Introduction to CAST (part 2) How and Why

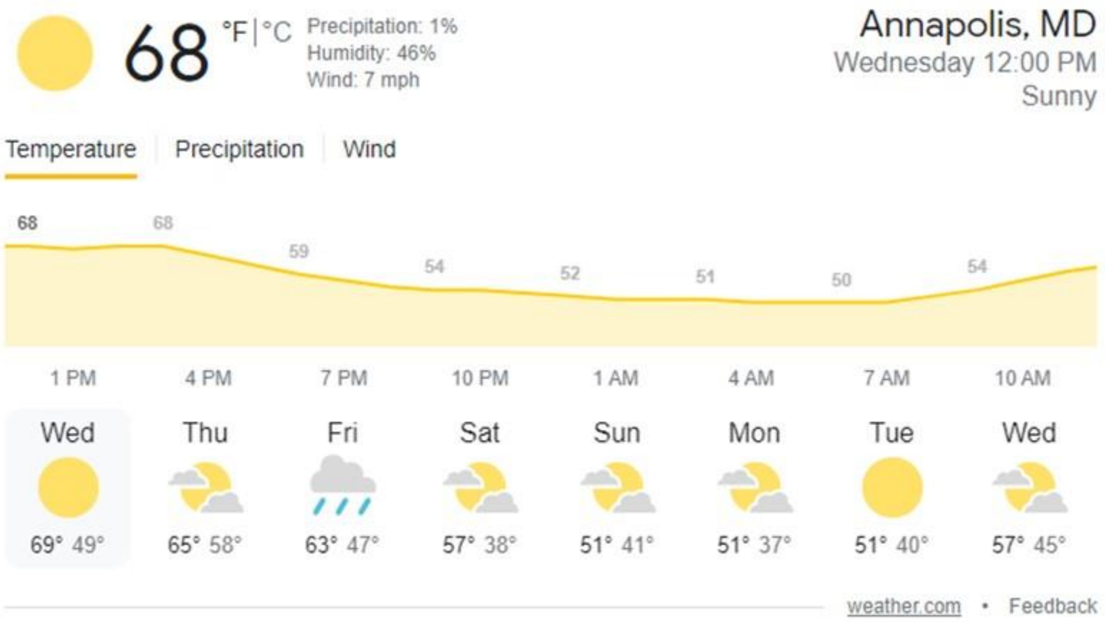
Gary Shenk 11/01/2022

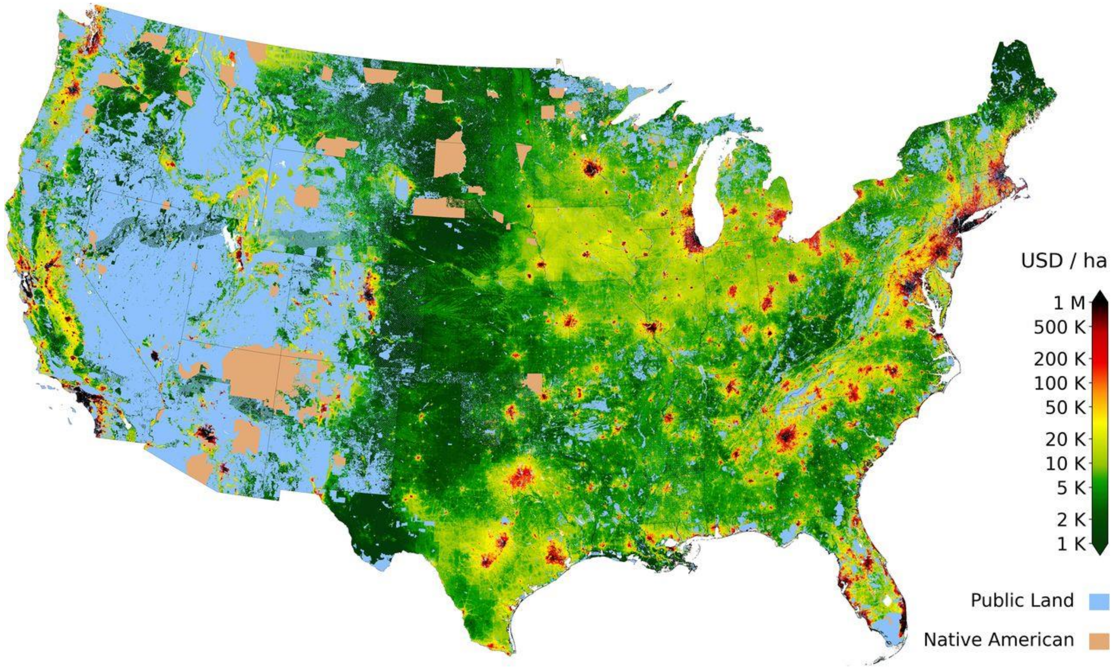
AMT Introduction to CAST

- Model Purpose
- Model Structure
- Responsibility of the AMT
- AMT considerations
  - Importance of consistent data
  - Scale
- CAST in the overall context of Phase 7 model development

Types of Models

- **Prediction**
  - **Temporal**
  - **Spatial**
- Research
- Scenarios

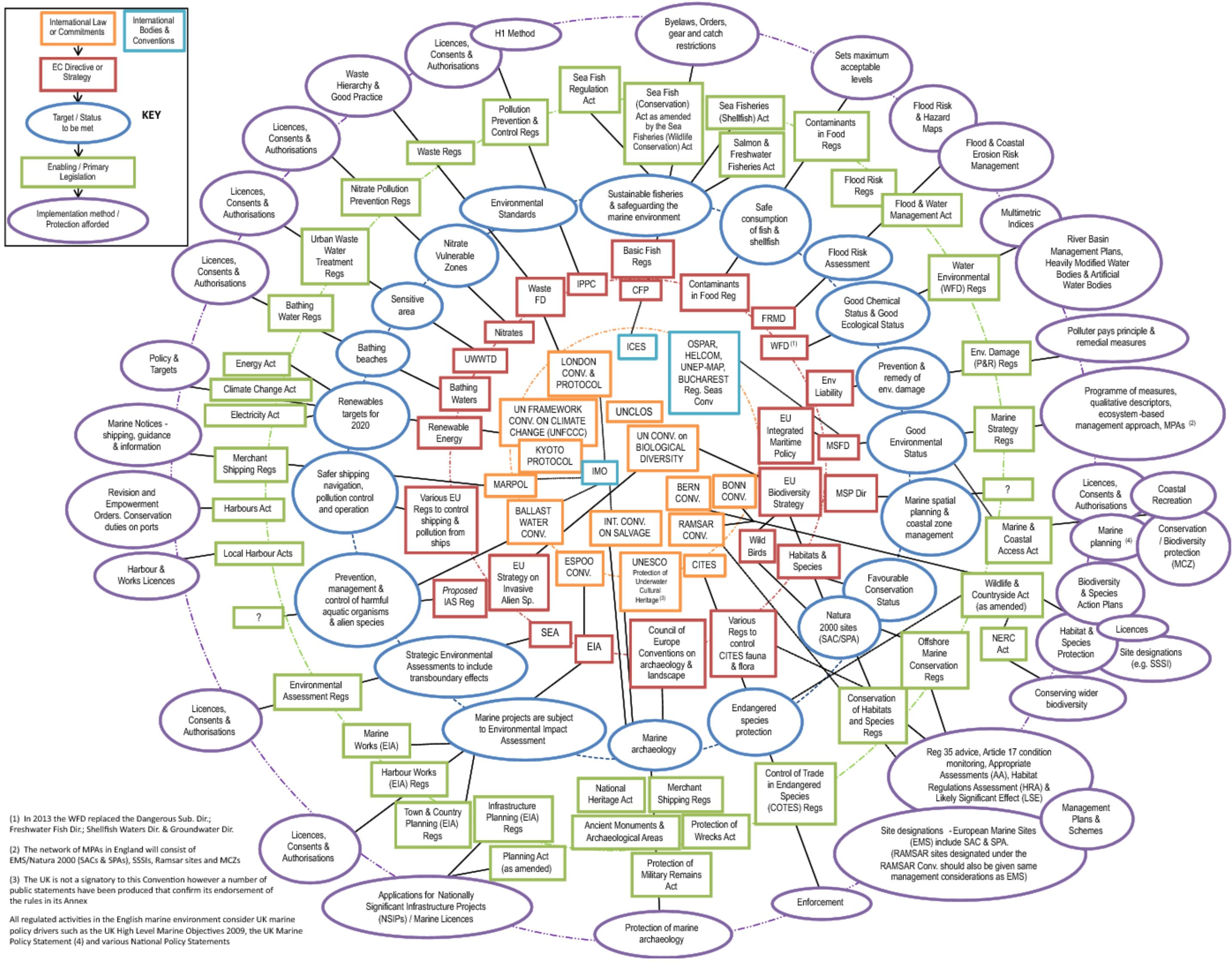




Nolte, C., 2020. High-resolution land value maps reveal underestimation of conservation costs in the United States. *Proceedings of the National Academy of Sciences*, *117*(47), pp.29577-29583.

Types of Models

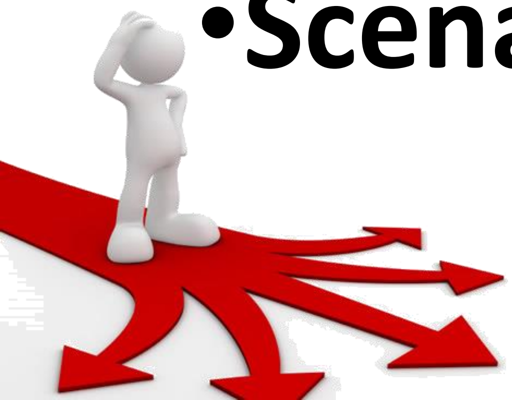
- Prediction
  - Temporal
  - Spatial
- **Research**
- Scenarios



How do things fit together and influence each other?

Types of Models

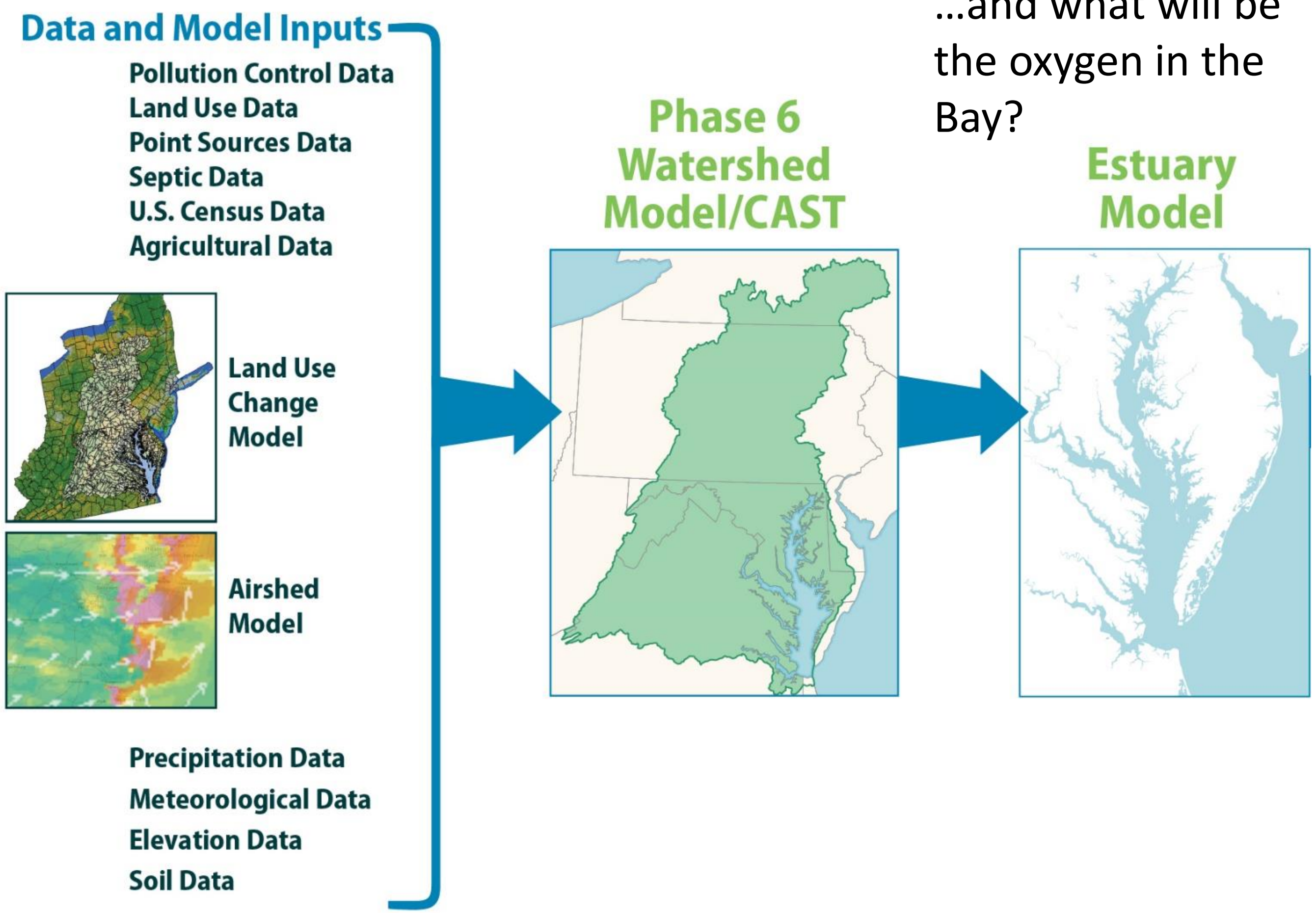
- Prediction
  - Temporal
  - Spatial
- Research
- **Scenarios** ✓



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 Bay?



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.

CAST Structure

CAST is a simple model

Inputs (Fertilizer, Manure, Atmospheric Deposition, Fixation, Wastewater)

*****

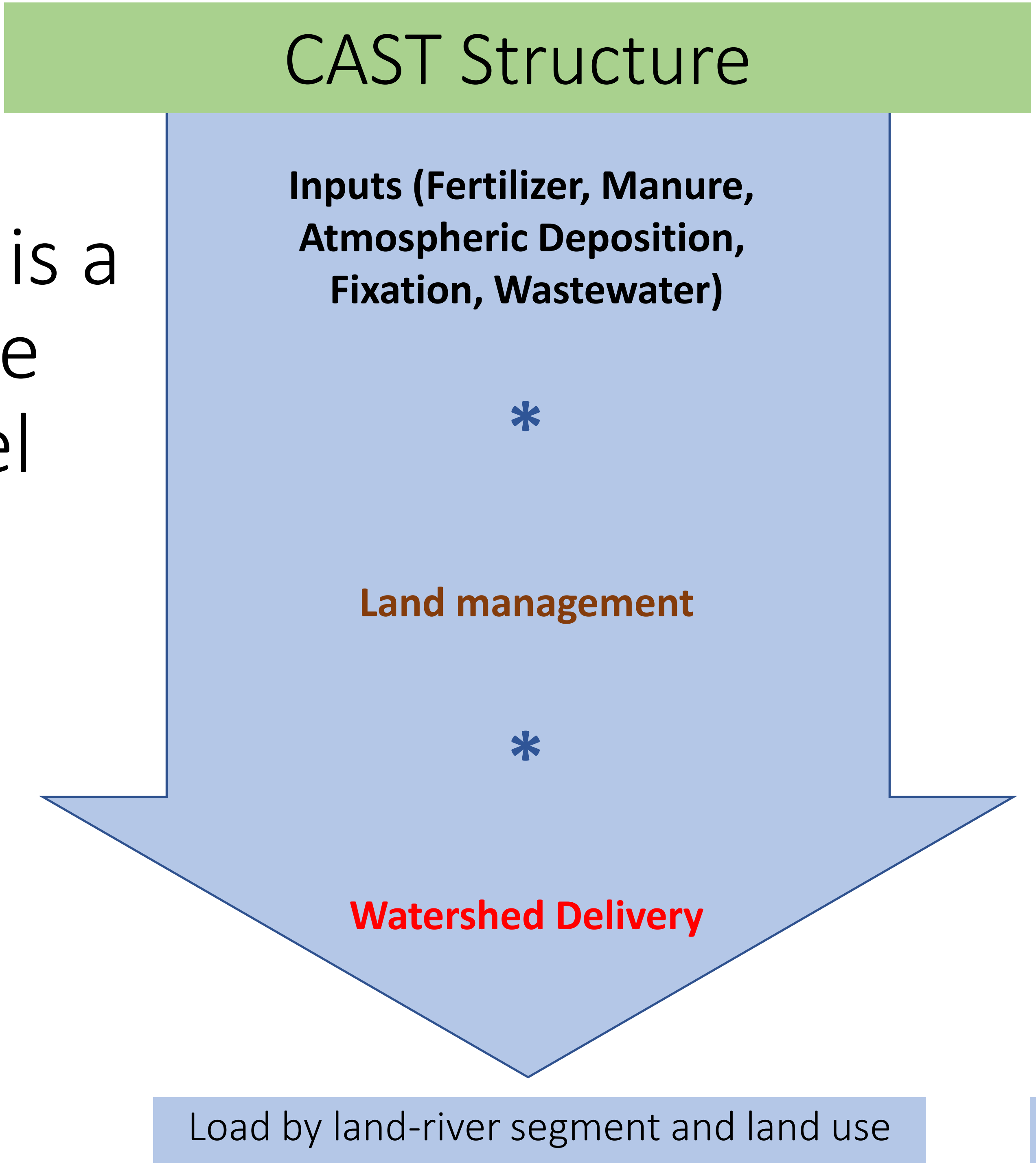
Land management

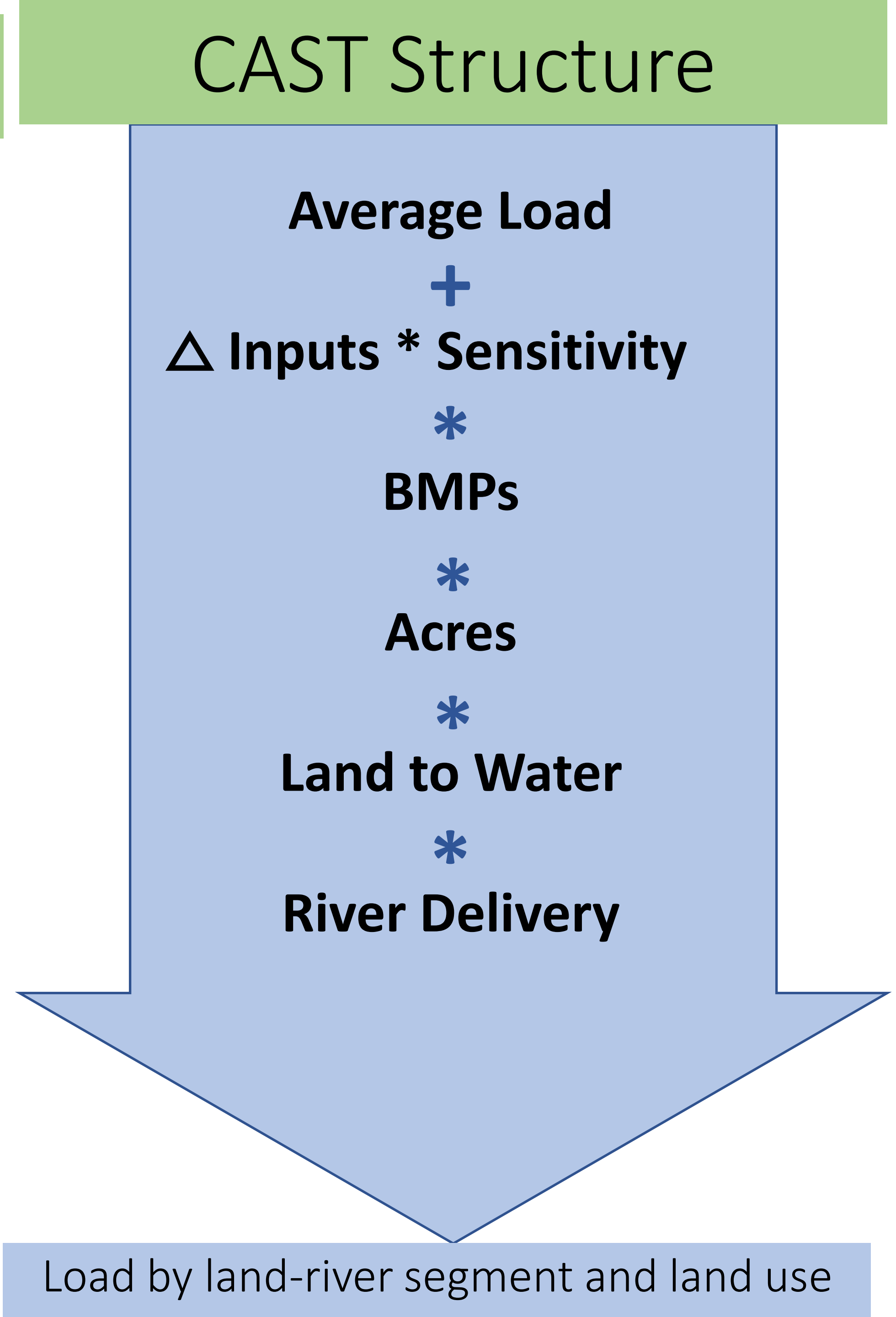
*****

Watershed Delivery

Load by land-river segment and land use

CAST is a simple model





CAST Structure

Illustrative example

Average Load

+

△ Inputs * Sensitivity

*****

BMPs

*****

Acres

*****

Land to Water

*****

River Delivery

Load by land-river segment and land use

Average nitrogen load to stream for double cropped ag land watershed wide is 40 pounds per acre

CAST Structure

Illustrative example

Average Load

+

△ Inputs * Sensitivity

*****

BMPs

*****

Acres

*****

Land to Water

*****

River Delivery

Load by land-river segment and land use

Your area applies 115 pounds of fertilizer while the watershed-wide average is 140.

Each additional pound of fertilizer results in 0.2 lbs of runoff

40 + (115-140) * 0.2 = 35 lbs/acre

CAST Structure

Illustrative example

Average Load

+

△ Inputs * Sensitivity

*****

BMPs

*****

Acres

*****

Land to Water

*****

River Delivery

Load by land-river segment and land use

BMPs are applied which give, in aggregate, a 20% reduction

35 * (1-.20) = 28 lbs/acre

CAST Structure

Illustrative example

Average Load

+

△ Inputs * Sensitivity

*****

BMPs

*****

Acres

*****

Land to Water

*****

River Delivery

Load by land-river segment and land use

There are 100 acres of double cropped land in this segment

28 lbs/acre * 100 acres = 2800 lbs

CAST Structure

Illustrative example

Average Load

+

△ Inputs * Sensitivity

*****

BMPs

*****

Acres

*****

Land to Water

*****

River Delivery

Load by land-river segment and land use

The land here is 50% leaker than average due to high groundwater recharge in the piedmont carbonate

The river system reduces loads by 30%

2800 lbs * 1.5 * (1-.30) = 2940 lbs
Delivered to the Bay from this land use and segment

Keep It Simple

Average Load

+

△ Inputs * Sensitivity

*****

BMPs

*****

Acres

*****

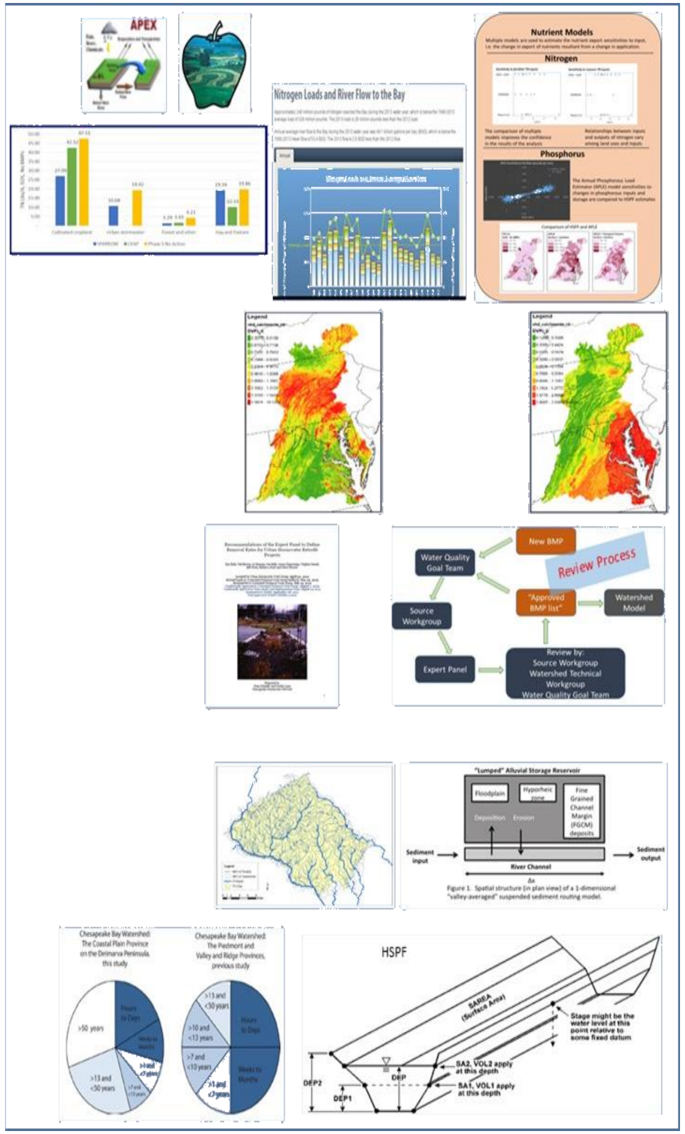
Land to Water

*****

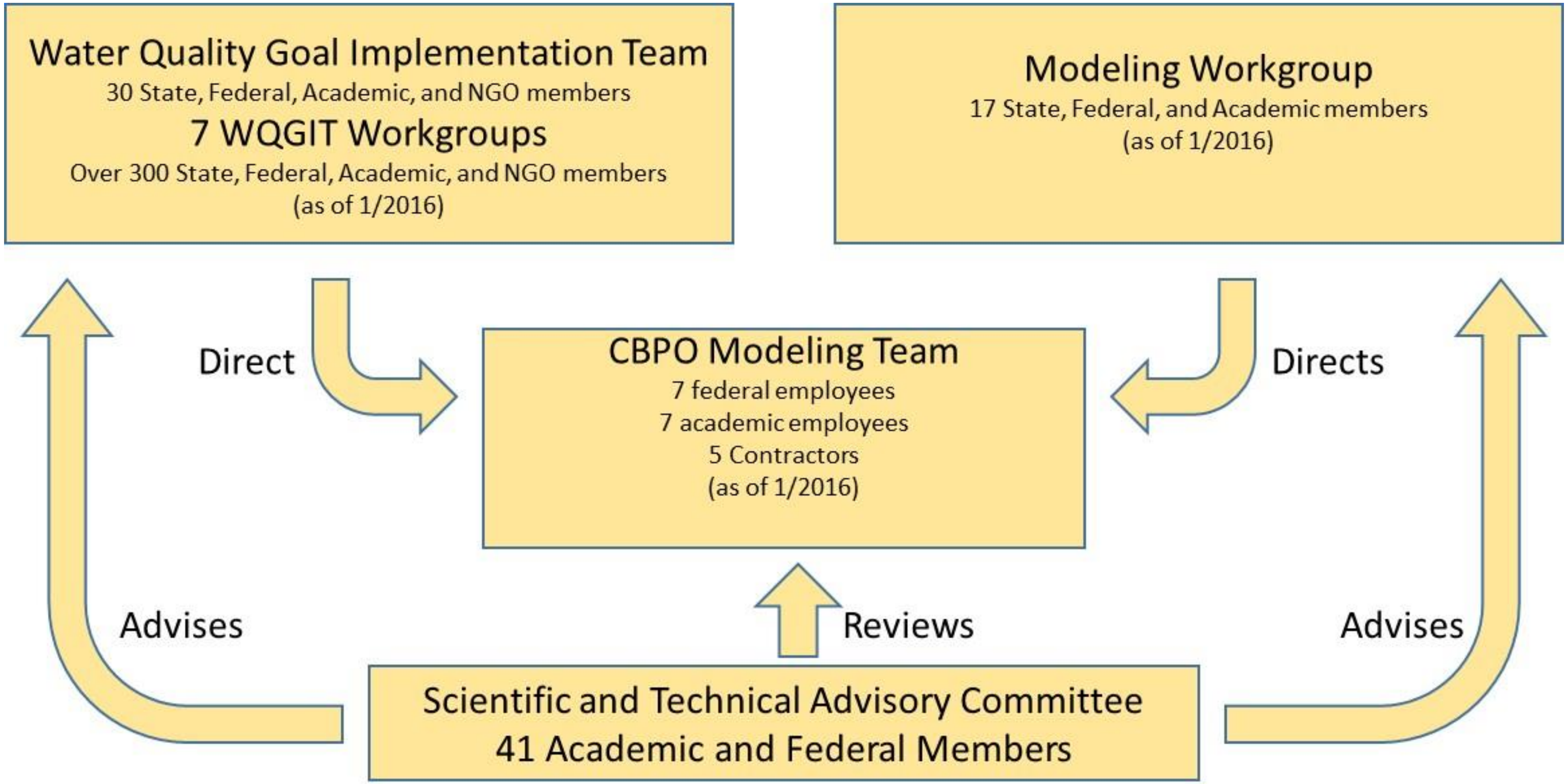
River Delivery

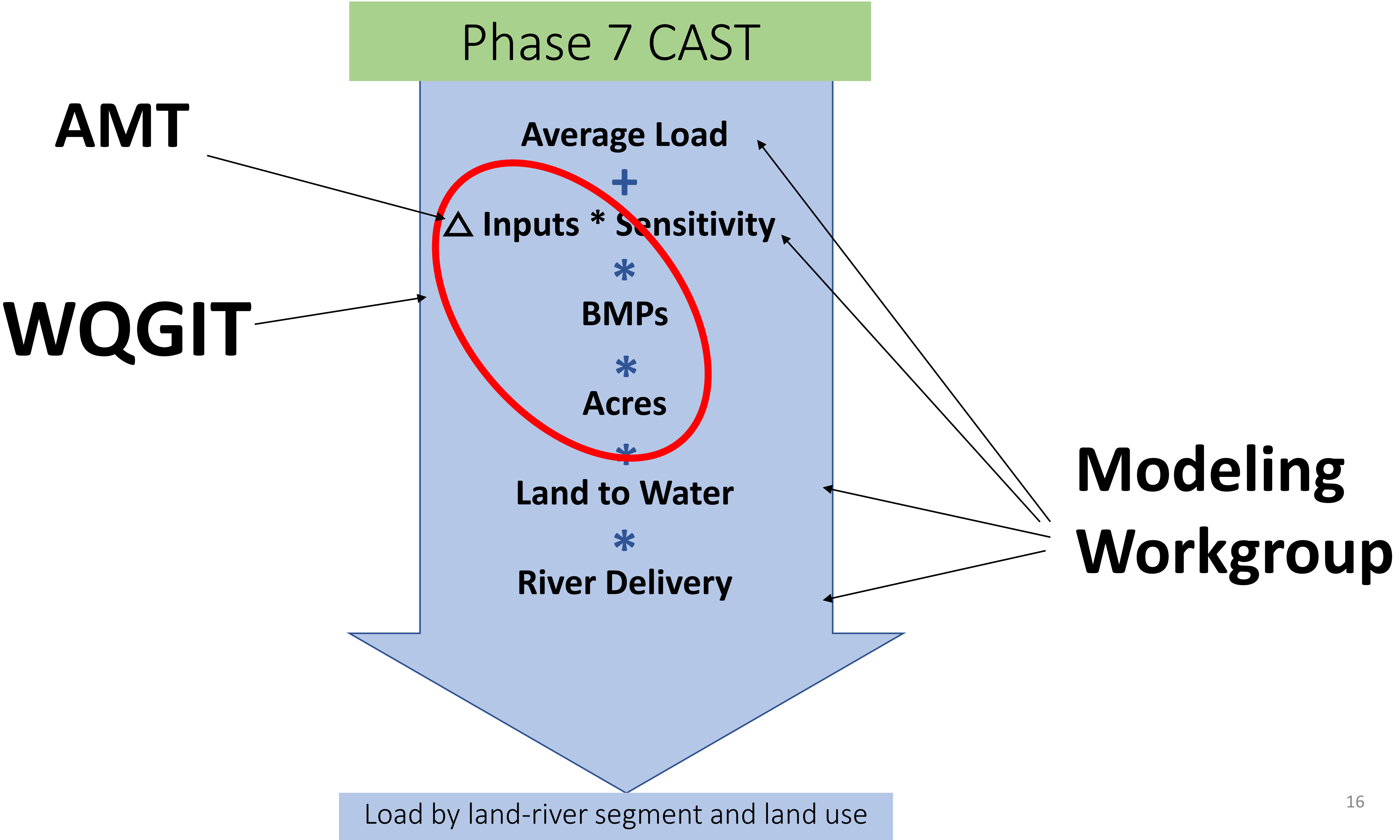
Load by land-river segment and land use

Include Everything

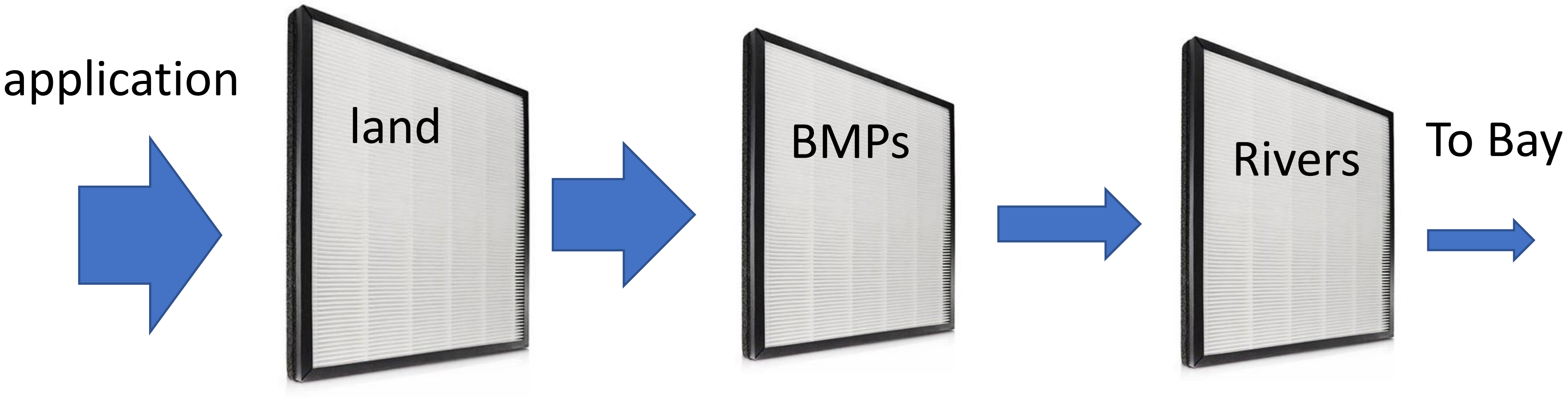


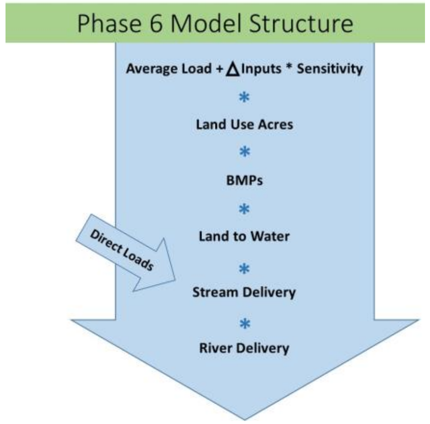
Modeling governance




Phase 7 CAST
AMT
WQGIT
Average Load
+
△ Inputs * Sensitivity
*
BMPs
*
Acres
*
Land to Water
*
River Delivery
Modeling
Workgroup
Load by land-river segment and land use

Nitrogen Conceptual Model

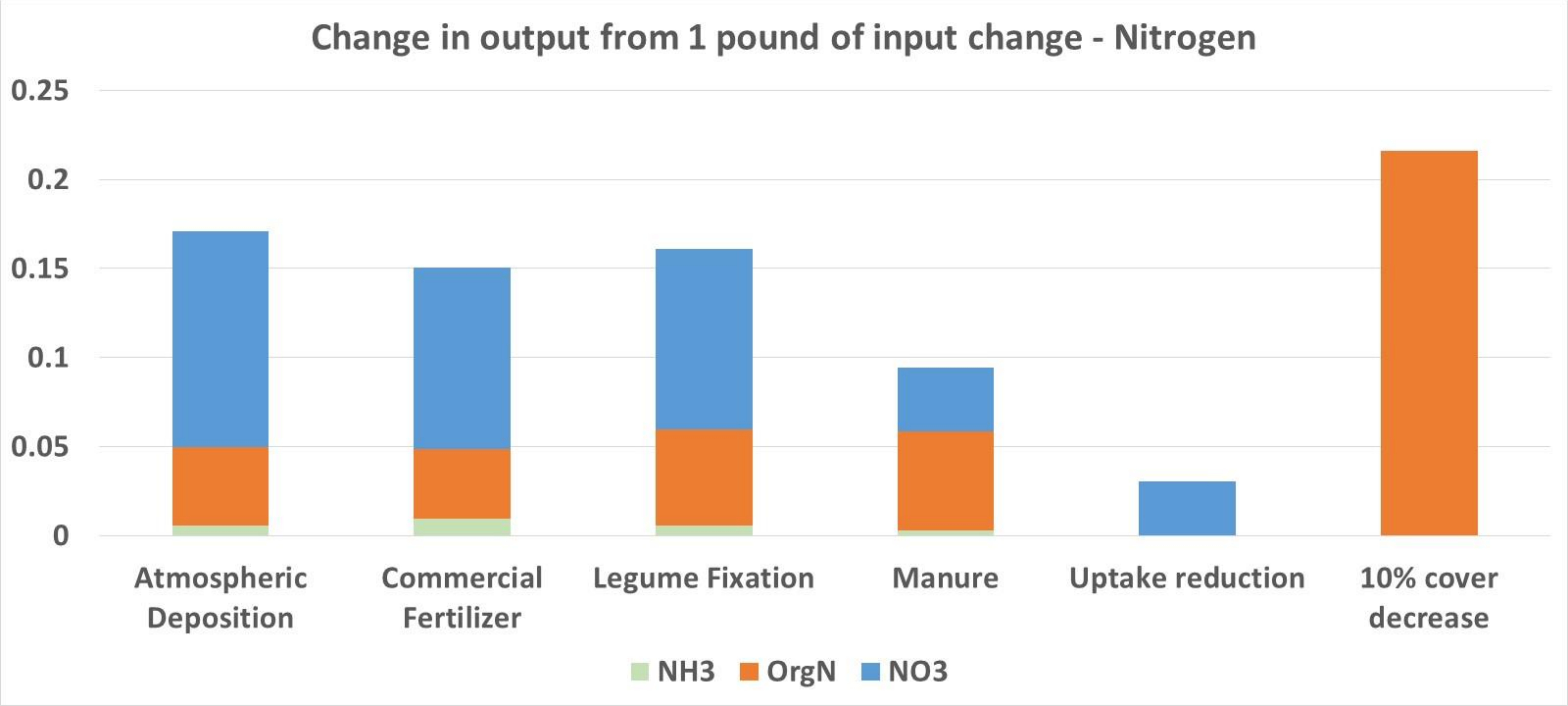




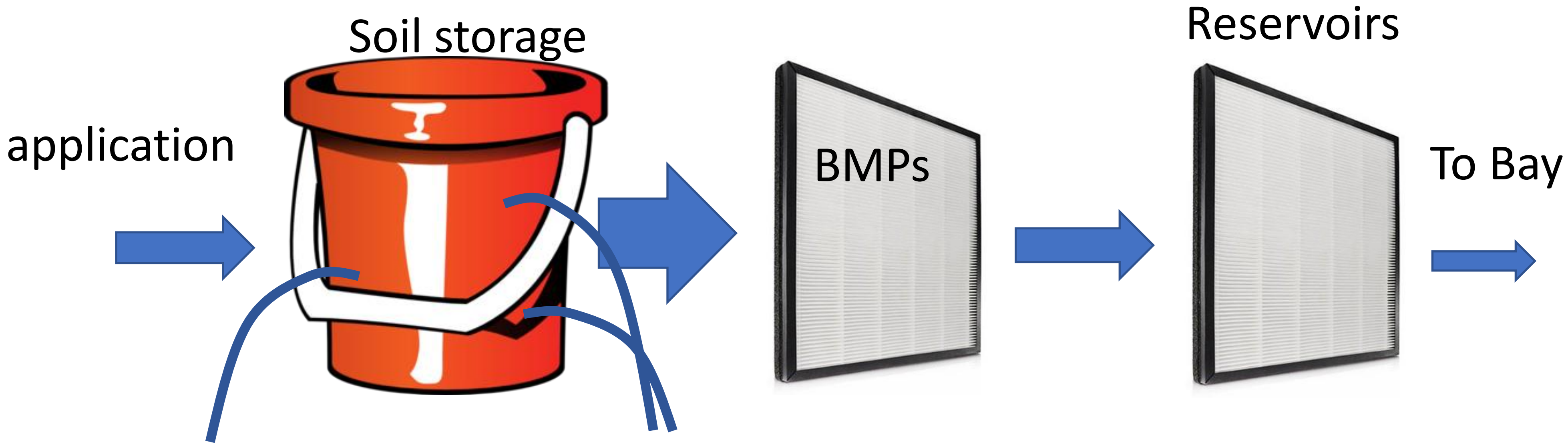
The watershed is conceptualized as a series of filters

Double Cropped land

Sensitivities – all else being equal…



Phosphorus Conceptual Model



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

P Sensitivities

Input	Input Unit	Average Slope	Median Slope	Median S_R	Relative Sensitivity
Soil P	ppm	0.017	0.015	0.696	Moderately sensitive
Sediment Washoff	ton/ac	0.181	0.168	0.633	Moderately sensitive
Stormflow	Inches	0.064	0.057	0.403	Moderately sensitive
Water Extractable P	lbs/acre	0.021	0.018	0.187	Slightly sensitive
Manure	lbs/acre	0.008	0.007	0.111	Slightly sensitive
Fertilizer	lbs/acre	0.005	0.004	0.068	Slightly sensitive
Uptake	lbs/acre	0.000	0.000	0.000	Insensitive

P Sensitivities

Requires estimate of soil P
dependent on inputs and uptake
Presentation tomorrow

Input	Input Unit	Average Slope	Median Slope	Median S_R	Relative Sensitivity
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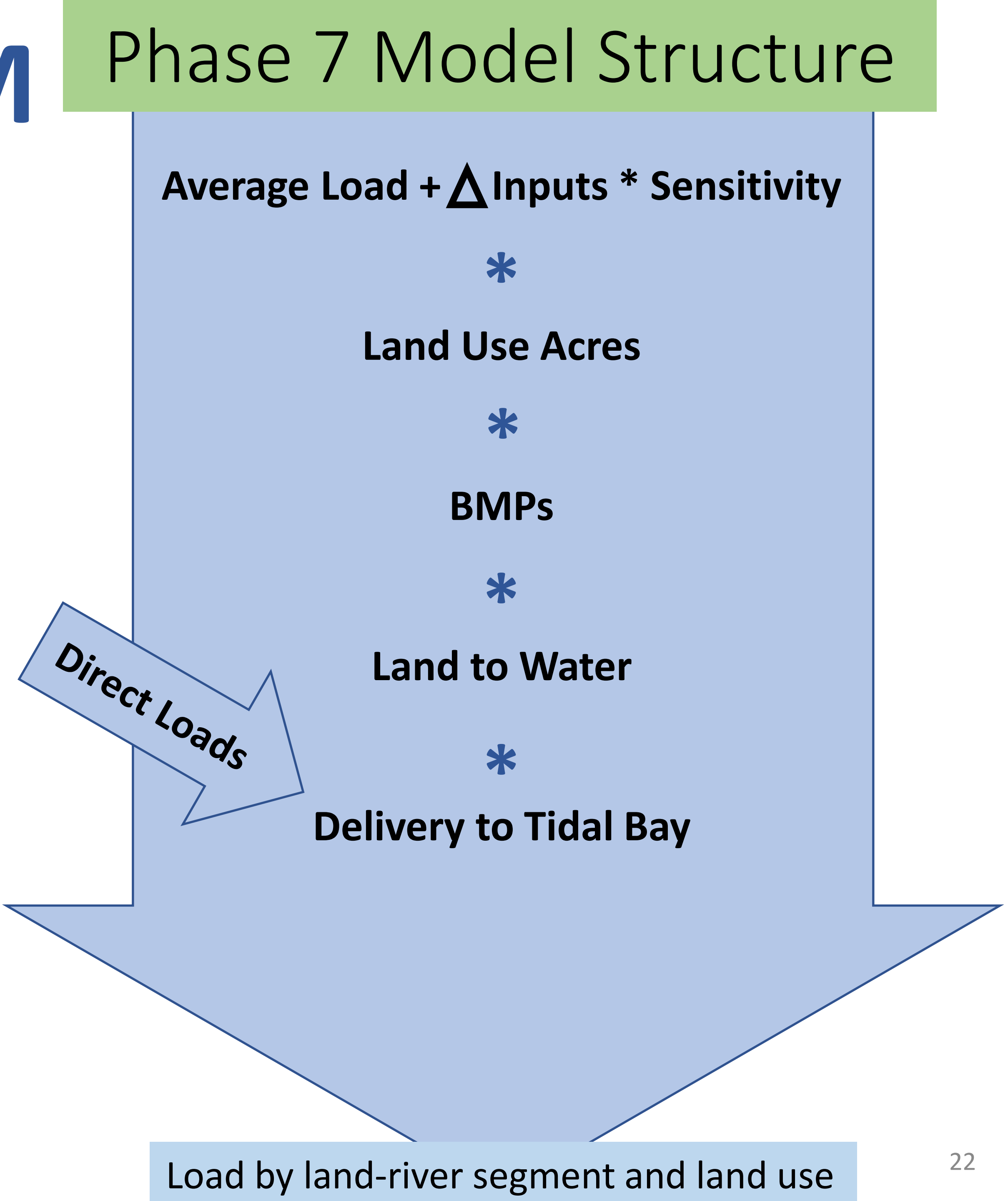
~~**Uptake**~~	~~lbs/acre~~	~~0.000~~	~~0.000~~	~~0.000~~	~~Insensitive~~

Cast/CalCast/DM

Phase 7
CAST

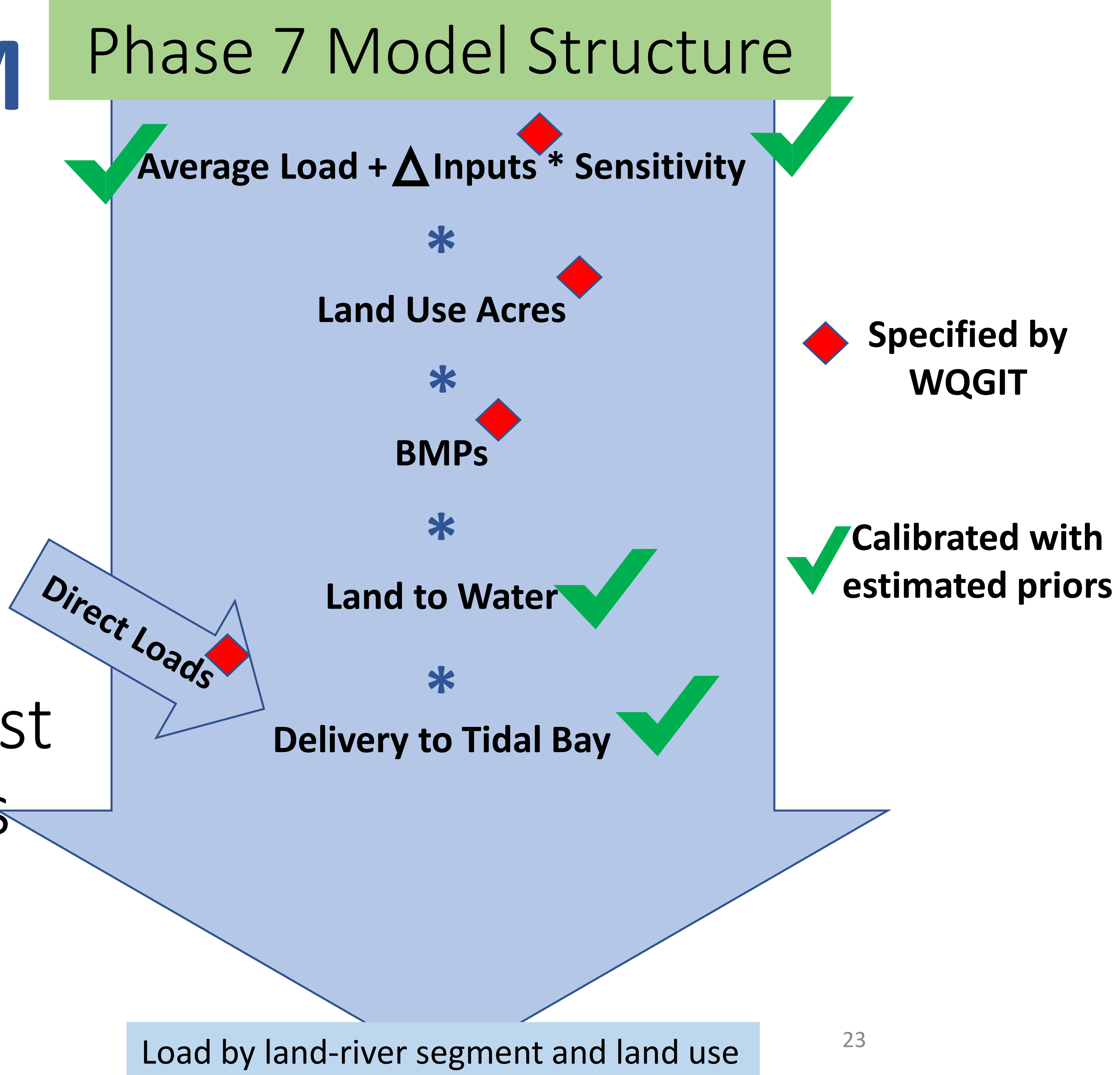
Deterministic Scenario Tool:
1 set of loads for 1 set of inputs



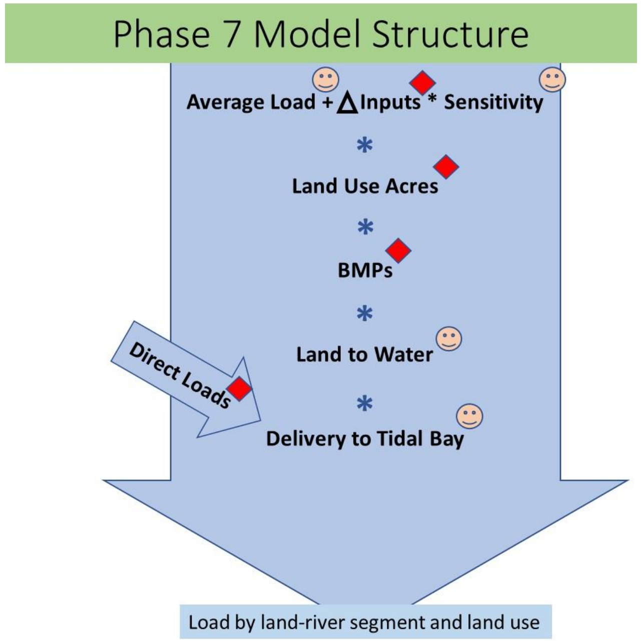
Cast/CalCast/DM

Phase 7
CalCAST

Tool for finding parameters that best match observations



CalCAST - Hypothesis-testing tool



$$\sum_t \text{Load}_{g,t} = \sum_t \sum_c \left(\left(\sum_l \text{NPS}'_{g,l,c,t} \right) + \left(\sum_s \text{Direct}'_{g,s,c,t} \right) \right)$$

$$\text{Direct}'_{g,s,c,t} = \text{Direct}_{s,c,t} \times \text{Del}_{g,c}$$

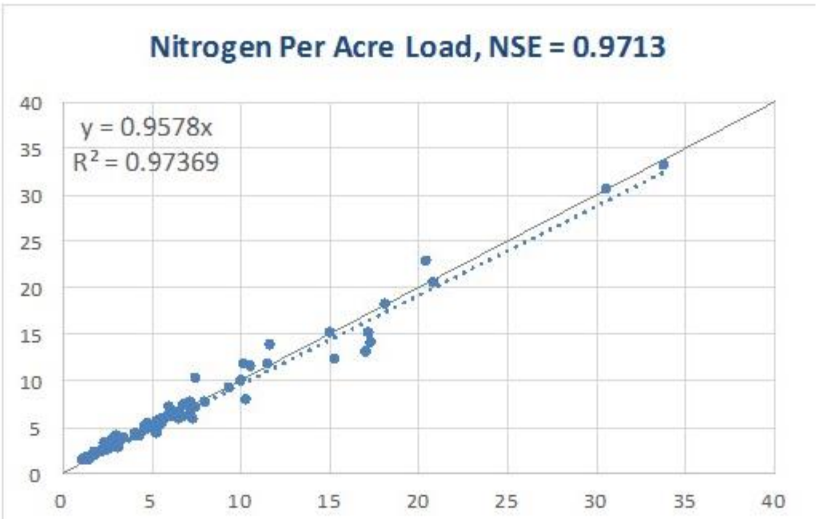
$$\text{NPS}'_{g,l,c,t} = \sum_{\text{layer}=1}^{2} \sum_{\hat{t}=t-40}^{t} \left(\text{NPS}_{l,c,\hat{t}} \times \text{layF}_{l,c,\text{layer}} \times \text{lag}_{l,c,\text{layer},\hat{t}-(t-41)} \right) \times L2W_{l,c} \times \text{Del}_{g,c}$$

$$\text{NPS}_{l,c,t} = \left(\text{Ave}_l + \sum_i \left(\left(\text{Input}_{i,l,c,t} - \widehat{\text{Input}}_{i,l} \right) \times \text{Sens}_{i,l} \right) \right) \times \text{Acres}_{l,c,t} \times \text{BMP}_{l,c,t}$$

$$\text{Ave}_l = \frac{RC_{cl_l} \times AC_{cl_l}}{\sum_{cl} (RC_{cl} \times AC_{cl})} \times \frac{G \times RL_l}{\sum_{l \in cl} (RL_l \times AL_l)} = CLR \times RC_{cl_l} \times RL_l$$

$$\text{Sens}_{i,l} = \text{Sens}_{i,cl_l} \times RL_l$$

Annual Bayesian Sparrow-like Construction

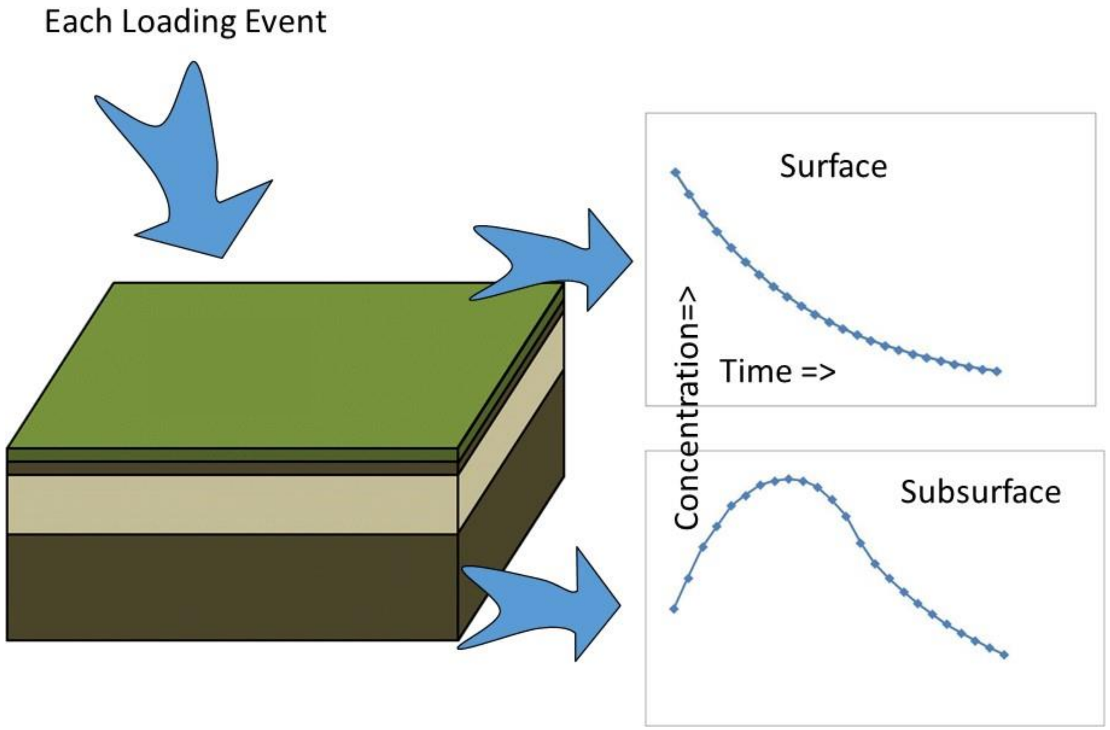


Can be easily modified to determine how different data sets help predict water quality

Cast/CalCast/DM

Phase 7
Dynamic Model

Tool for
- loading estuarine models
- Comparing against observations
- Other potential collaborative projects
- Process understanding



Model Use-- TMDL question:

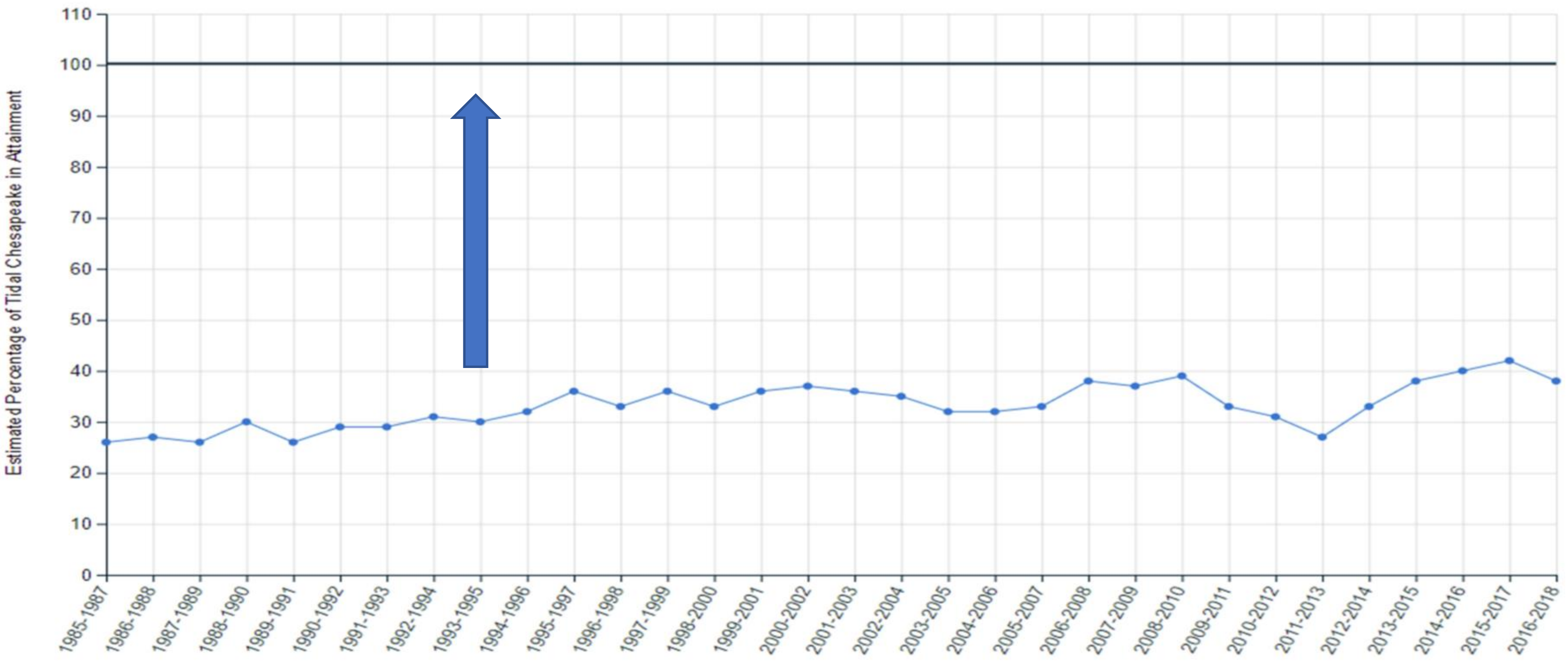
How must nitrogen, phosphorus, and sediment load change from 1995 to meet water quality standards

Important considerations for how to build the model

Water Quality Standards Attainment (1985-2018)

Water quality is evaluated using three parameters: dissolved oxygen, water clarity or underwater grass abundance, and chlorophyll a (a measure of algae growth).

VIEW CHART VIEW TABLE

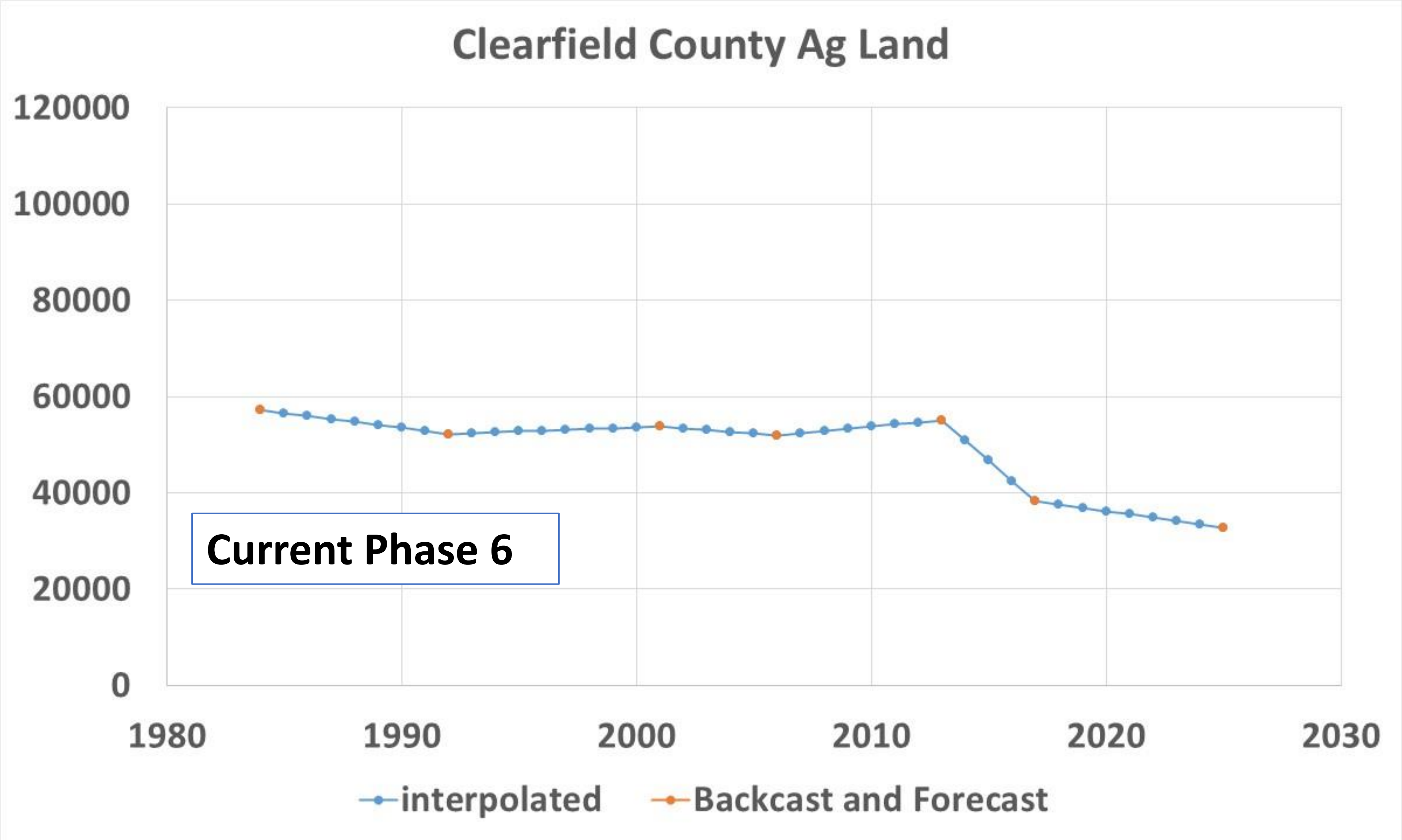


Select a date range:

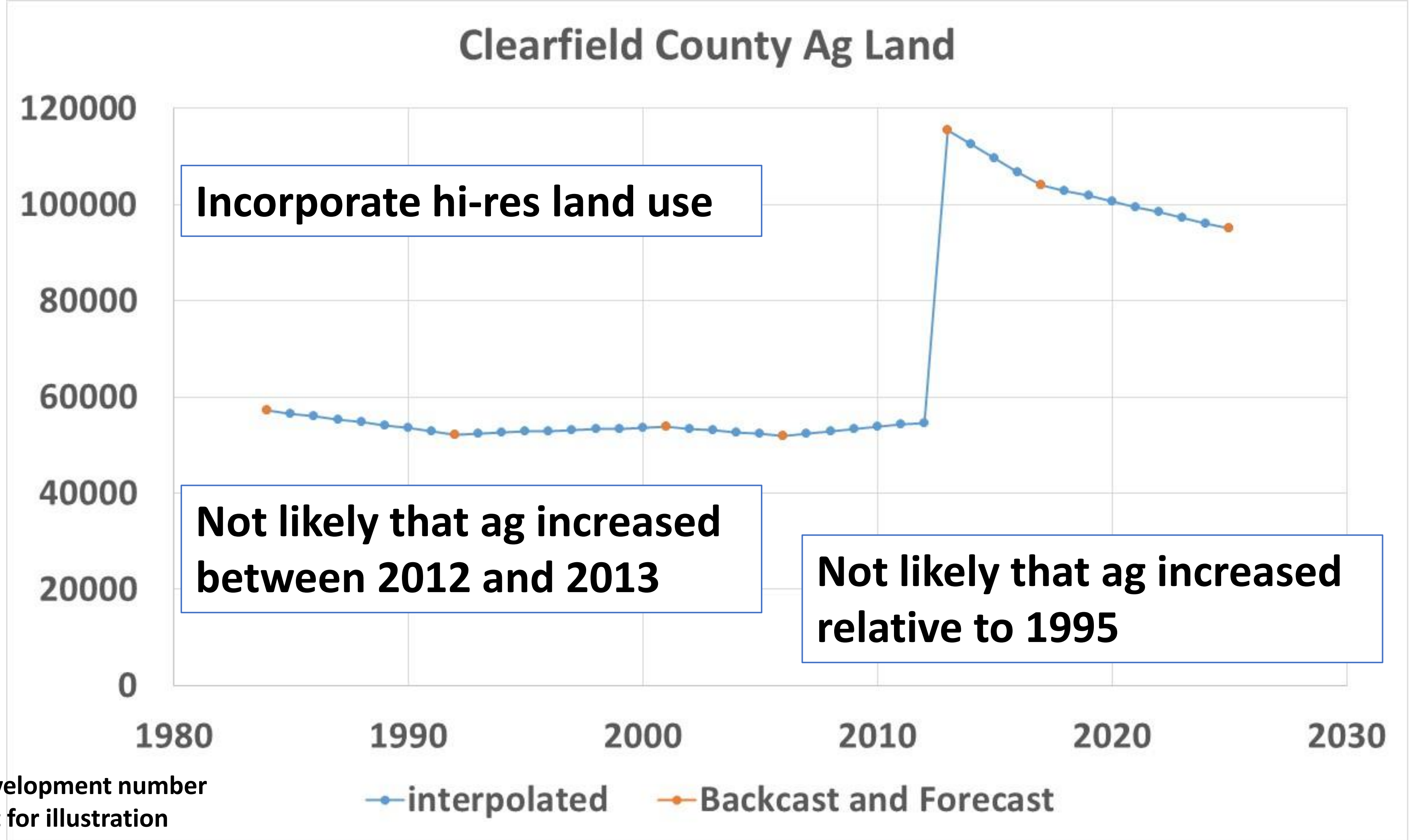
Consistency > Accuracy

Accuracy of the trend is more important that the absolute value

Consistency example

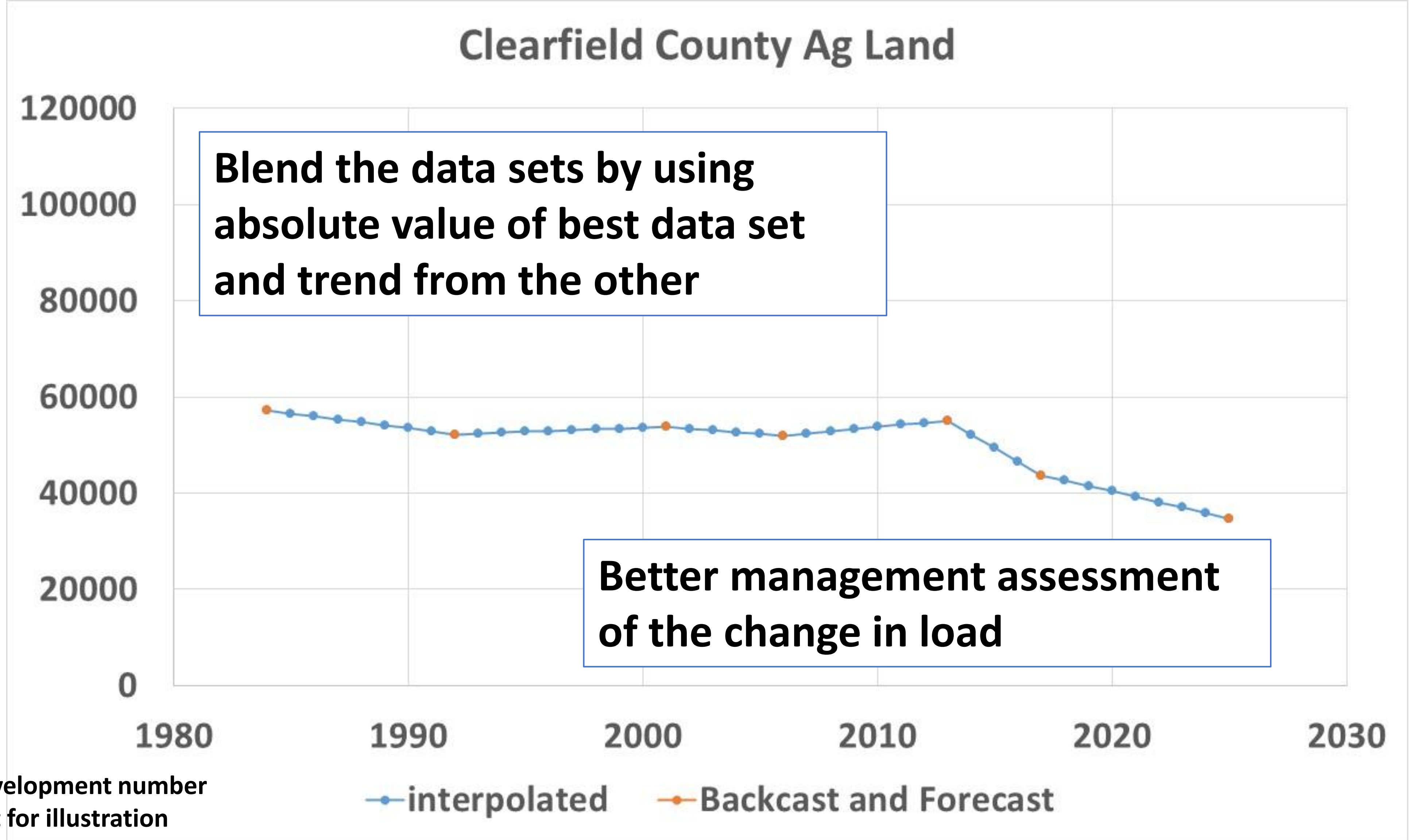


Consistency example



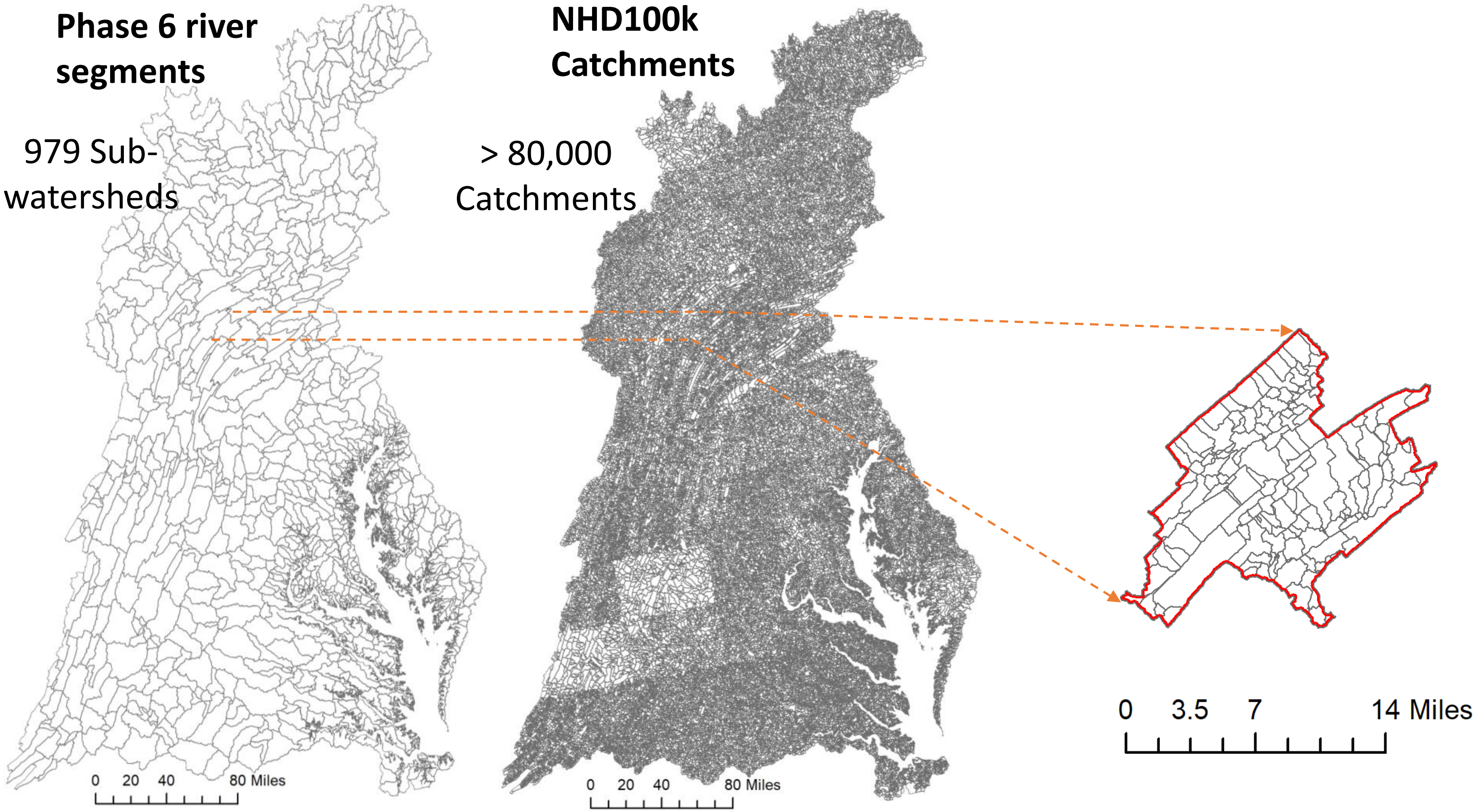
2013 is current development number
2017 and 2025 just for illustration

Consistency example

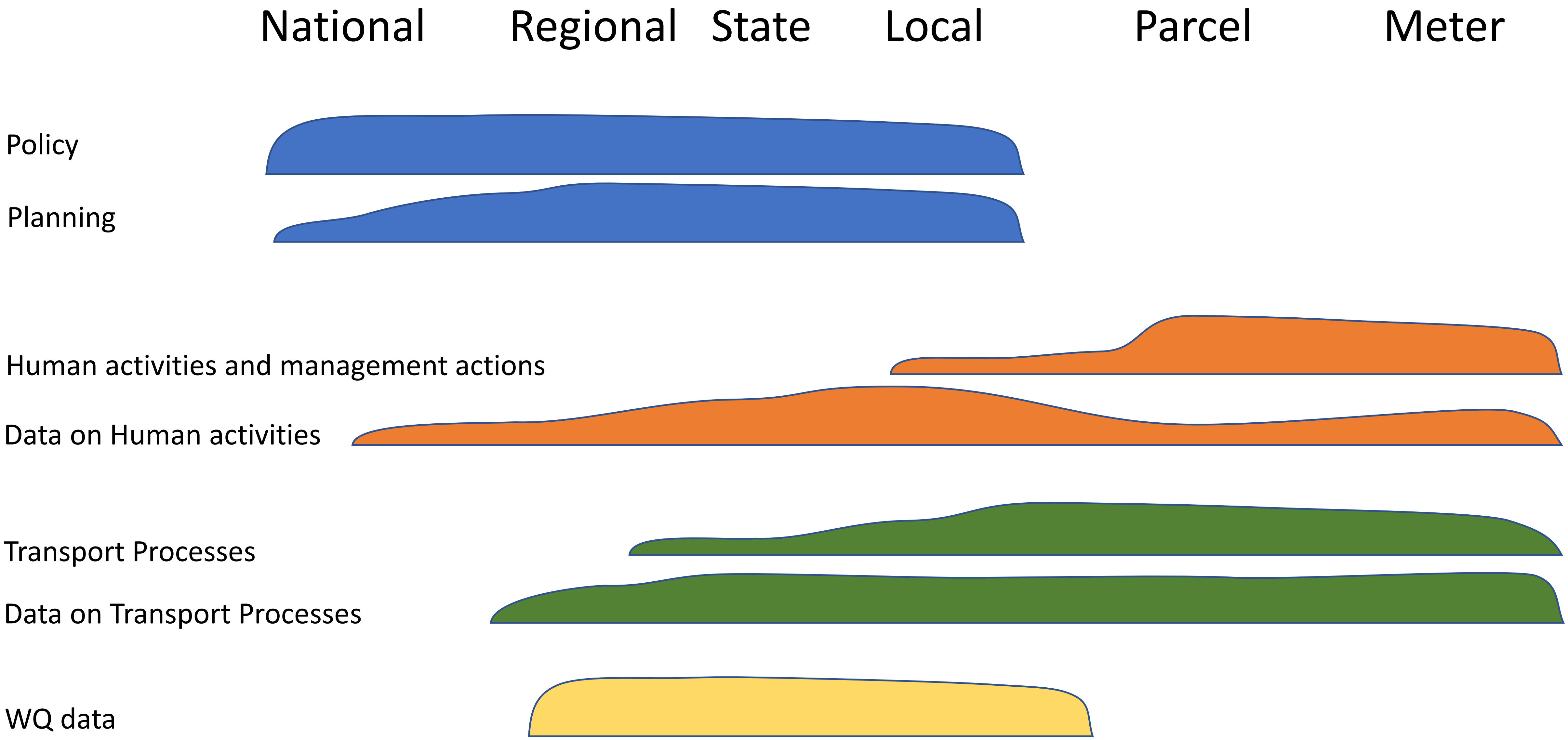


2013 is current development number
2017 and 2025 just for illustration

Spatial Scale – available scales



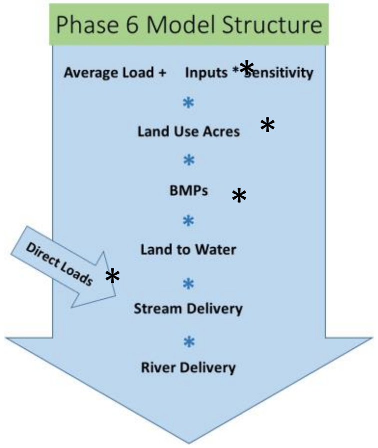
Scale in the Chesapeake Bay TMDL (Watershed)



All graphics are conceptual only

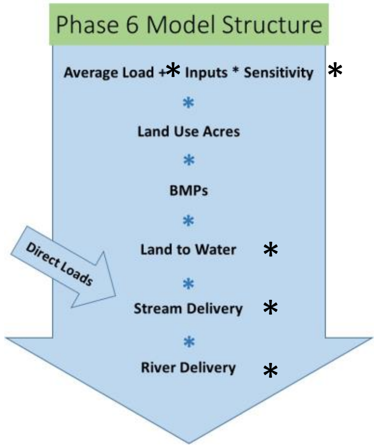
Scale

CAST7



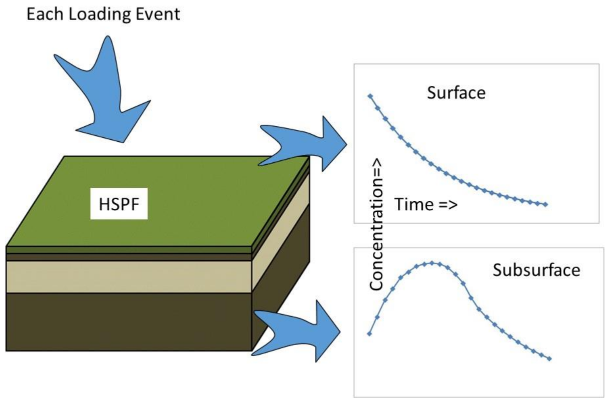
Whatever scale is needed for management

CalCAST7



NHD scale to capture local monitoring

Dynamic Model7



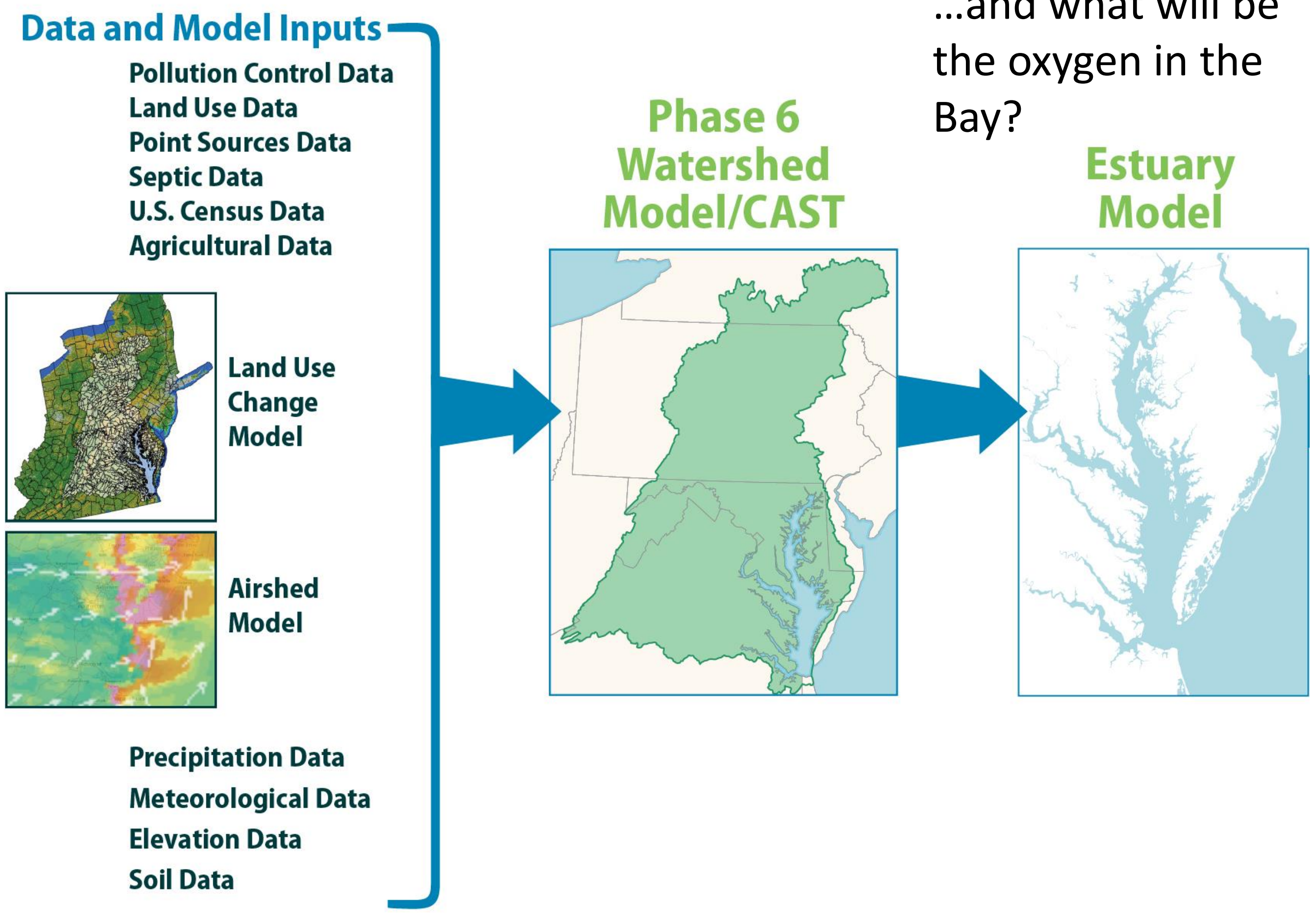
NHD scale to load the estuarine models

CAST in context of CBP TMDL models

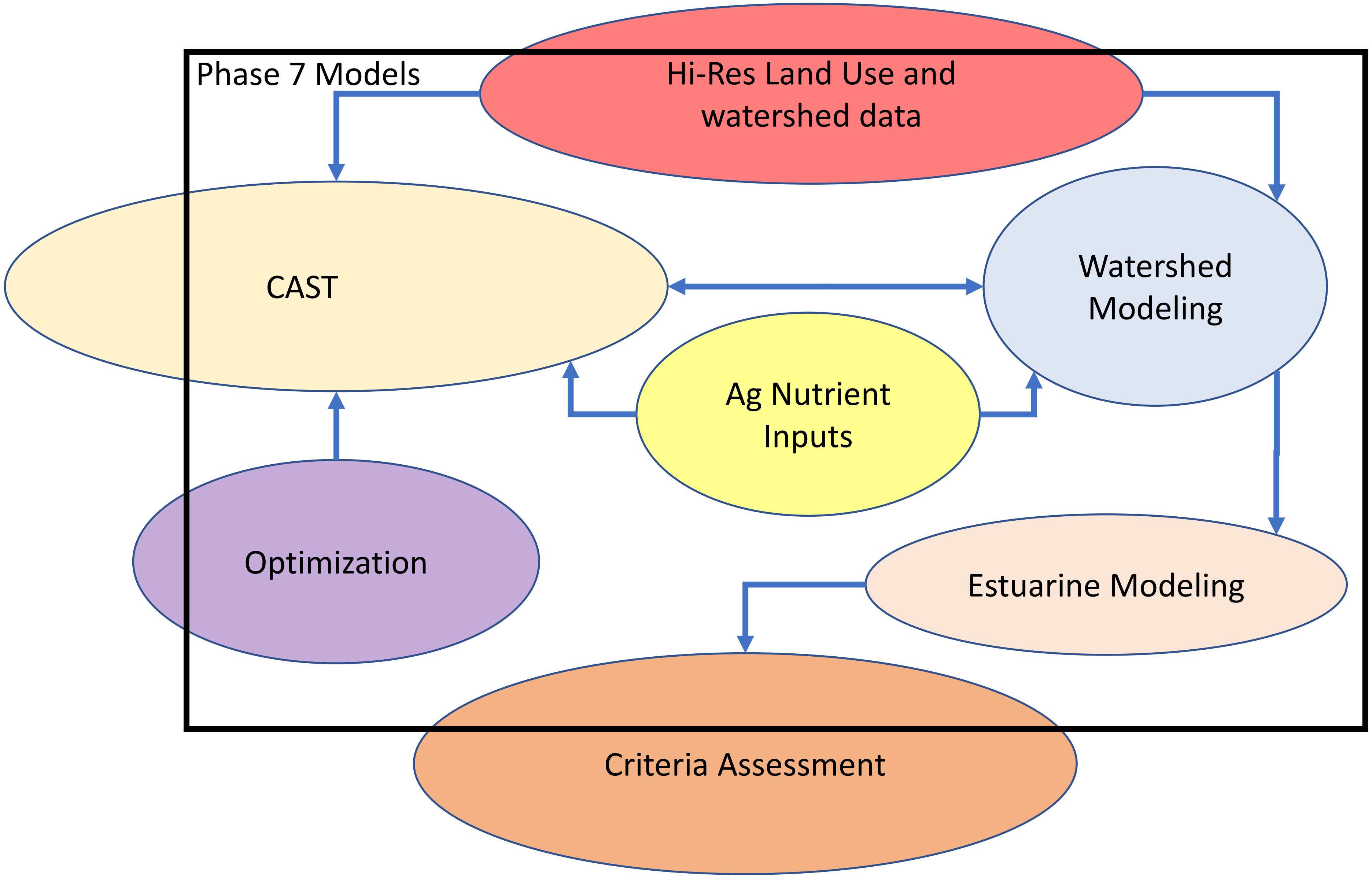
If we change what we do on the landscape…

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

…and what will be the oxygen in the Bay?

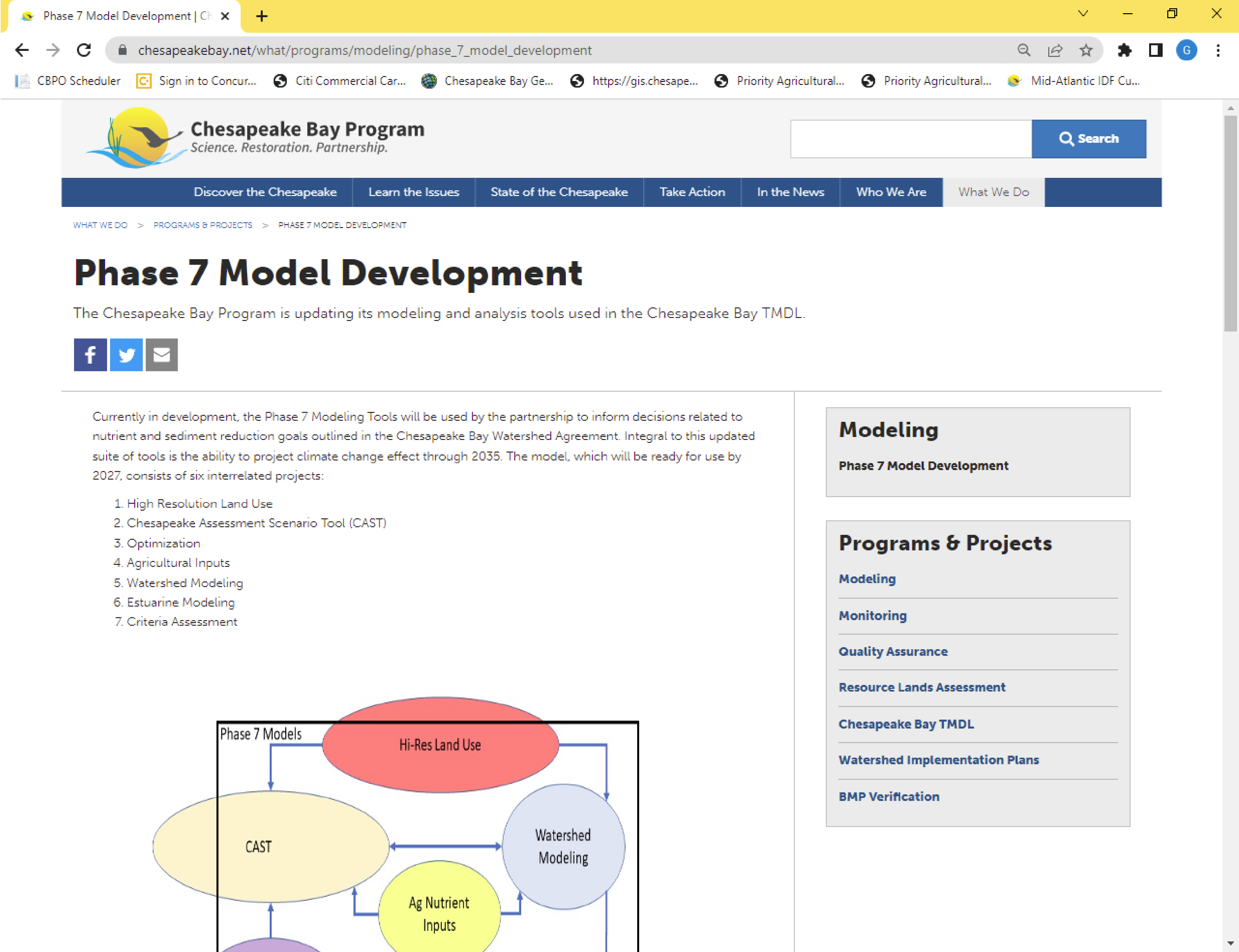


Phase 7 Development Tracks



Web page

- Overview
- Seven Projects
  - Descriptions
  - Documents
- Linked from
  - Modeling Workgroup
  - WQGIT
  - Many WQGIT WGs


Phase 7 Model Development | Ch

chesapeakebay.net/what/programs/modeling/phase_7_model_development

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WHAT WE DO > PROGRAMS & PROJECTS > PHASE 7 MODEL DEVELOPMENT

Phase 7 Model Development

The Chesapeake Bay Program is updating its modeling and analysis tools used in the Chesapeake Bay TMDL.

Currently in development, the Phase 7 Modeling Tools will be used by the partnership to inform decisions related to nutrient and sediment reduction goals outlined in the Chesapeake Bay Watershed Agreement. Integral to this updated suite of tools is the ability to project climate change effect through 2035. The model, which will be ready for use by 2027, consists of six interrelated projects:

1. High Resolution Land Use
2. Chesapeake Assessment Scenario Tool (CAST)
3. Optimization
4. Agricultural Inputs
5. Watershed Modeling
6. Estuarine Modeling
7. Criteria Assessment

Modeling

Phase 7 Model Development

Programs & Projects

Modeling

Monitoring

Quality Assurance

Resource Lands Assessment

Chesapeake Bay TMDL

Watershed Implementation Plans

BMP Verification

Watershed Model Plan – Big Picture

2022	2022	2022	2022	2023	2023	2023	2023	2024	2024	2024	2024	2025	2025	2025	2025	2026	2026	2026	2026
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Work plan			Build	Work plan	Build Models			Work plan	Build Models			Work plan	Build Models			Review Models			
Build Model Structure				Improve Models												Review Models			

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  - Scale
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