Chesapeake Bay Partnership's 2019 Climate Change Assessment

CHAMP Annual Joint Meeting – October 2019

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[1] Penn State, [2] US EPA, [3] USGS

Draft results have *not* been approved by CBP Modeling Workgroup
Please do not cite or circulate

Presentation outline

- 2017 Climate Assessment
- Refinements
- 2019 Climate Assessment (Draft) Results
- Understanding and Explaining Model Results

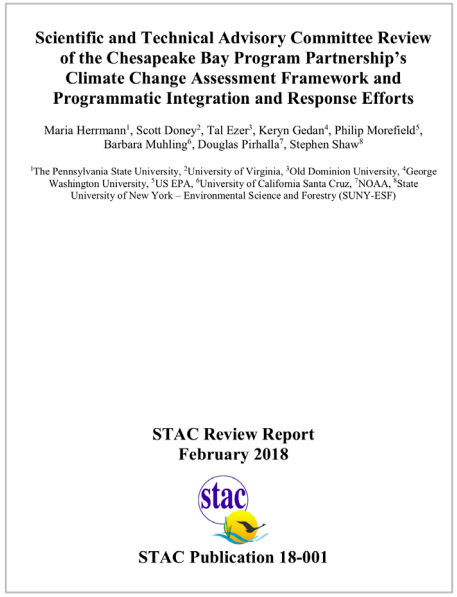
1. 2017 Climate Assessment

- 2025 and 2050 future risks of climate were assessed as compared to 1995 climate (i.e. 1991-2000 TMDL average hydrology period).
- STAC workshop recommendations, CBP Modeling Workgroup and Climate Resiliency Workgroup decisions, and CHAMP/stakeholder collaboration were used[1][2][3].


The Development of Climate Projections for Use in Chesapeake Bay Program Assessments

STAC Workshop Report
March 7-8, 2016
Annapolis, MD

STAC Publication 16-006


Scientific and Technical Advisory Committee Review of the Chesapeake Bay Program Partnership's Climate Change Assessment Framework and Programmatic Integration and Response Efforts

Maria Herrmann[1], Scott Doney[2], Tal Ezer[3], Keryn Gedan[4], Philip Morefield[5], Barbara Muhling[6], Douglas Pirhalla[7], Stephen Shaw[8]

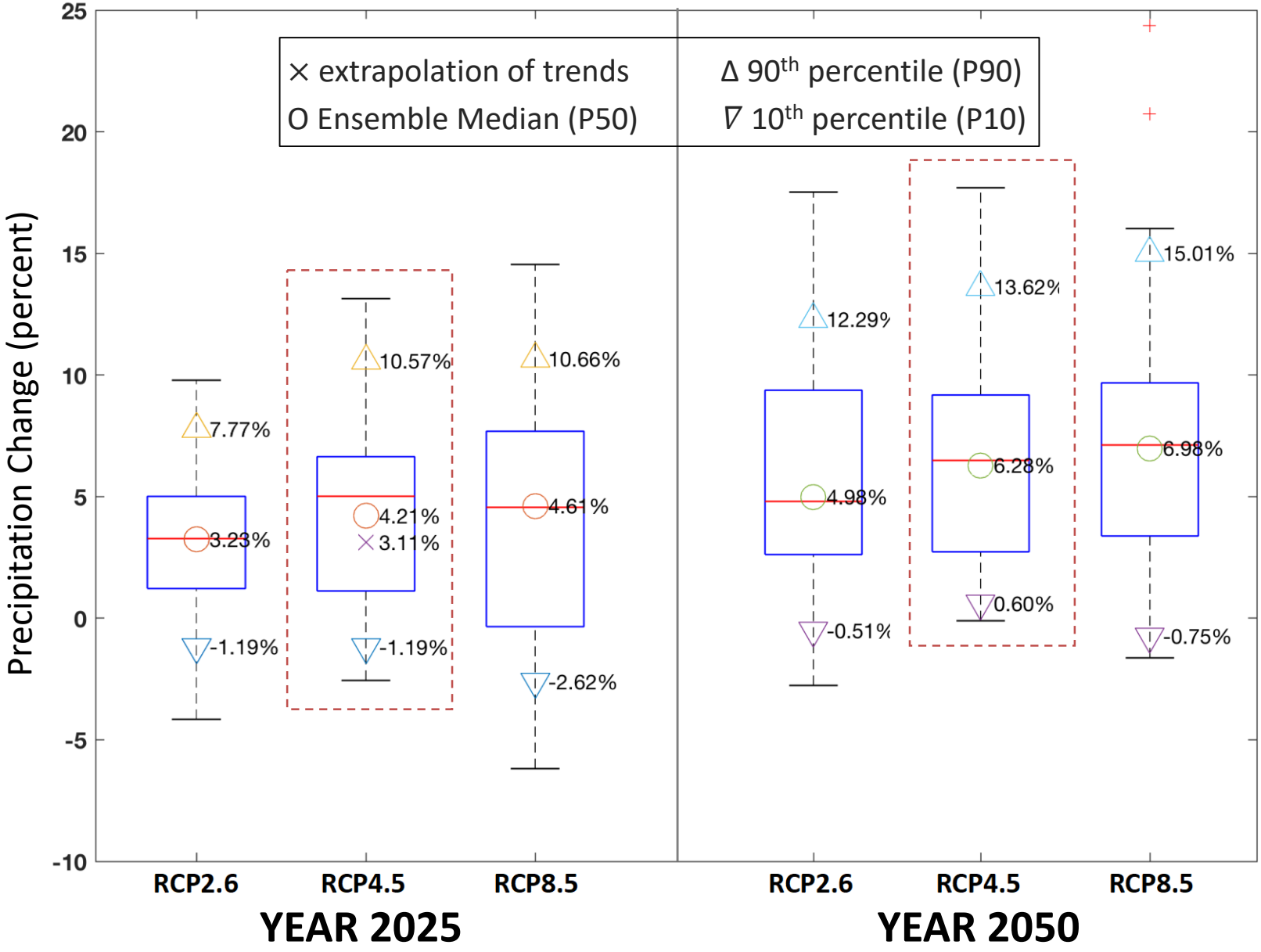
[1]The Pennsylvania State University, [2]University of Virginia, [3]Old Dominion University, [4]George Washington University, [5]US EPA, [6]University of California Santa Cruz, [7]NOAA, [8]State University of New York – Environmental Science and Forestry (SUNY-ESF)

STAC Review Report
February 2018

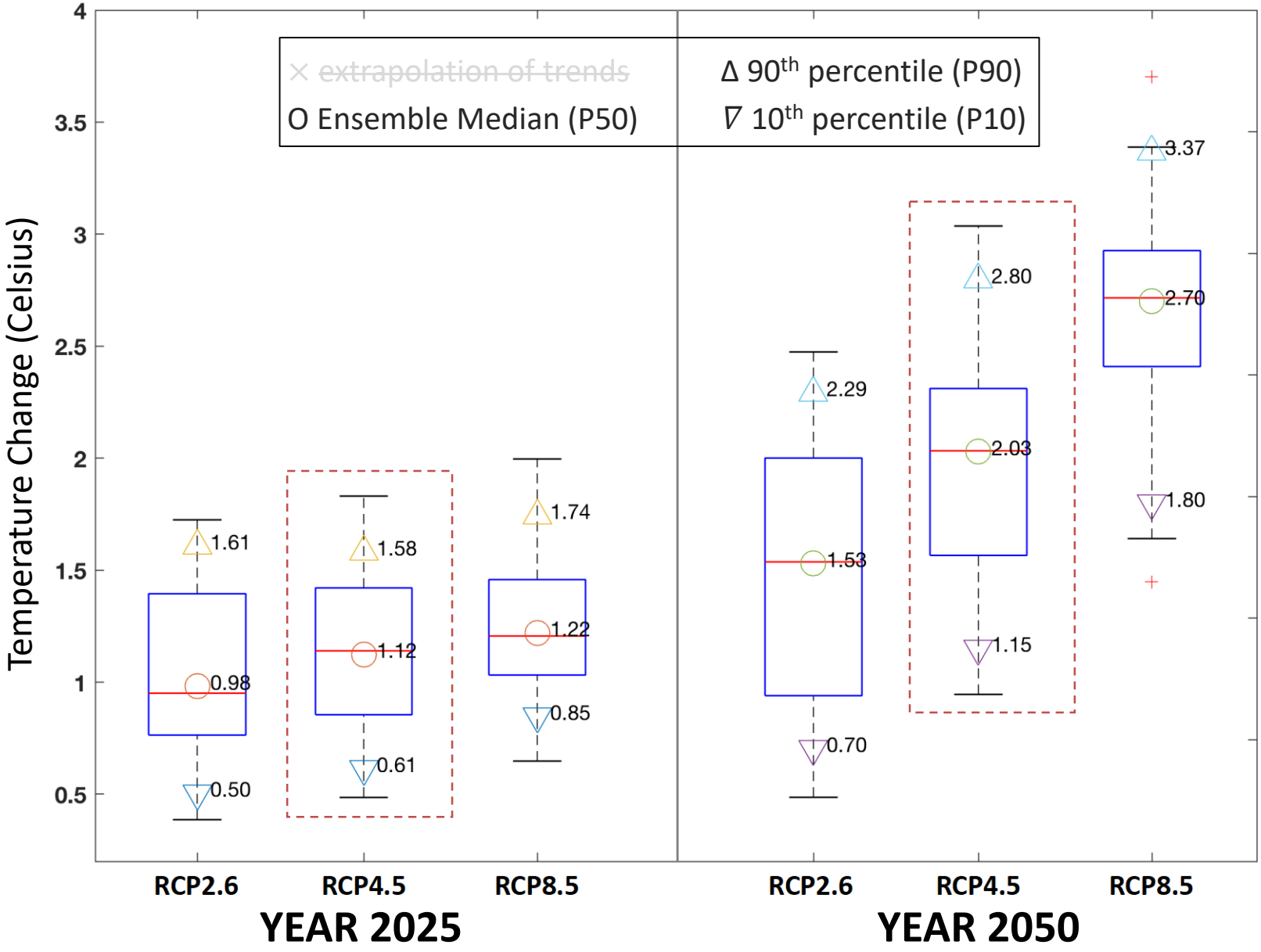
STAC Publication 18-001

[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

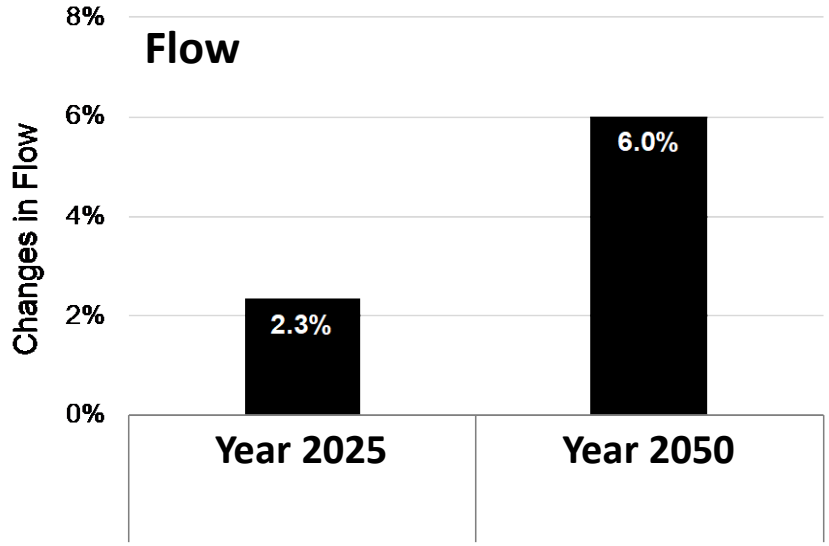
Summary of precipitation change

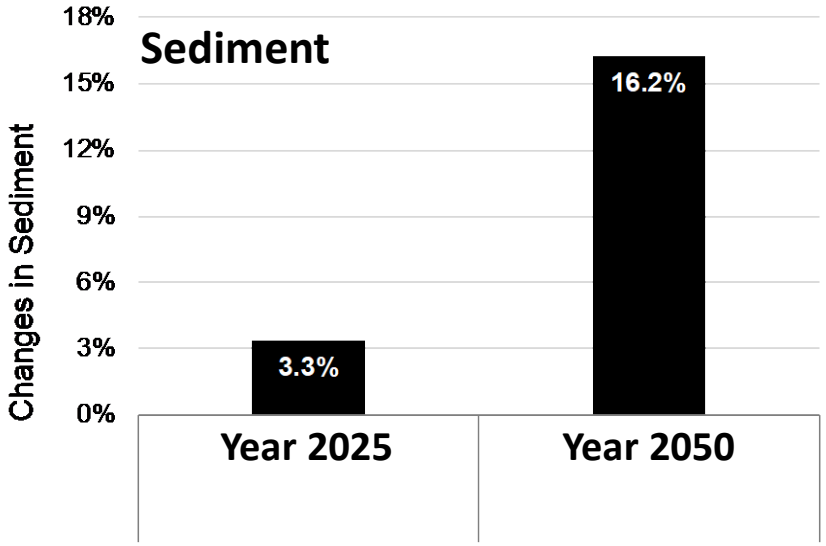


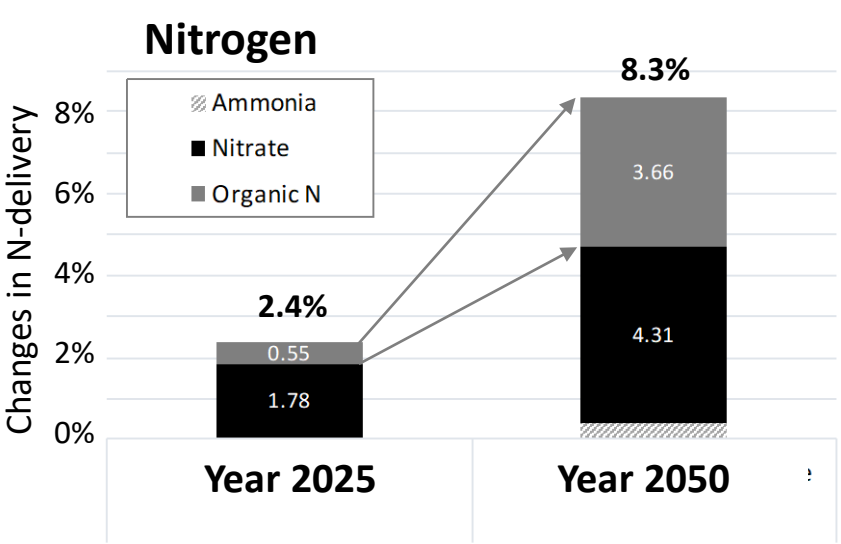
Summary of temperature change

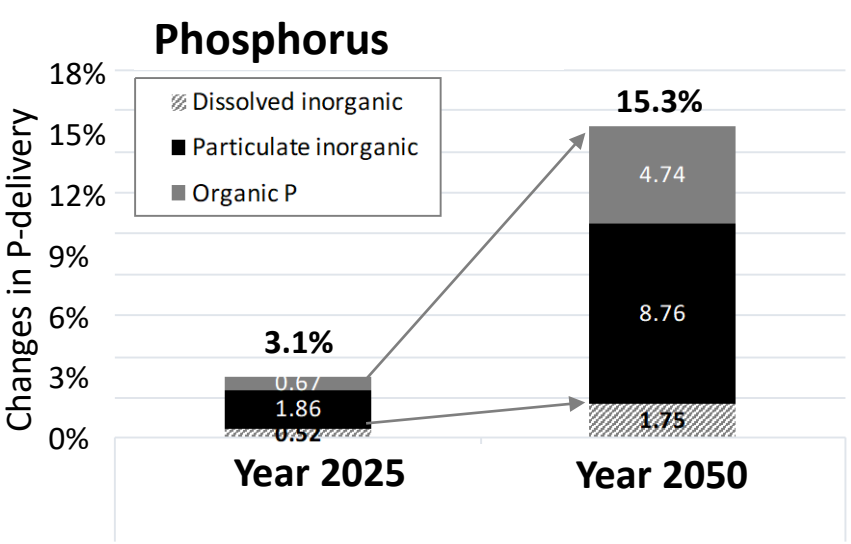


Summary of changes in delivery









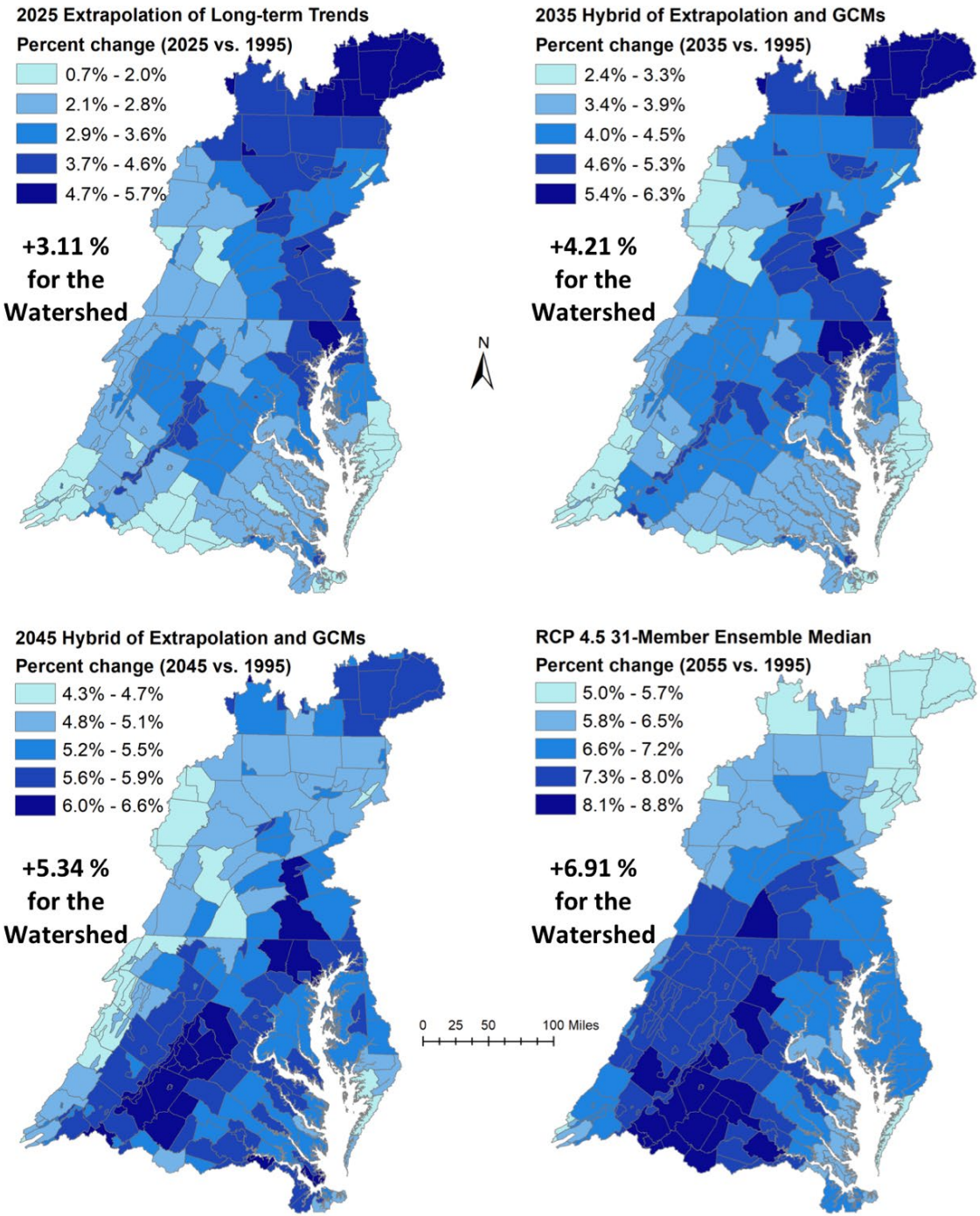
***2025 rainfall**: based on the extrapolation of long-term trends; **All Else**: median of 31-member RCP4.5 downscaled GCMs*

2. Refinements – CBP 2019 Climate Assessment

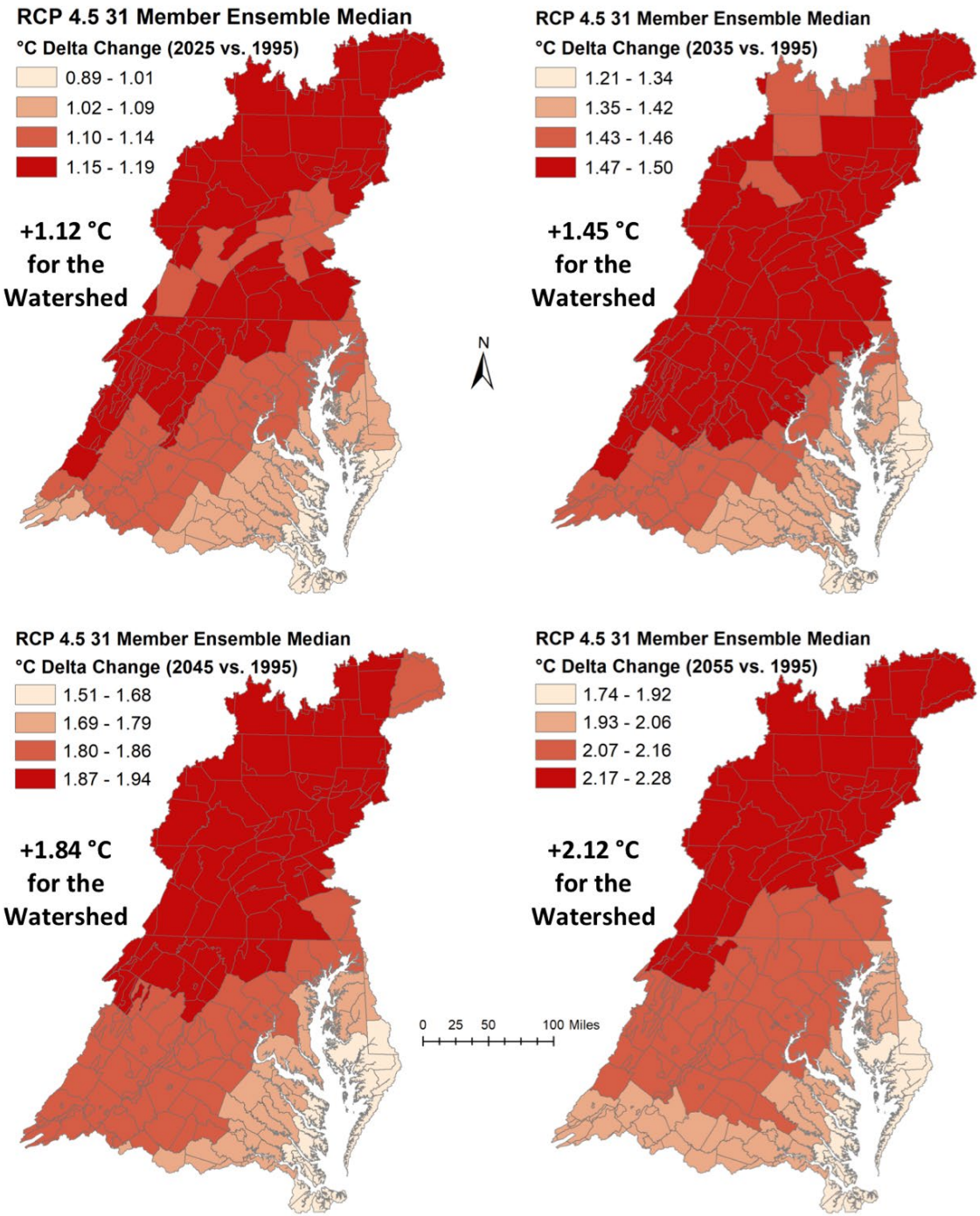
The direction of CBP decision makers, the guidance of STAC, and the collaboration with CHAMP was collectively applied in the CBP 2019 Climate Assessment.

- Assessment of 2025, 2035, 2045, and 2055
- Incorporation of future land use and population projections
- Sensitivity of atmospheric deposition to climate (rainfall)
- Nitrogen speciation responses to future hydrology
- Phosphorus response of developed load sources
- Phosphorus storage response of agricultural load sources
- Combined sewer overflow discharge and future rainfall
- Model method refinements
- Better integration with CAST (time-averaged model)
- ~~BMP performance/efficiency under future climate~~
- ~~Socioeconomic changes to future climate~~

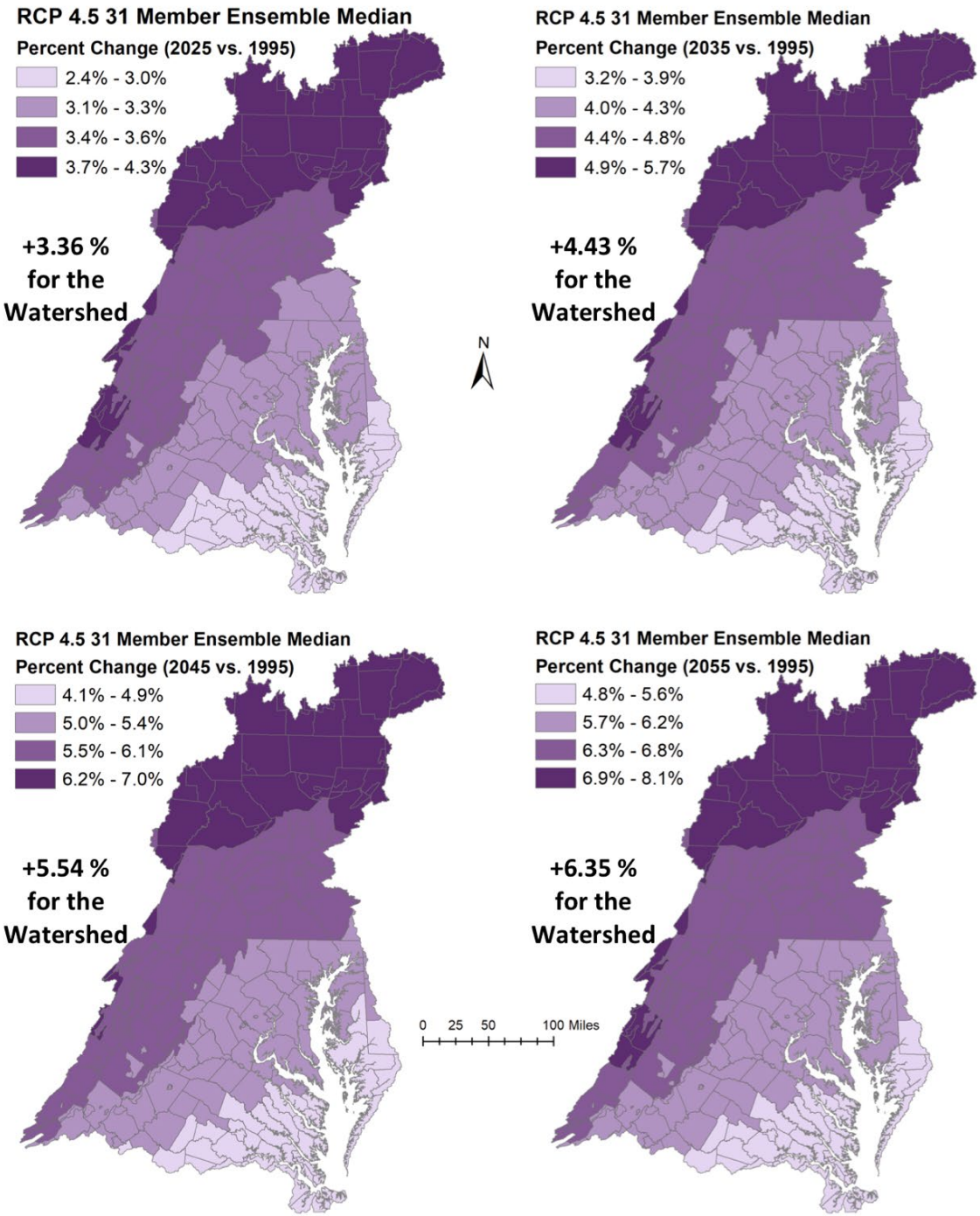
Rainfall

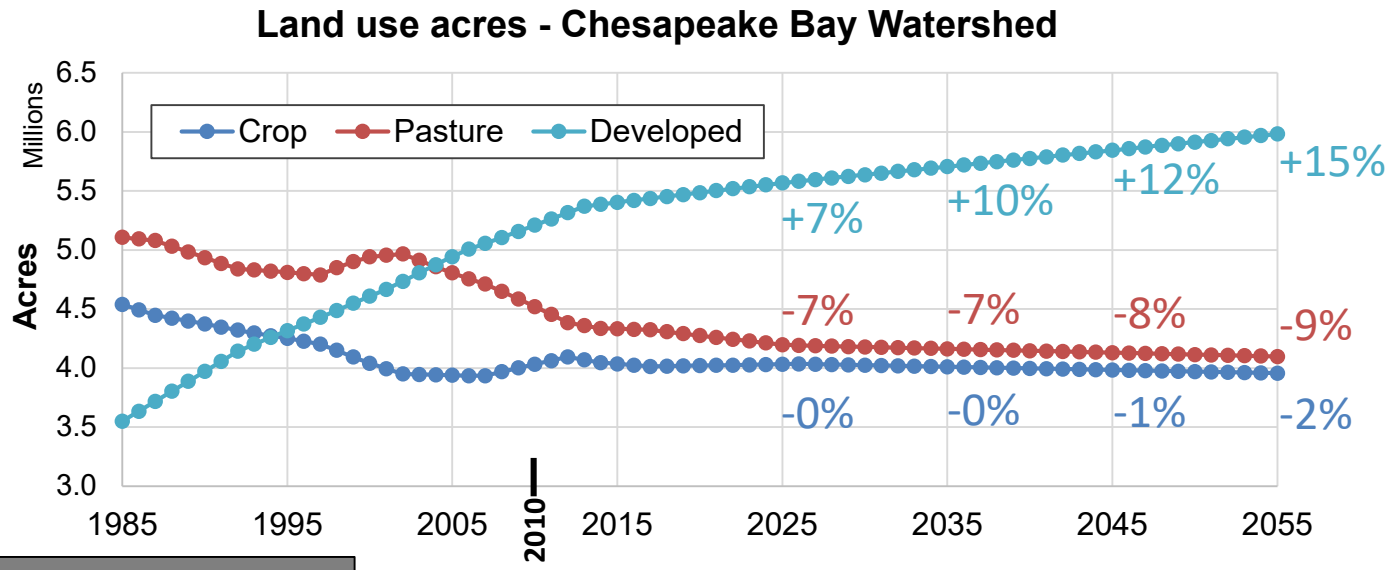

2025 Extrapolation of Long-term Trends
Percent change (2025 vs. 1995)
0.7% - 2.0%
2.1% - 2.8%
2.9% - 3.6%
3.7% - 4.6%
4.7% - 5.7%
+3.11 % for the Watershed
2035 Hybrid of Extrapolation and GCMs
Percent change (2035 vs. 1995)
2.4% - 3.3%
3.4% - 3.9%
4.0% - 4.5%
4.6% - 5.3%
5.4% - 6.3%
+4.21 % for the 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

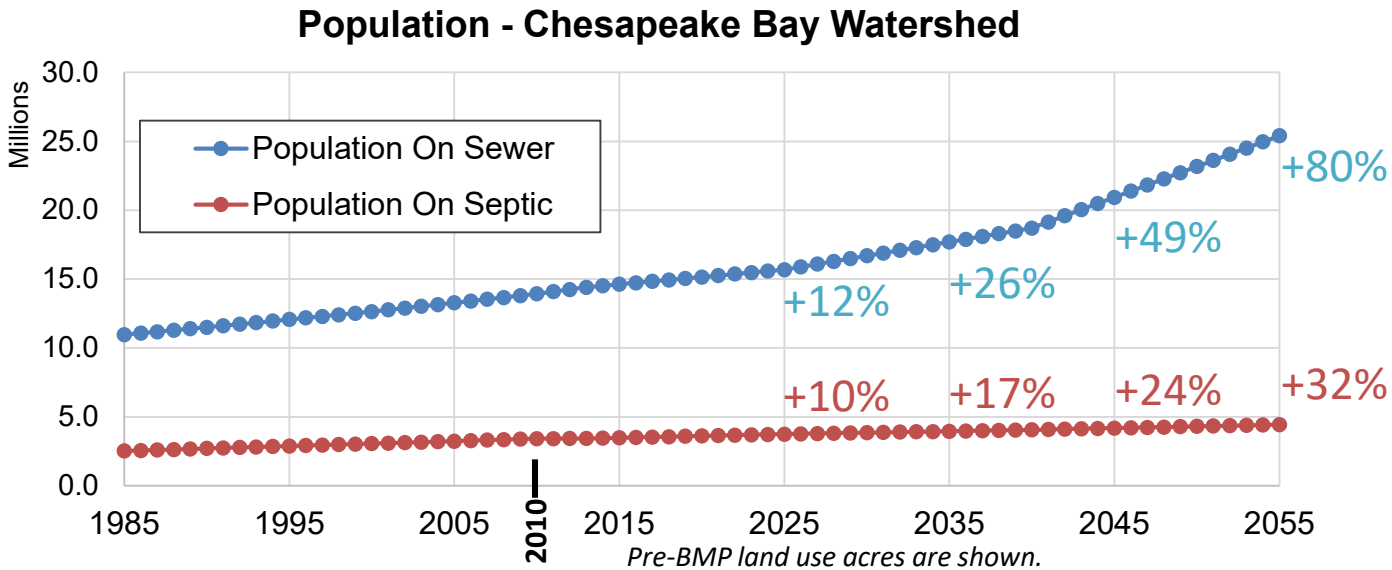


PET


RCP 4.5 31 Member Ensemble Median
Percent Change (2025 vs. 1995)
2.4% - 3.0%
3.1% - 3.3%
3.4% - 3.6%
3.7% - 4.3%
+3.36 % for the Watershed
RCP 4.5 31 Member Ensemble Median
Percent Change (2035 vs. 1995)
3.2% - 3.9%
4.0% - 4.3%
4.4% - 4.8%
4.9% - 5.7%
+4.43 % for the Watershed
N
RCP 4.5 31 Member Ensemble Median
Percent Change (2045 vs. 1995)
4.1% - 4.9%
5.0% - 5.4%
5.5% - 6.1%
6.2% - 7.0%
+5.54 % for the Watershed
RCP 4.5 31 Member Ensemble Median
Percent Change (2055 vs. 1995)
4.8% - 5.6%
5.7% - 6.2%
6.3% - 6.8%
6.9% - 8.1%
+6.35 % for the Watershed
0 25 50 100 Miles



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



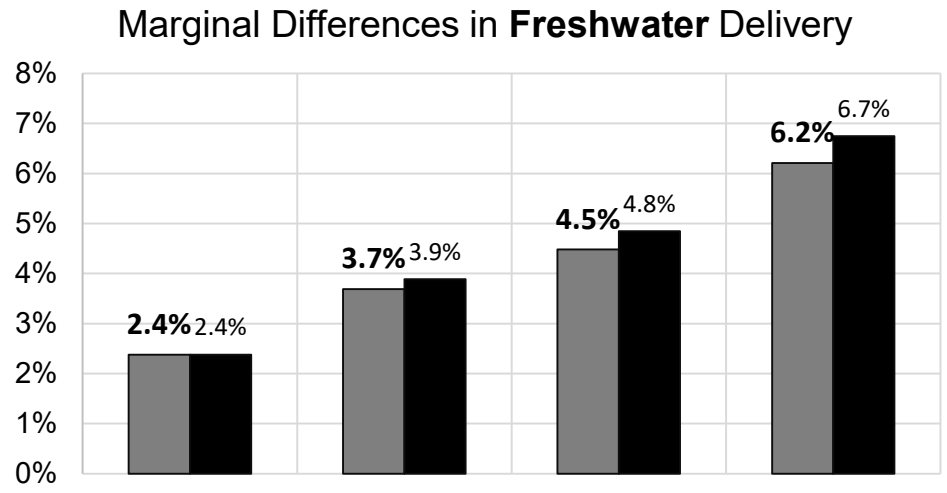
Pre-BMP land use acres are shown.
Percent changes are shown with respect to 2010 (with WIP2 level of effort)

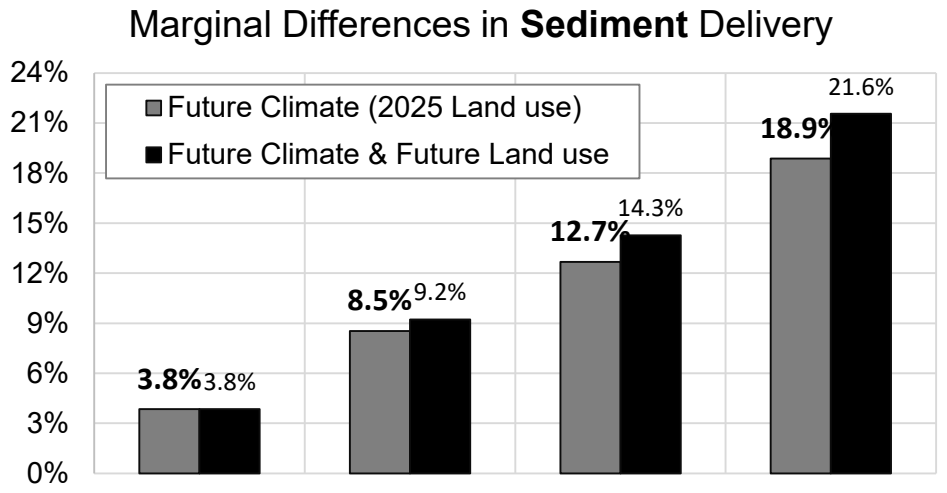
[1] https://www.chesapeakebay.net/channel_files/35723/20190402_-_bhatt_-_mwqm_-_2019_climate_change_assessment.pdf

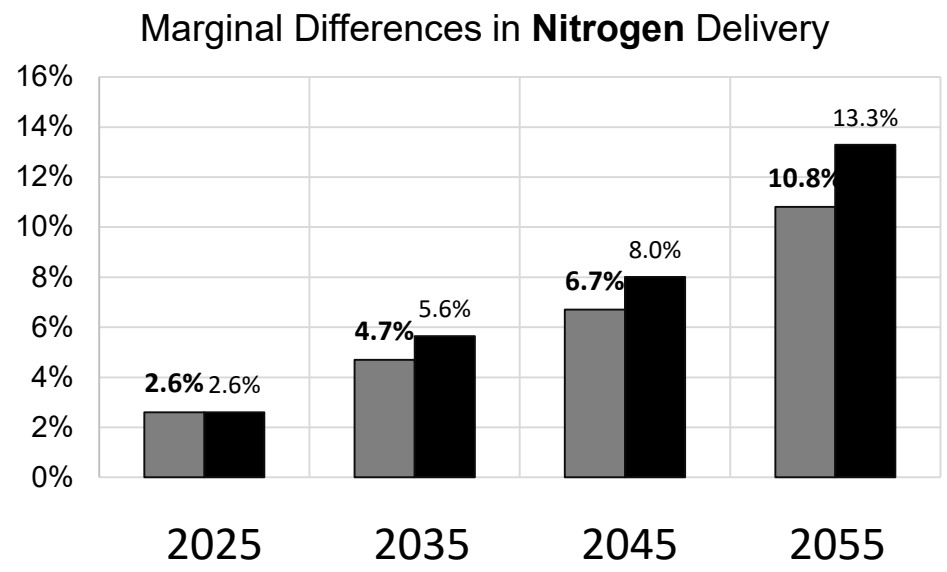
3. 2019 Climate Assessment (Draft) Results

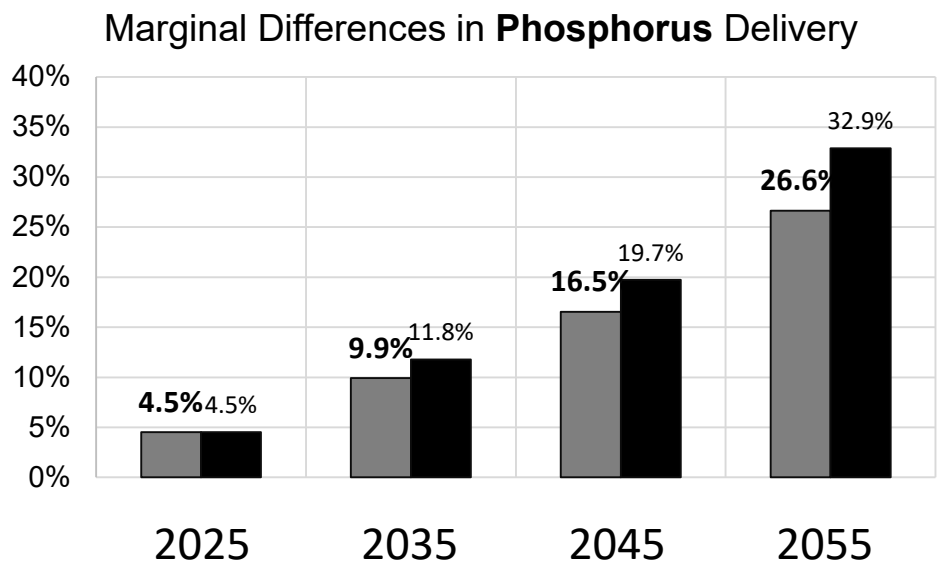
- **Watershed model simulations were made for –**
  - **(1) Future climate with fixed 2025 land use and management practices at Phase 3 Planning Target level of effort, and**
  - **(2) Future climate as well as future land use.**

2019 Climate Assessment (Draft) Results









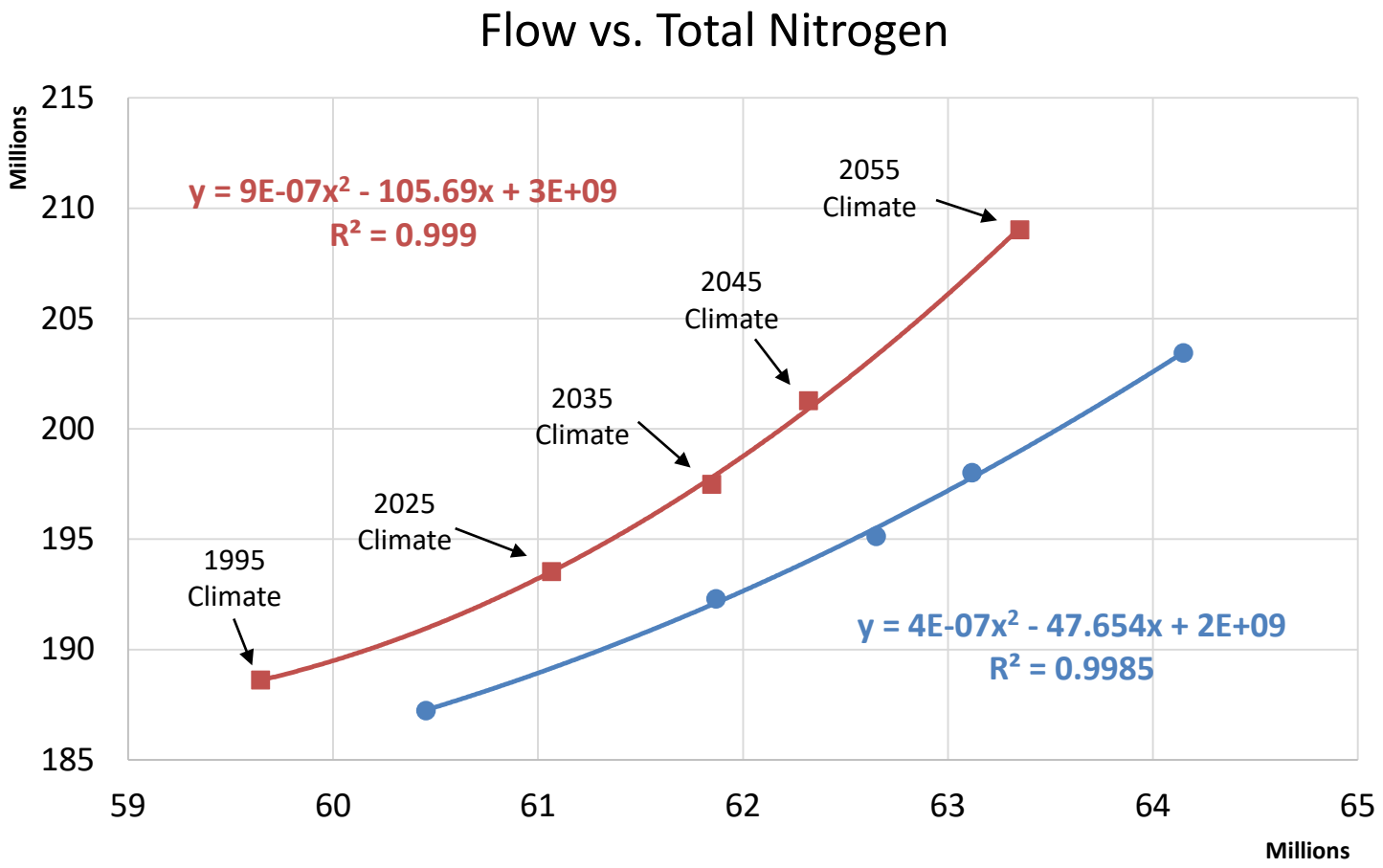
4. Understanding and Explaining Model Results

- **Water quality responses – how does watershed delivery of nitrogen and phosphorus changes with flow?**
- **Hydrologic responses – how does flow changes with rainfall and potential evapotranspiration (temperature)?**

Nitrogen response

2017 climate assessment (WIP2 LOE)
2019 refined climate assessment (Planning Target LOE)

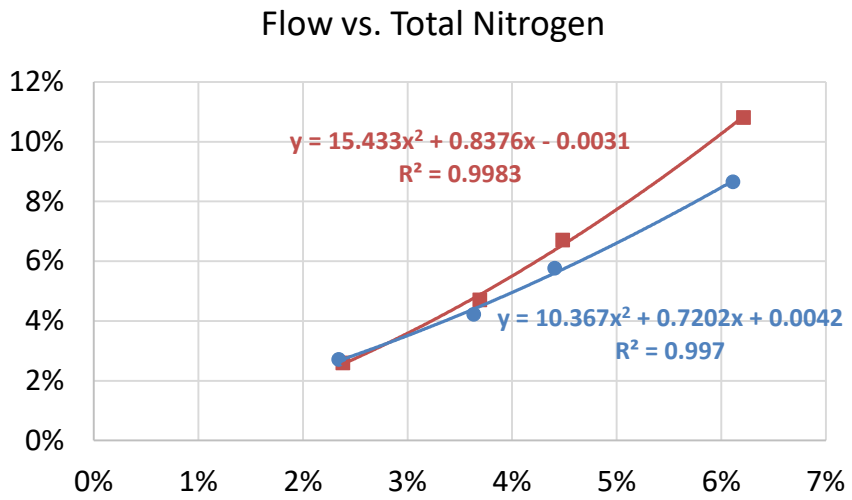
i.e. different land use and management effort

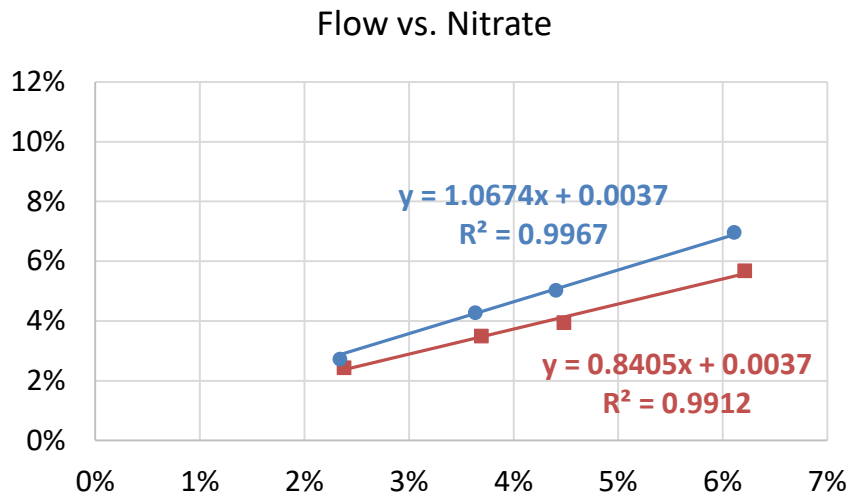


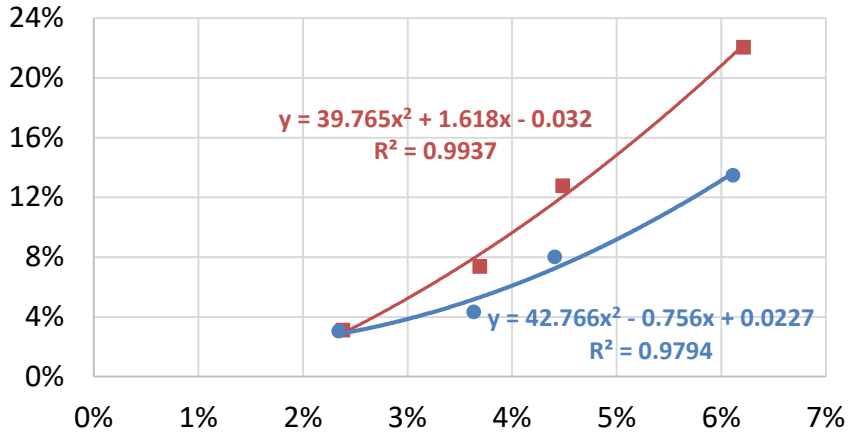
Units – Flow in ac-ft; Nitrogen/Phosphorus in lbs; Sediment in tons.

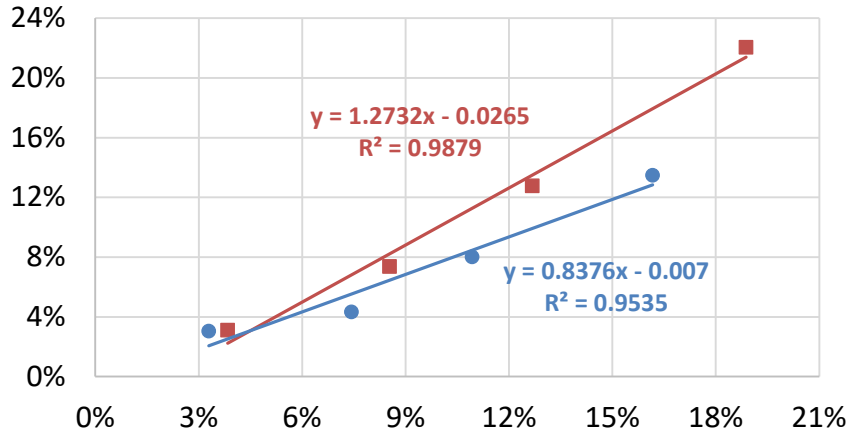
Nitrogen response

2017 climate assessment (WIP2 LOE)
2019 refined climate assessment (Planning Target LOE)





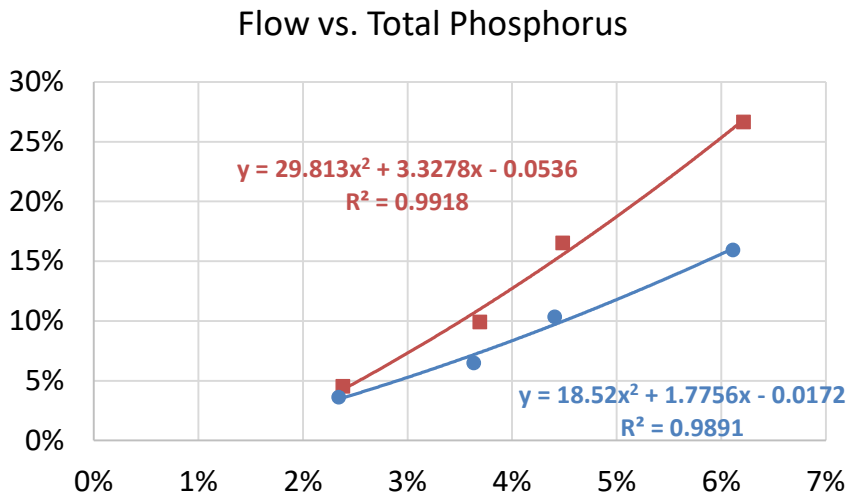


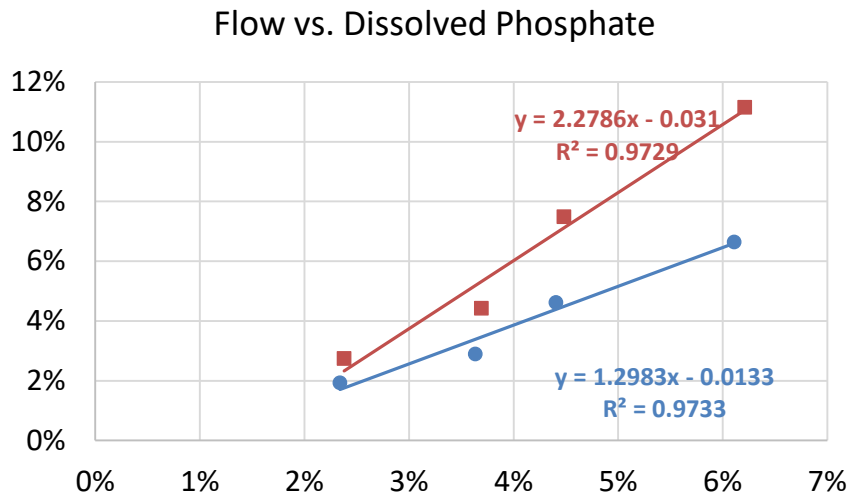


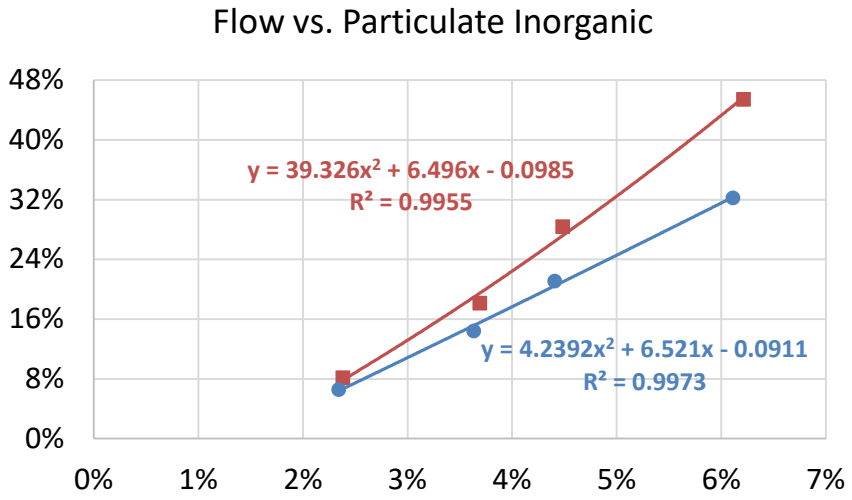
Percent difference in response for 2025, 2035, 2045, and 2055 climate with respect to that for 1995 are shown.

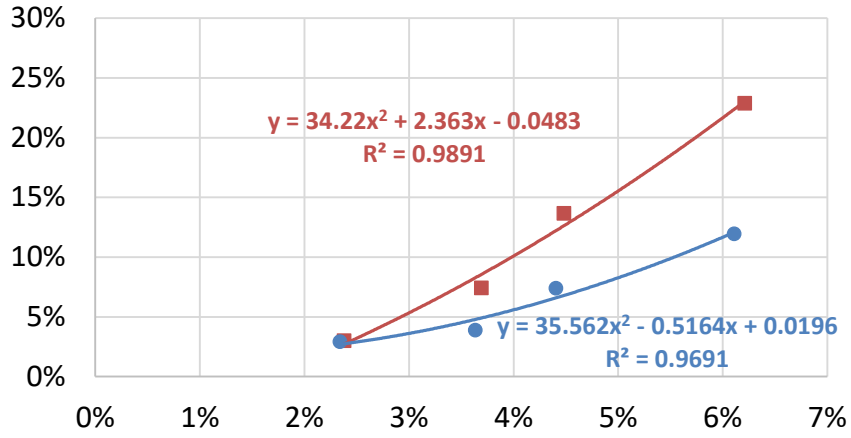
Phosphorus response

2017 climate assessment (WIP2 LOE)
2019 refined climate assessment (Planning Target LOE)





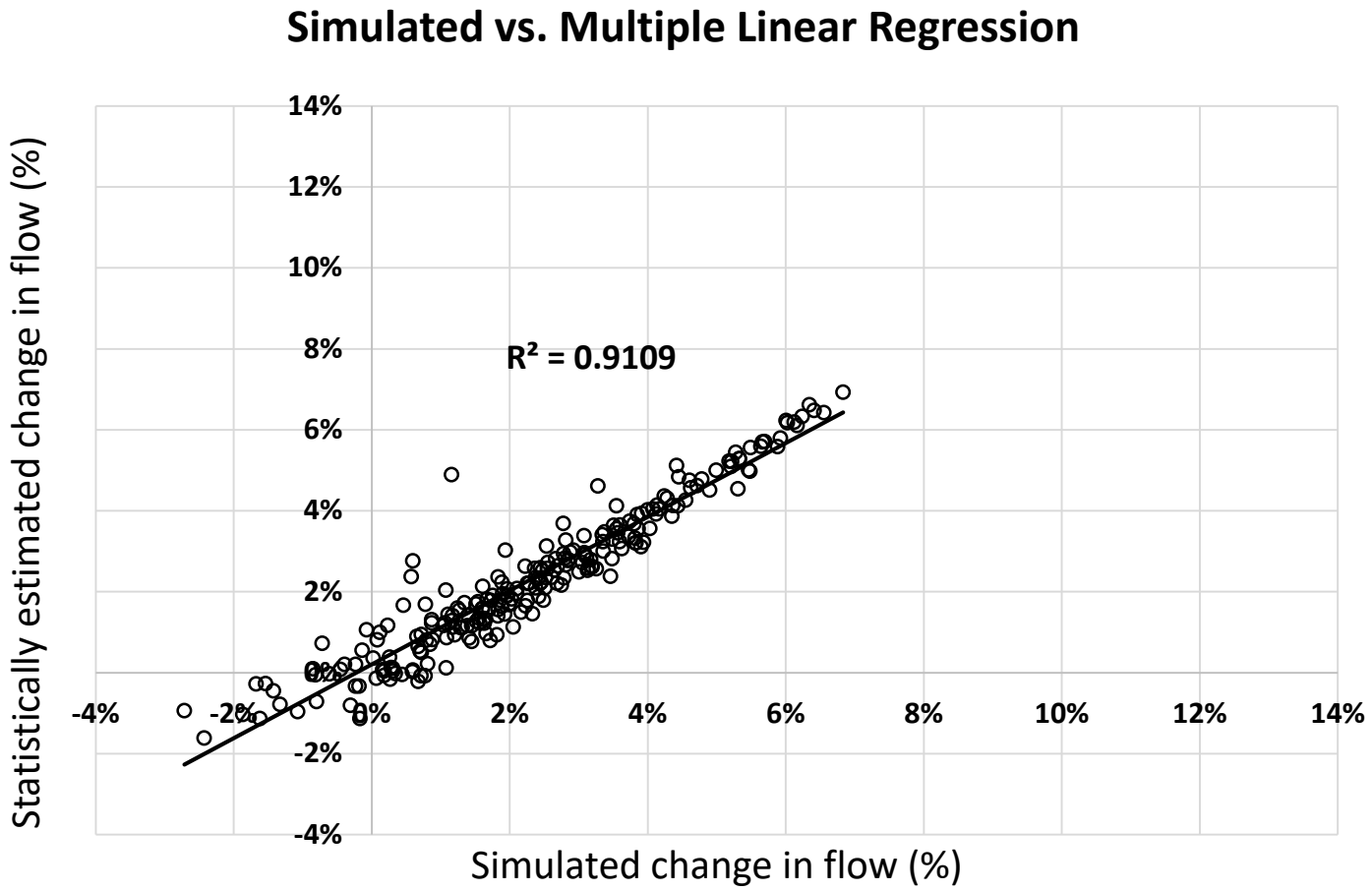




Percent difference in response for 2025, 2035, 2045, and 2055 climate with respect to that for 1995 are shown.

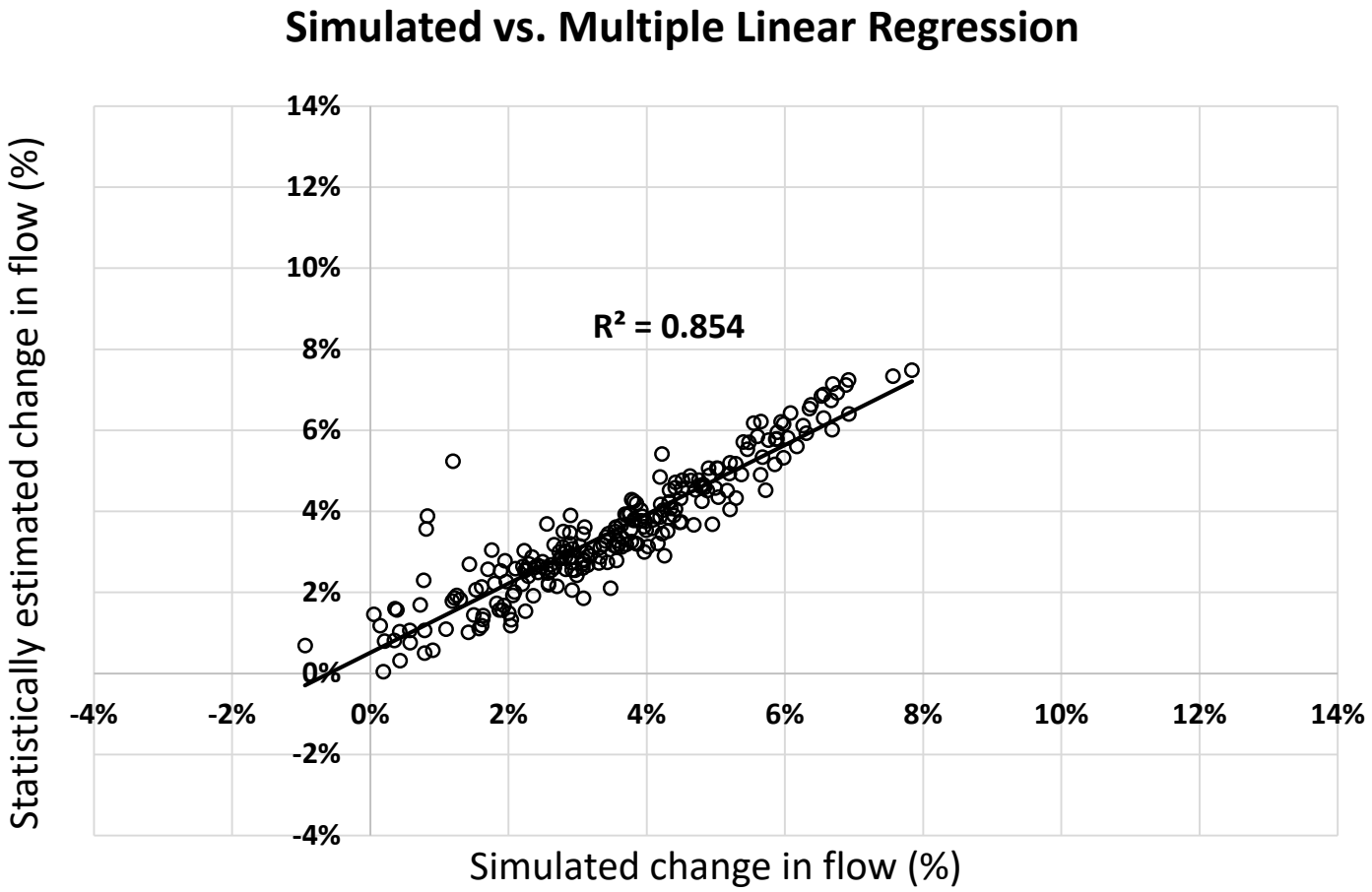
Flow response (2025)

Water quality responses can be explained by changes in flow.
Can we explain changes in flow response?



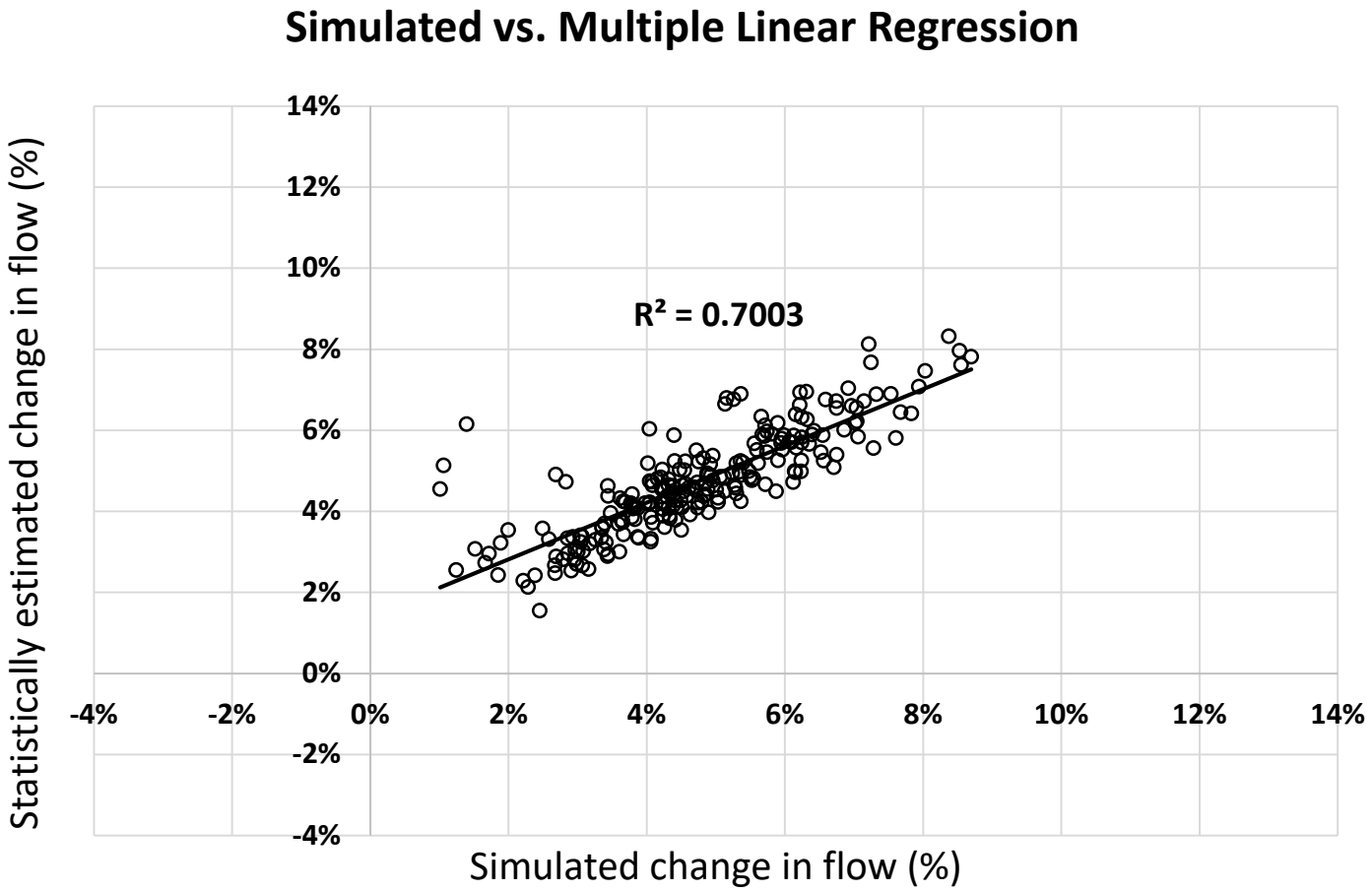
$$(\%\triangle \text{Flow}) = m_1 \times (\%\triangle \text{Rainfall}) + m_2 \times (\%\triangle \text{PET}) + c$$

Flow response (2035)



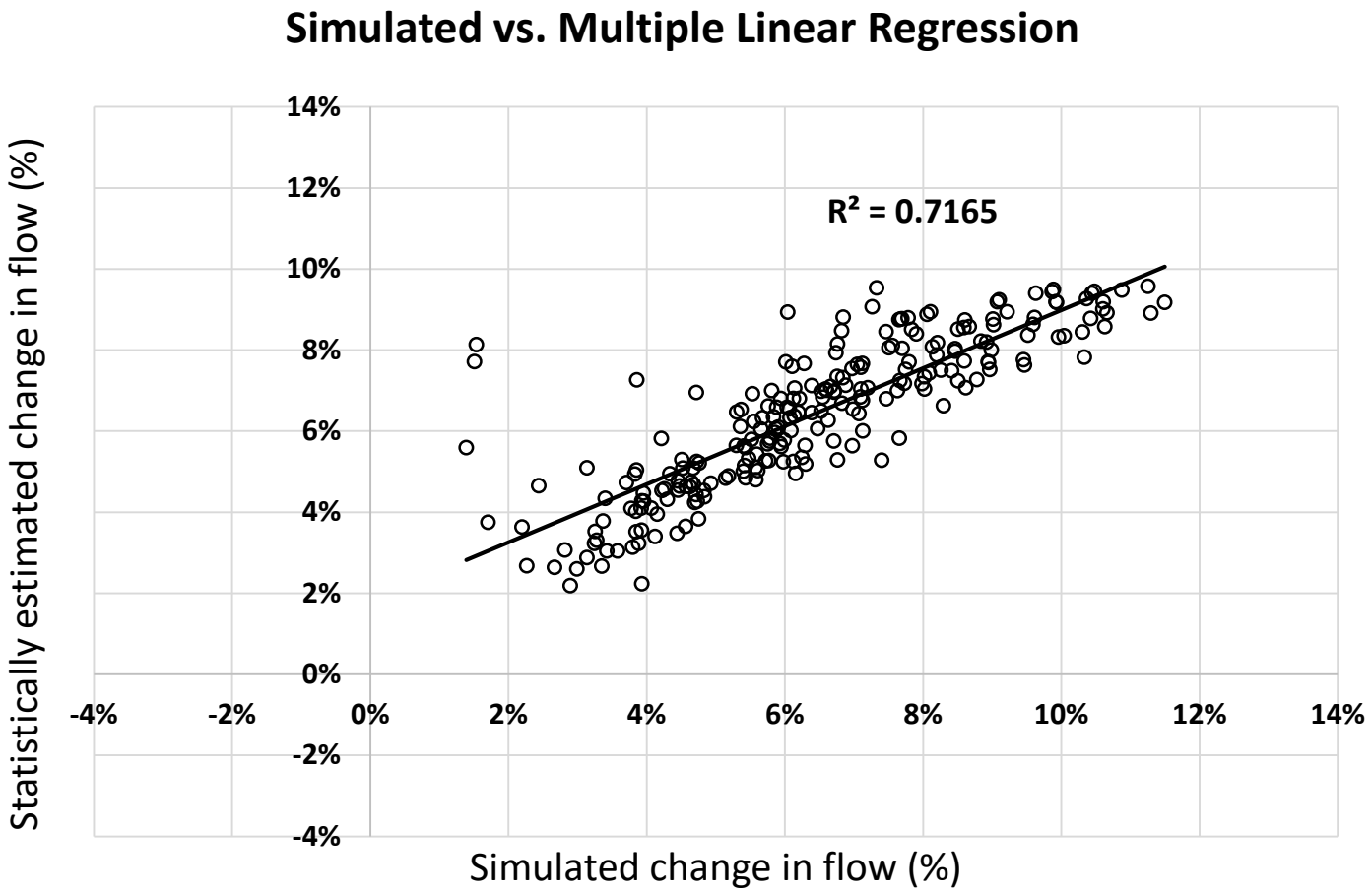
$$(\%\triangle \text{Flow}) = m_1 \times (\%\triangle \text{Rainfall}) + m_2 \times (\%\triangle \text{PET}) + c$$

Flow response (2045)



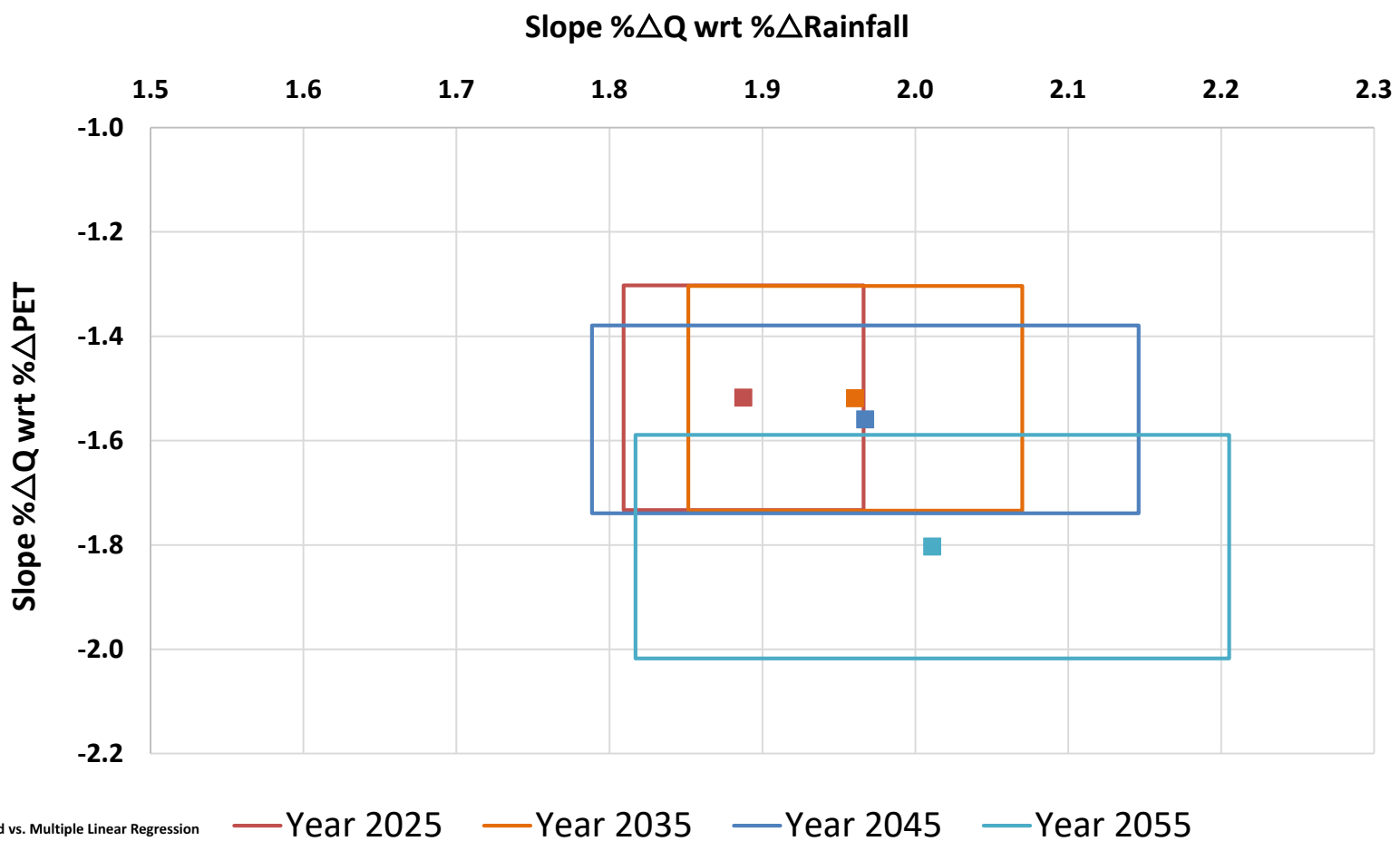
$$(\%\triangle \text{Flow}) = m_1 \times (\%\triangle \text{Rainfall}) + m_2 \times (\%\triangle \text{PET}) + c$$

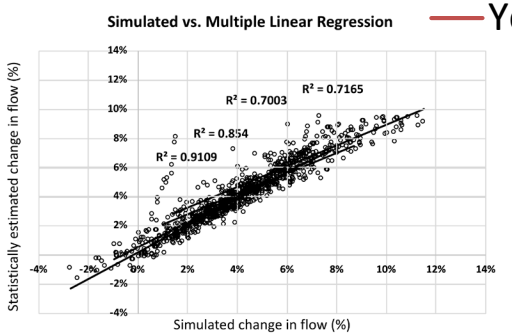
Flow response (2055)



$$(\%\triangle \text{Flow}) = m_1 \times (\%\triangle \text{Rainfall}) + m_2 \times (\%\triangle \text{PET}) + c$$

Flow response – land segments (counties)

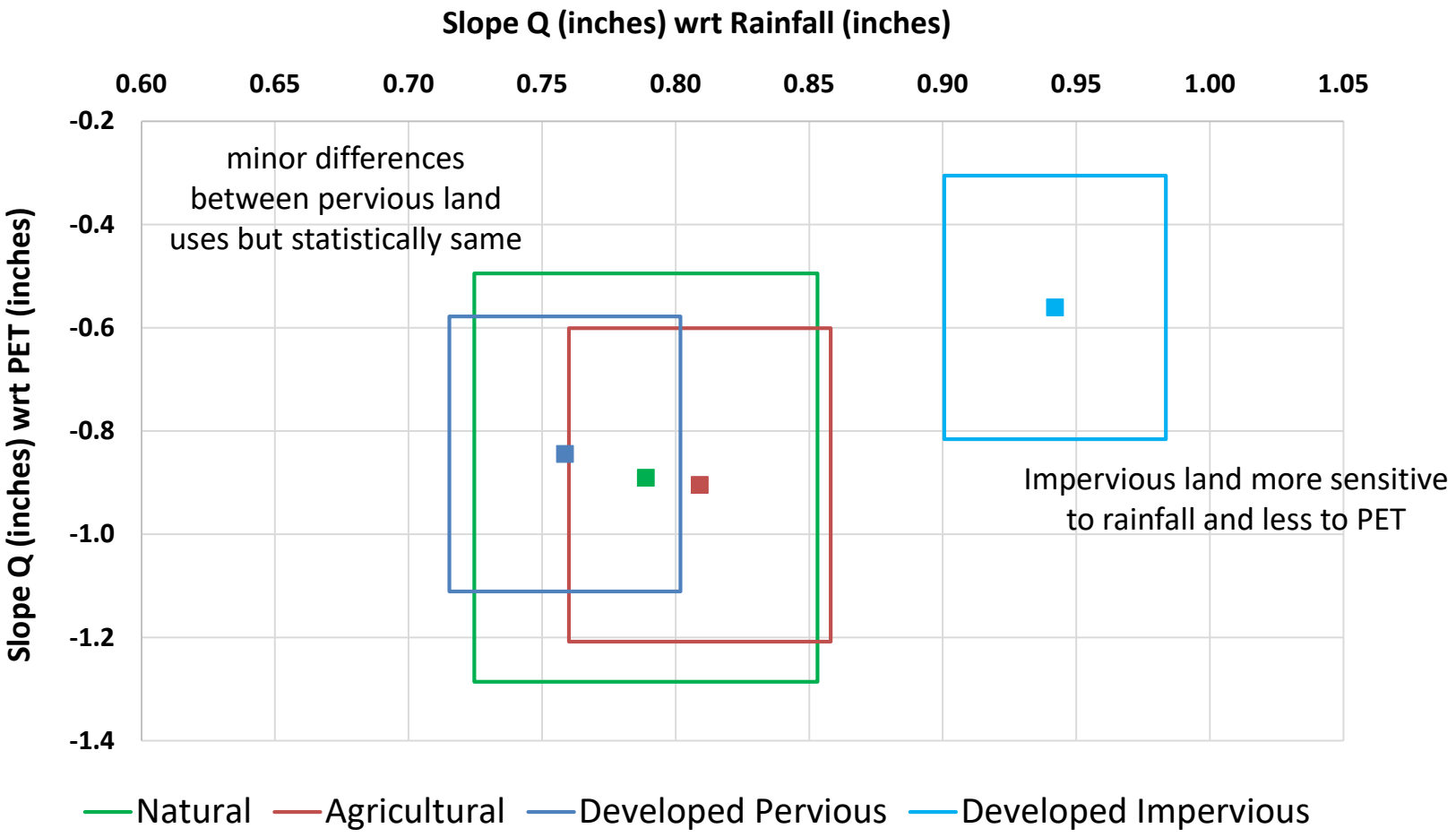




Markers show estimated slopes

Boxes show 95% confidence interval

Flow response – land uses



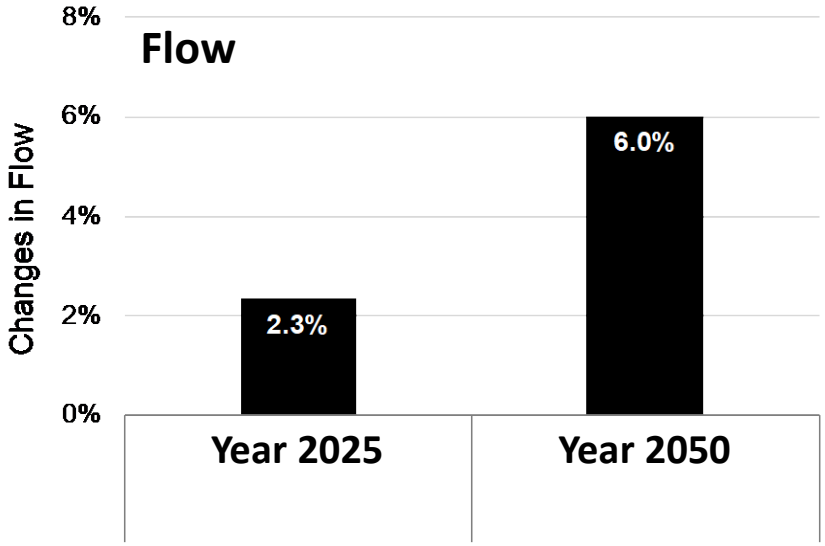
Markers show estimated slopes

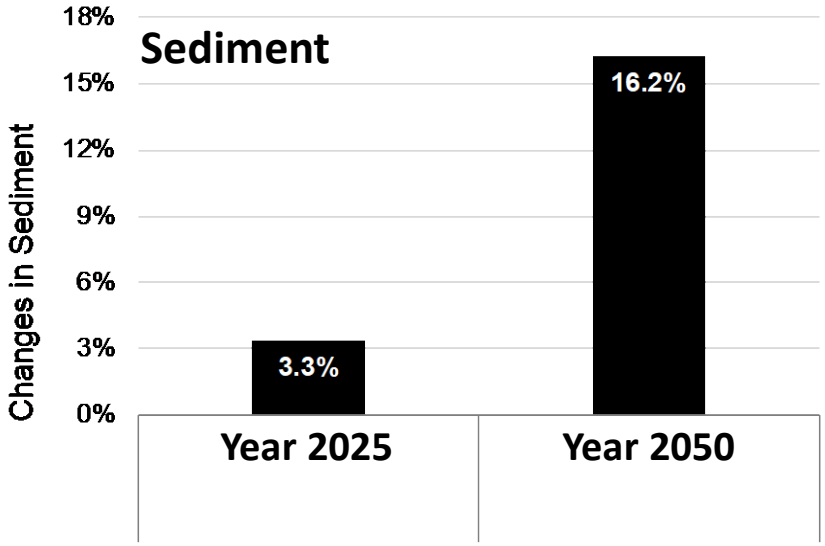
Boxes show 95% confidence interval

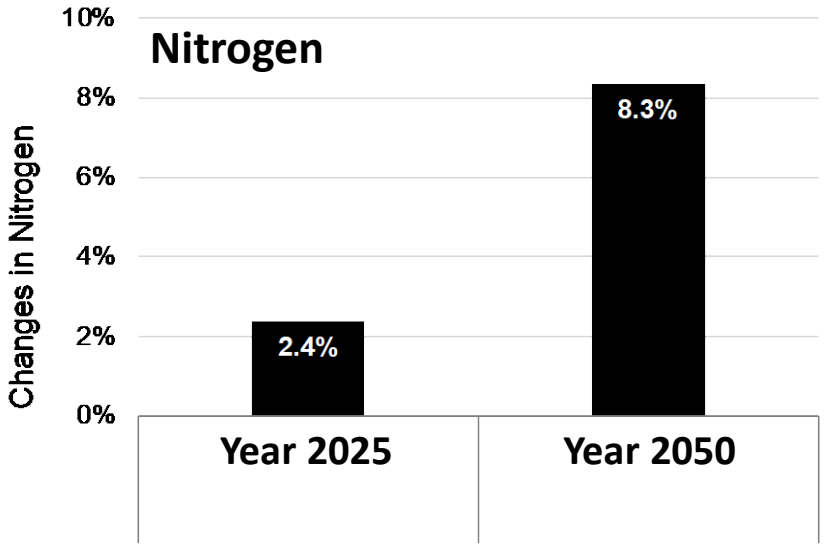
Summary

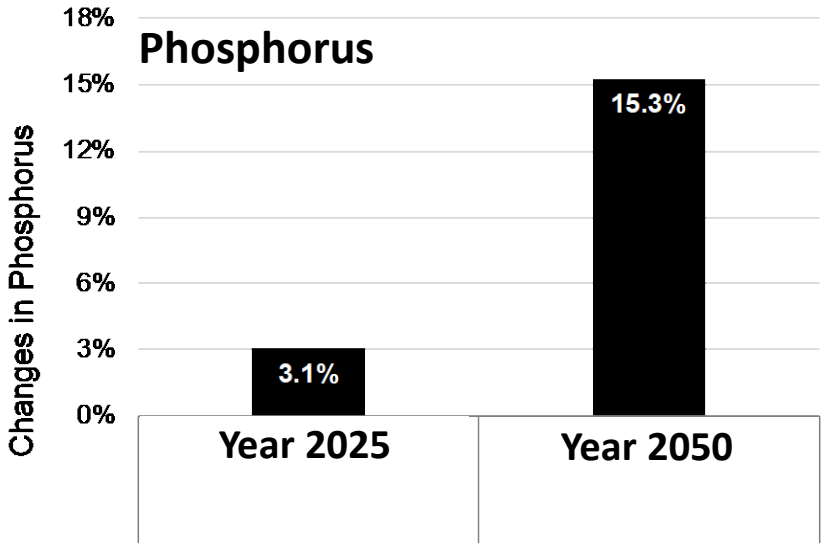
- **Wetter and warmer future climate of 2025, 2035, 2045 and 2055 resulted in incremental increases in freshwater, nutrients and sediment deliveries.**
- **Although small, but changes in land use (i.e. more development and population) further increased the nutrient and sediment deliveries.**
- **Both water quality and flow responses can be explained using abstractions of model results or simple statistical (surrogate) models as a function of △rainfall and △potential evapotranspiration.**

Summary of changes in delivery





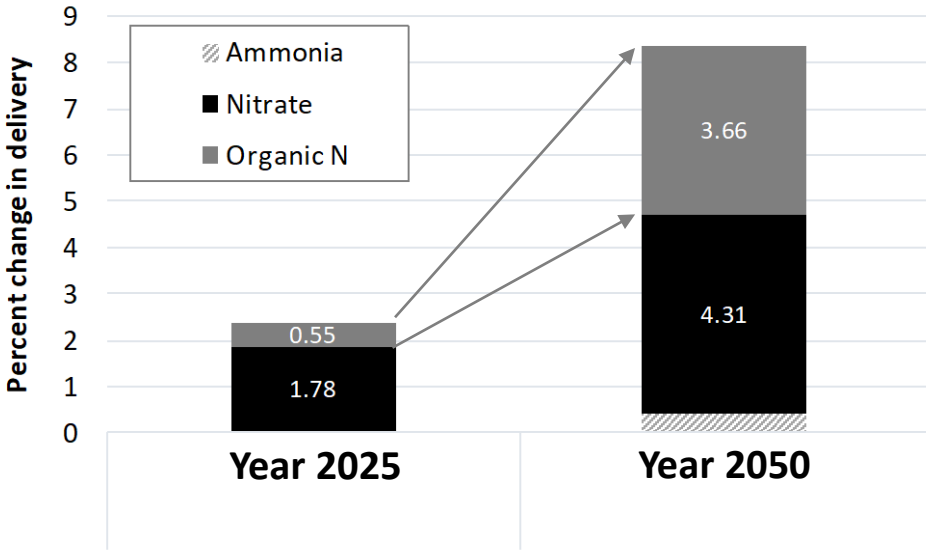




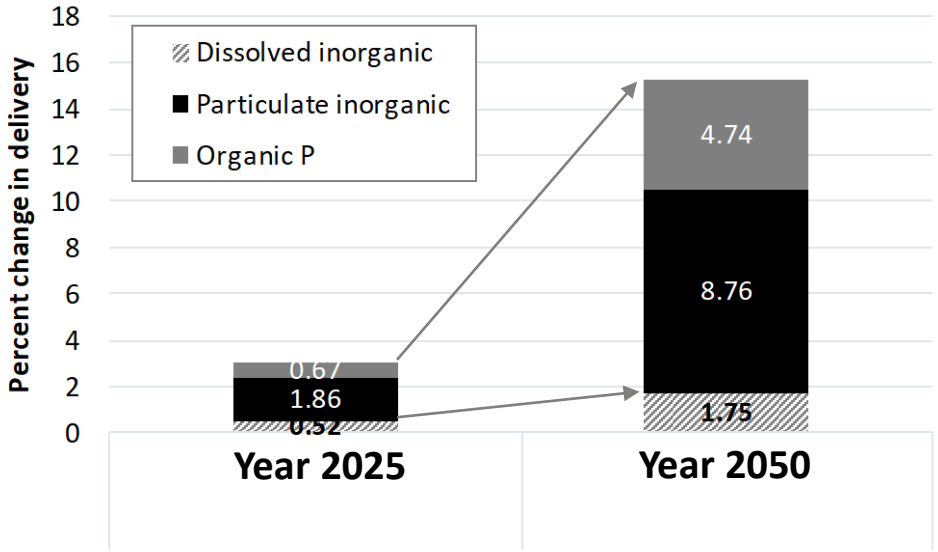
***2025 rainfall**: based on the extrapolation of long-term trends; **All Else**: median of 31-member RCP4.5 downscaled GCMs*

Nitrogen and phosphorus species

Simulated changes in nitrogen delivery



Simulated changes in phosphorus delivery

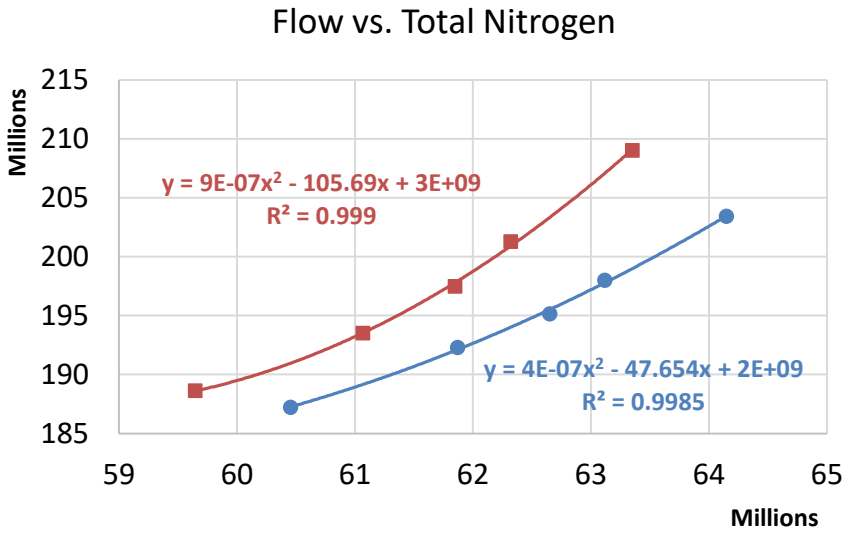


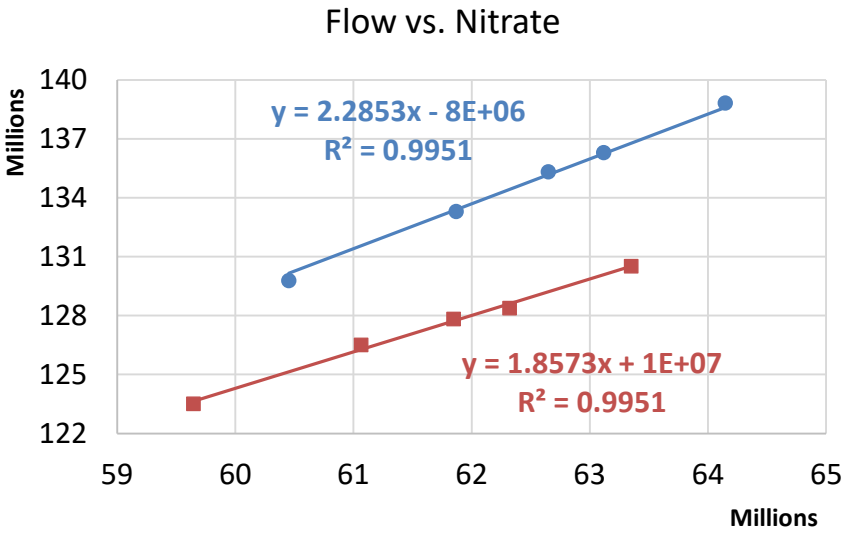
Arrows show relatively more increase in organic nitrogen as compared to inorganic.

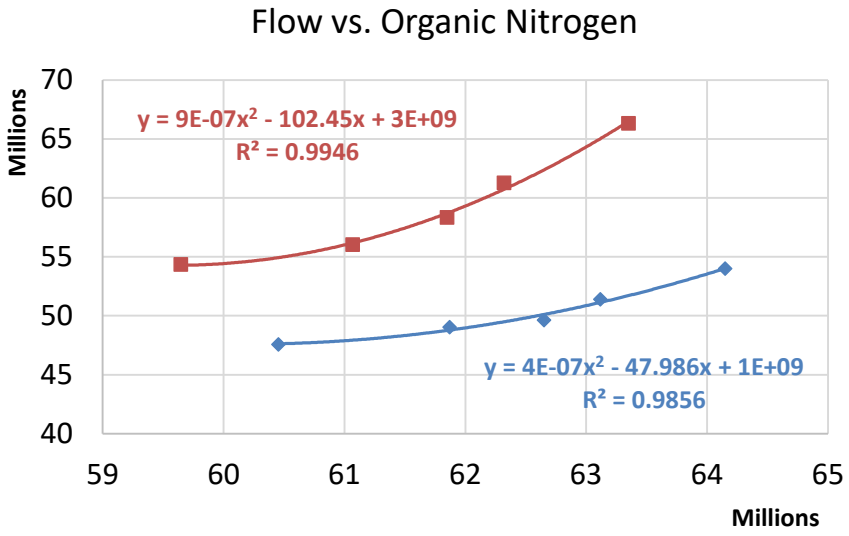
Arrows show relatively more increase in particulate phosphorus as compared to dissolved inorganic phosphorus.

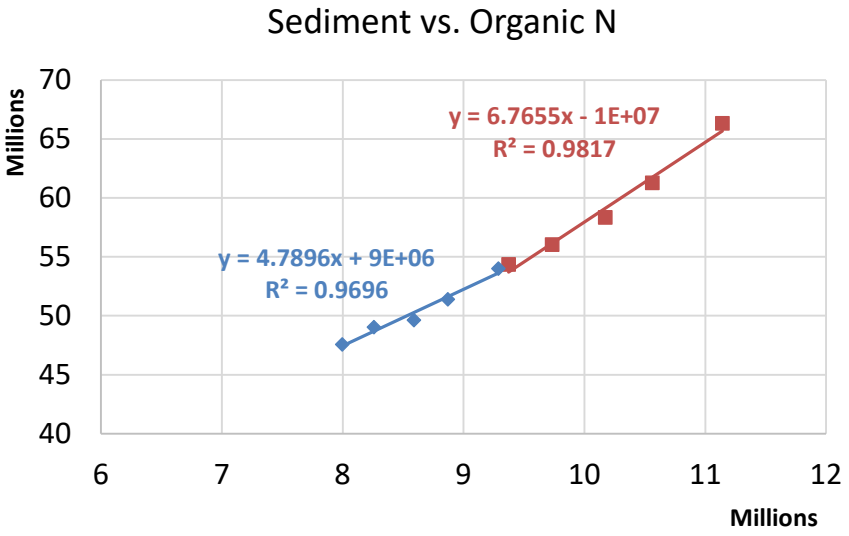
Nitrogen response

2017 climate assessment (WIP2 LOE)
2019 refined climate assessment (Planning Target LOE)





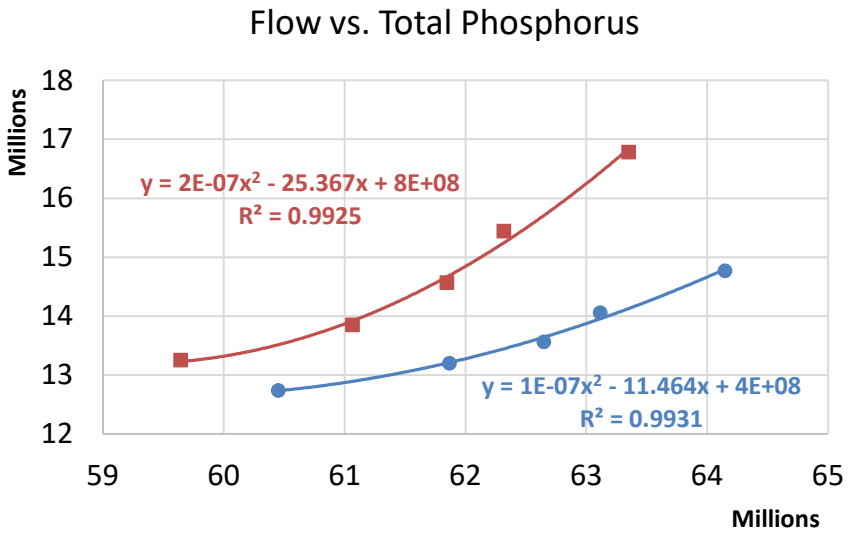


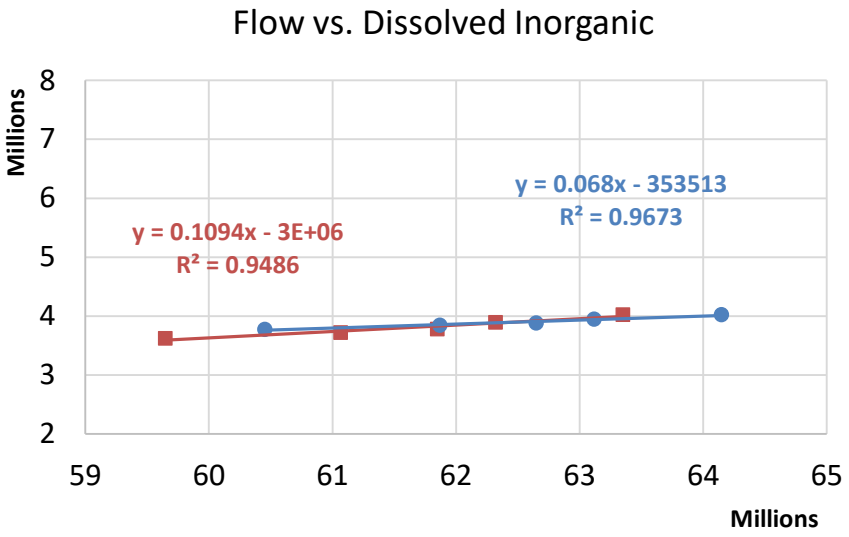


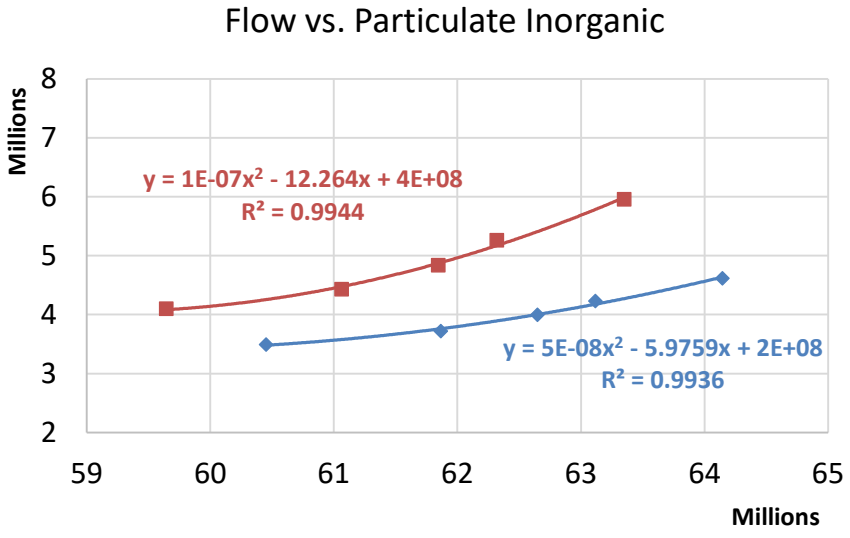
Units – Flow in ac-ft; Nitrogen/Phosphorus in lbs; Sediment in tons.

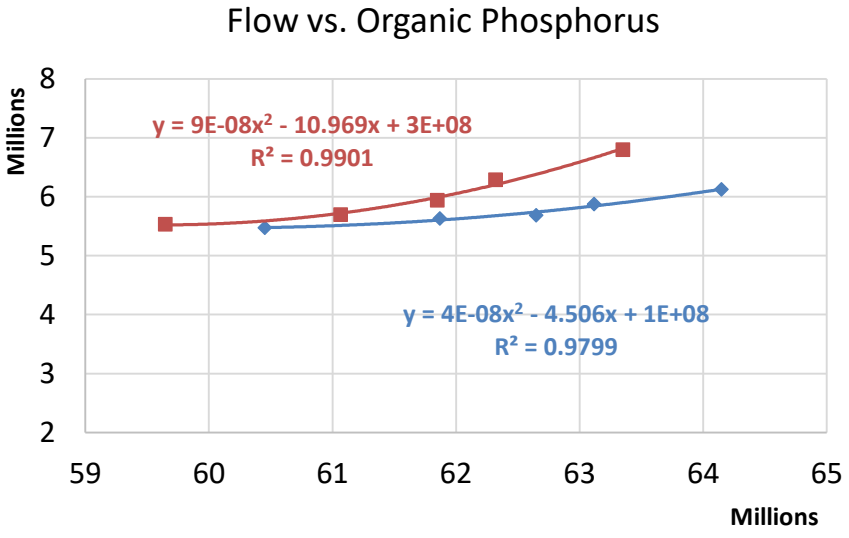
Phosphorus response

2017 climate assessment (WIP2 LOE)
2019 refined climate assessment (Planning Target LOE)

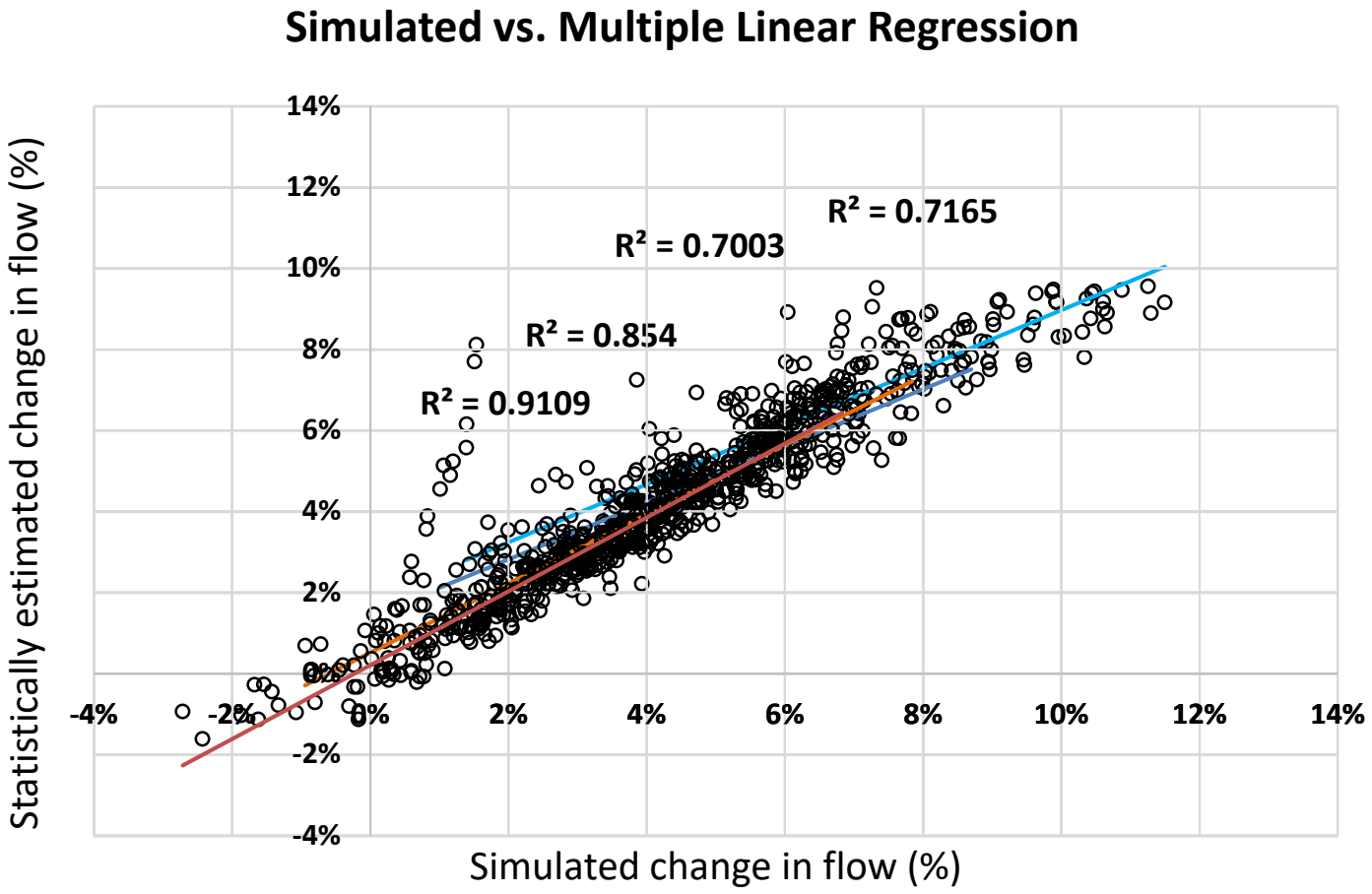




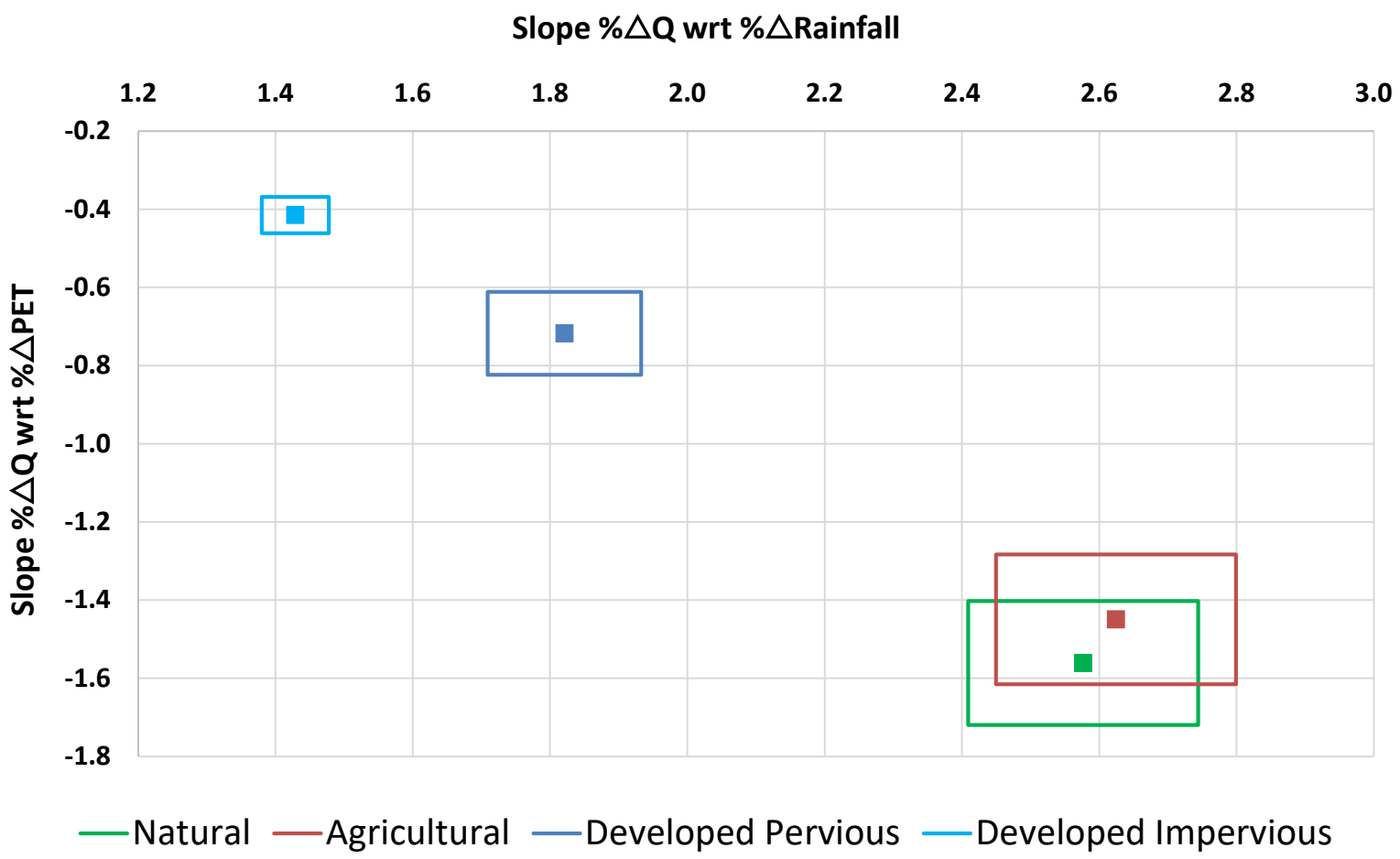




Units – Flow in ac-ft; Nitrogen/Phosphorus in lbs; Sediment in tons.


Simulated vs. Multiple Linear Regression
Statistically estimated change in flow (%)
Simulated change in flow (%)
R² = 0.7165
R² = 0.7003
R² = 0.854
R² = 0.9109
14%
12%
10%
8%
6%
4%
2%
0%
-2%
-4%
-4%
-2%
0%
2%
4%
6%
8%
10%
12%
14%

Flow response – land uses



Markers show estimated slopes

Boxes show 95% confidence interval