The Chesapeake TMDL Calculation

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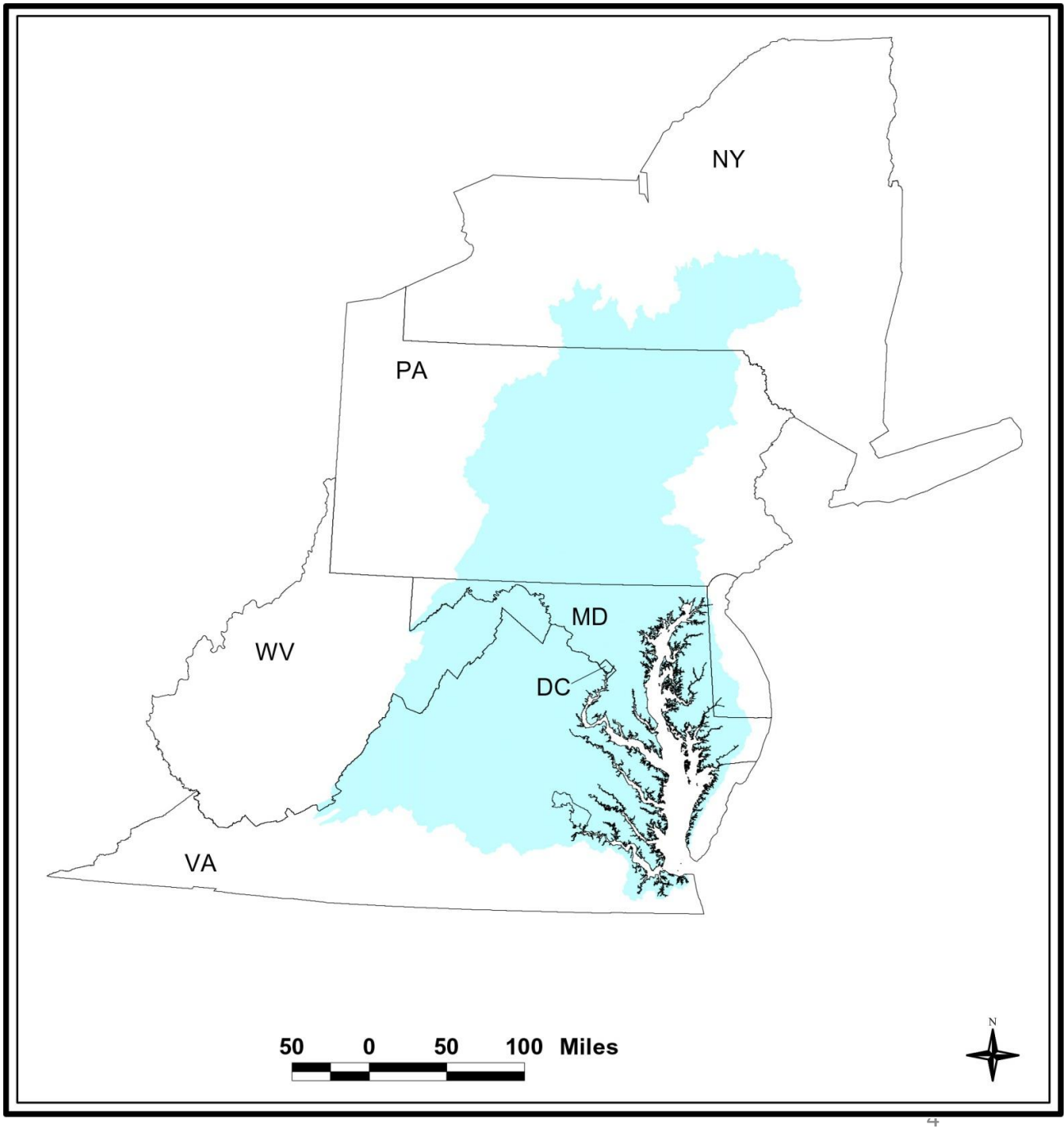
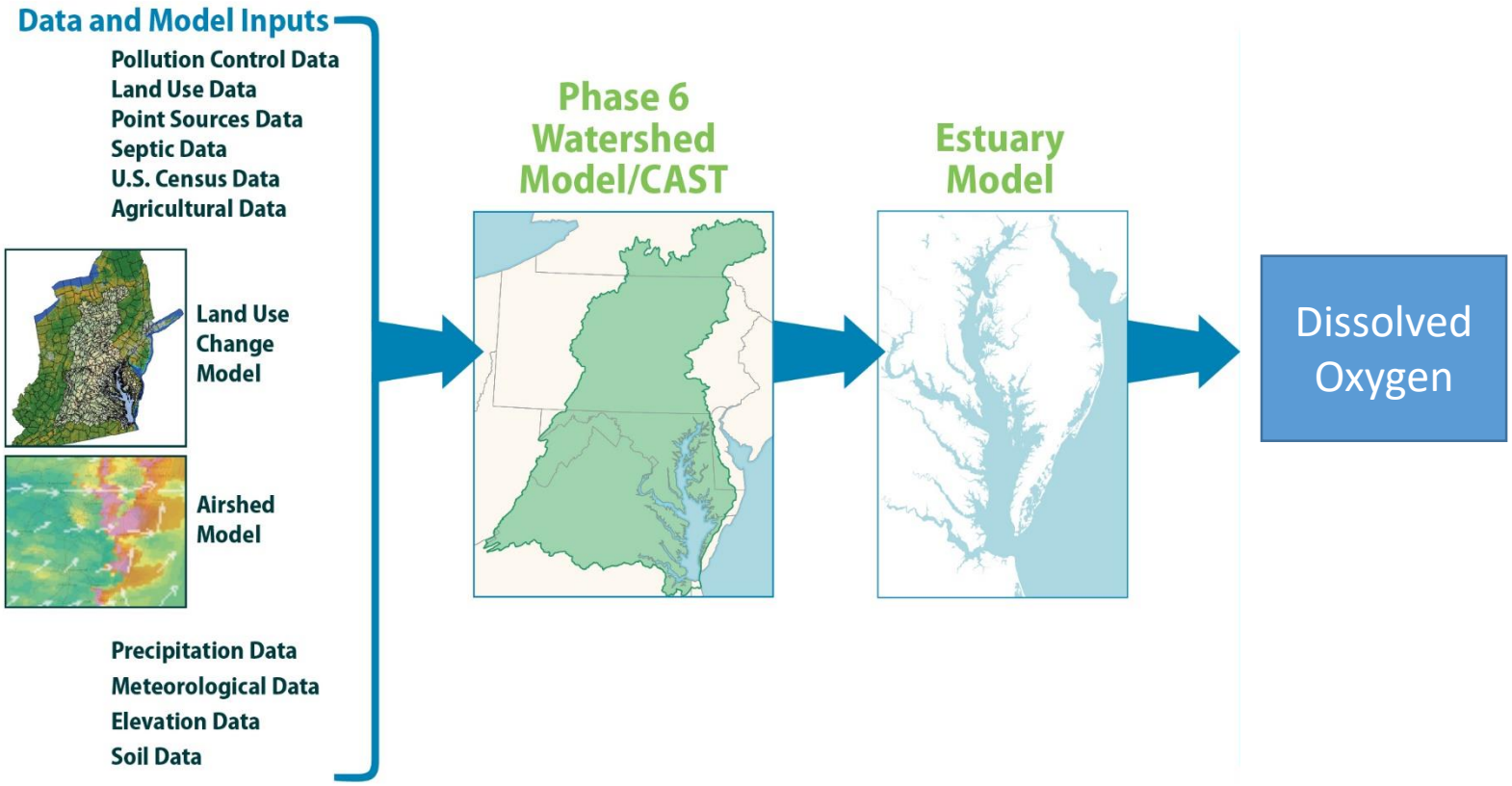
Less of this…

More of this…

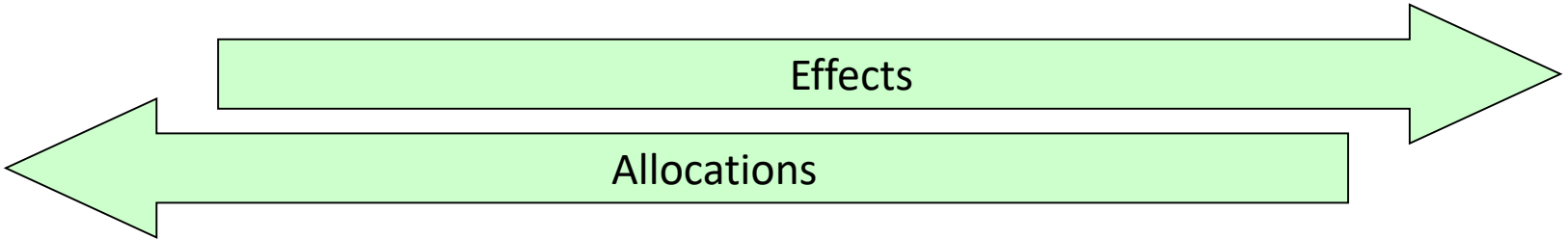
Chesapeake Bay Statistics

- Six states and DC
- 64,000 sq miles
- 18 million people
- 10,000 miles of shoreline
- 21 feet average depth
- 15:1 ratio of watershed to tidal surface waters





What management practices to we need to implement to achieve appropriate dissolved oxygen?



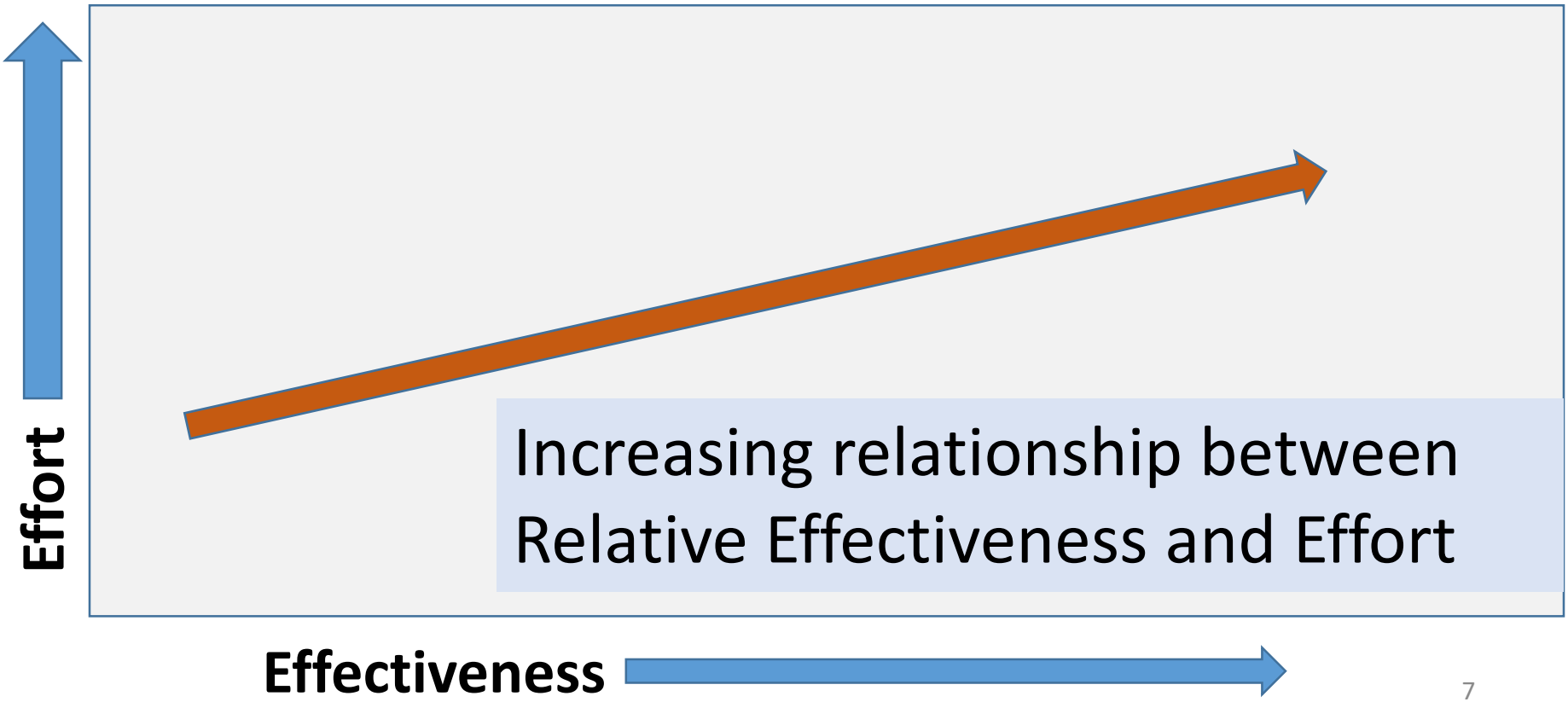
TMDL sets limits on total N and P

Geography		Planning Target	
Basin	State	Nitrogen	Phosphorus
Potomac	DC	2.42	0.130
Eastern Shore	DE	4.55	0.108
Eastern Shore	MD	15.21	1.286
Patuxent	MD	3.21	0.301
Potomac	MD	15.30	1.092
Susquehanna	MD	1.18	0.053
Western Shore	MD	10.89	0.948
Susquehanna	NY	11.53	0.587
Eastern Shore	PA	0.45	0.025
Potomac	PA	6.11	0.357
Susquehanna	PA	66.59	2.661
Western Shore	PA	0.02	0.001
Eastern Shore	VA	1.43	0.164
James	VA	25.92	2.731
Potomac	VA	16.00	1.892
Rappahannock	VA	6.85	0.849
York	VA	5.52	0.556
James	WV	0.04	0.005
Potomac	WV	8.18	0.427

- Based on analysis of spatial effectiveness
- Some modification due to speciation and timing in special cases

Guidelines for Planning Targets

- Areas that contribute the most to the problem must do the most to resolve the problem.



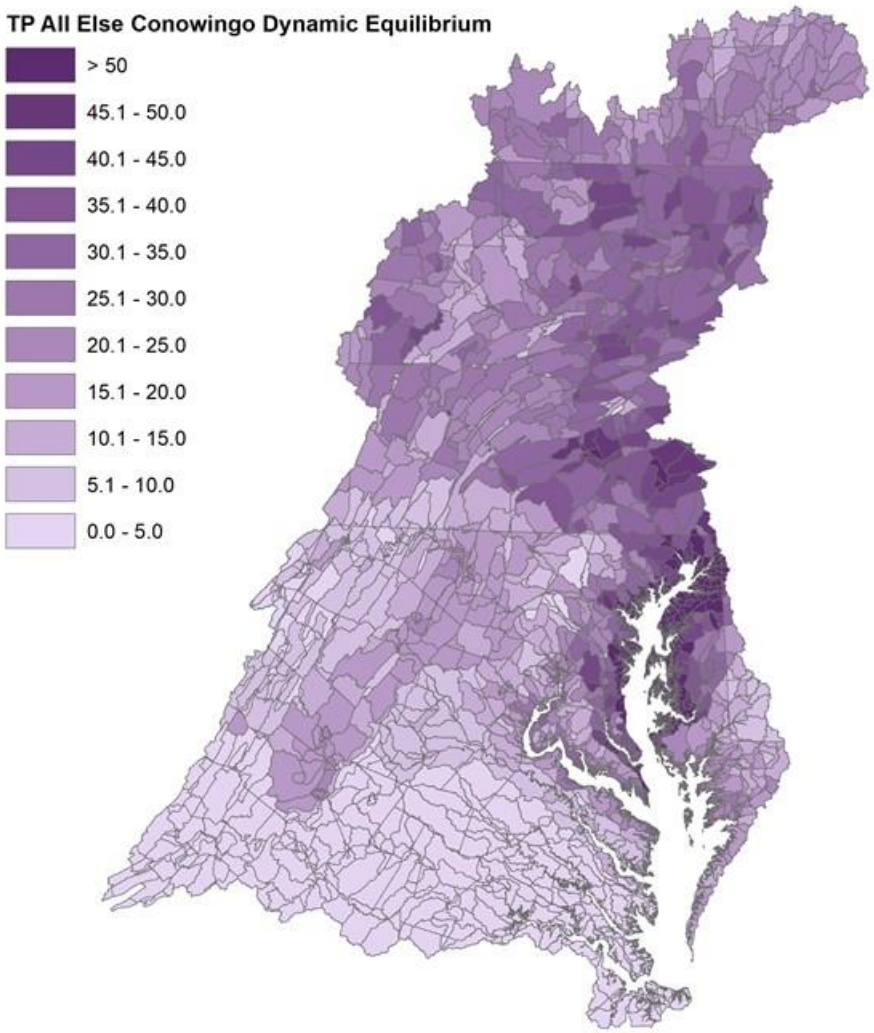
Determining Who Contributes the Most

Key factors:

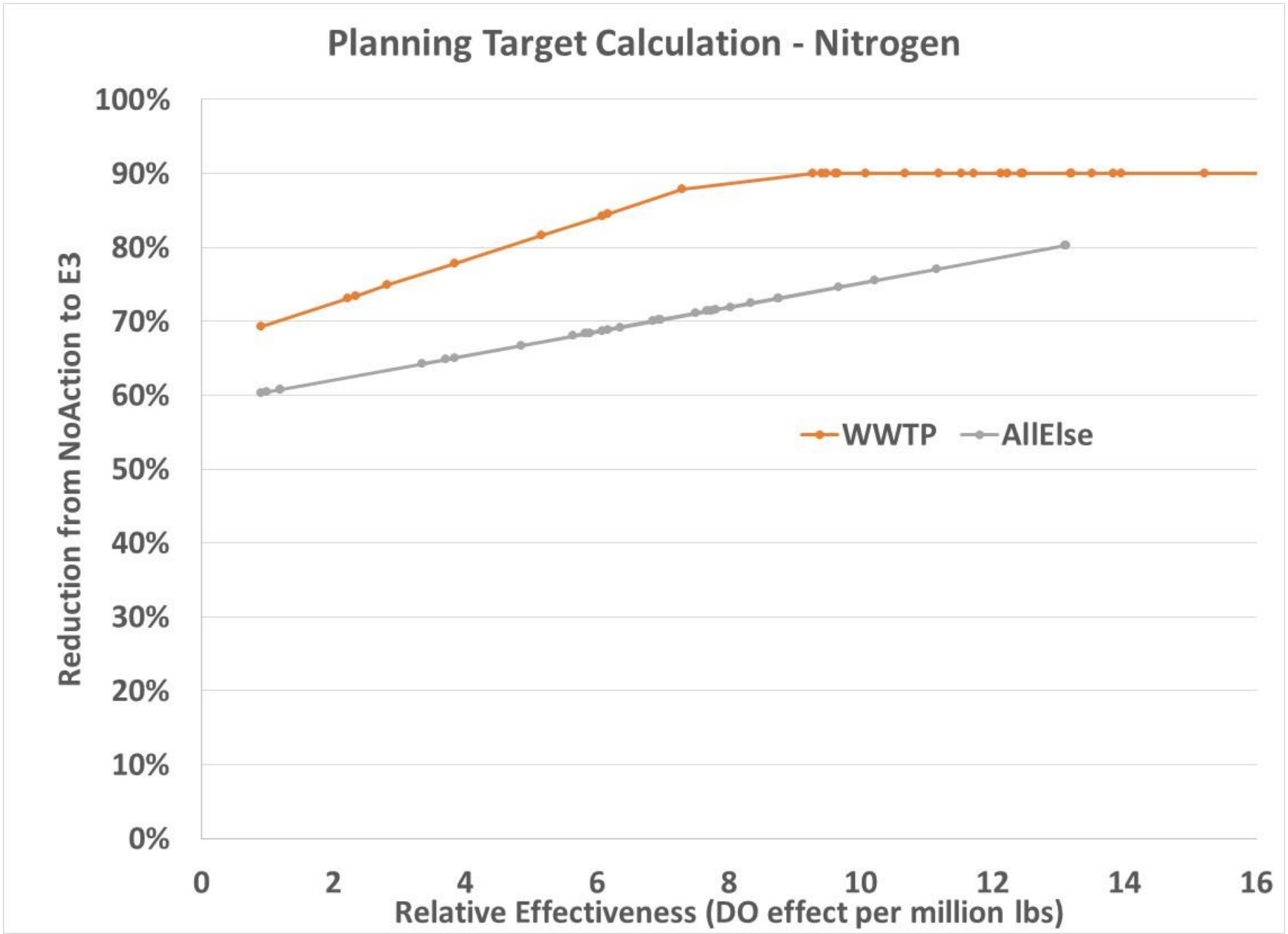
Watershed Transport
- Watershed Characteristics
- Travel time
- Existence of impoundments

Position along mainstem bay
- Estuarine circulation

Existence of riverine estuary



Watershed delivery:
Pound delivered per pound produced
Estuarine delivery
Oxygen reduced per pound delivered
Overall Effectiveness
Oxygen reduced per pound produced



Exchanges based on Geography

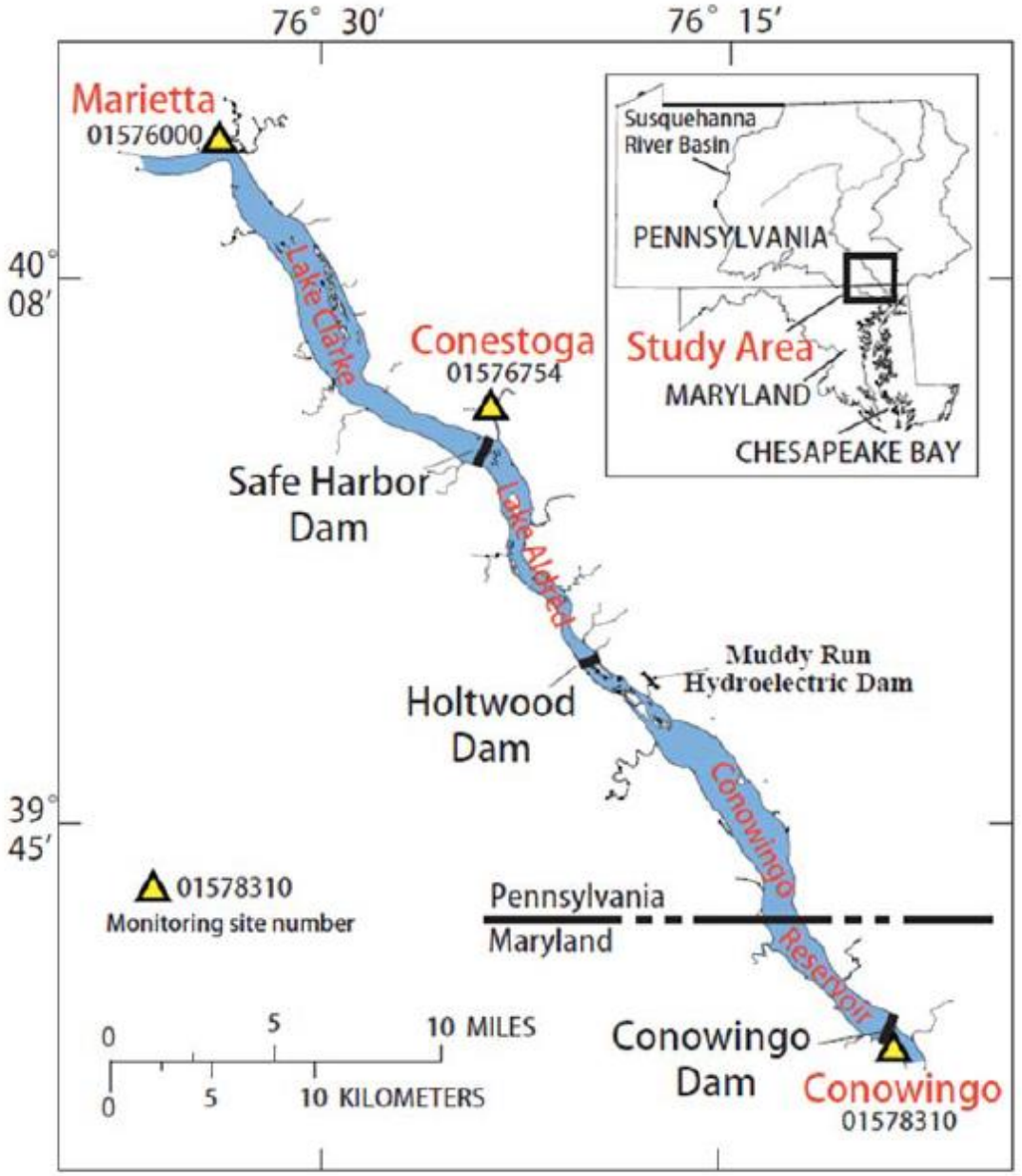
ug/l Oxygen per Mlbs

GeoBasin	N	P
Susquehanna	16.3	38.5
Western Shore	14.1	35.3
Patuxent AFL	10.9	27.5
Patuxent BFL	13.5	35.7
Potomac AFL	14.0	22.2
Potomac BFL	13.2	22.2
Rappahannock AFL	8.1	11.8
Rappahannock BFL	9.3	15.5
York AFL	4.6	9.1
York BFL	5.2	8.7
James AFL	2.6	7.7
James BFL	2.4	7.4
Upper Eastern Shore	10.7	31.8
Middle Eastern Shore	11.2	43.2
Lower Eastern Shore	9.8	25.2
Virginia Eastern Shore	15.2	20.4
Atmospheric Deposition	15.8	

In the Susquehanna, a pound of TP is worth a little over twice as much as a pound of TN

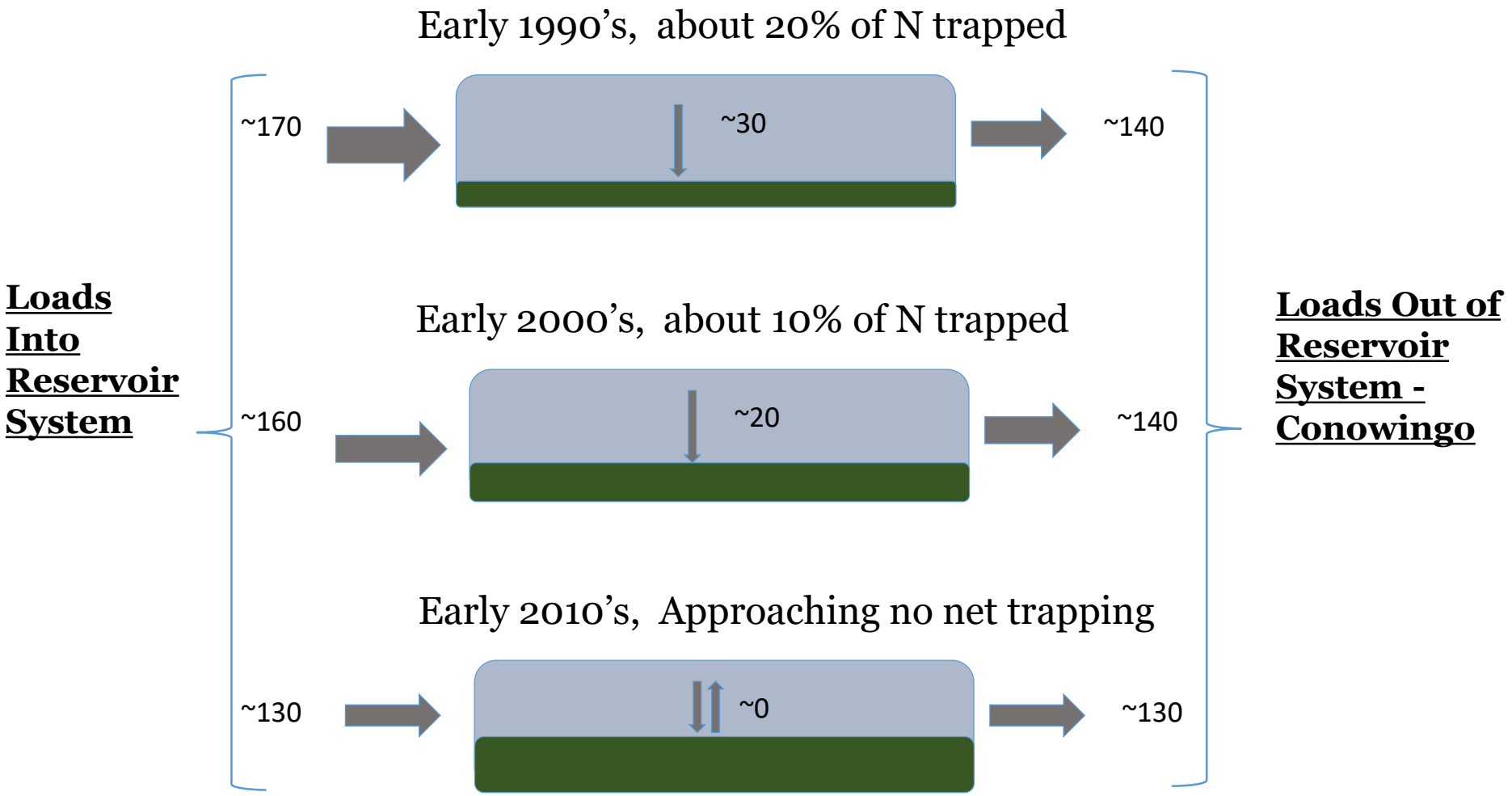
A pound of TP from the Potomac is worth almost twice as much as a pound from the Rappahannock above fredericksburg

Lower Susquehanna River Reservoirs



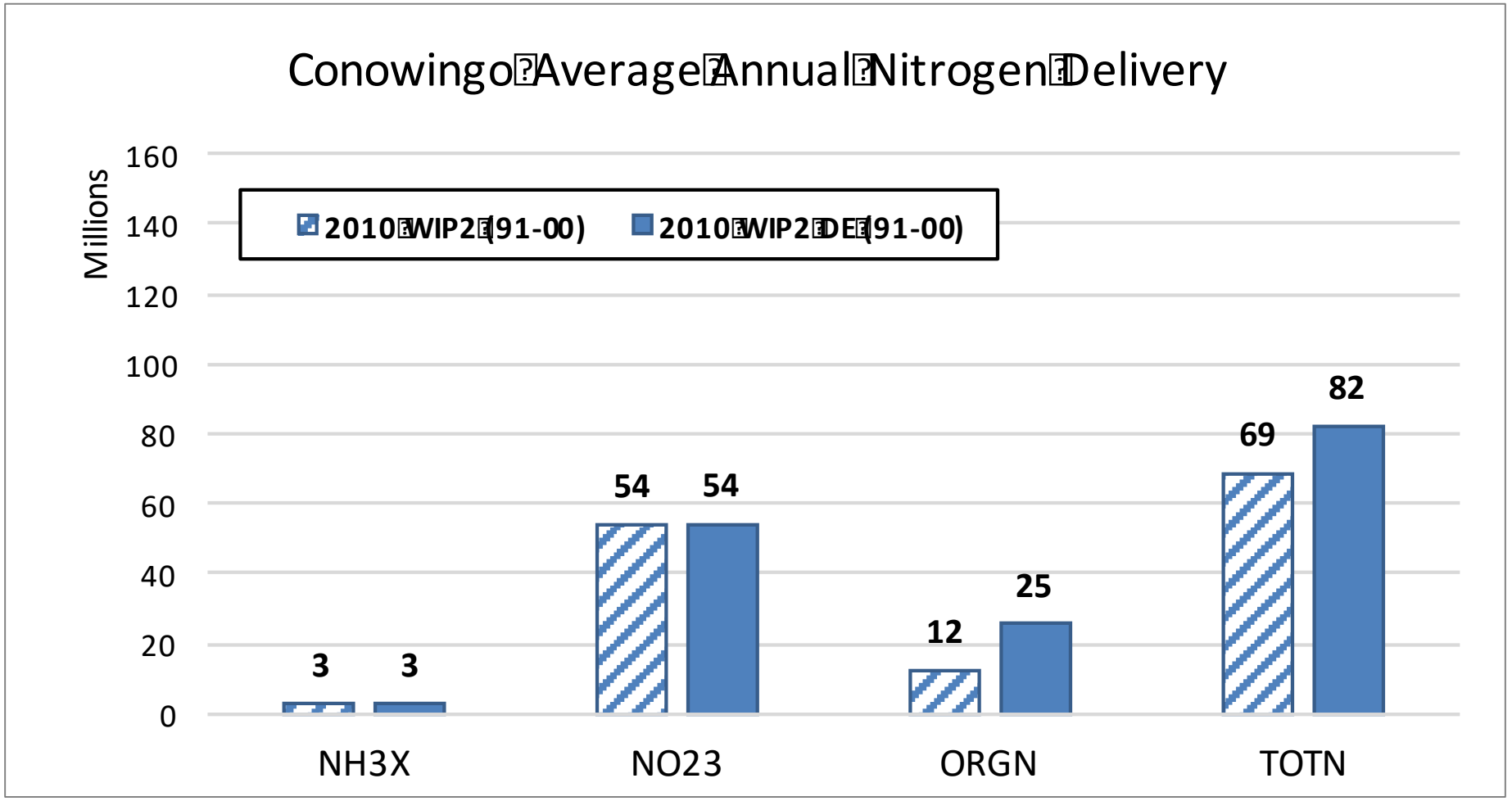
Sources: Langland, USGS, Bay Journal, Lower Susquehanna River Keeper

Nitrogen Loads Into, Trapped Within and Exiting the Reservoir System: 1990s-2010s



Source: Data from USGS (2016), http://cbrim.er.usgs.gov/loads_query.html
loads are approximate and in units of million lbs/year using estimates for 1992, 2002, and 2012

Conowingo Effect on Loads at the WIP2 condition



13 Million additional lbs of TN (and 1.8 million lbs of TP)
But much of it organic and delivered in large storms

Calculate Conowingo Effect in million cubic meters of additional unallowable hypoxia

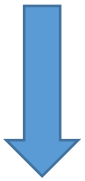
Deep Water	Designated Use	Volume	WIP Red Percent	WIP red volume	WIP + Conowingo	WIP+C red volume
CB3MH	DW	864	0.05%	0	0.05%	0
CB4MH	DW	2854	5.00%	143	5.52%	158
MD5MH	DW	2097	0.94%	20	1.09%	23
VA5MH	DW	1605	0.00%	0	0.00%	0
POMMH	DW	1839	0.00%	0	0.00%	0
CB3MH	DC	390	0.00%	0	0.00%	0
CB4MH	DC	2126	5.87%	125	8.04%	171
MD5MH	DC	2875	0.00%	0	0.00%	0
VA5MH	DC	1848	0.00%	0	0.00%	0
				288		352
					Conowingo Difference	**64**

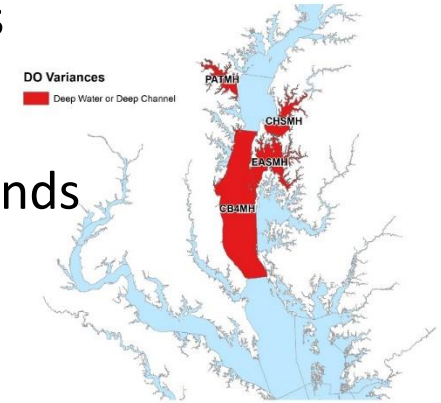
Tested reductions from upstream sources that would result in 64 million cubic meter decrease in hypoxia

Estimated Loads to the Bay with Conowingo Dam and Reservoir at Infill Conditions

Additional Nitrogen Load: 13 million pounds

Additional Phosphorus Load: 1.8 million pounds





HOWEVER: These are less bioavailable nutrients and its delivery to Bay is dependent on large storm events. Equivalent to 6 million pounds of Nitrogen and 0.26 million pounds of Phosphorus

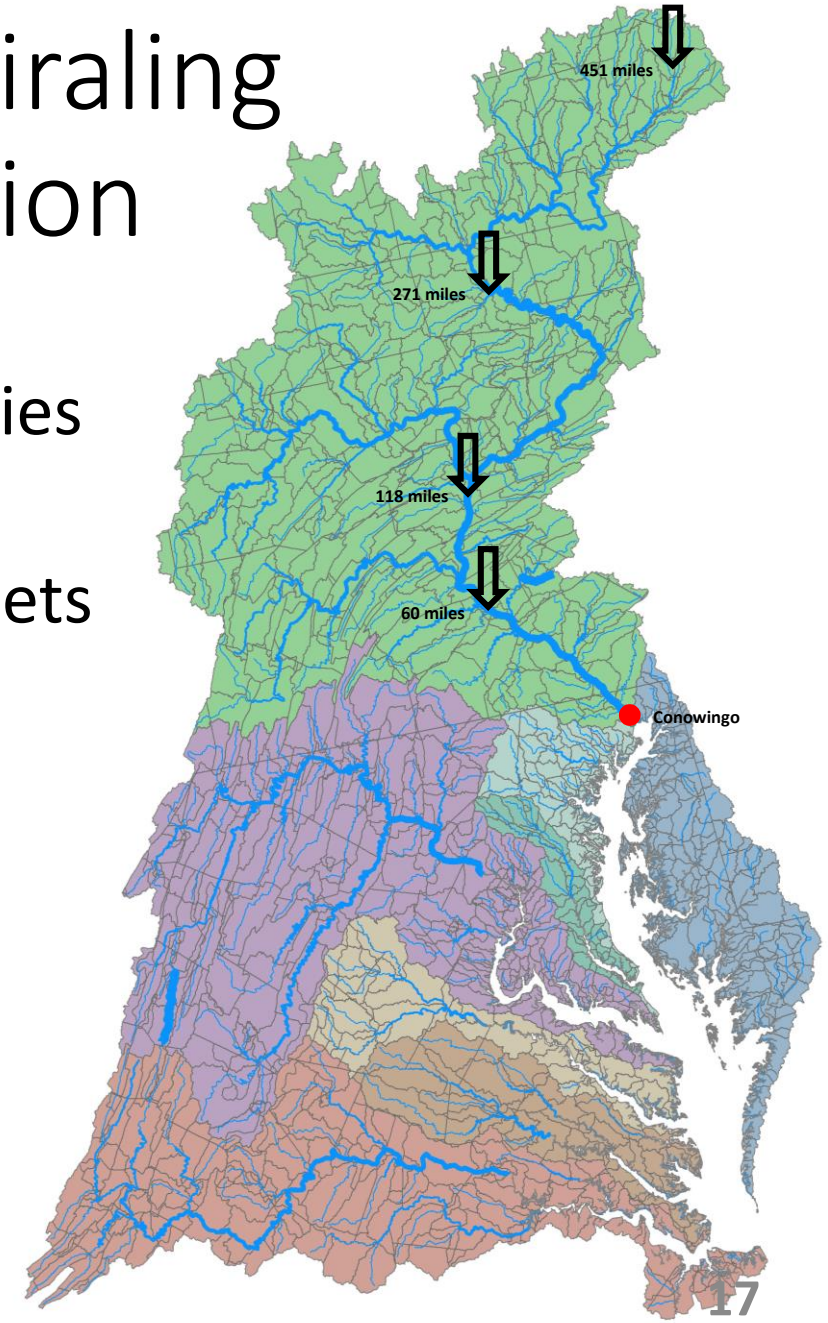
‘Currency’ of the TMDL

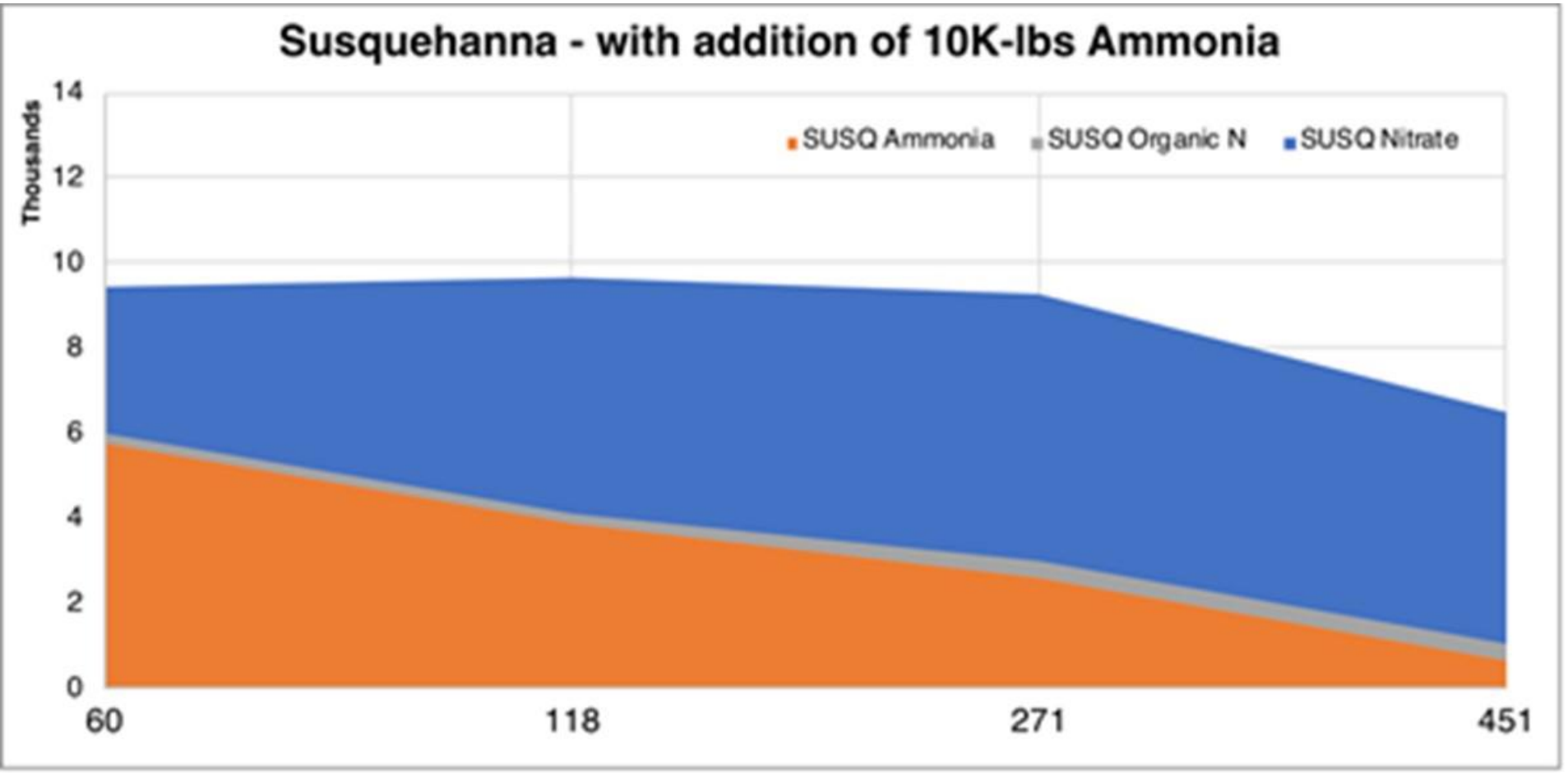
- Goals are counted in TN and TP
- Goals are set and exchanged in units of oxygen
  - Spatial exchanges
  - TN:TP exchanges
  - Conowingo effect
  - Preliminary climate change analysis (not shown)
- Oxygen is the mathematical currency of the TMDL

Test of nutrient spiraling in the CBP simulation

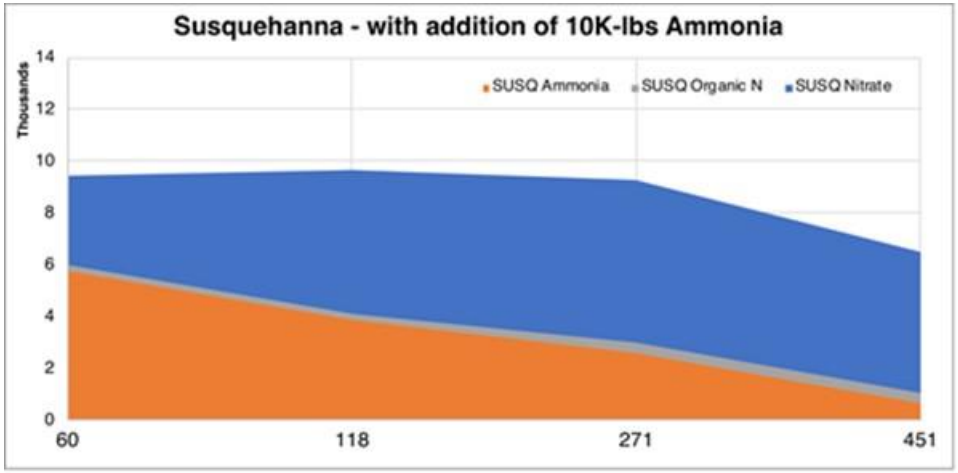
- Added single nutrient species at several points upstream
- Checked for species at outlets

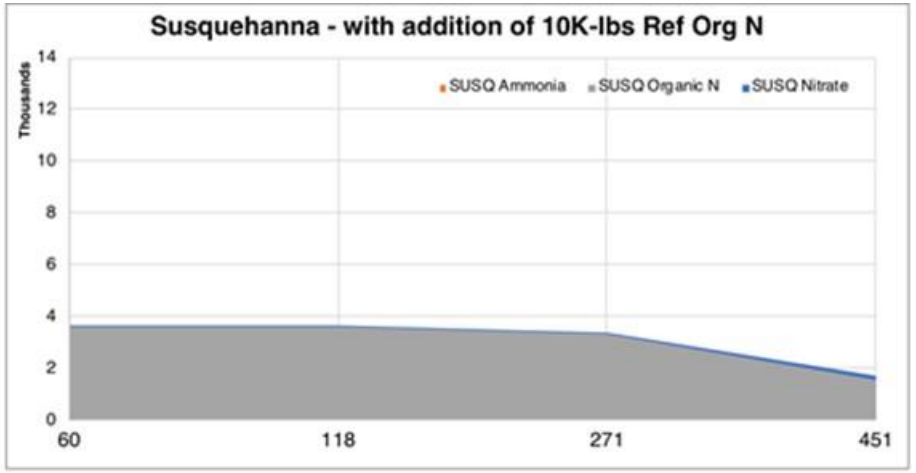
- Only large rivers





Addition point (miles upstream)


Susquehanna - with addition of 10K-lbs Ammonia
Thousands
14
12
10
8
6
4
2
0
SUSQ Ammonia
SUSQ Organic N
SUSQ Nitrate
60
118
271
451


Susquehanna - with addition of 10K-lbs Ref Org N
Thousands
14
12
10
8
6
4
2
0
SUSQ Ammonia
SUSQ Organic N
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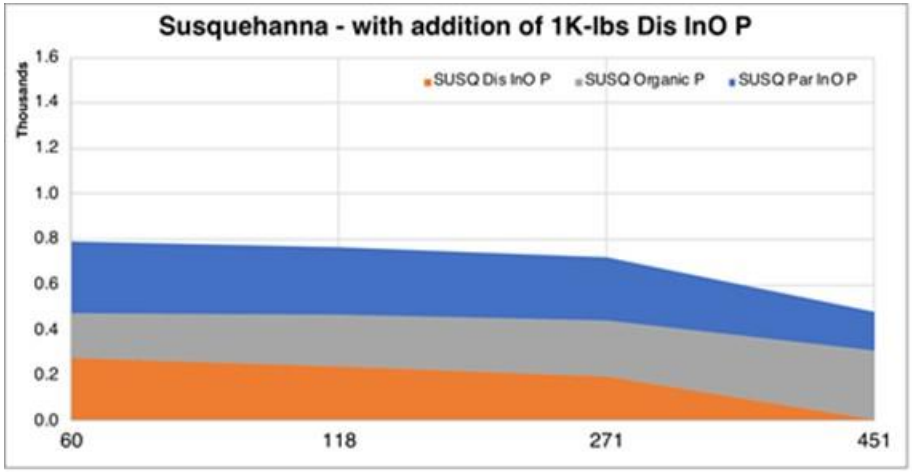
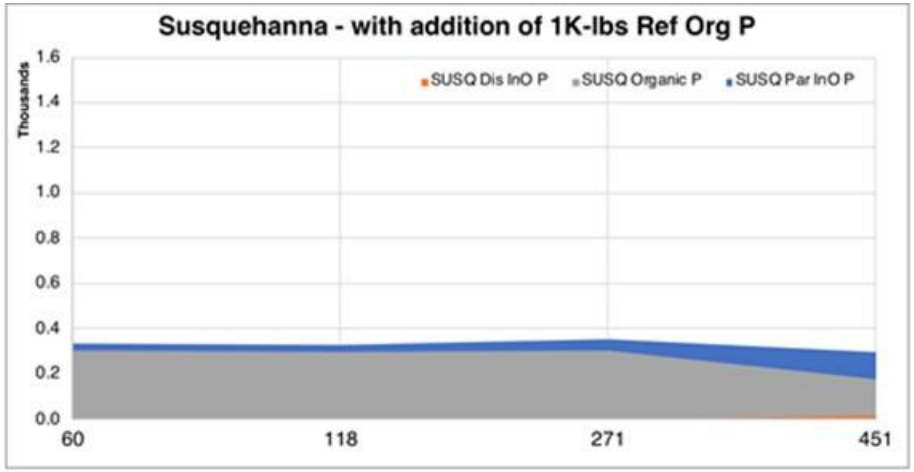
60
118
271
451


Susquehanna - with addition of 1K-lbs Dis InO P
Thousands
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
SUSQ Dis InO P
SUSQ Organic P
SUSQ Par InO P
60
118
271
451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SUSQ Organic P
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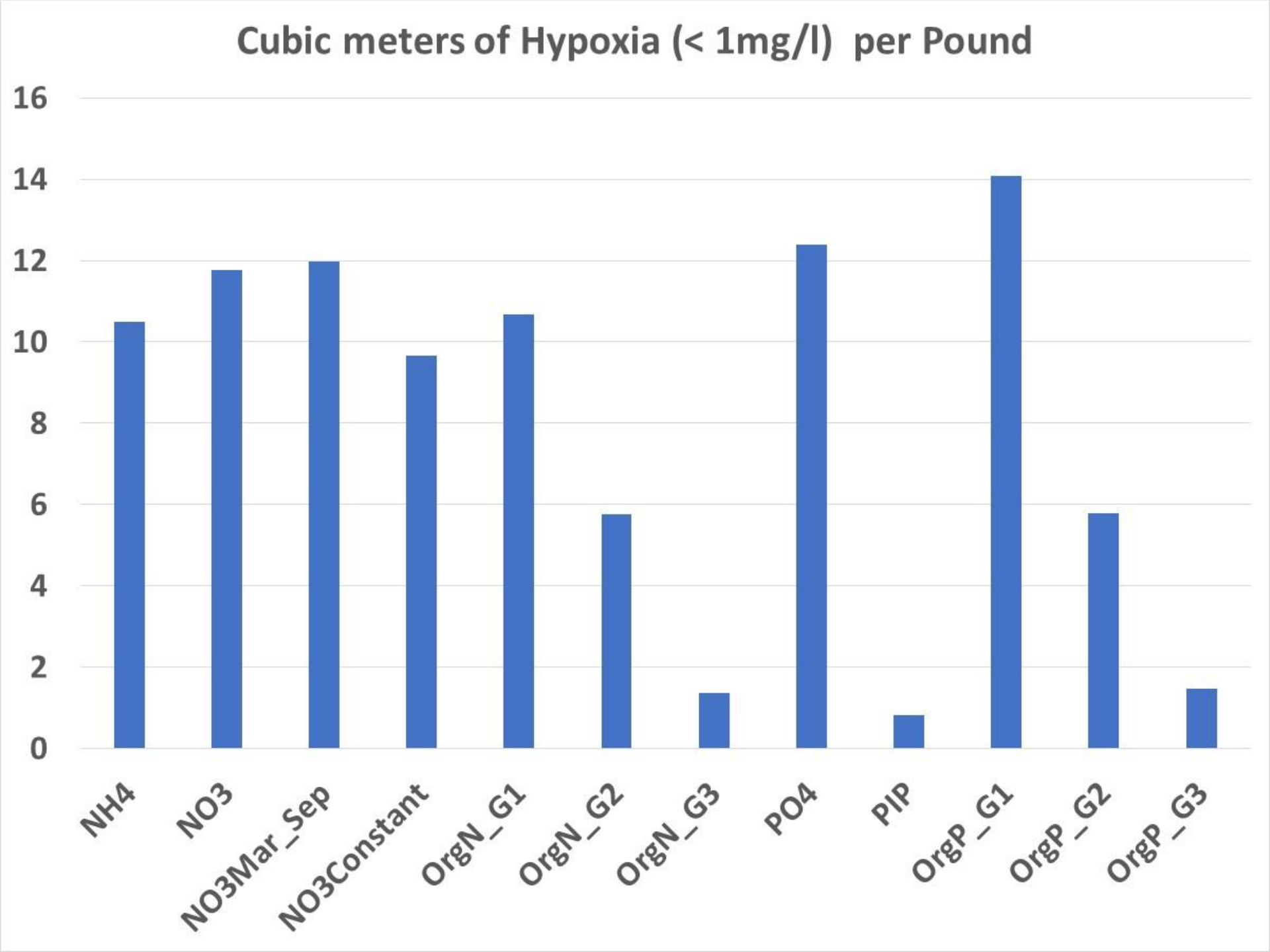
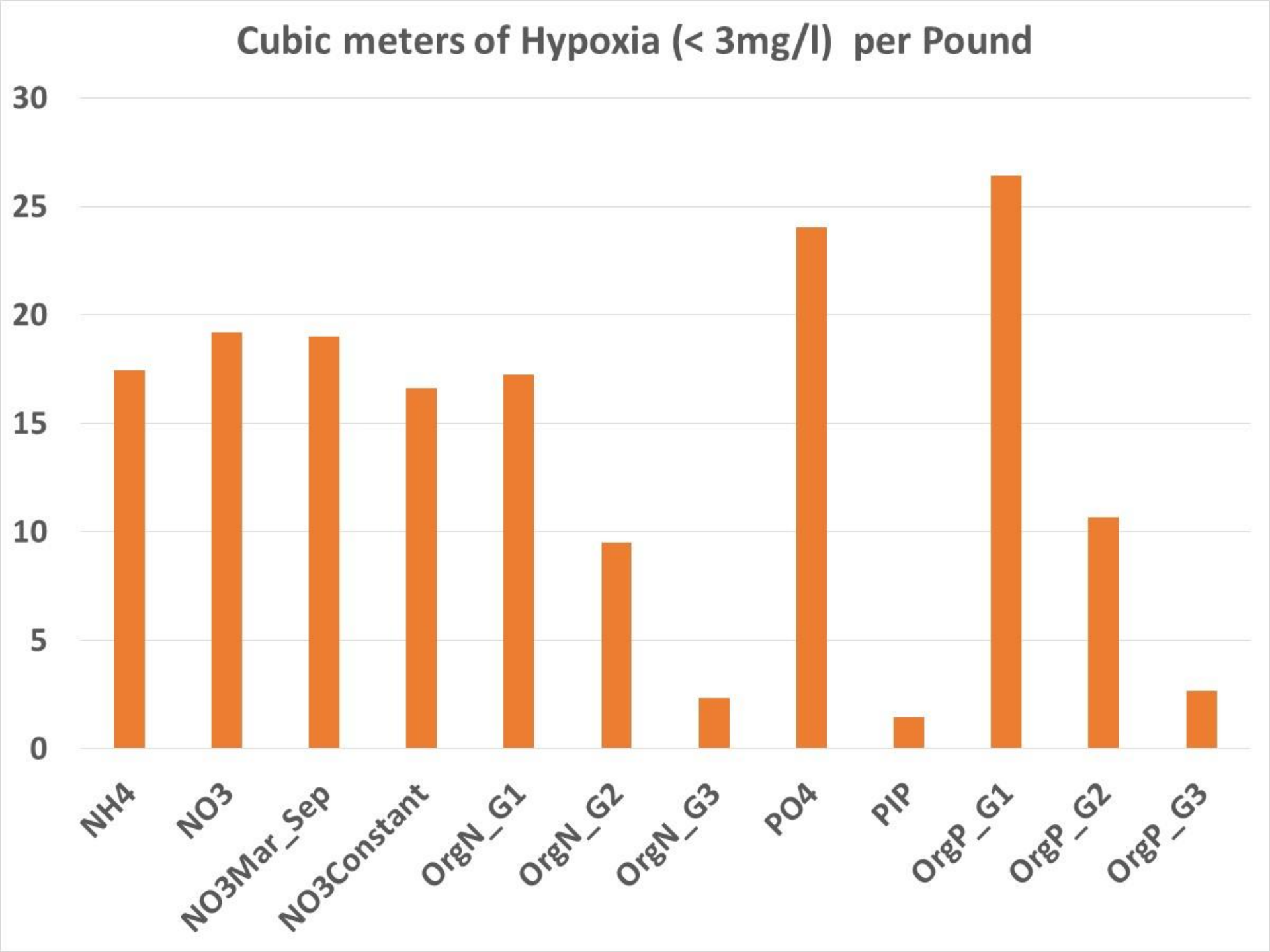
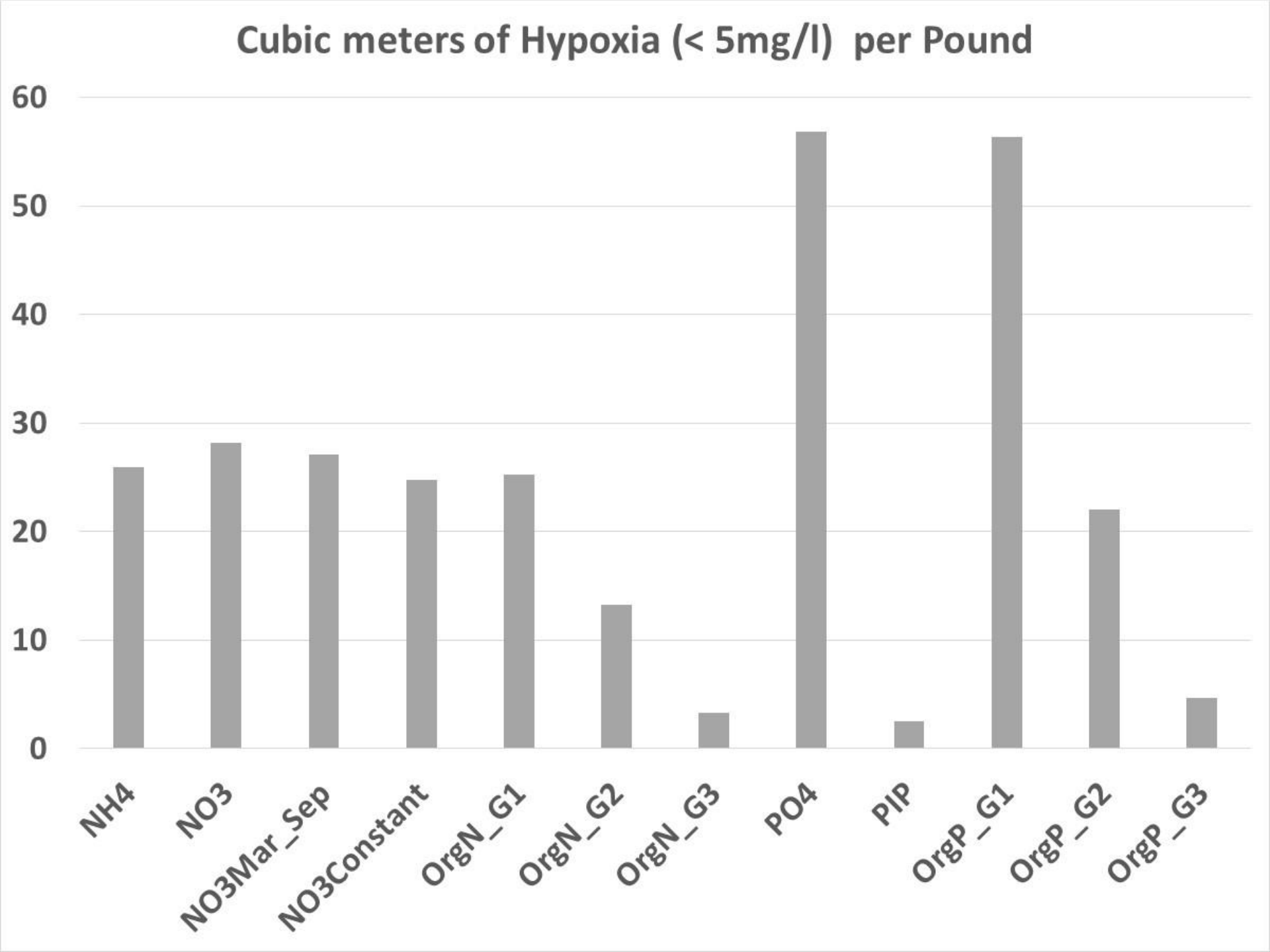
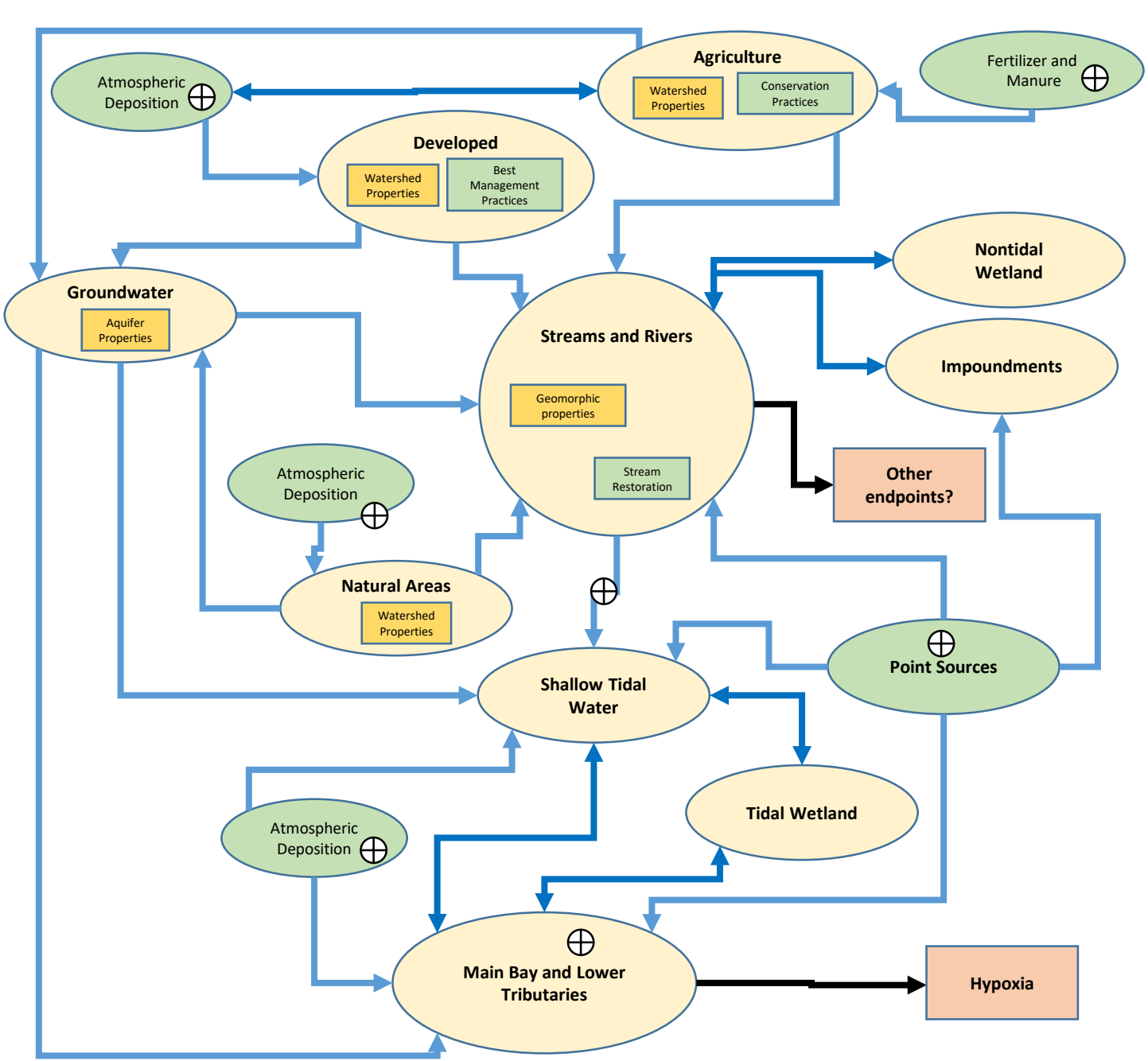
60
118
271
451


Cubic meters of Hypoxia (< 1mg/l) per Pound
16
14
12
10
8
6
4
2
0
NH4
NO3
NO3Mar_Sep
NO3Constant
OrgN_G1
OrgN_G2
OrgN_G3
PO4
PIP
OrgP_G1
OrgP_G2
OrgP_G3


Cubic meters of Hypoxia (< 3mg/l) per Pound
30
25
20
15
10
5
0
NH4
NO3
NO3Mar_Sep
NO3Constant
OrgN_G1
OrgN_G2
OrgN_G3
PO4
PIP
OrgP_G1
OrgP_G2
OrgP_G3


Cubic meters of Hypoxia (< 5mg/l) per Pound
60
50
40
30
20
10
0
NH4
NO3
NO3Mar_Sep
NO3Constant
OrgN_G1
OrgN_G2
OrgN_G3
PO4
PIP
OrgP_G1
OrgP_G2
OrgP_G3

Conceptual model of nutrient-driven hypoxia related to nutrient species and timing



Environments

Natural Factors

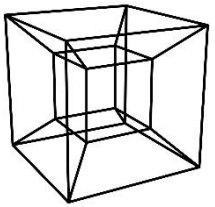
Management Levers

Management Endpoint

⊕ This symbol denotes a flux or effect that is reasonably well monitored specifically for nutrient species and timing

Blue Arrows represent a nutrient flux between environments. All fluxes are understood to have characteristics related to species and timing.

Climate change is an extra dimension



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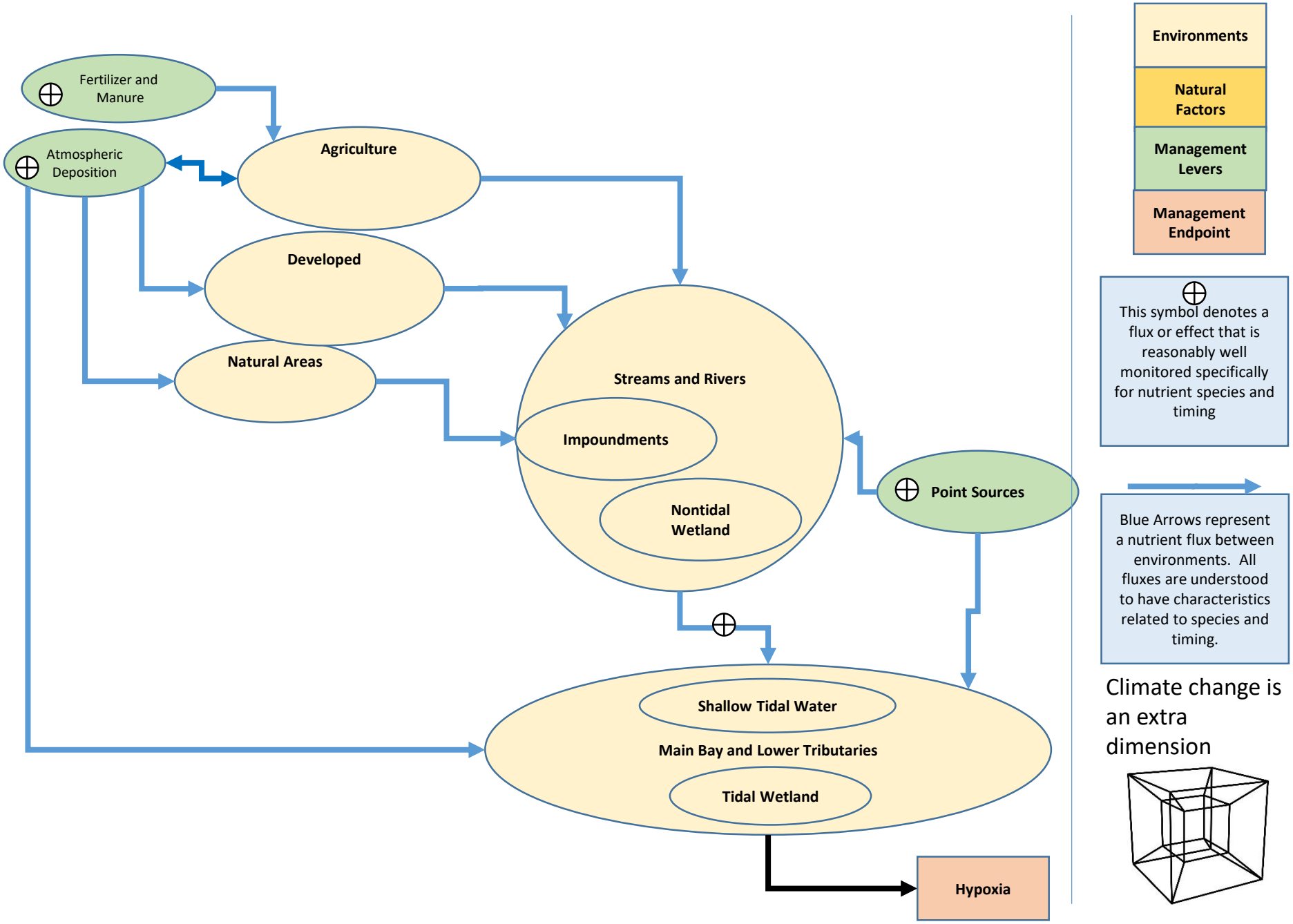
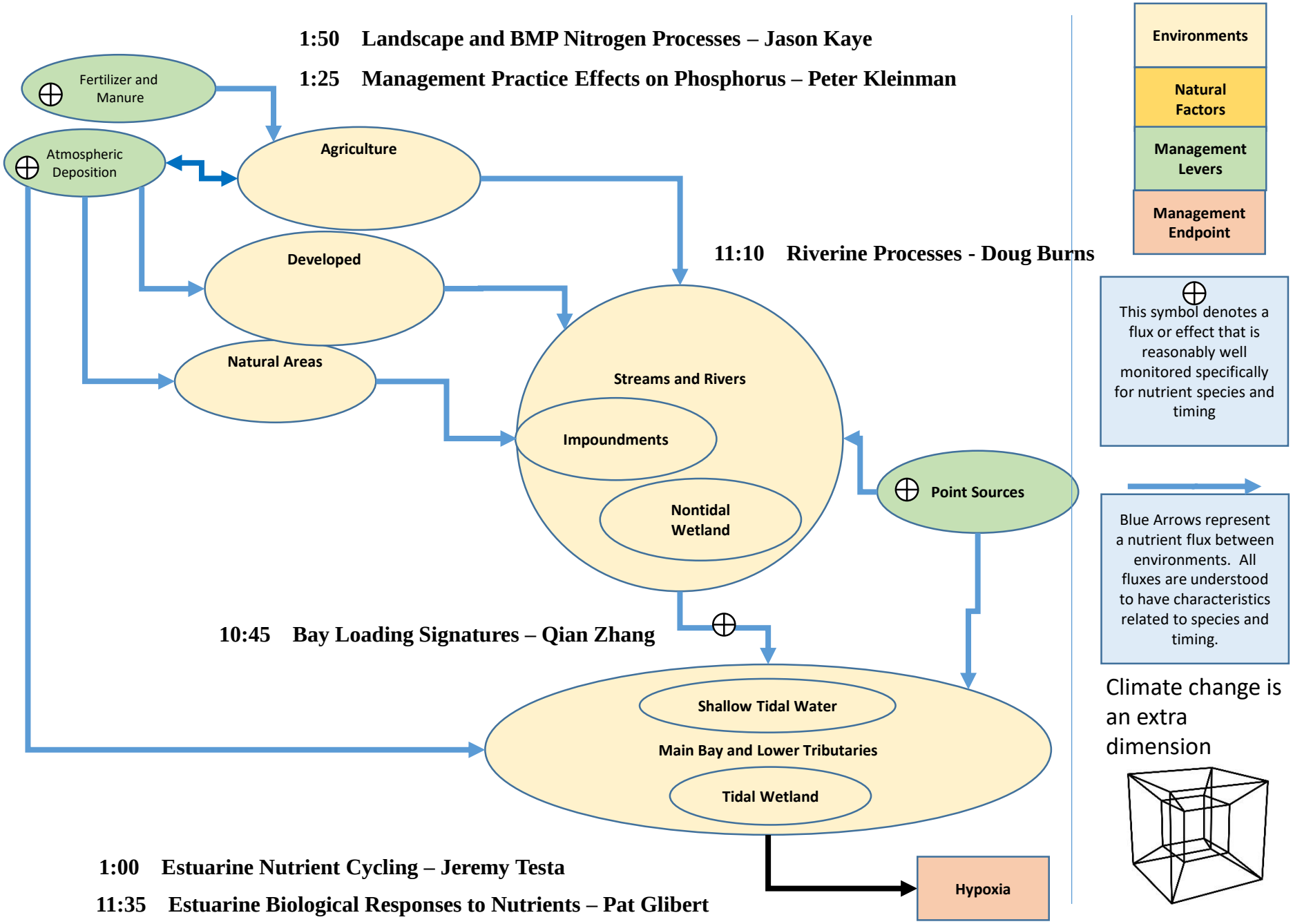


Conceptual model of nutrient-driven hypoxia related to nutrient species and timing

1:50 Landscape and BMP Nitrogen Processes – Jason Kaye

1:25 Management Practice Effects on Phosphorus – Peter Kleinman



11:10 Riverine Processes - Doug Burns

10:45 Bay Loading Signatures – Qian Zhang

1:00 Estuarine Nutrient Cycling – Jeremy Testa

11:35 Estuarine Biological Responses to Nutrients – Pat Glibert

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