Applying Watershed Models to Inform Phosphorus Management in a Changing Climate

David S. Andrews[1], Sarah Trick[2], Joseph Chairvolotti[3], **Andrew S. Brainard[1]**, David A. Matthews[1]

[1] Upstate Freshwater Institute
[2] Jefferson County Soil and Water Conservation District
[3] Oswego County Soil and Water Conservation District

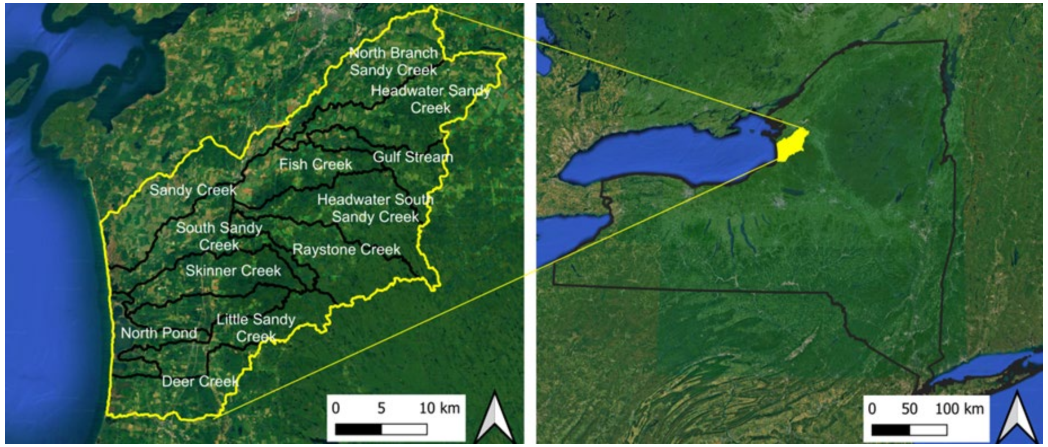
2026 NYSFOLA Annual Conference
May 8, 2026

Overview

many

- The challenge(s) of water quality management
  ^
- Models as useful tools

Case study! *Watershed modeling*



Sandy Creeks area of NYS
eastern shore of Lake Ontario

The Challenge

Water quality management can be bewildering.

Action!

(4) Will it work? → **Expectations**

If so, **(3)** What do we do? → **Alternatives, cost-benefit**

If so, **(2)** Should we do anything? → **Consensus, buy-in**

(1) Do we have a water quality issue / concern? → **Monitoring, analysis**

The Challenge

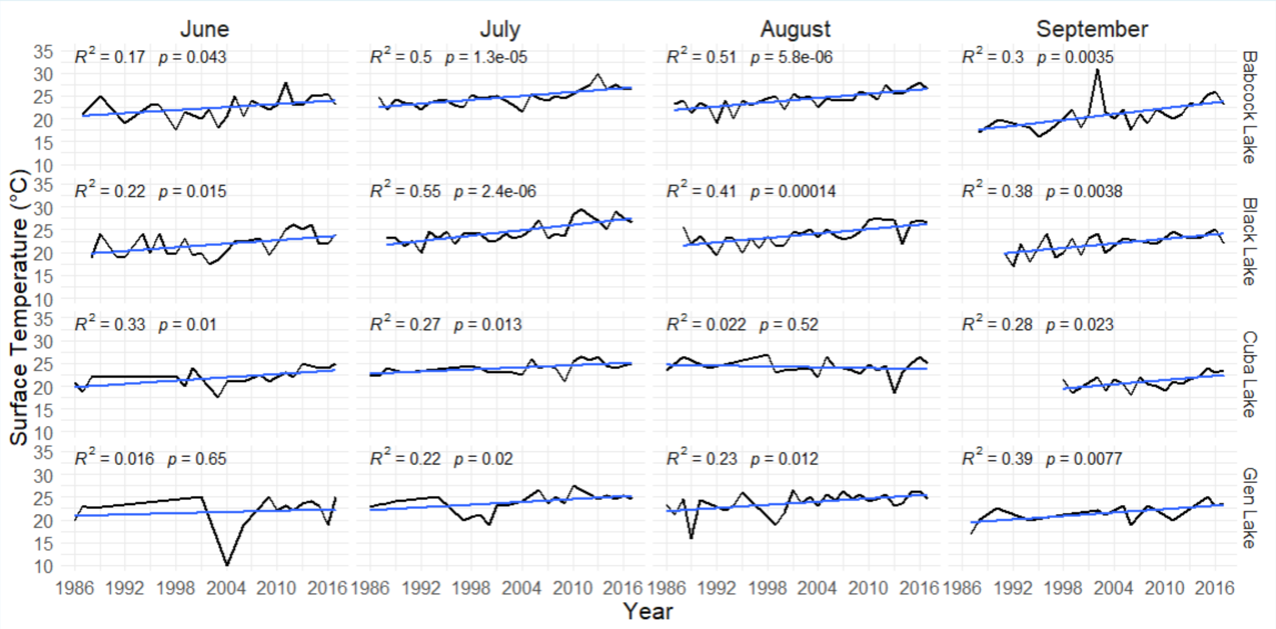
Will actions today be applicable to future conditions?

… with a changing climate

Increased surface water temperatures may affect:

- Phytoplankton growth
- Recycling of nutrients
- Lake stratification

Increased <u>lake</u> surface temperatures



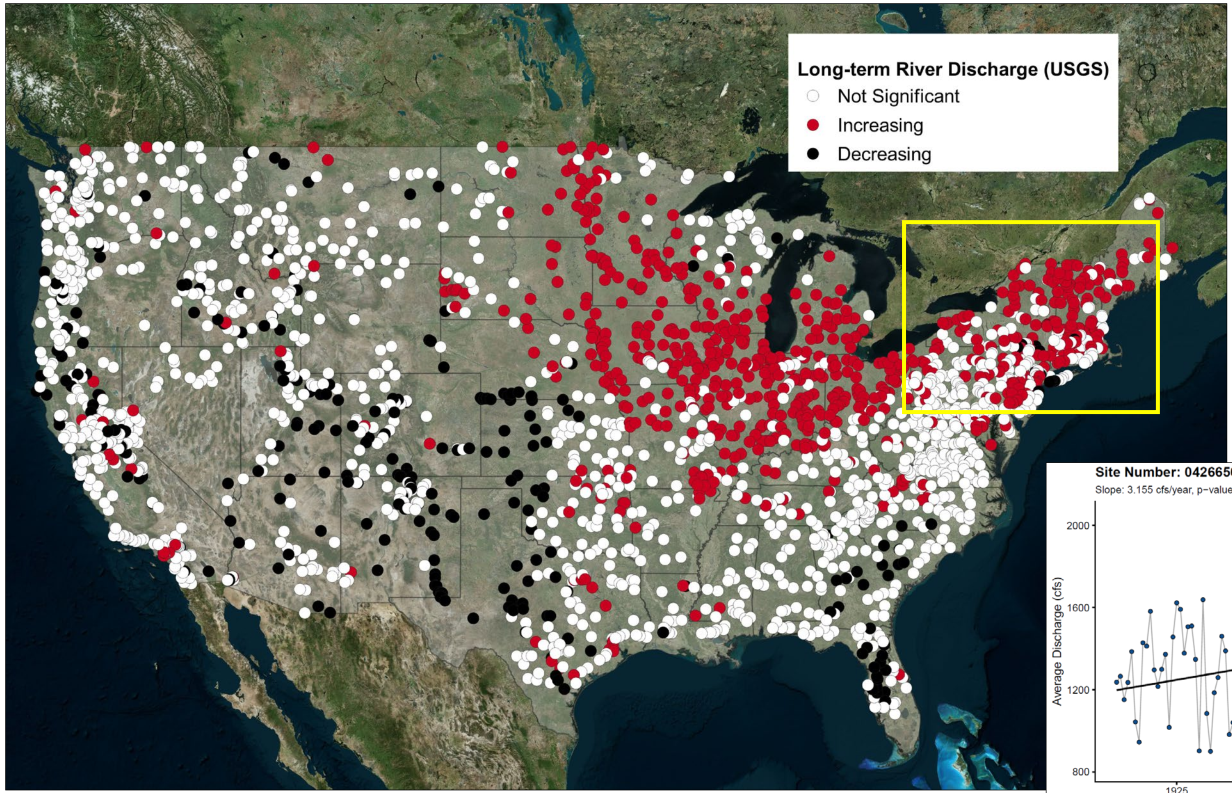
+0.6°C/ decade **+0.7°C/ decade** **+1.1°C/ decade**

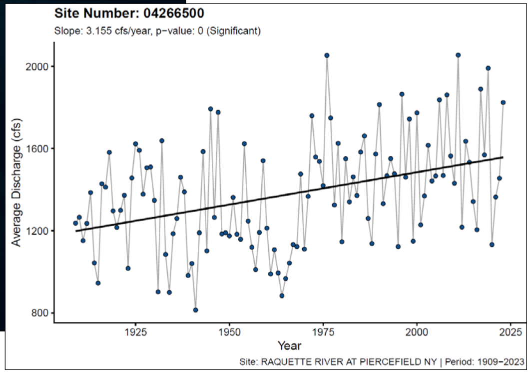
Caves *et al.*, unpubl.

The Challenge

Will actions today be applicable to future conditions?

Long-term trends in river discharge





Brainard *et al.*, unpubl.

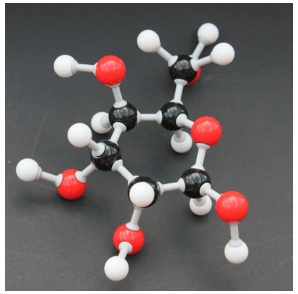
53% of USGS gauges in NYS showed increasing annual discharge (through 2023)

<u>NE Climate Scenarios</u>:
Increased air temperature, increase precipitation

Will management alternative(s) overcome potential increased flow and nutrient loading?

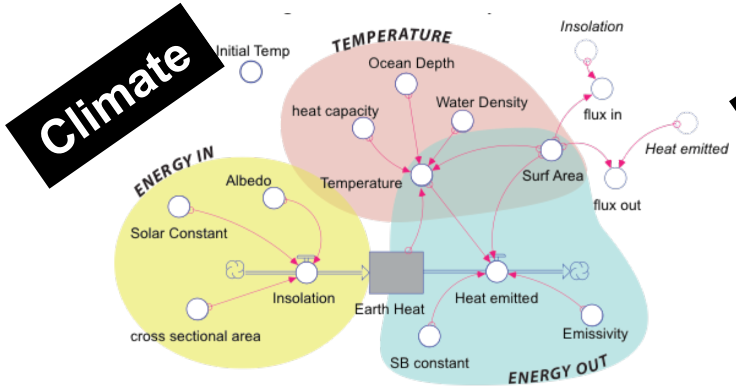
Models

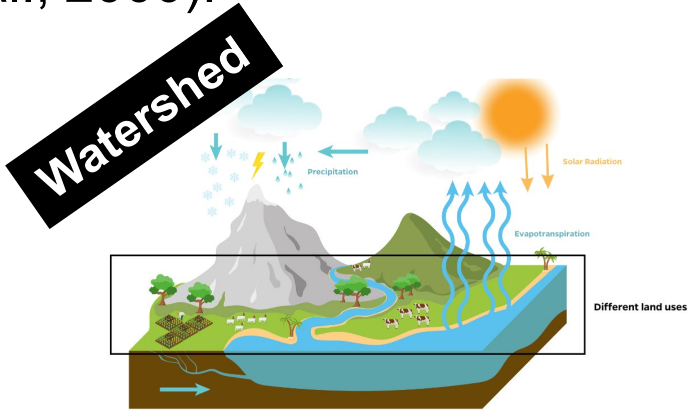
“A simplification of reality that is constructed to gain insights into select attributes of a particular physical, biological, economic, or social system.” (NRC, 2007)



Many more examples…

Computation models = “relationship among components of a system using mathematical representations” (Van Waveren et al., 2000).



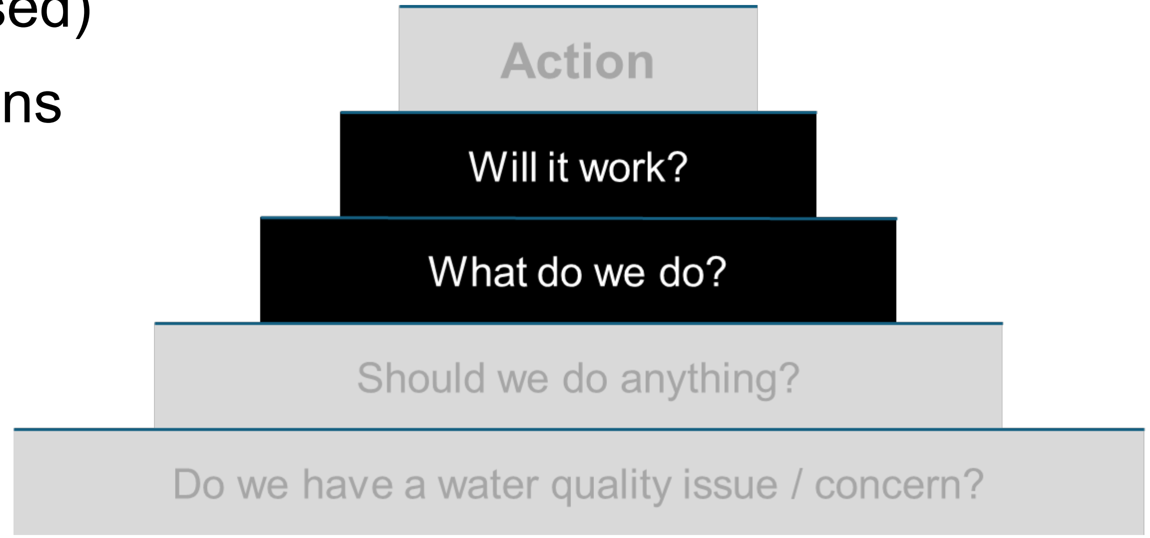


Dave Andrews, Sen. Research Scientist

Models

TOOLS

- Extend monitoring data
- Evaluate future conditions, management interventions, and past actions (hindcast)
- Help to identify priority actions (evidence-based)
- Build shared alignment on issues and solutions



Watershed Modeling

TOOLS

Inputs:
- Land use/land cover
- Soils
- Point source(s)
- Septic systems
- Weather (temperature, precipitation)
- Existing Best Management Practices (BMPs)
- Etc.

→ **Watershed model** →

Outputs:
- Stream flow
- Nutrient load

CALIBRATE
(adjusting model coefficients)

Monitoring data

Compare to measured flow/monitoring data

CONFIRM/TEST
(without adjusting coefficients)

Monitoring data

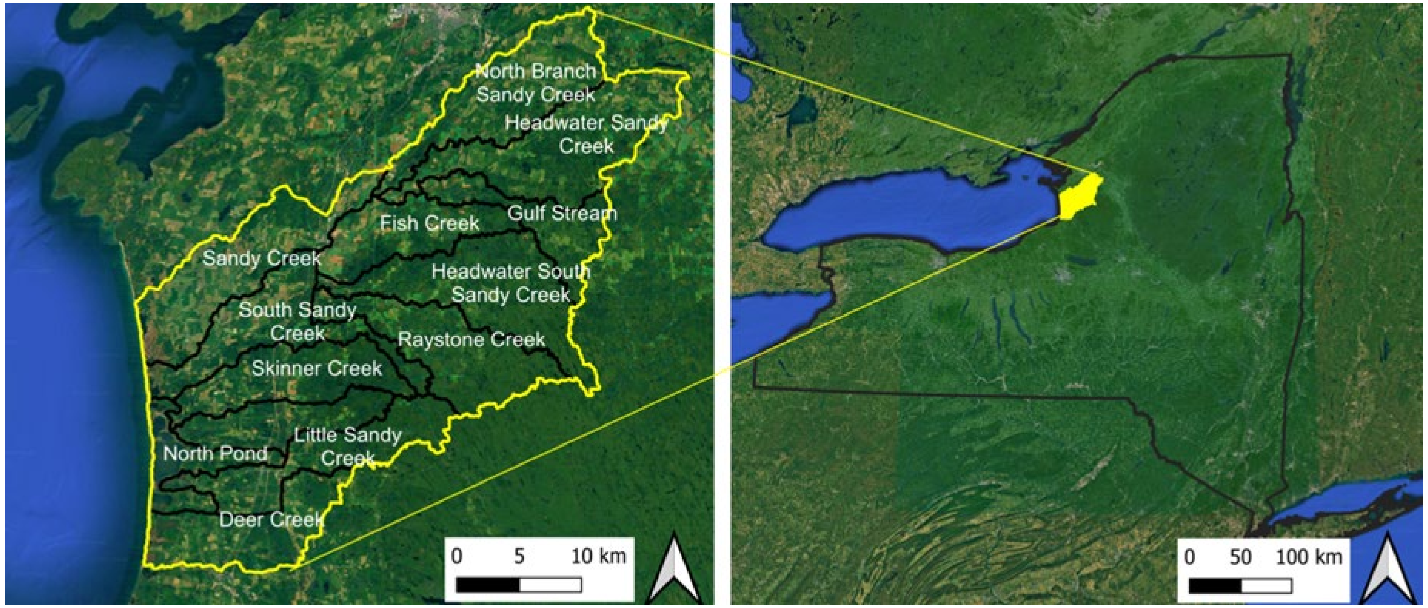
Compare to measured flow/monitoring data

Are models usable for intended purpose?

Case Study

Sandy Creeks area of NYS
eastern shoreline of Lake Ontario

In support of developing a Nine Element Watershed Plan (9EP)



Generalized Watershed Loading Function (GWLF-E)
Model

13 subwatersheds

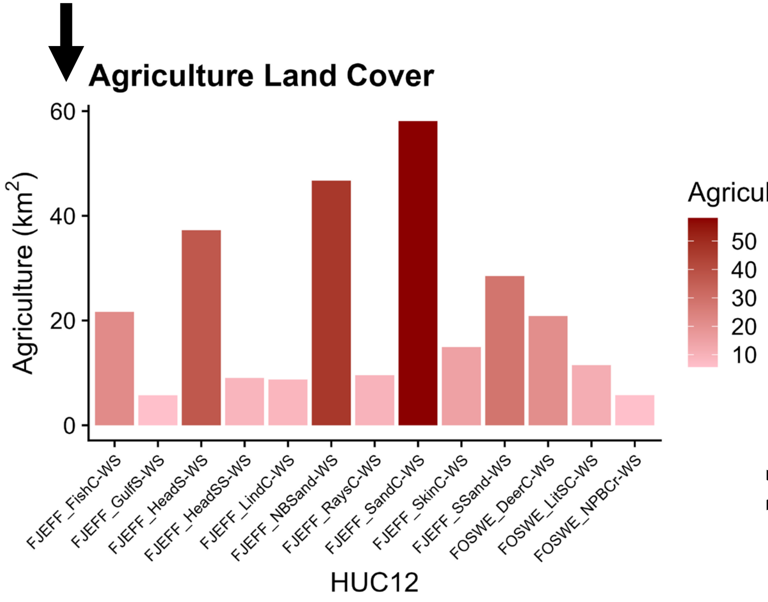
~ 1,000 km^2 study area

Case Study

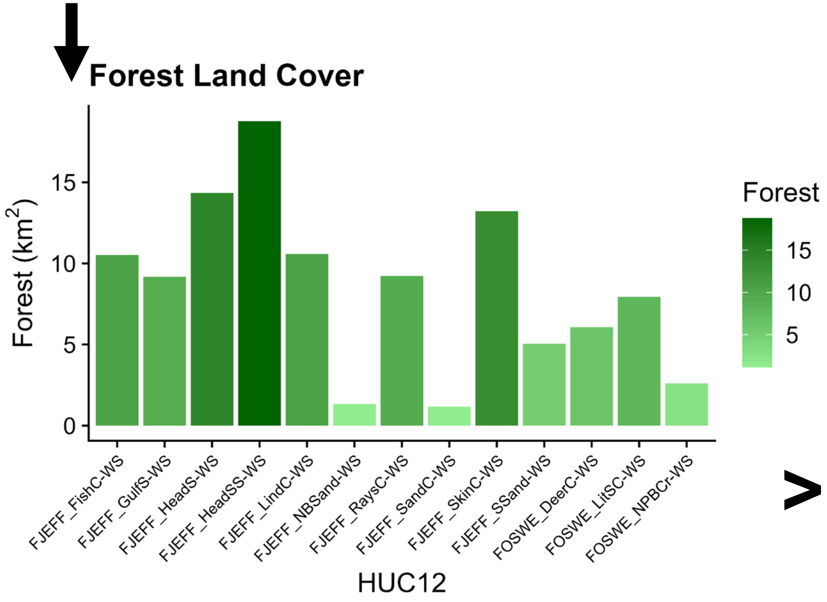
Sandy Creeks area of NYS

eastern shoreline of Lake Ontario

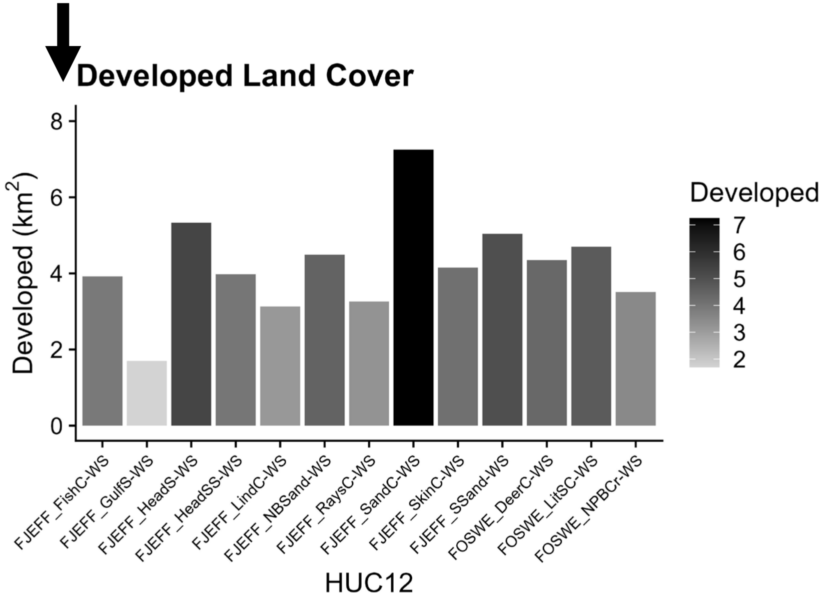
Land use covers a mix of agricultural, forested, and low-density residential areas



>



>



- Variability in land use/land cover

Case Study

Sandy Creeks area of NYS
eastern shoreline of Lake Ontario

Focus: Total phosphorus (TP)

5 total scenarios informed by stakeholders (9EP)

Quantify Current Phosphorus Loading

Estimate how much TP is reaching streams from different land uses and sources across all 13 subwatersheds

Evaluate Future Scenarios

Test management actions and climate change before they are implemented

Look Back at Existing BMPs

Hindcast what loading would look like today without management practices already in place

Objectives to support 9EP

Case Study

Sandy Creeks area of NYS
eastern shoreline of Lake Ontario

Subwatershed	Flow	Total P
Skinner	✓	✗
Sandy Cr.	✓	✓
S. Sandy	✓	✓
Raystone	✓	✓
N. Pond	✓	✗
N. Branch SC	✓	✗
Little Sandy	✓	✓
Lindsey	✓	✓
Headwaters SSC	✓	✓
Headwaters SC	✓	✓
Gulf Str.	✓	✓
Fish Creek	✓	✓
Deer Creek	✓	✓

Model performance

$\text{Flow}_{\text{calibrate}}$ – NSE ≥ 0.5

$\text{Flow}_{\text{confirm}}$ – NSE ≥ 0.5

TP – NSE ≥ 0.5; PBIAS ± 70%

✗ = Greater uncertainty in modeled output

Model behavior conformed to expectations

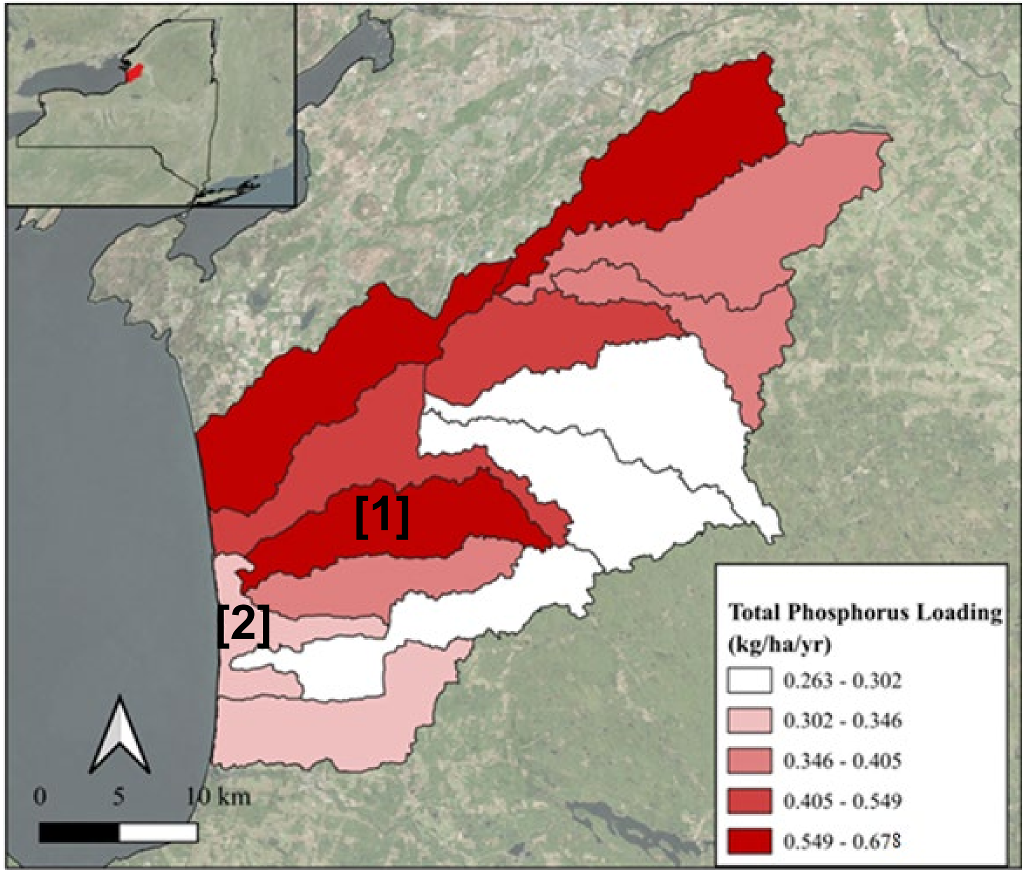
NYSDEC Review: Modeling results were independently reviewed and approved by the New York State Department of Environmental Conservation through a Modeling Usability Assessment Report (MUAR).
The full technical report will be publicly available.

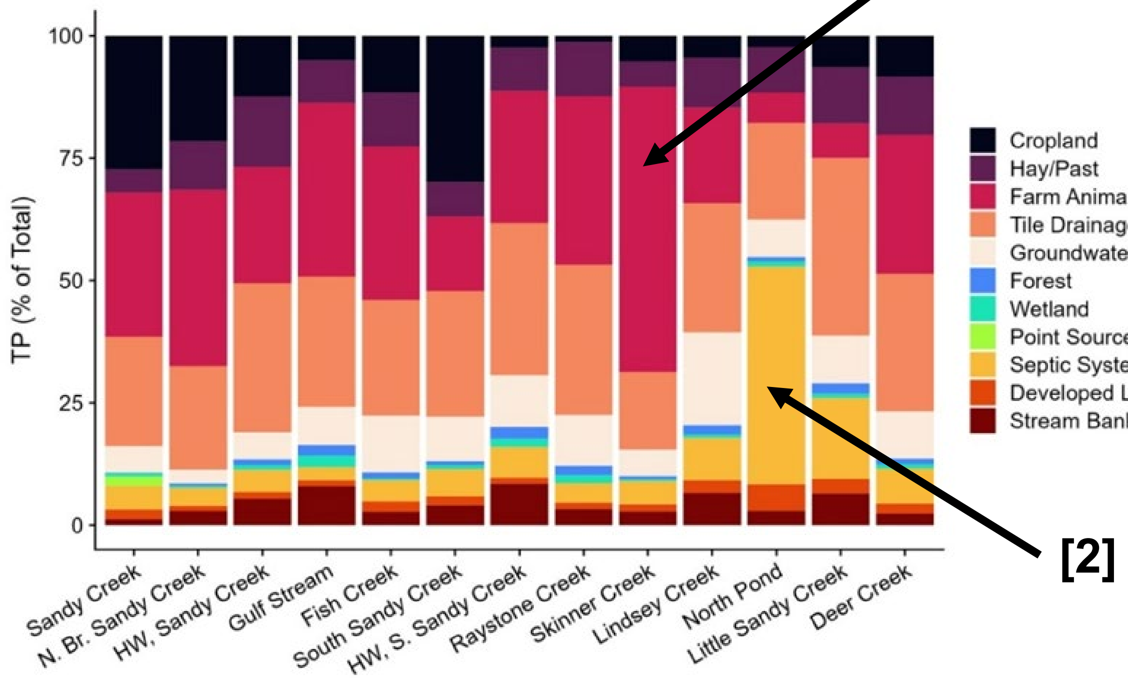
Case Study

Sandy Creeks area of NYS
eastern shoreline of Lake Ontario

What are the Sources of Phosphorus?

Relative source contributions across the 13 study subwatersheds **(2014-2023)**





Baseline (current):
0.3 - 0.7 kg/ha/year range of TP loading rates

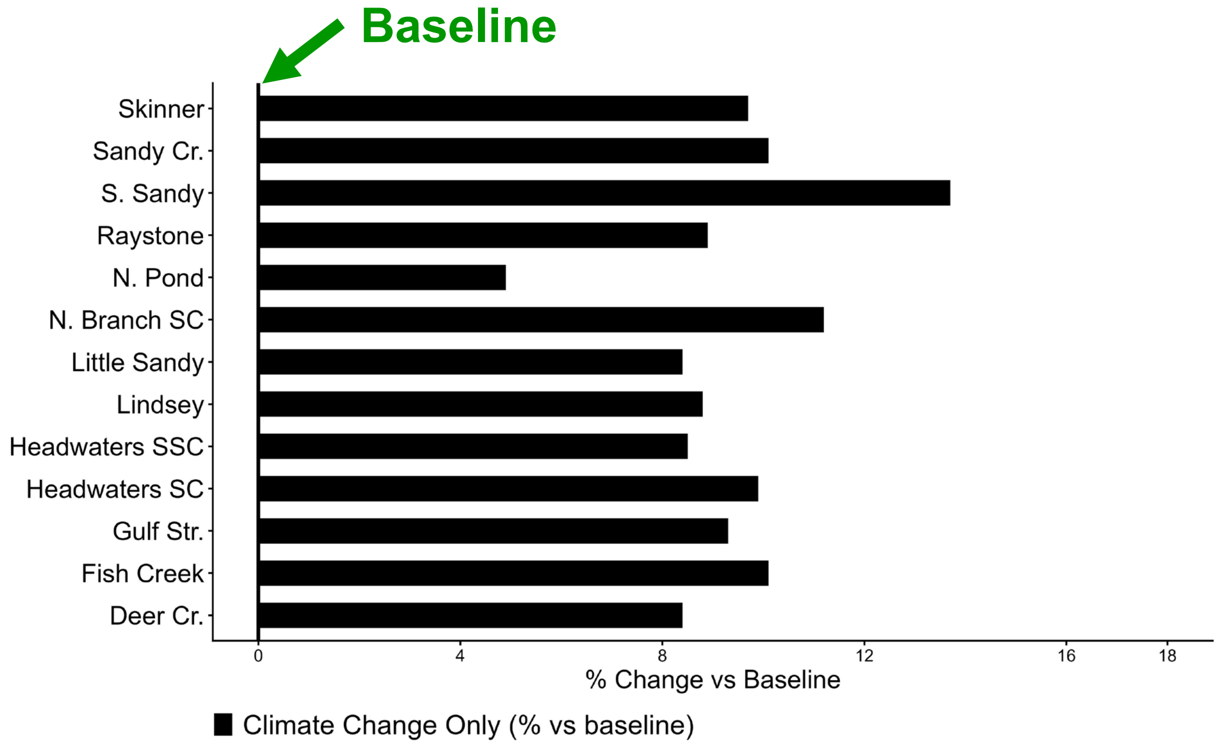
Case Study

Sandy Creeks area of NYS
eastern shoreline of Lake Ontario

Looking Ahead - **Climate Change**

SCENARIO 1

Modeled phosphorus loading by 2050 (RCP4.5 scenario)



(+) 5 - 14%

Modeled increase in TP loading
(avg. ~ 10% across all subwatersheds)

Sets a new baseline

Management actions & BMPs that overcome modeled increase in TP loads

RCP4.5 = moderate greenhouse gas emissions scenario that projects roughly a 10% increase in precipitation and warmer air temperatures by 2050. Used as a planning horizon for this study

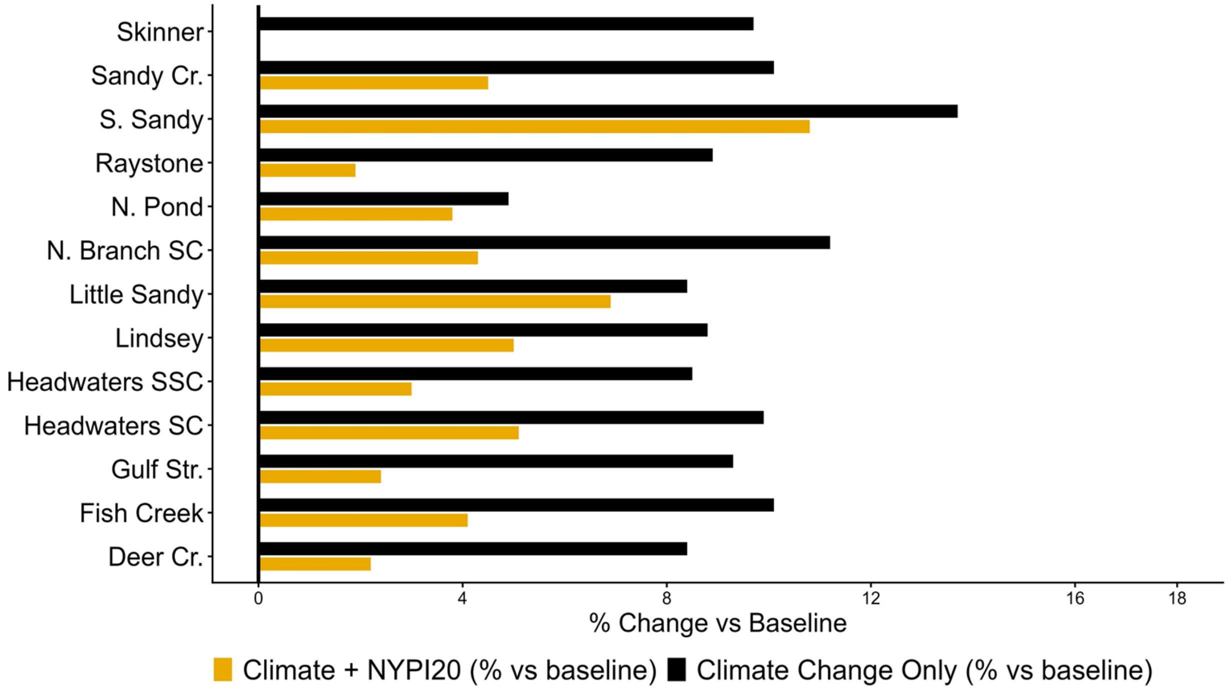
Case Study

Sandy Creeks area of NYS
eastern shoreline of Lake Ontario

Agricultural Management – NY-PI 2.0

SCENARIO 2

→ Limiting manure application near streams in floodplain areas (within 300 ft.)



Most subwatersheds showed a TP load reduction, **but not enough to overcome effects of climate change**

⚠ The model assumed a blanket restriction on all manure application based on proximity to streams. Real-world application of NY-PI 2.0 does not limit manure application within 300-ft of streams if (a) testing indicates it can occur, or (b) BMPs are implemented.

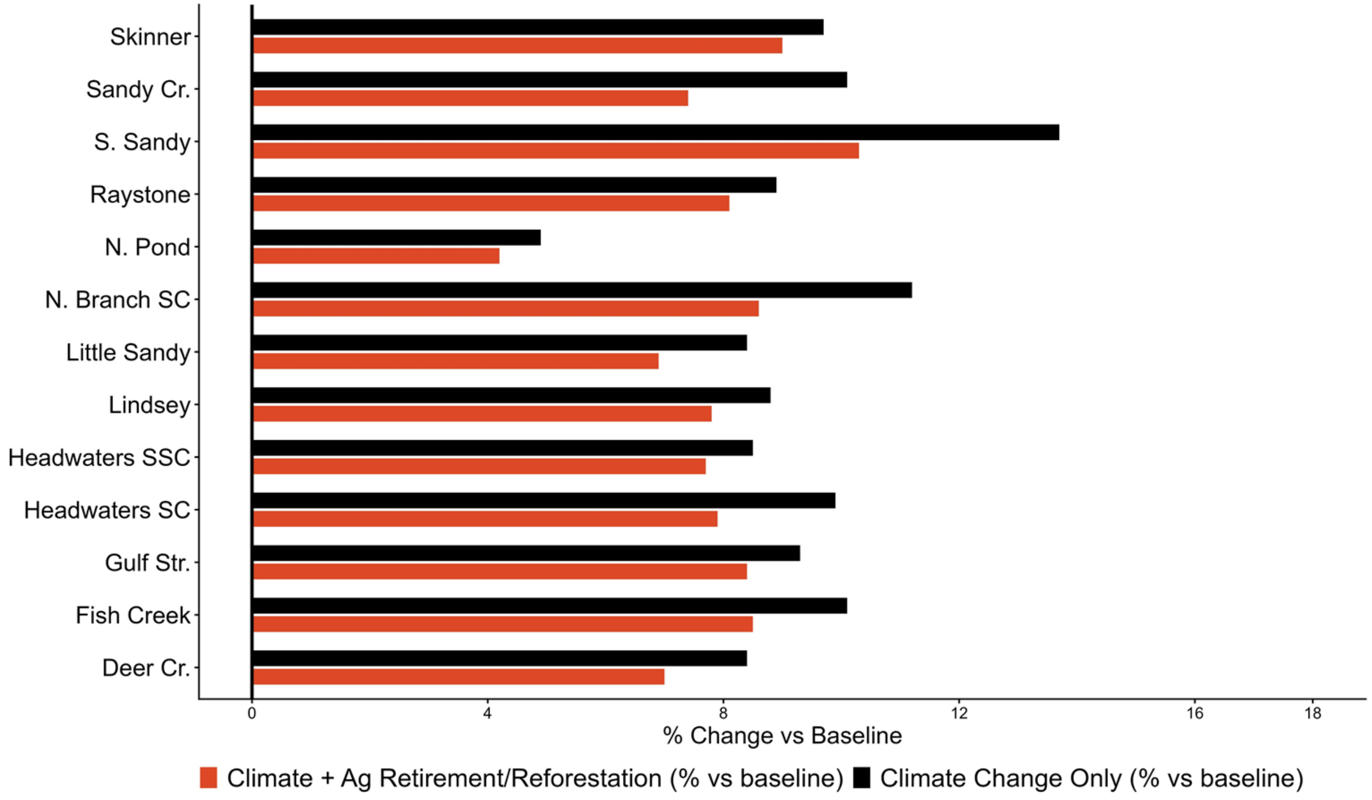
Case Study

Sandy Creeks area of NYS
eastern shoreline of Lake Ontario

Ag Land Retirement & Reforestation

SCENARIO 3

→ Retirement and reforestation of agricultural land (10% per subwatershed)



Modest decrease in TP loading relative to climate change

Potential as a component to multi-strategy approach

Case Study

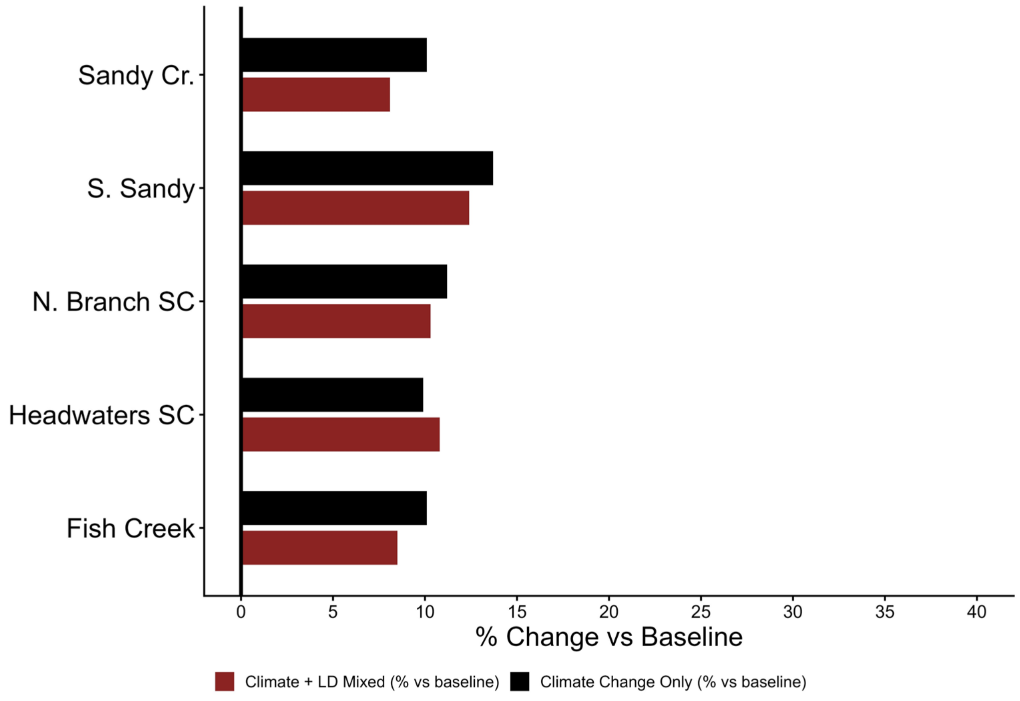
Sandy Creeks area of NYS
eastern shoreline of Lake Ontario

Land Use Change & Development

SCENARIO 4

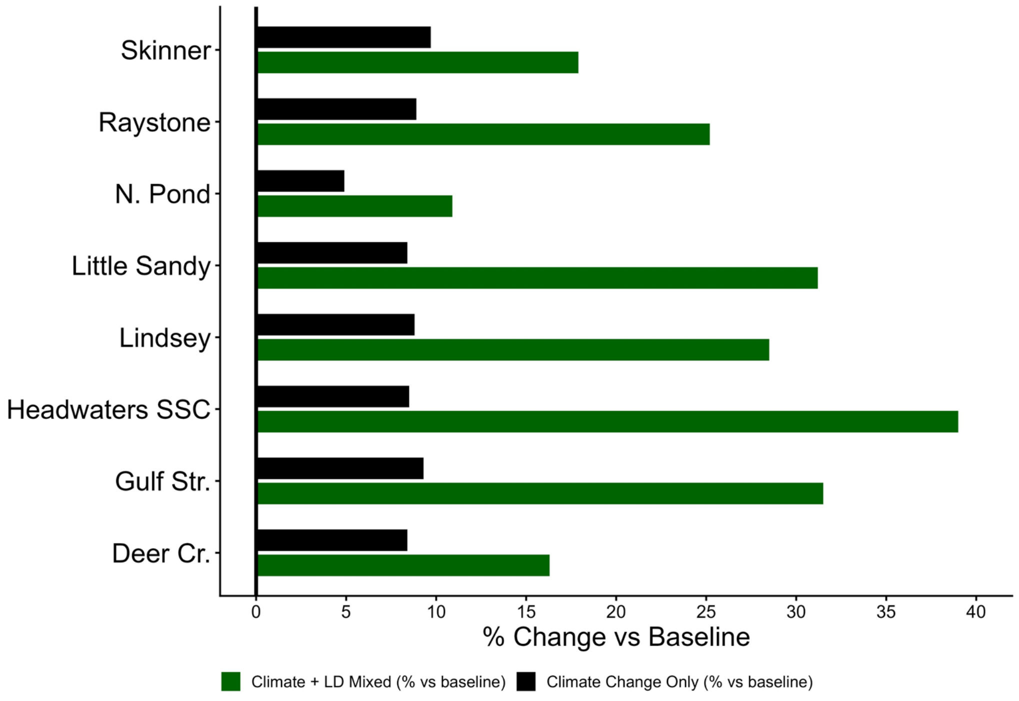
→ Conversion of agricultural or forested land to low-density residential development

Agricultural subwatersheds



Marginal decreases/increases in modeled TP loading

Forested subwatersheds



Relatively large increases in modeled TP loading

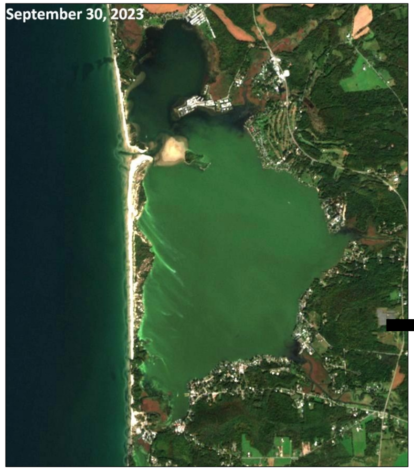
Case Study

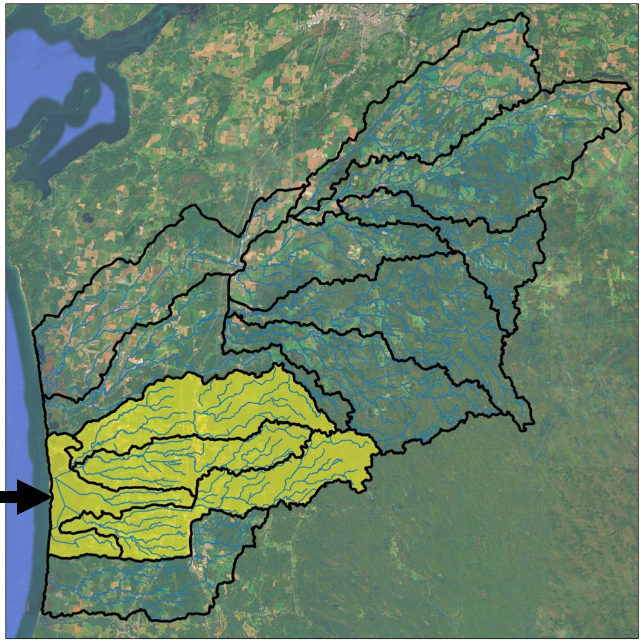
Sandy Creeks area of NYS
eastern shoreline of Lake Ontario

SCENARIO 5

Septic System Mitigation

→ **Addressing all septic failures in four subwatersheds draining to Sandy Pond**





Subwatershed	Septic Systems (estimate)	**Net TP Change** (repair/replace all + climate)
North Pond	1,061	−43% ✓
Little Sandy Creek	977	−12% ✓
Lindsey Creek	344	−1% ✓
Skinner Creek	483	+5%

✓ Modeled TP load overcomes impact from climate change

Case Study

Sandy Creeks area of NYS
eastern shoreline of Lake Ontario

What's already working?

HINDCAST

Remove all existing **agricultural** BMPs from model …

Modeled TP loads would be
6 - 36% HIGHER

BMPs accounted for in the model:

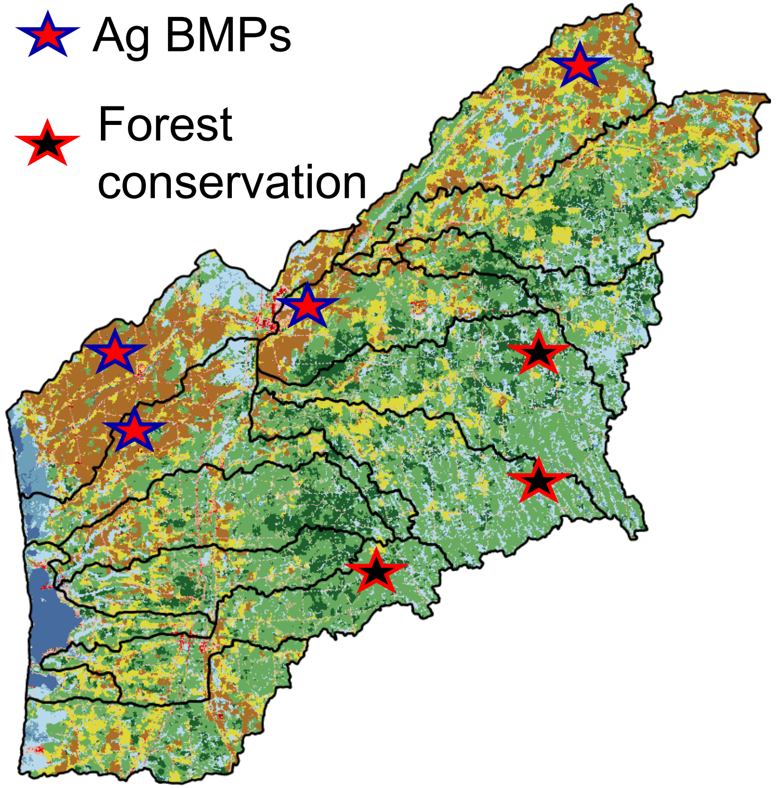
- Cover crops
- Conservation tillage
- Stripcropping/contour farming
- Conservation plans
- Nutrient management
- Grazing land management
- Agricultural land retirement

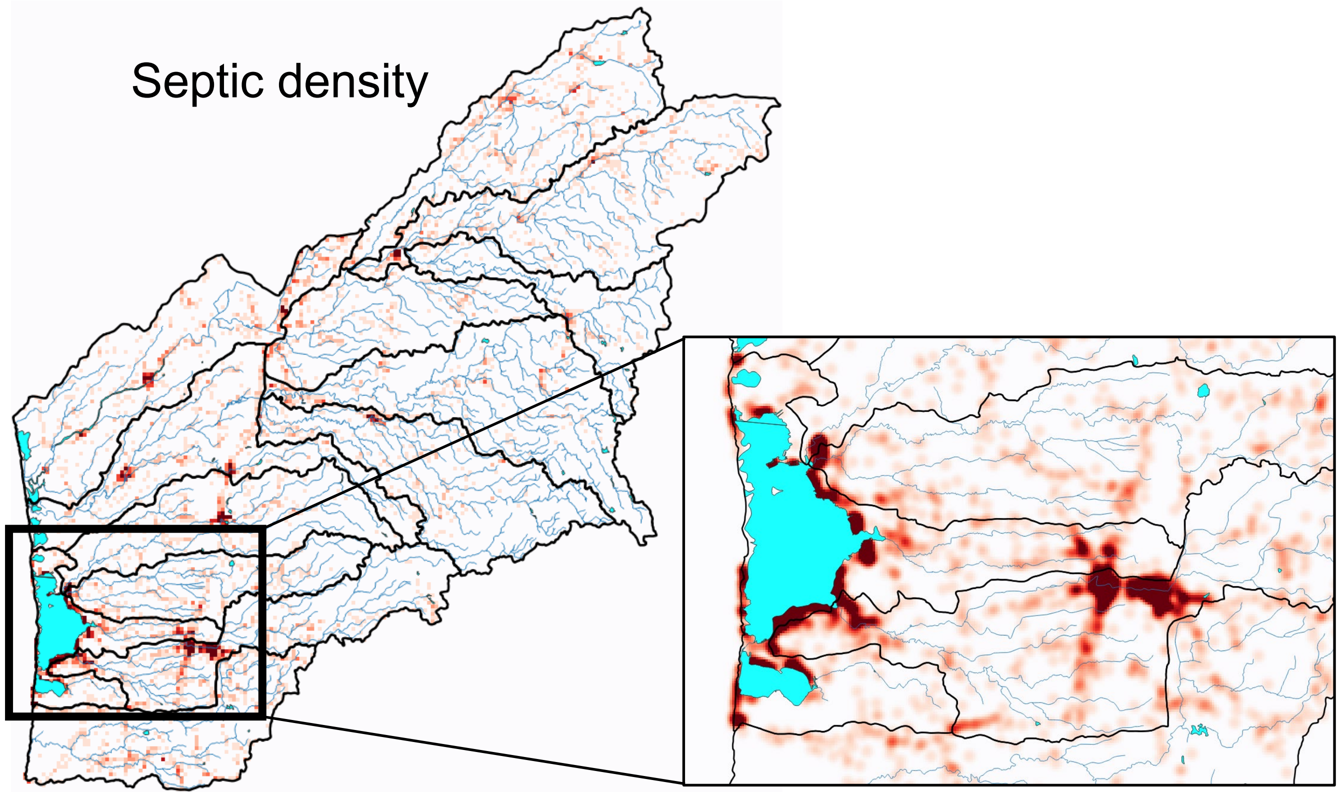
Case Study

Sandy Creeks area of NYS
eastern shoreline of Lake Ontario

CONCLUSIONS

No single modeled scenario enough for <u>entire project area</u>



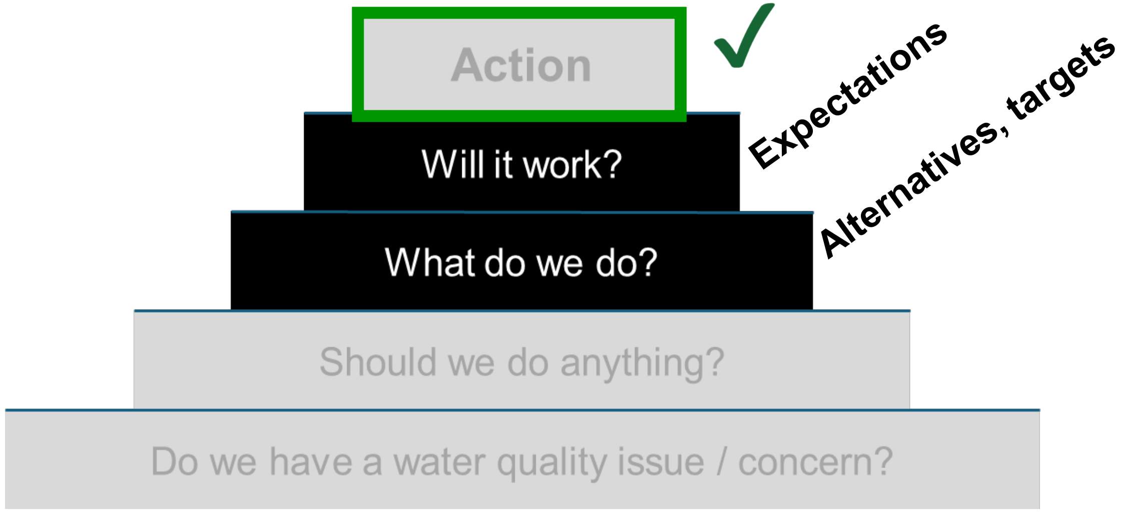


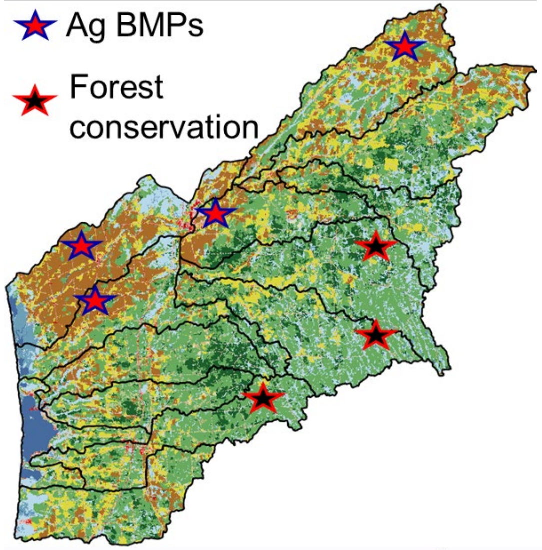
Case Study

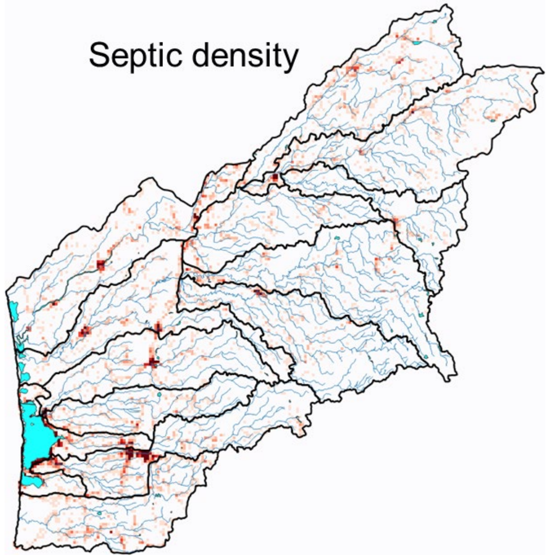
Sandy Creeks area of NYS
eastern shoreline of Lake Ontario

CONCLUSIONS

Modeling helped to provide **objective** support for where to target management actions







Summary

Challenges in water quality management

- Limited resources
- Information gaps
- Uncertainty about future condition(s)

Models can be helpful!

- Quantify current conditions – extend value of monitoring data
- Evaluate future scenarios and management alternatives
- Uncertainty about future condition(s)

Not all models are created equally …
specific questions, objectives, and purposes

Thank you!

Funding provided by:
Finger Lakes – Lake Ontario Watershed Protected Alliance (SWCDs)
(FLLOWPA)

Contact:
Andrew Brainard, Ph.D.
asbrainard@upstatefreshwater.org

UPSTATE FRESHWATER INSTITUTE

Jefferson County NYS
Soil & Water Conservation District

OSWEGO COUNTY
SOIL AND WATER
Conservation District