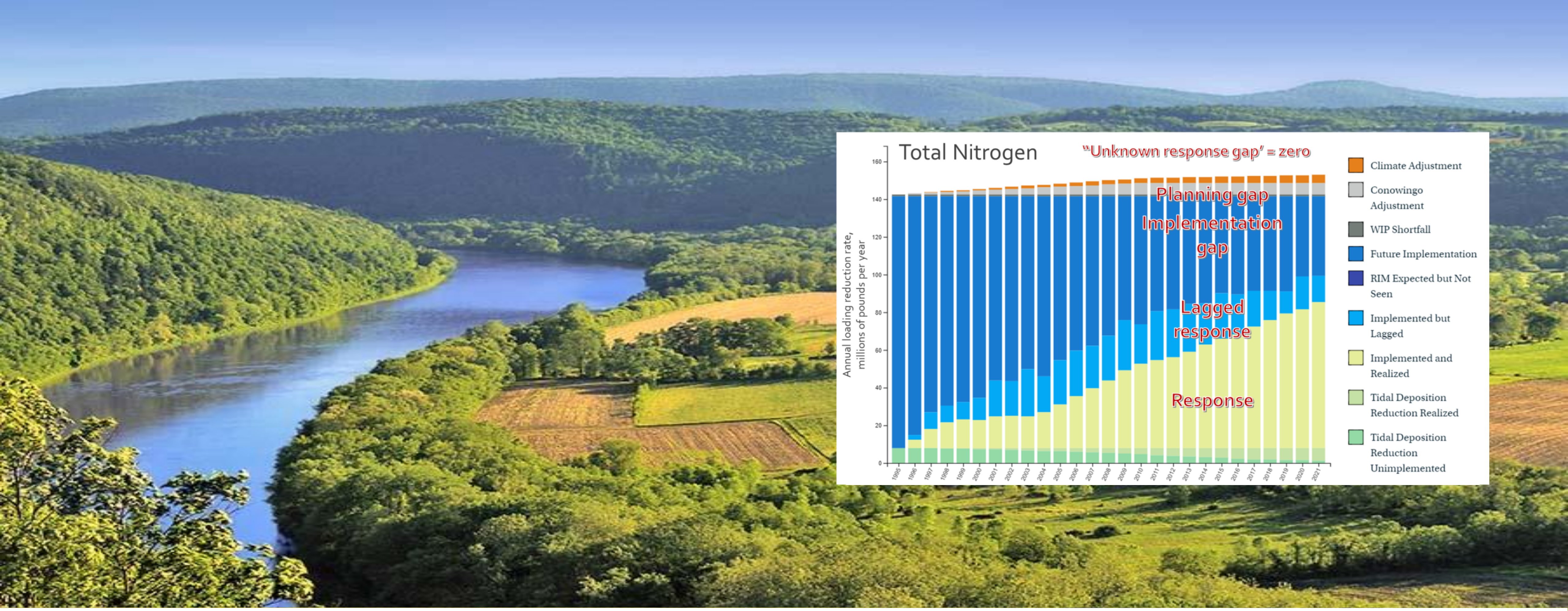
# The Chesapeake Bay Total Maximum Daily Load (Bay TMDL) Indicator

Chesapeake Bay Program

# Outline

**Part I: Introduction to the Bay TMDL indicator**

**Part II: Demonstration of the station-level Bay TMDL indicator (the METRIC tool)**




# Part I:
# Introduction to the Bay TMDL indicator

# Outline

**Part I: Introduction to the Bay TMDL indicator**

- Background, motivations and objective.
- Categories and data sources of the indicator.
- Application to the entire Chesapeake Bay watershed.
- Application to the Nontidal Network stations.

**Part II: Demonstration of the station-level Bay TMDL indicator (the METRIC tool)**

# Background

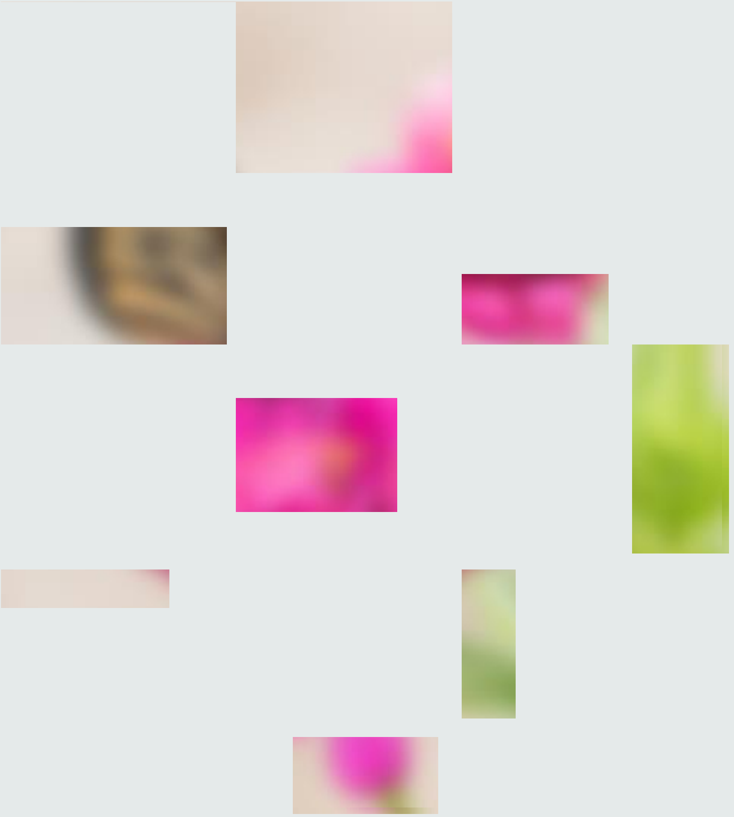
- Since the 1980s, coordinated management efforts have been carried out by Chesapeake Bay Program partners to curb eutrophication.
- In 2010, the Chesapeake Bay TMDL was established to enforce nutrient load reductions.
- Under the Bay TMDL, reduction goals have been established for each jurisdiction in the watershed, and Watershed Implementation Plans (WIPs) have been developed by the jurisdictions.
- It is critical to "continually improve our capacity to monitor and assess the effects of the management actions being taken to implement the…TMDL…and improve water quality" (Chesapeake Executive Council, 2014).

## Natural System

Photo credit: CBP

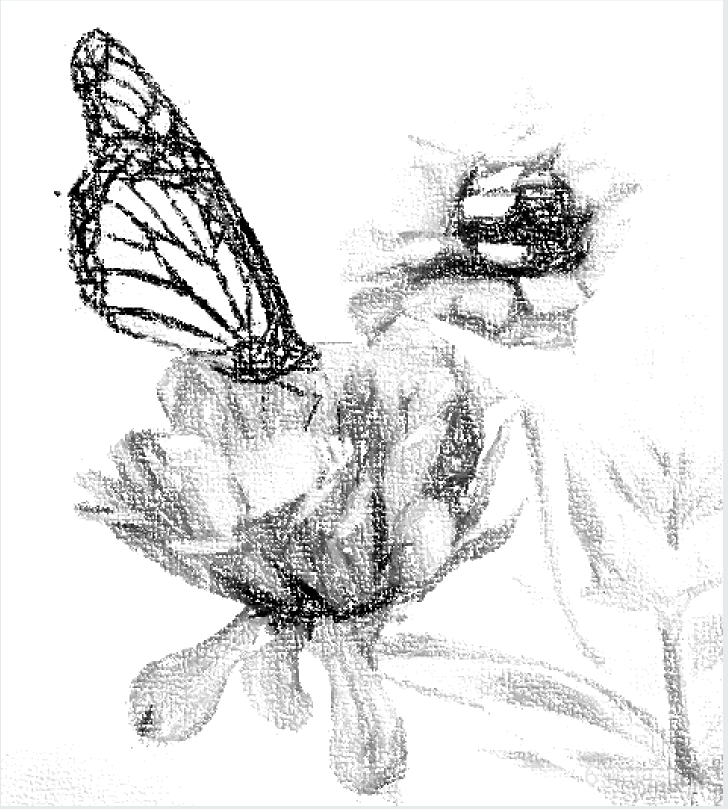
## Monitoring

Reality,
Imprecise, Incomplete



## Modeling

Precise, Complete,
Not Reality

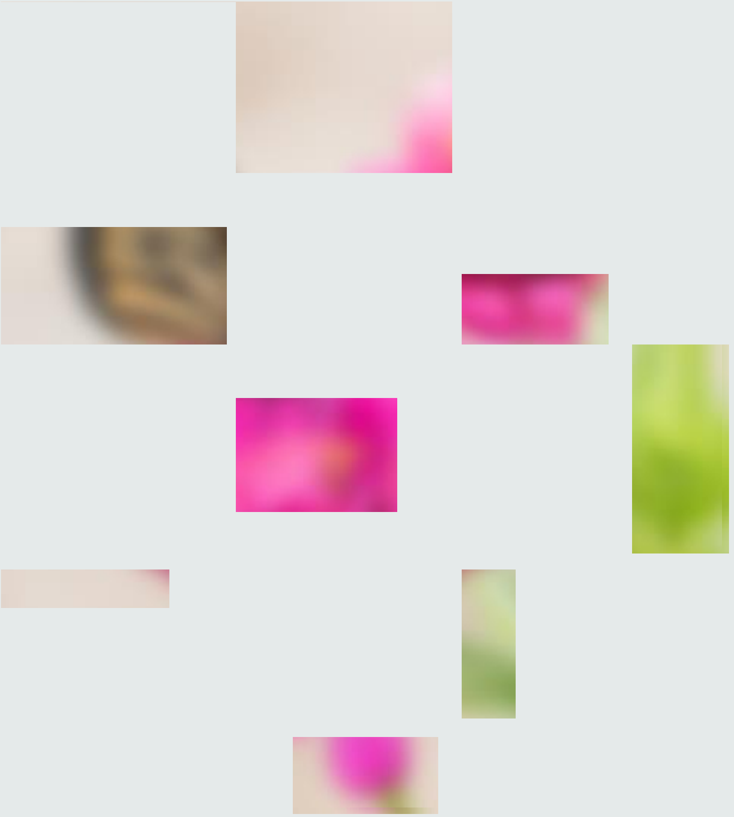


## Natural System

Photo credit: CBP

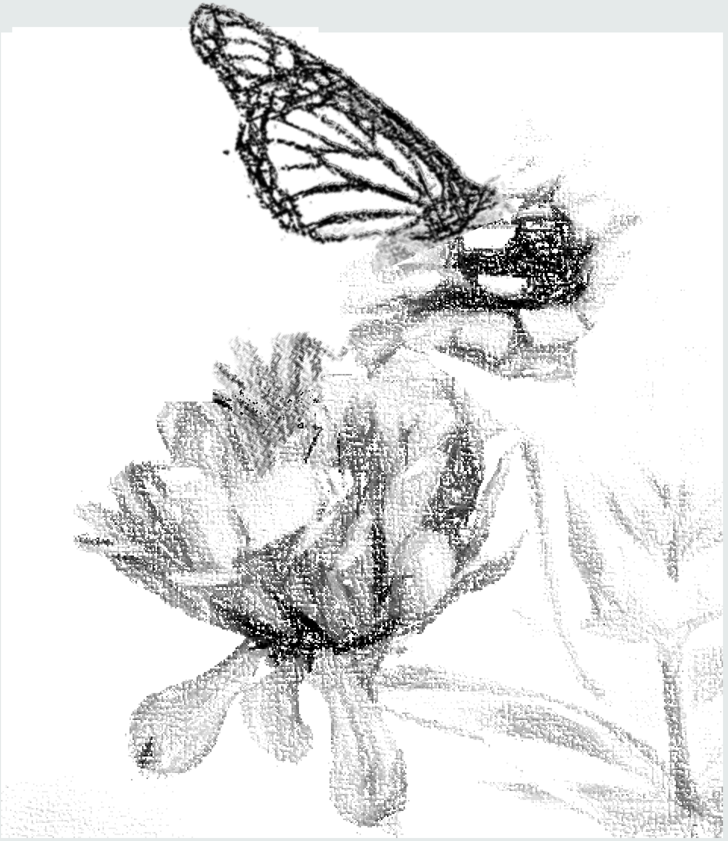
## Monitoring

Reality,
Imprecise, Incomplete



## Modeling

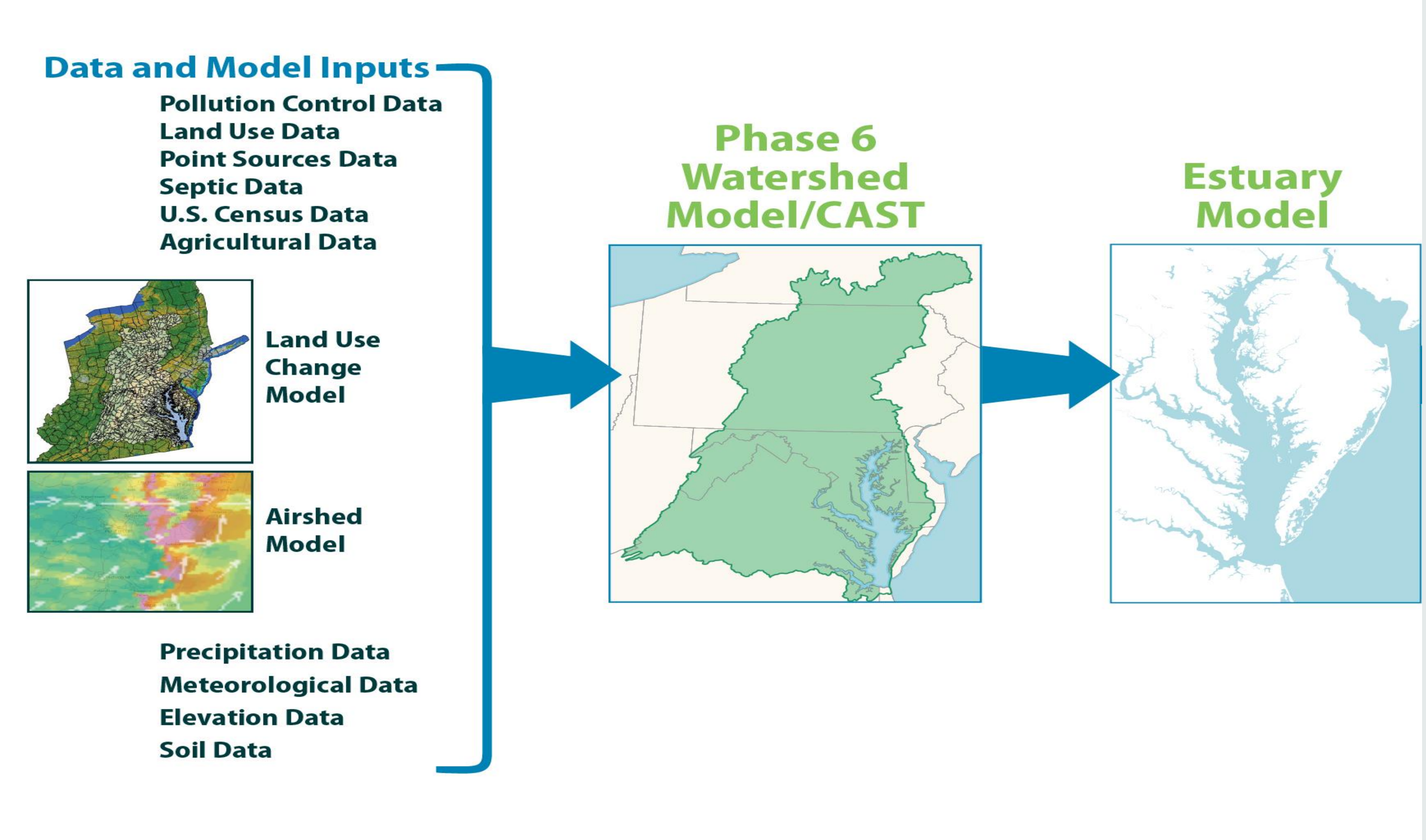
Can be used to
plan for the future



If we change what we do on the landscape…

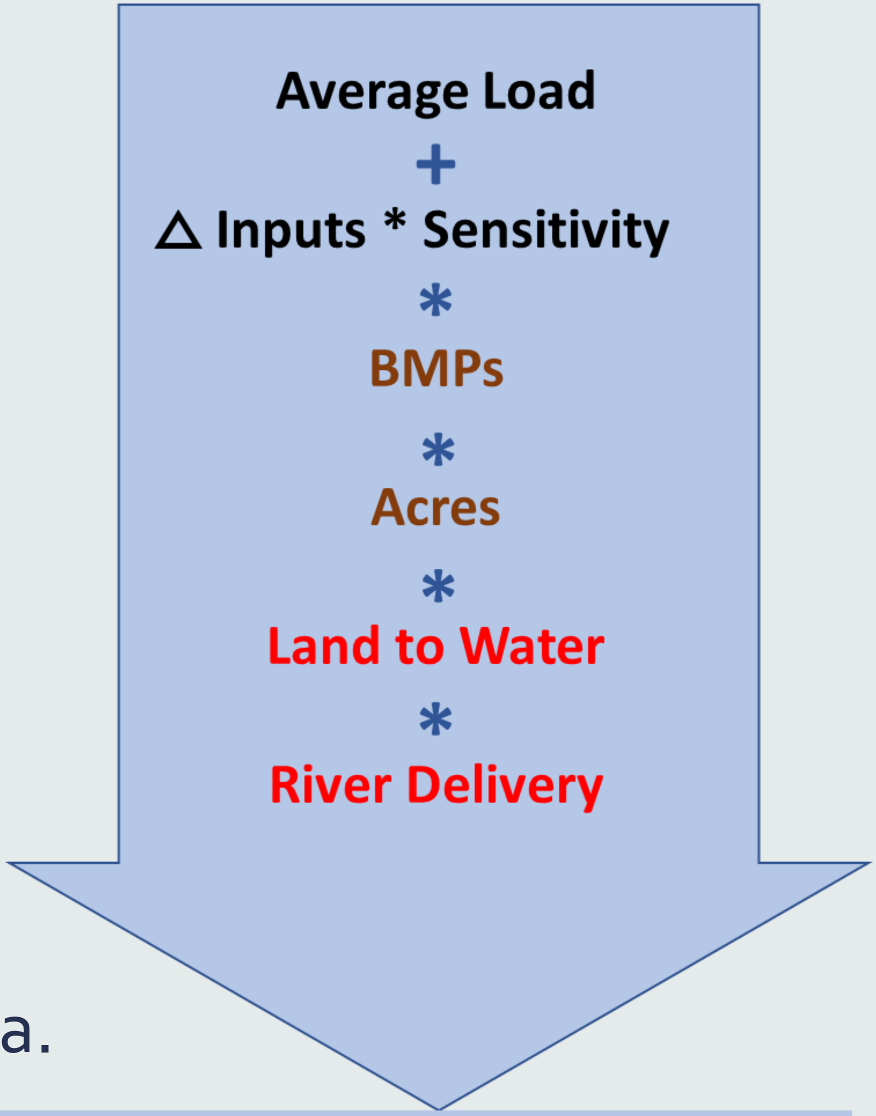
…how will that change N, P and SS?

…and dissolved oxygen in the Bay?



# Modeling vs. monitoring

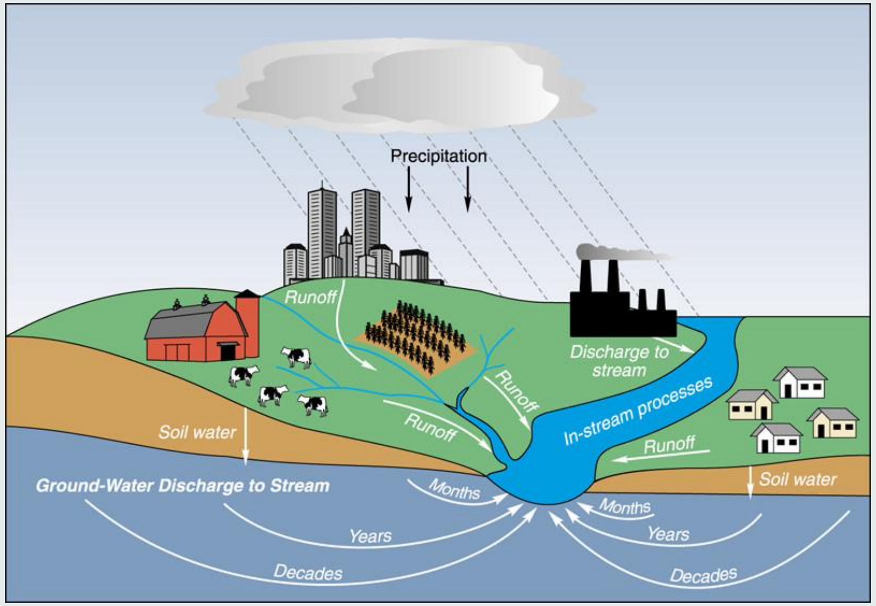
- The Watershed Model
  - Integrates knowledge of land use, nutrient inputs and watershed processes.
  - Estimates how changes in climate, land use, nutrient inputs and management practice implementation will affect water quality.
- Monitoring data
  - River water-quality monitoring data and estimated loads.
  - Point source and atmospheric deposition data.




Load by land-river segment and land use

# Modeling vs. monitoring

- Monitored and model-expected trends often differ in magnitude and even direction, which may be attributed to several factors (Ator et al., 2020):
  a) Uncertainty in the Watershed Model (e.g., model inputs, BMP effectiveness, representation of watershed processes),
  b) Uncertainty in the monitored trend (e.g., sampling frequencies, coverage),
  c) Natural lags between implementation of management practices and realization of water-quality improvement, and
  d) Competing factors (e.g., climate change and reservoir function).




Source: USGS

# Objective of the Bay TMDL indicator

- To explicitly quantify the progress toward annual nutrient load reductions in response to implemented management practices.
- The indicator addresses critical management questions – i.e.,
  a) *What reductions are expected from past management actions and have been observed in the monitoring data?*
  b) *What reductions are expected from past management actions but have not been observed due to lags times?*
  c) *What reductions are expected but not yet observed in monitoring?*
  d) *What reductions are needed from planned future management actions?*
- As new data become available each year, the indicator will be regularly updated to assess the latest progress toward meeting the TMDL goals.

# Data sources of the indicator

- River monitoring data: Observed (i.e., realized) load reduction
  - Computed using the USGS WRTDS flow-normalization method.
- Watershed Model (CAST) data: Expected load reduction in the long term
  - Computed using the Chesapeake Bay Program Watershed Model.
  - Based on long-term average hydrology (1990-2000).
  - Does not consider lags.
- Dynamic Watershed Model data: Expected load reduction with lags
  - Based on time-variable hydrology.
  - Considers lags in nutrient application and delivery but not lags in BMP efficiency (assuming 100% efficiency once implemented).

# Categories of the indicator

- Response (i.e., implemented and realized): Load reductions due to actions in the WIPs that have been both estimated in the models and seen in monitoring data.
- Lagged response gap (i.e., implemented but lagged): Load reductions that are expected in the future due to actions that have already taken place, but not yet been realized due to natural lag times.
- Unknown response gap (i.e., RIM expected but not seen): Load reductions in the River Input Monitoring (RIM) watershed that have been estimated by the model while accounting for lag times but are not seen in the monitoring data.
- Implementation gap (i.e., future implementation): Expected load reductions from the future management implementations of the WIPs.
- Planning gap (i.e., WIP shortfall): Reductions necessary for achieving water quality standards that are not planned for in the WIPs (WIP shortfall).

# Application to the entire Chesapeake Bay watershed

CHESAPEAKE PROGRESS

Search

Abundant Life | Clean Water | Conserved Lands | Engaged Communities | Climate Change | About Us

## Water Quality

### Goal

***Reduce pollutants to achieve the water quality necessary to support aquatic living resources and protect human health.***

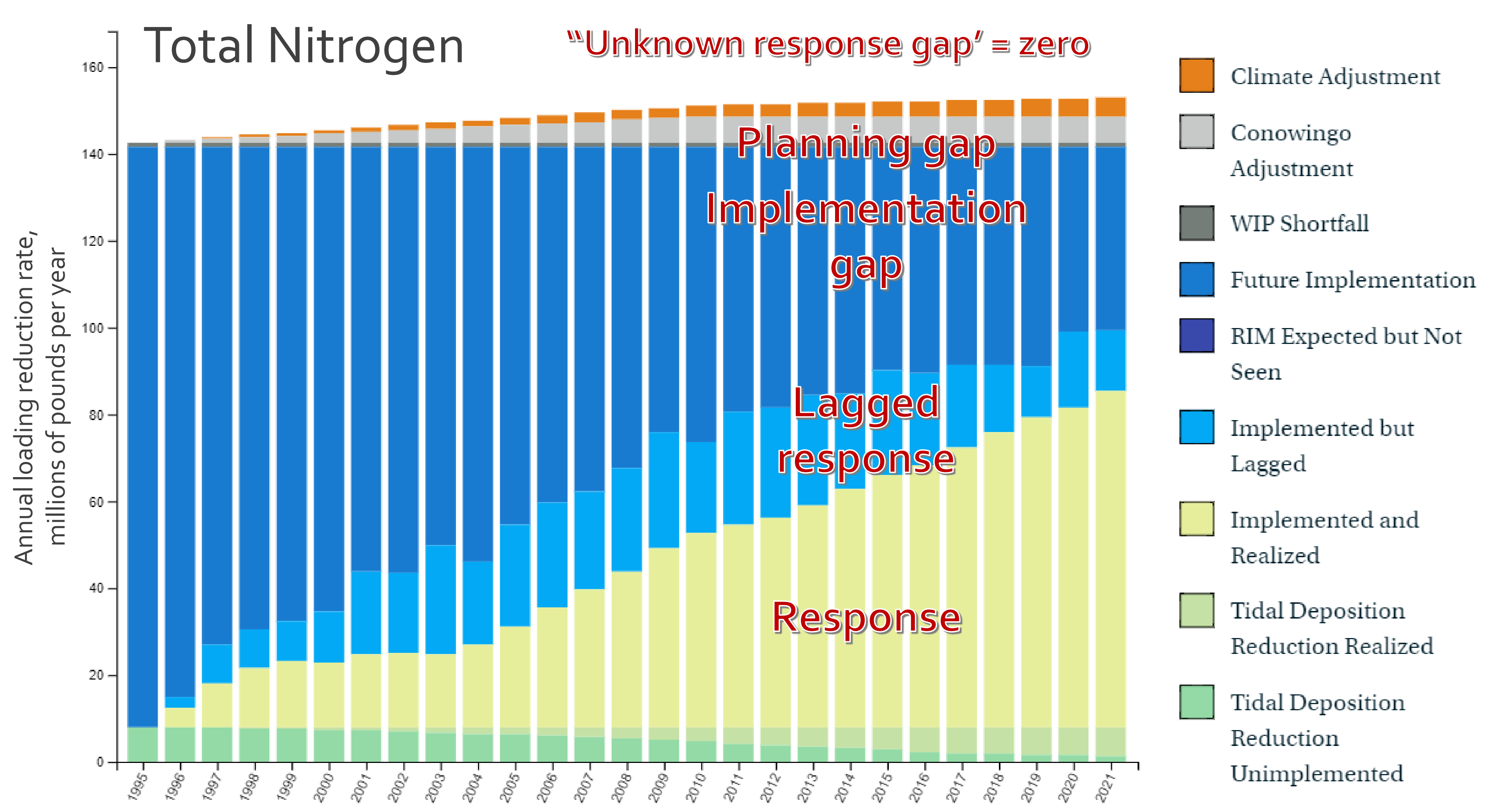
### Outcomes

Each goal is linked to a set of outcomes, or time-bound and measurable targets that will directly contribute to its achievement. Learn more on the outcome pages listed below.

- 2017 Watershed Implementation Plans (WIPs) →
- 2025 Watershed Implementation Plans (WIPs) →
- Water Quality Standards Attainment and Monitoring →

https://www.chesapeakeprogress.com/clean-water/water-quality

# Application to the entire Chesapeake Bay watershed

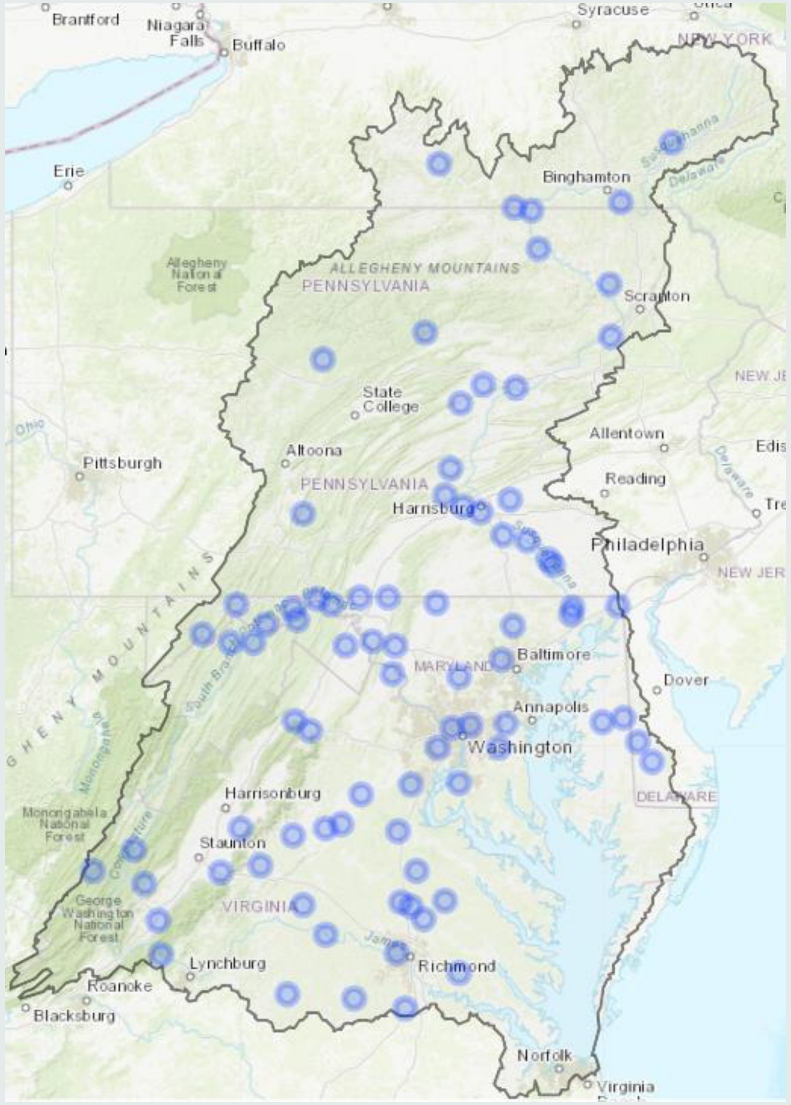


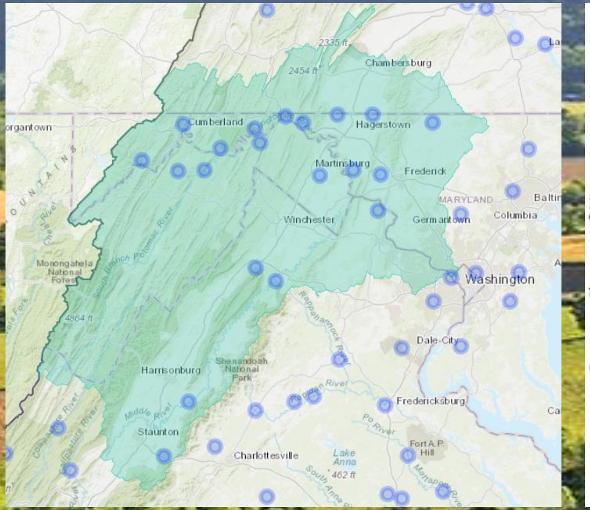
# Bay TMDL indicator vs. Modeled Load Reduction (MLR) indicator

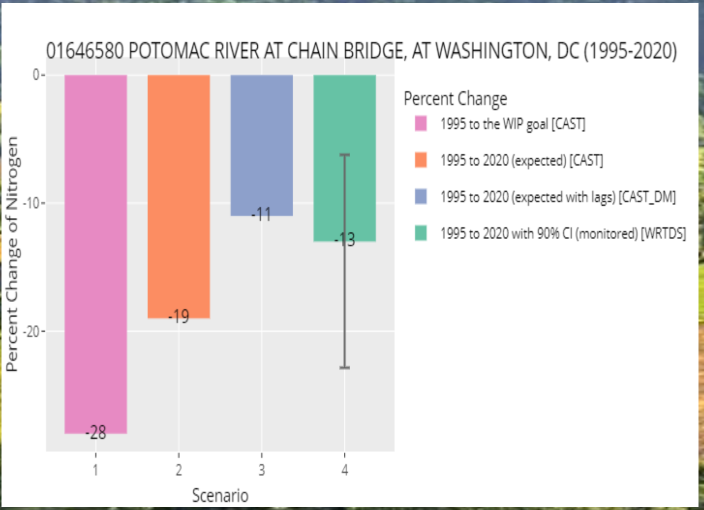
| | MLR Indicator | Bay TMDL Indicator |
|---|---|---|
| Data | CAST data | CAST data and monitoring data |
| Purpose | measures the progress in implementing the WIPs | measures the success of the implementation |
| Beginning year | 1985 | 1995 (baseline year that marks the end of the 1993-1995 critical period used for assessing water quality standards attainment) |
| Ending year | 2022 (most recent year of the CAST data) | 2021 (most recent year of approved riverine monitoring data for load and trend assessments) |

# Application to the Nontidal Network stations

- The indicator can be applied to subwatersheds where modeling and monitoring data exist.
- An effort has been made to apply the indicator to the Nontidal Network (NTN) stations, including 83 stations for nitrogen, 66 for phosphorus and 66 for sediment.
- These station-level results can help managers gauge expectations on the trajectory and pace of reduction progress at more localized scales.
- This information is available to the CBP partnership through a new Shiny app.






# Part II
# Demonstration of the station-level Bay TMDL indicator (the METRIC tool)

# Outline

**Part I: Introduction to the Bay TMDL indicator**

**Part II: Demonstration of the station-level Bay TMDL indicator (the METRIC tool)**

- App interface.
- Three examples.

# App interface

## Monitored and Expected Total Reduction Indicator for the Chesapeake (METRIC)

Purpose

* This app is designed for comparing the monitored load trend and CAST-estimated load trend for the Chesapeake Bay Non-Tidal Network (NTN) stations.
* This app contains load and trend data for 83, 66, and 66 NTN stations for Total Nitrogen (TN), Total Phosphorus (TP), and Suspended Sediment (SS), respectively.
* This app is an extension to the Chesapeake Bay Total Maximum Daily Load (TMDL) Indicator, which has been approved and published on Chesapeake Progress.

User selection

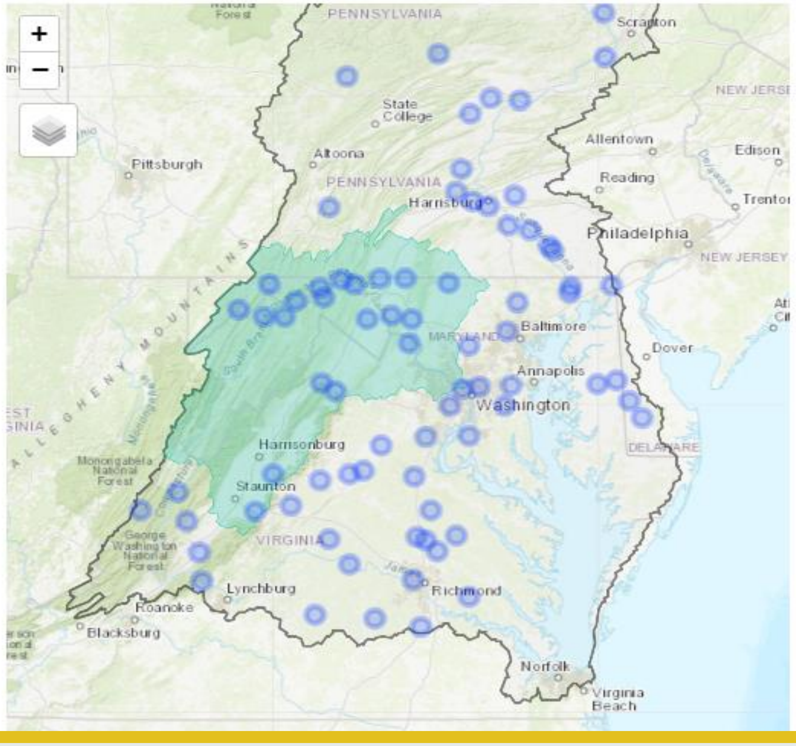
Step 1: Select the water-quality parameter:

◉ Total Nitrogen ○ Total Phosphorus ○ Suspended Sediment

Step 2: Select the monitoring station by clicking either Map or Table:

Map | Data Table

Tip: Move mouse cursor to any circle marker to show the station name.




Results

About | Timeseries | WIP Goal | Progress | Download

### Station

The selected station is POTOMAC RIVER AT CHAIN BRIDGE, AT WASHINGTON, DC:
* USGS ID: 01646580
* Area (mi^2): 11573
* Major Basin: Potomac MD
* Latitude: 38.929555
* Longitude: -77.116923

### Data Availability

Total Nitrogen: 1985-2020.
Total Phosphorus: 1985-2020.
Suspended Sediment: 1985-2020.

### Data Type

WRTDS: Monitored load - computed using the USGS WRTDS flow-normalization method (source).

CAST: Expected load in the long term - computed using the time-averaged version of the Chesapeake Bay Program Phase 6 Watershed Model (source).

CAST_DM: Expected load with lags - computed using the dynamic version of the Chesapeake Bay Program Phase 6 Watershed Model (source).

### Methodology

The TMDL indicator framework (source).

### Contact

Qian Zhang (UMCES @ CBPO).

### Contributors

Qian Zhang (UMCES @ CBPO), Gopal Bhatt (PSU @ CBPO), Isabella Bertani (UMCES @ CBPO), and others.

# Purpose

- **METRIC: Monitored and Expected Total Reduction Indicator for the Chesapeake.**
- This app is designed for comparing the monitored load trend and CAST-estimated load trend for the Chesapeake Bay Non-Tidal Network (NTN) stations.
- This app contains load and trend data for 83, 66, and 66 NTN stations for Total Nitrogen (TN), Total Phosphorus (TP), and Suspended Sediment (SS), respectively.
- This app is an extension to the Chesapeake Bay Total Maximum Daily Load indicator, which has been approved and published on Chesapeake Progress.

# User Selection

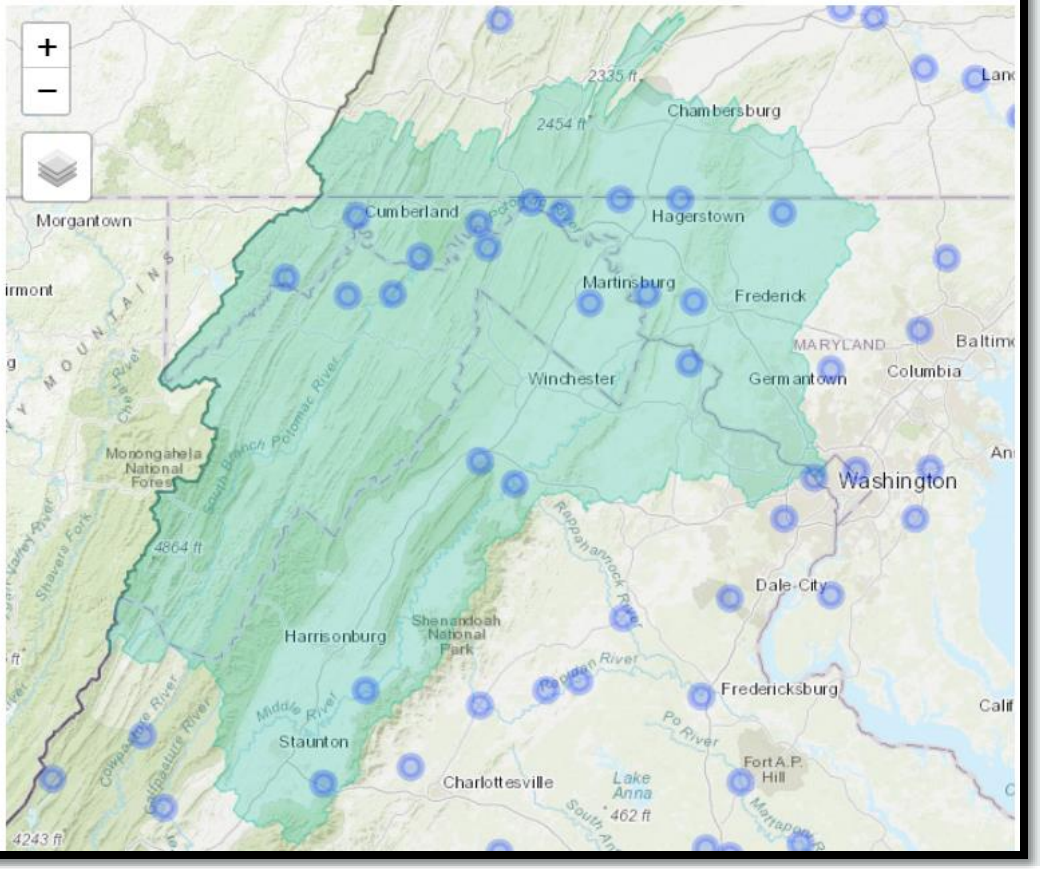
Step 1: Select the water-quality parameter:

◉ Total Nitrogen ○ Total Phosphorus ○ Suspended Sediment

Step 2: Select the monitoring station by clicking either Map or Table:

Map | Data Table

Tip: Move mouse cursor to any circle marker to show the station name.




Step 1: Select the water-quality parameter:

◉ Total Nitrogen ○ Total Phosphorus ○ Suspended Sediment

Step 2: Select the monitoring station by clicking either Map or Table:

Map | Data Table

Tip: Use search box or re-rank the columns to filter stations.

| USGS_Gage_ID | USGS_Gage_Name | Area_km2 | Basin | Parameters |
|---|---|---|---|---|
| All | Potomac | All | All | All |
| 01608500 | SOUTH BRANCH POTOMAC RIVER NEAR SPRINGFIELD, WV | 3785.5 | Potomac WV | TN, TP, SS |
| 01646580 | POTOMAC RIVER AT CHAIN BRIDGE, AT WASHINGTON, DC | 29973.2 | Potomac MD | TN, TP, SS |

# Results:
# About

About | Timeseries | WIP Goal | Progress | Download

## Station

The selected station is POTOMAC RIVER AT CHAIN BRIDGE, AT WASHINGTON, DC:

* USGS ID: 01646580
* Area (mi^2): 11573
* Major Basin: Potomac MD
* Latitude: 38.929555
* Longitude: -77.116923

## Data Availability

Total Nitrogen: 1985-2020.
Total Phosphorus: 1985-2020.
Suspended Sediment: 1985-2020.

## Data Type

WRTDS: Monitored load - computed using the USGS WRTDS flow-normalization method (source).

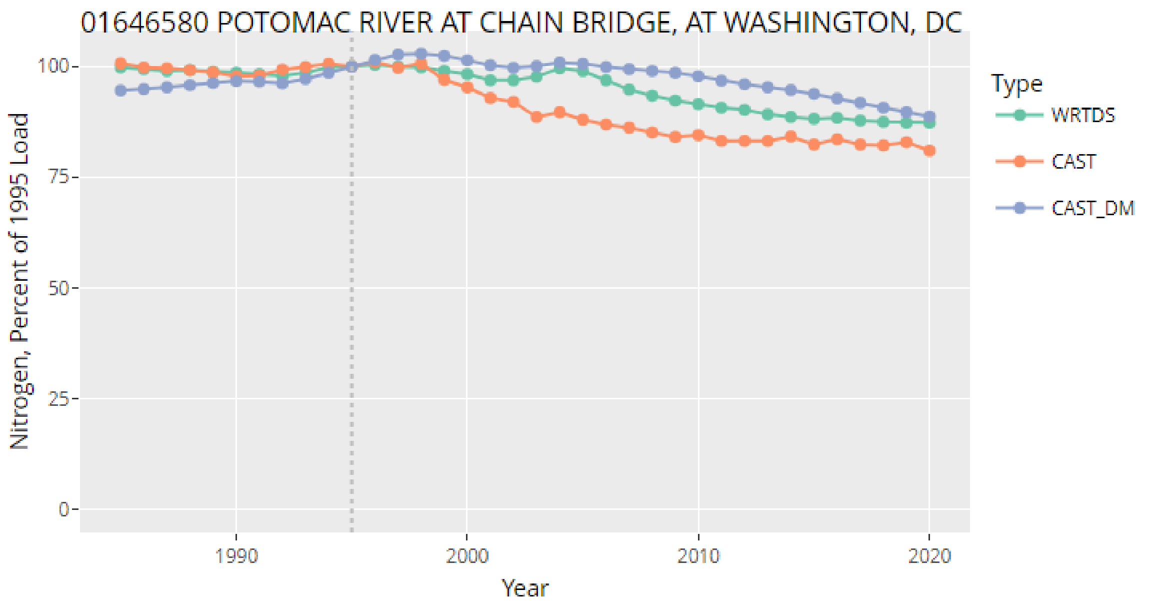
CAST: Expected load in the long term - computed using the Chesapeake Bay Program Watershed Model (source).

CAST_DM: Expected load with lags - computed using the Chesapeake Bay Program Watershed Model (source).

About | Timeseries | WIP Goal | Progress | Download

# Results:
# Timeseries

## Interactive Plot




(Note: To obtain values in million pounds (Mlbs), refer to the Data Table below.)

## Data Type

WRTDS: Monitored load - computed using the USGS WRTDS flow-normalization method (source).

CAST: Expected load in the long term - computed using the Chesapeake Bay Program Watershed Model (source).

CAST_DM: Expected load with lags - computed using the Chesapeake Bay Program Watershed Model (source).

## Data Table

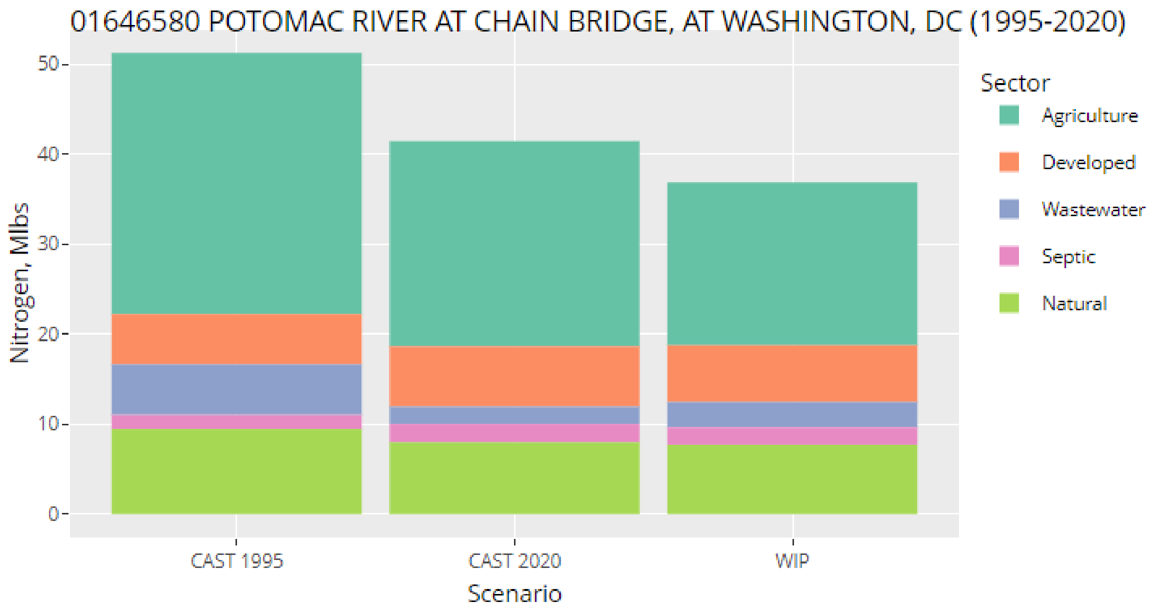
Show 50 entries    Search:

| | ID | Parameter | Year | WRTDS, Mlbs | CAST, Mlbs | CAST_DM, Mlbs |
|---|---|---|---|---|---|---|
| 1 | 01646580 | Nitrogen | 1985 | 51.7 | 51.6 | 48.6 |
| 2 | 01646580 | Nitrogen | 1986 | 51.5 | 51.1 | 48.7 |

# Results:
# WIP Goal

About | Timeseries | WIP Goal | Progress | Download

## Interactive Plot




## Data Type

CAST: Expected load in the long term - computed using the Chesapeake Bay Program Watershed Model (source).

## Data Table

Show 50 entries

Search:

| | ID | Parameter | Scenario | Agriculture | Developed | Natural | Septic | Wastewater | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 01646580 | Nitrogen | CAST 1995 | 29 | 5.61 | 9.49 | 1.53 | 5.62 | 51.2 |
| 2 | 01646580 | Nitrogen | CAST 2020 | 22.8 | 6.69 | 8.01 | 2.02 | 1.92 | 41.5 |
| 3 | 01646580 | Nitrogen | WIP | 18.1 | 6.27 | 7.71 | 1.94 | 2.83 | 36.9 |

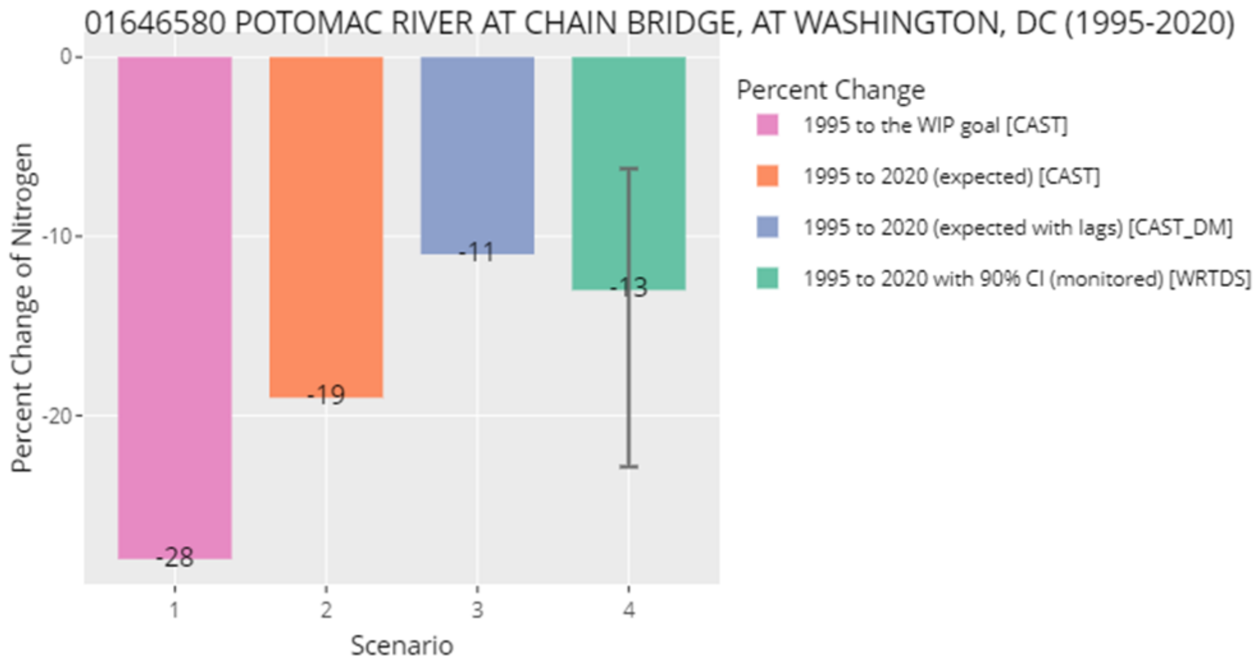
Showing 1 to 3 of 3 entries

Previous 1 Next

# Results: Progress

About | Timeseries | WIP Goal | Progress | Download

## Interactive Plot




(Note 1: Negative values indicate load reductions; positive values indicate load increases.)

(Note 2: To obtain values in million pounds (Mlbs), multiply the percent change shown in this plot by the CAST load in the first year of the assessment period, which is available in the Data Table under the About tab.)

## Data Type

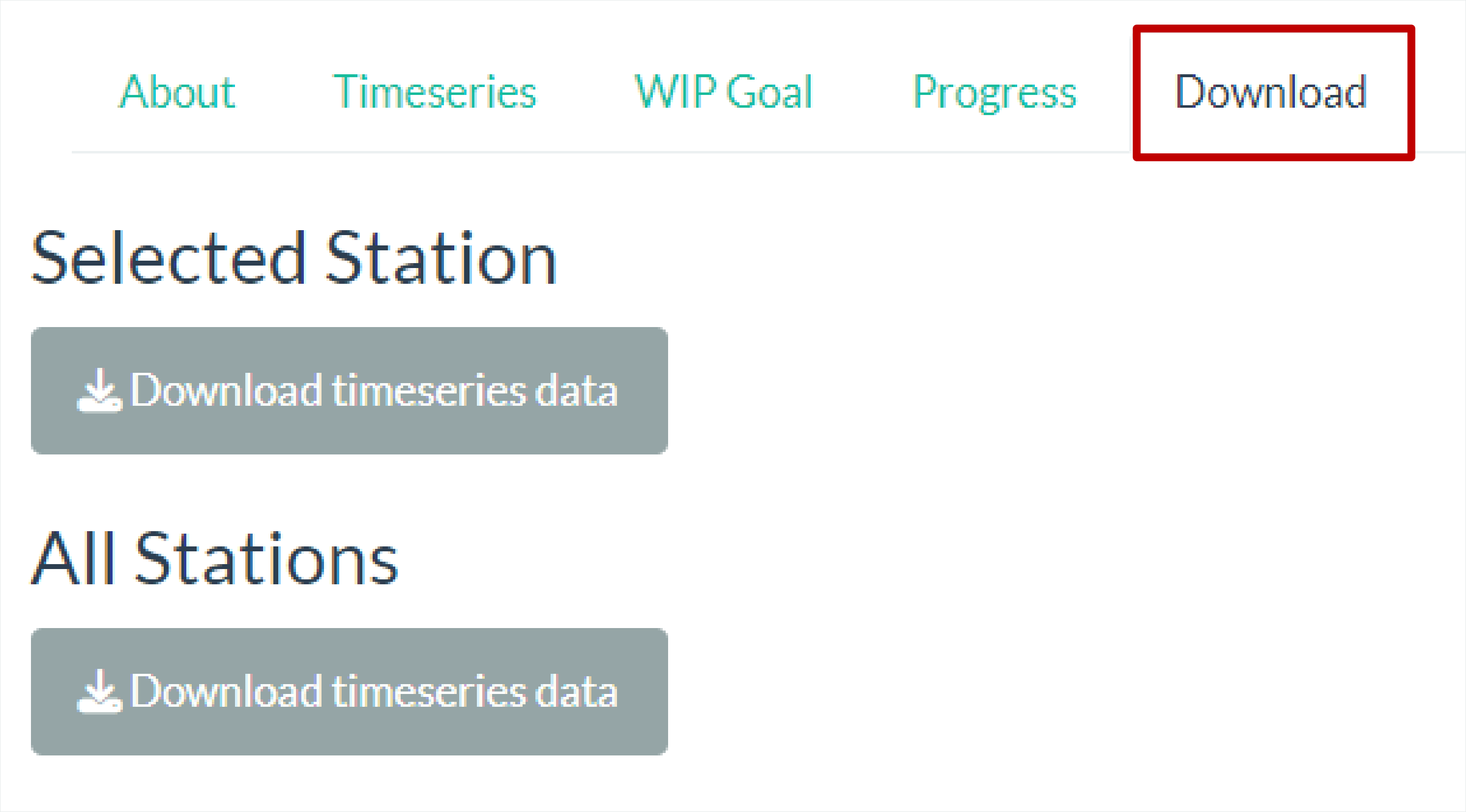
WRTDS: Monitored load - computed using the USGS WRTDS flow-normalization method (source).

CAST: Expected load in the long term - computed using the Chesapeake Bay Program Watershed Model (source).

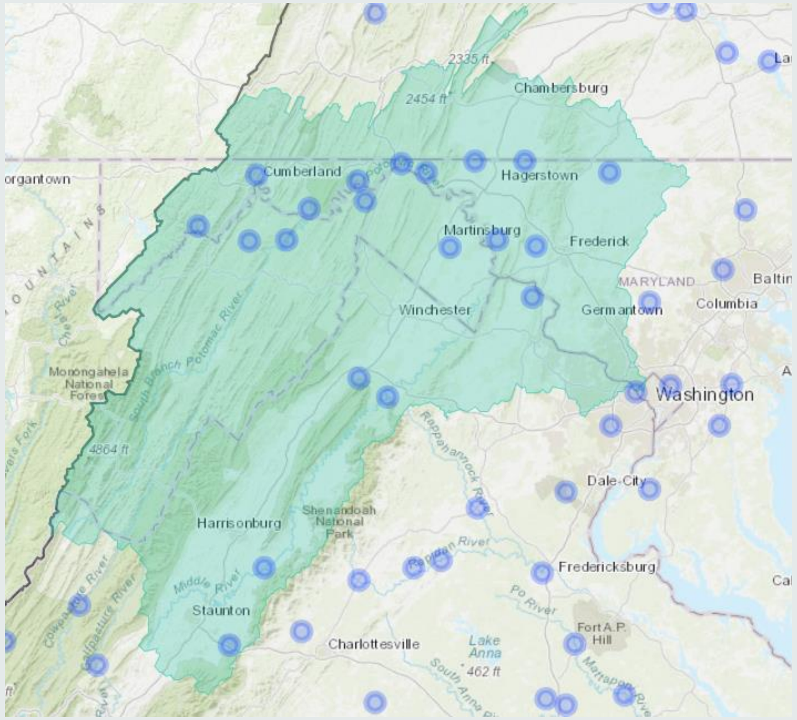
CAST_DM: Expected load with lags - computed using the Chesapeake Bay Program Watershed Model (source).

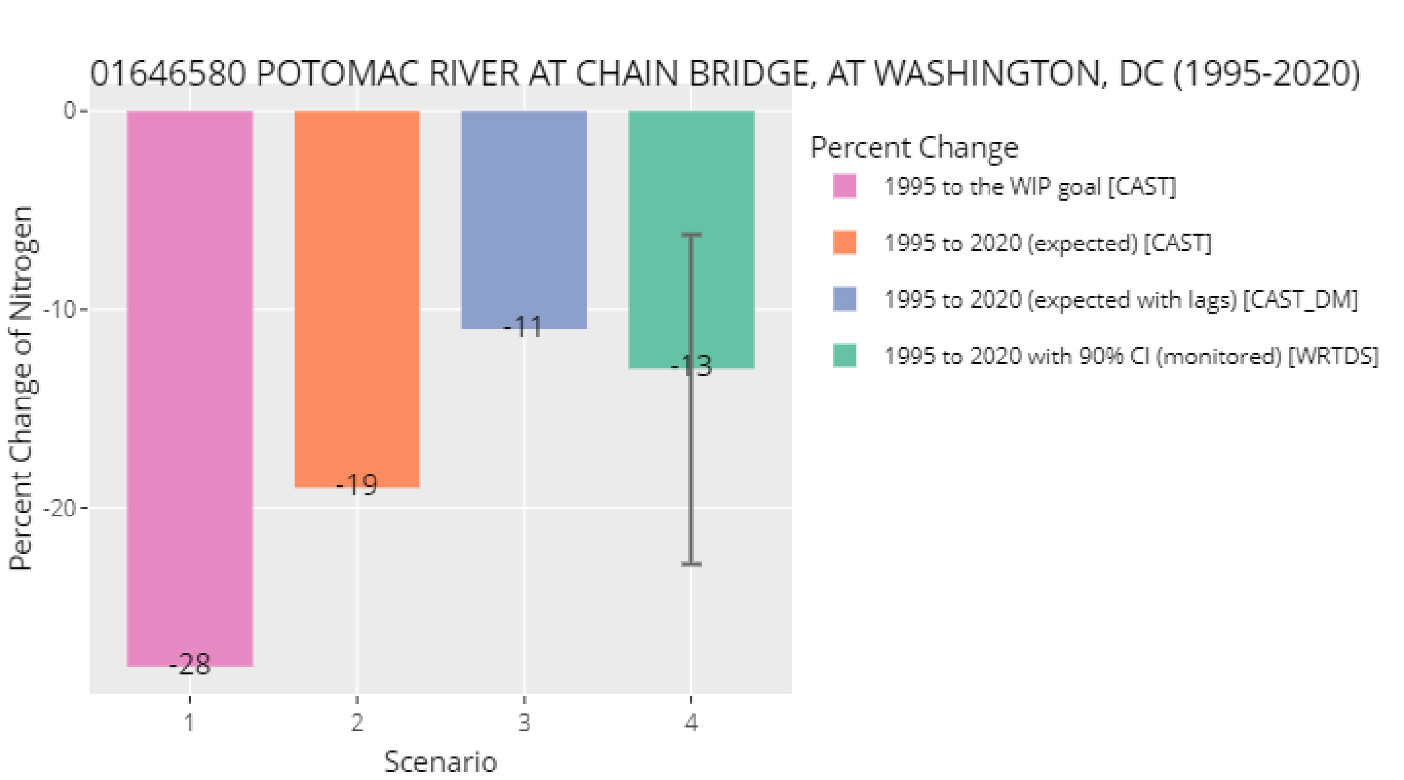
## Interpretive Text

# Results:
# Download



# Example 1: **01646580 Potomac River** Total Nitrogen



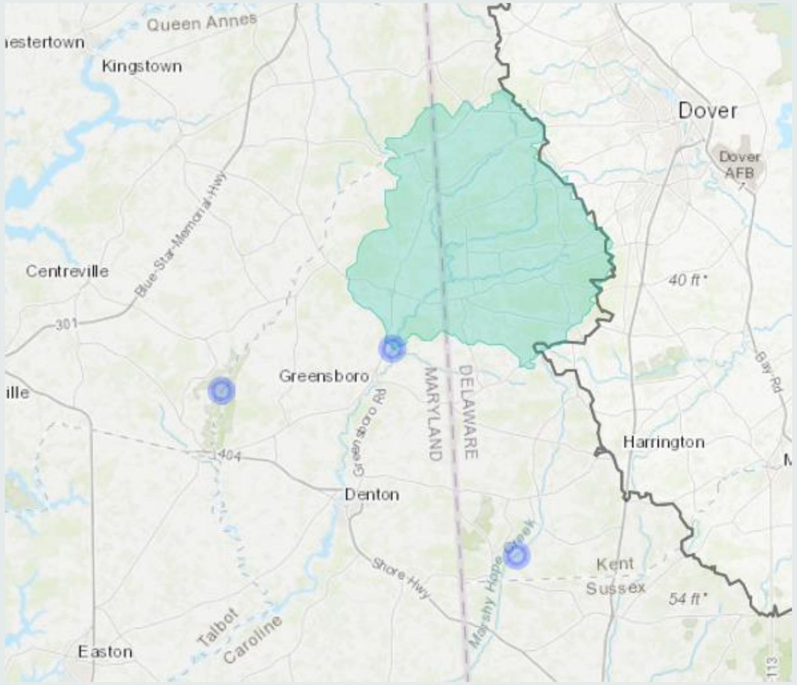



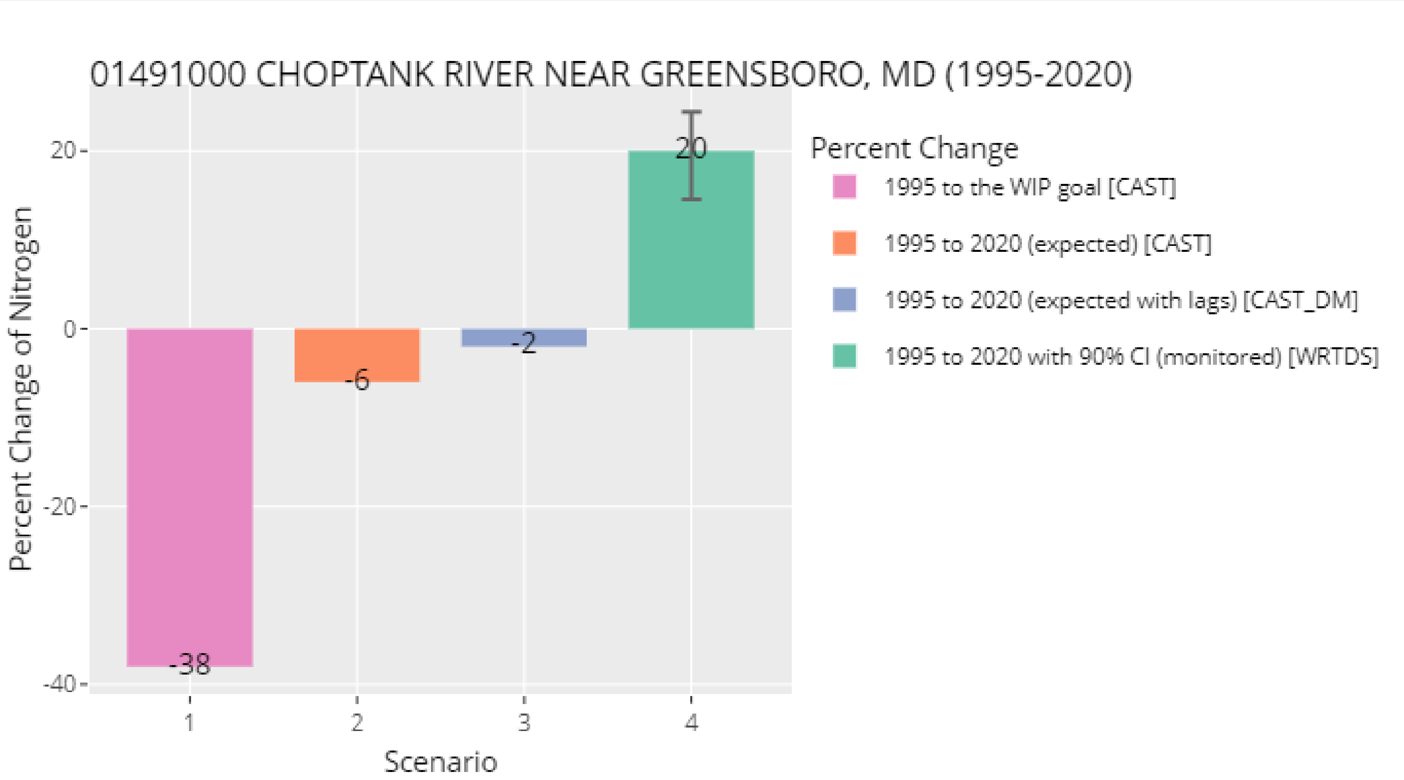

**Interpretive Text**

1. CAST estimates a 28 percent reduction in the long term from implementation of the WIP using 2025 land use and inputs.
2. CAST estimates a 19 percent reduction in the long term from 2020 land use, inputs, and management practices.
3. The Dynamic Watershed Model estimates that only a 11 percent reduction would have been seen by 2020, accounting for lags, sampling frequency, and other factors.
4. The river monitoring data show a 13 percent reduction with a 90% uncertainty range between 6 and 23 percent reduction.

**Implication**: The observed response is as expected in 2020.

# Example 2: **01491000 Choptank River** Total Nitrogen



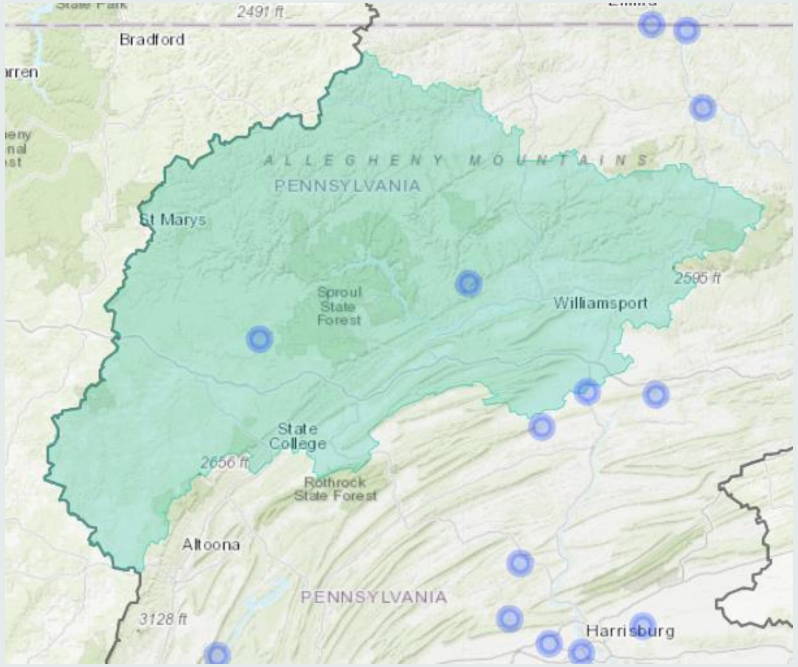



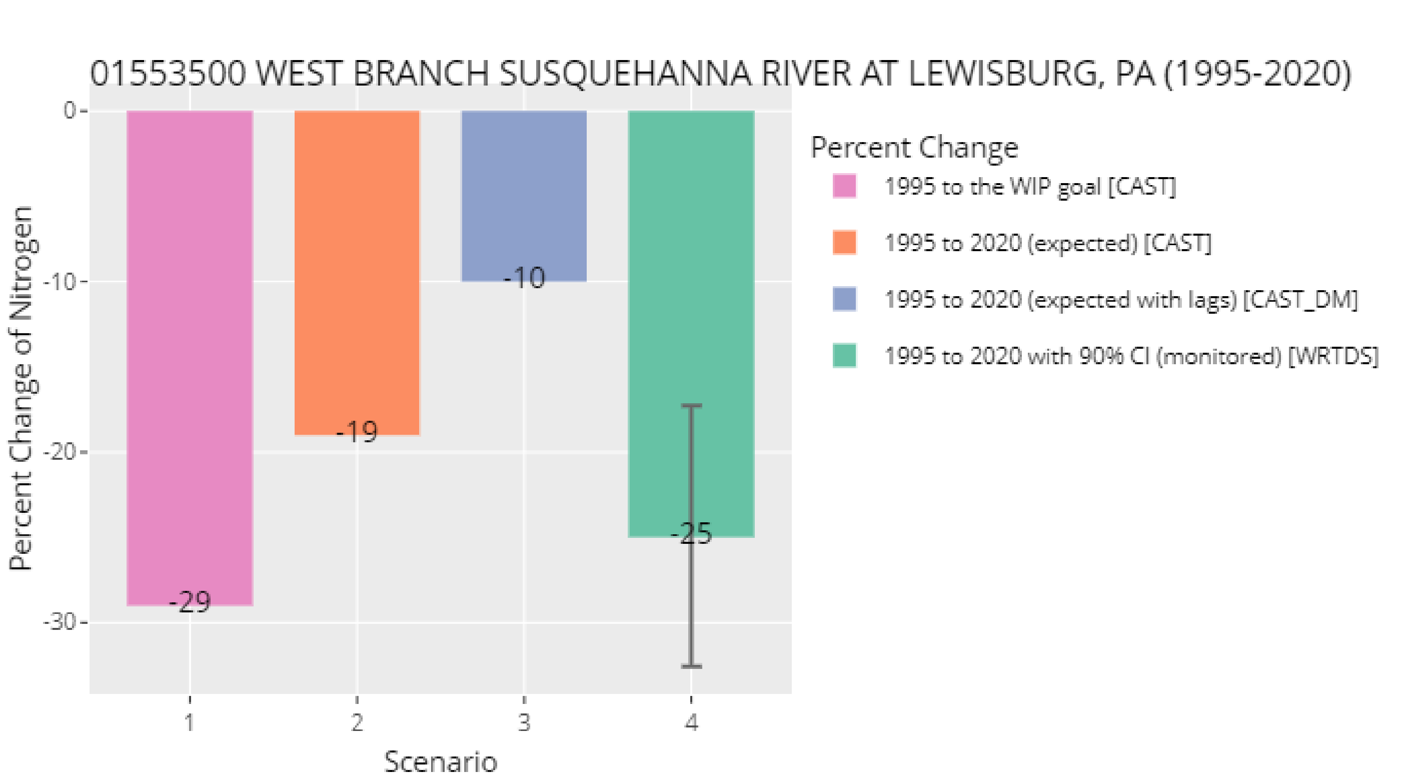

**Interpretive Text**

1. CAST estimates a 38 percent reduction in the long term from implementation of the WIP using 2025 land use and inputs.
2. CAST estimates a 6 percent reduction in the long term from 2020 land use, inputs, and management practices.
3. The Dynamic Watershed Model estimates that only a 2 percent reduction would have been seen by 2020, accounting for lags, sampling frequency, and other factors.
4. The river monitoring data show a 20 percent increase with a 90% uncertainty range between 15 and 24 percent increase.

**Implication**: The observed response is less than expected in 2020.

# Example 3: **01553500 West Branch Susquehanna River** Total Nitrogen




**Interpretive Text**

1. CAST estimates a 29 percent reduction in the long term from implementation of the WIP using 2025 land use and inputs.
2. CAST estimates a 19 percent reduction in the long term from 2020 land use, inputs, and management practices.
3. The Dynamic Watershed Model estimates that only a 10 percent reduction would have been seen by 2020, accounting for lags, sampling frequency, and other factors.
4. The river monitoring data show a 25 percent reduction with a 90% uncertainty range between 17 and 33 percent reduction.

**Implication**: The observed response is more than expected in 2020.

# Partnership vetting (Thank you!)

- 09/2021 CBPO discussions
- 07/2022 USGS-led Factors Affecting Trends Group
- 08/2022 Status and Trends Workgroup
- 10/2022 Watershed Technical Workgroup
- 11/2022 WQGIT
- 03/2023 Status and Trends Workgroup
- 03/2023 WQGIT – Approved
- 04/2023 Modeling Workgroup
- 10/2023 Integrated Trends Analysis Team
- 11/2023 Peer-reviewed publication in Ecological Indicators
- 2023 Various groups including USGS, NRCS, DEP, PA 4R Alliance

* Each meeting produced recommendations that strengthened the product.

# Main developers

- Qian Zhang (UMCES @ CBPO; qzhang@chesapeakebay.net)
- Gary Shenk (USGS @ CBPO; gshenk@chesapeakebay.net)
- Gopal Bhatt (PSU @ CBPO; gbhatt@chesapeakebay.net)
- Isabella Bertani (UMCES @ CBPO; ibertani@chesapeakebay.net)




# Thank you!