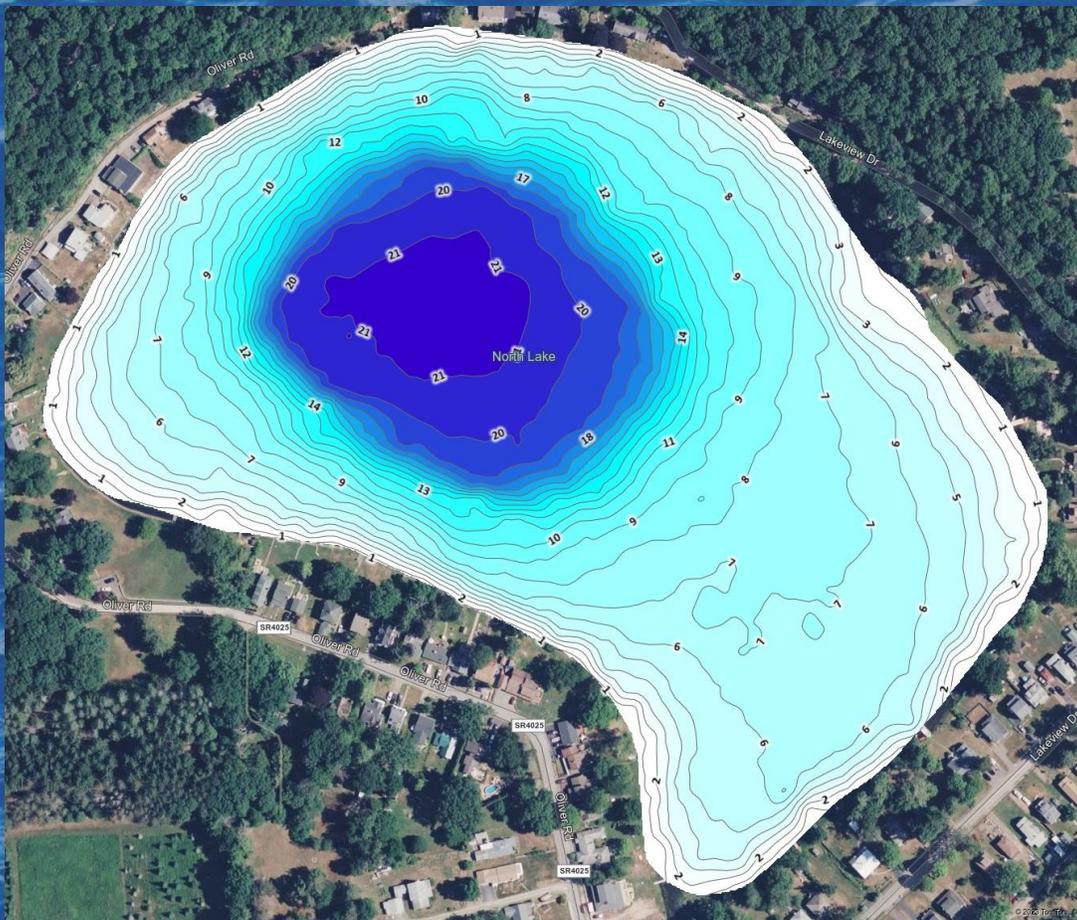




2023

# North Lake Improvement Association Annual Scan Results



We Simplify the Science™



## 2023 North Lake Evaluation

Sonar scans of North Lake were performed in 2018, 2021, and 2023. This year's scan took place on October 9<sup>th</sup>. This report compares the scans to show how the lake has changed since evaluations began. We will look at the following key metrics: depth and volume, vegetation biovolume, dissolved oxygen, and water quality.

### Results of this year's scan show:

1. **Improvements in average depth, maximum depth, and volume since 2021**
2. **A small increase in vegetative cover and reduction in vegetation biovolume**
3. **Evenly distributed DO throughout the water column**
4. **High nutrient concentrations**

## Background

North Lake has had an inversion system in place since 2007 and has implemented a bioaugmentation program periodically since then. The system consisted originally of thirteen diffusers supplied by one (1) 5-hp and two (2) ¾-hp compressors. In 2017, the compressor was upgraded. This is a brief timeline of activities and North Lake Improvement Association's spending on the project:

- 2007: system was installed, biological products were applied
- 2007-2017, system operated with occasional upgrades and periodic bioaugmentation
- 2017: Major compressor upgrade, annual bioaugmentation begins
- 2018: Equipment and maintenance supply purchases, bioaugmentation, sonar scan by Clean-Flo
- 2019: Purchase of variable frequency drive (VFD) for compressor, compressor motor replaced, maintenance supplies, and bioaugmentation
- 2020: Maintenance supplies and bioaugmentation
- 2021: Sonar scan by Clean-Flo, maintenance supplies purchased, bioaugmentation
- 2022: Maintenance supplies purchased and bioaugmentation

In 2023, the North Lake Improvement Association was awarded a grant to pay for a full-scale biological restoration program for the lake. Most of the money from this grant was allocated toward bioaugmentation products and Clean-Flo product application services. The following table shows products applied since 2017, for which full records are available. As illustrated, the quantity of products applied this year far exceeds previous years.

North Lake Bioaugmentation Products by Year								
Year	CFLO (lb)	Clean & Clear (gal)	BioBooster (gal)	Lake Clear	Nutrient Sponge-Bag	Nutrient Sponge-Granular (lb)	Winter Warrior (lb)	Winter Warrior Booster (lb)
2017	10		45		5	40	50	5
2018	65		80				25	3
2019	20	35	60		6		25	3
2020	5	30	35					
2021	2	5	30	45				
2022	6	2	20					
2023		180	360		50			

## Depth and Volume

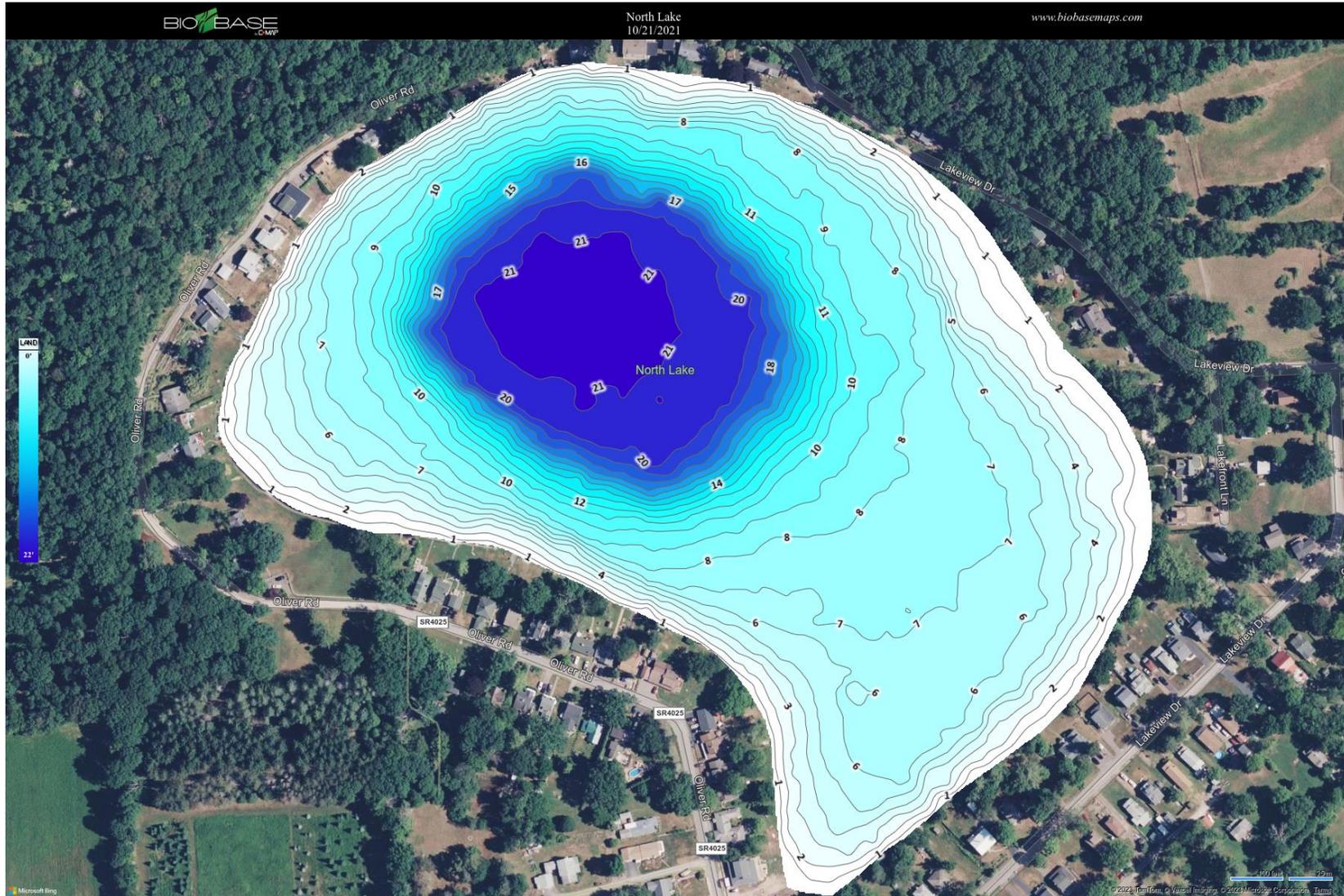
This year's scan reveals minor changes in North Lake's depth and volume. In 2021, the volume of the lake was 365 acre-feet, or 119 million gallons. The average depth was 9.2 feet and the maximum depth was 21.6 feet. In 2023, the volume of the lake was 374 acre-feet, or 121 million gallons. The average depth in 2023 was 9.4 feet and the maximum depth was 21.9 feet. Between 2021 and 2023, the maximum depth increased by 0.3 ft (3.6 inches), average depth increased by 0.2 ft (2.4 inches), and the volume increased by 2 million gallons. The table below summarizes these metrics since 2018.

North Lake 2018-2023 Depth and Volume Changes by Scan Date						
	10/22/2018	10/20/2021	10/24/2023	2021-2023 Change	2021-2023 Change (%)	2018-2023 Change
Average Depth (ft)	9.4	9.2	9.4	0.2	2.17%	0.0%
Maximum Depth	22.2	21.6	21.9	0.3	1.39%	-1.4%
Volume (acre-ft)	375.5	364.8	373.6	8.8	2.41%	-0.5%
Volume (Mgal)	122.3	118.9	121.7	2.9	2.41%	-0.5%
2017-2023 Sediment Reduction by Scan Date						
Muck Removed (added), Cu.Yd.		(17,263)	14,197	<b>14,197</b>		(3,065)

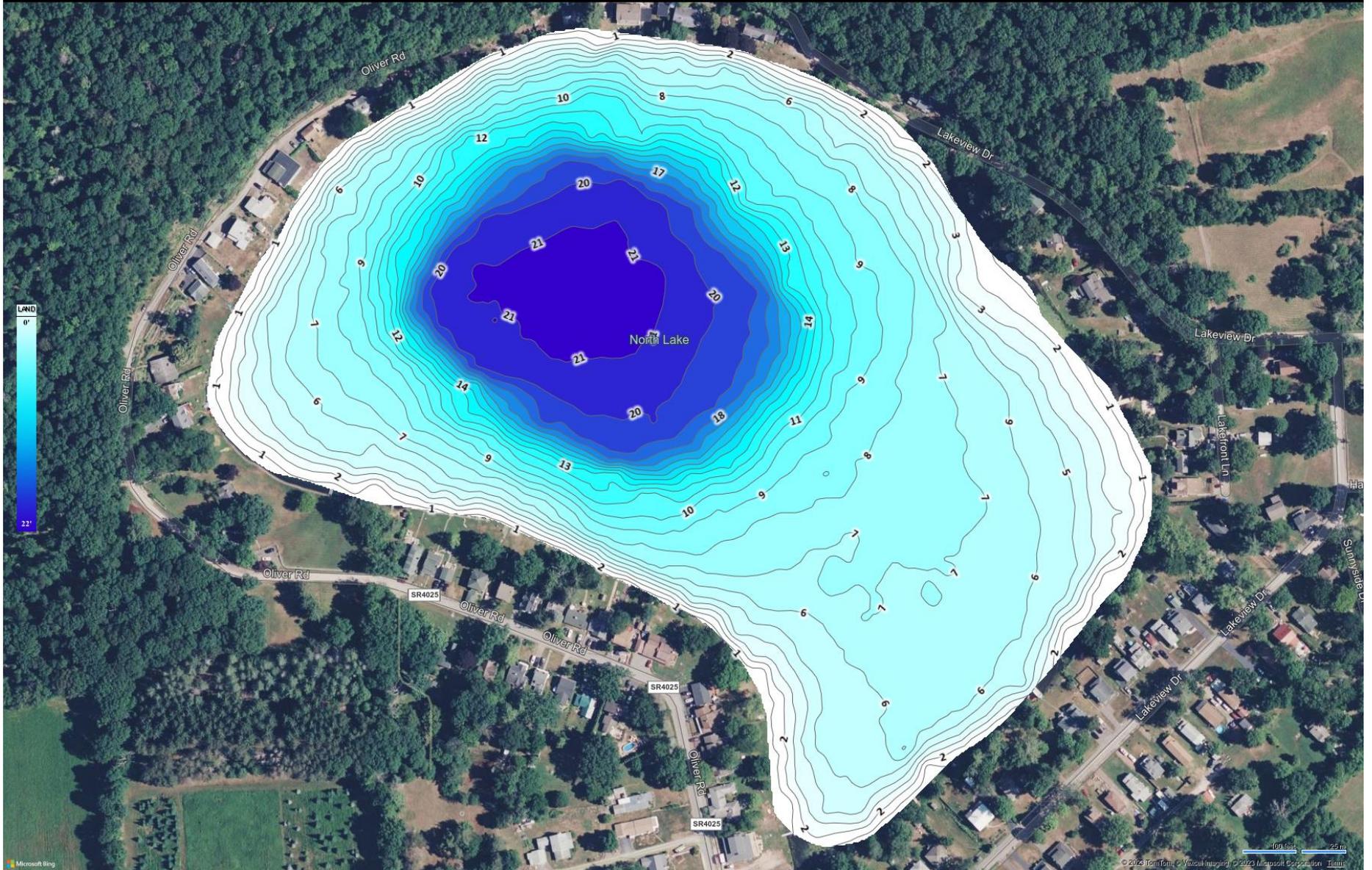
The values show that there was deterioration in volume and depth between 2018 and 2021. The significance of these results is that the bioaugmentation program has reversed the trend of decreasing depth and volume. Increasing depth and volume are a direct measure of the removal of organic sediment and the nutrients that the sediment contains.

A scan was not done in 2022. Given the changes that data between 2018 and 2021 reveal, it is likely that the lake became shallower between 2021 and 2022. Given that, the actual muck digested to achieve the increase in depth in volume recorded in 2023 would be greater than shown by the improvements between 2021 and 2023. The importance to the overall restoration effort of digesting organic sediment is that it will limit the availability of nutrients embedded in the muck to vegetation and algae.

The maps below show depth contours in the lake. The color scale ranges from white-to-blue, shallow-to-deep, respectively. The differences between contours from 2021 and 2023 are difficult to perceive on these maps. We have conducted more detailed analysis of specific areas of the lake to identify where depth and volume have either increased or decreased. This is shown in the “polygon” analysis that follows these maps.



**North Lake Bottom Contours 2021**

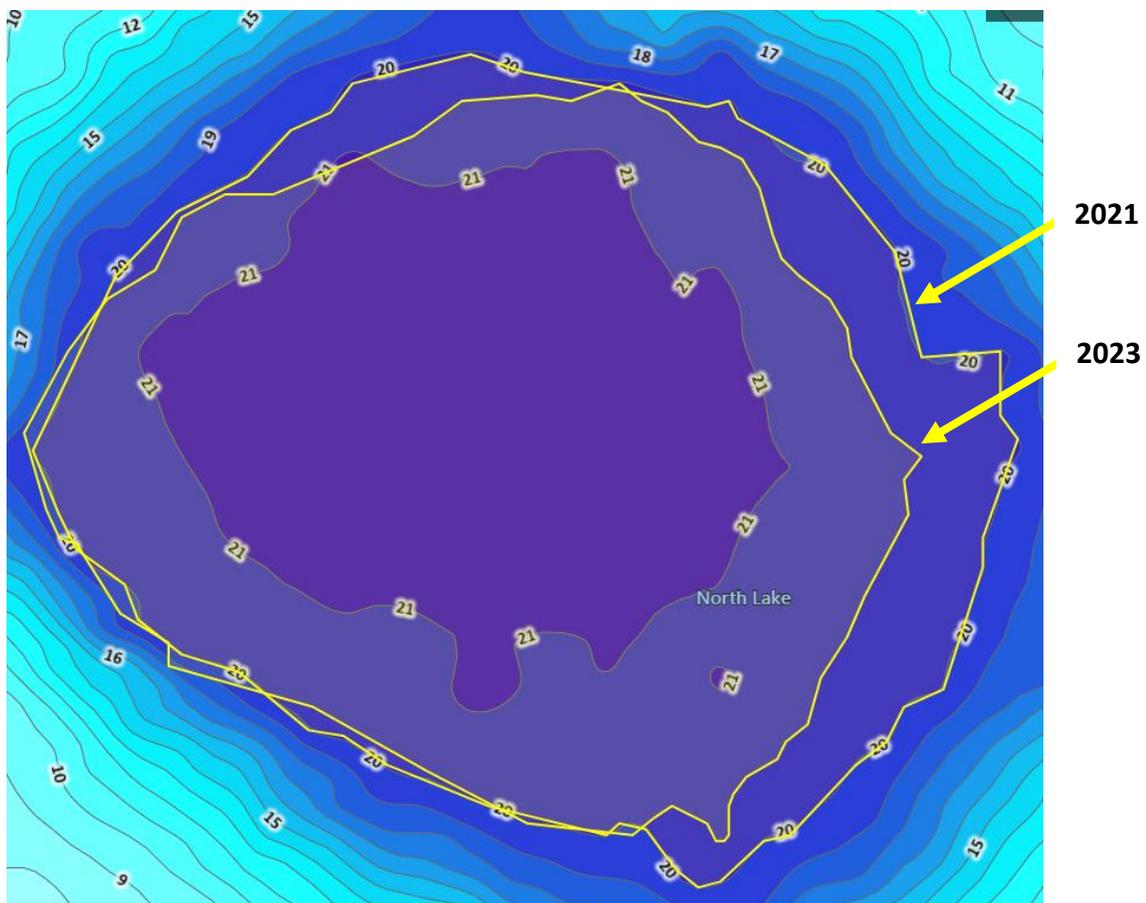


North Lake Bottom Contours 2023

## Polygon Analysis - Depth

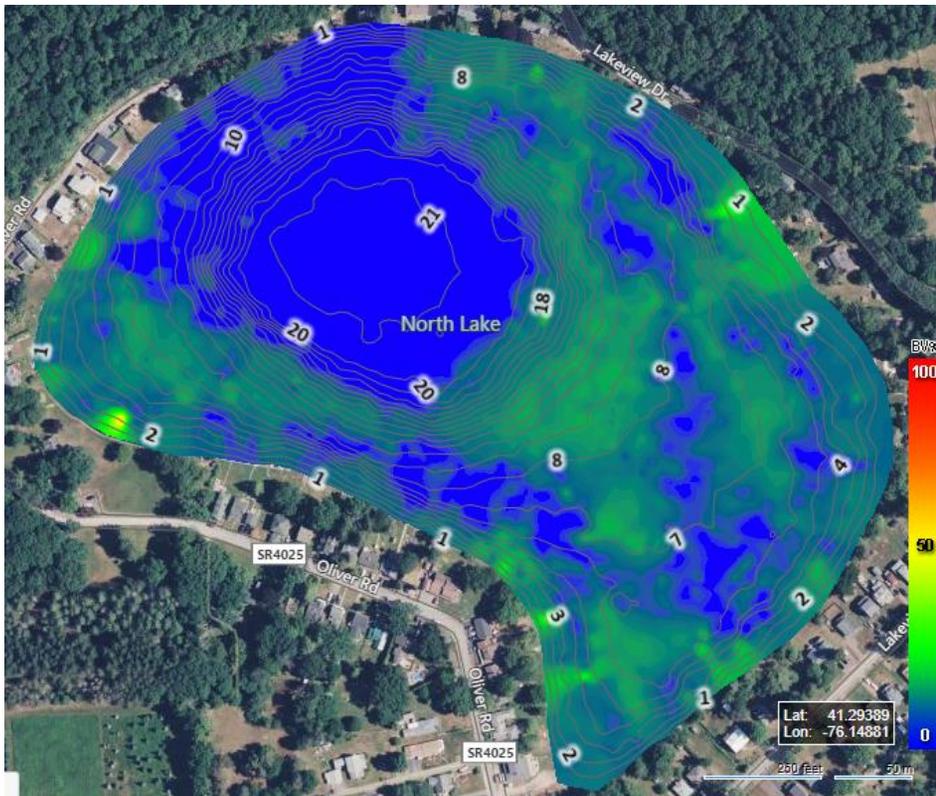
To further investigate depth and volume changes since 2022, a polygon analysis was performed on the deepest contour of North Lake. Polygon analysis compares metrics for specific areas of the lake and helps to determine where the most significant year-over-year changes have occurred. The figure below shows the polygon analysis for the 20' contour in North Lake between 2021 and 2023. The volume in this area decreased by 17.6 acre-ft (17.1%). This is due primarily to the decrease in *area* of the 20' contour. The loss in volume is compensated for by the increase in depth in other areas of the lake, in particular the eastern half. However, loss in this area is the largest factor suppressing a *greater* increase in depth and volume between 2021 and 2023. We believe that the primary cause of depth reduction by the shrinking 20' contour is the deposition of dead algae from the heavy bloom that occurred in July and August. The yellow lines in the figure below show the 20' contour from 2021 (outer line) and 2023 (inner line).

NORTH LAKE 20' CONTOUR				
Description	October 2021	October 2023	2022-2023	% Change
Polygon Area (acre)	4.90	4.10		
Water Volume (acre ft)	102.90	85.28	-17.62	-17.1%
Water Depth Avg (ft)	20.86	20.83	-0.03	-0.1%
Water Depth Max (ft)	21.56	21.86	0.30	1.4%
Vegetation Avg BV (%)	5.23	0.00	-5.23	-100.0%
Vegetation Cover (%)	0.13	0.00	-0.13	-100.0%

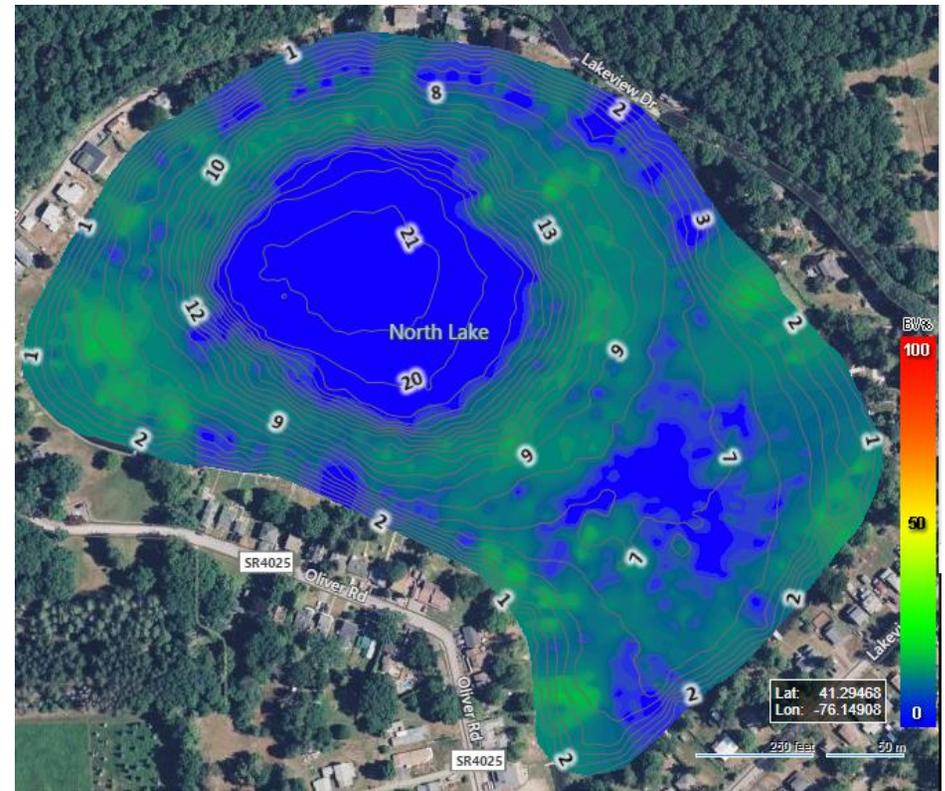


## Vegetative Biovolume Maps

The maps below show the coverage and density of vegetation in the water column in North Lake. The color scale represents increasing percentages from blue to red. The maps show a changing distribution and density of vegetation in multiple spots in the lake. The greatest reduction took place in the middle of the eastern side and on the eastern edge of the deep hole. We also see a reduction in concentration across the entire lake, shown by darker shades of green. However, as the tables show below there was no reduction in the aggregate coverage or concentration of vegetation. This is not a bad thing in and of itself, but indicates a persistent high concentration of nutrients that are probably originating both from influx from the watershed and the existing nutrient stockpile in the lake.



North Lake Vegetative Biovolume 2021



North Lake Vegetative Biovolume 2023

The tables below quantify the coverage and biovolume of vegetation in 2018, 2021, and 2023. The amount of the lake's area covered by vegetation (PAC) decreased between 2018 and 2023 from 62.1% to 53.0%. Between 2021 and 2023 it increased from 50.4% to 53.0%. The average percentage of the lake water column occupied by vegetation (Avg BVw), a measure of vegetative density, decreased from 7.3% to 4.3% between 2018 and 2023. The decrease in Avg BVw between 2021 and 2023 was 0.2%. These are modest changes and indicate several important things: 1) Vegetation is still prolific and is being driven by nutrient-rich muck on the bottom of the lake and 2) High nutrient levels in the water column are also driving the growth of vegetation. This was also made evident by the algae bloom this summer, and by sampling results that indicated high phosphorous concentration.

2018 Vegetation Survey Summary						
PAC	Avg. BVp	SD BVp	Avg BVw	SD BVw	Depth Range	Depth Avg
62.1%	11.7%	± 9.9%	7.3%	± 9.7%	0.23-22.20 ft	9.44 ft

2021 Vegetation Survey Summary						
PAC	Avg. BVp	SD BVp	Avg BVw	SD BVw	Depth Range	Depth Avg
50.4%	8.9%	± 3.3%	4.5%	± 5.0%	0.21 - 21.56 ft	9.18 ft

2023 Vegetation Survey Summary						
PAC	Avg. BVp	SD BVp	Avg BVw	SD BVw	Depth Range	Depth Avg
53.0%	8.2%	± 2.0%	4.3%	± 4.3%	0.23 - 21.86 ft	9.40 ft

## Dissolved Oxygen and Temperature

The table below compares depth, temperature, and dissolved oxygen (DO) levels. A healthy lake will be well-mixed and have DO levels above 5 mg/. When the DO is under 5 mg/L, the aquatic life will be stressed or may not be able to survive at all, and dissolved nutrients will be released from the lake's sediment. Through the operation of the inversion system, North Lake shows no temperature stratification and maintained DO that is sufficient to support a healthy aquatic ecosystem through 2023.

North Lake Temperature and DO 2023						
Depth (ft)	6/15/2023		8/8/2023		10/9/2023	
	°F	DO mg/L	°F	DO mg/L	°F	DO mg/L
1.0	68.9	7.3	76.1	6.6	62.6	6.4
2.0	68.9	7.3	75.7	6.3	62.6	6.4
4.0	68.9	7.3	75.7	6.4	62.6	6.3
6.0	68.7	7.3	75.7	6.4	62.6	6.2
8.0	68.7	7.2	75.7	6.3	62.6	6.0
10.0	68.7	7.2	75.7	6.2	62.5	6.0
12.0	68.5	7.1	75.7	6.0	62.4	6.0
14.0	68.5	7.1	75.6	5.7	62.3	6.0
16.0	68.4	7.1	75.4	4.8	62.2	6.1
18.0	67.8	6.2			61.7	6.0
20.0	68.2	6.1				

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## Nutrients

Clean-Flo took several laboratory samples for total phosphorous (TP), orthophosphate (OP), and total kjehldal nitrogen (TKN) during the season to evaluate nutrient concentrations. Analyses were performed by Trace Analytical Laboratories, Inc. In general, TP should be below 0.02 mg/l to avoid nuisance algae growth. Orthophosphate is the form of phosphorus that is most bioavailable and should be lower than TP, substantially lower than 0.02 mg/L. TKN indicates the presence of various forms of nitrogen that may spur the growth of vegetation and algae. In addition, nitrate and ammonium samples were taken with the YSI meter to further understand concentrations of nitrogen. The following table shows results for 2023.

Both lab sampling events showed high TP. The August sampling showed extremely high TP. This was primarily a consequence of the large algae bloom. Phosphorous is used by algae to grow, and samples for TP will reflect the phosphorous that they have consumed. Where there are large concentrations of algae, there will be high TP concentrations and low OP concentrations. OP was below the “detection limit” (the concentration below which the lab instruments are unable to detect). This is good, but does not necessarily indicate a total absence of OP. The TKN, nitrate, and ammonium levels indicate a significant presence of nitrogen. This may suggest that it is being released from the sediment in the absence of DO. This should be further investigated next year.

North Lake Nutrients			
Analysis	6/15/2023	8/8/2023	10/9/2023
Total Phosphorous (mg/L)	0.022	0.630	-
Orthophosphate (mg/L)	<0.010	<0.010	-
Total Kjehdahl Nitrogen (mg/L)		72.00	
Nitrate (mg/L) - YSI	4.20	7.30	
Ammonium (mg/L) - YSI	NA	NA	0.48

## Conclusions

- North Lake’s inversion system is effectively mixing the lake and maintaining healthy DO levels
- There were modest improvements in the lake’s depth and volume between 2021 and 2023
- Bottom-rooted vegetation increased in coverage and decreased in concentration marginally
- The large algae bloom and sampling this season indicate high nutrient concentrations
- Sources of nutrients are not certain but must be addressed

## Recommendations

- Further investigation of nutrient inputs should be done in 2024, focusing in particular on streams
- Managing nutrients and algae are the top priority for 2024. There are several ways to address this:
  - Make changes to the allocation of products within the limitations of the grant funding
  - More frequent dosing of the micronutrient product BioBooster to encourage the growth of beneficial algae species
- Diffuser balancing in 2024
- More frequent sampling for nutrients and dissolved oxygen
- Two samples for algae analysis during midsummer applications by Clean-Flo Staff