LAKE WAUKEWAN | SEDIMENT ANALYSIS

TO: Troy Brown, Town of Meredith
FROM: Laura Diemer, FB Environmental Associates
SUBJECT: Sediment Analysis for Lake Waukewan
DATE: August 8, 2023
CC: Forrest Bell & Evan Ma, FB Environmental Associates

With the assistance of Steve Landry of the New Hampshire Department of Environmental Services (NHDES) and local volunteers, Frank Murphy and Jamie Irving, FB Environmental Associates (FBE) conducted sediment testing of Lake Waukewan in Meredith, NH on June 8, 2023. Sediments were analyzed for elemental ratios of phosphorus, aluminum, and iron to assess vulnerability to internal phosphorus loading, which has been shown to fuel historic cyanobacteria blooms in Lake Waukewan. FBE selected sites in a gradient of water depths around the lake (Figure 1) to understand spatial variability in sediment chemistry and better assess future risk of internal phosphorus loading in the possible event that the extent of anoxia (which triggers internal phosphorus loading in lakes) expands to impact a larger area of the lake.

SEDIMENT COLLECTION

The top 4 inches (10 cm) of sediment was collected from five locations around Lake Waukewan using coring equipment provided by Steve Landry of NHDES. For each intact core retrieved from the lake bottom, excess water was siphoned off and gloves were used to bag the sample to prevent contamination. Sediment cores were deposited in labeled zipped locked bags, double-bagged, and placed in a cooler for overnight shipping to the University of Wisconsin-Stout Center for Limnological Research and Rehabilitation Laboratory for analysis of moisture content, bulk density, organic content, total phosphorus, total iron, total aluminum, and biologically labile and refractory phosphorus.

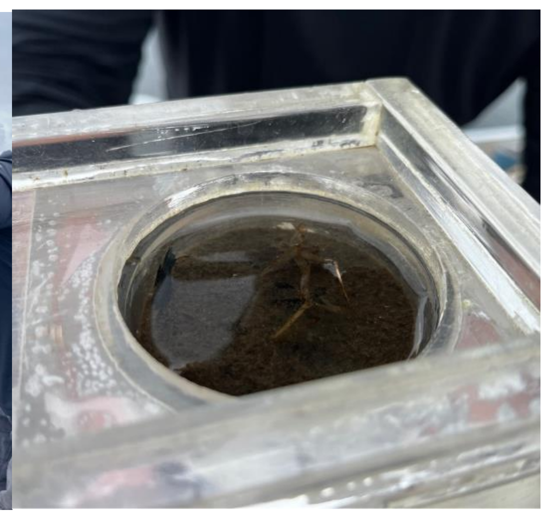
The following summarizes field observations for the five collected cores:

Site LW-S2 is located at the northern deep spot (Mayo station) in 65 ft of water. Bottom sediments were extremely soft and mucky. Stratified layers of sediment were observed in the core, and the top-most layer was smooth and silty to the touch.

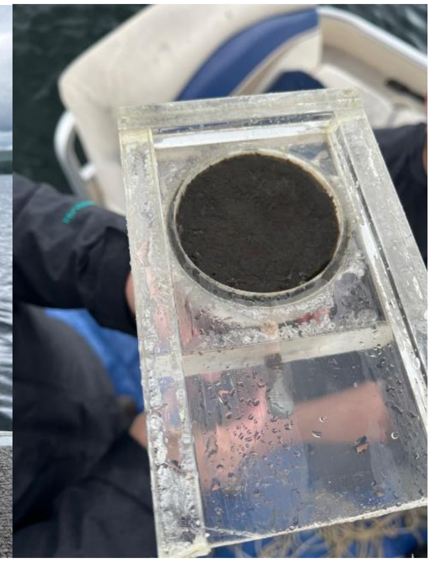
Additionally, iron-oxidizing bacteria were found at the sediment surface. This is evidence of iron oxidation, suggesting oxic conditions at the sediment-water interface at the time of collection in early summer.

Site LW-S3 is located in the northwestern area of the lake near the Snake River inlet in 13 ft of water. The Snake River outlet area is considered prime wetlands. The lake bottom could be seen from the boat. The sediment was soft until refusal at 6 inches (15 cm). The texture of the sediment was slightly gritty, suggesting coarser sediment composition compared to the deep spots. However, the core held its shape, suggesting that there may also be higher clay content here than at other sites. Benthic plant matter was found on the coring equipment.

Site LW-S4 is located in the southeastern area of the lake near the intake pipe in 17 ft of water. The top layer of sediment was loose followed by firmer layers. The sediment had a grittier texture than other sites, suggesting that sand was present in greater proportions at this site. A small benthic plant was found at the sediment surface.



Site LW-S5 is located east of the southern deep spot (Winona station) in 37 ft of water. The sediment was mucky and felt smooth and silty in texture. There was a noticeable color gradation in the core, with lighter colors located deeper in the sediment.



Site LW-S6 is located to the northwest and upstream of the southern deep spot (Winona station) in 43 ft of water. Based on the morphometry of the lake, water likely flows through this site before reaching the deep spot. The sediment was very fine and silty in texture. Closer to the deep spot, there were rocks, tree branches, and clay on the lake bottom that made core collection too difficult.

RESULTS

In 2023, FBE collected five lake bottom sediment cores (top 4 inches) to test for susceptibility of internal phosphorus loading within Lake Waukewan. Sediment testing included analysis of phosphorus fractions by sequential lab extractions, as well as analysis of total phosphorus, total iron, and total aluminum (Table 1).

Phosphorus fractions analyzed included loosely bound phosphorus, iron bound phosphorus, labile organic phosphorus, calcium bound phosphorus, and aluminum bound phosphorus. Loosely bound phosphorus is the most readily available fraction for uptake by algae. Iron bound phosphorus is phosphorus bound to iron which can be released under low oxygen conditions. Labile organic phosphorus is phosphorus bound to organic matter that is slowly released during decomposition. Calcium bound phosphorus is phosphorus bound to calcium and can be released under acidic conditions. Aluminum bound phosphorus is phosphorus bound to aluminum which is permanently retained within bottom sediments.

Results show that loosely bound phosphorus is low at all depths in the lake, particularly LW-S4 near the intake pipe and outlet in the southern area of the lake which exhibited very low organic matter content (3.4%). Iron and aluminum bound phosphorus are both higher in deeper areas of the lake (especially LW-S2 at the northern deep spot Mayo station) compared to shallower areas, which is expected given that sediments tend to migrate to deeper parts of the lake over time. Iron bound phosphorus is particularly high at the Winona deep spot (Site LW-S2), which aligns with the observations of iron-oxidizing bacteria on the surface of the core. Labile organic phosphorus is highest in the deepest parts of the lake, particularly around the two deep spots, indicating that the biogenic fraction of phosphorus (in addition to the iron bound phosphorus) may be a significant source of phosphorus release to the hypolimnion. Calcium bound phosphorus is relatively consistent at all depths measured in the lake.

A high ratio of aluminum to iron and aluminum to phosphorus means that there is enough aluminum to permanently bind settled phosphorus, keeping the internal load in the lake low. Typically, a ratio of 3:1 or greater between aluminum and iron (Al:Fe) indicates that aluminum is present in enough abundance relative to iron that phosphorus is more likely to permanently bind to aluminum in the sediments. Additionally, a ratio of 25:1 or greater between aluminum and phosphorus (Al:P) indicates that there is enough aluminum to bind with available phosphorus. **Results show that Lake Waukewan is vulnerable to internal loading due to Al:Fe ratios less than 3 and Al:P ratios less than 25 for all five sampled sites (shallow and deep areas of the lake) (Table 1).**

The ratio of iron bound phosphorus to calcium bound phosphorus can reveal which chemical condition (acidic or alkaline) may stimulate the maximum release of phosphorus from lake sediments (Huang et al., 2005). **Results show that the Winona deep spot (LW-S2) would achieve maximum release of phosphorus from lake sediments under alkaline conditions due to a high Fe-P:Ca-P ratio (Table 1). The Snake River outlet area (LW-S3) would achieve maximum release of phosphorus from lake sediments under acidic conditions due to a Fe-P:Ca-P ratio less than 0.5 (Table 1).** Lake Trophic Survey Report data indicate that bottom water pH for Lake Waukewan ranges from 6.2 to 6.5, possibly curbing the maximum release potential for phosphorus in Lake Waukewan sediments. Note, however, that the pH at the sediment-water interface and within the sediments may be different and is currently not known.

Table 1. Sediment testing results. Data were analyzed by the University of Wisconsin-Stout Center for Limnological Research and Rehabilitation. Red indicates conditions favorable for release of phosphorus under anoxic conditions. Green indicates conditions favorable for release of phosphorus under acidic conditions, and blue indicates conditions favorable for release of phosphorus under alkaline conditions. P=Phosphorus. Al=Aluminum. Fe=Iron. Ca=Calcium.

Site	Loosely-bound P (mg/g)	Iron-bound P (mg/g)	Labile organic P (mg/g)	Aluminum-bound P (mg/g)	Calcium-bound P (mg/g)	Total P (mg/g)	Total Fe (mg/g)	Total Al (mg/g)	Al:Fe	Al:P	Fe-P: Ca-P
LW-S2	0.032	0.298	0.437	0.495	0.115	1.377	20.00	14.20	1.5	11.8	2.59
LW-S3	0.024	0.064	0.260	0.162	0.199	0.709	7.43	6.67	1.9	10.8	0.32
LW-S4	0.021	0.076	0.072	0.137	0.151	0.457	9.45	5.62	1.2	14.1	0.50
LW-S5	0.031	0.093	0.406	0.404	0.162	1.096	11.10	13.20	2.5	13.8	0.58
LW-S6	0.032	0.118	0.424	0.426	0.218	1.218	13.50	15.60	2.4	14.7	0.54

If Al:Fe <3, favorable for release of P under anoxic conditions.
If Al:P <25, favorable for release of P under anoxic conditions.
If Fe-P:Ca-P <0.5, favorable for release of P under low pH (acidic) conditions.
If Fe-P:Ca-P >0.6, favorable for release of P under high pH (alkaline) conditions.

NEXT STEPS & RECOMMENDATIONS

Results indicate that at all depths Lake Waukewan is vulnerable to internal phosphorus loading, which is estimated to contribute 5% of the total phosphorus load to Lake Waukewan. Given that climate change is increasing water temperatures and expanding the extent of anoxic zones in many lakes across New England, we recommend that robust monitoring of dissolved oxygen and temperature conditions and total phosphorus throughout the water column at the two deep spots continue and that the watershed management plan be revisited and updated to identify new sources of phosphorus and determine actions to reduce the amount of phosphorus entering Lake Waukewan. The Town of Meredith and the Waukewan Watershed Advisory Committee is already pursuing grant opportunities for expanding monitoring and updating the watershed management plan. These efforts will be critical to tracking trends in internal loading in the lake and mitigating threats, all for the long-term protection of the lake.

WORKS CITED

Huang, Q., Wang, Z., Wang, C., Wang, S., J, X. (2005). Phosphorus release in response to pH variation in the lake sediments with different ratios of iron-bound P to calcium-bound P. Chemical Speciation and Bioavailability, 17(2), 55-61.

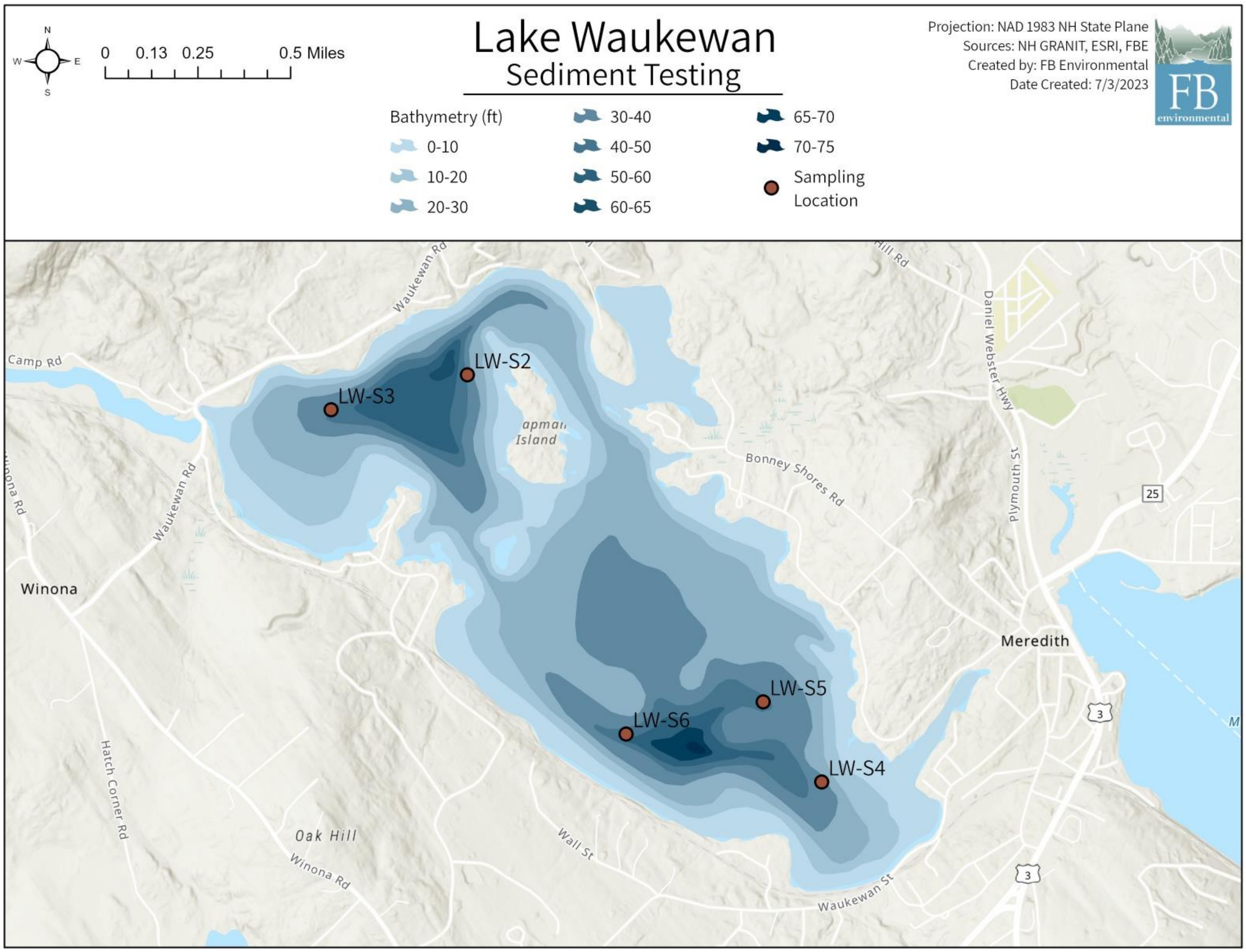


Figure 2. Sediment sampling locations on Lake Waukewan. Sampling locations were selected at a variety of depths and at or near the deepest spots in the lake.