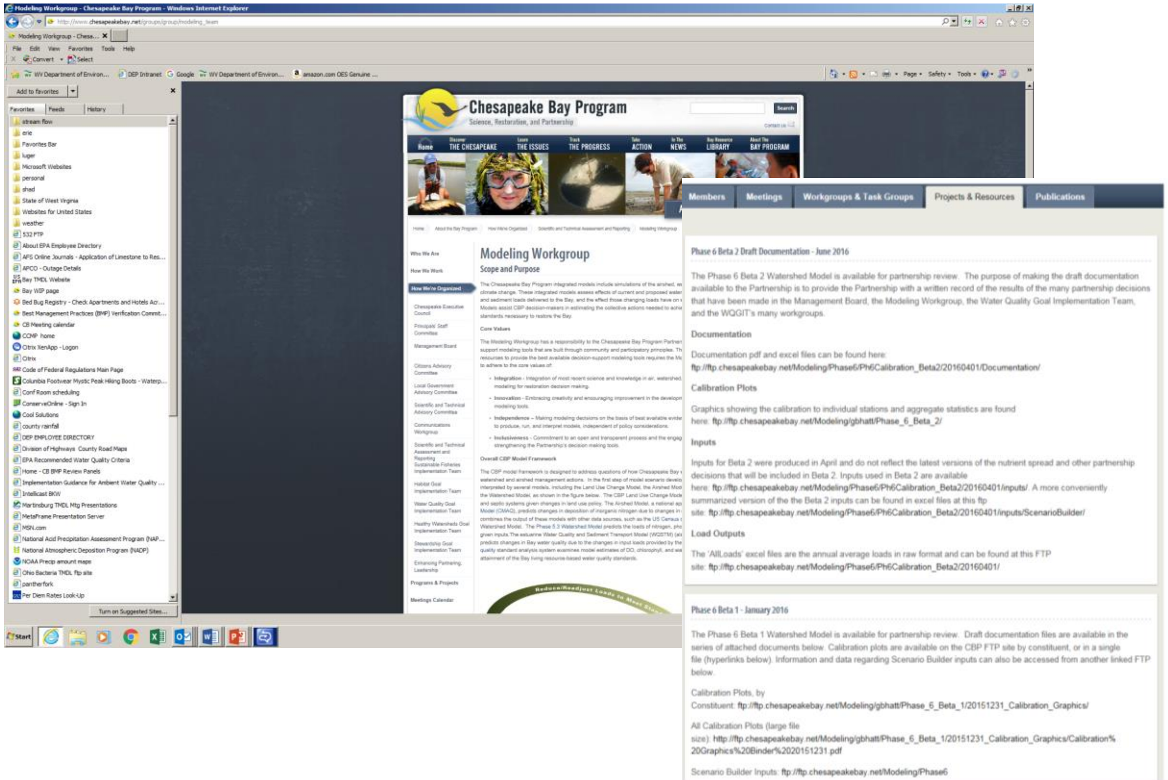
Chesapeake Bay Program Phase 6 Watershed Model

Gary Shenk – USGS - Chesapeake Bay Program

7/20/16

Documentation



- See MWG Webpage
- http://www.chesapeakebay.net/groups/group/modeling_team
- Will be periodically updated
- Webinars here too

Partnership Feedback on Modeling

- **Water Quality Goal Implementation Team**
  - Need more **transparent and easier** to understand decision-support tools to enable successful engagement of local partners

- **Scientific and Technical Advisory Committee**
  - Multiple Models
  - Phosphorus
  - Complex Reservoir Dynamics
  - Fine-scale processes

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- **Scientific and Technical Advisory Committee**
  - Multiple Models
  - Phosphorus
  - Complex Reservoir Dynamics
  - Fine-scale processes

Keep it Simple!!

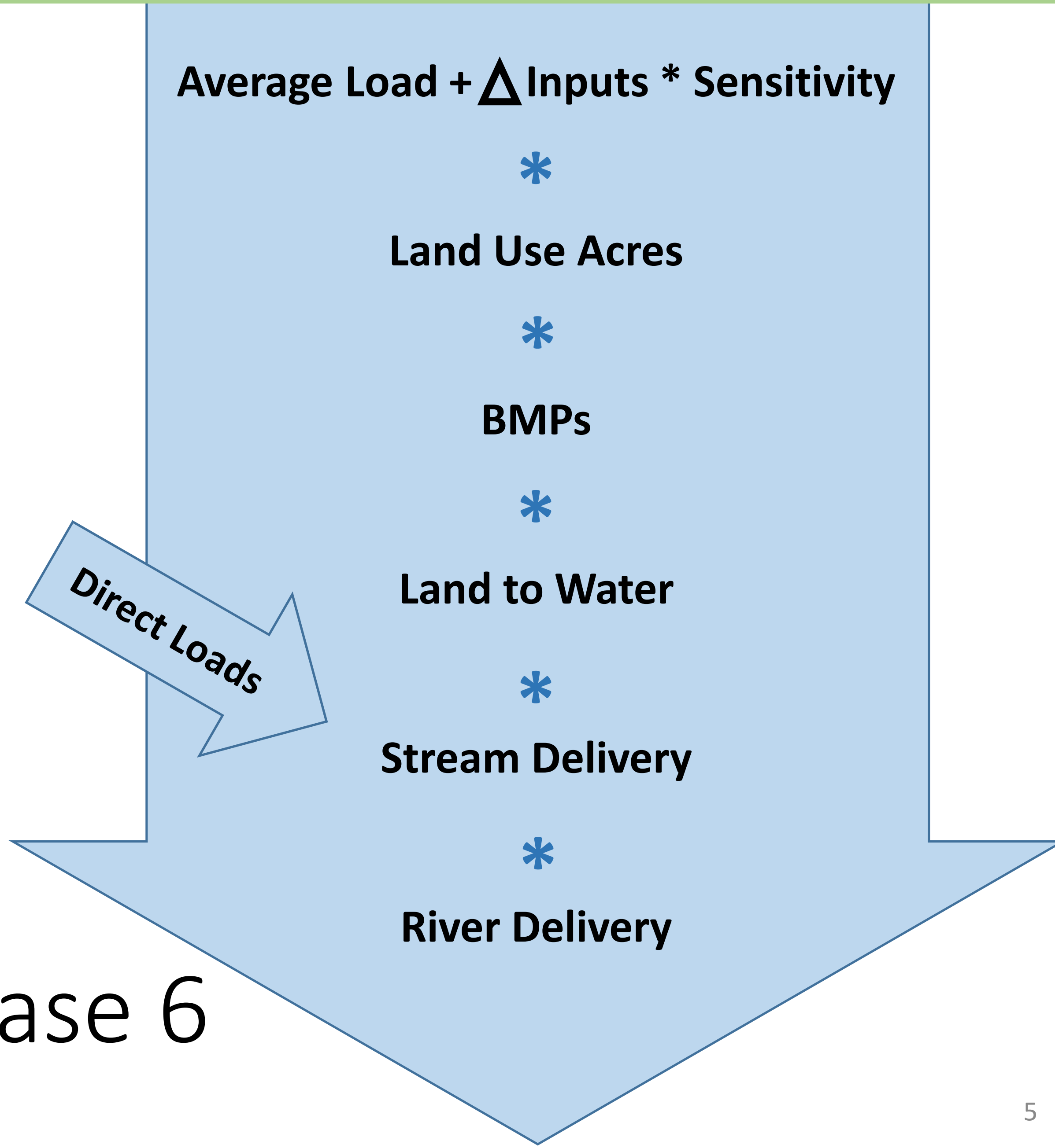
↕

Include Everything!!!

Phase 6 Model Structure







Phase 6

Multiple Lines of Evidence And multiple models

Multiple models

Average Load + Δ Inputs * Sensitivity

*

Land Use Acres

*

BMPs

Scenario Builder

*

Estimated with Sparrow
Estimated by Land Data team

Land to Water

*

Estimated with Sparrow
Estimated by USGS / WVU / land data team

Stream Delivery

*

River Delivery

Simulated in HSPF
Calibrated with data, WRTDS, and Sparrow

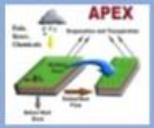
Setting | Calculation | Science Quality

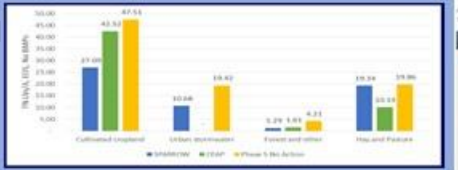
Delivered Load from a land use =

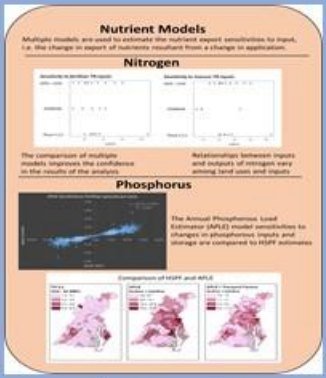
Avg No BMP Nutrient Load

+

Sensitivity * Change in Inputs







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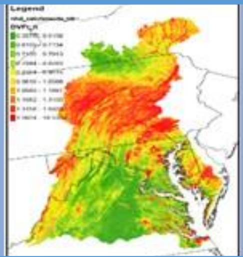
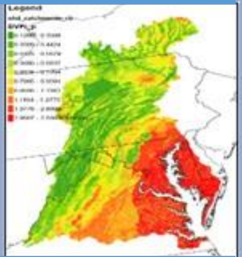
Land to water

SPARROW
For nitrogen:
Soil, vegetation,
and climate variables



SPARROW
For Phosphorus
Soil, slope,
and climate
variables



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BMPs

Effect of BMPs

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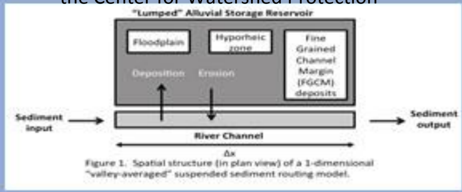
Stream Delivery

Sparrow

Potential models from USGS and
the Center for Watershed Protection



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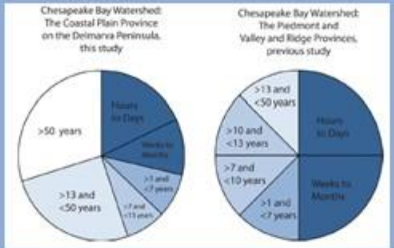
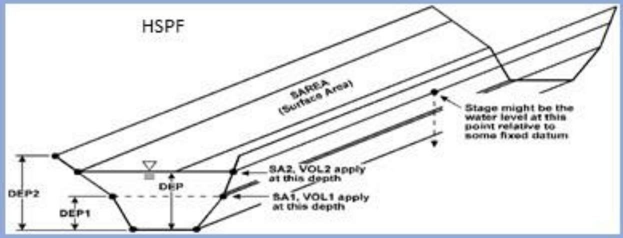
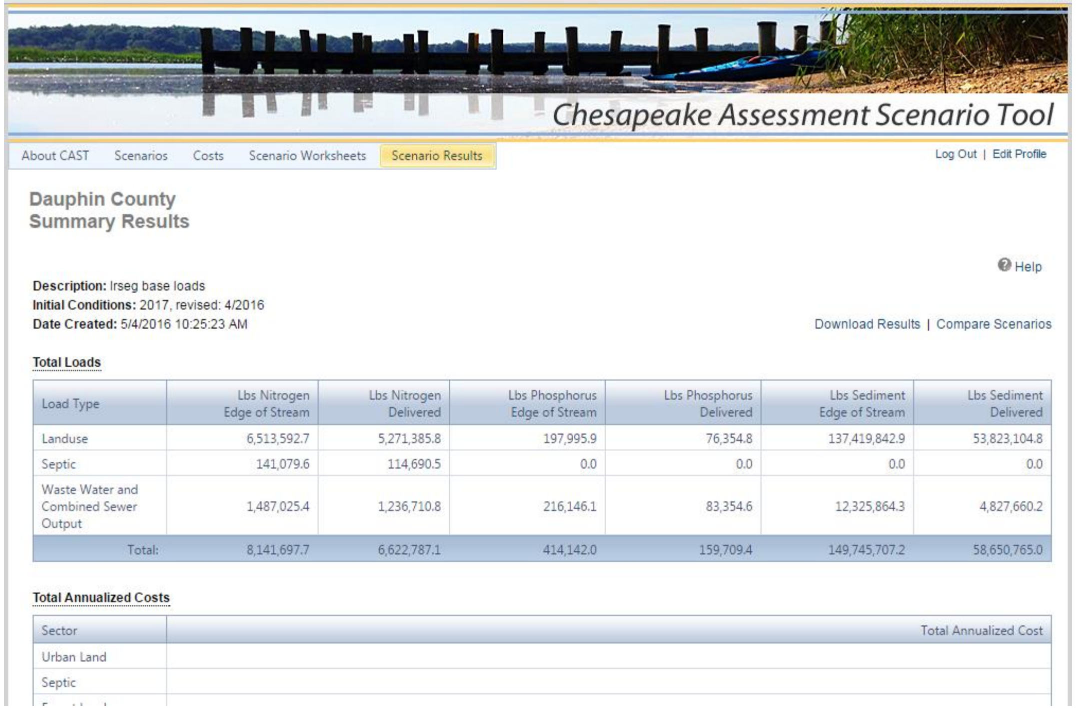
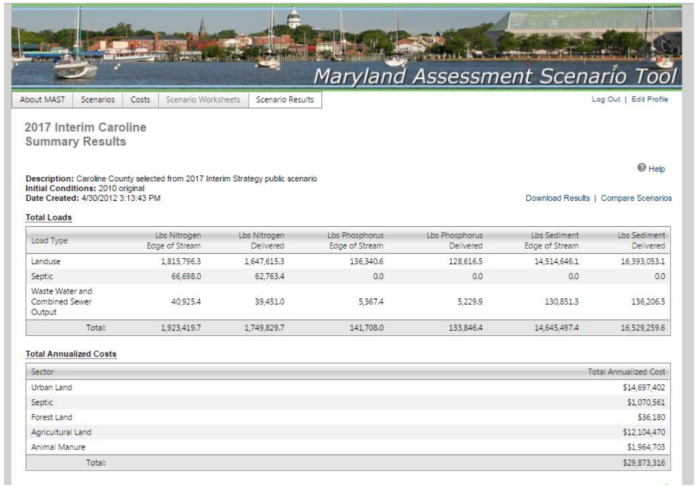
River Delivery

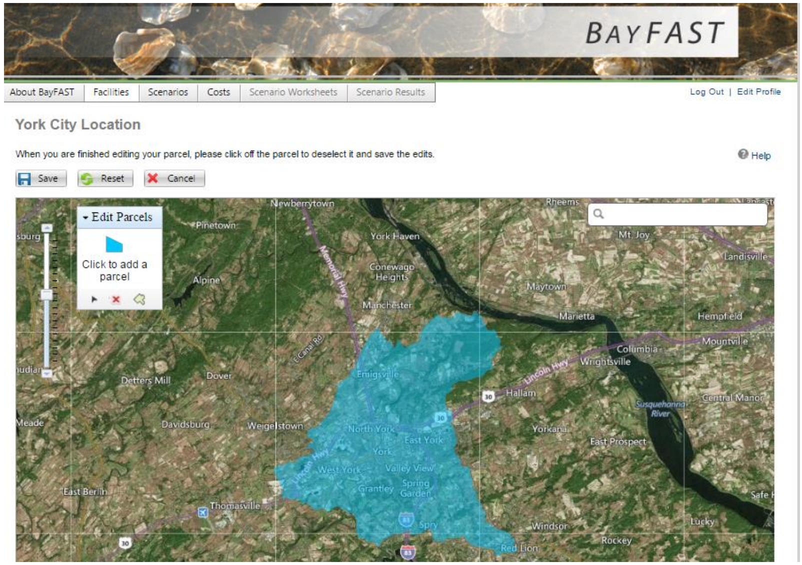




On-Line Tools

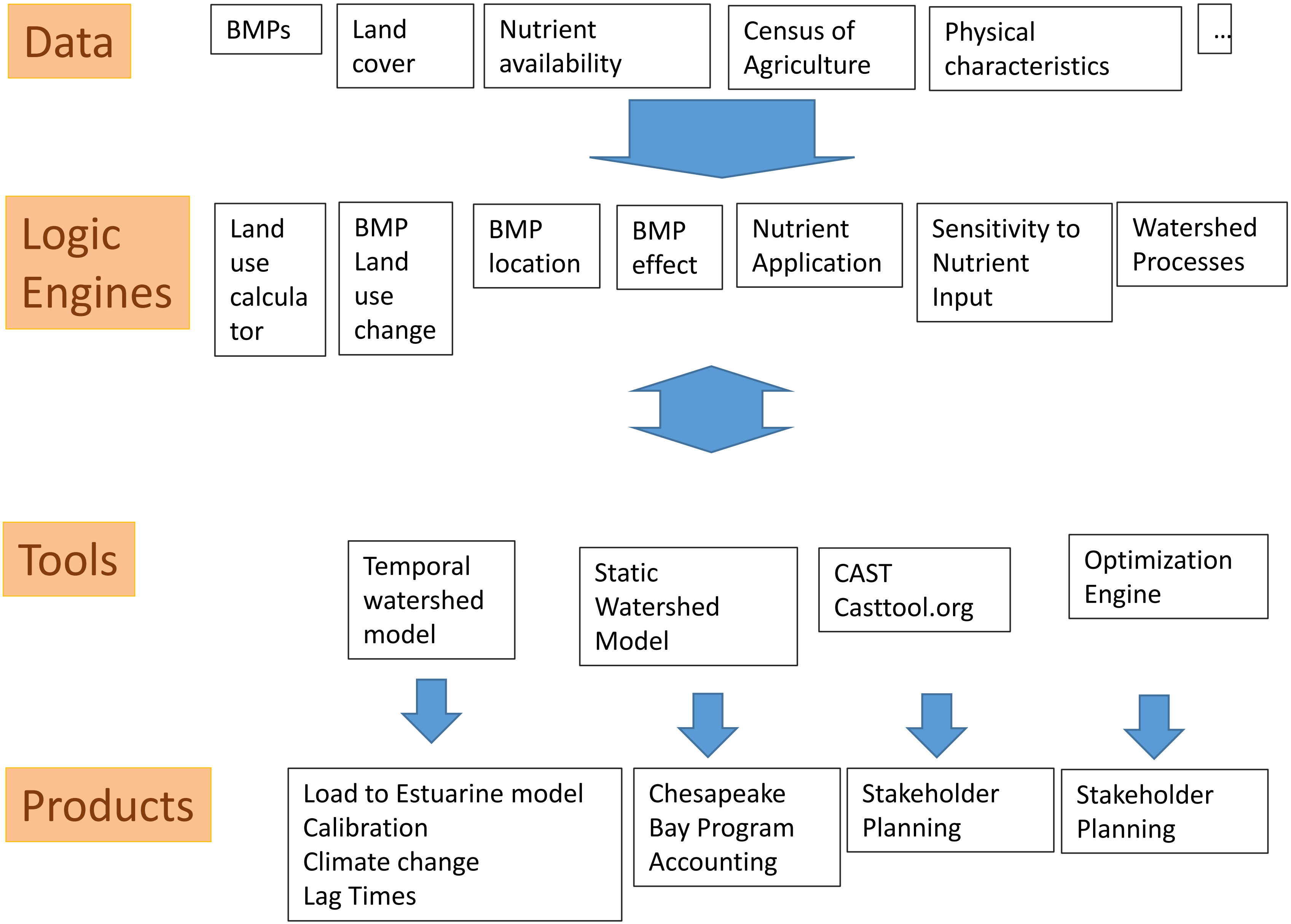






Slide from Olivia Devereux

CBP Watershed Simulation



‘ Phase 5 Scenario Builder’

Data

- BMPs
- Land cover
- Nutrient availability
- Census of Agriculture
- Physical characteristics
- …

Logic Engines

- Land use calcula tor
- BMP Land use change
- BMP location
- BMP effect
- Nutrient Application
- Sensitivity to Nutrient Input
- Watershed Processes

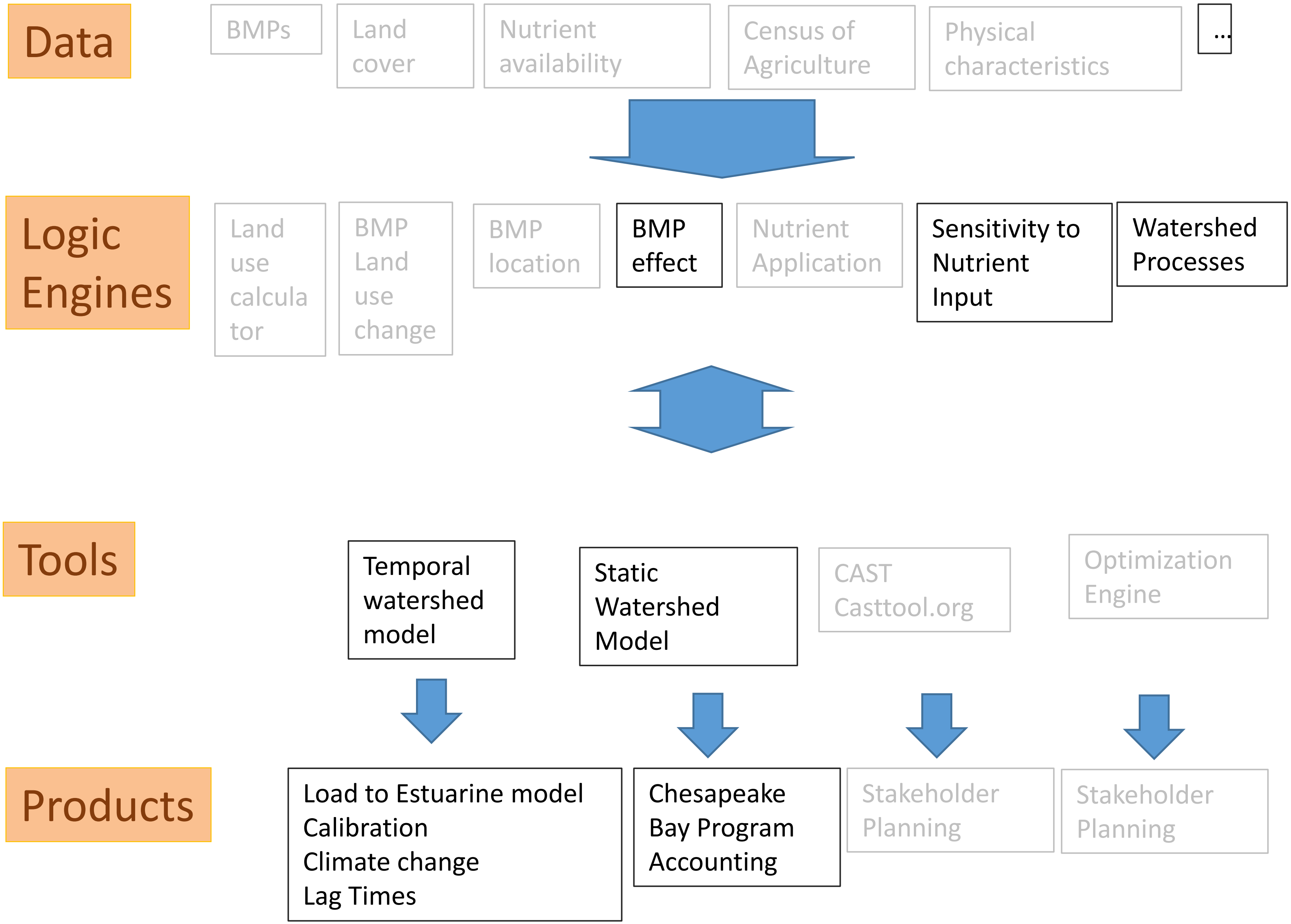
Tools

- Temporal watershed model
- Static Watershed Model
- CAST Casttool.org
- Optimization Engine

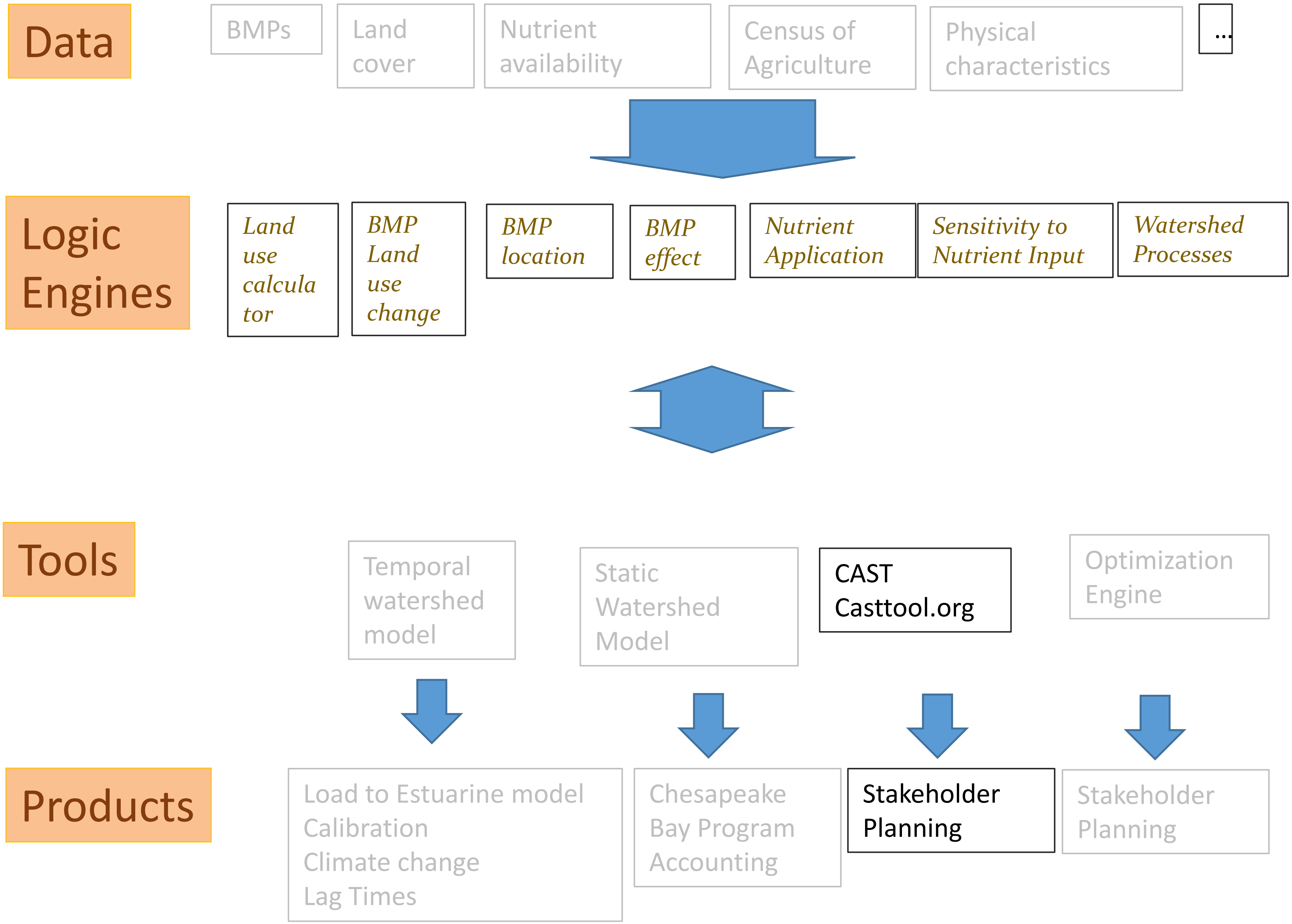
Products

- Load to Estuarine model Calibration Climate change Lag Times
- Chesapeake Bay Program Accounting
- Stakeholder Planning
- Stakeholder Planning

‘ Phase 5 Watershed Model’



‘Phase 5 CAST’


Data
BMPs
Land cover
Nutrient availability
Census of Agriculture
Physical characteristics
...
Logic Engines
Land use calculator
BMP Land use change
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Nutrient Application
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Tools
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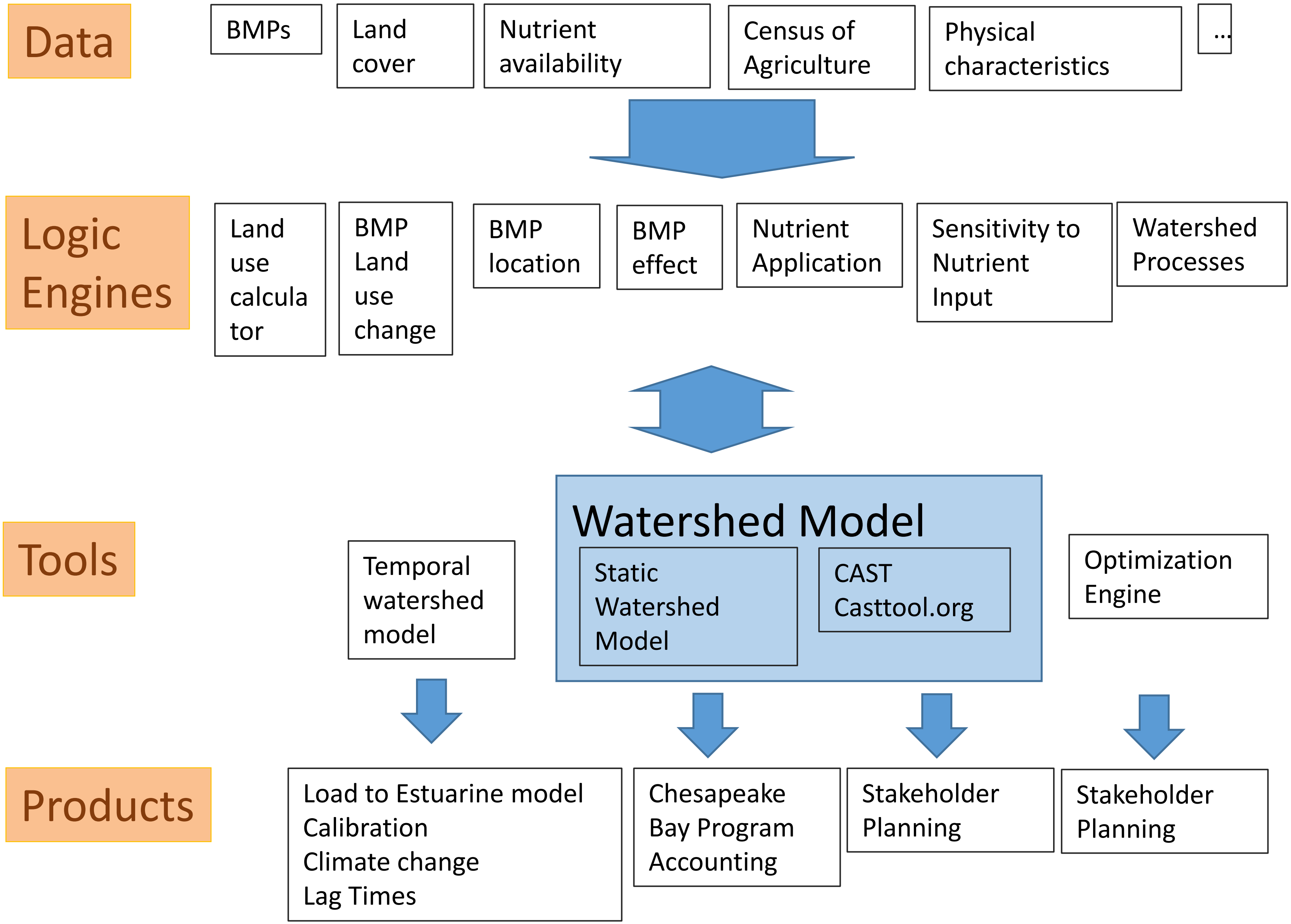
CAST
Casttool.org
Optimization Engine
Products
Load to Estuarine model
Calibration
Climate change
Lag Times
Chesapeake Bay Program Accounting
Stakeholder Planning
Stakeholder Planning

CAST = WSM = Scenario Builder



Phase 6 Model Structure





Average Load + Δ Inputs * Sensitivity

*****

Land Use Acres

*****

BMPs

*****

Land to Water

Direct Loads

*****

Stream Delivery

*****

River Delivery

Phase 6

Phase 6 Model Documentation

Section 1: Overview

Section 2: Average Loads + Section 3: Inputs * Section 4: Sensitivity

*

Section 5: Land Use

*

Section 6: BMPs

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Section 7: Land to Water

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Section 8: Direct Loads

Section 9: Stream Delivery

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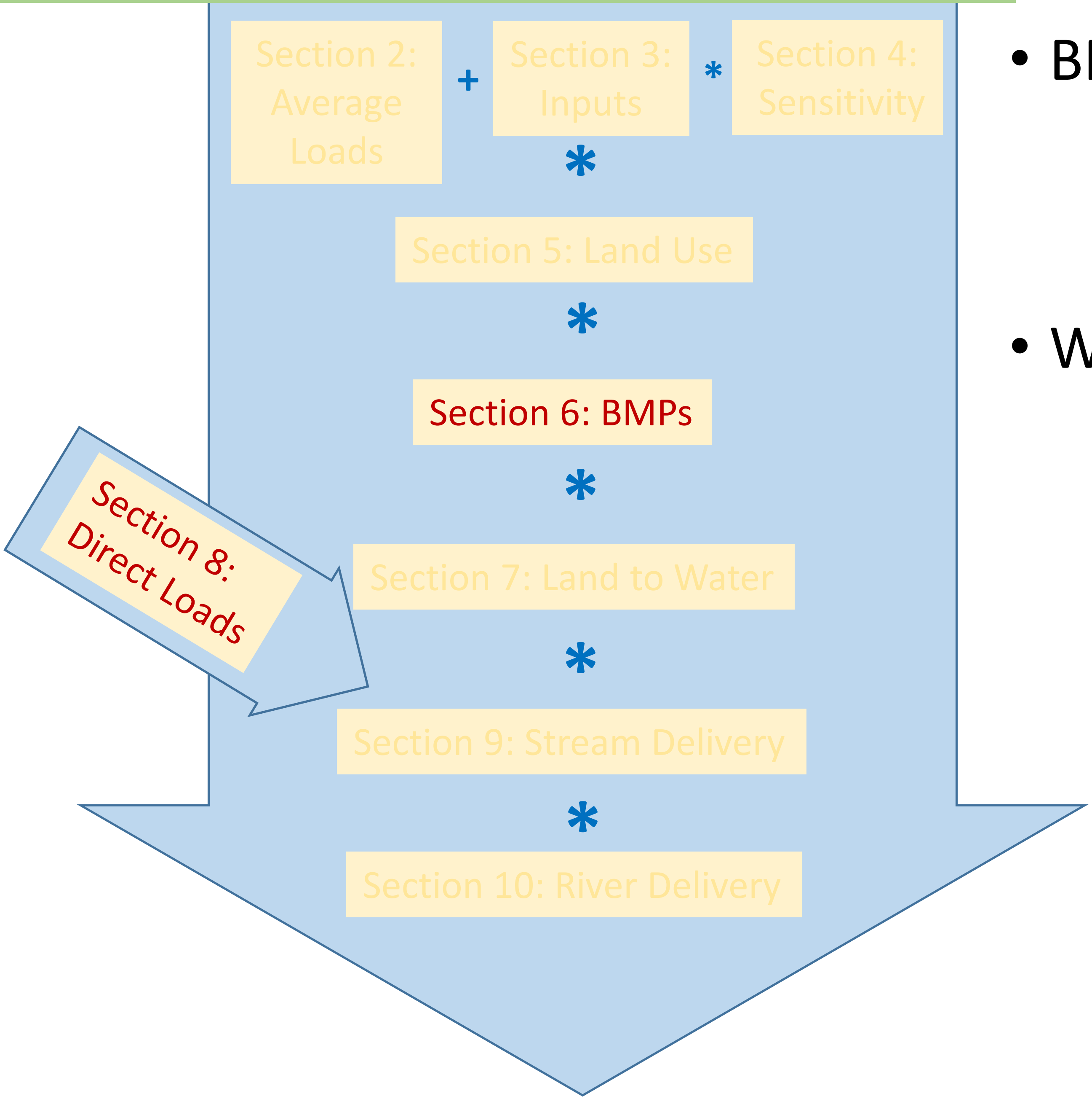
Section 10: River Delivery

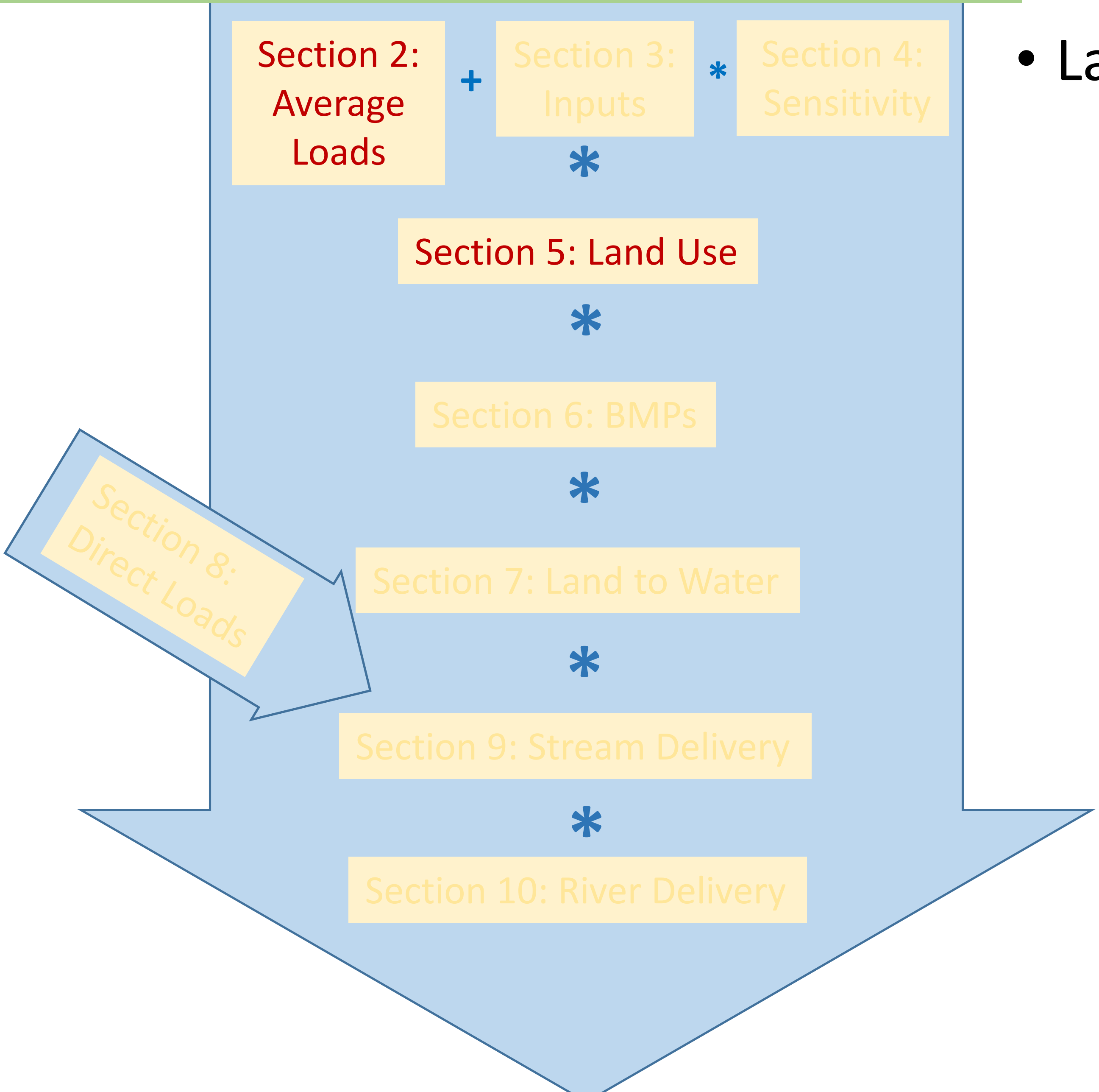
Section 11: Applications

Phase 6 Model Documentation



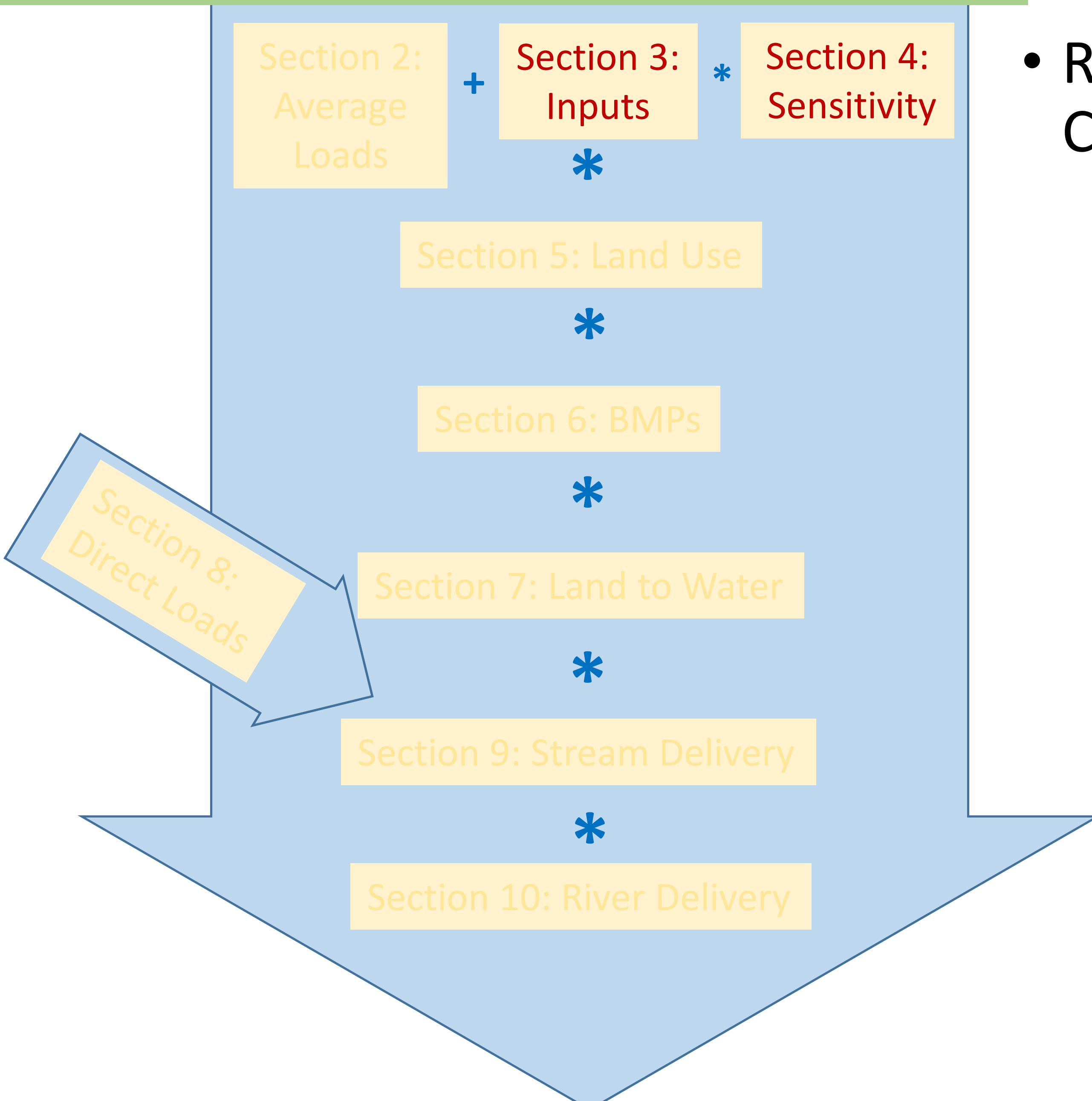
- BMPs
  - Section 6 BMPs
  - Separate review process
- WWTP
  - Section 8 Direct Loads
  - Submitted Data

Phase 6 Model Documentation



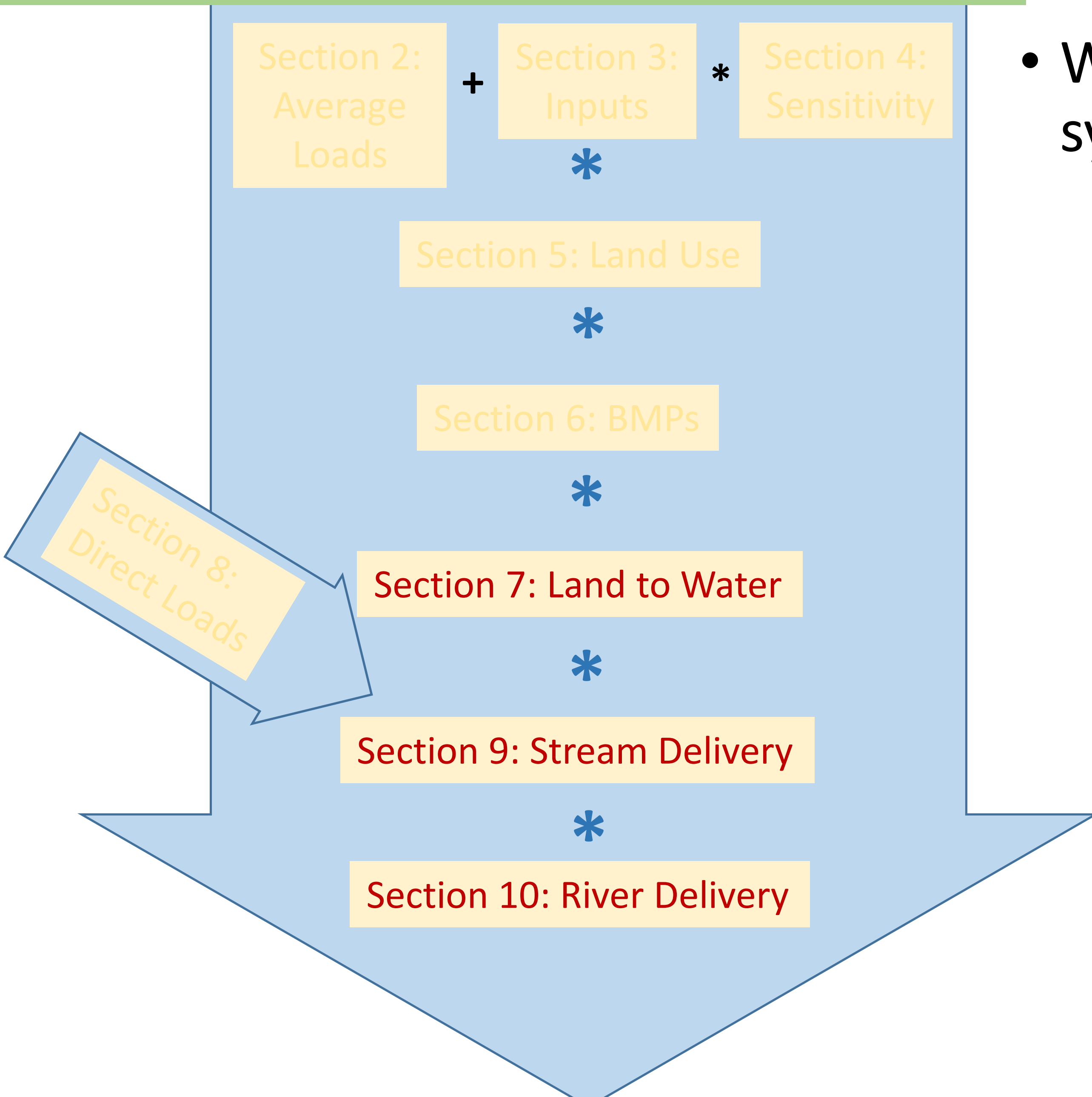
- Land use Change
  - Section 5 Land use
    - Not final
  - Section 2 Average Loads
    - Modeling workgroup
    - WQGIT workgroups

Phase 6 Model Documentation



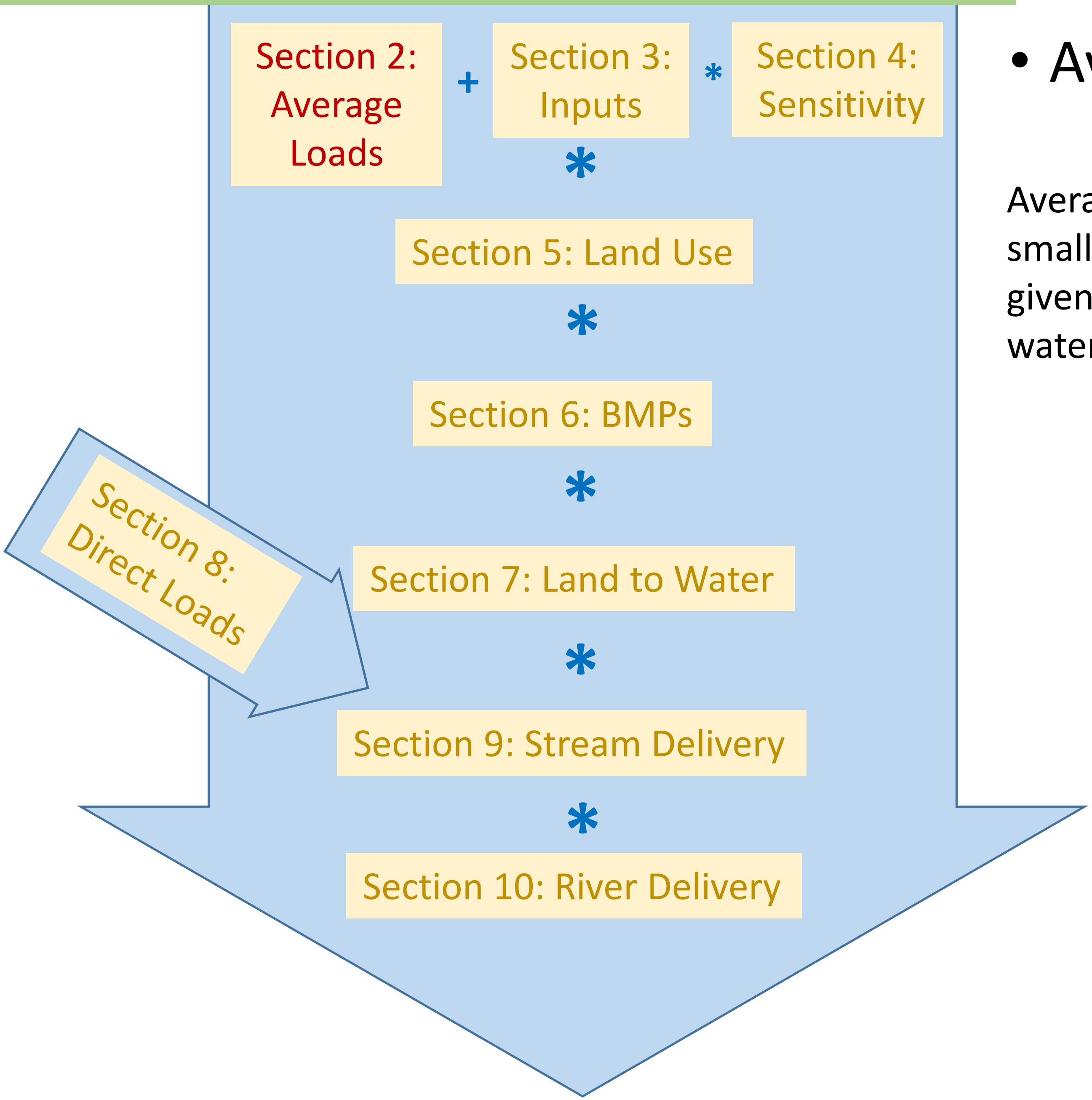
- Response to Change in Input
  - Section 3 Inputs
    - ‘scenario builder’
    - WQGIT workgroups
  - Section 4 Sensitivity
    - Modeling workgroup

Phase 6 Model Documentation



- Watershed Delivery system
  - Spatially distribute loads
  - Check for agreement with monitoring data
    - Modeling workgroup

Phase 6 Model Documentation



- Average Loads

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

Average Loads

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

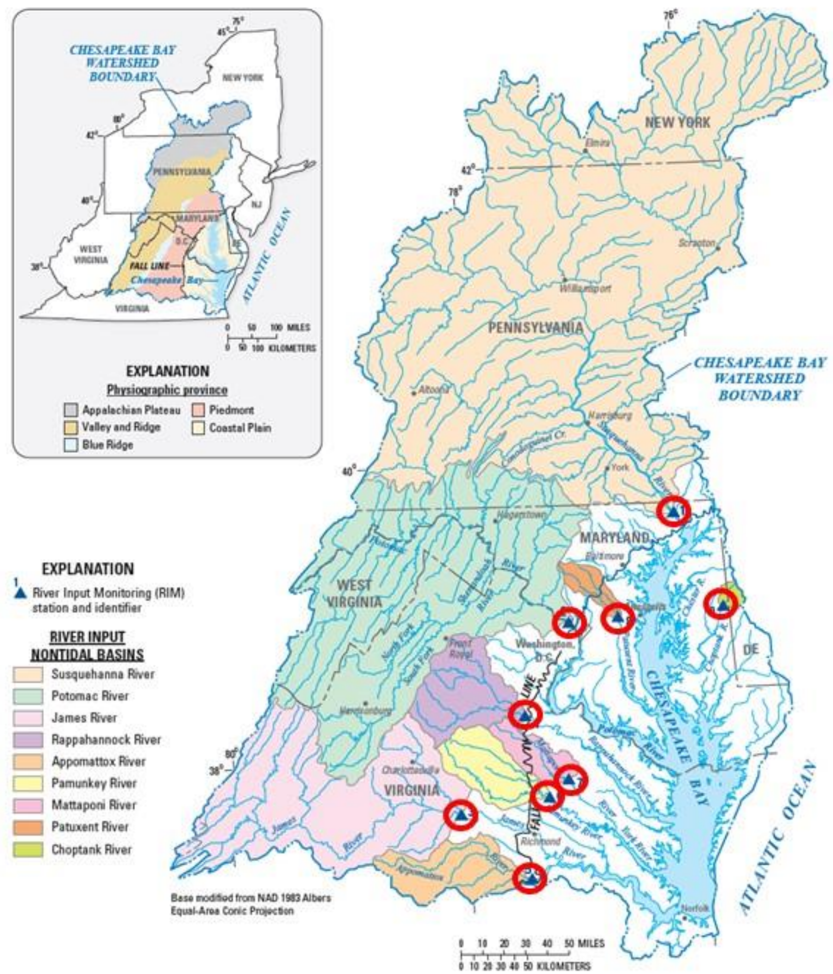
Estimate Total Non-point Source

Modeling Workgroup

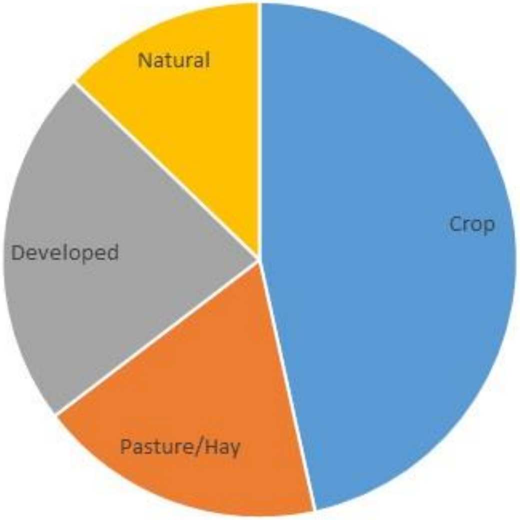
Monitoring Data

subtract point source

divide by transport



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

Divide into broad classes -- Nitrogen

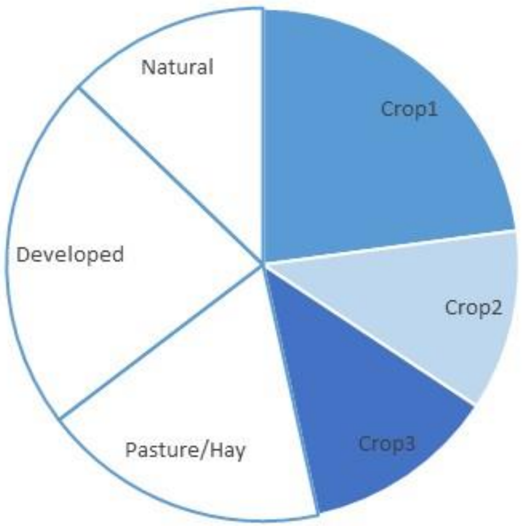
Sector	Crop	Pasture/ Hay	Developed	Natural
Acres*	4,361,964	5,156,450	5,289,606	24,788,695
P532 Export Rate (pounds per acre)	47.5	19.9	19.4	4.2
CEAP Export Rate (pounds per acre)	42.5	10.2	Not used	1.6
SPARROW Export Rate with BMP effects removed (pounds per acre)	22.9	10.2	8.9	0.4
Average Ratio to Crop Rate	1.00	0.37	0.40	0.05
Average Sector Export Rate (pounds per acre)	46.65	15.36†	18.62	2.26

** Note that no target is calculated for 1,148,100 acres in the land uses: permitted feeding space, non-permitted feeding space, and combined sanitary sewer and water.*

† The afo/cfo load of 9,063,059 pounds is removed from pasture.

Average Loads

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



Split Classes into individual land uses

WQGIT Workgroups

Multiple lines of evidence to develop ratios

- for example silage is 16% higher than grain

Split classes into individual land uses – Crop Nitrogen

Target Sector	Land Use	Export Rate Ratio	Export Rate (pounds per acre per year)
Cropland	Full Season Soybeans	0.71	54
	Grain with Manure	1.4	106
	Grain without Manure	1	76
	Other Agronomic Crops	0.45	34
	Silage with Manure	1.62	122
	Silage without Manure	1.16	88
	Small Grains and Grains	0.84	64
	Small Grains and Soybeans	0.79	60
	Specialty Crop High	1.34	101
	Specialty Crop Low	0.31	23
Pasture	Ag Open Space	0.43	9
	Legume Hay	0.74	16
	Other Hay	1.04	23
	Pasture	1	22

Beta 2

Target Sector	Land Use	Export Rate Ratio	Export Rate (pounds per acre per year)
Developed	Non-Regulated Tree Canopy over Impervious	0.91	40
	Non-Regulated Tree Canopy over Turfgrass	0.38	17
	Non-Regulated Turf Grass	0.5	22
Natural	True Forest	1	3

Beta 2 pie was too large

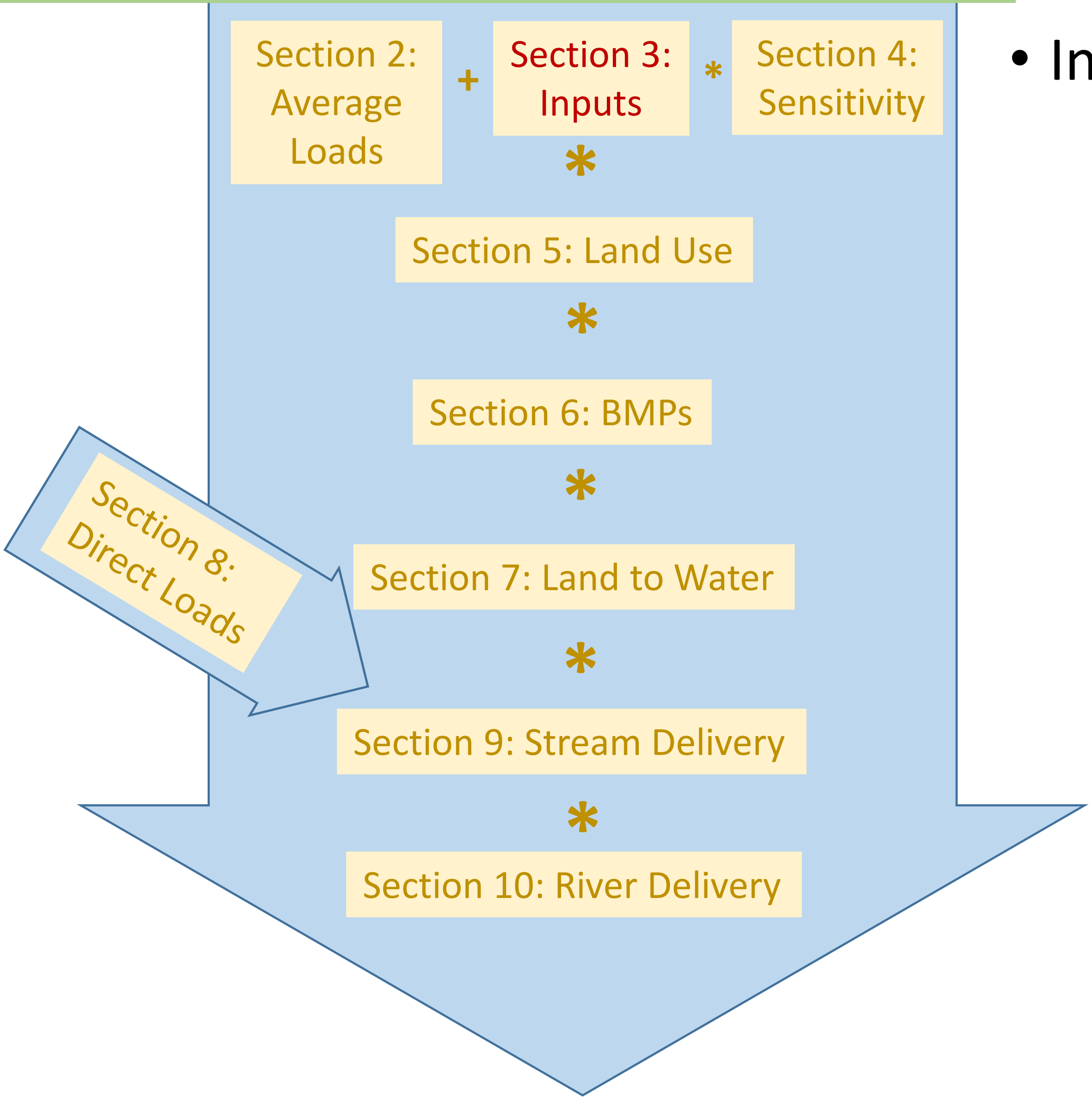
Estimate Total Non-point Source
Modeling Workgroup
Monitoring Data
subtract point source
divide by transport

- Modifications to method for Beta 3
  - Assumed lower attenuation in rivers
  - Updated point source values

Beta 3 values

Target Sector	Land Use	Beta 3 N	Beta 3 P
Cropland	Full Season Soybeans	24	1.4
	Grain with Manure	48	1.5
	Grain without Manure	33	1.5
	Other Agronomic Crops	16	2.0
	Silage with Manure	54	1.6
	Silage without Manure	38	1.6
	Small Grains and Grains	28	1.2
	Small Grains and Soybeans	34	1.5
	Specialty Crop High	43	2.8
	Specialty Crop Low	11	2.2
Pasture	Ag Open Space	4	1.1
	Legume Hay	7	0.6
	Other Hay	10	0.6
	Pasture	9	0.8

Phase 6 Model Documentation

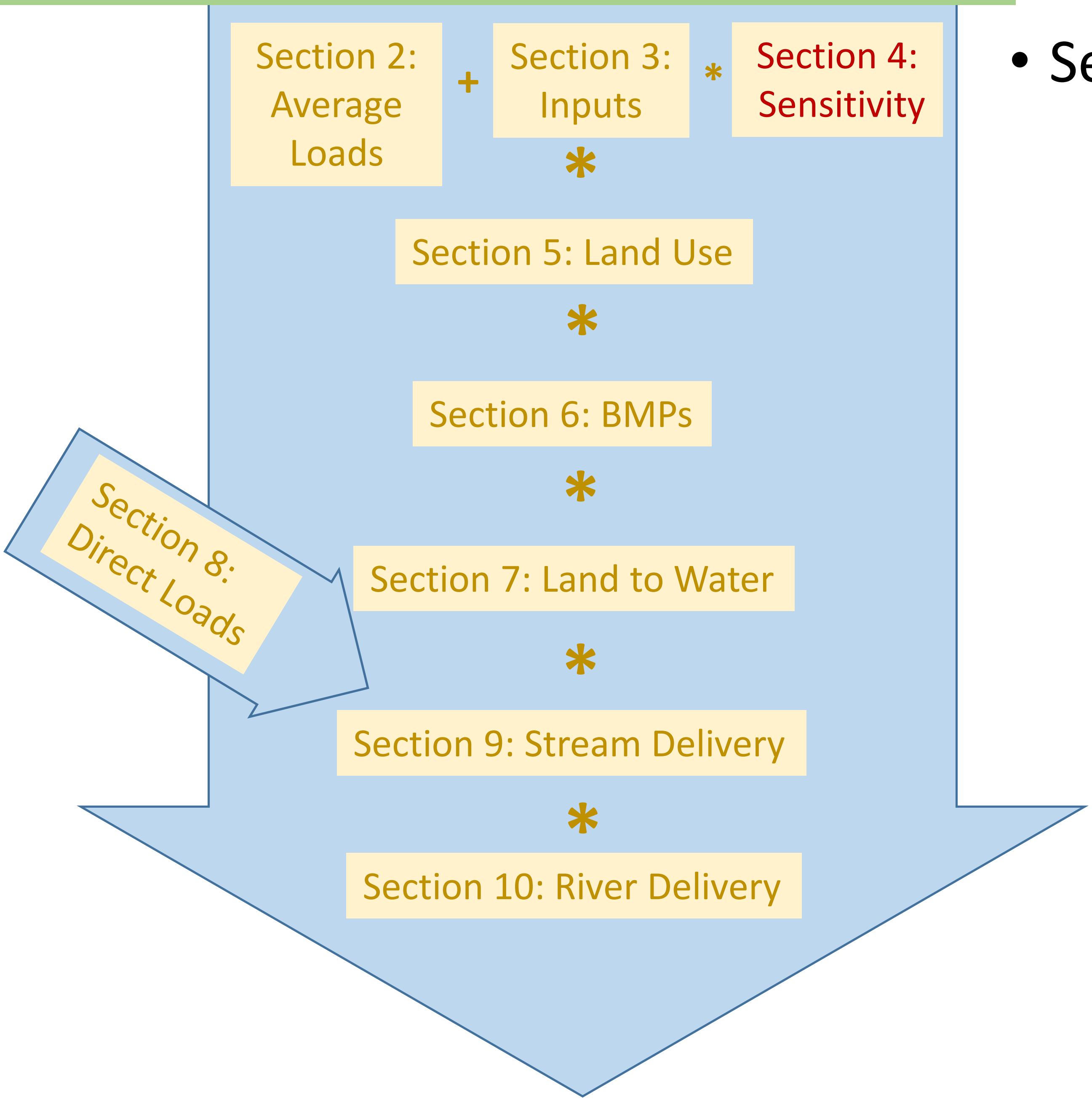


- Inputs
  - Manure
  - Inorganic fertilizer
  - Legume fixation
  - Uptake
  - Crop cover
  - Plowing effects

Atmospheric Deposition

- Currently using phase 5.3.2
- Expecting Data set from Penn State for Beta 4
- Data set will be modified by scenarios in CMAQ

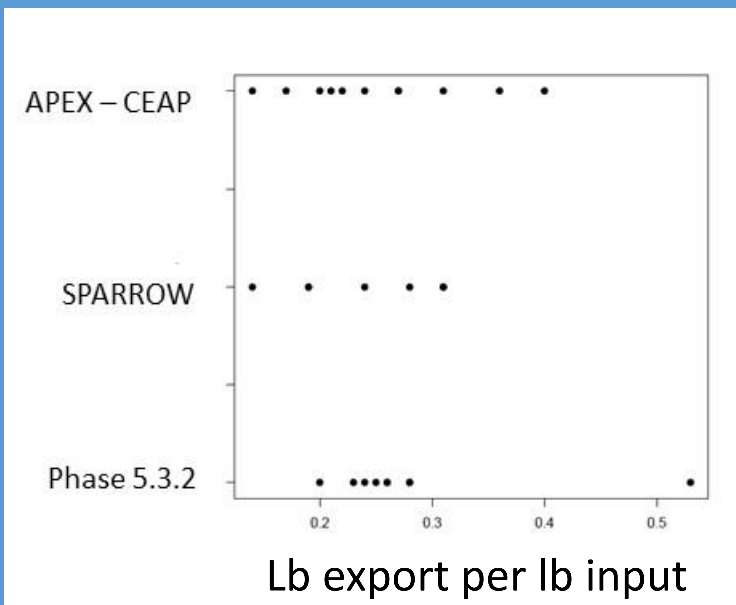
Phase 6 Model Documentation



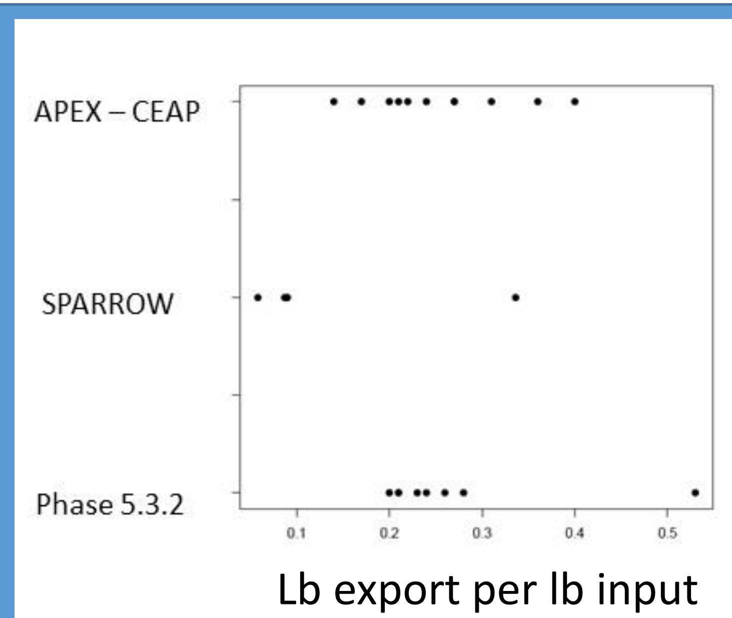
- Sensitivity
  - Change in output per change in input

Nitrogen Sensitivity

Definition – Average Change in export per change in input



Commercial Fertilizer

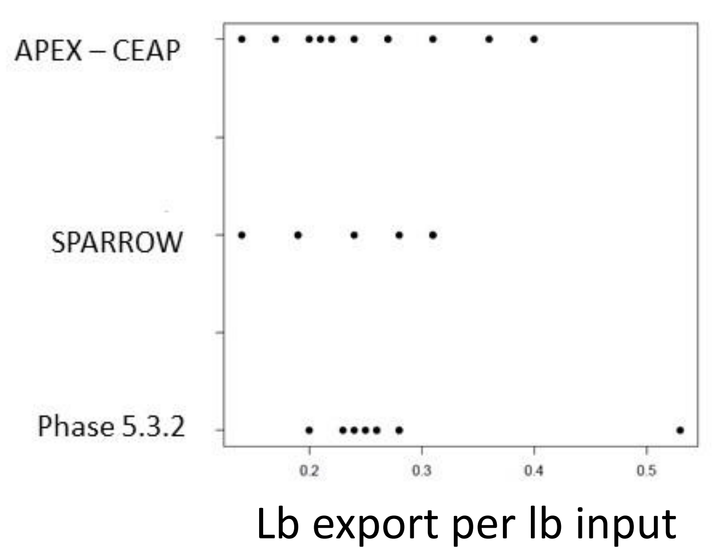


Manure

Multiple Model comparison – All in general agreement on the average effect

Nitrogen Sensitivity

Definition – Average Change in export per change in input



Commercial Fertilizer

Modeling Workgroup Decision:

Use Phase 5.3.2 for global sensitivities

- Supported by CEAP and SPARROW results
- Answers the right question
    - ***Change*** in export per ***change*** in input
- No direct access to APEX-CEAP
- Sparrow had different land use classifications

Sensitivity of Phase 5 Hightill with Manure land use

	NH3	NO3	ORGN
Atmospheric Deposition	0.01	0.226	0.083
Fertilizer	0.018	0.19	0.073
Manure	0.005	0.067	0.104
Fixation	0.01	0.19	0.101
Crop Uptake	0	-0.057	0
Vegetative Cover	-0.012	0.012	-0.404

Sensitivities are modified according to relative loading rates

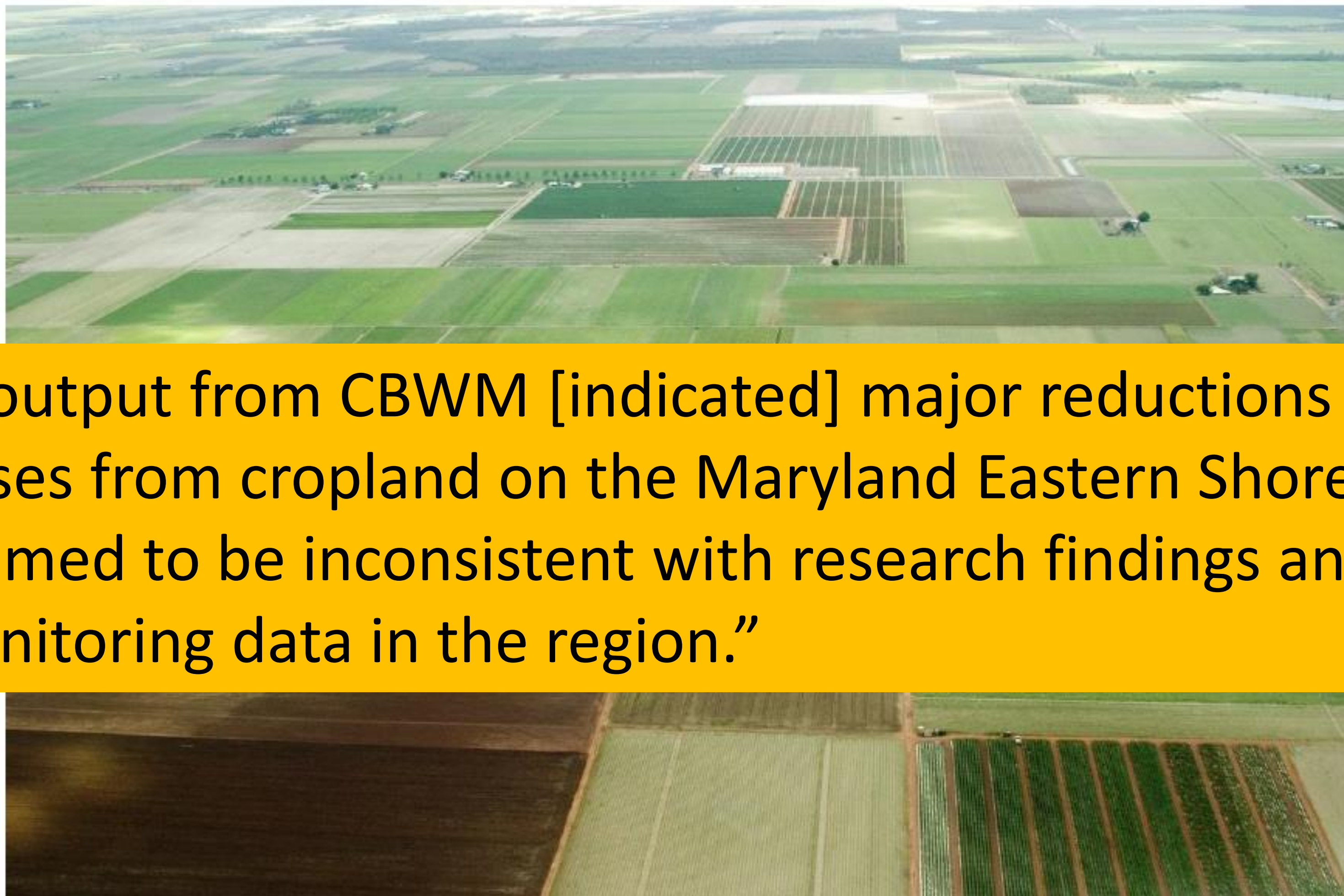
P5.3.2 hwm = p6 gwm (grain with manure)

What about other land uses?
Adjust by load ratio => Small Grains is 60% of Grain with manure load

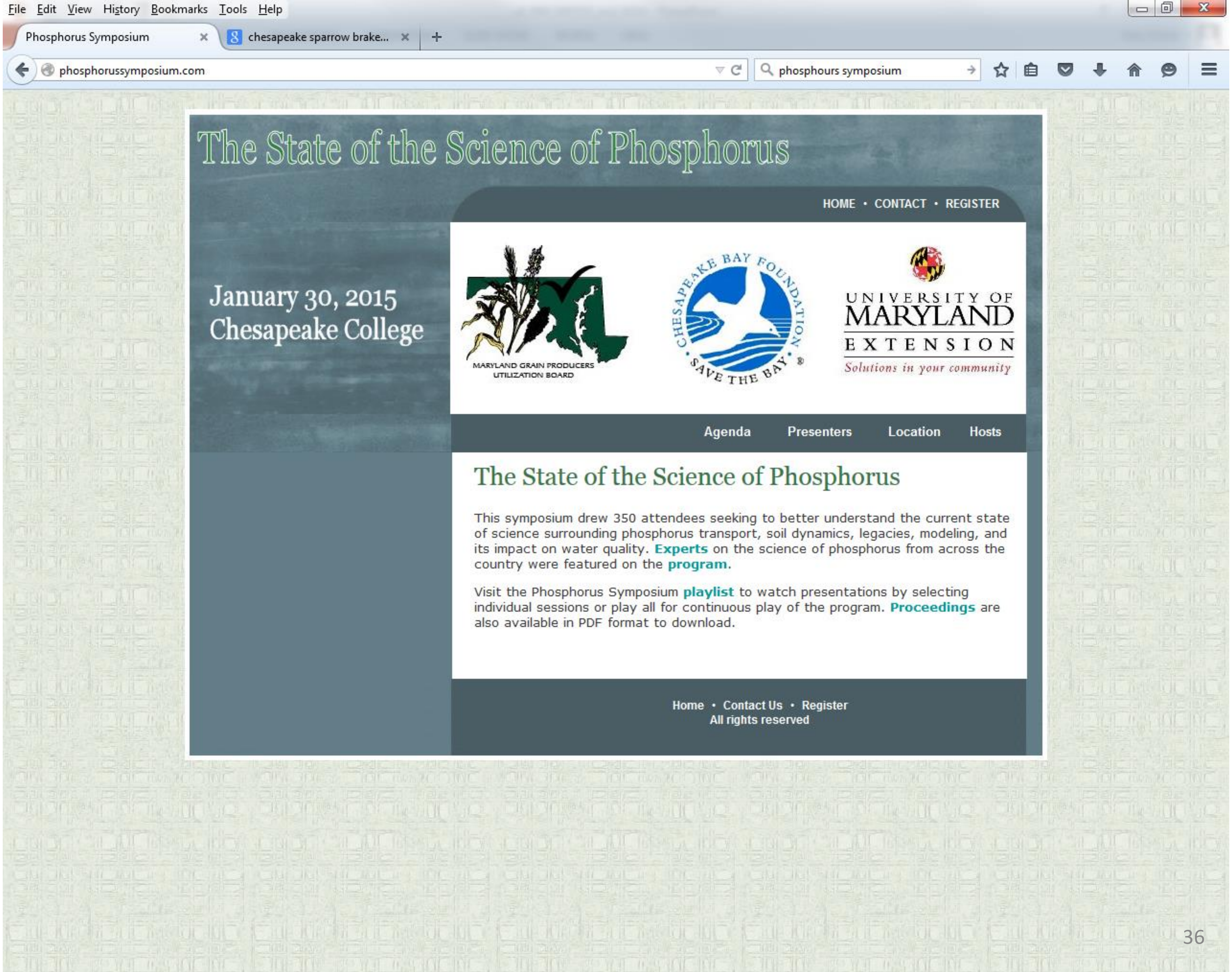
Adjusted sgg sensitivity = gwm sensitivity * 60%

STAC Guidance on Phosphorus

A Review of Agricultural P-dynamics in the Chesapeake Bay Watershed Model



"…output from CBWM [indicated] major reductions in P losses from cropland on the Maryland Eastern Shore that seemed to be inconsistent with research findings and monitoring data in the region."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SAVE THE BAY
UNIVERSITY OF MARYLAND EXTENSION
Solutions in your community
Agenda
Presenters
Location
Hosts
The State of the Science of Phosphorus
This symposium drew 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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Phosphorus Conceptual Model

Phosphorus

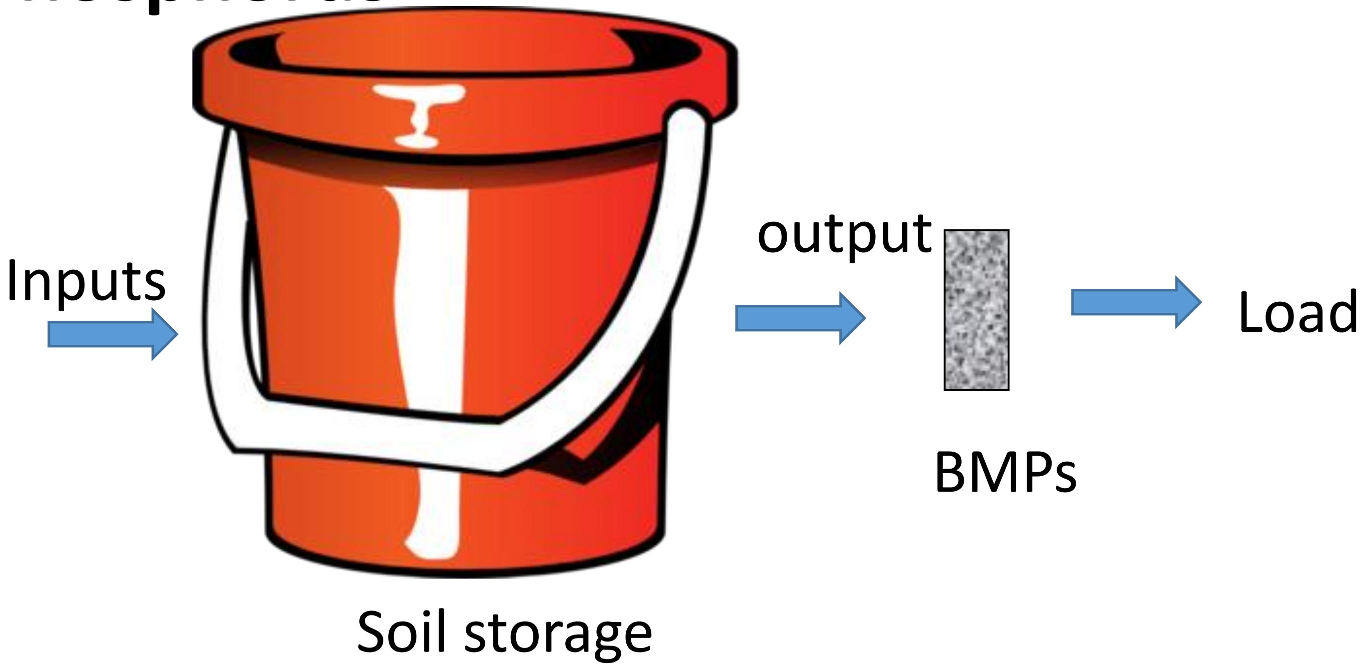
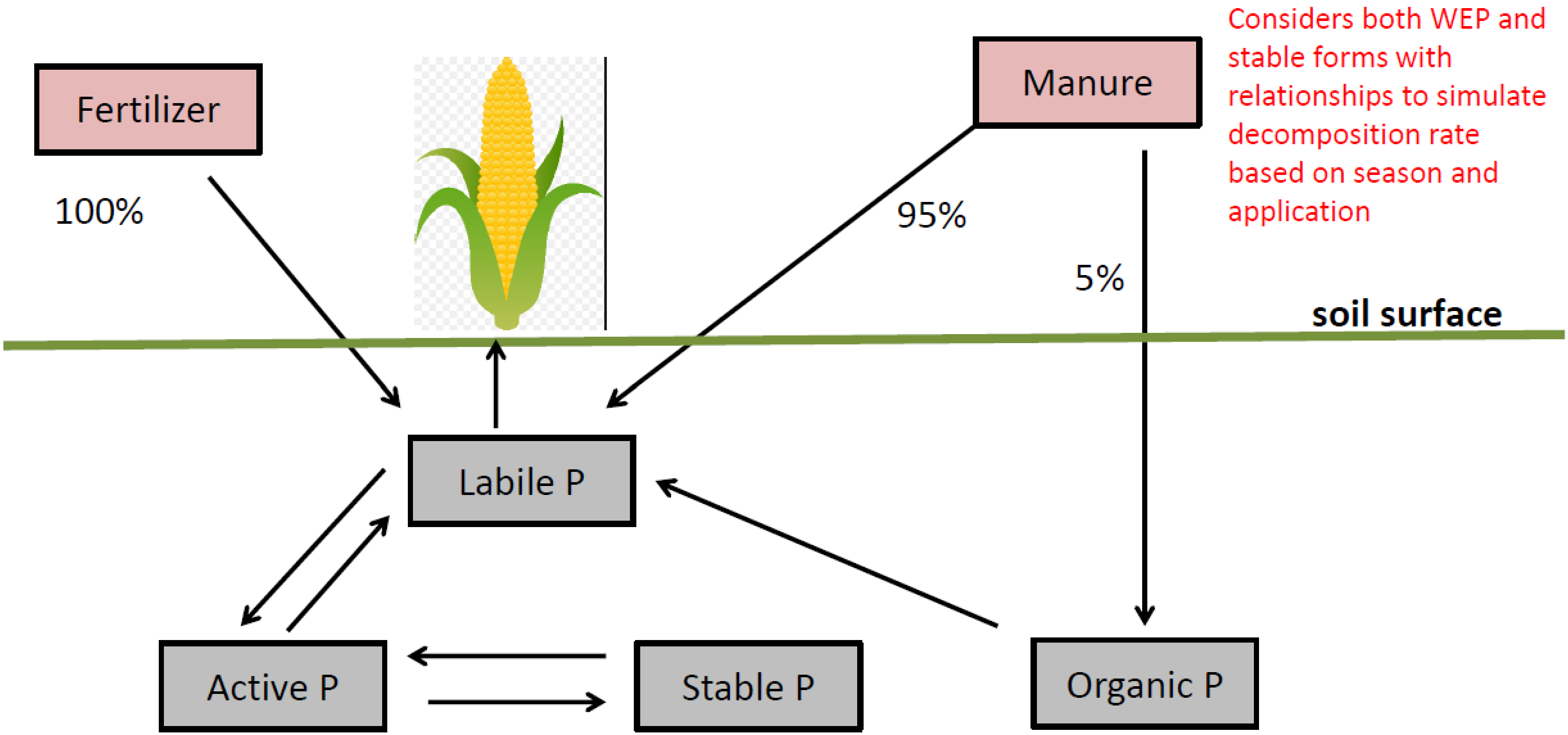


Diagram of APLE Nutrient Sources and Soil Pools

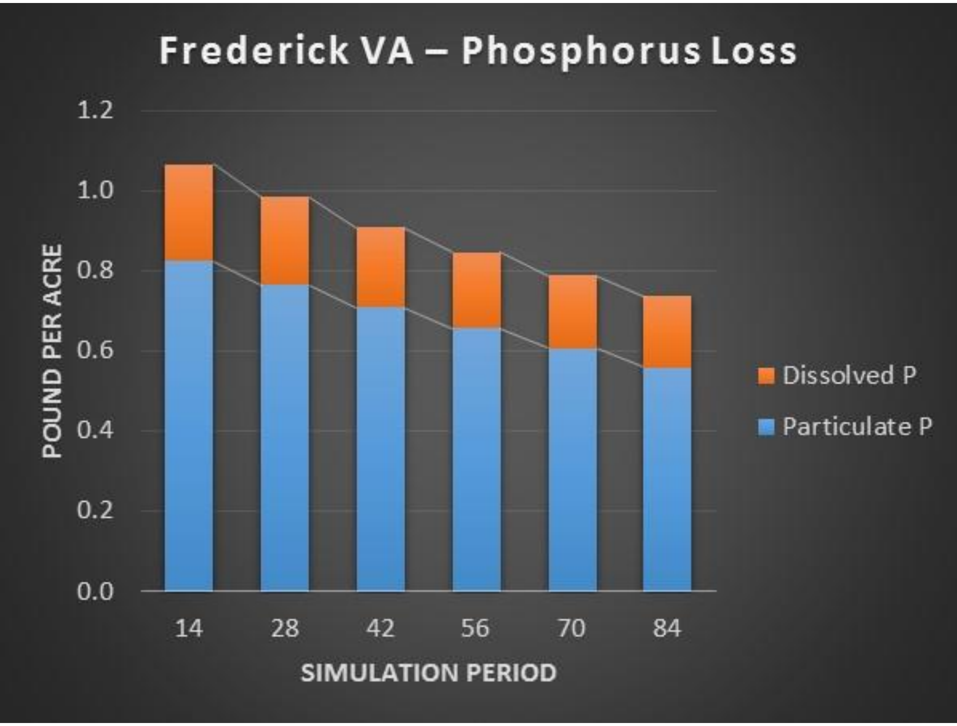


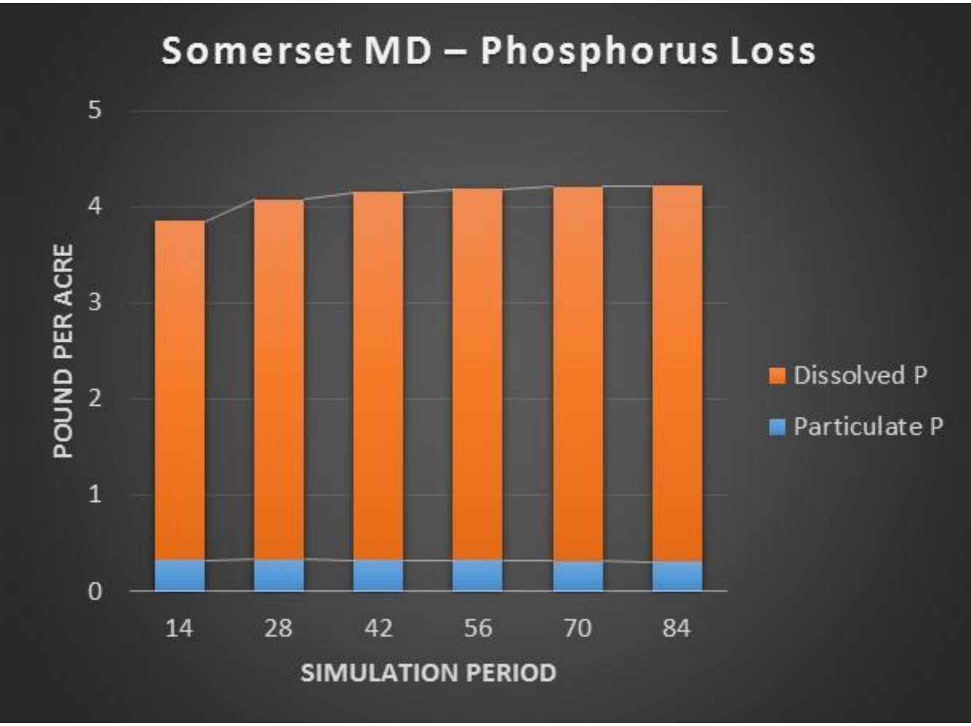
Equations to estimate Manure runoff P, Fertilizer runoff P, Sediment P loss, and Dissolved Soil P runoff

(Adapted from Vadas, et al. 2007)

Low input County

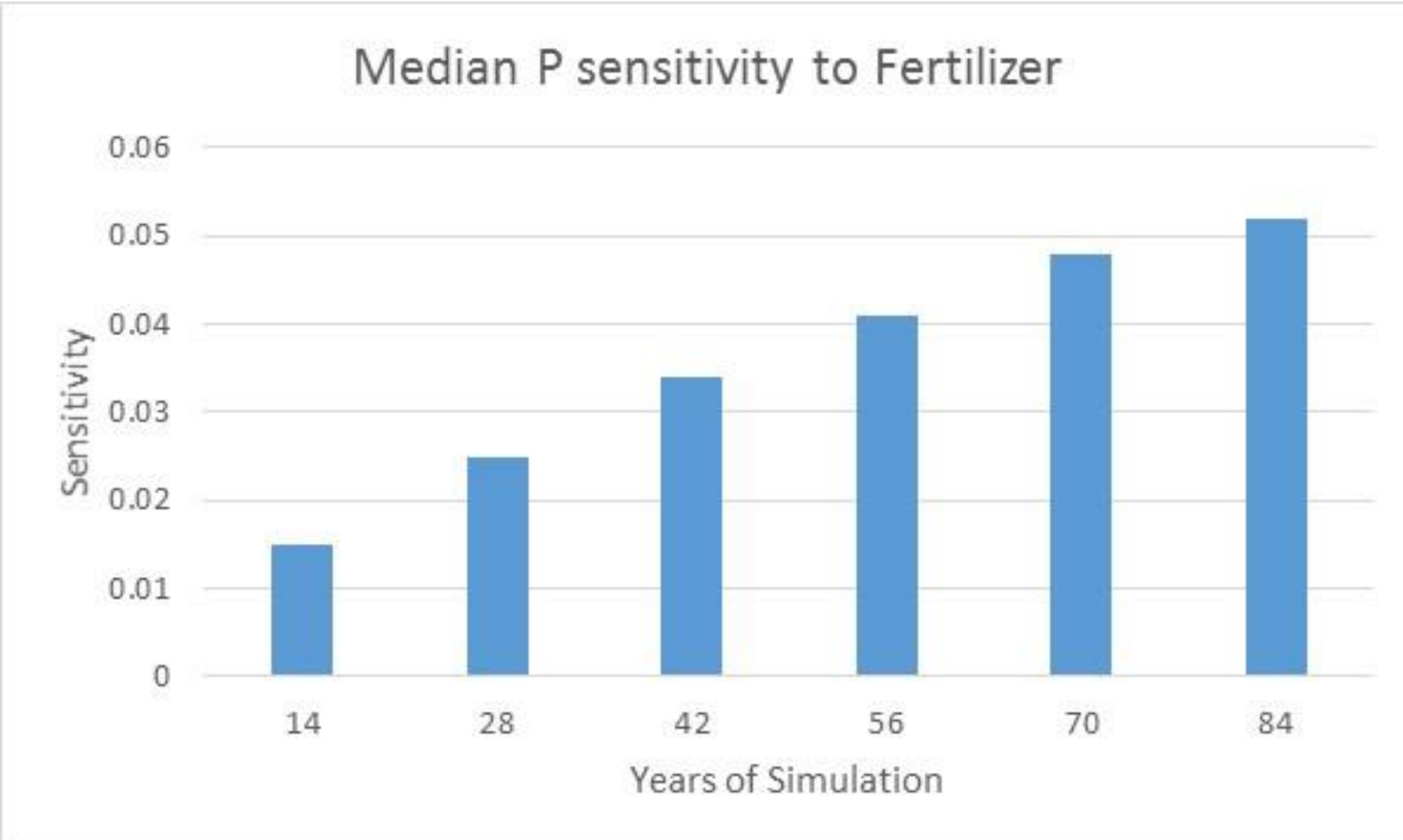
High input County





The concept of a sensitivity to inputs is problematic because the long term simulations do not level off

Different Simulation Periods to Evaluate Sensitivities



APLE Hightill Landuse Sensitivities using Constant Mehlich 3 Soil P

Table 1. Phosphorus Loss APLE Model Sensitivity to change in inputs

Inputs	Units	MEDIAN SLOPE	MEDIAN SR	Relative Sensitivity
Mehlich	ppm	0.015	0.696	Sensitive
Sediment	ton/ac	0.168	0.633	Sensitive
Runoff	inches	0.057	0.403	Moderately sensitive
Manure	lbs/acre	0.007	0.111	Slightly sensitive
Fertilizer	lbs/acre	0.004	0.068	Slightly sensitive
Uptake	lbs/acre	0	0	Insensitive

APLE Hightill Landuse Sensitivities using Constant Mehlich 3 Soil P

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~~Fertilizer~~	~~lbs/acre~~	~~0.004~~	~~0.068~~	Slightly sensitive
~~Uptake~~	~~lbs/acre~~	~~0~~	~~0~~	Insensitive

Requires estimate of soil P

Summary of Soil P data sources

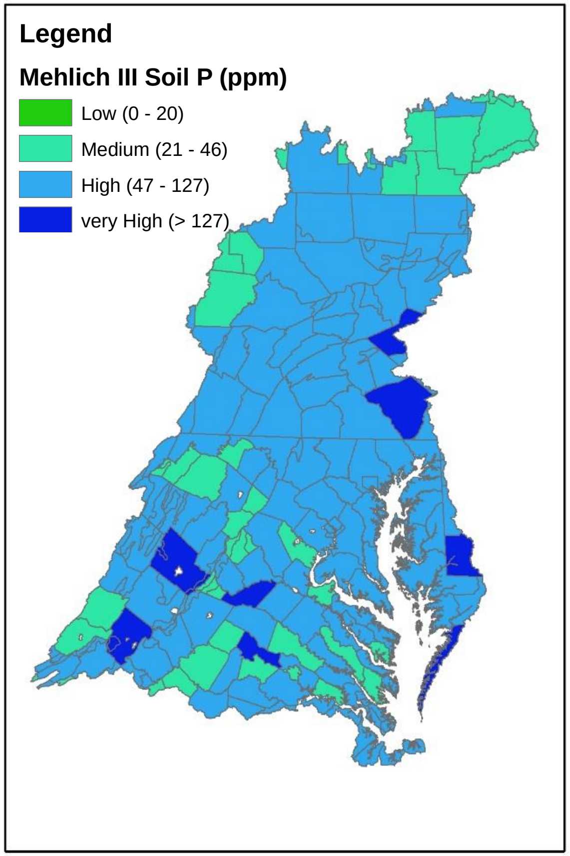
SOURCE	YEARS	LOCATION	UNITS	SAMPLE TYPE
AgriAnalysis	2003 - 2014	DE,MD,NY,PA,VA,WV	Phos lbs/ac	by county & zip code
Penn State University	2001 - 2014	PA	Mehlich III soil P (ppm)	by county and by crop
Virginia Tech Soil Testing Lab	Average of 2012-2014	VA	Mehlich III soil P (ppm)	by county and by crop
University of Maryland	1954 - 2002	MD	number of samples	by county
University of Maryland	1992	DE,MD,NY,PA,VA,WV	Mehlich III soil P (ppm)	by county

Soil P Landuse Ratios

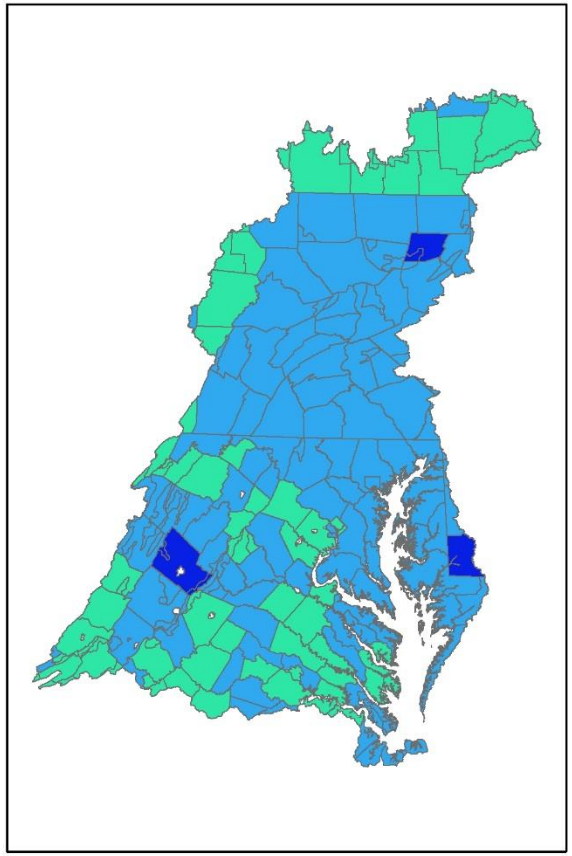
Landuse	Landuse name	PA		VA	
		Average Mehlich III	Ratio	Average Mehlich III	Ratio
ALL	ALL	102		85	
sch	Specialty Crop High	190	1.9	146	1.7
scl	Specialty Crop Low	151	1.5	120	1.4
oac	Other Agronomic Crops	132	1.3	106	1.3
swm	Silage with Manure	90	0.9	88	1.0
gwm	Grain with Manure	89	0.9	76	0.9
soy	Full Season Soybeans	83	0.8	64	0.8
sgg	Small Grains and Grains	76	0.7	72	0.8
ohy	Other Hay	73	0.7	58	0.7
lhy	Legume Hay	73	0.7	58	0.7
pas	Pasture	66	0.6	56	0.7

- PA and VA provided soil P data by crop.
- The average soil P ratios were applied to other states’ soil P datasets.

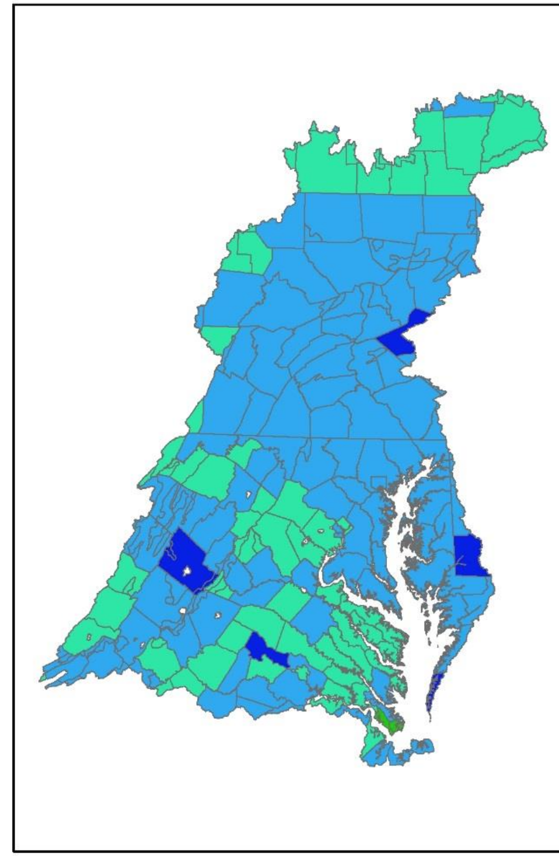
Small Grains and Grains (sgg)



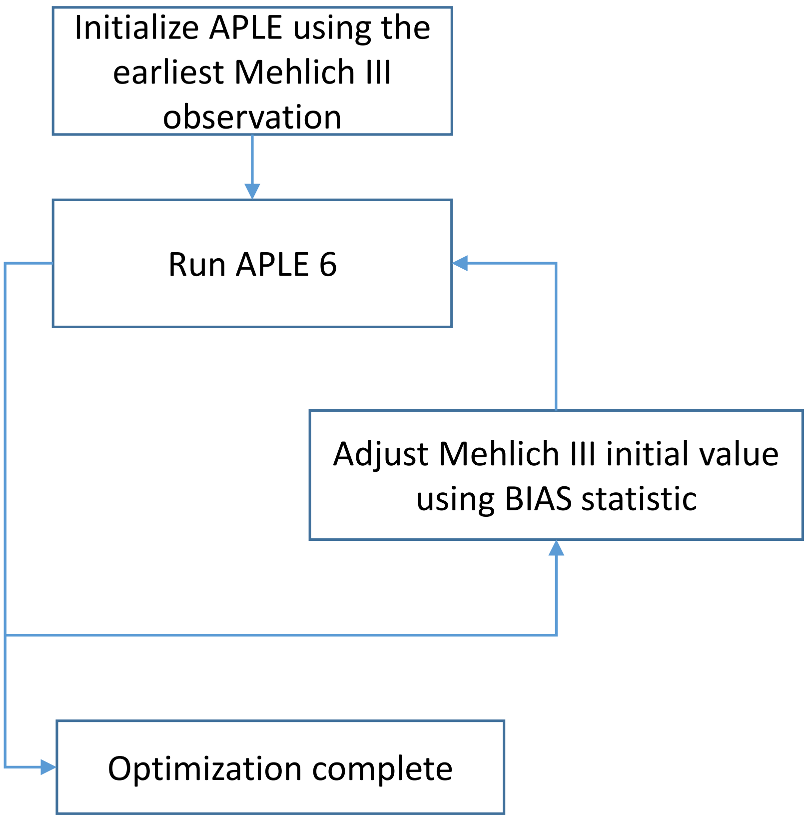
Other Hay (ohy)

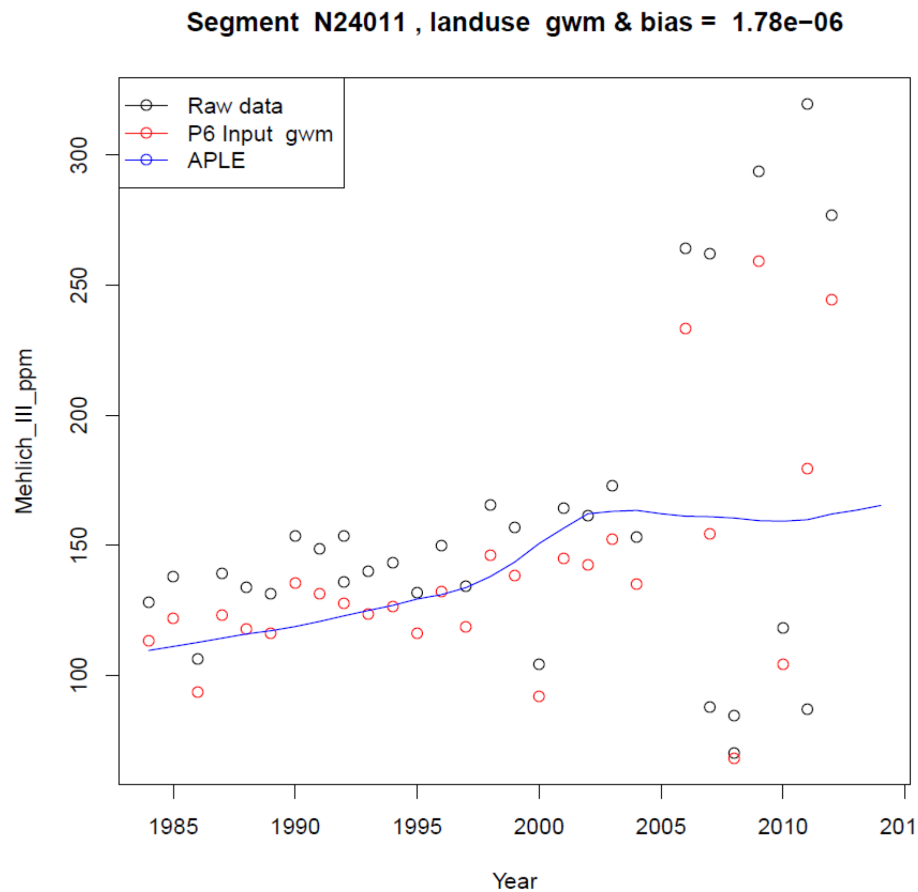


Legume Hay (lhy)

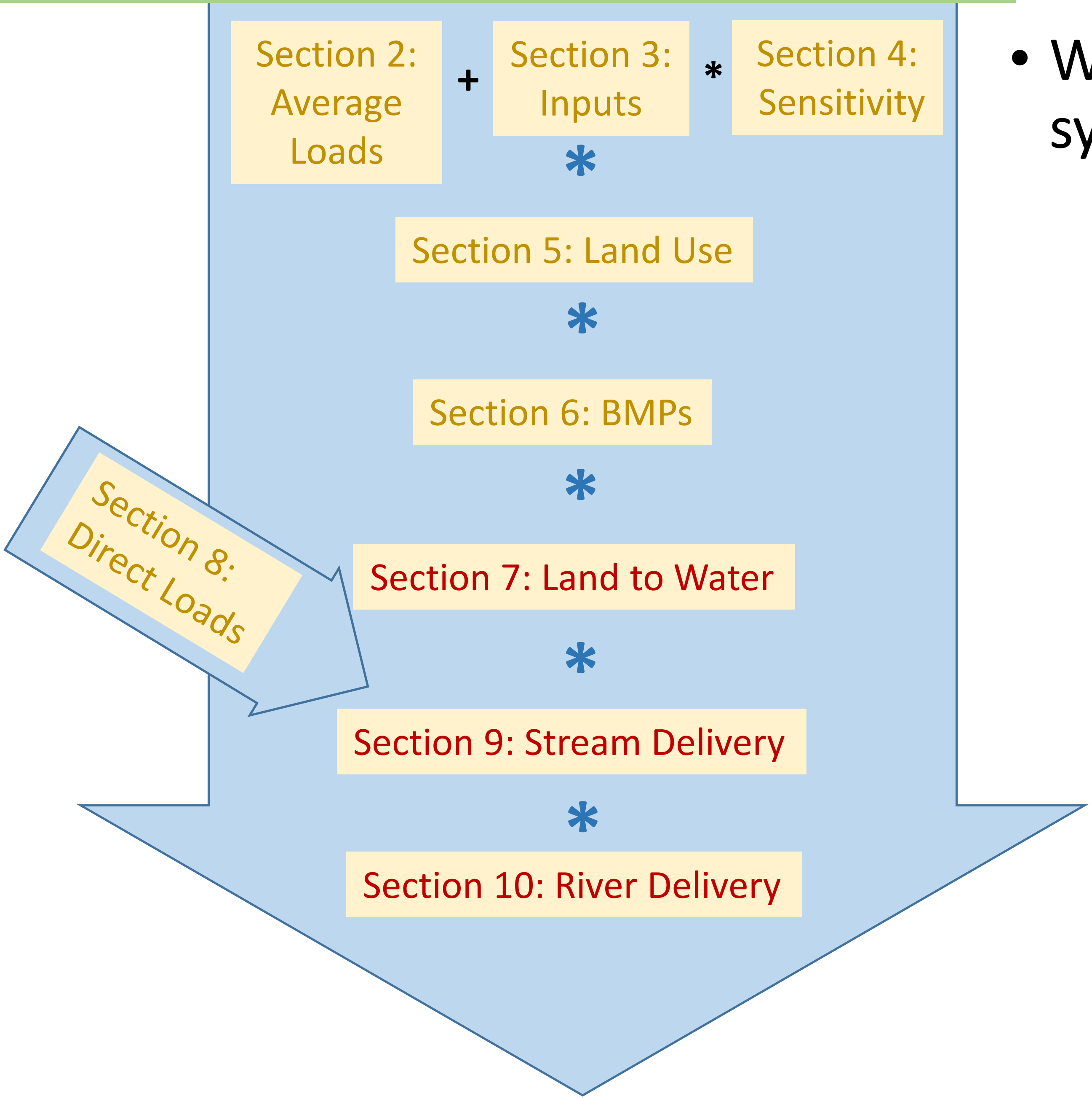


Soil P History





Phase 6 Model Documentation

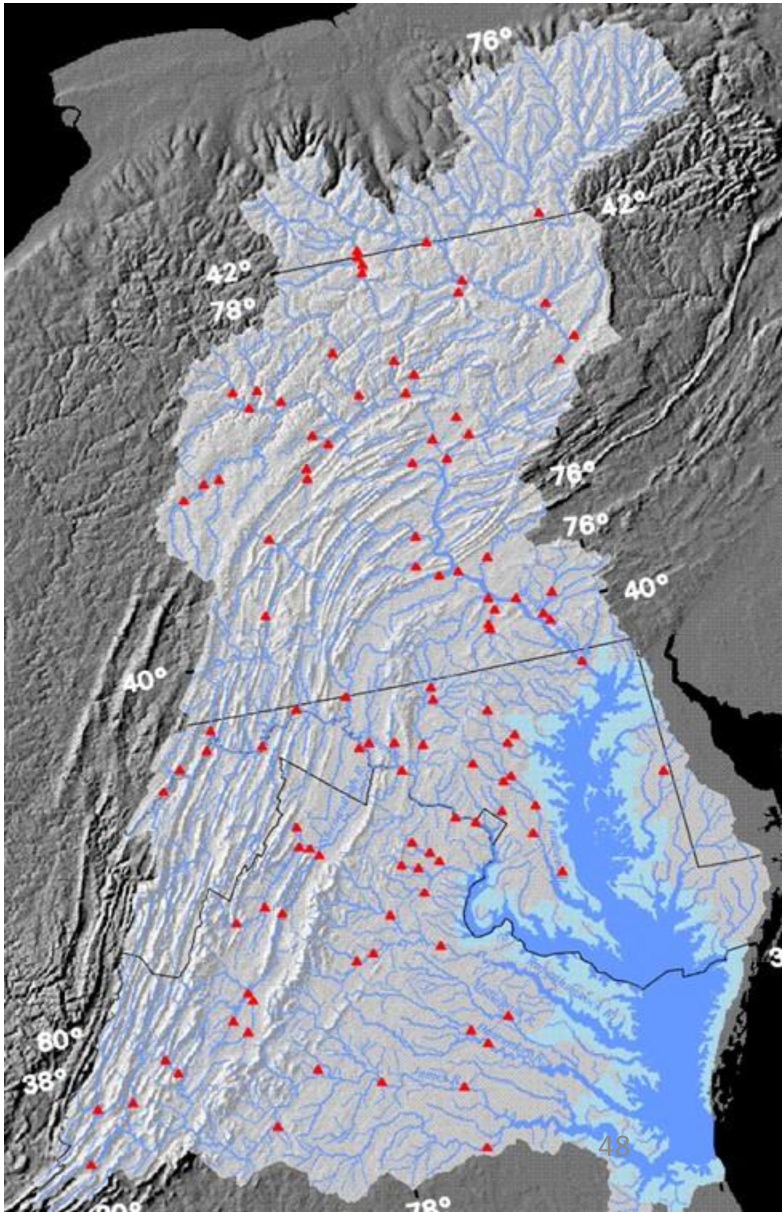


- Watershed Delivery system
  - Spatially distribute loads
  - Check for agreement with monitoring data
    - Modeling workgroup

$$LOAD_i = \left\{ \sum_{j \in J(i)} \left[\sum_{n=1}^{N} S_{n,j} \beta_n \exp(-\alpha' Z_j) \right] \prod_m \exp(-\delta_m^s T_{i,j,m}) \prod_l 1/(1+\lambda^r q_{i,j,l}^{-1}) \right\} \exp(\varepsilon_i)$$

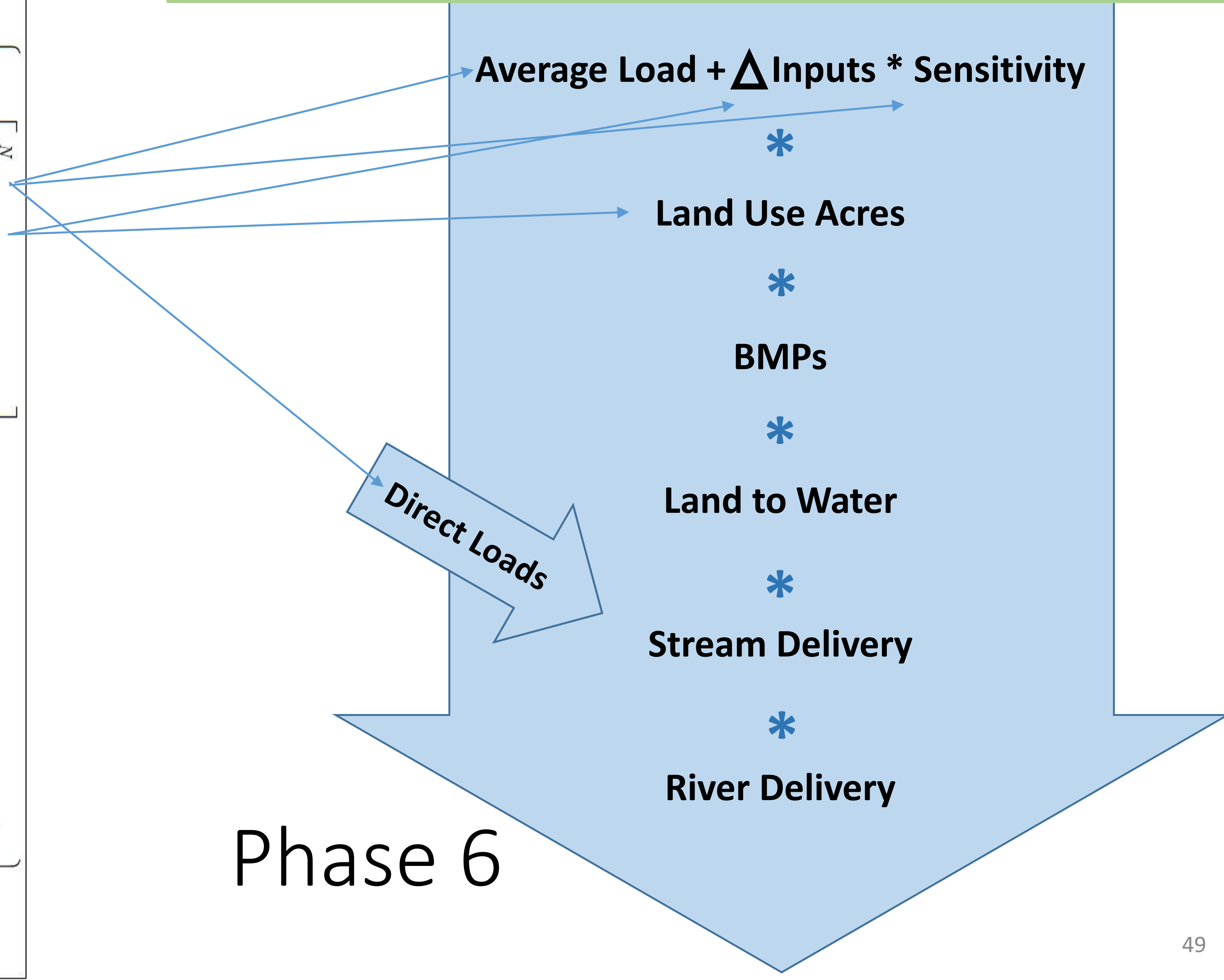
USGS Sparrow Model

- Regression Model
- Gain knowledge about the watershed based on observations



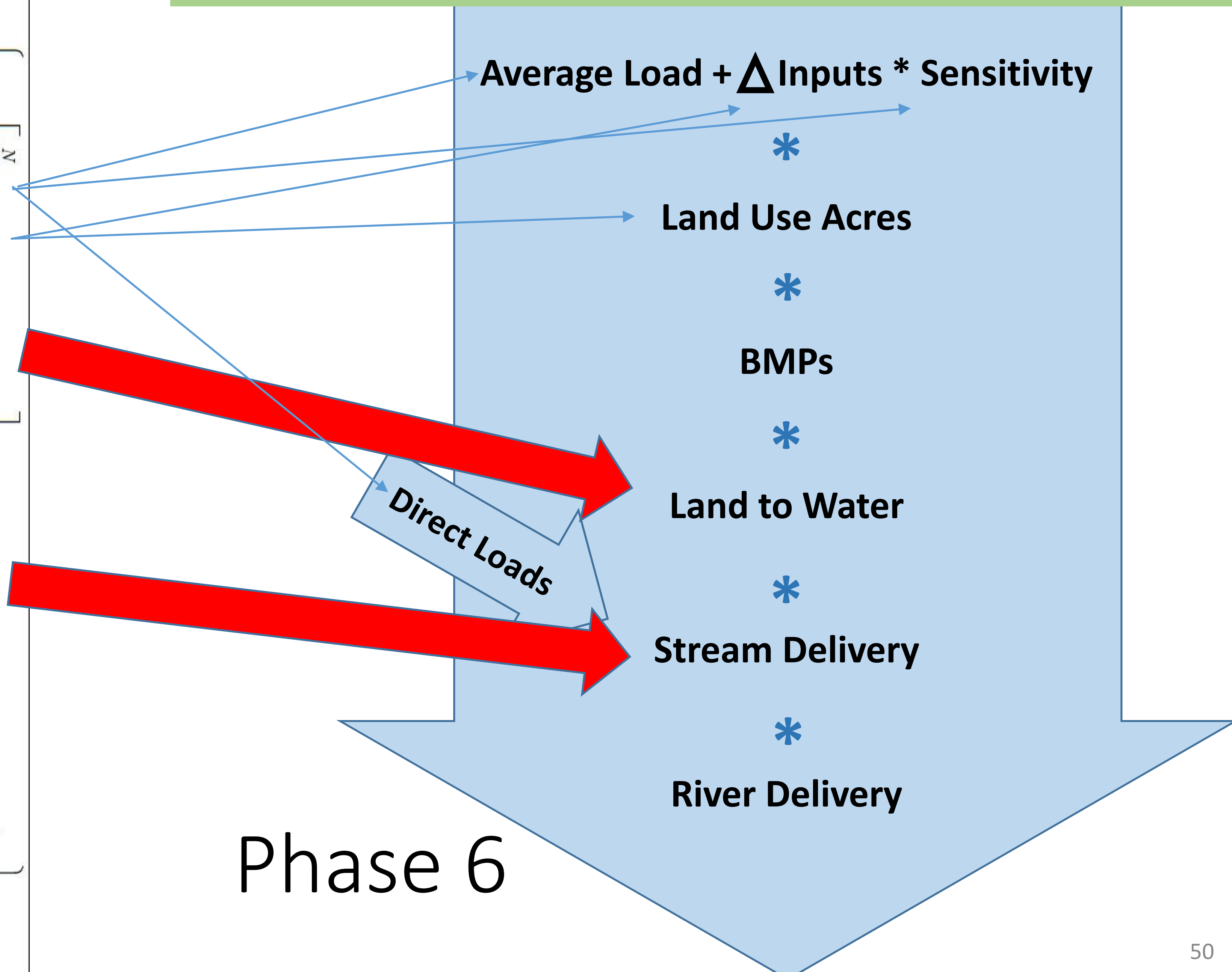
Phase 6 Model Structure

$$LOAD_i = \left\{ \sum_{j \in J(i)} \left[\sum_{n=1}^{N} S_{n,j} \beta_n \exp(-\alpha' Z_j) \right] \prod_m \exp(-\delta_m^s T_{i,j,m}) \prod_l 1/(1+\lambda^r q_{i,j,l}^{-1}) \right\} \exp(\varepsilon_i)$$

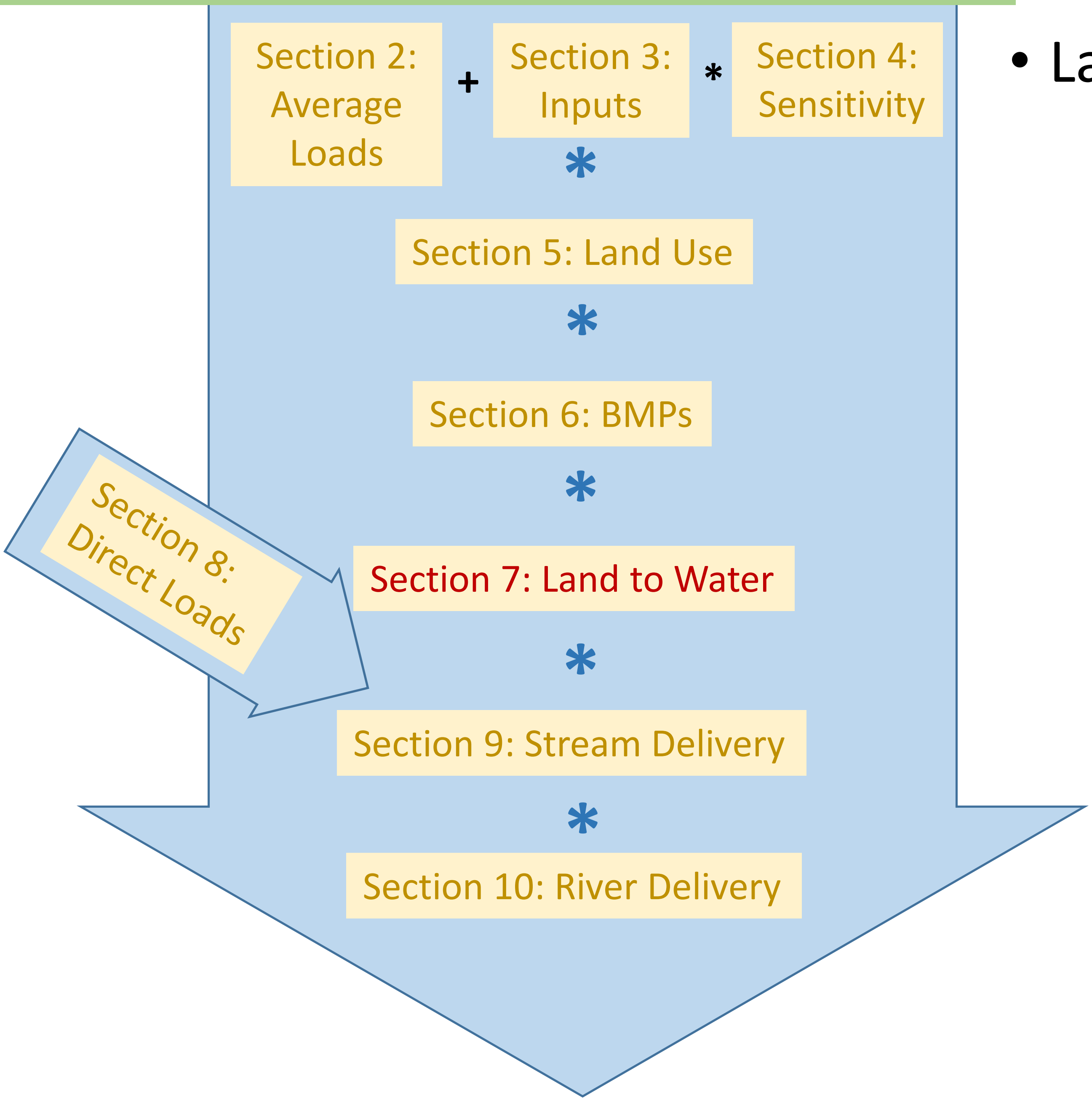


Phase 6 Model Structure

$$LOAD_i = \left\{ \sum_{j \in J(i)} \left[\sum_{n=1}^{N} S_{n,j} \beta_n \exp(-\alpha' Z_j) \right] \prod_m \exp(-\delta_m^s T_{i,j,m}) \prod_l 1/(1+\lambda^r q_{i,j,l}^{-1}) \right\} \exp(\varepsilon_i)$$



Phase 6 Model Documentation



- Land to Water
  - Loads are already edge-of-stream but based on large averages
  - L2W factors spatially distribute the loads based on watershed characteristics
  - L2W factors have no net effect on the overall loads

Catchment and Reach Attributes Used in SPARROW Models

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

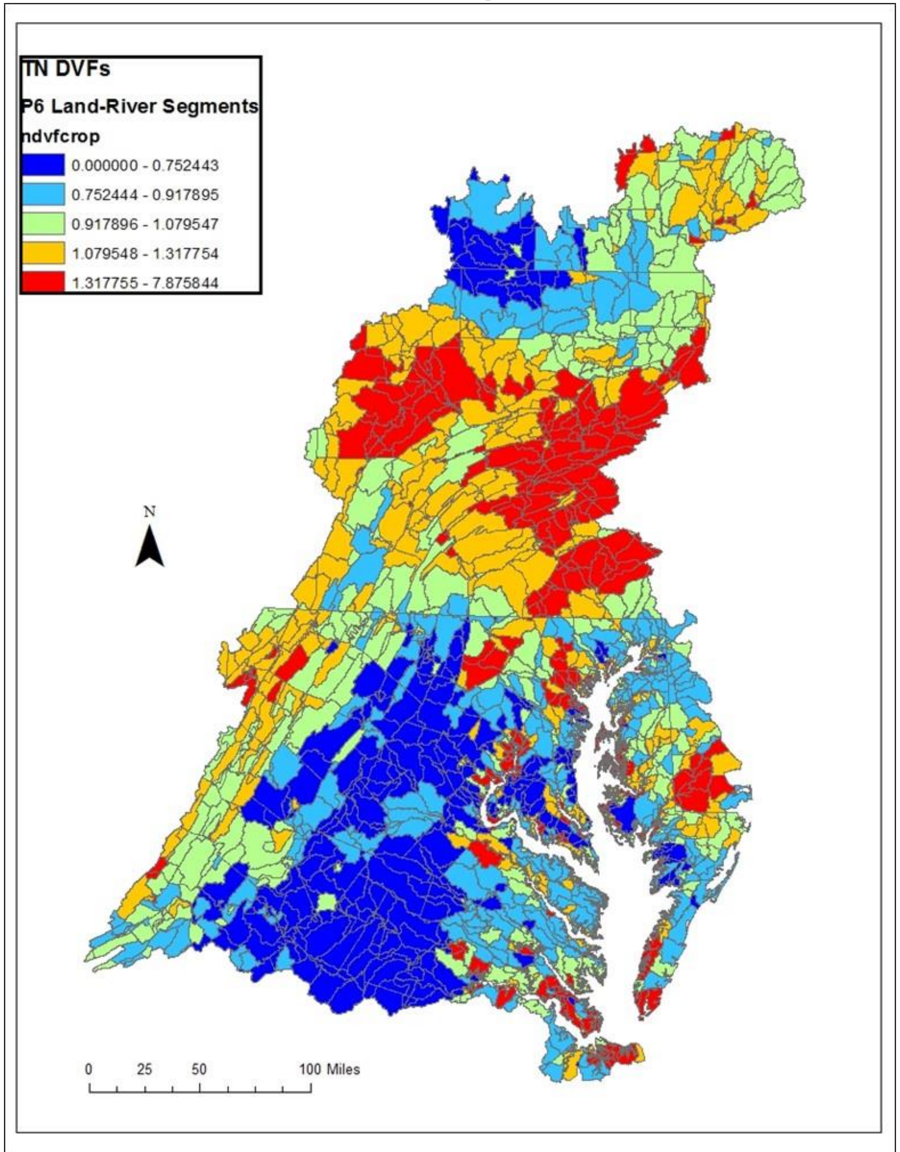
Catchment and Reach Attributes Used in SPARROW Models

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

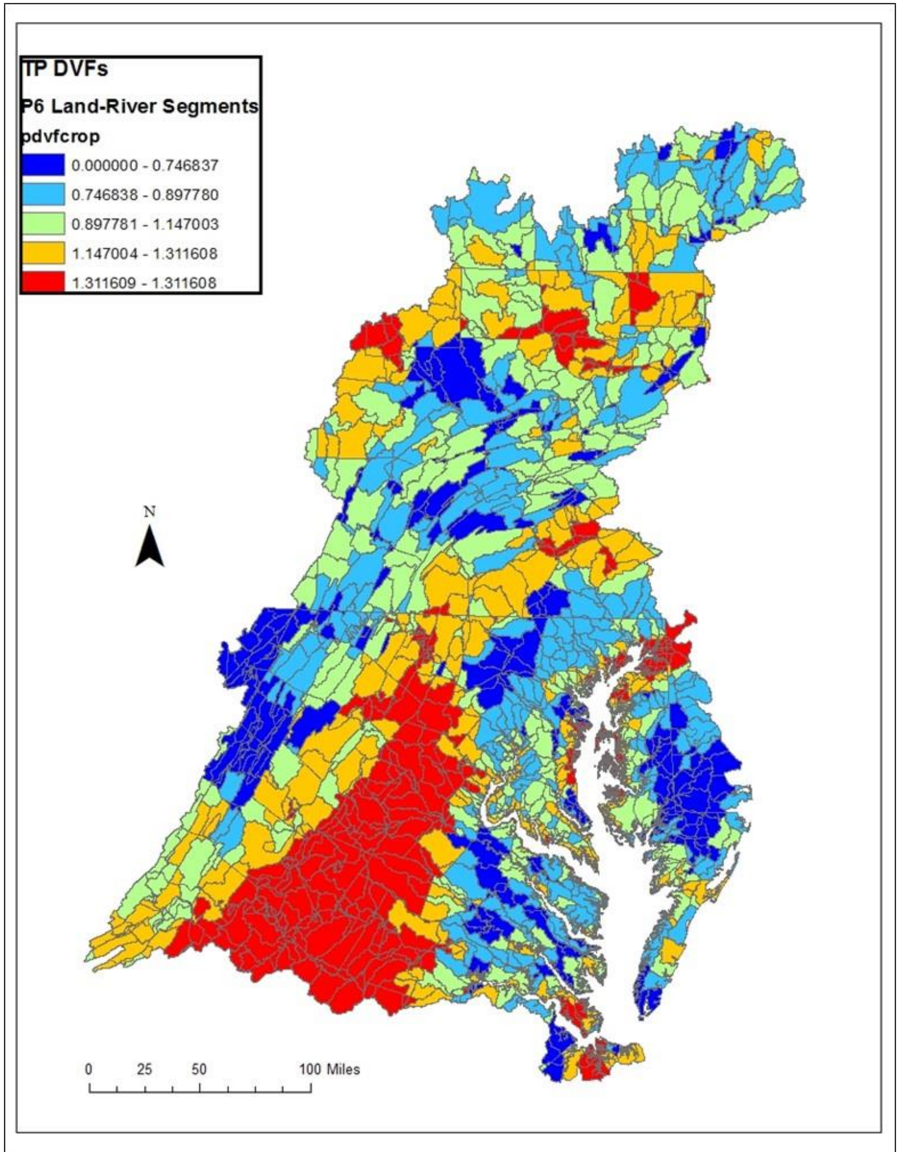
* Not used in Beta 2 calculations because redundant with APLE sensitivities to runoff and erosion

Crop L2W Factors

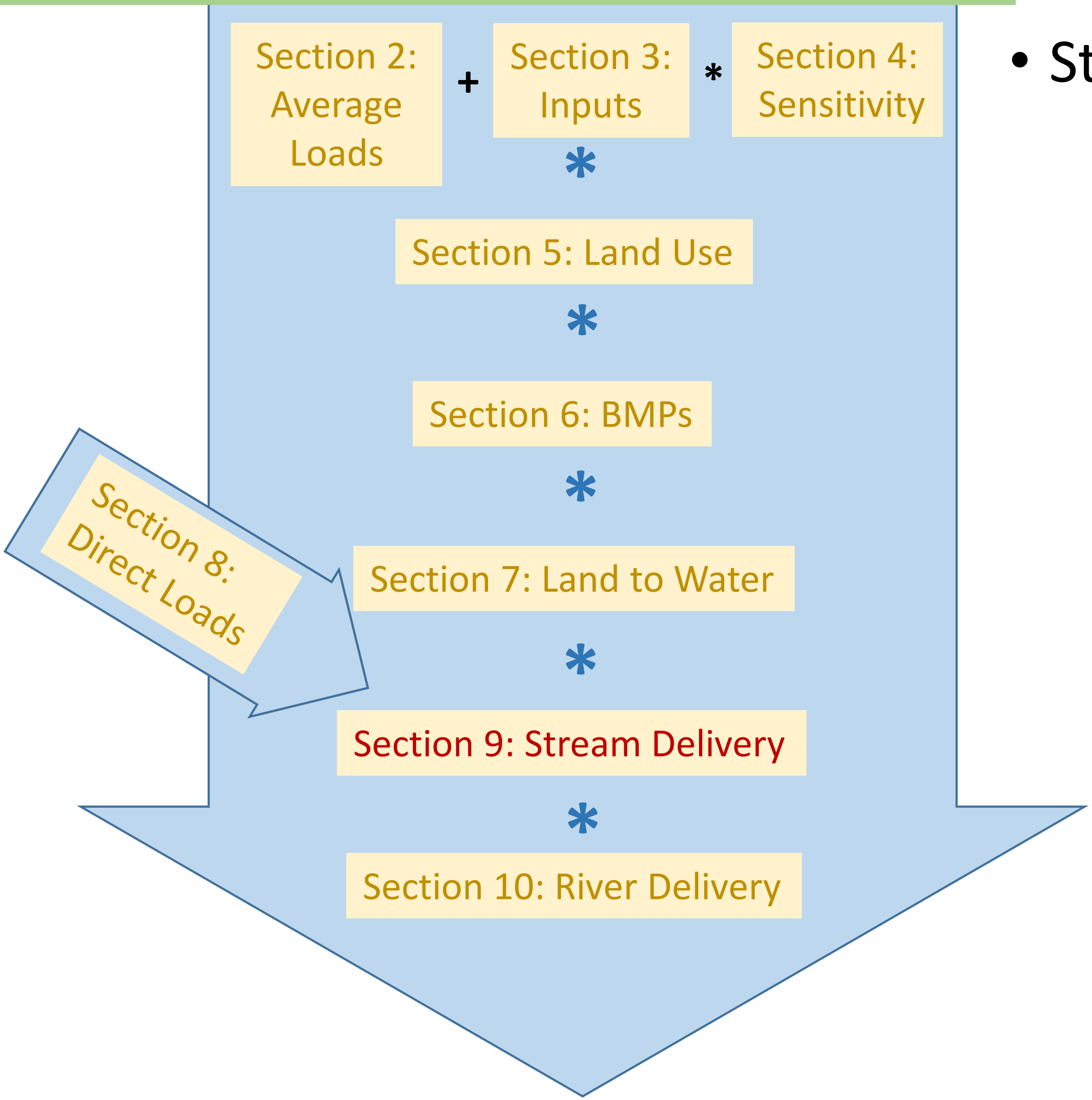
Nitrogen



Phosphorus



Phase 6 Model Documentation



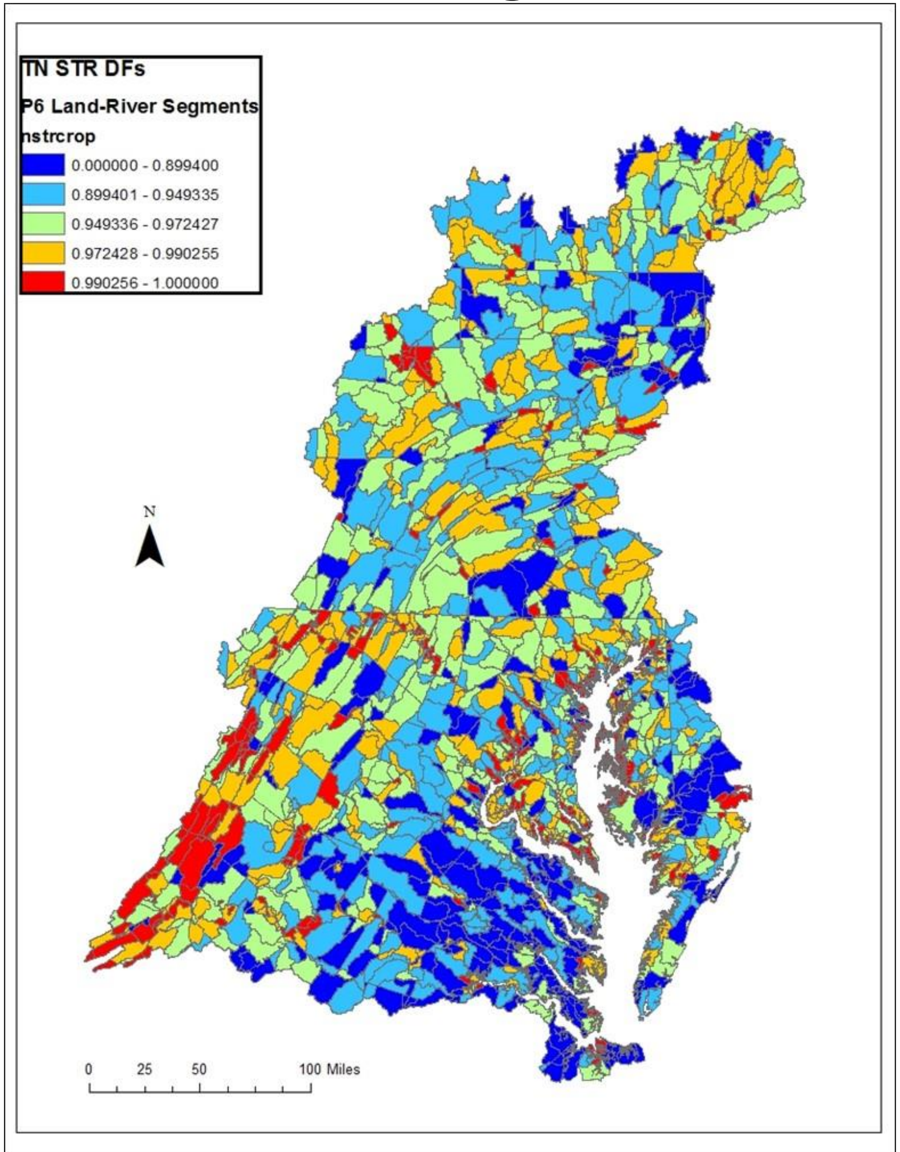
- Stream Delivery
  - The effect of small streams
  - Roughly 1st – 3rd order
  - Smaller than a river segment
  - Not simulated with HSPF

Catchment and Reach Attributes Used in SPARROW Models

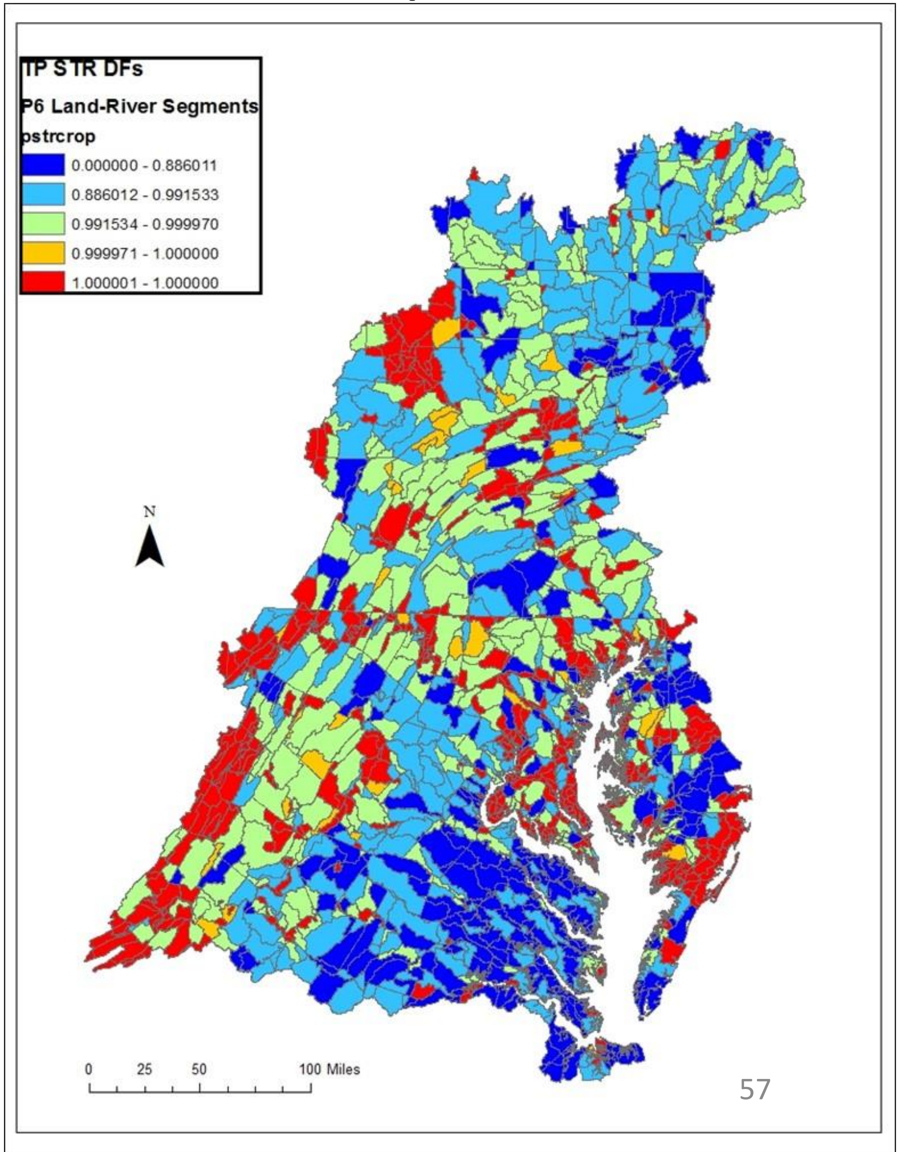
Explanatory Variable	Nitrogen	Phosphorus
Stream-to-River Factors (Aquatic Decay)	Impoundments: Hydraulic loading rate Rivers and streams: Average annual temperature Travel time	Impoundments: Hydraulic loading rate Rivers and streams: No losses represented

Stream-to-River Delivery Factors

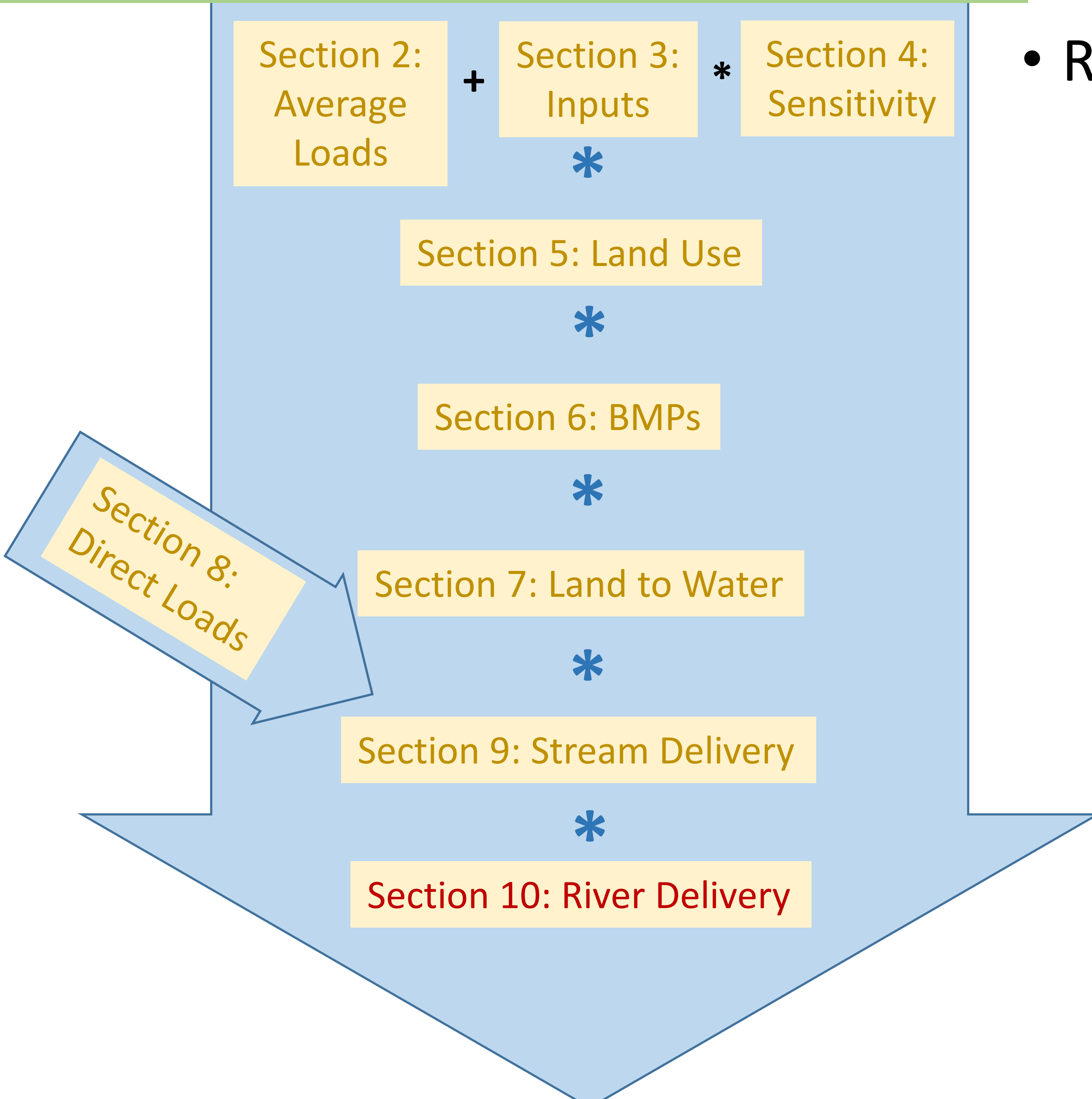
- Nitrogen



- Phosphorus

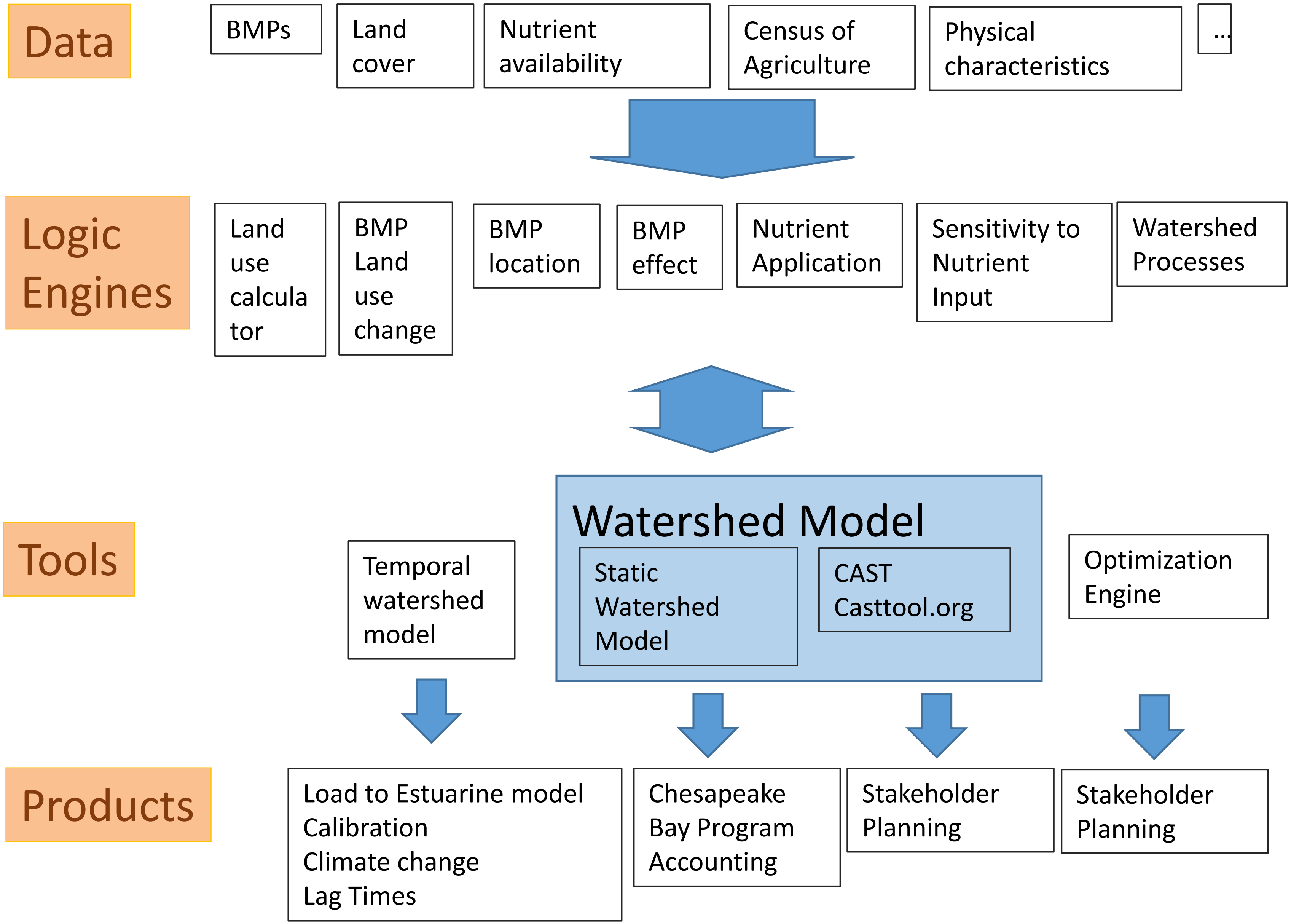


Phase 6 Model Documentation

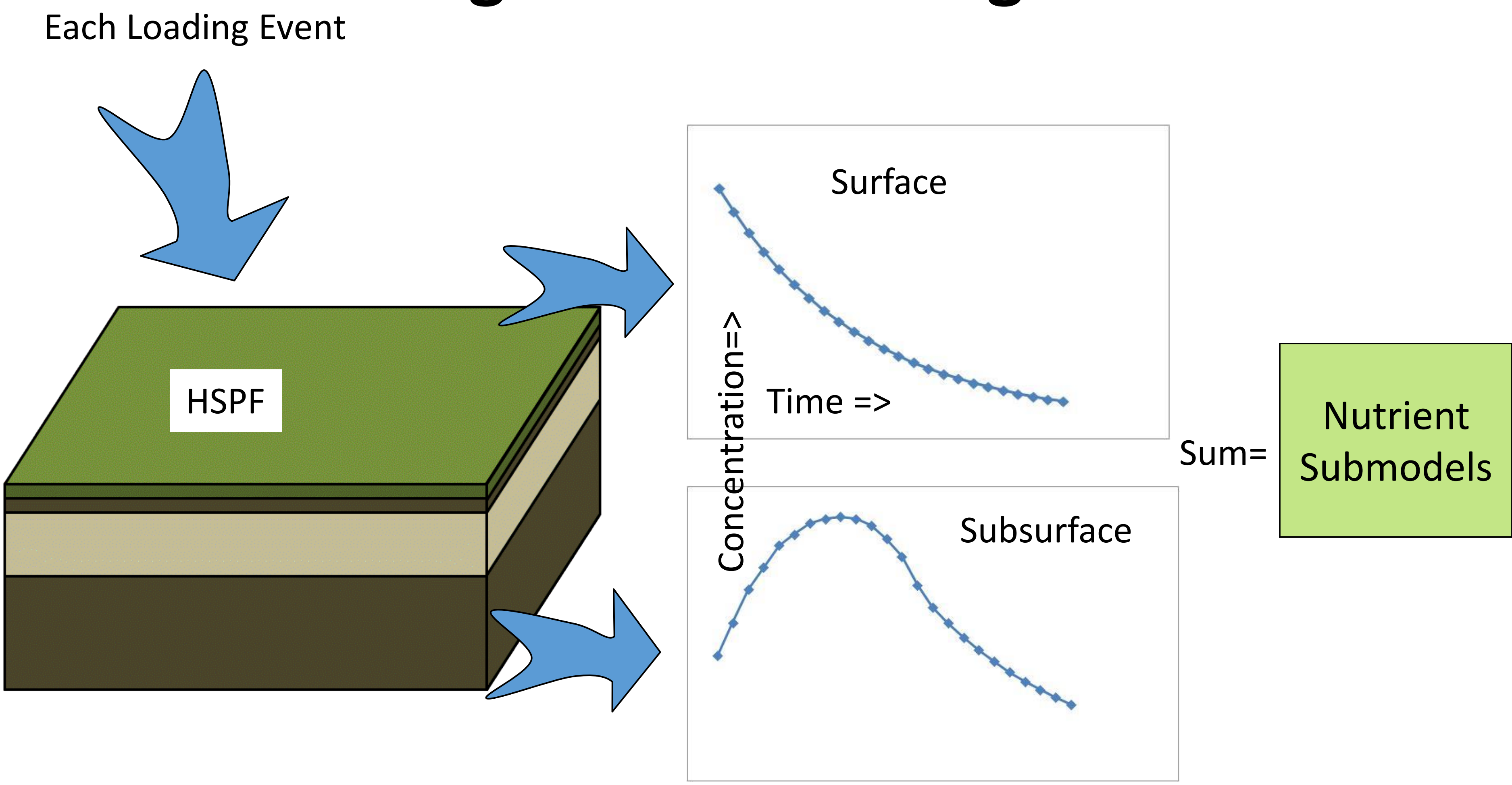


- River Delivery
  - The effect of large rivers
  - Each river segment has exactly one large river
    - except for some coastal plain segments with no river
  - Simulated with HSPF

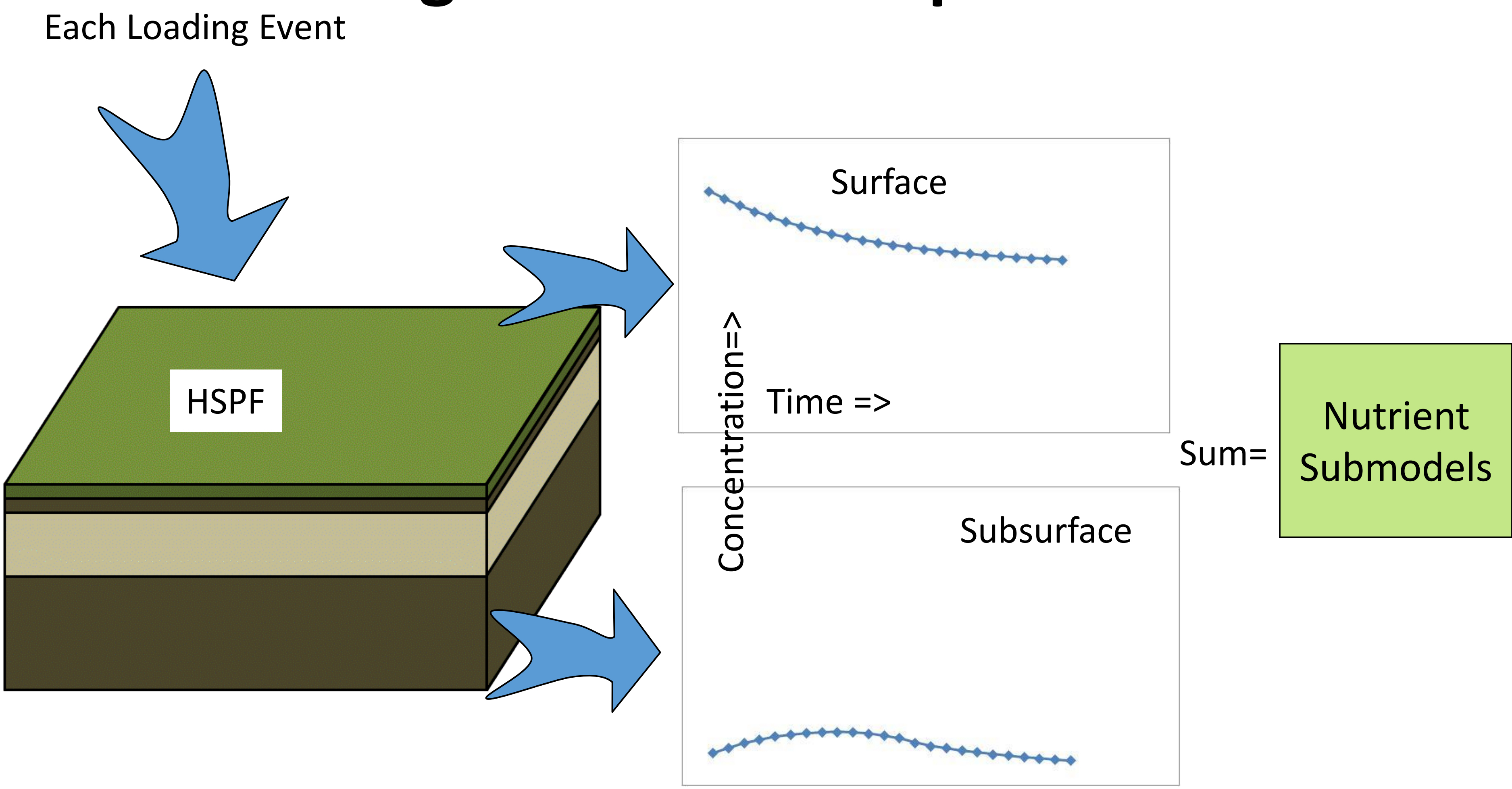
CAST = WSM = Scenario Builder



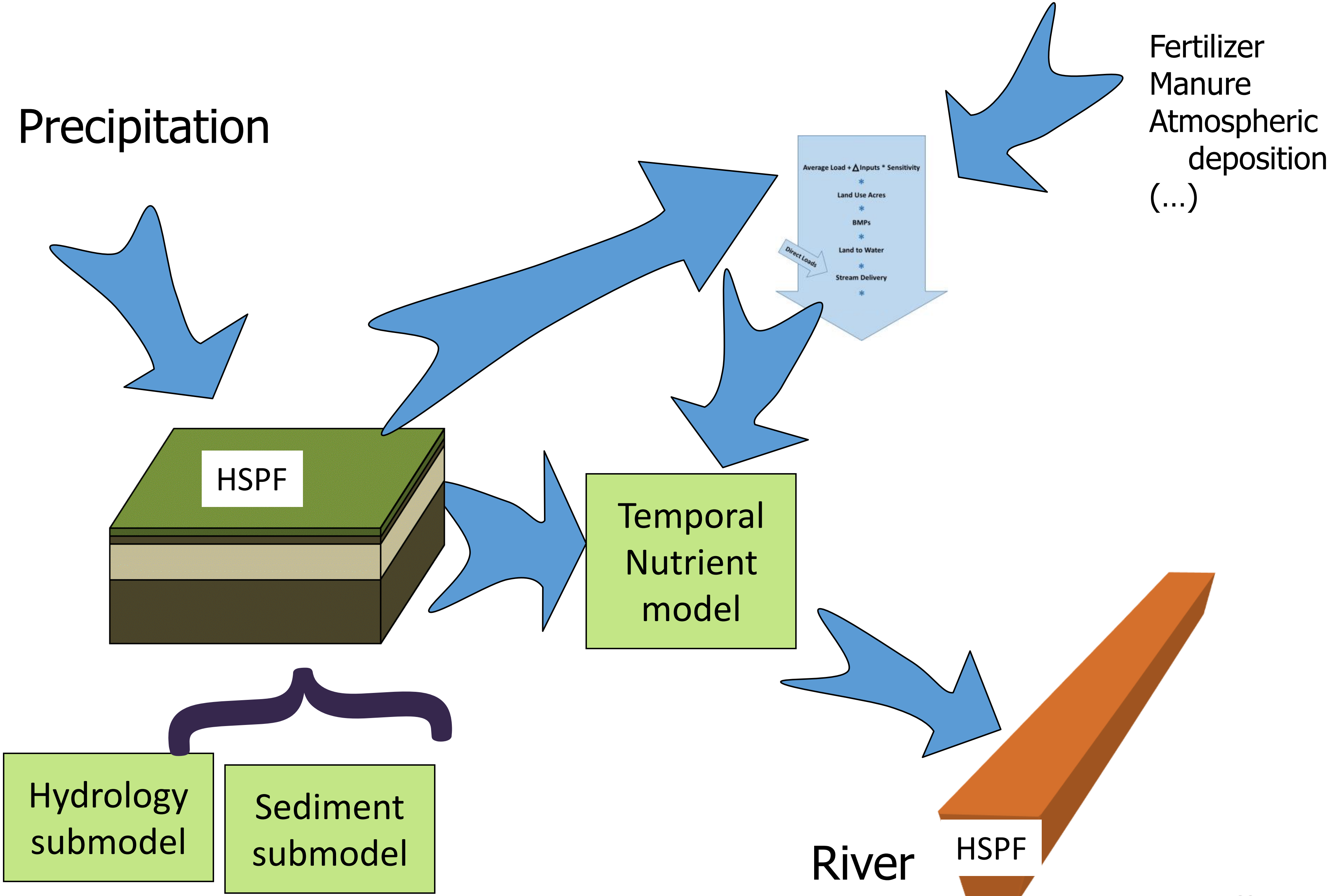
Lag Models - Nitrogen



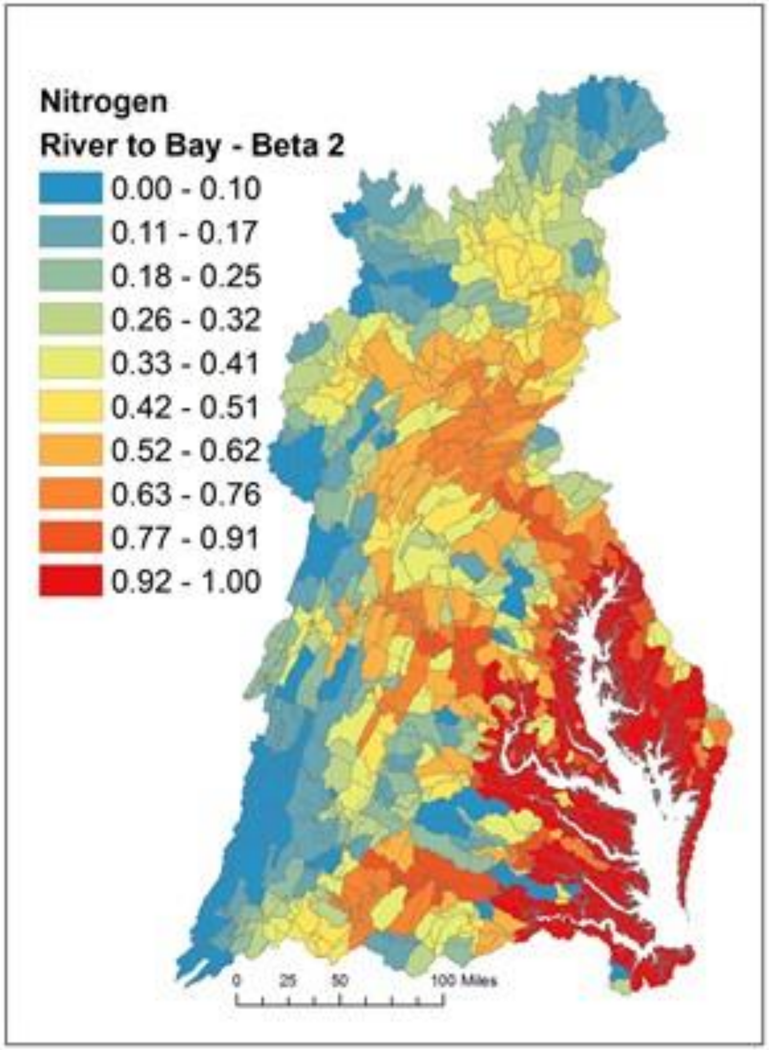
Lag Models - Phosphorus

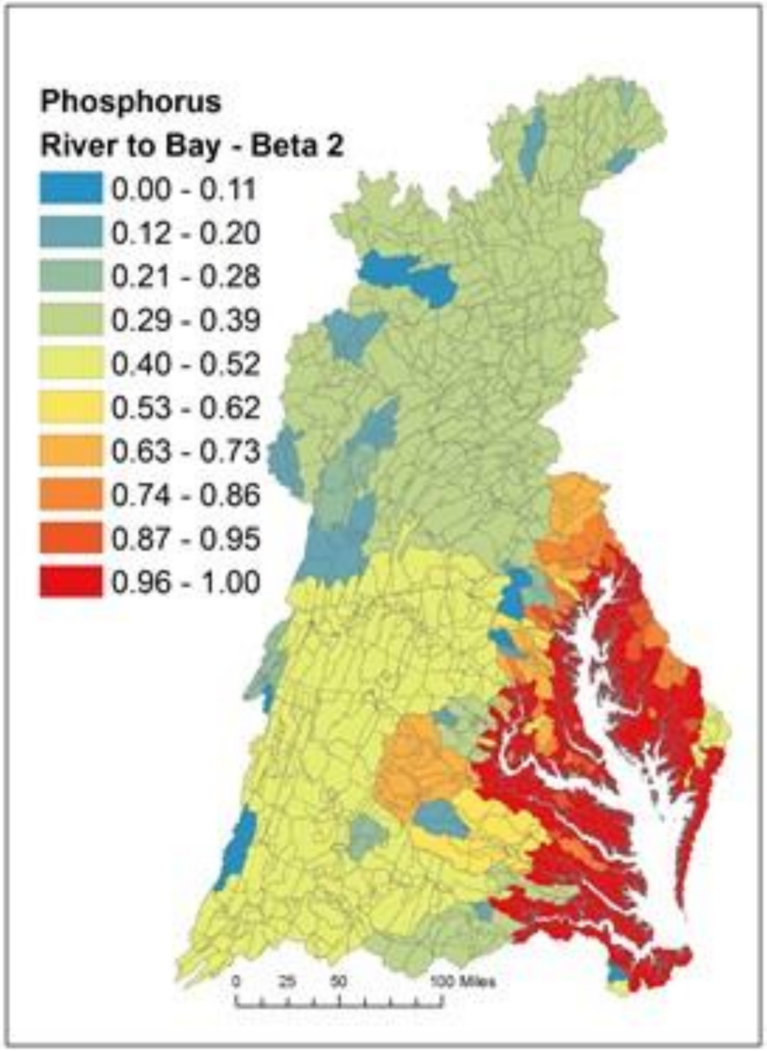


Model to compare against Observations



Delivery factors





Moment of Truth

- Phase 5 – Complex process model
- Phase 6 - Simple models built of partnership decisions

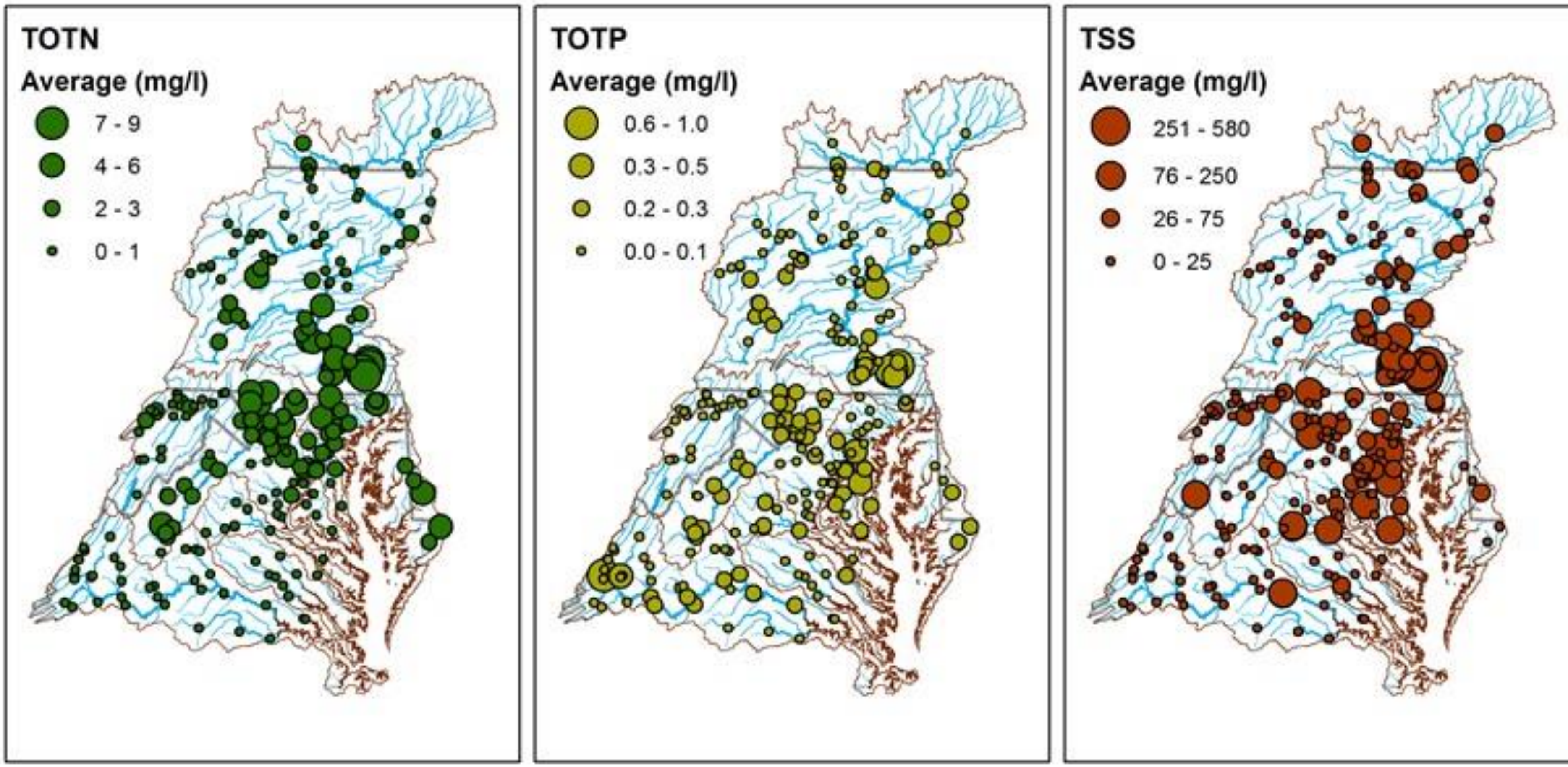
… but does it work?

Compare

Heavily-Calibrated Phase 5.3.2

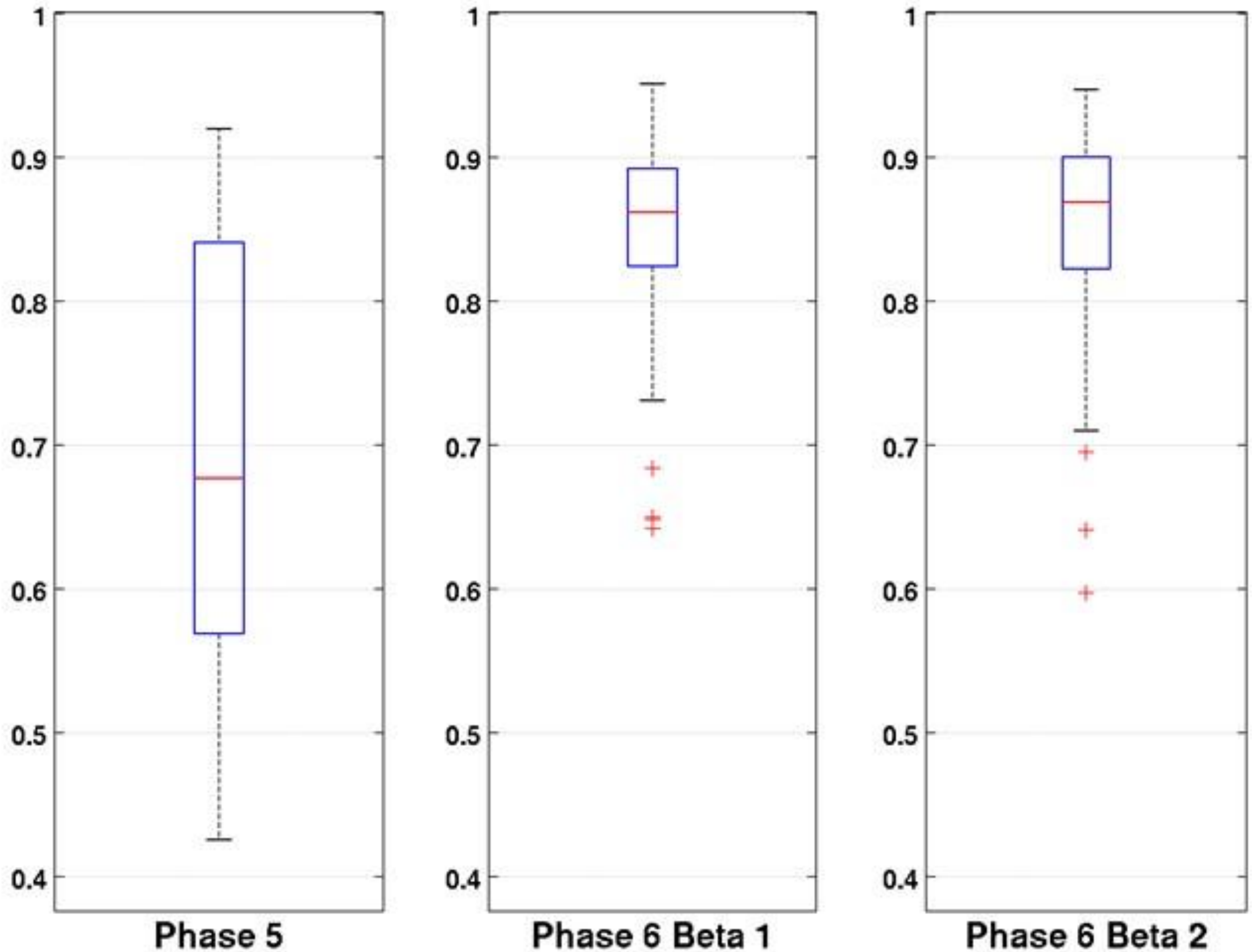
Lightly-Calibrated Phase 6

Monitoring Stations

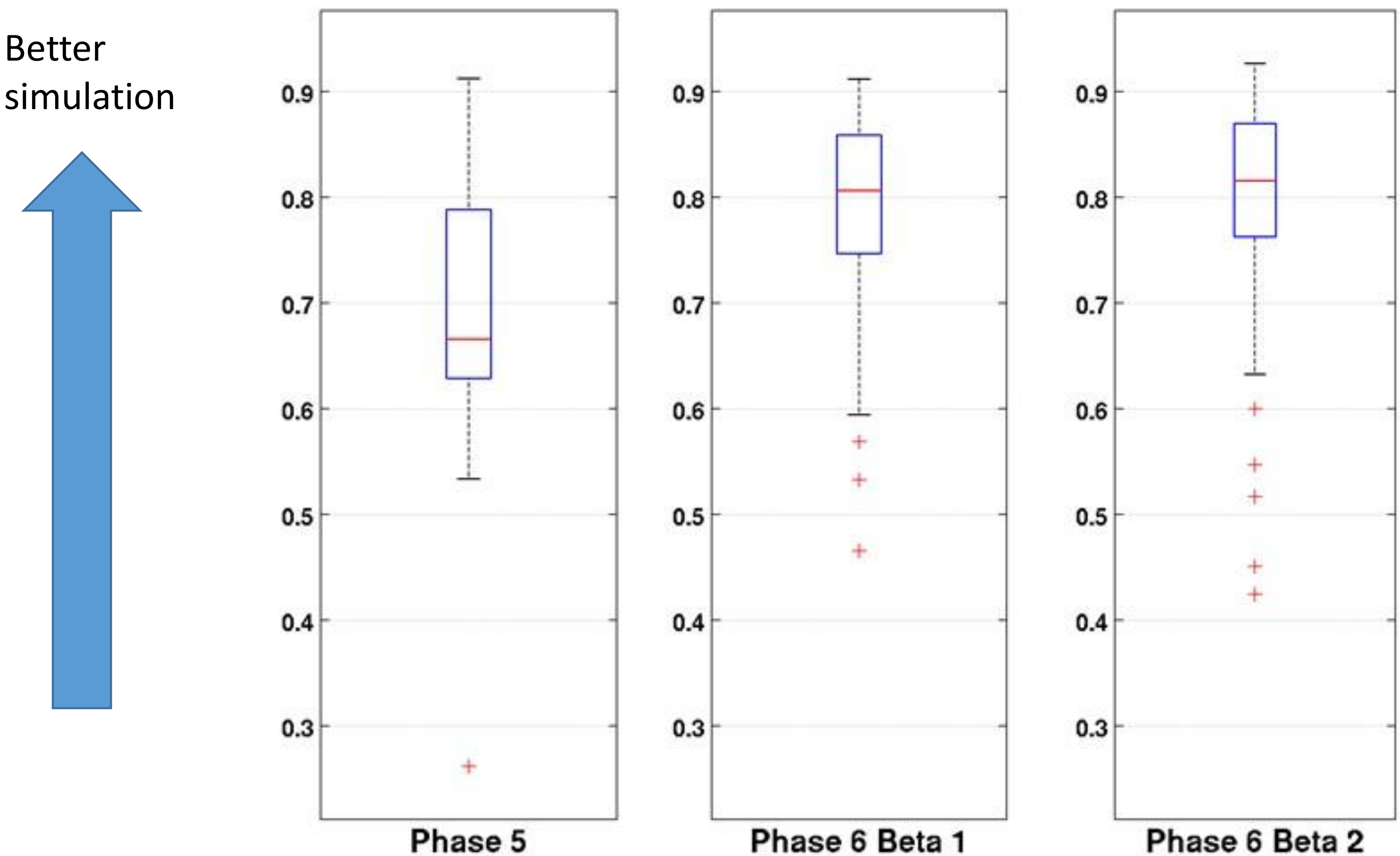


Nitrogen Seasonal Correlation

Better simulation



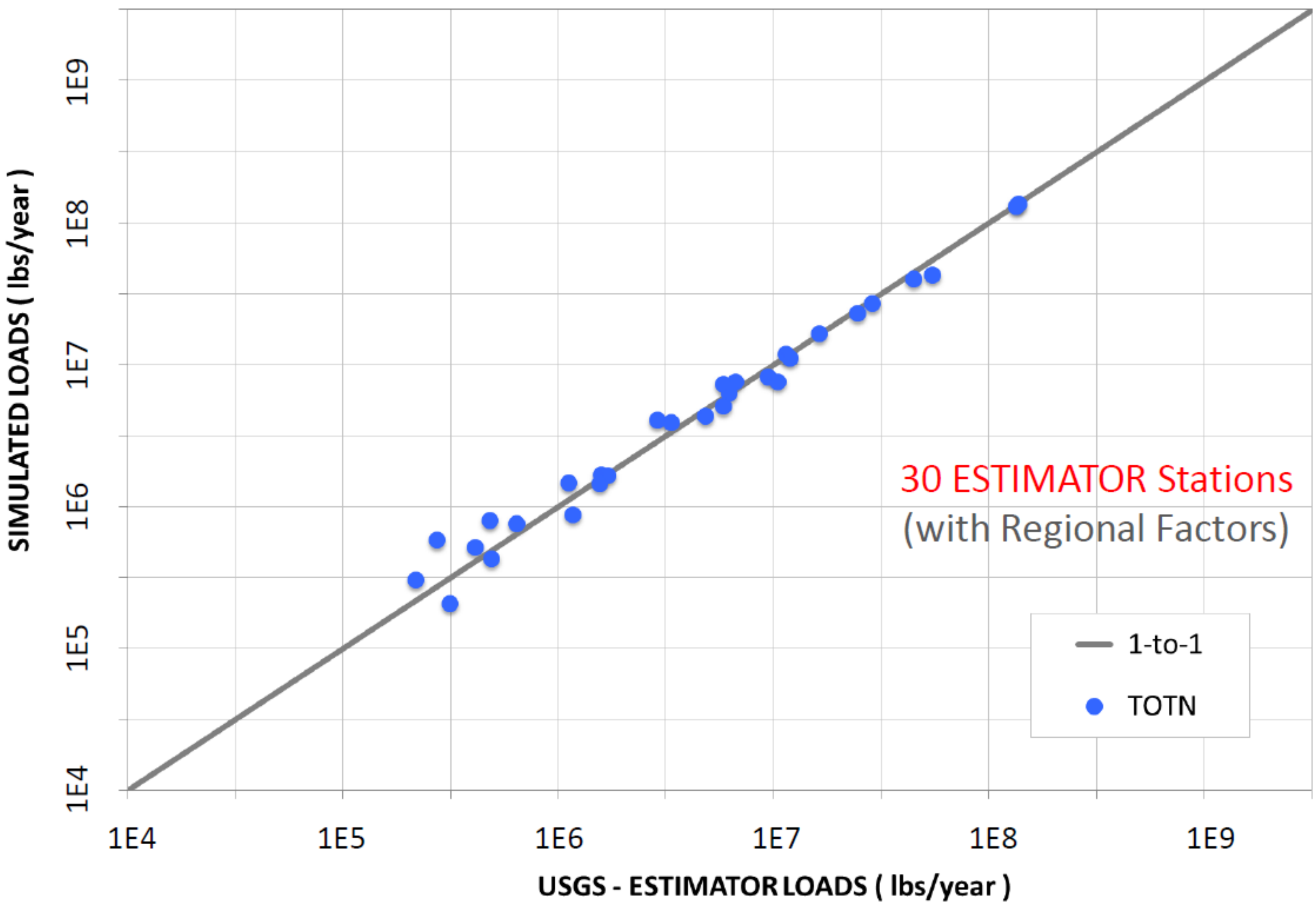
Phosphorus Seasonal Correlation



PHASE 5

NITROGEN

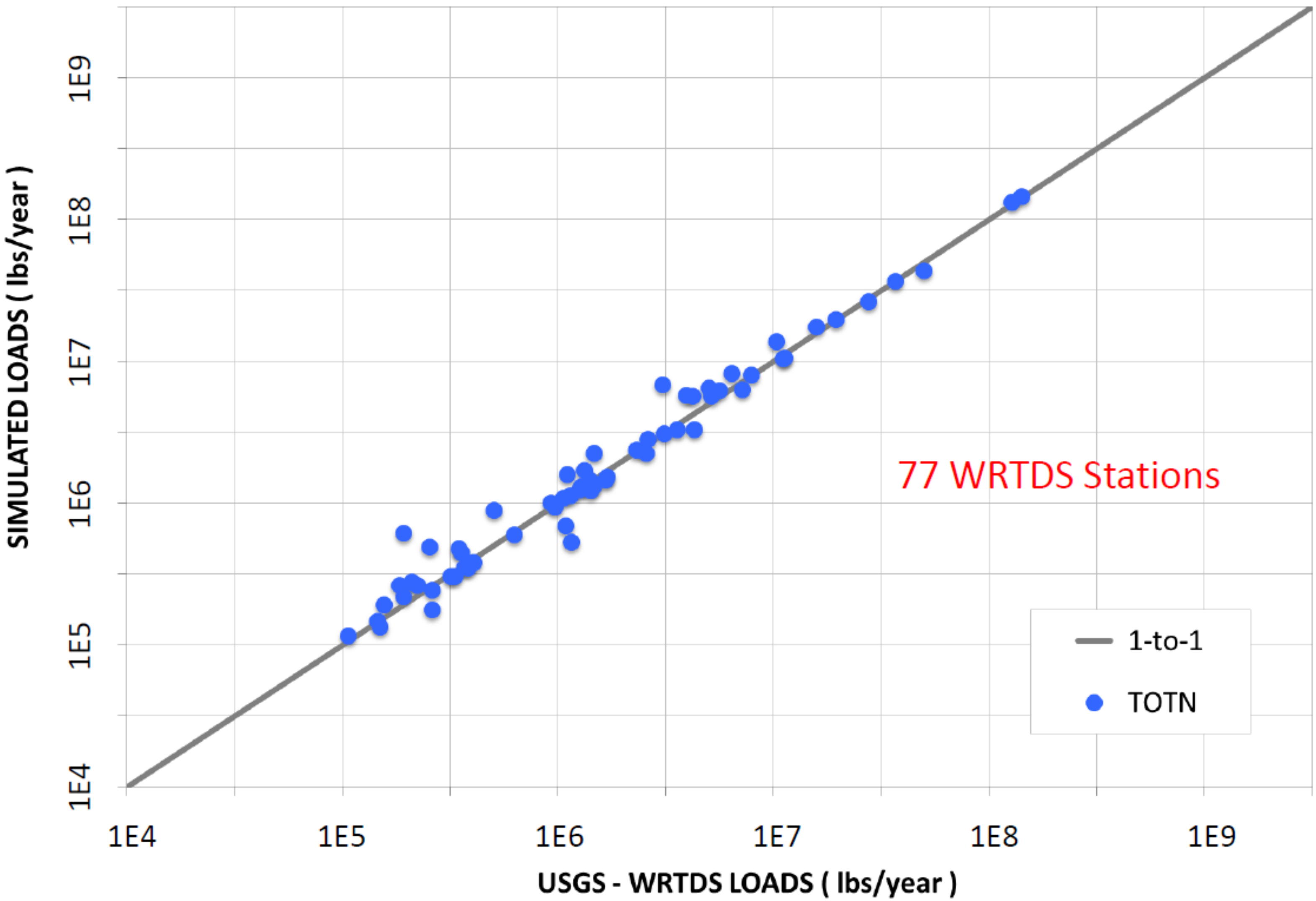
Load



PHASE 6
BETA 2

Load

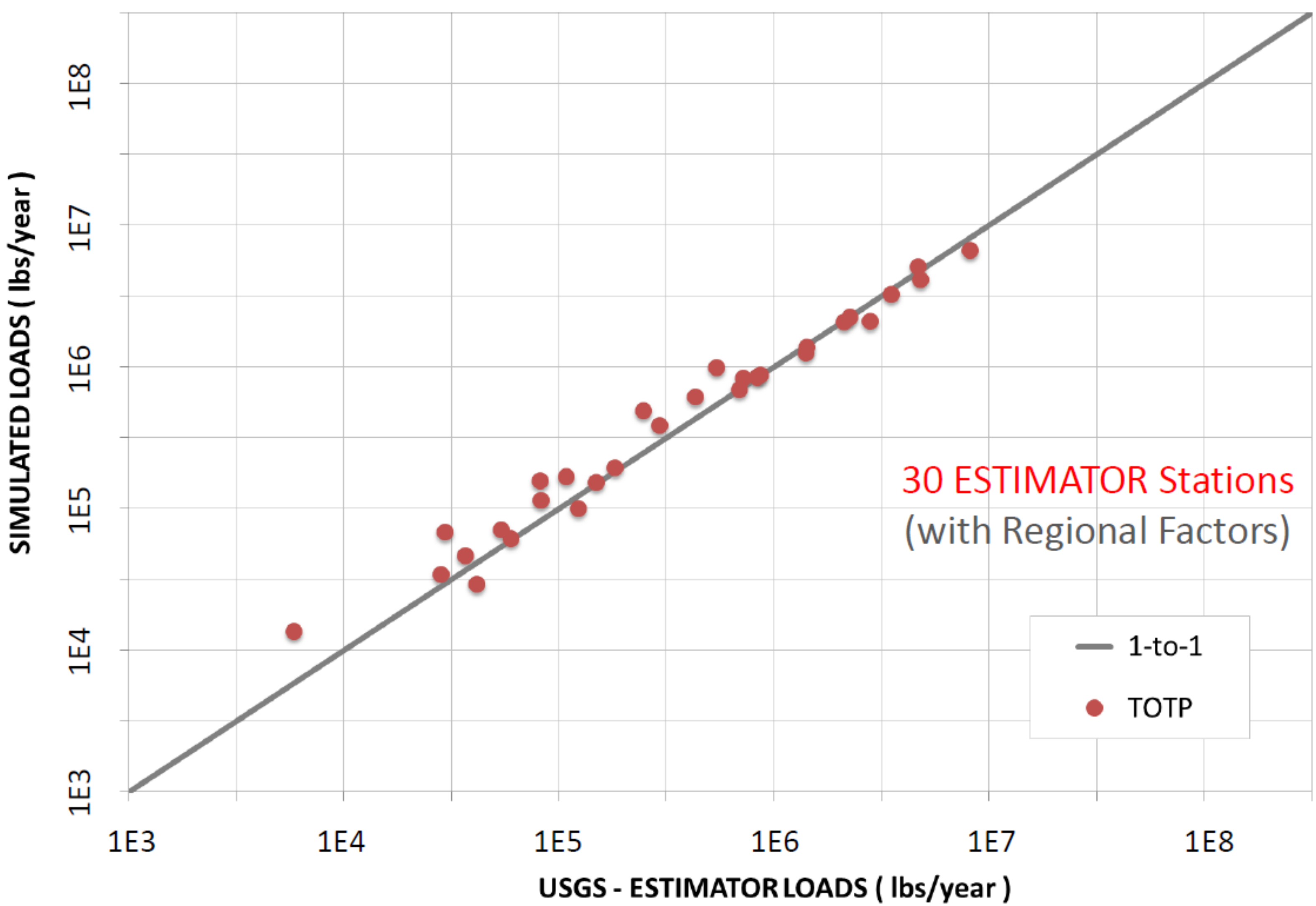
NITROGEN



PHASE 5

PHOSPHORUS

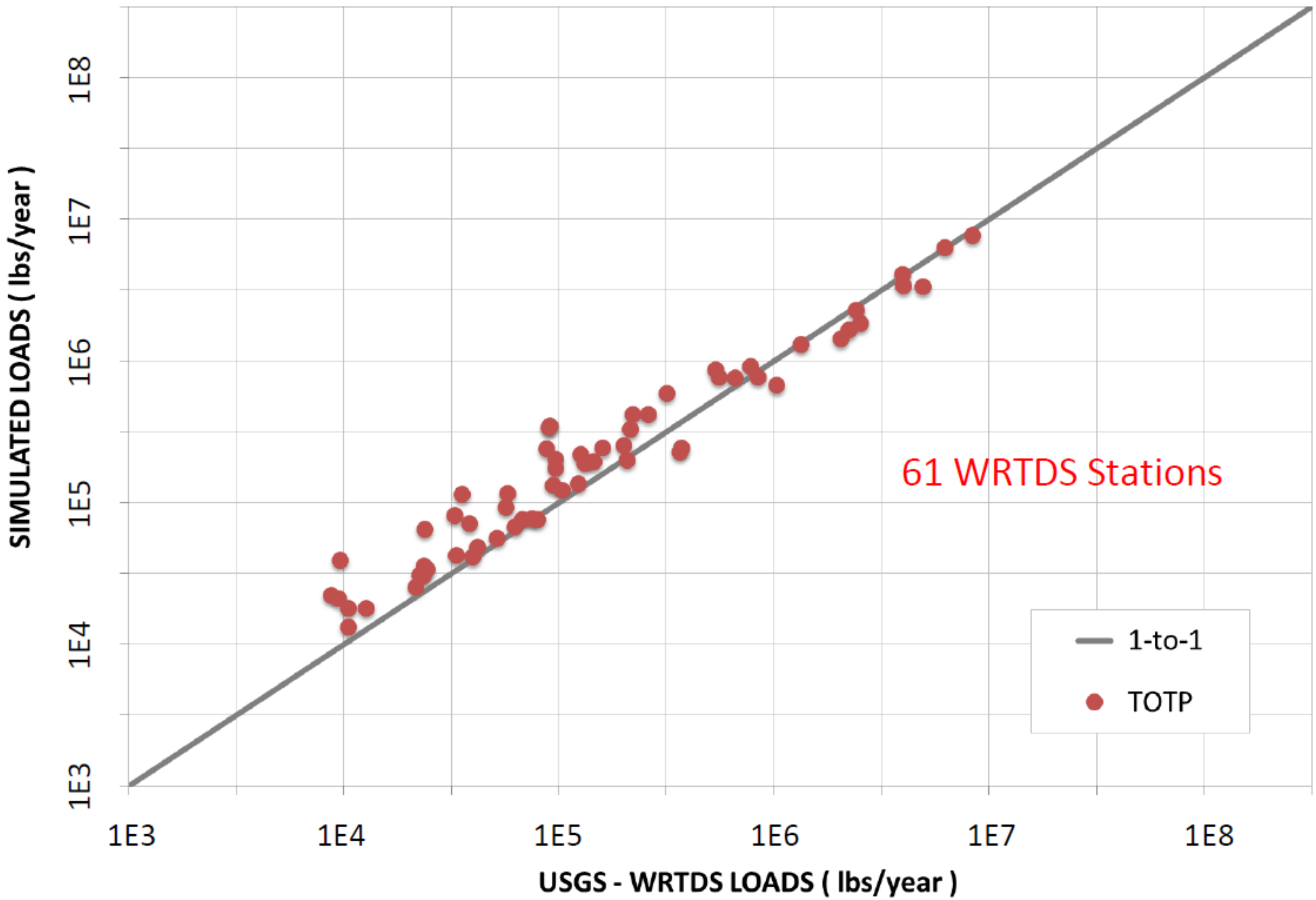
Load



PHASE 6
BETA 2

Load

PHOSPHORUS



Non-Tidal Water Quality Dashboard | WRTDS/WSM Dashboard

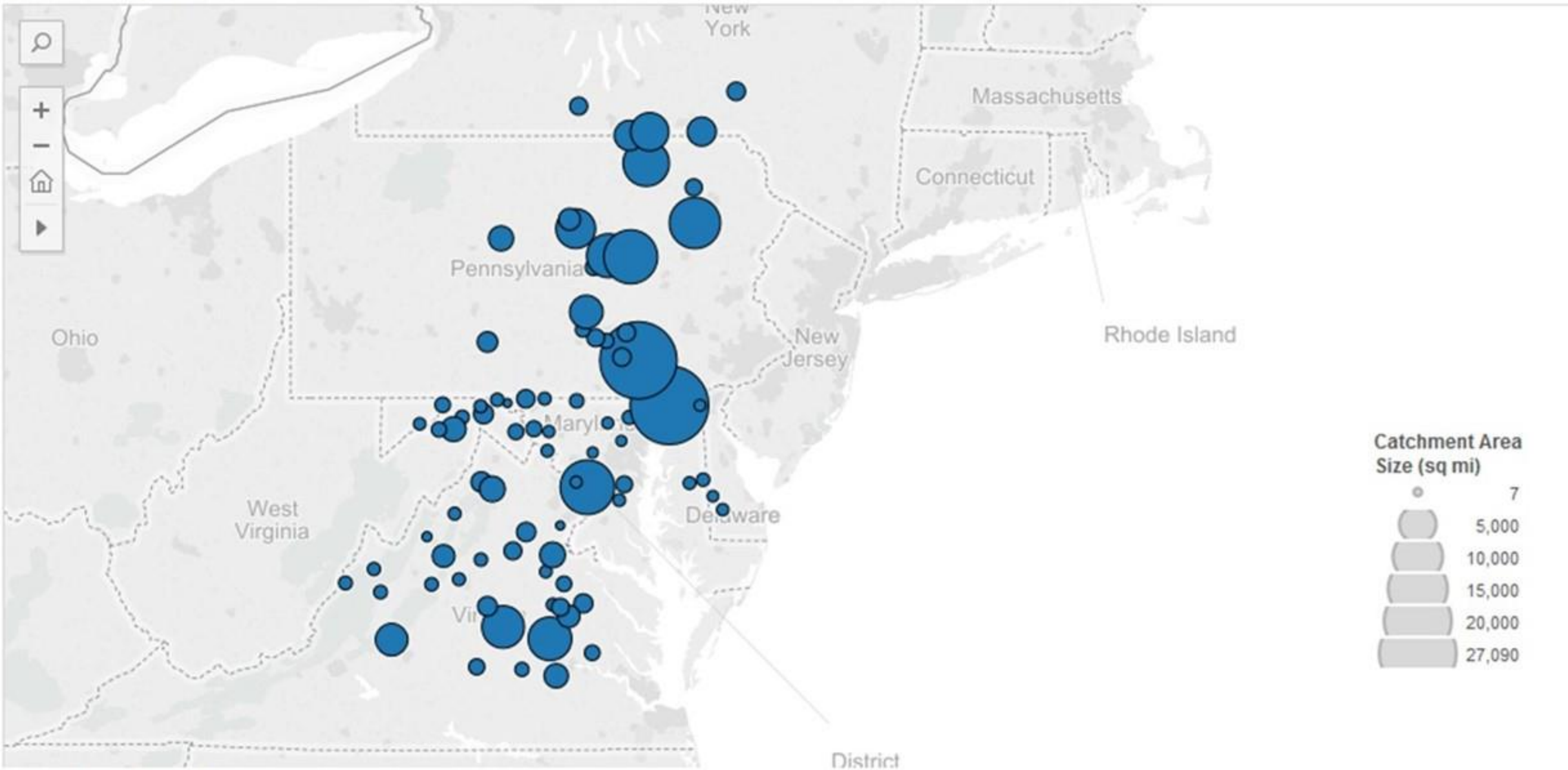
Chesapeake Bay Non-Tidal WRTDS/WSM Data

Select a parameter from the dropdown menu, then select a monitoring station from the map. The WRTDS and WSM values will be shown on the chart below. More information on the Watershed Model can be found at: http://www.chesapeakebay.net/groups/group/modeling_team

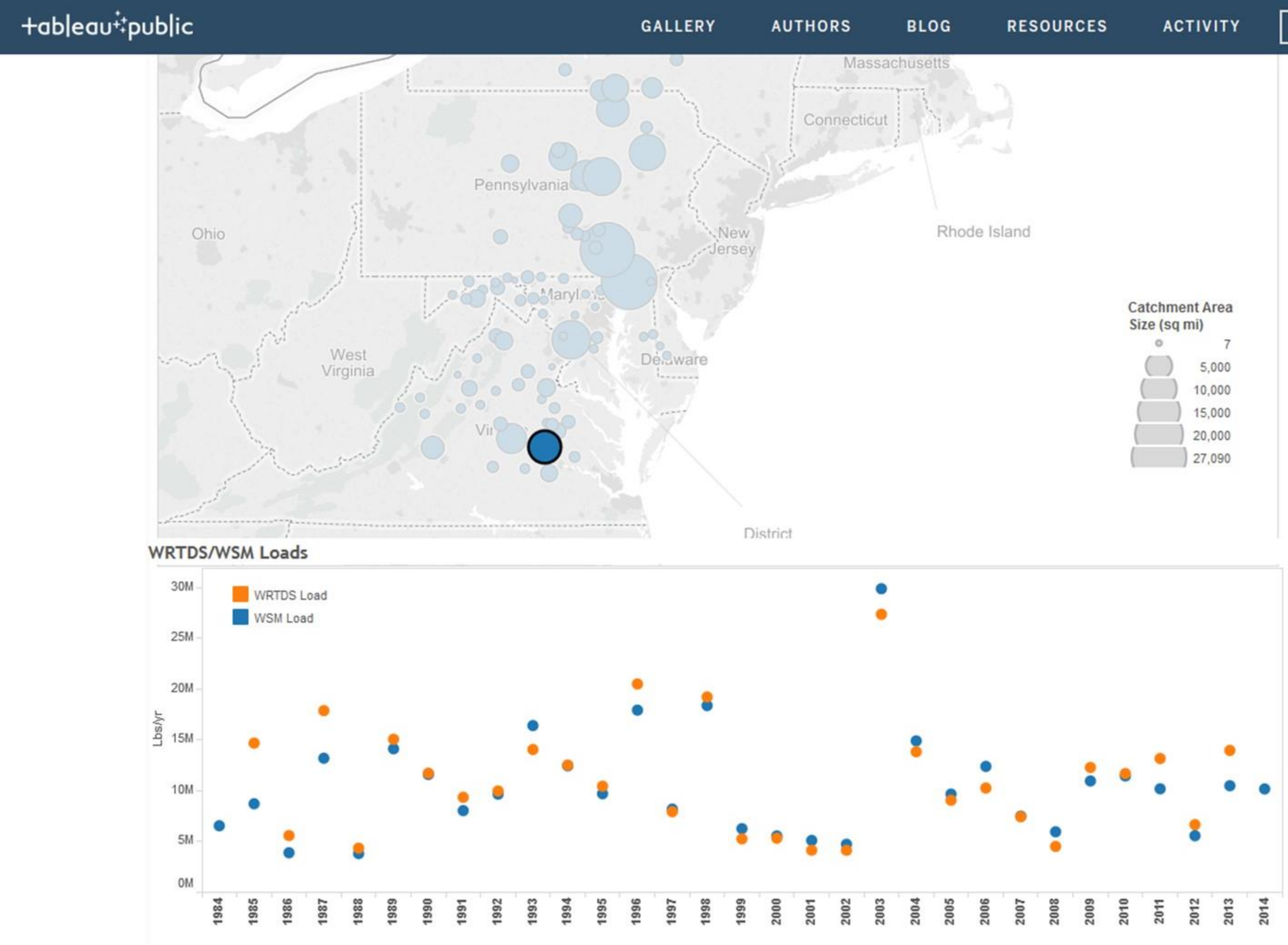
Parameter

Total nitrogen

Non-tidal Stations



WRTDS/WSM Loads



+ableau+public
GALLERY
AUTHORS
BLOG
RESOURCES
ACTIVITY
Massachusetts
Connecticut
Pennsylvania
Ohio
New Jersey
Rhode Island
West Virginia
Delaware
District
Catchment Area Size (sq mi)
7
5,000
10,000
15,000
20,000
27,090
WRTDS/WSM Loads
WRTDS Load
WSM Load
Lbs/yr
30M
25M
20M
15M
10M
5M
0M
1984
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2014

Major refinements Beta 1 => Beta 2

- Extreme flow events
- Sediment overhaul
- Updated physical watershed data
  - Land to water
  - Stream to river
  - Small reservoirs
  - Groundwater nitrate lag
- Updated input data
  - Point source correction
  - Monitoring data

Beta 3 updates - August

- Overall Calibration Strategy
  - Examining assumptions throughout model

- Inputs
  - Update nutrient input data methods
  - Biosolids as a separate input

- Watershed representation
  - 8 new impoundments and reservoirs
  - better groundwater nitrate lags

- Scenarios – a few key scenarios

Beta 4 updates - December

- Overall Calibration Strategy
  - Examining assumptions throughout model

- Inputs
  - Updated nutrient inputs
  - Atmospheric deposition dataset
  - BMP history
  - BMP effects

- Watershed representation
  - Streambed and Shoreline loads
  - Representation of Conowingo
  - Updated Sparrow factors

- Scenarios – climate change

Phase 6 updates – April 2017

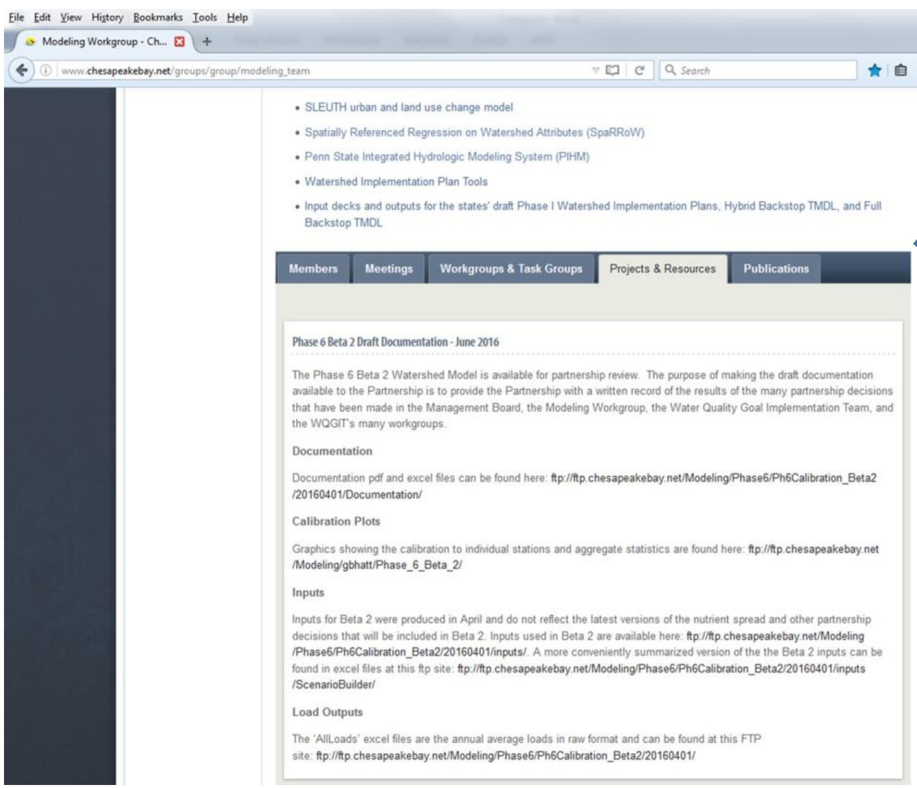
- Inputs
  - Land use

… and that's it

How to get more information

Modeling Workgroup website on Chesapeakebay.net

Scroll down to
'projects & resources' tab



- SLEUTH urban and land use change model
- Spatially Referenced Regression on Watershed Attributes (SpaRRoW)
- Penn State Integrated Hydrologic Modeling System (PIHM)
- Watershed Implementation Plan Tools
- Input decks and outputs for the states' draft Phase I Watershed Implementation Plans, Hybrid Backstop TMDL, and Full Backstop TMDL

Members | Meetings | Workgroups & Task Groups | Projects & Resources | Publications

Phase 6 Beta 2 Draft Documentation - June 2016

The Phase 6 Beta 2 Watershed Model is available for partnership review. The purpose of making the draft documentation available to the Partnership is to provide the Partnership with a written record of the results of the many partnership decisions that have been made in the Management Board, the Modeling Workgroup, the Water Quality Goal Implementation Team, and the WQGIT's many workgroups.

Documentation

Documentation pdf and excel files can be found here: ftp://ftp.chesapeakebay.net/Modeling/Phase6/Ph6Calibration_Beta2/20160401/Documentation/

Calibration Plots

Graphics showing the calibration to individual stations and aggregate statistics are found here: ftp://ftp.chesapeakebay.net/Modeling/gbhatt/Phase_6_Beta_2/

Inputs

Inputs for Beta 2 were produced in April and do not reflect the latest versions of the nutrient spread and other partnership decisions that will be included in Beta 2. Inputs used in Beta 2 are available here: ftp://ftp.chesapeakebay.net/Modeling/Phase6/Ph6Calibration_Beta2/20160401/inputs/. A more conveniently summarized version of the the Beta 2 inputs can be found in excel files at this ftp site: ftp://ftp.chesapeakebay.net/Modeling/Phase6/Ph6Calibration_Beta2/20160401/inputs/ScenarioBuilder/

Load Outputs

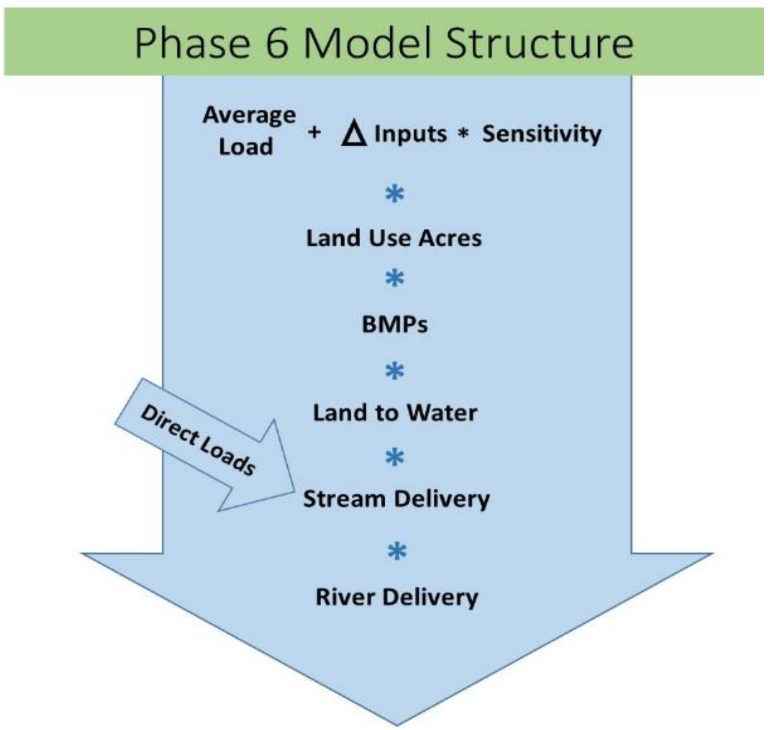
The 'AllLoads' excel files are the annual average loads in raw format and can be found at this FTP site: ftp://ftp.chesapeakebay.net/Modeling/Phase6/Ph6Calibration_Beta2/20160401/

Set up a state-specific meeting

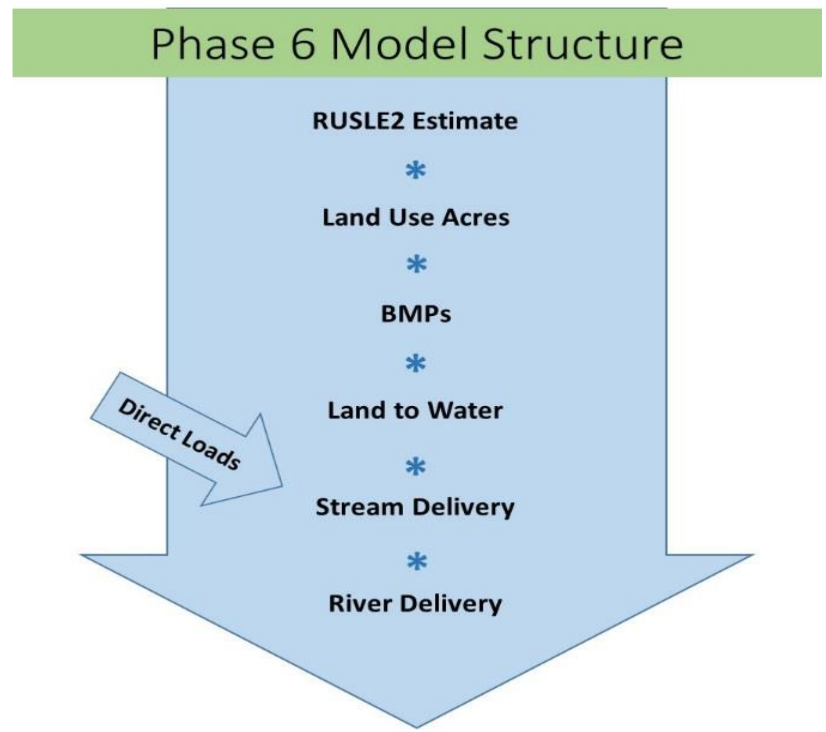
Back pocket sediment

Sediment is similar to nutrients but no sensitivity

Nutrients

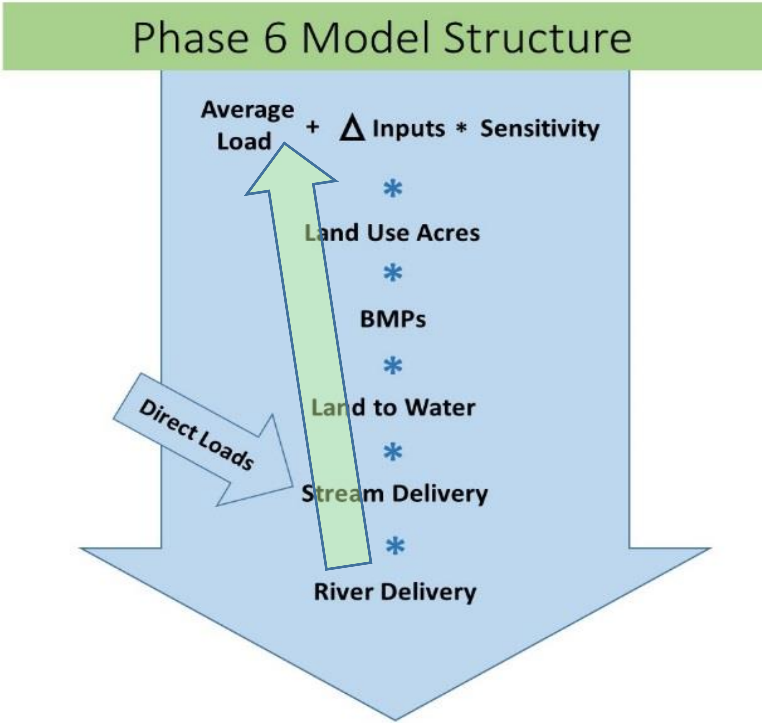


Sediment

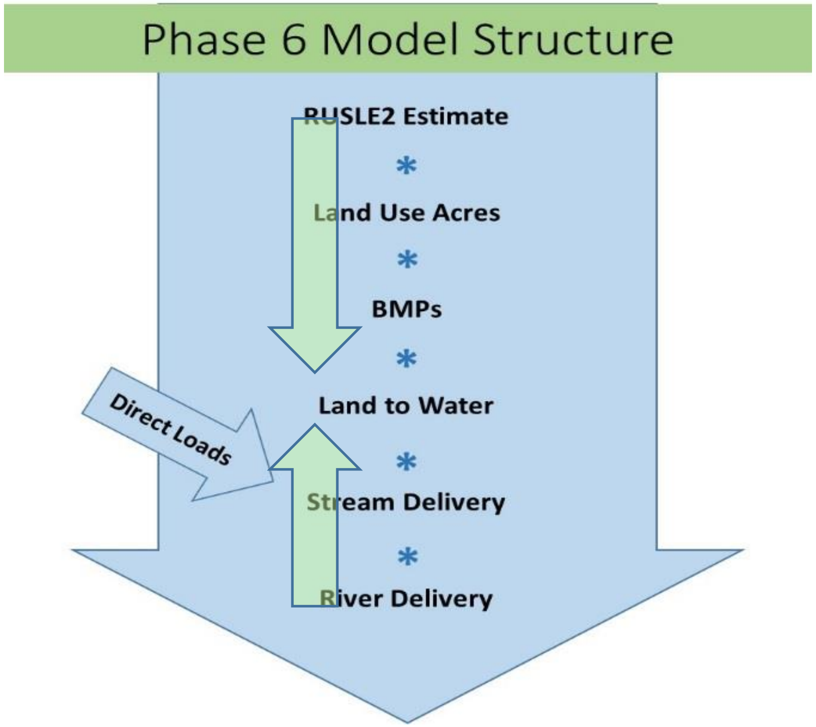


Mass Balance at the L2W step rather than the average load step

Nutrients



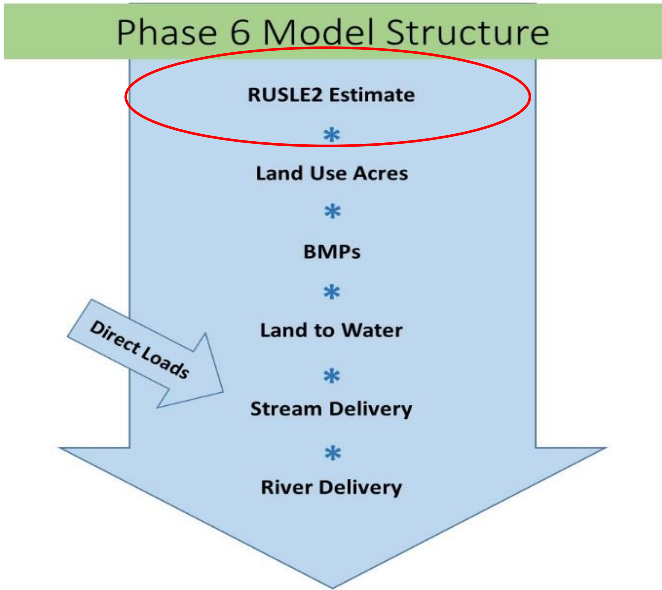
Sediment



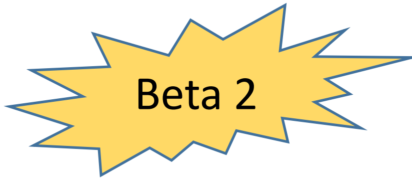
RUSLE2 = Edge-of-Field Loads

Beta 2

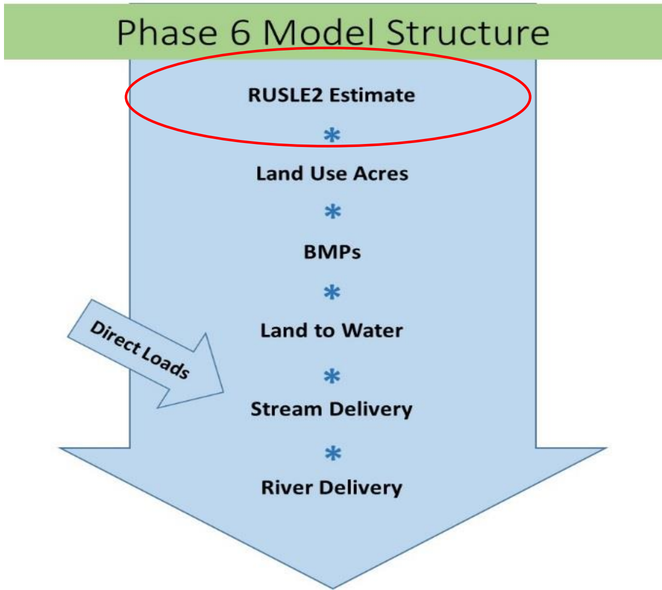
- Evaluated at the 10m Pixel Level
- Summarized to LRseg and land use
  - Forest
  - Open Space
  - Crop
  - Pasture
  - Turfgrass
  - Tree Canopy over Turfgrass



RUSLE2 => A = RKLSCP

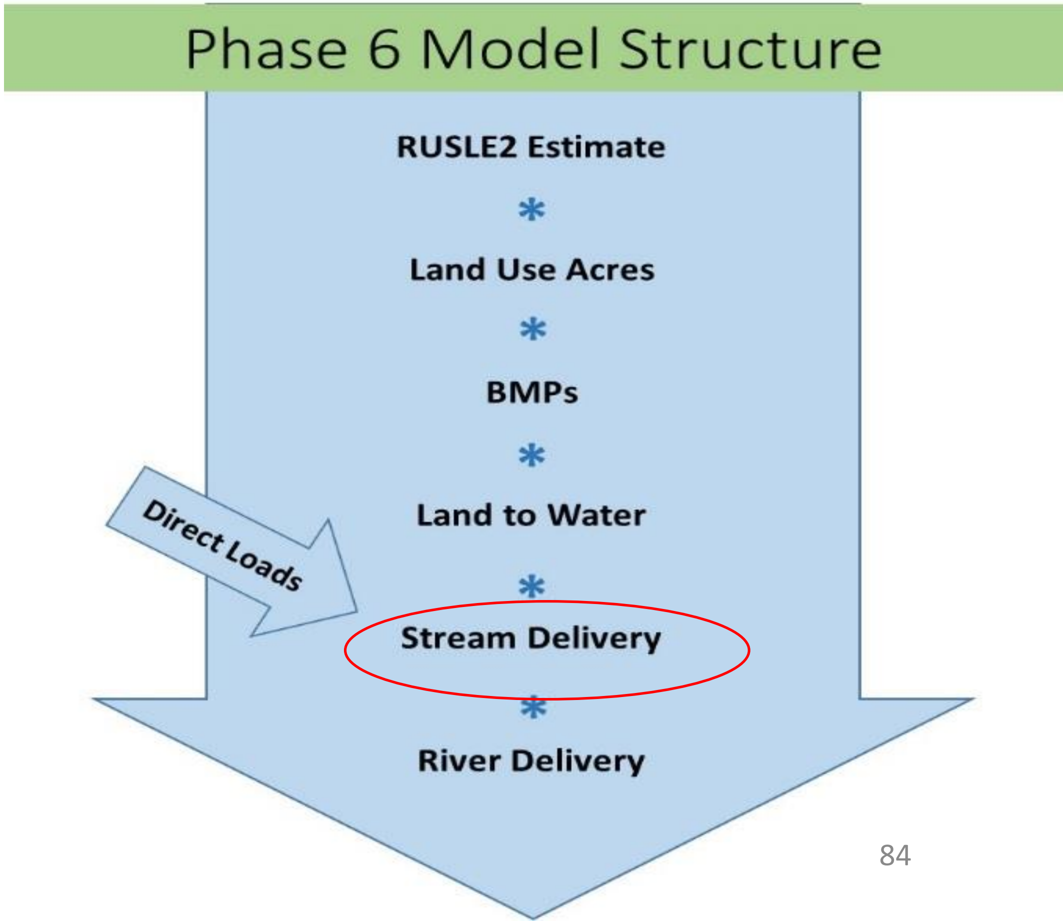


- R = Runoff
  - $= 1.24P^{1.36}$ P from PRISM
- K = Erodibility
  - from STATSGO and gSSURGO
- LS = slope length
  - $= (\text{Flow Accumulation x Cell Resolution} / 22.1)^{0.4} \times (\text{Sin}(\text{Slope} \times 0.01745) / 0.09)^{1.4} \times 1.4$
- C = Cover
  - from Tetratech and AgWG
- P = Practice
  - = 1 since no action loads



Stream Delivery – Ag and Natural

- Will be Greg Noe / Peter Claggett stream mass balance
- Assumed to be 1 until completed



Beta 2

Stream Delivery – Developed

- Center for Watershed Protection Work

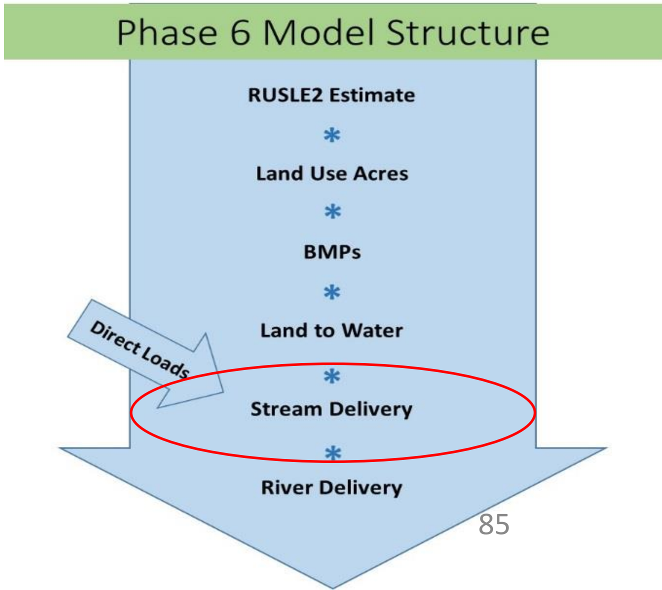
$$SSR = 1 - \frac{Upland\ Load}{Total\ Watershed\ Load}$$

Stream Source Load = Land Source Load * SSR / (1 – SSR)

SSR = 1.4085 * (fraction Impervious)

+ 0.5341 * (fraction CD soils)

- 0.2828

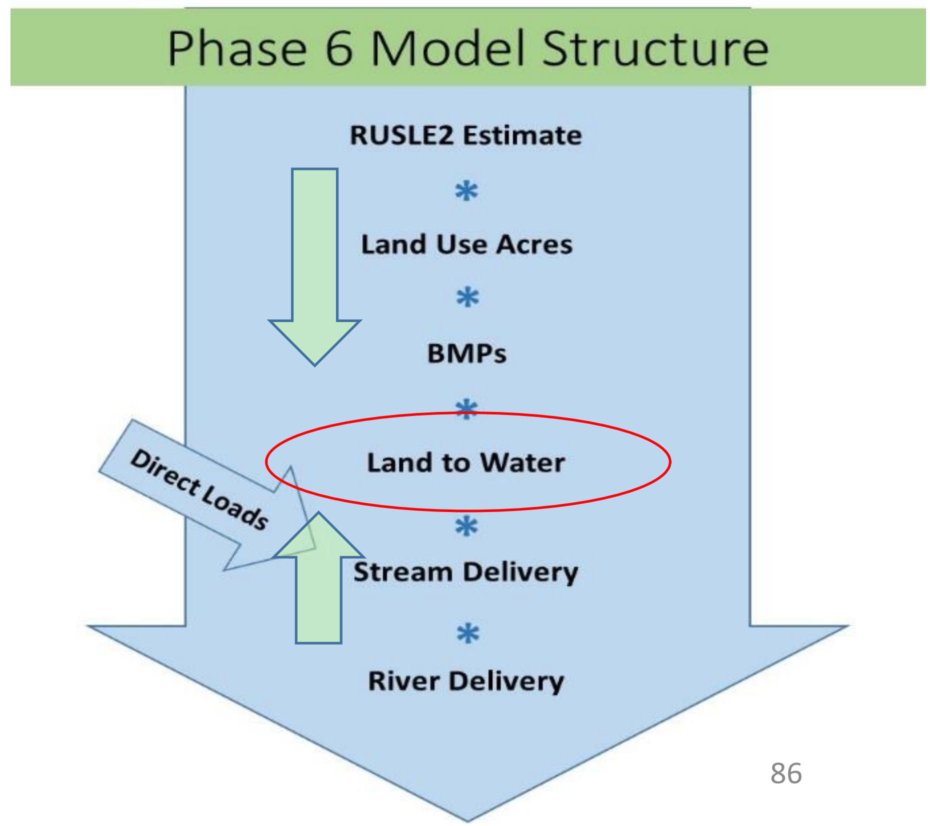


Land to Water – calculate average

- [(RUSLE2 * acres * BMPs * L2W) + SD] * RD = RIM Load

- L2W = [(RIM / RD) - SD] / (RUSLE2 * acres * BMPs)

- L2W = 0.25

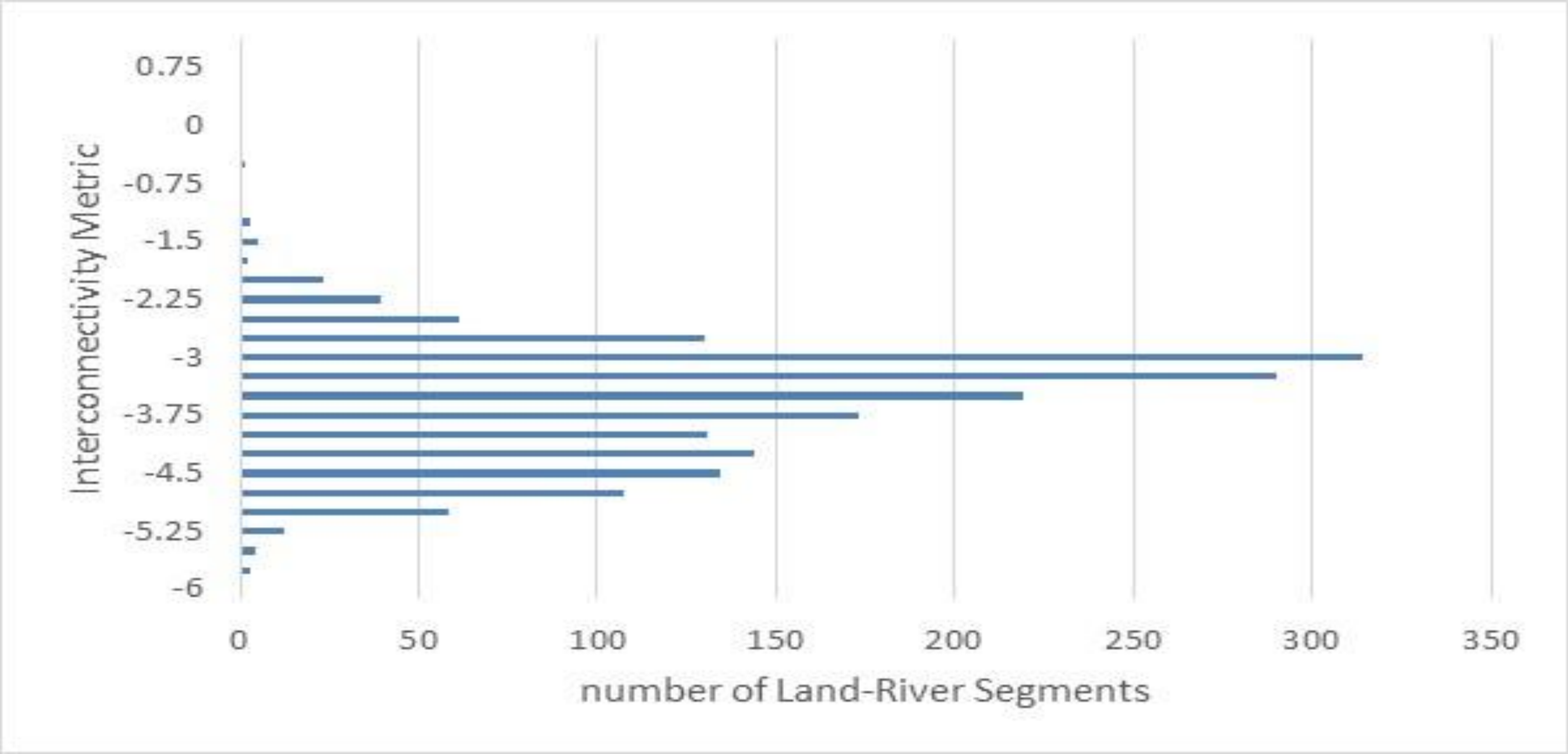


Beta 2

Interconnectivity Metric

Beta 2

Calculation related to Slope, Area, Flowpath Length, and Roughness

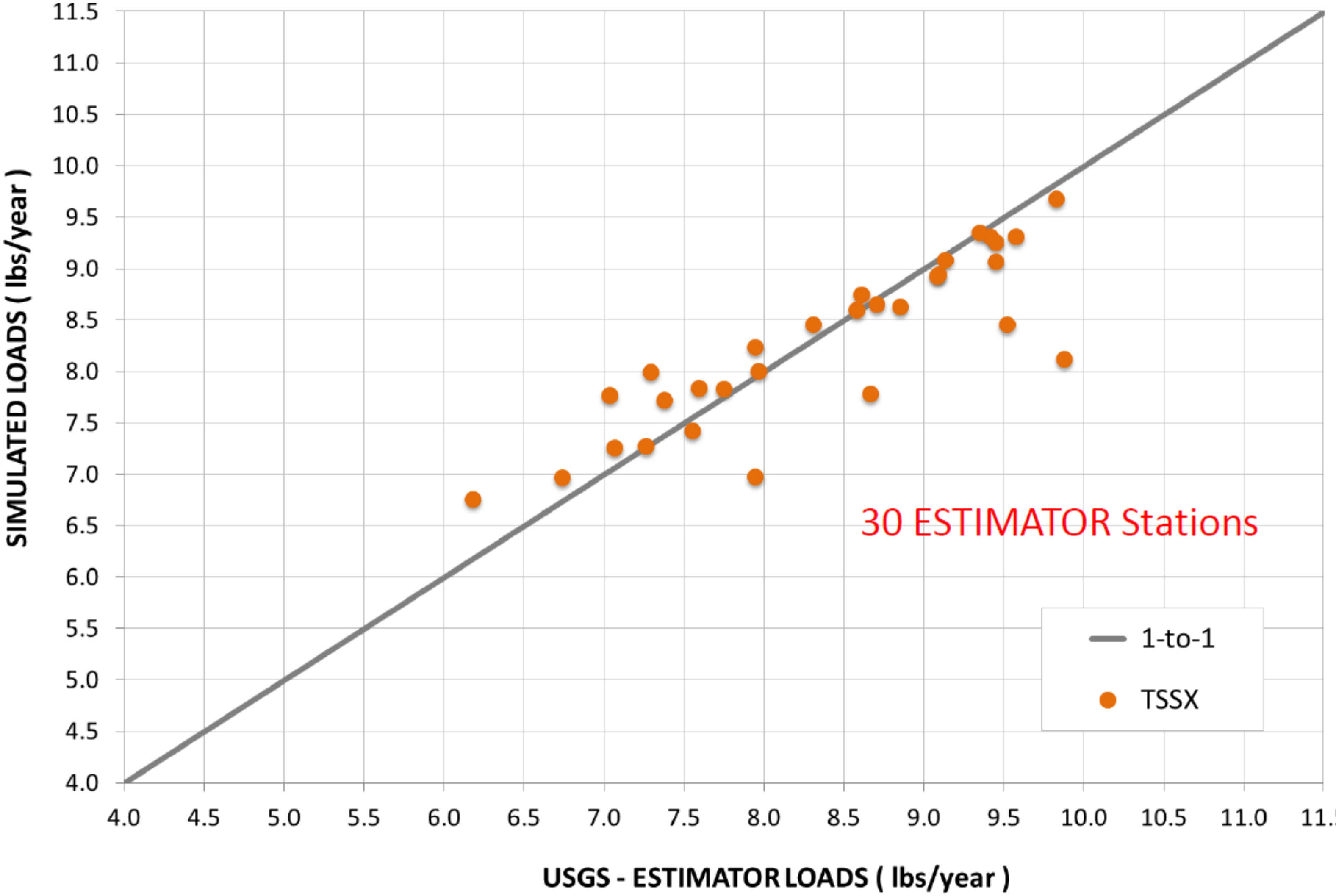


Peter Claggett and David Saavedra (UMBC)

PHASE 5

SEDIMENT

Load



PHASE 6
BETA 2

SEDIMENT

Load