Background
Phosphorus (P)-laden runoff has been associated with lake eutrophication throughout the upper Midwest United States. Although P has been considered immobile in groundwater systems, an ongoing investigation at UW-Eau Claire suggests P is highly mobile and present in large quantities in the groundwater system. The potential impact of P in groundwater contributing to lake eutrophication has implications on land-use practice and healthy lake management.

This study seeks to quantify P loading through groundwater discharge in Mud Lake in Barron County, WI. Mud Lake was selected as a site of interest for:
1. high groundwater P concentrations in Chetek identified by Bartnik et al. (2016) and Wiest et al. (2017)
2. the lake is known to experience seasonal eutrophication
3. the lake size is practical for sampling (332 acres)
4. the site is easily accessible
5. the landowners have been cooperative
6. the lake is geographically close to Eau Claire
7. the land use and geology are typical of Western WI

Methods

FIELD METHODS
(1) In 2019, nine (9) mini-wells (5 ft length, 1/2" ID, 4" screen) were installed around the perimeter of the lake. Mini well locations (Fig 5) were selected based on land-owner permission, ease of access, and achieving well-distributed spacing (10 wells were installed in 2018).
(2) Hydraulic conductivity at each site was determined through slug or constant head tests following well installation.
(3) Water levels inside and outside the well were collected using a water level meter.
(4) On site water quality was measured for surface (in situ) and groundwater (low flow sampling) using an Aqua TROLL 600 Multiparameter Sonde.
(5) Surface and groundwater samples were collected through low flow sampling, filtered and preserved in the field using a 0.45 or 0.20 µm filter and nitric acid.
(6) Lake bottom sediments were collected for analysis of sediment chemistry and phosphorus sorption. Sediments were dried in a low temperature oven for 24 hours.

RESULTS

Results

Phosphorus (DI Water Extraction)

Fig 5 (left). Sampling averages during the 2018 field season. Lake subdivisions are considered representative for each mini well. Shading indicates average P concentration by groundwater. Average P concentrations in shallow groundwater were highest on the East side of the lake. This is consistent with the positioning of Mud Lake in the drainage basin (Fig 2). Surface P concentrations appear to be reflective of the flow-through conditions.

Average P Flux (g/day)

MW 1 8.25E+01
MW 2 6.65E+02
MW 3 4.18E+02
MW 4 6.26E+01
MW 5 1.04E+03
MW 6 1.59E+04
MW 7 1.95E+04
MW 8 4.53E+03
MW 9 4.55E+01

Table 1. Average P flux discharge (Q) for each mini well.

Average P Flux (g/day)

MW 1 8.25E+01
MW 2 6.65E+02
MW 3 4.18E+02
MW 4 6.26E+01
MW 5 1.04E+03
MW 6 1.59E+04
MW 7 1.95E+04
MW 8 4.53E+03
MW 9 4.55E+01

Total 4.36E+04

Additional Discussion

• Redox conditions (high ORP, high dissolved oxygen, low Fe and Mn) indicate oxygenated conditions. This suggests P is mobile due to excessive concentrations rather than anoxia.
• 2019 data-to-date show P concentrations that are not consistent with 2018 P concentrations, suggesting that a variable source (such as agriculture) plays a large role in the groundwater P.

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