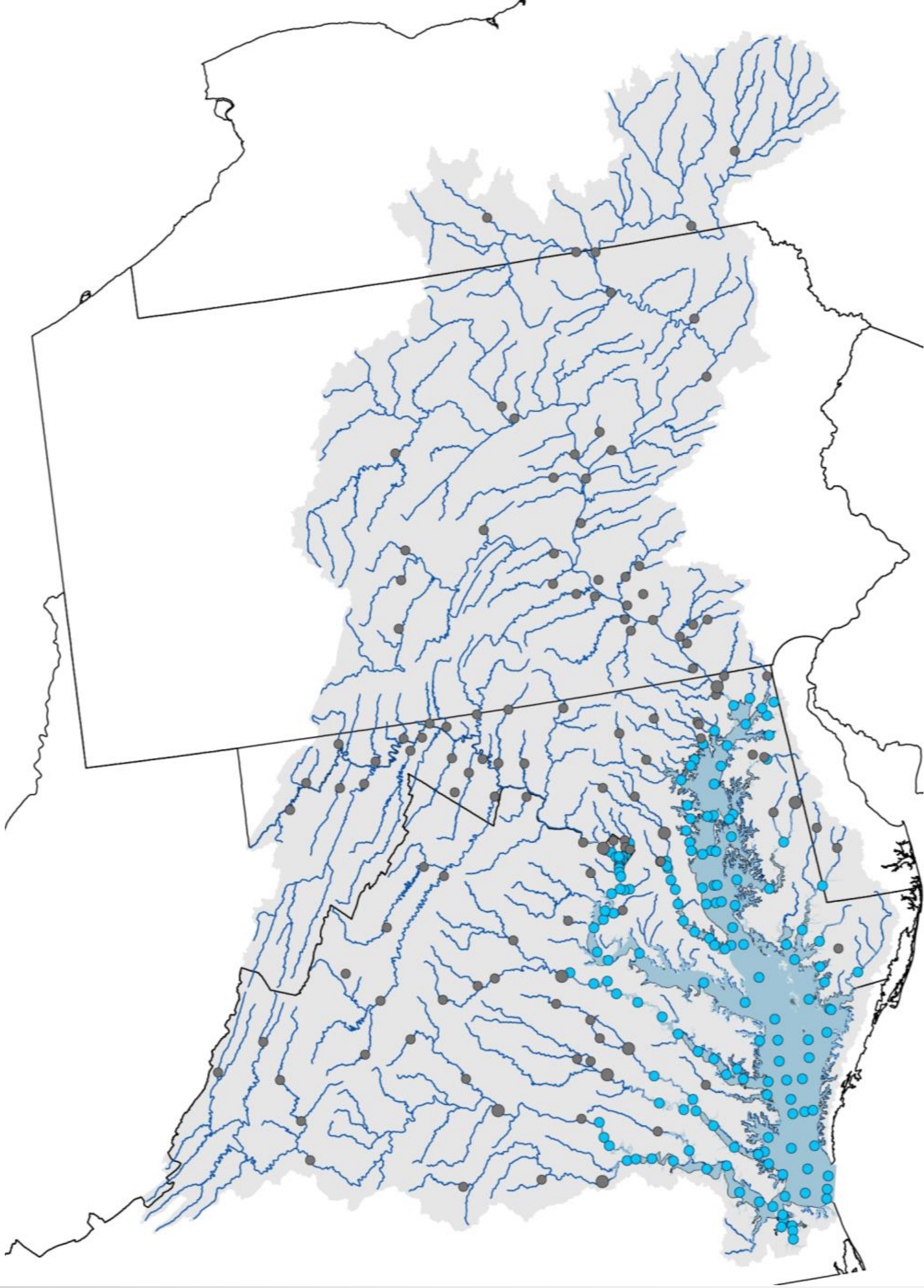
Nontidal and Tidal Nutrient Trends:
An exploration of monitoring data

October 25th 2023

Objective: to compare long-term monitored total nitrogen and total phosphorus changes in tidal and nontidal Chesapeake Bay stations[1].



A collaborative analysis team:

- Chris Mason, James Colgin, Alex Soroka, and Doug Moyer (USGS):
  NTN load & trend computation and analysis
- Rebecca Murphy and Qian Zhang (UMCES/CBP), Mukhtar Ibrahim (MWCOG), Renee Karrh (MDDNR), and Mike Lane (ODU)
  Tidal trend computation and analysis
- Kaylyn Gootman (EPA), Breck Sullivan (USGS), and Alex Gunnerson (CRC):
  ITAT leadership
- Jimmy Webber, John Clune, and Alex Soroka (USGS):
  SIMPLE team

These slides were originally presented to ITAT on December 7th 2022

[1] This presentation is based on results available in 2021. It has not been updated with the most recent trend results (through water year 2022).

A comparison of nontidal nutrient trends and tidal responses can help inform management activities

There are numerous physical, chemical, and biological factors that influence Bay water quality, including effects of river flows, extreme weather events, and watershed nutrient loads.

After accounting for variation in freshwater flow, nutrient improvements in the Bay were explained by reductions in watershed river load and point source nutrient discharges (Murphy and others, 2022).

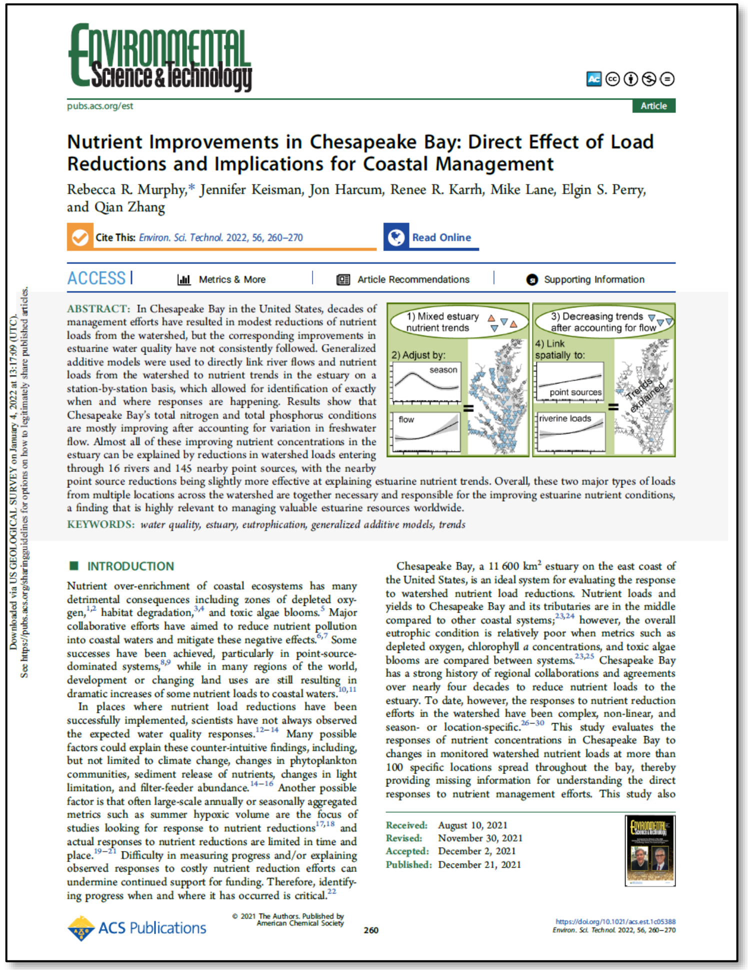
A continued evaluation of nontidal nutrient trends and tidal responses can help inform watershed management activities and evaluate their effects.

How do tidal and nontidal trends differ…

...by region/tributary?

...by constituent (N v P, total v dissolved)?

…over time (long-term vs short-term changes)?



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Nutrient Improvements in Chesapeake Bay: Direct Effect of Load Reductions and Implications for Coastal Management

Rebecca R. Murphy,* Jennifer Keisman, Jon Harcum, Renee R. Karrh, Mike Lane, Elgin S. Perry, and Qian Zhang

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ABSTRACT: In Chesapeake Bay in the United States, decades of management efforts have resulted in modest reductions of nutrient loads from the watershed, but the corresponding improvements in estuarine water quality have not consistently followed. Generalized additive models were used to directly link river flows and nutrient loads from the watershed to nutrient trends in the estuary on a station-by-station basis, which allowed for identification of exactly when and where responses are happening. Results show that Chesapeake Bay's total nitrogen and total phosphorus conditions are mostly improving after accounting for variation in freshwater flow. Almost all of these improving nutrient concentrations in the estuary can be explained by reductions in watershed loads entering through 16 rivers and 145 nearby point sources, with the nearby point source reductions being slightly more effective at explaining estuarine nutrient trends. Overall, these two major types of loads from multiple locations across the watershed are together necessary and responsible for the improving estuarine nutrient conditions, a finding that is highly relevant to managing valuable estuarine resources worldwide.

KEYWORDS: water quality, estuary, eutrophication, generalized additive models, trends

INTRODUCTION

Nutrient over-enrichment of coastal ecosystems has many detrimental consequences including zones of depleted oxygen,[1,2] habitat degradation,[3,4] and toxic algae blooms.[5] Major collaborative efforts have aimed to reduce nutrient pollution into coastal waters and mitigate these negative effects.[6,7] Some successes have been achieved, particularly in point-source-dominated systems,[8,9] while in many regions of the world, development or changing land uses are still resulting in dramatic increases of some nutrient loads to coastal waters.[10,11]

In places where nutrient load reductions have been successfully implemented, scientists have not always observed the expected water quality responses.[12−14] Many possible factors could explain these counter-intuitive findings, including, but not limited to climate change, changes in phytoplankton communities, sediment release of nutrients, changes in light limitation, and filter-feeder abundance.[14−16] Another possible factor is that often large-scale annually or seasonally aggregated metrics such as summer hypoxic volume are the focus of studies looking for response to nutrient reductions[17,18] and actual responses to nutrient reductions are limited in time and place.[19−21] Difficulty in measuring progress and/or explaining observed responses to costly nutrient reduction efforts can undermine continued support for funding. Therefore, identifying progress when and where it has occurred is critical.[22]

Chesapeake Bay, a 11 600 km^2 estuary on the east coast of the United States, is an ideal system for evaluating the response to watershed nutrient load reductions. Nutrient loads and yields to Chesapeake Bay and its tributaries are in the middle compared to other coastal systems;[23,24] however, the overall eutrophic condition is relatively poor when metrics such as depleted oxygen, chlorophyll a concentrations, and toxic algae blooms are compared between systems.[23,25] Chesapeake Bay has a strong history of regional collaborations and agreements over nearly four decades to reduce nutrient loads to the estuary. To date, however, the responses to nutrient reduction efforts in the watershed have been complex, non-linear, and season- or location-specific.[26−30] This study evaluates the responses of nutrient concentrations in Chesapeake Bay to changes in monitored watershed nutrient loads at more than 100 specific locations spread throughout the bay, thereby providing missing information for understanding the direct responses to nutrient management efforts. This study also

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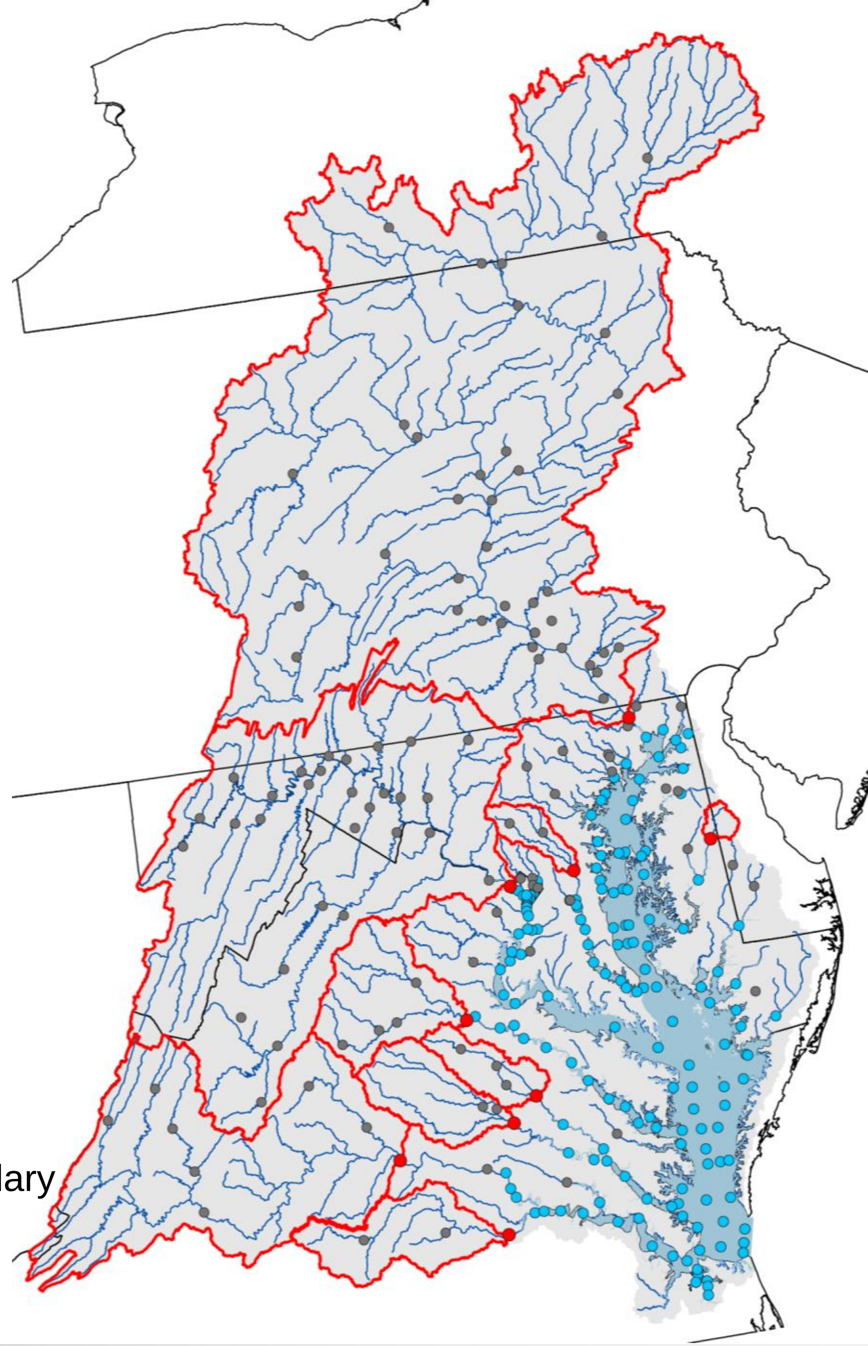
Nontidal Monitoring Network

Chris Mason, James Colgin, Alex Soroka, and Doug Moyer, (USGS)

- Nutrient and sediment concentrations, loads, and trends are computed biennially at the 123 station NTN.
- Computations are based on monthly and, for many stations, storm-targeted water-quality samples.
- Data are computed annually at 9 River Input Monitoring (RIM) stations, which have been monitored since 1985 and represent 78 percent of the Bay watershed.
- Concentrations, loads, and trends in flow-normalized data are computed using **Weighted Regressions on Time, Discharge, and Season (WRTDS**) and **WRTDS-K**.
- NTN loads and trends are computed through water year 2020 and are available online
- RIM loads and trends are computed through water year 2022 and are available online:
    - https://www.sciencebase.gov/catalog/item/62bdc7a4d34e82c548cec1e7



EXPLANATION

RIM monitoring station and boundary

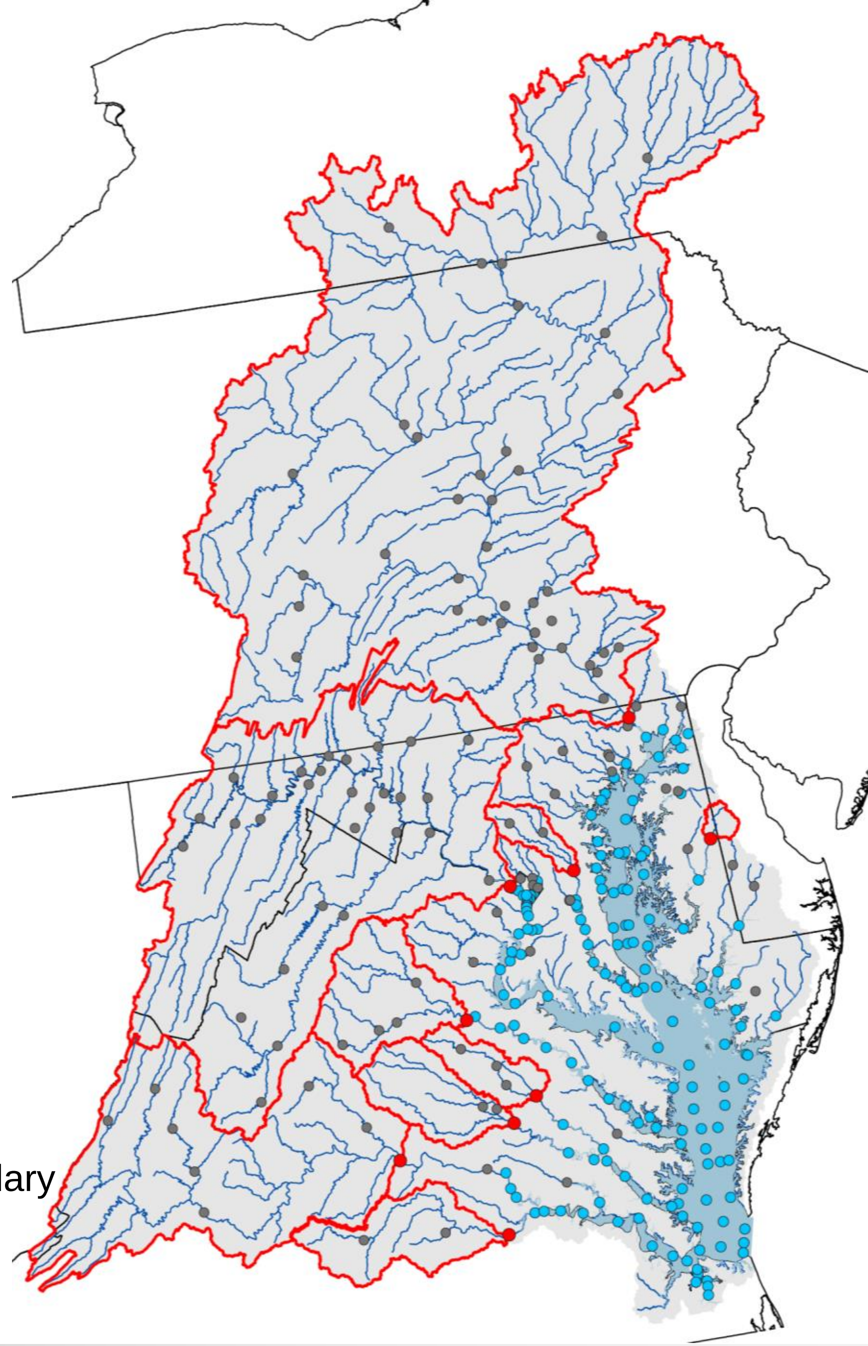
NTN monitoring station

Tidal monitoring station

Tidal Monitoring Network

Rebecca Murphy (UMCES/CBP), Mukhtar Ibrahim (MWCOG),
Renee Karrh (MDDNR, and Mike Lane (ODU)

- Nutrient, total suspended solid, dissolved oxygen, water temperature, Secchi depth, and chlorophyll a, trends are computed at more than 130 stations located throughout the Chesapeake Bay mainstem and tidal portions of numerous tributaries.
- Computations are based on water-quality data sampled monthly or bi-monthly, with many stations monitored since the mid-1980s.
- Flow-adjusted trends are computed using a **Generalized Additive Modeling (GAM)**.
- Data are computed through 2022 and are available online:
    - www.chesapeakebay.net/who/group/integrated-trends-analysis-team



EXPLANATION

RIM monitoring station and boundary

NTN monitoring station

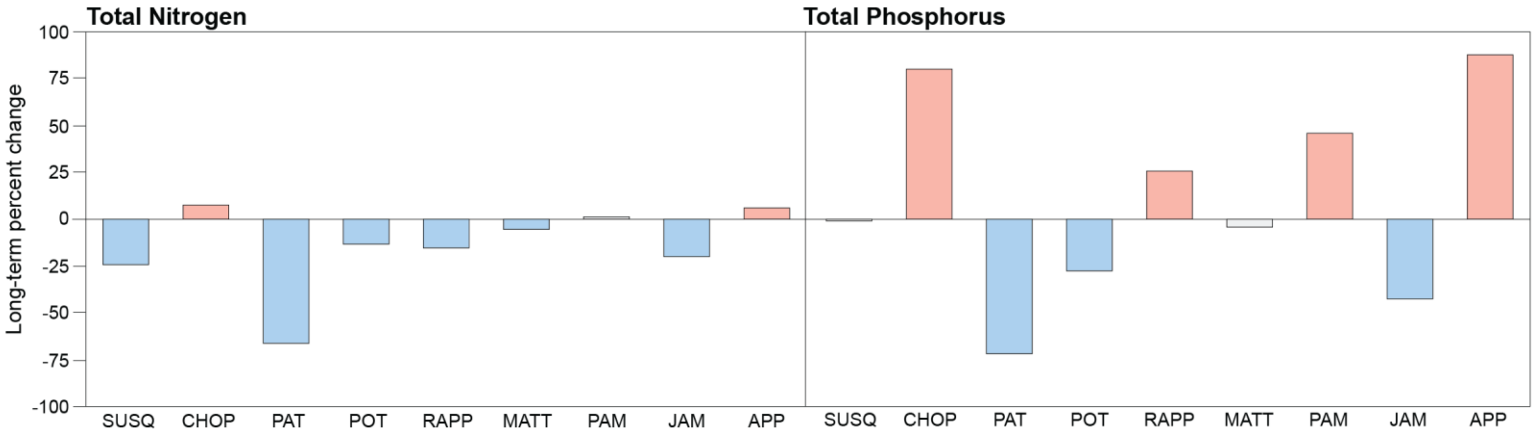
Tidal monitoring station

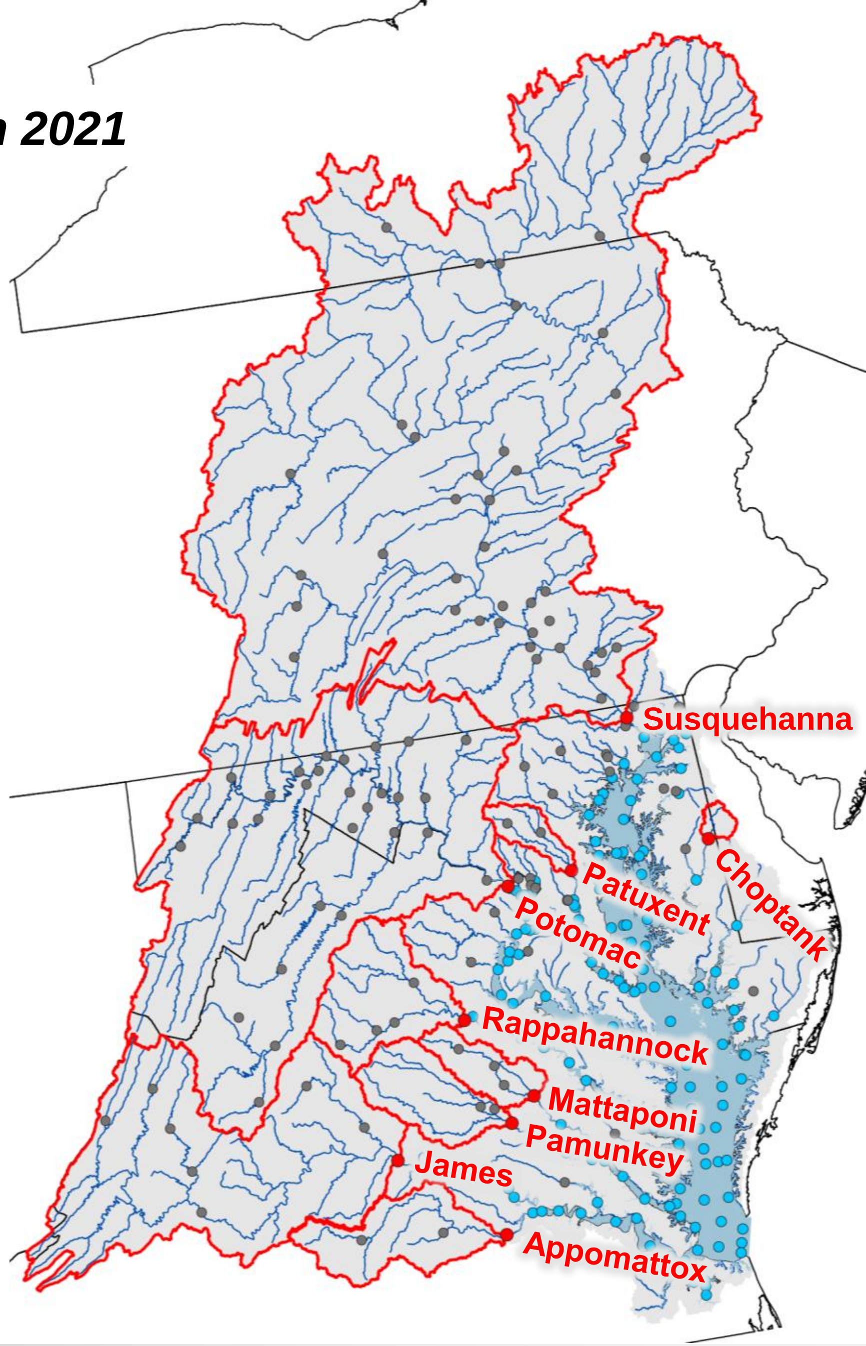
Nontidal Network

Long-Term Flow-Normalized Nutrient Load Trends, RIM Stations, Through 2021

Long-term trends improved for TN at 6 stations and for TP at 3 stations

RIM Station	TN Trend Direction	TP Trend Direction
Susquehanna	Improved	No Change
Choptank	Degraded	Degraded
Patuxent	Improved	Improved
Potomac	Improved	Improved
Rappahannock	Improved	Degraded
Mattaponi	Improved	No Change
Pamunkey	No Change	Degraded
James	Improved	Improved
Appomattox	Degraded	Degraded



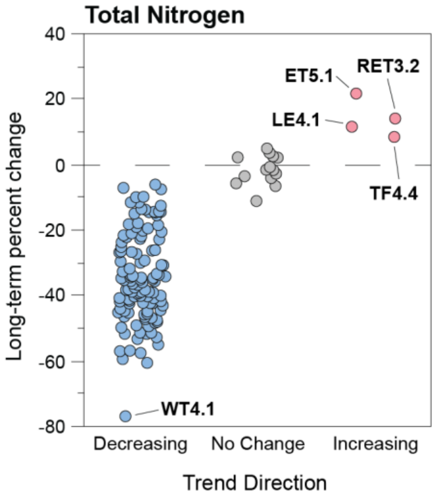


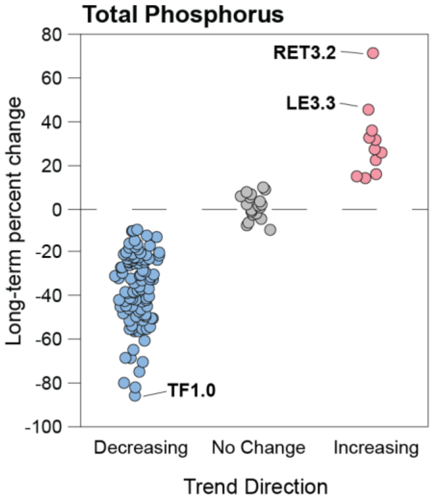
Tidal Network

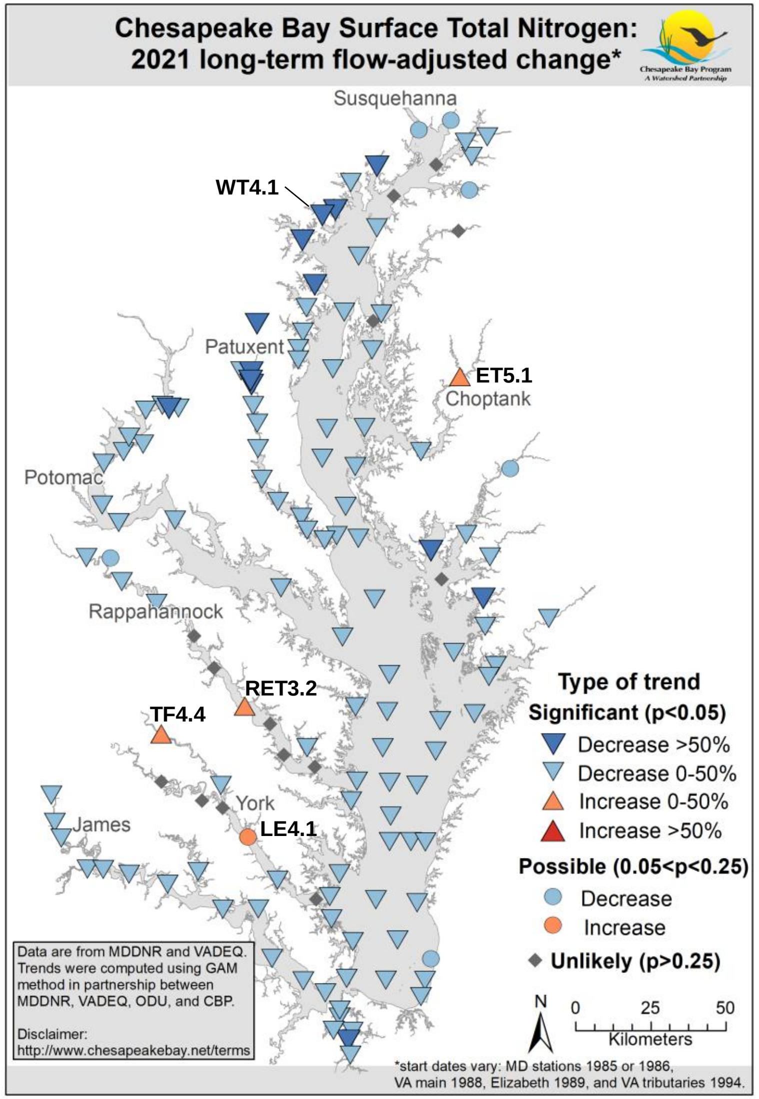
Long-Term Flow-Adjusted Surface Nutrient Concentration Trends, Through 2021

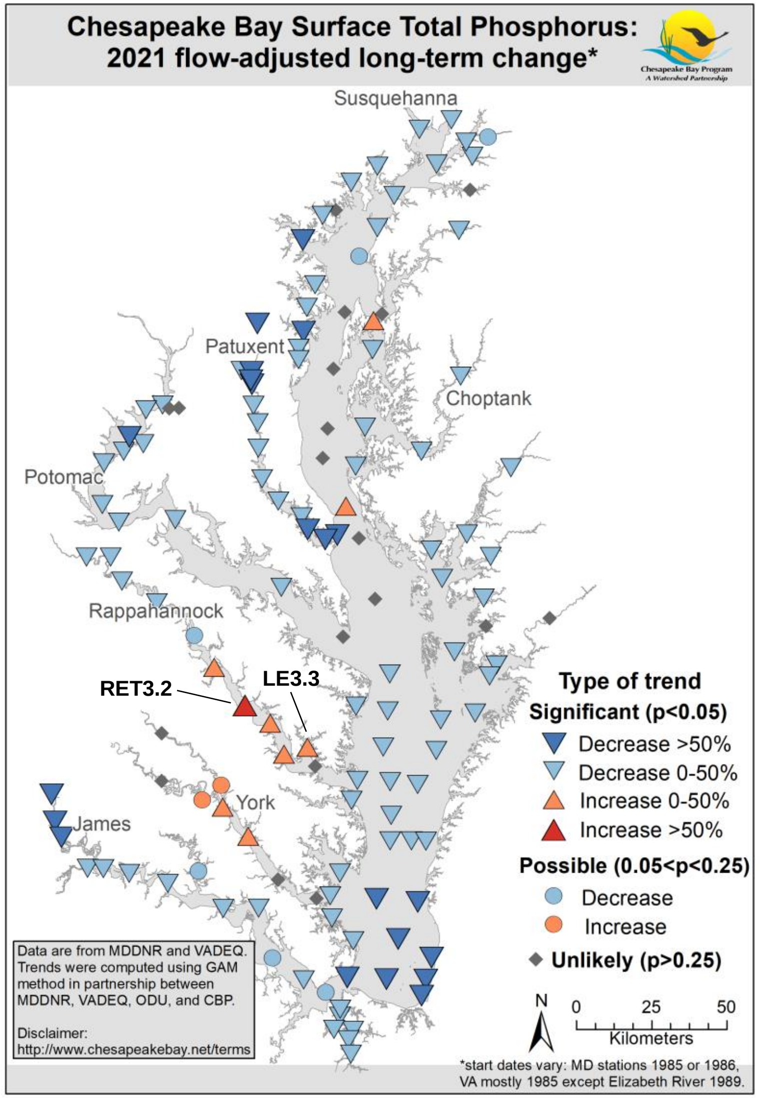
Flow-adjusted TN and TP concentrations improved over a long-term period at most stations.

Parameter	Trend Direction	Percent
Flow-Adjusted Surface TN Concentration, n = 138	Improved	87
	No Change	10
	Degraded	3
Flow-Adjusted Surface TP Concentration, n = 138	Improved	78
	No Change	14
	Degraded	8

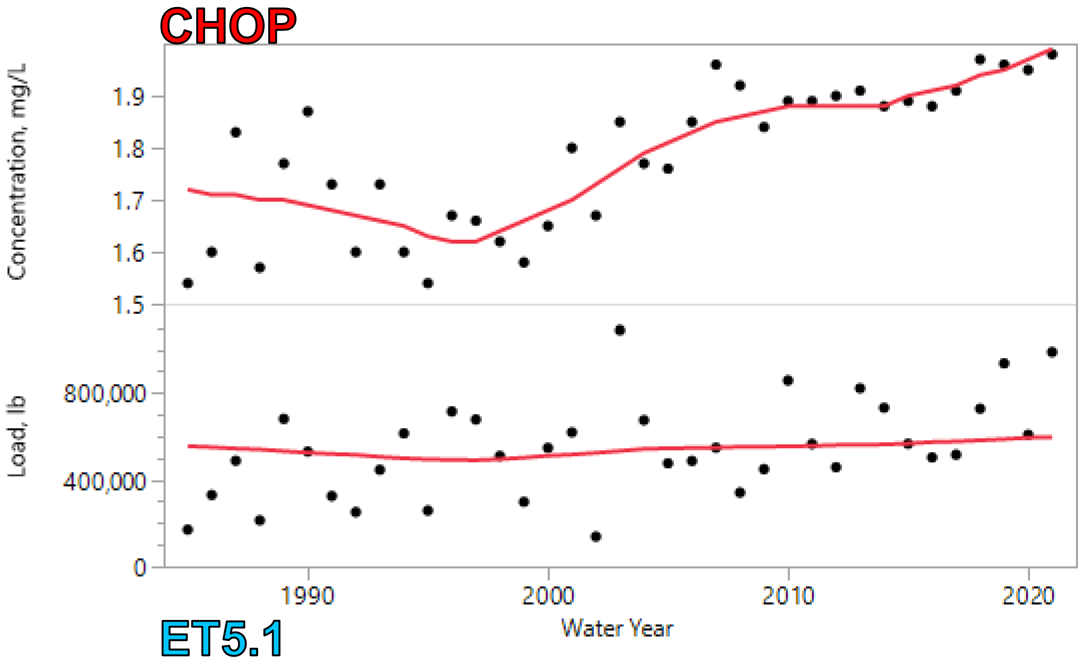


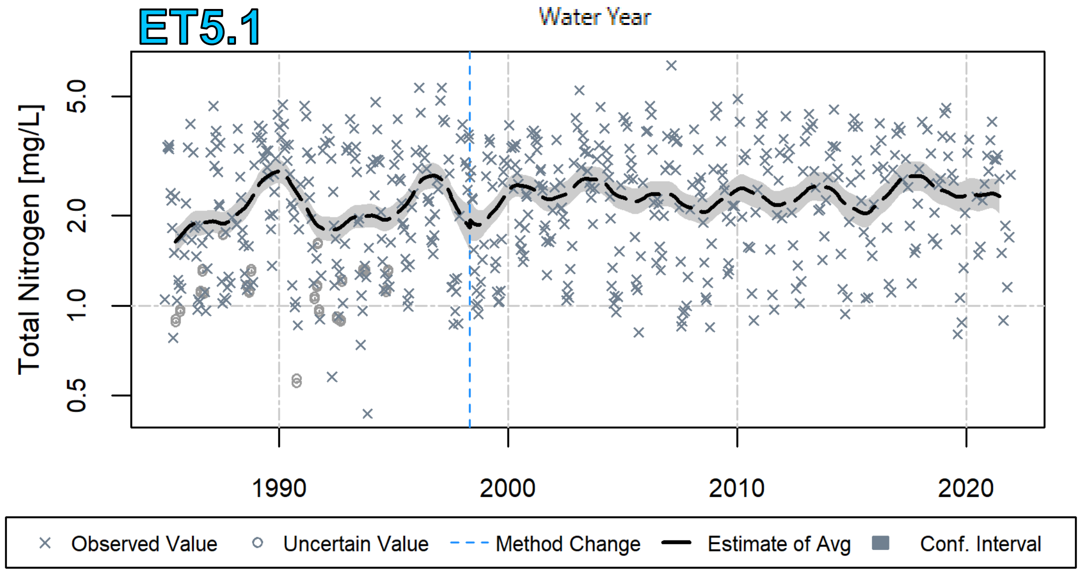


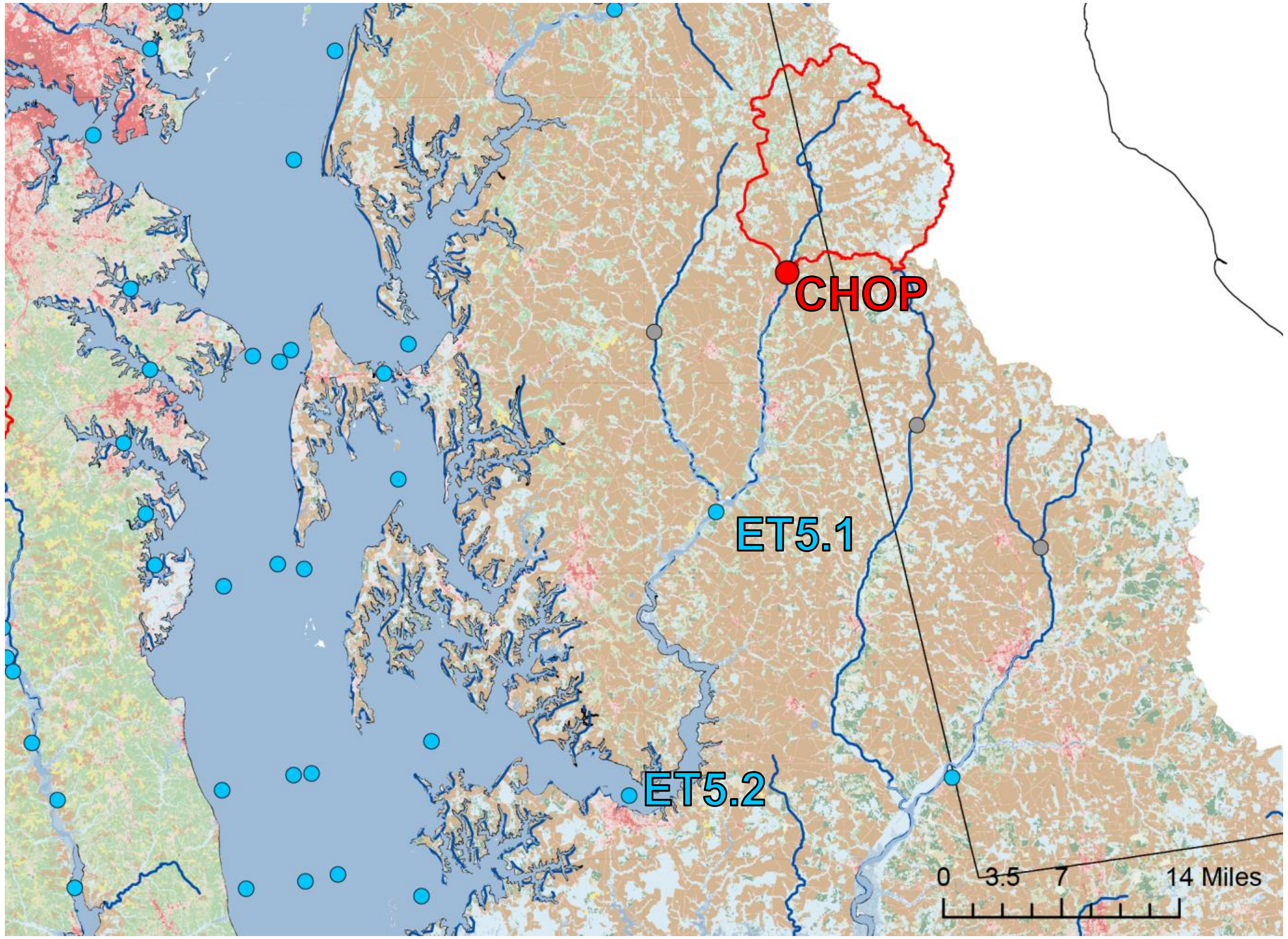




Choptank TN: RIM Increasing, Tidal Increasing







CHOP: +0.3 mg/L* (increasing) +41,900 lb** (increasing)

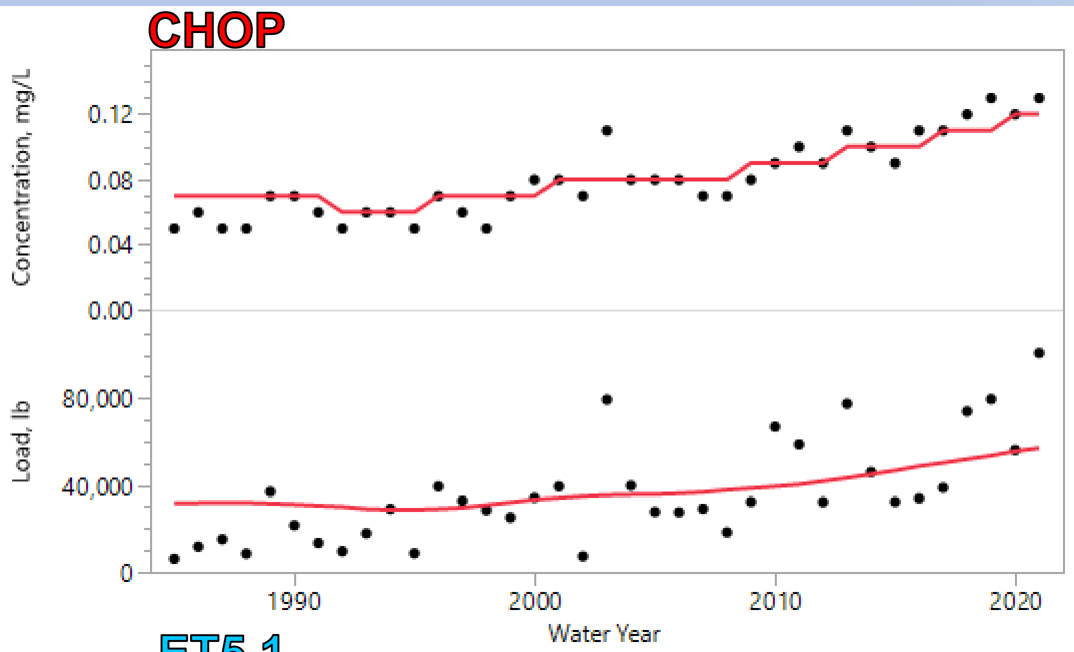
ET5.1: +0.2 mg/L*** (increasing)

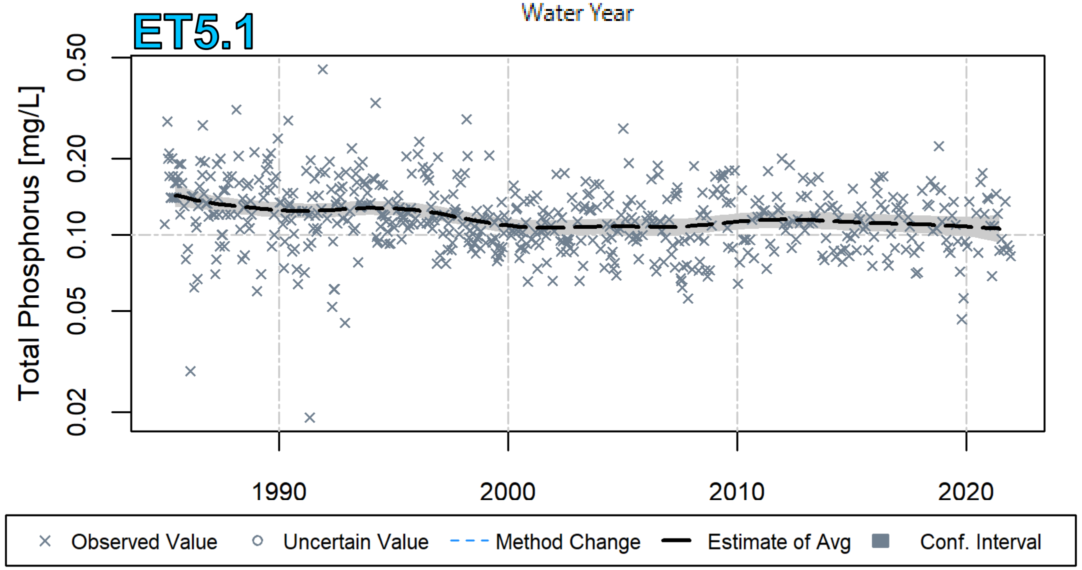
ET 5.2: -0.5 mg/L*** (decreasing)

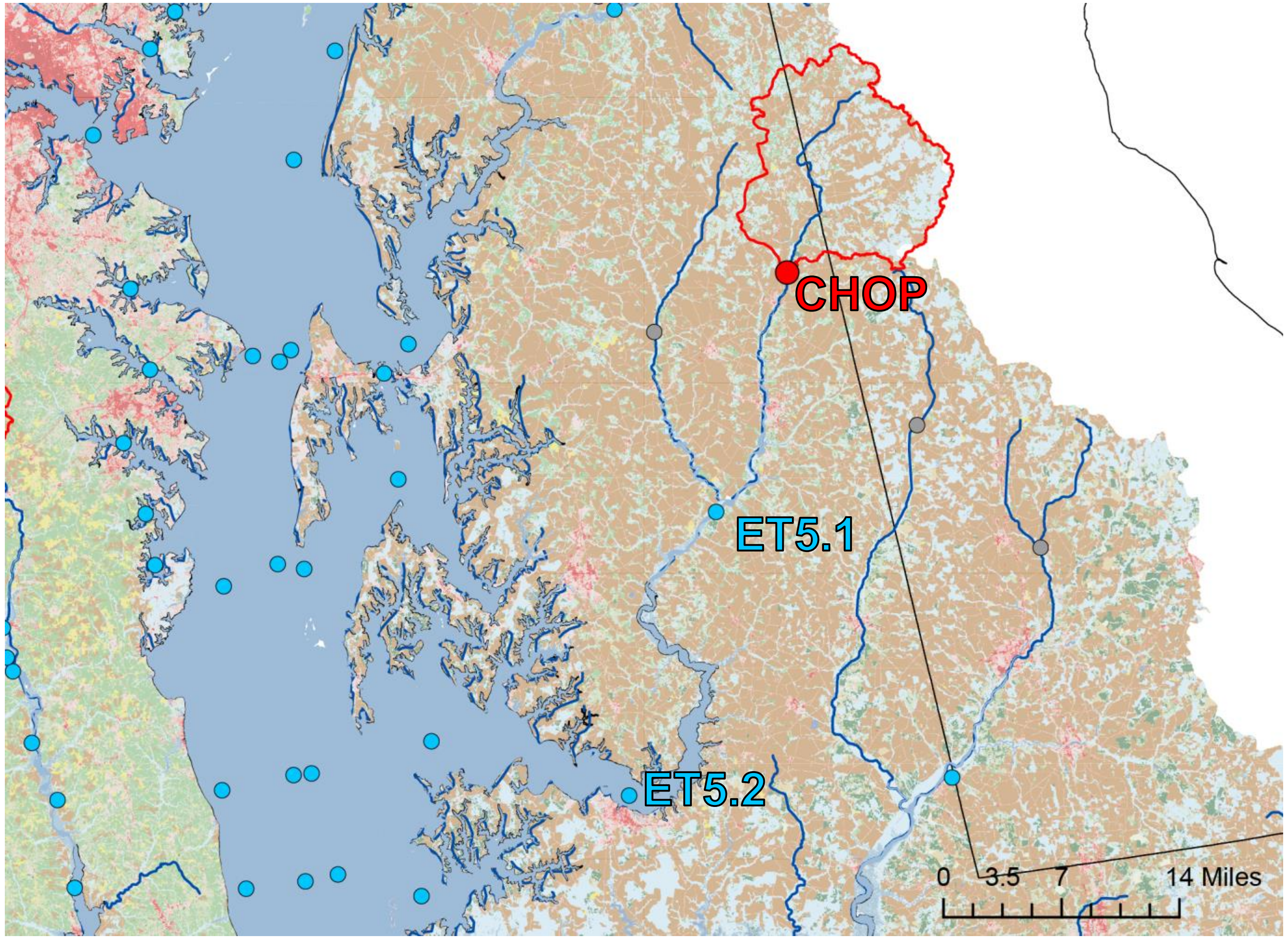
*Flow-normalized concentration (1985 – 2021) **Flow-normalized load (1985 – 2021)

***Surface flow-adjusted concentration (1985 – 2021)

Choptank TP: RIM Increasing, Tidal Decreasing



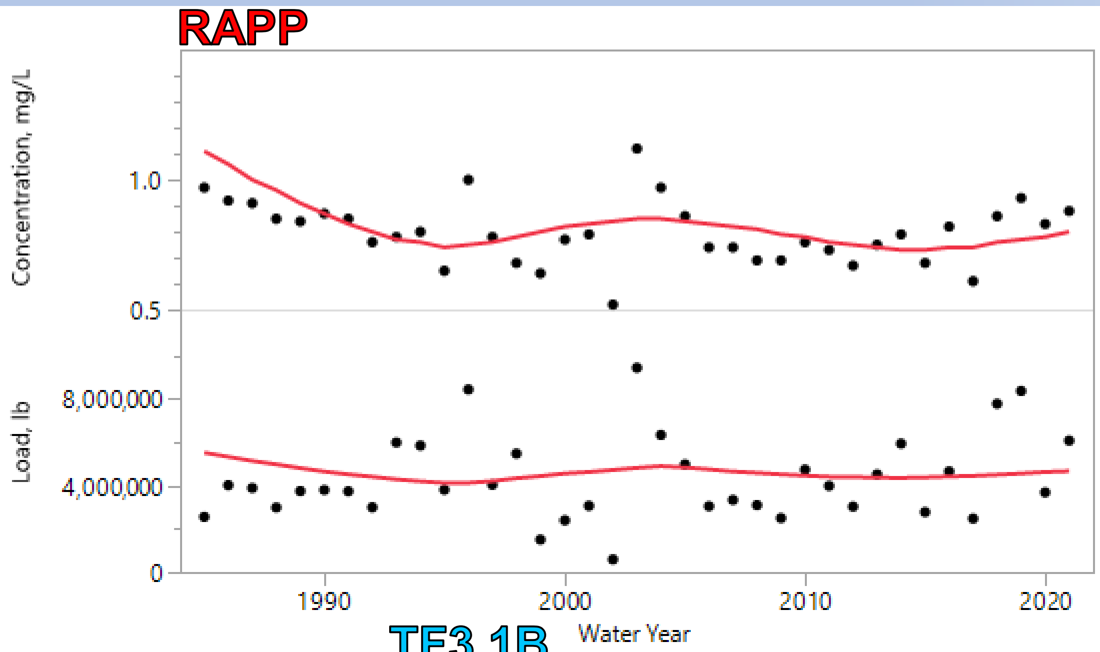


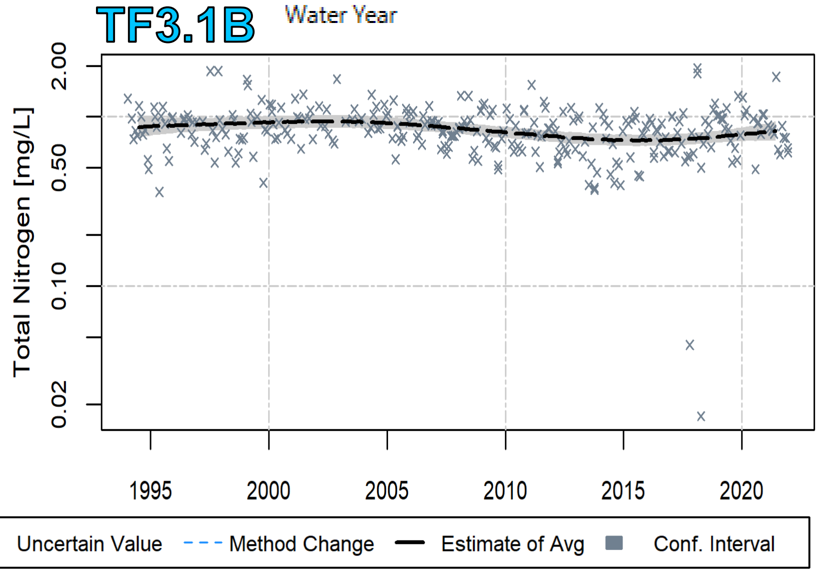


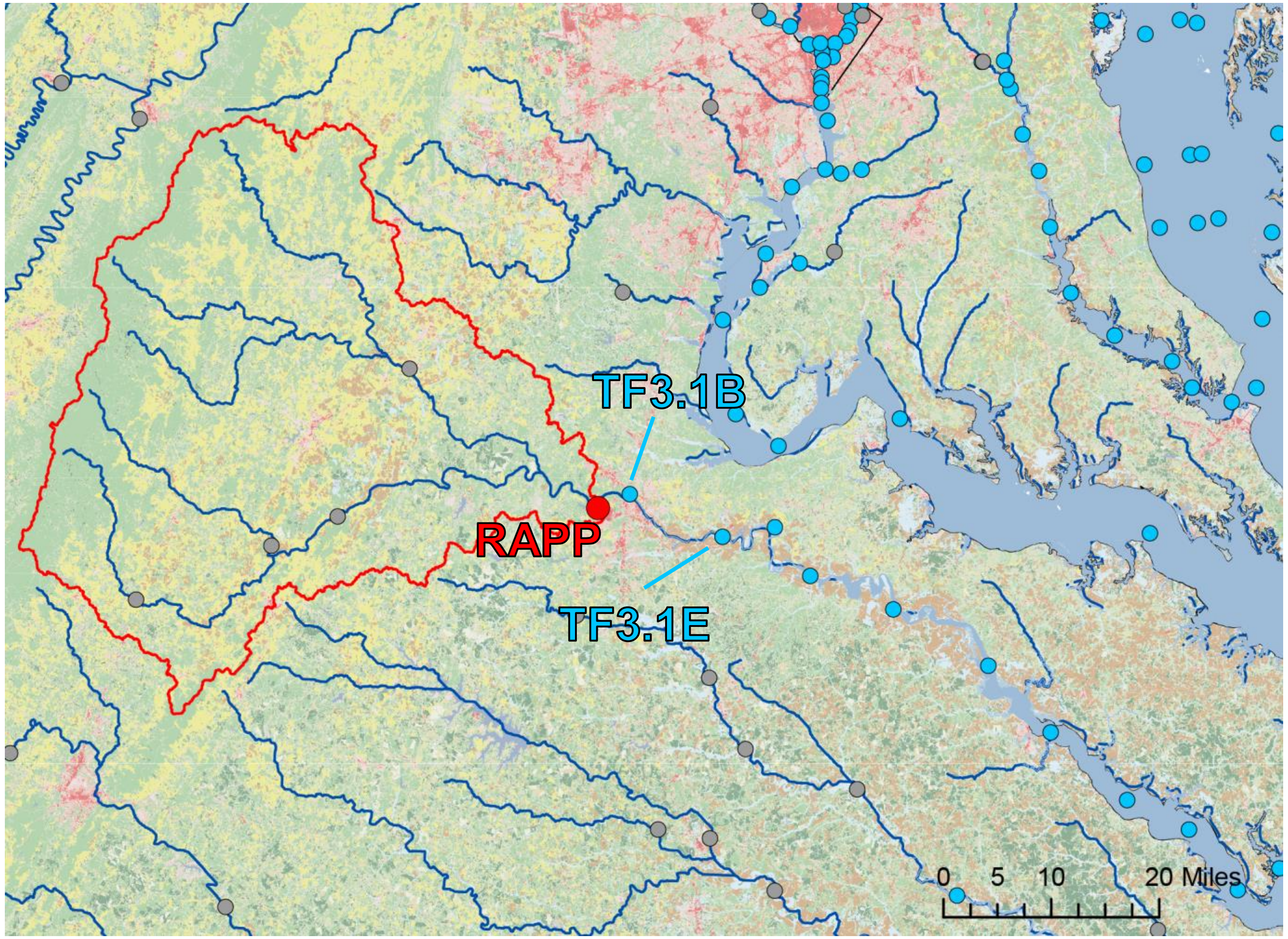
CHOP: +0.05 mg/L* (increasing) +25,400 lb** (increasing)
ET5.1: -0.3 mg/L*** (decreasing)
ET 5.2: -0.5 mg/L*** (decreasing)

*Flow-normalized concentration (1985 – 2021) **Flow-normalized load (1985 – 2021)
***Surface flow-adjusted concentration (1985 – 2021)

Rappahannock TN: RIM Decreasing, Tidal Decreasing







RAPP: -0.3 mg/L* (decreasing) -850,000 lb** (decreasing)

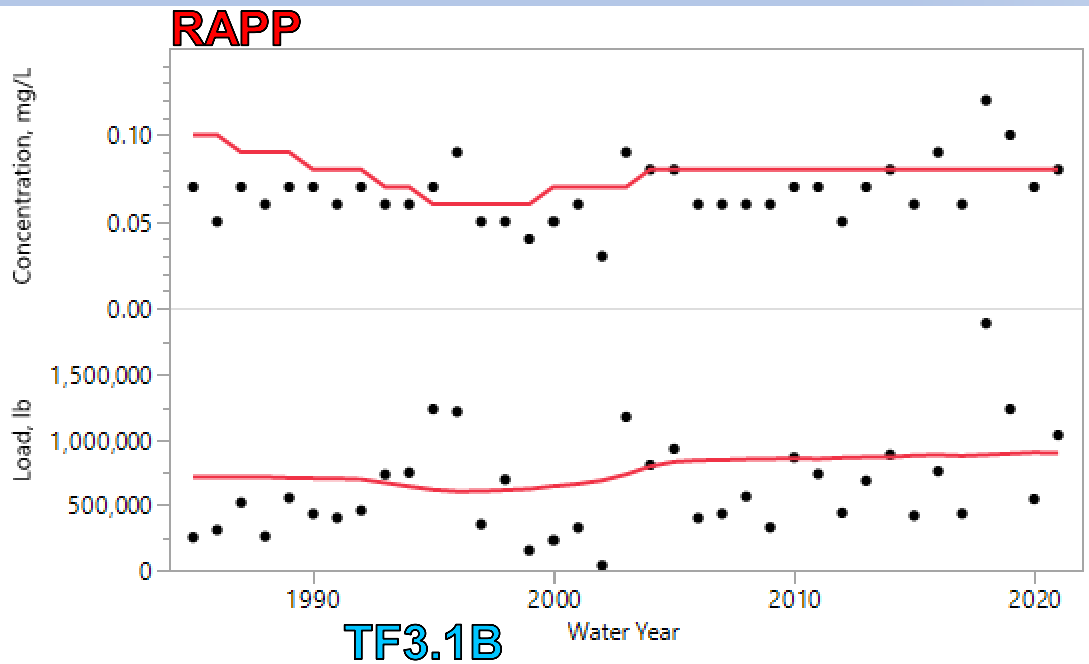
TF3.1B: -0.2 mg/L*** (decreasing)

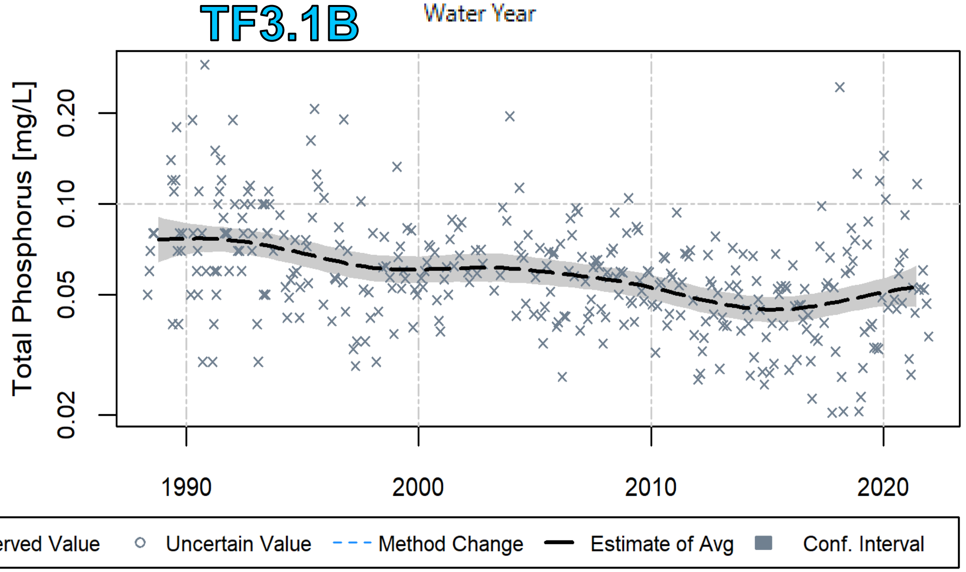
TF3.1E: -0.4 mg/L*** (decreasing)

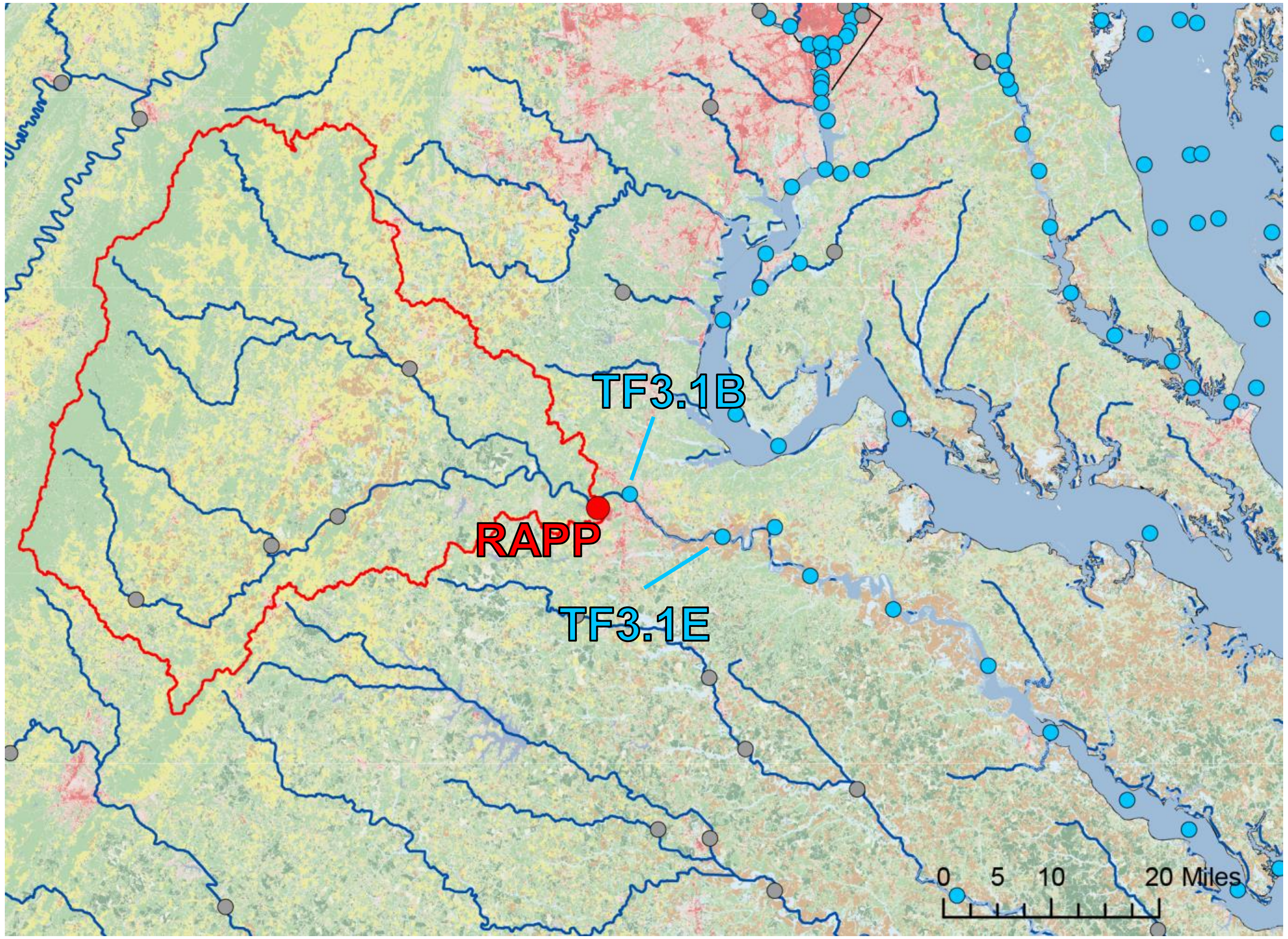
*Flow-normalized concentration (1985 – 2021) **Flow-normalized load (1985 – 2021)

***Surface flow-adjusted concentration (1994 – 2021)

Rappahannock TP: RIM Decreasing, Tidal Decreasing



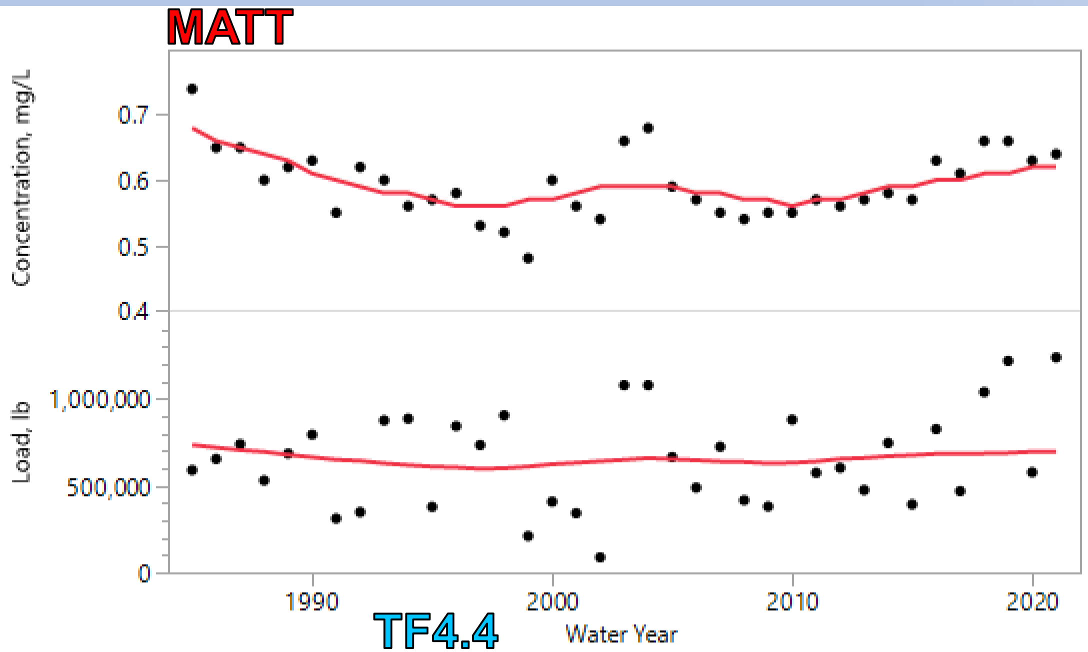


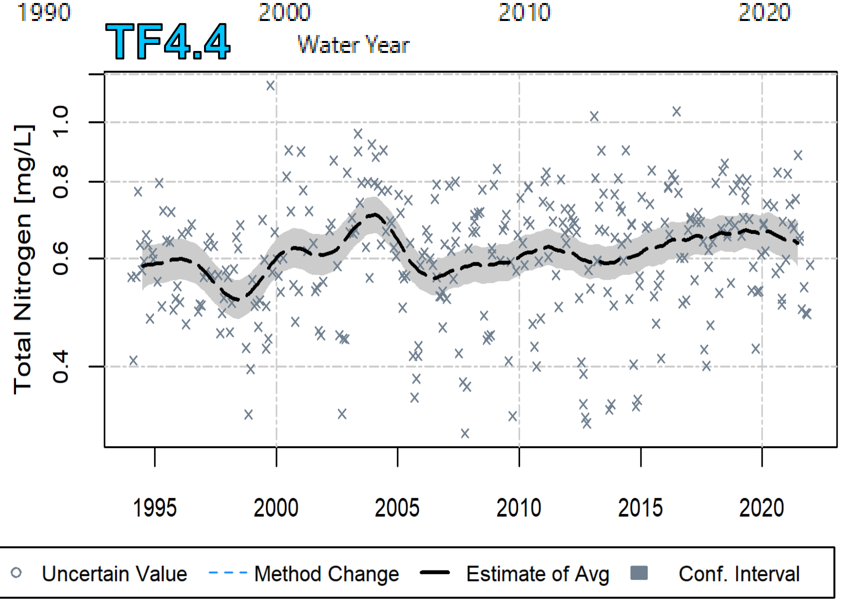


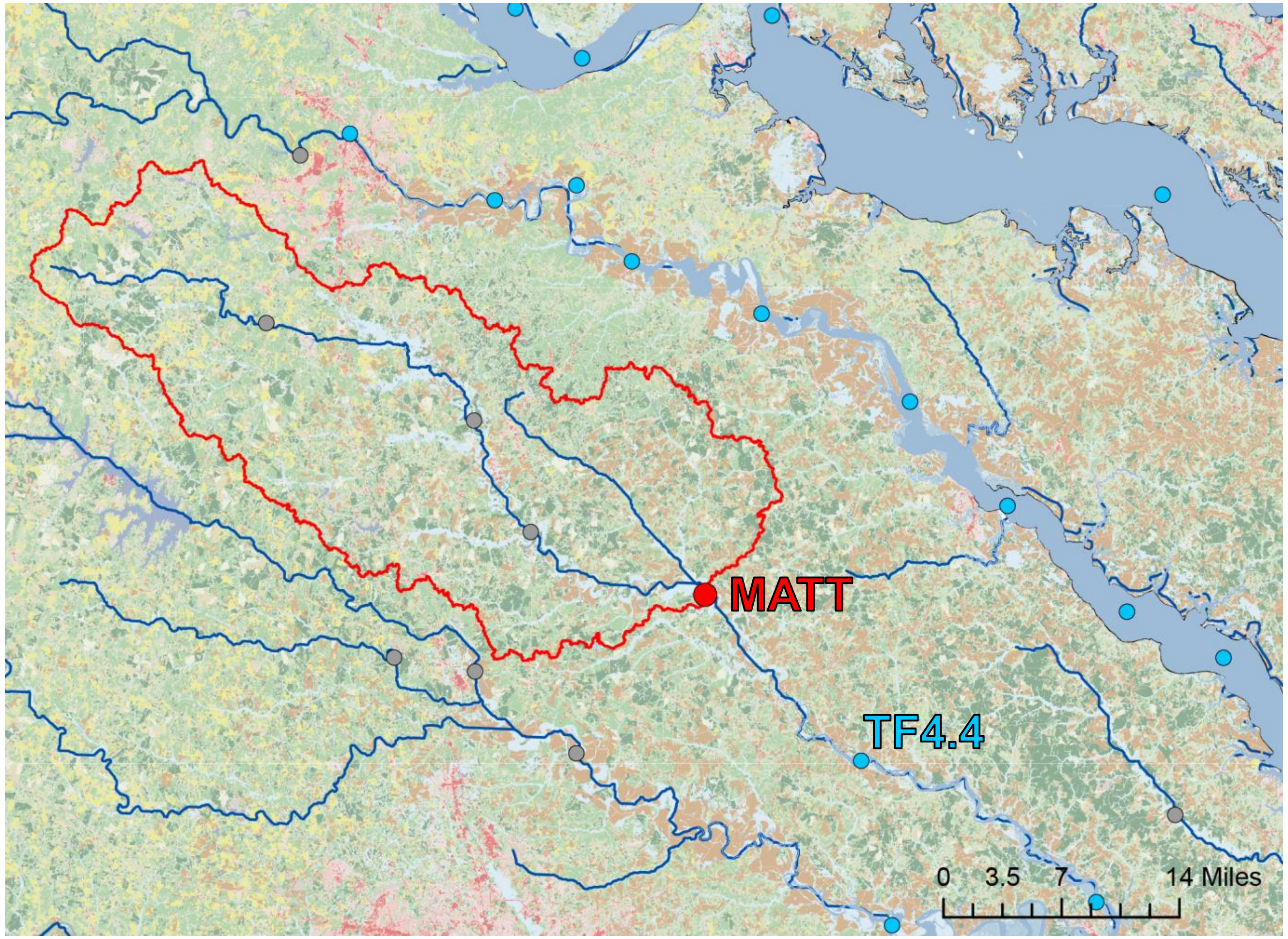
RAPP: -0.02 mg/L* (decreasing) +184,000 lb** (increasing)
TF3.1B: -0.4 mg/L*** (decreasing)
TF3.1E: -0.5 mg/L*** (decreasing)

*Flow-normalized concentration (1985 – 2021) **Flow-normalized load (1985 – 2021)
***Surface flow-adjusted concentration (1988 – 2021)

Mattaponi TN: RIM Decreasing, Tidal Increasing







MATT: -0.05 mg/L* (decreasing) -40,000 lb** (decreasing)

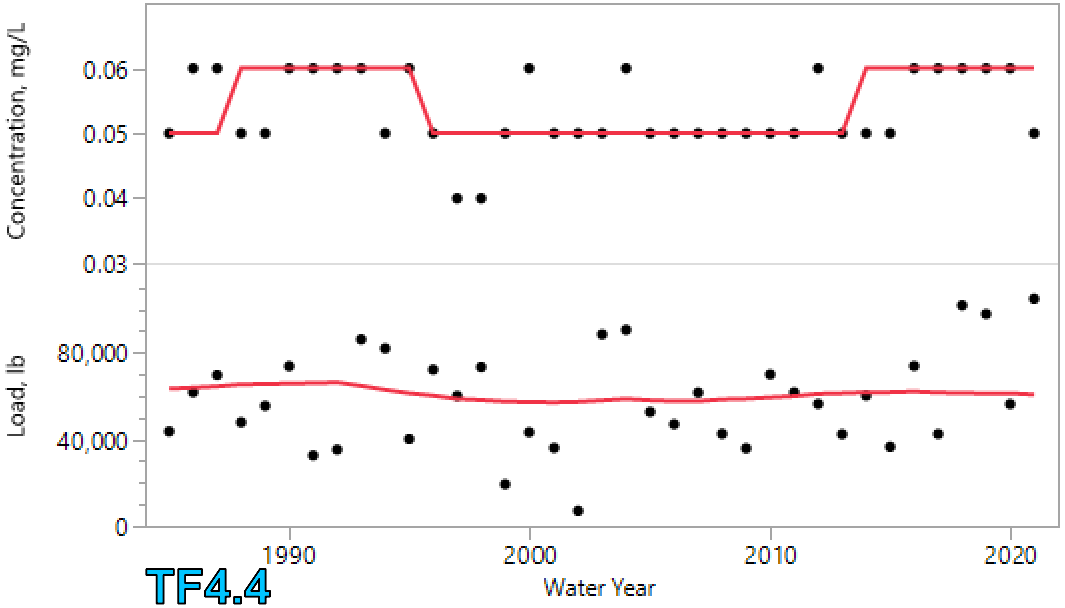
TF4.4: +0.08 mg/L*** (increasing)

*Flow-normalized concentration (1985 – 2021) **Flow-normalized load (1985 – 2021)

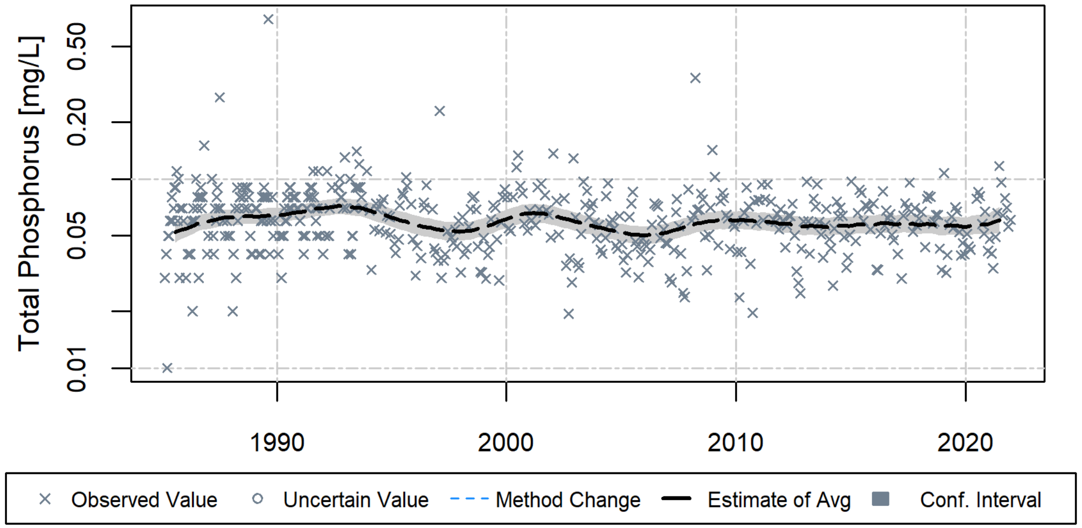
***Surface flow-adjusted concentration (1994 – 2021)

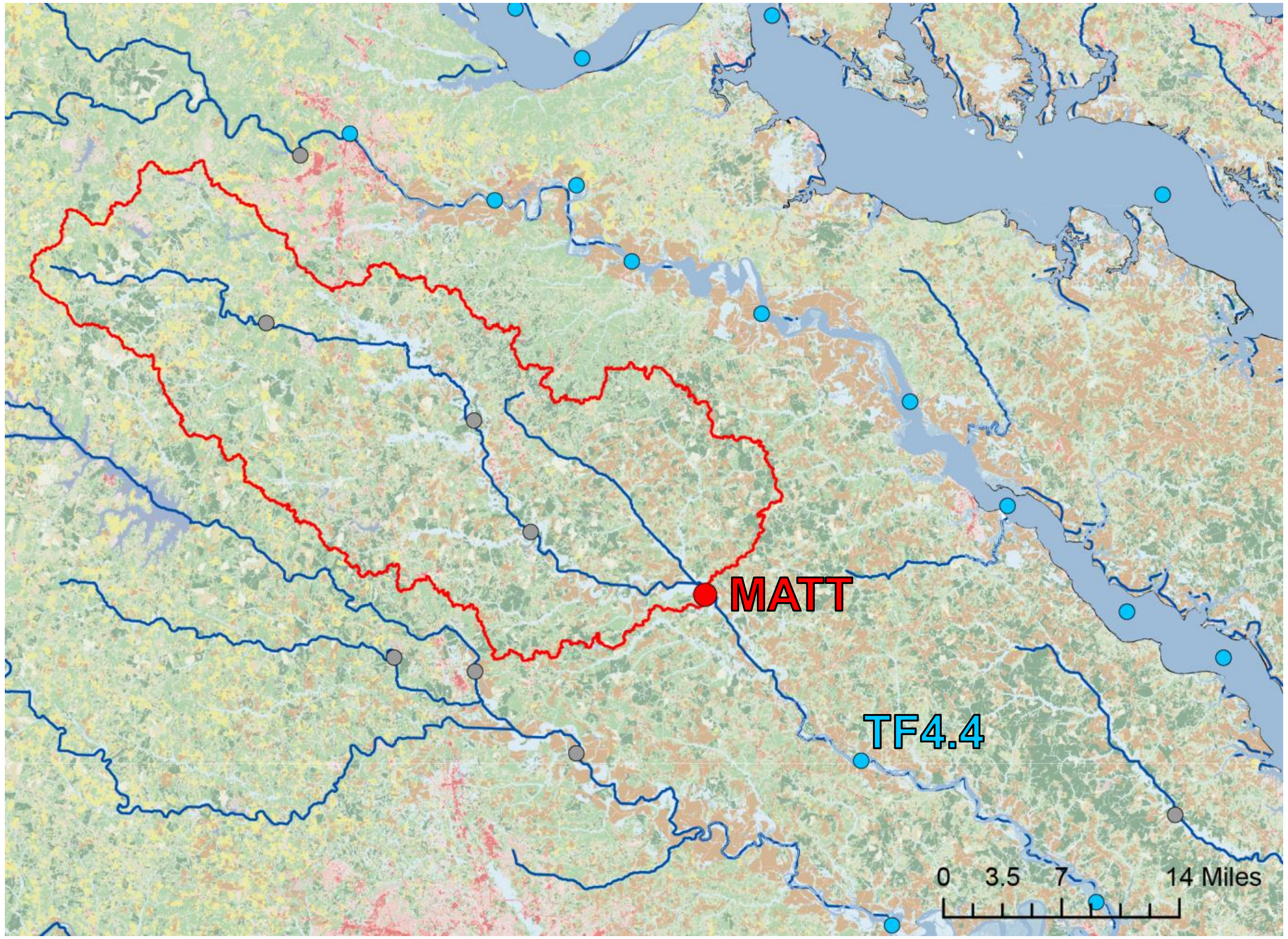
Mattaponi TP: RIM No Change, Tidal No Change

MATT



TF4.4





MATT: +0.00 mg/L* (no change) -2,700 lb** (no change)

TF4.4: +0.08 mg/L*** (no change)

*Flow-normalized concentration (1985 – 2021) **Flow-normalized load (1985 – 2021)

***Surface flow-adjusted concentration (1985 – 2021)

Feedback From ITAT: December 7th, 2022

- It's great to see all these data compared in one space because, despite their differences, they tell a story about water-quality in the Chesapeake Bay watershed.
- Consideration of the following factors could help strengthen nontidal and tidal water-quality linkages:
  - Methodology: We should consider trend differences potentialliy caused by methodology. Nontidal trends are computed with WRTDS. Tidal trends are computed with GAMs. Nontidal trends are computed with water years; tidal trends are computed with calendar years.
  - Below RIM Contributions: We cannot overlook the below RIM load contributions. We can use modeled estimates of points and nonpoint source loads to improve nontidal and tidal linkages.
  - Dynamic Tidal Conditions: Estuaries are very dynamic and can be a source and sink of nutrients. There could be many reasons for differing nontidal and tidal trend results, including changes in dissolved oxygen and nutrient residence times.
- Are there dominant factors that explain both nontidal and tidal trends?
  - Do changes in land use or climate explain nutrient and sediment trends?
  - Is the distance between nontidal and tidal stations important to consider?
- Should we more clearly communicate these combined trend results to our partners?
  - Tidal and nontidal trends are included on the Chesapeake Bay Watershed Data Dashboard and are included in the tributary summary documents.
  - Should additional products be developed to meet individual partner needs (fact sheets, storymaps, etc.)?