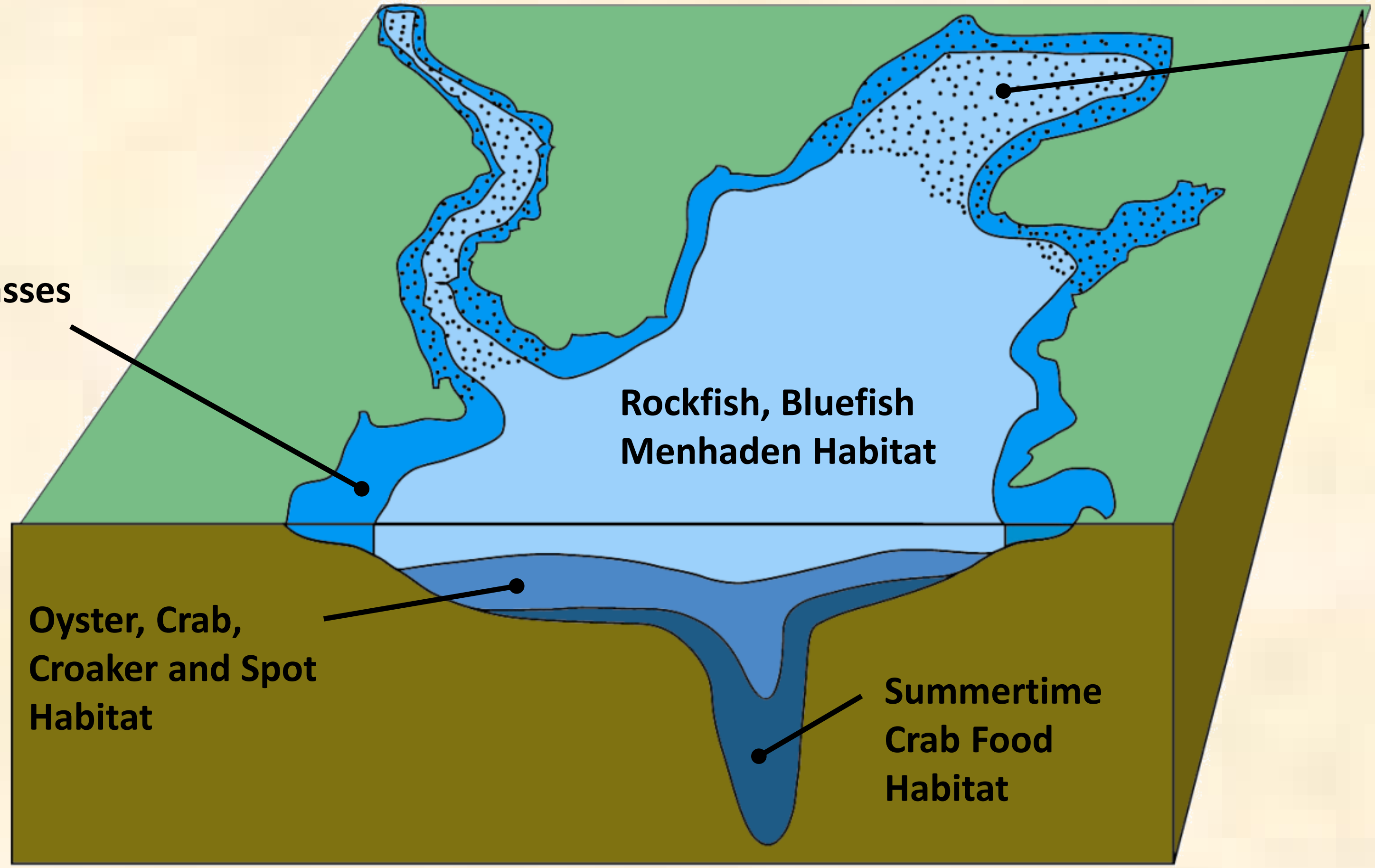
Providing an assessment of tidal water quality attainment to guide development of the Phase 3 Watershed Implementation Plans (WIPs) for the period 2018 to 2025, as well as to provide information to CBP decision makers on other aspects of the 2017 Midpoint Assessment management decisions, such as the influence the expansion of oyster aquaculture and sanctuaries has on Chesapeake water quality.

Bay Dissolved Oxygen Criteria

Minimum Amount of Oxygen (mg/L) Needed to Survive by Species



Local "Zoning" for Bay and Tidal River Fish, Crab and Grasses Habitats

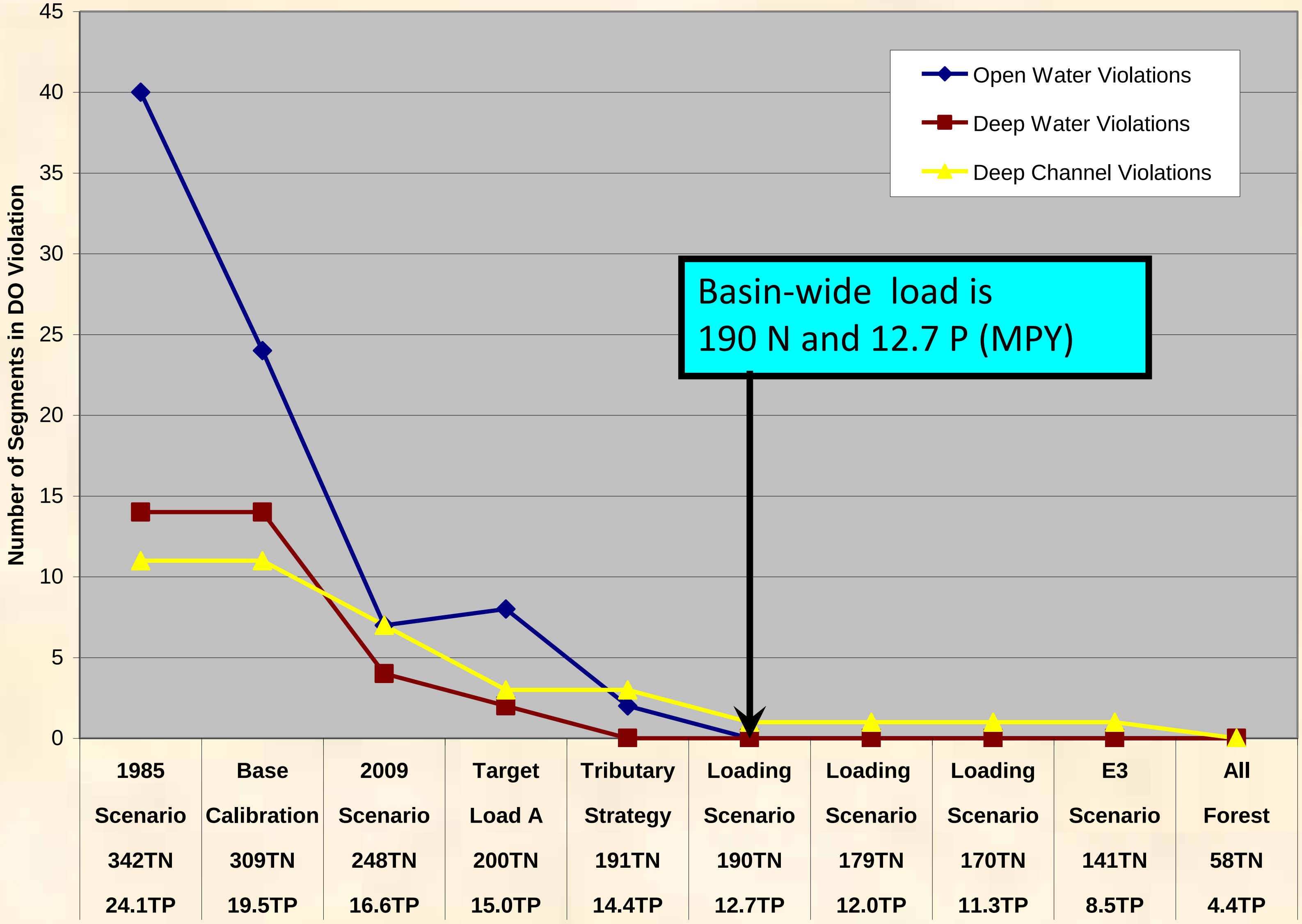


Redefined 'swimmable/fishable' in terms the public could relate to

Guidelines for Allocations

- Allocated N and P loads must result in attainment of water quality standards.
- Areas that contribute the most to the problem must do the most to resolve the problem.

Dissolved Oxygen Criteria Attainment



Determining Who Contributes the Most

Two key factors:

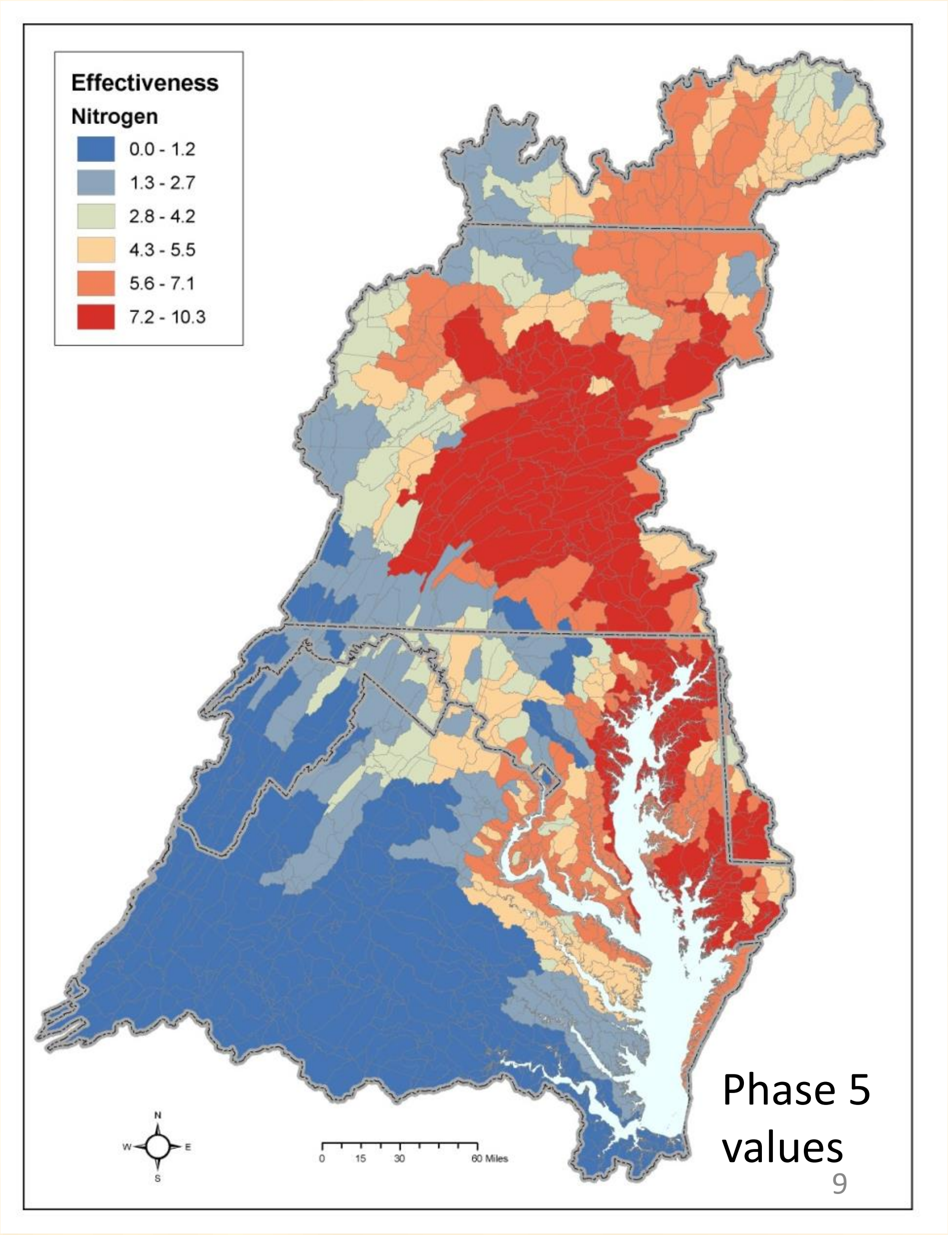
Distance from Tidal water
- Riverine transport

Position along mainstem Bay
- Estuarine circulation

Riverine delivery:
Pound delivered to tidal water per pound input from watershed

Estuarine delivery
Deep water oxygen reduced per pound nutrient delivered to tidal water

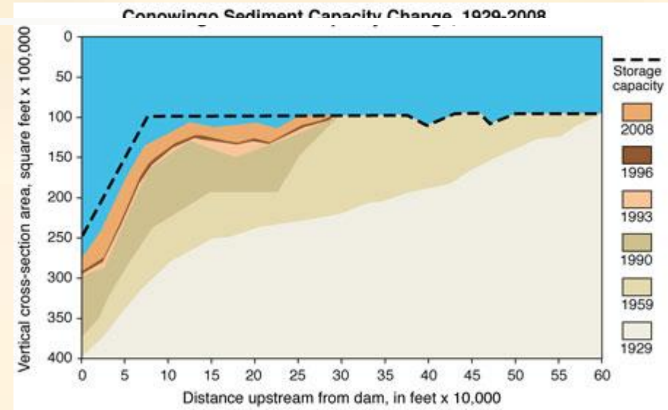
Overall Effectiveness
Deep water oxygen reduced per pound input from the watershed



Understanding how the 'dynamic equilibrium' of Conowingo infill influences nutrient loads from the Lower Susquehanna and provide insights on economically efficient approaches to offset the increased nutrient loads in order to fully attain water quality standards.

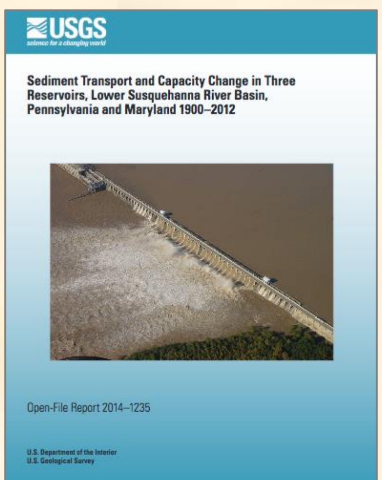
Brief Review of Conowingo Infill

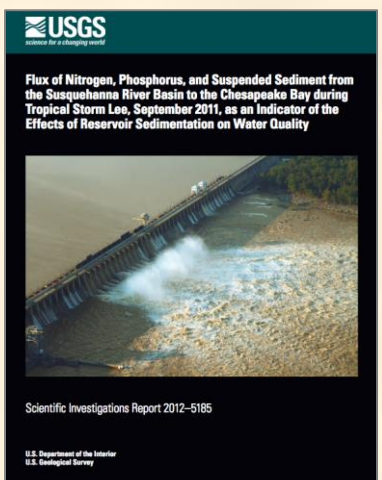
- Conowingo is nearing dynamic equilibrium, which has reduced its ability to trap sediment and nutrients.

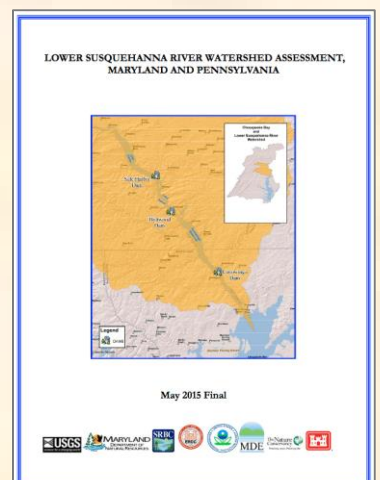


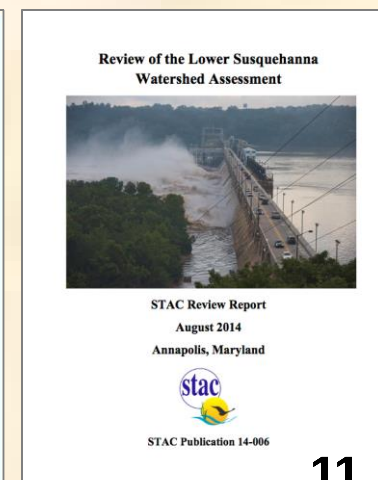
Source: Graph, Michael Langland, U.S. Geological Survey

- Since 2010 multiple research articles have provided an analysis of changes in transport, which are incorporated in this analysis.



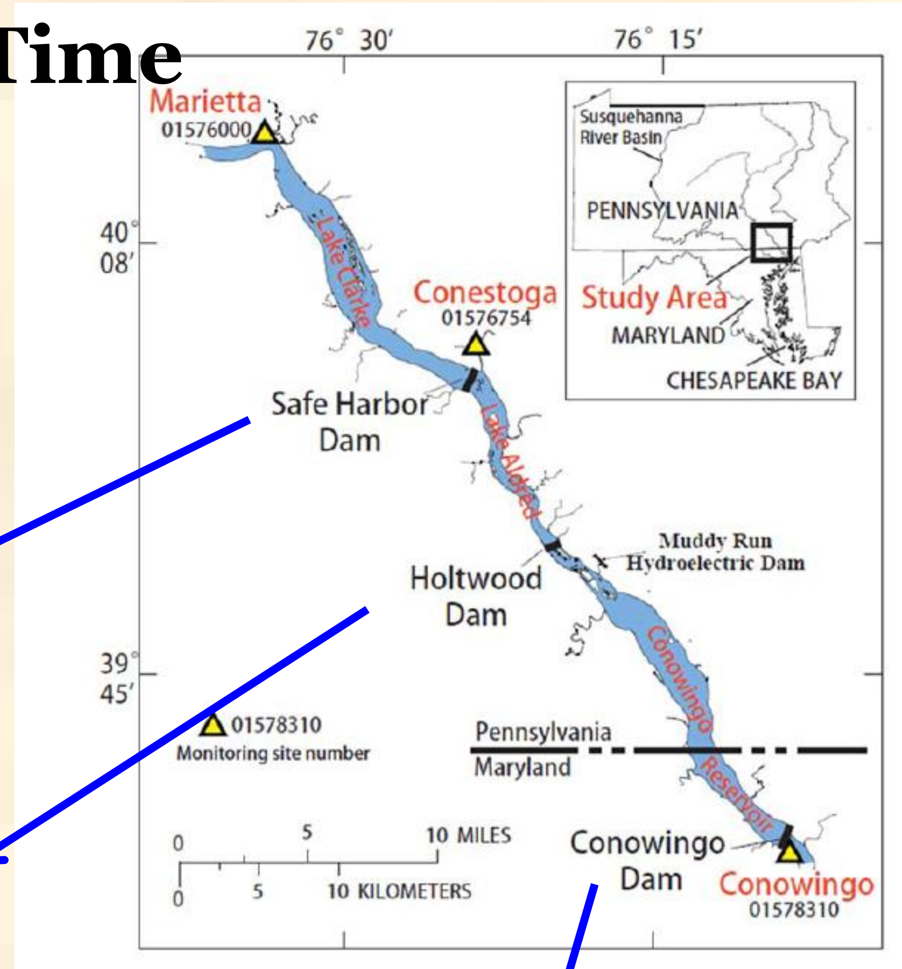


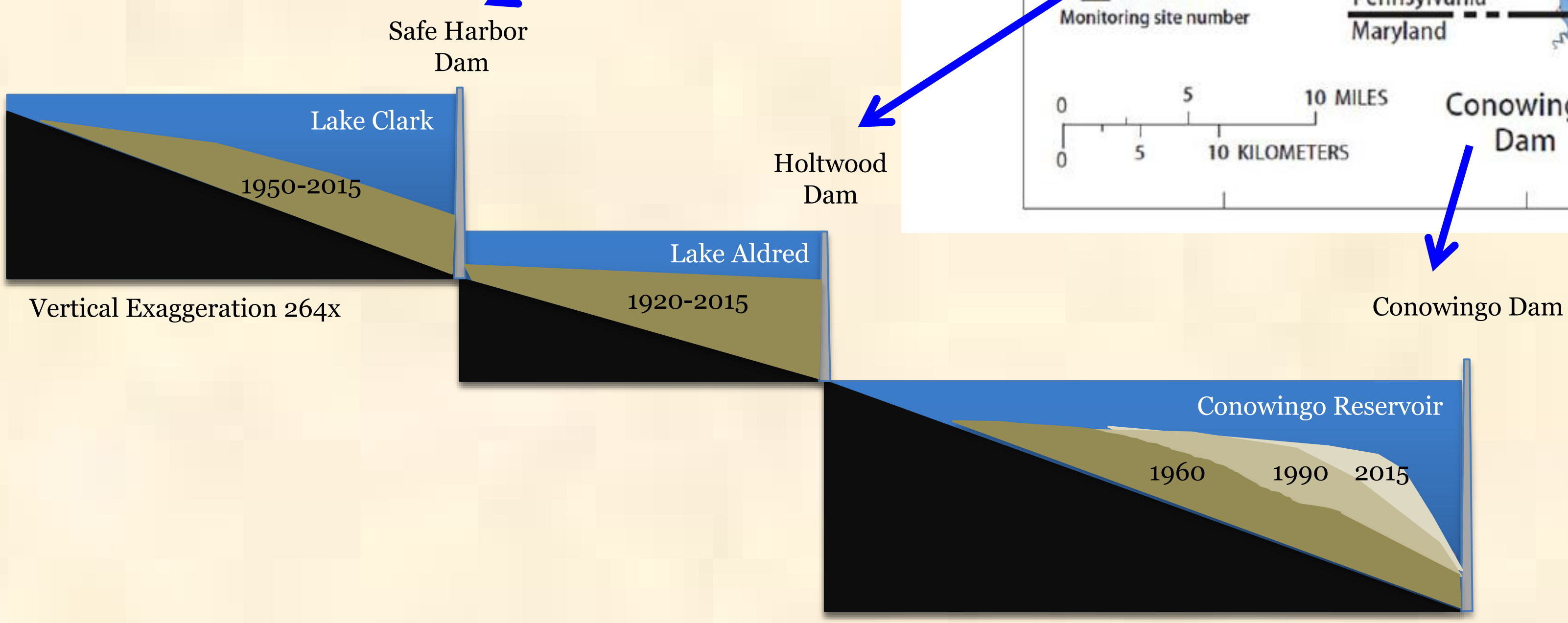




Reservoirs Filling Over Time

The Lower Susquehanna system of reservoirs has been filling over time, with the upper two reservoirs losing trapping capacity in the 1960s, and Conowingo Reservoir more recently.

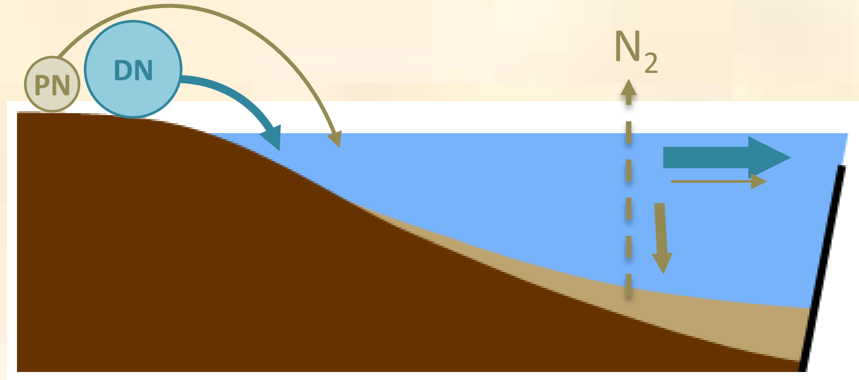




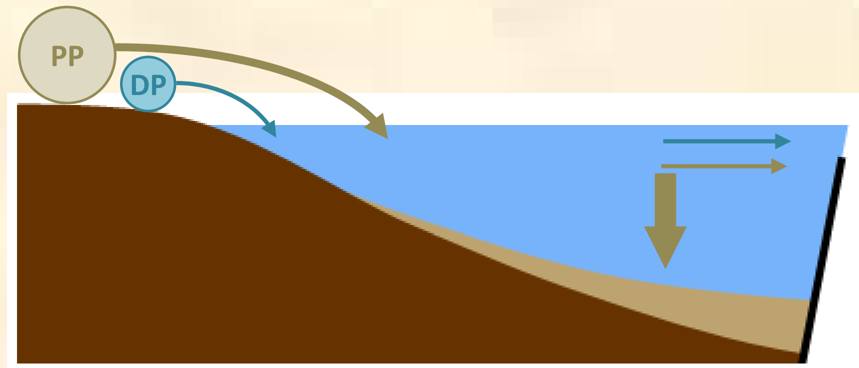
Source: Langland and Blomquist, USGS, personal communication

Differences in Trapping Effectiveness

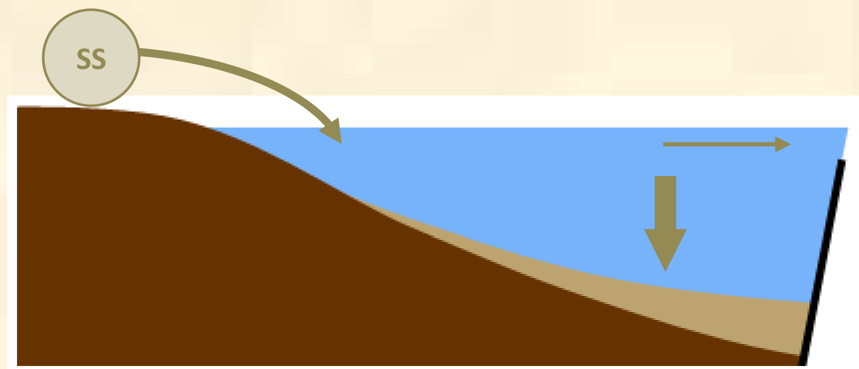
Nitrogen



Phosphorus



Sediment



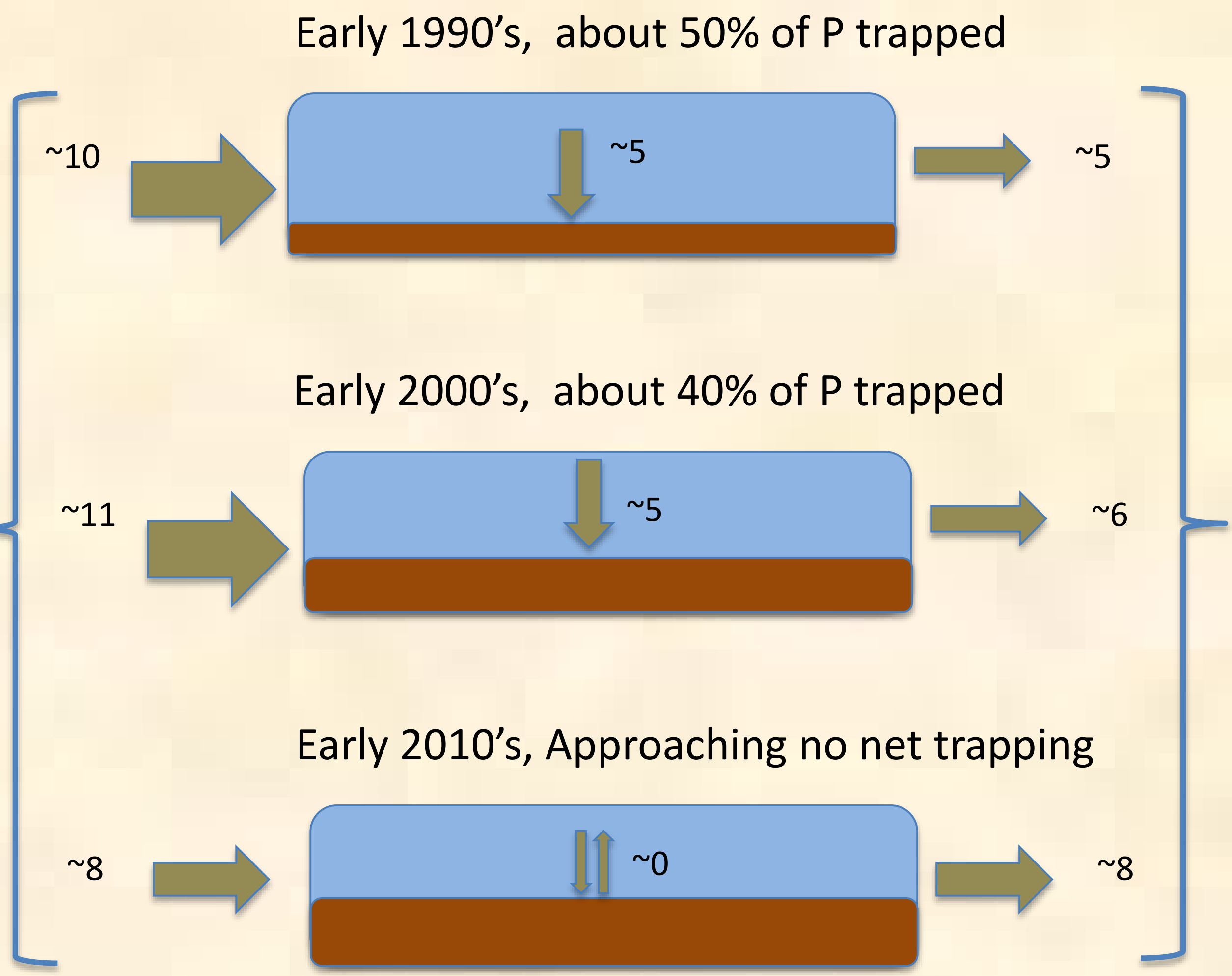
Key:	
PN=	Particulate Nitrogen
DN=	Dissolved Nitrogen
PP=	Particulate Phosphorus
DP=	Dissolved Phosphorus
SS=	Suspended Sediment

Source: Currey, MDE, Personal Communication

Phosphorus Loads Into, Trapped Within and Exiting the Reservoir System: 1990s-2010s

Loads Into Reservoir System

Long term improving trend



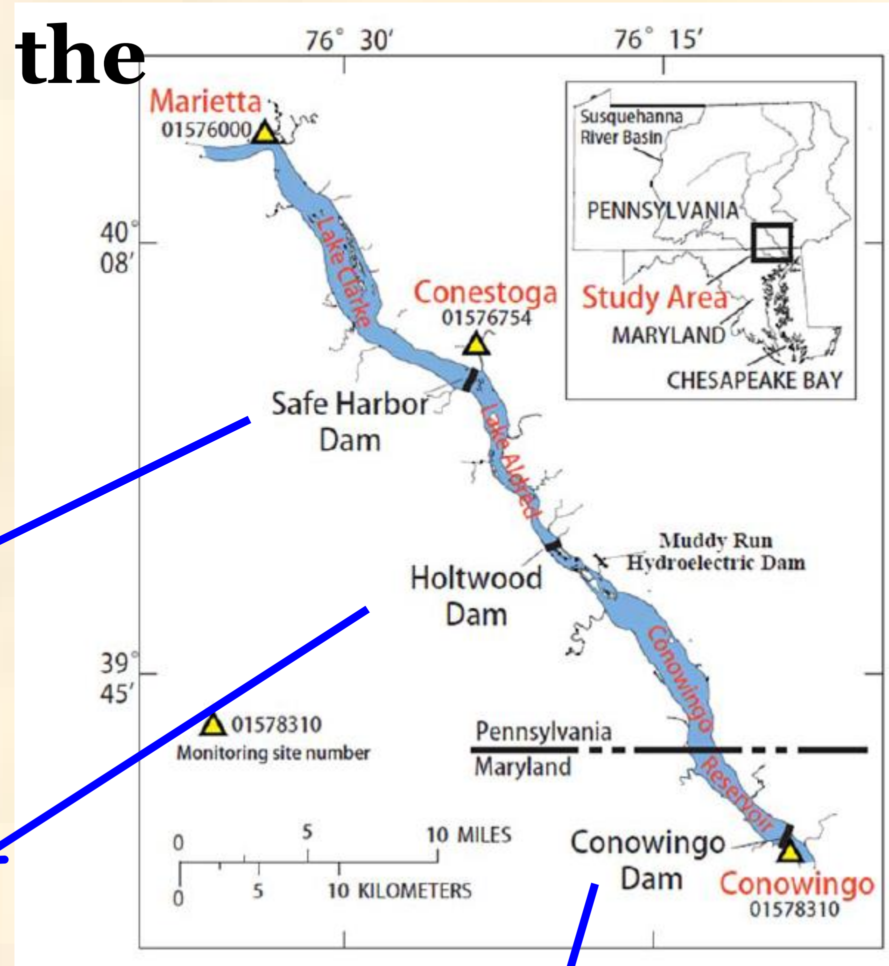
Loads Out of Reservoir System - Conowingo

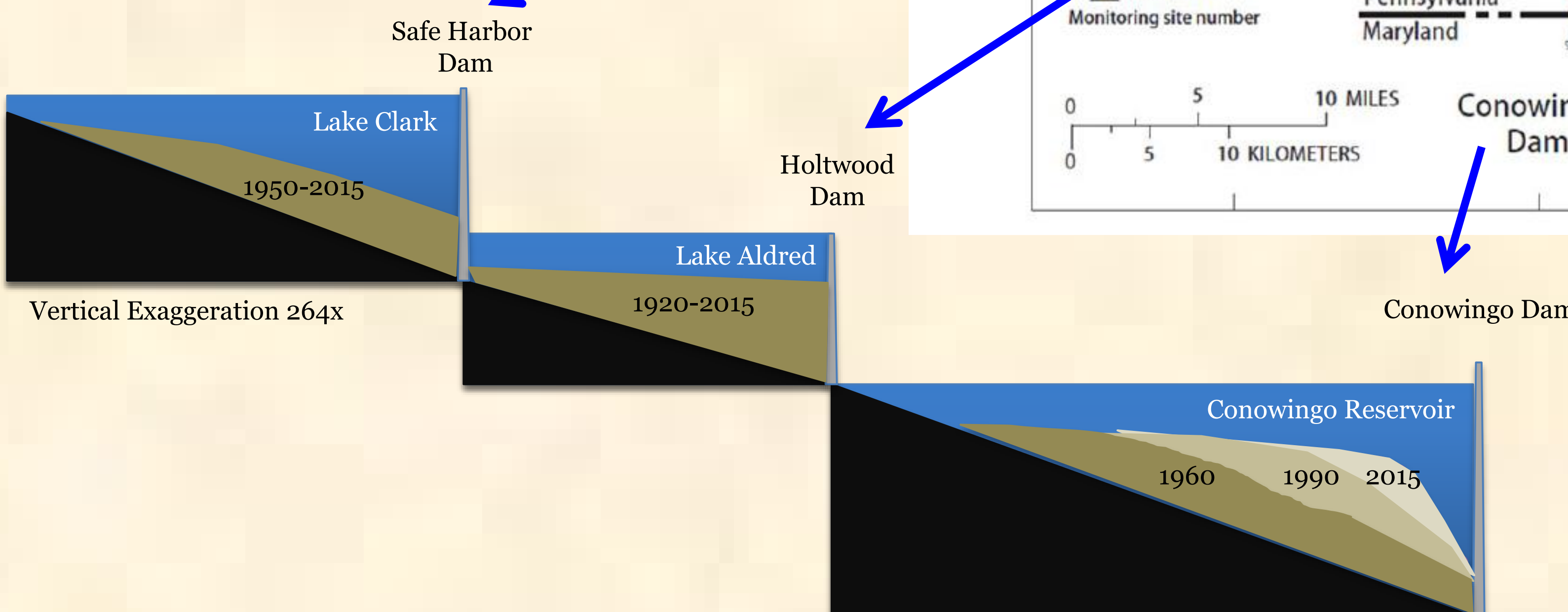
Long term degrading trend

Source: Data from USGS (2016), http://cbrim.er.usgs.gov/loads_query.html
loads are approximate and in units of million lbs/year using estimates for 1992, 2002, and 2012

What has changed with the Phase 6 Model?

The upper two reservoirs behind Safe Harbor and Holtwood dams have been simulated with HEC-RAS giving the CBP, for the first time, detailed sediment load estimates over all flows

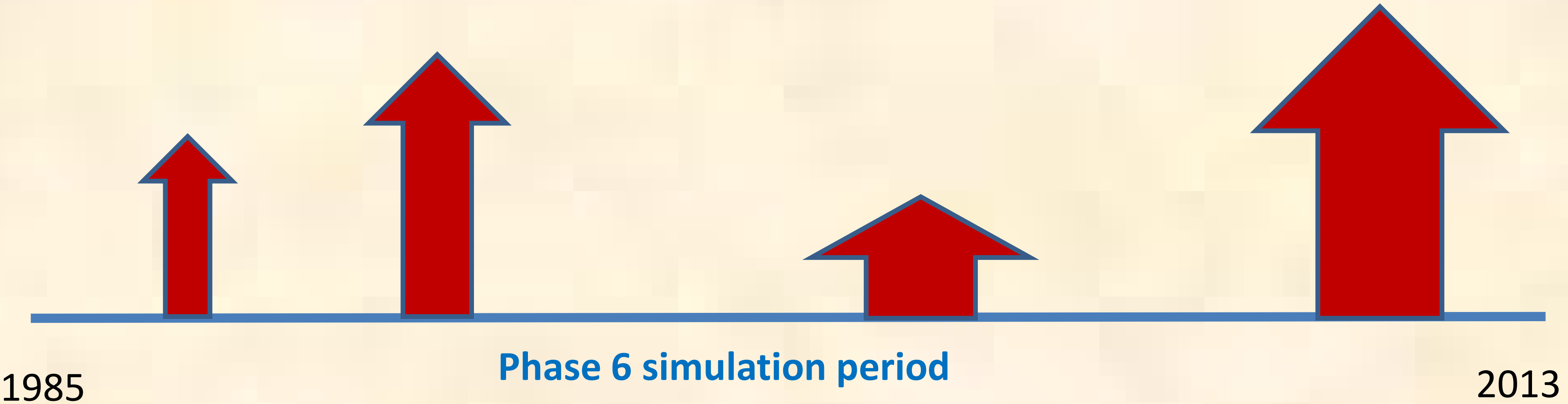




Source: Langland and Blomquist, USGS, personal communication

What has changed in the Phase 6 Model?

Decreasing settling rate for particulates over time consistent with observations.

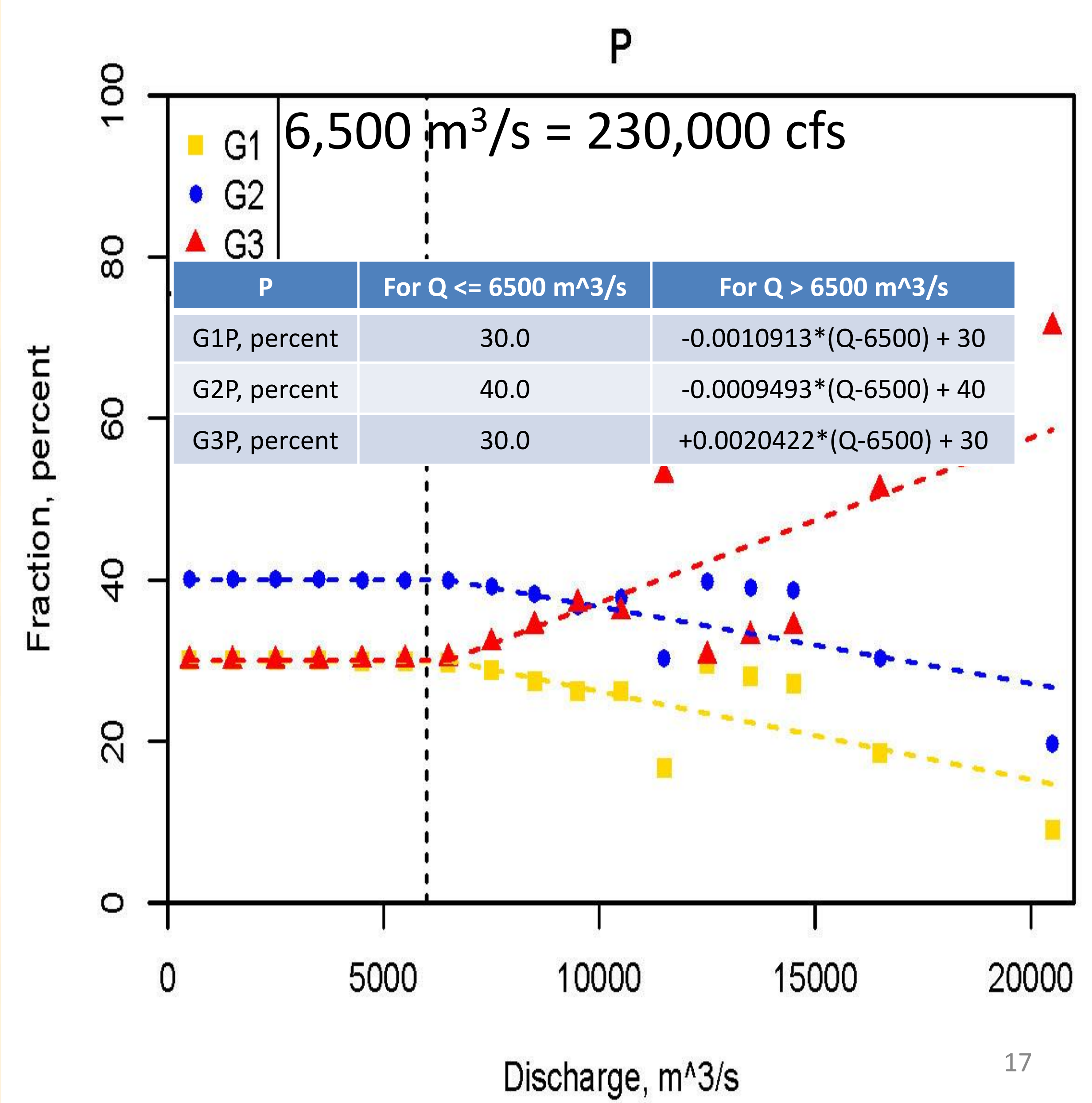


Increased erosion from the Conowingo sediment bed, consistent with observations, during high follow periods.

What's changing in the Water Quality Sediment Transport Model (WQSTM)?

G1, G2, and G3 Organic Phosphorus

Consistent with research and observations, proportionately more reactive particulate organic material is scoured from Conowingo and transported to tidal water under high flow events (when flow is greater than ~ 230,000 cfs).



P	For Q <= 6500 m^3/s	For Q > 6500 m^3/s
G1P, percent	30.0	-0.0010913*(Q-6500) + 30
G2P, percent	40.0	-0.0009493*(Q-6500) + 40
G3P, percent	30.0	+0.0020422*(Q-6500) + 30

Initial, Preliminary Conclusions on Conowingo Infill:

- The Phase 6 Models have the ability to represent salient aspects of dynamic equilibrium in the Conowingo Reservoir including decreasing deposition and increased scour over time, consistent with observations.

- The research and monitoring of Conowingo infill since 2010 has provided key support to model changes and provided new and useful information on changing deposition and settling rates with increased infill and on the dynamics of G1, G2, and G3 in terms of flow and scour, i.e., a higher G3 fraction but lower G1 and G2 fractions at high flows (> 230,000 cfs).

- The current best estimates of the increase in net transport of phosphorus loads to the Chesapeake due to Conowingo infill is about 2 million pounds which results in an estimated 1-3% increase in nonattainment of the Deep Channel DO water quality standard.

18

Estimating the influence of increased temperature, precipitation, tidal wetland loss, sea level rise, and other climate factors on tidal water quality.

Stationarity is Forever Assured

Under the 2010 decision rules stationarity is assured.
But precipitation, temperature, and sea level have all been observed to have increased over the last century.

The 1991-2000 ten year average hydrology set the state-basin target loads and the 1993-95 critical period was used to examine the assimilation capacity of the Bay for nutrient loads. The full 1985 -2013 full simulation period is used for sensitivity scenarios and to better understand changes over time in the Chesapeake watershed and Bay.

Phase 6 simulation period

1985 1991 2000 2013

10 Year Average Hydrology

1991 2000

1993-95 Critical Period

1993-95

Stationarity is (Properly) Dead

To reestablish realistic precipitation, temperature, and sea level estimates for 2025, yet still preserve the standing 10 year average hydrology and critical period, the estimated delta, or difference, in the observed changes for 30 years, i.e., between 1995 and 2025 is applied to the precipitation, temperature, and sea level data time series.

Phase 6 simulation period

1985 1991 2000 2013

10 Year Average Hydrology

1991 2000

1993-95 Critical Period

What's changed in the 2017 CBP Models

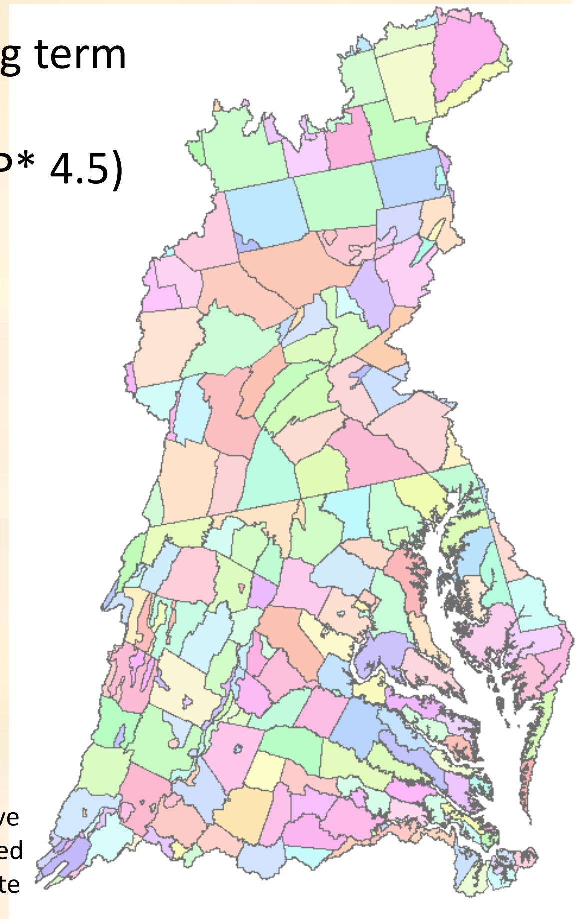
- The ability to separately or combined, examine the influence of estimated 2025 conditions have on Bay hypoxia:
  - Changes in precipitation volume
  - Increased precipitation intensity
  - Changes in watershed flows (Q)
  - Increased temperature (T)
  - Changes in evapotranspiration
  - Increased watershed loads
  - Changes in sea level (SL)
  - Tidal wetland attenuation of nutrients and sediment
- This is a work in progress using the Beta 3 Watershed Model and the Beta 4 WQSTM to provide the best estimate available today of 2025 conditions compared to the 1995 TMDL conditions. We need to run the analysis on the final Watershed and WQSTM models.

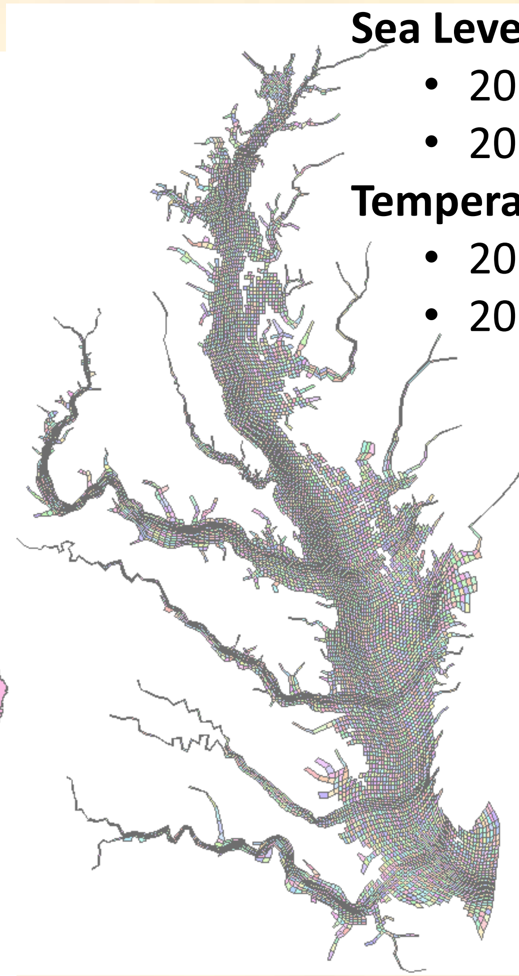
Model Climate Inputs Were Developed with STAC Workshop and Climate Resiliency Workgroup Guidance

Precipitation Volume
- 2025: +3.1% (long term trends)
- 2050: +6.2% (RCP* 4.5)

Temperature: RCP 4.5
- 2025: +1.1 ^{o}C
- 2050: +1.94 ^{o}C

CO_2 Concentration:
Meinhausen et al., 2011
- 2025: 427 ppm
- 2050: 487 ppm





Sea Level Rise: CRWG**
- 2025: +0.3 m
- 2050: +0.5 m

Temperature: RCP 4.5
- 2025: +0.95 ^{o}C
- 2050: +1.86 ^{o}C

*RCP 4.5 signifies a specific Representative Concentration Pathway scenario as defined by the Intergovernmental Panel on Climate Change

**Based upon guidance provided by the Climate Resiliency Workgroup

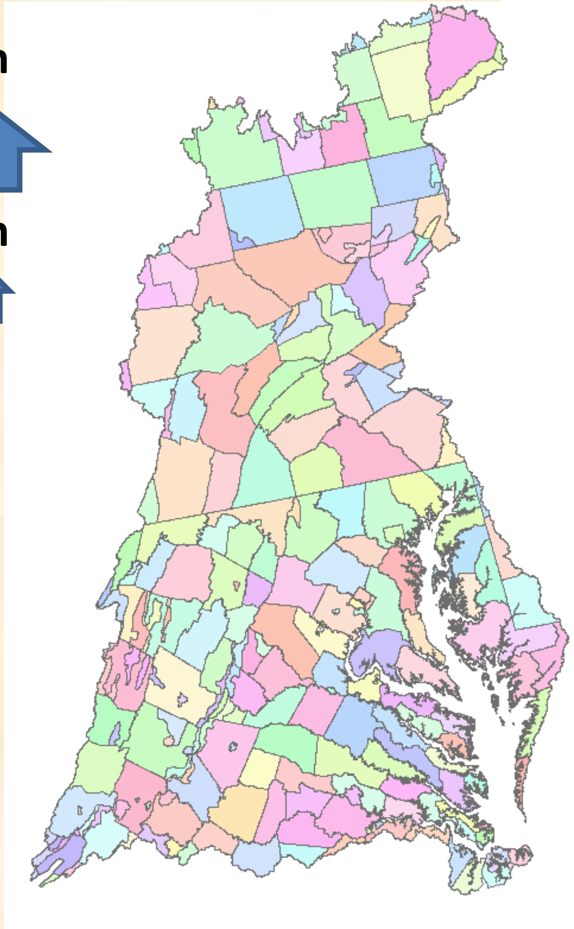
Keeping Score With Tidal Bay Hypoxia

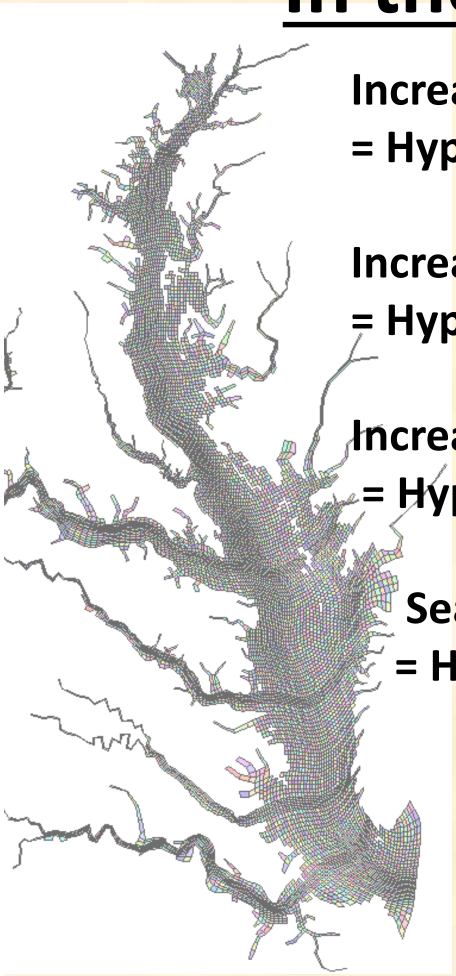
In the Watershed

Increased Precipitation Volume = Hypoxia ↑

Increased Precipitation Intensity = Hypoxia ↑

Increase in Temp and Evapotranspiration = Hypoxia ↓





In the Estuary

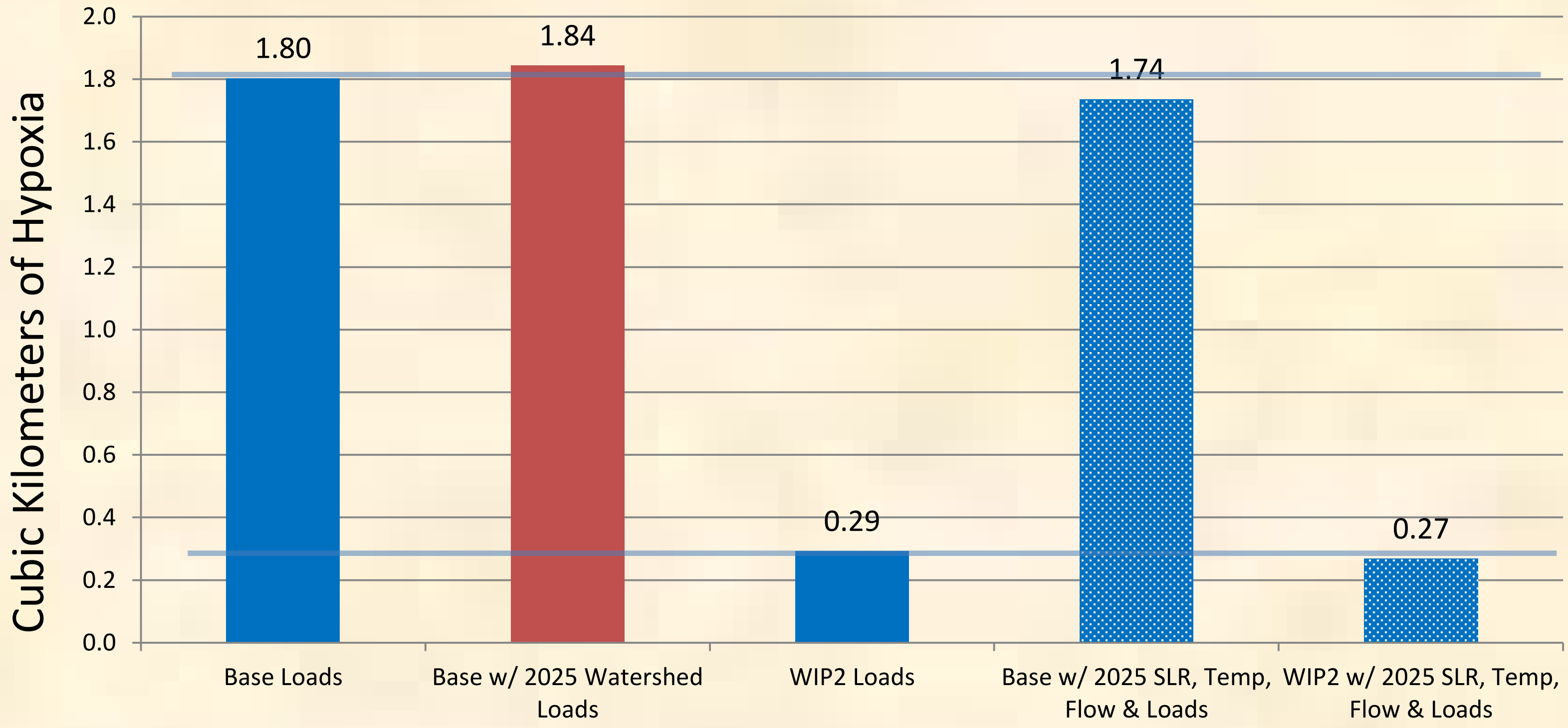
Increased WS Loads = Hypoxia ↑

Increased WS Flows = Hypoxia ↓

Increased Temperature = Hypoxia ↑

Sea Level Rise = Hypoxia ↓

Why does hypoxia decrease under estimated under 2025 temperature, precipitation, and sea level despite higher estimated watershed loads?

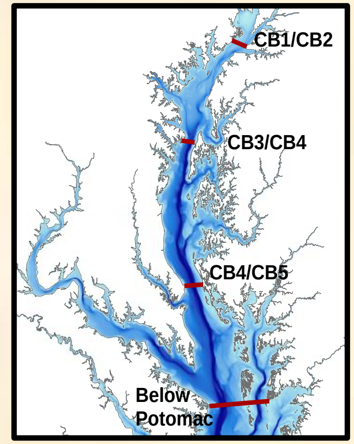


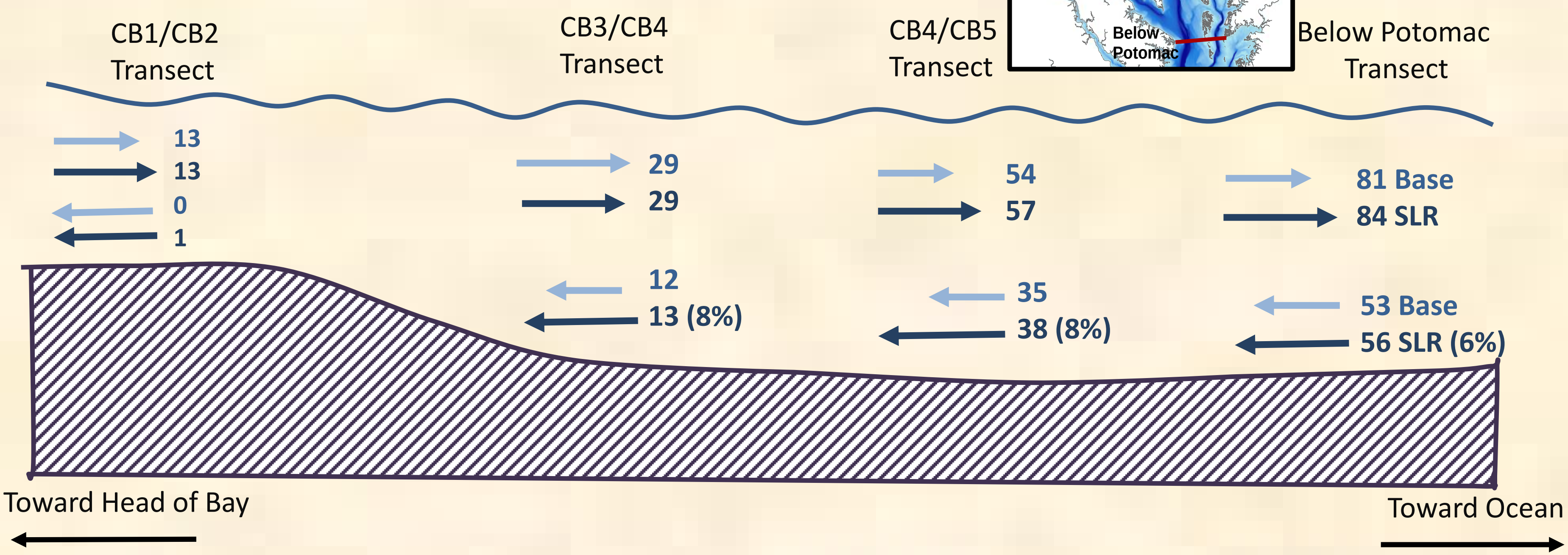
DO <1 mg/l annual average daily hypoxia from 1991 to 2000 over the summer hypoxic season of May through September.

solid blue = key scenario, solid red = sensitivity scenario, stippled blue = 2025 climate scenario

Cross-transect DO fluxes (kg/s): Base Case versus Sea Level Rise (SLR) Scenario

To put into context, 3.2 kg/sec of O_2 delivered to bottom waters at the edge of the deep water channel (Below Potomac Transect) is equivalent to delivering the volume of air in a box larger than 1 kilometer long, 1 kilometer wide, and 1 kilometer tall each day.





Base = Beta 4 Calibration. SLR = 0.3m Sea Level Rise Scenario representing relative Chesapeake sea level rise from 1995 to 2025. Units in mean kg DO per second (m^3/s) for 1991 to 2000 hydrodynamics.

Conclusions

- This is a work in progress using the Beta 3 Watershed Model and the Beta 4 WQSTM to provide the best estimate available today. Need to run the analysis on the final Watershed and WQSTM models.
- The CBP Modeling Workgroup is factoring into the Chesapeake Bay assessment tools the latest research on climate change with guidance from the STAC and the Climate Resiliency Workgroup.
- Influence of 2025 sea level rise is estimated to be a small but positive influence on Chesapeake hypoxia.

Conclusions *(continued)*

- Estimated 2025 temperature increases has a negative influence on Chesapeake hypoxia.

- Future work is oriented toward developing a range of climate change estimates to reflect different assumptions of rainfall intensity for 2025 estimates and different future estimated greenhouse gas concentrations (Representative Concentration Pathways (RCPs)) for 2050.