# Moving Towards Sustainable Land Management in the Chesapeake Bay Through Novel Engagement Strategies

Tamie Veith[1], Heather Gall[2], James Shortle[2], Rob Brooks[2], and Peter Kleinman[1]

[1]USDA Agricultural Research Service
[2]Pennsylvania State University

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**Abstract**

Each state and district within the Chesapeake Bay watershed has cooperated with the Chesapeake Bay Program (CBP) to develop local Watershed Implementation Plans (WIPs) that identify the type and quantity of best management practices (BMPs) that, if implemented, are estimated to meet 2025 Total Maximum Daily Load (TMDL) goals for Bay water quality. However, top-down management of large regions, such as the 167,000-km2 Bay catchment, is often necessarily limited by the feasibility of providing implementation plans that are customized by watershed hydro-physiographic characteristics and socio-political considerations. The Bay simulation model divides the catchment into watersheds of approximately 350 km2 each; these watersheds become the Bay model's smallest overland management unit. We used Bay WIP plans, local information, and a hydrologic model called Topo-SWAT to model three of these smallest-unit watersheds in more local detail. Our smallest management unit became contiguous, similarly managed, cropland areas (i.e., one or several neighboring agricultural fields) and these management units were further divided by the topographic wetness index. Our watersheds represent three distinct hydrological and geochemical regions within the Chesapeake Bay catchment, namely Appalachian Valley and Ridge – karst, Appalachian Valley and Ridge – nonkarst, and Appalachian Piedmont. We modeled three scenarios for each watershed: baseline (pre-WIP), WIP implementation, and "smarter" WIP placement where we targeted BMP placements for cost-effectiveness. We then compared results among scenarios as well as across watersheds. We are interested to see how well the models agree at the watershed outlet, discover cost-effective BMP placements within each watershed that meet WIP goals, and compare our findings across the physiographic regions to determine how they can guide regional planning.

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## Abstract

Each state and district within the Chesapeake Bay watershed has cooperated with the Chesapeake Bay Program (CBP) to develop local Watershed Implementation Plans (WIPs) that identify the type and quantity of best management practices (BMPs) that, if implemented, are estimated to meet 2025 Total Maximum Daily Load (TMDL) goals for Bay water quality. However, top-down management of large regions, such as the 167,000-$km^2$ Bay catchment, is often necessarily limited by the feasibility of providing implementation plans that are customized by watershed hydro-physiographic characteristics and socio-political considerations. The Bay simulation model divides the catchment into watersheds of approximately 350 $km^2$ each; these watersheds become the Bay model's smallest overland management unit. We used Bay WIP plans, local information, and a hydrologic model called Topo-SWAT to model three of these smallest-unit watersheds in more local detail. Our smallest management unit became contiguous, similarly managed, cropland areas (i.e., one or several neighboring agricultural fields) and these management units were further divided by the topographic wetness index. Our watersheds represent three distinct hydrological and geochemical regions within the Chesapeake Bay catchment, namely Appalachian Valley and Ridge -- karst, Appalachian Valley and Ridge – nonkarst, and Appalachian Piedmont. We modeled three scenarios for each watershed: baseline (pre-WIP), WIP implementation, and "smarter" WIP placement where we targeted BMP placements for cost-effectiveness. We then compared results among scenarios as well as across watersheds. We are interested to see how well the models agree at the watershed outlet, discover cost-effective BMP placements within each watershed that meet WIP goals, and compare our findings across the physiographic regions to determine how they can guide regional planning.

## Case Study Watersheds

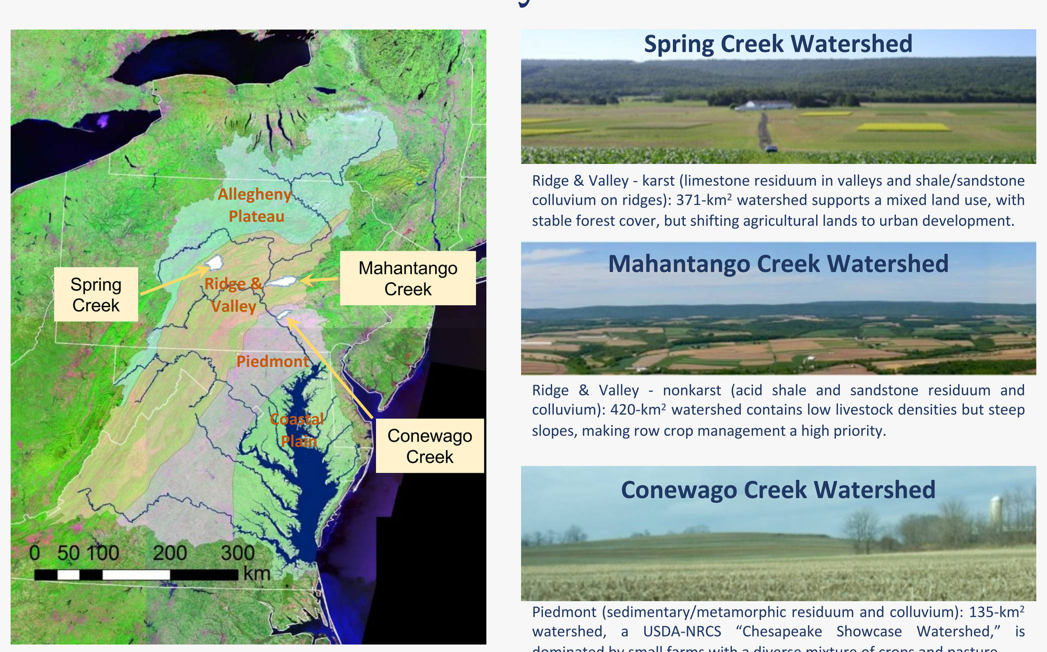



**Figure 1. Chesapeake Bay and selected case study watersheds.**

**2017 Oversight Status** (Ongoing / Enhanced / Backstop)

| | Agriculture | Urban/Suburban | Wastewater | Trading/Offsets |
|---|---|---|---|---|
| Delaware | Enhanced Oversight | Ongoing Oversight | Ongoing Oversight | Ongoing Oversight |
| District of Columbia | Not Applicable | Ongoing Oversight | Ongoing Oversight | Ongoing Oversight |
| Maryland | Ongoing Oversight | Enhanced Oversight | Ongoing Oversight | Ongoing Oversight |
| New York | Ongoing Oversight | Ongoing Oversight | Enhanced Oversight | Ongoing Oversight |
| Pennsylvania | Backstop Actions Level | Backstop Actions Level | Ongoing Oversight | Enhanced Oversight |
| Virginia | Ongoing Oversight | Ongoing Oversight | Ongoing Oversight | Ongoing Oversight |
| West Virginia | Ongoing Oversight | Ongoing Oversight | Ongoing Oversight | Ongoing Oversight |

**Figure 2. 2017 EPA oversight status for Bay states.**
Source: EPA, 2017

## Scenario Development for Water Quality Modeling

- Scenario A: "baseline"
  *represent state of the watershed around 2012*
- Scenario B: "WIP"
  *meet WIP-determined coverage area per BMP*
- Scenario C: "Smarter" WIP
  *place WIP BMPs where most effective until goal is met; don't worry about matching WIP-estimated coverage area*
- Scenario D: "Local Objectives"
  *incorporate additional issues raised by watershed stakeholders*
- Scenario E: "Transformational Change"
  *best case scenarios; likely requiring paradigm shifts and policy changes*

Highlighted Results

## "Shared Discovery" Research Approach

Via community workshops, Penn State Center for Nutrient Solutions (CNS) actively engaged stakeholders to determine preferences for using limited resources to achieve water quality improvement goals. This information, in combination with state WIP goals, guided model scenario development and enabled locally-relevant land management recommendations.

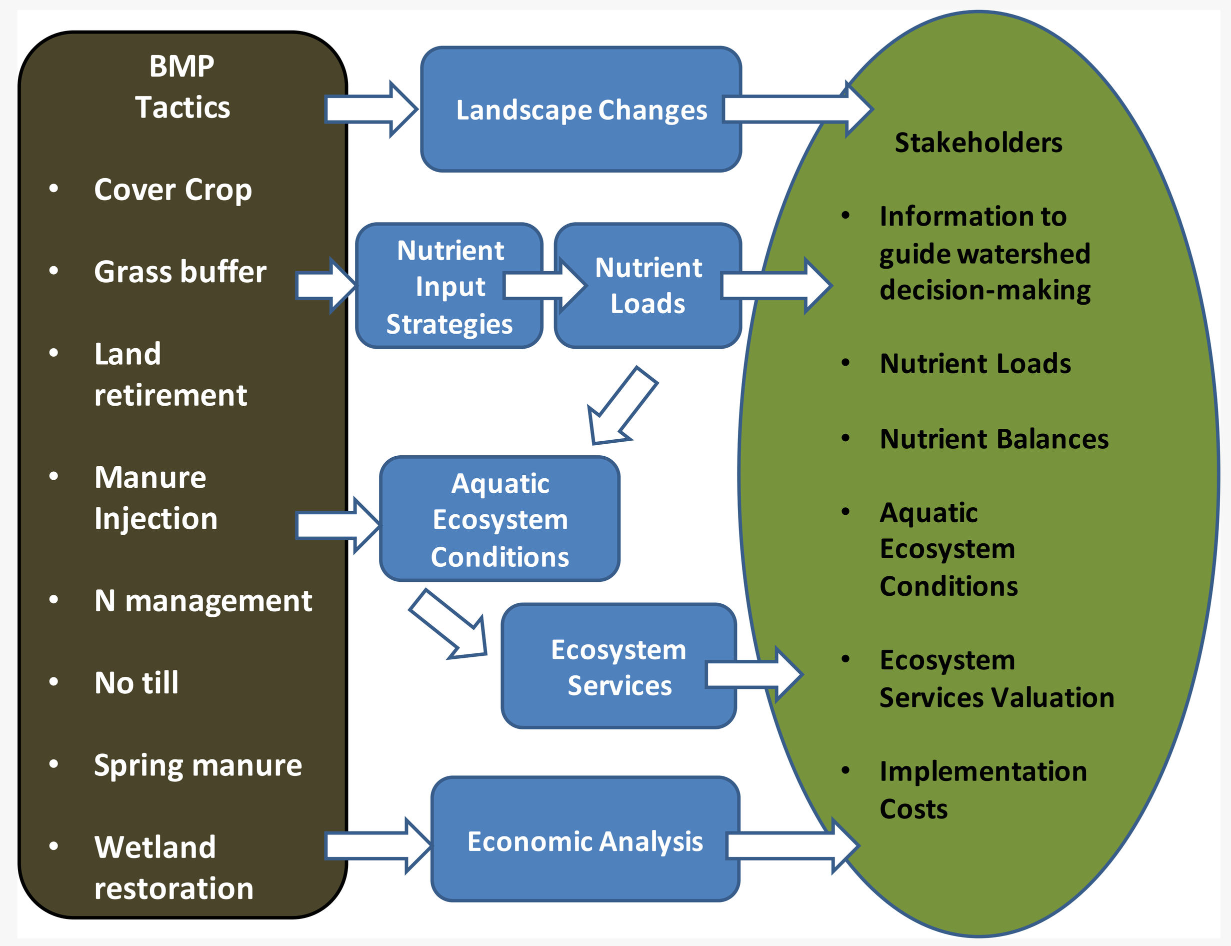



**Figure 3. Schematic of overall research and engagement approach.**

## Scenario Modeling with Soil & Water Assessment Tool

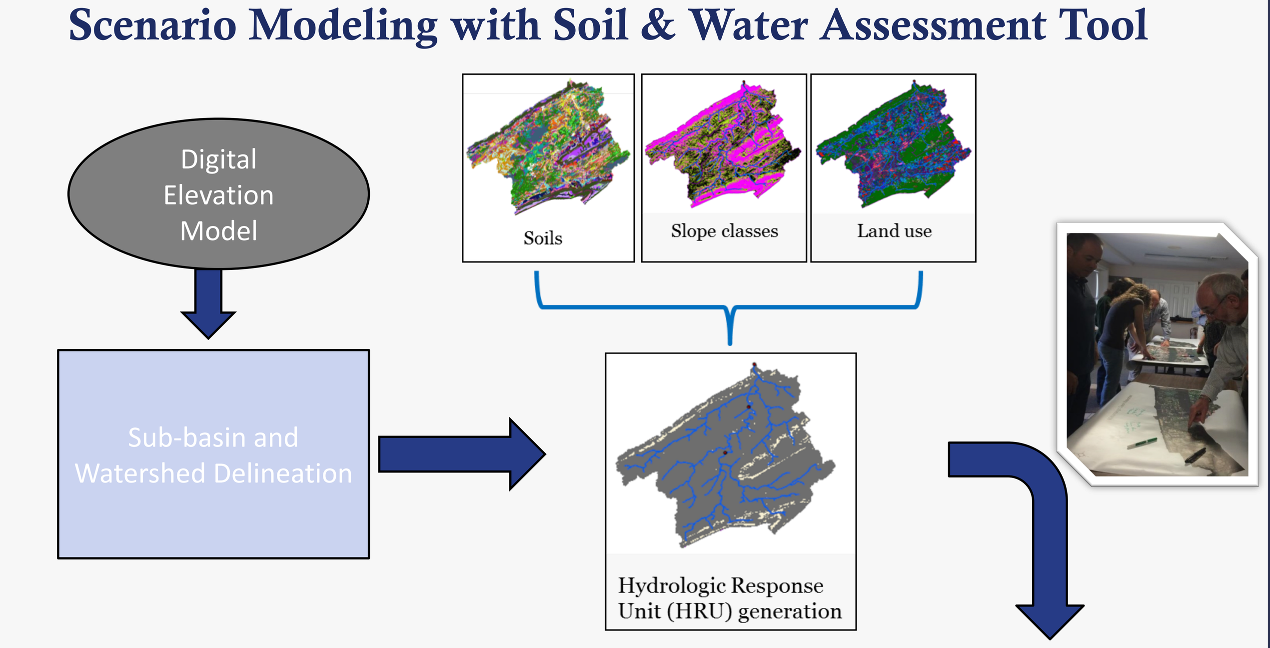



**Figure 4. Schematic of SWAT model input and output.**

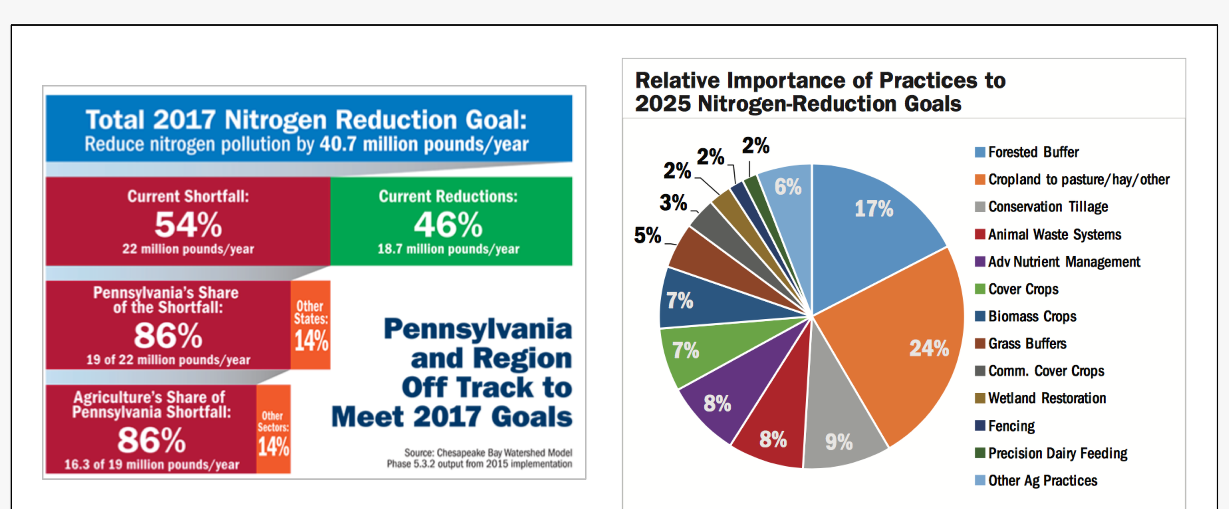



**Figure 5. Pennsylvania BMP portfolio to meet nitrogen reduction goals.**
Source: Chesapeake Bay Watershed Model, 2015

## Spatially targeting critical source areas uses suites of lower-cost, management-based BMPs

**Spring Creek**

| | PA Phase II | | Scenario B | | Scenario C | |
|---|---|---|---|---|---|---|
| | WIP guide for watershed | | WIP as simulated in SWAT | | placement in SWAT | |
| BMP | Target ha | USD/ha | Converted ha | Cost (USD) | Converted ha | Cost (USD) |
| cover crops | 1520 | $ 55.00 | 1520 | $83,600 | 3692 | $203,066 |
| conservation tillage | 385 | $ 7.40 | 385 | $2,849 | | |
| enhanced N mang. | | $ 6.90 | | | 6154 | $42,459 |
| no-till management | 261 | $ 7.40 | 261 | $1,931 | 1296 | $9,590 |
| land retirement | 1473 | $ 299.40 | 1473 | $440,887 | | |
| manure injection | 97 | $ 29.00 | 97 | $2,823 | 3692 | $107,071 |
| trees outside buffer | 24 | $ 195.00 | 24 | $4,746 | | |
| forest buffer | 183 | $ 90.00 | 183 | $16,430 | | |
| grass buffer | 134 | $ 63.00 | 134 | $8,434 | 160 | $10,080 |
| Total | 4077 | | 4077 | $561,701 | 14994 | $372,266 |

**Mahantango**

| | PA Phase II | | Scenario B | | Scenario C | |
|---|---|---|---|---|---|---|
| | WIP guide for watershed | | WIP as simulated in SWAT | | placement in SWAT | |
| BMP | Target ha | USD/ha | Converted ha | Cost (USD) | Converted ha | Cost (USD) |
| cover crops | 3981 | $ 55.00 | 4131 | $227,228 | 2453 | $134,940 |
| conservation tillage | 5340 | $ 7.40 | 5346 | $39,563 | | |
| enhanced N mang. | | $ 6.90 | | | 4907 | $33,858 |
| no-till management | 356 | $ 7.40 | 470 | $3,477 | 4416 | $32,680 |
| land retirement | 2509 | $ 299.40 | 2194 | $656,754 | | |
| manure injection | 185 | $ 29.00 | 202 | $5,868 | 2944 | $85,380 |
| trees outside buffer | 356 | $ 195.00 | 385 | $75,168 | | |
| forest buffer | 2509 | $ 90.00 | 23 | $2,044 | | |
| grass buffer | 185 | $ 63.00 | 236 | $14,868 | 174 | $10,962 |
| Total | 15421 | | 12988 | $1,024,969 | 14895 | $297,820 |

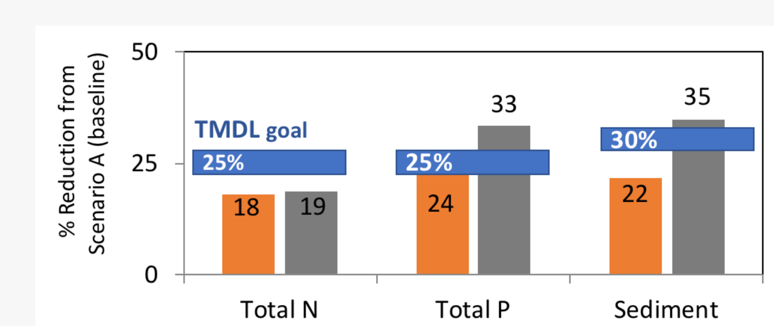
**Conewago**

| | PA Phase II | | Scenario B | | Scenario C | |
|---|---|---|---|---|---|---|
| | WIP guide for watershed | | WIP as simulated in SWAT | | placement in SWAT | |
| BMP | Target ha | USD/ha | Converted ha | Cost (USD) | Converted ha | Cost (USD) |
| cover crops | 1301 | $ 55.00 | 1243 | $68,372 | 1629 | $89,607 |
| conservation tillage | 670 | $ 7.40 | 670 | $4,958 | | |
| enhanced N mang. | | $ 6.90 | | 0 | 3394 | $23,420 |
| no-till management | 670 | $ 7.40 | 670 | $4,958 | 815 | $6,028 |
| land retirement | 399 | $ 299.40 | 771 | $230,837 | | |
| manure injection | 97 | $ 29.00 | 84 | $2,436 | 2037 | $59,059 |
| trees outside buffer | 195 | $ 195.00 | 47 | $9,165 | | |
| forest buffer | 87 | $ 90.00 | 45 | $4,050 | | |
| grass buffer | 36 | $ 63.00 | 45 | $2,835 | 90 | $5,670 |
| Total | 3454 | | 3575 | $327,611 | 7965 | $183,784 |

## "Smart" placement of WIP management-based BMPs improves nutrient reductions, and costs less.

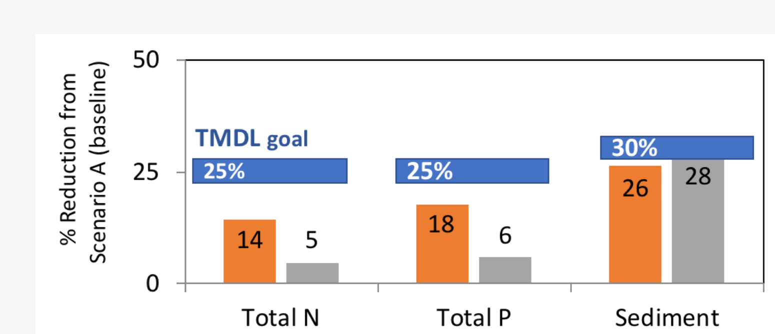
**Spring Creek**

*BMP cost*
$15/ha: WIP
$10/ha: "smart"



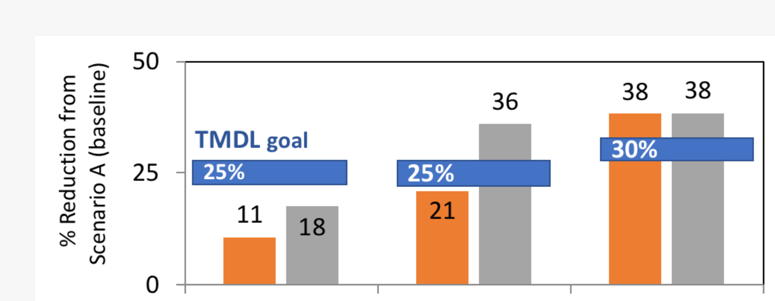

**Mahantango**

*BMP cost*
$24/ha: WIP
$ 7/ha: "smart"

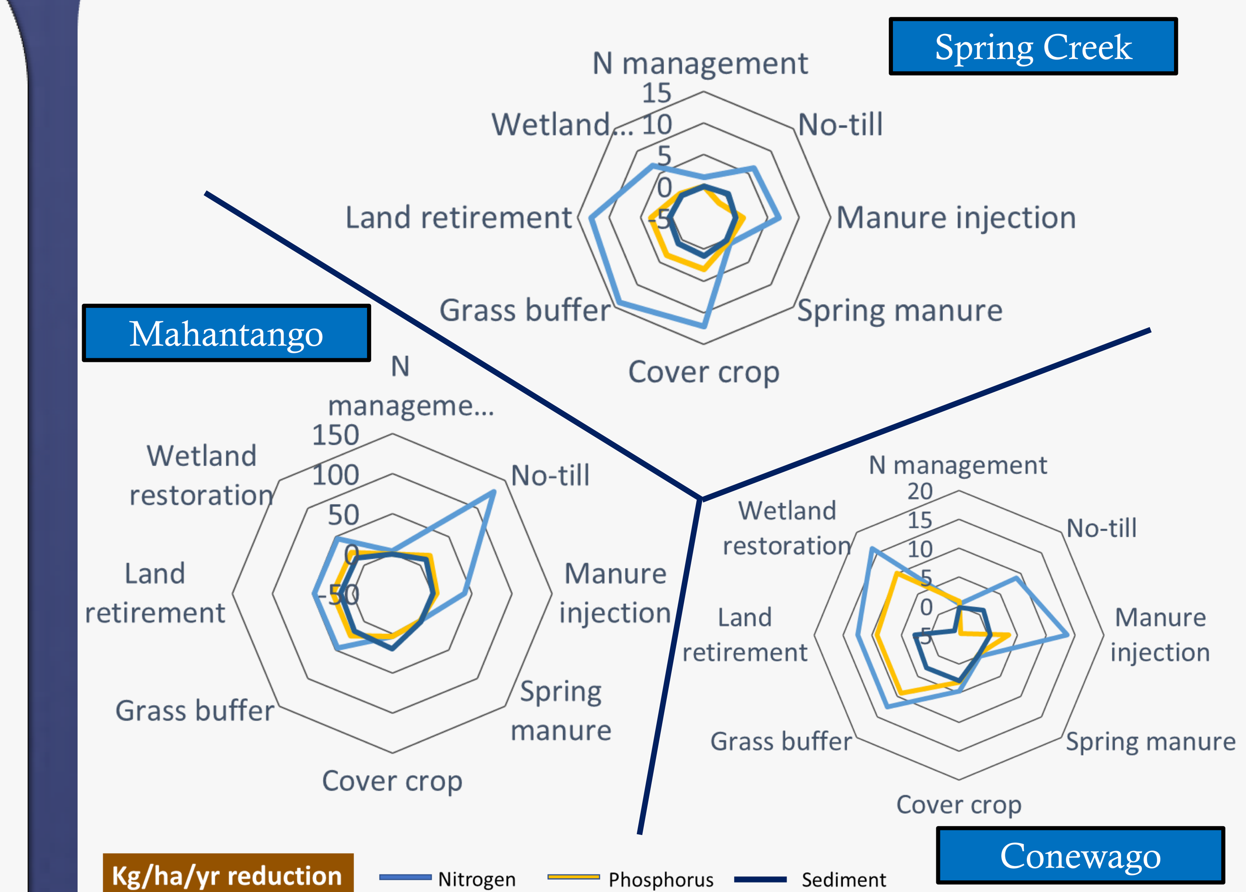



**Conewago**

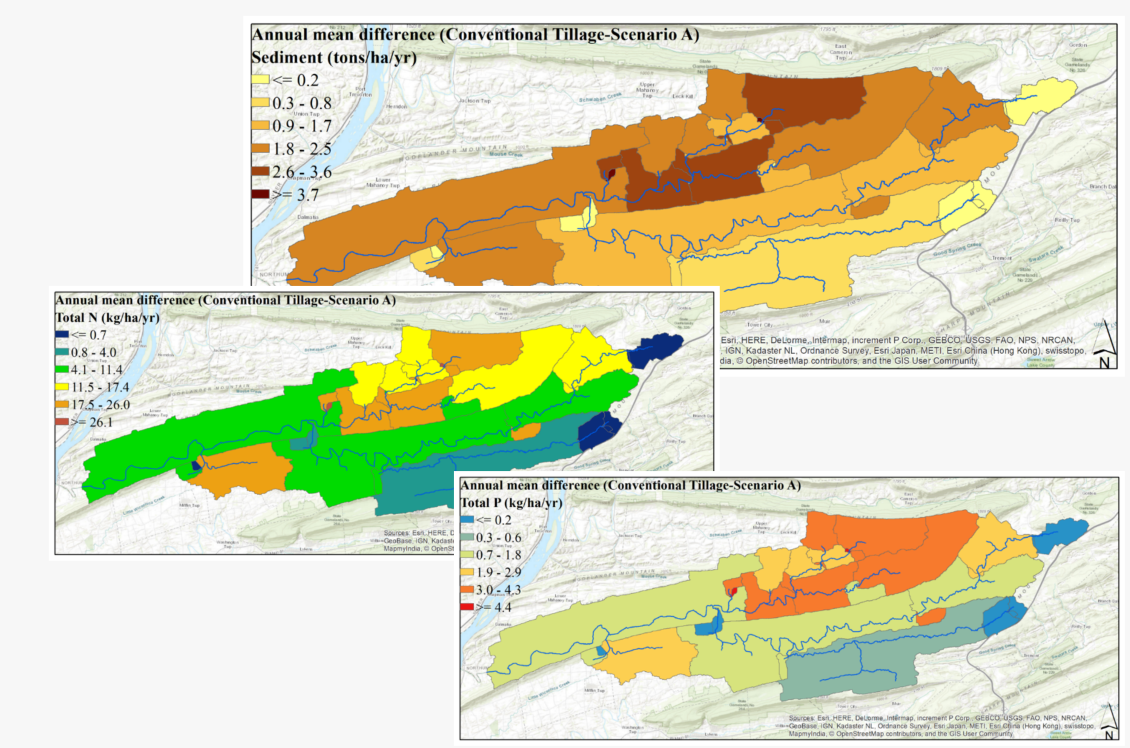
*BMP cost*
$24/ha: WIP
$14/ha: "smart"




## Physiographic Regions Matter




## Quantifying Current Impact Boosts Morale




## Lessons Learned & Major Outcomes

- We can meet Bay's target load reduction at lowest cost by
  - No-till: reducing periods of soil disruption and bareness
  - Protecting stream edges
  - Making the most of manure and nutrients
    *(incorporation and precision application)*
- In-field management changes => low cost and big reward
  *(improve soil health, reduce nutrient and erosion losses)*
  - Manure timing and incorporation
  - Conservation tillage
  - Add cover crops and legumes to reduce N needs
- Space, place, and timing of stressors & management-related activities matter greatly
- Suites of management-based BMPS in critical areas leaves $$ for community improvements *(e.g., streambeds, wetlands, rain gardens)*

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