Do Landscape Water Storage Features Mediate Nutrient Loads in the Upper Mississippi River Basin?

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Although this work was reviewed by EPA and approved for publication, it may not necessarily reflect official Agency policy.

Great Plains and Midwest Harmful Algal Blooms Workshop, February 4-5, 2020
Nutrient issues persist in the UMRB

Excess nutrients (nitrogen, phosphorus) eutrophication and harmful algal blooms along the freshwater to marine continuum

Source: T Marsee, Michigan Sea Grant

Source: 2011 Algal Bloom Lake Erie Credit: MERIS/NASA; processed by NOAA/NOS/NCCOS
Landscape surface water storage as a solution

Existing or restorable surface water storage features

Pael et al. (2016) Harmful Algae
Non-floodplain wetlands (NFWs): primary surface water storage features

CN Jones et al. (2018) Hydrological Processes
Conceptual model: NFWs for mediating nutrients at watershed scales

Golden et al. 2019, Environmental Science & Technology
Landscape water storage and watershed nutrient conditions

• Limited understanding of how landscape water storage features (wetlands, floodplains) interact with nutrient sources to affect stream nutrient loading, particularly in large river basins

• **Research Question**: How do wetlands, as landscape water storage features, mediate water quality across a range of land use and environmental gradients?
A first glimpse:

Relationships among riverine nitrate, wetland cover (%), and crop cover (%)

Hansen et al. (2018) *Nature Geoscience*
A first glimpse:

Our data agree!

(A teaser for the forthcoming slides...)
UMRB contributes more TN and TP to the Gulf of Mexico than other portions of the Mississippi River Basin.
EXPLANATORY VARIABLES

Geospatial Data
e.g., land cover, agriculture and atmospheric N and P inputs

Climate Data
e.g., precipitation

Wetland and Wetland Flowpath Metrics
e.g., area & type, flowpath frequency & magnitude

RESPONSE VARIABLES

[TN]

88 gages >= 25 records

Legend

[Kilometers]

75 150 300

UMRB Watersheds
UMRB Boundary

[TP]

123 gages >= 25 records
32 were used

Legend
- Gages with TP Records (1995-2007)

[Kilometers]

75 150 300

UMRB Watersheds
UMRB Boundary

Mengistu et al. (In prep)
Wetland flowpath metrics to nearest surface water

- **Type** - Riparian (bidirectional), non-riparian surface, non-riparian subsurface
- **Magnitude** - Very fast, fast, moderate, slow, very slow travel times
- **Frequency** - High, moderate, low
- **Impact** - None, low, high

From Rains et al. (2016) Hydrological Processes

Leibowitz et al. (Submitted)
Summary of Results

• Agriculture is statistically related to elevated TN and TP in UMRB watersheds.

• Wetland flowpath metrics improved the prediction of TN and TP concentrations.

• Wetlands and their water flow path-associated characteristics revealed mediating roles to reduce TN and TP concentration in streams.

• Wetland transport metrics related to attenuating flows along the wetland to stream flowpath (e.g., high porosity, Manning’s N) and variables such as the density of wetlands were related to lower TN and TP concentrations.
Next, we are...

...Integrating NFWs into large-scale process-based watershed models for future water quality projections

What does this mean, exactly? We’re considering NFWs and surface depressions in models to predict flood, drought, and nutrient conditions across watersheds. This typically does not happen.
Landscape and Floodplain Storage

Improved accuracy with spatially explicit inclusion of landscape water storage capacity

High-resolution SWAT model
- ~16,000 river reaches
- ~0.5 million sq km basin

10m DEM and Water body inventories

Surface storage: area and volume

Spatially explicit inclusion in a modified SWAT model

~ nearly 0.9 million modeled surface depressions
**BASIN HYDROLOGIC DYNAMICS**

*Average annual water yield*

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**Without surface depressions**

- **Model[NoStorage]**

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**With surface depressions**

- **Model[Storage]**

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**Water yield (mm/year)**

- 50 - 100
- 100 - 150
- 150 - 200
- 200 - 250
- 250 - 300
- 300 - 350
- 350 - 400
- 400 - 450
- 450 - 500
- 500 - 550
- 550 - 600

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**Significance of change**

- □ p > 0.05
- • p < 0.05
Integrating NFWs into watershed models: impacts on nutrients

Cedar River Watershed
Iowa, US
16,000 km²

Golden et al. 2019, Environmental Science & Technology
Subbasin Yields of Nitrate-N

a) Model without non-floodplains wetlands  

b) Model with non-floodplains wetlands

Average annual NO₃-N (x10⁻² kg/km²)

- 0.20 – 0.65
- 0.65 – 0.85
- 0.85 – 0.95
- 0.95 – 1.00
- 1.00 – 1.05
- 1.05 – 1.10
- 1.10 – 1.25
- 1.25 – 4.50

Golden et al. 2019, Environmental Science & Technology
Take-home

• Water storage features, and specifically NFWs, show promise for mediating watershed-scale aquatic nutrient conditions but more research is needed

• Integrating NFWs into process-based watershed models is critical for getting the “best” water quality projections for climate variations, land cover change, and other future management scenarios
What’s next?

• Asking questions such as: Where in the UMRB can nutrients be most efficiently processed and removed for decreased N and P loading to surface waters?

• Applying data mining approaches to wetland flowpath metrics with TN and TP as response variables

• Linking SWAT floodplain/wetland and hydrological modeling to nutrients across the river basin to do this

• Begin transferring what we learned to other large river basins

• Thoughts and feedback welcome! golden.heather@epa.gov; lane.charles@epa.gov; christensen.jay@epa.gov