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Modeling Mercury Exposure at Different Scales in the McTier Creek Watershed and Edisto River Basin, SC, USA

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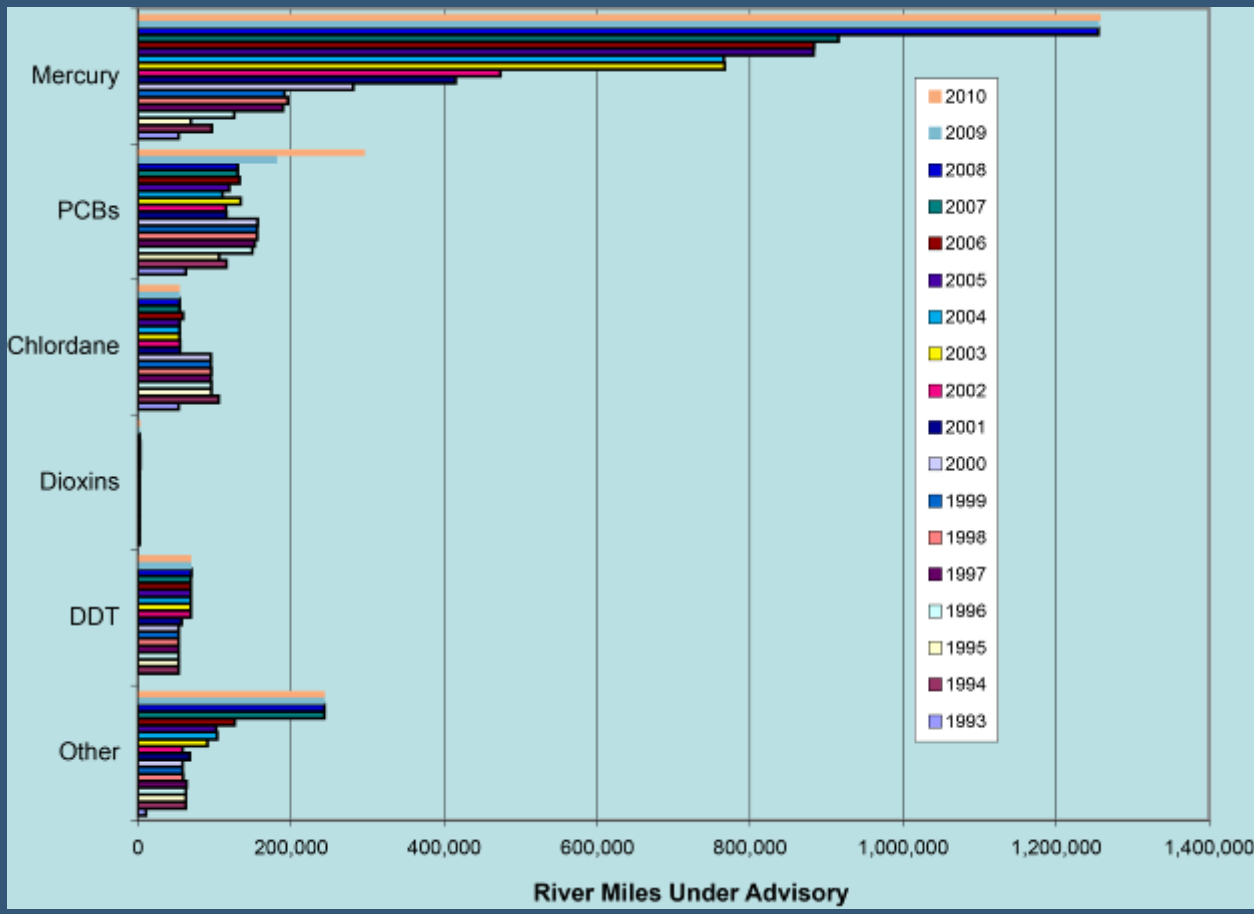
Presentation Outline

- Research Background
- Research Motivation
- Goal and Questions
- Research Approach
- Results
- Parallel Research and Future Work

Research Background

- In the USA as of 2010
  - Hg fish advisories
    - 50 states
    - 1 US territory
    - 3 tribes
  - 80% of all fish advisories in US surface waters are at least partially due to mercury
  - 2,100,000 km of rivers
  - 3,710 Hg Advisories



http://water.epa.gov/scitech/swguidance/fishshellfish/fishadvisories/technical_factsheet_2010.cfm

Research Motivation

- 80% of all fish advisories in US surface waters are at least partially due to Hg
- > 2,000,000 km of rivers have Hg fish consumption advisories
- Almost 4,000 water bodies are listed on State Clean Water Act Section 303(d) as impaired due to Hg, triggering the development and implementation of Total Maximum Daily Loads (TMDLs) for Hg
- Hg comes from a variety of sources, all of these sources must be accounted for in the TMDL process
- Streams and rivers are intimately linked with their watersheds and incorporating out-of-channel processes and loading sources is critical to understanding Hg exposure

Overall Research Goals

Understand and minimize mercury exposure to wildlife and humans by improving the understanding of mercury fate and transport in watersheds and surface waters

Research Questions

- What processes and factors govern mercury exposure concentrations in streams and rivers?
- How can we better inform the development of mercury TMDLs that are often developed for large basins (series of 8 digit HUCs)?
- How can we use mechanistic, differential mass-balance models to better understand what governs mercury exposure concentrations in:
  - Streams
  - Rivers
  - Headwater watersheds
  - Regional basins

Research Approach

- Use mechanistic, differential mass balance models to simulate Hg fate and transport
- Use multiple scales of models to investigate processes at different scales
- Use focused reach study to inform sub-basin and basin watershed modeling of Hg
- Use watershed model to inform spatially explicit regional basin

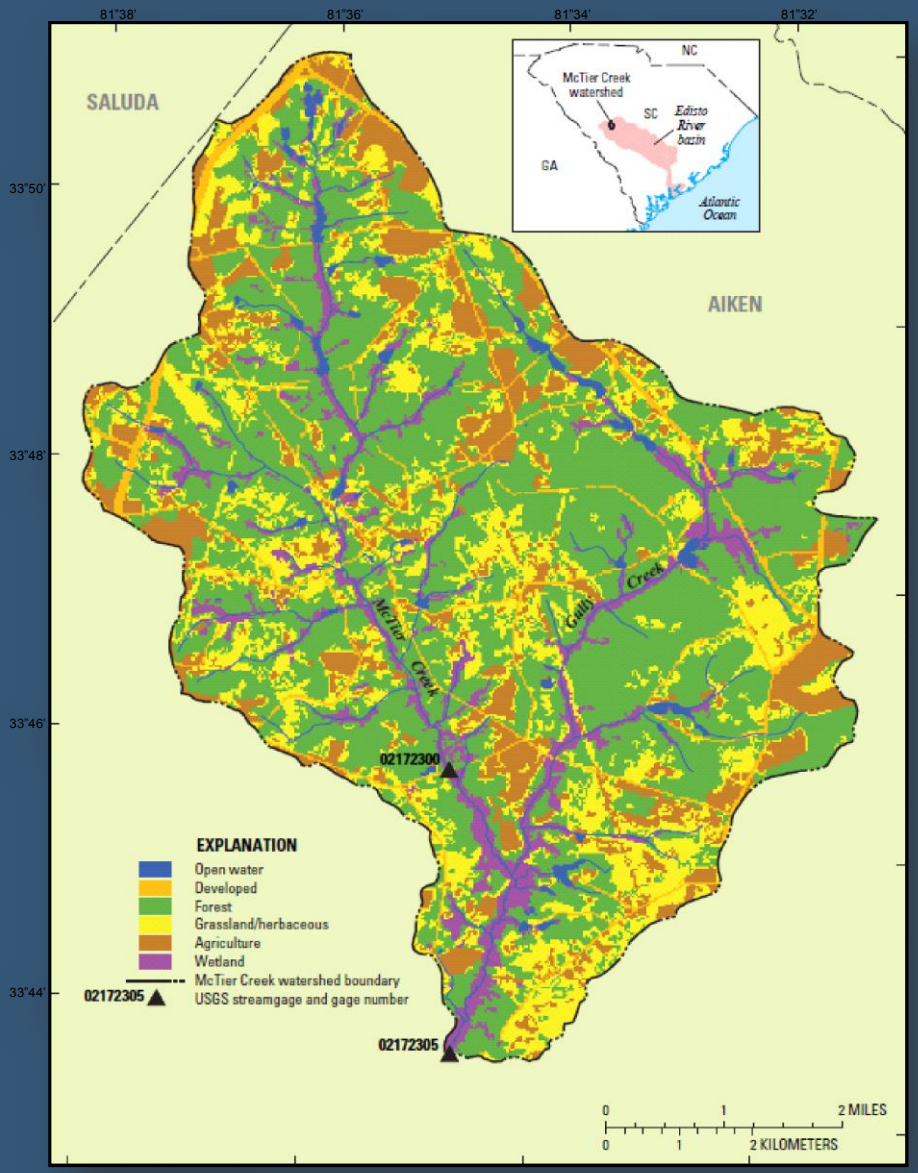
Research Approach: Mechanistic Models

Spatially and temporally explicit mechanistic, differential mass balance model

- *Watershed Model: Visualizing Ecosystems for Land Management Assessment for Hg (VELMA-Hg) (see poster session)*
  - Simulates
    - Hydrology (Runoff, subsurface for 4 soil layers)
    - Carbon: Dissolved Organic and Soil Organic
    - Nitrogen: Ammonium, Nitrate, Dissolved Organic
    - Mercury: MeHg, Hg(II)
    - Processes: methylation, demethylation, reduction/evasion

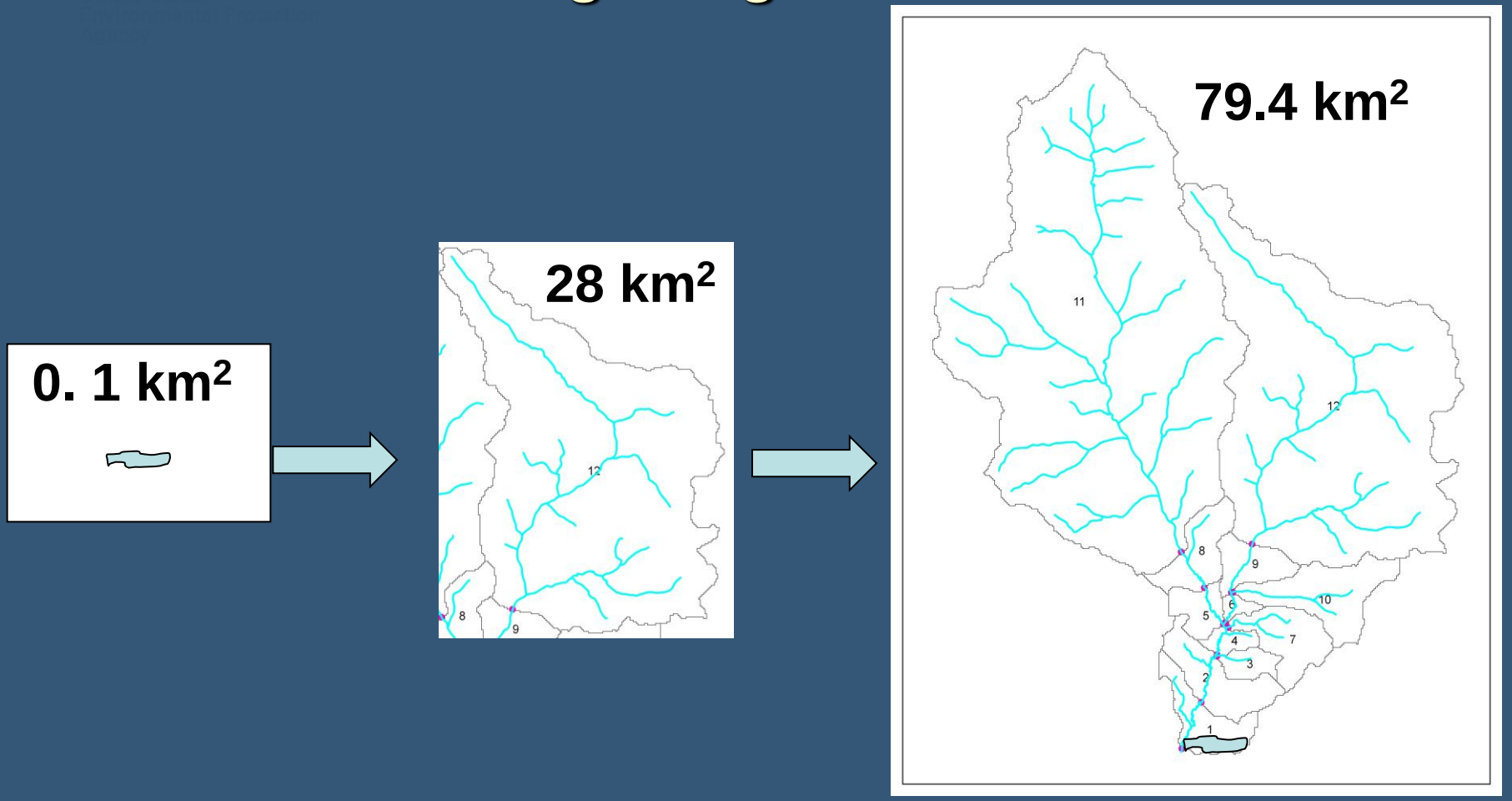
Study Site: McTier Creek Watershed, SC, US

- Sand Hills region of Upper Coastal Plain, SC
- 79 km^2 drainage area
- Mixed land cover: 49% forest, 21% grassland and herbaceous, 16% agriculture, 8% wetland, 5% developed, 1% open water
- Shallow groundwater system
  - Low – normal flow: toward stream channel
  - High flow: same with increased area of groundwater-surface water exchange



Land-cover data from 2001
National Land Cover Dataset (Homer and others, 2004)
Albers projection, NAD83 datum,
Central Meridian - 95 00 00

Research Approach: Modeling Range of Scales

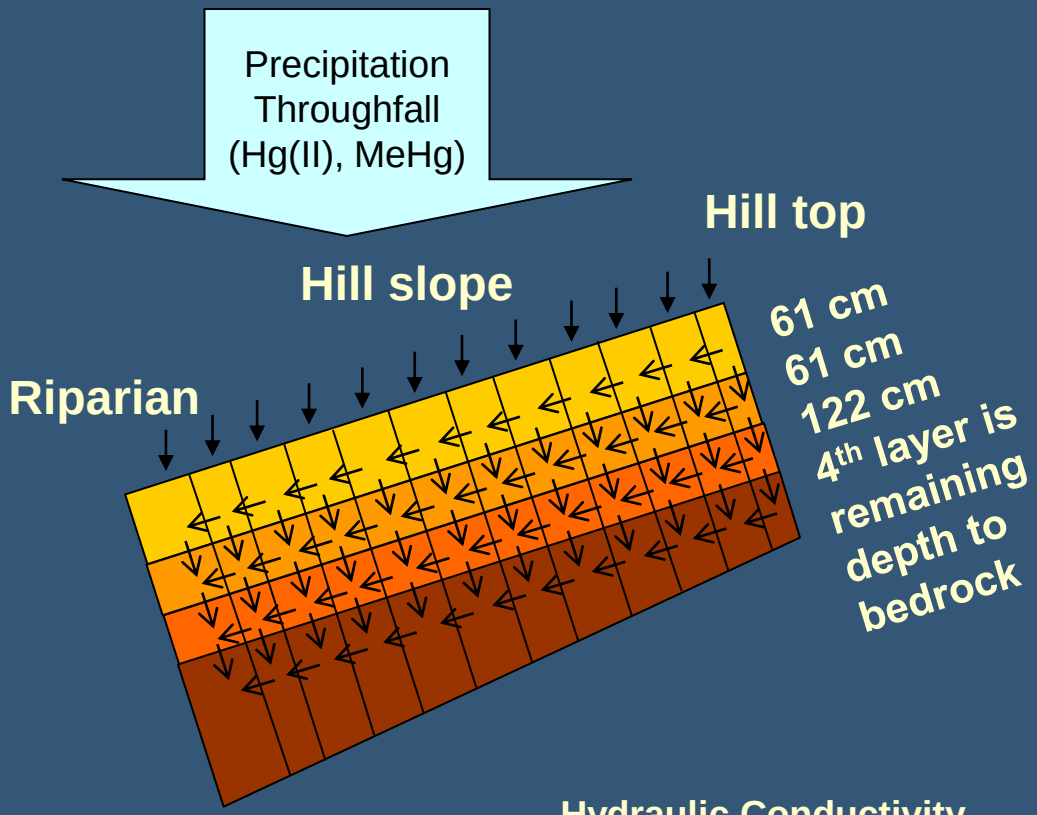


Focused Reach → sub-watershed → watershed

Focused Reach Study:

Sampling
- HgT and MeHg concentrations in soil
- Sampled at different depths
- Provides spatial snapshot of Hg concentrations

Modeling
- VELMA watershed model
- Calibrated rate constants using observed data
- Simulates soil concentrations
    - (Hg, N, C)
- Output: Q, Hg(II) and MeHg



Hydraulic Conductivity

	Vertical	Lateral
Layer 1	4.4 m/d	4.1 m/d
Layer 2	2.0 m/d	0.1 m/d
Layer 3	3.2 m/d	4.1 m/d
Layer 4	0.16 m/d	0.074 m/d

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Focused Reach Study: Methylation/Demethylation

Methylation Rate = k_m x [Hg(II)] x $Q_{10,m}^{(Tm-20)}$ x Soil Saturation

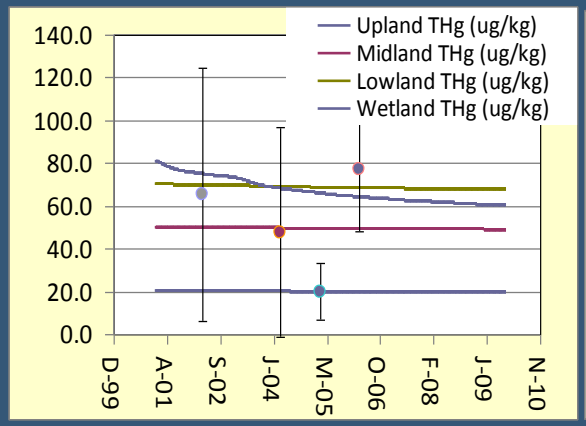
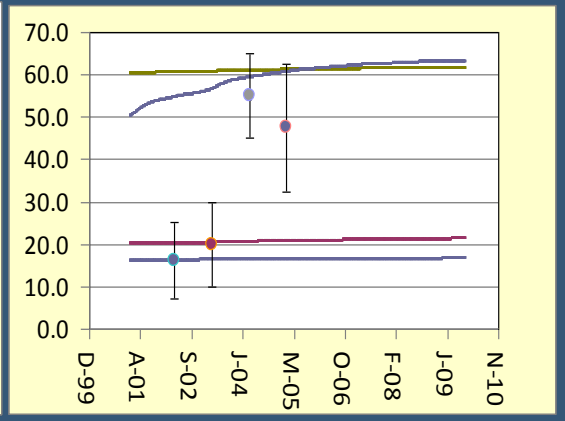
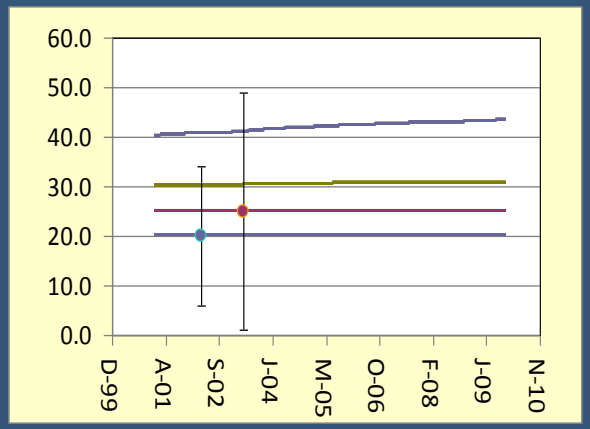
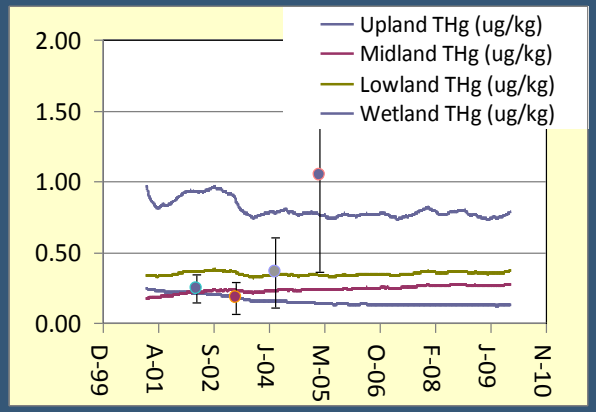
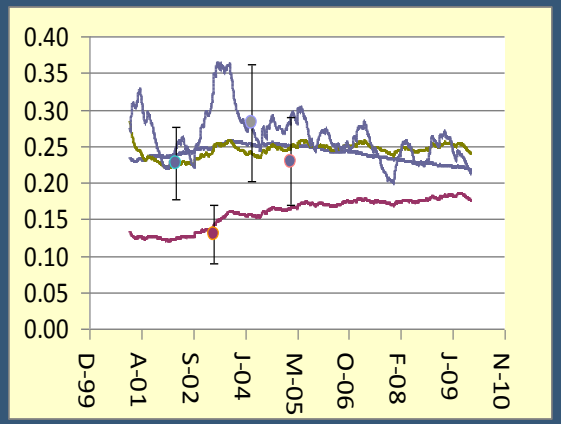
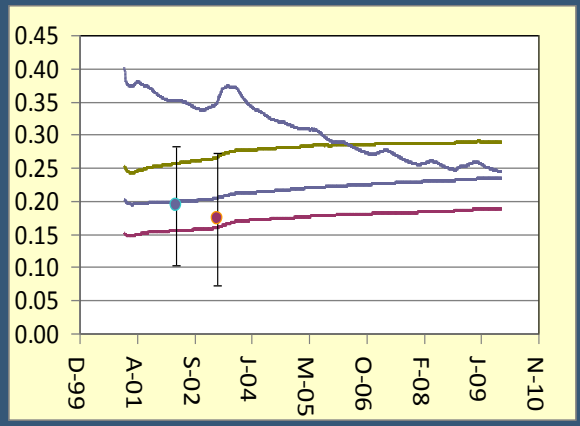
Demethylation Rate = k_d x [MeHg] x $Q_{10,d}^{(Td-20)}$ x Soil Saturation

Rate Constant	Zone	Layer	Value
k_m	Riparian, uplands	All	0.007 d^{-1}
	Wetlands	All	0.01 d^{-1}
k_d	All	Layers 1,2,4	0.015 d^{-1}
	All	3	0.03 d^{-1}
$Q_{10,m}$	All	All	1.14
$Q_{10,d}$	All	All	1.04
T_m	All	All	15
T_d	All	All	22

Laboratory and field study being used to parameterize constants

Comparing observed stream concentrations and soil concentrations for evaluation

Focused Reach Study: Soil Mercury Concentrations and Simulations

	Layer 1	Layer 2	Layer 3
HgT			
MeHg			

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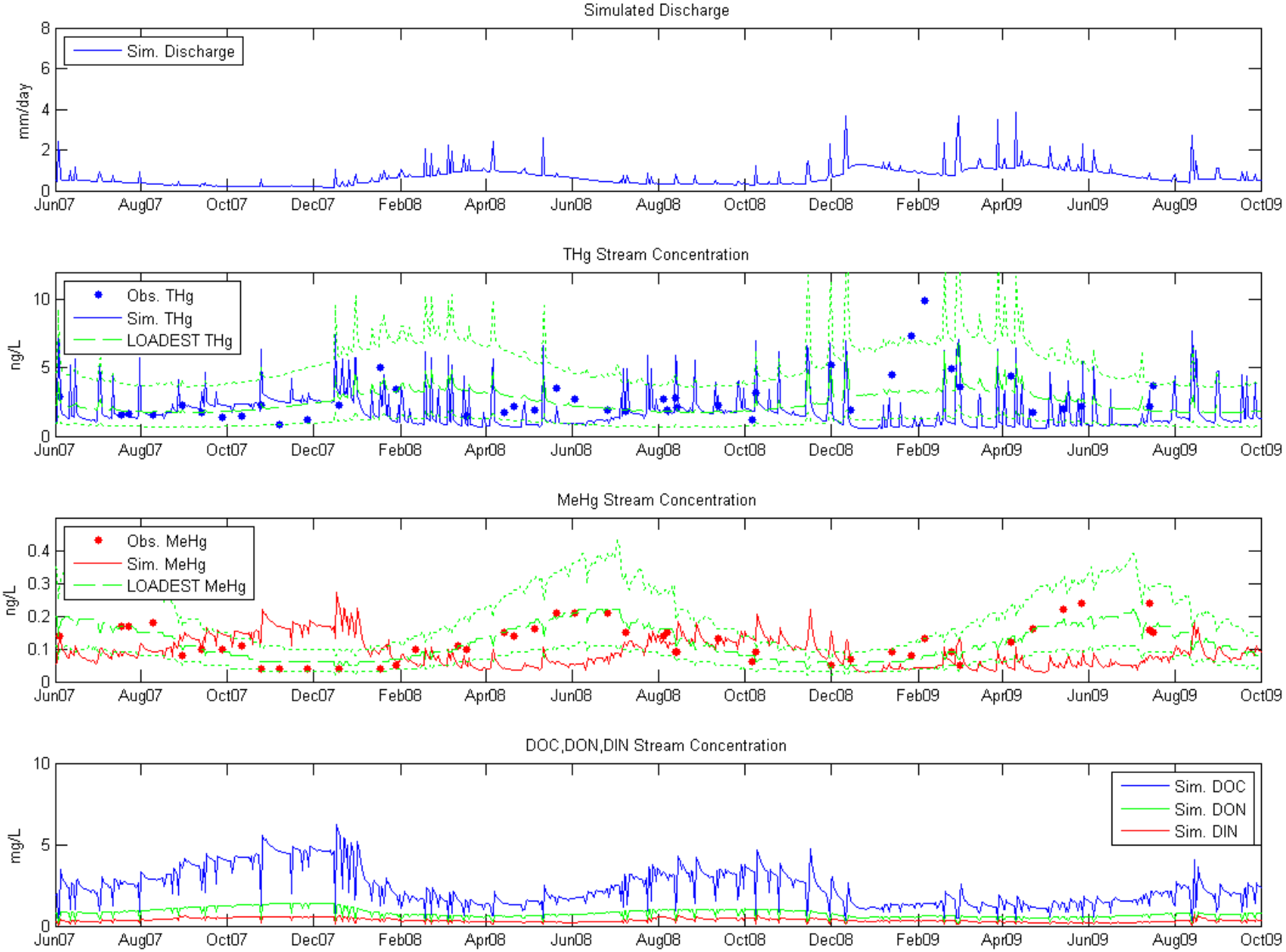
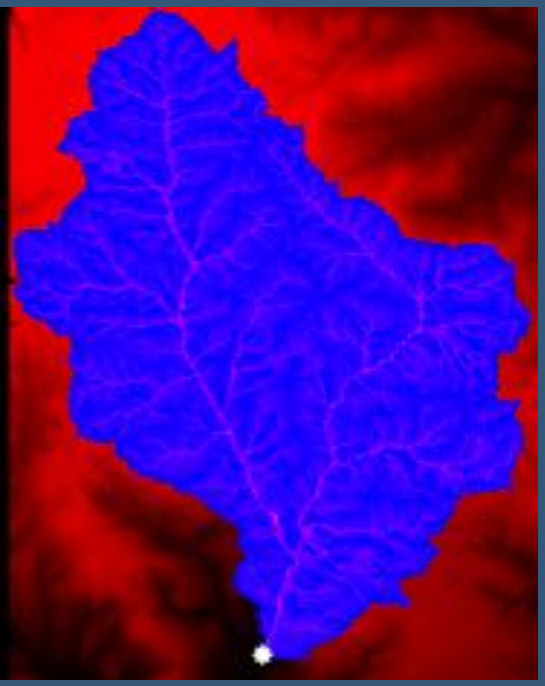
Focused Reach

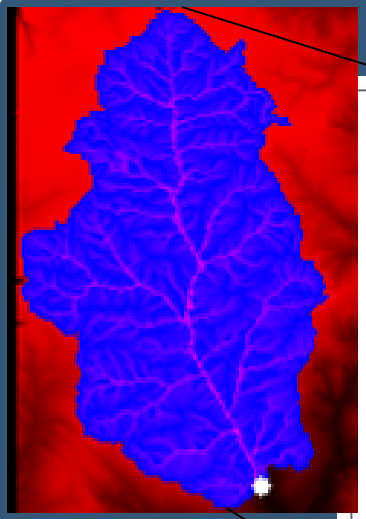


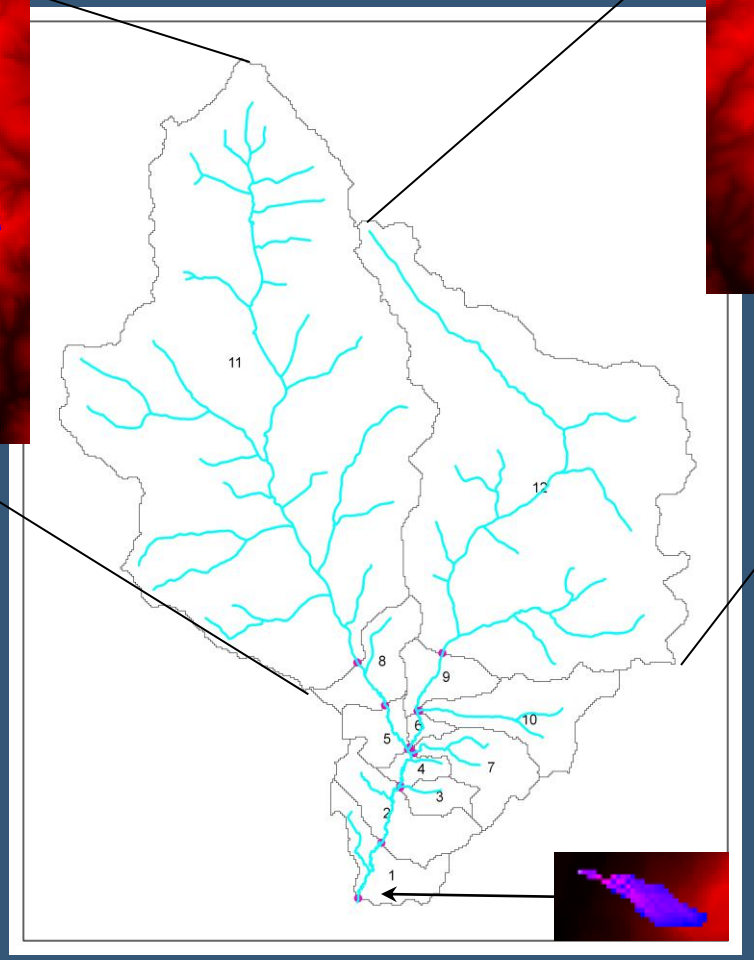
McTier Creek Watershed Modeling: VELMA

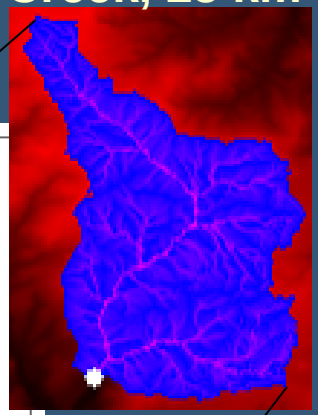
Monetta Gauge, 28 km²

Gully Creek, 25 km²







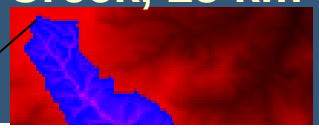


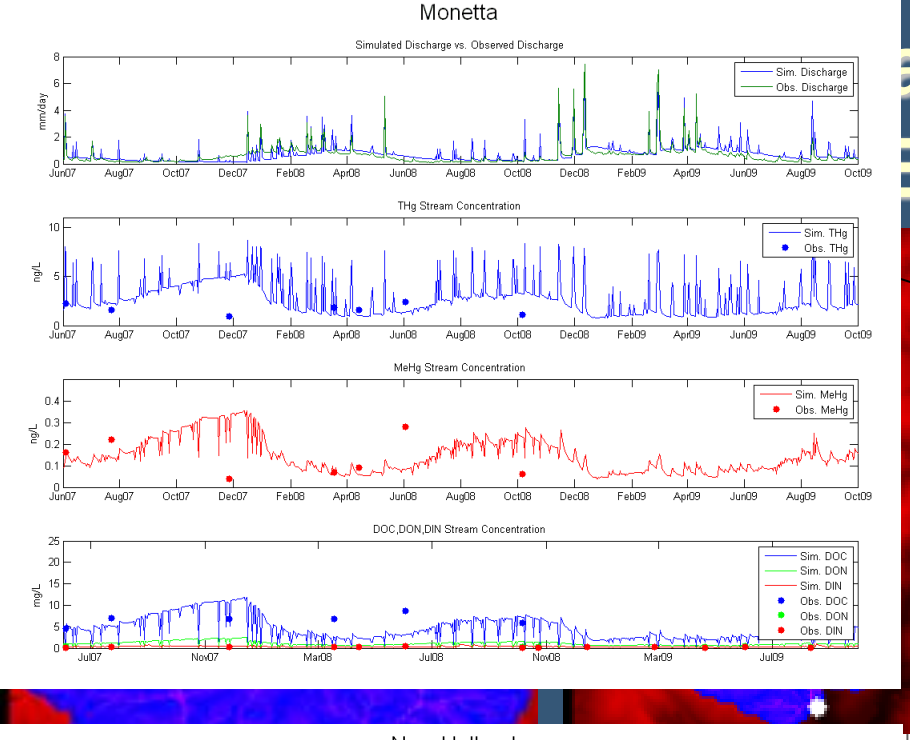
New Holland, 79.4 km²

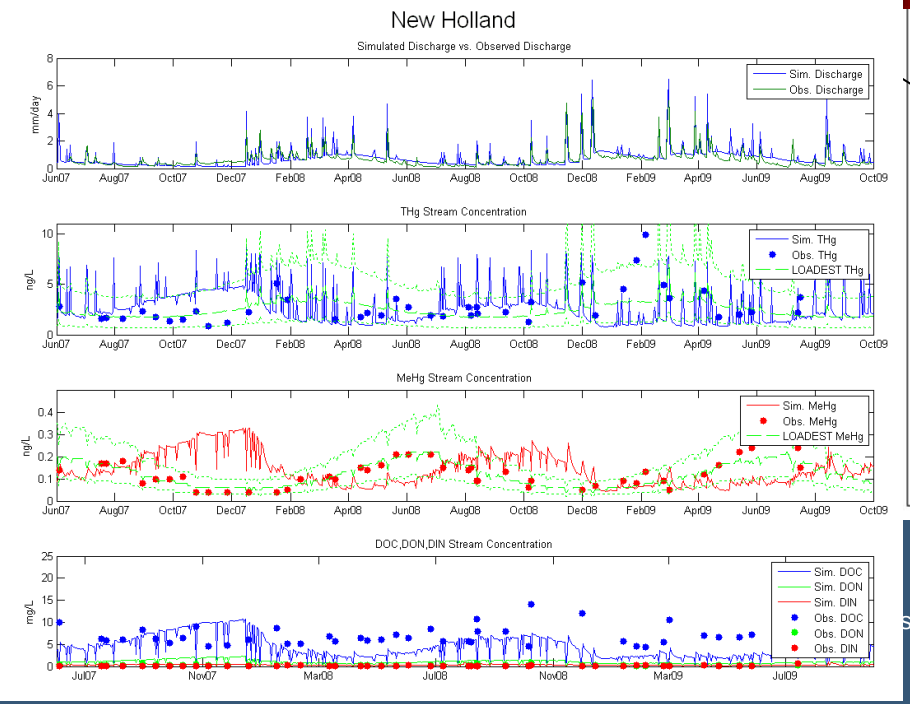
Focused Reach, 0.1 km²

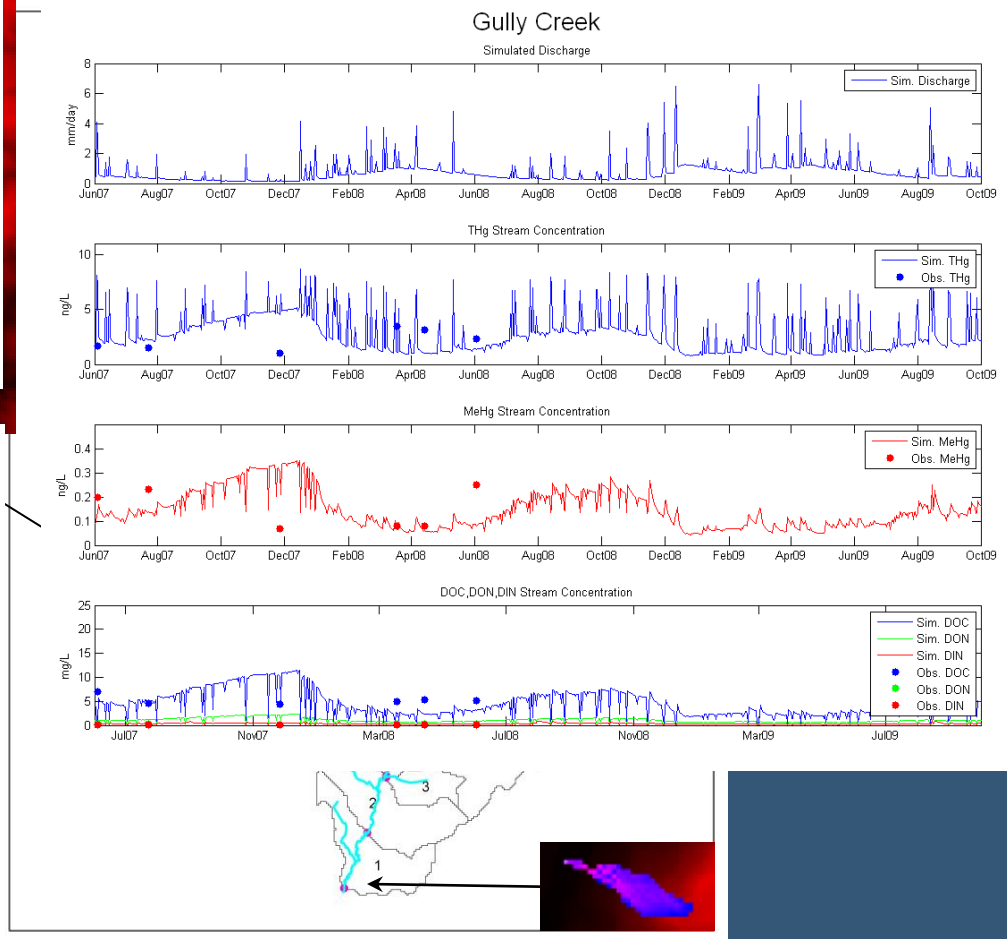
atershed Modeling:
ELMA

Gully Creek, 25 km²









Focused Reach, 0.1 km²

Summary

Combination of a field study and modeling efforts
provides insight into biogeochemical cycling of mercury that neither could afford on its own

Comparison with observed and LOADEST values indicates THg stream concentrations are captured well in VELMA simulations
→ Processes governing THg @ McTier Creek are well represented

VELMA simulates MeHg stream concentrations are out of synch with observed concentrations.
→ Processes governing MeHg @ McTier Creek not as well represented
→ MeHg follows trend of DOC and T, but observed MeHg don't
→ Importance of the wetlands
→ Importance of flow paths

Future Research

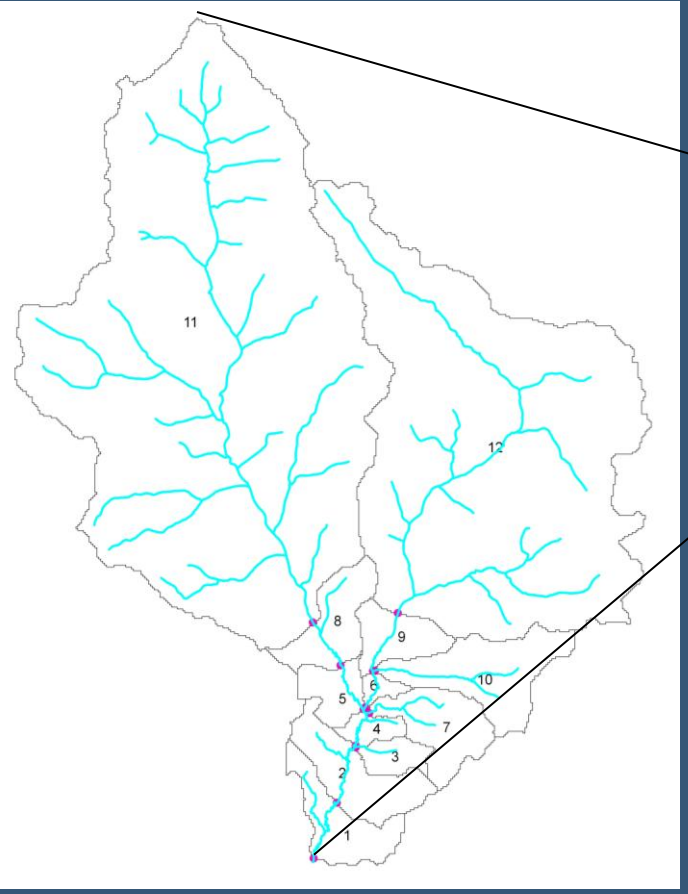
- VELMA simultaneously simulates
  - DON (Dissolved Organic Nitrogen),
  - DIN (Dissolved Inorganic Nitrogen),
  - and DOC (Dissolved Organic Carbon)

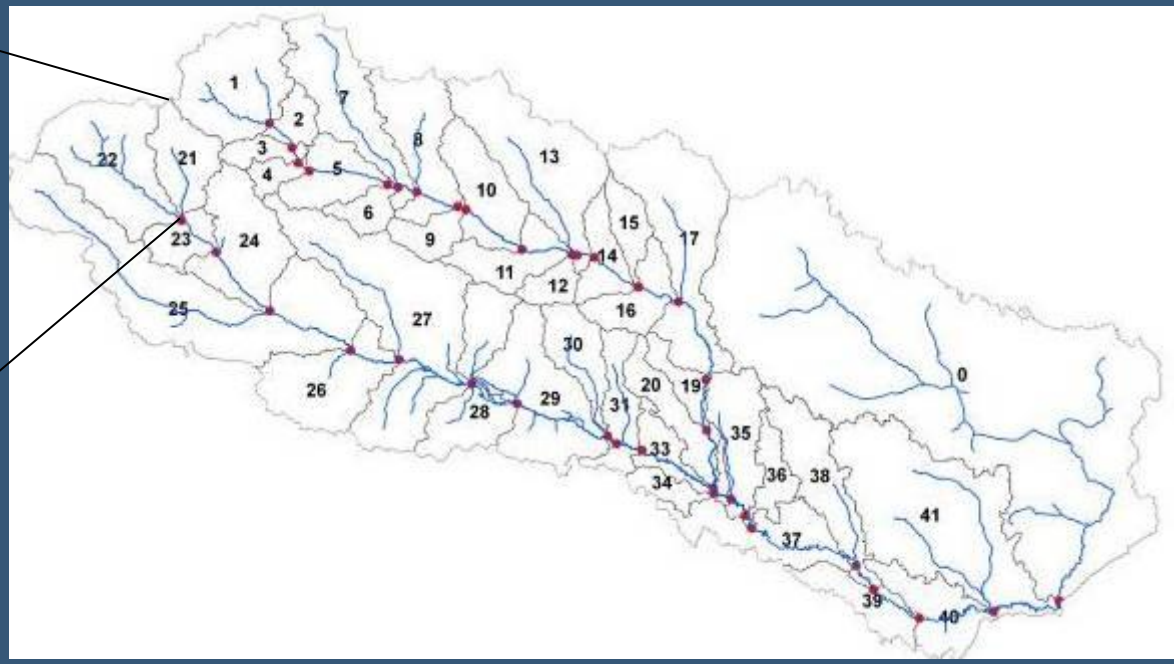
- Investigate their importance and their feasible impacts on Hg exposure concentrations

- Linking VELMA to WASP to BASS to simulate fish tissue concentrations to link atmospheric Hg deposition to human and wildlife exposure (source to receptor)

- Continual improvements on VELMA (land use, land cover)

Future Research





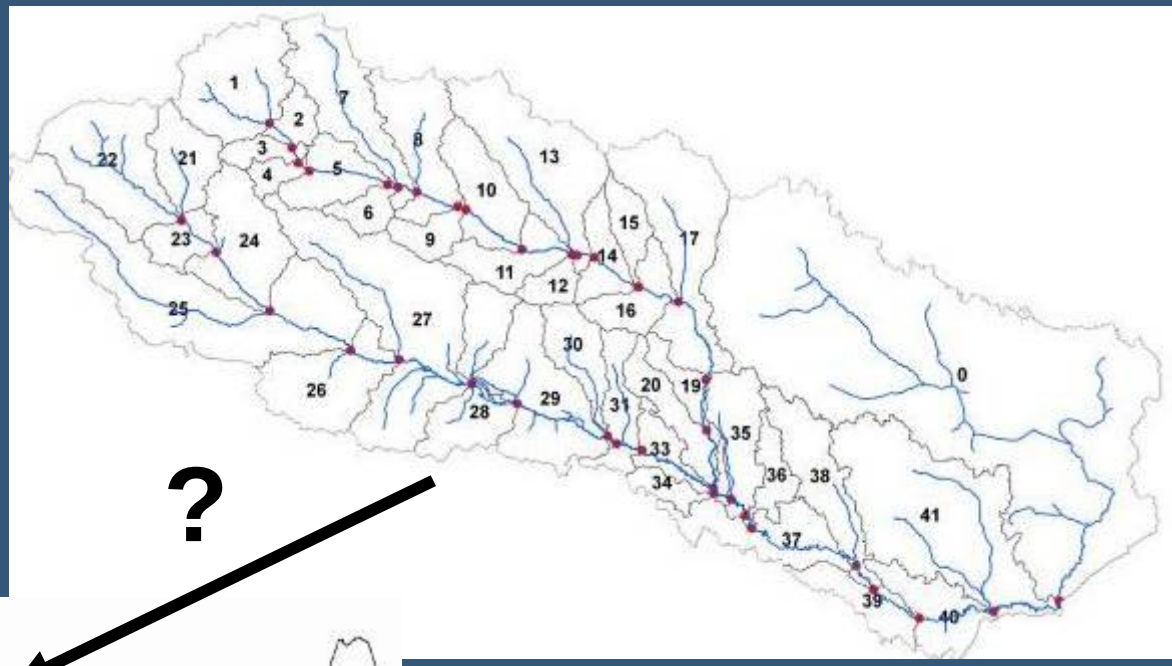
Using focused reach study to inform McTier Creek (HUC12),

Can we then use McTier Creek to inform regional scale?

→South Fork Edisto (HUC8)?
→North **and** South Fork Edisto?

Future Research

How far can we zoom out?



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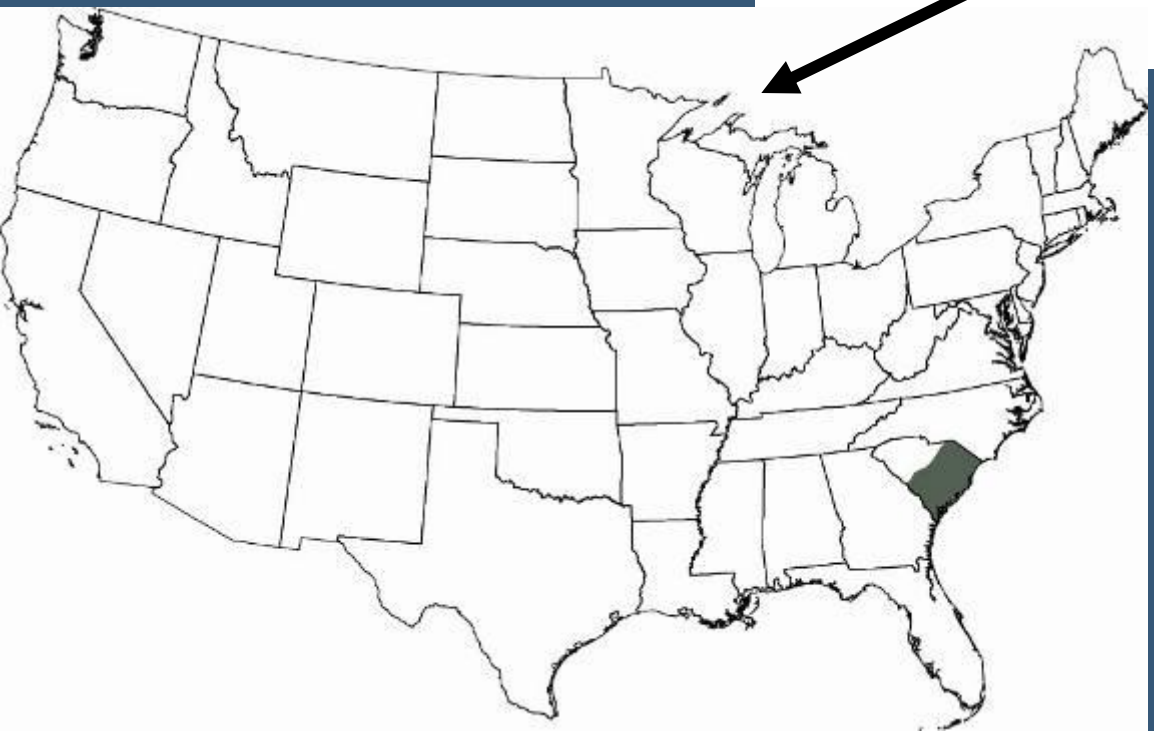
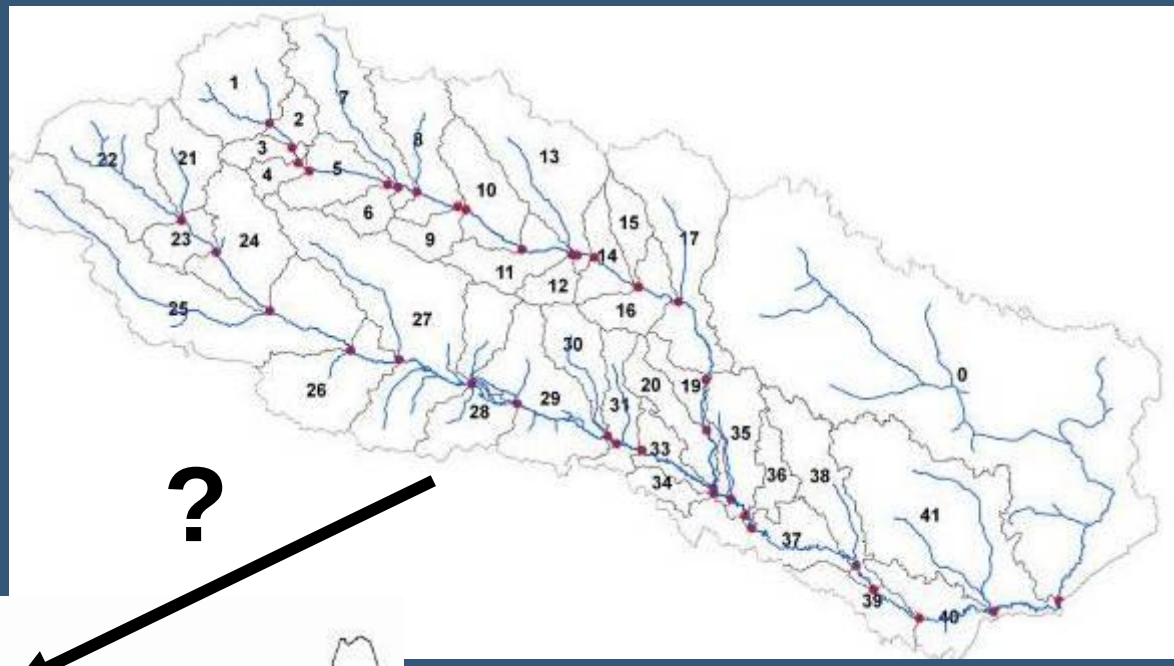


South Carolina Coastal Plain

Future Research

How far can we zoom out?



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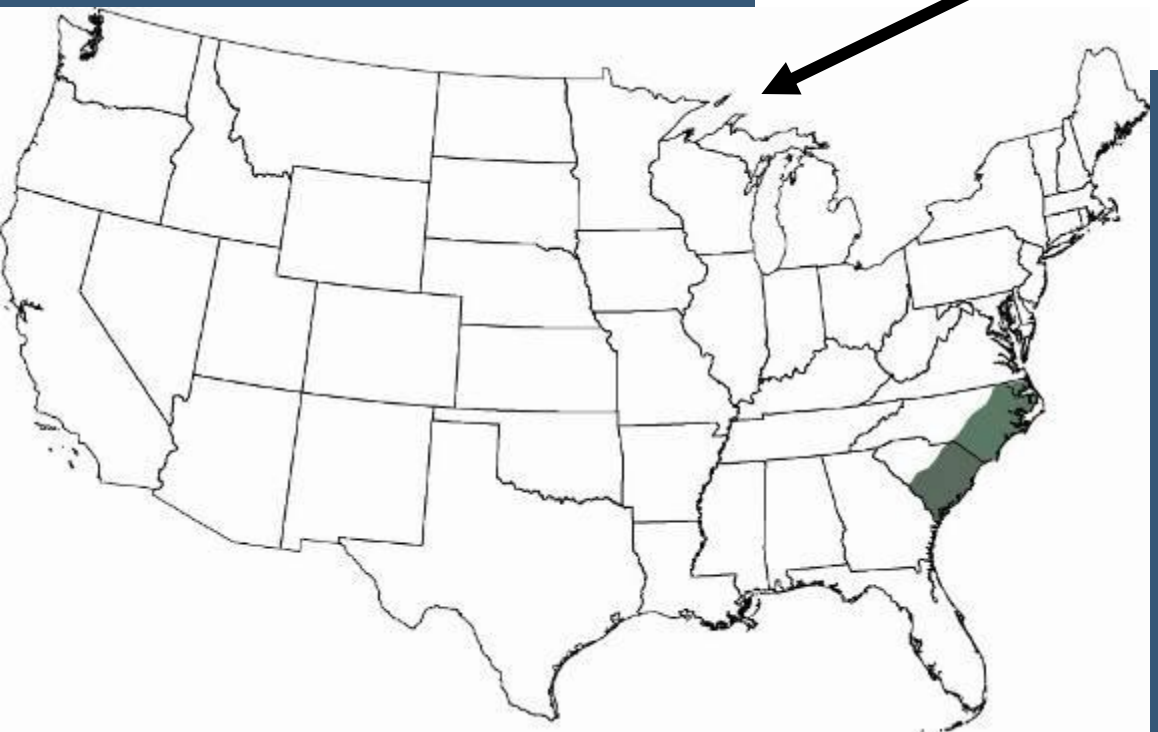
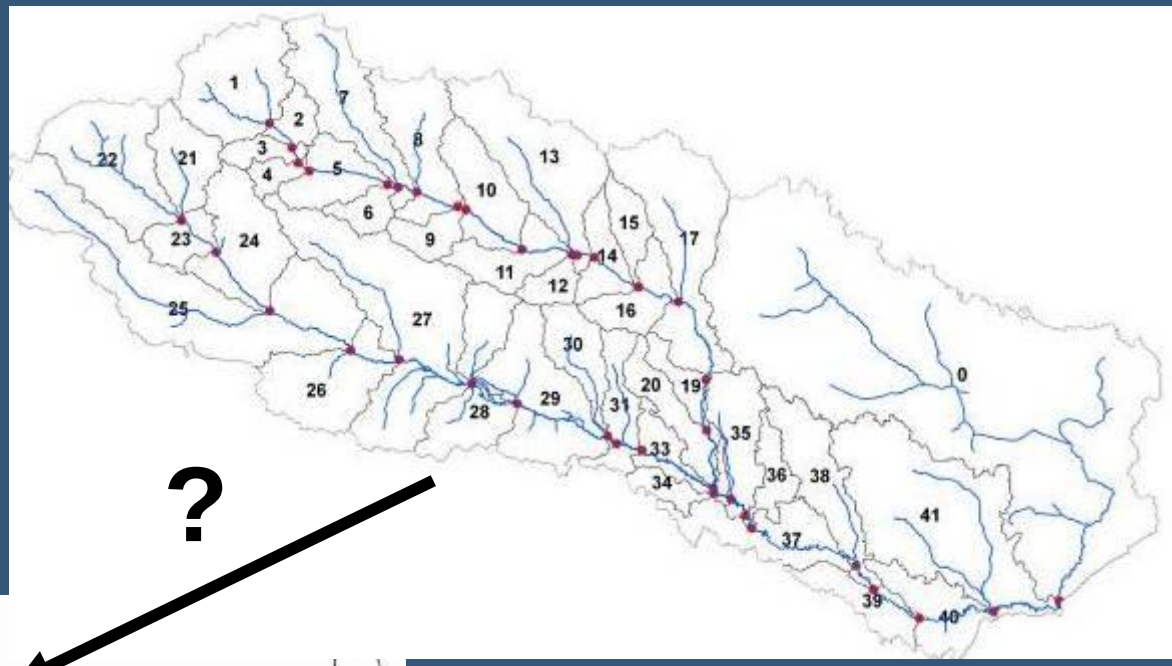


Coastal Plain of the Carolinas

Future Research

How far can we zoom out?



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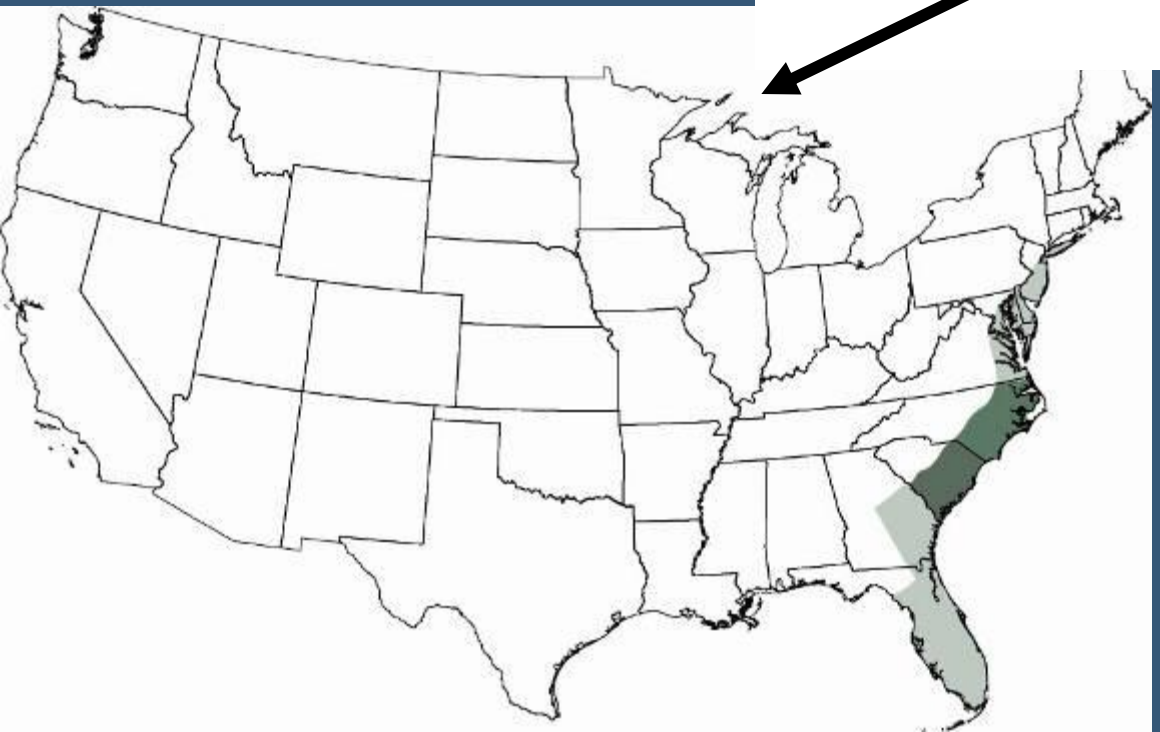
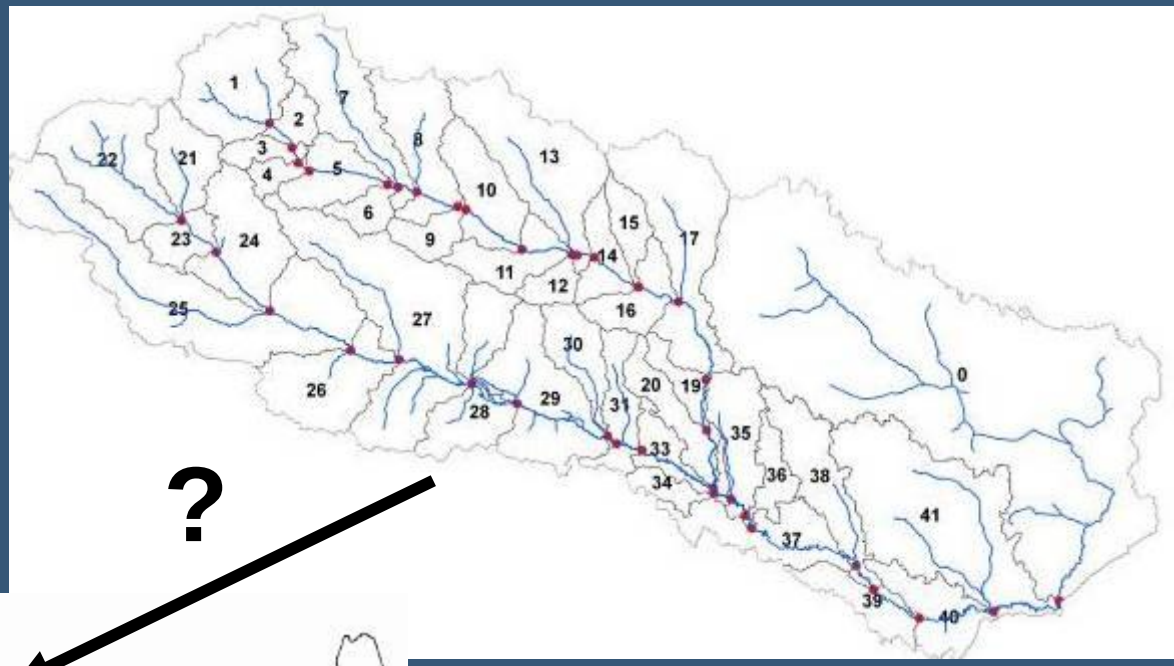


Atlantic Coastal Plain

Future Research

How far can we zoom out?



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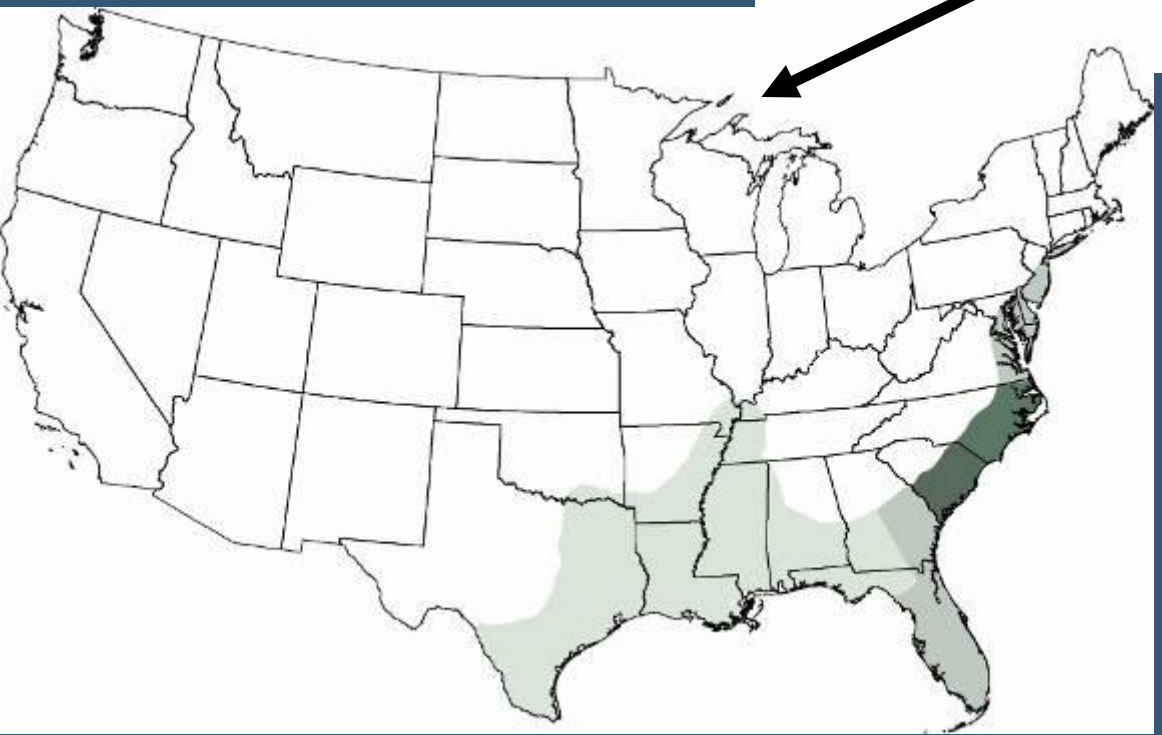

Coastal Plain