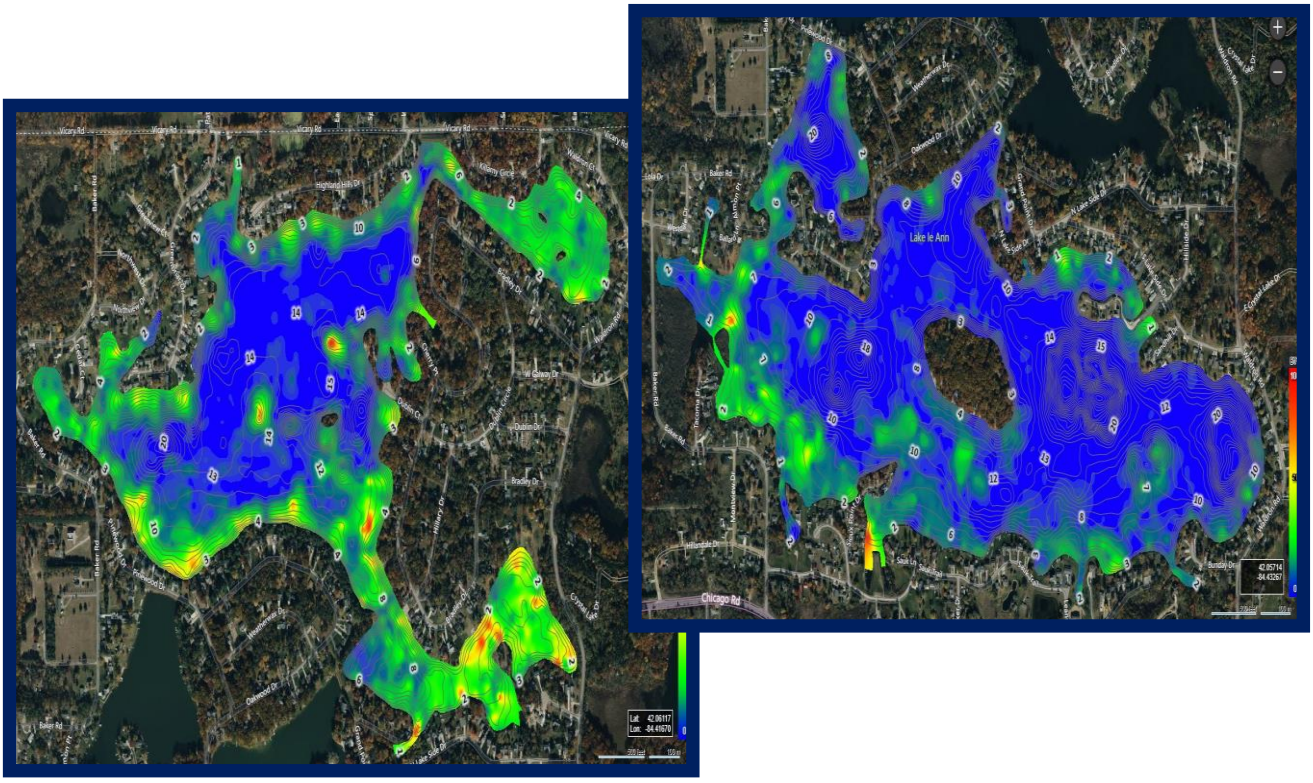
Lake LeAnn 2023 LFA
Evaluation Data, Accumulative Conclusions, and 2024 Management Recommendations
Hillsdale County, Michigan



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Lake LeAnn 2023 Limnological Evaluation Data and 2024 Management Recommendations Hillsdale County, Michigan

1.0 2023 EXECUTIVE SUMMARY

Lake LeAnn is highly impaired with multiple nutrient sources that are difficult to reduce—including abundant septic systems, use of lawn fertilizers and numerous drains. RLS discourages the use of all fertilizers as they have high concentrations of nitrogen that fuel blue-green algal blooms. Additionally, poorly maintained septic systems lead to significant nutrient loads to the lake which further exacerbate algae growth. Reduction of the blue-green algae in the lake is critical for improving water clarity and quality. All riparians have these responsibilities for helping to restore Lake LeAnn.

The laminar flow aeration (LFA) technology is helping to increase dissolved oxygen and reduce bottom muck; however, the previously applied Bioblast® formula was not reducing the blue-green algal blooms. As a result, RLS recommended the use of a highly effective water filtration agent (TimberHarvest Biochar®) which significantly removes nutrients such as phosphorus and inorganic nitrogen and total suspended solids. This product is housed in specialized filtration bags and placed on docks, hoists, boats, and in drainage areas (pending an EGLE-approved permit). It is an EPA-certified product with many cases of documented efficacy.

Based on the 2023 evaluation, Lake LeAnn contains 5 invasive aquatic plant species which includes the submersed hybrid Eurasian Watermilfoil (EWM), Curly-leaf Pondweed (CLP), and Starry Stonewort and the emergents Purple Loosestrife and Phragmites. Continued surveys and vigilance are needed to ensure that additional invasives do not enter Lake LeAnn. Aquatic herbicide treatments are recommended on a spot-treatment basis only to effectively reduce the invasives over time. In 2023, there was one sizeable aquatic herbicide treatment on May 11 that included 27.5 acres of milfoil and 20 acres of Curly-leaf Pondweed in the north basin and 30 acres of milfoil and 10 acres of Curly-leaf Pondweed in the south basin. All milfoil was treated with a combination of ProcellaCOR® and diquat and the Curly-leaf Pondweed was treated with diquat. Due to the strong presence of blue-green algae in both basins, targeted treatments with the use of the non-copper based peroxide, Phycomycin® were conducted on May 25, June 21, and August 24. These should be limited to small areas since they can also reduce favorable agal taxa.

Mitigation of shoreline vegetation should proceed to encourage a natural shoreline for optimal lake health. Additionally, improvements to the CSA drains with the use of biochar to reduce total phosphorus and inorganic nitrogen is recommended. Some improvements have already occurred, resulting in reduced total suspended solids to the lake basins.

The overall improvements of the LFA system have been modest relative to muck reduction, increased in dissolved oxygen, and declines in some nutrients. There has been a slight reduction in sediment muck and also dense aquatic vegetation biovolume. The latter was possible through the targeted aquatic vegetation herbicide treatments. Much progress has been made at reducing the submersed invasive species in the lake basins, but germination of desirable native aquatic plants is needed. At least 33% of the total lake surface area should have aquatic vegetation at any time to effectively compete with blue-green algae for nutrient uptake. Much more improvement is needed to reduce the presence of blue-green algal blooms and increase water clarity in upcoming years.

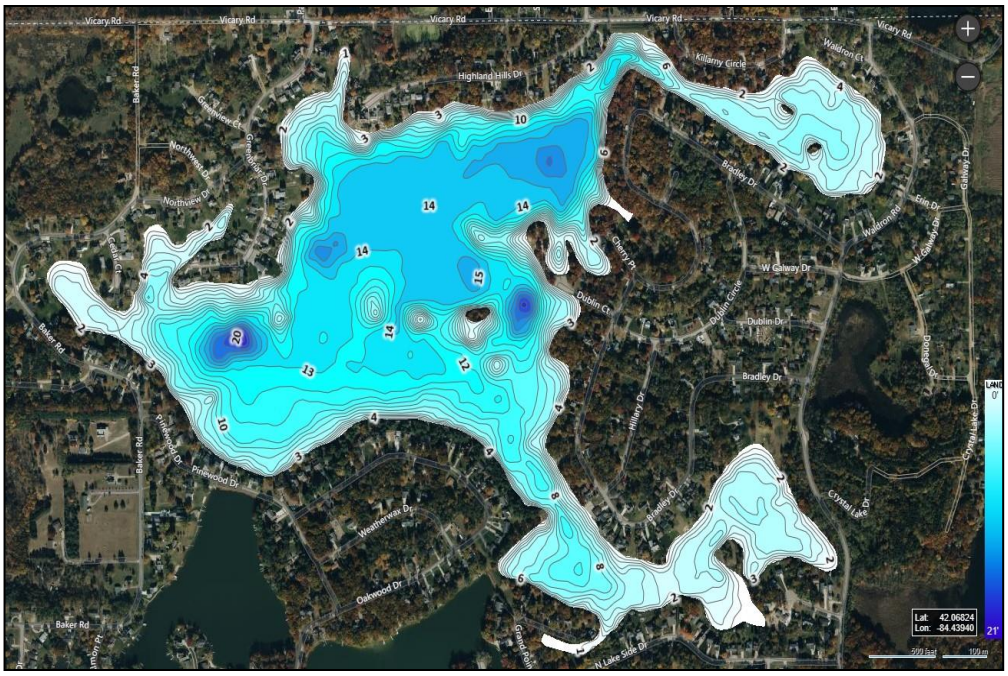

Figure 1. Lake LeAnn (north basin) depth contour map (RLS, 2023).

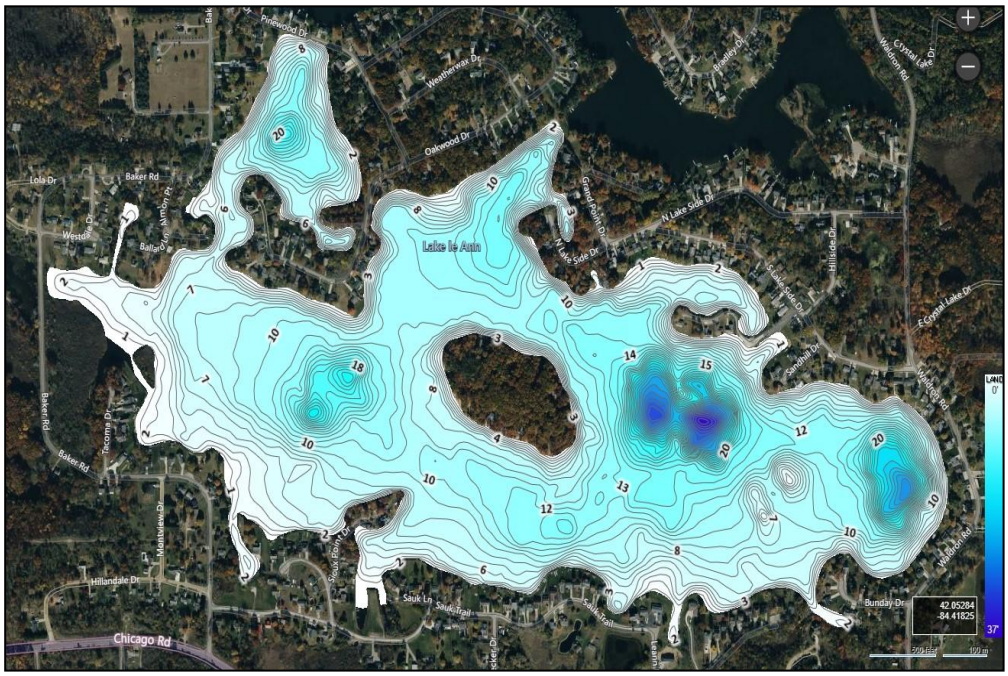

Figure 2. Lake LeAnn (south basin) depth contour map (RLS, 2023).

1.1 Summary of Lake LeAnn Aeration Operations:

This report represents a statistical analysis of the first set of baseline data for 2019 and Year 1 (2021) as well as Year 2 (2022) and Year 3 (2023). The sampling in 2023 consisted of the physical water quality parameters including water depth (measured in 0.5-meter increments), water temperature (measured in °C), dissolved oxygen (measured in mg/L), pH (measured in Standard Units), specific conductivity (measured in mS/cm), and secchi disk transparency (in feet). Additionally, at each site at the top, middle, and bottom depths of deep basins and mid-depth in shallow basins, chemical water quality parameters included total phosphorus, total inorganic nitrogen (both in mg/L), and in situ chlorophyll-a in micrograms per liter. The LFA system operated from April 1 to November 30, 2023.

1.2 Summary of Aeration Operation Purpose/Goals:

Lake LeAnn is a well-recreated lake and is utilized by many for fishing, swimming, boating, and waterfront living. In recent years, the lake has become dominated by aggressive invasive aquatic vegetation such as Curly-leaf Pondweed, Eurasian Watermilfoil, Starry Stonewort, Purple Loosestrife, and Phragmites. In addition, the lake has become mucky in many areas and is also experiencing toxic cyanobacteria blooms and watershed inputs of nutrients and solids. The residents have desired a more holistic approach to addressing both the aquatic plant and algae issues as well as the muck reduction. The residents desired a lake restoration strategy that would make the lake healthier and accomplish the following objectives:

The primary objectives of the implemented LFA/bioaugmentation system for Lake LeAnn include:

1) Reduction of nuisance toxic cyanobacteria algae throughout the lake.
2) Increase in water clarity/transparency
3) Increase in water column dissolved oxygen
4) Reduction of muck in problem areas.
5) Reduction of nuisance rooted submersed aquatic vegetation such as Eurasian Watermilfoil and Curly-leaf Pondweed.
6) Reduction of lake water column nutrients

2.0 LAKE LEANN 2023 SAMPLING METHODS & PARAMETERS

Restorative Lake Sciences sampled 10 locations in 2023 (5 in the south basin and 5 in the north basin) as well as the drains entering both basins. Additionally, RLS also sampled the Mirror Lake Outlet. The outlet sampling was not contracted in 2023, but RLS collected the data.

As mentioned in Section 1.1 above, the sampling scope in 2023 was reduced with physical parameters such as depth, water temperature, dissolved oxygen, pH, conductivity, and Secchi transparency that were collected at 0.5-meter increments and throughout the water column profile. Chemical water quality parameters such as total phosphorus, total inorganic nitrogen, and in situ chlorophyll-a measured were measured in all N=10 locations of the north and south basins. A bottom hardness scan and biovolume scan was conducted for both basins. RLS also sampled the lake phytoplankton (algal) communities given the strong presence of blue-green algae in 2023.

Additionally, all CSA's were evaluated for flow and sampled for all physical parameters including flow as well as total phosphorus, ortho-phosphorus, total inorganic nitrogen, total Kjeldahl nitrogen, and total suspended solids. The April 26, 2023 CSA sampling date omitted the parameters of SRP, TKN, and TSS due to sampling error.

The basin samples and the CSA samples were collected on April 26, 2023, July 25, 2023, and September 19, 2023. All sampling location maps for the lake basins and drains are shown below in Figures 3-4.

All chemical water samples were collected at the specified depths (one each at the top, middle, and bottom depths of the deep basin sampling sites and at mid-depth for shallow sites) using a 4-liter VanDorn horizontal water sampler with weighted messenger (Wildco® brand). Water quality physical parameters (such as water temperature, dissolved oxygen, conductivity, and pH) were measured with a calibrated Eureka Manta 2® multi-probe meter as a profile through the water column at the sampling sites. All water samples were maintained on ice in a large cooler prior to being placed into the laboratory fridge. Total phosphorus was titrated and analyzed in the laboratory according to method SM 4500-P E and total inorganic nitrogen was analyzed according to method EPA 350.1 Rev. 2. All the aforementioned chemical parameters were analyzed at Trace Analytical Laboratories in Muskegon, Michigan.

Chlorophyll-*a* was analyzed in situ with a calibrated Turner Designs® fluorimeter used to measure algal pigment in lakes with blue-green algal blooms. This gives a more accurate assessment of the actual Chl-a versus a profile reading that may skew Chl-a results to a much lower concentration. Prior to analysis of the samples as described above, water samples were placed in clean, unpreserved polyethylene bottles for ortho-phosphorus and total suspended solids and placed in H_2SO_4-preserved, clean, polyethylene bottles for total phosphorus analysis.

Algal community samples were placed in brown glass 1-liter bottles as recommended in the EGLE Guidance and analyzed within 72 hours after collection. Samples used for microscopic analysis of algal community composition were counted with a Sedgewick Rafter® Counting Cell under high power objective on a bright-field Zeiss® compound microscope. Multiple 1 micro-liter (µL) aliquots were used to determine the relative abundance of algal genera in the samples.

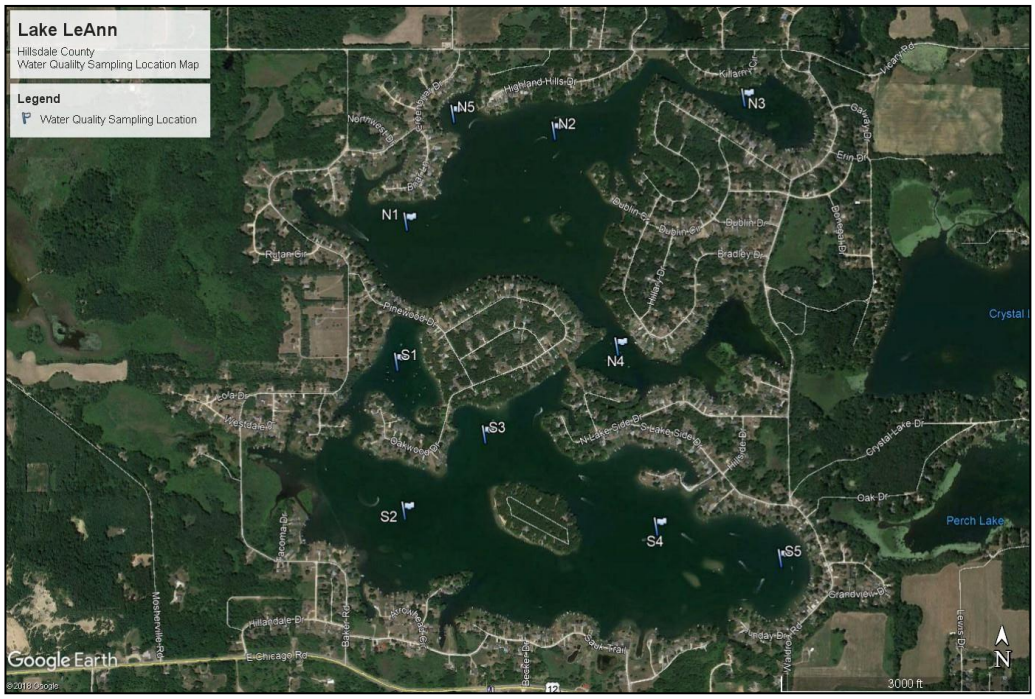

Figure 3. 2021-2023 water quality sampling locations on Lake LeAnn.

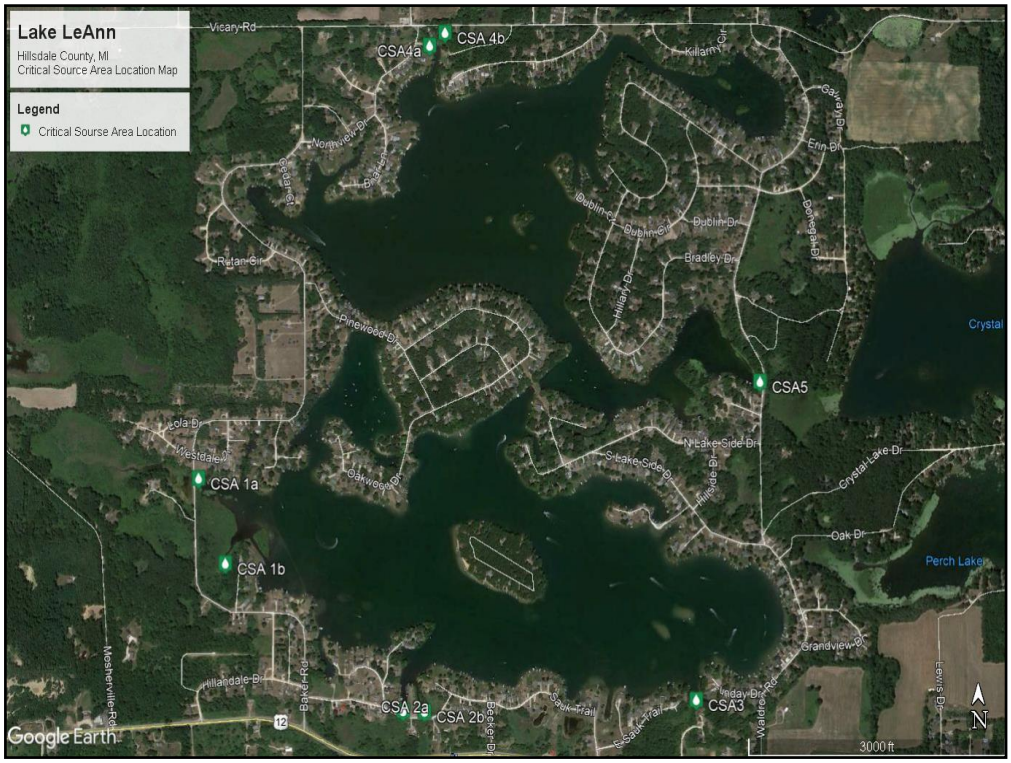

Figure 4. 2019-2023 drain sampling locations on Lake LeAnn.

3.0 LAKE LEANN 2023 WATER QUALITY SAMPLING RESULTS

All 2023 deep basin physical water quality data is shown in Tables 1-6. 2023 chemical water quality data is shown in Tables 7-12. Mirror Lake outlet data is shown in Table 13. 2023 CSA drain physical and chemical water quality data is shown below in Tables 14-16. NOTE: Drain sampling is not usually required as a condition of the LFA permit; however, the data is being collected to evaluate current and future measurements to determine mitigation implementation efficacy.

3.1 Lake LeAnn Physical Water Quality Data:

Table 1. Lake LeAnn north basin April 26, 2023 physical water quality data.

Site	Depth (m)	Temp C	DO (mg/L)	pH (SU)	Cond (mS/cm)
1 North	0	10.8	11.1	8.6	1618
	0.5	10.9	11.2	8.6	1539
	1	11	11.2	8.6	1662
	1.5	11	11.2	8.6	1464
	2	10.9	11.2	8.6	1535
	2.5	10.8	11.2	8.6	1550
	3	10.6	11.2	8.6	835
	3.5	10.6	11.2	8.6	828
	4	10.6	11.0	8.6	661
	4.5	10.5	10.9	8.6	512
	5	10.2	10.8	8.5	753
	5.5	10.2	10.7	8.5	1454
	6	10.2	10.7	8.5	1319
	6.5	10.3	10.7	8.5	1225
2 North	0	11.7	11.2	8.6	708
	0.5	11.6	11.2	8.6	733
	1	11.6	11.2	8.6	648
	1.5	11.5	11.2	8.6	741
	2	11.1	11.1	8.6	1511
	2.5	10.9	11.0	8.6	940
	3	10.8	11.0	8.6	1593
	3.5	10.8	11.1	8.6	924
	4	10.7	10.9	8.6	1096
	4.5	10.6	10.7	8.5	882
3 North	0	12.4	12.0	8.6	707
	0.5	12.1	12.2	8.7	506
	1	11.3	12.5	8.7	1156
	1.5	11.1	12.5	8.7	1159
	2	10.2	13.0	8.7	1404
	2.5	10.3	13.3	8.7	1404
4 North	0	12.4	11.6	8.7	870
	0.5	12.1	11.9	8.7	894
	1	11.5	12.1	8.7	1069
	1.5	10.6	12.6	8.7	1432
	2	10.1	12.7	8.7	1573
	2.5	9.9	12.9	8.7	754

5 North	0	11.8	11.6	8.7	733
	0.5	11.4	11.7	8.7	852
	1	10.9	11.9	8.7	737
	1.5	10.9	11.6	8.7	741
	2	10.8	11.5	8.7	1490
	2.5	10.7	11.4	8.7	1496
	MEAN	**11.0**	**11.5**	**8.6**	**1088**
	STD DEV	**0.6**	**0.7**	**0.1**	**364**

Table 2. Lake LeAnn south basin April 26, 2023 physical water quality data.

Site	Depth (m)	Temp C	DO (mg/L)	pH (SU)	Cond (mS/cm)
1 South	0	12.6	10.8	8.5	789
	0.5	12.6	11.1	8.5	580
	1	12.4	11.1	8.5	504
	1.5	12.5	11.4	8.5	544
	2	12.4	11.1	8.5	544
	2.5	11.7	11.1	8.5	645
	3	11.5	11.8	8.5	801
	3.5	11.3	11.2	8.5	835
	4	11.3	11.3	8.5	856
	4.5	11.3	11.3	8.5	815
	5	11.2	11.2	8.5	859
	5.5	11.1	11.1	8.5	835
	6	11.0	11.0	8.5	548
	6.5	10.9	10.7	8.4	546
2 South	0	11.3	11.7	8.6	831
	0.5	11.4	11.8	8.6	1402
	1	11.4	11.8	8.6	1464
	1.5	11.5	11.8	8.5	1556
	2	11.3	11.8	8.5	1535
	2.5	11.4	11.8	8.5	878
	3	11.3	11.8	8.5	902
	3.5	11.3	11.8	8.5	811
	4	11.0	11.8	8.5	551
	4.5	10.7	11.9	8.5	551
	5	10.7	11.9	8.5	558
	5.5	10.6	11.9	8.5	551
	6	10.6	11.9	8.5	551
	6.5	10.5	11.8	8.5	551
	7	10.5	11.7	8.5	551
3 South	0	12.2	11.1	8.5	714
	0.5	12.1	11.4	8.6	906
	1	12.2	11.5	8.6	882
	1.5	12.1	11.5	8.6	1272
	2	12.0	11.6	8.5	874

	2.5	11.8	11.6	8.5	990
	3	11.8	11.6	8.5	862
4 South	0	12.2	11.5	8.5	1478
	0.5	12.2	11.5	8.5	1163
	1	12.1	11.6	8.5	1764
	1.5	11.9	11.6	8.5	799
	2	11.8	11.6	8.5	1378
	2.5	11.6	11.6	8.5	809
	3	11.5	11.6	8.5	941
	3.5	11.5	11.6	8.5	979
	4	11.5	11.6	8.5	711
	4.5	11.2	11.6	8.5	1507
	5	10.9	11.4	8.5	1509
	5.5	10.7	11.3	8.5	1237
	6	10.3	11.1	8.5	886
	6.5	10.3	11.1	8.5	553
	7	10.2	10.9	8.5	553
	7.5	10.2	10.8	8.5	553
	8	10.1	10.8	8.4	661
	8.5	10.1	10.6	8.4	834
	9	10.1	10.2	8.4	771
	9.5	10.1	9.9	8.4	872
	10	10.1	7.4	8.3	877
	10.5	10.1	10.0	8.4	859
	11	10.1	9.6	8.4	715
5 South	0	12.3	11.5	8.7	675
	0.5	12.2	11.6	8.6	1145
	1	12.2	11.6	8.6	1129
	1.5	12.1	11.6	8.6	1500
	2	11.9	11.6	8.6	1550
	2.5	11.6	11.6	8.6	1550
	3	11.3	11.7	8.6	1650
	3.5	11.3	11.7	8.5	1675
	4	11.0	11.7	8.5	1675
	4.5	10.7	11.6	8.5	1550
	5	10.3	11.4	8.5	903
	5.5	10.2	11.2	8.5	1208
	6	10.1	11.2	8.5	1413
	6.5	10.1	10.8	8.5	918

	7	10.1	10.7	8.5	851
	7.5	10.1	10.6	8.4	783
	8	10.0	3.0	7.9	731
	MEAN	**11.2**	**11.2**	**8.5**	**957**
	STD DEV	**0.8**	**1.2**	**0.1**	**361**

Table 3. Lake LeAnn north basin July 25, 2023 physical water quality data.

Site	Depth (m)	Temp C	DO (mg/L)	pH (SU)	Cond (mS/cm)
1 North	0	26.8	8.7	8.5	505
	0.5	26.6	8.8	8.5	505
	1	26.6	8.9	8.5	505
	1.5	26.2	8.9	8.5	506
	2	26	8.8	8.5	504
	2.5	25.7	8.8	8.5	505
	3	25.6	8.8	8.5	505
	3.5	25.4	8.5	8.4	506
	4	25.3	8.0	8.4	507
	4.5	25.1	7.7	8.3	508
	5	25	7.4	8.3	508
	5.5	25	6.7	8.2	509
	6	24.9	6.0	8.2	510
	6.5	24.9	4.4	8.1	511
2 North	0	27.8	8.4	8.4	505
	0.5	27	8.6	8.4	506
	1	27.1	8.9	8.5	506
	1.5	26.9	9.2	8.5	508
	2	25.7	9.1	8.5	505
	2.5	25.7	9.1	8.5	505
	3	25.4	9.0	8.5	506
	3.5	25.2	8.9	8.4	507
	4	25.1	8.7	8.4	508
	4.5	24.7	8.0	8.2	512
3 North	0	27.4	9.1	8.5	490
	0.5	27.8	10.2	8.7	488
	1	27.1	10.8	8.7	485
	1.5	26.8	11.3	8.7	482
	2	26.4	11.7	8.8	480
4 North	0	28	10.0	8.5	493
	0.5	28	10.2	8.6	487
	1	27.6	10.5	8.5	488
	1.5	26.9	10.7	8.6	474
	2	26.2	11.1	8.6	477
	2.5	25.5	11.2	8.5	490
	3	24.9	10.2	8.2	588

5 North	0	27.2	9.0	8.5	505
	0.5	26.9	9.1	8.6	505
	1	26.7	9.3	8.6	505
	1.5	26.3	9.3	8.5	505
	2	26	9.3	8.5	504
	2.5	25.7	9.2	8.5	505
	3	25.5	8.6	8.4	507
	MEAN	**26.2**	**9.0**	**8.5**	**503**
	STD DEV	**1.0**	**1.4**	**0.1**	**16.7**

Table 4. Lake LeAnn south basin July 25, 2023 physical water quality data.

Site	Depth (m)	Temp C	DO (mg/L)	pH (SU)	Cond (mS/cm)
1 South	0	27.9	8.8	8.2	600
	0.5	27.3	9.3	8.4	582
	1	26.5	10.0	8.4	613
	1.5	25.9	10.3	8.5	593
	2	25.6	10.4	8.5	619
	2.5	25.3	10.3	8.4	622
	3	25.2	9.8	8.4	631
	3.5	25.1	9.4	8.3	540
	4	25.0	8.6	8.2	547
	4.5	24.8	7.3	8.0	561
	5	24.7	5.6	7.9	568
	5.5	23.4	4.1	7.8	565
	6	21.7	2.7	7.5	565
	6.5	19.5	1.5	7.3	561
2 South	0	27.5	8.0	8.3	537
	0.5	27.1	8.3	8.3	537
	1	26.3	8.8	8.3	538
	1.5	26.0	8.8	8.3	537
	2	25.5	8.0	8.3	535
	2.5	25.3	9.1	8.3	535
	3	25.1	9.2	8.4	537
	3.5	24.8	8.9	8.3	540
	4	24.5	8.1	8.3	544
	4.5	24.5	7.1	8.3	544
	5	24.5	6.5	8.2	543
	5.5	24.5	6.3	8.2	544
	6	24.4	6.2	8.2	548
	6.5	24.3	5.7	8.1	547
	7	24.3	4.7	8.0	549
3 South	0	27.5	8.2	8.2	535
	0.5	26.9	8.5	8.3	534
	1	26.0	9.0	8.3	534
	1.5	25.8	9.3	8.3	534
	2	25.7	9.5	8.4	534
	2.5	25.5	9.5	8.4	534
	3	25.3	9.4	8.4	535

	3.5	25.0	8.3	8.3	541
4 South	0	27.9	8.7	8.3	535
	0.5	27.5	9.4	8.3	534
	1	26.9	9.6	8.3	534
	1.5	26.5	9.7	8.3	533
	2	26.4	9.7	8.4	533
	2.5	25.9	9.8	8.4	533
	3	25.6	9.7	8.4	534
	3.5	25.3	9.5	8.3	535
	4	25.2	9.0	8.3	536
	4.5	25.0	8.5	8.2	537
	5	24.8	8.0	8.2	538
	5.5	24.4	7.5	8.1	542
	6	22.1	6.3	8.1	554
	6.5	18.5	3.9	8.0	561
	7	16.5	2.0	7.9	560
	7.5	13.7	1.0	7.9	559
	8	12.7	0.6	7.9	561
	8.5	12.0	0.5	8.0	566
	9	11.2	0.4	8.0	570
	9.5	10.9	0.2	8.0	574
	10	10.5	0.2	8.0	577
	10.5	10.2	0.2	8.0	583
	11	10.0	0.1	7.9	588
5 South	0	28.3	8.8	8.2	534
	0.5	28.3	9.0	8.3	535
	1	27.6	9.3	8.3	535
	1.5	26.9	9.6	8.4	534
	2	26.1	9.7	8.4	532
	2.5	25.8	9.7	8.4	533
	3	25.6	9.5	8.4	534
	3.5	25.5	9.2	8.3	534
	4	23.4	8.9	8.3	535
	4.5	25.1	8.6	8.3	536
	5	25	8.4	8.3	536
	5.5	24.7	7.9	8.2	539
	6	23.3	7.6	8.1	551
	6.5	21.4	5.3	8.0	561
	7	17.1	3.2	7.9	567

	7.5	14.4	2.0	7.9	573
	8	13.0	1.3	7.8	583
	8.5	11.8	1.0	7.8	592
	9	11.1	0.8	7.8	602
	9.5	11.1	0.5	7.8	607
	MEAN	**22.9**	**6.9**	**8.2**	**554**
	STD DEV	**5.4**	**3.3**	**0.2**	**25.0**

Table 5. Lake LeAnn north basin September 19, 2023 physical water quality data.

Site	Depth (m)	Temp C	DO (mg/L)	pH (SU)	Cond (mS/cm)
1 North	0	20.9	9.1	8.9	485
	0.5	20.9	9.3	8.9	485
	1	20.7	9.3	8.9	485
	1.5	20.6	9.4	8.9	485
	2	20.6	9.4	8.9	485
	2.5	20.6	9.2	8.9	485
	3	20.5	9.1	8.9	486
	3.5	20.4	9	8.9	486
	4	20.2	8.9	8.9	486
	4.5	20.2	8.8	8.9	487
	5	20.2	8.7	8.9	487
	5.5	20.2	8.6	8.9	487
	6	20.1	8.6	8.9	487
2 North	0	20.6	9	8.9	484
	0.5	20.6	8.9	8.9	485
	1	20.6	8.9	8.9	484
	1.5	20.6	8.9	8.9	485
	2	20.6	8.9	8.9	484
	2.5	20.5	8.9	8.9	484
	3	20.5	8.9	8.9	484
	3.5	20.5	8.8	8.9	485
	4	20.5	8.8	8.9	485
	4.5	20.4	8.7	8.9	484
3 North	0	20.6	9.5	8.9	458
	0.5	20.4	9.5	9	458
	1	20.4	9.5	9	465
	1.5	20.2	9.6	9	464
	2	20.1	9.7	9	465
4 North	0	20.2	9.5	8.9	495
	0.5	20.2	9.3	8.9	490
	1	20.5	9.4	8.9	492
	1.5	20.5	9.5	8.9	493
	2	20.4	9.5	8.9	494
	2.5	20.1	9.5	8.9	496
	3	20.1	9.4	8.9	495
5 North	0	21.3	9.3	8.9	485
	0.5	20.8	9.4	8.9	484

	1	20.7	9.5	8.9	483
	1.5	20.7	9.5	8.9	484
	2	20.6	9.5	8.9	484
	2.5	20.5	9.5	8.9	484
	3	20.5	9.5	8.9	485
	MEAN	**20.5**	**9.2**	**8.9**	**484**
	STD DEV	**0.3**	**0.3**	**0.0**	**9**

Table 6. Lake LeAnn south basin September 19, 2023 physical water quality data.

Site	Depth (m)	Temp C	DO (mg/L)	pH (SU)	Cond (mS/cm)
1 South	0	21.7	9.6	8.9	503
	0.5	21.2	9.5	8.9	503
	1	21.2	9.6	8.9	504
	1.5	21.1	9.6	8.9	504
	2	21.1	9.6	8.9	504
	2.5	21.0	9.5	8.9	504
	3	21.0	9.5	8.9	504
	3.5	21.0	9.5	8.9	504
	4	21.0	9.4	8.9	504
	4.5	21.0	9.4	8.9	505
	5	21.0	9.4	8.9	505
	5.5	20.9	9.3	8.9	506
	6	20.9	9.3	8.8	507
	6.5	20.8	9	8.8	509
2 South	0	21.0	9.7	8.8	519
	0.5	21.0	9.6	8.8	519
	1	21.0	9.6	8.8	519
	1.5	21.0	9.6	8.9	519
	2	21.0	9.7	8.9	519
	2.5	21.0	9.7	8.9	519
	3	21.0	9.7	8.9	519
	3.5	21.0	9.7	8.9	519
	4	21.0	9.7	8.8	520
	4.5	21.0	9.7	8.8	521
	5	21.0	9.6	8.8	521
	5.5	20.5	9.5	8.8	521
	6	20.5	9.4	8.8	521
	6.5	20.5	9.3	8.8	521
	7	20.5	9.2	8.8	522
3 South	0	21.2	9.8	8.9	516
	0.5	21.2	9.5	8.9	516
	1	21.2	9.5	8.9	517
	1.5	21.2	9.5	8.9	517
	2	21.0	9.4	8.8	517
	2.5	21.0	9.3	8.8	517
	3	21.0	9.3	8.8	517
4 South	0	21.2	9.3	8.8	518

	0.5	21.1	9.3	8.8	518
	1	21.1	9.3	8.8	518
	1.5	21.1	9.3	8.8	518
	2	21.1	9.3	8.8	518
	2.5	21.1	9.3	8.8	518
	3	21.1	9.3	8.8	518
	3.5	21.0	9.3	8.8	518
	4	21.0	9.3	8.8	518
	4.5	21.0	9.3	8.8	518
	5	21.0	9.2	8.8	518
	5.5	21.0	9.2	8.8	518
	6	21.0	9.2	8.8	519
	6.5	21.0	9.2	8.8	519
	7	20.7	9	8.8	520
	7.5	18.9	5.8	8.1	558
	8	15.9	2.4	7.9	589
	8.5	13.8	1.2	7.8	597
	9	12.5	0.8	7.8	604
	9.5	11.8	0.5	7.7	611
	10	11.2	0.4	7.7	620
	10.5	10.9	0.3	7.7	627
	11	10.7	0.2	7.7	632
	11.5	10.5	0.1	7.6	650
	12	10.3	0.1	7.6	675
5 South	0	21.3	9	8.8	518
	0.5	21.3	9.4	8.8	518
	1	21.3	9.4	8.8	518
	1.5	21.3	9.4	8.8	518
	2	21.3	9.4	8.8	518
	2.5	21.2	9.5	8.8	518
	3	21.2	9.5	8.8	518
	3.5	21.1	9.5	8.8	518
	4	21.1	9.4	8.8	518
	4.5	21.1	9.4	8.8	518
	5	21.1	9.3	8.8	518
	5.5	20.8	9.2	8.8	518
	6	20.7	9.2	8.8	519
	6.5	20.7	9	8.8	521
	7	20.6	8.6	8.7	524

	7.5	20.4	8.2	8.5	531
	8	18.8	7.3	7.8	581
	8.5	15.7	2.7	7.6	646
	9	13.6	0.7	7.5	667
	9.5	12.7	0.6	7.5	710
	MEAN	**19.7**	**8.0**	**8.6**	**535**
	STD DEV	**3.1**	**3.1**	**0.4**	**45**

3.2 Lake LeAnn Chemical Water Quality Data (2023).

Table 7. Lake LeAnn north basin April 26, 2023 chemical water quality data.

SITE	SECCHI (ft)	CHL-a (mcg/L)	SITE	TP (mg/L)	TIN (mg/L)	NH3 (mg/L)	NO3 (mg/L)	NO2 (mg/L)
1 North	4.5	11	1 North Top	0.021	0.100	0.010	0.100	0.100
2 North	4.3	11	1 North Mid	0.028	0.100	0.016	0.100	0.100
3 North	3	11	1 North Bot	0.020	0.100	0.010	0.100	0.100
4 North	3.4	11	2 North Top	0.017	0.100	0.010	0.100	0.100
5 North	3.6	11	2 North Mid	0.018	0.100	0.010	0.100	0.100
MEAN	**3.8**	**11**	2 North Bot	0.019	0.100	0.018	0.100	0.100
STD DEV	**0.6**	**0**	3 North Mid	0.021	0.100	0.016	0.100	0.100
			4 North Mid	0.021	0.100	0.019	0.100	0.100
			5 North Mid	0.027	0.100	0.021	0.100	0.100
			MEAN	**0.021**	**0.1**	**0.014**	**0.100**	**0.100**
			STD DEV	**0.0**	**0**	**0.0**	**0**	**0**

Table 8. Lake LeAnn south basin April 26, 2023 chemical water quality data.

SITE	SECCHI (ft)	CHL-a (mcg/L)	SITE	TP (mg/L)	TIN (mg/L)	NH3 (mg/L)	NO3 (mg/L)	NO2 (mg/L)
1 South	5.6	3	1 South Top	0.021	0.100	0.025	0.100	0.100
2 South	4.6	4	1 South Mid	0.024	0.100	0.026	0.100	0.100
3 South	5.3	4	1 South Bot	0.031	0.100	0.035	0.100	0.100
4 South	4.4	5	2 South Top	0.023	0.100	0.022	0.100	0.100
5 South	5.1	3	2 South Mid	0.025	0.100	0.027	0.100	0.100
MEAN	**5.0**	**3.8**	2 South Bot	0.024	0.100	0.025	0.100	0.100
STD DEV	**0.5**	**0.8**	3 South Mid	0.022	0.100	0.029	0.100	0.100
			4 South Top	0.019	0.100	0.022	0.100	0.100
			4 South Mid	0.023	0.100	0.021	0.100	0.100
			4 South Bot	0.022	0.150	0.040	0.110	0.100
			5 South Top	0.020	0.100	0.020	0.100	0.100
			5 South Mid	0.022	0.100	0.021	0.100	0.100
			5 South Bot	0.019	0.100	0.027	0.100	0.100
			MEAN	**0.023**	**0.104**	**0.026**	**0.101**	**0.100**
			STD DEV	**0.0**	**0.0**	**0.0**	**0.0**	**0**

Table 9. Lake LeAnn north basin July 25, 2023 chemical water quality data.

SITE	SECCHI (ft)	CHL-a (mcg/L)	SITE	TP (mg/L)	TIN (mg/L)	NH3 (mg/L)	NO3 (mg/L)	NO2 (mg/L)
1 North	3.6	13	1 North Top	0.210	0.100	0.020	0.100	0.100
2 North	3.5	9	1 North Mid	0.036	0.100	0.073	0.100	0.100
3 North	3.8	13	1 North Bot	0.160	0.100	0.034	0.100	0.100
4 North	4.6	11	2 North Top	0.034	0.100	0.035	0.100	0.100
5 North	3.3	11	2 North Mid	0.033	0.100	0.021	0.100	0.100
MEAN	**3.8**	**11.4**	2 North Bot	0.036	0.100	0.010	0.100	0.100
STD DEV	**0.5**	**1.7**	3 North Mid	0.025	0.100	0.031	0.100	0.100
			4 North Mid	0.024	0.100	0.010	0.100	0.100
			5 North Mid	0.036	0.730	0.730	0.100	0.100
			MEAN	**0.066**	**0.170**	**0.107**	**0.100**	**0.100**
			STD DEV	**0.1**	**0.2**	**0.2**	**0**	**0**

Table 10. Lake LeAnn south basin July 25, 2023 chemical water quality data.

SITE	SECCHI (ft)	CHL-a (mcg/L)	SITE	TP (mg/L)	TIN (mg/L)	NH3 (mg/L)	NO3 (mg/L)	NO2 (mg/L)
1 South	2.8	4	1 South Top	0.019	0.100	0.010	0.100	0.100
2 South	3.3	5	1 South Mid	0.018	0.100	0.010	0.100	0.100
3 South	2.8	4	1 South Bot	0.057	4.5	4.5	0.100	0.100
4 South	3.3	7	2 South Top	0.018	0.100	0.024	0.100	0.100
5 South	3.1	8	2 South Mid	0.015	0.100	0.020	0.100	0.100
MEAN	**3.1**	**5.6**	2 South Bot	0.018	0.100	0.030	0.100	0.100
STD DEV	**0.3**	**1.8**	3 South Mid	0.010	0.100	0.023	0.100	0.100
			4 South Top	0.025	0.100	0.012	0.100	0.100
			4 South Mid	0.023	0.170	0.170	0.100	0.100
			4 South Bot	0.051	1.7	1.7	0.100	0.100
			5 South Top	0.019	0.100	0.021	0.100	0.100
			5 South Mid	0.020	0.100	0.690	0.100	0.100
			5 South Bot	0.055	3.3	3.3	0.100	0.100
			MEAN	**0.027**	**0.813**	**0.808**	**0.100**	**0.100**
			STD DEV	**0.0**	**1.5**	**1.5**	**0**	**0**

Table 11. Lake LeAnn north basin September 19, 2023 chemical water quality data.

SITE	SECCHI (ft)	Chl-a (mcg/L)	SITE	TP (mg/L)	TIN (mg/L)	NH3 (mg/L)	NO3 (mg/L)	NO2 (mg/L)
1 North	3.4	5	1 North Top	0.029	0.010	0.010	0.1	0.1
2 North	3.2	6	1 North Mid	0.029	0.015	0.015	0.1	0.1
3 North	3.1	6	1 North Bot	0.032	0.010	0.010	0.1	0.1
4 North	2.8	7	2 North Top	0.029	0.100	0.010	0.1	0.1
5 North	3.1	3	2 North Mid	0.028	0.100	0.020	0.1	0.1
MEAN	**3.1**	**5.4**	2 North Bot	0.033	0.100	0.019	0.1	0.1
STD DEV	**0.2**	**2**	3 North Mid	0.026	0.100	0.010	0.1	0.1
			4 North Mid	0.032	0.100	0.011	0.1	0.1
			5 North Mid	0.038	0.100	0.019	0.1	0.1
			MEAN	**0.031**	**0.071**	**0.014**	**0.1**	**0.1**
			STD DEV	**0.0**	**0.0**	**0.0**	**0**	**0**

Table 12. Lake LeAnn south basin September 19, 2023 chemical water quality data.

SITE	SECCHI (ft)	CHL-a (mcg/L)	SITE	TP (mg/L)	TIN (mg/L)	NH3 (mg/L)	NO3 (mg/L)	NO2 (mg/L)
1 South	4.1	10	1 South Top	0.022	0.010	0.010	0.1	0.1
2 South	3.8	10	1 South Mid	0.025	0.010	0.010	0.1	0.1
3 South	3.9	7	1 South Bot	0.025	0.014	0.014	0.1	0.1
4 South	4.3	7	2 South Top	0.025	0.010	0.010	0.1	0.1
5 South	4	7	2 South Mid	0.020	0.010	0.010	0.1	0.1
MEAN	**4.0**	**8.2**	2 South Bot	0.021	0.028	0.028	0.1	0.1
STD DEV	**0.2**	**1.6**	3 South Mid	0.035	0.014	0.014	0.1	0.1
			4 South Top	0.02	0.013	0.013	0.1	0.1
			4 South Mid	0.27	0.047	0.047	0.1	0.1
			4 South Bot	0.053	4.7	4.7	0.1	0.1
			5 South top	0.026	0.016	0.016	0.1	0.1
			5 South Mid	0.022	0.026	0.026	0.1	0.1
			5 South Bot	0.084	6.7	6.7	0.1	0.1
			MEAN	**0.050**	**0.892**	**0.892**	**0.1**	**0.1**
			STD DEV	**0.1**	**2.2**	**2.2**	**0**	**0**

Table 13. Lake LeAnn North Mirror Lake Outlet Water Quality Data (2023).

DATE	Temp C	DO (mg/L)	pH (SU)	Cond (mS/cm)	TP (mg/L)	TIN (mg/L)	NH3 (mg/L)	NO3 (mg/L)	NO2 (mg/L)
4/26/2023	13.4	1.2	8.6	703	0.021	0.100	0.016	0.1	0.1
7/25/2023	28.5	8.9	8.4	505	0.021	0.100	0.010	0.1	0.1
9/19/2023	21.4	9.2	8.9	481	0.025	0.010	0.010	0.1	0.1

3.3 Lake LeAnn 2023 CSA (Drain) Physical & Chemical Water Quality Data Tables:

Previous analyses demonstrated that the CSA's around the lake contribute nutrient and sediment loads to the lake which lead to water quality degradation over time. Such degradation has currently resulted in the occurrence of internal loading within the lake. The LLPOA has partnered with the Hillsdale County Conservation District for drain improvements. Additionally, the Hillsdale County Road Commission addressed a road issue at Baker and Northview roads during the spring of 2023 to reduce sediment loads to the lake.

CSA Water Quality Parameters Measured:

Water quality parameters such as dissolved oxygen, water temperature, pH, conductivity, flow rate, total dissolved solids, total suspended solids, total phosphorus, ortho-phosphorus, total inorganic nitrogen (specifically ammonia, nitrate, and nitrite), and total Kjeldahl nitrogen were measured at each of the CSA areas under flowing conditions. Samples consisted of preserved grab bottles which were placed on ice and transported to the NELAC-certified laboratory for analysis. Samples and water quality measurements were collected on April 26, 2023, July 25, 2023, and September 19, 2023. Measurements were taken with a calibrated Eureka Manta II® multi-parameter probe.

Table 14. Lake LeAnn Flowing CSA Drain Water Quality Data (April 26, 2023). Note: TKN, TSS, and SRP were accidentally omitted for this period).

	CSA	Temp C	DO (mg/L)	pH (SU)	Cond (mS/cm)	TP (mg/L)	TIN (mg/L)	NH3 (mg/L)	NO3 (mg/L)	NO2 (mg/L)	Flow (cfs)
	2A	15.0	10.0	8.1	713	0.011	0.390	0.017	0.380	0.100	1.2
	2B	14.7	9.6	8.0	707	0.016	0.560	0.017	0.540	0.100	1.3
	1B	11.9	9.4	7.8	803	0.010	1.2	0.012	1.1	0.100	1.1
	1A	15.4	11	8.2	968	0.014	0.100	0.057	0.100	0.100	2.9
	4B	16.2	9.5	7.9	621	0.530	2.1	0.031	2.1	0.100	0.7
	4A	10.1	9.7	7.6	3474	0.034	2.00	0.066	1.9	0.100	0.1
	3	14.4	8.1	7.8	1097	0.011	0.190	0.029	0.160	0.100	0.2
MEAN		**14.0**	**9.6**	**7.9**	**1198**	**0.089**	**0.934**	**0.033**	**0.897**	**0.100**	**1.1**
STD DEV		**2.2**	**0.9**	**0.2**	**1017**	**0.2**	**0.8**	**0.0**	**0.8**	**0**	**0.9**

Table 15. Lake LeAnn Flowing CSA Drain Water Quality Data (July 25, 2023).

CSA	Temp C	DO (mg/L)	pH (SU)	Cond (mS/cm)	TP (mg/L)	SRP (mg/L)	TKN (mg/L)	TIN (mg/L)	NH3 (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TSS (mg/L)	Flow (cfs)
1A	27.6	8.4	8.7	522	0.010	0.010	0.7	0.100	0.026	0.100	0.100	10	0.2
1B	12.6	8.9	8.3	778	0.010	0.010	0.5	1.0	0.010	1.0	0.100	10	0.2
2A	15.8	9.1	8.0	645	0.010	0.010	0.5	0.350	0.010	0.350	0.100	10	0.2
2B	15.7	9.0	7.8	677	0.010	0.010	0.5	0.830	0.010	0.830	0.100	10	0.2
MEAN	**17.9**	**8.9**	**8.2**	**656**	**0.010**	**0.010**	**0.6**	**0.570**	**0.014**	**0.570**	**0.100**	**10**	**0.2**
STD DEV	**6.6**	**0.3**	**0.4**	**106**	**0**	**0**	**0.1**	**0.4**	**0.0**	**0.4**	**0**	**0**	**0.0**

Table 16. Lake LeAnn Flowing CSA Drain Water Quality Data (September 19, 2023).

CSA	Temp C	DO (mg/L)	pH (SU)	Cond (mS/cm)	TP (mg/L)	SRP (mg/)	TKN (mg/L)	TIN (mg/L)	NH3 (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TSS (mg/L)	Flow (cfs)
2A	14.9	9.5	8.4	661	0.071	0.010	0.9	0.470	0.010	0.470	0.100	12.0	1.65
2B	13.6	10	8.3	684	0.011	0.010	0.5	1.2	0.010	1.2	0.100	10.0	1.24
1B	11.9	8.9	7.9	772	0.054	0.010	1.1	1.2	0.010	1.2	0.100	10.0	0.2
1A	19.2	9.8	8.5	531	0.010	0.010	0.5	0.012	0.012	0.100	0.100	10.0	2.03
MEAN	**14.9**	**9.6**	**8.3**	**662**	**0.037**	**0.010**	**0.7**	**0.721**	**0.011**	**0.743**	**0.100**	**10.5**	**1.3**
STD DEV	**3.1**	**0.5**	**0.3**	**100**	**0.0**	**0**	**0.3**	**0.6**	**0.001**	**0.5**	**0**	**1**	**0.8**

3.4 Lake LeAnn 2023 Phytoplankton Community:

Algal Community Composition Data:

Although this data was not contracted in 2023, RLS decided to collect this data given the strong presence of blue-green algae in both basins with blooms present in both lake basins. The algal genera were determined from a 500-ml composite water sample collected over the 9 deep basins of Lake LeAnn on September 19, 2023. Sub-samples were collected from the 500-ml sample and placed in a Sedgewick Rafter counting chamber for analysis under a Zeiss® compound bright field microscope. Tables 17 and 18 below show the algal taxa present in the samples collected.

Figure 5. A large-scale blue-green algal bloom on North Lake LeAnn (September, 2023).

Figure 6. *Microcystis*, a blue-green algae found in both lake basins (RLS, 2023).

Table 17. Counts (# cells per 1 mL sub-sample) for each genera of algae found at each sampling location (n=4) in the north lake basin of Lake LeAnn (September 19, 2023).

Taxa Present	Type	N1	N2	N3	N4
Chlorella sp.	G	9	5	1	8
Closterium sp.	G	6	3	0	0
Haematococcus sp.	G	13	10	9	2
Mougeotia sp.	G	2	2	2	0
Ulothrix sp.	G	16	14	11	9
Gleocystis sp.	G	4	1	0	3
Microcystis sp.	BG	>20,000	>20,000	>20,000	>15,000
Oscillatoria sp.	BG	2	2	2	0
Fragillaria sp.	D	9	9	1	2
Navicula sp.	D	15	11	0	12
Synedra sp.	D	11	9	5	11

Note: G = green algae (Chlorophyta); BG = blue-green algae (Cyanophyta); D = diatoms (Bacillariophyta).

Table 18. Counts (# cells per 1 mL sub-sample) for each genera of algae found at each sampling location (n=5) in the south lake basin of Lake LeAnn (September 19, 2023).

Taxa Present	Type	S1	S2	S3	S4	S5
Chlorella sp.	G	2	1	0	0	0
Haematococcus sp.	G	9	3	8	0	0
Mougeotia sp.	G	1	1	3	6	1
Pediastrum sp.	G	2	0	5	1	1
Ulothrix sp.	G	3	11	2	0	5
Microcystis sp.	BG	16,500	16,500	>16,500	11,800	14,500
Navicula sp.	D	5	2	5	1	0
Synedra sp.	D	11	8	4	13	2

3.5 Lake LeAnn Aquatic Vegetation Biovolume Data

A whole-lake scan of the aquatic vegetation in Lake LeAnn was conducted on September 19, 2023 with a WAAS-enabled Lowrance HDS 9® GPS with variable frequency transducer. This data included 8,640 data points in the north basin and 6,712 data points in the south basin. Points were then uploaded into a cloud software program to reveal maps that displayed depth contours, sediment hardness, and aquatic vegetation biovolume (Figures 7-8). On these maps, the color blue refers to areas that lack vegetation. The color green refers to low-lying vegetation. The colors red/orange refer to tall-growing vegetation. There are many areas around the littoral (shallow) zone of the basins that contain low-growing plants like Chara. In addition, any canopies or lily pads will show as red color on the map. For this reason, the scans are conducted in conjunction with a whole lake GPS survey to account for individual species identification of all aquatic plants in the lake. Tables 19 and 20 show the biovolume categories by plant cover during the September 19, 2023 scan and survey.

The Point-Intercept Survey method is used to assess the presence and percent cumulative cover of submersed, floating-leaved, and emergent aquatic vegetation within and around the littoral zones of inland lakes. With this survey method, sampling locations are geo-referenced (via GPS waypoints) and assessed throughout the entire lake to determine the species of aquatic macrophytes present and density of each macrophyte which are recorded onto a data sheet.

Each separate plant species found in each sampling location is recorded along with an estimate of each plant density. Each macrophyte species corresponds to an assigned number. There are designated density codes for the aquatic vegetation surveys, where a = found (occupying < 2% of the surface area of the lake), b = sparse (occupying 2-20% of the surface area of the lake), c = common, (occupying 21-60% of the surface area of the lake), and d = dense (occupying > 60% of the surface area of the lake).

The survey of the north basin of Lake LeAnn consisted of 154 sampling locations around the littoral zone and the survey of the south basin consisted of 193 sampling locations and was conducted in spring during April 26-27, 2023 with follow-up post treatment surveys later in the season to confirm treatment efficacy. Data were placed in a table showing the relative abundance of each aquatic plant species found and a resultant calculation showing the frequency of each plant, and cumulative cover.

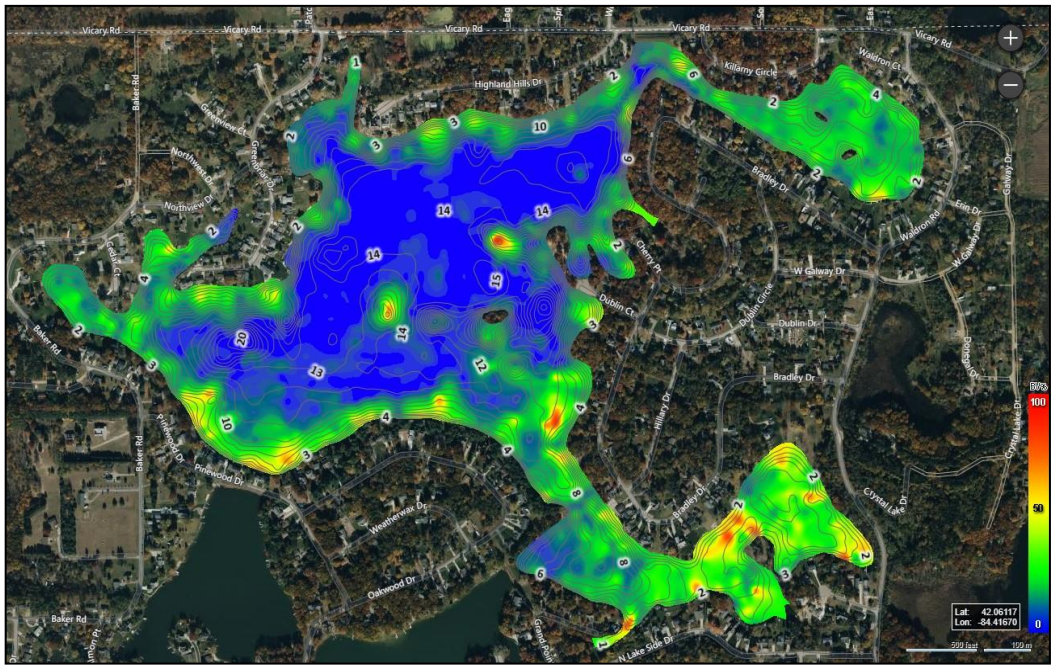

Figure 7. Aquatic plant biovolume of all aquatic plants in north Lake LeAnn, Hillsdale County, Michigan (September 19, 2023). Note: Red color denotes high-growing aquatic plants, green color denoted low-growing aquatic plants, and blue color represents a lack of aquatic vegetation.

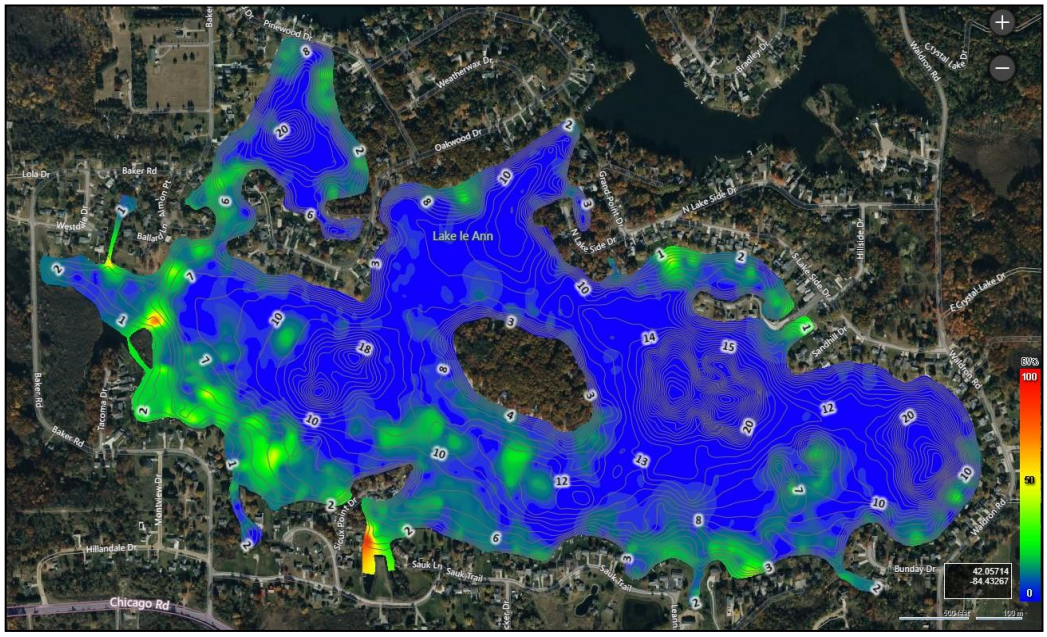

Figure 8. Aquatic plant biovolume of all aquatic plants in south Lake LeAnn, Hillsdale County, Michigan (September 19, 2023). Note: Red color denotes high-growing aquatic plants, green color denoted low-growing aquatic plants, and blue color represents a lack of aquatic vegetation.

Table 19. Lake LeAnn north basin aquatic vegetation biovolume by category (relative cover on September 19, 2023).

Biovolume Cover Category	% Relative Cover of Bottom by Category
<5%	43.11
5-20%	28.87
20-40%	15.0
40-60%	8.9
60-80%	1.5
>80%	1.5

Table 20. Lake LeAnn south basin aquatic vegetation biovolume by category (relative cover on September 19, 2023).

Biovolume Cover Category	% Relative Cover of Bottom by Category
<5%	76.38
5-20%	19.41
20-40%	4.4
40-60%	1.6
60-80%	0.1
>80%	0.2

During the April 26-27, 2023 survey, the north basin of Lake LeAnn contained 6 native submersed, 2 floating-leaved, and 1 emergent aquatic plant species, for a total of 9 native aquatic macrophyte species (Table 21). There was a gain of one submersed species that is likely due to recent successful milfoil and Curly-leaf Pondweed management. The south basin of Lake LeAnn contained 9 native submersed, 2 floating-leaved, and 1 emergent aquatic plant species, for a total of 12 native aquatic macrophyte species (Table 22). There was a gain of 5 submersed aquatic plant species that included 3 different species of naiads. This could also be attributed to recent management of invasives.

The dominant native aquatic plants in the north basin of the lake included Coontail (53.9% of the sampling sites), and *Elodea* (13.6% of the sampling sites). The dominant native aquatic plants in the south basin of the lake included *Chara* (43.0% of the sampling sites), and the native macro alga *Nitella* (10.4% of the sampling sites).

A late-season survey of both lakes was also conducted on September 19, 2023. Since blue-green algae was prevalent in over 93% of the sampling locations on both lakes, the survey required intensive raking of the lake bottom for proper identification. A total of 103 locations were sampled on North Lake LeAnn and a total of 54 locations were sampled on South Lake LeAnn. During this survey, the north basin of Lake LeAnn contained 9 native submersed, 2 native floating-leaved, and 2 native emergent aquatic plant species for a total of 13 species. The most dominant included Coontail (34%) and Wild Celery (26.2%). The south basin of Lake LeAnn contained 11 native submersed, 2 native floating-leaved, and 1 native emergent aquatic plant species for a total of 14 species. The most dominant species included White Waterlily (61.1%) and *Chara* (44.4%).

RLS discourages the treatment of any native submersed aquatic plants as the lake needs those species in the absence of invasive cover by milfoil and Curly-leaf Pondweed. All invasives should be treated however, as continued growth leads to spread and further loss of native submersed aquatic plant species. Figures 9-12 below display the treatment areas in 2023 where targeted treatments of invasive species were needed to reduce milfoil and Curly-leaf Pondweed. A large-scale treatment of milfoil (27.5 acres) occurred on May 11 in the North Basin with the use of ProcellaCOR® and diquat at doses of 4 PDU and 1 ga/acre, respectively. Additionally, 20 acres of nuisance Curly-leaf Pondweed were also treated in the north basin with diquat at a dose of 1 gal/acre. In the south basin, 30 acres of milfoil were treated with use of ProcellaCOR® and diquat and doses of 4 PDU and 1 ga/acre, respectively. Additionally, 10 acres of nuisance Curly-leaf Pondweed were treated with diquat at 1 gal/acre.

Phycomycin® blue-green algae treatments were conducted on May 25, June 21, and August 24. Phycomycin® is a non-copper peroxide specifically used on blue-green algae but may also reduce other desirable algal taxa in treatment areas. Thus, it should only be used in localized nearshore areas since other forms of algae are needed in the water column of deeper lake basins to support the zooplankton population and the lake fishery.

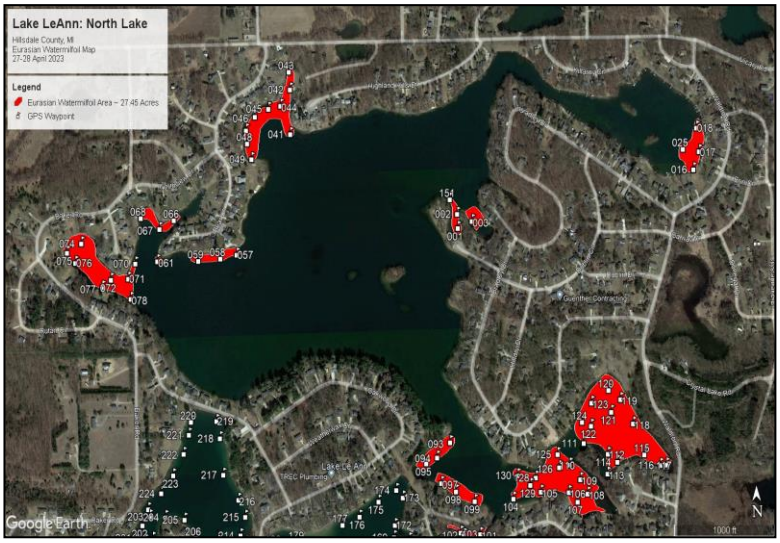

Figure 9. North Lake LeAnn April, 2023 treatment map.

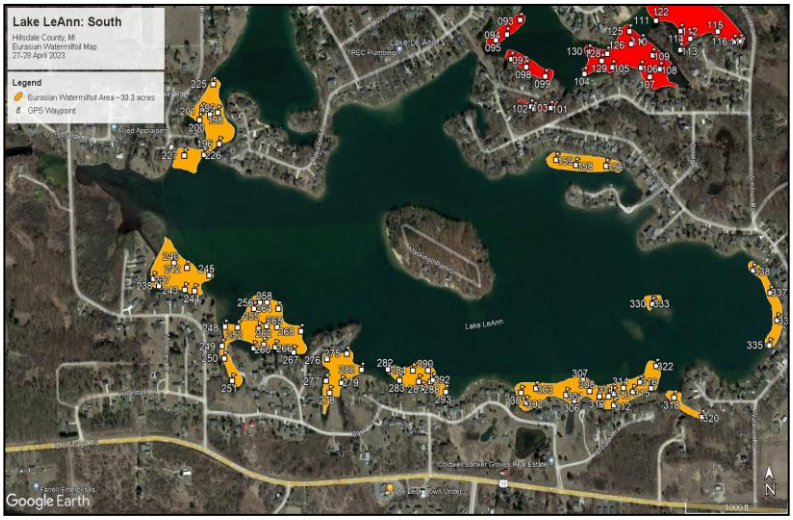

Figure 10. South Lake LeAnn April, 2023 treatment map.

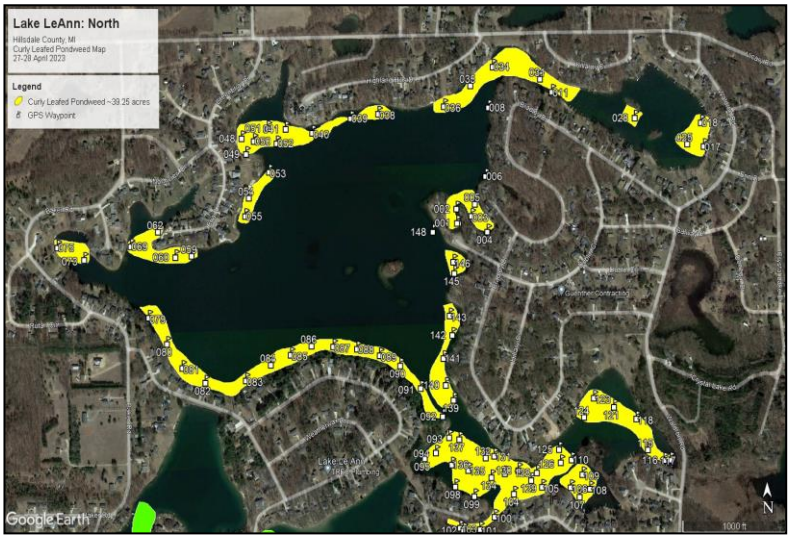

Figure 11. North Lake LeAnn April, 2023 treatment map.

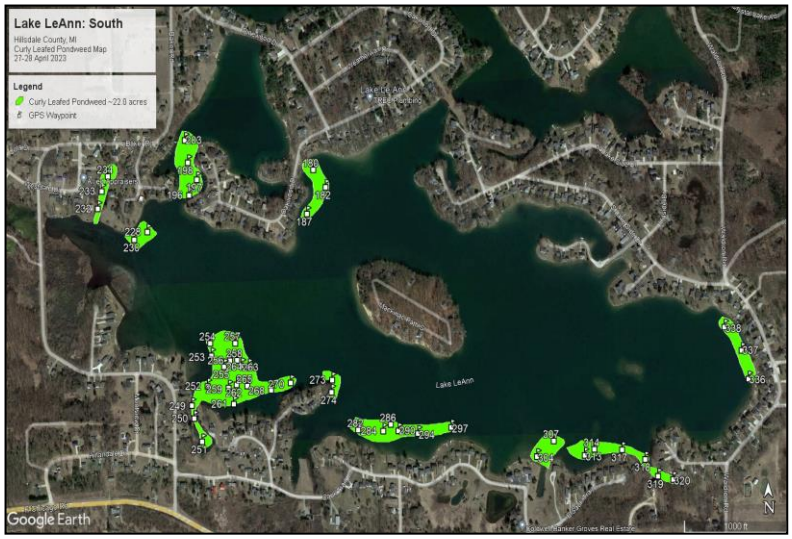

Figure 12. South Lake LeAnn April, 2023 treatment map

Table 21. Lake LeAnn north basin native aquatic plants (April 26, 2023).

Aquatic Plant Common Name	Aquatic Plant Latin Name	A level	B level	C level	D level	% Sites Found
Muskgrass	*Chara vulgaris*	6	9	3	1	12.3
Flat-stem Pondweed	*Potamogeton zosteriformis*	3	0	0	0	1.9
Smooth Stonewort	*Nitella* sp.	3	2	4	0	5.8
Sago Pondweed	*Stuckenia pectinata*	1	0	0	0	0.6
Coontail	*Ceratophyllum demersum*	31	33	18	1	53.9
Common Waterweed	*Elodea canadensis*	13	6	2	0	13.6
White Waterlily	*Nymphaea odorata*	5	3	0	0	5.2
Yellow Waterlily	*Nuphar variegata*	2	0	0	0	1.3
Cattails	*Typha latifolia*	2	1	0	0	1.9

Table 22. Lake LeAnn south basin native aquatic plants (April 26, 2023).

Aquatic Plant Common Name	Aquatic Plant Latin Name	A level	B level	C level	D level	# Sites Found
Muskgrass	*Chara vulgaris*	71	12	0	0	43.0
Flat-stem Pondweed	*Potamogeton zosteriformis*	2	0	0	0	1.0
Illinois Pondweed	*Potamogeton illinoensis*	4	0	0	0	2.1
Smooth Stonewort	*Nitella* sp.	17	3	0	0	10.4
Southern Naiad	*Najas guadalupensis*	1	0	0	0	0.5
Slender Naiad	*Najas flexilis*	1	0	0	0	0.5
Brittle Naiad	*Najas marina*	0	0	1	0	0.5
Coontail	*Ceratophyllum demersum*	1	0	0	0	0.5
Common Waterweed	*Elodea canadensis*	1	0	0	0	0.5
White Waterlily	*Nymphaea odorata*	1	0	0	0	0.5
Yellow Waterlily	*Nuphar variegata*	3	0	0	0	1.6
Cattails	*Typha latifolia*	1	0	0	0	0.5

Table 23. Lake LeAnn north basin native aquatic plants (September 19, 2023).

Aquatic Plant Common Name	Aquatic Plant Latin Name	A level	B level	C level	D level	% Sites Found
Muskgrass	*Chara vulgaris*	9	1	0	0	9.7
Illinois Pondweed	*Potamogeton zosteriformis*	9	8	0	0	16.5
Floating-leaf Pondweed	*Potamogeton natans*	4	6	0	0	9.7
Flat-stem Pondweed	*Potamogeton zosteriformis*	1	0	0	0	1.0
Sago Pondweed	*Stuckenia pectinata*	5	0	0	0	4.9
Large-leaf Pondweed	*Potamogeton amplifolius*	0	2	0	0	1.9
Coontail	*Ceratophyllum demersum*	20	15	0	0	34.0
Common Waterweed	*Elodea canadensis*	2	0	0	0	1.9
Wild Celery	*Vallisneria americana*	19	8	0	0	26.2
White Waterlily	*Nymphaea odorata*	1	0	0	0	1.0
Yellow Waterlily	*Nuphar variegata*	20	0	0	0	19.4
Cattails	*Typha latifolia*	3	5	0	0	7.8
Iris	*Iris* sp.	1	0	0	0	1.0

Table 24. Lake LeAnn south basin native aquatic plants (September 19, 2023).

Aquatic Plant Common Name	Aquatic Plant Latin Name	A level	B level	C level	D level	# Sites Found
Muskgrass	*Chara vulgaris*	11	13	0	0	44.4
Flat-stem Pondweed	*Potamogeton zosteriformis*	1	0	0	0	1.9
Illinois Pondweed	*Potamogeton illinoensis*	5	1	0	0	11.1
Smooth Stonewort	*Nitella* sp.	0	1	0	0	1.9
Large-leaf Pondweed	*Potamogeton amplifolius*	1	0	0	0	1.9
Floating-leaf Pondweed	*Potamogeton natans*	4	0	0	0	7.4
Sago Pondweed	*Stuckenia pectinata*	3	3	0	0	11.1
Slender Naiad	*Najas flexilis*	1	2	0	0	5.6
Coontail	*Ceratophyllum demersum*	1	0	0	0	1.9
Common Waterweed	*Elodea canadensis*	0	1	0	0	1.9
Wild Celery	*Vallisneria americana*	8	3	0	0	20.4
White Waterlily	*Nymphaea odorata*	5	24	4	0	61.1
Yellow Waterlily	*Nuphar variegata*	2	4	0	0	11.1
Cattails	*Typha latifolia*	2	5	0	0	13.0

3.6 Lake LeAnn Bottom Hardness Scan and Data:

A bottom sediment hardness scan was conducted of the entire lake bottom on September 19, 2023. The bottom hardness maps show (Figures 13-14) that most of the lake bottom consists of fairly consolidated sediment throughout the lake with a few areas with soft organic bottom. This is not surprising given the amount of sandy loams in the region which contribute to lake geology. Tables 25-26 below show the categories of relative bottom hardness with 0.0-0.1 referring to the softest and least consolidated bottom and >0.4 referring to the hardest, most consolidated bottom for the two lake basins. This scale does not mean that any of the lake contains a truly "hard" bottom but rather a bottom that is more cohesive and not flocculent.

Table 25. Lake LeAnn north basin relative hardness of the lake bottom by category or hardness and percent cover of each category (September 19, 2023).

Lake Bottom Relative Hardness Category	# GPS Points in Each Category (Total =7,986)	% Relative Cover of Bottom by Category
0.0-0.1	15	0.07
0.1-0.2	429	1.70
0.2-0.3	4910	56.23
0.3-0.4	2612	41.98
>0.4	20	0.02

Table 26. Lake LeAnn south basin relative hardness of the lake bottom by category or hardness and percent cover of each category (September 19, 2023).

Lake Bottom Relative Hardness Category	# GPS Points in Each Category (Total =11,647)	% Relative Cover of Bottom by Category
0.0-0.1	6	0.01
0.1-0.2	712	0.48
0.2-0.3	7358	51.26
0.3-0.4	3552	48.25
>0.4	19	0.0

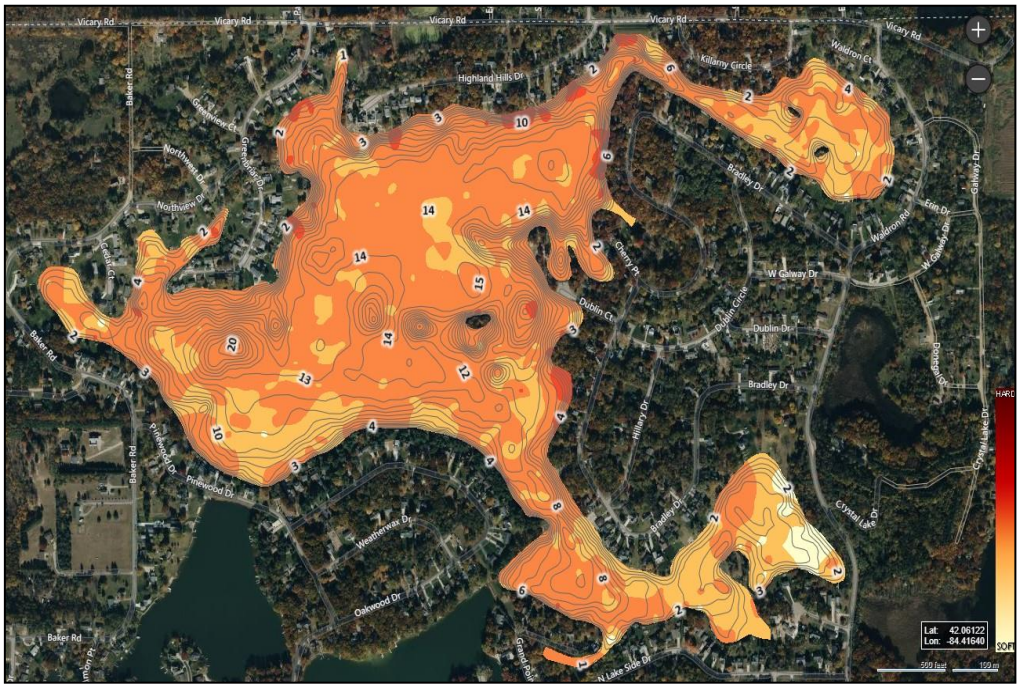

Figure 13. Lake LeAnn north basin sediment relative hardness map (September 19, 2023).

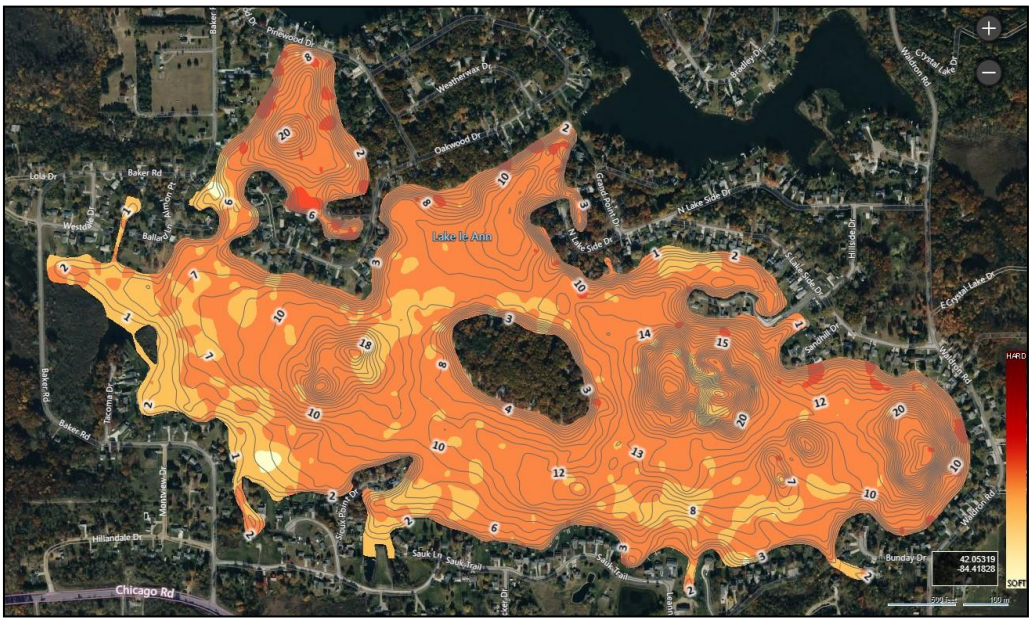

Figure 14. Lake LeAnn south basin sediment relative hardness map (September 19, 2023)

4.0 LAKE LEANN 2019-2023 CONCLUSIONS AND RECOMMENDATIONS FOR 2024

The implementation of the LFA technology and concomitant use of bioaugmentation (beneficial bacteria) in Lake LeAnn occurred in 2021-2023. This was to begin initiation of the primary goals addressed in the earlier sections above. Specifically, the lake needs more native aquatic vegetation, less invasive aquatic plant species, less cyanobacteria, and less nutrients. As noted earlier, the nutrient concentrations in the lake are indicative of eutrophic waters with elevated phosphorus, nitrogen, and chlorophyll-a. Additional impairments include low dissolved oxygen with depth in non-aerated locations, and reduced water clarity through low secchi transparency readings. The nutrients have multiple sources which include drains entering the lake, septic systems, and other land uses such as fertilizer usage.

The Sections below (I-VI) display the 2019 mean baseline data set and the post-LFA mean data sets (2021-2023). The following sub-sections below summarize an analysis of all collected data from 2019 and 2021-2023 with comparisons. The Mirror Lake Outlet data was added post 2019 by EGLE and thus 2021-2023 data has been collected at the outlet. All data collected has been analyzed and are summarized below with descriptive statistic tables that include means and standard deviations.

Management recommendations for 2024 are listed and mentioned in Section VI below.

Statistical Summary of Baseline (2019), Year 1 (2021), Year 2 (2022), and Year 3 (2023) Lake LeAnn LFA Data:

I. Lake Basin Water Quality Parameters:

The tables below (27-33) display the means and standard deviations for both lake basins in 2019 (baseline) and 2021-2023 (Years 1-3 of LFA operation) as well as the Mirror Lake outlet from Lake LeAnn. This analysis allowed for a seasonal comparison of baseline to post-LFA conditions for all water quality parameters. Additional conclusions for other parameters measured in the basins are discussed in the additional sections below. Based on this complete and comprehensive data analysis, the following conclusions can be made:

North Basin:

1. The mean in situ chlorophyll-a July and September concentrations have declined with time.
2. The mean April, July, and September Secchi transparency have declined with time.
3. The mean April TIN has declined with time, but the July and September TIN have increased with time.
4. The mean April and September TP has declined with time, but July has increased with time.
5. The mean dissolved oxygen concentrations have increased with time.

South Basin:

1. The in situ chlorophyll-a July concentrations have declined with time but the September concentrations increased with time. The April concentrations have remained the same.
2. The April Secchi transparency has increased with time, but the July and September Secchi transparency has declined with time.
3. The April TIN has declined with time, but the July and September TIN have increased with time.
4. The April and September TP have increased with time, but the July TP has declined with time.
5. The mean dissolved oxygen concentrations have increased with time.

Table 27. Descriptive statistics of all water quality parameters in the North Basin of Lake LeAnn for LFA parameters collected in April/May of 2019, 2021, 2022, and 2023.

Water Quality Parameter	2019 Baseline April/May Means ± SD	2021 Year 1 April/May Means ± SD	2022 Year 2 April/May Means ± SD	2023 Year 3 April/May Means ± SD
Water temp (°C)	12.9±0.9	13.2±0.6	15.3±0.9	11.0±0.6
pH (S.U.)	8.3±0.1	8.5±0.1	8.1±0.1	8.6±0.1
Dissolved oxygen (mg/L)	10.1±0.6	11.6±0.9	9.9±0.4	11.5±0.7
Conductivity (mS/cm)	509±3.6	502±9.0	557±176	1088±364
Secchi transparency (ft)	8.4±1.6	10.2±2.4	4.7±0.9	3.8±0.6
Lab Chlorophyll-a (µg/L)	0.134±0.3	0.606±0.4	0.700±1.6	NA
Total Kjeldahl nitrogen (mg/L)	0.6±0.1	0.5±0.1	1.0±0.3	NA
Total inorganic nitrogen (mg/L)	0.240±0.0	0.027±0.0	0.118±0.0	0.100±0.0
Ammonia nitrogen (mg/L)	0.073±0.0	0.027±0.0	0.042±0.0	0.014±0.0
Nitrate nitrogen (mg/L)	0.166±0.0	0.100±0.0	0.113±0.0	0.100±0.0
Nitrite nitrogen (mg/L)	0.100±0.0	0.100±0.0	0.100±0.0	0.100±0.0
Total phosphorus (mg/L)	0.025±0.0	0.016±0.0	0.027±0.0	0.021±0.0
Ortho-phosphorus (mg/L)	0.010±0.0	0.010±0.0	0.010±0.0	NA
Total suspended solids (mg/L)	25±12	10.0±0.0	10.2±2.0	NA

Table 28. Descriptive statistics of all water quality parameters in the North Basin of Lake LeAnn for LFA parameters collected in July of 2019, 2021, 2022 and 2023.

Water Quality Parameter	2019 Baseline July Means ± SD	2021 Year 1 July Means ± SD	2022 Year 2 July Means ± SD	2023 Year 3 July Means ± SD
Water temp (°C)	21.2±2.6	25.5±0.4	25.9±0.3	26.2±1.0
pH (S.U.)	8.5±0.1	8.5±0.2	8.0±0.3	8.5±0.1
Dissolved oxygen (mg/L)	7.3±2.1	9.4±1.2	7.7±1.2	9.0±1.4
Conductivity (mS/cm)	584±75	425±86	720±134	503±17
Secchi transparency (ft)	6.1±0.1	6.2±0.6	3.5±1.1	3.8±0.5
Lab Chlorophyll-a (µg/L)	0.340±0.7	3.8±2.5	1.8±2.4	NA
Total Kjeldahl nitrogen (mg/L)	1.2±0.9	0.5±0.0	0.7±0.3	NA
Total inorganic nitrogen (mg/L)	0.172±0.4	0.012±0.0	0.100±0.0	0.170±0.2
Ammonia nitrogen (mg/L)	0.172±0.4	0.012±0.0	0.029±0.0	0.107±0.2
Nitrate nitrogen (mg/L)	0.100±0.0	0.100±0.0	0.100±0.0	0.100±0.0
Nitrite nitrogen (mg/L)	0.100±0.0	0.100±0.0	0.100±0.0	0.100±0.0
Total phosphorus (mg/L)	0.047±0.0	0.034±0.0	0.030±0.0	0.066±0.1
Ortho-phosphorus (mg/L)	0.026±0.0	0.010±0.0	0.011±0.0	NA
Total suspended solids (mg/L)	10.5±1.4	10.0±0.0	14.2±7.3	NA

Table 29. Descriptive statistics of all water quality parameters in the North Basin of Lake LeAnn for LFA parameters collected in September of 2019, 2021, 2022, and 2023

Water Quality Parameter	2019 Baseline Sept Means ± SD	2021 Year 1 Sept Means ± SD	2022 Year 2 Sept Means ± SD	2023 Year 3 September Means ± SD
Water temp (°C)	22.6±1.2	23.7±0.8	22.5±1.0	20.5±0.3
pH (S.U.)	8.4±0.2	8.6±0.1	8.5±0.2	8.9±0.0
Dissolved oxygen (mg/L)	8.2±2.2	9.0±1.1	10.1±1.5	9.2±0.3
Conductivity (mS/cm)	472±13	480±1.8	477±5.2	484±9.0
Secchi transparency (ft)	3.3±0.1	3.5±0.5	1.8±0.2	3.1±0.2
Lab Chlorophyll-a (µg/L)	0.0±0.0	2.8±2.0	14.2±6.9	NA
Total Kjeldahl nitrogen (mg/L)	1.0±0.3	1.0±0.5	1.3±0.3	NA
Total inorganic nitrogen (mg/L)	0.057±0.1	0.100±0.0	0.116±0.0	0.071±0.0
Ammonia nitrogen (mg/L)	0.057±0.1	0.036±0.0	0.025±0.0	0.014±0.0
Nitrate nitrogen (mg/L)	0.100±0.0	0.100±0.0	0.113±0.0	0.100±0.0
Nitrite nitrogen (mg/L)	0.100±0.0	0.100±0.0	0.100±0.0	0.100±0.0
Total phosphorus (mg/L)	0.037±0.0	0.047±0.0	0.057±0.0	0.031±0.0
Ortho-phosphorus (mg/L)	0.010±0.0	0.013±0.0	0.013±0.0	NA
Total suspended solids (mg/L)	10.6±1.9	21.0±10.0	10.7±2.0	NA

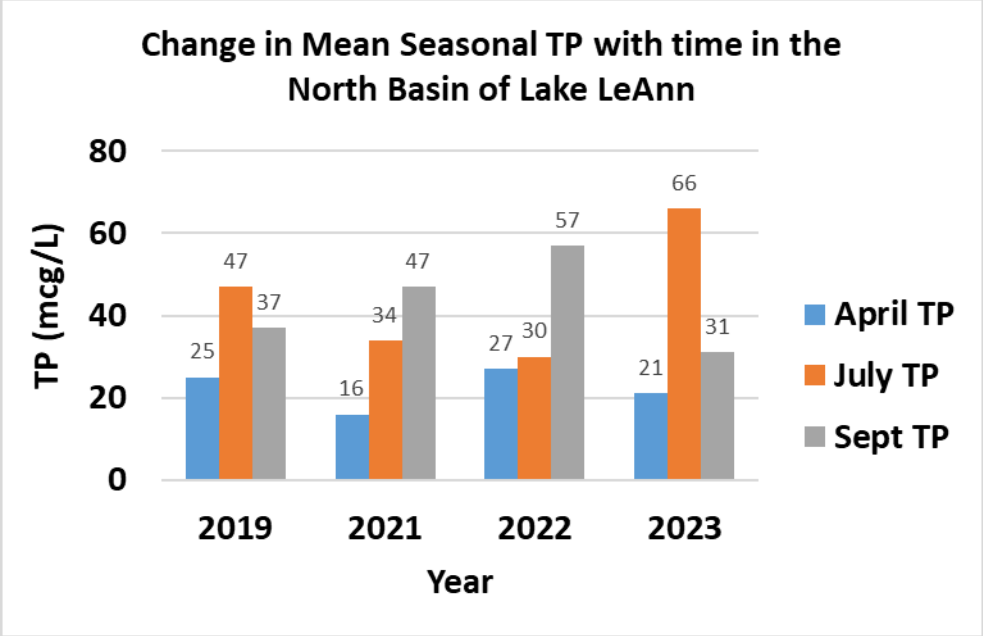

Figure 15. Change in mean seasonal TP with Time in the North Basin of Lake LeAnn.

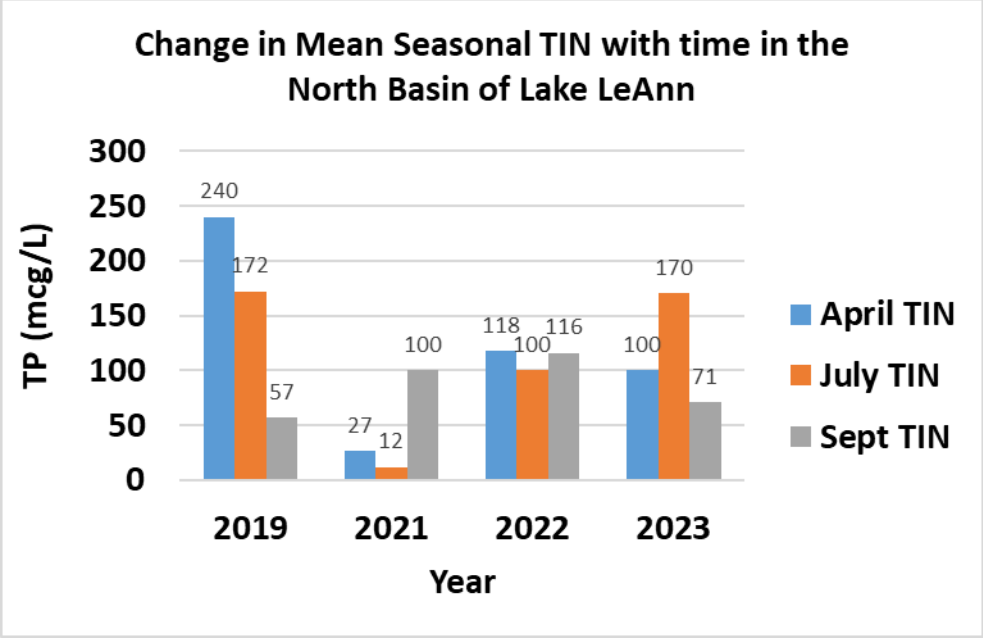

Figure 16. Change in mean seasonal TIN with Time in the North Basin of Lake LeAnn.

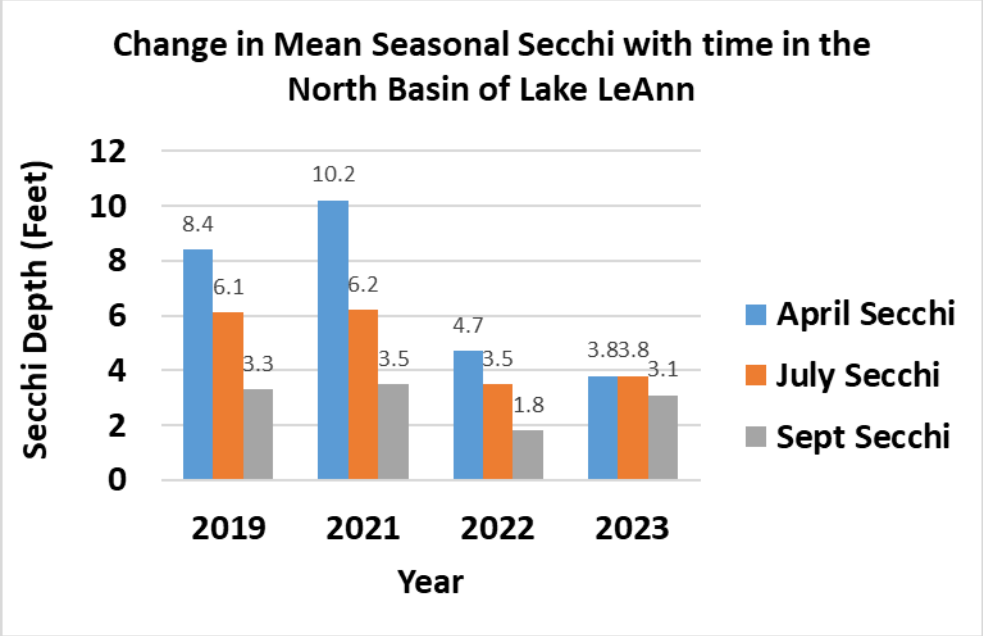

Figure 17. Change in mean seasonal Secchi with Time in the North Basin of Lake LeAnn.

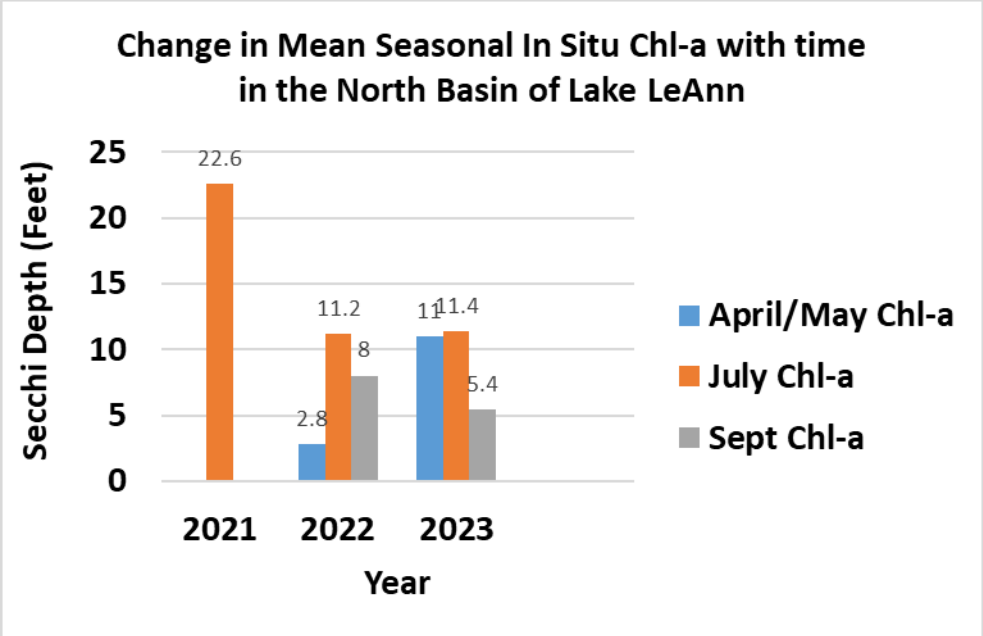

Figure 18. Change in mean seasonal in situ Chl-a with Time in the North Basin of Lake LeAnn.

Table 30. Descriptive statistics of all water quality parameters in the South Basin of Lake LeAnn for LFA parameters collected in April/May of 2019, 2021, 2022, and 2023.

Water Quality Parameter	2019 Baseline April/May Means ± SD	2021 Year 1 April/May Means ± SD	2022 Year 2 April/May Means ± SD	2023 Year 3 April/May Means ± SD
Water temp (°C)	12.7±1.1	12.6±1.1	14.1±1.9	11.2±0.8
pH (S.U.)	8.4±0.1	8.4±0.1	8.3±0.1	8.5±0.1
Dissolved oxygen (mg/L)	10.3±0.7	10.3±0.7	10.5±1.6	11.2±1.2
Conductivity (mS/cm)	544±5.3	541±4.6	711±150	957±361
Secchi transparency (ft)	6.0±0.9	7.5±0.5	3.8±0.5	5.0±0.5
Chlorophyll-a (µg/L)	1.8±2.5	0.8±0.8	1.6±1.7	3.8±0.8
Total Kjeldahl nitrogen (mg/L)	0.5±0.0	0.5±0.1	0.7±0.2	NA
Total inorganic nitrogen (mg/L)	0.223±0.1	0.104±0.1	0.254±0.3	0.104±0.0
Ammonia nitrogen (mg/L)	0.035±0.0	0.104±0.1	0.045±0.1	0.026±0.0
Nitrate nitrogen (mg/L)	0.191±0.1	0.100±0.0	0.173±0.2	0.101±0.0
Nitrite nitrogen (mg/L)	0.100±0.0	0.100±0.0	0.133±0.1	0.100±0.1
Total phosphorus (mg/L)	0.018±0.0	0.015±0.0	0.017±0.0	0.023±0.0
Ortho-phosphorus (mg/L)	0.010±0.0	0.010±0.0	0.010±0.0	NA
Total suspended solids (mg/L)	16.1±11.0	10.0±0.0	12.4±4.9	NA

Table 31. Descriptive statistics of all water quality parameters in the South Basin of Lake LeAnn for LFA parameters collected in July of 2019, 2021, 2022, and 2023.

Water Quality Parameter	2019 Baseline July Means ± SD	2021 Year 1 July Means ± SD	2022 Year 2 July Means ± SD	2023 Year 3 July Means ± SD
Water temp (°C)	23.9±4.8	22.4±5.0	23.1±5.5	22.9±5.4
pH (S.U.)	8.5±0.1	8.1±0.4	8.0±0.3	8.2±0.2
Dissolved oxygen (mg/L)	6.7±3.5	6.8±4.2	6.2±3.3	6.9±3.3
Conductivity (mS/cm)	494±49	536±25	552±45	554±25
Secchi transparency (ft)	8.7±1.0	2.8±0.2	4.2±0.6	3.1±0.3
Chlorophyll-a (µg/L)	0.5±0.6	2.5±2.3	1.1±1.1	5.6±1.8
Total Kjeldahl nitrogen (mg/L)	1.1±1.2	1.0±0.7	1.0±0.7	NA
Total inorganic nitrogen (mg/L)	0.253±0.8	0.456±0.8	0.270±0.5	0.813±1.5
Ammonia nitrogen (mg/L)	0.253±0.8	0.456±0.8	0.239±0.5	0.808±1.5
Nitrate nitrogen (mg/L)	0.100±0.0	0.100±0.0	0.100±0.0	0.100±0.0
Nitrite nitrogen (mg/L)	0.100±0.0	0.100±0.0	0.100±0.0	0.100±0.0
Total phosphorus (mg/L)	0.039±0.1	0.042±0.0	0.024±0.0	0.027±0.0
Ortho-phosphorus (mg/L)	0.012±0.0	0.010±0.0	0.010±0.0	NA
Total suspended solids (mg/L)	13.7±11.0	10.0±0.0	10.0±0.0	NA

Table 32. Descriptive statistics of all water quality parameters in the South Basin of Lake LeAnn for LFA parameters collected in September of 2019, 2021, 2022, and 2023.

Water Quality Parameter	2019 Baseline Sept Means ± SD	2021 Year 1 Sept Means ± SD	2022 Year 2 Sept Means ± SD	2023 Year 3 Sept Means ±SD
Water temp (°C)	21.2±2.6	21.9±3.4	20.8±3.4	19.7±3.1
pH (S.U.)	8.4±0.1	8.3±0.5	8.2±0.4	8.6±0.4
Dissolved oxygen (mg/L)	7.1±2.5	7.7±3.1	7.6±3.0	8.0±3.1
Conductivity (mS/cm)	570±74	526±42	544±37	535±45
Secchi transparency (ft)	5.5±2.2	3.0±0.2	5.8±0.3	4.0±0.2
Chlorophyll-a (µg/L)	0.0±0.0	6.2±7.8	1.7±1.8	8.2±1.6
Total Kjeldahl nitrogen (mg/L)	1.1±1.0	1.9±2.2	1.2±1.3	NA
Total inorganic nitrogen (mg/L)	0.397±1.0	0.800±1.6	0.484±1.2	0.892±2.2
Ammonia nitrogen (mg/L)	0.397±1.0	0.700±1.6	0.433±1.2	0.892±2.2
Nitrate nitrogen (mg/L)	0.100±0.0	0.100±0.0	0.100±0.0	0.100±0.0
Nitrite nitrogen (mg/L)	0.100±0.0	0.100±0.0	0.100±0.0	0.100±0.0
Total phosphorus (mg/L)	0.023±0.0	0.024±0.0	0.057±0.0	0.050±0.1
Ortho-phosphorus (mg/L)	0.012±0.0	0.010±0.0	0.011±0.0	NA
Total suspended solids (mg/L)	10.0±0.0	60.0±136	10.8±1.9	NA

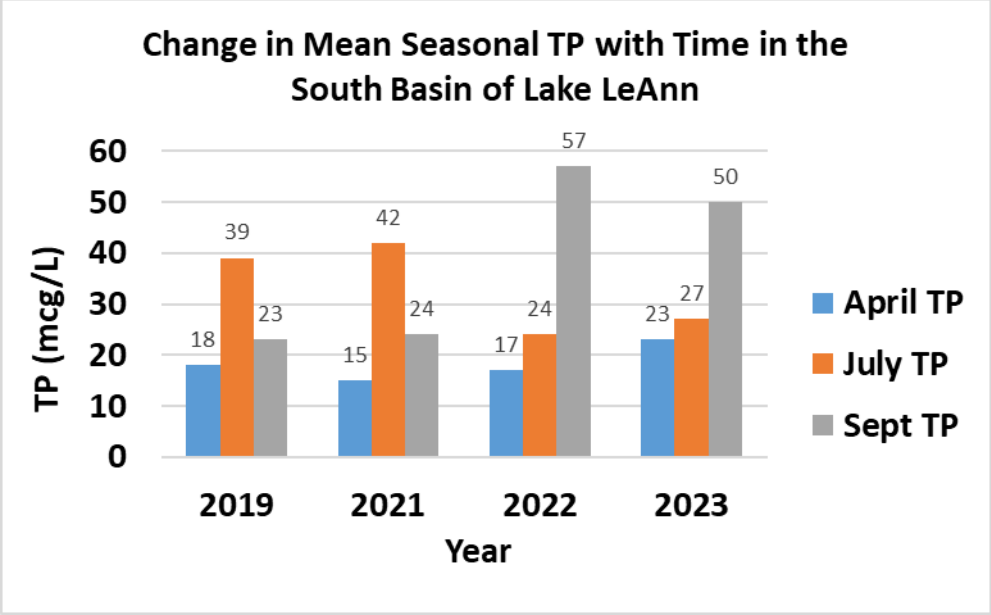

Figure 19. Change in mean seasonal TP with Time in the South Basin of Lake LeAnn.

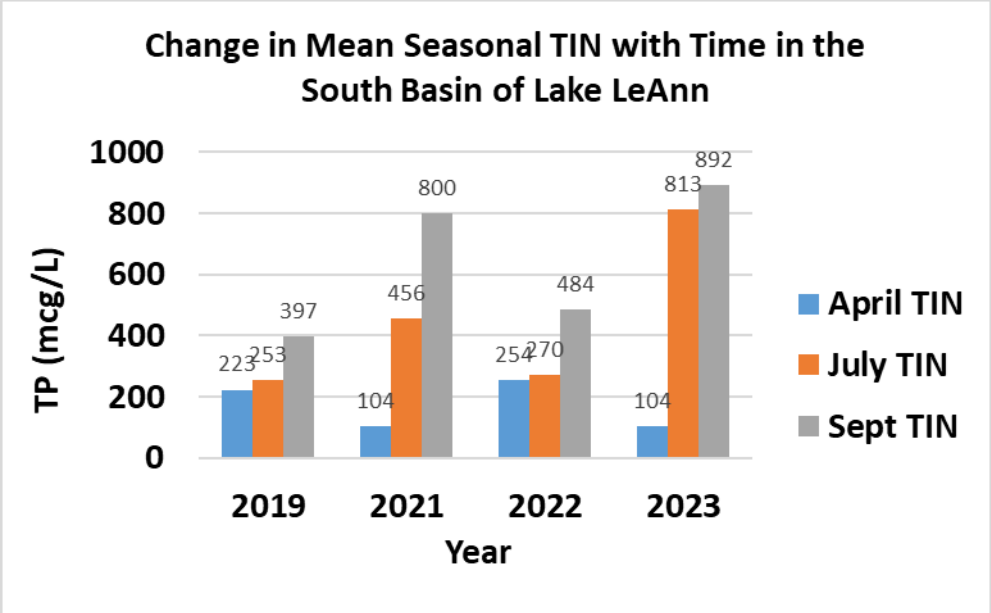

Figure 20. Change in mean seasonal TIN with Time in the South Basin of Lake LeAnn.

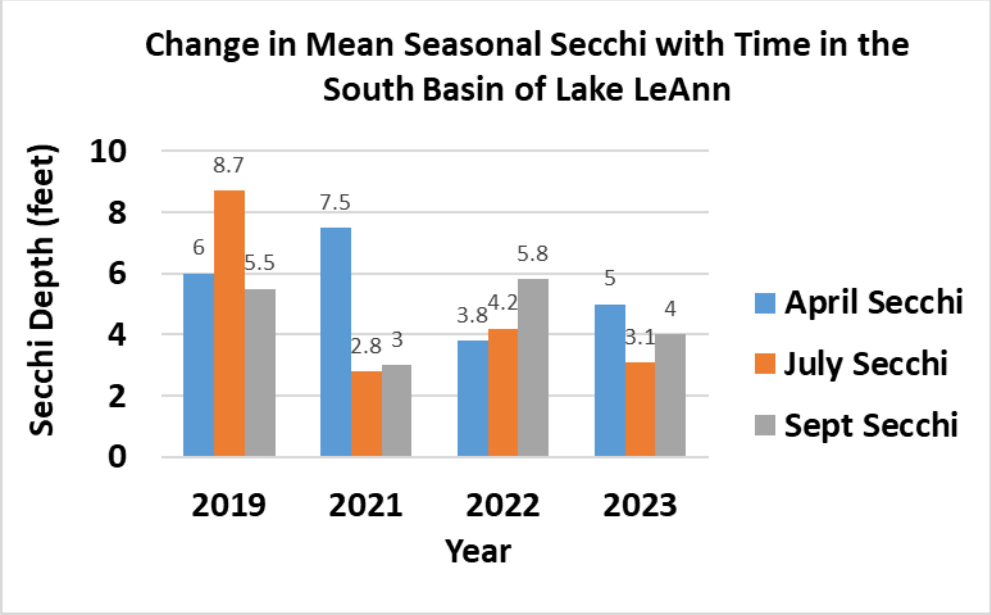

Figure 21. Change in mean seasonal Secchi with Time in the South Basin of Lake LeAnn.

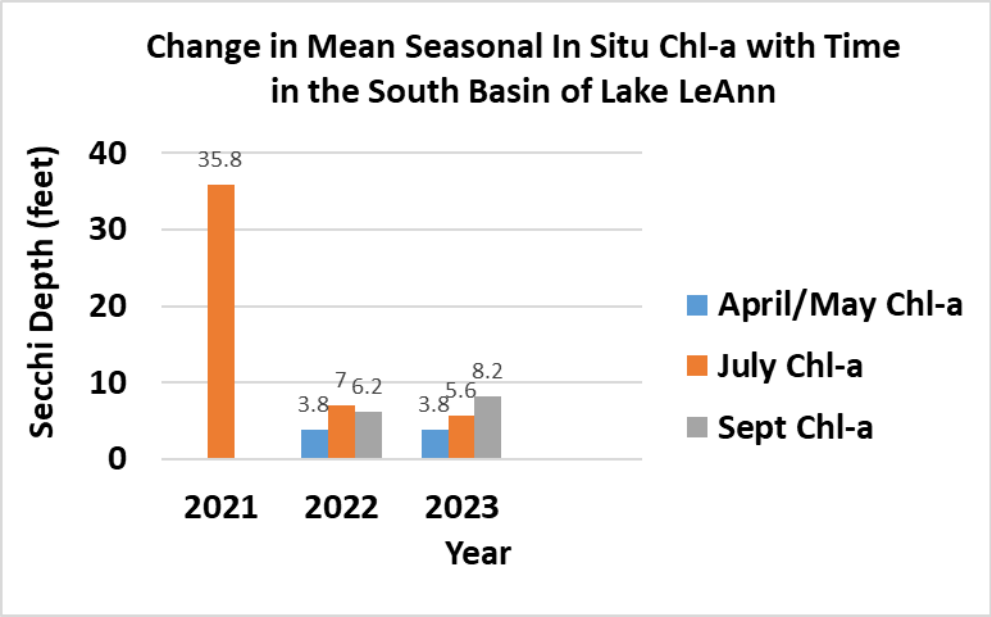

Figure 22. Change in mean seasonal Chl-a with Time in the South Basin of Lake LeAnn.

Table 33. Descriptive statistics of all water quality parameters in the Outlet of Lake LeAnn to Mirror Lake for LFA baseline parameters collected in April/May, July, and September of 2021-2023.

Water Quality Parameter	2021 Means ± SD	2022 Means ± SD	2023 Means ±SD
Water temp (°C)	22.1±6.7	22.5±4.5	21.1±7.6
pH (S.U.)	8.6±0.1	8.3±0.3	8.6±0.3
Dissolved oxygen (mg/L)	10.4±0.2	9.0±1.0	6.4±4.5
Conductivity (mS/cm)	483±16	601±191	563±122
Total Kjeldahl nitrogen (mg/L)	0.7±0.3	0.7±0.3	NA
Total inorganic nitrogen (mg/L)	0.045±0.0	0.100±0.0	0.070±0.1
Ammonia nitrogen (mg/L)	0.047±0.0	0.019±0.0	0.016±0.0
Nitrate nitrogen (mg/L)	0.100±0.0	0.100±0.0	0.100±0.0
Nitrite nitrogen (mg/L)	0.100±0.0	0.100±0.0	0.100±0.0
Total phosphorus (mg/L)	0.031±0.0	0.034±0.0	0.026±0.0
Ortho-phosphorus (mg/L)	0.010±0.0	0.020±0.0	NA
Total suspended solids (mg/L)	14.0±6.9	10.0±0.0	NA

II. Drains/CSA's

In 2019, CSA's 1A (S1), 2A (S2), S3, and N4 were sampled as they were flowing. In 2021, CSA's 1A, 2A, 1B, and 2B were sampled as they were flowing. In 2022, CSA's 1A, 2A, 1B, and 2B were also sampled as they were flowing. In 2023, CSA's 1A, 1B, 2A, 2B, 3, 4A, and 4B were flowing in April. In July and September, 2023, only CSA's 1A, 1B, 2A, and 2B were flowing. With four data sets for two of the sites (CSA 1A and CSA 2A), RLS developed trend graphs to demonstrate the changes in key parameters such as total phosphorus (TP) and total inorganic nitrogen (TIN).

CSA 1A has demonstrated a strong decrease in TP and TIN with time (Figures 23-24). CSA 2A has demonstrated an increase in TP in 2023 and an increase in 2022 with a decline to historic levels in 2023 (Figures 25-26). Continued mitigation of these CSA drains is recommended with biochar to remove the nutrients and decrease both TP and TIN. Recent mitigation efforts in 2A and 2B have resulted in reduction of solids in both drains with less transport to the lake basin.

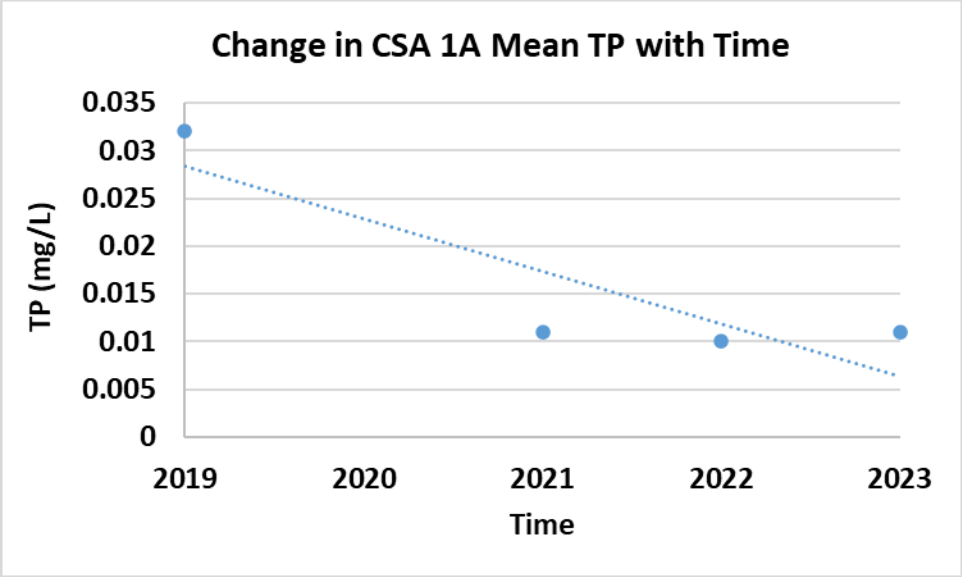

Figure 23. Change in CSA 1A mean TP with time (2019-2023).

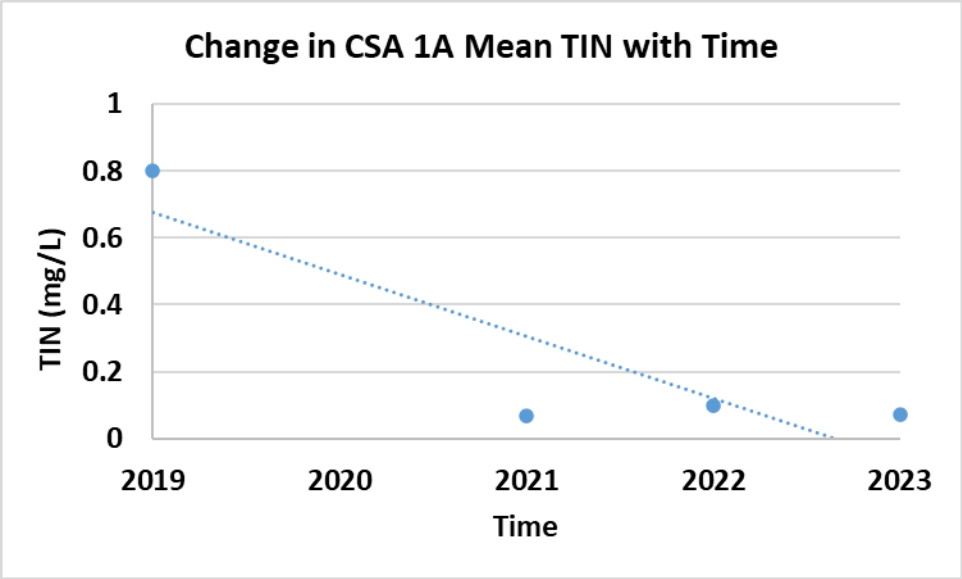

Figure 24. Change in CSA 1A mean TIN with time (2019-2023).

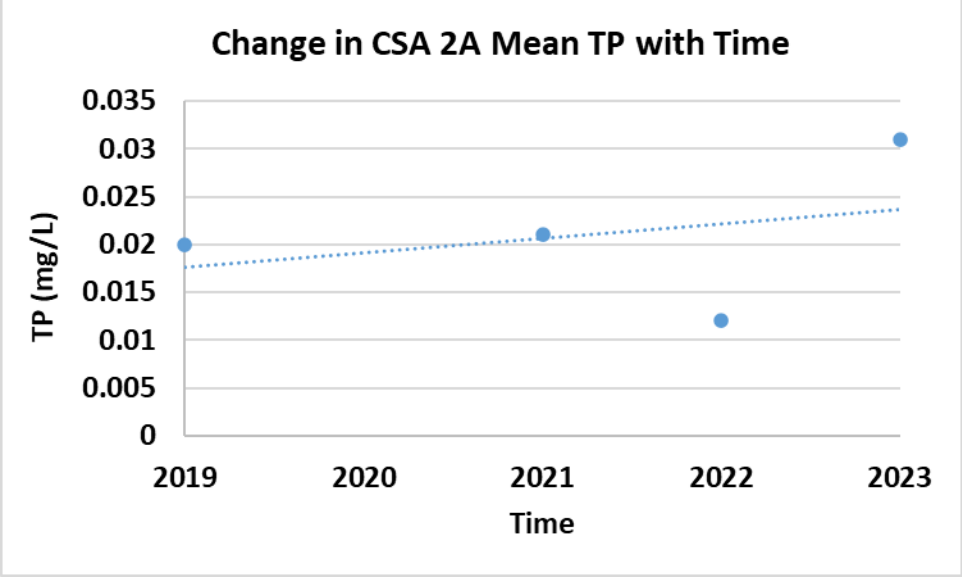

Figure 25. Change in CSA 2A mean TP with time (2019-2023).

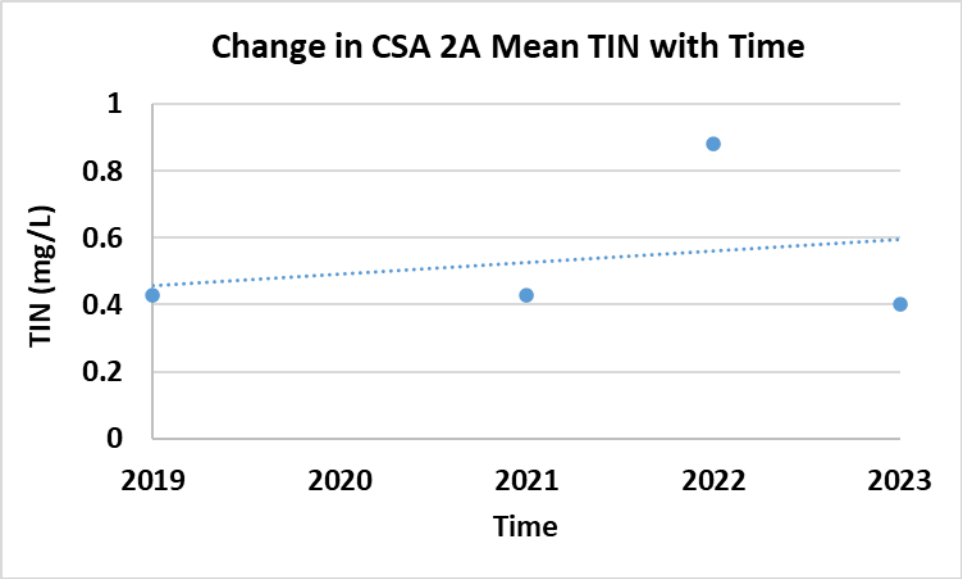

Figure 26. Change in CSA 2A mean TIN with time (2019-2023).

III. Aquatic Vegetation Biovolume

There have been modest reductions in the highest biovolume cover categories (60-80% and >80%) with time in both basins (Tables 34-35). This could be attributed to intensive efforts to reduce canopy invasives such as Eurasian watermilfoil and Curly-leaf Pondweed. It is most beneficial to aim for a goal of increased low-growing cover that allows light to reach the bottom to encourage germination of favorable native aquatic plants. The south basin in particular has shown favorable increases in the low-growing category.

Table 34. Lake LeAnn north basin aquatic vegetation biovolume by category percent cover of each category (relative cover 2019, 2021-2023).

Biovolume Cover Category	2019 % Relative Cover of Bottom by Category	2021 % Relative Cover by Category	2022 % Relative Cover by Category	2023 % Relative Cover by Category
<5%	59.7	32.1	56.6	43.1
5-20%	15.7	29.1	23.6	28.9
20-40%	9.9	19.8	12.6	15.0
40-60%	5.5	12.0	5.4	8.9
60-80%	3.4	2.0	0.7	1.5
>80%	5.7	4.3	1.1	1.5

Table 35. Lake LeAnn south basin aquatic vegetation biovolume by category percent cover of each category (relative cover 2019, 2021-2023).

Biovolume Cover Category	2019 % Relative Cover of Bottom by Category	2021 % Relative Cover by Category	2022 % Relative Cover by Category	2023 % Relative Cover by Category
<5%	58.0	70.3	71.1	76.4
5-20%	22.3	22.7	22.1	19.4
20-40%	12.3	5.0	4.7	4.4
40-60%	3.2	1.0	1.3	1.6
60-80%	1.8	0.3	0.3	0.1
>80%	2.4	0.6	0.5	0.1

IV. Sediment Relative Hardness:

The relative hardness of sediments in the north basin has slightly increased over time and the softest bottom category has decreased slightly over time for both basins (Tables 95-96). This is a small favorable outcome. The intermediate categories have remained relatively similar over the years but both basins had a favorable increase in the second-most consolidated category (0.3-0.4) since the LFA program began.

Table 36. Lake LeAnn north basin relative hardness of the lake bottom by category or hardness and percent cover of each category (relative cover).

Lake Bottom Relative Hardness Category	2019 Relative Cover %	2021 Relative Cover %	2022 Relative Cover %	2023 Relative Cover %
0.0-0.1	0.7	0.3	0.2	0.07
0.1-0.2	18.4	6.5	5.4	1.70
0.2-0.3	48.4	63.6	61.5	56.23
0.3-0.4	32.5	29.4	32.7	41.98
>0.4	0.01	0.1	0.2	0.02

Table 37. Lake LeAnn south basin relative hardness of the lake bottom by category or hardness and percent cover of each category (relative cover).

Lake Bottom Relative Hardness Category	2019 Relative Cover %	2021 Relative Cover %	2022 Relative Cover %	2023 Relative % Cover
0.0-0.1	0.5	0.0	0.1	0.01
0.1-0.2	18.2	8.7	6.1	0.48
0.2-0.3	49.9	64.9	63.2	51.26
0.3-0.4	31.3	26.4	30.5	48.25
>0.4	0.1	0.0	0.1	0.0

V. Phytoplankton:

In 2023, there was an over-abundance of blue-green algae in both lake basins. This reduced the number of favorable algae such as green algae and diatoms. Efforts must be made to reduce the blue-green algae to protect the biodiversity of favorable algae and improve water clarity and quality.

In addition to the phytoplankton data and the chlorophyll-a data referenced above, RLS also began measuring total chlorophyll with a calibrated in situ Turner Designs® fluorimeter. This method is EPA approved and is used to determine concentrations of chlorophyll-a at the surface, since most blue-green algae have gas vacuoles and are buoyant on the lake surface. RLS has found that even with proper sampling methods for chlorophyll-a laboratory methods, in situ numbers can be much higher. This is because the laboratory chlorophyll-a method measures the pigment in a composite sample and not solely at the surface. If the majority of the algae is at the surface and the samples are homogenized, then there is a higher chance that chlorophyll-a will remain undetected or low. The in situ data in Tables 38-39 clearly show a decline in chlorophyll-a over time since LFA began but numbers did increase in 2023 with prevalent blue-green algal blooms present in both basins. Blue-green algae cells are small but numerous and will increase the chlorophyll-a present in affected areas.

Table 38. Lake LeAnn North Basin in situ chlorophyll-a concentrations (2021-2023).

Sampling Location	July 19, 2021	May 10, 2022	July 12, 2022	Sept 15, 2022	Apr 26 2023	July 25 2023	Sept 19 2023
North #1	28	3	12	6	11.0	13.0	5.0
North #2	20	3	12	9	11.0	9.0	6.0
North #3	25	2	17	9	11.0	13.0	6.0
North #4	20	NA	5	7	11.0	11.0	7.0
North #5	20	3	10	9	11.0	11.0	3.0
MEAN	**22.6**	**2.8**	**11.2**	**8**	**11.0**	**11.4**	**5.4**

Table 39. Lake LeAnn South Basin in situ chlorophyll-a concentrations (2021-2023).

Sampling Location	19 July 2021	10 May 2022	12 July 2022	15 Sept 2022	Apr 26 2023	July 25 2023	Sept 19 2023
South #1	38	2	7	6	3.0	5.0	10.0
South #2	35	4	8	8	4.0	5.0	10.0
South #3	38	4	6	5	4.0	4.0	7.0
South #4	33	5	8	5	5.0	7.0	7.0
South #5	35	4	6	7	3.0	8.0	7.0
MEAN	**35.8**	**3.8**	**7.0**	**6.2**	**3.8**	**5.8**	**8.2**

VI. Management Recommendations for 2024:

The overall improvements of the LFA system have been modest relative to muck reduction, increased in dissolved oxygen, and declines in some nutrients. Much more improvement is needed to reduce the presence of blue-green algal blooms and increase water clarity in upcoming years. In 2024, the LFA program will be in its 4th year with one more year remaining until a new permit would be issued. RLS hopes to see considerable improvements with the proposed tasks listed below.

Continued whole-lake surveys and targeted control of the invasive Eurasian Watermilfoil, Curly-leaf Pondweed, and Starry Stonewort are needed to allow for germination and colonization of native aquatic plant species to improve biodiversity in Lake LeAnn. The Eurasian Watermilfoil in particular was showing strong signs of herbicide resistance and thus the new systemic herbicide ProcellaCOR® was used in 2022 and 2023 given its evaluated efficacy and longer-lasting control. RLS was present to oversee the herbicide applications with very little milfoil and Curly-leaf Pondweed remaining at the end of 2023. Care must be taken to avoid removal of too much aquatic vegetation as this can exacerbate blue-green algal blooms by allowing for less competition from plants for nutrients.

The BioBlast® bioaugmentation formula did not yield desired results over the past two years and thus RLS recommended the use of TimberChar Nutrient Harvesting Filters® biochar which is an EPA-certified product that has successfully reduced nutrients and solids in other lakes thereby reducing blue-green algal blooms and improving water clarity. This product will be distributed to lakefront owners on Lake LeAnn in 2024 and will be evaluated as a part of the current lake restoration program. Filter bags will also be used to reduce nutrients in the CSA's pending state approval.

RLS encourages the LLPOA to work with its residents to follow lakeshore best management practices (BMP's) such as proper annual inspection and pumping of septic systems and drain fields, protection of lakeshore emergent vegetation, preventing usage of all lawn fertilizers and watering with lake water instead, and public education and outreach. If nutrient loads to the lake are not reduced, the efficacy of the LFA system will be reduced and blue-green algal blooms will continue to thrive and further reduce water clarity and quality.