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Water Environment | Scientists Engineers

Connecting phosphorus loads to cyanobacteria biomass using the Western Lake Erie Ecosystem Model

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Western Lake Erie Ecosystem Model (WLEEM) Verhamme et al., 2016, *JGLR*

--developed and enhanced for GLWQA Annex 4

--three-dimensional, fine-scale, process-based

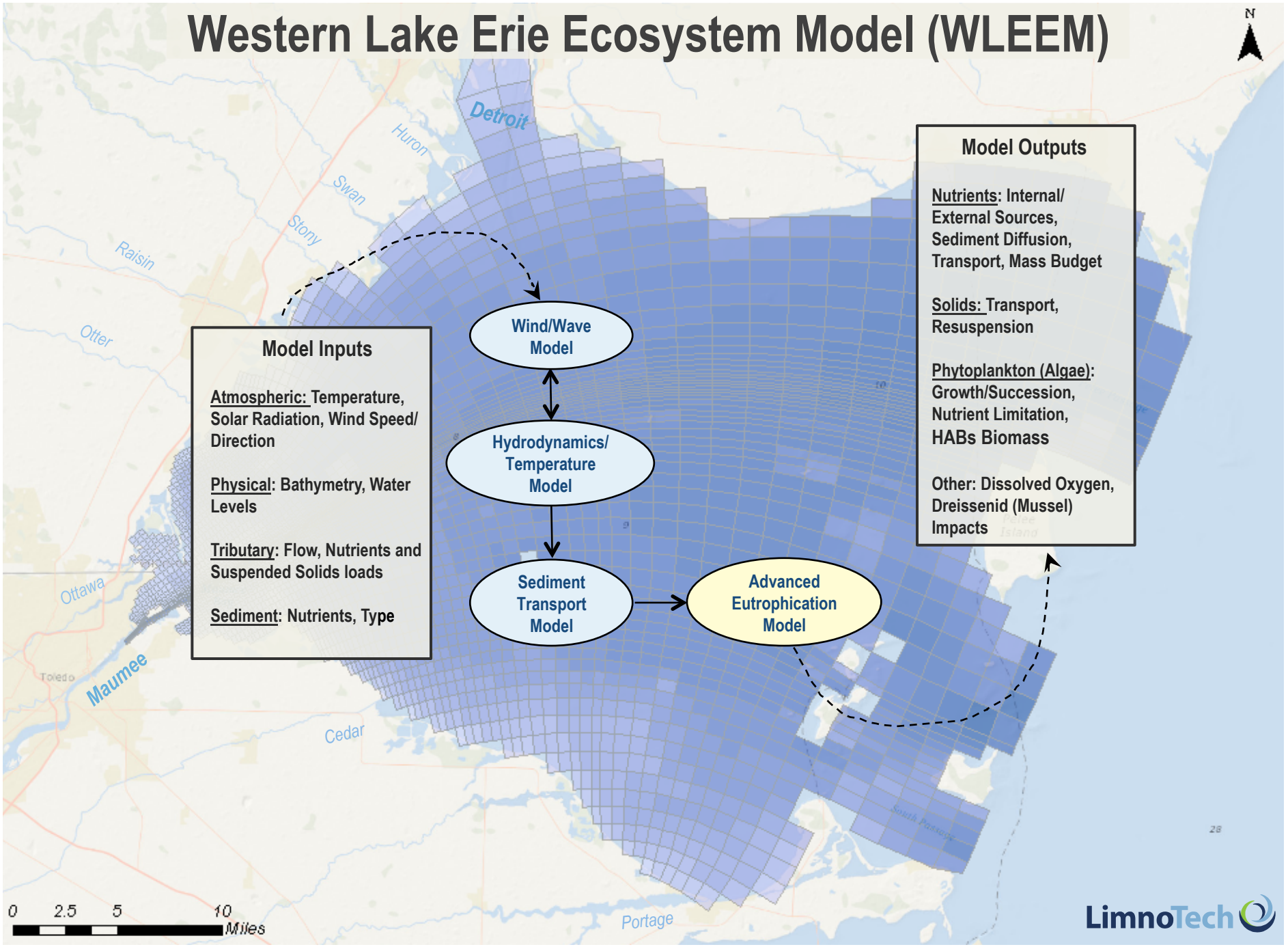
--links hydrodynamic, sediment transport, and in-lake biogeochemical/ecological processes

Used to:

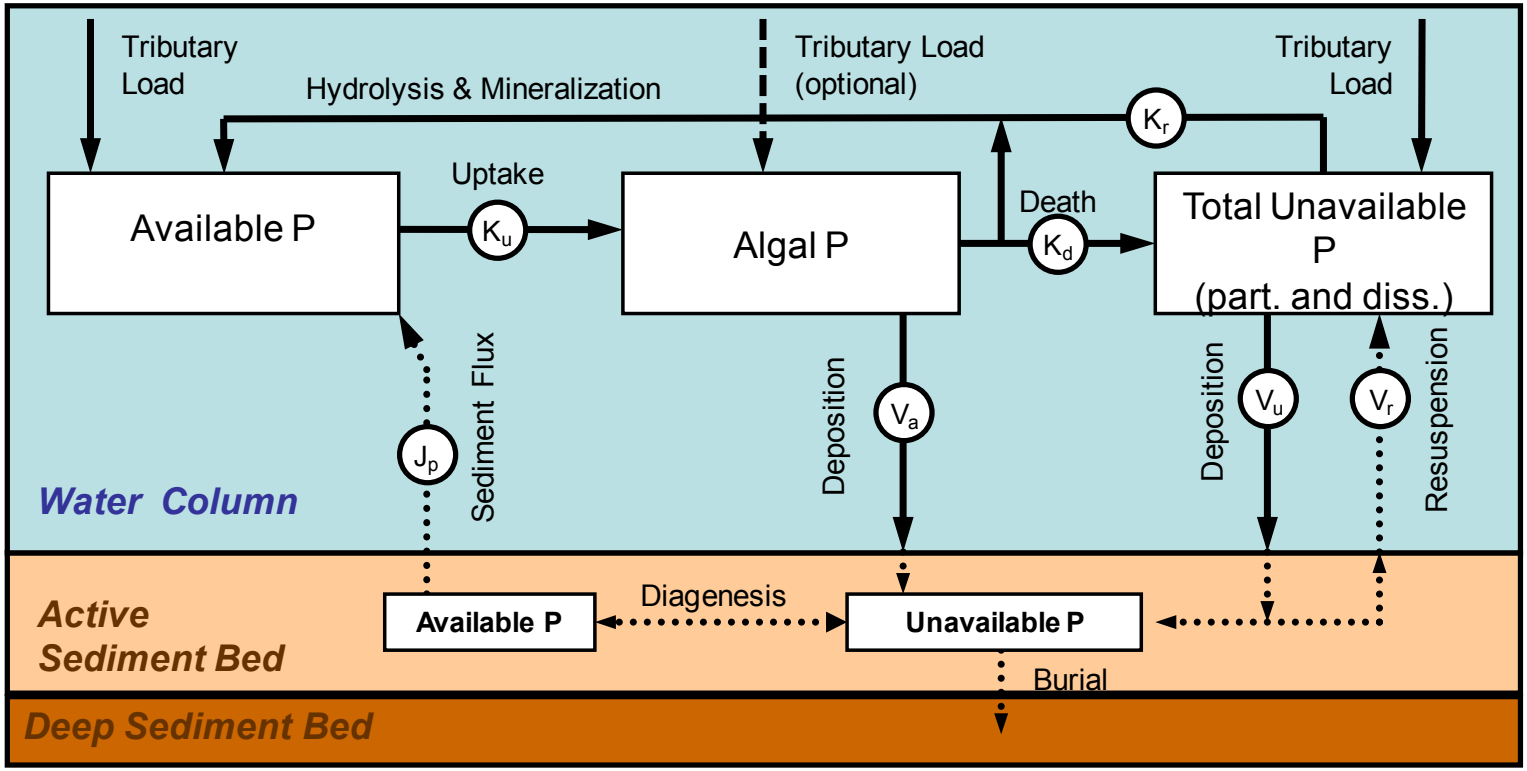
(1) relate spring P loading to summer cyanobacteria biomass

(2) assess system sensitivity to multiple variables (e.g., sediment fluxes, mussels, lag in recovery time)

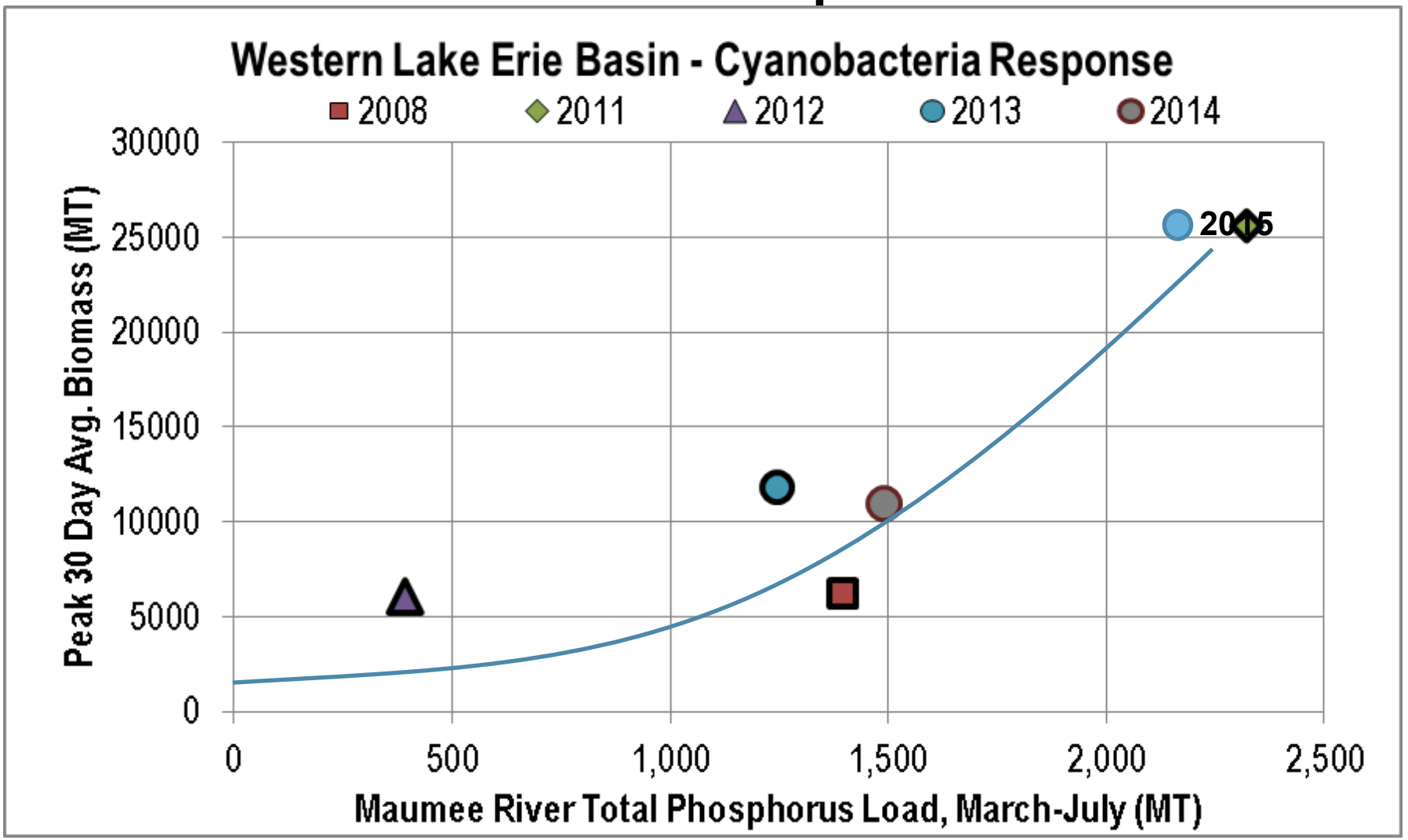
Western Lake Erie Ecosystem Model (WLEEM)



P Cycling


Tributary Load
Hydrolysis & Mineralization
Tributary Load (optional)
Tributary Load
K_r
Uptake
Available P
K_u
Algal P
Death
K_d
Total Unavailable P (part. and diss.)
Sediment Flux
J_p
Deposition
V_a
Deposition
V_u
V_r
Resuspension
Water Column
Active Sediment Bed
Available P
Diagenesis
Unavailable P
Burial
Deep Sediment Bed

Baseline Load-Response Data



2016 Forecast and Actual

1 Nov 2016 HABs Bulletin (overweight of 2015 residual)

--Stumpf, Wynne, Davis, Dupuy

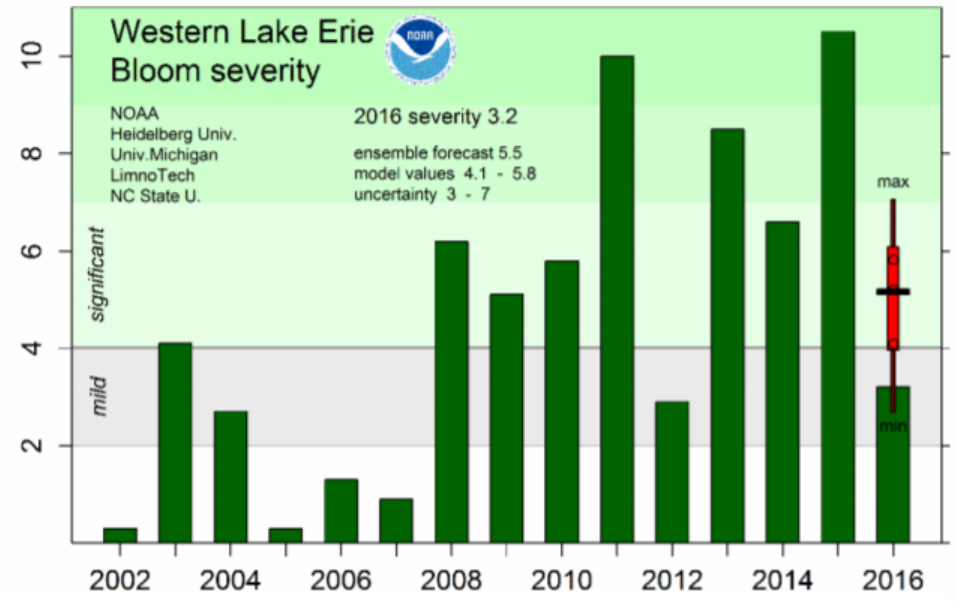


Figure 1. Bloom severity index for 2002-2016, and the forecast for 2016. 2011 is 10, 2015 is 10.5. The index is based on the amount of biomass over the peak 30-days. The 2016 bloom had a severity of 3.2, between 2003 and 2004.

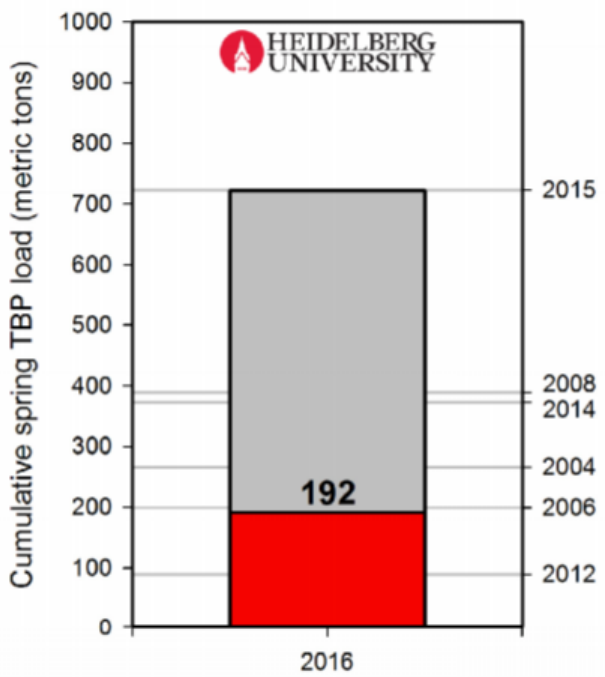
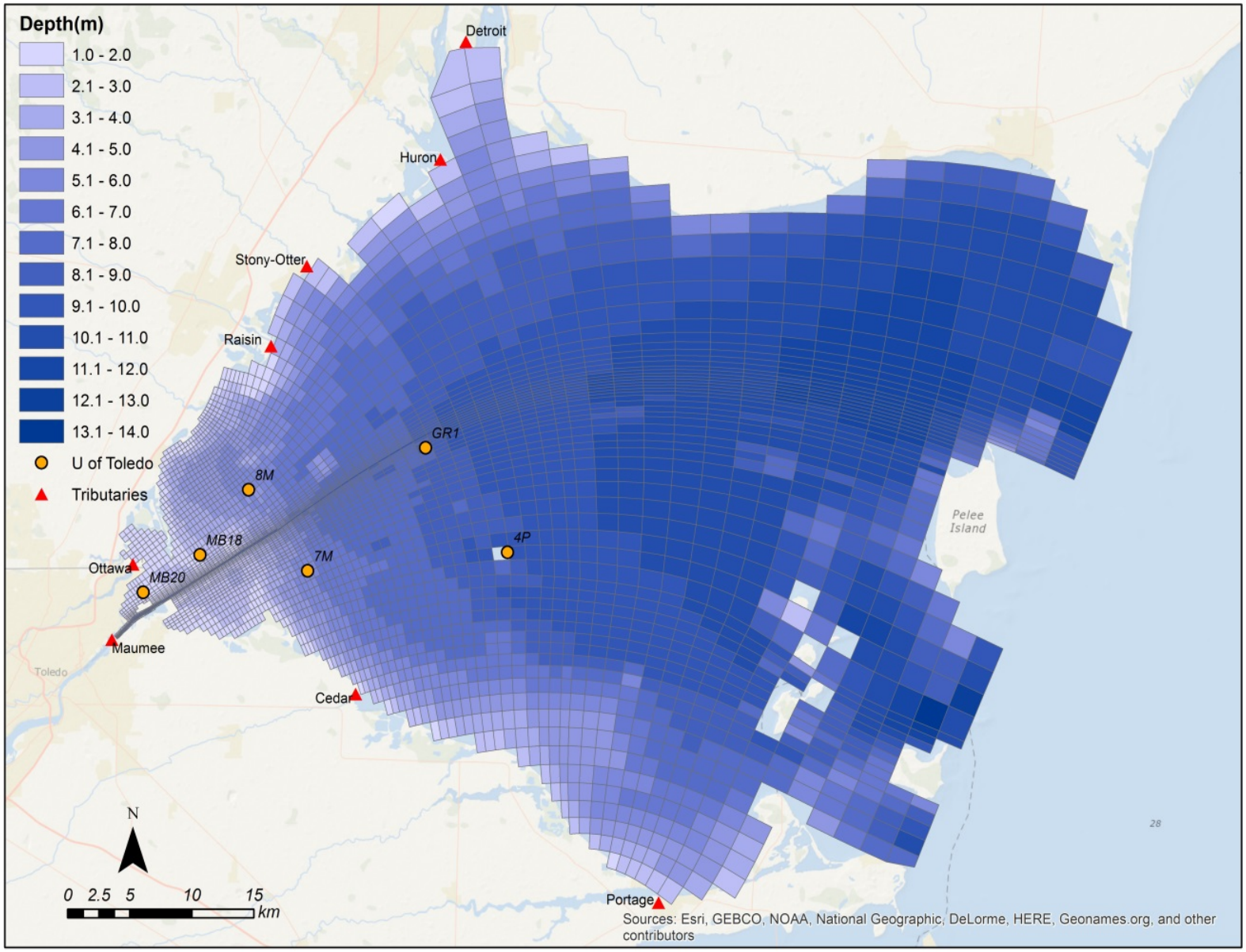


Figure 2. Total bioavailable phosphorus from the Maumee River for 2016 compared to some other years. Data collected by Heidelberg University.

Model/Data Comparison

1. Time Series Plots
2. P-Flux Bar Charts
3. Model Grid Maps

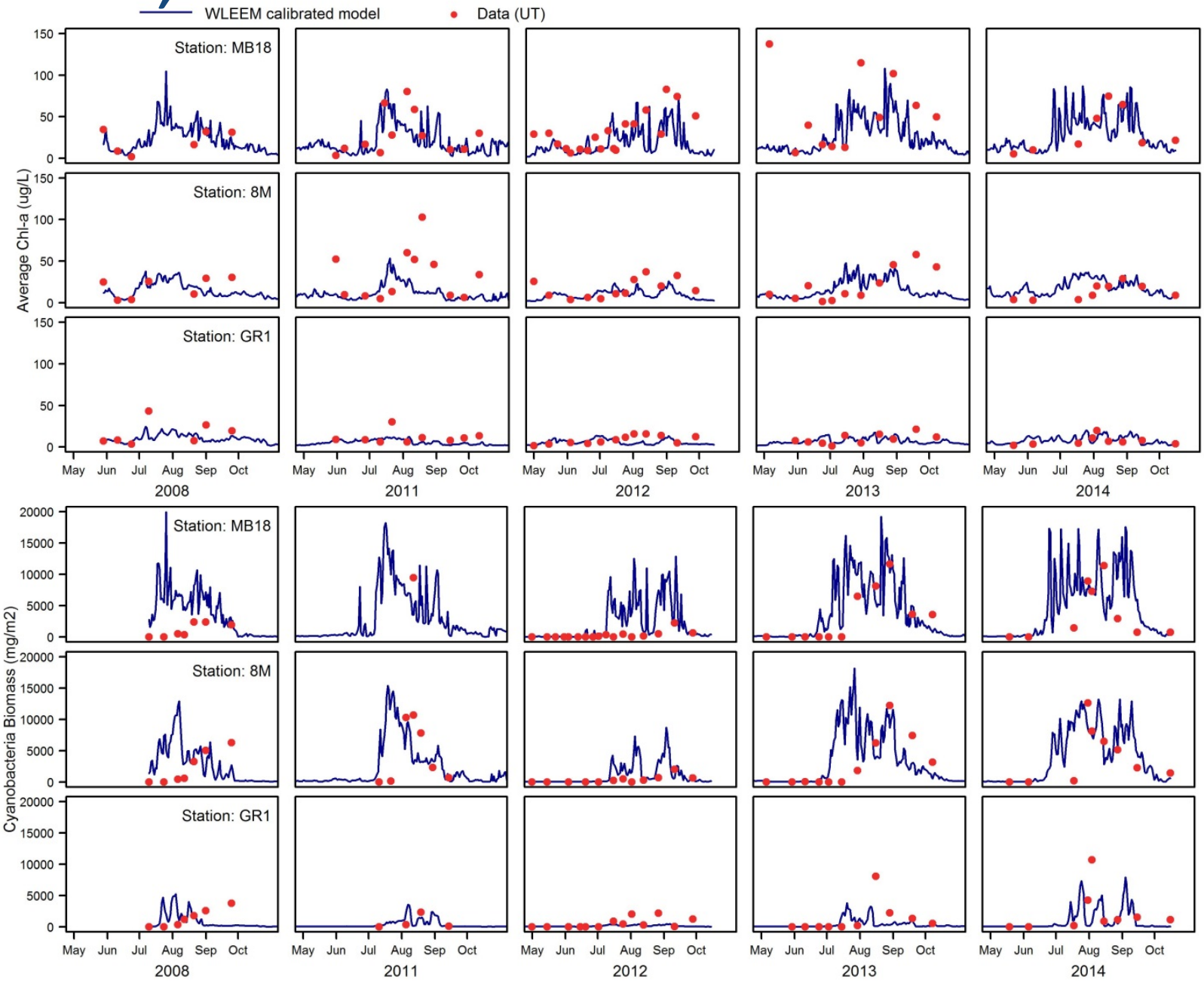
Station map


Depth(m)
1.0 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 7.0
7.1 - 8.0
8.1 - 9.0
9.1 - 10.0
10.1 - 11.0
11.1 - 12.0
12.1 - 13.0
13.1 - 14.0
U of Toledo
Tributaries
Detroit
Huron
Stony-Otter
Raisin
GR1
8M
MB18
7M
4P
Ottawa
MB20
Maumee
Toledo
Cedar
Portage
Pelee Island
N
0 2.5 5 10 15
km
Sources: Esri, GEBCO, NOAA, National Geographic, DeLorme, HERE, Geonames.org, and other contributors

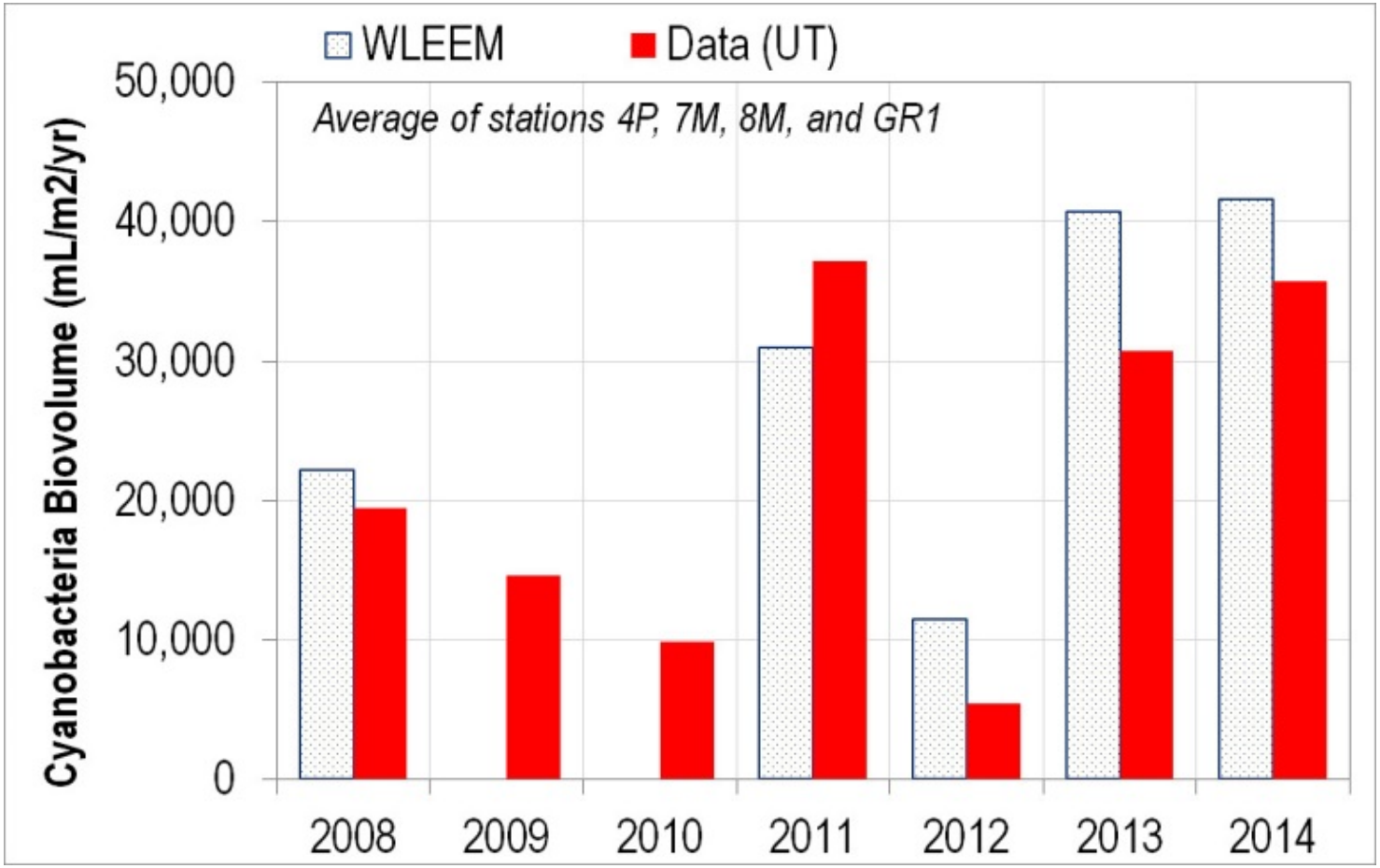
2008, 2011-2014

Chlorophyll

Cyanobacteria



2014 Samples vs. Model



2014 Satellite vs. Model

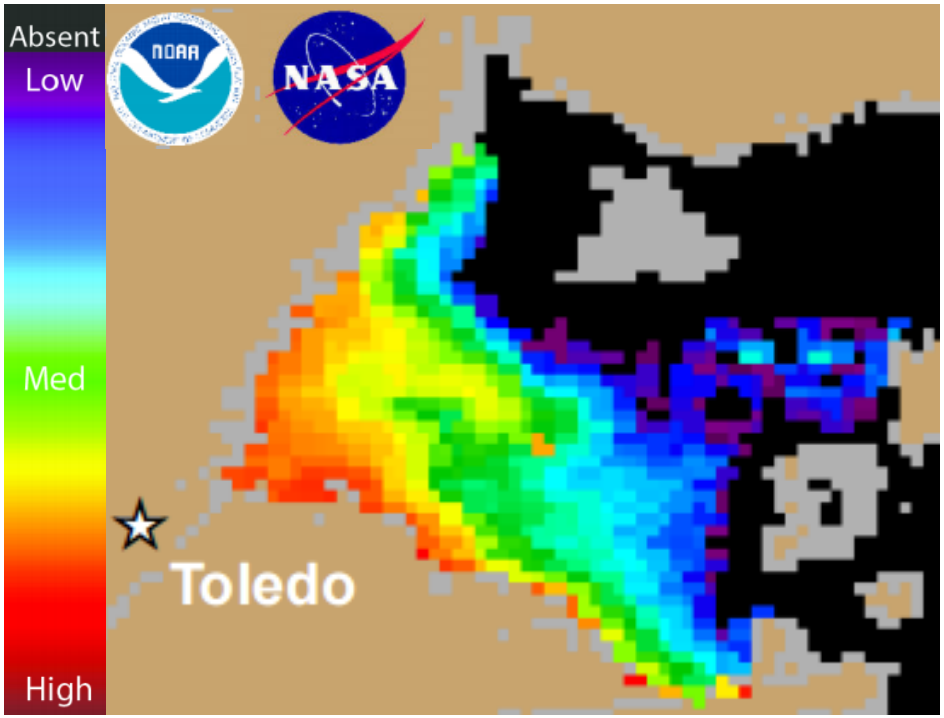
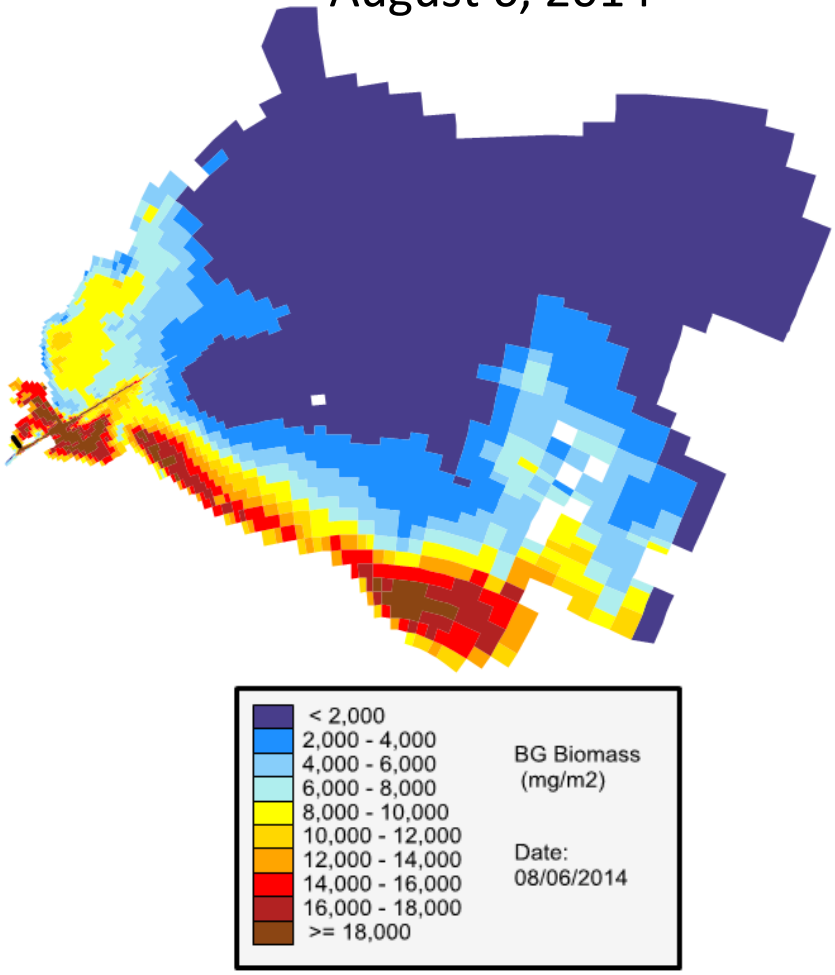


Figure 1. Cyanobacterial Index from NASA's MODIS-Terra data collected 6 August 2014 at 1:35 pm. Grey indicates clouds or missing data. Black represents no cyanobacteria detected. Colored pixels indicate the presence of cyanobacteria. Cooler colors (blue and purple) indicate low concentrations and warmer colors (red, orange, and yellow) indicate high concentrations. The estimated threshold for cyanobacteria detection is 35,000 cells/mL.

WLEEM Baseline
August 6, 2014



Sediment Diagenesis sub-model

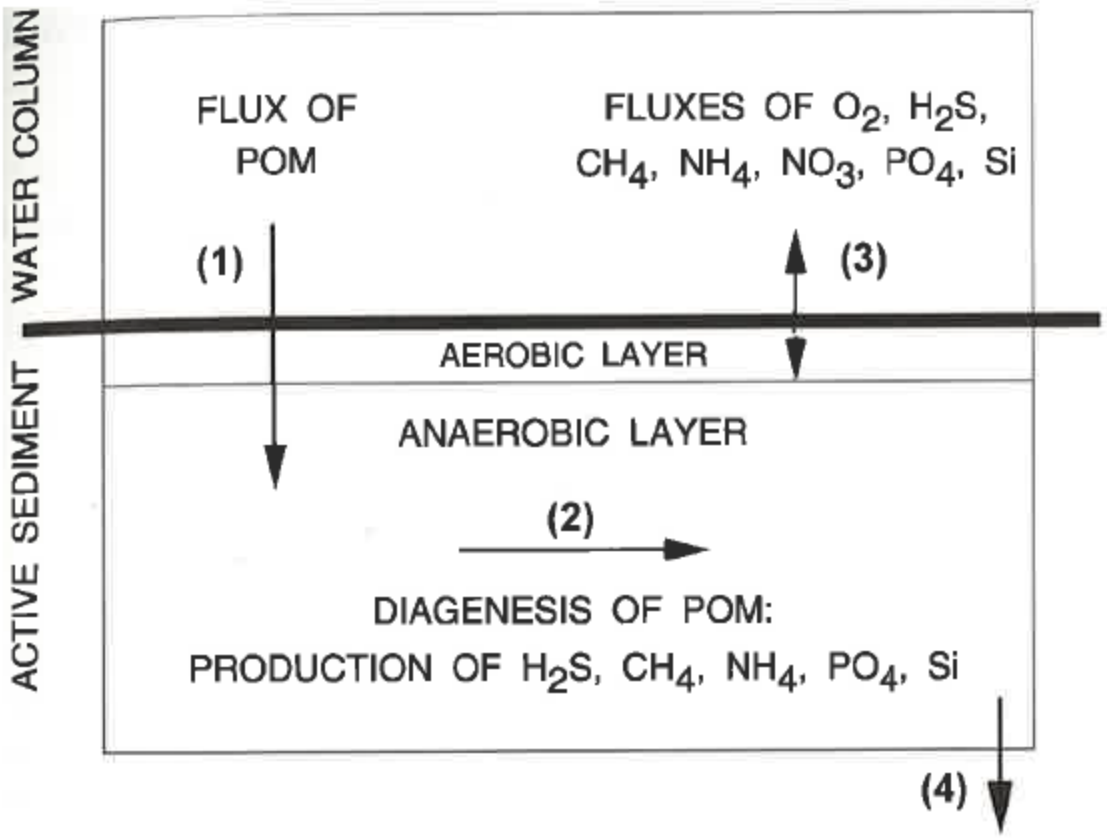
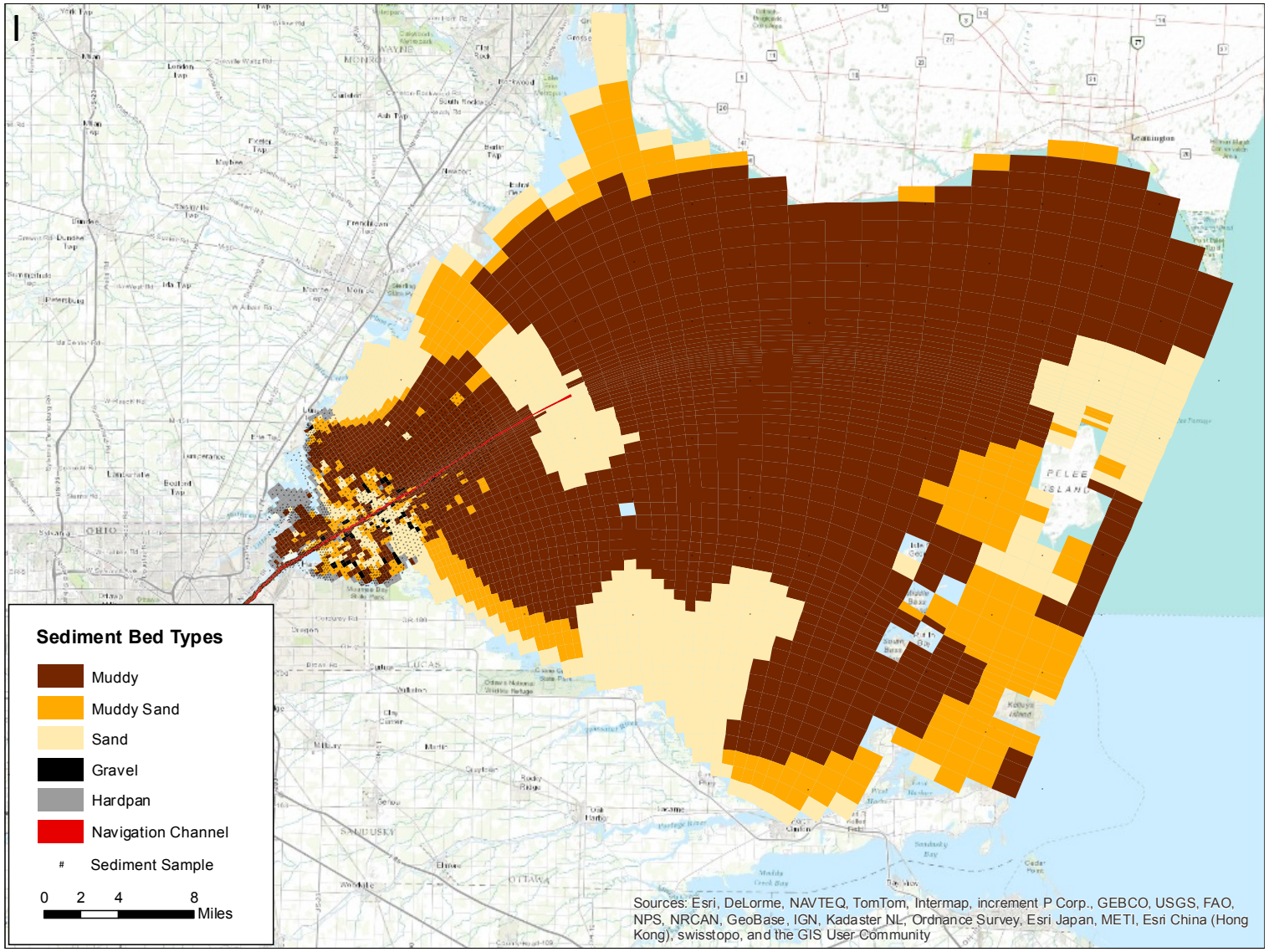


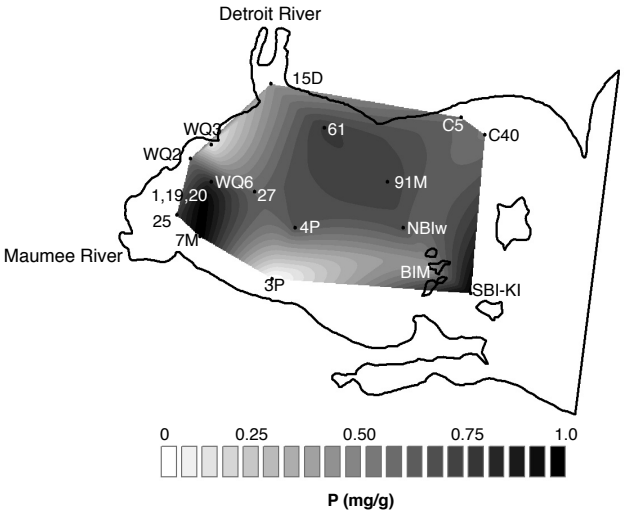
Fig. 2.1 Schematic of the nutrient and oxygen sediment flux model.

Includes temperature compensation

Bed sediment types

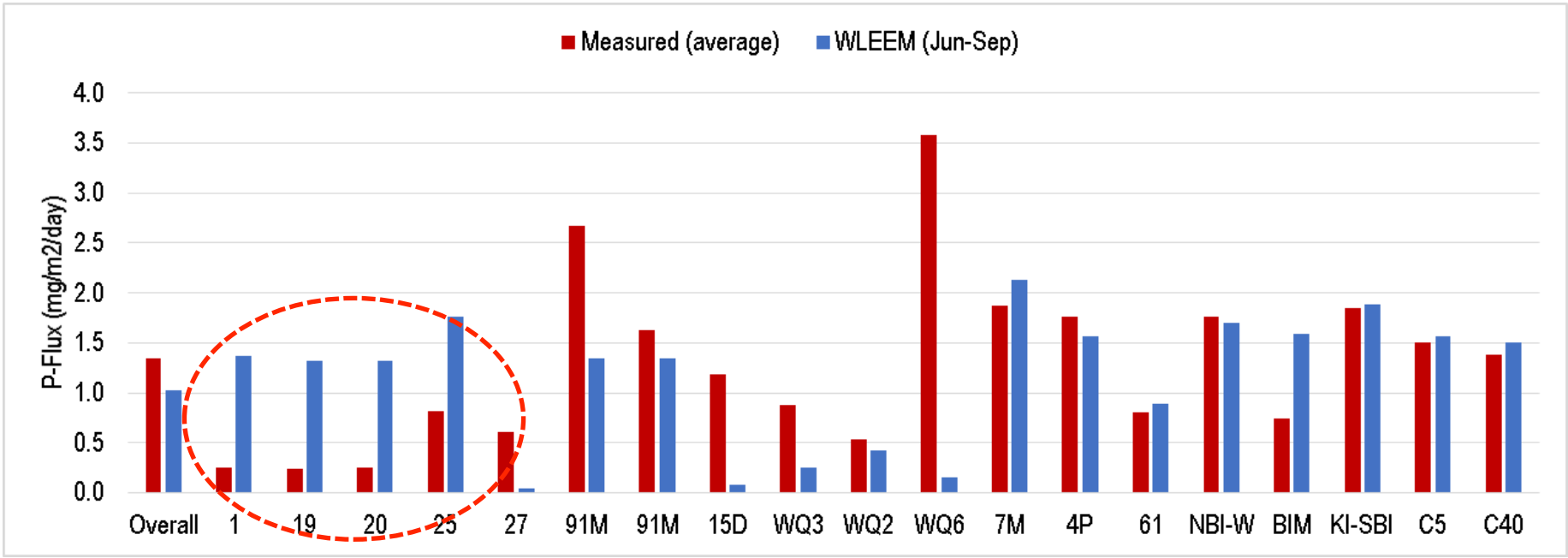


2014 Sediment P Flux

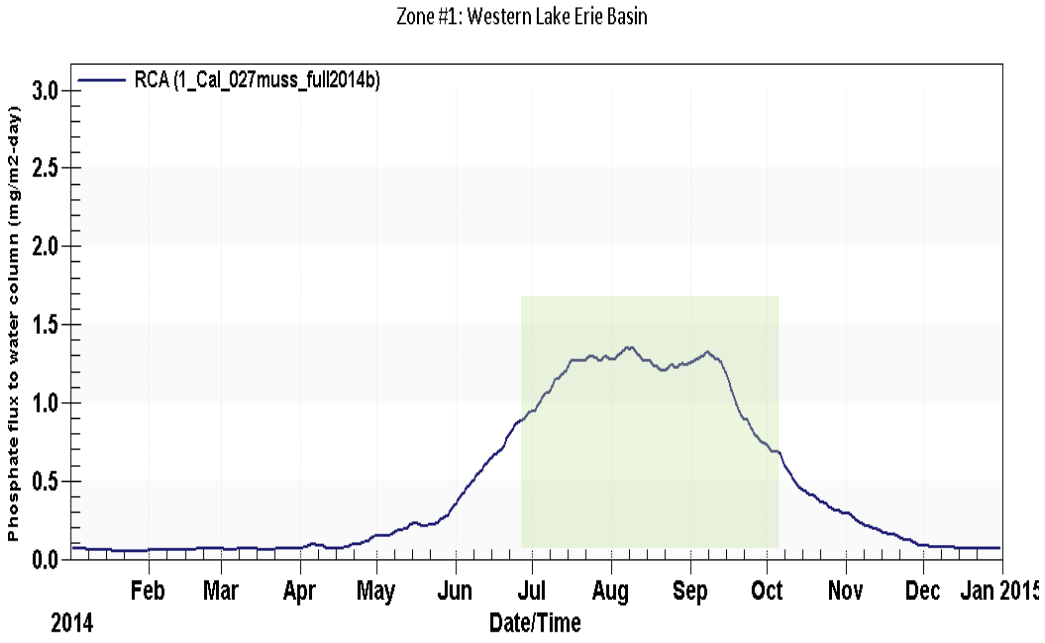


From Matisoff et al.: The average summertime aerobic P flux was **1.35 mg/m2/d**, with a 95% confidence interval of **0.95 to 1.79 mg/m2/d**

WLEEM flux from June to Sept: **0.66 to 1.25 mg/m2/d**



Jan-Dec 2014
Diffusive Phosphorus Flux
Temporal Variability



WLEEM

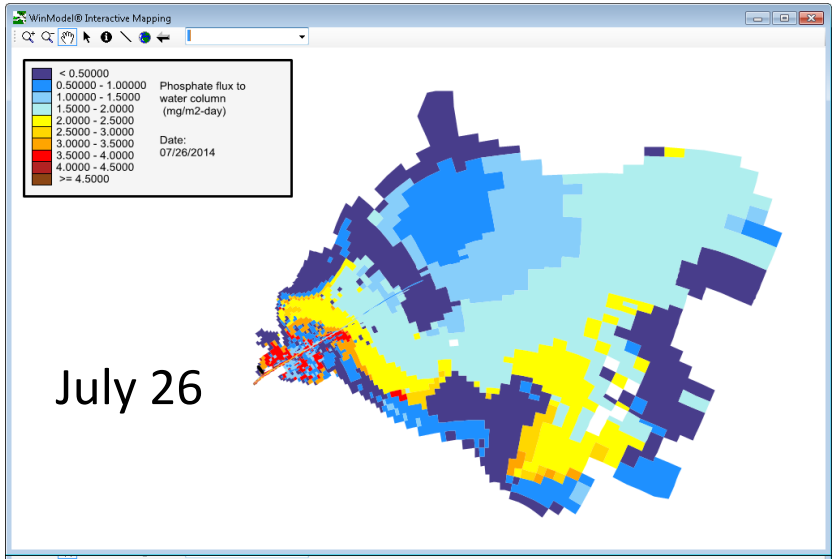
Month	Entire Basin Diffusion (MT)	Entire Basin Flux (mg/m^2-day)
Jan	5.18	0.06
Feb	4.98	0.06
Mar	5.77	0.06
Apr	8.05	0.09
May	19.82	0.21
Jun	**59.30**	**0.66**
Jul	**108.70**	**1.18**
Aug	**115.10**	**1.25**
Sep	**93.59**	**1.05**
Oct	41.44	0.45
Nov	15.22	0.17
Dec	6.48	0.07

484 MT	0.44 mg/m^2-day

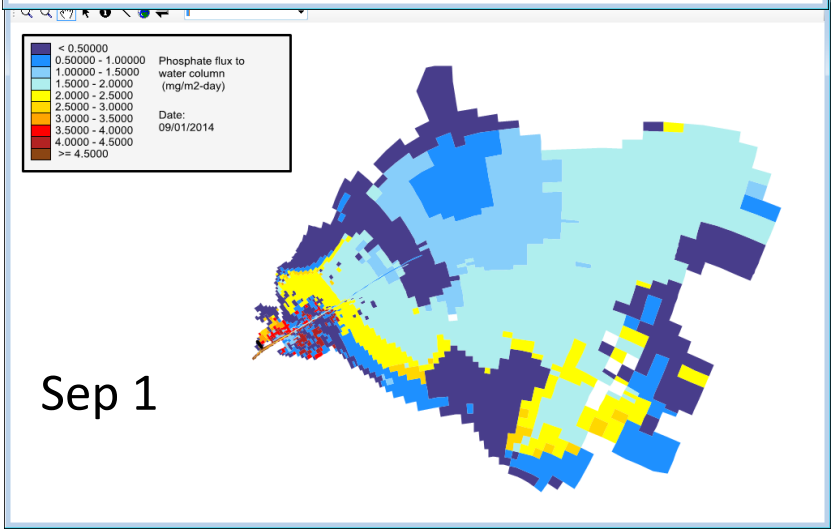
Jan-Dec 2014
Diffusive Phosphorus Flux

Spatial Variability

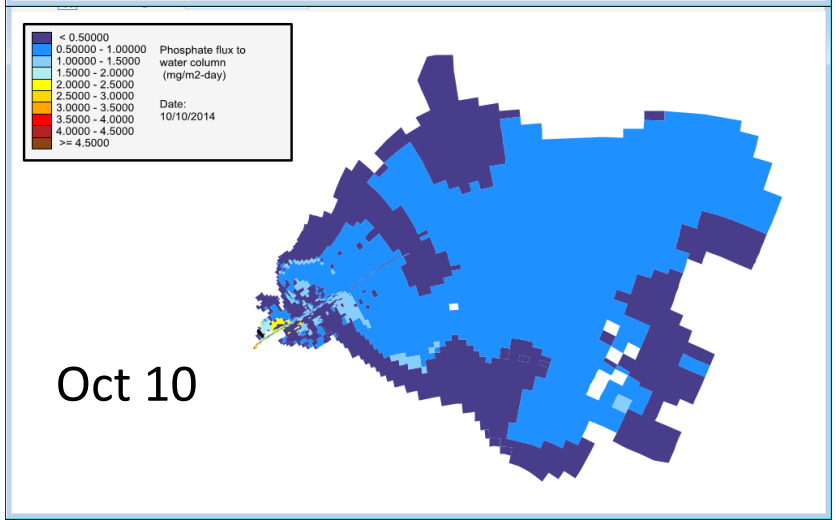
June 5



July 26



Sep 1

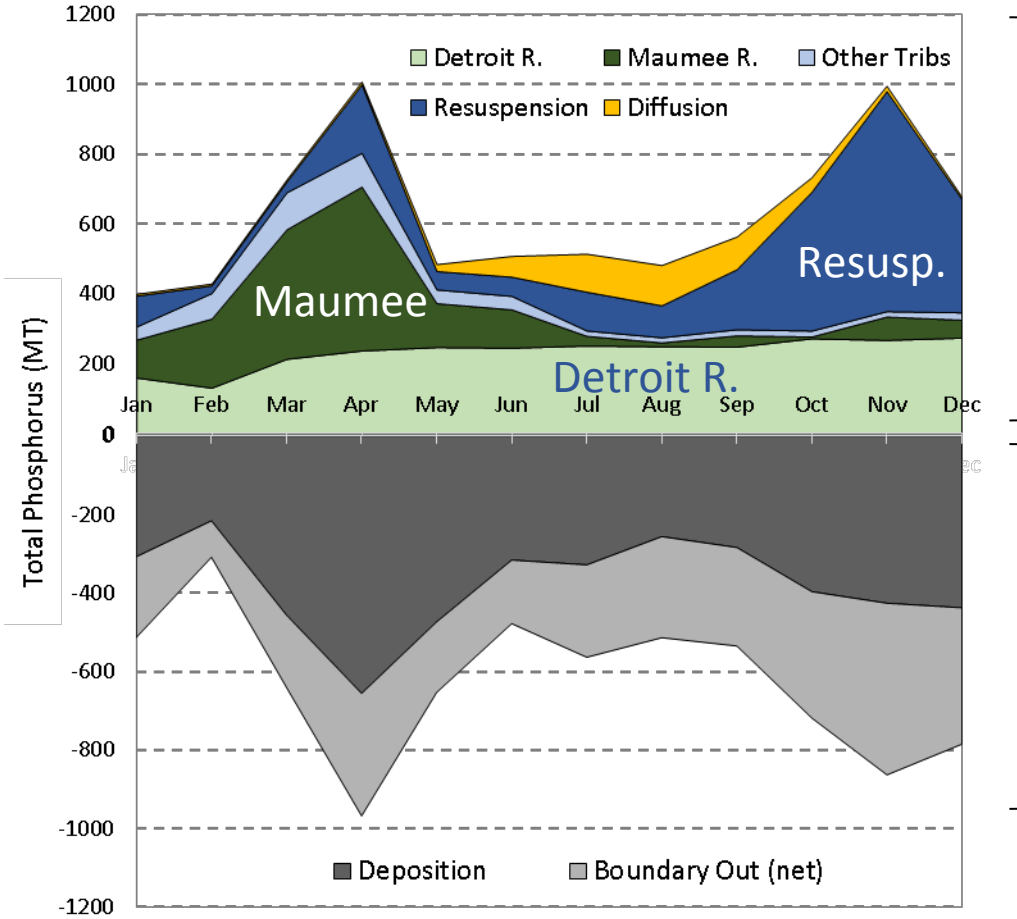


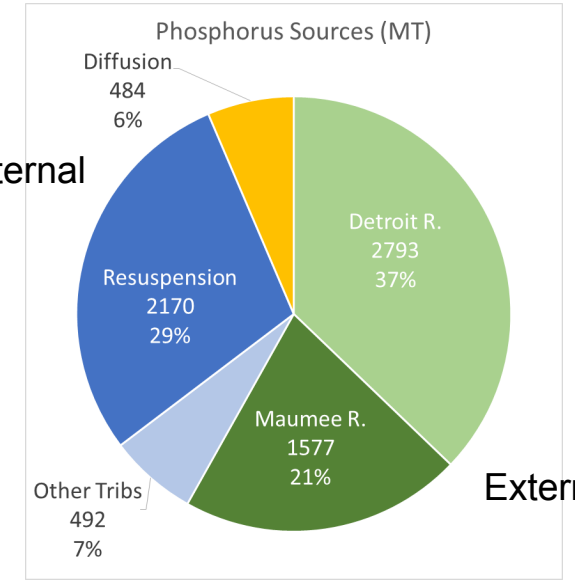
Oct 10

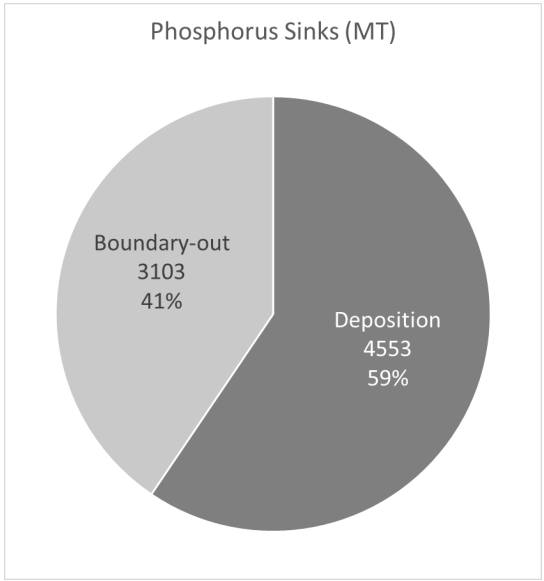
Model Application and Discussion

1. Phosphorus Mass Balance
2. Diagnostic Scenarios

Jan-Dec 2014
WLEB Phosphorus Mass Balance

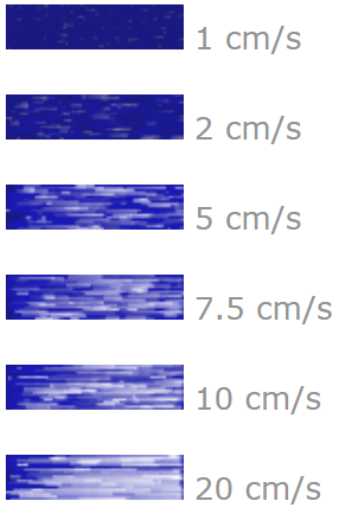


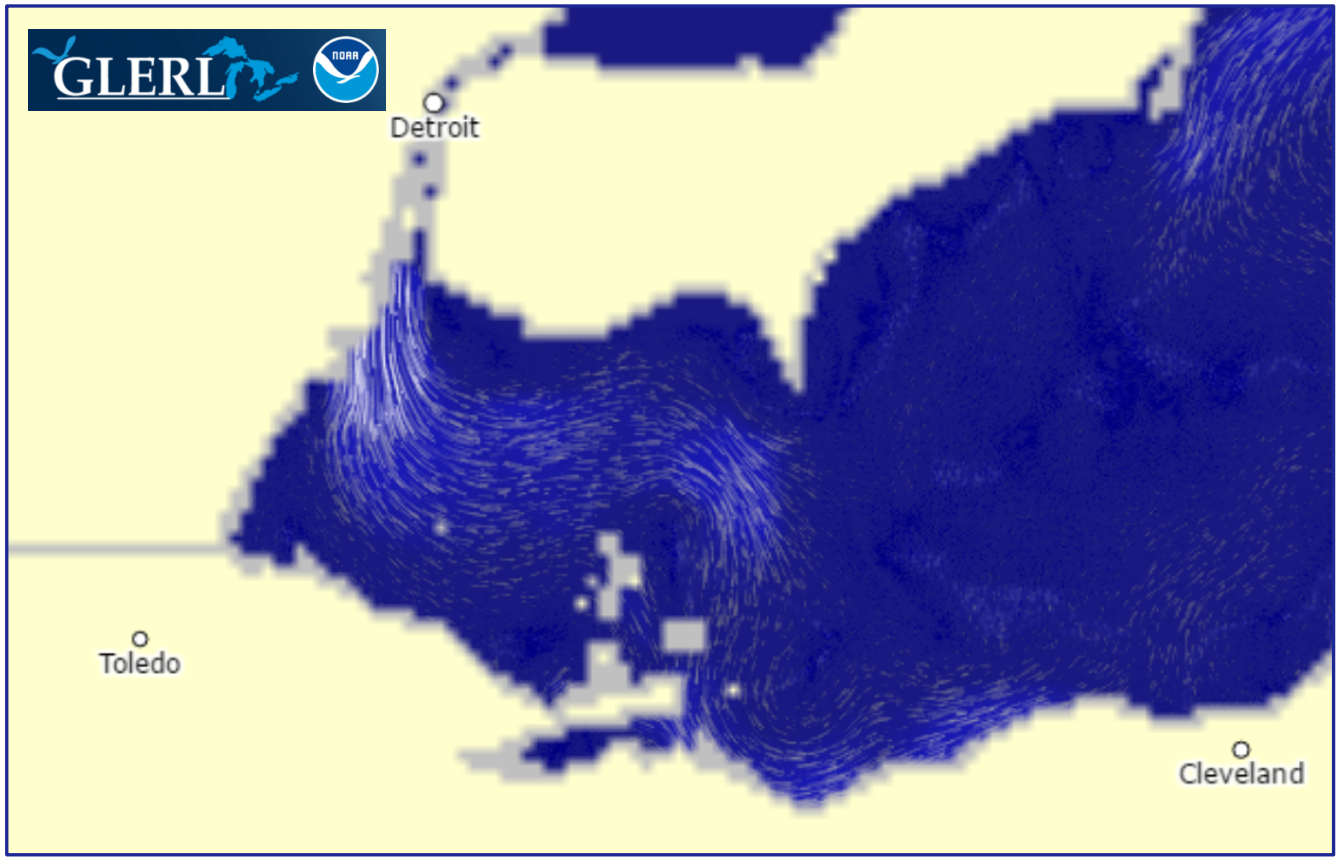




Detroit River Plume "Shunting"

July 2013
Depth-Averaged
Currents



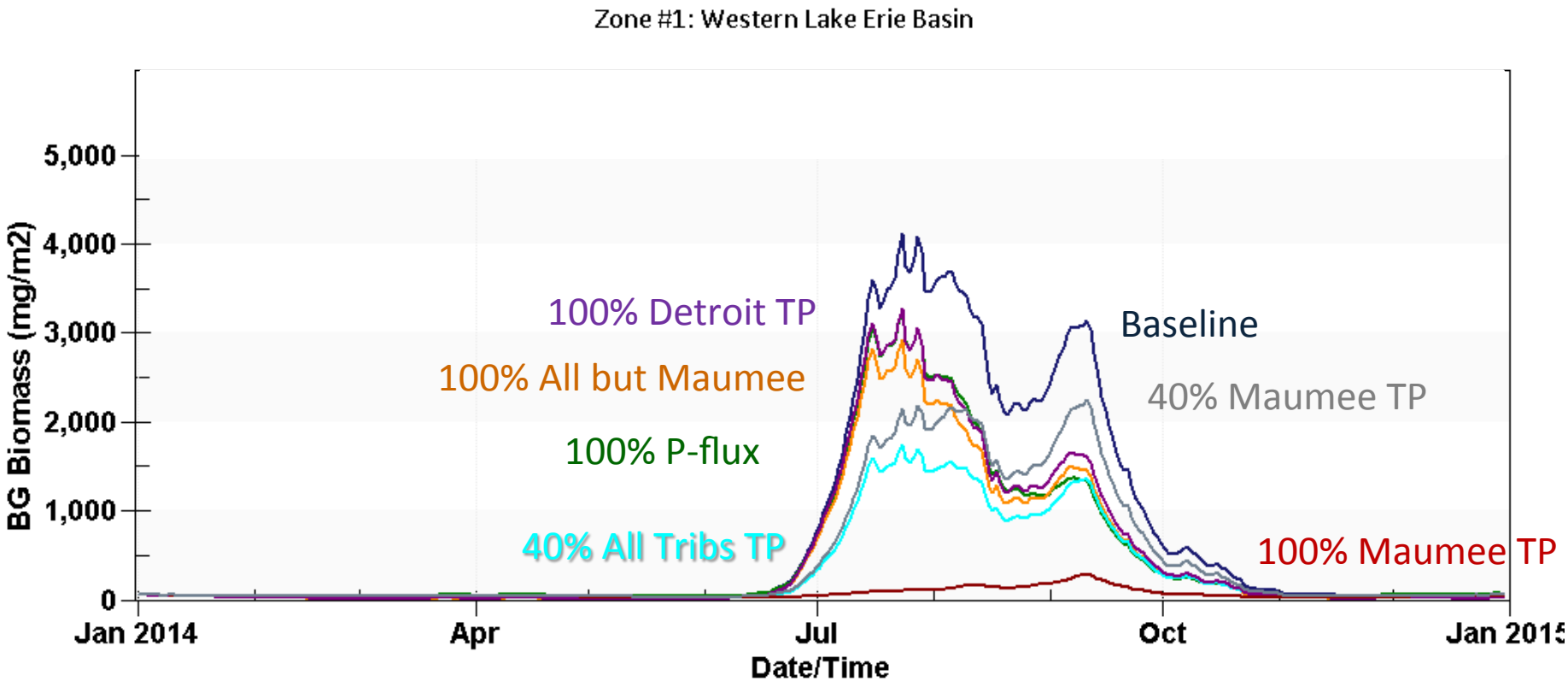


Model Diagnostic Scenarios

- Annex 4 recommendations
  - 40% TP reduction from all external sources
  - 40% TP reduction from Maumee R. only
- Tributary sensitivity
  - Maumee R. only
  - Detroit R. only
  - all external sources except Maumee R.
- Internal P fluxes
  - Eliminate sediment P-flux
  - Eliminate P Resuspension
- Dreissenid sensitivity (increase by 10x)

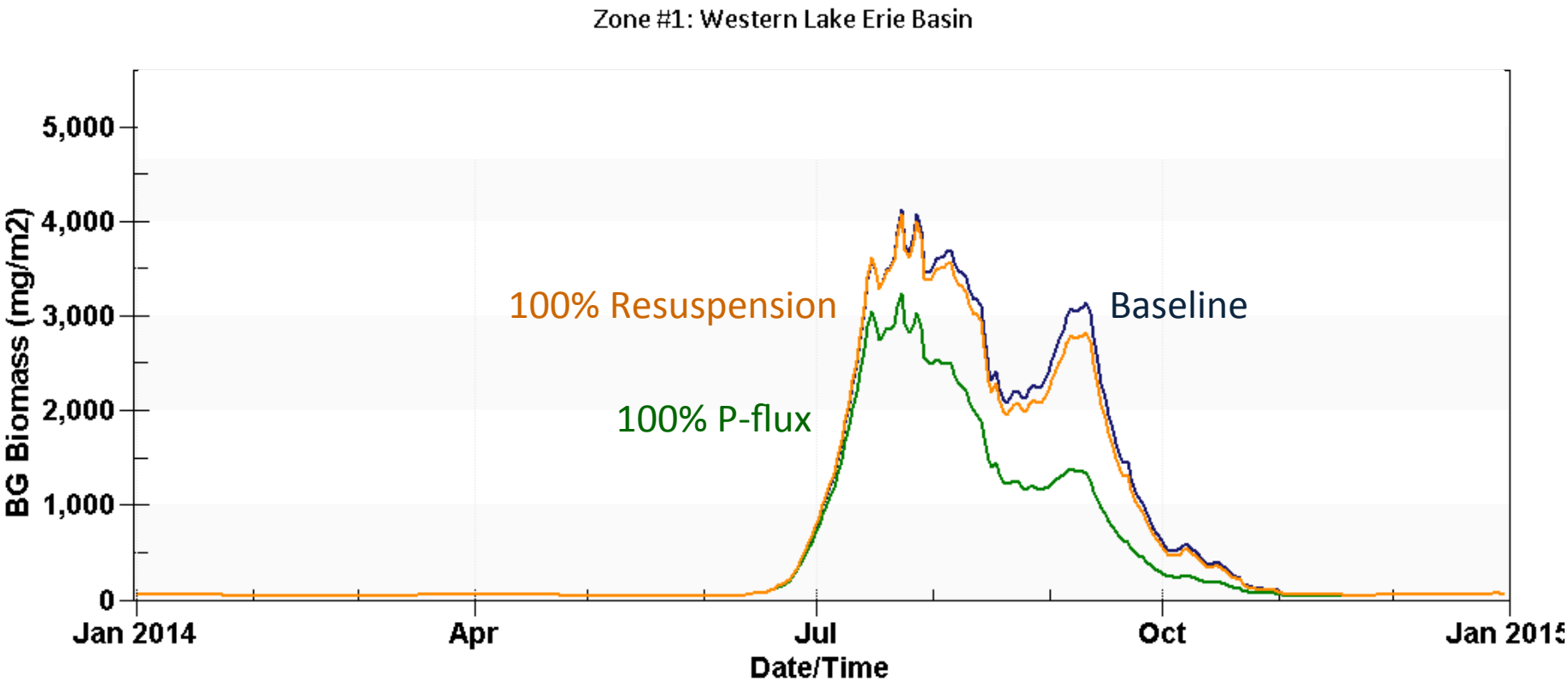
Model Diagnostic Scenarios

TP Load Reduction Scenarios

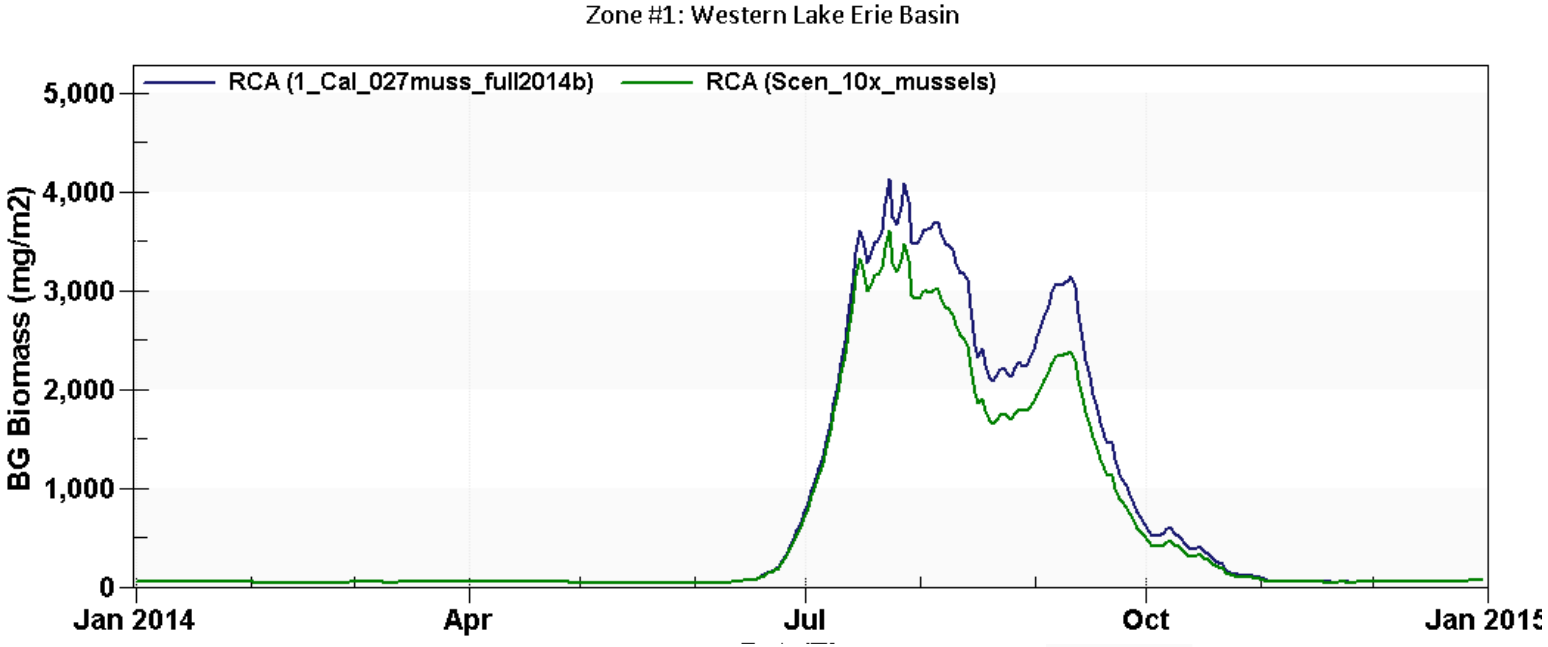


Model Diagnostic Scenarios

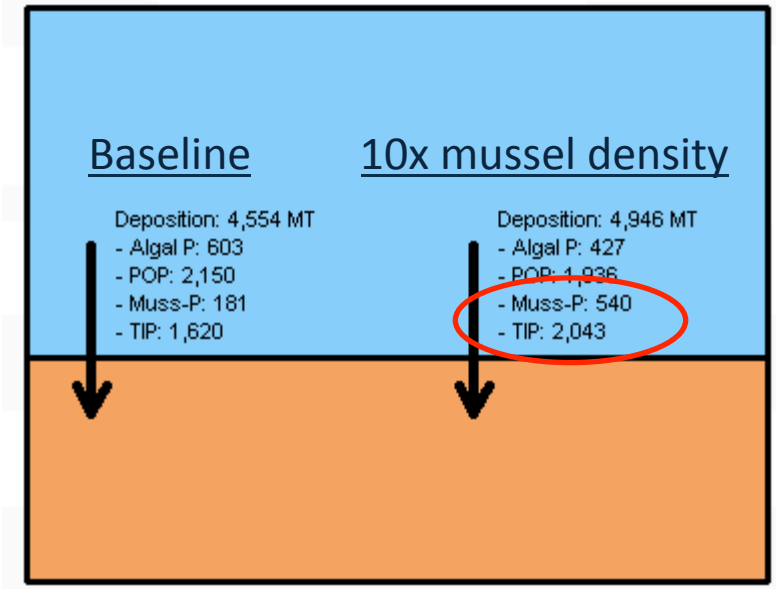
TP Load Reduction Scenarios: Internal Loads



Model Diagnostic Scenarios

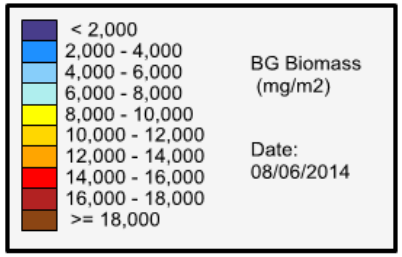


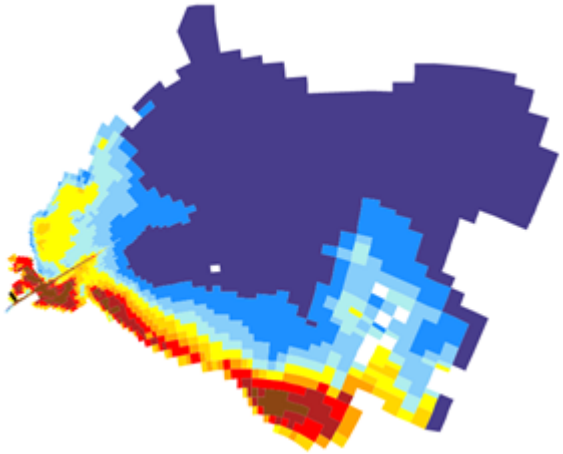
Increasing mussel density resulted in more P-deposition, and therefore less P in the water column, which inhibited cyanobacteria growth



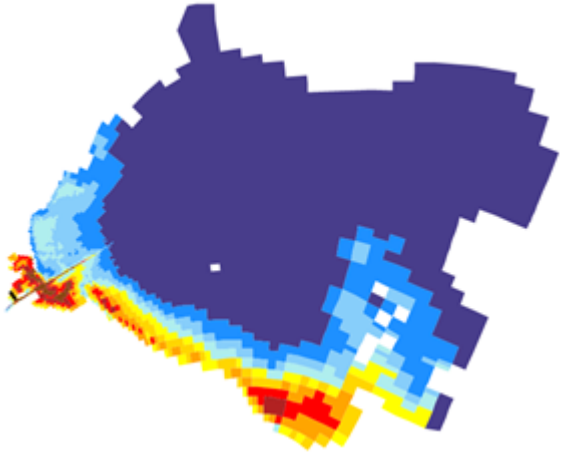
Model Diagnostic Scenarios

TP Load Reduction Scenarios

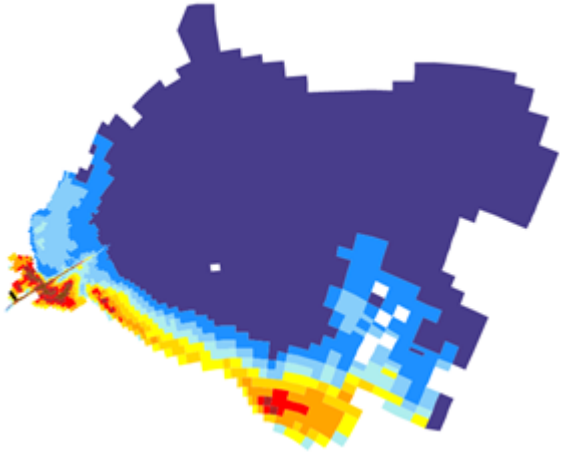




Baseline



↓ 100% Detroit TP



↓ 100% all but Maumee

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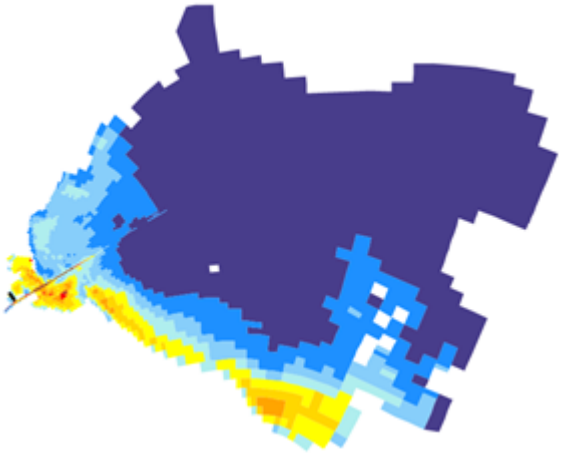
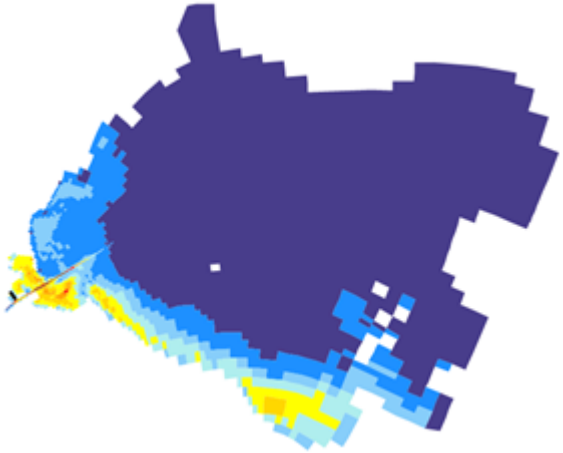


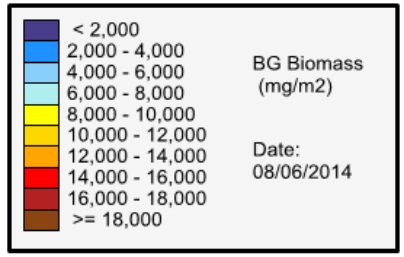
↓ 40% Maumee TP

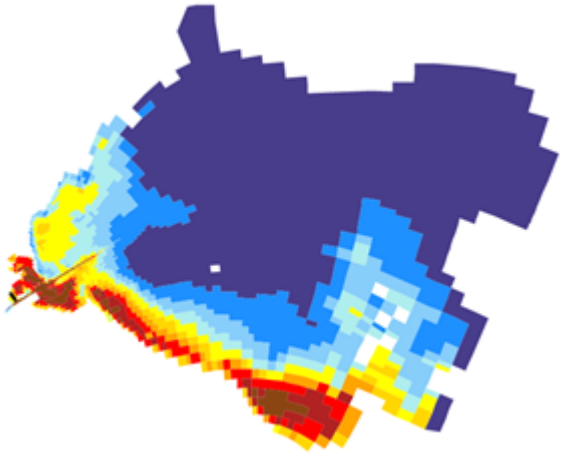


↓ 40% All Tribs TP

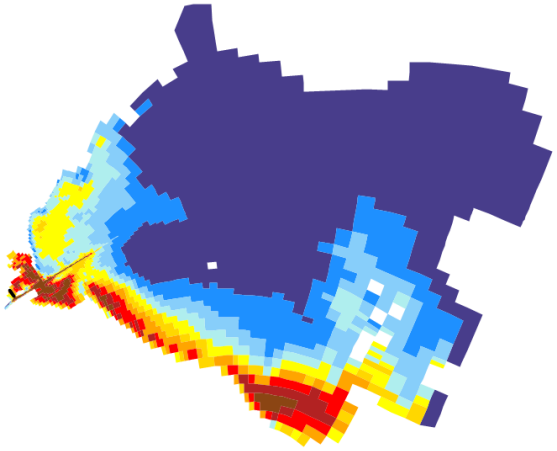
Model Diagnostic Scenarios

TP Load Reduction Scenarios

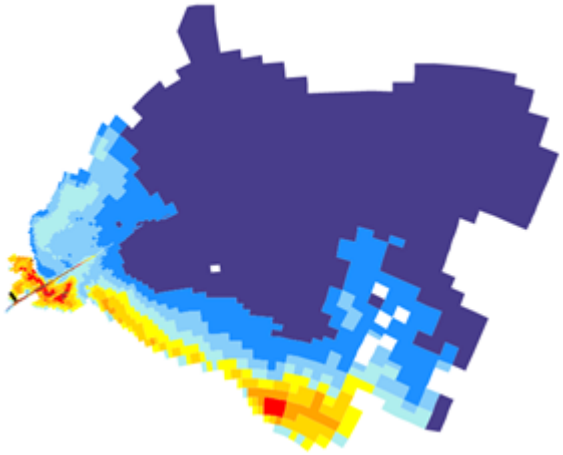




Baseline



↓ 100% Resuspension

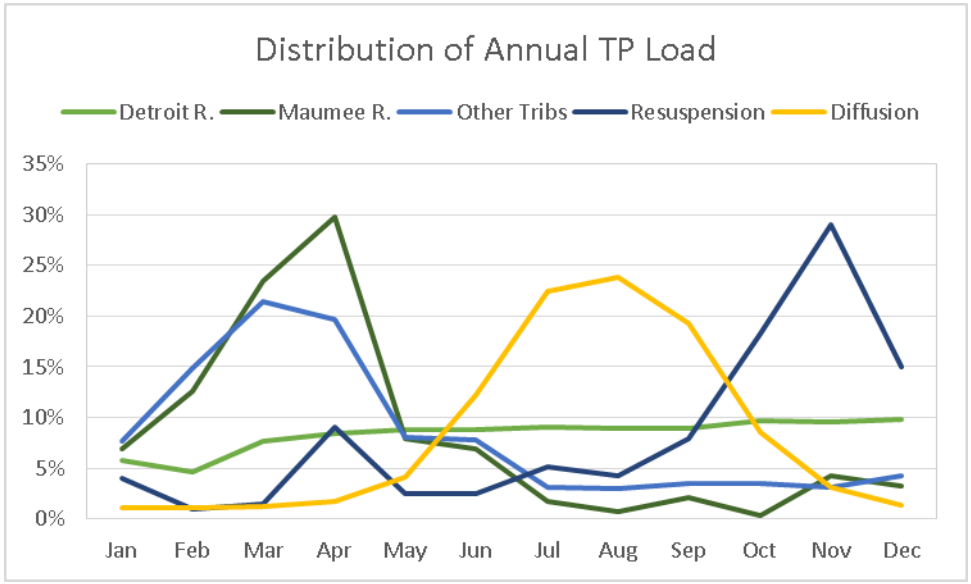


↓ 100% P-flux

August 6, 2014

Ranking of Bloom Drivers

- Maumee River TP most important (but timing offset)
- Diffusive P-flux moderate importance (no offset)
- Detroit River TP low importance (background)
- Resuspension of TP, mussels, least important



Next Steps

- Establish operational version of model for management (add infrastructure and support)
- Expand model to central and eastern Lake Erie to simulate hypoxia and *Cladophora*
- Apply to other embayments and lakes (Ontario next; additional Green Bay and Saginaw Bay applications)
- Incorporate cyanobacterial toxin production

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Questions?

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