Chesapeake Bay Program Phase 6 Climate Change Model Initial Findings

Urban Stormwater Workgroup – January 2020

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Presentation Outline

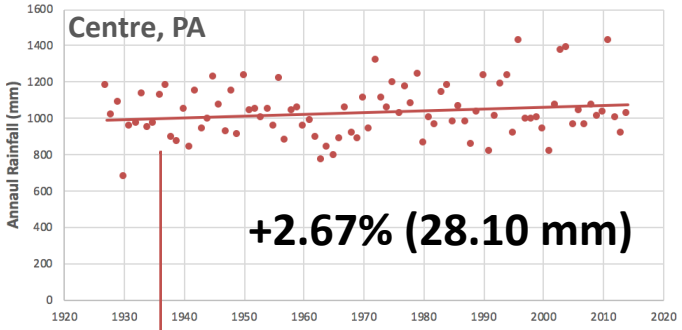
- Brief Overview
- Summary of Inputs and Methods
- Climate Assessment Results – Initial Findings
- Understanding and Explaining Model Results

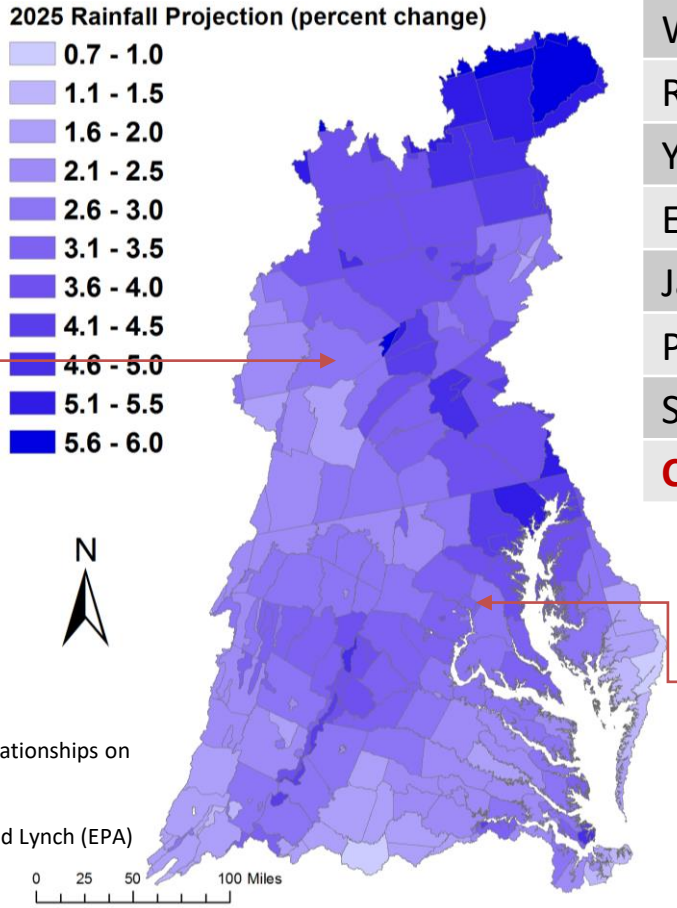
CBP – Climate Assessment

- **The direction of CBP decision makers, the guidance of STAC and workshop recommendations, CBP Modeling Workgroup and Climate Resiliency Workgroup decisions, and stakeholder collaboration were collectively applied in the CBP Climate Assessment [1][2][3][4].**

[1] http://www.chesapeake.org/pubs/360_Johnson2016.pdf
[2] http://www.chesapeake.org/pubs/386_Herrmann2018.pdf
[3] https://www.chesapeakebay.net/channel_files/32232/gopal_bhatt_-_champ_-_application_of_phase_6_watershed_model_for_climate_change_assessment.pdf
[4] https://www.chesapeake.org/stac/events/chesapeake-bay-program-climate-change-modeling-2-0/

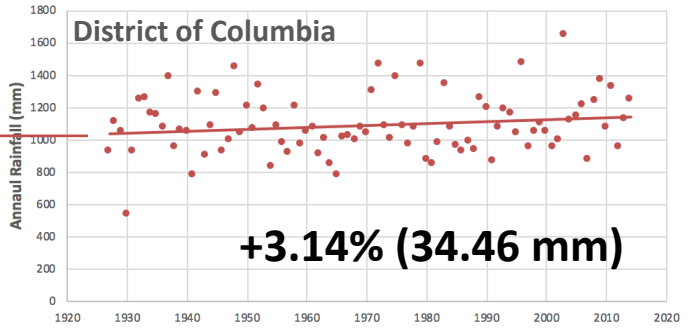
Long term rainfall volume trends





Estimated 30-year change between 2025 and 1995 using 88-year annual PRISM[1] rainfall data

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%**

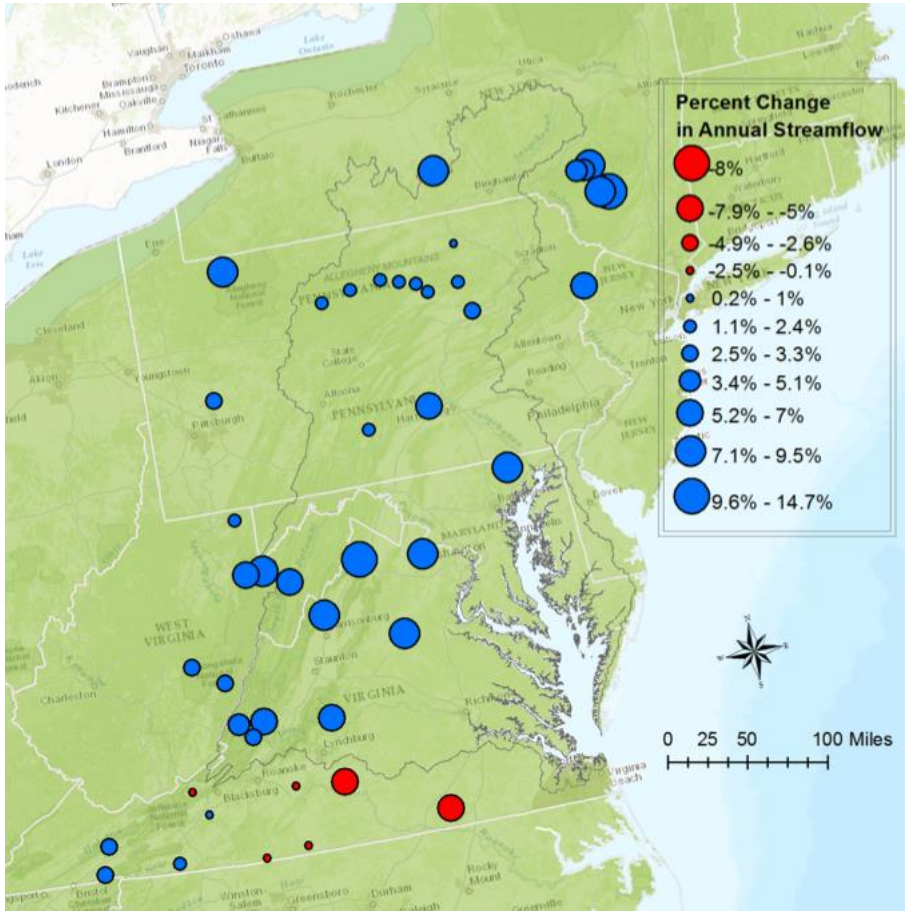


[1] Parameter-elevation Relationships on Independent Slopes Model

Data Source: Rice (USGS) and Lynch (EPA)

Changing Watershed – climate and land use

Annual streamflow has increased between 1 to 17% since 1940



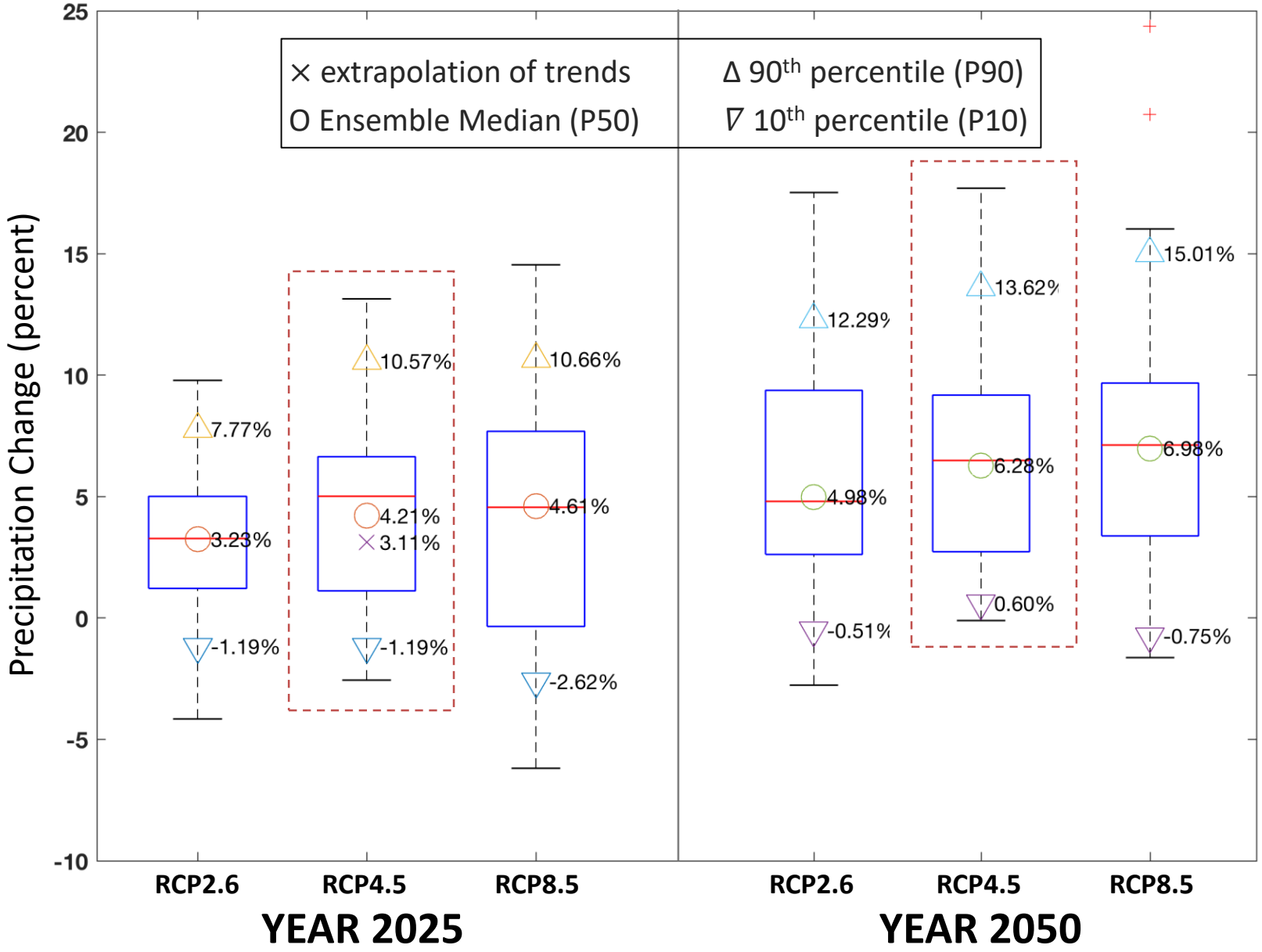
The map shows percent changes in the 30-year annual average streamflow for rivers and streams (HCDN,USGS GAGES-II, 1940-2014). U.S. Environmental Protection Agency. 2016. Climate change indicators in the United States, 2016. Fourth edition. EPA 430-R-16-004 [2]

USGS station ID	Precipitation		Discharge	
	Slope	p-value	Slope	p-value
04252500	0.0007	**0.0011**	0.0021	**<0.0001**
01512500	0.0008	**0.0007**	0.0016	**0.0028**
01503000	0.0007	**0.0022**	0.0013	**0.0181**
01531000	0.0006	**0.0219**	0.0018	**0.0030**
01531500	0.0007	**0.0044**	0.0016	**0.0029**
01532000	0.0006	**0.0374**	0.0015	**0.0330**
01534000	0.0005	**0.0497**	0.0015	**0.0120**
01550000	0.0005	**0.0493**	0.0019	**0.0015**
01543000	0.0004	0.1000	0.0018	**0.0058**
01545500	0.0004	0.0953	0.0017	**0.0026**
01536500	0.0006	**0.0078**	0.0016	**0.0027**
01551500	0.0005	0.0612	0.0017	**0.0017**
01439500	0.0005	0.0972	0.0007	0.1661
01541500	0.0003	0.2357	0.0017	**0.0017**
01540500	0.0006	**0.0111**	0.0016	**0.0023**
01541000	0.0004	0.0985	0.0016	**0.0021**
01567000	0.0004	0.1577	0.0011	**0.0250**
01570500	0.0005	**0.0260**	0.0013	**0.0088**
North-South Split				
01562000	0.0004	0.1693	0.0007	0.2082
01638500	0.0004	0.1150	0.0008	0.1026
01608500	0.0004	0.1725	0.0010	0.0833
01636500	0.0005	0.1245	0.0008	0.0624
01606500	0.0003	0.1958	0.0009	0.1108
01668000	0.0006	0.0794	0.0004	0.4727
02035000	0.0003	0.2653	−0.0001	0.8243
02019500	0.0002	0.4333	0.0003	0.4836
03488000	0.0003	0.2480	0.0006	0.2841

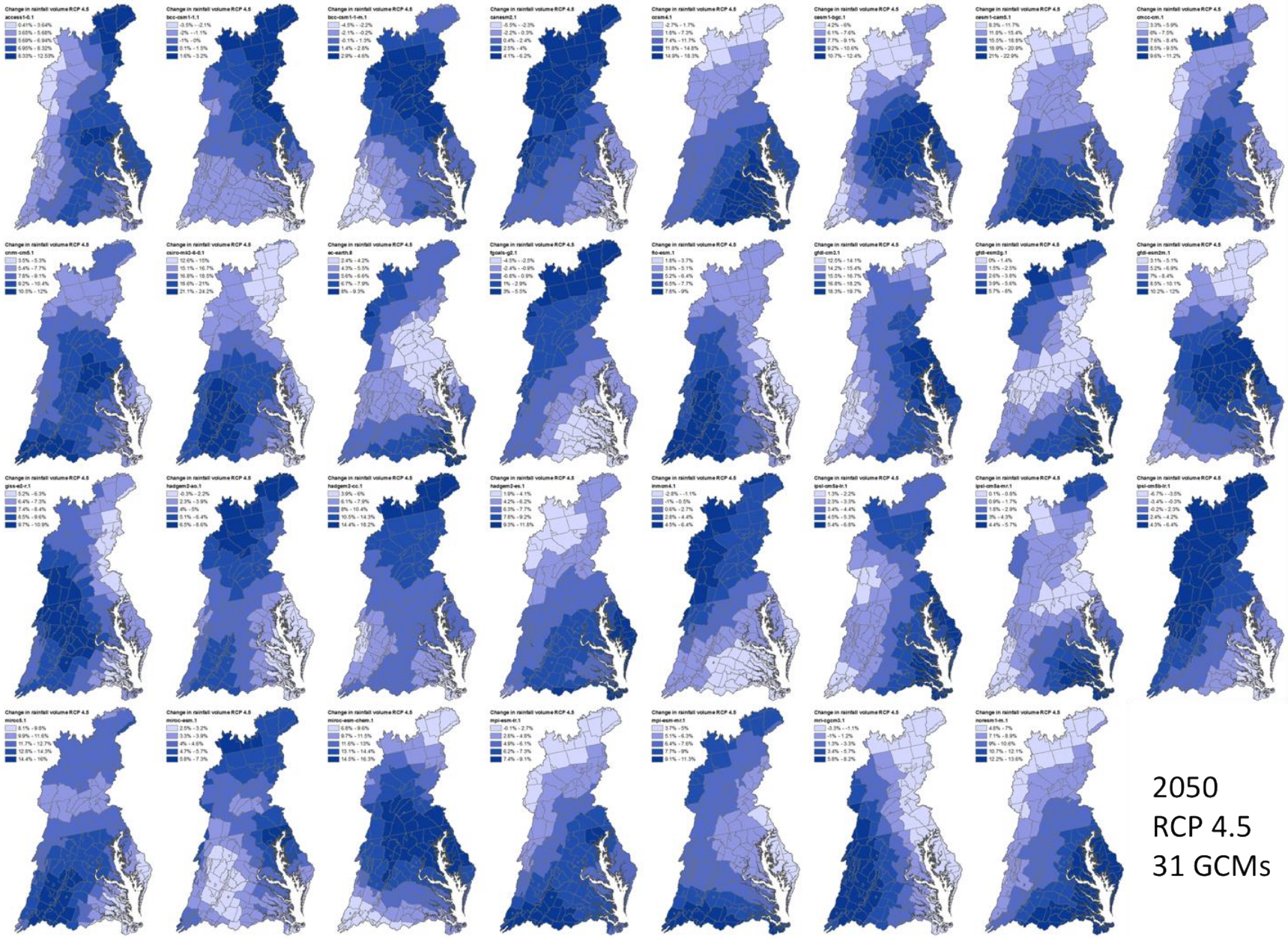
Karen C. Rice, Douglas L. Moyer, and Aaron L. Mills, 2017. Riverine discharges to Chesapeake Bay: Analysis of long-term (1927 - 2014) records and implications for future flows in the Chesapeake Bay basin *JEM* 204 (2017) 246-254

[1] Lins, H.F. 2012. USGS Hydro-Climatic Data Network 2009 (HCDN-2009). U.S. Geological Survey Fact Sheet 2012-3047. https://pubs.usgs.gov/fs/2012/3047.
[2] U.S. EPA. 2016. Climate change indicators in the United States. www.epa.gov/climate-indicators; https://www.epa.gov/sites/production/files/2016-08/documents/climate_indicators_2016.pdf

Summary of precipitation change

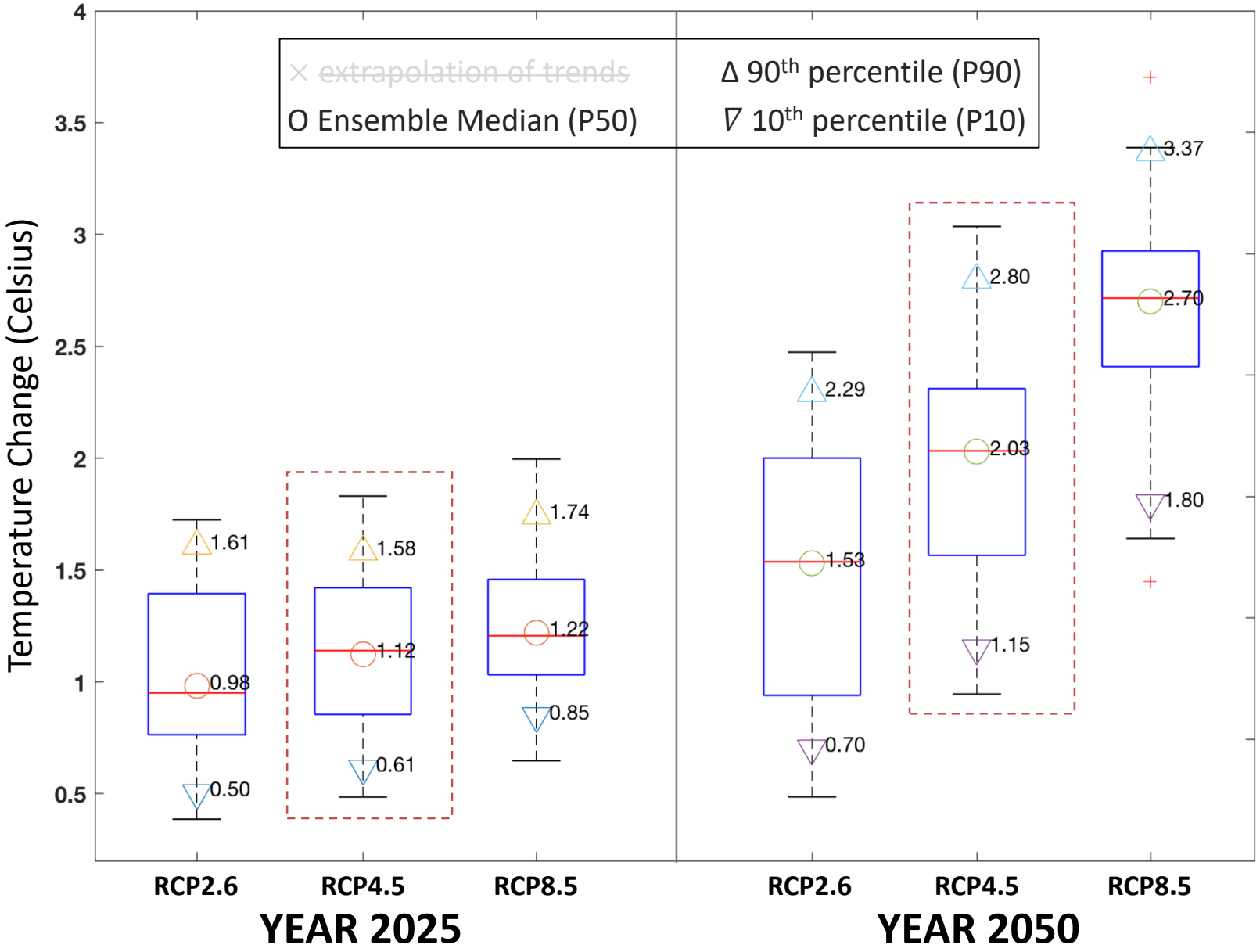


Ensemble of Downscaled Global Climate Models

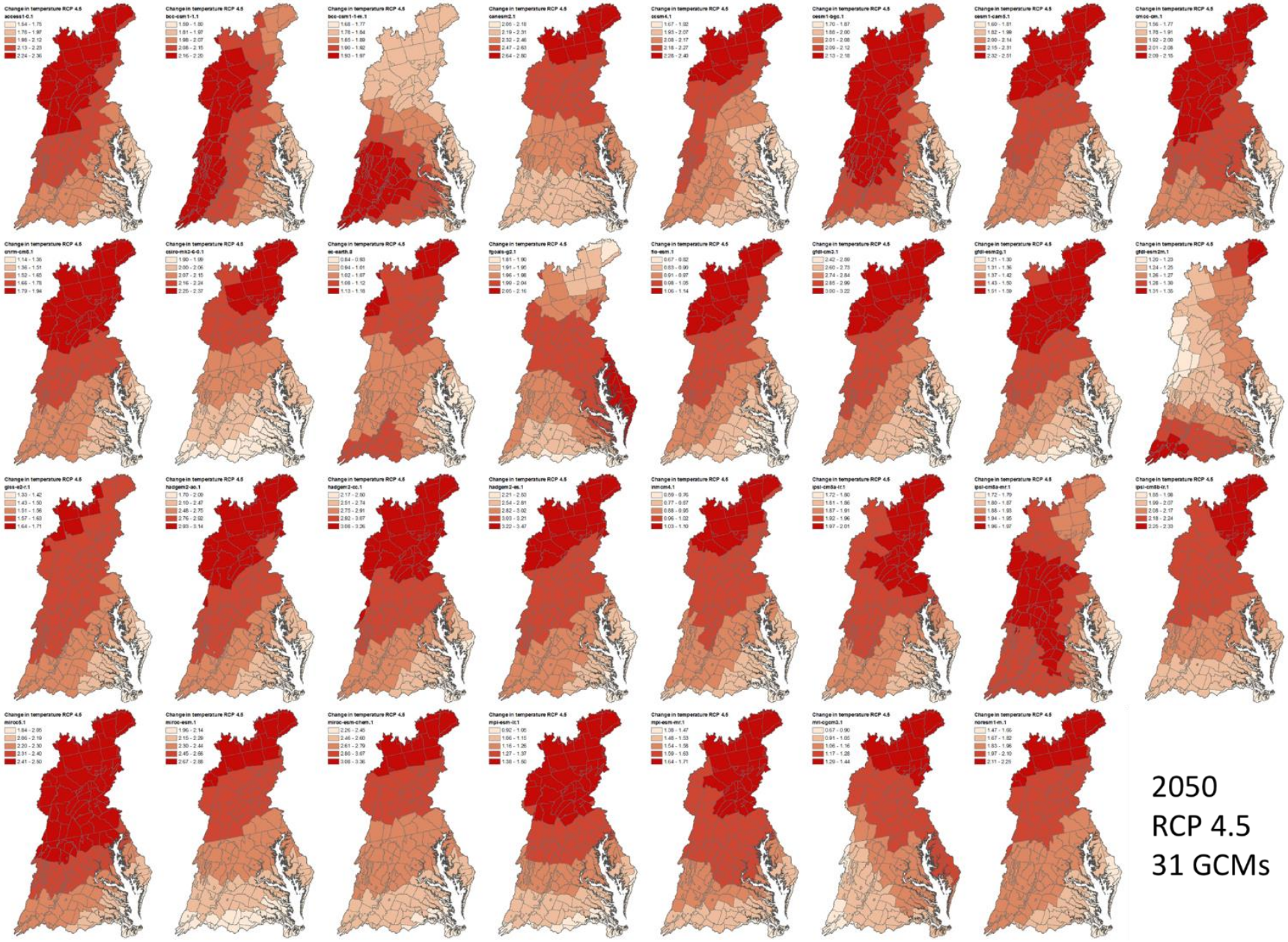


2050
RCP 4.5
31 GCMs

Summary of temperature change

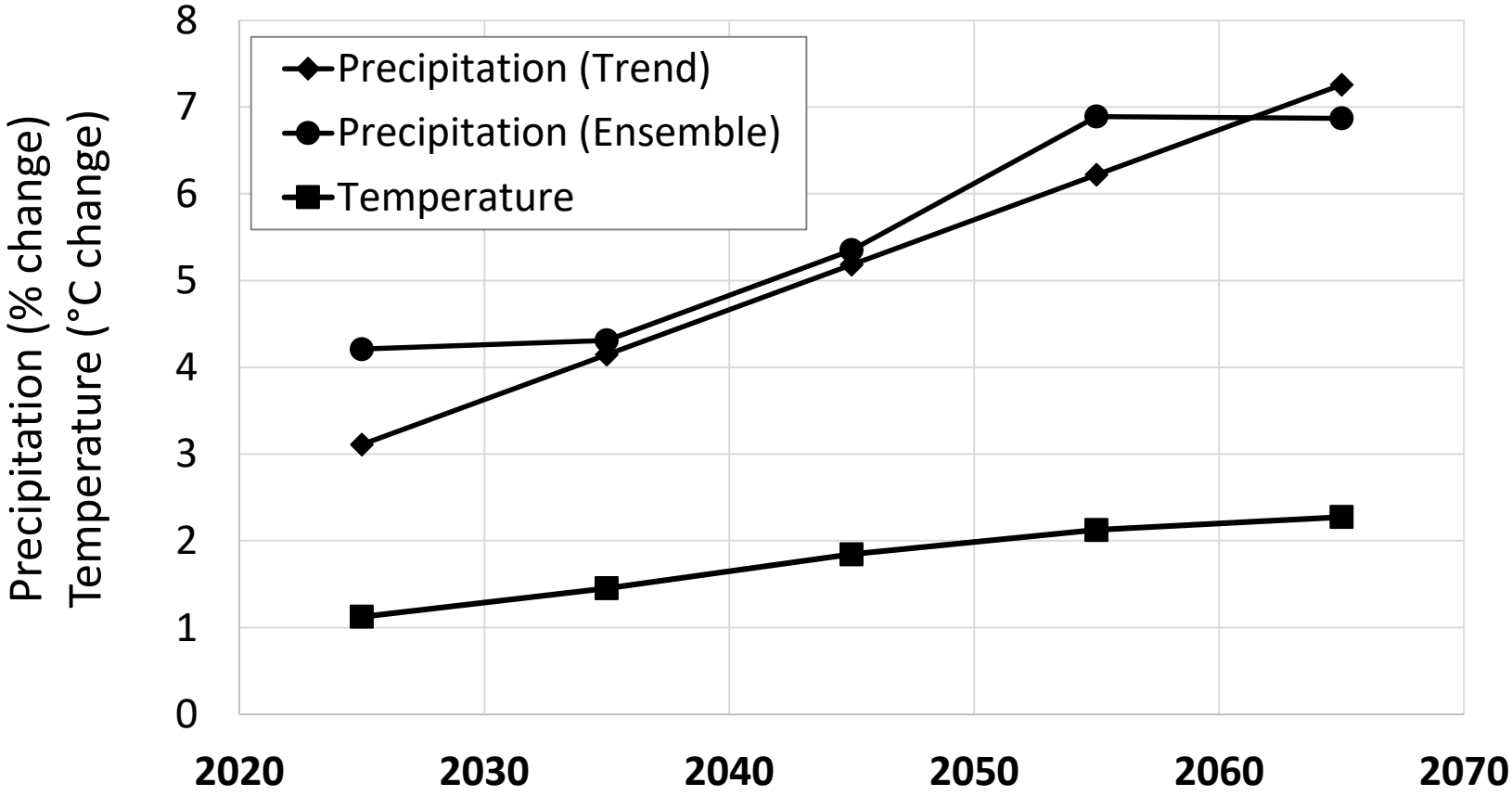


Ensemble of Downscaled Global Climate Models



Climate delta change from 1995

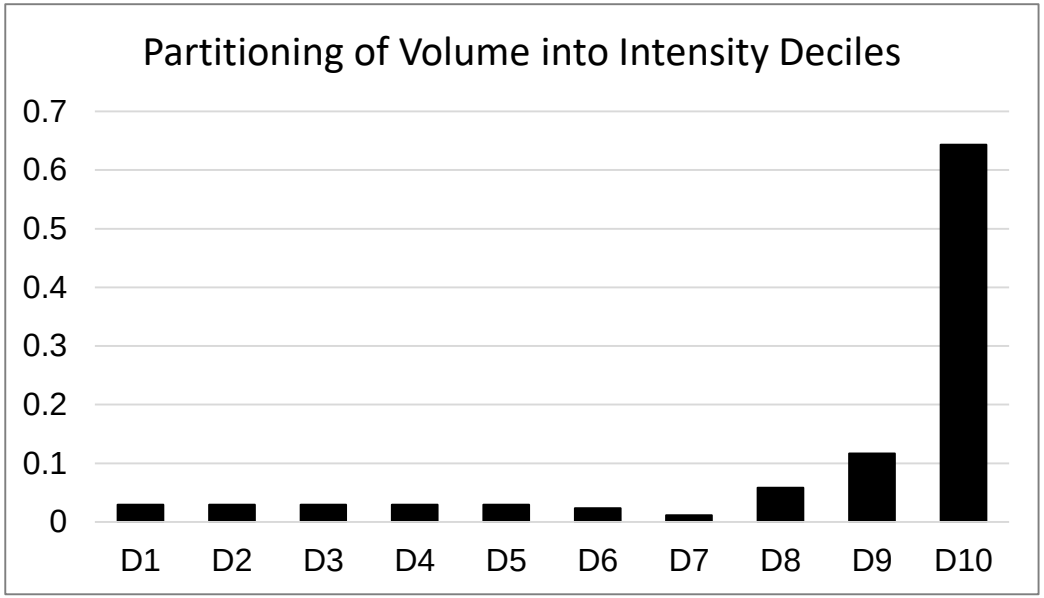
Spatially aggregated over the Chesapeake Bay Watershed



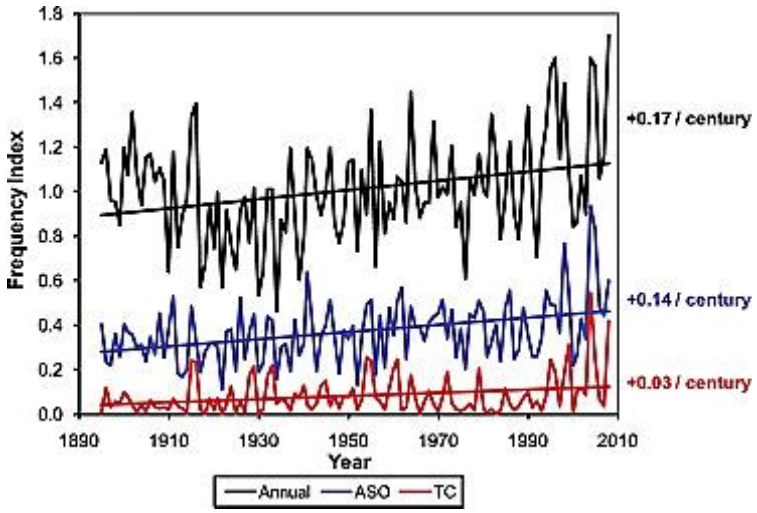
***Trend**: extrapolation of long-term (88-year) linear trends*
***Ensemble**: 31-member ensemble of RCP4.5 GCMs (BCSD)*

Climate delta change from 1995

More volume into higher intensity events

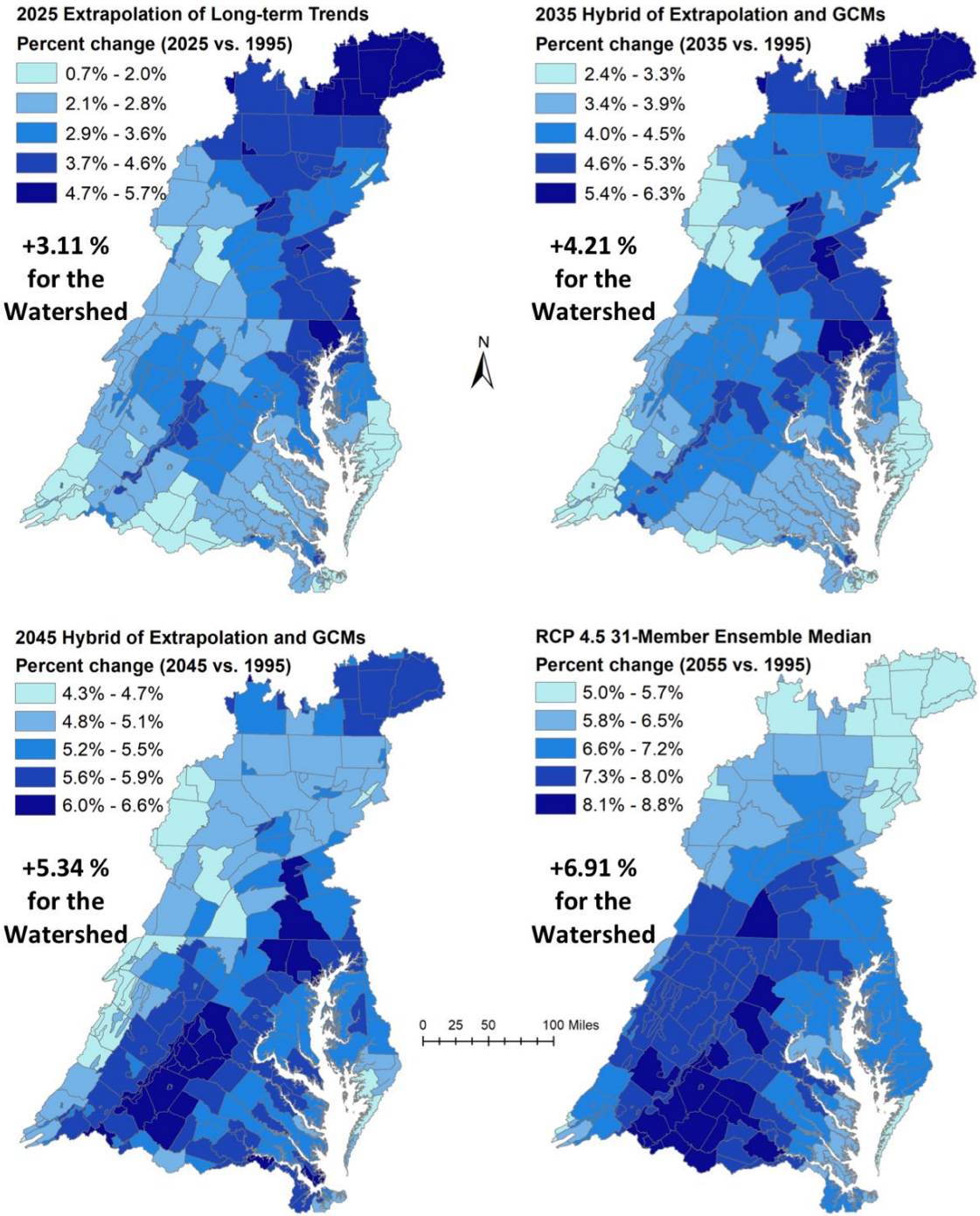


Reproduced from Groisman et al., 2004

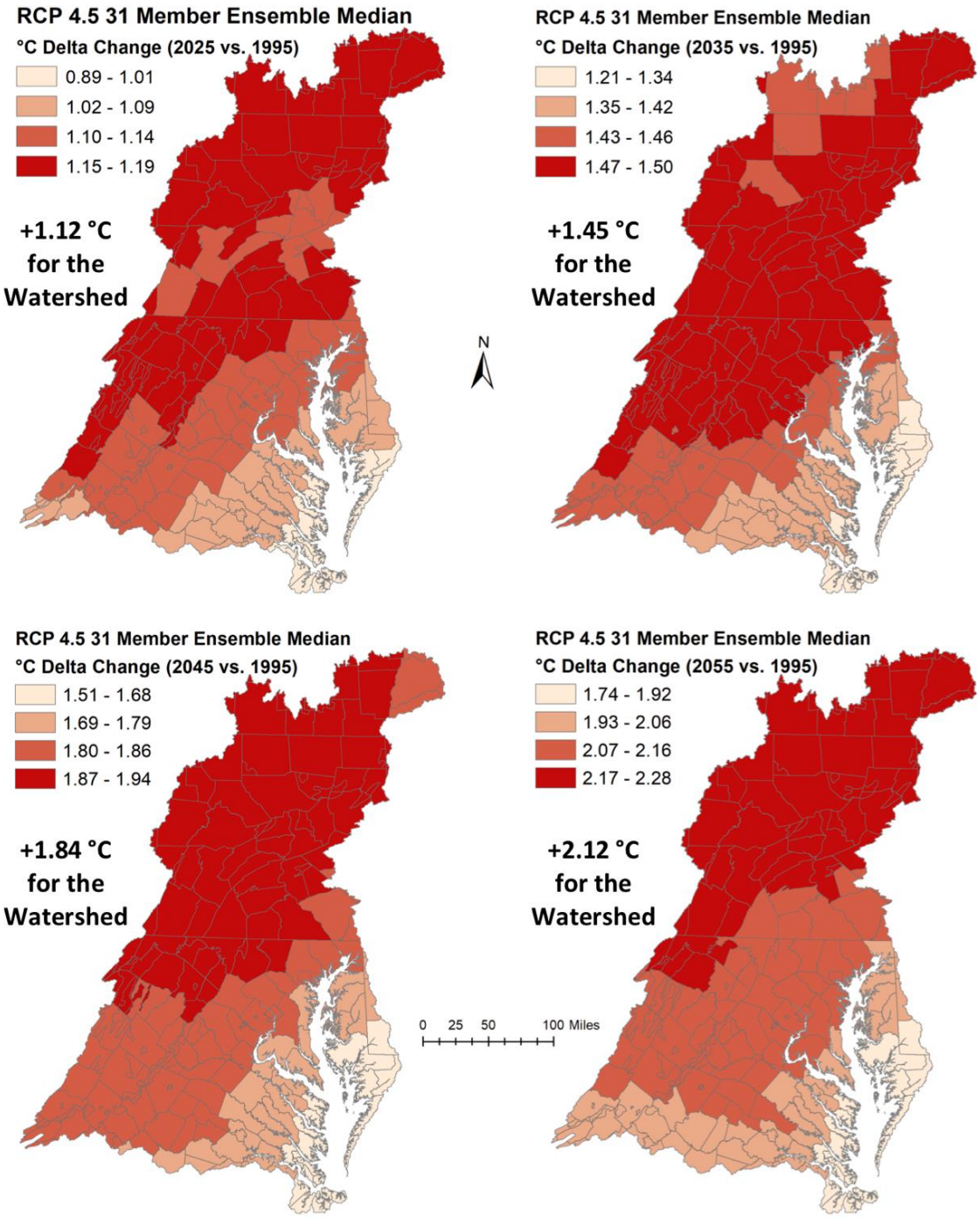


National average heavy precipitation event index (HPEI) for the entire year (annual, black), for August through October (ASO, blue), and for heavy events associated with tropical cyclones (TC, red). [Kunkel et al., 2010]

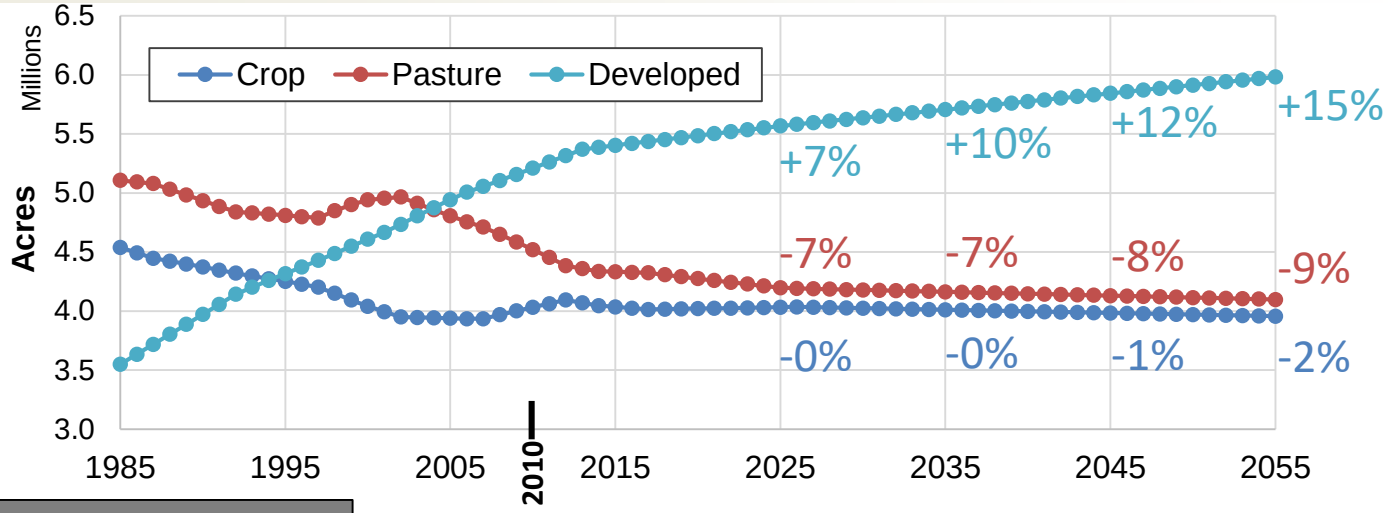
Rainfall


2025 Extrapolation of Long-term Trends
Percent change (2025 vs. 1995)
0.7% - 2.0%
2.1% - 2.8%
2.9% - 3.6%
3.7% - 4.6%
4.7% - 5.7%
+3.11 % for the Watershed
2035 Hybrid of Extrapolation and GCMs
Percent change (2035 vs. 1995)
2.4% - 3.3%
3.4% - 3.9%
4.0% - 4.5%
4.6% - 5.3%
5.4% - 6.3%
+4.21 % for the Watershed
N
2045 Hybrid of Extrapolation and GCMs
Percent change (2045 vs. 1995)
4.3% - 4.7%
4.8% - 5.1%
5.2% - 5.5%
5.6% - 5.9%
6.0% - 6.6%
+5.34 % for the Watershed
RCP 4.5 31-Member Ensemble Median
Percent change (2055 vs. 1995)
5.0% - 5.7%
5.8% - 6.5%
6.6% - 7.2%
7.3% - 8.0%
8.1% - 8.8%
+6.91 % for the Watershed
0 25 50 100 Miles

Temperature

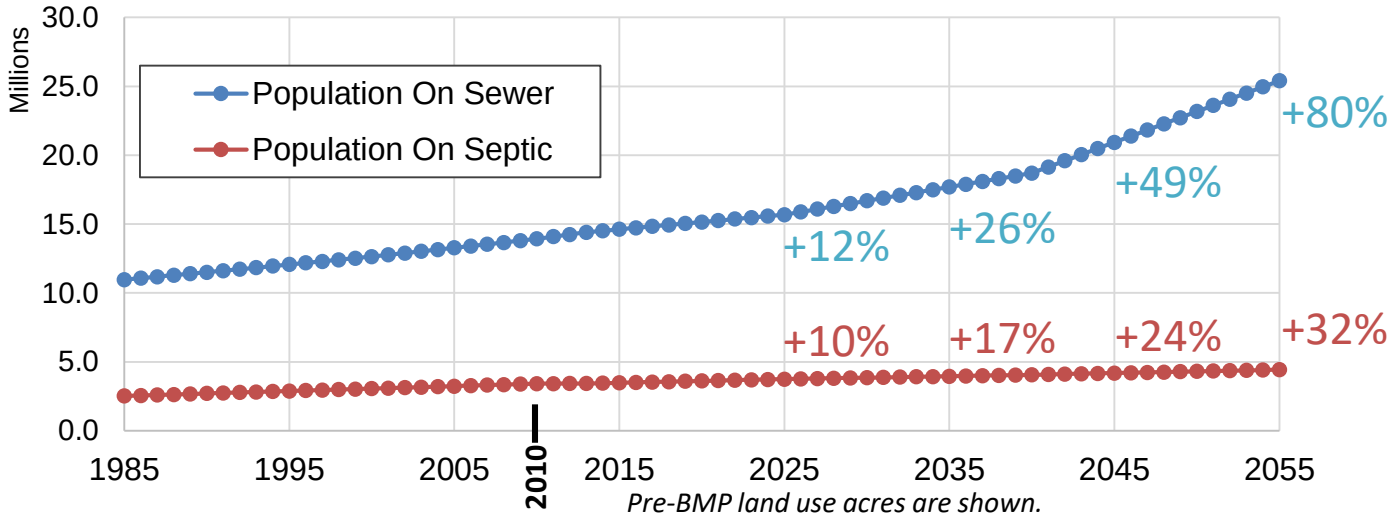


Land use acres - Chesapeake Bay Watershed



Chesapeake Bay Land Change Model
(CBLCM Version 4 – *Claggett, P., et al.*)

Population - Chesapeake Bay Watershed



Pre-BMP land use acres are shown.
Percent changes are shown with respect to 2010 (with WIP2 level of effort)

[1] https://www.chesapeakebay.net/channel_files/35723/20190402_-_bhatt_-_mwqm_-_2019_climate_change_assessment.pdf

Uncertainties and Limitations

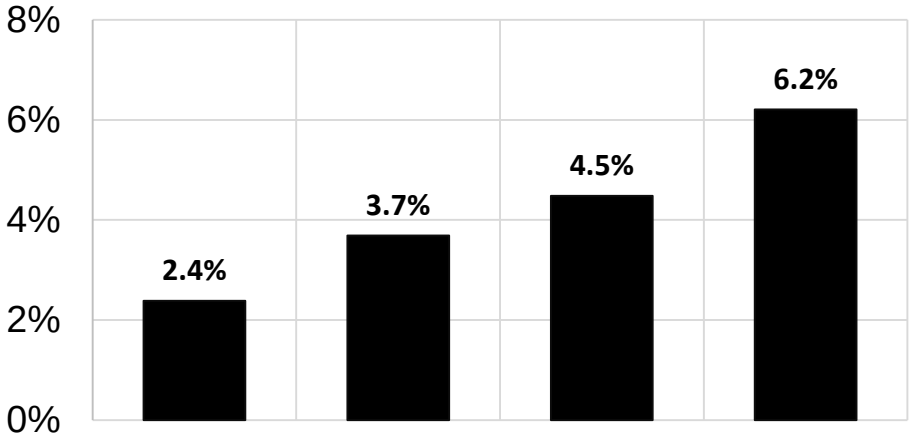
- Sources of uncertainty – e.g., climate projections, delta method, rainfall intensity, PET methods, estimation of water quality responses
- Lack of data on BMP performance or effectiveness under future climate
- Socioeconomic changes due to future climate were not included

CBP – Climate Assessment Results (Initial Findings)

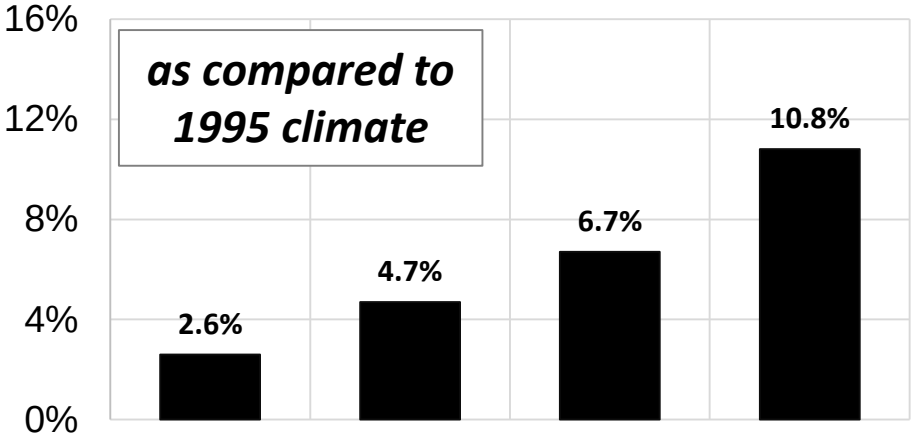
- **Watershed model simulations were made for –**
  - **(1) Estimating marginal differences in delivery with future climate as compared to that of 1995 climate**
    - **While holding management practices at Phase 3 Planning Target level of effort and 2025 land use**
  - **(2) Estimating the marginal impact of future land use since 2025.**

Estimated Water Quality Responses

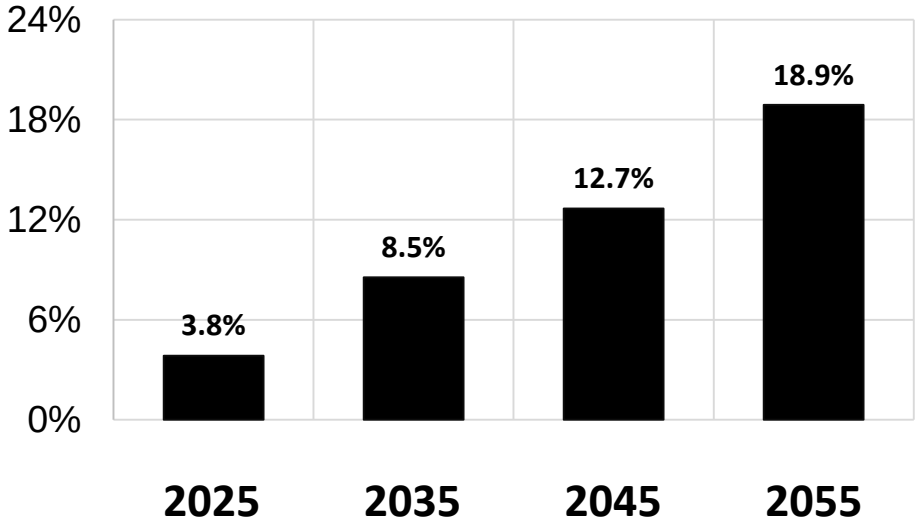
Marginal Differences in **Freshwater** Delivery



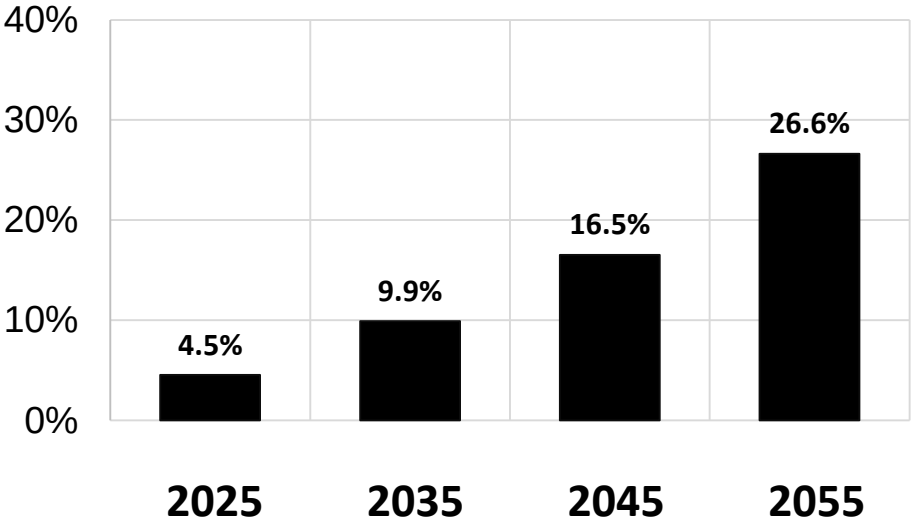
Marginal Differences in **Nitrogen** Delivery



Marginal Differences in **Sediment** Delivery

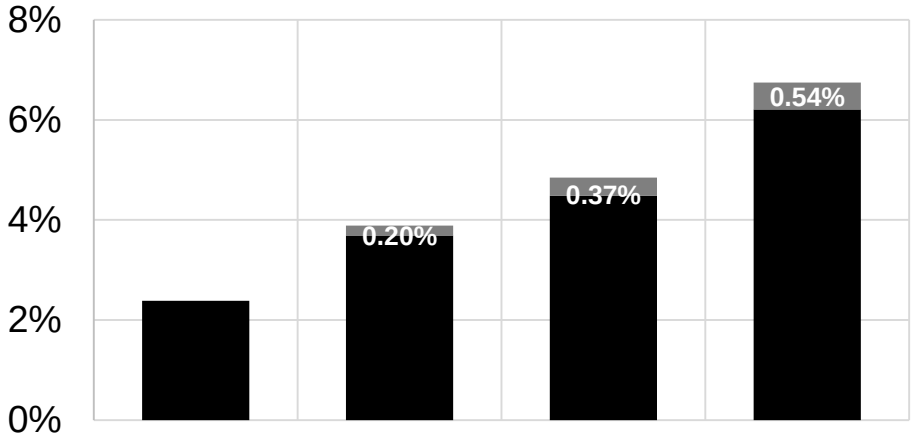


Marginal Differences in **Phosphorus** Delivery

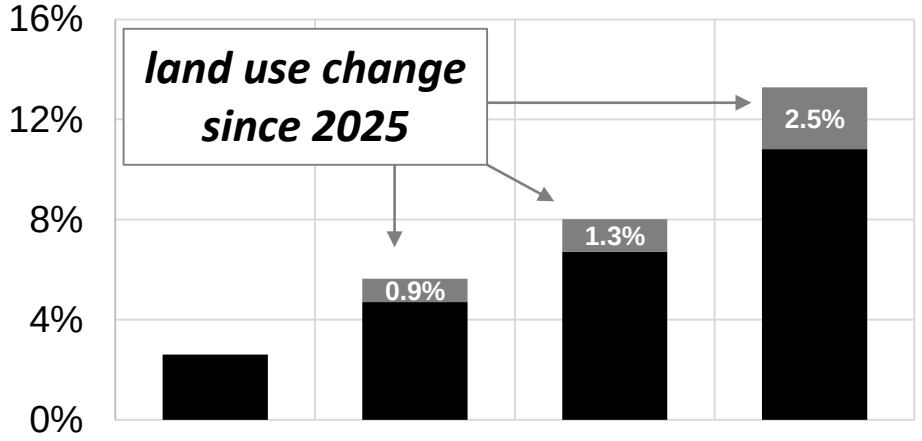


Estimated Water Quality Responses

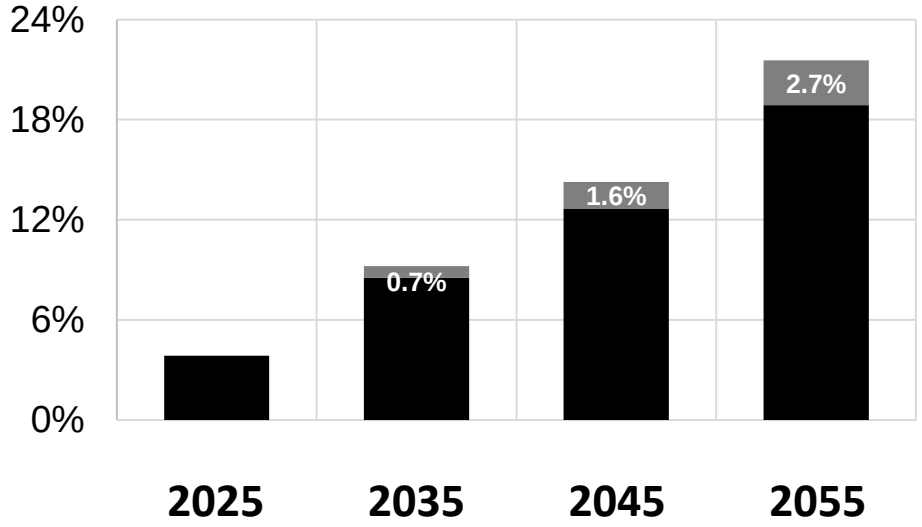
Marginal Differences in **Freshwater** Delivery



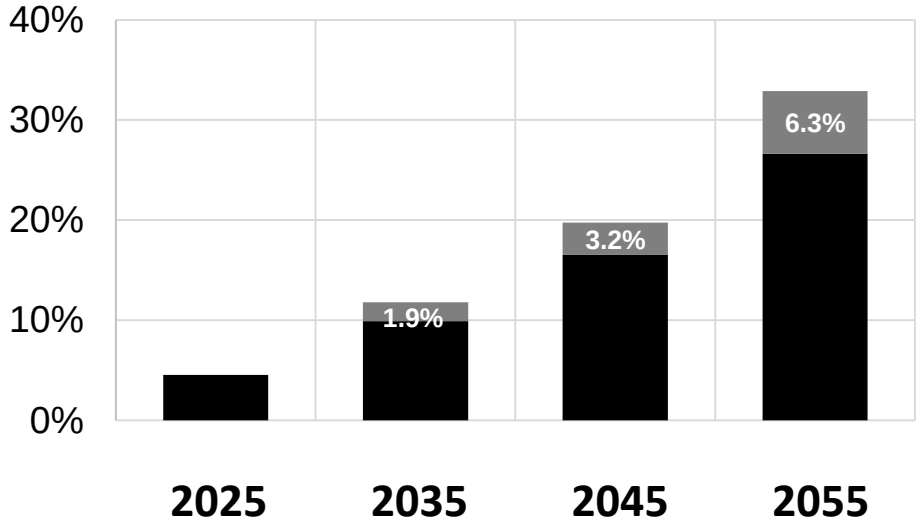
Marginal Differences in **Nitrogen** Delivery



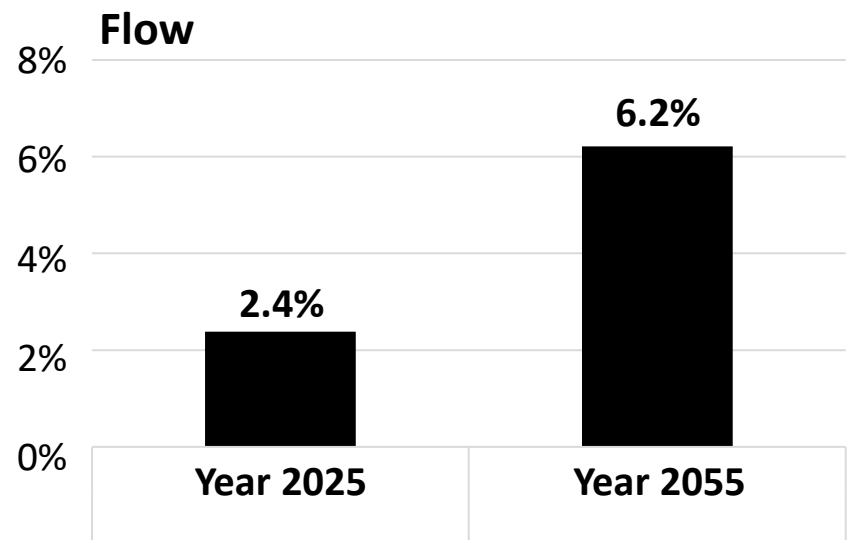
Marginal Differences in **Sediment** Delivery

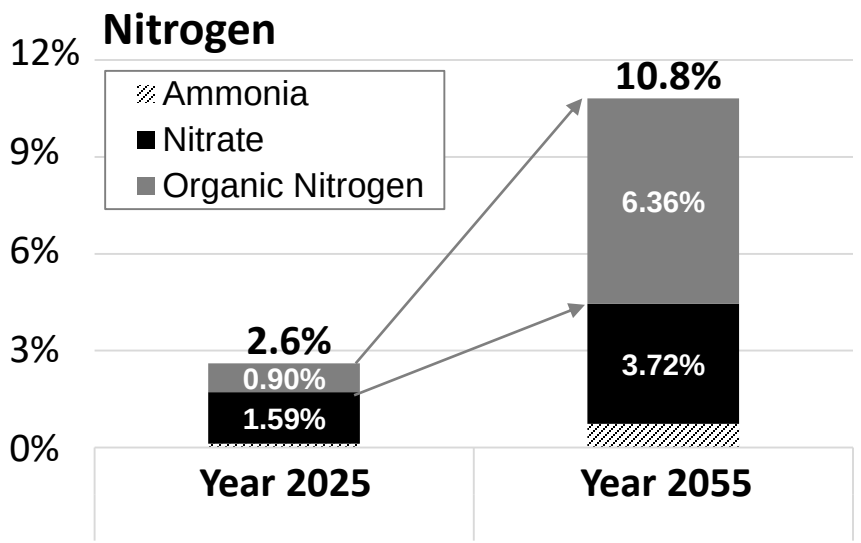


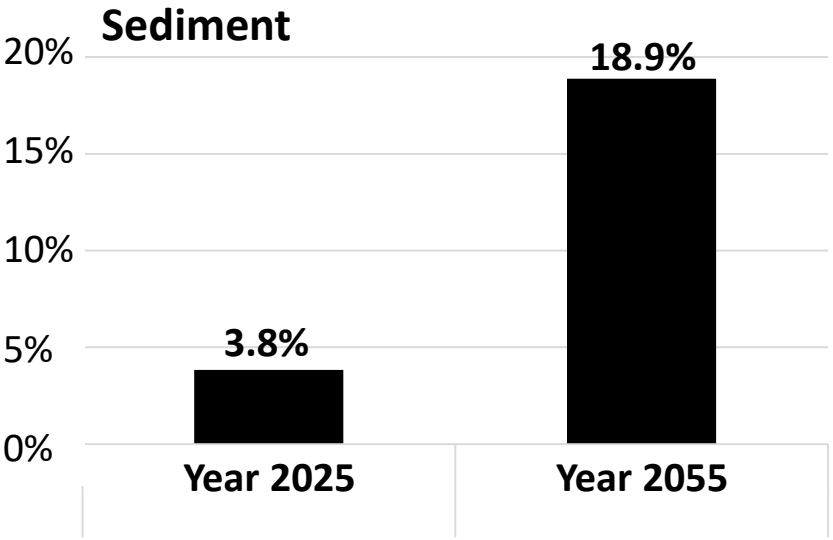
Marginal Differences in **Phosphorus** Delivery

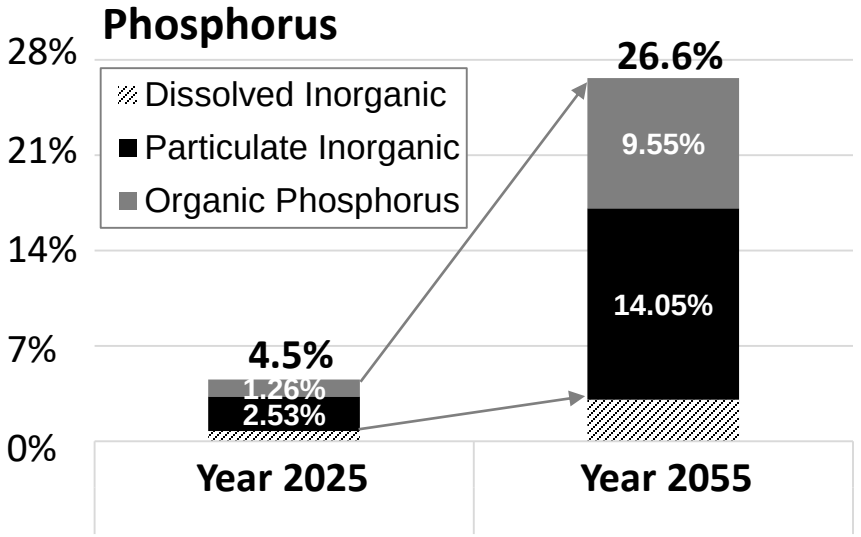


Nutrient Speciation – 2025 and 2055

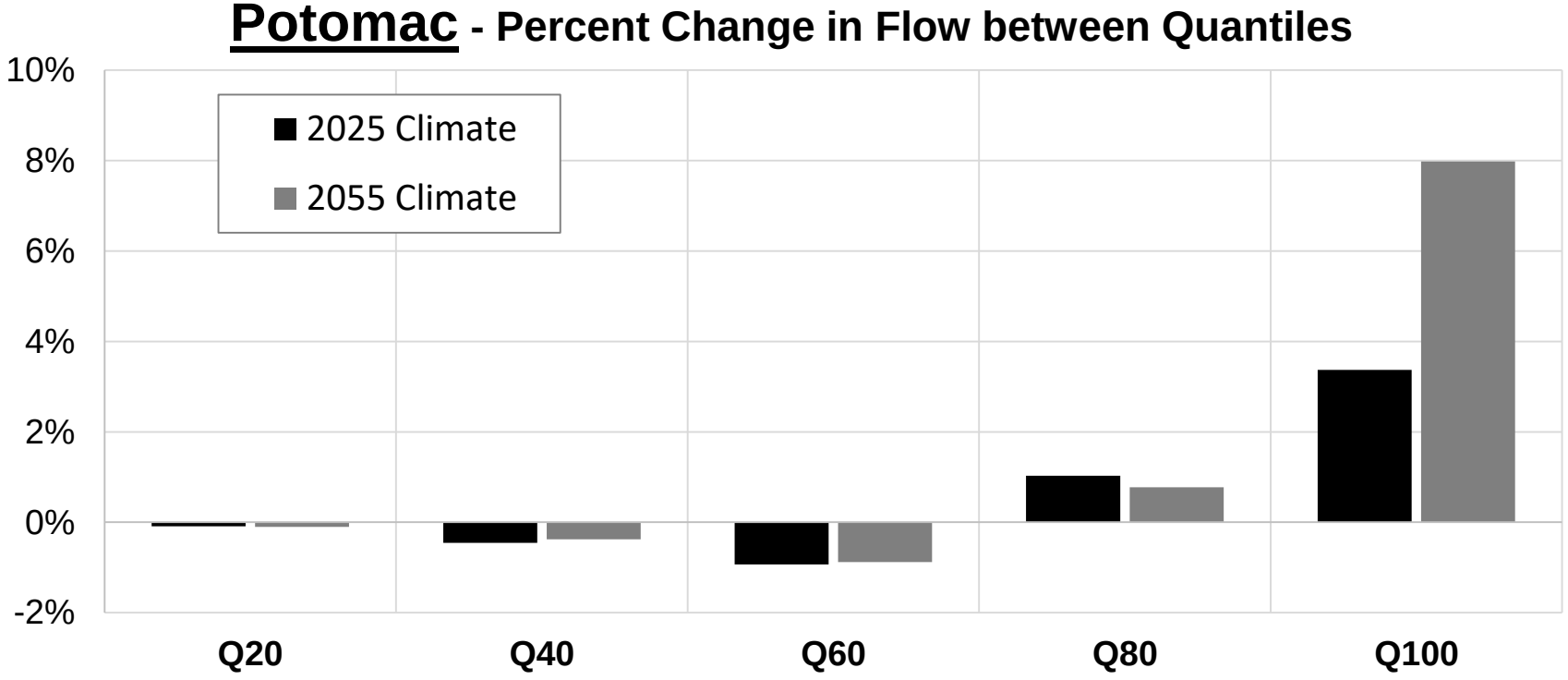






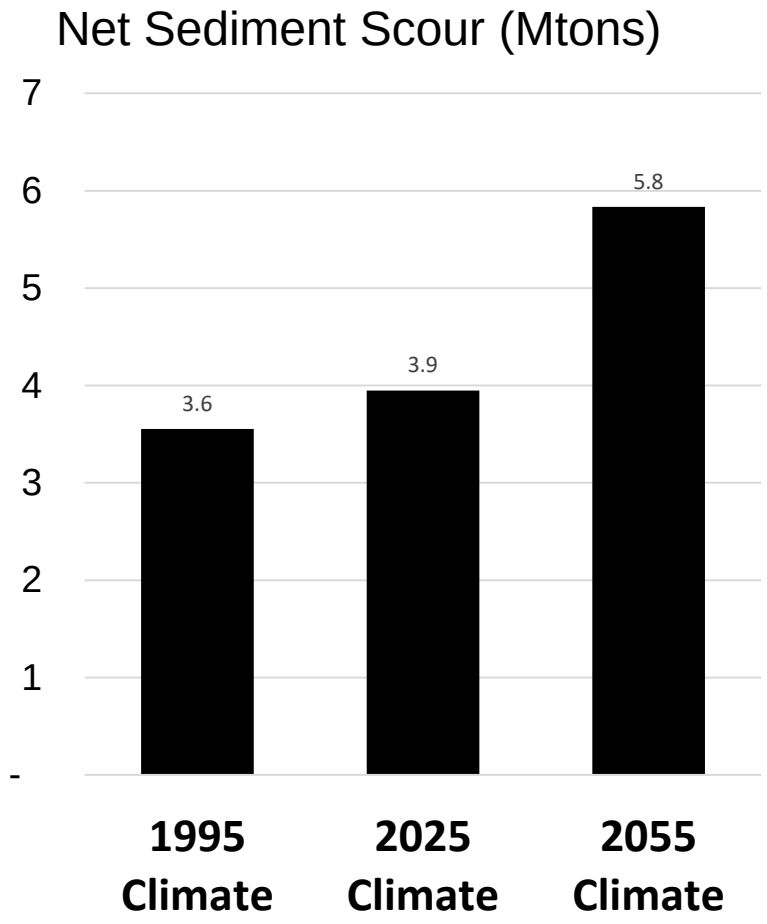


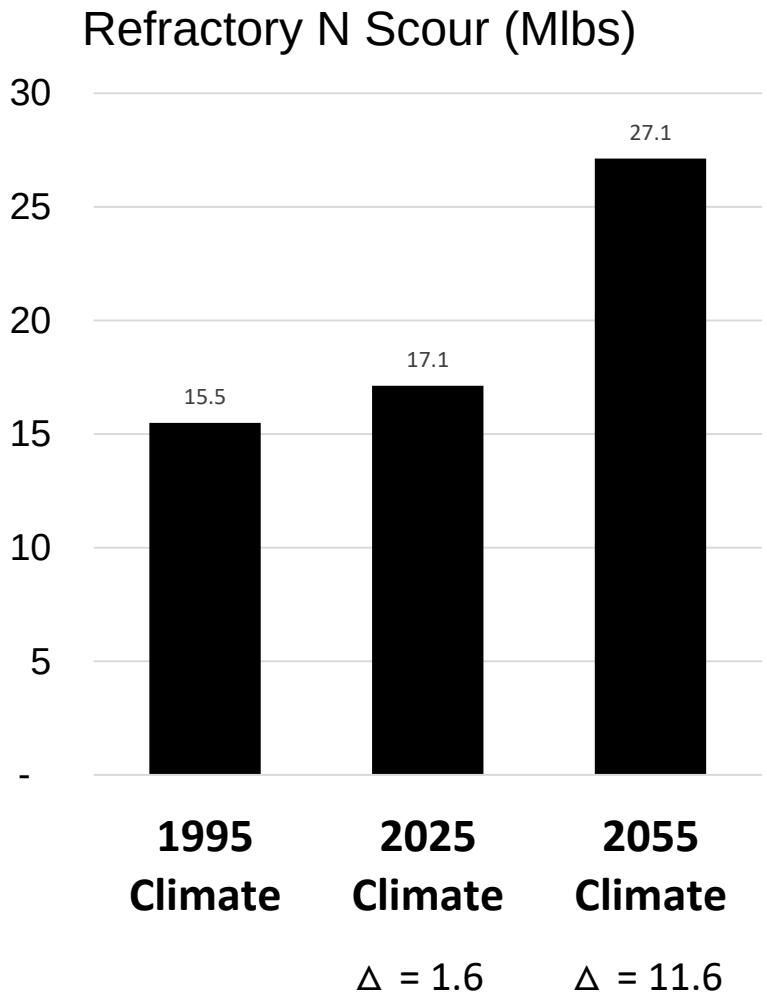
Changes in Flow Regime



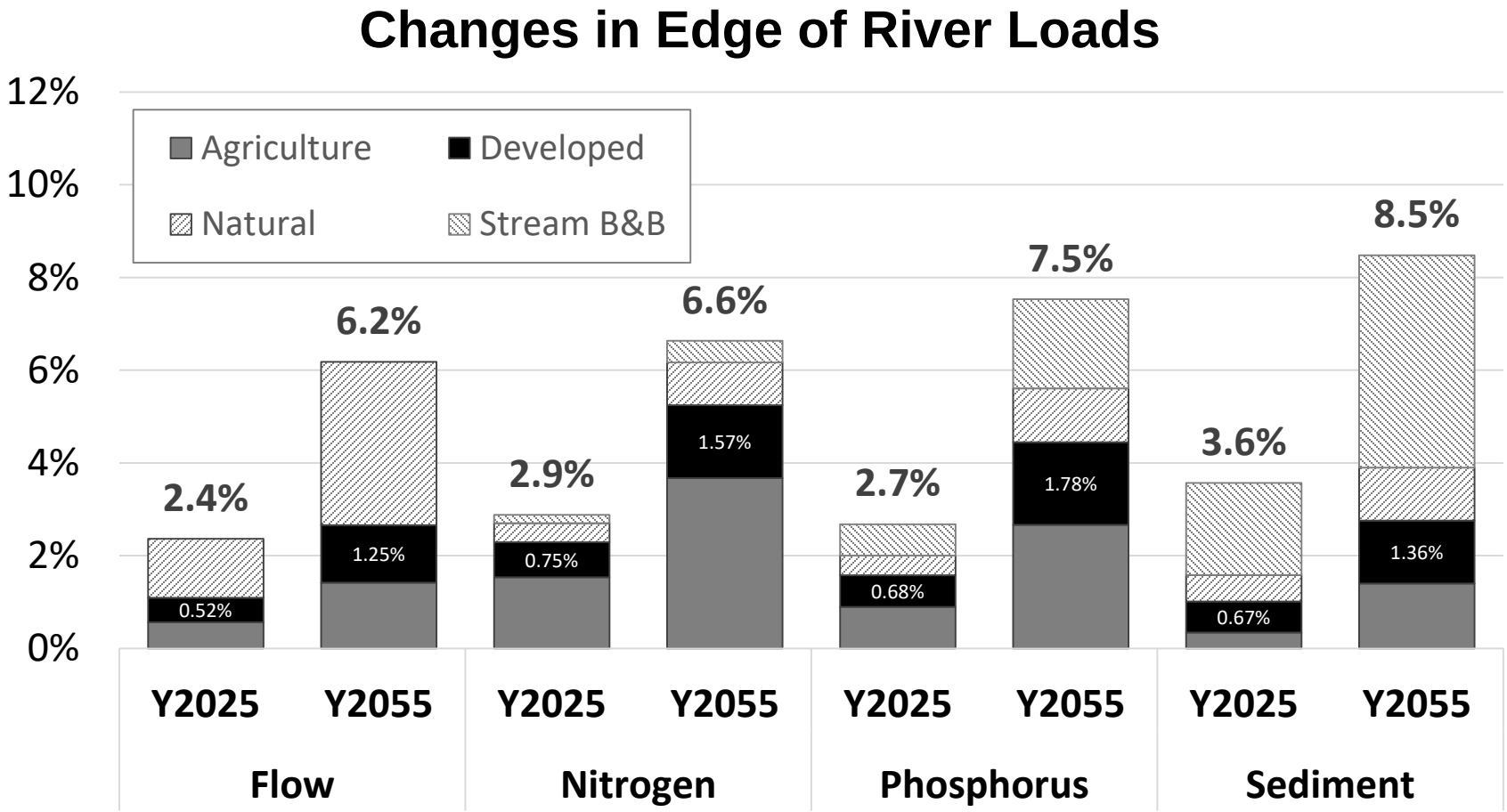
Increases in higher flow quantiles impact mobilization and transport of sediment and nutrients (in particulate form) – "*riverine nutrient competency*".

Riverine Processes – refractory organic scour



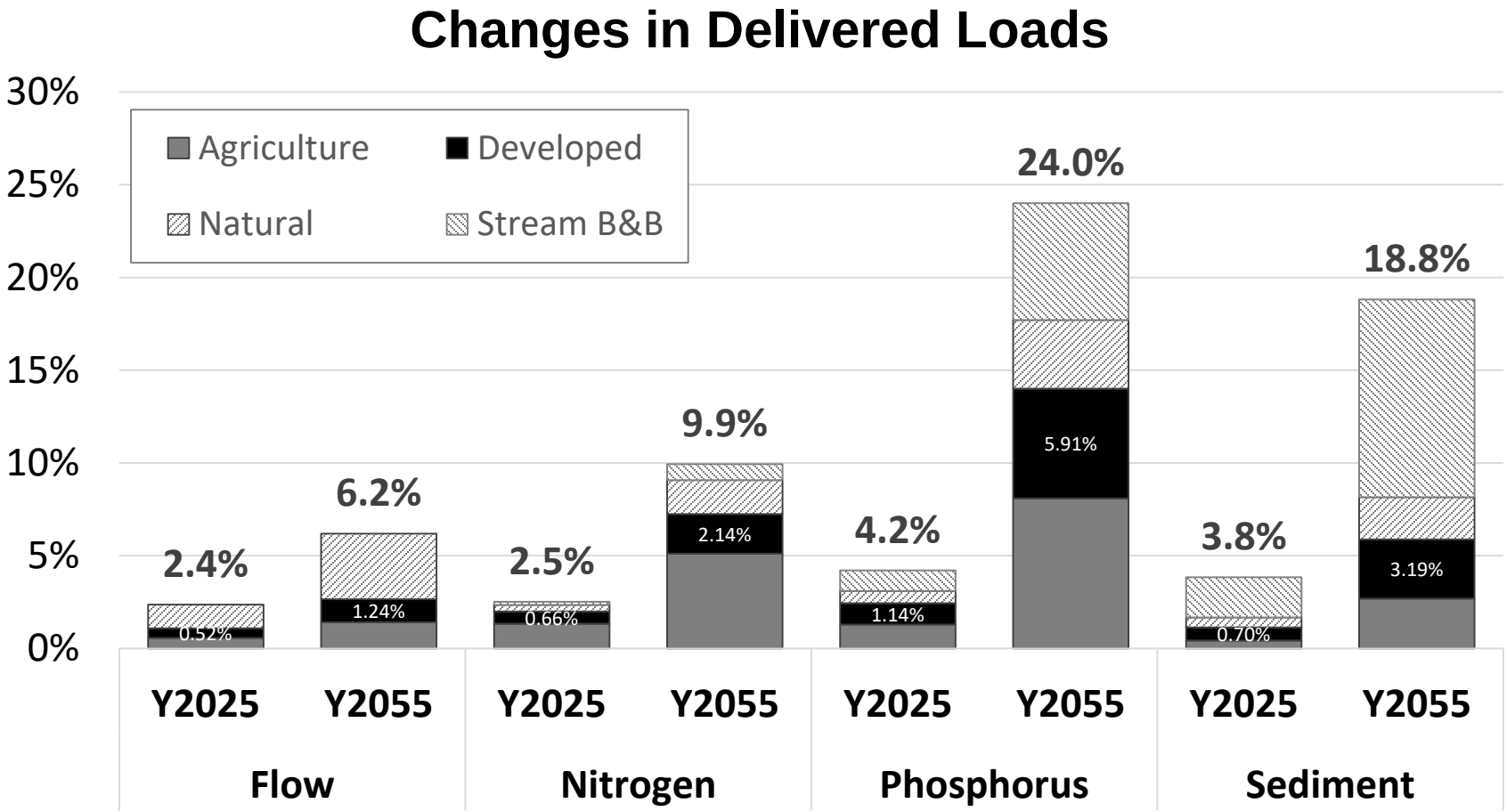


Edge of River Loads



% change with respect to delivered loads under 1995 climate

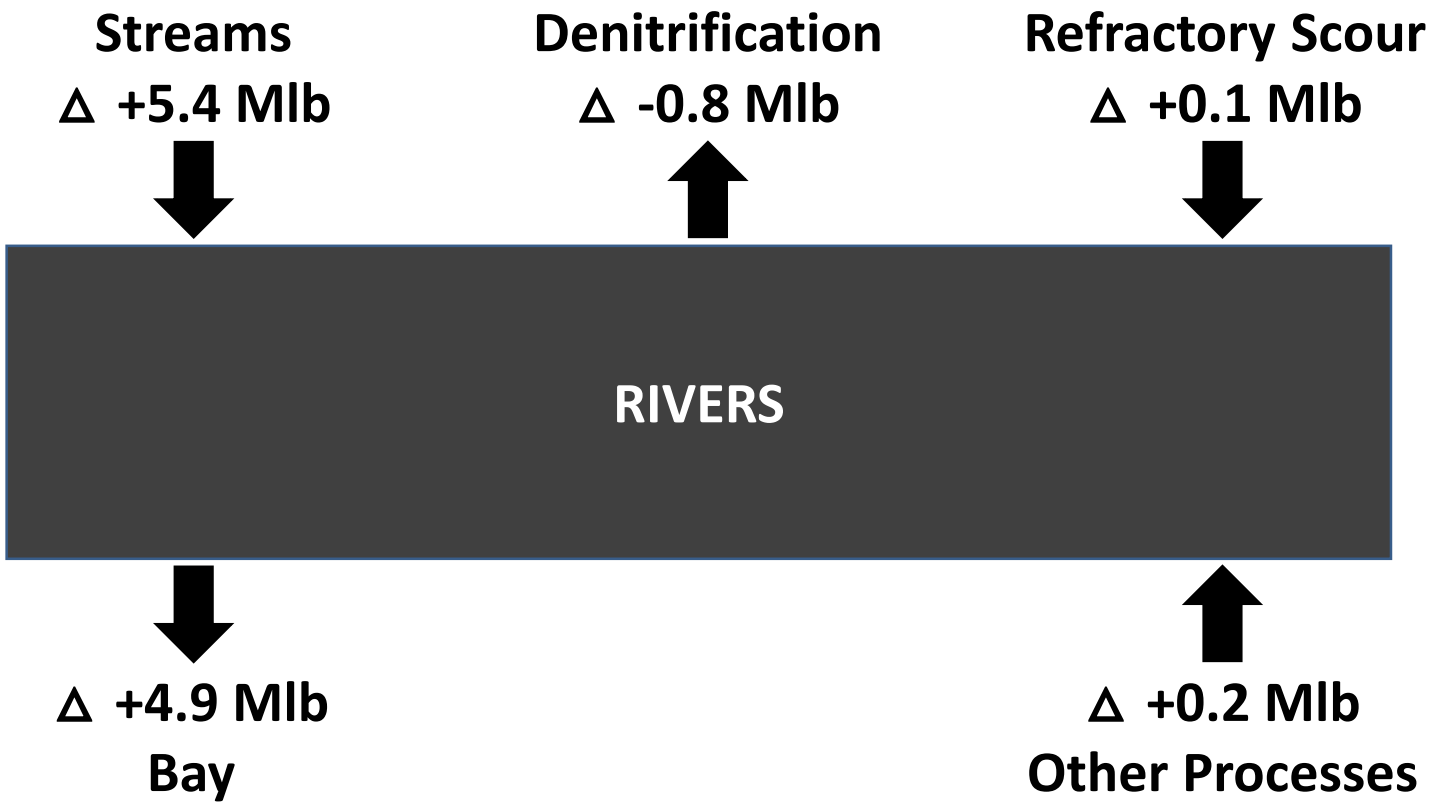
Edge of Tide (Delivered) Loads



% change with respect to delivered loads under 1995 climate

Summary of Nitrogen Budget

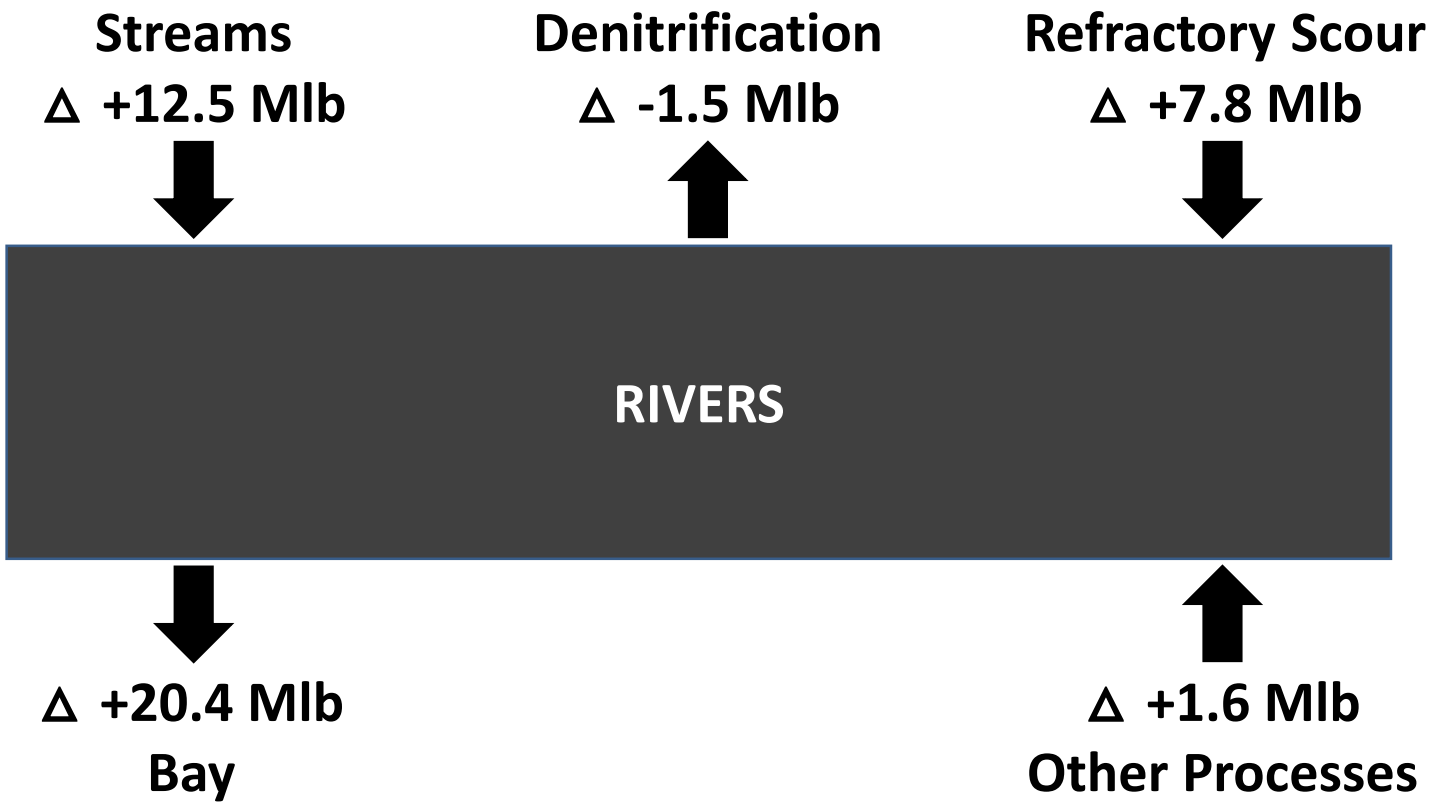
2025 Climate (marginal change in watershed response)



Deltas (Δ) show change with respect to 1995 climate.

Summary of Nitrogen Budget

2055 Climate (marginal change in watershed response)

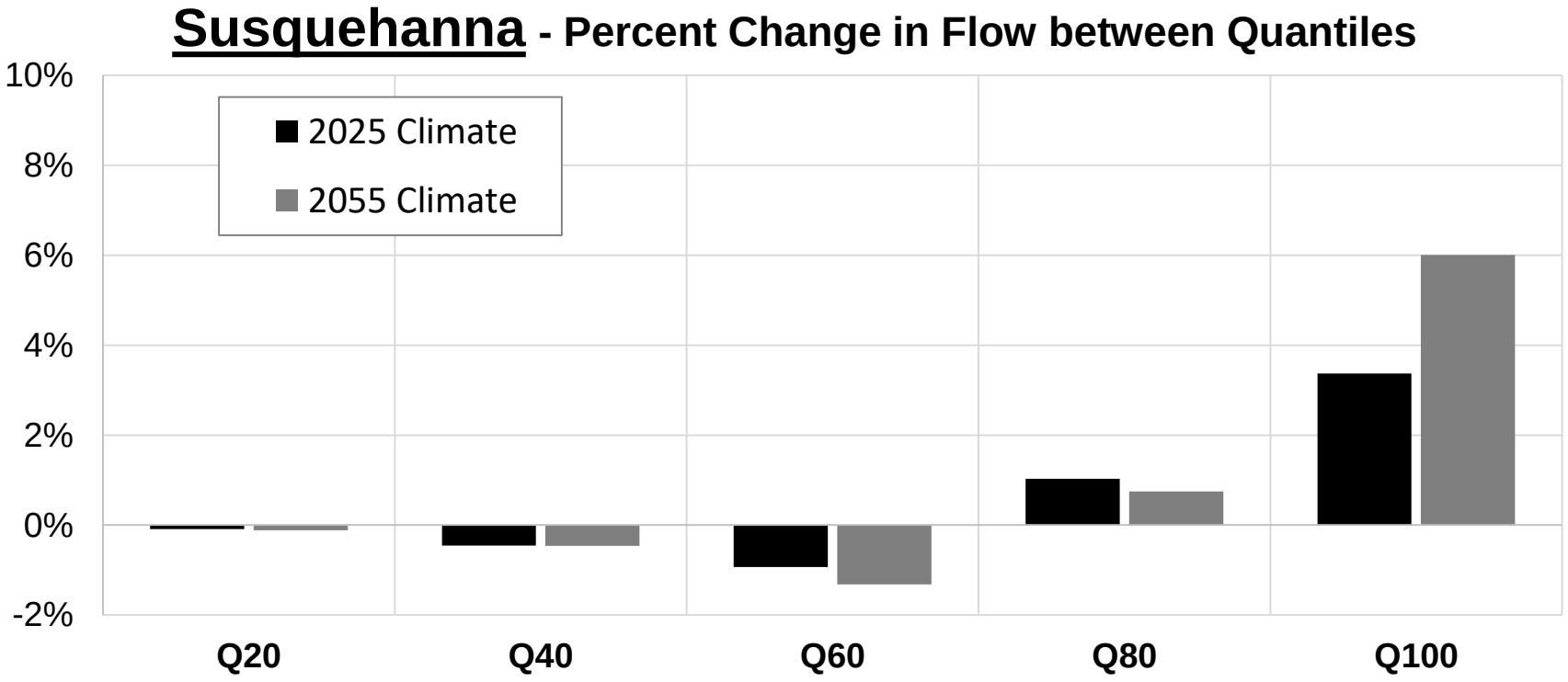


Deltas (Δ) show change with respect to 1995 climate.

Summary

- Progress has been made in the Chesapeake restoration.
- Wetter, warmer, and more crowded future add additional challenges – with increases in nutrients and sediment loads.
- Future climate impacts both land and riverine processes that contribute to changes in nitrogen and phosphorus loads.
- Relatively higher proportion of particulate nitrogen and phosphorus with increasingly wetter climate (i.e. increasing riverine nutrient competency).

Changes in Flow Regime



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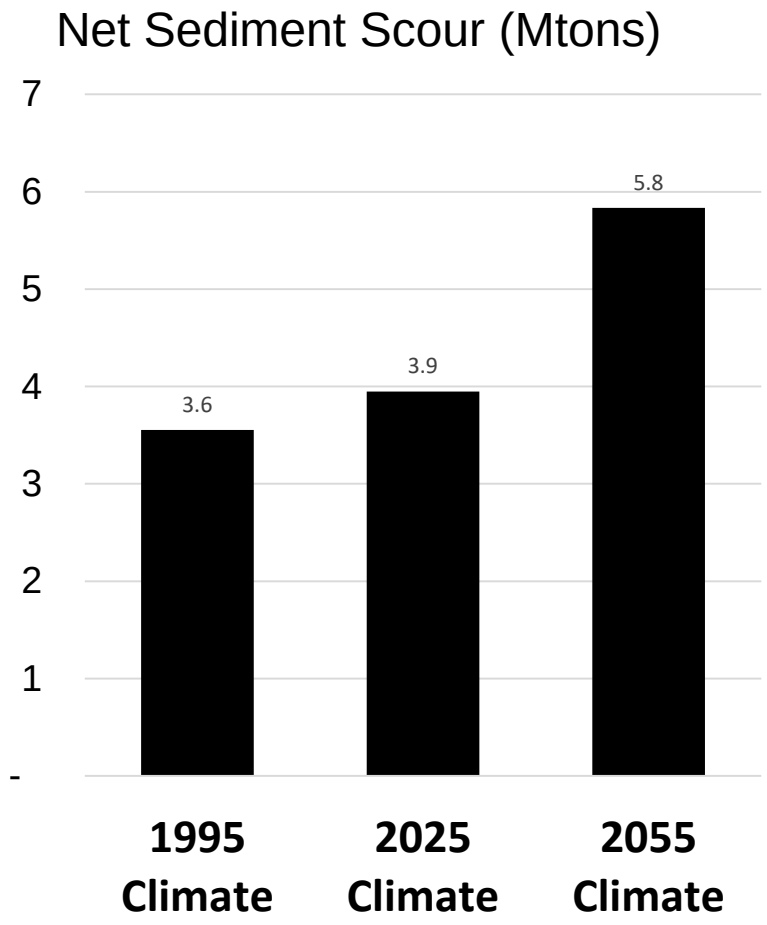
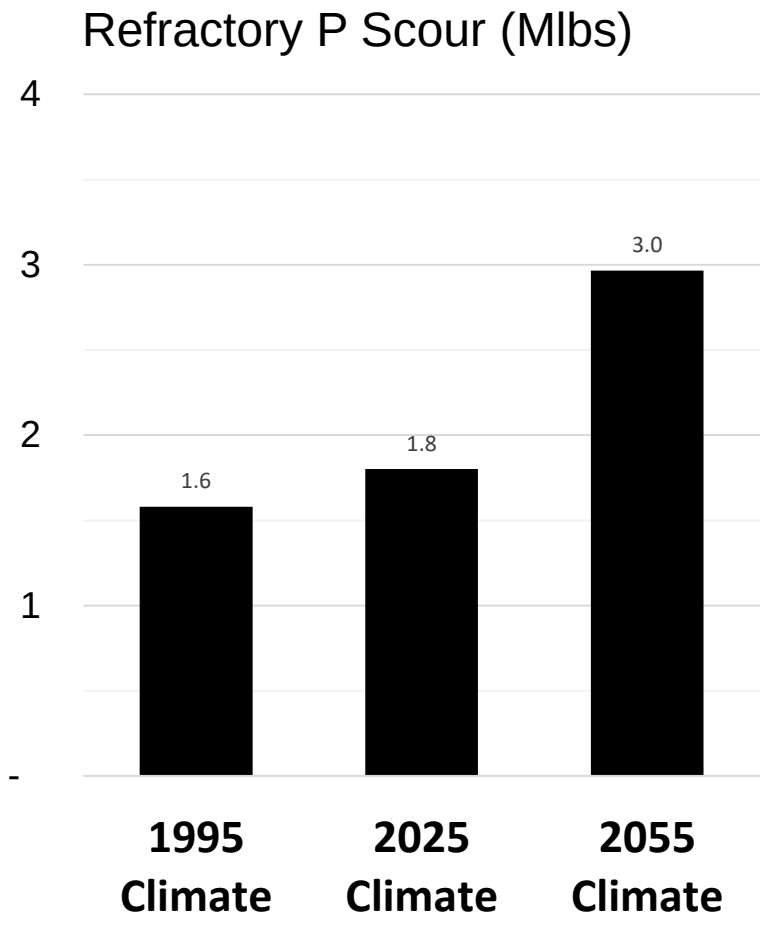
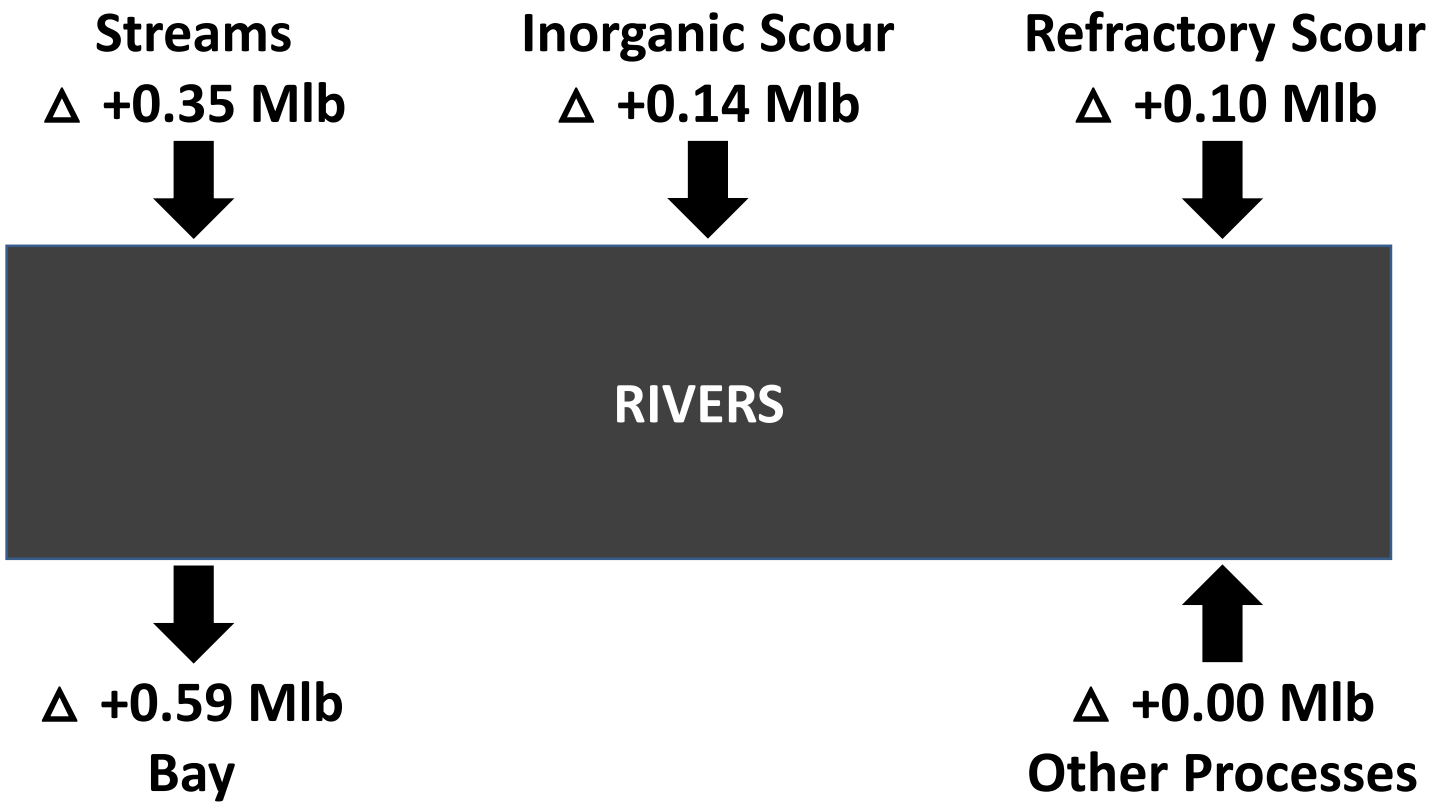




Summary of Phosphorus Budget

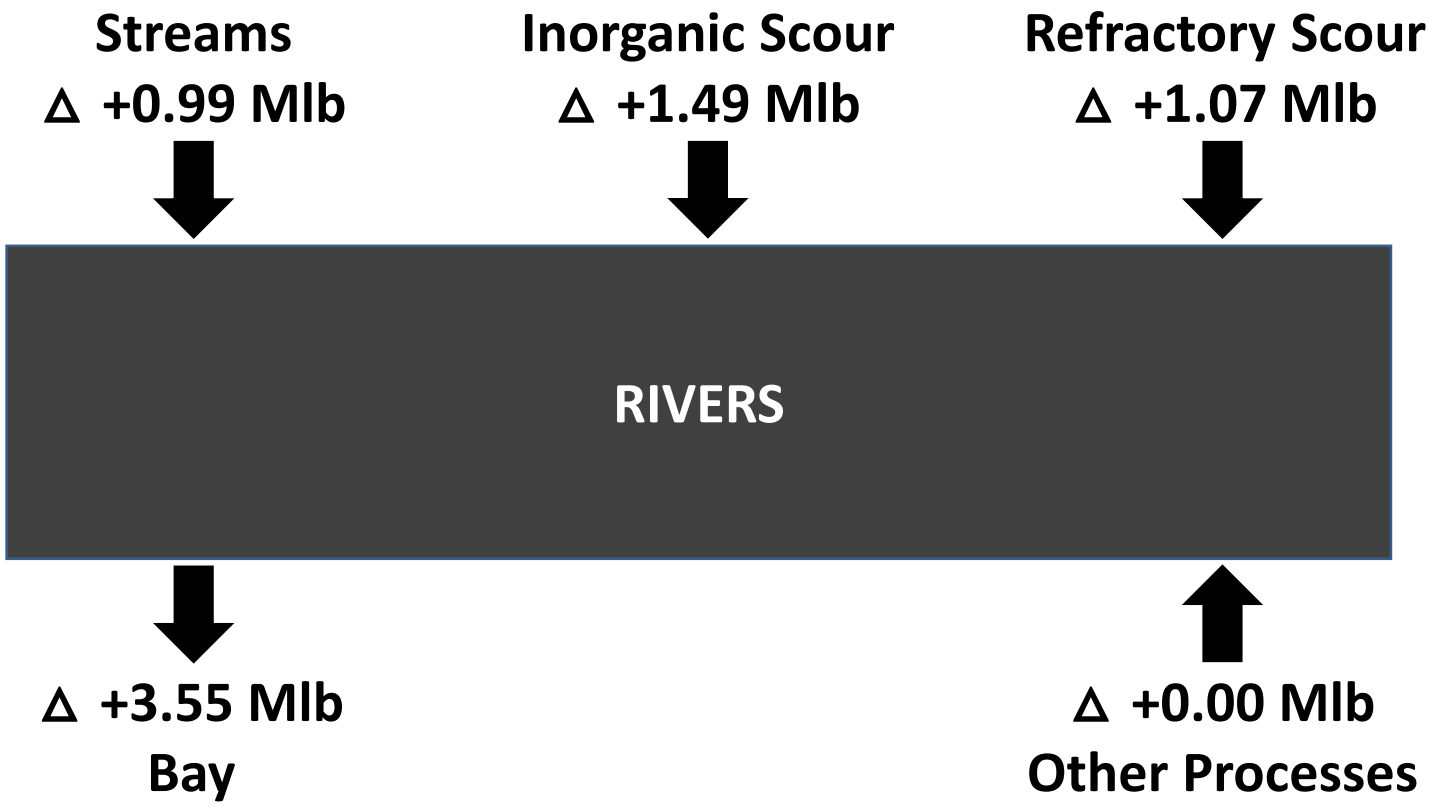
2025 Climate (marginal change in watershed response)



Deltas (Δ) show change with respect to 1995 climate.

Summary of Phosphorus Budget

2055 Climate (marginal change in watershed response)



Deltas (Δ) show change with respect to 1995 climate.