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Lake Peekskill 2021 Annual Report

Town of Putnam Valley
265 Oscawana Lake Road
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Background

In 2018, Clean-Flo responded to a request for proposal issued by the Town of Putnam Valley for the design, installation, and operation and maintenance of a system to generally improve Lake Peekskill's water quality, and specifically to reduce the incidence and severity of harmful algae blooms (HABs). Based on the information provided in the RFP, Clean-Flo designed the system and submitted a proposal for an oxygenation-inversion system and bioaugmentation program. The project was awarded to Clean-Flo, and the system was installed in June of 2018.

As part of Clean-Flo's contract, a preliminary scan of the lake and water quality sampling was performed in spring 2018. The purpose of the scan and sampling was to establish baseline conditions for water quality, depth, and vegetation. Since 2018, Clean-Flo has performed annual scans to assess progress the system has made in restoring the lake. The most recent scan was performed in October this year, and the results of the scan, as well as comparison to the 2020 scan, are described in this report.

The annual scans and sampling performed on the lake have shown significant improvements over the course of time, despite minor setbacks caused by the COVID-19 pandemic, maintenance issues, and changes in the lake's ecology caused by unanticipated external inputs into the lake.

In 2020, travel restrictions due to COVID-19 prevented routine maintenance, product application, and testing visits, thereby allowing cyanobacteria populations to gain some momentum toward the end of the year. However, based on water and sediment testing data, there has been a net decrease in nutrient levels and an overall change in the dominant algae species from those typically responsible for HABs to beneficial diatoms and green algae. In late 2020 Town of Putnam Valley staff reported that a leak had been detected in one of the airlines where the airlines enter the lake near the compressor shed and spares and equipment was sent so that repairs could be undertaken. During our final service and maintenance visit in October 2020 the system appeared to be operating correctly.

In 2021 problems were noted with the oxygenation levels in the lake, which were rectified during service and maintenance visits by rebalancing airflows to diffusers from the manifold. Similar problems reoccurred and water quality conditions were not maintained at standards achieved in previous years. Late in the year, after relocation and cleaning of diffusers, and excavating the airlines running from the compressor house into the lake, it was discovered that some airlines had ruptured. It is believed that this was caused by excessive UV exposure, although we have never experienced such an incident before. Corrugated piping was installed between the compressor shed and the lake to protect airline from UV exposure. After the maintenance work was completed, the system returned to operating at capacity. Photographs of the repairs this year are shown in Appendix 1.

2021 Summary

On October 20th, 2021, the most recent sonar scan was conducted on Lake Peekskill, while water samples and sediment samples were collected from sampling sites in the lake. Dissolved Oxygen (DO) and temperature readings were also taken at each of the sampling sites. Sampling data from the water, sediment, and YSI handheld meter were compiled in tables that can be found in the following sections.

The 2021 sampling data and sonar scan show that nutrient levels varied over the season and have not shown significant reductions since 2020. The algal community has improved, such that species responsible for HABs (harmful cyanobacteria) have been reduced, and beneficial green algae and diatoms are now dominant. Blooms were observed both in 2020 and 2021. Toxin testing by the State of New York determined that cyanotoxins were not present in 2020 but were present in 2021. Blooms in both years resulted in beach closures. The apparent reduction in the effectiveness of the system is believed to be due to the rupture in the airlines as described above.

Depth and volume increased since the 2020 scan and have increased significantly since the beginning of the project. Vegetation coverage and intensity decreased significantly in 2021. By and large, these results show the continued effectiveness of Clean-Flo's system and bioaugmentation program.

Water Quality and Sediment Sampling

Water samples were taken on April 29th, May 25th, and July 25th, 2021. Samples were analyzed for total phosphorus (TP), orthophosphate, and algae. Samples were taken at four locations, with the exception of algal community, which were only taken at S1, S2, and S3, in accordance with the contract. Sediment samples were also taken at all four locations to analyze total organic carbon (TOC) and phosphorus levels in the sediment. The sample locations in the lake are shown in Figure 1 below. The sample results and analysis are illustrated in the following sections.

Figure 1. Sampling locations on Lake Peekskill

Dissolved Oxygen

Dissolved oxygen (DO) readings were obtained with a handheld YSI water quality meter. DO is a measure of the amount of oxygen in the water column available to aquatic organisms. Generally, DO levels should be greater than 5 mg/L to sustain a healthy ecosystem. DO at the surface is generally higher due to the exchange of oxygen between the atmosphere and the surface water, whereas DO is lower at the lake bottom due to decreased contact with the atmosphere and increased biochemical oxygen demand (BOD) caused by the decomposition of organic matter.

DO data from 2020 and 2021 are displayed in Tables 1 and 2, respectively. Oxygen levels fluctuated in the deepest part of the lake (Sample location S2) throughout 2020. Compared to May and June of 2020 at S2 (Table 1), the lowest oxygen levels before hitting sediment were 0.59 mg/L and 0.03 mg/L, at 20 feet and 22 feet deep, respectively. Furthermore, DO was less than 5.1 mg/L below 14 feet depth. These levels indicated insufficient oxygenation by the diffuser at this location. This was likely by the leak in the airline. The Town of Putnam Valley personnel repaired the airline in the summer of 2020. The August 2020 sampling showed that the repairs had resolved the problem (see DO increase at S2 from 12 feet down to the bottom from 6/24/20 to 8/19/20). However, the DO levels dropped again between August and October, at S2, S3, and S4, suggesting that the fix might only have been temporary.

Table 1- DO data from 2020. DO expressed in mg/L, deepest readings measured at sediment level

	5/21/2020				6/24/2020				8/19/2020				10/7/2020			
Depth (ft)	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
2	11.3	11.43	11.72	11.8	9.1	9.76	10.13	10.04	7.56	6.51	6.83	7.95		8.55	8.49	8.6
4	11.27	11.44	11.7	11.76	9	9.5	9.77	9.99	7.45	6.5	6.82	7.82	8.67	8.55	8.46	
6	11.13	11.43	11.69	11.78	8.99	9.27	9.48	9.69	7.41	6.47	6.81	7.79	8.67	8.55	8.38	8.48
8	10.99	11.39	11.61	11.7	7.92	9.07	9.21	9.43	7.4	6.49	6.75	7.76	8.57	8.55	8.11	8.32
10	10.53	11.41	11.38	11.6		8.04	8.33	7.39		6.48	6.75	7.58	6.24	8.54	8	8.29
12		11.45	10.85	10.96		5.1	2.52	4.31		6.49	5.75	6.68		8.54	3.11	4.76
14		11.37				4.33				6.5				8.53		
16		10.86				3.7				6.5				8.54		
18		9.96				3.01				6.48				8.53		
20		9.9				0.59				6.49						
22		6.94				0.03				6.49						

Table 2 illustrates DO levels measured in 2021. In April, DO levels indicated that the system was operating properly. Oxygen levels in April sampling were well above the 5 mg/L threshold. In May of 2021, however, low oxygen levels were recorded at depths greater than 16 feet at location S2. Upon inspection, it appeared once again that insufficient air was being supplied to the deepest diffuser near S2. This prevented oxygenation and mixing in that area, which was primarily responsible for the depleted DO.

In consulting with town personnel, it became apparent that some of the airlines near the shoreline had cracked and were releasing air. Clean-Flo concluded that UV radiation from sunlight had weakened and cracked the airline, which resulted in the insufficient air supply to the diffuser closest to S2. In response, Clean-Flo replaced the airline between the shed and the lake and installed corrugated piping to cover it. After testing DO levels just after repairs (see data at S2 on 10/20/21 in Table 2), the system was back to full operation and was oxygenating the deepest area of the lake as designed. We expect that further monitoring will indicate that a healthy oxygen level is being maintained in the deepest parts of the lake.

Table 2 – DO Data from 2021. DO expressed in mg/L, deepest readings measured at sediment level

	4/29/2021				5/25/2021				7/19/2021				10/20/2021			
Depth (ft)	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
2	10.31	10.37	10.51	10.58	9.14	8.88	9.03	9.27	9.84	9.98	10.73	11.5	8.8	8.9	9.04	8.74
4	10.36	10.23	10.3	10.32	9.14	8.81	9.02	9.18	7.96	9.07	9.2	10.92	8.81	8.87	9.02	8.76
6	10.38	10.13	10.15	10.29	9.18	8.77	8.96	9.02	7.34	8.36	9	9.92	8.83	8.87	8.97	8.75
8	10.35	10.11	10.13	10.25	9.12	8.48	8.85	9.05	6.67	8.28	8.75	8.95	8.82	8.81	8.66	8.63
10		10.07	10.09	9.66	8.86	8.43	8.61	8.85	6.42	8.08	7.99	8.46	8.75	8.65	8.59	8.34
12		10.04		8.77		8.43				6.53	6.9	6.71		8.56		7.57
14		9.63				8.42				5.59				8.47		
16		9.48				8.44				4.93				8.43		
18		9.39				8.44				0.92				8.45		
20		9.07				4.01				0.16				8.41		
22		7.89				1.26				0.14				8.23		
24										0.08				7.86		

Water Samples

Water sampling and analysis are used on Lake Peekskill to evaluate nutrient concentrations and algal community in the water column. Total phosphorus (or TP) levels should generally be 0.02 mg/l or less to avoid nuisance algae growth. Orthophosphate is the form of Phosphorus that is most bioavailable and should be lower than TP. Algal samples are taken in order to measure the prevalence of harmful cyanobacteria, species of which are capable of causing HABs. In general, any harmful cyanobacteria is undesirable, but the most important condition is that these species should be at lower concentrations than those at which they might become toxic.

Algae water samples were taken at the surface, and the phosphorus and orthophosphate water samples were taken 1 foot from the bottom with a Van Dorn Beta water sampler. Samples were analyzed by SGS for total phosphorus and orthophosphate, and the algae samples were analyzed by Phycotech. Typically, phosphorus will be higher at the bottom of the lake than at the surface, where algae are able to use phosphorus as a food source. However, unlike other species of algae, cyanobacteria can descend to the bottom to access nutrients there, hence the importance of analyzing phosphorus levels at the bottom of the water column.

Table 3 shows phosphorous results for 2020 and 2021. Average total phosphorus (TP) was relatively high at the beginning of 2020 but decreased substantially toward the middle of summer. There was a small peak in August, when biological activity is typically at its peak, but these levels decreased by October. It should be noted however that these levels were all above the maximum recommended concentration of TP for algae control.

2021 saw more consistent levels over the course of the summer, with levels not rising above 0.05 mg/L. Because of changes in the analytical methods used by the laboratory to measure phosphorous, it was not detected in concentrations below 0.05 mg/L. Thus, it is possible that phosphorous in 2021 was still higher than the recommended 0.02 mg/L threshold. Despite this, the 2021 results show that since 2020 there has been a substantial reduction in the average concentrations of phosphorous. It should also be noted that since the project began in 2018, there has been a reduction in the average total phosphorous of approximately 5X.

Table 3 – Average Total Phosphorus Levels 2020-2021

Sampling Date:	**5/21/2020**	**6/24/2020**	**8/19/2020**	**10/7/2020**	**4/29/2021**	**5/25/2021**	**7/20/2021**
Total P mg/l	0.2285	0.0348	0.0935	0.046	<0.05	<0.05	<0.05

Table 4 below shows orthophosphate levels from 2020 through 2021. As a component of TP, orthophosphate should typically be considerably lower in concentration than 0.02 mg/L for algae control. It is possible that levels started lower in 2020, increased due to biological activity increasing in mid-summer, then decreased in late summer when nutrient demand from vegetation and algae are at a peak. In 2021, levels again remained below 0.05 mg/L, indicating some consistency in concentration. It should be noted that since the project began in 2018, there has been a reduction in the average orthophosphate of approximately 8X.

Table 4 – Average Orthophosphate Levels 2020-2021

Sampling Date:	**5/21/2020**	**6/24/2020**	**8/19/2020**	**10/7/2020**	**4/29/2021**	**5/25/2021**	**7/20/2021**
Ortho PO_4 mg/l	≤0.005	0.0045	0.001	0.0035	<0.05	<0.05	<0.05

Algae Samples

Algae samples were analyzed for different species of algae that vary in significance. Table 5 gives a guide of the different groups of algae screened for and what they indicate about the water environment.

Table 5. Guide for Algae Analysis.

	Functional Group	What does it indicate?
BG	Non-harmful Cyanobacteria	Generally benign and indicative of good water quality.
CER	Ceratium	Often present in tannic/high organic content water bodies. Active migrator in the water column. May cause significant taste and odor at high densities.
CP	Cryptophytes & Dinoflagellates	Often dominate in spring, or in tannic/high organic content water bodies. Generally indicate good water quality.
DY	Chrysophytes, Haptophytes & Diatoms	Generally indicate good water quality. If high densities, can cause significant taste and odor.
E	Euglenophytes	Often present in high organic content water bodies. Co-occurs with Cryptophytes and non-coliform bacteria. High densities can be indicative of poor water quality.
G	Chlorophytes	Generally indicate good water quality. If very high densities, indicates high nitrate concentrations.
TO	Taste and Odor Producers	Algae that often produce taste and odor issues. Diatoms that can produce taste and odor problems, but do so less often, are not included in this group.
HAB	Harmful Cyanobacteria	May produce toxins, but not always producing. Toxins are generally detectable above 5000 cells/mL. Indicative of poor water quality often with high phosphate or low TN:TP ratios.
M	Miscellaneous	All other groups, generally neutral. Includes small Chlorophytes or Cyanobacteria less than 9um in diameter.
U	Unclassified	Images that the classifier cannot confidently identify. Includes small flagellates entrained in detritus, taxa not yet included in the classifier, partial images and images with multiple taxa.

Table 6 shows algae data from water samples taken in 2020. The data express the algae cell count per volume of water (cells per milliliter), which is a measure of concentration. As can be seen in Table 6, harmful algae blooms (HABs) levels were low early in the summer, indicating successful suppression by other beneficial algae species. Chlorophytes (Green algae) were the dominant species present in the lake up until August, when harmful cyanobacteria appeared and a harmful algae bloom occurred. At the spike, the cyanobacteria levels were around 25% of the total algae population, which was considerably higher in population numbers than the threshold for toxin production risk. Clean-Flo's response to this spike was an extra Bio Booster application, which mitigated the bloom. This was evidenced by the lowered HABs concentrations shown in the October sampling. Water testing for cyanotoxins was done by the State of New York in the late summer of 2020 and results indicated that toxins were not present.

Table 6. Algal Community 2020.

Algal Biovolume	5/21/2020			6/24/2020			8/19/2020			10/7/2020		
cells/ml	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
BG (Non-Harmful Cyanobacteria)	46	39	242	518	590	399	5,861	5,355	8,827	1897	1926	3893
CP (Cryptophytes)	40	25	32	18	211	92	146	122	82	15	259	70
DY (Diatoms, Chrysophytes, etc)	4,519	4,725	4,884	3,584	5,196	4,561	3,034	1,658	1,353	1190	1519	1276
E (Euglenophytes)	3	-	-	0	0	9	61	30	20	4	-	2
G (Chlorophytes)	7,199	7,115	8,362	6,723	7,371	8,567	17,861	14,908	14,151	4169	5171	4394
HAB (Harmful Cyanobacteria)	0	0	0				10,386	8,063	8,393	106	58	4
M (Miscellaneous)	46	55	69	331	727	237	307	413	306	78	43	40
U (Unclassified)	219	349	443	565	899	473	878	639	502	263	330	279
TO (Taste & Odor producers)				52	78	20	363		83		27	7
Total Cells/mL	12,072	12,308	14,031	11,791	15,073	14,359	38,896	31,189	33,715	7,721	9,334	9,964
% HAB	0	0	0	0.00%	0.00%	0.00%	26.70%	25.85%	24.89%	1.38%	0.62%	0.04%

Table 7 shows algae data from water samples taken in 2021. The beginning of the summer season saw considerable levels of chlorophytes and diatoms, which are beneficial species and suppress cyanobacteria by outcompeting them for resources. Diatoms and Chlorophytes comprised the majority of the algae population throughout most of 2021. At their peak, harmful cyanobacteria comprised a small percentage of the population (maximum 2.6%) in July. As in 2020, the concentration of harmful cyanobacteria increased over the summer in 2021. Despite cyanobacteria's being over 25 times lower in 2021 than in 2020, a bloom occurred in 2021 that resulted in beach closures, and testing by New York indicated the presence of low levels of cyanotoxins. Despite this, scientific literature indicates that cyanobacteria levels below 20,000 cells/mL—even if they are producing toxins—the toxins present are unlikely to exceed recommended limits for the recreational use of lakes.

Table 7. Algal Community 2021

Algal community	4/29/2021			5/25/2021			7/20/2021		
cells/ml	S1	S2	S3	S1	S2	S3	S1	S2	S3
BG (Non-Harmful Cyanobacteria)	166	556	3,237	72	109	661	505	698	1,177
CP (Cryptophytes)	6	6	12	11	0	11	1,186	2,094	2,480
DY (Diatoms, Chrysophytes, etc)	483	1,641	2,429	194	299	905	325	185	145
E (Euglenophytes)	1	2	0	0	0	3	19	11	3
G (Chlorophytes)	755	611	623	4,085	4,124	5,223	17,841	17,687	16,678
HAB (Harmful Cyanobacteria)	0	0	0	0	0	0	438	565	358
M (Miscellaneous)	37	33	74	56	213	168	143	102	63
U (Unclassified)	189	194	193	38	49	77	534	630	382
TO (Taste & Odor producers)	0	0	0	0	0	0	0	0	0
Total Cells/mL	1,636	3,043	6,567	4,456	4,795	7,048	20,991	21,973	21,286
% HAB	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.09%	2.57%	1.68%

The 2021 bloom shows that there is not a direct correlation between the overall concentrations of harmful cyanobacteria and the likelihood of a bloom that produces toxins. Cyanobacteria consists of numerous species, some of which are more likely to produce toxins. Although concentrations of cyanobacteria in July of 2021 were extremely low compared to 2020, the presence of certain more harmful species created worse results. What this signifies in the big picture is that a priority objective of the restoration program is to eliminate harmful cyanobacteria altogether.

Figure 3 illustrates the algal population data from 2020 and 2021 organized by sample site and date sampled. Across the board, the growth of HAB species accelerated through the 2020 season. This was likely a result of the negative impact of the COVID-19 pandemic on maintenance schedules and product applications. In particular, the application of Bio Booster – the product primarily responsible for the suppression of HABs species – was delayed. This, along with the damaged airline in the oxygenation system, led to a HAB in mid-summer. Extra Bio Booster applications shortly thereafter mitigated the bloom, which was confirmed by the NY Health Department's tests of water samples taken from the swimming areas of Lake Peekskill. In 2021, HABs concentrations were relatively tiny, and algal populations were dominated by chlorophytes (green algae) and diatoms. As mentioned above, however, this did not prevent a harmful bloom and appearance of toxins.

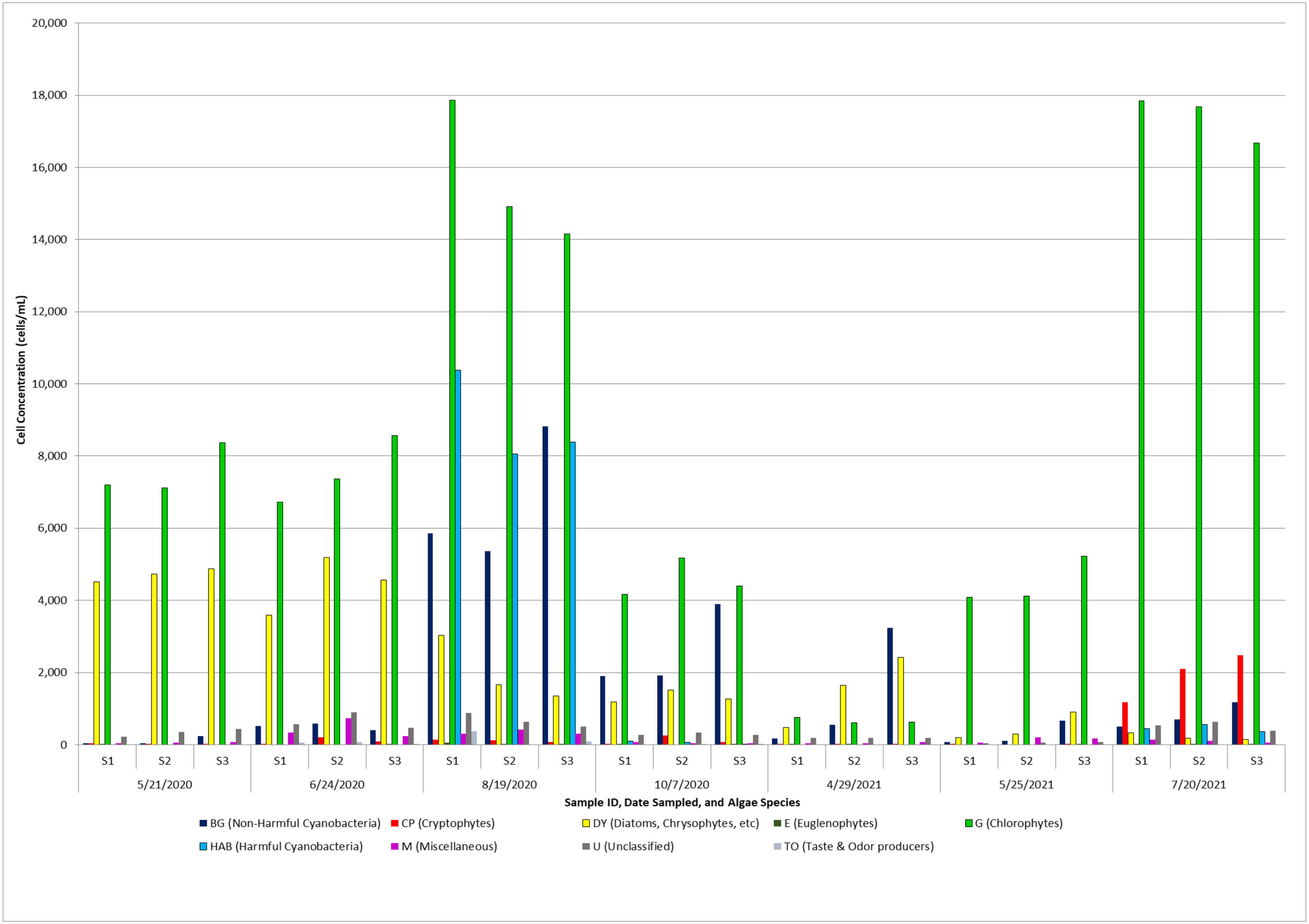

Figure 2. Algal Community 2020 & 2021.

Sediment Samples

Sediment samples were taken with an Ekman Dredge in all 4 sample locations and analyzed for phosphorous and Total Organic Carbon (TOC). Based on the analysis of the sediment samples displayed in Table 8, average phosphorus (P) levels in 2020 were above the recommended threshold in May and October, but significantly below the threshold in June and August. Phosphorus levels in 2021 were highest in the early stages of summer and lowest in the middle of May. The high average from April was most likely caused by the unusually high spike in P levels at S2. Since the project began in 2018 there has been a reduction of average phosphorous concentrations from 925 mg/kg to 400 mg/kg, or 57%.

Table 8. Average Phosphorus in Sediment 2020 and 2021.

Sampling Date:	5/21/2020	6/24/2020	8/19/2020	10/7/2020	4/29/2021	5/25/2021	7/20/2021
P mg/kg	801	250*	185*	880	820	749	785

*signifies only one of the site samples had detectable phosphorous

Figure 4 provide a graphic comparison of phosphorus levels in the lake sediments since the beginning of the project. Sites with no data can be assumed to have results that were lower than laboratory detection limits. The increases observed in 2021 are likely attributable to the maintenance issues with the deepest diffuser that may have negatively affected phosphorous levels as well. As illustrated, the average sediment phosphorous concentrations have decreased from 925 mg/kg to 400 mg/kg, or 57%.

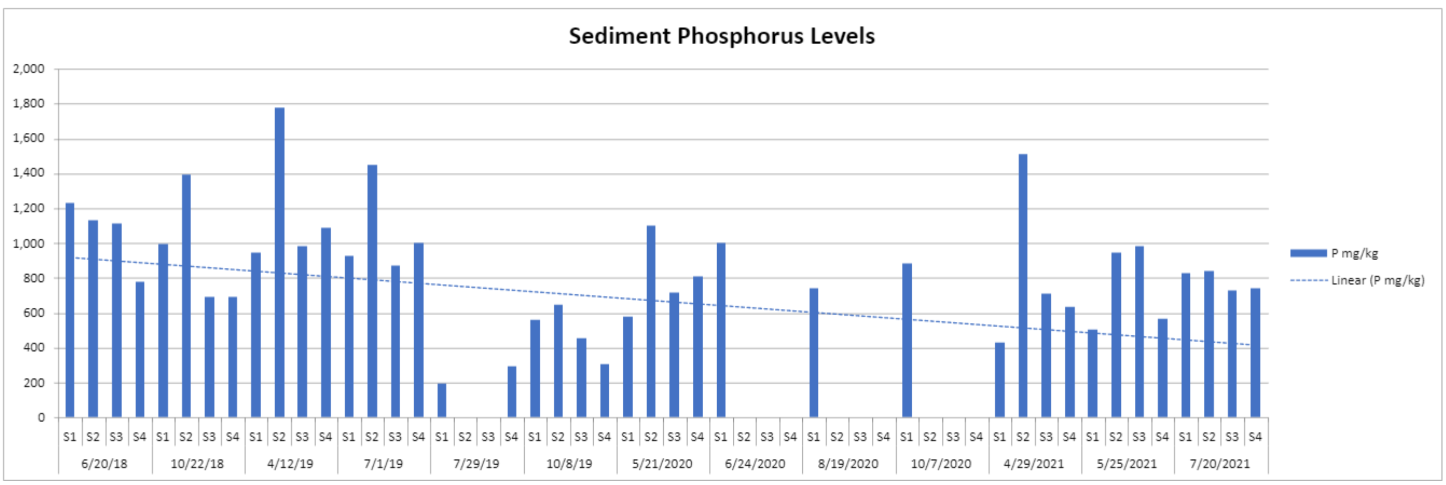

Figure 4. Sample Site Phosphorous in Sediment 2018-2021

The TOC data presented in Table 9 and in Figure 5 indicate that there have been relatively consistent concentrations of organic matter in the sediment since the project began, with the exception of a substantial dip in the summer of 2020. This was likely due to the performance of the Clean-Flo oxygenation-inversion system and Clean & Clear™ applications – which prioritize muck reduction – in the 2020 season. TOC results are not an indication of organic muck removal. Instead, they indicate that the organic content of the muck has remained relatively constant and that therefore there remains considerable amounts of organic matter still to remove. This is born out by the continued depth and volume increases that have been observed annually.

Table 9. Average TOC 2020-2021

Sampling Date:	5/21/2020	6/24/2020	8/19/2020	10/7/2020	4/29/2021	5/25/2021	7/20/2021
TOC mg/kg	186,550	13,400	13,500	132,750	165,000	213,250	135,525

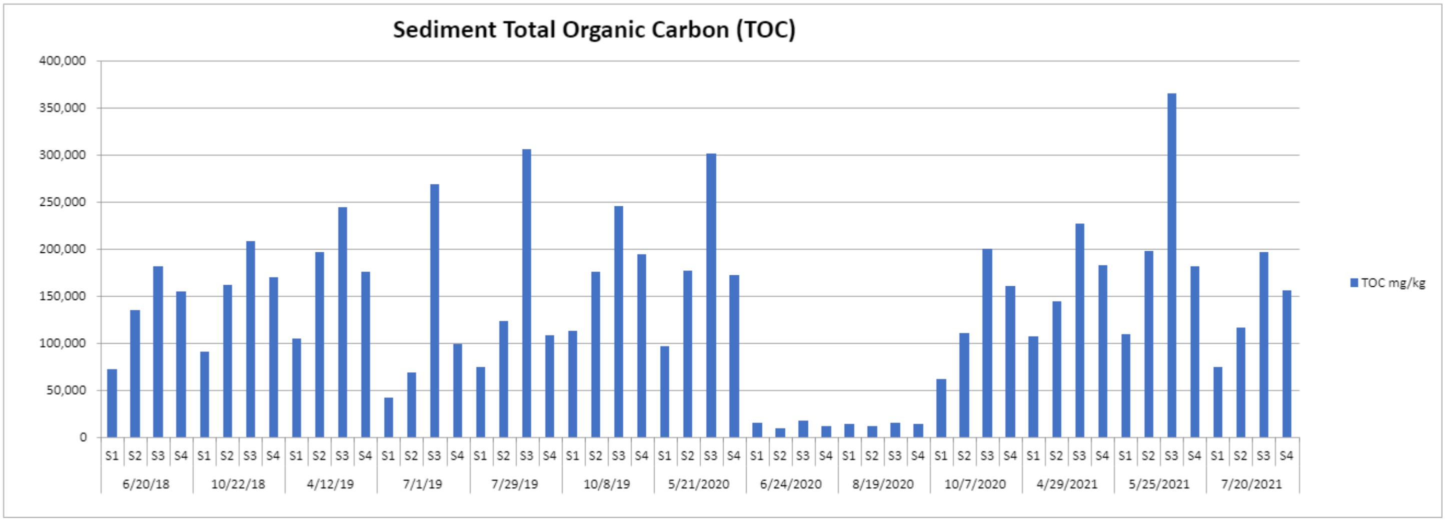

Figure 5. Total Organic Carbon (TOC) in Sediment 2018-2021

Sonar Scan and Mapping

The sonar scan of the lake was completed on October 20th, 2021 and is compared to the October 2020 sonar scan. The scans were conducted with a Lowrance Elite-7 Ti² fish finder/chartplotter with broadband sounder technology, built-in GPS antenna and high-definition mapping. The data obtained was uploaded to Biobase GIS, a cloud-based mapping service, to produce contour and vegetative biovolume maps, and to analyze vegetation quantitatively.

A permanent water level benchmark is used to equalize depth data obtained during the scans. The benchmark for Lake Peekskill is the top of the spillway on the southeastern end of the lake. The water level at the time of the 2021 scan was 1 inch above the spillway, which is 4 inches lower than the original water level from the initial scan. This water level was accounted for by application of data offsets in Biobase.

Bathymetry (Depth) Maps

The contour maps with contours at 1-foot intervals for the lake are shown in Figure 6. From 2020 to 2021, the lake has increased in depth. In the 2020 bathymetry map, there was a small 25-ft contour in the deepest region of the lake. In 2021, this contour expanded to roughly twice its size in 2020. Figure 6 illustrates increases in the size of the deepest contours in greater detail. A similar increase of the size of the 14-foot contour between 2020 and 2021 is also evident. In 2020, the average depth was 12.01 feet, and the maximum depth was 25.19 feet. The average depth from the 2021 scan is 12.09 ft and the max depth is 25.35 ft, which are increases 0.08 ft (1 inch) and 0.16 ft (2 inches), respectively. In 2020, the lake had a volume of 721.83 acre-feet (235.2 million gallons). It now has a volume of 727.17 acre-feet (236.9 million gallons), an increase of 5.34 acre-feet (1.7M gallons). This increase is due to the decomposition of 8,615 cubic yards of organic sediment, or roughly 574 triaxle truck loads.

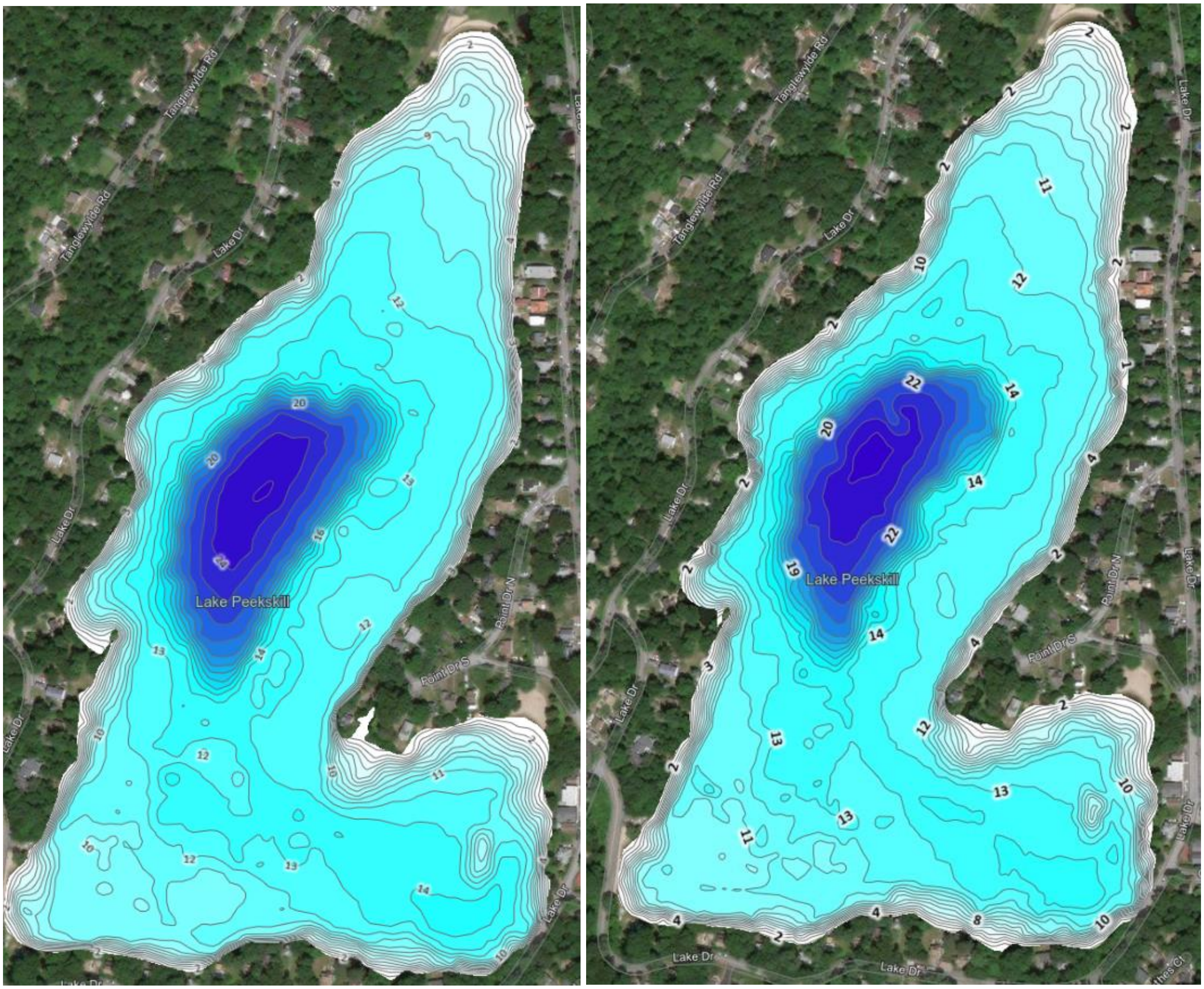

Figure 6. Bathymetry (Depth) Maps (2020 and 2021) – The deepest reading obtained in the lake in 2020 was 25.14 ft (2020 map on left). The deepest reading obtained in the lake in 2021 was 25.35 ft (2021 map on right).

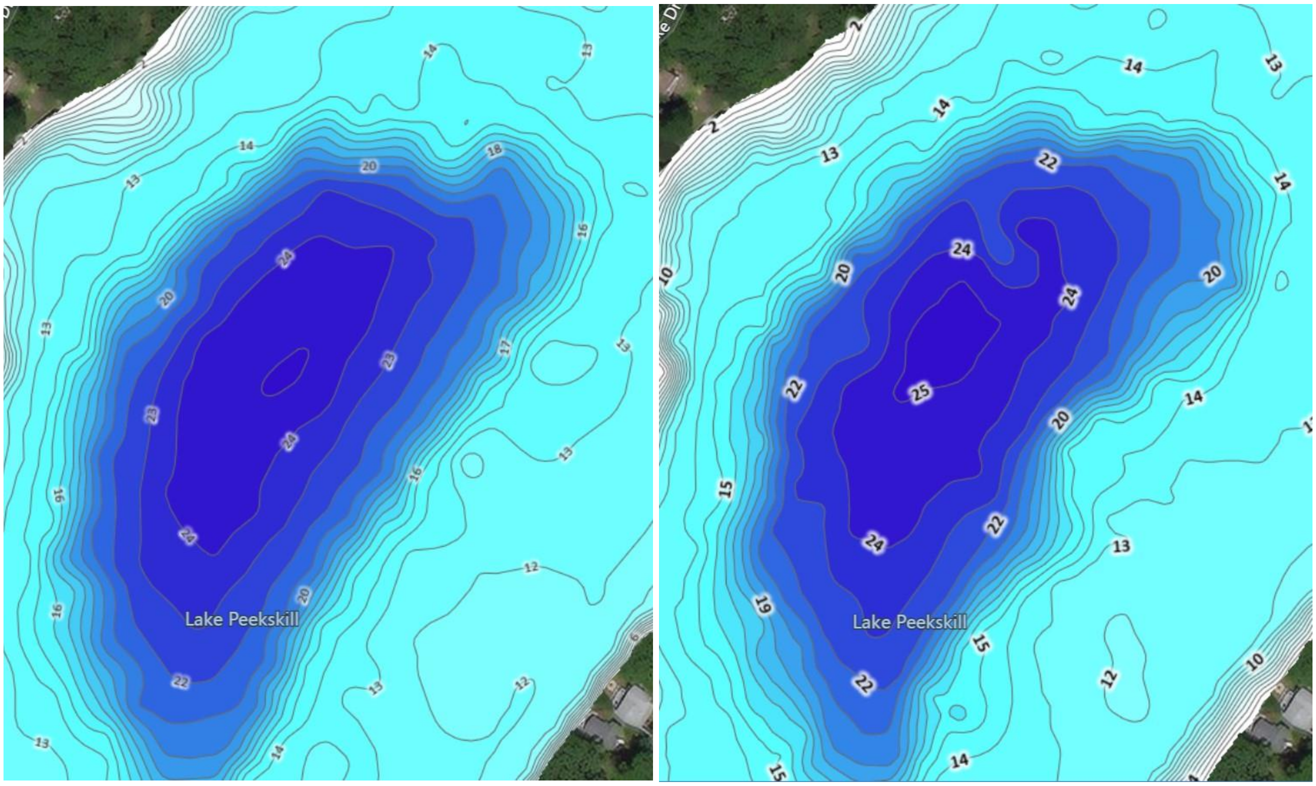

Figure 7. Deep Region Maps (2020 & 2021). Deep region contours in 2020 (left) and same region in 2021 (right)

<u>Vegetative Biovolume</u>

Biovolume maps display where vegetation growth was recorded by the sonar scan, and the density of growth of those areas. The dark blue regions in the maps are devoid of vegetation growth, while the light green and red regions have low to high biovolume, respectively. The Survey Summaries represent statistics generated from data obtained by the scans.

Figures 8 illustrates vegetative biovolume in Lake Peekskill in 2020 and 2021. The maps show reduction of vegetation along the northern shorelines and south-central portion of the lake. The appearance of small, higher-intensity patches of vegetation in the deepest contours in 2021 may reflect the maintenance issues with the deepest diffuser and corresponding greater availability of nutrients to plants in this area.

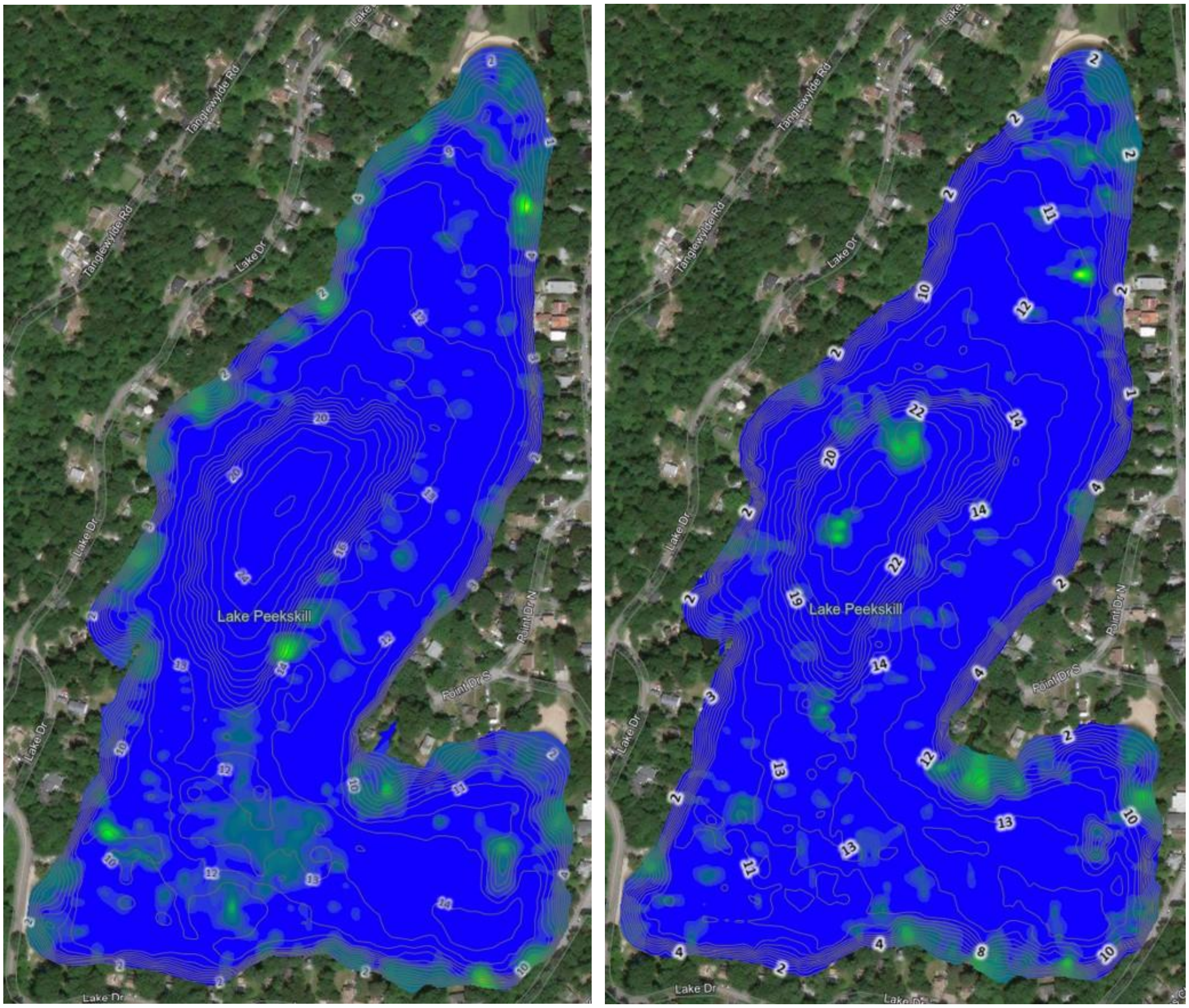

Figure 8. Vegetative Biovolume map of Lake Peekskill from the 2020 scan (left) and map from 2021 (right). The measurement scale shows that red is the highest biovolume followed by yellow, green, and then blue.

Tables 10 and 11 quantify the coverage and density of vegetation in 2020 and 2021. The amount of the lake's area covered by vegetation (Grid PAC) was 7.7% in 2020 and dropped to 4.4% by 2021. The average percentage of the water column occupied by vegetation (Grid BVw) in 2020 was 0.6% and dropped to 0.4% by 2021. These represent year-over-year gains of 33% and 43%, respectively.

Table 10. Vegetation Coverage and Density 2020

Survey Summary

	Type ?	PAC ?	Avg BVp ?	SD BVp ?	Avg BVw ?	SD BVw ?	Depth Range	Avg Depth	Distance	No.Points
Full Survey	Point	11.8%	8.8%	±6.8%	1.0%	±3.5%	2.67 - 25.19 ft	13.20 ft	8.13 miles	6213
	Grid	7.7%	7.9%	±4.2%	0.6%	±2.4%	0.27 - 25.06 ft	12.01 ft	-	670

Table 11. Vegetation Coverage and Density 2021

Survey Summary

Type ?	PAC ?	Avg BVp ?	SD BVp ?	Avg BVw ?	SD BVw ?	Depth Range	Depth Avg	Distance	No. Depth Records
Point	8.1%	9.0%	± 8.9%	0.7%	± 3.3%	3.01 - 25.35 ft	13.717 ft	5.859 miles	2810
Grid	4.4%	8.6%	± 4.0%	0.4%	± 2.0%	0.30 - 25.27 ft	12.097 ft	NA	17026

Conclusions

Lake Peekskill has improved since the time of the 2020 scan, and significantly overall since the Clean-Flo oxygenation-inversion system and bioaugmentation program have been in operation. Treatments and sampling during the 2020 season were affected by COVID-19 which, in conjunction with damaged airline in the oxygenation system, led to the algal bloom observed in August 2020.

Water quality results indicated varying oxygen levels in the deepest areas of the lake, which at times dropped below the threshold of 5 mg/L for healthy aquatic life. The varying DO is attributable to the maintenance issues with the deepest diffuser. Similarly, nutrient levels in water and sediment, and TOC levels in sediment, have fluctuated over the last year. Although some of the increases observed can be attributed to the diffuser issue, they may also be explained by the inconsistent product applications in 2020, and nutrient inputs into the lake by stormwater runoff. By and large, however, there have been significant reductions in nutrient concentrations in both water and sediment since the project began.

The algal community data shows tremendous improvements since 2020 by a transition from high levels of harmful cyanobacteria to domination of the community by beneficial diatoms and green algae. Whereas HABs species comprised as much as 26% of the algal concentration in the late summer of 2020 and a harmful algae bloom occurred, the HAB species represented a maximum concentration of 2.6% in the late summer of 2021. Despite the considerable reduction overall, the concentrations in 2021 were still sufficient to produce a harmful bloom, and toxins were detected in sampling performed by the State.

The sonar scans show a marked increase in depth and volume since 2020. The average depth and maximum depth have increased by 0.08 ft (1 inch) and 0.16 ft (2 inches), respectively. The increase in depth has increased the volume of the lake by 5.34 acre-feet (1.7M gallons). This corresponds to the decomposition and effective removal of 8,615 cubic yards of organic sediment, or roughly 574 triaxle truck loads.

The average volume of and coverage by vegetation in the lake have decreased since 2020. Volume decreased from 0.6% to 0.4%, and coverage decreased from 7.7% to 4.4%. These are equal to year-over-year reductions of 33% and 43%, respectively, and indicate the continuing positive transitions of the lake from oxygen-poor and nutrient-rich, to oxygen-rich and nutrient-balanced.

Recommendations

Clean-Flo recommends the continued operation and maintenance of the oxygenation-inversion system. We also recommend that the product application program be re-evaluated and the strategy updated for the 2022 season. The priority target for 2022 should be the elimination of harmful cyanobacteria. Product selection and location of applications will also account for any changes to the Town's objectives. In view of an updated strategy, alternative methods of product delivery, including automated dosing, should also be considered.

Follow-up sampling and bathymetric analysis should be conducted in 2022 to continue monitoring the progress of the lake. To continue annual progress, it is recommended that the system remain in operation as much as possible throughout the year. Given that the system must be shut down during the winter season for safety reasons, it should be restarted in 2022 as soon as the lake is free of ice.

APPENDIX 1

AIRLINE REPAIRS PERFORMED BY CLEAN-FLO IN 2021

Image 1: Airlines between the shed and the shoreline were excavated to locate break in airline to deepest diffuser. Airlines for all diffusers were replaced in this section with high-temperature airline.

Image 2: The break in the airline to the deepest diffuser was discovered and repaired.

Image 3: New airline between the shed and waterline was enclosed with corrugated UV-resistant pipe

Image 4: Overview of repairs, with corrugated pipe buried and extending into lake. The pipe extends approximately 10 feet into the lake, as does the new, high-temp airline. This will protect the airline from degradation by UV rays and reduce the likelihood of splits or ruptures.