

# The Chesapeake Bay Program's Phase 6 Watershed Model

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Gopal Bhatt<sup>3</sup>, Isabella Bertani<sup>5</sup>, Andrew Sommerlot<sup>5</sup>, Matt Johnston<sup>4</sup>, and many others

**Chesapeake Bay Program Partnership**

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**USDA Legacy Phosphorus Modeling Workshop**

12/15/2021

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# Summary - The Phase 6 (2017 version) of the CBP watershed model...

- Was developed through participatory modeling
- Has a dramatically simplified structure relative to previous versions
- Does not create knowledge, but rolls up what we know from other sources into an integrated tool
- Shows excellent agreement to observations spatially, but not temporally

# Types of Models

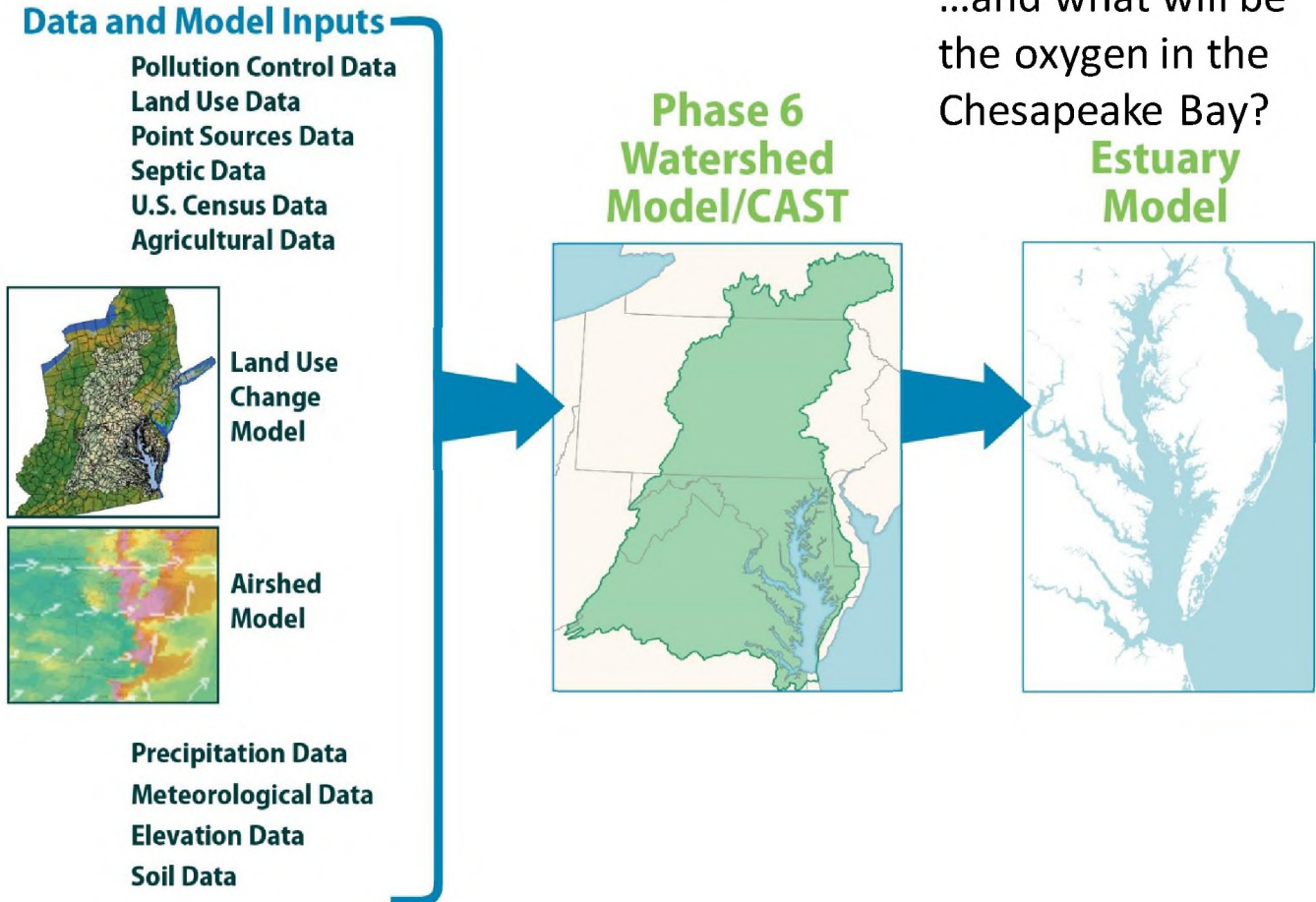
- Prediction
  - Temporal
  - Spatial
- Research
- Scenarios ✓



If we change what we do on the landscape...

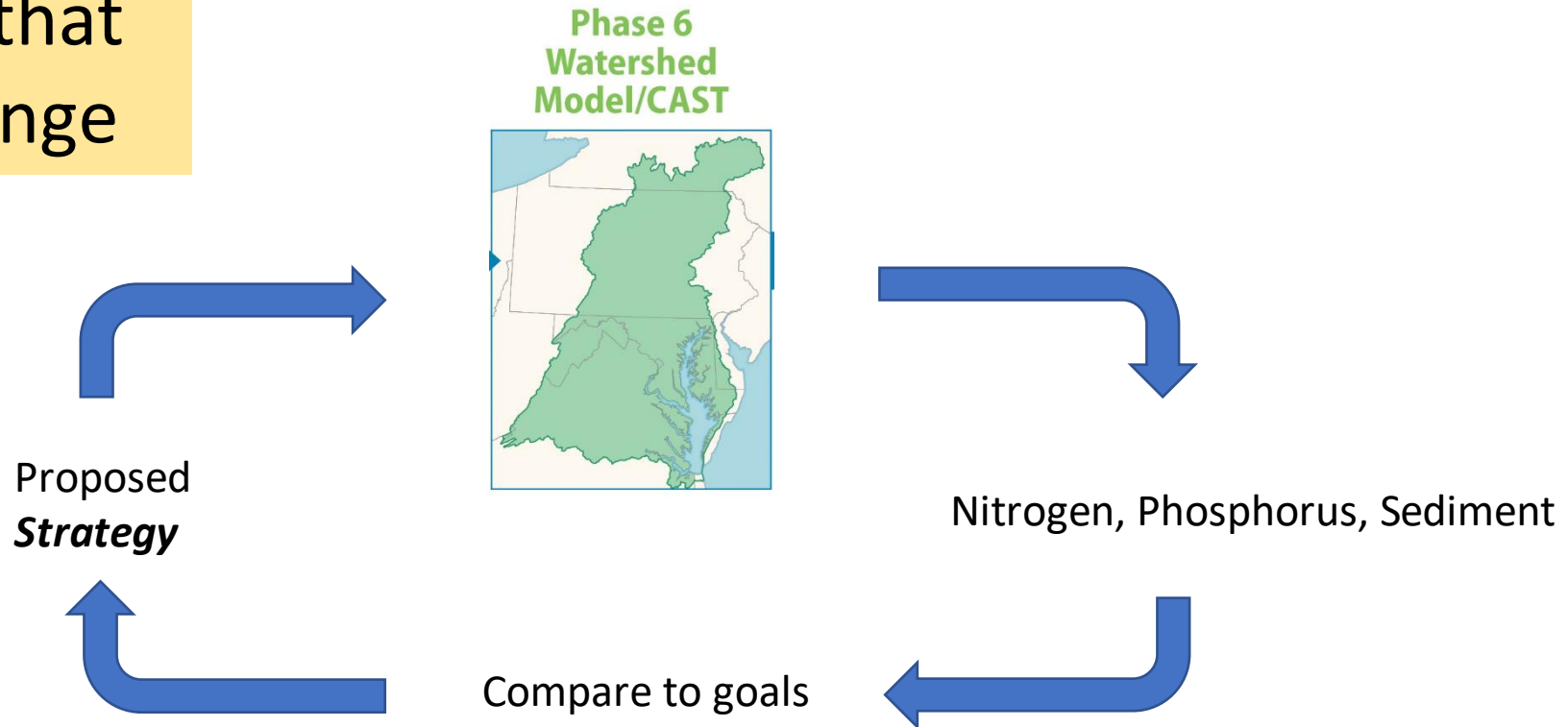
...how will that change nitrogen, phosphorus, and sediment?

...and what will be the oxygen in the Chesapeake Bay?



# General Use Case of CBP WSM (CAST)

Organization that  
can make change



# Chesapeake Assessment Scenario Tool

HOME SCENARIOS RESULTS COST PROFILES HOW TO ABOUT CONTACT US

## CAST PLANNING TOOLS

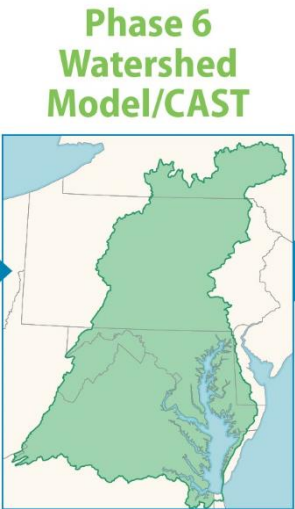
Logging in to CAST allows users to rapidly develop scenarios for reducing nitrogen, phosphorus and sediment with varying best management practices to streamline environmental planning. Costs are provided so users may select the most cost-effective practices to reduce pollutant loads.

### Welcome

gshenk@chesapeakebay.net

Manage Your Profile

Log Off



## RESOURCES

### MODEL DOCUMENTATION

Find information about the Phase 6 model, its documentation and links to calibration data, model review webinars and files.

Learn More

### DEVELOP A PLAN

Get answers to your questions about how to use CAST to develop a plan.

Develop A Plan

### SOURCE DATA

Download data tables including information on load sources and agencies, BMPs, animals, geographic references and delivery factors.

View Source Data

### RIVER TRENDS

Scientists calculate flow-adjusted trends in nitrogen, phosphorus and sediment levels to better determine whether pollution has changed over time.

View Trends

### MAP TOOLS, BMPs & VERIFICATION

View Geographical Information and Shapefiles, BMPs and Verification information.

Learn More

### TRACK TMDL PROGRESS

Information on how to submit progress data via NEIEN and view implementation data on meeting the Chesapeake Bay TMDL.

Track TMDL Progress

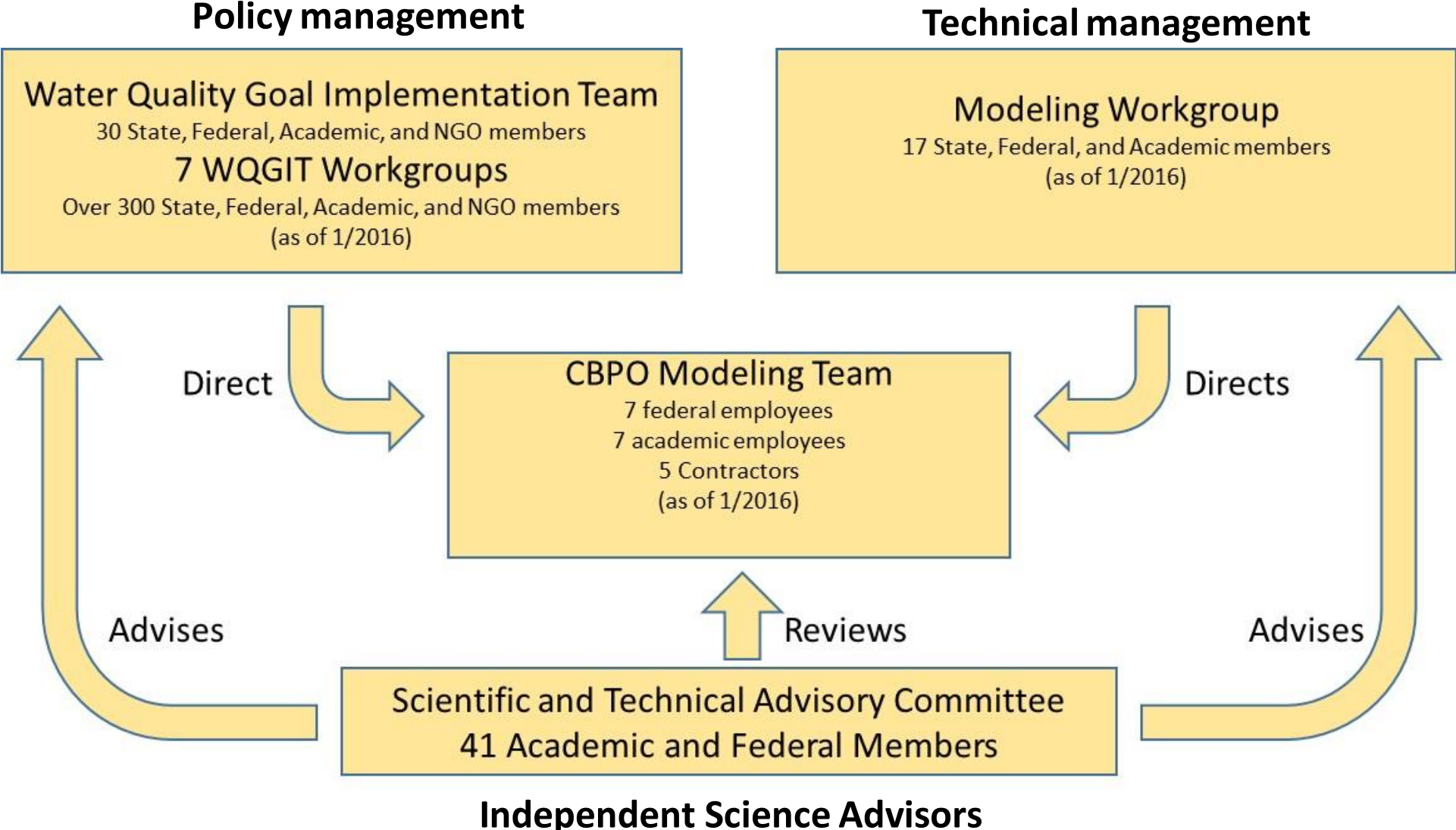
1000s of scenarios in 2018

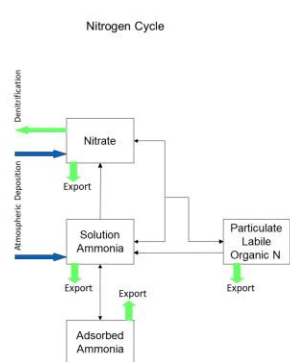


- The Chesapeake Bay Program is a partnership
  - Federal agencies
  - State agencies
  - Local governments
  - Non-profit organizations
  - Academic institutions

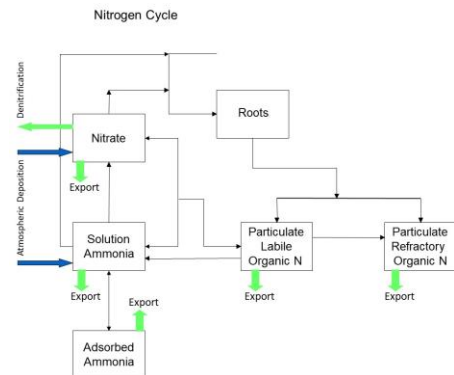


# Modeling governance

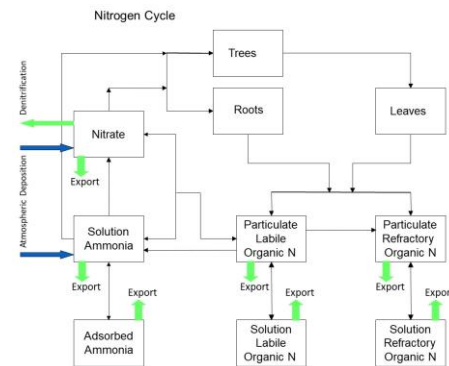




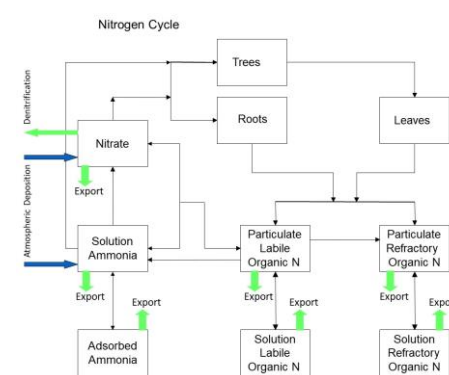
1980s  
HSPF



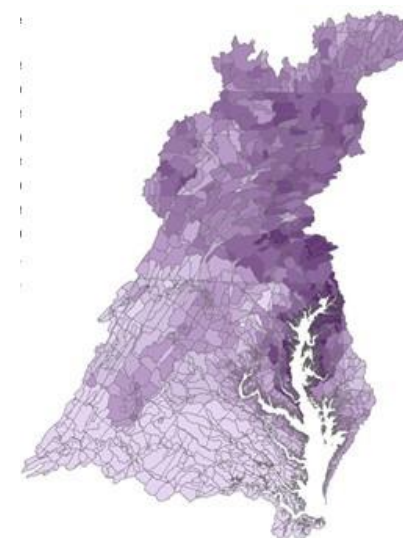
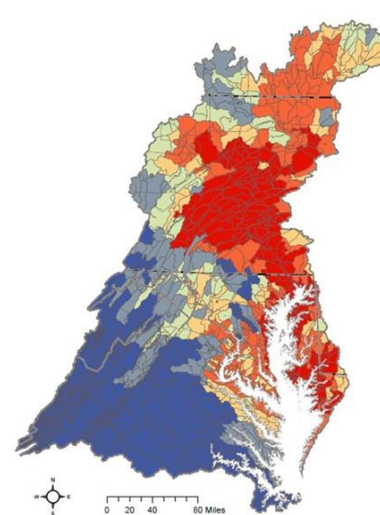
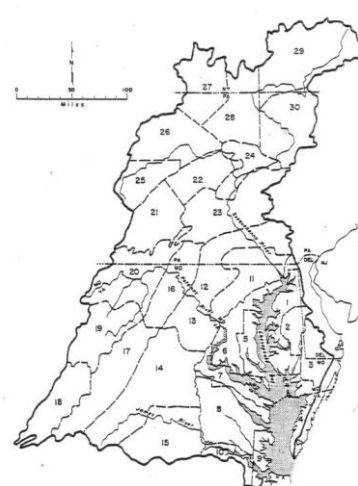
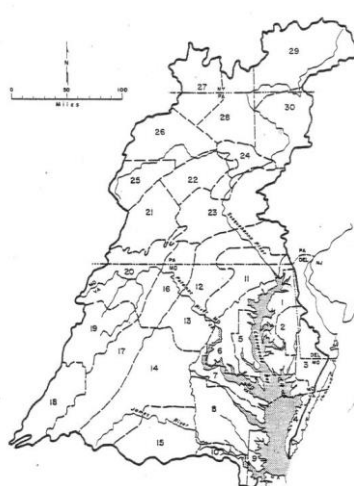
1990s  
HSPF



2000s  
HSPF



2010s  
HSPF







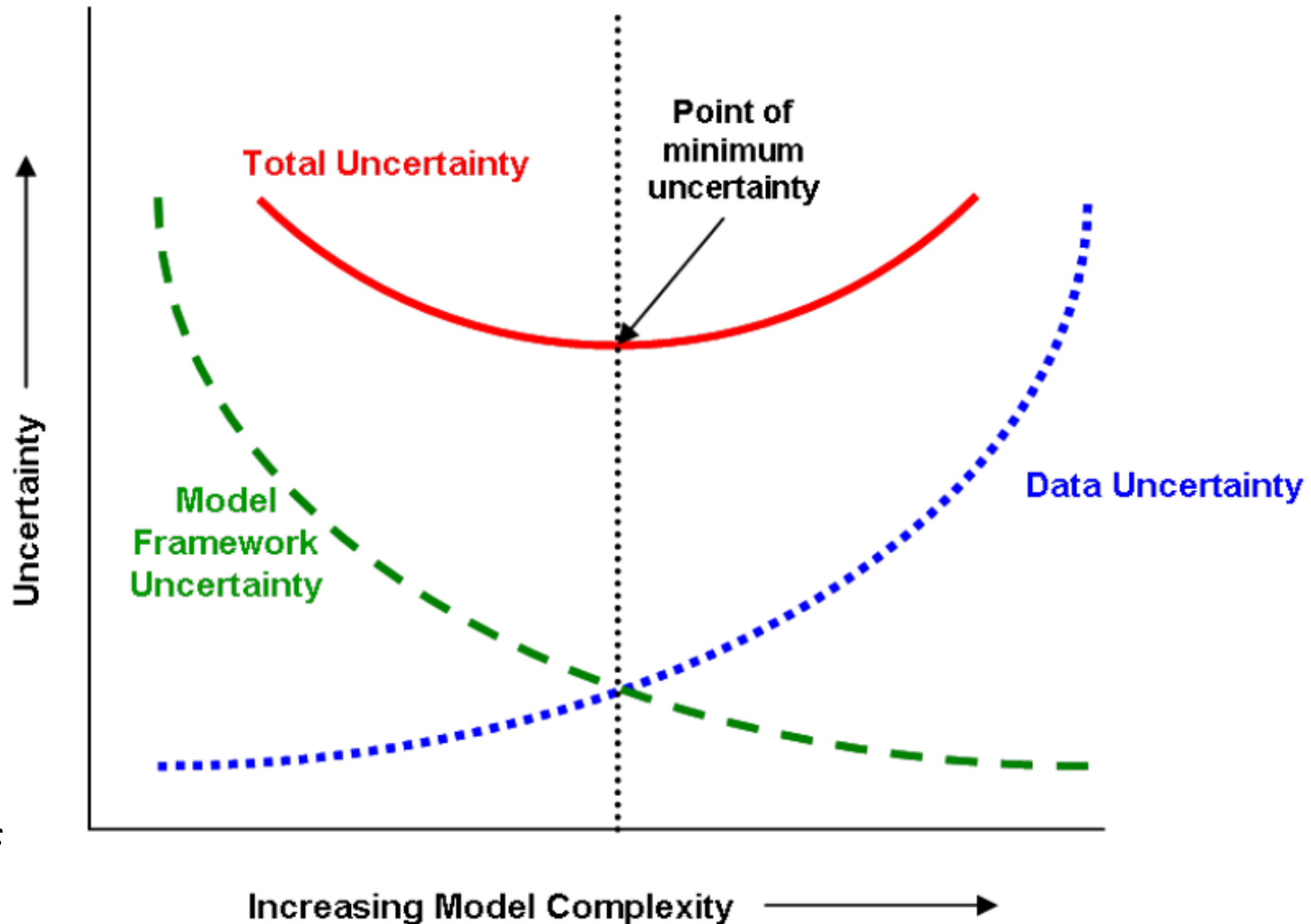
## Phase 6 Watershed model for 2017

- Understandable model
- Better and more local input data
- More use of monitoring data
- Inclusive process

# Pure Statistical Model

Silence on important management questions

What is the effect of a forest buffer?



# Pure Process Model

Unrealistic results in a subset of instances

Relationship between model framework uncertainty and data uncertainty, and their combined effect on total model uncertainty. Application niche uncertainty would scale the total uncertainty. Adapted from Hanna (1988) and EPA (2009a).

# Research Model ↔ Management Model

- Statistical Research Model
  - What can you learn from observations
- Process Research Model
  - What can you learn from aggregating processes
- Management model
  - Given everything that you've learned, what are the likely effects of potential anthropogenic changes.

# Main Prediction of the Watershed Model for decision support

- Change in long-term anthropogenic load of N and P
  - BMPs
  - WWTP
  - Land use Change
  - Response to Change in inputs
- Why do we need a dynamic model?

# Phase 6 Model Structure



**Average Load +  $\Delta$  Inputs \* Sensitivity**

**\***

**Land Use Acres**

**\***

**BMPs**

**\***

**Land to Water**

**\***

**Stream Delivery**

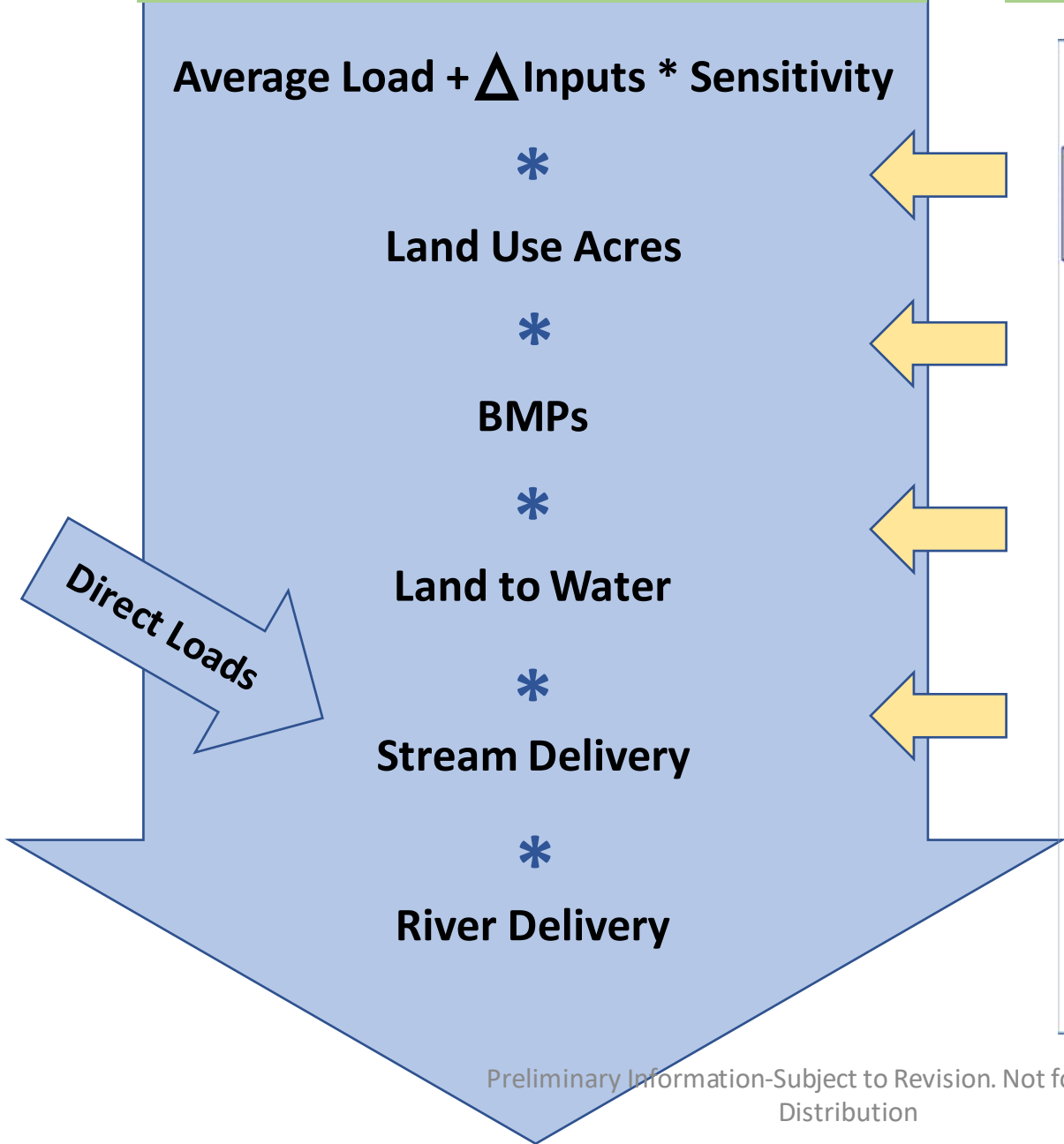
**\***

**River Delivery**

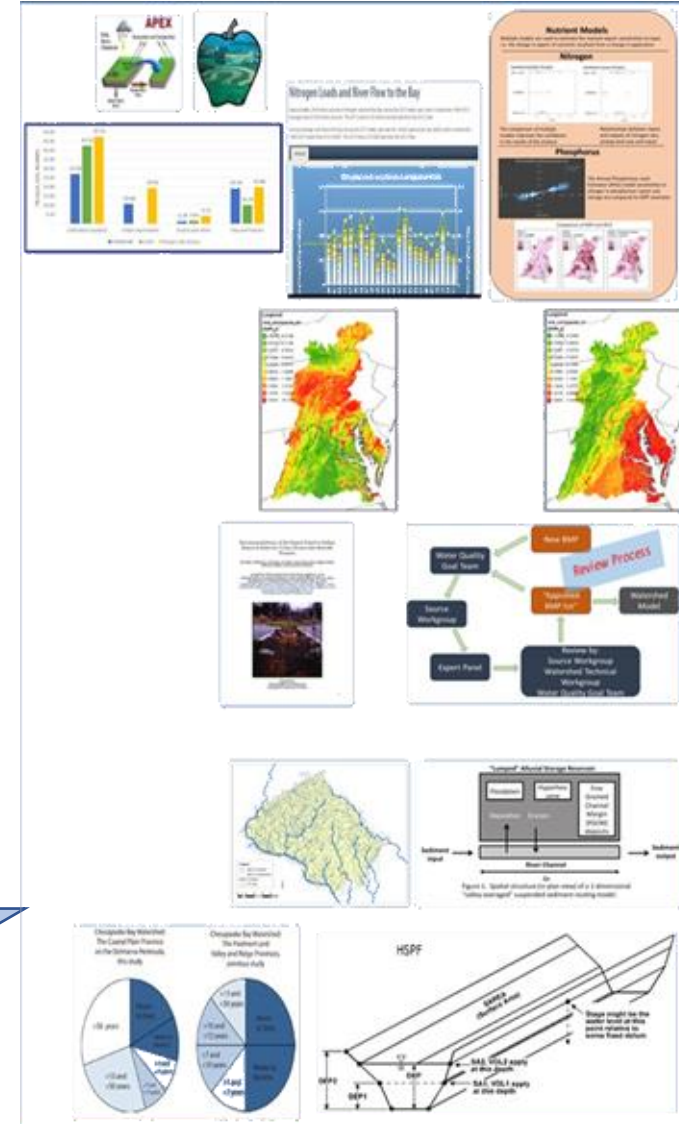
## Phase 6

Preliminary Information-Subject to Revision. Not for Citation or Distribution

# Keep It Simple



# Include Everything



- SWAT
- APEX
- APLE
- Sparrow
- HSPF
- All used

# Phase 6 Model Structure



Average Load +  $\Delta$  Inputs \* Sensitivity

\*

Land Use Acres

\*

BMPs

\*

Land to Water

\*

Stream Delivery

\*

River Delivery

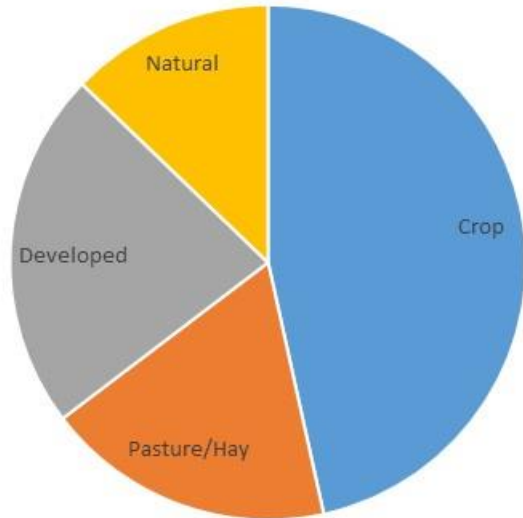
Direct Loads

## Phase 6

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# Average Loads

Average Loads – Average edge-of-small-stream loading rate for a given land use for the entire CB watershed



Divide into Broad Classes

***Modeling Workgroup***

Multiple models

*Phase 5.3.2*

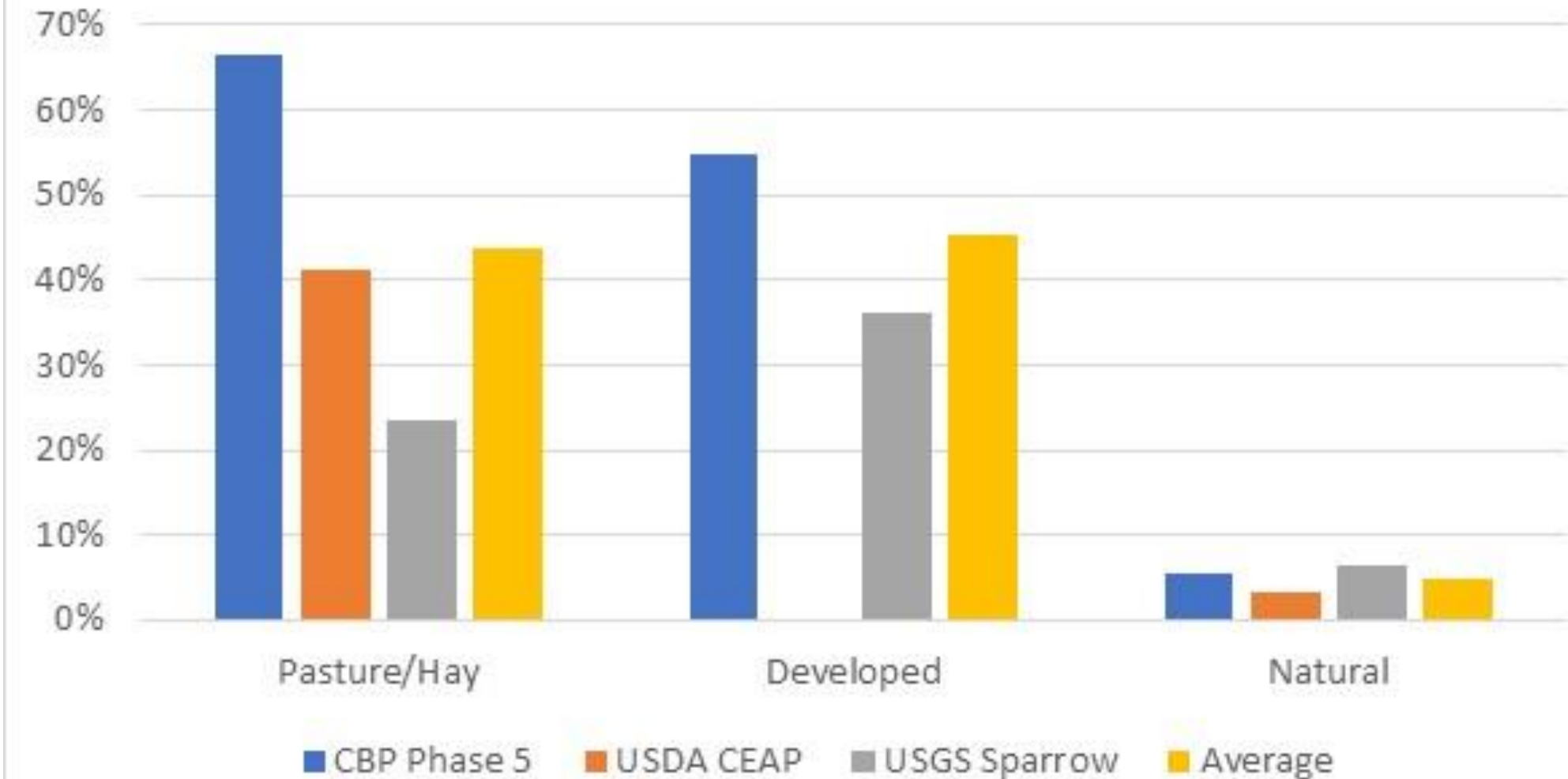
*Sparrow*

*CEAP*



# Multiple model averaging

P loading rate relative to crop



# Phase 6 Model Structure



Average Load +  $\Delta$  Inputs \* Sensitivity

\*

Land Use Acres

\*

BMPs

\*

Land to Water

\*

Stream Delivery

\*

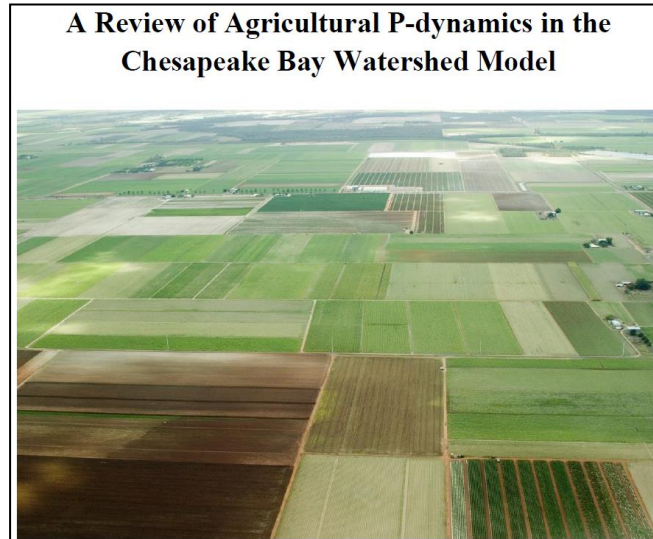
River Delivery

Direct Loads

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# Scientific Direction on Agricultural P



- Track drawdown and buildup of soil P reservoirs by segment as a source of P runoff
- Get better manure, fertilizer, application method, and soil P data
- Account for management (method, timing, tillage, etc)

The State of the Science of Phosphorus

January 30, 2015  
Chesapeake College

HOME • CONTACT • REGISTER

Agenda Presenters Location Hosts

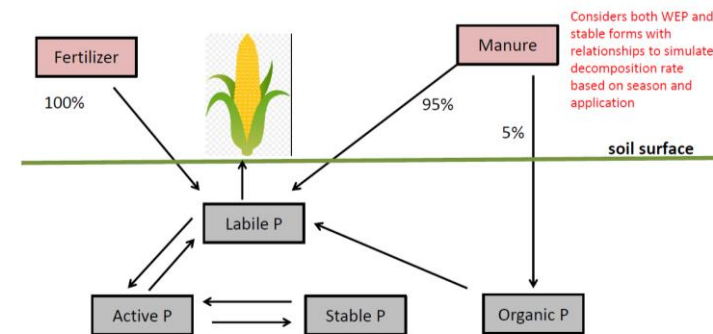
The State of the Science of Phosphorus

This symposium draw 350 attendees seeking to better understand the current state of science surrounding phosphorus transport, soil dynamics, legacies, modeling, and its impact on water quality. Experts on the science of phosphorus from across the country were featured on the program.

Visit the Phosphorus Symposium [playlist](#) to watch presentations by selecting individual sessions or play all for continuous play of the program. [Proceedings](#) are also available in PDF format to download.

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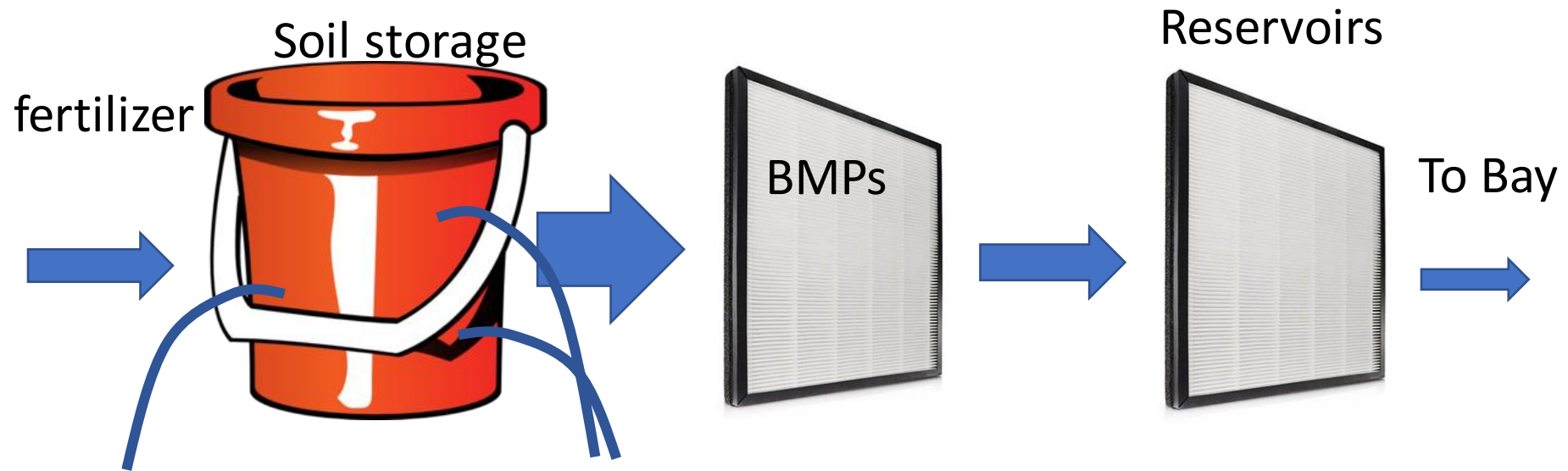
Diagram of APLE Nutrient Sources and Soil Pools



Equations to estimate Manure runoff P, Fertilizer runoff P, Sediment P loss, and Dissolved Soil P runoff

(Adapted from Vadas, et al. 2007)

# Phosphorus Conceptual Model



For phosphorus, the amount of storage in the soil is the most important thing

# APPLE Hightill Landuse Sensitivities using Constant Mehlich 3 Soil P

**Table 1. Phosphorus Loss APPLE Model Sensitivity to change in inputs**

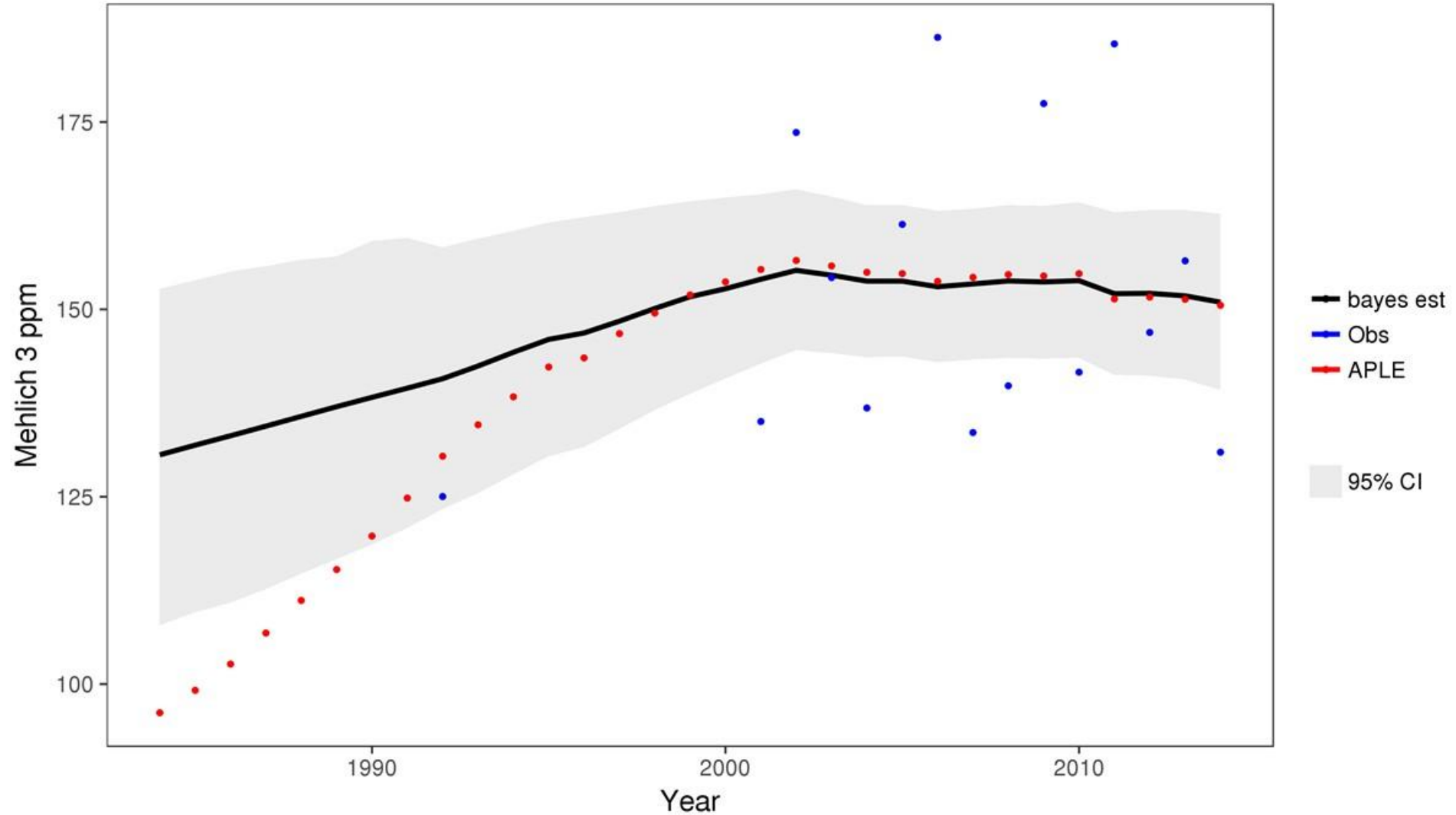
| Inputs                | Units               | MEDIAN SLOPE     | MEDIAN SR        | Relative Sensitivity          |
|-----------------------|---------------------|------------------|------------------|-------------------------------|
| Mehlich               | ppm                 | 0.015            |                  |                               |
| Sediment              | ton/ac              | 0.168            | 0.633            | Sensitive                     |
| Runoff                | inches              | 0.057            | 0.403            | Moderately sensitive          |
| <del>Manure</del>     | <del>lbs/acre</del> | <del>0.007</del> | <del>0.111</del> | <del>Slightly sensitive</del> |
| <del>Fertilizer</del> | <del>lbs/acre</del> | <del>0.004</del> |                  | <del>Slightly sensitive</del> |
| <del>Uptake</del>     | <del>lbs/acre</del> | <del>0</del>     |                  |                               |



Requires estimate of soil P

# Soil P estimate – Lancaster county PA

N42071 Est Soil History



# Phase 6 Model Structure



Average Load +  $\Delta$  Inputs \* Sensitivity

\*

Land Use Acres

\*

BMPs

\*

Land to Water

\*

Stream Delivery

\*

River Delivery

Direct Loads

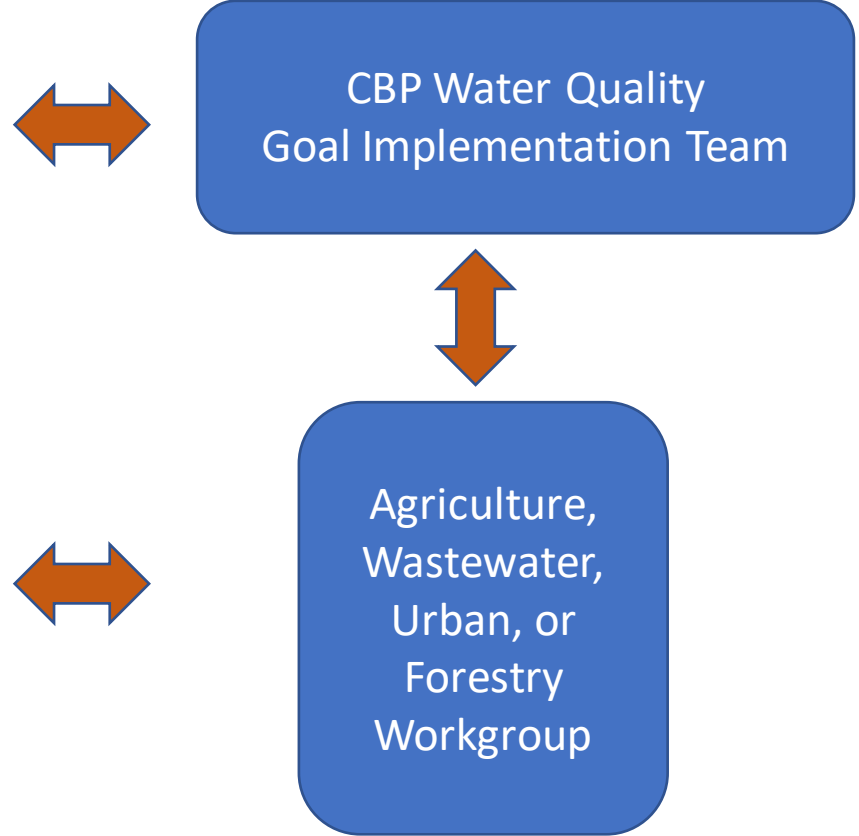
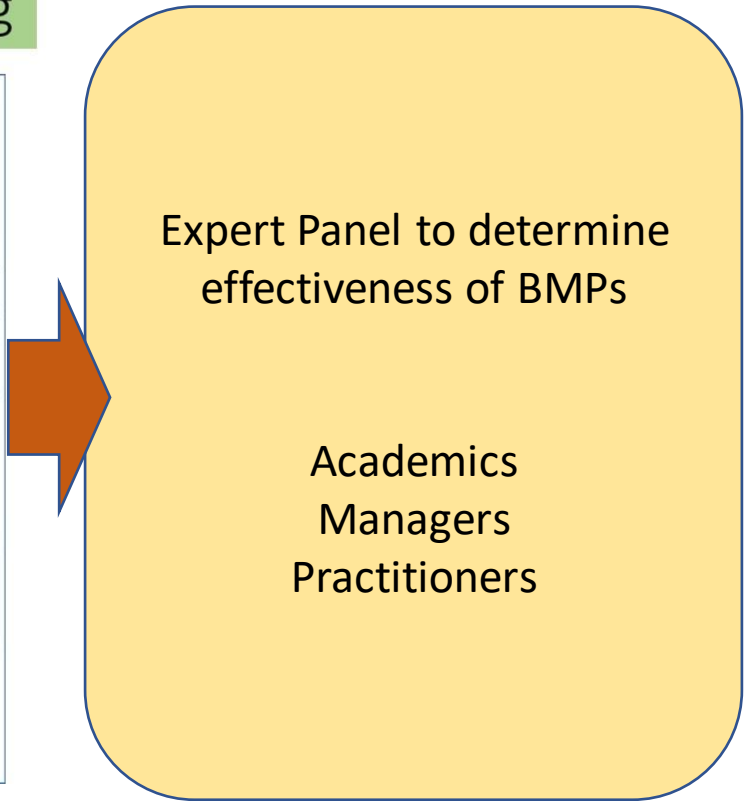
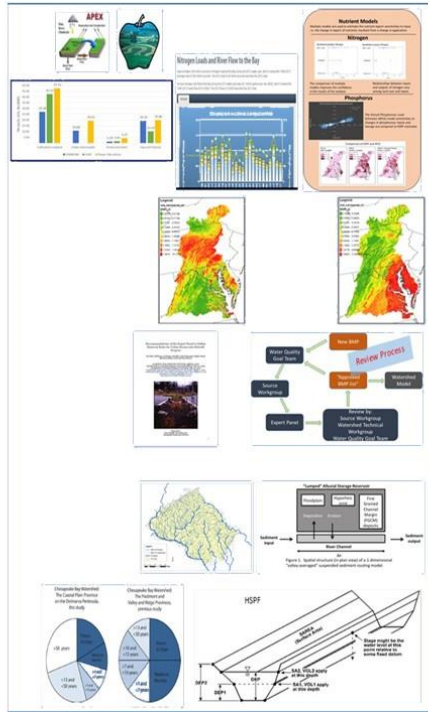
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# Collaborative Stakeholder-Expert Processes – BMP effectiveness

Include Everything





# Phase 6 Model Structure



Average Load +  $\Delta$  Inputs \* Sensitivity

\*

Land Use Acres

\*

BMPs

\*

Land to Water

\*

Stream Delivery

\*








River Delivery

Direct Loads

## Phase 6

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# Catchment Attributes Used in SPARROW Models

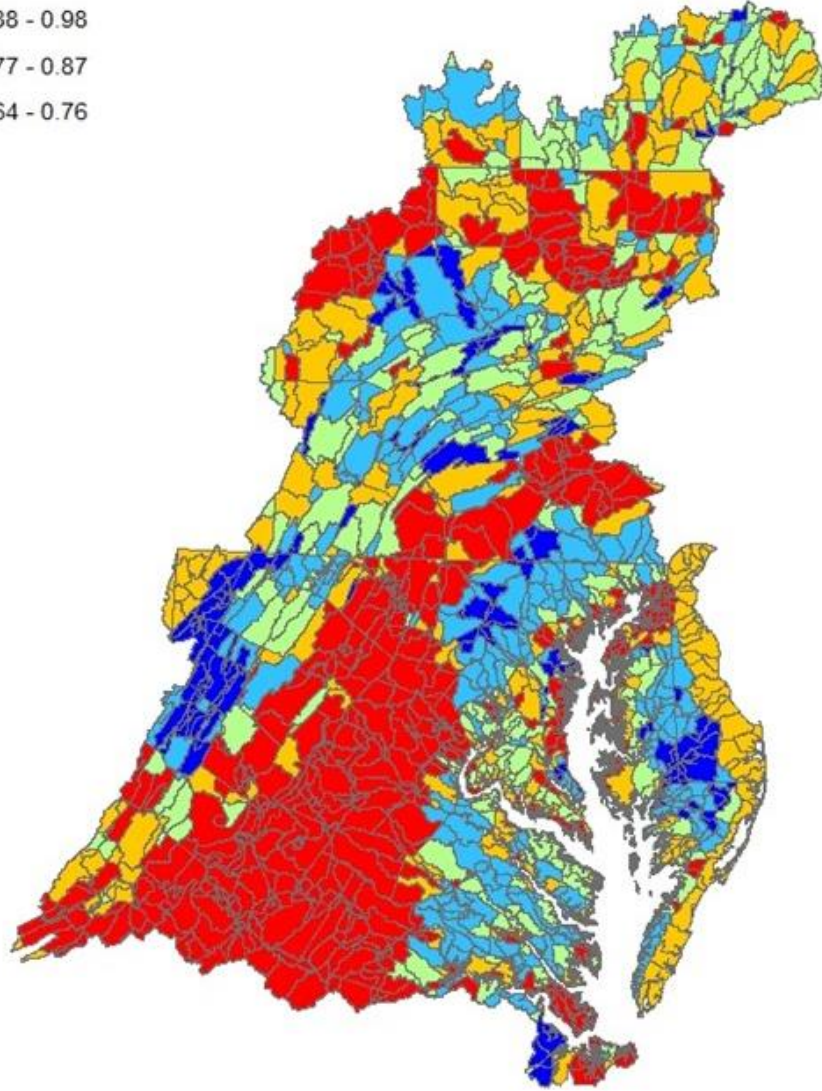
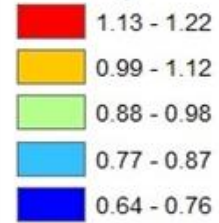
| Explanatory Variable   | Nitrogen                                                                                                                    | Phosphorus                                                                                                                     |
|------------------------|-----------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| Land-to-Water Delivery | 1. % catchment in Piedmont carbonate     | 1. <del>% catchment in Coastal Plain</del>  |
|                        | 2. Groundwater discharge                                                                                                    | 2. <del>Precipitation*</del>                |
|                        | 3. Available soil water capacity         | 3. <del>Soil erodibility*</del>             |
|                        | 4. <del>Enhanced vegetative index</del>  | 4. well-drained soils                       |

Precipitation and Soil erodibility already represented and runoff and erosion Coastal Plain captured by legacy soil P not accounted for in this version of Sparrow

## Phosphorus Delivery Variation Factors

### P6 Land River Segments

#### pdvfcrop



Land to Water factors for

# Crop

- Well-drained soils ↓

# Phosphorus

# Phase 6 Model Structure



Average Load +  $\Delta$  Inputs \* Sensitivity

\*

Land Use Acres

\*

BMPs

\*

Land to Water

\*

Stream Delivery

\*

River Delivery

Direct Loads

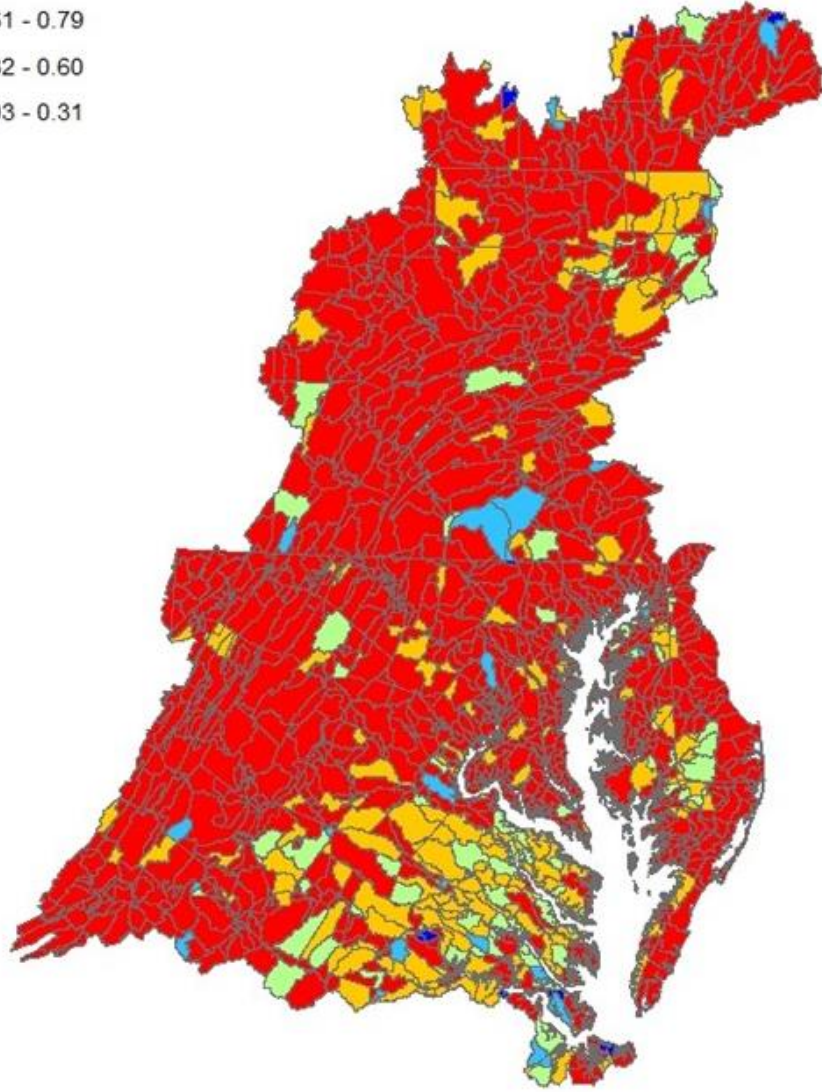
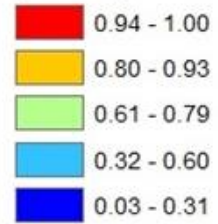
## Phase 6

Preliminary Information-Subject to Revision. Not for Citation or Distribution

## Phosphorus Stream-to-River Factors

### P6 Land River Segments

#### pstrcrop



Stream to River factors for

# Crop

Reservoirs



# Phosphorus

# Adding time dimension for calibration



Average Load +  $\Delta$  Inputs \* Sensitivity

\*

Land Use Acres

\*

BMPs

\*

Land to Water

\*

Stream Delivery

\*

River Delivery

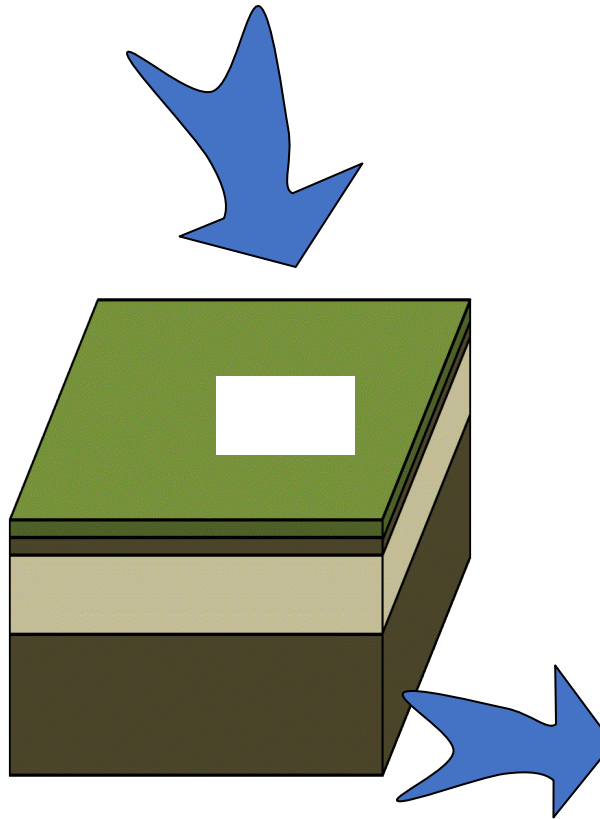
Direct Loads

time

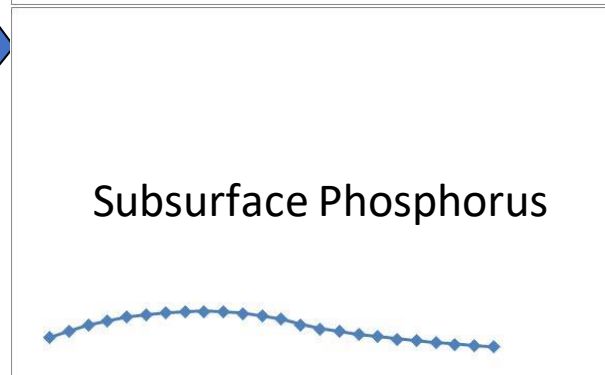
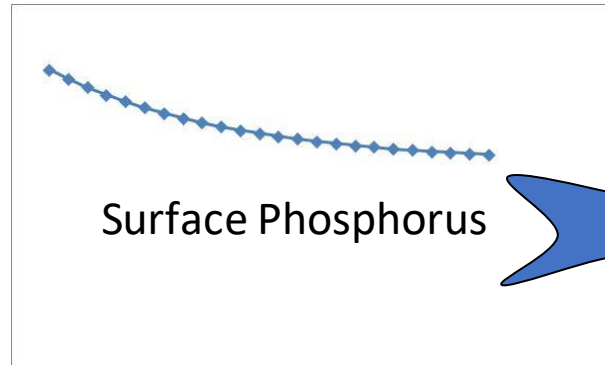
Phase 6

# Lag Models

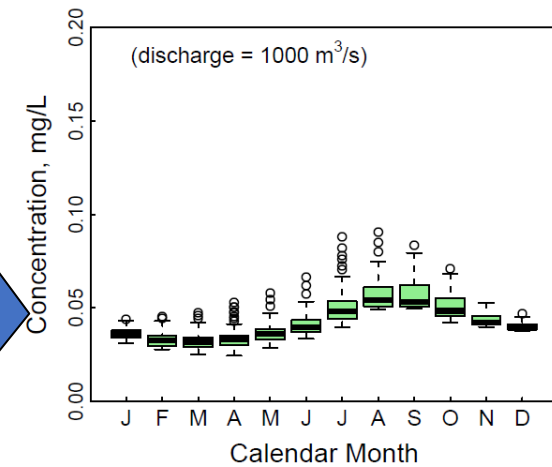
Each Loading Event



Surface nitrogen



Calibrated to match  
Observed seasonality



# Stakeholder Science

- Transparent science is more palatable to stakeholders
- Multiple lines of evidence has scientific support

... but does it work?

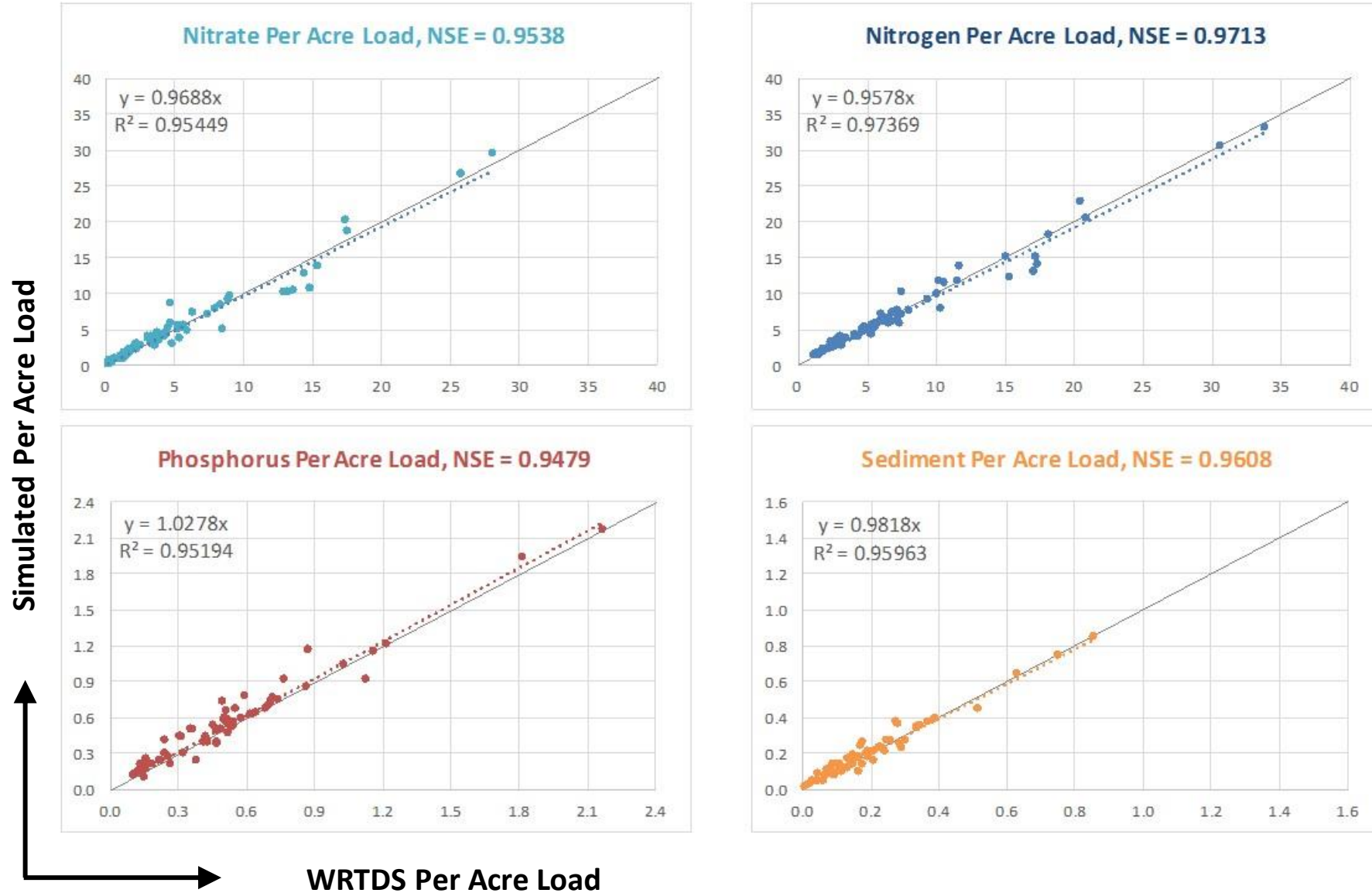
Compare

2010 Phase 5 Process Model

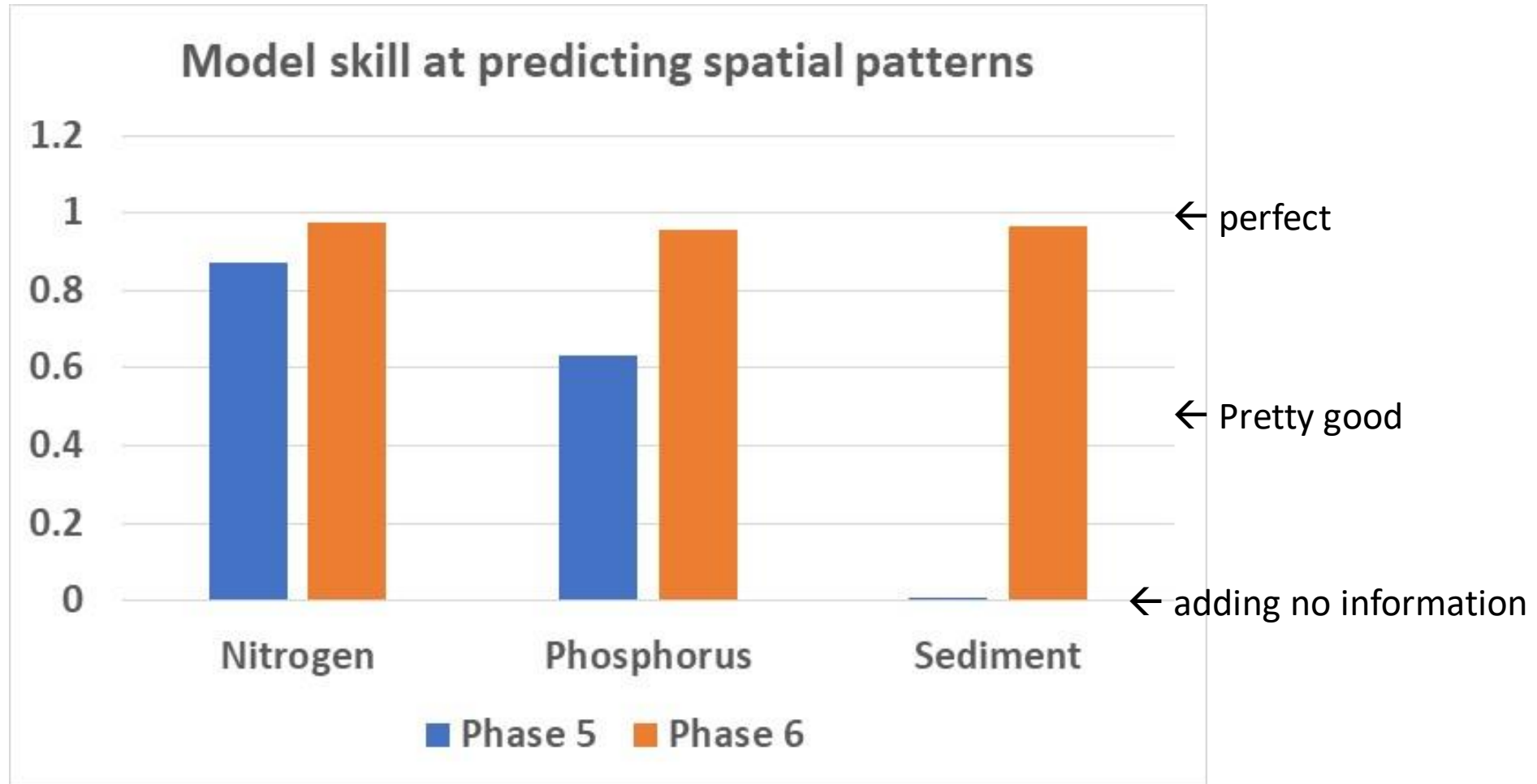
2017 Phase 6 Stakeholder Model



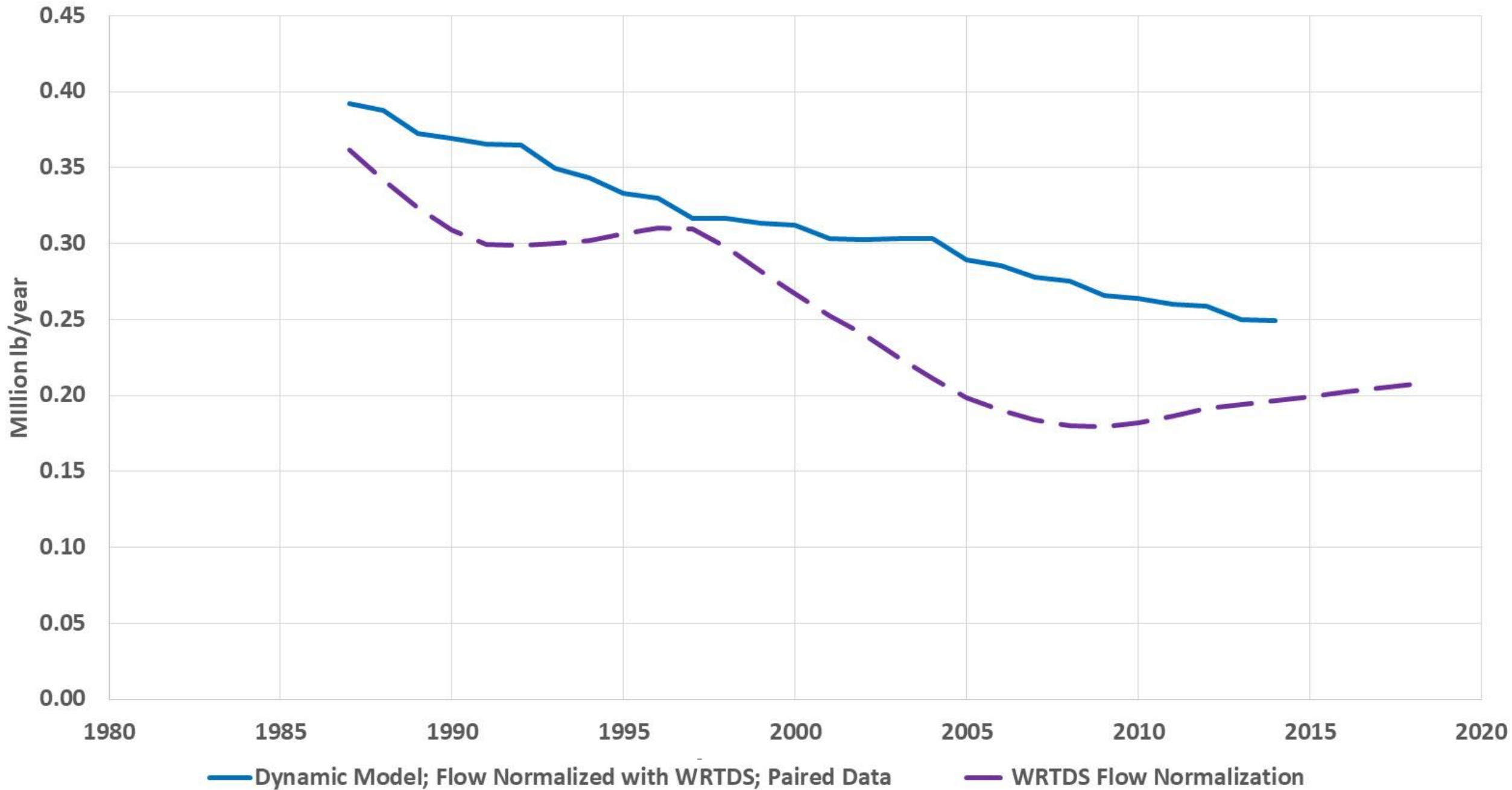
# DRAFT 2017 Model – geographic efficiencies



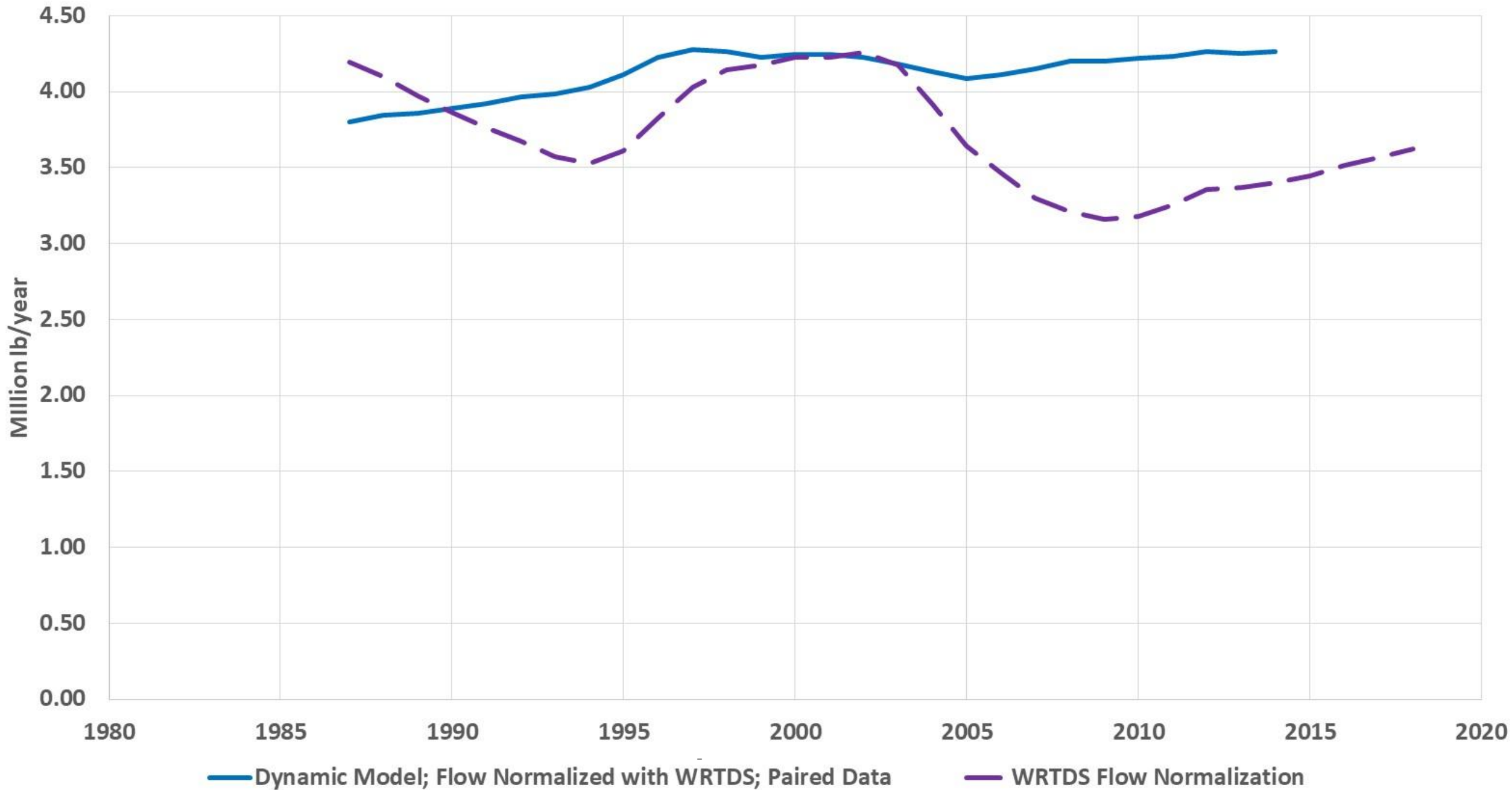
# How well did it work?



# Conestoga River at Conestoga, PA TP



# Susquehanna River at Marietta, PA TP



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