Phosphorus retention in riparian wetlands restored on formerly farmed land: Key drivers & lessons for future restoration

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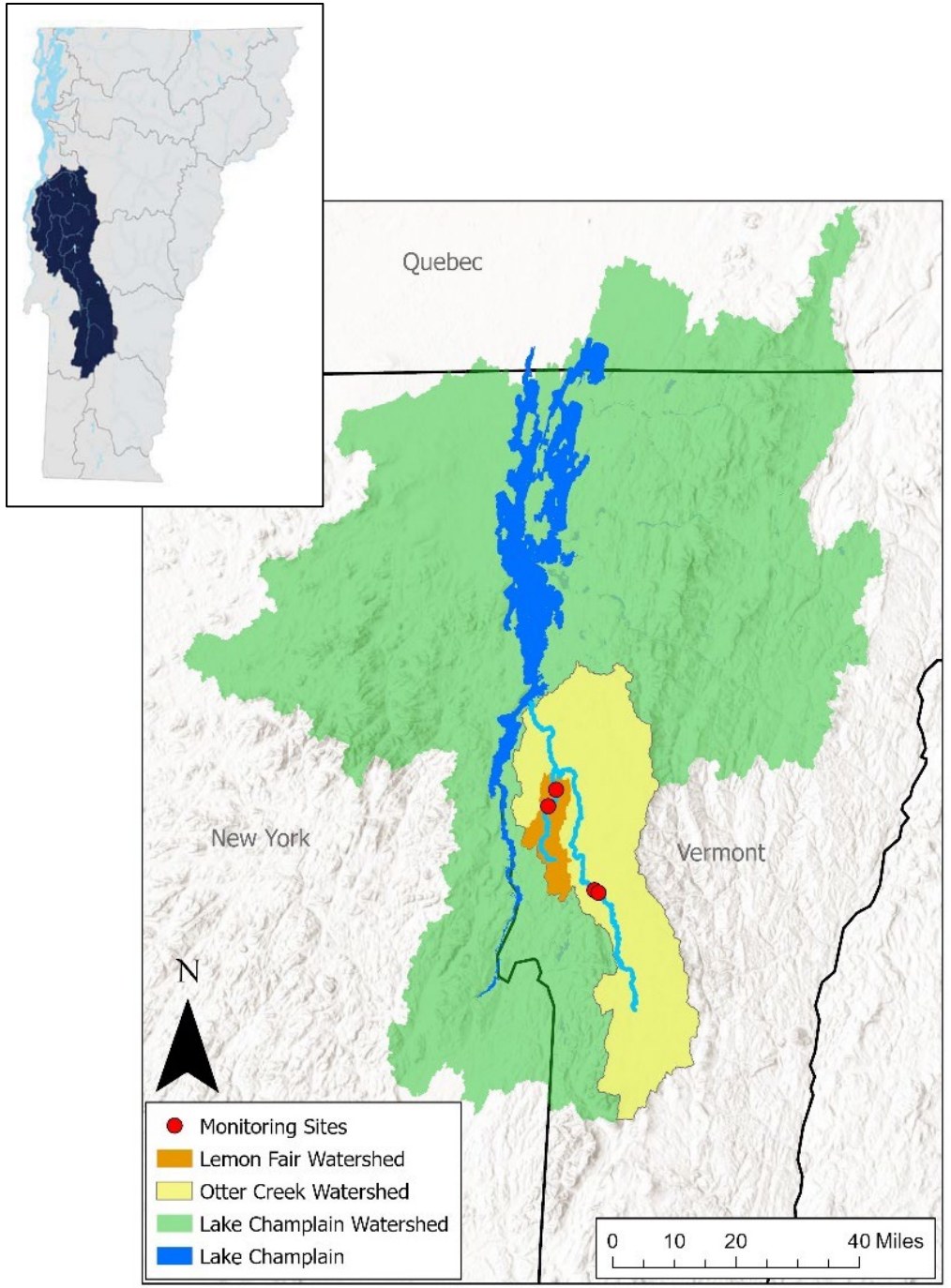
Wetland restoration as a nature-based solution

- Excessive phosphorus (P) loading in the Lake Champlain Basin is one of the greatest water quality challenges in the region (US EPA 2016; LCBP 2024).
- Wetlands can provide large-scale water filtering services, though generalizations about P retention efficacy are hard to make.
- On former agricultural lands, legacy P in soils can be released under flood conditions.

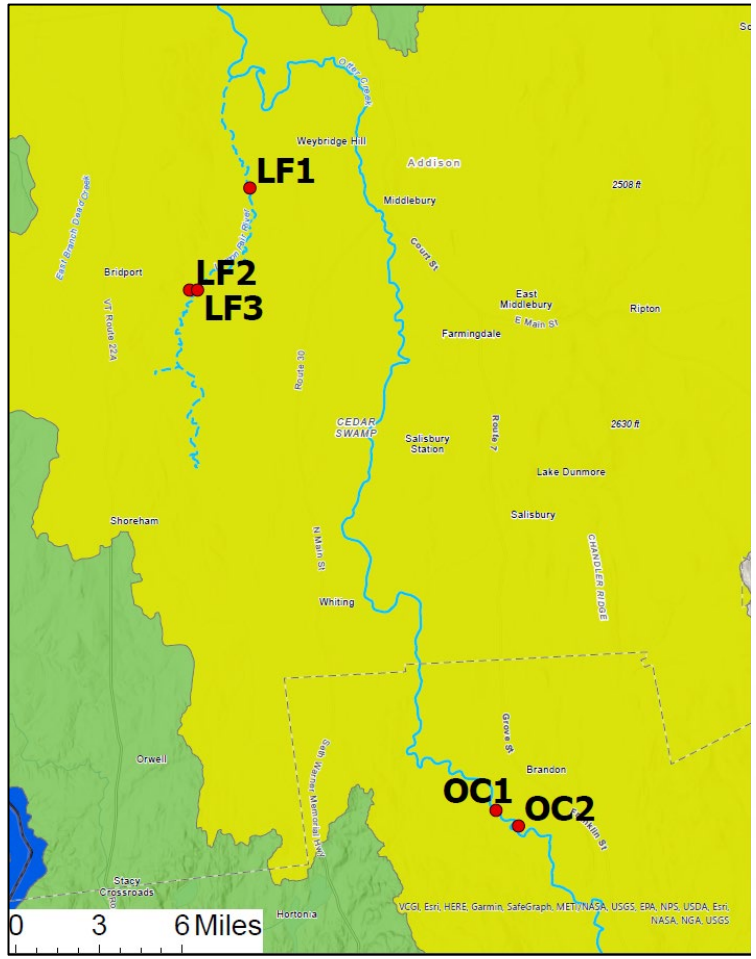
Research Objectives

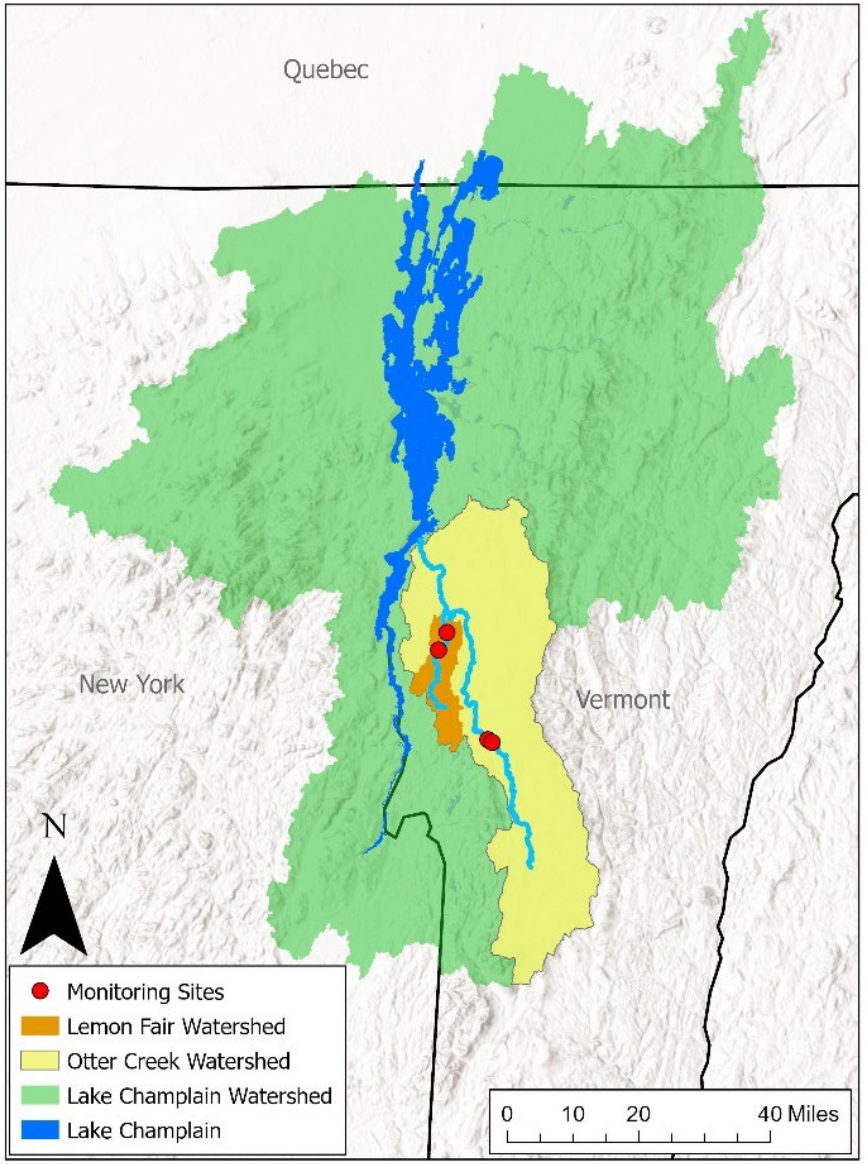
- Quantify the water quality benefits of restored riparian wetlands on formerly farmed land in the Lake Champlain Basin
- Focus on phosphorus, including both particulate and dissolved forms



Monitoring Locations

- Riparian wetlands that experience seasonal flooding
- Former ag lands currently under NRCS conservation easement
- Along Otter Creek (larger) & Lemon Fair River (smaller)
- Time since farming varies from 4 to 15+ years

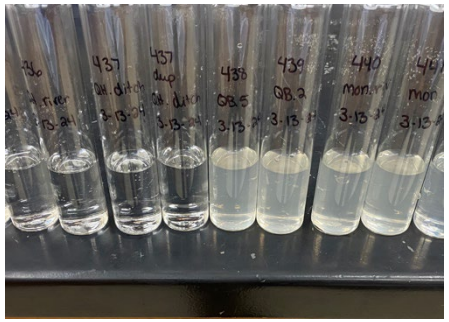


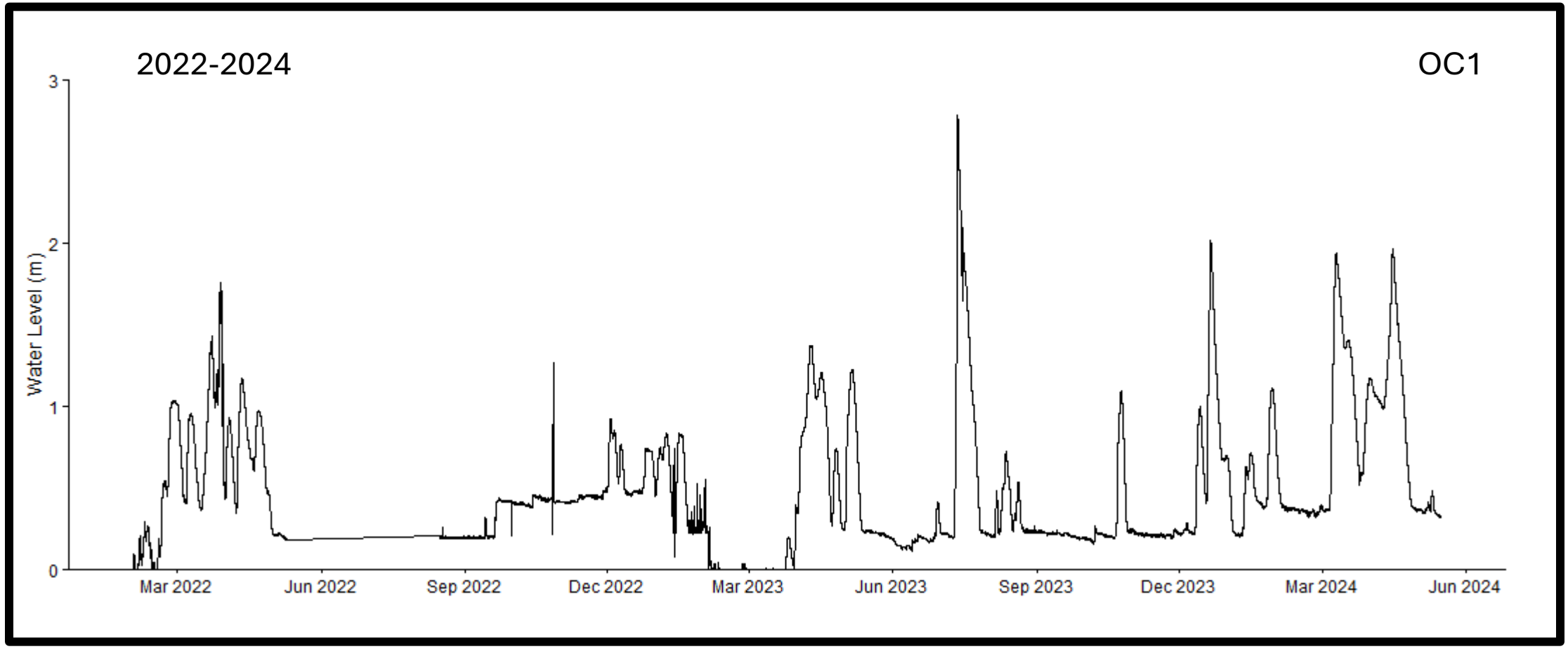


Inset map: Sam Buswell

Methods

- Field Monitoring
  - Hydrology (water level dynamics)
  - Dissolved oxygen @ soil-water interface
  - Water quality during flood events
  - Accretion of mineral & organic material
  - Soil properties, incl. soil P storage capacity
- Use of HEC-RAS models to inform HRT estimates
- wetlandP modeling to estimate net P retention (Wiegman et al. 2024 JEED)





	Flood Peak	LF1	LF2	LF3	OC1	OC2
Number of Events	0.5-1 m	10	18	5	14	10
	1-1.5 m	5	1	3	4	5
	>1.5 m	3	1	0	5	1
TOTAL		18	20	8	23	16

Field Evidence of P Retention

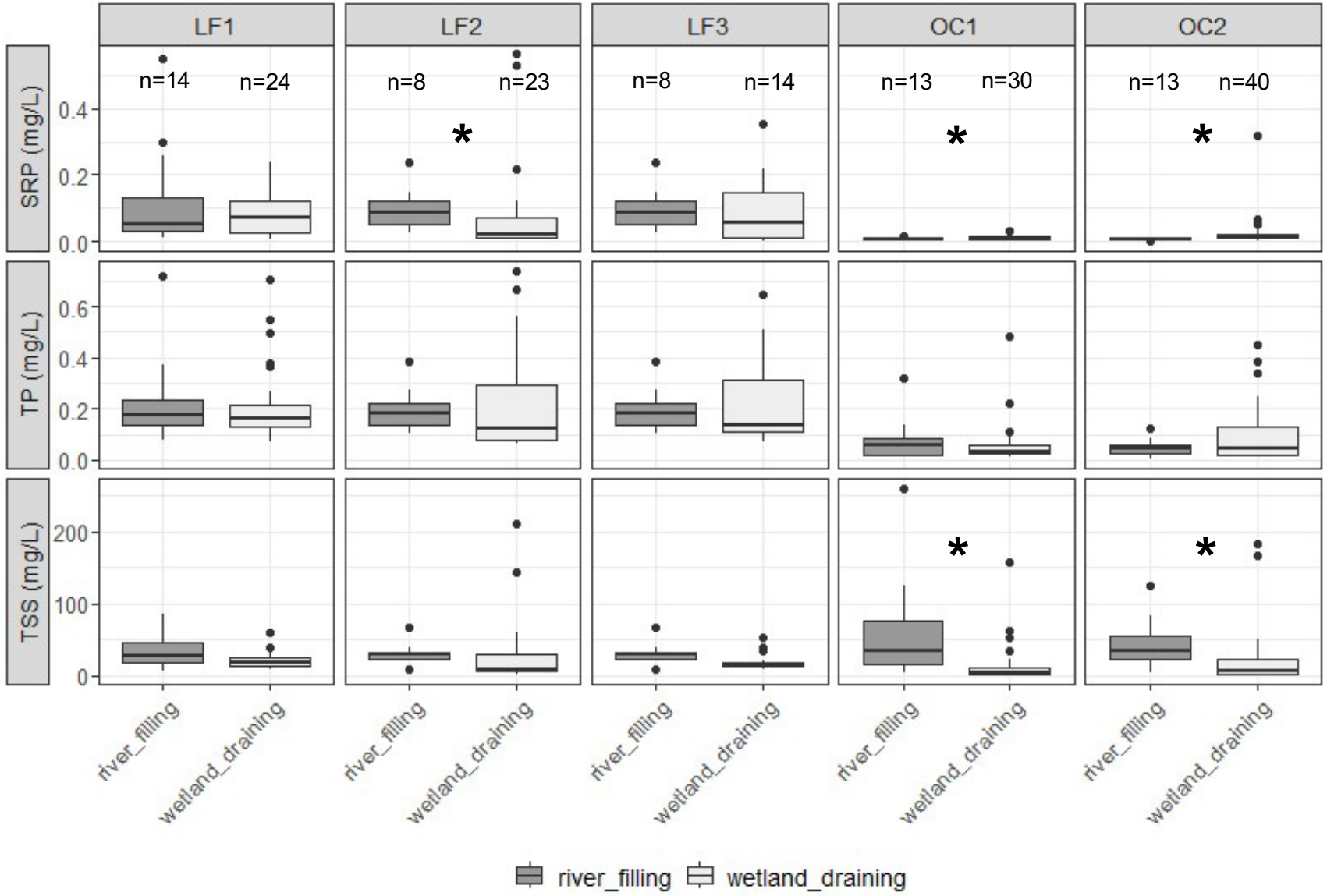
1. SRP, TP, TSS (mg/L) in influent river water ≥ wetland draining water

2. Well oxygenated waters during floods (internal release of SRP from soils is greater under anaerobic conditions, Wiegman et al. 2022 Biogeochem.)

3. Accretion indicative of sediment deposition during flood events

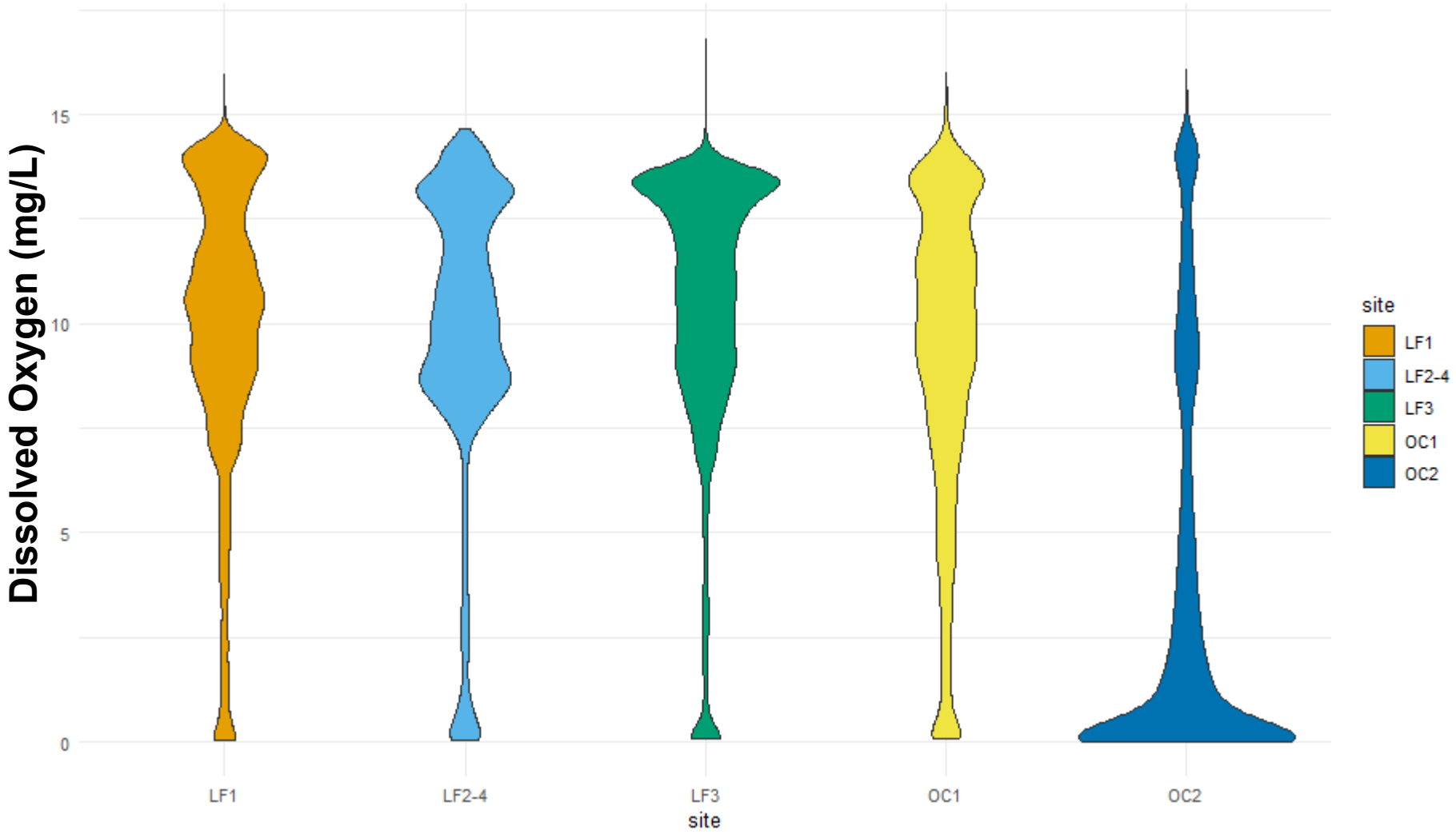
4. Positive soil P storage capacity (less potential for internal SRP release)

SRP, TP, TSS (mg/L) typically similar or lower in wetland draining water than in influent river water

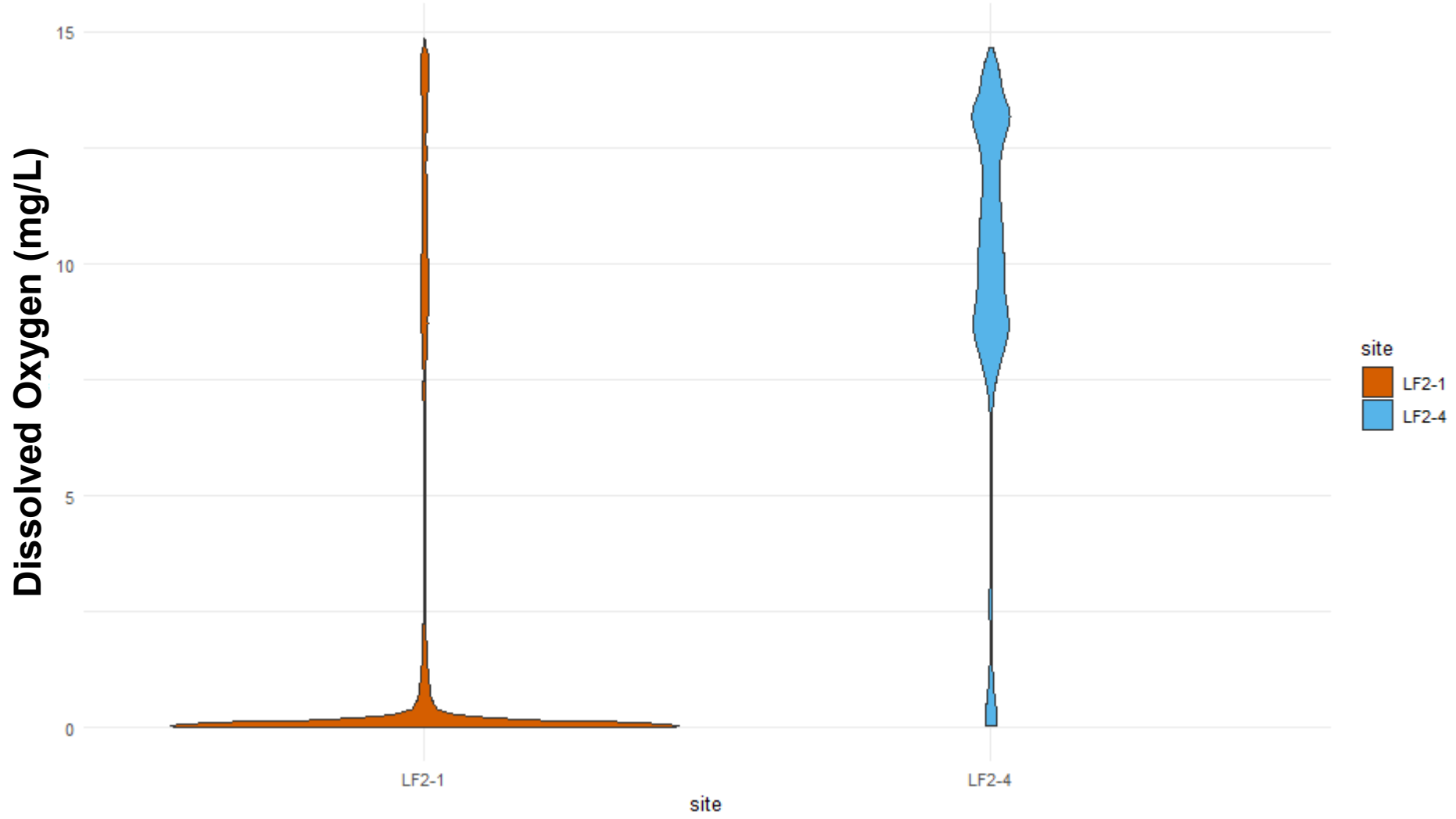


* Indicates significant differences ($p<0.05$, Mann Whitney U)

Well oxygenated waters during floods at most locations

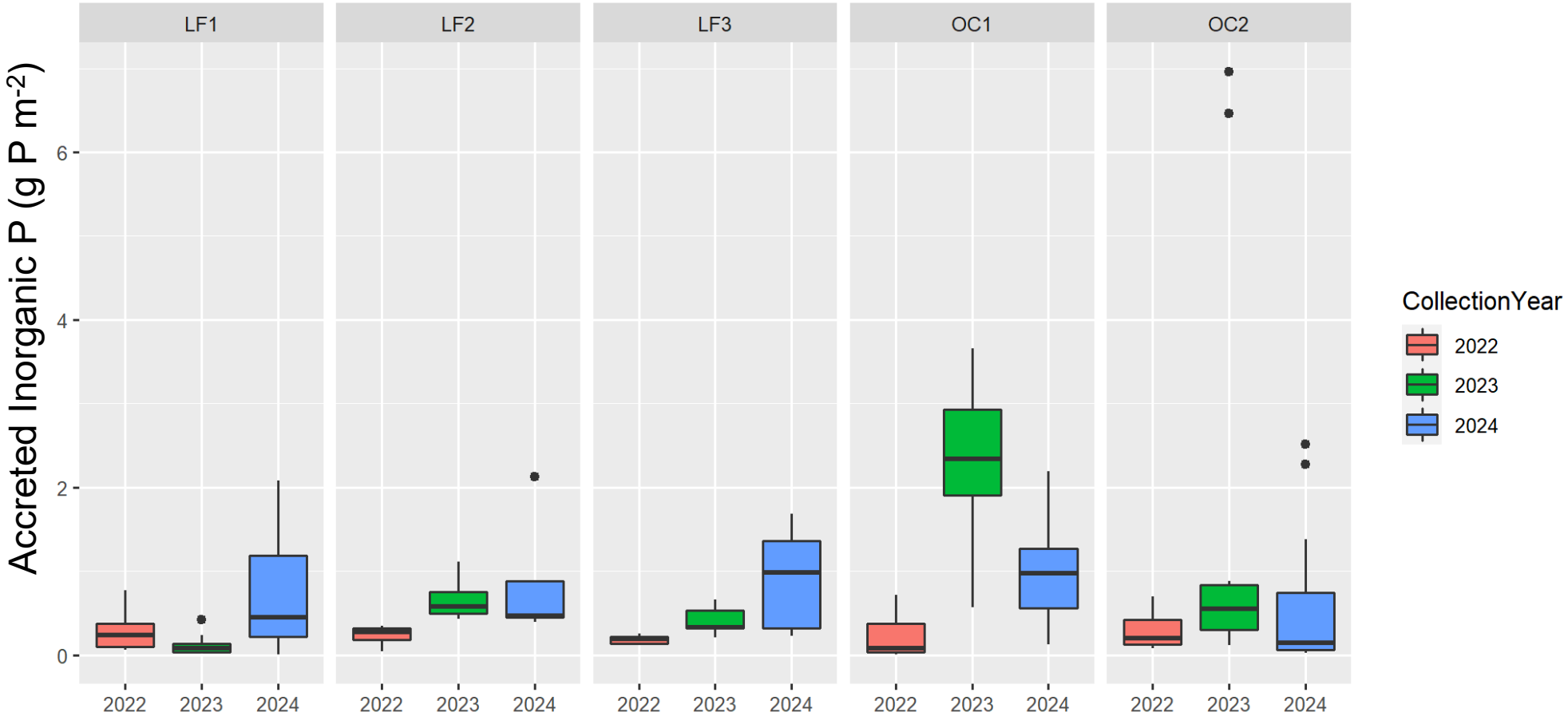


… with localized exceptions



Evidence of sediment deposition during flood events, especially following a major flood pulse

- Our past work has shown that inorganic P (IP) in accreted material is the best estimate for P associated with deposited riverine sediment during floods (Wiegman et al. 2024 J. Ecol. Eng. Design)

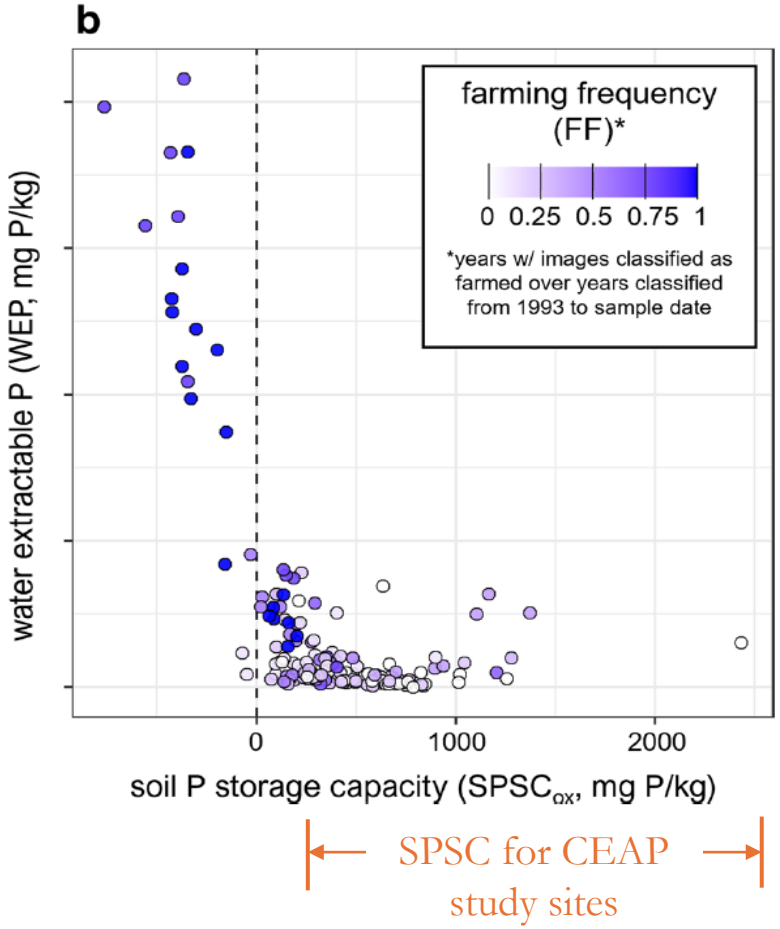


Positive soil P storage capacity (SPSC) Mean > 1000 mg P/kg

- Positive SPSC indicates that a soil is more likely to serve as a P sink (Nair et al. 2015; Dari et al. 2018)

- SPSC at the 5 field sites in this study ranged from 260 to 2539 mg P/kg

Data from riparian soils in Lake Champlain Basin
Wiegman et al. (2022) Biogeochemistry



wetlandP model

- Inputs: Water level and climate records, river water quality metrics, site-specific soil and vegetation properties, hydraulic residence time
- Output: net TP retention at each site

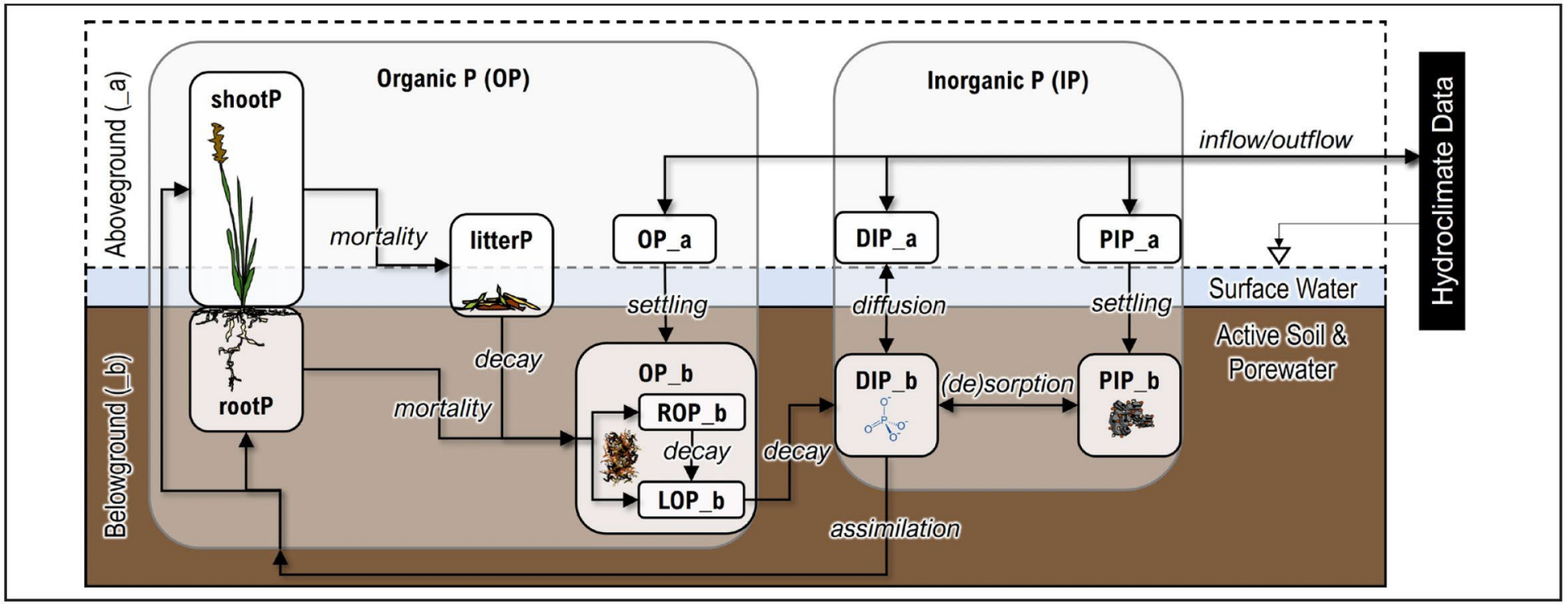
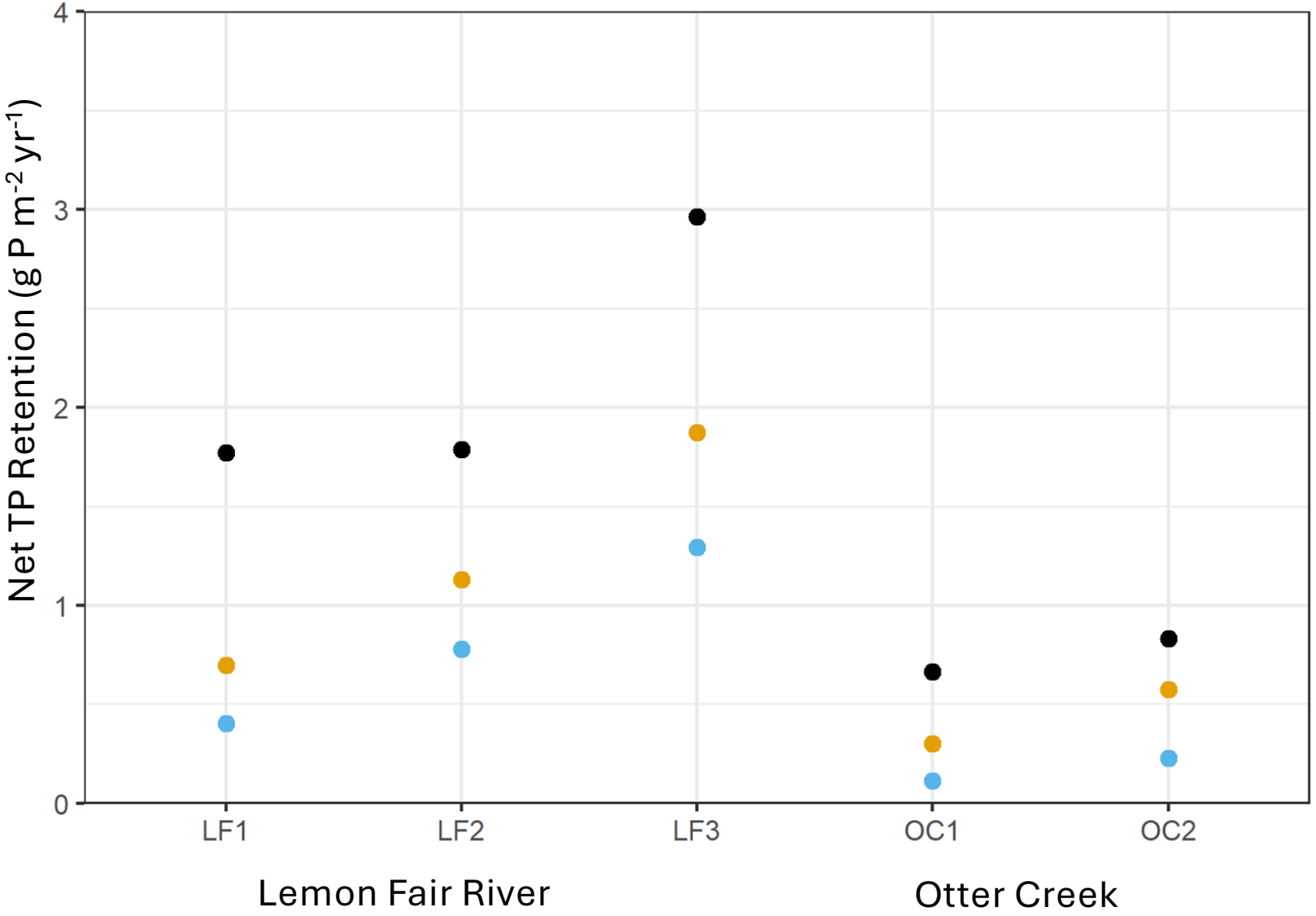


Fig. 1 Conceptual diagram of *wetlandP* model domain, compartments, state variables, and processes. Flows of phosphorus (P) are represented by lines with arrows and the associated process for each flow is labeled in italics. State variables are represented in boxes with bold text. ROP = Refractory OP, LOP = Labile OP, DIP = Dissolved IP, PIP = Particulate IP.

Wiegman et al. (2024) Journal of Ecological Engineering Design

Preliminary CEAP Modeling Results



River Water Quality Parameters

- Q3
- median
- Q1

Assumptions

- 2-year simulation (February 2022-2024)
- Site-specific power model of hydraulic residence time (HRT)
- Stokes' law for particle settling

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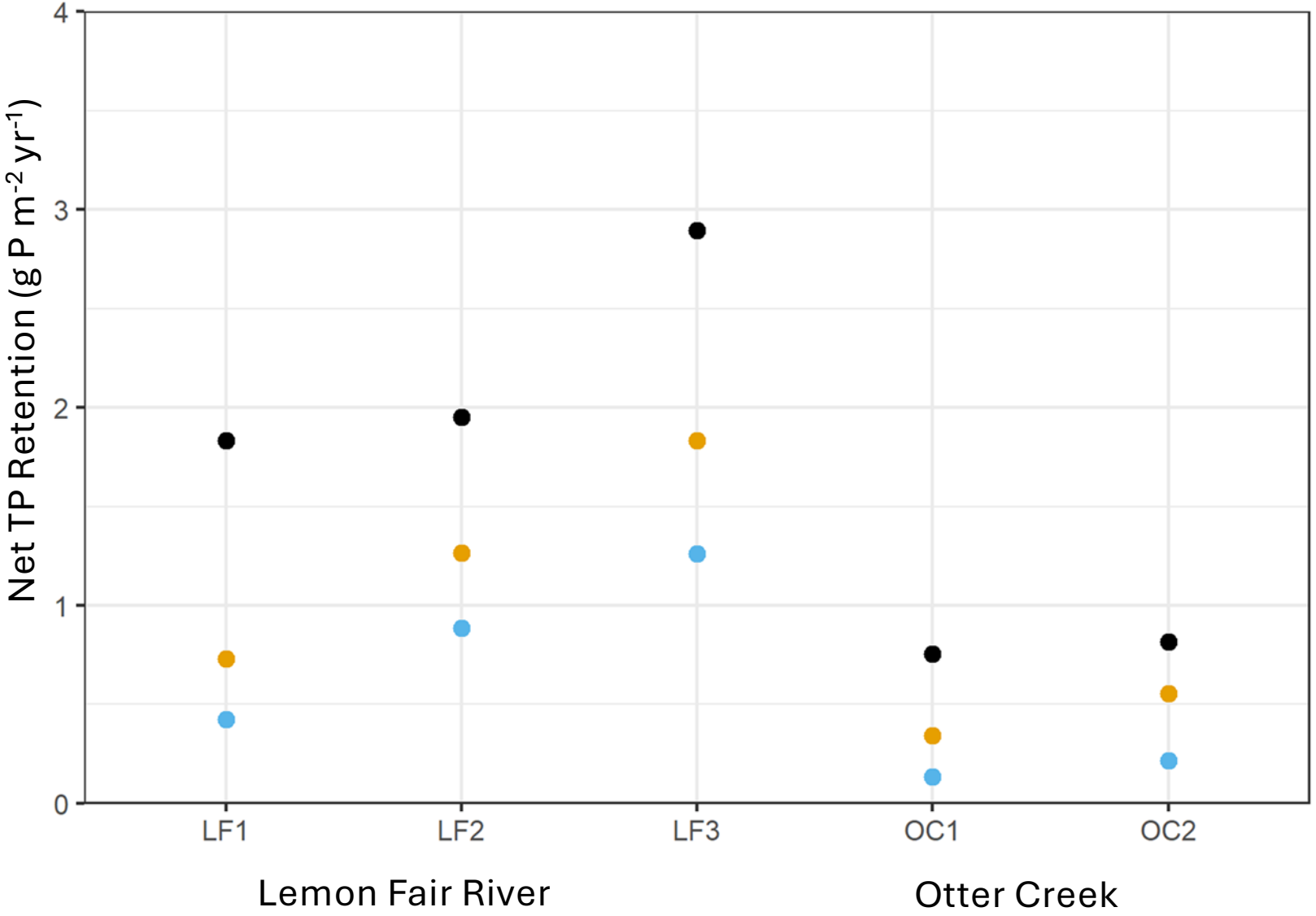


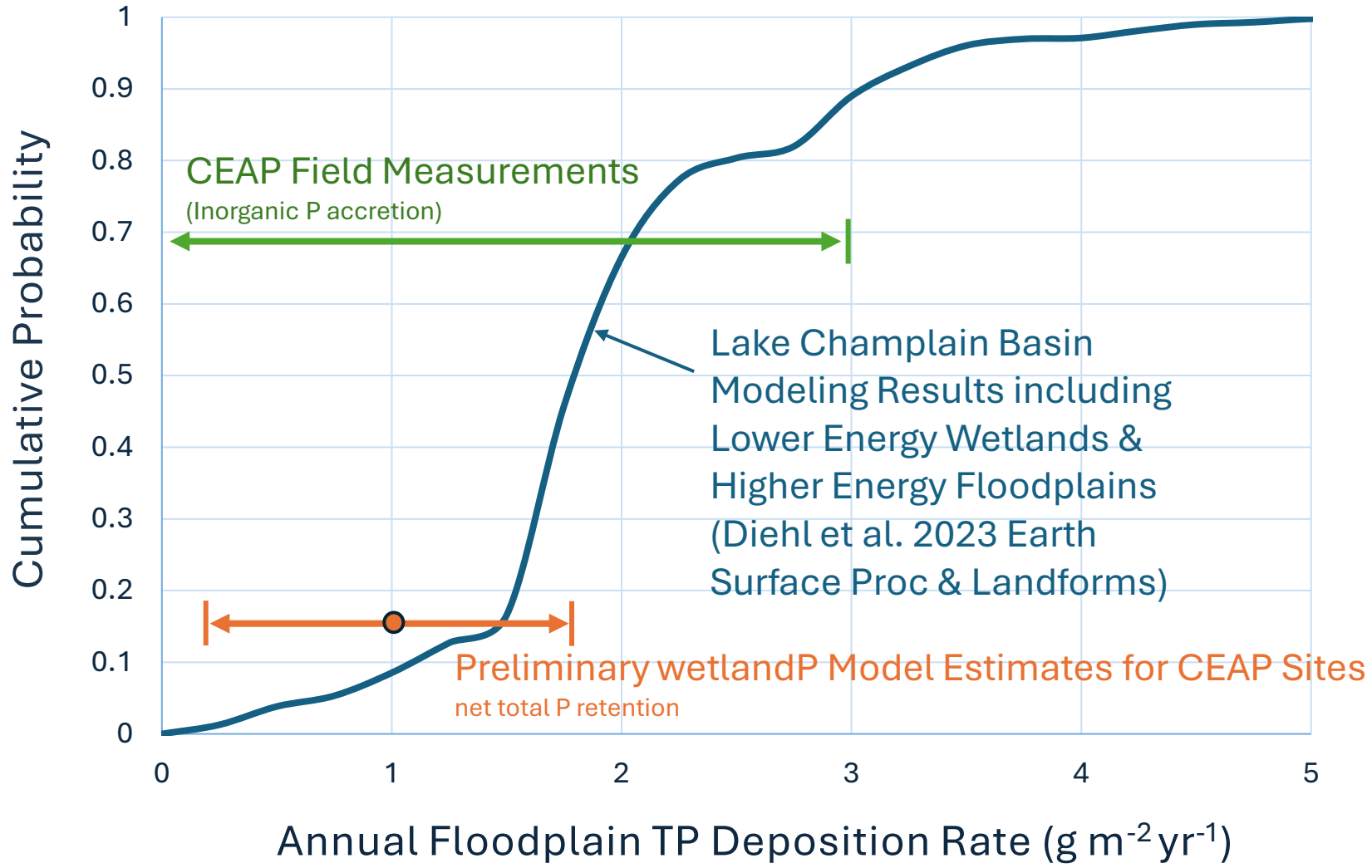
River Water Quality Parameters

- Q3
- median
- Q1

Assumptions

- 2-year simulation (February 2022-2024)
- HRT = 10 days
- Stokes' law for particle settling

How representative are the results from the 5 study sites?



Conclusions

- Model estimates and field evidence indicate net TP retention at all five study sites (avg ≈ 1 g P m^{-2} yr^{-1}), suggesting wetland restoration is improving downstream water quality in Vermont.

- Influent river water quality is influential in determining net P retention. Sites with higher P in influent river waters showed higher net P retention.

- Considering hydrology, river water quality, and soil properties is important for restoration site selection.

Complementary to CEAP:

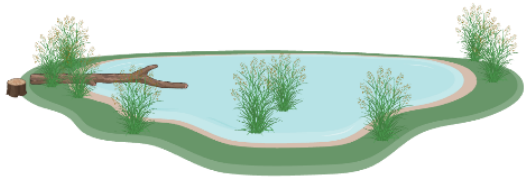
New project funded by the Lake Champlain Basin Program for 2025-2027

Focus:

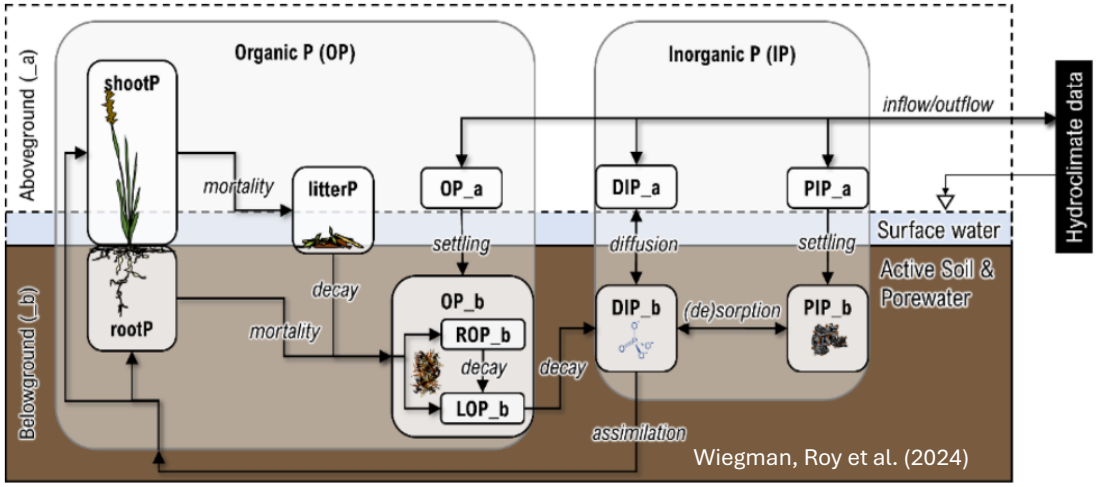
(1) Expand research to non-floodplain wetlands
(2) Building a simplified web tool to facilitate wetland P retention estimates for wide range of floodplain & non-floodplain wetlands.

A) Collect detailed site-level data:

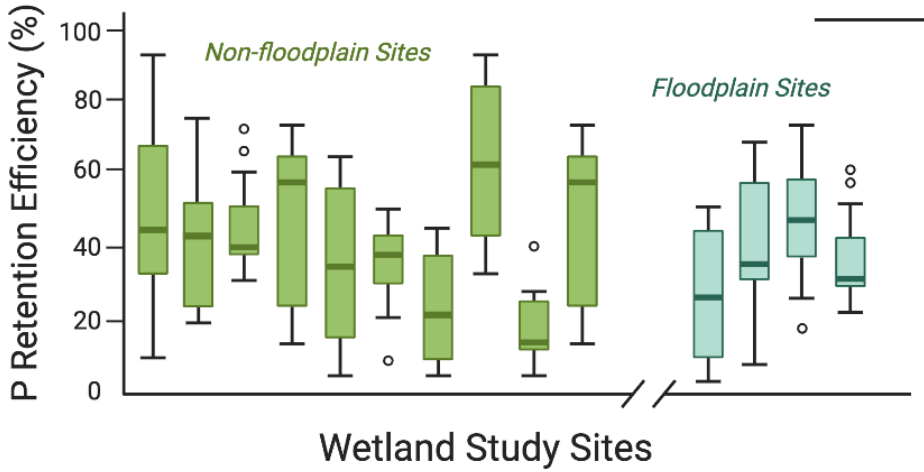
- water level
- HRT
- soil P stocks
- SPSC
- vegetation P stock
- influent water quality



B) Run 'wetlandP' model simulations

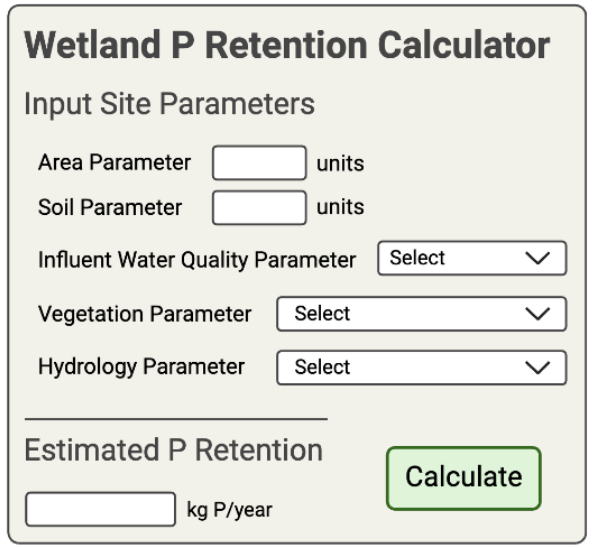


C) Generate range of net P retention estimates for different input combinations



*Not real data

D) Build simplified web tool



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Questions?

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