Economic and Ecosystem Service Targeting of Nutrient Control Efforts in the Chesapeake Bay Watershed

Presented by

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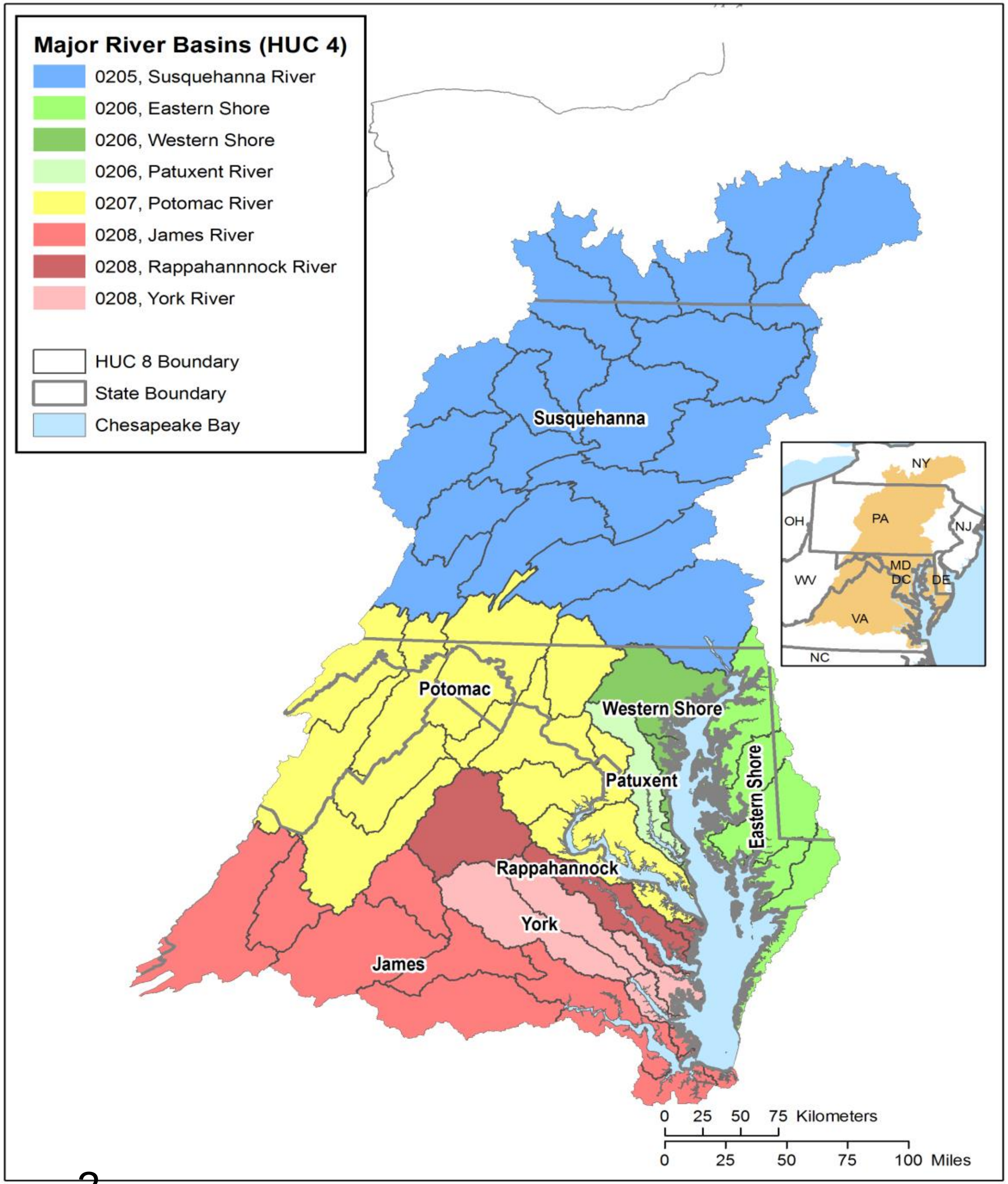


- The Chesapeake Bay watershed includes:
  - 64,000 sq mile area
  - 6 states plus DC
  - 8 major basins
- Chesapeake Bay Total Maximum Daily Load (TMDL)
  - established by EPA in 2010
  - “pollution diet” for nitrogen, phosphorus, and sediment

TMDL Allocations Define Load Reductions Targets

Load Reduction Targets by Basin (millions of lbs)

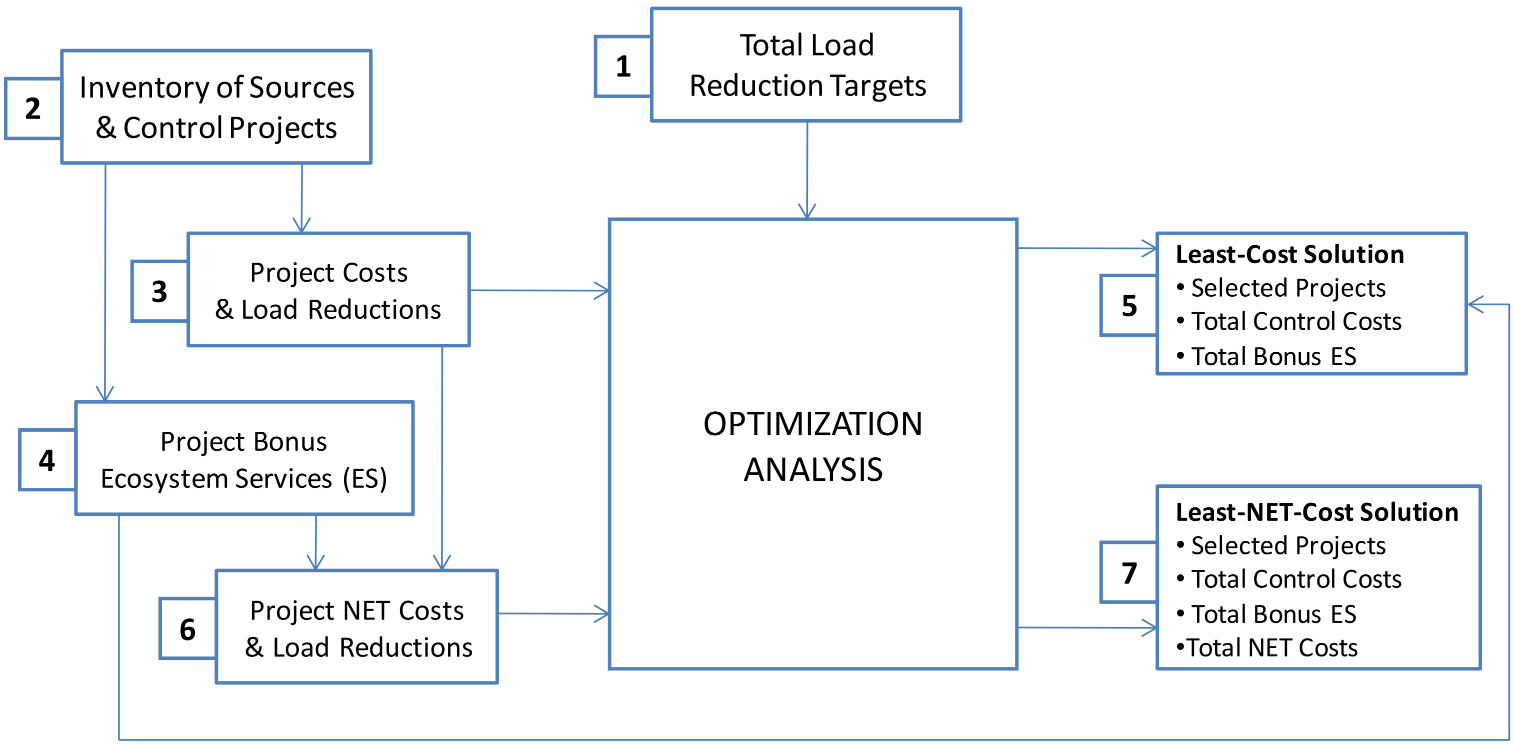
Basin	Nitrogen[a]	Phosphorus	Sediment
Eastern Shore of Chesapeake Bay	4.74	0.27	38.88
James River Basin	8.18	0.89	326.23
Patuxent River Basin	0.20	0.05	7.67
Potomac River Basin	6.77	1.03	509.72
Rappahannock River Basin	1.01	0.18	51.90
Susquehanna River Basin	33.14	1.16	529.02
Western Shore of Chesapeake Bay	4.91	0.26	38.24
York River Basin	0.95	0.08	23.80
Total	**59.91**	**3.92**	**1525.47**

[a] Excludes expected reductions in delivered loads attributable to non-tidal atmospheric deposition in the watershed

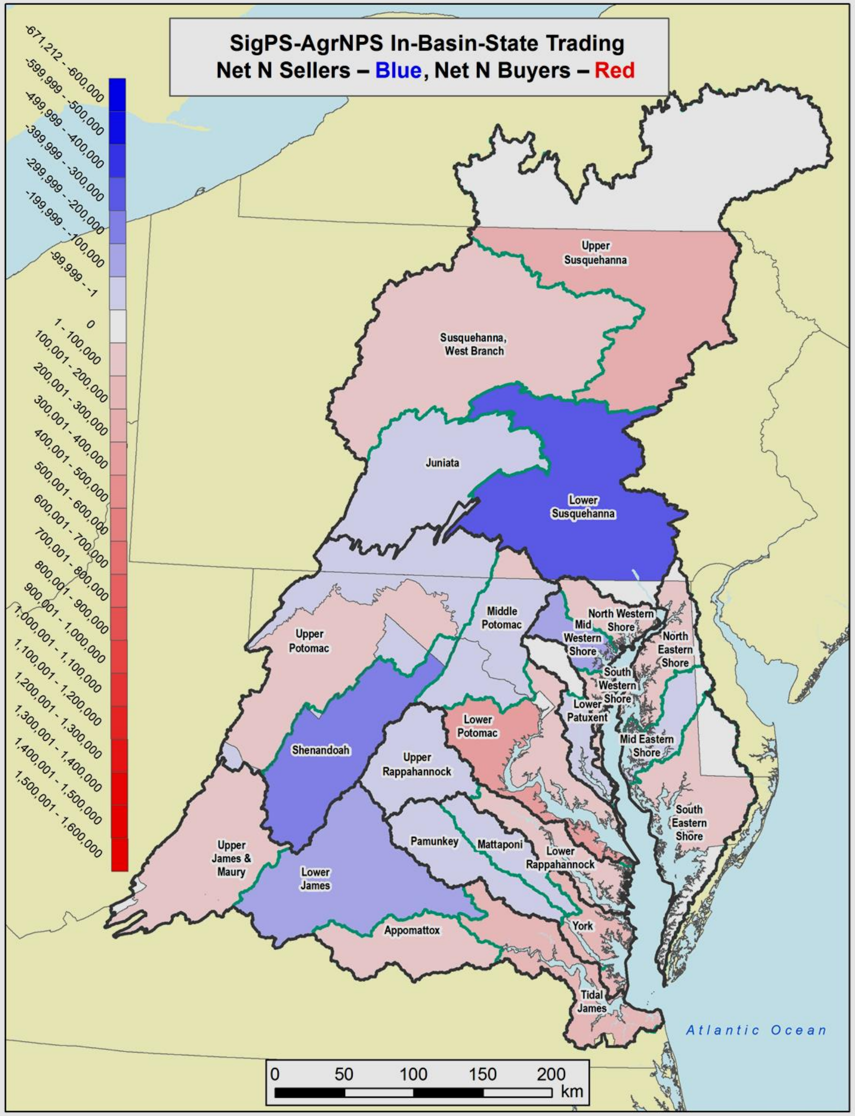
Key Questions for this Research

- What mix of nutrient control projects would meet the TMDL goals for the lowest total cost?
- How does this mix compare to the states' TMDL watershed implementation plans (WIPs)?
  - Point source (PS) vs. non-point source (NPS) contributions
  - Spatial distribution of load reductions
- What mix of projects would meet the TMDL goals for the least total NET cost?
  - NET cost = costs - ecosystem service **co**-benefits
  - Co-benefits include carbon sequestration, recreation, and improvements to **freshwater quality**
- How does this least-NET-cost mix compare to the TMDL and least-cost mix?

Modeling Framework



Effect of Least-Cost Approach on Load Reductions



- Results from Nutrient Credit Trading Analysis
- Compared to WIPs, least-cost solution shifts the spatial distribution of N load reductions
  - closer to the Bay
  - towards more agricultural areas

Estimating Water Quality Co-Benefits per Pound of Nutrient Reduction by River Segment

- <u>Step 1</u>: Estimate TN, TP, DO, BOD5, TSS concentrations by river segment, for scenarios with and without TMDL (from Ches Bay Program's Watershed Model -- CBWM)

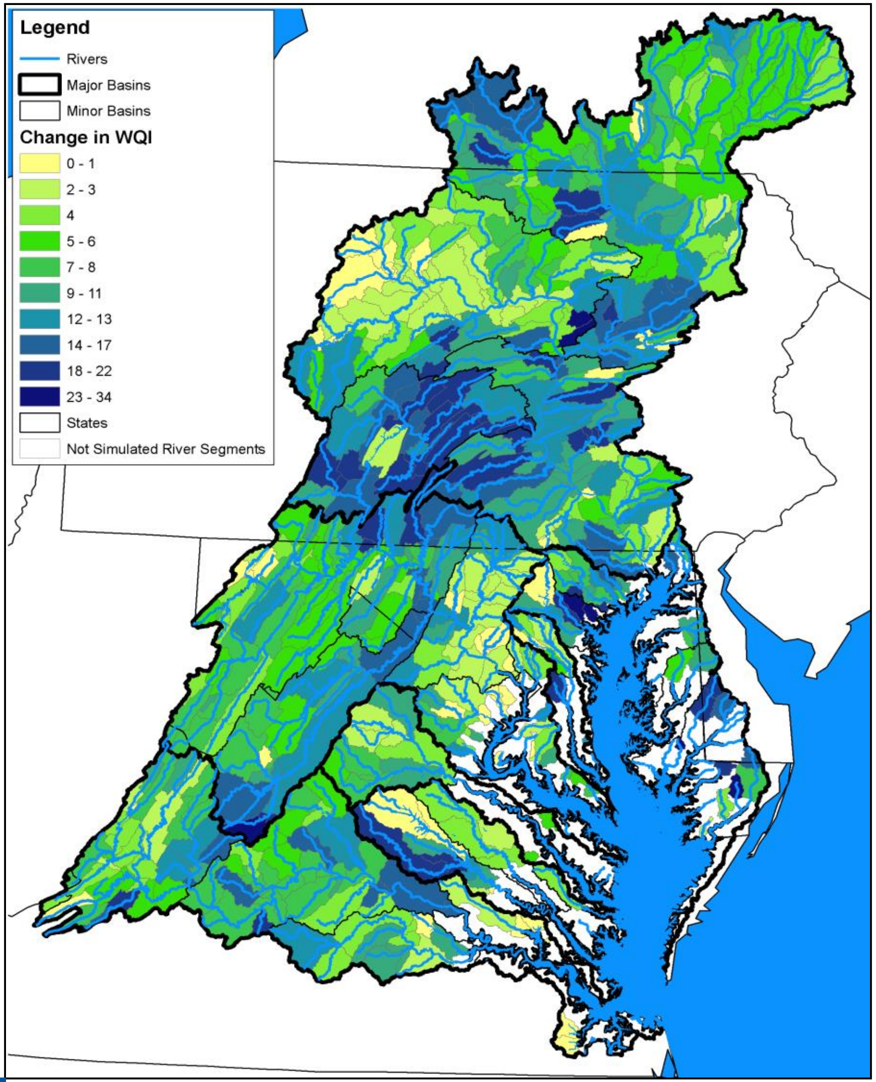
- <u>Step 2</u>: Combine concentrations into composite 100-pt water quality index (WQI) for each segment *i* and scenario

$$WQI_i = f(TN_i, TP_i, DO_i, BOD5_i, TSS_i)$$

- <u>Step 3</u>: Use benefit transfer function to estimate total willingness to pay (WTP) for WQI changes in each segment

$$WTP_i = \overline{wtp}(\Delta WQIi, lengthi, X) * population$$

Spatial Distribution of WQI Increases due to TMDL

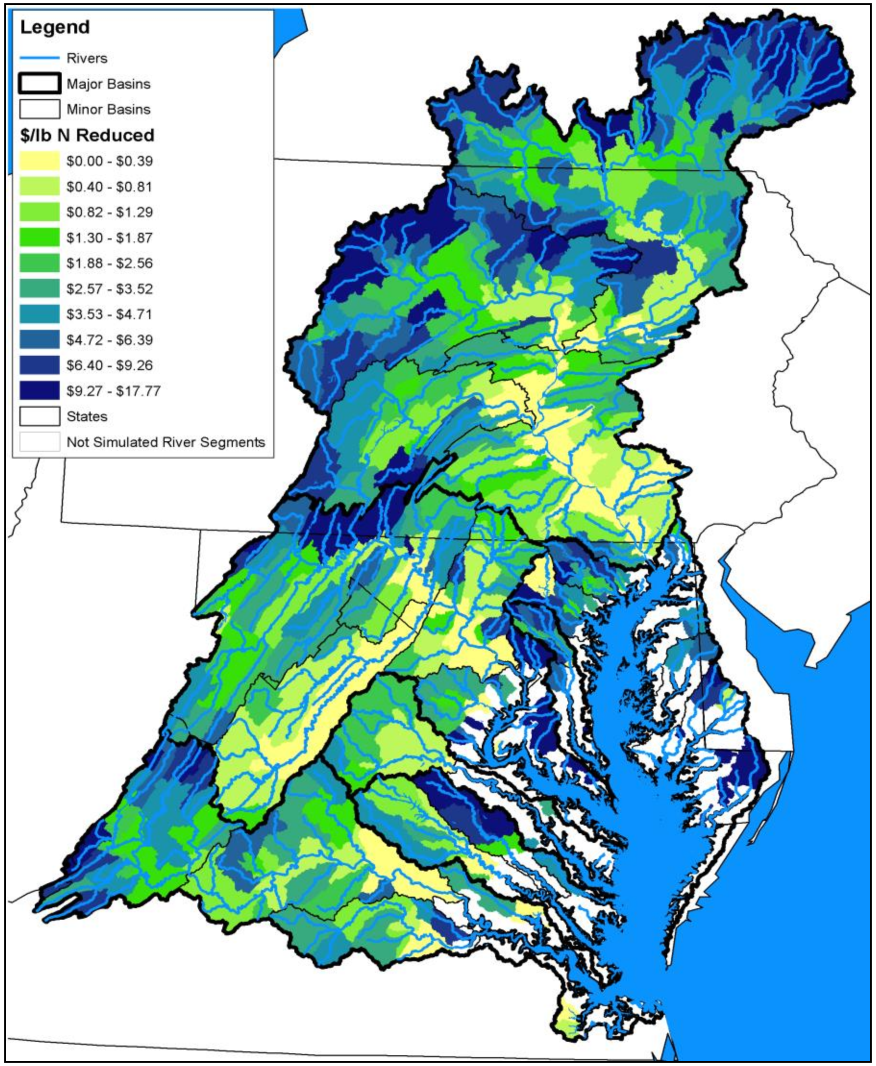


- Water quality improvements in freshwater segments are broadly distributed across the watershed

Estimating Water Quality Co-Benefits per Pound of Nutrient Reduction by River Segment (Cont'd)

- Step 4: For each segment, apportion WTP equally to each pound of load reduction received from upstream (accounting for attenuation)
- Step 5: For each segment, estimate total value of load reduction in the segment, by summing values received by all downstream segments
- Step 6: For each segment, estimate average value per lb of load reduced in the segment (divide by segment's total load reduction)

Estimated Value per Pound of N Load Reduction

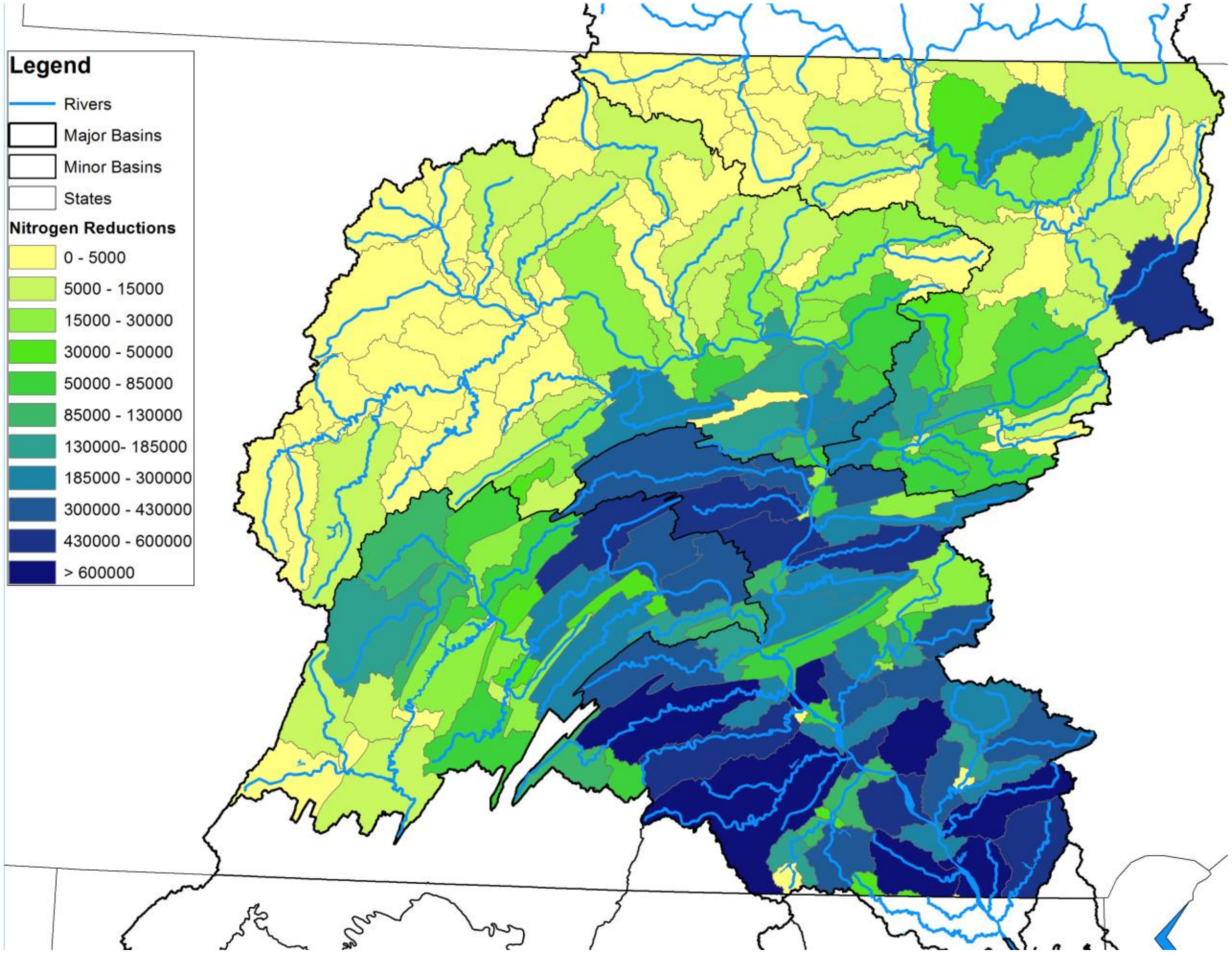


- Higher valued load reductions tend to be located in more upstream segments
  - Less dilution in smaller streams, so larger per-pound impacts
  - More downstream miles affected

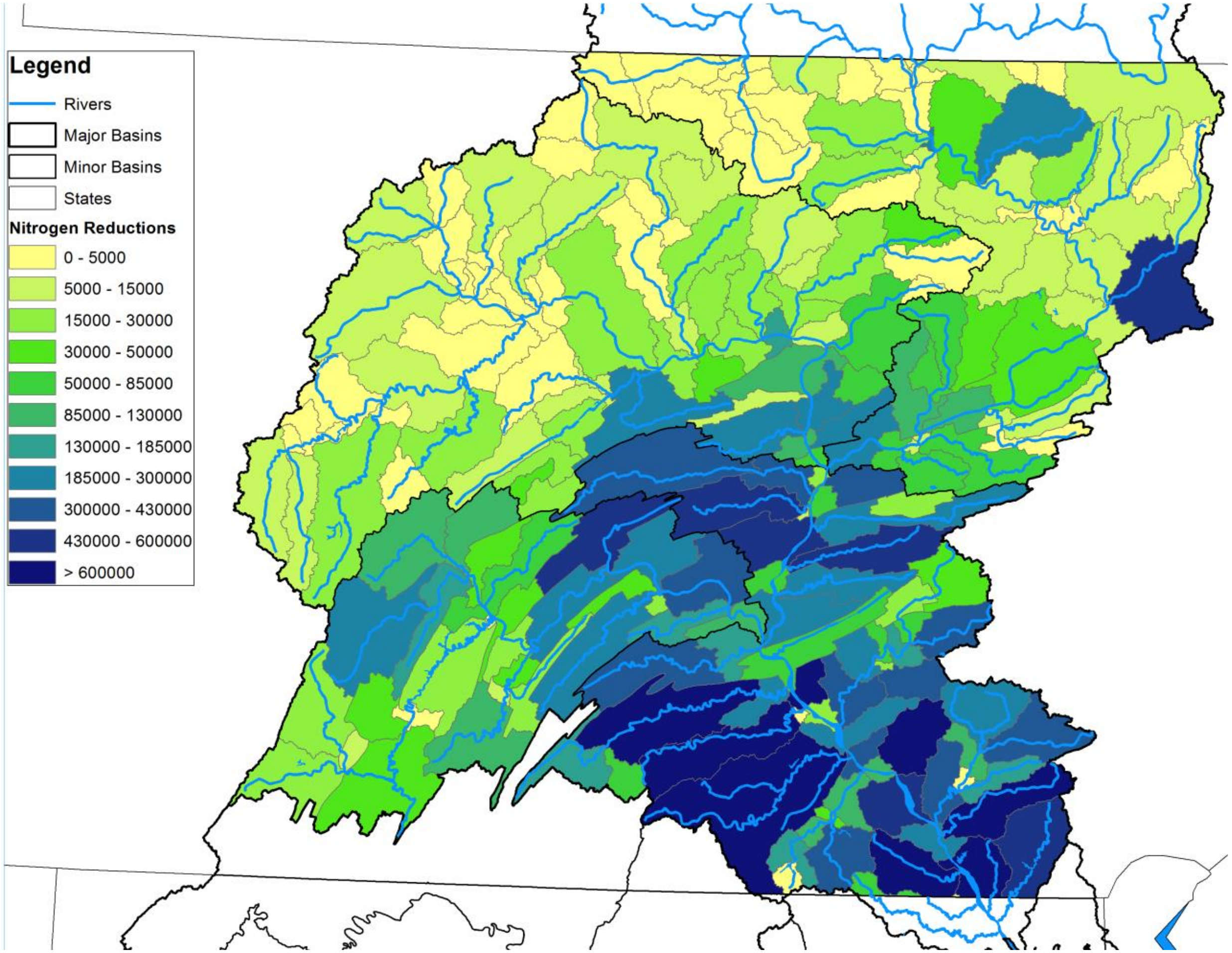
Scenario Results – Susquehanna, PA

Parameter	Source	Scenario: TMDL	Scenario: Cost Minimizing	Scenario: NET Cost Minimizing
N Load Reductions (mil. lbs/yr)	**Total**	**25.4**	**25.4**	**25.4**
	PS	4.7	3.6	3.2
	AgNPS	20.7	21.8	22.2
P Load Reductions (mil. lbs/yr)	**Total**	**0.7**	**0.7**	**0.7**
	PS	0.3	0.3	0.3
	AgNPS	0.5	0.5	0.5
Control Costs ($ mil./yr)	**Total**	**$280.0**	**$142.7**	**$158.9**
	PS	$60.0	$24.0	$21.1
	AgNPS	$220.0	$118.7	$137.7
Co-Benefits ($ mil./yr)	**Total**	**$137.2**	**$103.9**	**$135.3**
	PS	$29.0	$24.9	$26.2
	AgNPS	$108.2	$79.1	$109.1
NET Costs ($ mil./yr)	**Total**	**$142.8**	**$38.8**	**$23.6**
	PS	$31.0	($0.9)	($5.0)
	AgNPS	$111.8	$39.6	$28.6
Freshwater Quality Benefits	PS	$29.0	$24.9	$26.2
	AgNPS	$86.9	$62.1	$82.1
Carbon Benefits	AgNPS	$21.0	$16.7	$26.6
Hunting Benefits	AgNPS	$0.3	$0.2	$0.4

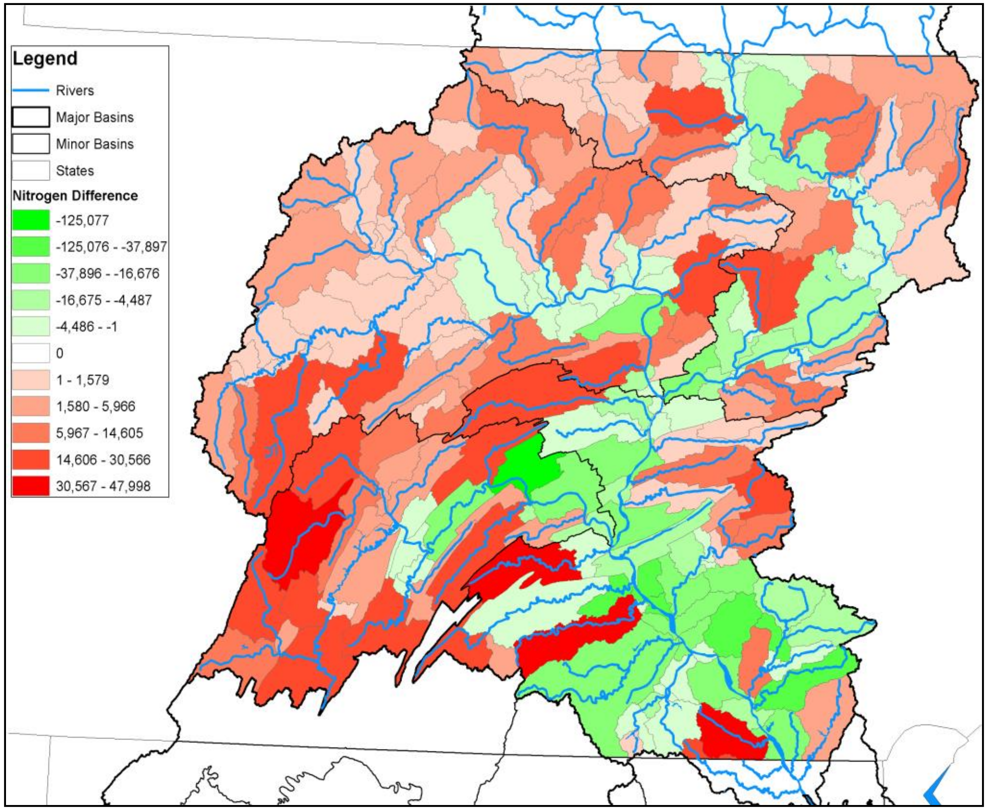
Spatial Distribution of N Reductions with Least-Cost Approach



Spatial Distribution of N Reductions with Least-NET-Cost Approach



Spatial Distribution of Difference in N Load Reductions



Comparing least-NET-cost approach with least-cost approach

- Accounting for co-benefits causes load reductions to shift farther from the Bay

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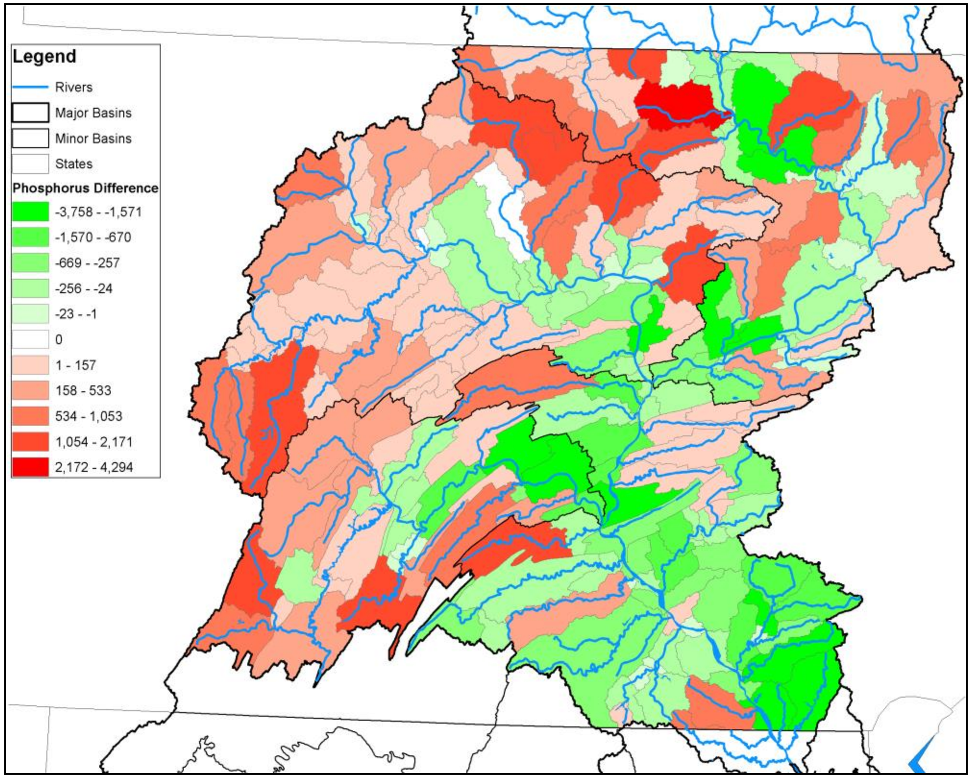
Spatial Distribution of Difference in P Load Reductions



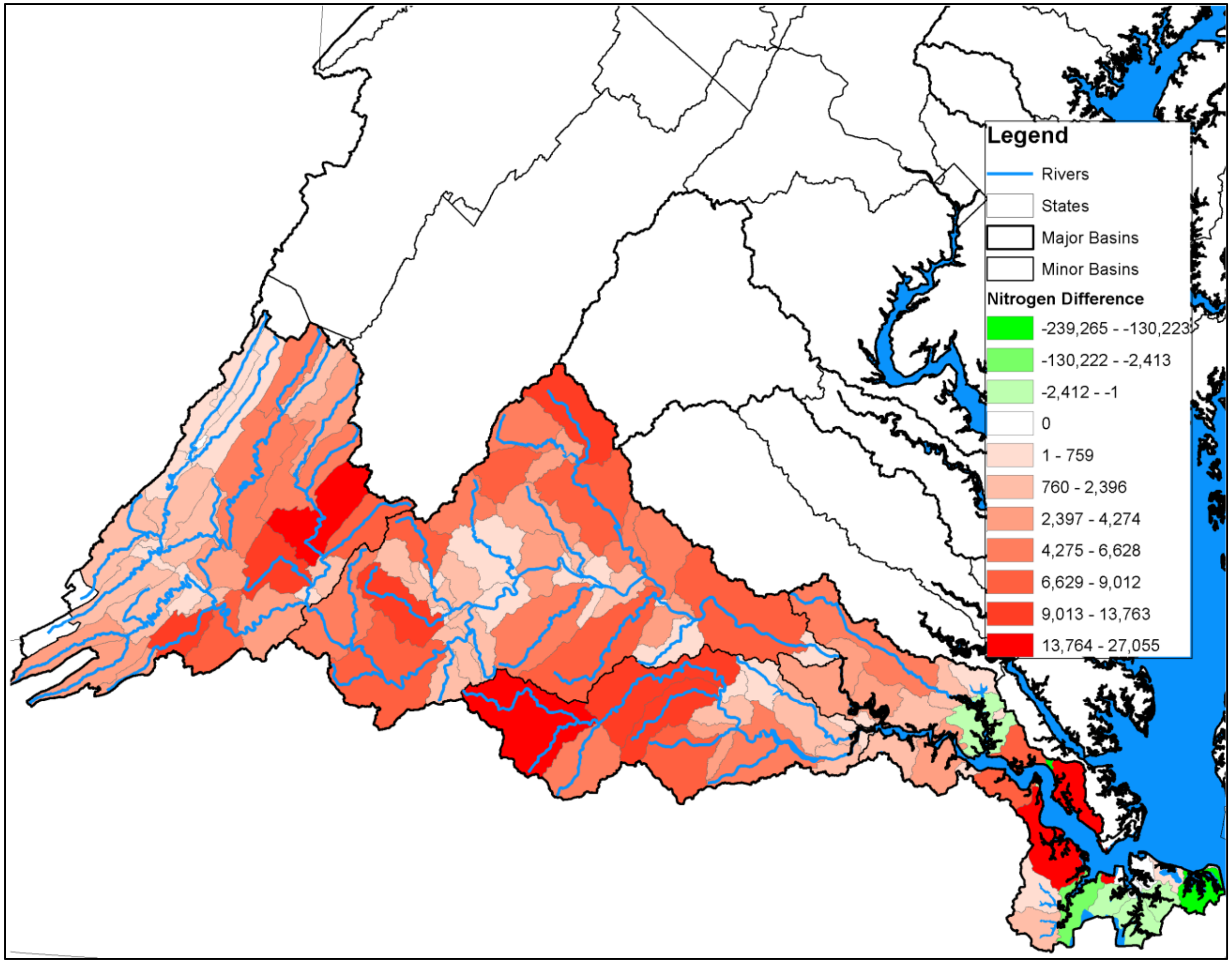
Comparing least-NET-cost approach with least-cost approach

- Accounting for co-benefits causes load reductions to shift farther from the Bay

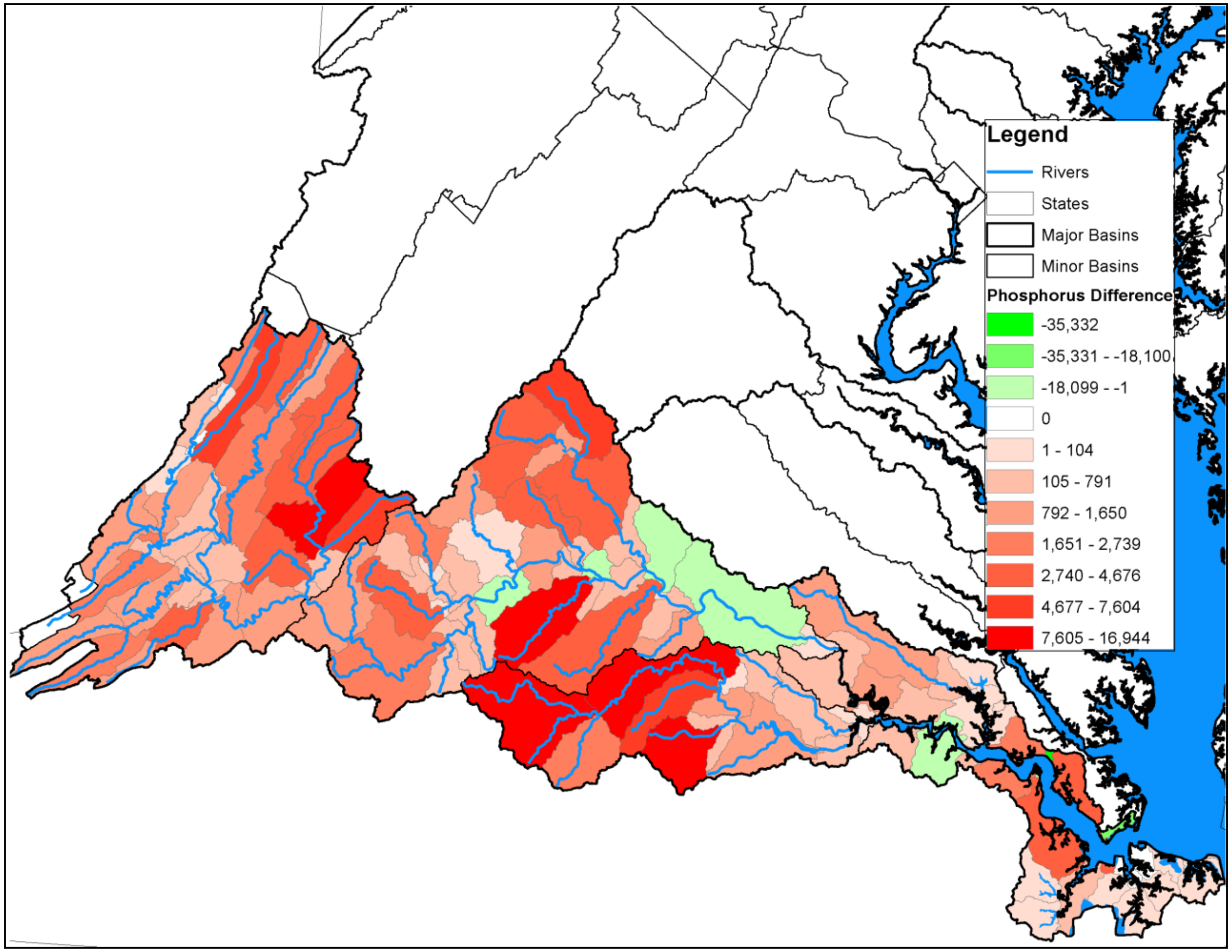
Scenario Results – James River, VA

Parameter	Source	Scenario: TMDL	Scenario: Cost Minimizing	Scenario: NET Cost Minimizing
N Load Reductions (mil. lbs/yr)	**Total**	**11**	**11**	**11**
	PS	9.6	9.2	8.8
	AgNPS	1.4	1.8	2.1
P Load Reductions (mil. lbs/yr)	**Total**	**0.9**	**0.9**	**1.1**
	PS	0.6	0.4	0.3
	AgNPS	0.3	0.5	0.7
Control Costs ($ mil./yr)	**Total**	**$188.0**	**$101.2**	**$118.5**
	PS	$138.0	$84.6	$75.7
	AgNPS	$50.0	$16.7	$42.8
Co-Benefits ($ mil./yr)	**Total**	**$41.8**	**$39.0**	**$81.1**
	PS	$6.3	$3.5	$3.6
	AgNPS	$35.5	$35.5	$77.4
NET Costs ($ mil./yr)	**Total**	**$146.2**	**$62.2**	**$37.5**
	PS	$131.7	$81.1	$72.1
	AgNPS	$14.5	($18.8)	($34.6)
Freshwater Quality Benefits	PS	$6.3	$3.5	$3.6
	AgNPS	$24.4	$26.4	$45.4
Carbon Benefits	AgNPS	$11.1	$9.0	$31.8
Hunting Benefits	AgNPS	$0.1	$0.1	$0.2

Spatial Distribution of Difference in N Load Reductions



Spatial Distribution of Difference in P Load Reductions



Conclusions

- In all scenarios, freshwater quality co-benefits are large, even compared to carbon sequestration benefits
- Least-NET-cost scenario does not necessarily result in highest co-benefits
  - In Susquehanna, the TMDL scenario does
- Compared to the least-cost scenario, the least-NET-cost scenario shifts load reductions
  - from PS to agricultural NPS
  - to areas farther from the Bay
- Providing additional incentives for upstream load reductions could improve the overall efficiency (in a NET-cost sense) of meeting TMDL goals