Phosphorus:
Lessons from 10+ Years of Numeric Standards for Wisconsin's Waters

2023 Phosphorus Conference Report:
Academic Research Agenda 2023-2033

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A. Introduction

Wisconsin passed some of the nation's earliest and most comprehensive phosphorus regulations in 2010. Phosphorus pollution poses a significant threat to the health and stability of Wisconsin's waters. Excess phosphorus runoff to surface waters produces an ecological imbalance that leads to nuisance or harmful algal blooms, fish kills, and human illness. Waterbodies impaired by phosphorus pollution threaten public health, reduce recreational use, and decrease property values.

Phosphorus: Lessons from 10+ Years of Numeric Standards for Wisconsin's Waters was a statewide conference held in February 2023 to evaluate the past decade of Wisconsin's phosphorus regulatory implementation and assess the rules' impact on water quality. One of the primary conference goals was to help inform the University of Wisconsin System's future research on phosphorus. This academic research agenda is a product from the statewide phosphorus conference and is a part of a more comprehensive report.

B. Academic Research Agenda

Conference presenters and participants worked together to identify phosphorus research gaps and questions for University of Wisconsin System researchers to study and answer in the next decade. Three phosphorus research areas to prioritize are: (1) agricultural phosphorus management; (2) monitoring, evaluating, and scaling policies/programs; and (3) phosphorus in the environment and water quality. Questions for each area are listed below grouped by theme. Some questions address more than one priority area.

1. **Agricultural phosphorus management**
    - *Transformative agricultural system change*: If the goal is to recalibrate land management with water quality across watersheds…
        - What proportion and configuration of agricultural land within a watershed should be in well managed grazed perennial grasslands to meet established water quality goals?
        - Can cropping systems be configured and managed to meet phosphorus and other societal goals simultaneously (i.e.,

profitable farming; nitrogen, soil, and carbon retention; biodiversity and habitat; flood reduction; thriving and vital communities)?

- *Water quality goals*: Given that agricultural phosphorus management goals (specifically Wisconsin Phosphorus Index target value of 6) are not aligned with river and lake water quality goals (see TMDL agricultural targets)…
    - What forms of new incentives or regulations can improve alignment between phosphorus management guidelines and TMDL targets for excess phosphorus leaving agricultural fields?
    - Are watershed-based agricultural TMDL targets implemented effectively?
    - What should the Wisconsin Phosphorus Index target value be to meet water quality criteria? (See Section 3, Phosphorus in the environment and water quality, subsection: "Measuring phosphorus reduction and the impact on water quality" for a question about using LiDAR to more accurately assess agricultural phosphorus runoff and recalculating Wisconsin Phosphorus Index values).
    - What is a reasonable timeframe over which this regulatory change should occur?
    - When can we reasonably expect water bodies to meet numeric phosphorus criteria if the Wisconsin Phosphorus Index target values are set at levels designed to meet water quality criteria?
- *Farmer behavior and land management practices*: Recognizing the cumulative environmental impacts of many individual decisions by farmers, further exacerbated by climate change…
    - What influences farmers to change practices, such as implementing land conservation or converting to grasslands, to reduce phosphorus runoff?
    - What are the best ways to incentivize more farmers to adopt best management practices, nutrient management plans, and other crop management systems?

  - What farm-specific variables (size, business type, products, etc.) most heavily influence participation in incentive-based programs?
  - What are the most effective elements of farmer-to-farmer initiatives to maximize reductions in agricultural phosphorus inputs to Wisconsin waterbodies?
  - What do the most successful Producer-Led Watershed Groups have in common in terms of reducing phosphorus concentrations in local waterways?
  - What are the most effective methods for maximizing farmer participation in Producer-Led Watershed Groups?
  - How can networks of conservation professionals best support Producer-Led Watershed Groups?
  - What technologies or techniques can farms employ to draw down soil test phosphorus levels at an expedited rate?
  - How do corn subsidies for biofuel production impact farmers' behavior and land management practices?
  - What parts of the Farm Bill could be amended to remove subsidies for farm practices that increase phosphorus runoff?
- *Concentrated Animal Feeding Operations (CAFOs)*: Specifically regarding CAFOs…
  - To what extent do outfalls from tile drains on fields where CAFOs are spreading liquid manure contribute to total phosphorus loads?
  - How can technologies or techniques for farms that draw down soil test phosphorus levels at an expedited rate be integrated into the acreage utilized by CAFOs for manure spreading?
- *Quantifying costs and benefits*: Focusing more closely on market-like and value-added opportunities…
  - What are the costs and benefits of an emission trading system where farmers generate and sell emission reduction credits by capturing methane gas with biodigesters?
  - Could grassland farmers sell carbon credits for sequestering carbon and make this type of farming even more attractive?

- What are the true costs and benefits of the current agricultural system and is it a net positive or negative for society in terms of environmental and human health?
- How can we account for externalized costs of the current agricultural production system, such as soil degradation, GHG emissions, and water impairment?
- What are the projected trends in agricultural production (especially for CAFOs and dairy farming) over the next 20 years and what would it take to offset the economics of large-scale operations in favor of smaller, lower entry fee, and more ecologically sustainable operations?
- How can farms more effectively pass pollution control costs onto consumers while remaining competitive?
- How will the depletion of U.S. mineral phosphorus sources impact the costs and management of phosphorus for agricultural production?
- What is the economic impact of sustainable, watershed-scale management focusing on ecological restoration and water quality?

2. **Monitoring, evaluating, and scaling policies/programs**
   - *County-level phosphorus management*: Recognizing the multiple roles carried out by Wisconsin counties…
     - What are the advantages and disadvantages of placing conservation authority in county land and water offices?
     - What are the long-term effects of local county manure ordinances on total phosphorus concentration and water quality?
     - What percentage of NR 151 violations are resolved through county offices? For those unresolved, what factors contributed to the outcome?
   - *Tracking and reporting progress*: With high variability in approaches and wide data gaps…
     - What are the best key performance indicators to use for tracking

and reporting progress?
    - What is the relationship between phosphorus criteria and listing or removing waters from the 303(d) list of impaired waters? This should be monitored over time.
    - Do conservation practices funded by cost-share programs generate measurable, long-term crop and nutrient management changes?
    - How do nutrient management plans and market-like compliance options (adaptive management and water quality trading) contribute to measurable, long-term impacts on water quality improvement?
    - How can satellite-based remote sensing data be better leveraged to monitor agricultural management changes and implementation of conservation practices? How can these datasets be developed and widely shared while respecting data privacy concerns?
- *Scaling successes*: In order to reach statewide and regional impacts…
    - How can smaller, successful water quality trading and adaptive management programs be scaled up to reduce larger, nonpoint sources of phosphorus?
    - Given that water quality trading and adaptive management exist due to demanding phosphorus regulations for point sources, what mechanisms could mandate that agricultural producers participate in the market-based approach?
    - Will the new Clearinghouse for nutrient trading in Wisconsin result in more point to non-point trades with measurable decreases in phosphorus levels in surface waters?
- *Challenges and opportunities associated with nutrient regulations:*
    - In what ways have regulations failed to protect water quality, and what can we learn from these shortcomings?
    - What forms of novel land/nutrient management regulation would see less opposition in the political and agribusiness spheres?
    - What are operational challenges and opportunities for CAFO-permitted fields to achieve TMDL-based agricultural phosphorus targets?

3. **Phosphorus in the environment and water quality**
    - *Legacy phosphorus in sediment and soil*: Addressing the substantial accumulation of soil phosphorus over time…
        - How long will it take to reduce legacy phosphorus in soils?
        - How do we account for the release of legacy (stored) phosphorus and the lag time effect of phosphorus management strategies for reducing phosphorus loading in rivers versus lakes?
        - What are effective technologies and solutions to reduce legacy phosphorus release from sediments, soils, floodplains, streambeds, and water bodies?
    - *Forms of phosphorus*: How do different forms of phosphorus (e.g., organic, inorganic, particulate) interact with regional geology and aquatic ecosystems to contribute to phosphorus pollution and impact water quality?
    - *Nuisance or Harmful Algal Blooms (HABs)*: Recognizing the negative public and environmental health impacts of HABs…
        - Are HABs happening more often and in more places?
        - What clues do nearshore hydrodynamics provide in understanding why cyanobacteria blooms (HABs) tend to happen where they do?
        - How does the intake and excretion of phosphorus by invasive dreissenid (zebra and quagga) mussels affect HABs in the Great Lakes versus inland lakes and nearshore versus offshore? How does the presence of dreissenid mussels affect phosphorus management strategies?
    - *Measuring phosphorus reduction and the impact on water quality*:
        - How well do field and watershed scale models reflect measured phosphorus and sediment losses?
        - What existing data and technology gaps must be overcome for development of a nearshore phosphorus model, which is required to set phosphorus effluent limits for point sources to protect Great Lakes nearshore waters? (See Wis. Adm. Code § NR 217.13(4)).
        - Considering the effects dreissenid mussels have had on in-lake phosphorus cycling, is there an optimal phosphorus load for Lake

Michigan (or other Great Lakes) that will support a productive offshore fish community while minimizing the problem of nuisance algae in the nearshore zone?

- What are the limitations of periodic (e.g., monthly) sampling of phosphorus in streams that commonly miss the storm events that transport the vast majority of phosphorus? Should phosphorus reduction monitoring focus primarily on low-flow phosphorus concentration or accurate (but more costly) annual phosphorus load?
- How can scientists gain a more thorough understanding of the relationships between types/quantities of nutrients applied, soil chemistry, physical field parameters, and physical drainage parameters to build a mechanistic model that can simulate and predict nutrient loading to water via tiles? Can this type of mechanistic model be built into Wisconsin's SnapPlus software without diminishing its value as a nutrient management planning tool for farm operations?
- Can technologically advanced tools such as LiDAR be used to more accurately assess the flow path of runoff phosphorus from agricultural fields to surface waterbodies, so that Wisconsin Phosphorus Index values can be truly reflective of actual agricultural phosphorus delivery?

- *Hydrologic restoration*:
  - Has hydrologic alteration (i.e., tiling, ditching, compaction) of Wisconsin watersheds accelerated channel migration and increased phosphorus loading from eroding streambanks? If so, to what degree?
  - How should wetland restoration projects be designed to maximize phosphorus capture and filtration?
- *Climate change*: Acknowledging the increasing frequency and intensity of severe weather events…
  - How should phosphorus management plans be adapted in response to a warmer, wetter climate with more frequent and intense rain events?

- How should phosphorus reduction strategies be adjusted to mitigate climate change (i.e., by promoting grasslands to sequester carbon while reducing runoff of phosphorus)?
- As the climate warms, what is the absorptive capacity or tipping point for waterbodies not currently heavily affected by agricultural phosphorus pollution?
- How will a longer growing season (up to 6 weeks longer) affect agriculture in terms of crop selection, double cropping, etc. in the next 20 years?

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