Enhancing Phosphorus Reduction Strategies through Biogeochemical Research in a TMDL Watershed

Integrating research and extension in a southwest Michigan TMDL watershed

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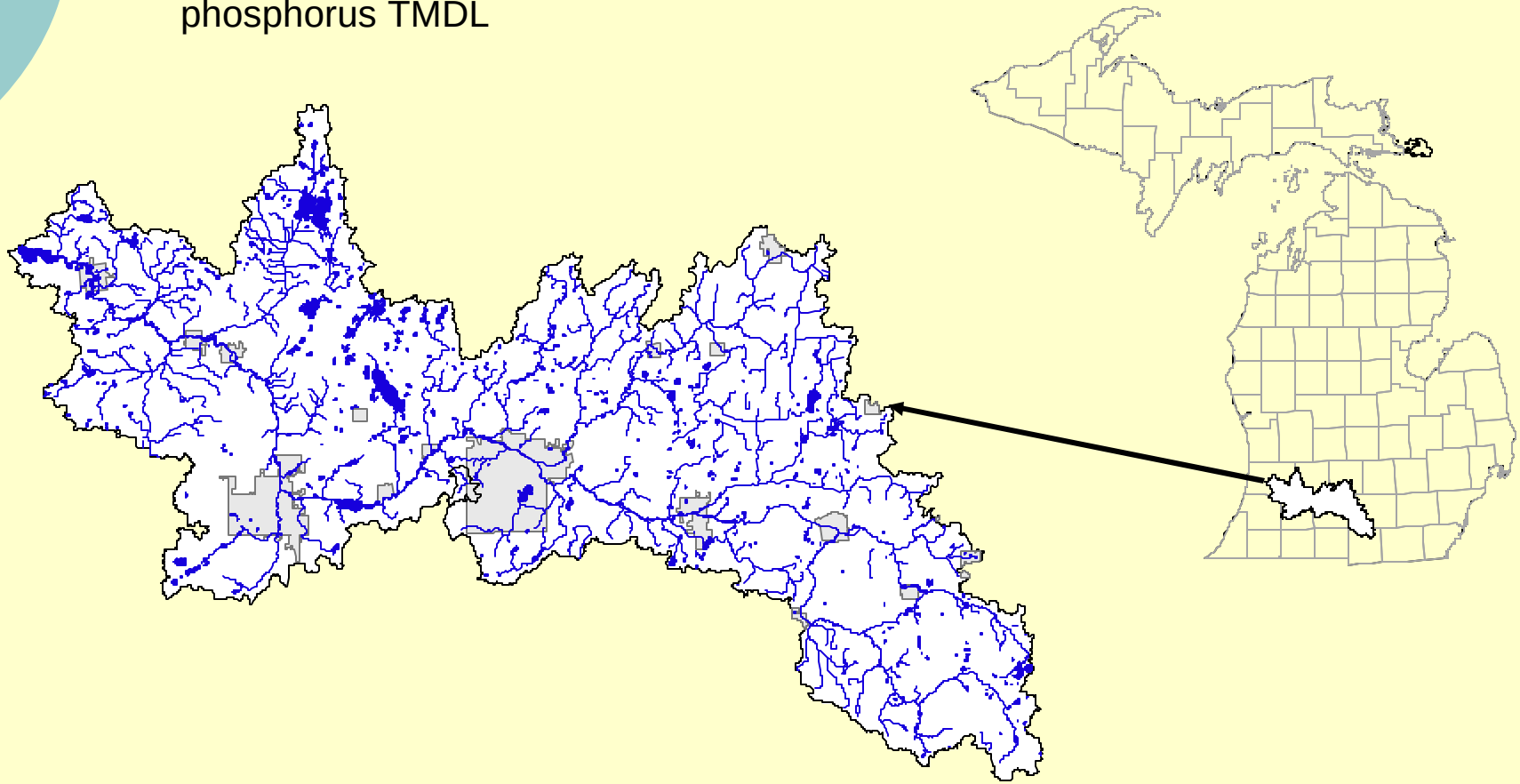
MICHIGAN STATE UNIVERSITY W.K. KELLOGG BIOLOGICAL STATION AN INTEGRATED LEARNING ENVIRONMENT

Enhancing Phosphorus Reduction Strategies in the Kalamazoo River Basin

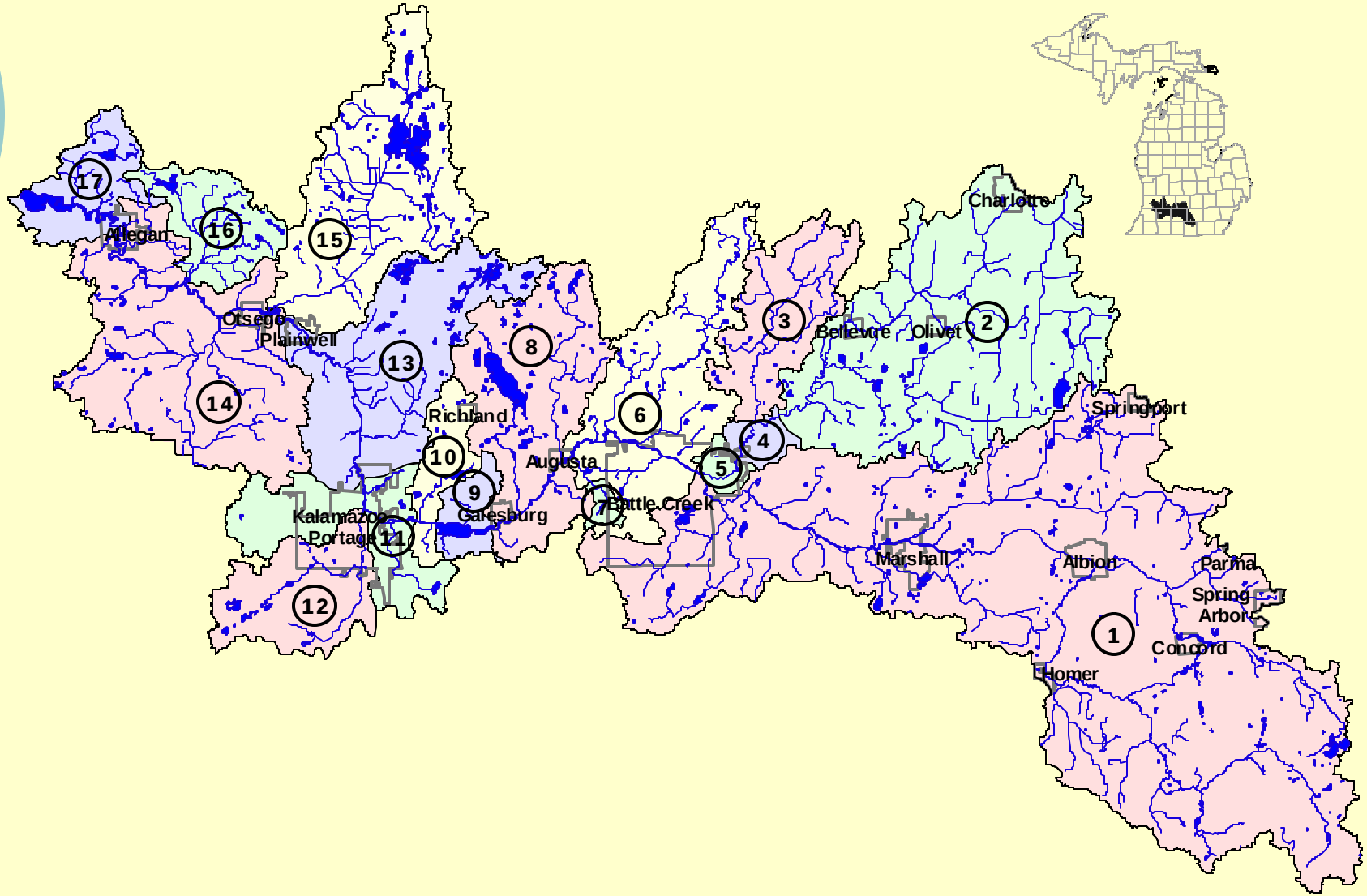
- CSREES water quality project goals
  1. Characterize the sources, fate and transport of phosphorus in the TMDL watershed
  2. Integrate research, education, and extension to enhance phosphorus reduction strategies through the stakeholder driven TMDL organization

Lake Allegan/Kalamazoo River phosphorus TMDL watershed

- 5,232 km^2 watershed in Southwest Michigan
- Agricultural watershed
- Nationally recognized stakeholder driven phosphorus TMDL



Research – Subwatersheds



Research - Sampling

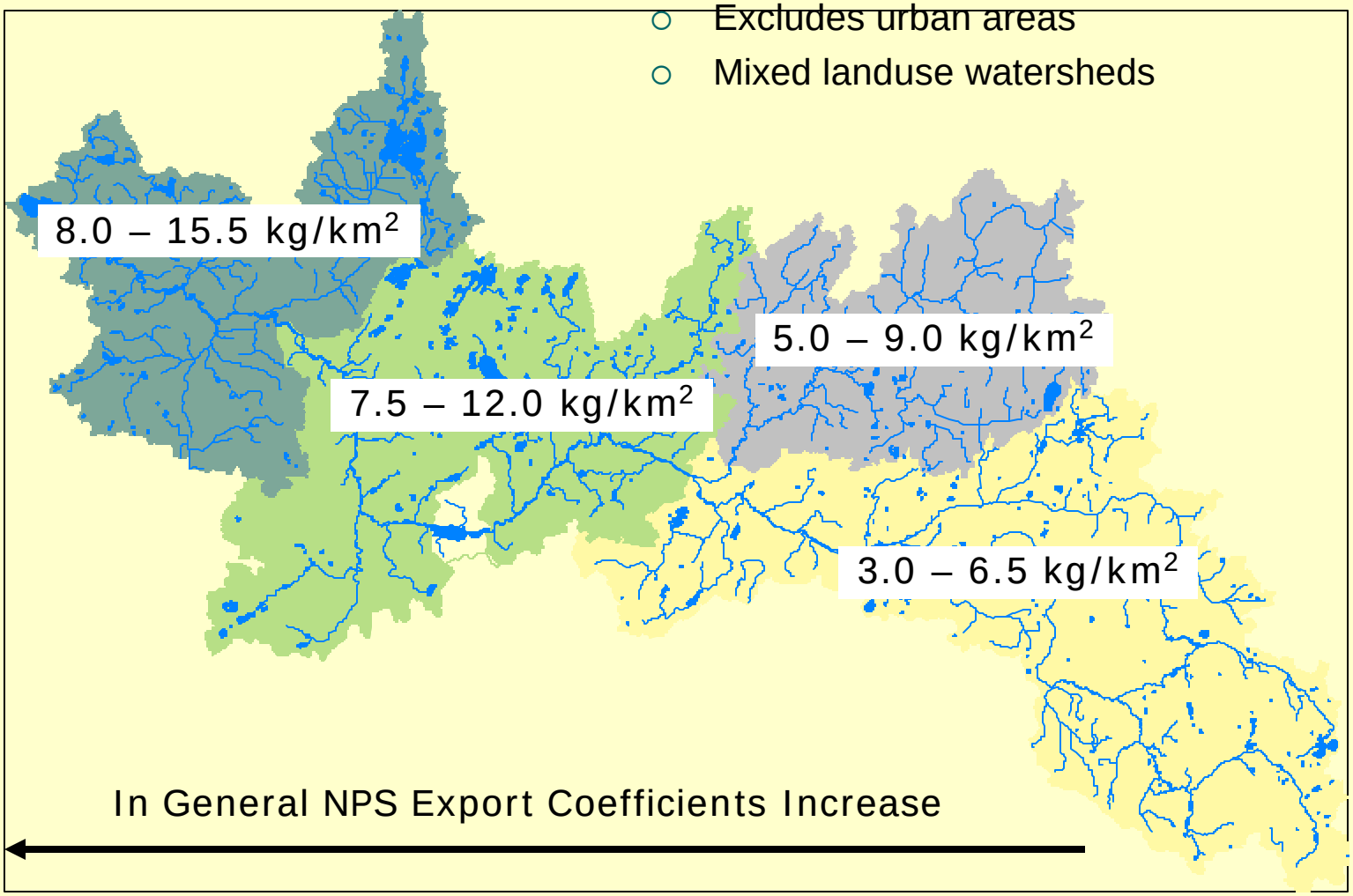
- **Auto-samplers**
  - **Daily composite TP**
- **Weekly grab samples**
  - **TP, TDP, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, NO_3^{-}, SO_4^{2-}, alkalinity, temperature, pH, specific conductance, DO, %DO, chlorophyll A**
- **Synoptic samplings – four total**
  - **Weekly + Sc, Ti, V, Zn, Cr, Co, Cu, As, Se, Rb, Mo, Sn, Pb, Mn, Fe Sr, Ba, U, Al, B, Ni, Cd, Ag**
- **Discharge**
  - **USGS gaging stations**
  - **Isco autosampler stage**

Research – Discussion

- **Review preliminary results and implications for the TMDL**
  - **2005 and 2006 growing seasons**
  - **Phosphorus Sources**
  - **Phosphorus Transport and Fate**
- **Preliminary conclusions**
- **Future work**

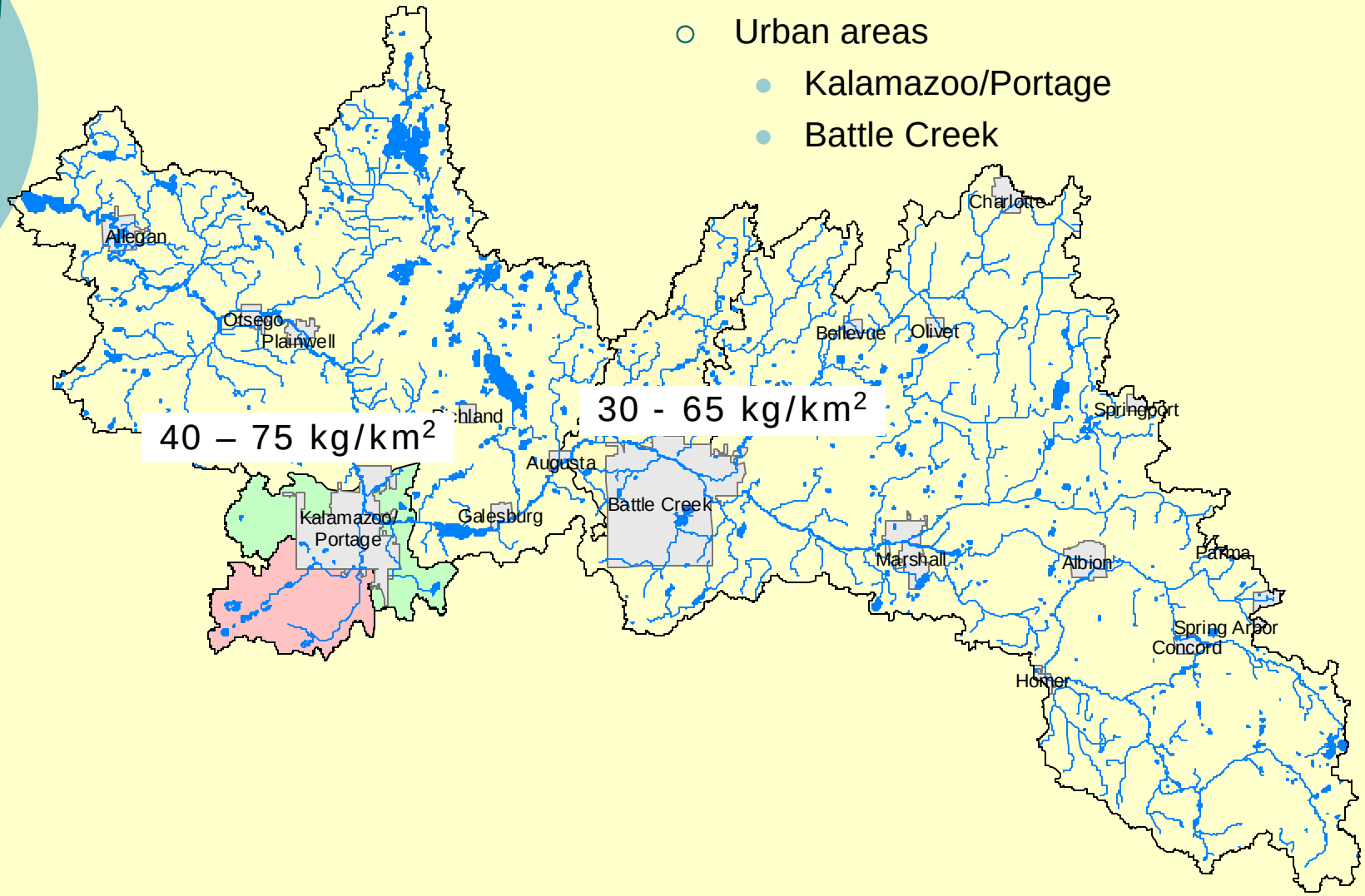
Phosphorus Sources
Growing Season NPS TP Exports

- Excludes urban areas
- Mixed landuse watersheds



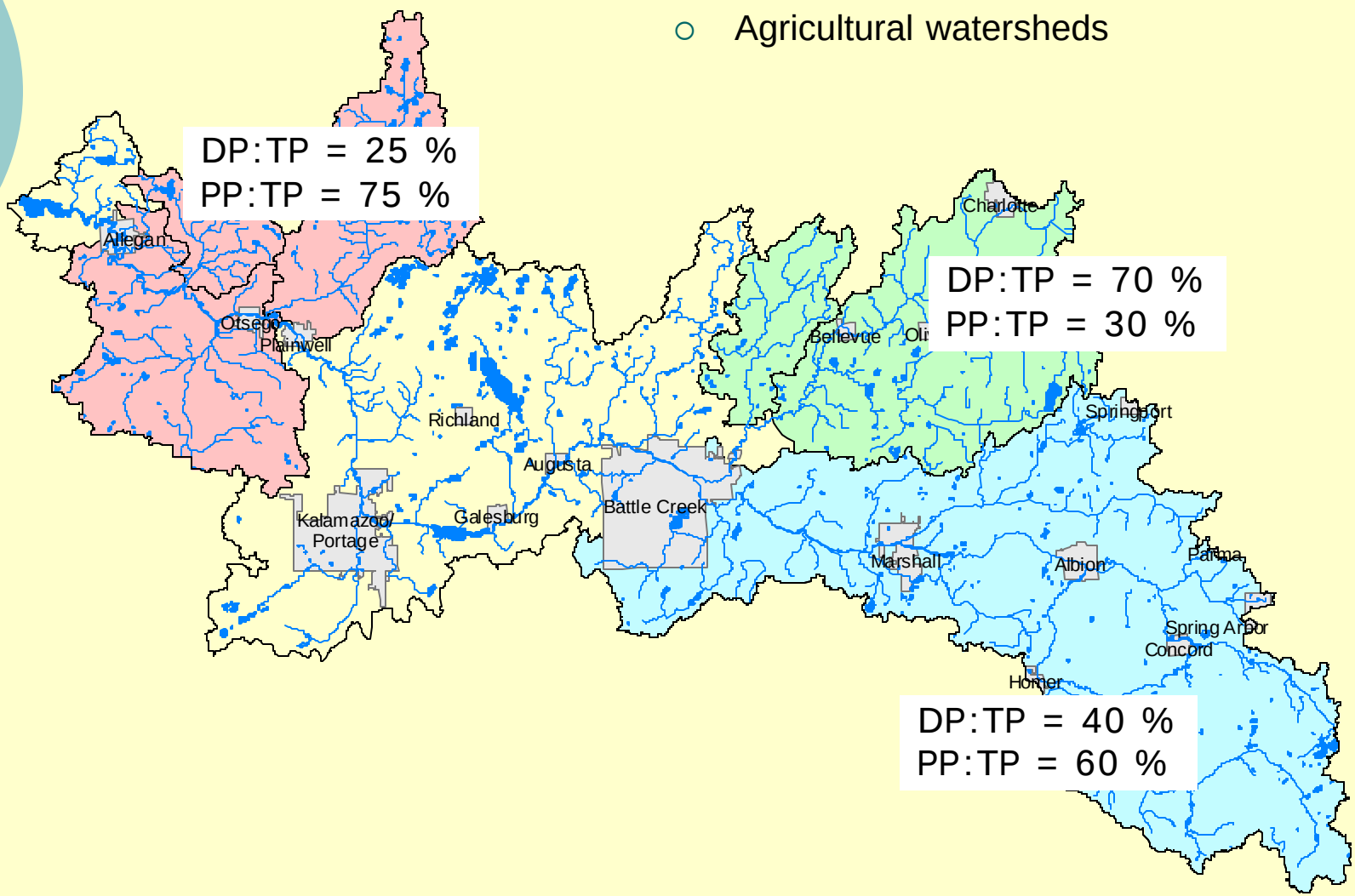
Phosphorus Sources
Growing Season Urban NPS TP Exports

- Urban areas
  - Kalamazoo/Portage
  - Battle Creek



Phosphorus Sources
Phosphorus Fractions

- Agricultural watersheds

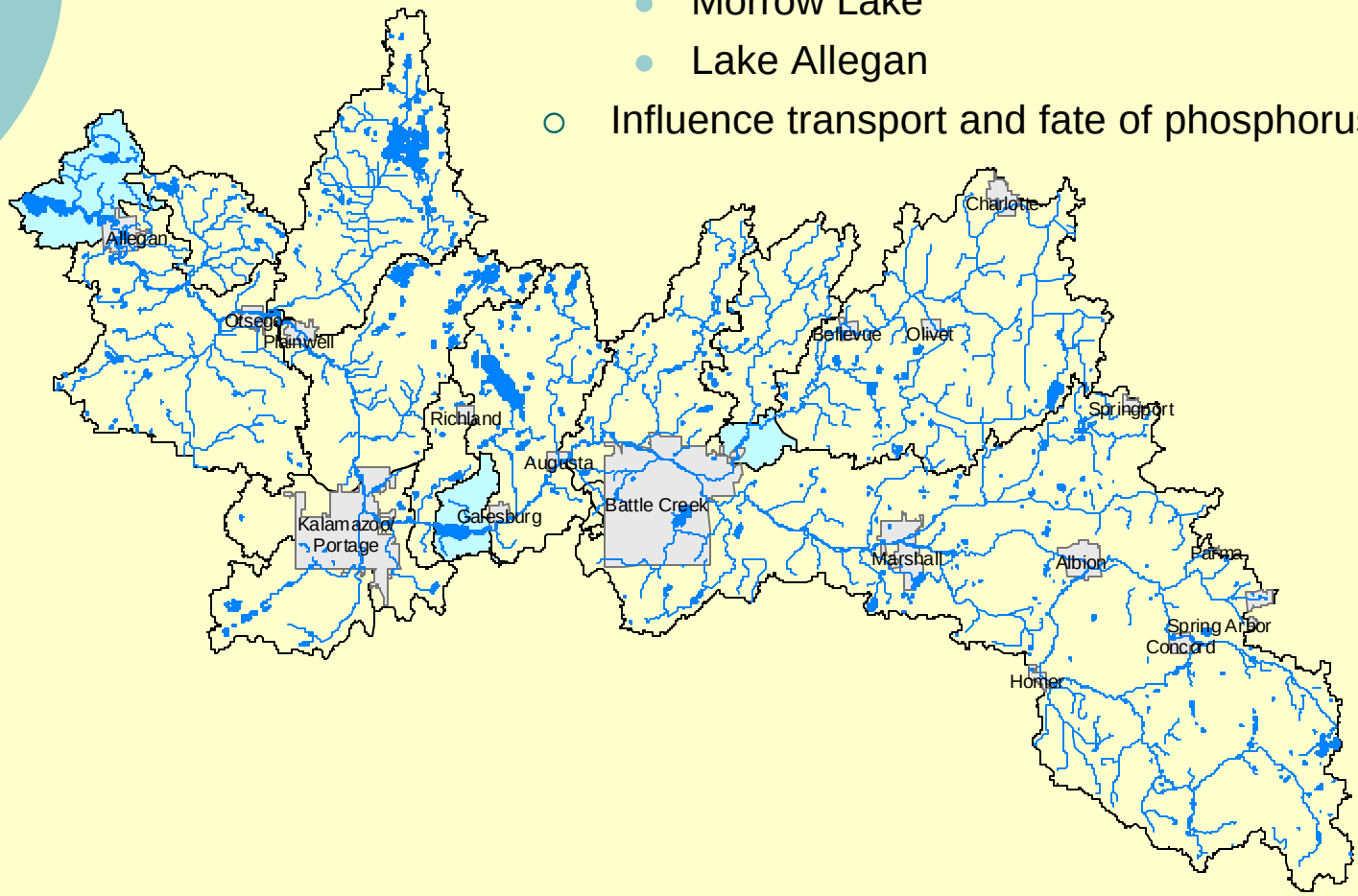


Phosphorus Sources
Implications to the TMDL

- Urban exports
  - Municipal storm water management
- Agricultural Exports
  - Phosphorus fractions must be considered
    - High particulate phosphorus watersheds
      - Soil conservation BMPs more effective
      - Reduce sediment to stream system
    - High dissolved phosphorus watersheds
      - Soil conservation BMPs less effective
      - Nutrient management more effective
      - Reduce phosphorus inputs

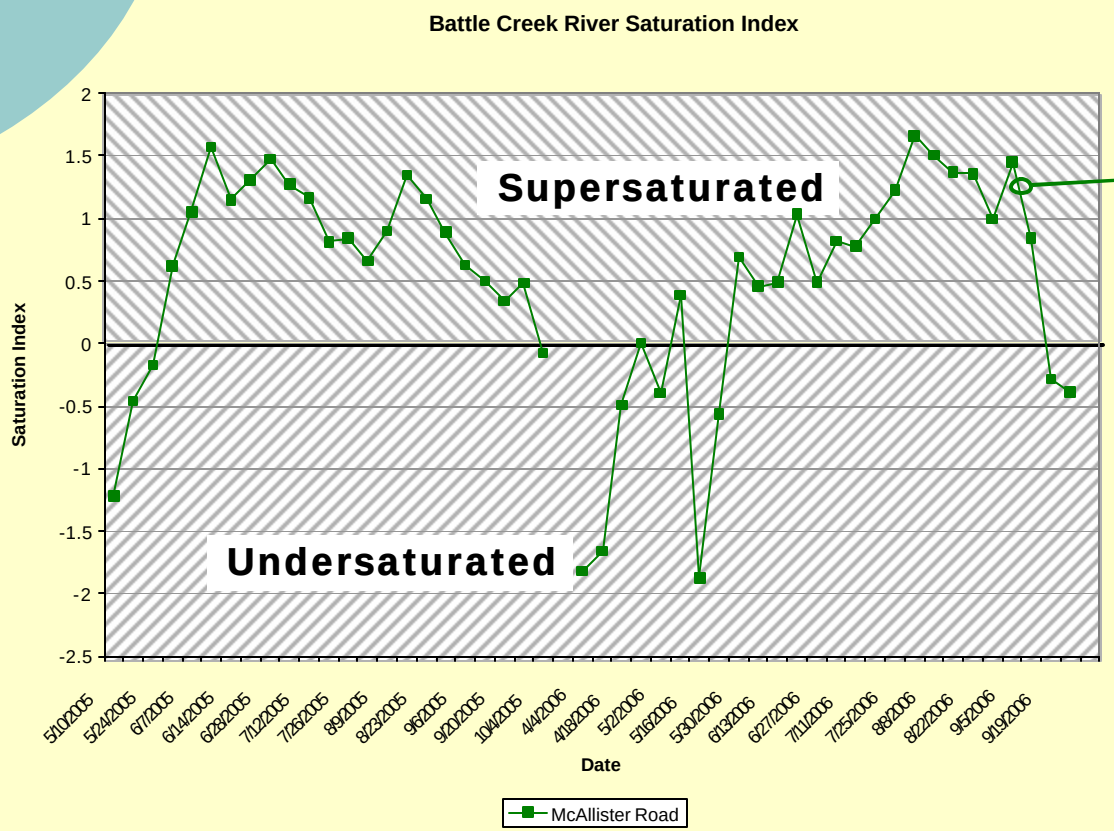
Phosphorus Transport and Fate Impoundments

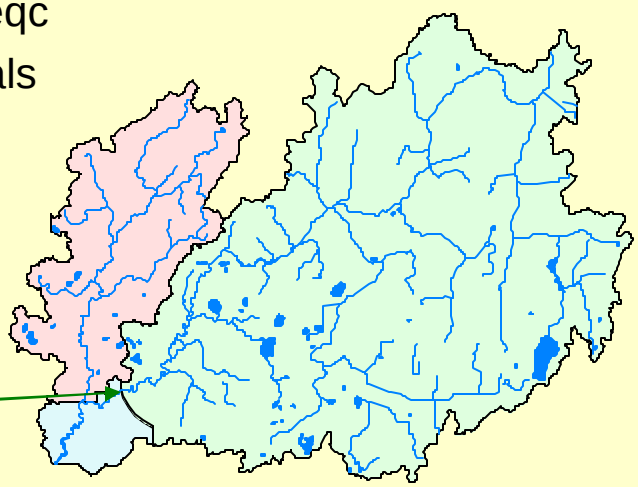
- Three Impoundments
  - Emmett Street Dam
  - Morrow Lake
  - Lake Allegan
- Influence transport and fate of phosphorus



Phosphorus Fate and Transport
Emmett Street Dam

- Stream Chemistry Equilibrium – USGS Phreeqc
- Saturation Index - Calcium Phosphate Minerals





- High Concentration of DP
- P is supersaturated with respect to hydroxyappatite

Phosphorus Fate and Transport
Emmett Street Dam

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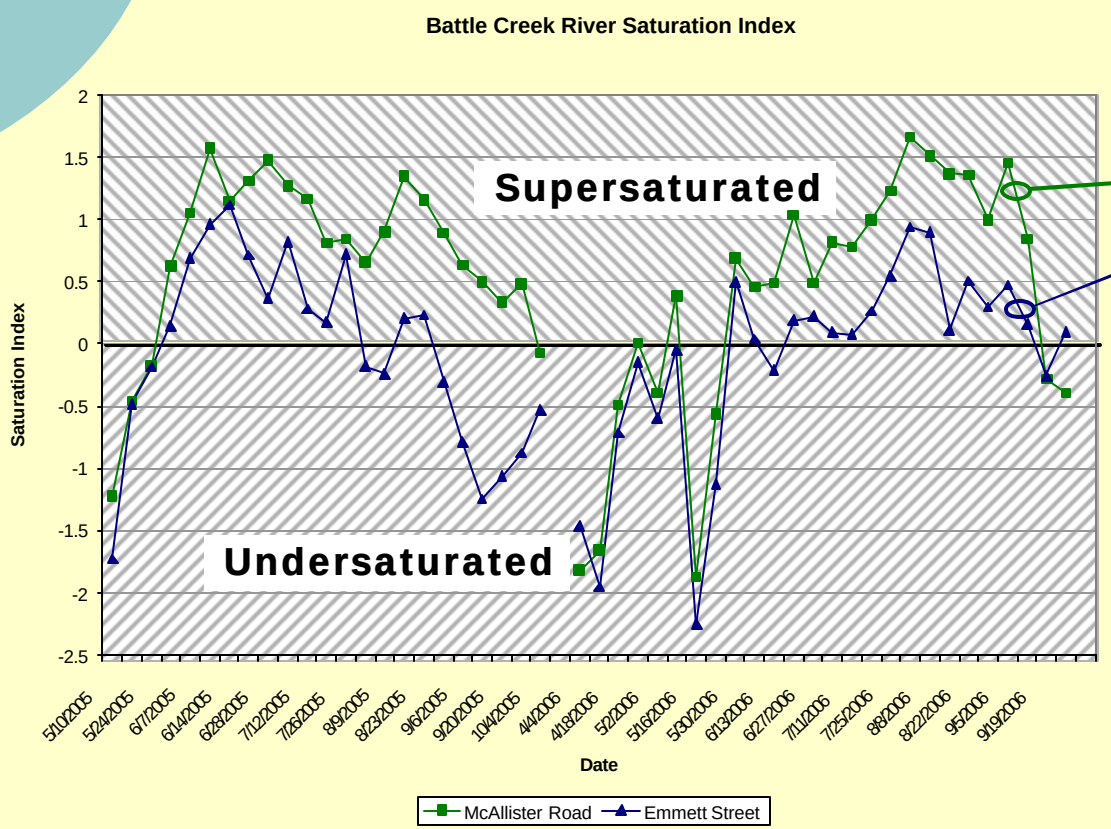
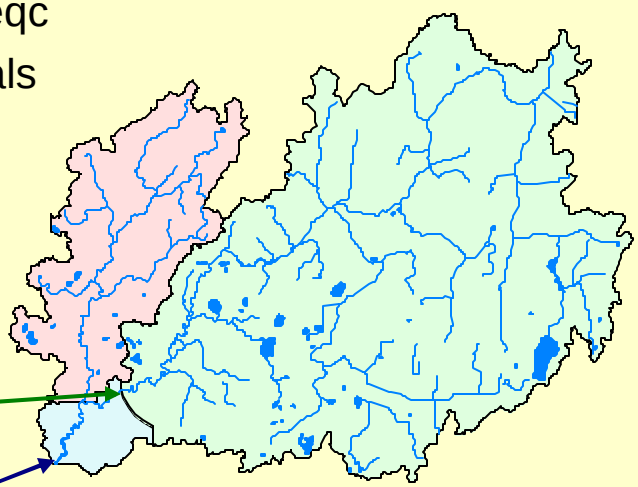
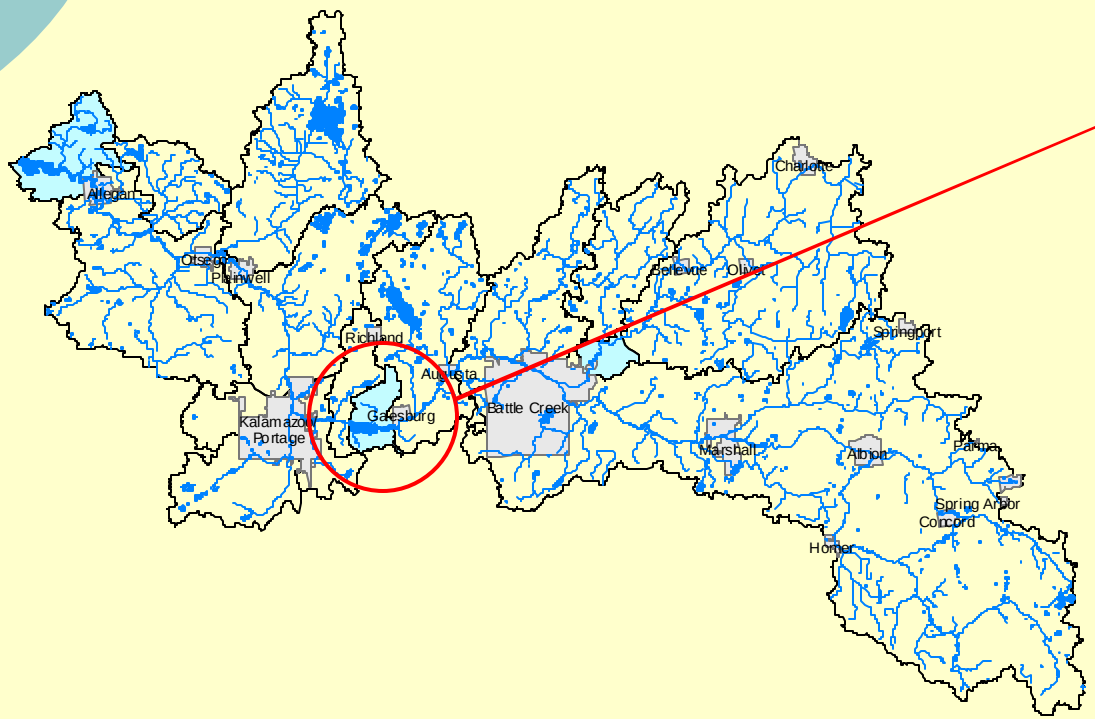


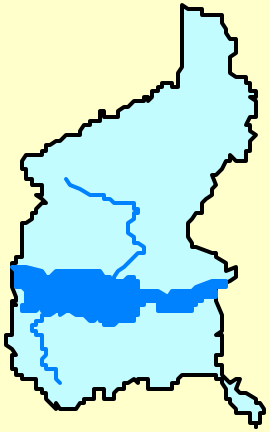


- Impoundment sinked 15% (2000 kg) of P entering
- 60% (1200 kg) DP
- Suggest DP precipitation

Phosphorus Fate and Transport
Morrow Lake

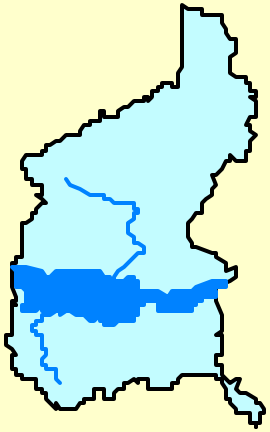
- 4.4 km^2 impoundment
- Located approximately 2/3 down the watershed
- Mediates P transport





Phosphorus Fate and Transport Morrow Lake

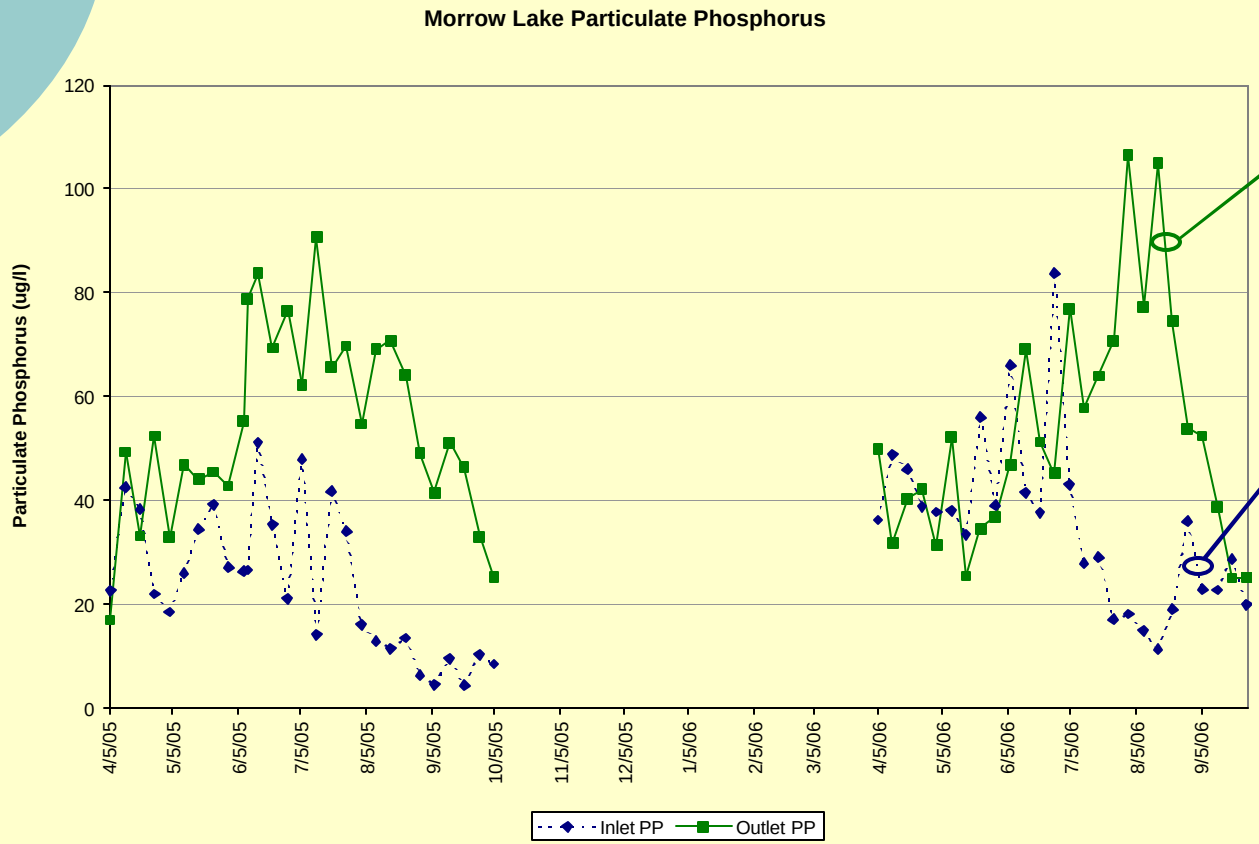
- Outlet growing season mean TP concentration relatively constant
- Varying inlet concentrations

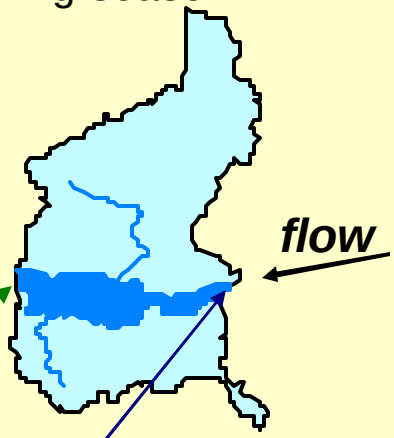


Morrow Lake Total Phosphorus		
Year	Inlet Concentation µg/l	Outlet Concentration µg/l
1994		68.5
1999		70.1
2000		74.8
2001		67.5
2005	48.3	71.6
2006	62.4	70.4

Phosphorus Fate and Transport
Morrow Lake

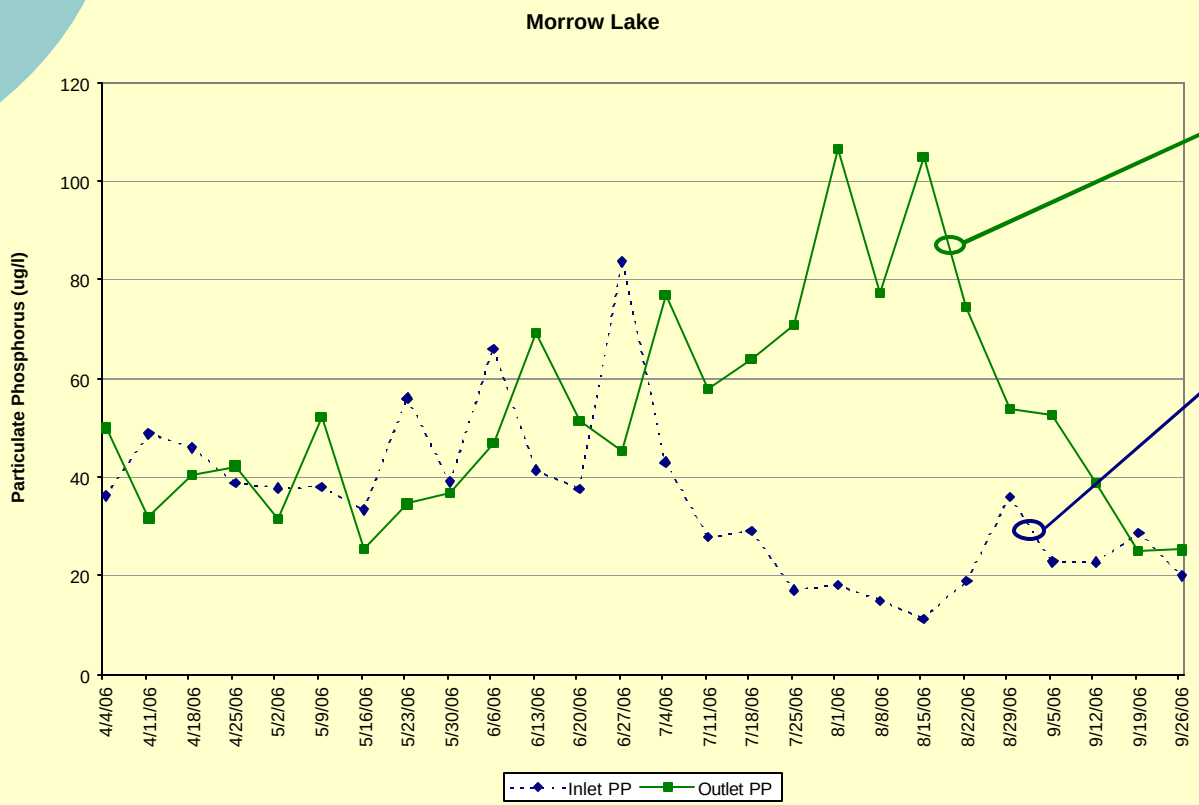
- Inlet to outlet particulate phosphorus increases during growing season
- Sourced P
  - 2005: 8600 kg
  - 2006: 4300 kg

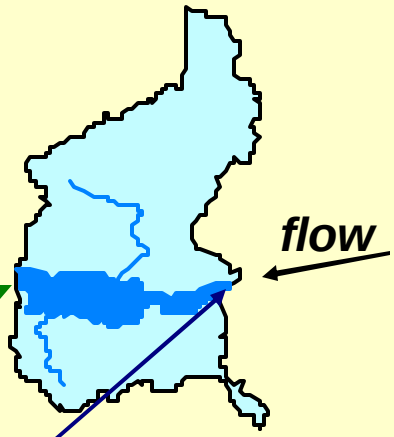




Phosphorus Fate and Transport
Morrow Lake

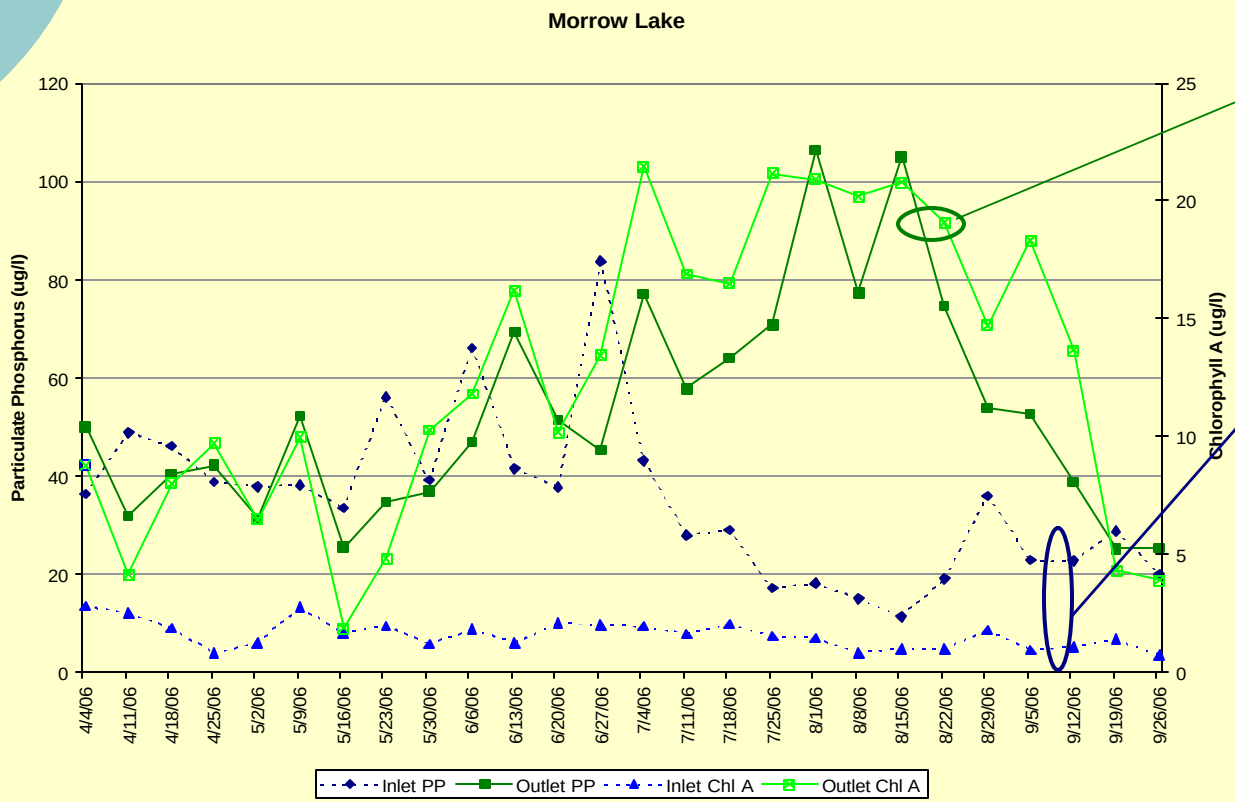
- Dissolved phosphorus decreased
- Dissolved nitrate decreased
- Algal activity suspected

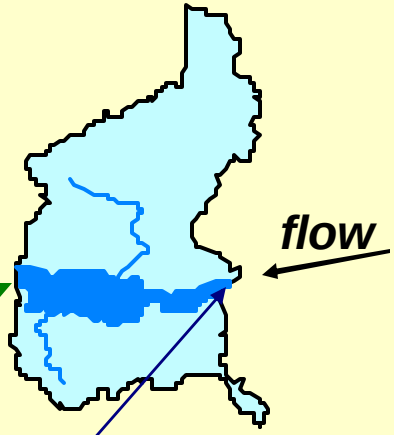




Phosphorus Fate and Transport
Morrow Lake

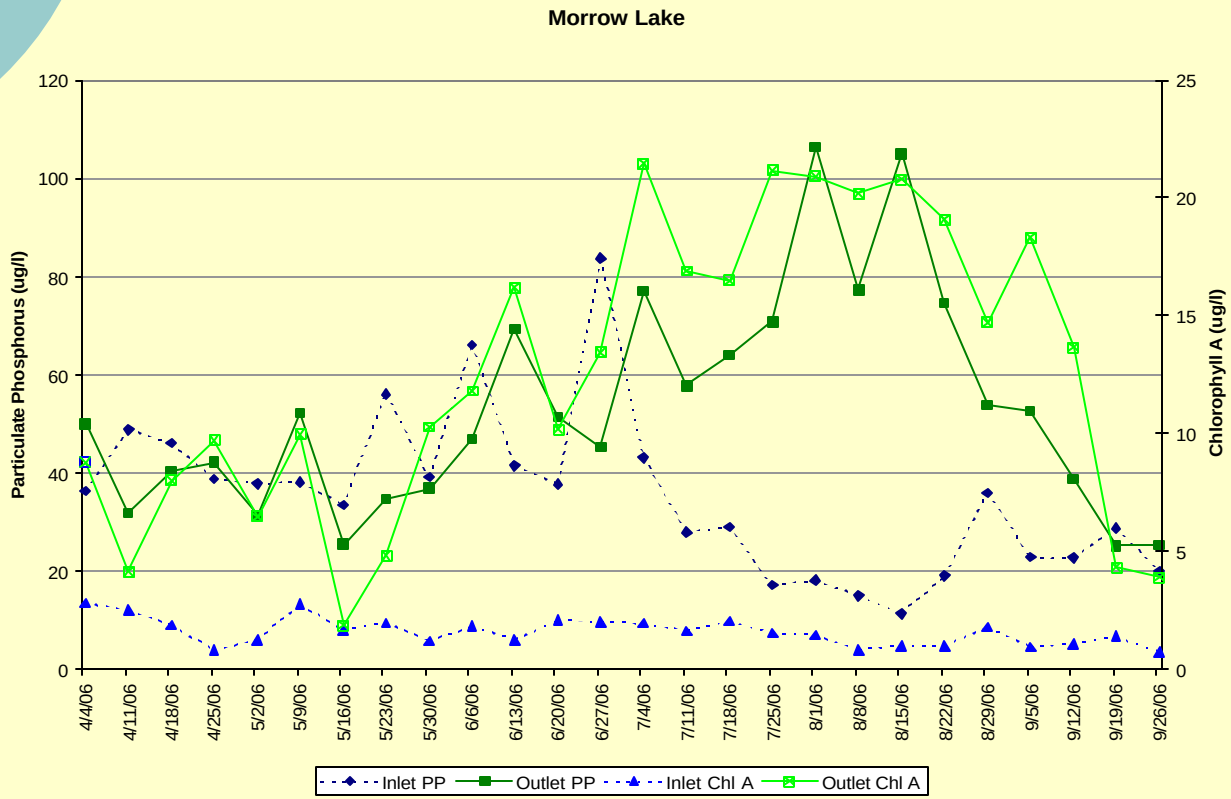
- 2006 Chlorophyll A sampled
- Chlorophyll A increases with particulate phosphorus

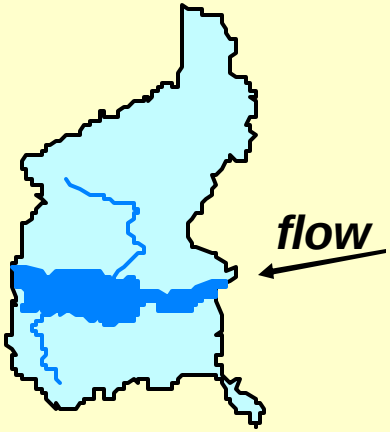


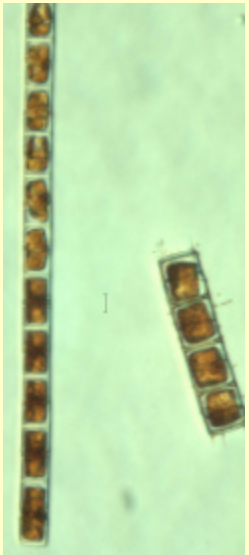


Phosphorus Fate and Transport Morrow Lake

- 2006 Chlorophyll A sampled
- Chlorophyll A increases with particulate phosphorus
- Algae identified and biovolumes estimated
  - Aulacoseira granulata dominant



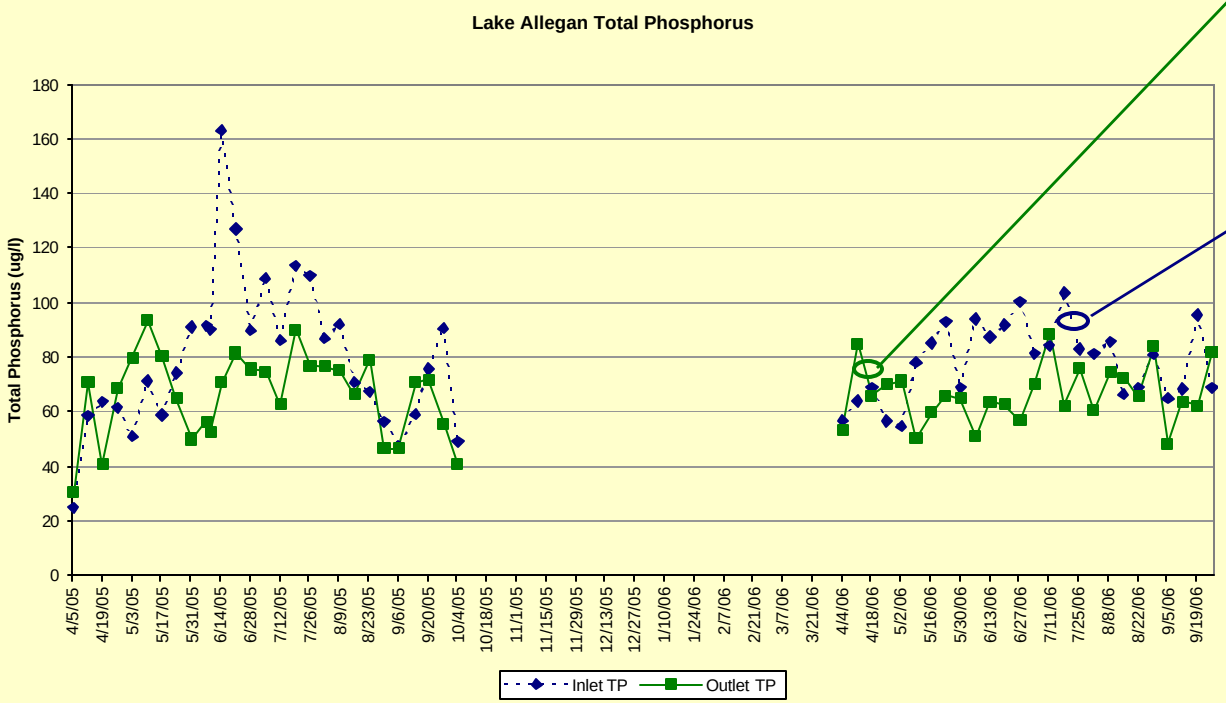


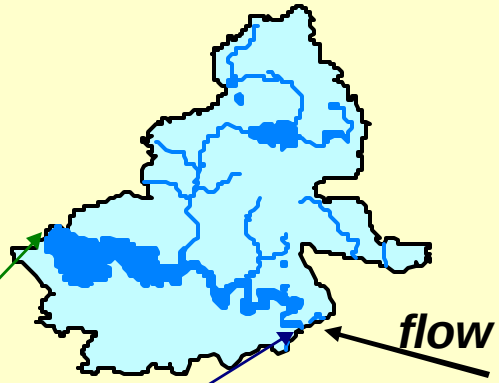


Aulacoseira granulata

Phosphorus Fate and Transport
Lake Allegan

- Impaired waterbody
- Sinking P
- 2006: 13,000 kg

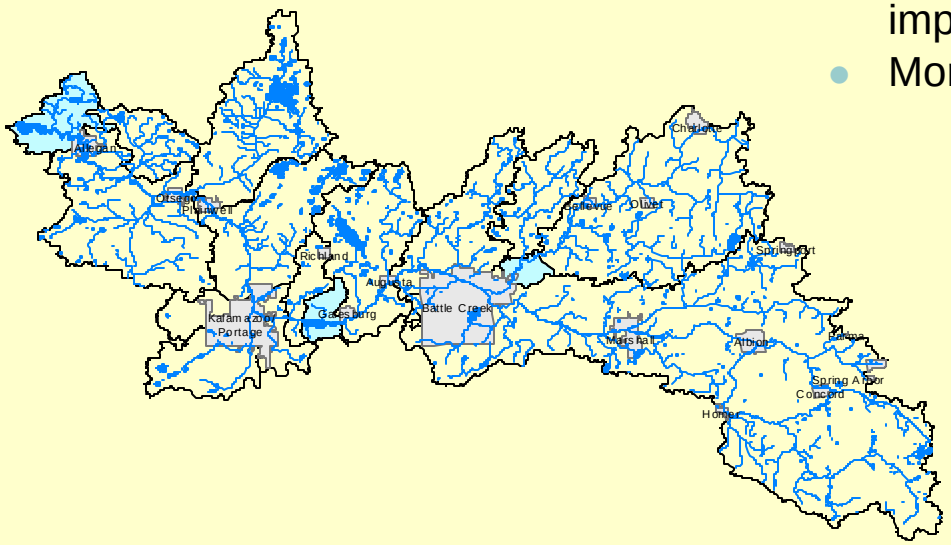




Phosphorus Fate and Transport Implications to the TMDL

- Emmett Street Dam Impoundment
  - Continue to sink and store phosphorus
  - Until DP levels are reduced below saturation
  - Future potential for additional phosphorus export

- Morrow Lake Impoundment
  - Sources and sinks phosphorus
  - Dependant on inlet DP concentration
  - Phosphorus reductions upstream will be offset by algal activity
  - Only phosphorus reductions after the outlet will impact Lake Allegan the impaired waterbody
  - Morrow Lake outlet mean approximately 70 µg/l



- Lake Allegan Impoundment
  - Morrow Lake is reference
  - Lake Allegan inlet TMDL goal set at 72 µg/l
  - Continues to sink phosphorus
  - Slows improvement

Preliminary Conclusions

- Detailed phosphorus and chemistry data is required to develop TMDL phosphorus reduction strategies
- Phosphorus analysis should include phosphorus forms
- BMP recommendations should be based on phosphorus forms
- Impoundments should be evaluated to determine their impact on the transport and fate of phosphorus
- Target reduction must consider the long term impact of phosphorus processes

Future Work

- Refine and expand phosphorus export estimates
- Identify spatial and temporal trends
- Develop relationships between stream chemistry, watershed characteristics and phosphorus processes
- Communicate research results to the TMDL stakeholders
- Assist TMDL stakeholders in developing phosphorus reduction strategies

We gratefully acknowledge the following entities for their support

- USDA-CSREES Water Quality Program
- Lake Allegan/Kalamazoo River Phosphorus TMDL Implementation Committee
- Michigan Department of Environmental Quality
- MSU Extension Water Quality Area of Expertise Team

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