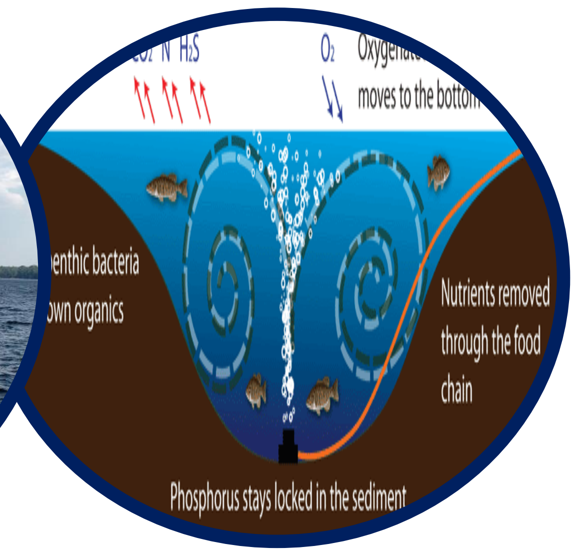
Paradise Lake Baseline and Year 1 Inversion Oxygenation Data Report 2018-2019 Emmet County, Michigan



Pursuant to MDEQ Permit # 12-24-0001-P

Prepared by: Restorative Lake Sciences
Dr. Jennifer L. Jermalowicz-Jones
18406 West Spring Lake Road
Spring Lake, Michigan 49456
www.restorativelakesciences.com
info@restorativelakesciences.com

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1.0 PROJECT INTRODUCTION & SUMMARY

Paradise Lake (Figure 1) is a 1,878-acre, shallow, eutrophic lake with a maximum depth of 15.1 feet (Gannon and Paddock, 1974). Paradise Lake is located in sections 7, 18, 10-15, 23, and 24 of Emmet and Cheboygan Counties (T.38N, R.34W). Over the past decade, the lake has become colonized with zebra mussels (*Dreissena polymorpha*), which have resulted in increased light transparency of the lake water and have caused accelerated growth rates of all aquatic vegetation, including the exotic submersed aquatic plant, Eurasian Watermilfoil (*Myriophyllum spicatum*).

Invasive milfoil has become a threat to the native aquatic vegetation communities in Paradise Lake, severely impedes navigation and recreational activities within the lake, creates a swimming hazard in areas of dense canopy growth, and has been shown to decrease lakefront property values (Halstead et *al*., 2003). Previous surveys by aquatic scientists from RLS during July of 2009, consisted of 609 grid sampling locations located throughout Paradise Lake and determined that approximately 497 acres of *M. spicatum* existed in the lake.

The lake also contains a moderate amount of submersed native vegetation that includes pondweeds and other native milfoil species. The recommended approach for treatment of the EWM infestation in Paradise Lake was integrated management with weevil stocking in protected areas where their reproductive life cycle success is most probable and where the *M. spicatum* canopy is least likely to be disturbed by boat propeller action (i.e. the most highly trafficked and developed areas). Weevils were stocked in Paradise Lake from 1998 until 2014 after which they were no longer available for commercial application. In areas where the EWM was highly dense and the canopy is extensive (i.e. West Basin), use of laminar flow aeration was recommended and was installed in 2012 by Lake Savers, LLC. The laminar flow aeration approach was also selected as it would also not interfere with the weevil life cycle and would possibly provide favorable conditions for the weevil. The use of mechanical harvesting would have led to fragmentation of milfoil and the use of dredging would be cost-prohibitive. The Paradise Lake Improvement Board (PLIB) and the Carp Lake Township community desired a natural, chemical-free approach for the milfoil control. It was decided and agreed upon that all natural alternatives should be tried before other less desirable options were considered. Although no bacteria were applied to the lake in previous years, it was applied to the lake in 2018 to try to reduce the milfoil canopy. Approximately 70,000 gallons of BioBlast® bioaugmentation was applied to the West Basin on June 15, 2019 by EverBlue Lakes, LLC.

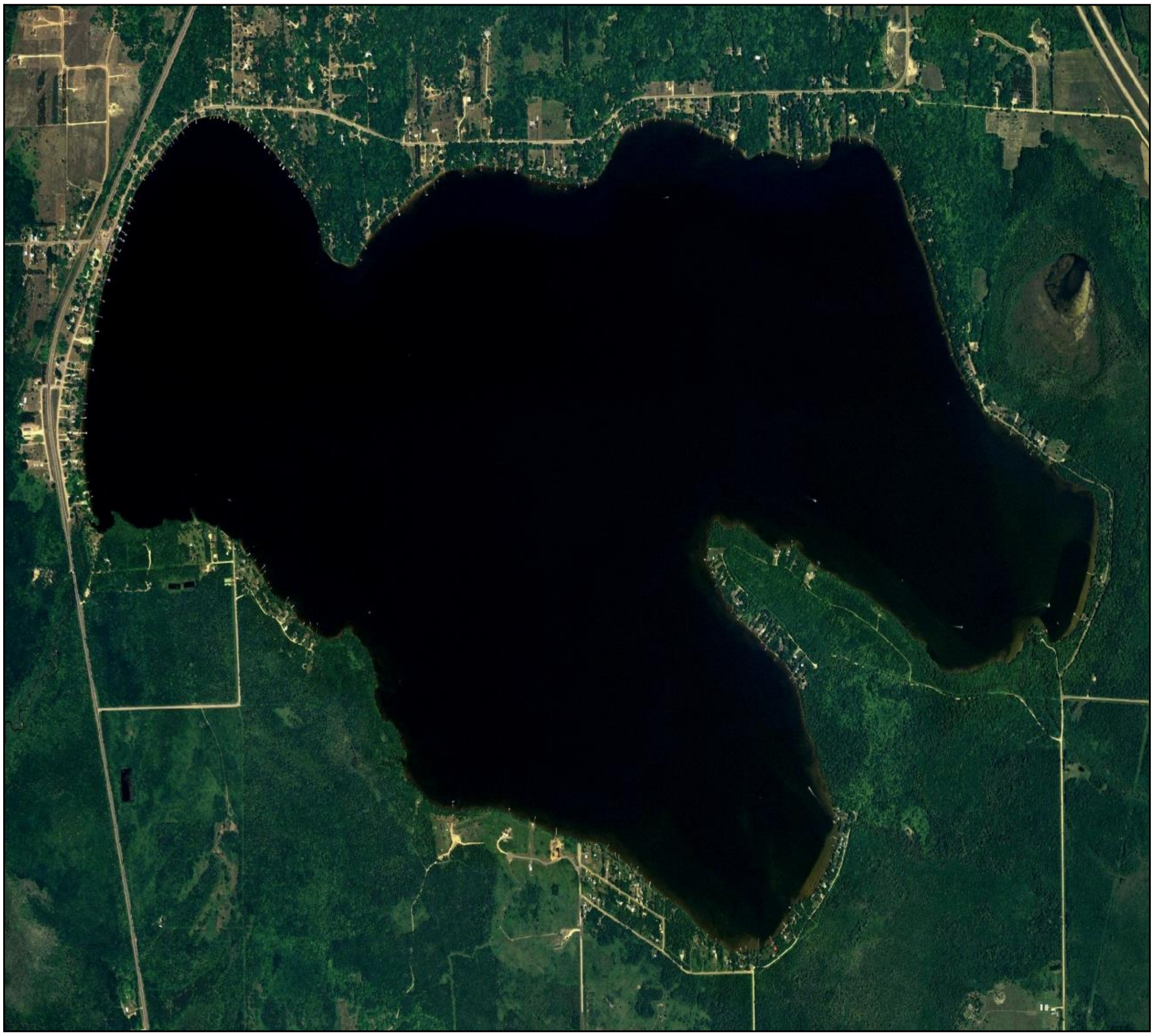

Figure 1. Aerial Photograph of Paradise Lake, Emmet and Cheboygan Counties, Michigan.

1.1 Summary of Paradise Lake Aeration Operations:

Laminar Flow Aeration (LFA) was installed in the 400-acre West Basin of Paradise Lake in 2012. Operation began later in the summer and the lake was monitored by RLS. Beginning in 2018, the MDEQ instituted LFA sampling and reporting requirements which are followed in this report. There are 57 (12-inch) ceramic diffusers and 77,400 feet of self-sinking airline in addition to three onshore air compressors that comprise the West Basin LFA system (Figure 2). This report serves as the new baseline and Year 1 post-aeration data requirement for MDEQ aeration permit #12-24-0001-P.

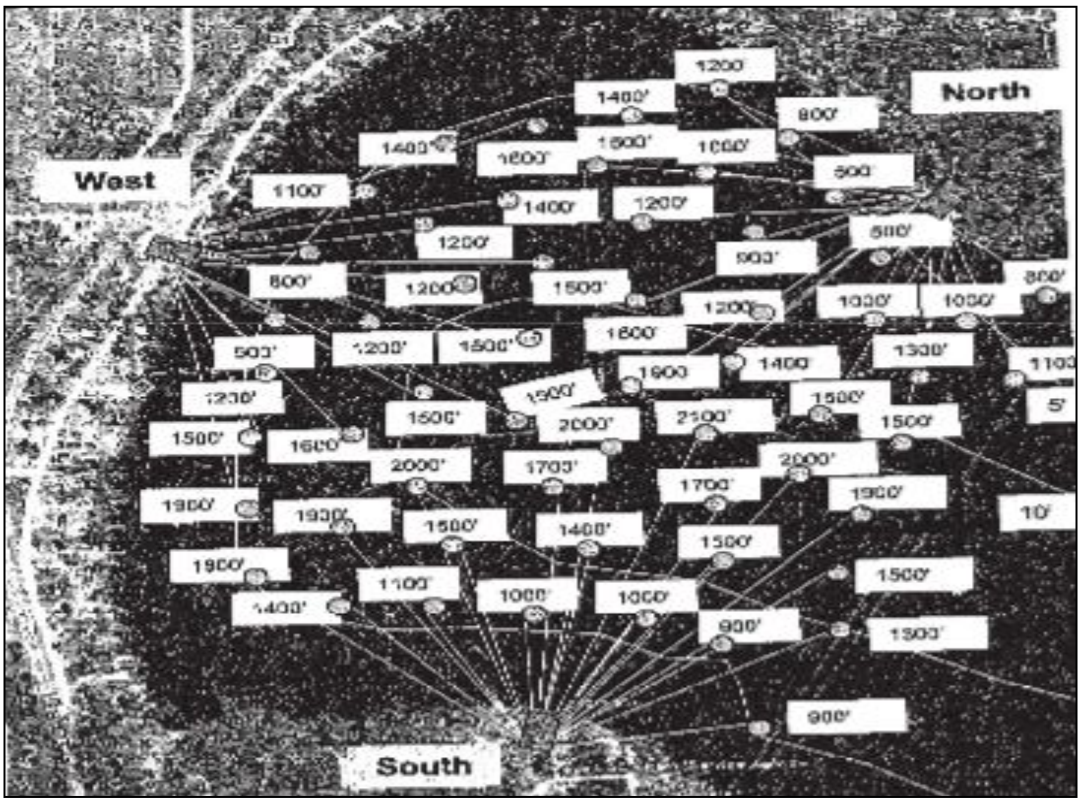

Figure 2. LFA Diffuser locations in the Paradise Lake West Basin LFA system.

1.2 Summary of Aeration Operation Objectives/Goals:

Paradise Lake is a large public lake and is utilized for fishing, swimming, boating, and waterfront living. Since 1998, Paradise Lake has been battling an invasive Eurasian Watermilfoil (EWM) problem. In 2012, it was decided by the Paradise Lake Improvement Board (PLIB) and public during well-attended public hearings to implement an LFA system in the West Basin of Paradise Lake.

The overall goal was to reduce the milfoil in the West Basin where it was the most dominant and canopied. In recent years, the lake has become dominated by aggressive aquatic vegetation over-growth and has become mucky in many areas. The lake residents have desired a more holistic approach to addressing both the aquatic plant 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 system for Paradise Lake include:

1) Reduction of invasive EWM in the West Basin of Paradise Lake

2) Reduction of muck/organic matter in the West Basin

1.3 Summary of Additional Lake Management Activities in Paradise Lake:

There were no aquatic herbicides, harvesting, or DASH activities noted in Paradise Lake in 2018 or in previous years. There was however, an enzyme/bacteria solution applied to the lake on July 8, 2018 by Lake Savers with the approved Rule 97 permit. No bacteria or enzymes were applied in previous years. The 2018 solution consisted of 200 lbs. of Simple Water Solution formula which is on the approved list of Rule 97 products by the MDEQ. Approximately 70,000 gallons of BioBlast® bioaugmentation was applied to the West Basin on June 15, 2019 by EverBlue Lakes, LLC. Lastly, a mechanical harvest of the lake was conducted in the northeast region of the lake to reduce the canopied EWM in that area. The approximate area of removal was around 30 acres.

2.0 PARADISE LAKE SAMPLING METHODS & PARAMETERS MEASURED

2.1 Summary of Equipment/Sampling Devices/Replicates/Parameters Measured:

Restorative Lake Sciences sampled 8 locations in the West Basin and an additional one location in the north shore region where LFA was proposed. Since the new MDEQ permit was not issued until July 3, 2018, RLS sampled the West Basin and north shore area on July 9, 2018 and September 18, 2018 and again on May 28, 2019, July 9, 2019, and September 29, 2019. Additional through the ice water quality sampling also occurred on February 21, 2019 where the ice was 24 inches in thickness.

All chemical water samples were collected at the specified permit depths (one each at middle depth of 5.0 feet at the sampling 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, total dissolved solids and pH) were measured with a calibrated Eureka Manta II® multi-probe meter at middle depths of the sampling sites. Total phosphorus was titrated and analyzed in the laboratory according to method SM 4500-P E. Ortho-phosphorus was titrated and analyzed in the laboratory according to method SM 4500-P E. Total suspended solids were analyzed for each sample using SM 2540 D-97. All of the aforementioned chemical parameters were analyzed at NELAC-certified Trace Analytical Laboratories in Muskegon, Michigan.

Chlorophyll-*a* was collected with a composite sampler throughout the euphotic zone. The sampler is depth-integrated and collects algae from throughout the entire water column, Chlorophyll-*a* was analyzed using method SM 10200H by Trace Analytical Laboratories in Muskegon, Michigan. 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. Chlorophyll-*a* samples were placed in glass brown amber 1-liter bottles with glutaraldehyde as a preservative and analyzed within 1 week after collection. All water samples were maintained on ice in a large cooler prior to being placed into the laboratory fridge.

Secchi transparency was measured in the photic zone by taking a mean of two measurements—the depth at which the Secchi disk disappeared and re-appeared. The Secchi disk was deployed on the starboard side of the boat.

Samples used for microscopic analysis of algal community composition were preserved with glutaraldehyde and counted with a Sedgewick Rafter® Counting Cell under high power objective on a bright-field Zeiss® compound microscope. A 500-ml homogenized subsample of the total (1L) sample collected was used to determine the relative abundance of algal genera in the samples. These algae were classified by relative abundance of percent of the total sample occupied by three classes of algae which included the Chlorophyta (green algae), Cyanophyta (blue-green algae), and Basillariophyta (diatoms).

2.2 Sampling Dates and Locations/GPS Coordinates:

RLS sampled 8 locations within the West Basin and one location near the north shore. The latter was collected as a baseline in case RLS recommended increasing the LFA zone into that region. As required by the new July 3, 2018 MDEQ LFA permit, RLS sampled the aforementioned areas on July 9, 2018 and again on September 18, 2018 and again on May 28, 2019, July 9, 2019, and September 29, 2019. Additional data will be collected as required by the MDEQ for the aeration permit in future years. All water quality samples were collected at mid-depth from the sampling locations according to Figure 3. The GPS coordinates for these locations are also noted in Table 1 below.

Figure 3. 2018-2019 water quality sampling locations on the Paradise Lake West Basin and at the North (East) shore (sampled in 2018 only), Emmet County, MI.

Table 1. GPS locations for each of the 8 West Basin sampling sites and the North shore (East 1) sampling site in Paradise Lake (2018-2019).

Sampling Site	GPS North	GPS West
A	N45º 41.364'	W84º 46.024'
B	N45° 41.419’	W 84° 45.989’
C	N45° 41.388’	W 84° 46.264’
D	N 45° 41.245’	W 84° 46.328’
E	N 45° 41.784’	W 84° 46.372’
F	N 45° 41.588’	W 84° 46.455’
G	N 45° 41.145’	W 84° 45.957’
H	N 45° 41.403’	W 84° 46.657’
East 1 (North shore)	N 45° 41.740’	W 84° 44.827’

3.0 PARADISE LAKE 2018 BASELINE WATER QUALITY SAMPLING RESULTS

At the beginning of a new MDEQ permit cycle, the first year is considered baseline whereas the second and last years of the 5-year permit are all considered post-baseline. This allows scientists such as RLS to determine the true efficacy of the LFA system on each particular lake.

All baseline physical water quality data is shown in Tables 2-5 below. Baseline chemical water quality data is shown in Tables 6-9 below. Secchi transparency for the West Basin on July 9, 2018 was approximately 5.9 feet and the measurement for the West Basin on September 18, 2018 was 11.6 feet.

3.1 Paradise Lake Baseline Physical Water Quality Data Tables:

The following data tables display the physical water quality data collected from both the West Basin and north shore area of Paradise Lake on July 9, 2018 and on September 18, 2018. Physical water quality parameters collected include location, depth, water temperature, dissolved oxygen, pH, specific conductivity, and total dissolved solids.

Table 2. Pre-Aeration Data in the West Basin on July 9, 2018.

Sample Location	Depth (m)	Water Temp (°C)	Dissolved Oxygen (mg/L)	pH (S.U.)	Specific Conductivity (Ms/cm)	Total Dissolved Solids (mg/L)
B	0	24.7	8.3	8.7	237	152
	0.5	24.7	8.3	8.7	237	152
	1.0	24.6	8.3	8.7	237	152
	1.5	24.6	8.3	8.7	237	152
	2.0	24.2	8.3	8.7	237	152
	2.5	24.2	8.3	8.7	237	152
	3.0	24.2	8.2	8.7	237	152
	3.5	24.2	8.2	8.6	237	152
C	0	24.9	8.3	8.7	237	152
	0.5	24.9	8.3	8.7	237	152
	1.0	24.9	8.3	8.7	237	152
	1.5	24.6	8.4	8.7	237	152
	2.0	24.3	8.4	8.7	237	151
	2.5	24.3	8.3	8.7	237	151
	3.0	24.3	8.3	8.7	237	151
D	0	25.3	8.5	8.8	236	151
	0.5	25.3	8.6	8.7	236	151
	1.0	25.0	8.7	8.8	236	150
	1.5	24.7	8.8	8.8	235	150
	2.0	24.3	8.9	8.8	234	150
	2.5	23.8	8.9	8.7	235	151
G	0	25.3	8.7	8.8	235	150
	0.5	25.2	8.8	8.8	235	150
	1.0	25.0	8.9	8.8	235	151
	1.5	24.3	8.9	8.8	235	150
	2.0	24.0	8.8	8.8	234	150
H	0.5	24.9	8.5	8.8	236	151

	1.0	**24.9**	**8.6**	**8.8**	**236**	**151**
	1.5	**24.9**	**8.8**	**8.8**	**236**	**151**
	2.0	**24.6**	**8.9**	**8.8**	**237**	**151**
	2.5	**24.1**	**8.8**	**8.7**	**237**	**152**
	3.0	**23.9**	**8.7**	**8.7**	**237**	**152**
F	**0.5**	**25.5**	**8.6**	**8.8**	**235**	**150**
	1.0	**25.3**	**9.0**	**8.8**	**235**	**150**
	1.5	**24.7**	**9.1**	**8.7**	**234**	**149**
	2.0	**24.0**	**8.9**	**8.7**	**233**	**149**
	2.5	**23.9**	**8.9**	**8.8**	**233**	**149**
E	**0.5**	**25.6**	**8.5**	**8.7**	**238**	**152**
	1.0	**25.6**	**8.7**	**8.7**	**238**	**152**
	1.5	**25.5**	**8.8**	**8.7**	**237**	**152**
A	**0.5**	**25.2**	**8.3**	**8.8**	**235**	**150**
	1.0	**25.2**	**8.5**	**8.8**	**235**	**150**
	1.5	**25.2**	**8.7**	**8.8**	**235**	**150**
	2.0	**25.2**	**8.8**	**8.8**	**235**	**150**
	2.5	**24.0**	**8.9**	**8.7**	**235**	**151**
	3.0	**24.2**	**8.9**	**8.7**	**235**	**151**
	3.5	**24.1**	**8.8**	**8.7**	**236**	**151**
	4.0	**24.0**	**8.7**	**8.7**	**235**	**150**

Table 3. Pre-Aeration Data in the north shore area on July 9, 2018

Sample Location	**Depth (m)**	**Water Temp (°C)**	**Dissolved Oxygen (mg/L)**	**pH (S.U.)**	**Specific Conductivity (Ms/cm)**	**Total Dissolved Solids (mg/L)**
East 1 (north shore)	**0**	**24.9**	**8.5**	**8.5**	**236**	**151**
	0.5	**24.9**	**8.6**	**8.6**	**236**	**151**
	1.0	**24.9**	**8.8**	**8.8**	**236**	**151**
	1.5	**24.6**	**8.9**	**8.8**	**237**	**151**
	2.0	**24.1**	**8.8**	**8.7**	**237**	**152**
	2.5	**23.9**	**8.7**	**8.7**	**237**	**152**

Table 4. Pre-Aeration Data in the West Basin on September 18, 2018.

Sample Location	Depth (m)	Water Temp (°C)	Dissolved Oxygen (mg/L)	pH (S.U.)	Specific Conductivity (Ms/cm)	Total Dissolved Solids (mg/L)
B	1.5	22.2	8.6	8.8	237	152
	2.0	22.2	8.7	8.8	237	152
	2.5	22.2	8.7	8.8	237	152
	3.0	22.2	8.7	8.8	237	152
	3.5	21.7	8.4	8.7	238	152
C	0	22.0	8.5	8.8	237	151
	0.5	22.0	8.5	8.8	237	151
	1.0	22.0	8.6	8.8	237	151
	1.5	22.1	8.6	8.8	237	151
	2.0	22.0	8.7	8.8	237	151
	2.5	22.0	8.7	8.8	237	152
	3.0	21.2	8.5	8.6	238	152
D	0	21.9	8.3	8.7	238	152
	0.5	22.0	8.1	8.7	238	152
	1.0	22.0	8.1	8.7	238	152
	1.5	22.0	8.0	8.7	238	152
	2.0	21.9	8.0	8.7	238	152
	2.5	22.0	8.0	8.7	238	152
G	0	21.9	8.2	8.7	239	153
	0.5	21.9	7.9	8.7	238	153
	1.0	22.0	7.8	8.7	238	153
	1.5	22.0	7.8	8.7	238	153
	2.0	22.0	7.8	8.6	238	153
	2.5	21.9	7.7	8.6	239	153
E	0	22.8	9.1	9.1	218	140
	0.5	22.7	9.3	9.1	218	140
	1.0	22.7	9.5	9.1	218	140
	1.5	22.7	9.6	9.1	218	140
F	0	22.4	8.8	9.0	227	146
	0.5	22.4	8.8	9.0	227	145
	1.0	22.4	8.9	9.0	227	146
	1.5	22.4	8.9	9.0	227	145
	2.0	22.4	8.9	9.0	227	145
H	0	21.5	9.1	8.8	236	151

	0.5	**21.6**	**8.8**	**8.8**	**236**	**151**
	1.0	**21.6**	**8.6**	**8.8**	**236**	**151**
	1.5	**21.6**	**8.5**	**8.8**	**236**	**151**
	2.0	**21.6**	**8.5**	**8.8**	**236**	**151**
	2.5	**21.5**	**8.3**	**8.7**	**238**	**153**

Table 5. Pre-Aeration Data in the north shore area on September 18, 2018.

Sample Location	Depth (m)	Water Temp (°C)	Dissolved Oxygen (mg/L)	pH (S.U.)	Specific Conductivity (Ms/cm)	Total Dissolved Solids (mg/L)
East 1 (north shore)	**0**	**22.4**	**8.6**	**8.9**	**236**	**151**
	0.5	**22.4**	**8.6**	**8.9**	**236**	**151**
	1.0	**22.4**	**8.7**	**8.9**	**236**	**151**
	1.5	**22.4**	**8.7**	**8.9**	**236**	**151**
	2.0	**22.4**	**8.7**	**8.9**	**236**	**151**
	2.5	**22.3**	**8.8**	**8.9**	**238**	**152**

3.2 Paradise Lake Baseline Chemical Water Quality Data Tables:

The following data tables display the chemical water quality data collected from both the West Basin and north shore area of Paradise Lake on July 9, 2018 and on September 18, 2018. Chemical water quality parameters consisted of sample location, total phosphorus (TP), ortho-phosphorus (also known as SRP), total suspended solids (TSS), total Kjeldahl nitrogen (TKN), total inorganic nitrogen (TIN), ammonia nitrogen ($NH3+$), and chlorophyll-*a*.

Table 6. Pre-Aeration Data in the West Basin on July 9, 2018.

Sample Location	TP (mg/L)	Ortho-P (mg/L)	TSS (mg/L)	TKN (mg/L)	TIN (mg/L)	NH3+ (mg/L)	Chl-a
B	0.016	<0.010	<10	<0.50	0.032	0.032	1.07
C	0.018	<0.010	<10	0.64	0.040	0.040	0.712
D	0.013	<0.010	<10	<0.50	0.018	0.018	0
G	0.014	<0.010	<10	<0.50	0.015	0.015	0.356
H	0.020	<0.010	<10	1.2	0.037	0.037	0.178
F	0.011	<0.010	<10	<0.50	0.019	0.019	0
E	0.017	<0.010	<10	<0.50	0.013	0.013	0.178
A	0.019	<0.010	<10	0.73	0.024	0.024	0.890

Table 7. Pre-Aeration Data in the north shore area on July 9, 2018.

Sample Location	TP (mg/L)	Ortho-P (mg/L)	TSS (mg/L)	TKN (mg/L)	TIN (mg/L)	NH3+ (mg/L)	Chl-a
East 1	0.019	<0.010	<10	0.76	0.018	0.018	1.60
East 1	0.018	<0.010	<10	0.91	0.017	0.017	0

Table 8. Pre-Aeration Data in the West Basin on September 18, 2018

Sample Location	TP (mg/L)	Ortho-P (mg/L)	TSS (mg/L)	TKN (mg/L)	TIN (mg/L)	NH3+ (mg/L)	Chl-a
B	<0.010	<0.010	<10	0.72	<0.010	<0.010	0
C	<0.010	<0.010	<10	0.78	<0.010	<0.010	0
D	<0.010	<0.010	<10	0.75	<0.010	<0.010	0
G	<0.010	<0.010	<10	0.67	<0.010	<0.010	0
H	0.011	<0.010	<10	0.68	<0.010	<0.010	0
F	0.010	<0.010	<10	0.62	<0.010	<0.010	0
E	0.011	<0.010	<10	0.80	<0.010	<0.010	0
A	<0.010	<0.010	<10	0.72	<0.010	<0.010	0

Table 9. Pre-Aeration Data in the north shore area on September 18, 2018

Sample Location	TP (mg/L)	Ortho-P (mg/L)	TSS (mg/L)	TKN (mg/L)	TIN (mg/L)	NH3+ (mg/L)	Chl-a
East 1	<0.010	<0.010	<10	0.93	<0.010	<0.010	0

3.3 Paradise Lake Baseline Water Quality Parameter Profiles/Graphs/Raw Data Summary:

In order to visually see the changes in some water quality parameters with time and depth, graphs that plot depth versus a water quality parameter can be useful in addition to data tables. For this project, there was negligible change in depth with water quality parameters such as water temperature, dissolved oxygen, pH, specific conductivity, total suspended solids, and ortho-phosphorus among depths. In addition, this permit required water samples collected from the middle-depth (all collected at 5.0 feet) at each of 8 sampling locations. These samples were all collected at the same depth and thus depth integrated profiles with other parameters could also not be attained. Raw data are contained in Appendix A along with corresponding laboratory reports.

Weather conditions during the July 9, 2018 sampling event were 82°F and sunny with calm winds. Weather conditions during the September 18, 2018 sampling event were 68°F, misty, with winds out of the west around 10-15 mph. This information was also recorded on the data sheets.

3.4 Paradise Lake Baseline Phytoplankton Community Data:

The algal genera were determined from composite water samples collected over the 8 sampling locations in the West Basin of Paradise Lake in July and September of 2018 were analyzed with a Zeiss® compound bright-field microscope. The genera present included the Chlorophyta (green algae): *Haematococcus* sp., *Chlorella* sp., *Staurastrum* sp., *Scenedesmus* sp., *Cladophora* sp., *Mougeotia* sp., *Pediastrum* sp., and *Radiococcus* sp., The Cyanophyta (blue-green algae): G*leocapsa* sp., and *Oscillatoria* sp.; the Bascillariophyta (diatoms*): Cymbella* sp., *Navicula* sp., *Fragilaria* sp., *Synedra* sp., *Rhoicosphenia* sp., and *Tabellaria* sp. The aforementioned species indicate a diverse algal flora and represent a good diversity of algae. A breakdown of the relative proportion of each for the West Basin and north shore for both sampling dates is shown in Table 10 below.

Table 10. Relative abundance of algal taxa in Paradise Lake (July 9, 2018 and September 18, 2018).

Sampling Date	Sampling Location	% Green Algae	% Blue-green Algae	% Diatoms
7-9-18	**B**	58	3	39
	C	52	1	47
	D	60	0	40
	G	38	2	60
	H	46	6	48
	F	41	3	56
	E	62	1	37
	A	57	6	37
	East 1	69	4	27
9-18-18	**B**	41	6	53
	C	61	4	35
	D	52	1	47
	G	67	2	31
	H	32	1	67
	F	40	5	55
	E	35	4	61
	A	43	7	50
	East 1	39	2	59

3.5 Paradise Lake Baseline West Basin Aquatic Vegetation Bio Volume Scan/Data:

A lake scan using a Lowrance HDS 8® sonar unit with GPS software was used to create an aquatic vegetation bio volume map (Figure 4) of the lake on August 20, 2014 as a baseline. An additional scan of the West Basin was conducted by RLS on September 18, 2018. The bio volume map below shows the relative aquatic vegetation bio volume in Paradise Lake. The blue areas represent no vegetation whereas green areas represent low-growing vegetation and red areas represent high-growing vegetation.

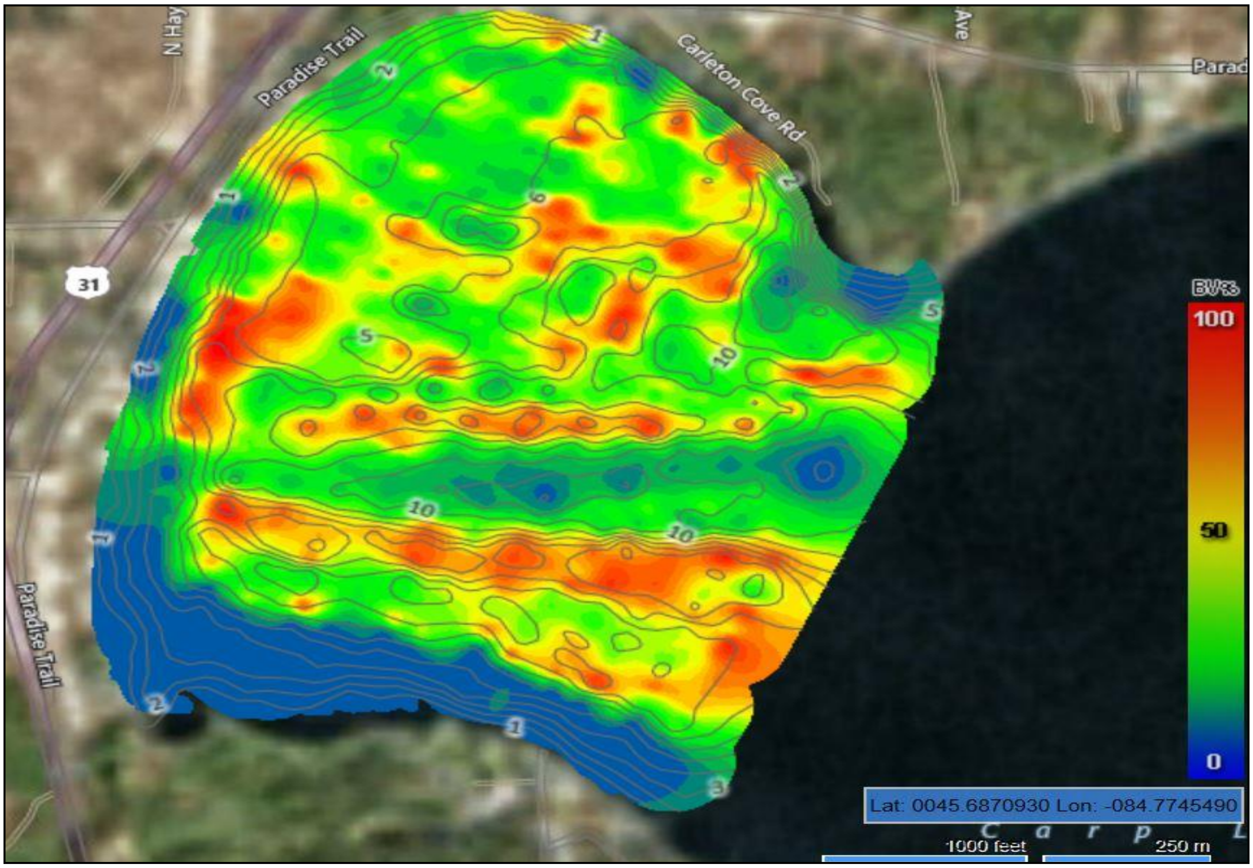

Figure 4. An aquatic vegetation bio volume scan map of the West Basin of Paradise Lake (RLS, 2014).

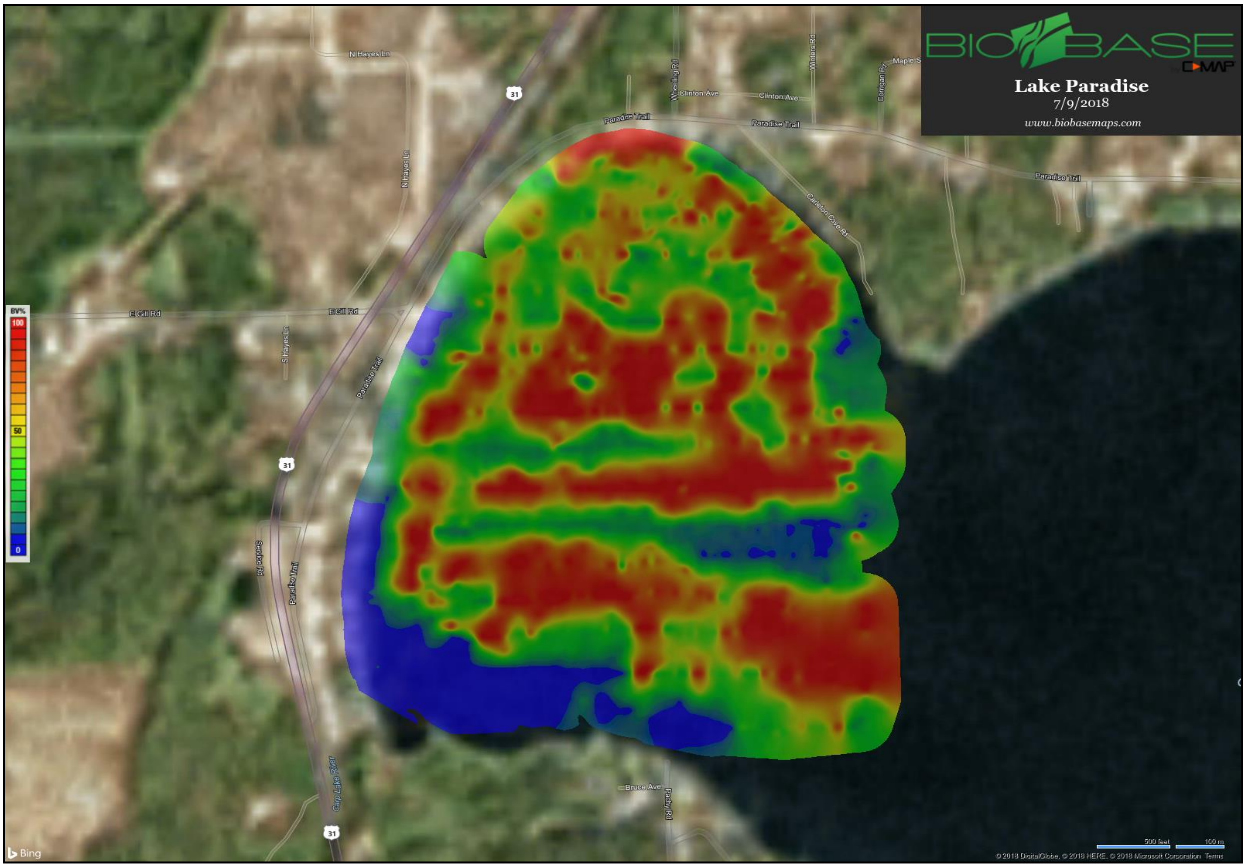

Figure 5. An aquatic vegetation bio volume scan map of the West Basin of Paradise Lake (RLS, 2018).

Table 11. Aquatic vegetation bio volume comparisons of 2014 to 2018 in the West Basin of Paradise Lake.

Aquatic Vegetation Biovolume % Cover	2014	2018
0-5%	11.35	13.46
5-20%	21.55	24.54
20-40%	27.20	17.45
40-60%	14.50	7.57
60-80%	12.10	6.89
>80%	13.29	30.10

A GPS Point-Intercept Survey was conducted in the West Basin of Paradise Lake on October 28, 2013 and again on September 18, 2018. The relative abundance of each aquatic plant species can be found on the data tables below (Table 12 and 13). In 2013, the estimated EWM cover was approximately 20.4% of the West Basin whereas in 2018 it was measured around 18.2% cover. The two most common native aquatic plant species included Robbins Pondweed which was estimated at 29.1% cover in the West Basin in 2013 and at 25.1% cover in 2018. White-stem Pondweed was also common and occupied 20.1% cover in 2013 and 18.5% cover in 2018. The presence of these two pondweeds in the corresponding densities minimizes some of the potential for milfoil to further expand in the West Basin and even in some areas of the remainder of the lake system.

The whole-lake aquatic vegetation bio volume scans demonstrated a measurable increase in the highest bio volume category (>80%) by 2018 but a decrease in the next two highest bio volume categories and an increase in the two lowest bio volume categories. This is consistent with the findings that the dense EWM polygons have been increasing but the low-growing vegetation has been increasing in areas that were not previously colonized.

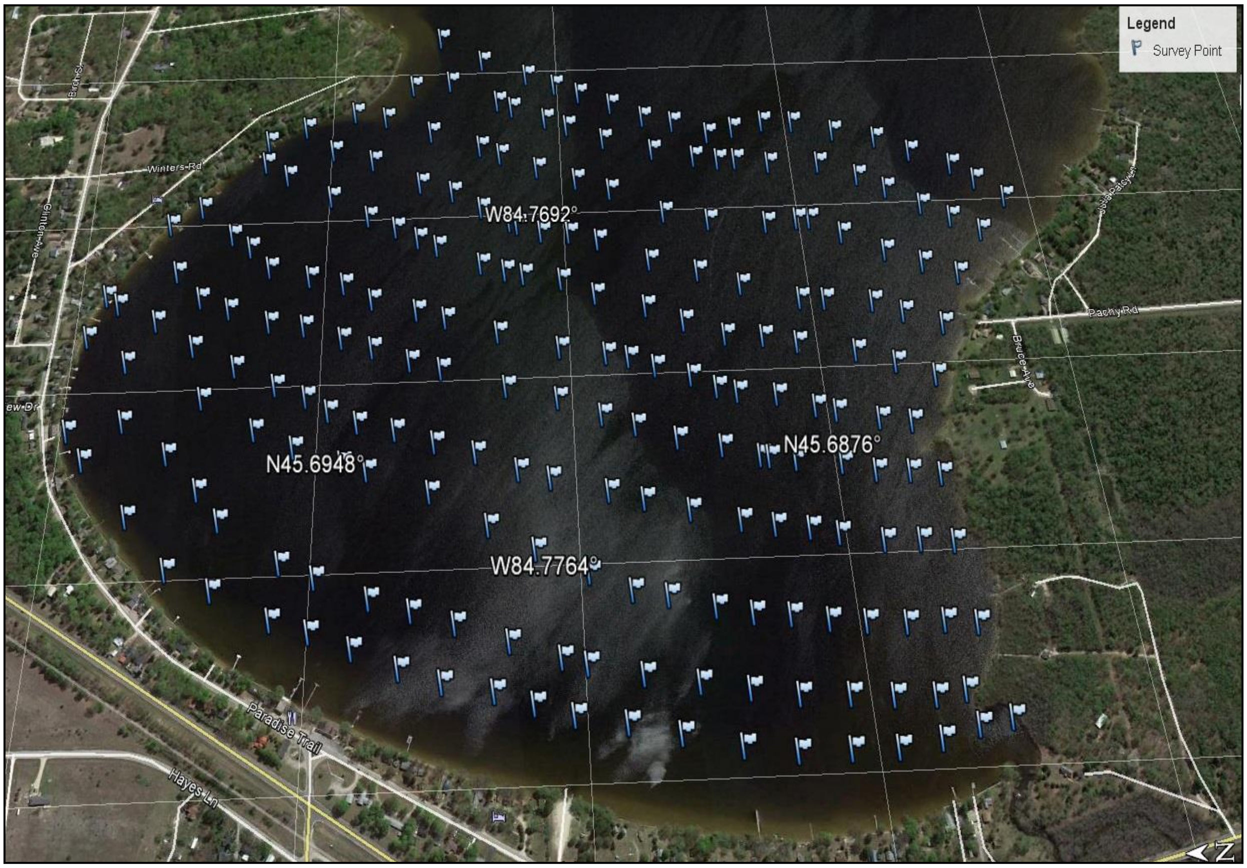

Figure 6. Aquatic plant sampling locations in the West Basin of Paradise Lake collected on October 28, 2013 and again on September 18, 2018.

Table 12. Paradise Lake West Basin aquatic vegetation survey data (October 28, 2013).

LAKE NAME- PARADISE LAKE-WEST BASIN POST-AERATION **COUNTY- EMMET** **SURVEY DATE: October 28, 2013**

Standard Aquatic Vegetation Summary Sheet SURVEY BY: JLJ, MJS

		Total number of AVAS's 220 for each Density Category				Calculations				Sum of Previous Four Columns	Total Number of AVAS's	Quotient of Column 9 divided by Column 10		
		A	B	C	D	Category A x 1	Category B x10	Category C x 40	Category D x 80					
Code No	Plant Name	1	2	3	4	5	6	7	8	9	10	11	Code No	Plant Name
1	Eurasian Watermilfoil	8	7	32	39	8	70	1280	3120	4478	220	20.4	1	EurasianWatermilfoil
2	Curly leaf Pondweed					0	0	0	0	0	220	0.0	2	Curly leaf Pondweed
3	Chara	4	24	10		4	240	400	0	644	220	2.9	3	Chara
4	Thinleaf Pondweed					0	0	0	0	0	220	0.0	4	Thinleaf Pondweed
5	Flatstem Pondweed	2	16	4		2	160	160	0	322	220	1.5	5	Flatstem Pondweed
6	Robbins Pondweed	12	23	56	49	12	230	2240	3920	6402	220	29.1	6	Robbins Pondweed
7	Variable leaf Pondweed	12	27	12		12	270	480	0	762	220	3.5	7	Variable leaf Pondweed
8	Whitestem Pondweed	2	54	43	27	2	540	1720	2160	4422	220	20.1	8	Whitestem Pondweed
9	Richardsons Pondweed	6	54	36	19	6	540	1440	1520	3506	220	15.9	9	Richardsons Pondweed
10	Illinois Pondweed	17	22	5		17	220	200	0	437	220	2.0	10	Illinois Pondweed
11	Large leaf Pondweed	6	11	7	19	6	110	280	1520	1916	220	8.7	11	Large leaf Pondweed
12	American Pondweed					0	0	0	0	0	220	0.0	12	American Pondweed
13	Floating leaf Pondweed					0	0	0	0	0	220	0.0	13	Floating leaf Pondweed
14	Water Stargrass					0	0	0	0	0	220	0.0	14	Water Stargrass
15	Wild Celery	5	62	6	2	5	620	240	160	1025	220	4.7	15	Wild Celery
16						0	0	0	0	0	220	0.0	16	
17	Northern Watermilfoil					0	0	0	0	0	220	0.0	17	Northern Watermilfoil
18	Whorled Watermilfoil	2	55	4	1	2	550	160	80	792	220	3.6	18	Whorled Watermilfoil
19	Leafless Watermilfoil					0	0	0	0	0	220	0.0	19	Leafless Watermilfoil
20	Coontail					0	0	0	0	0	220	0.0	20	Coontail
21	Elodea	10	22	8	15	10	220	320	1200	1750	220	8.0	21	Elodea
22	Bladderwort Large	12	8	14	2	12	80	560	160	812	220	3.7	22	Bladderwort Large
23	Bladderwort-mini					0	0	0	0	0	220	0.0	23	Bladderwort-mini
24	Buttercup					0	0	0	0	0	220	0.0	24	Buttercup
25	Southern Naiad					0	0	0	0	0	220	0.0	25	Southern Naiad
26	Slender Naiad	15	56	25	4	15	560	1000	320	1895	220	8.6	26	Slender Naiad
27	Spikerush					0	0	0	0	0	220	0.0	27	Spikerush
28	Ribbon leaf Pondweed					0	0	0	0	0	220	0.0	28	Ribbon leaf Pondweed
29	Small leaf Pondweed					0	0	0	0	0	220	0.0	29	Small leaf Pondweed
30	White Waterlily					0	0	0	0	0	220	0.0	30	White Waterlily
31	Yellow Waterlily	4	3			4	30	0	0	34	220	0.2	31	Yellow Waterlily
32	Watershield					0	0	0	0	0	220	0.0	32	Watershield
33	Duckweed					0	0	0	0	0	220	0.0	33	Duckweed
34						0	0	0	0	0	220	0.0	34	
35	Watermeal					0	0	0	0	0	220	0.0	35	Watermeal
36	Arrowhead					0	0	0	0	0	220	0.0	36	Arrowhead
37	Pickerelweed					0	0	0	0	0	220	0.0	37	Pickerelweed
38	Arrow Arum					0	0	0	0	0	220	0.0	38	Arrow Arum
39	Cattails	4	4	3	3	4	40	120	240	404	220	1.8	39	Cattails
40	Bulrushes	4	3	2	4	4	30	80	320	434	220	2.0	40	Bulrushes
41						0	0	0	0	0	220	0.0	41	
42	Swamp Loosestrife					0	0	0	0	0	220	0.0	42	Swamp Loosestrife
43	Purple Loosestrife					0	0	0	0	0	220	0.0	43	Purple Loosestrife
44	Yellow Iris					0	0	0	0	0	220	0.0	44	Yellow Iris
												136.5		

Table 13. Paradise Lake West Basin aquatic vegetation survey data (September 18, 2018).

LAKE NAME- PARADISE LAKE-WEST BASIN PRE-AERATION COUNTY- EMMET SURVEY DATE: SEPTEMBER 18, 2(

Standard Aquatic Vegetation Summary Sheet SURVEY BY: GLJ

		Total number of AVAS's 220 for each Density Category				Calculations Category	Category	Category	Category	Sum of Previous Four Columns	Total Number of AVAS's	Quotient of Column 9 divided by Column 10		
		A	B	C	D	A x 1	B x10	C x 40	D x 80					
Code No	Plant Name	1	2	3	4	5	6	7	8	9	10	11	Code No	Plant Name
1	Eurasian Watermilfoil	4	1	36	32	4	10	1440	2560	4014	220	18.2	1	EurasianWatermilfoil
2	Curly leaf Pondweed					0	0	0	0	0	220	0.0	2	Curly leaf Pondweed
3	Chara	7	29	12	1	7	290	480	80	857	220	3.9	3	Chara
4	Thinleaf Pondweed	2	1	1		2	10	40	0	52	220	0.2	4	Thinleaf Pondweed
5	Flatstem Pondweed	5	22	10	1	5	220	400	80	705	220	3.2	5	Flatstem Pondweed
6	Robbins Pondweed	15	26	51	40	15	260	2040	3200	5515	220	25.1	6	Robbins Pondweed
7	Variable leaf Pondweed	10	22	8	3	10	220	320	240	790	220	3.6	7	Variable leaf Pondweed
8	Whitestem Pondweed	4	42	27	32	4	420	1080	2560	4064	220	18.5	8	Whitestem Pondweed
9	Richardsons Pondweed	10	60	31	24	10	600	1240	1920	3770	220	17.1	9	Richardsons Pondweed
10	Illinois Pondweed	18	24	2	1	18	240	80	80	418	220	1.9	10	Illinois Pondweed
11	Large leaf Pondweed	16	20	2	19	16	200	80	1520	1816	220	8.3	11	Large leaf Pondweed
12	American Pondweed					0	0	0	0	0	220	0.0	12	American Pondweed
13	Floating leaf Pondweed					0	0	0	0	0	220	0.0	13	Floating leaf Pondweed
14	Water Stargrass					0	0	0	0	0	220	0.0	14	Water Stargrass
15	Wild Celery	4	52	4	15	4	520	160	1200	1884	220	8.6	15	Wild Celery
16						0	0	0	0	0	220	0.0	16	
17	Northern Watermilfoil	1				1	0	0	0	1	220	0.0	17	Northern Watermilfoil
18	Whorled Watermilfoil	6	58	9	7	6	580	360	560	1506	220	6.8	18	Whorled Watermilfoil
19	Leafless Watermilfoil					0	0	0	0	0	220	0.0	19	Leafless Watermilfoil
20	Coontail					0	0	0	0	0	220	0.0	20	Coontail
21	Elodea	12	18	4	22	12	180	160	1760	2112	220	9.6	21	Elodea
22	Bladderwort Large	5	13	17	6	5	130	680	480	1295	220	5.9	22	Bladderwort Large
23	Bladderwort-mini					0	0	0	0	0	220	0.0	23	Bladderwort-mini
24	Buttercup					0	0	0	0	0	220	0.0	24	Buttercup
25	Southern Naiad					0	0	0	0	0	220	0.0	25	Southern Naiad
26	Slender Naiad	11	60	21	9	11	600	840	720	2171	220	9.9	26	Slender Naiad
27	Spikerush					0	0	0	0	0	220	0.0	27	Spikerush
28	Ribbon leaf Pondweed					0	0	0	0	0	220	0.0	28	Ribbon leaf Pondweed
29	Small leaf Pondweed					0	0	0	0	0	220	0.0	29	Small leaf Pondweed
30	White Waterlily					0	0	0	0	0	220	0.0	30	White Waterlily
31	Yellow Waterlily	3	4	2		3	40	80	0	123	220	0.6	31	Yellow Waterlily
32	Watershield	1				1	0	0	0	1	220	0.0	32	Watershield
33	Duckweed					0	0	0	0	0	220	0.0	33	Duckweed
34						0	0	0	0	0	220	0.0	34	
35	Watermeal					0	0	0	0	0	220	0.0	35	Watermeal
36	Arrowhead					0	0	0	0	0	220	0.0	36	Arrowhead
37	Pickerelweed					0	0	0	0	0	220	0.0	37	Pickerelweed
38	Arrow Arum					0	0	0	0	0	220	0.0	38	Arrow Arum
39	Cattails	5	5	5	2	5	50	200	160	415	220	1.9	39	Cattails
40	Bulrushes	3	4	4	3	3	40	160	240	443	220	2.0	40	Bulrushes
41						0	0	0	0	0	220	0.0	41	
42	Swamp Loosestrife					0	0	0	0	0	220	0.0	42	Swamp Loosestrife
43	Purple Loosestrife					0	0	0	0	0	220	0.0	43	Purple Loosestrife
44	Yellow Iris					0	0	0	0	0	220	0.0	44	Yellow Iris
												145.2		

3.6 Paradise Lake Baseline West Basin Sediment Bottom Hardness Scan/Data:

A benthic (bottom) scan using a Lowrance HDS 8® sonar unit with GPS software was used to create an aquatic sediment bottom hardness map (Figure 7) of the Paradise Lake West Basin on August 20, 2014 as a baseline. An additional scan of the West Basin was conducted on July 9, 2018 (Figure 8). The areas light beige in color represent soft, mucky bottom whereas areas that are red represent firmer bottom. Colors in the orange family represent intermediate bottom hardness types. This baseline information is important since it allows us to determine if the aeration system has reduced muck throughout the lake bottom. Table 14 below shows the actual numerical results from calculations based on the algorithm-based scans.

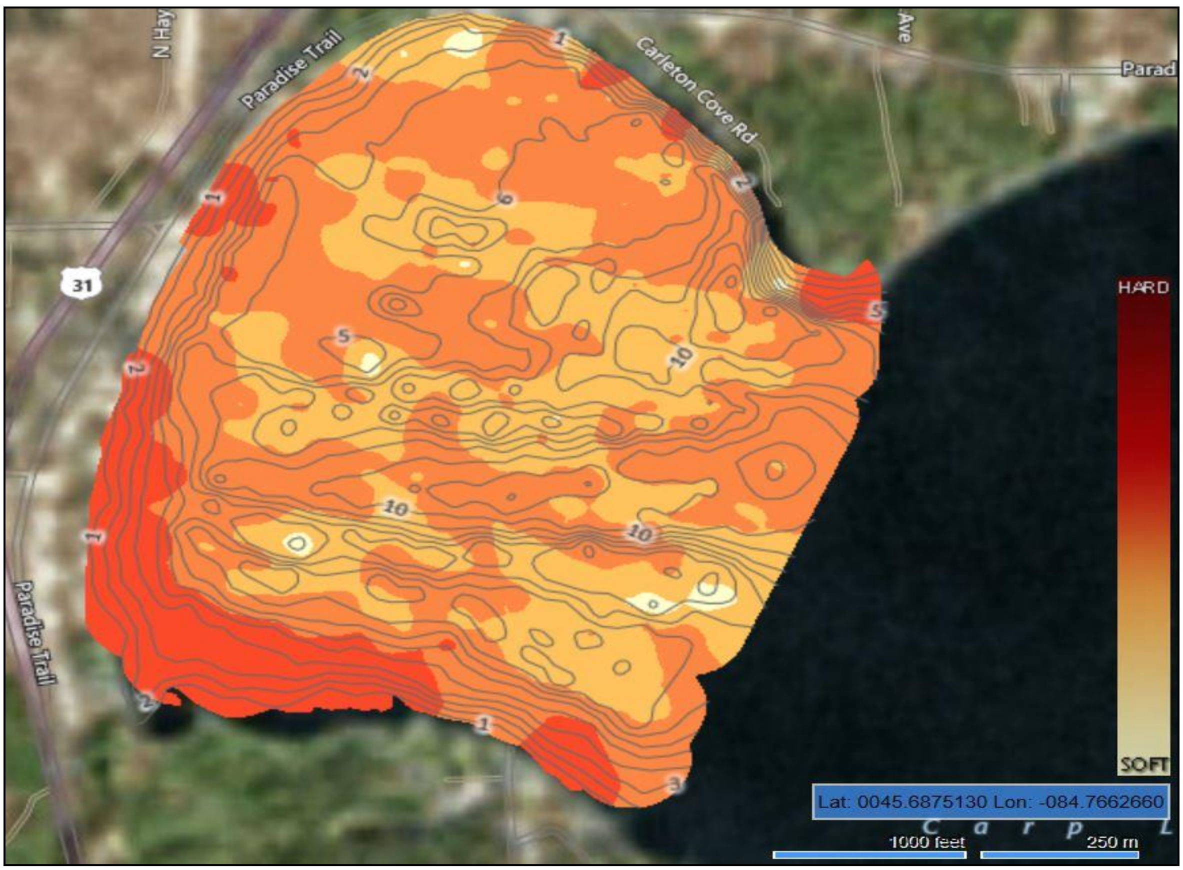

Figure 7. A bottom sediment hardness map of the Paradise Lake West Basin (RLS, 2014).

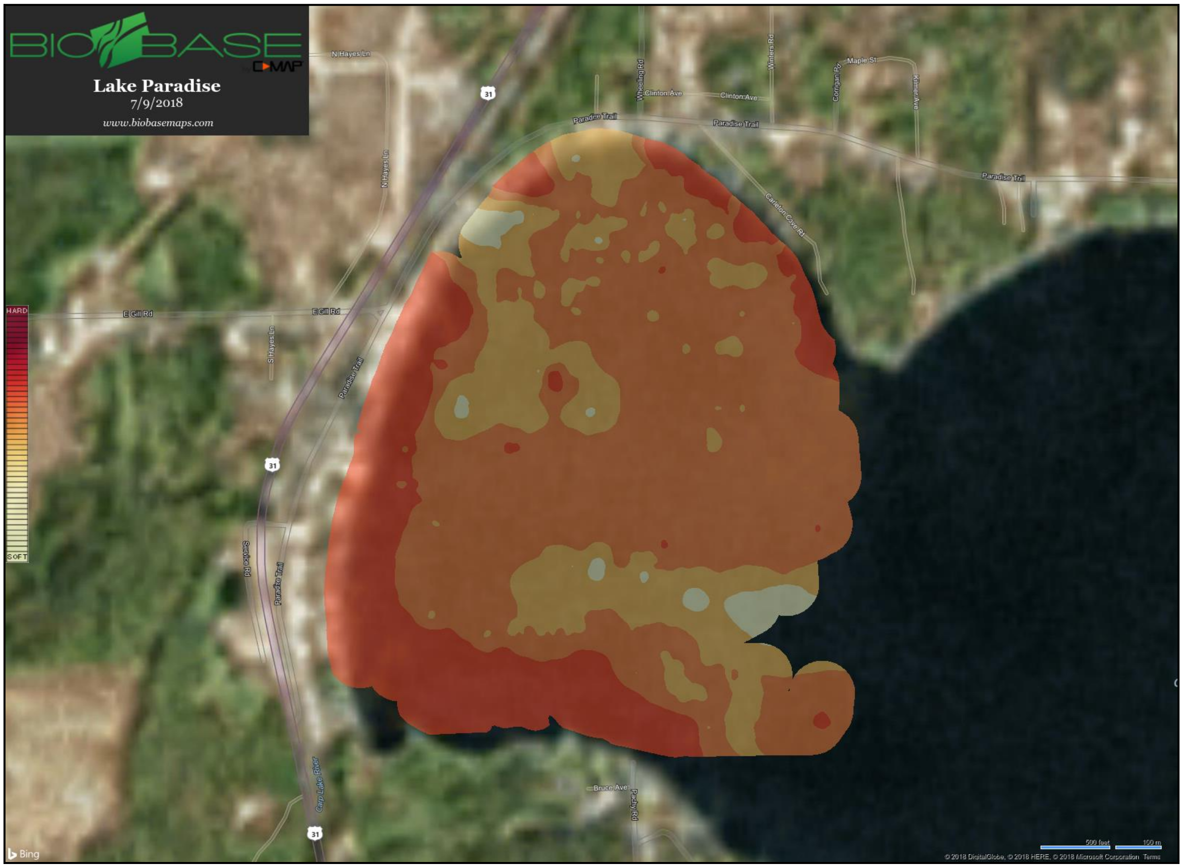

Figure 8. A bottom sediment hardness map of the Paradise Lake West Basin (RLS, 2018).

Table 14. Sediment bottom hardness in the West Basin of Paradise Lake in 2014 and 2018.

Sediment Hardness Category	2014 %	2018 %
<0.1	0.13	0.14
0.1-0.2	1.78	2.30
0.2-0.3	58.44	34.69
0.3-0.4	33.18	48.46
>0.4	6.47	14.41

3.7 Paradise Lake West Basin Sediment Organic Matter Data:

Sediment organic matter (OM) was measured in the 8 West Basin sampling sites on October 28, 2013 and again on September 18, 2018. It was also measured in years between these but these two data sets were used to look at long-term changes since they represent the earliest and latest data sets for this parameter. Table 15 below shows the comparisons of the sites for each of the two years. The particle composition of the Paradise Lake West Basin sediments consist of primarily sand and fibrous muck.

Table 15. Sediment OM in the West Basin of Paradise Lake in 2014 and 2018.

Sampling Site	OM 2014 %	OM 2018 %
WB 1	55	53
WB 2	60	40
WB 3	39	35
WB 4	50	38
WB 5	25	53
WB 6	3	46
WB 7	49	50
WB 8	1.6	44

4.0 PARADISE LAKE 2019 YEAR 1 WATER QUALITY SAMPLING RESULTS

At the beginning of a new MDEQ permit cycle, the first year is considered baseline whereas the second and last years of the 5-year permit are all considered post-baseline. This allows scientists such as RLS to determine the true efficacy of the LFA system on each particular lake.

All Year 1 physical water quality data is shown in Tables 16-19 below. Year 1 chemical water quality data is shown in Tables 20-22 below. Secchi transparency for the West Basin on May 28, 2019 was visible to the bottom (>11.0 feet), and the measurement for the West Basin on July 9, 2019 was also visible to the bottom (>11.0 feet). Finally, the Secchi measurement for the West Basin on September 29, 2019 was also visible to the bottom (>11.0 feet).

4.1 Paradise Lake Year 1 Physical Water Quality Data Tables:

The following data tables display the physical water quality data collected from both the West Basin and north shore area of Paradise Lake on May 28, 2019, July 9, 2019, and on September 29, 2019. Physical water quality parameters collected include location, depth, water temperature, dissolved oxygen, pH, specific conductivity, and total dissolved solids. NOTE: North Shore data was not collected in 2019 (as in 2018), since the PLIB decided not to use that baseline data to apply for an additional northeast shore LFA permit.

Table 16. Post-Aeration Data in the West Basin on May 28, 2019.

Sample Location	Depth (m)	Water Temp (°C)	Dissolved Oxygen (mg/L)	pH (S.U.)	Specific Conductivity (Ms/cm)	Total Dissolved Solids (mg/L)
B	0	18.1	8.7	8.7	229	142
	0.5	18.1	8.7	8.7	229	142
	1.0	18.1	8.5	8.5	229	144
	1.5	18.0	8.5	8.5	226	144
	2.0	18.0	8.5	8.5	226	144
	2.5	17.9	8.5	8.5	229	146
	3.0	17.9	8.5	8.5	231	146
	3.5	17.7	8.5	8.5	229	141
C	0	18.0	8.6	8.4	226	139
	0.5	18.0	8.6	8.4	226	140
	1.0	18.0	8.8	8.5	226	141
	1.5	18.0	8.8	8.5	227	141
	2.0	17.9	8.6	8.4	227	143
	2.5	17.8	8.6	8.4	229	139
	3.0	17.7	8.7	8.4	227	141
D	0	18.0	8.6	8.5	228	136
	0.5	18.0	8.6	8.4	228	135
	1.0	18.0	8.7	8.4	228	134
	1.5	18.0	8.7	8.4	230	139
	2.0	17.9	8.7	8.4	230	140
	2.5	17.8	8.7	8.4	230	140
G	0	18.1	8.9	8.6	231	141
	0.5	18.1	8.9	8.5	231	141
	1.0	18.0	8.8	8.5	233	141
	1.5	18.0	8.8	8.5	233	142

	2.0	17.9	8.8	8.5	233	141
H	0	18.0	8.7	8.4	231	140
	0.5	18.0	8.6	8.5	231	140
	1.0	18.0	8.6	8.5	231	141
	1.5	17.9	8.6	8.5	231	141
	2.0	17.9	8.8	8.4	228	141
	2.5	17.9	8.8	8.4	228	140
	3.0	17.8	8.8	8.4	229	143
F	0	18.1	8.7	8.5	226	140
	0.5	18.1	8.7	8.6	226	139
	1.0	18.0	8.5	8.6	226	144
	1.5	17.9	8.5	8.6	229	144
	2.0	17.9	8.5	8.4	233	144
	2.5	17.9	8.5	8.5	236	146
E	0	18.0	8.5	8.6	232	140
	0.5	18.0	8.5	8.7	233	139
	1.0	17.9	8.5	8.7	233	138
	1.5	17.9	8.5	8.6	233	141
A	0	18.0	8.8	8.5	222	136
	0.5	18.0	8.8	8.5	225	136
	1.0	18.0	8.8	8.5	225	136
	1.5	17.9	8.7	8.5	225	138
	2.0	17.9	8.7	8.5	227	139
	2.5	17.9	8.6	8.4	227	137
	3.0	17.9	8.7	8.5	222	136
	3.5	17.9	8.6	8.5	229	140
	4.0	17.9	8.7	8.5	223	139

Table 17. Post-Aeration Data in the West Basin on July 9, 2019.

Sample Location	Depth (m)	Water Temp (°C)	Dissolved Oxygen (mg/L)	pH (S.U.)	Specific Conductivity (Ms/cm)	Total Dissolved Solids (mg/L)
B	0	26.1	5.7	8.5	223	143
	0.5	25.3	6.9	8.5	223	143
	1.0	24.4	7.3	8.5	223	143
	1.5	24.1	7.6	8.5	223	142
	2.0	24.0	7.7	8.4	223	143
	2.5	24.0	7.6	8.4	223	143
	3.0	23.9	7.6	8.4	223	143
	3.5	23.8	7.4	8.4	223	143
C	0	25.6	7.9	8.3	223	143
	0.5	25.6	8.0	8.3	223	143
	1.0	25.5	8.0	8.3	223	143
	1.5	24.5	8.0	8.2	223	142
	2.0	24.1	8.1	8.2	222	142
	2.5	23.9	7.7	8.2	224	143
	3.0	23.8	7.5	8.2	224	143
	3.5	23.6	7.3	8.2	222	142
D	0	25.4	7.9	8.4	222	143
	0.5	25.3	7.8	8.4	222	142
	1.0	25.3	7.9	8.4	223	142
	1.5	24.4	7.9	8.4	222	142
	2.0	23.9	8.0	8.4	220	141
	2.5	23.6	8.1	8.4	220	141
	3.0	23.3	8.1	8.4	220	141
G	0	25.8	8.2	8.2	221	142
	0.5	25.8	8.2	8.2	221	142
	1.0	24.5	7.9	8.2	220	140
	1.5	23.9	8.0	8.2	220	141
	2.0	23.7	8.1	8.2	220	141
	2.5	23.6	8.1	8.2	220	141
H	0	25.8	7.6	8.4	224	144
	0.5	25.9	7.8	8.4	224	144
	1.0	25.9	7.8	8.4	224	144
	1.5	25.5	7.9	8.4	223	144
	2.0	24.2	8.2	8.4	222	142

	2.5	**23.9**	**8.0**	**8.4**	**225**	**144**
	3.0	**23.5**	**8.0**	**8.4**	**226**	**145**
F	**0**	**26.1**	**7.9**	**8.2**	**226**	**144**
	0.5	**26.2**	**7.8**	**8.2**	**226**	**145**
	1.0	**26.1**	**7.7**	**8.3**	**226**	**145**
	1.5	**26.0**	**7.6**	**8.3**	**226**	**144**
	2.0	**24.0**	**7.4**	**8.3**	**224**	**143**
	2.5	**23.8**	**7.5**	**8.3**	**224**	**143**
E	**0**	**25.7**	**7.7**	**8.5**	**225**	**146**
	0.5	**25.3**	**7.9**	**8.4**	**226**	**145**
	1.0	**25.0**	**7.9**	**8.4**	**226**	**144**
	1.5	**24.4**	**8.1**	**8.4**	**226**	**145**
	2.0	**24.3**	**8.1**	**8.4**	**225**	**144**
A	**0**	**26.5**	**7.7**	**8.4**	**226**	**145**
	0.5	**25.4**	**7.8**	**8.4**	**226**	**145**
	1.0	**24.3**	**7.9**	**8.4**	**227**	**145**
	1.5	**24.1**	**7.8**	**8.4**	**225**	**144**
	2.0	**24.0**	**7.8**	**8.4**	**225**	**144**
	2.5	**23.8**	**7.7**	**8.3**	**225**	**144**
	3.0	**23.6**	**7.8**	**8.3**	**224**	**143**
	3.5	**23.0**	**7.6**	**8.2**	**226**	**146**

Table 18. Post-Aeration Data in the West Basin on September 29, 2019.

Sample Location	Depth (m)	Water Temp (°C)	Dissolved Oxygen (mg/L)	pH (S.U.)	Specific Conductivity (Ms/cm)	Total Dissolved Solids (mg/L)
B	0	21.0	9.1	8.5	232	149
	0.5	21.0	9.1	8.5	233	150
	1.0	21.0	9.1	8.6	232	150
	1.5	21.0	9.1	8.6	232	150
	2.0	21.0	9.1	8.6	233	151
	2.5	21.0	8.9	8.5	236	150
	3.0	21.0	8.9	8.4	236	153
	3.5	21.0	8.9	8.4	239	153
C	0	21.0	8.9	8.5	230	150
	0.5	21.0	9.0	8.5	231	148
	1.0	21.0	9.0	8.5	232	148
	1.5	21.0	9.0	8.5	232	148
	2.0	21.0	8.9	8.4	235	148
	2.5	21.0	9.1	8.4	235	151
	3.0	21.0	9.0	8.4	235	151
D	0	21.0	8.9	8.4	231	146
	0.5	21.0	9.1	8.4	229	146
	1.0	21.0	9.1	8.5	230	146
	1.5	21.0	9.1	8.5	230	148
	2.0	21.0	8.9	8.4	229	148
	2.5	21.0	9.0	8.3	231	150
G	0	21.0	9.0	8.5	227	146
	0.5	21.0	8.9	8.5	227	148
	1.0	21.0	8.9	8.5	227	149
	1.5	21.0	8.9	8.4	230	150
	2.0	21.0	8.9	8.4	229	148
E	0	21.0	8.7	8.6	229	136
	0.5	21.0	8.7	8.6	229	136
	1.0	21.0	8.7	8.6	229	131
	1.5	21.0	8.8	8.5	229	131
F	0	21.0	8.6	8.4	226	139
	0.5	21.0	8.9	8.5	226	140
	1.0	21.0	8.9	8.5	229	139
	1.5	21.0	8.9	8.5	230	139

	2.0	**21.0**	**8.9**	**8.5**	**231**	**139**
	2.5	**21.0**	**8.9**	**8.4**	**231**	**139**
H	**0**	**21.0**	**8.7**	**8.5**	**229**	**139**
	0.5	**21.0**	**8.8**	**8.5**	**229**	**140**
	1.0	**21.0**	**8.8**	**8.6**	**226**	**138**
	1.5	**21.0**	**8.8**	**8.6**	**226**	**141**
	2.0	**21.0**	**8.8**	**8.6**	**221**	**142**
	2.5	**21.0**	**8.7**	**8.6**	**223**	**138**
	3.0	**21.0**	**8.8**	**8.5**	**226**	**140**

Table 19. Post-Aeration Data through the ice on February 21, 2019.

Depth (ft)	Temp (°C)	DO (mg/L)	pH (SU)	Cond (mS/cm)	TDS (mg/L)	Secchi (ft)
0	**0.8**	**10.4**	**6.9**	**266**	**170**	**4.9**
0.5	**0.9**	**9.8**	**7.1**	**265**	**170**	
1.0	**1.7**	**8.8**	**7.2**	**264**	**169**	
1.5	**3.6**	**8.0**	**7.2**	**270**	**175**	
2.0	**4.1**	**6.1**	**7.2**	**277**	**178**	
2.5	**4.3**	**5.1**	**7.3**	**280**	**179**	
3.0	**4.3**	**4.3**	**7.3**	**282**	**180**	

4.2 Paradise Lake Year 1 Chemical Water Quality Data Tables:

The following data tables display the chemical water quality data collected from both the West Basin of Paradise Lake on May 28, 2019, July 9, 2019, and on September 29, 2019. Chemical water quality parameters consisted of sample location, total phosphorus (TP), ortho-phosphorus (also known as SRP), total suspended solids (TSS), total Kjeldahl nitrogen (TKN), total inorganic nitrogen (TIN), ammonia nitrogen (NH_3^+), and chlorophyll-*a*.

Table 20. Post-Aeration Data in the West Basin on May 28, 2019.

Sample Location	TP (mg/L)	Ortho-P (mg/L)	TSS (mg/L)	TKN (mg/L)	TIN (mg/L)	NH3+ (mg/L)	Chl-a
B	0.027	<0.010	<10	<0.5	0.310	0.013	0
C	0.022	<0.010	<10	<0.5	0.350	0.016	0
D	0.018	<0.010	<10	<0.5	0.330	0.013	0
G	0.029	<0.010	<10	<0.5	0.350	0.013	0
H	0.026	<0.010	<10	<0.5	0.390	0.012	0
F	0.030	<0.010	<10	<0.5	0.370	0.014	0
E	0.025	<0.010	<10	<0.5	0.380	0.012	0
A	0.027	<0.010	<10	<0.5	0.310	0.012	1.96

Table 21. Post-Aeration Data in the West Basin on July 9, 2019.

Sample Location	TP (mg/L)	Ortho-P (mg/L)	TSS (mg/L)	TKN (mg/L)	TIN (mg/L)	NH3+ (mg/L)	Chl-a
B	0.011	<0.010	<10	<0.5	0.022	0.022	0
C	0.011	<0.010	<10	<0.5	0.027	0.027	0
D	0.012	<0.010	<10	<0.5	0.013	0.013	0
G	0.013	<0.010	<10	<0.5	0.023	0.023	0
H	0.013	<0.010	<10	0.5	0.021	0.021	0
F	0.013	<0.010	<10	<0.5	0.023	0.023	0
E	0.013	<0.010	<10	<0.5	0.023	0.023	0
A	0.014	<0.010	<10	0.7	0.034	0.034	0

Table 22. Post-Aeration Data in the West Basin on September 29, 2019

Sample Location	TP (mg/L)	Ortho-P (mg/L)	TSS (mg/L)	TKN (mg/L)	TIN (mg/L)	NH3+ (mg/L)	Chl-a
B	0.019	<0.010	<10	<0.5	0.290	0.017	0
C	0.020	<0.010	<10	<0.5	0.280	<0.010	0
D	0.016	<0.010	<10	<0.5	0.300	<0.010	0
G	0.016	<0.010	<10	<0.5	0.450	<0.010	0
H	0.016	<0.010	<10	<0.5	0.440	<0.010	0
F	0.018	<0.010	<10	<0.5	0.250	<0.010	0
E	0.019	<0.010	<10	<0.5	0.160	<0.010	0
A	0.024	<0.010	<10	<0.5	0.190	<0.010	0

4.3 Paradise Lake Water Quality Parameter Profiles/Graphs/Raw Data Summary:

In order to visually see the changes in some water quality parameters with time and depth, graphs that plot depth versus a water quality parameter can be useful in addition to data tables. For this project, there was negligible change in depth with water quality parameters such as water temperature, dissolved oxygen, pH, specific conductivity, total suspended solids, and ortho-phosphorus among depths. In addition, this permit required water samples collected from the middle-depth (all collected at 5.0 feet) at each of 8 sampling locations. These samples were all collected at the same depth and thus depth integrated profiles with other parameters could also not be attained. Raw data are contained in Appendix A along with corresponding laboratory reports.

Weather conditions during the May 28, 2019 sampling event were 64°F and sunny with calm winds. Weather conditions during the July 9, 2019 sampling event were calm and 72°F, and the conditions for September 29, 2019 sampling event were 52°F, misty, with winds out of the west around 10-20 mph. This information was also recorded on the data sheets.

4.4 Paradise Lake Year 1 Phytoplankton Community Data:

The algal genera were determined from composite water samples collected over the 8 sampling locations in the West Basin of Paradise Lake in May, July, and September of 2019 were analyzed with a Zeiss® compound bright-field microscope. The genera present included the Chlorophyta (green algae): *Haematococcus* sp., *Staurastrum* sp., *Scenedesmus* sp., *Chlorella* sp., *Cladophora* sp., *Mougeotia* sp., *Chrococcus* sp., and *Radiococcus* sp., The Cyanophyta (blue-green algae): G*leocapsa* sp., and *Oscillatoria* sp.; the Bascillariophyta (diatoms*): Navicula* sp*., Fragilaria* sp., *Synedra* sp., *Cymbella* sp., and *Tabellaria* sp. The aforementioned species indicate a diverse algal flora and represent a good diversity of algae. A breakdown of the relative proportion of each for the West Basin for the 2019 sampling dates is shown in Table 23 below.

Table 23. Relative abundance of algal taxa in Paradise Lake (May 28, 2019, July 9, 2019, and September 29, 2019).

Sampling Date	Sampling Location	% Green Algae	% Blue-green Algae	% Diatoms
5-28-19	**B**	45	0	55
	C	45	4	51
	D	58	0	42
	G	39	0	61
	H	54	0	46
	F	58	2	40
	E	32	1	67

	A	48	0	52
7-9-19	**B**	55	4	41
	C	68	2	30
	D	43	5	52
	G	33	0	67
	H	42	0	58
	F	56	0	44
	E	60	1	39
	A	53	0	47
9-29-19	**B**	45	3	52
	C	36	3	61
	D	52	1	47
	G	65	0	35
	H	53	1	46
	F	59	0	41
	E	62	0	38
	A	41	0	59

4.5 Paradise Lake West Basin Aquatic Vegetation Bio Volume Scan/Data:

A lake scan using a Lowrance HDS 8® sonar unit with GPS software was used to create an aquatic vegetation bio volume map (Figure 9) of the lake on August 20, 2014 as a baseline. An additional scan of the West Basin was conducted by RLS on September 18, 2018. The bio volume map below shows the relative aquatic vegetation bio volume in Paradise Lake. The blue areas represent no vegetation whereas green areas represent low-growing vegetation and red areas represent high-growing vegetation.

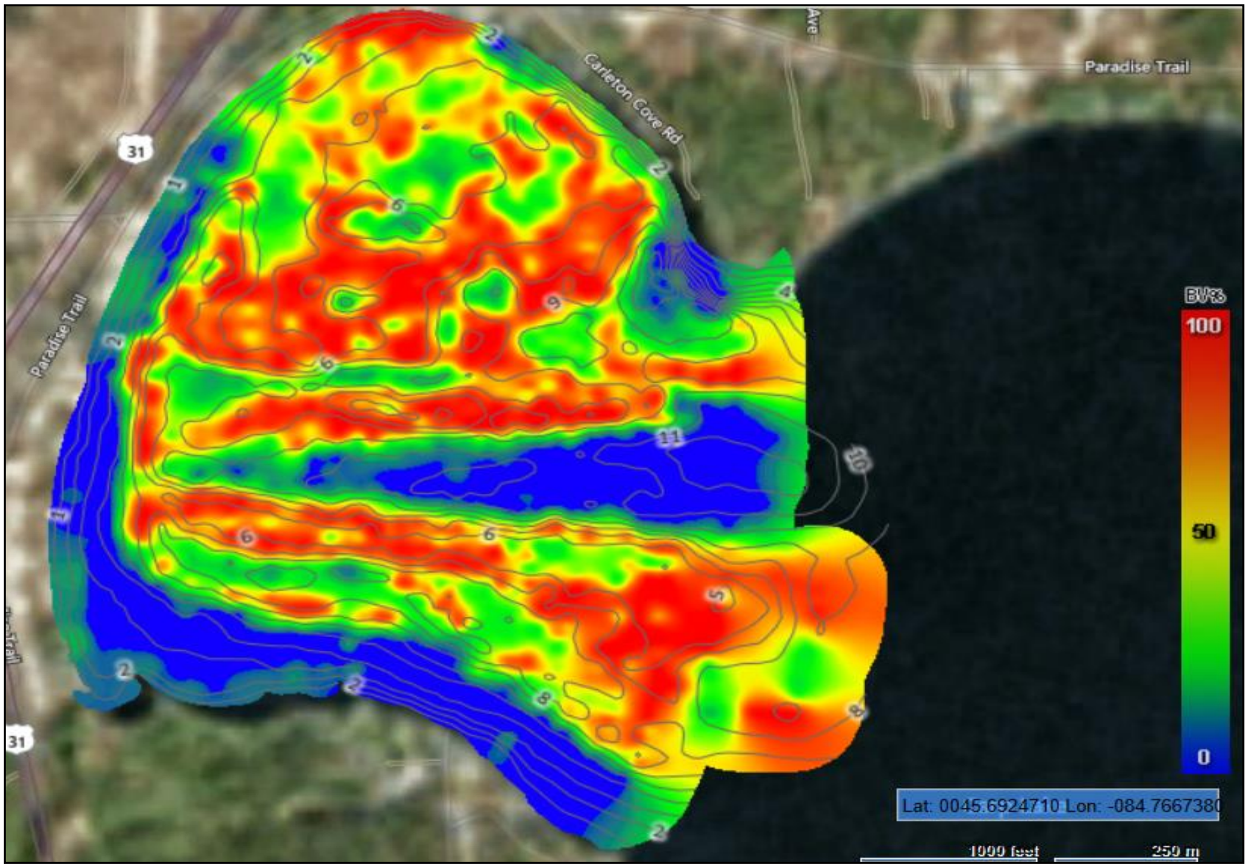

Figure 9. An aquatic vegetation bio volume scan map of the West Basin of Paradise Lake (RLS, 2019).

A GPS Point-Intercept Survey was conducted in the West Basin of Paradise Lake on October 28, 2013 and again on September 18, 2018 and again on September 29, 2019 (Figure 10). The relative abundance of each aquatic plant species can be found on the data tables below (Tables 25-27). In addition, a whole lake survey was conducted in 2019 (Figure 11; Table). In 2013, the estimated EWM cover was approximately 20.4% of the West Basin whereas in 2018 it was measured around 18.2% cover. The two most common native aquatic plant species included Robbins Pondweed which was estimated at 29.1% cover in the West Basin in 2013 and at 25.1% cover in 2018. White-stem Pondweed was also common and occupied 20.1% cover in 2013 and 18.5% cover in 2018. The presence of these two pondweeds in the corresponding densities minimizes some of the potential for milfoil to further expand in the West Basin and even in some areas of the remainder of the lake system.

Aquatic Vegetation Biovolume % Cover	2014	2018	2019
0-5%	11.35	13.46	27.4
5-20%	21.55	24.54	18.0
20-40%	27.20	17.45	14.5
40-60%	14.50	7.57	7.0
60-80%	12.10	6.89	5.6
>80%	13.29	30.10	27.6

Table 24. Changes in aquatic vegetation biovolume pre (201, 2018) and post (2019) LFA.

The whole-lake aquatic vegetation bio volume scans demonstrated a measurable increase in the highest bio volume category (>80%) by 2018 but a decrease in the next two highest bio volume categories and an increase in the two lowest bio volume categories. This is consistent with the findings that the dense EWM polygons have been increasing but the low-growing vegetation has been increasing in areas that were not previously colonized.

Figure 10. Aquatic plant sampling locations in the West Basin of Paradise Lake collected on October 28, 2013 and again on September 18, 2018 and on September 29, 2019.

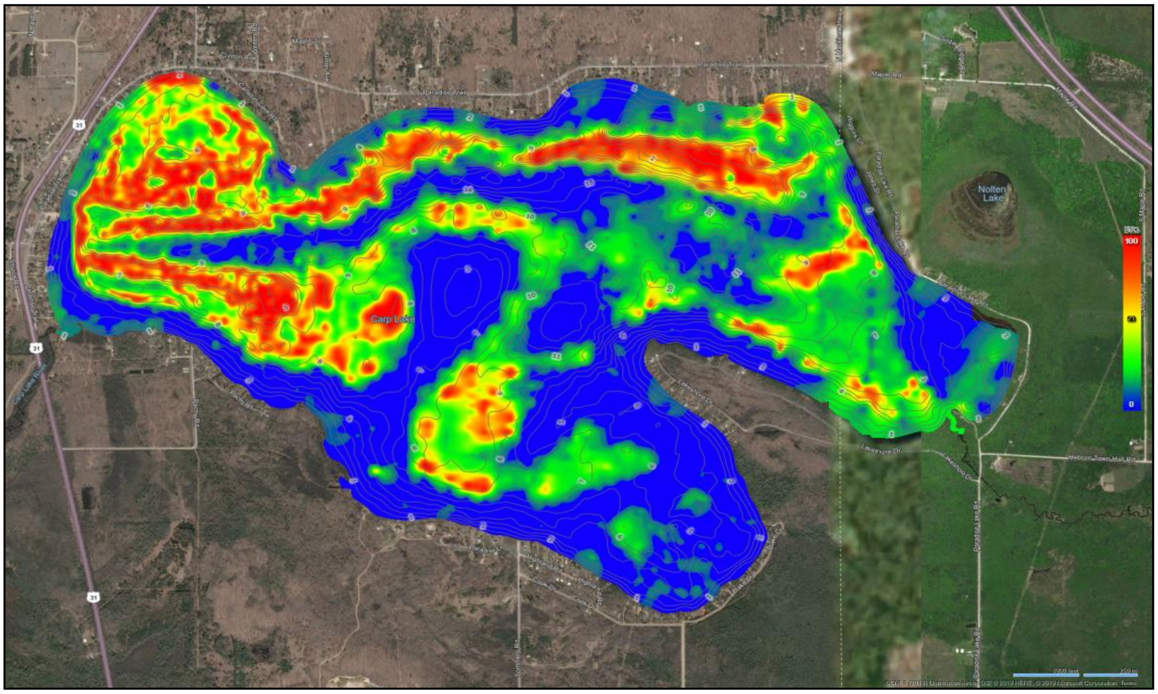

Figure 11. An aquatic vegetation bio volume scan map of Paradise Lake (RLS, 2019).

Table 25. Paradise Lake West Basin aquatic vegetation survey data (October 28, 2013).

LAKE NAME- PARADISE LAKE-WEST BASIN POST-AERATION COUNTY- EMMET SURVEY DATE: October 28, 2013

Standard Aquatic Vegetation Summary Sheet SURVEY BY: JLJ, MJS

		Total number of AVAS's 220 for each Density Category				Calculations Category	Category	Category	Category	Sum of Previous Four Columns	Total Number of AVAS's	Quotient of Column 9 divided by Column 10		
		A	B	C	D	A x 1	B x10	C x 40	D x 80					
Code No	Plant Name	1	2	3	4	5	6	7	8	9	10	11	Code No	Plant Name
1	Eurasian Watermilfoil	8	7	32	39	8	70	1280	3120	4478	220	20.4	1	EurasianWatermilfoil
2	Curly leaf Pondweed					0	0	0	0	0	220	0.0	2	Curly leaf Pondweed
3	Chara	4	24	10		4	240	400	0	644	220	2.9	3	Chara
4	Thinleaf Pondweed					0	0	0	0	0	220	0.0	4	Thinleaf Pondweed
5	Flatstem Pondweed	2	16	4		2	160	160	0	322	220	1.5	5	Flatstem Pondweed
6	Robbins Pondweed	12	23	56	49	12	230	2240	3920	6402	220	29.1	6	Robbins Pondweed
7	Variable leaf Pondweed	12	27	12		12	270	480	0	762	220	3.5	7	Variable leaf Pondweed
8	Whitestem Pondweed	2	54	43	27	2	540	1720	2160	4422	220	20.1	8	Whitestem Pondweed
9	Richardsons Pondweed	6	54	36	19	6	540	1440	1520	3506	220	15.9	9	Richardsons Pondweed
10	Illinois Pondweed	17	22	5		17	220	200	0	437	220	2.0	10	Illinois Pondweed
11	Large leaf Pondweed	6	11	7	19	6	110	280	1520	1916	220	8.7	11	Large leaf Pondweed
12	American Pondweed					0	0	0	0	0	220	0.0	12	American Pondweed
13	Floating leaf Pondweed					0	0	0	0	0	220	0.0	13	Floating leaf Pondweed
14	Water Stargrass					0	0	0	0	0	220	0.0	14	Water Stargrass
15	Wild Celery	5	62	6	2	5	620	240	160	1025	220	4.7	15	Wild Celery
16						0	0	0	0	0	220	0.0	16	
17	Northern Watermilfoil					0	0	0	0	0	220	0.0	17	Northern Watermilfoil
18	Whorled Watermilfoil	2	55	4	1	2	550	160	80	792	220	3.6	18	Whorled Watermilfoil
19	Leafless Watermilfoil					0	0	0	0	0	220	0.0	19	Leafless Watermilfoil
20	Coontail					0	0	0	0	0	220	0.0	20	Coontail
21	Elodea	10	22	8	15	10	220	320	1200	1750	220	8.0	21	Elodea
22	Bladderwort Large	12	8	14	2	12	80	560	160	812	220	3.7	22	Bladderwort Large
23	Bladderwort-mini					0	0	0	0	0	220	0.0	23	Bladderwort-mini
24	Buttercup					0	0	0	0	0	220	0.0	24	Buttercup
25	Southern Naiad					0	0	0	0	0	220	0.0	25	Southern Naiad
26	Slender Naiad	15	56	25	4	15	560	1000	320	1895	220	8.6	26	Slender Naiad
27	Spikerush					0	0	0	0	0	220	0.0	27	Spikerush
28	Ribbon leaf Pondweed					0	0	0	0	0	220	0.0	28	Ribbon leaf Pondweed
29	Small leaf Pondweed					0	0	0	0	0	220	0.0	29	Small leaf Pondweed
30	White Waterlily					0	0	0	0	0	220	0.0	30	White Waterlily
31	Yellow Waterlily	4	3			4	30	0	0	34	220	0.2	31	Yellow Waterlily
32	Watershield					0	0	0	0	0	220	0.0	32	Watershield
33	Duckweed					0	0	0	0	0	220	0.0	33	Duckweed
34						0	0	0	0	0	220	0.0	34	
35	Watermeal					0	0	0	0	0	220	0.0	35	Watermeal
36	Arrowhead					0	0	0	0	0	220	0.0	36	Arrowhead
37	Pickerelweed					0	0	0	0	0	220	0.0	37	Pickerelweed
38	Arrow Arum					0	0	0	0	0	220	0.0	38	Arrow Arum
39	Cattails	4	4	3	3	4	40	120	240	404	220	1.8	39	Cattails
40	Bulrushes	4	3	2	4	4	30	80	320	434	220	2.0	40	Bulrushes
41						0	0	0	0	0	220	0.0	41	
42	Swamp Loosestrife					0	0	0	0	0	220	0.0	42	Swamp Loosestrife
43	Purple Loosestrife					0	0	0	0	0	220	0.0	43	Purple Loosestrife
44	Yellow Iris					0	0	0	0	0	220	0.0	44	Yellow Iris
												136.5		

Table 26. Paradise Lake West Basin aquatic vegetation survey data (September 18, 2018).

LAKE NAME- PARADISE LAKE-WEST BASIN PRE-AERATION COUNTY- EMMET SURVEY DATE: SEPTEMBER 18, 2[illegible]

Standard Aquatic Vegetation Summary Sheet SURVEY BY: GLJ

		Total number of AVAS's 220 for each Density Category				Calculations				Sum of Previous Four Columns	Total Number of AVAS's	Quotient of Column 9 divided by Column 10		
		A	B	C	D	Category A x 1	Category B x10	Category C x 40	Category D x 80					
Code No	Plant Name	1	2	3	4	5	6	7	8	9	10	11	Code No	Plant Name
1	Eurasian Watermilfoil	4	1	36	32	4	10	1440	2560	4014	220	18.2	1	EurasianWatermilfoil
2	Curly leaf Pondweed					0	0	0	0	0	220	0.0	2	Curly leaf Pondweed
3	Chara	7	29	12	1	7	290	480	80	857	220	3.9	3	Chara
4	Thinleaf Pondweed	2	1	1		2	10	40	0	52	220	0.2	4	Thinleaf Pondweed
5	Flatstem Pondweed	5	22	10	1	5	220	400	80	705	220	3.2	5	Flatstem Pondweed
6	Robbins Pondweed	15	26	51	40	15	260	2040	3200	5515	220	25.1	6	Robbins Pondweed
7	Variable leaf Pondweed	10	22	8	3	10	220	320	240	790	220	3.6	7	Variable leaf Pondweed
8	Whitestem Pondweed	4	42	27	32	4	420	1080	2560	4064	220	18.5	8	Whitestem Pondweed
9	Richardsons Pondweed	10	60	31	24	10	600	1240	1920	3770	220	17.1	9	Richardsons Pondweed
10	Illinois Pondweed	18	24	2	1	18	240	80	80	418	220	1.9	10	Illinois Pondweed
11	Large leaf Pondweed	16	20	2	19	16	200	80	1520	1816	220	8.3	11	Large leaf Pondweed
12	American Pondweed					0	0	0	0	0	220	0.0	12	American Pondweed
13	Floating leaf Pondweed					0	0	0	0	0	220	0.0	13	Floating leaf Pondweed
14	Water Stargrass					0	0	0	0	0	220	0.0	14	Water Stargrass
15	Wild Celery	4	52	4	15	4	520	160	1200	1884	220	8.6	15	Wild Celery
16						0	0	0	0	0	220	0.0	16	
17	Northern Watermilfoil	1				1	0	0	0	1	220	0.0	17	Northern Watermilfoil
18	Whorled Watermilfoil	6	58	9	7	6	580	360	560	1506	220	6.8	18	Whorled Watermilfoil
19	Leafless Watermilfoil					0	0	0	0	0	220	0.0	19	Leafless Watermilfoil
20	Coontail					0	0	0	0	0	220	0.0	20	Coontail
21	Elodea	12	18	4	22	12	180	160	1760	2112	220	9.6	21	Elodea
22	Bladderwort Large	5	13	17	6	5	130	680	480	1295	220	5.9	22	Bladderwort Large
23	Bladderwort-mini					0	0	0	0	0	220	0.0	23	Bladderwort-mini
24	Buttercup					0	0	0	0	0	220	0.0	24	Buttercup
25	Southern Naiad					0	0	0	0	0	220	0.0	25	Southern Naiad
26	Slender Naiad	11	60	21	9	11	600	840	720	2171	220	9.9	26	Slender Naiad
27	Spikerush					0	0	0	0	0	220	0.0	27	Spikerush
28	Ribbon leaf Pondweed					0	0	0	0	0	220	0.0	28	Ribbon leaf Pondweed
29	Small leaf Pondweed					0	0	0	0	0	220	0.0	29	Small leaf Pondweed
30	White Waterlily					0	0	0	0	0	220	0.0	30	White Waterlily
31	Yellow Waterlily	3	4	2		3	40	80	0	123	220	0.6	31	Yellow Waterlily
32	Watershield	1				1	0	0	0	1	220	0.0	32	Watershield
33	Duckweed					0	0	0	0	0	220	0.0	33	Duckweed
34						0	0	0	0	0	220	0.0	34	
35	Watermeal					0	0	0	0	0	220	0.0	35	Watermeal
36	Arrowhead					0	0	0	0	0	220	0.0	36	Arrowhead
37	Pickerelweed					0	0	0	0	0	220	0.0	37	Pickerelweed
38	Arrow Arum					0	0	0	0	0	220	0.0	38	Arrow Arum
39	Cattails	5	5	5	2	5	50	200	160	415	220	1.9	39	Cattails
40	Bulrushes	3	4	4	3	3	40	160	240	443	220	2.0	40	Bulrushes
41						0	0	0	0	0	220	0.0	41	
42	Swamp Loosestrife					0	0	0	0	0	220	0.0	42	Swamp Loosestrife
43	Purple Loosestrife					0	0	0	0	0	220	0.0	43	Purple Loosestrife
44	Yellow Iris					0	0	0	0	0	220	0.0	44	Yellow Iris
												145.2		

Table 27. Paradise Lake West Basin aquatic vegetation survey data (September 29, 2019).

LAKE NAME- PARADISE LAKE-WEST BASIN POST-AERATION **COUNTY- EMMET** **SURVEY DATE: SEPTEMBER 29, 2019**

Standard Aquatic Vegetation Summary Sheet SURVEY BY: GLJ

Code No	Plant Name	Total number of AVAS's 220 for each Density Catagory A 1	B 2	C 3	D 4	Calculations Catagory A x 1 5	Catagory B x10 6	Catagory C x 40 7	Catagory D x 80 8	Sum of Previous Four Columns 9	Total Number of AVAS's 10	Quotient of Column 9 divided by Column 10 11	Code No	Plant Name
1	Eurasian Watermilfoil	18	4	17	27	18	40	680	2160	2898	220	13.2	1	EurasianWatermilfoil
2	Curly leaf Pondweed					0	0	0	0	0	220	0.0	2	Curly leaf Pondweed
3	Chara	4	24	19	2	4	240	760	160	1164	220	5.3	3	Chara
4	Thinleaf Pondweed	7	7	1	0	7	70	40	0	117	220	0.5	4	Thinleaf Pondweed
5	Flatstem Pondweed	6	15	8	4	6	150	320	320	796	220	3.6	5	Flatstem Pondweed
6	Robbins Pondweed	18	21	12	31	18	210	480	2480	3188	220	14.5	6	Robbins Pondweed
7	Variable leaf Pondweed	8	14	4	4	8	140	160	320	628	220	2.9	7	Variable leaf Pondweed
8	Whitestem Pondweed	6	18	22	34	6	180	880	2720	3786	220	17.2	8	Whitestem Pondweed
9	Richardsons Pondweed	9	37	36	21	9	370	1440	1680	3499	220	15.9	9	Richardsons Pondweed
10	Illinois Pondweed	22	21	5	7	22	210	200	560	992	220	4.5	10	Illinois Pondweed
11	Large leaf Pondweed	19	24	5	11	19	240	200	880	1339	220	6.1	11	Large leaf Pondweed
12	American Pondweed					0	0	0	0	0	220	0.0	12	American Pondweed
13	Floating leaf Pondweed					0	0	0	0	0	220	0.0	13	Floating leaf Pondweed
14	Water Stargrass					0	0	0	0	0	220	0.0	14	Water Stargrass
15	Wild Celery	5	36	7	10	5	360	280	800	1445	220	6.6	15	Wild Celery
16						0	0	0	0	0	220	0.0	16	
17	Northern Watermilfoil	2	1			2	10	0	0	12	220	0.1	17	Northern Watermilfoil
18	Whorled Watermilfoil	10	41	1	9	10	410	40	720	1180	220	5.4	18	Whorled Watermilfoil
19	Leafless Watermilfoil					0	0	0	0	0	220	0.0	19	Leafless Watermilfoil
20	Coontail					0	0	0	0	0	220	0.0	20	Coontail
21	Elodea	10	6	9	18	10	60	360	1440	1870	220	8.5	21	Elodea
22	Bladderwort Large	6	4	22	8	6	40	880	640	1566	220	7.1	22	Bladderwort Large
23	Bladderwort-mini					0	0	0	0	0	220	0.0	23	Bladderwort-mini
24	Buttercup					0	0	0	0	0	220	0.0	24	Buttercup
25	Southern Naiad					0	0	0	0	0	220	0.0	25	Southern Naiad
26	Slender Naiad	15	41	29	11	15	410	1160	880	2465	220	11.2	26	Slender Naiad
27	Spikerush					0	0	0	0	0	220	0.0	27	Spikerush
28	Ribbon leaf Pondweed					0	0	0	0	0	220	0.0	28	Ribbon leaf Pondweed
29	Small leaf Pondweed					0	0	0	0	0	220	0.0	29	Small leaf Pondweed
30	White Waterlily					0	0	0	0	0	220	0.0	30	White Waterlily
31	Yellow Waterlily	6	2	2		6	20	80	0	106	220	0.5	31	Yellow Waterlily
32	Watershield	1	1			1	10	0	0	11	220	0.1	32	Watershield
33	Duckweed					0	0	0	0	0	220	0.0	33	Duckweed
34						0	0	0	0	0	220	0.0	34	
35	Watermeal					0	0	0	0	0	220	0.0	35	Watermeal
36	Arrowhead					0	0	0	0	0	220	0.0	36	Arrowhead
37	Pickerelweed					0	0	0	0	0	220	0.0	37	Pickerelweed
38	Arrow Arum					0	0	0	0	0	220	0.0	38	Arrow Arum
39	Cattails	6	4	6	1	6	40	240	80	366	220	1.7	39	Cattails
40	Bulrushes	4	0	5	4	4	0	200	320	524	220	2.4	40	Bulrushes
41						0	0	0	0	0	220	0.0	41	
42	Swamp Loosestrife					0	0	0	0	0	220	0.0	42	Swamp Loosestrife
43	Purple Loosestrife					0	0	0	0	0	220	0.0	43	Purple Loosestrife
44	Yellow Iris					0	0	0	0	0	220	0.0	44	Yellow Iris
												127.1		

E:\RLSPROJECTS\Paradise Lake Emmet County, MI\Reports\ParadiseLakeAVASDataSeptember291019

Table 28. Paradise Lake aquatic vegetation survey data (September 29, 2019).

LAKE NAME: **Paradise Lake** SURVEY DATE: **29-Sep-2019**
COUNTY: **Emmet and Cheboygan** SURVEY BY: **GJ, KJ**

Plant Code	Plant Name	Total number of AVAS's for each Density Category				Category Calculations				Sum of Previous Four Columns	Total Number of AVAS's	Quotient of Sum / # of AVAS sites
		A	B	C	D	A x 1	B x10	C x 40	D x 80			
1	Eurasian milfoil	15	52	34	95	15	520	1360	7600	9495	430	**22.1**
2	Curly leaf pondweed	0	0	0	0	0	0	0	0	0	430	**0.0**
3	Chara	0	0	0	0	0	0	0	0	0	430	**0.0**
4	Thinleaf pondweed	0	0	0	0	0	0	0	0	0	430	**0.0**
5	Flatstem pondweed	5	8	10	1	5	80	400	80	565	430	**1.3**
6	Robbins pondweed	9	35	49	16	9	350	1960	1280	3599	430	**8.4**
7	Variable pondweed	6	2	1	0	6	20	40	0	66	430	**0.2**
8	Whitestem pondweed	52	213	25	4	52	2130	1000	320	3502	430	**8.1**
9	Richardsons pondweed	16	11	4	0	16	110	160	0	286	430	**0.7**
10	Illinois pondweed	6	13	1	1	6	130	40	80	256	430	**0.6**
11	Large leaf pondweed	5	9	4	1	5	90	160	80	335	430	**0.8**
12	American pondweed	0	1	0	0	0	10	0	0	10	430	**0.0**
13	Floating leaf pondweed	2	3	1	0	2	30	40	0	72	430	**0.2**
14	Water stargrass	1	2	0	0	1	20	0	0	21	430	**0.0**
15	Wild Celery	1	8	16	7	1	80	640	560	1281	430	**3.0**
16		0	0	0	0	0	0	0	0	0	430	**0.0**
17	Northern milfoil	1	0	3	0	1	0	120	0	121	430	**0.3**
18	M. verticillatum	16	5	7	10	16	50	280	800	1146	430	**2.7**
19	M. herterophyllum	1	0	0	0	1	0	0	0	1	430	**0.0**
20	Coontail	1	0	0	0	1	0	0	0	1	430	**0.0**
21	Elodea	9	5	2	2	9	50	80	160	299	430	**0.7**
22	Utricularia spp.	6	3	3	1	6	30	120	80	236	430	**0.5**
23	Bladderwort-mini	2	1	1	0	2	10	40	0	52	430	**0.1**
24	White water crowfoot	0	0	0	0	0	0	0	0	0	430	**0.0**
25	Najas spp.	1	0	3	0	1	0	120	0	121	430	**0.3**
26	Brittle naiad	2	2	1	0	2	20	40	0	62	430	**0.1**
27	Sago pondweed	1	0	1	0	1	0	40	0	41	430	**0.1**
28	Starry stonewort	0	0	0	0	0	0	0	0	0	430	**0.0**
29	European Water Clover	0	0	0	0	0	0	0	0	0	430	**0.0**
30	Nymphaea	5	2	1	0	5	20	40	0	65	430	**0.2**
31	Nuphar	1	0	2	0	1	0	80	0	81	430	**0.2**
32	Brasenia	0	0	0	0	0	0	0	0	0	430	**0.0**
33	Lemna minor	1	0	5	0	1	0	200	0	201	430	**0.5**
34	Spirodella	0	0	0	0	0	0	0	0	0	430	**0.0**
35	Watermeal	0	0	0	0	0	0	0	0	0	430	**0.0**
36	Arrowhead	0	0	0	0	0	0	0	0	0	430	**0.0**
37	Pickerelweed	0	0	0	0	0	0	0	0	0	430	**0.0**
38	Arrow Arum	0	0	0	0	0	0	0	0	0	430	**0.0**
39	Cattails	2	3	1	0	2	30	40	0	72	430	**0.2**
40	Bulrushes	1	26	9	1	1	260	360	80	701	430	**1.6**
41	Iris	1	0	0	0	1	0	0	0	1	430	**0.0**
42	Swamp Loosestrife	1	0	1	0	1	0	40	0	41	430	**0.1**
43	Purple Loosestrife	0	0	0	0	0	0	0	0	0	430	**0.0**
44	nitella	0	0	0	0	0	0	0	0	0	430	**0.0**
45	Phragmites	0	0	0	0	0	0	0	0	0	430	**0.0**
46	Flowering Rush	0	0	0	0	0	0	0	0	0	430	**0.0**
47	Wild Rice	0	0	0	0	0	0	0	0	0	430	**0.0**
48	Button Bush	0	0	0	0	0	0	0	0	0	430	**0.0**
49	Spike Rush	0	0	0	0	0	0	0	0	0	430	**0.0**
50	Beak Rush	0	0	0	0	0	0	0	0	0	430	**0.0**
51	Burr Reed	0	0	0	0	0	0	0	0	0	430	**0.0**
52	Water Pennywort	0	0	0	0	0	0	0	0	0	430	**0.0**
53	Twig Rush	0	0	0	0	0	0	0	0	0	430	**0.0**
54												
55												
												52.9

4.6 Paradise Lake West Basin Sediment Bottom Hardness Scan/Data:

A benthic (bottom) scan using a Lowrance HDS 8® sonar unit with GPS software was used to create an aquatic sediment bottom hardness map (Figure 12) of the Paradise Lake West Basin on August 20, 2014 as a baseline. An additional scan of the West Basin was conducted on July 9, 2018 (Figure 13) and in 2019 (Figure 14). Also, a whole lake scan was conducted in 2019 (Figure 15). The areas light beige in color represent soft, mucky bottom whereas areas that are red represent firmer bottom. Colors in the orange family represent intermediate bottom hardness types. This baseline information is important since it allows us to determine if the aeration system has reduced muck throughout the lake bottom. Table 29 below shows the actual numerical results from calculations based on the algorithm-based scans.

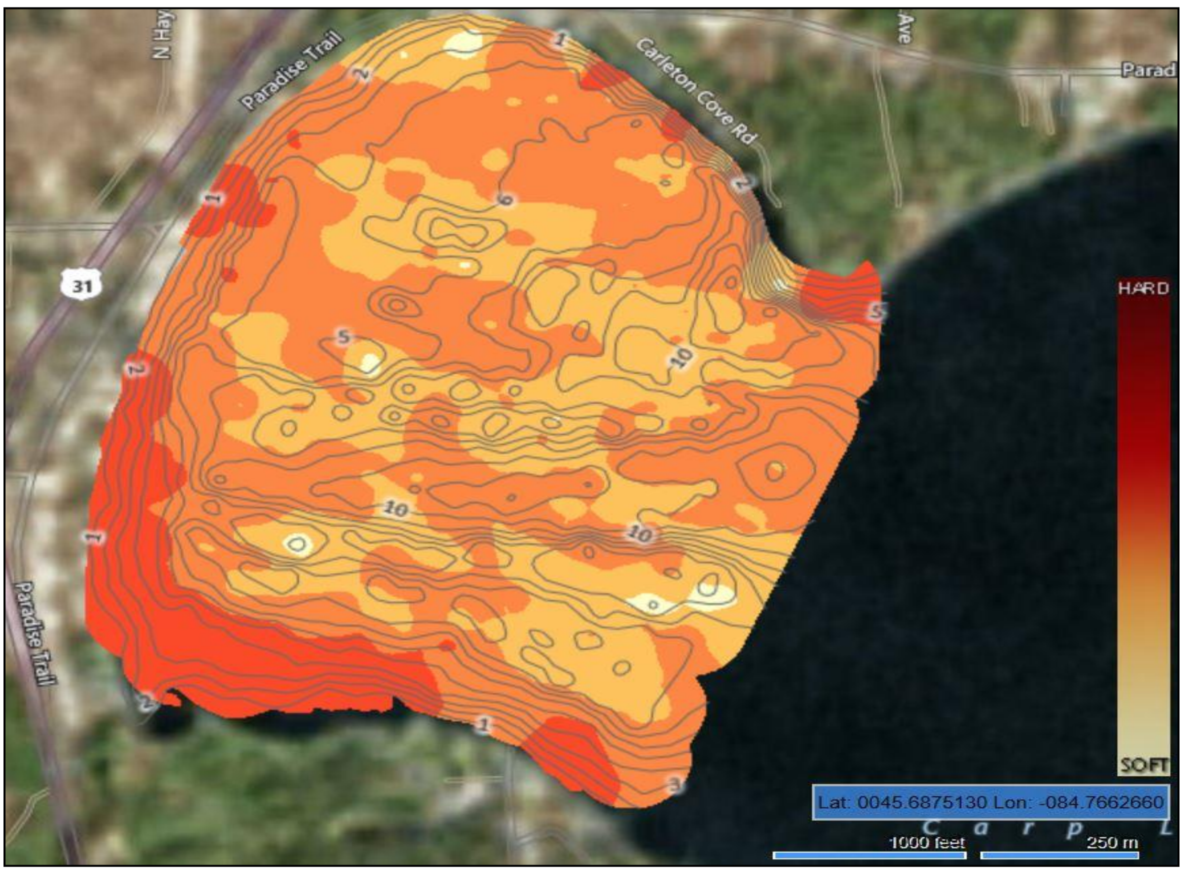

Figure 12. A bottom sediment hardness map of the Paradise Lake West Basin (RLS, 2014).

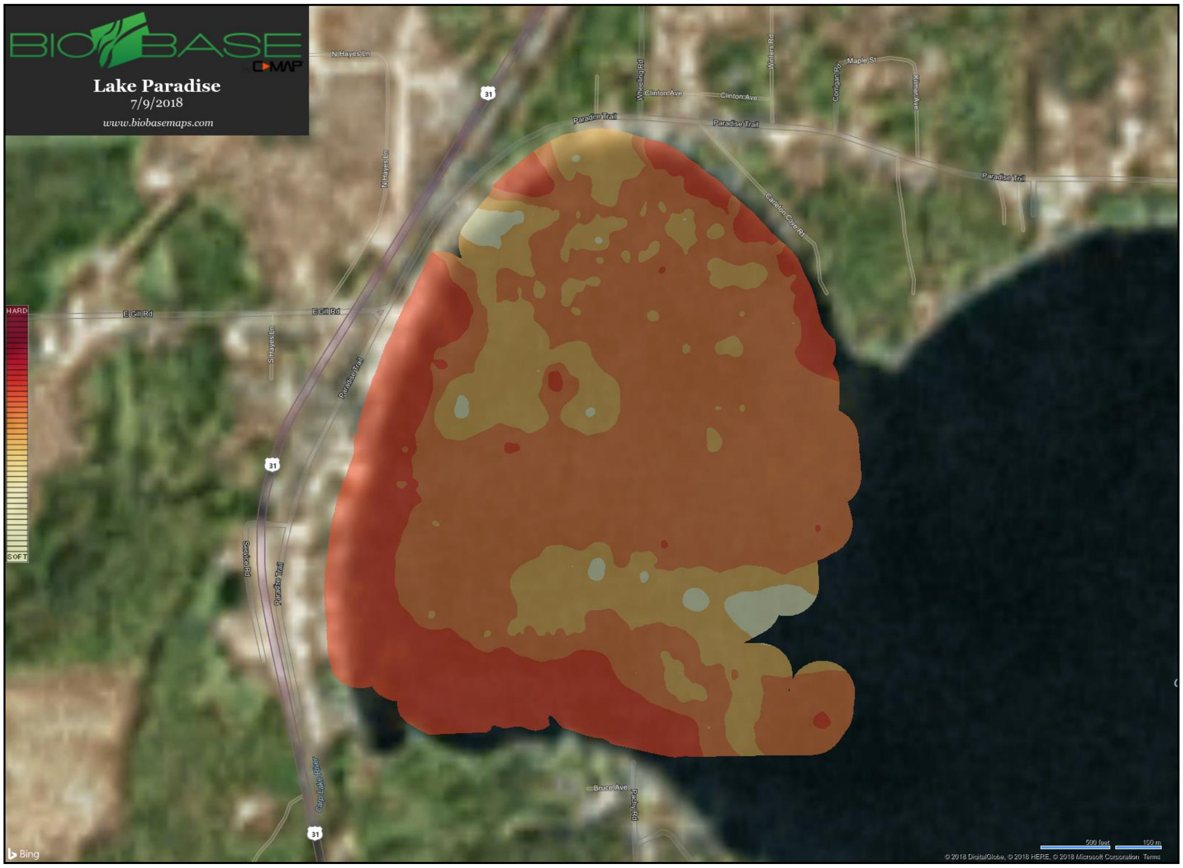

Figure 13. A bottom sediment hardness map of the Paradise Lake West Basin (RLS, 2018).

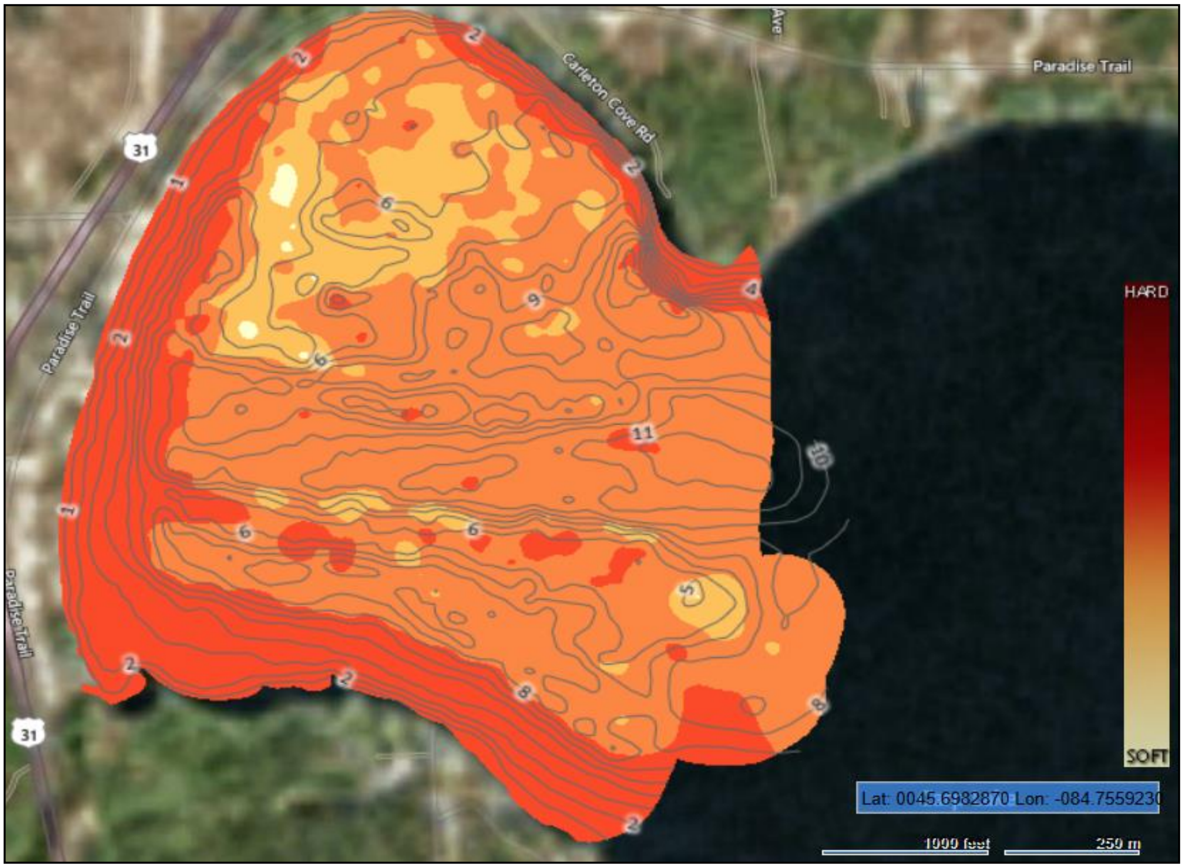

Figure 14. A bottom sediment hardness map of the Paradise Lake West Basin (RLS, 2019).

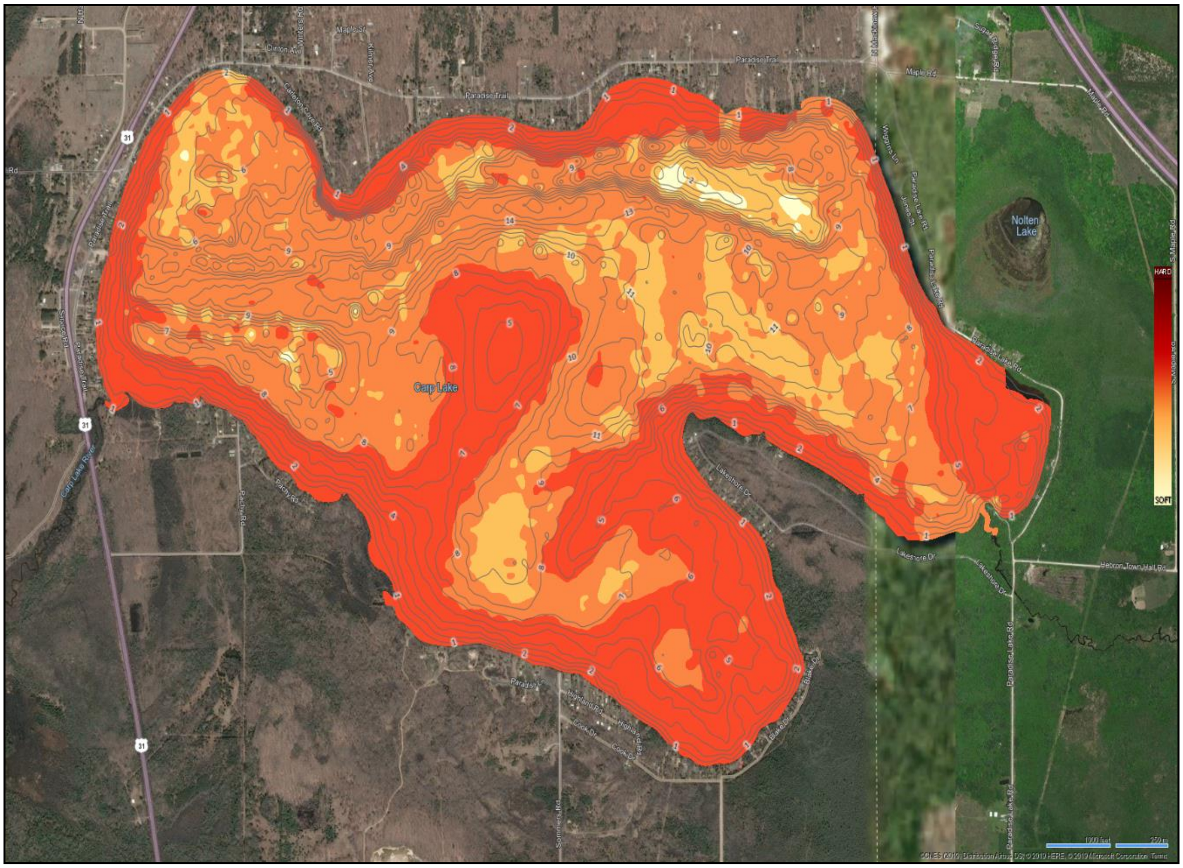

Figure 15. A bottom sediment hardness map of the Paradise Lake Basin (RLS, 2019).

Table 29. Sediment bottom hardness in the West Basin of Paradise Lake in 2014 and 2018 (baseline) and 2019 (post-LFA).

Sediment Hardness Category	2014 %	2018 %	2019 %
<0.1	0.13	0.14	0.03
0.1-0.2	1.78	2.30	1.10
0.2-0.3	58.44	34.69	21.0
0.3-0.4	33.18	48.46	54.6
>0.4	6.47	14.41	23.3

4.7 Paradise Lake West Basin Sediment Organic Matter Data:

Sediment organic matter (OM) was measured in the 8 West Basin sampling sites on October 28, 2013 and again on September 18, 2018. It was also measured in years between these, but these two data sets were used to look at long-term changes since they represent the earliest and latest data sets for this parameter. Table 30 below shows the comparisons of the sites for each of the two years. The particle composition of the Paradise Lake West Basin sediments consists of primarily sand and fibrous muck. No OM data was collected in 2019.

Table 30. Sediment OM in the West Basin of Paradise Lake in 2014 and 2018.

Sampling Site	OM 2014 %	OM 2018 %
WB 1	55	53
WB 2	60	40
WB 3	39	35
WB 4	50	38
WB 5	25	53
WB 6	3	46
WB 7	49	50
WB 8	1.6	44

5.0 PARADISE LAKE 2018-2019 WATER QUALITY DATA TRENDS AND COMPARISONS

Although LFA was installed into the West Basin of Paradise Lake in late 2012, RLS was able to compare older data sets to the more modern 2018-2019 data set to look for changes in variables over time. Since both of the sampling events in 2018 were considered “pre-aeration” as a new permit but were actually 5+ years post-aeration, it was beneficial to look at trends in means with time for certain parameters to determine how the environmental condition(s) of the West Basin have changed with time as a function of LFA implementation. RLS was able to calculate the means of all water quality parameters collected to date for the West Basin and demonstrate the trends for each parameter in the following graphs (Figures 16-23).

5.1 Paradise Lake Physical Water Quality Data Trends:

The following graphs display means of each water physical quality parameter collected by RLS with time in the West Basin. They allow us to determine how individual water quality parameters are changing with time, presumably relative to the operation of the LFA system.

Dissolved oxygen (Figure 16) has remained quite stable among years but had a slight drop in 2017 which may have been due to record warm temperatures. The concentrations are high and favorable for lake health.

Secchi depth (Figure 17) also exhibits a steady trend with a slight drop in 2017. The reason for that is unclear. The secchi depth measurements are quite favorable and indicate a clear-water system.

Total dissolved solids (Figure 18) increased over 50 mg/L in 2018 and the reason for this in unclear but it may indicate the presence of increased tannins from heavy rainfall events noted in 2018. These tannins originate in forest/wetland soils and given the abundant mucks and ponded soils around Paradise Lake may leach into the water directly though surface runoff during storm events.

The pH (Figure 19) of Paradise Lake has remained relatively stable with a slight upward trend. This is not surprising given the increased amount of aquatic vegetation observed in some areas of the lake. The photosynthetic activities of the vegetation increase and lead to an increase in pH.

The specific conductivity (Figure 20) in Paradise Lake has fluxed among years which is normal and due to changing ions of salts in the lake water. The values are low and favorable.

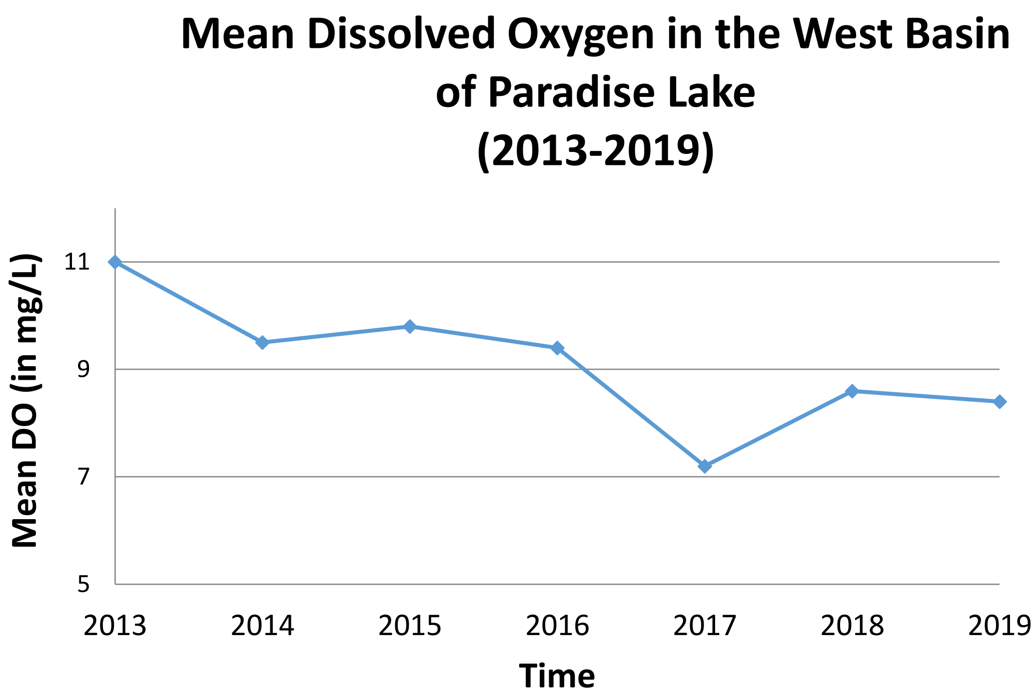

Figure 16. Mean DO in the West Basin of Paradise Lake (2013-2019).

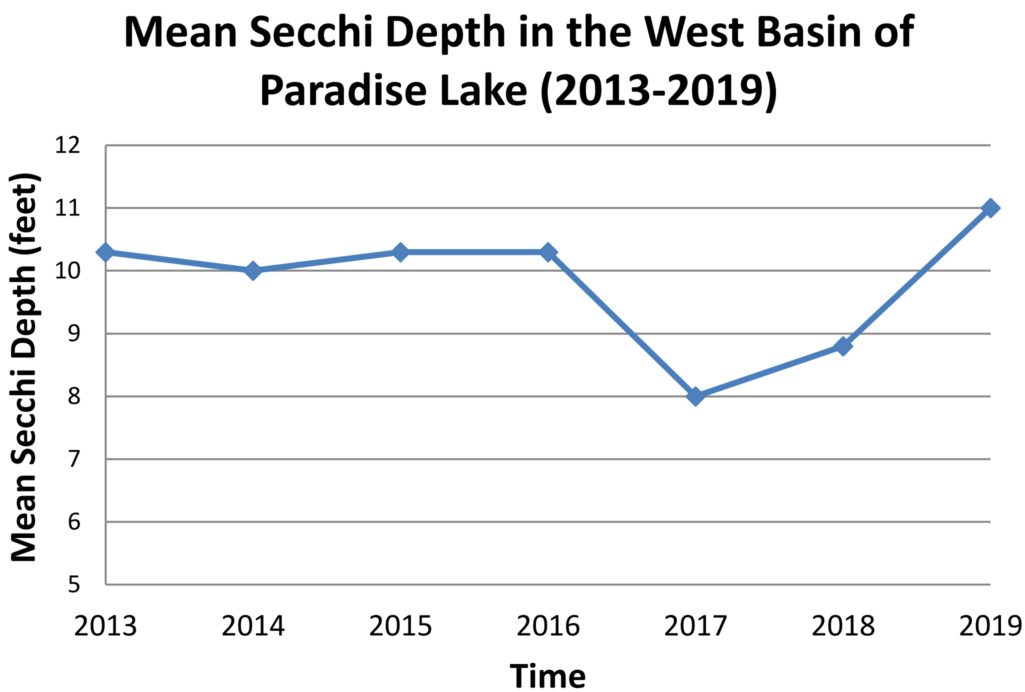

Figure 17. Mean Secchi depth in the West Basin of Paradise Lake (2013-2019).

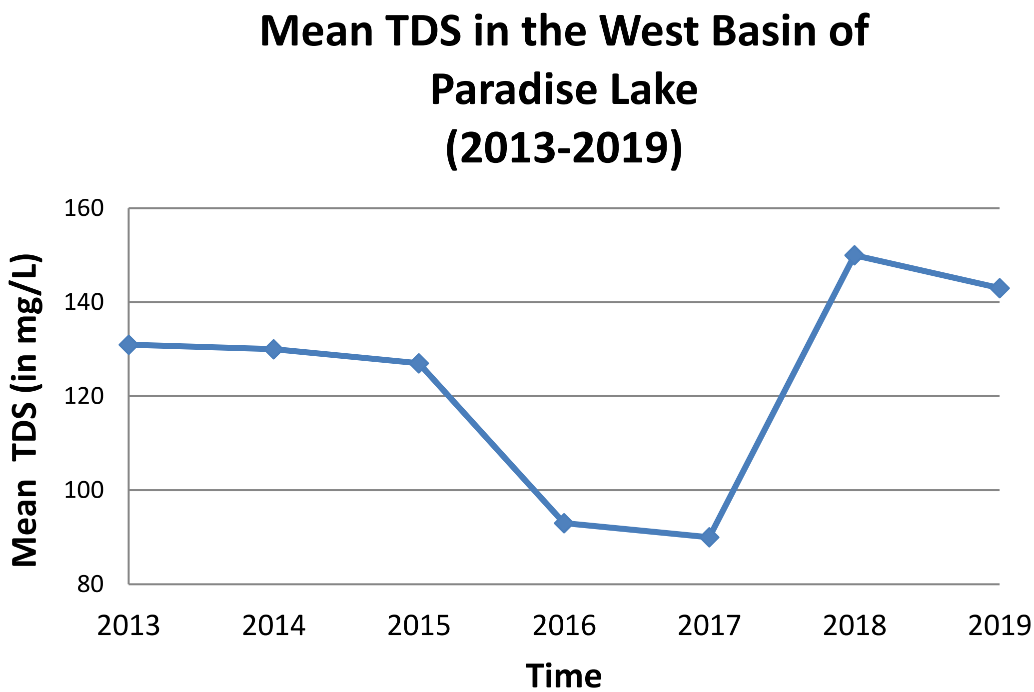

Figure 18. Mean TDS in the West Basin of Paradise Lake (2013-2019).

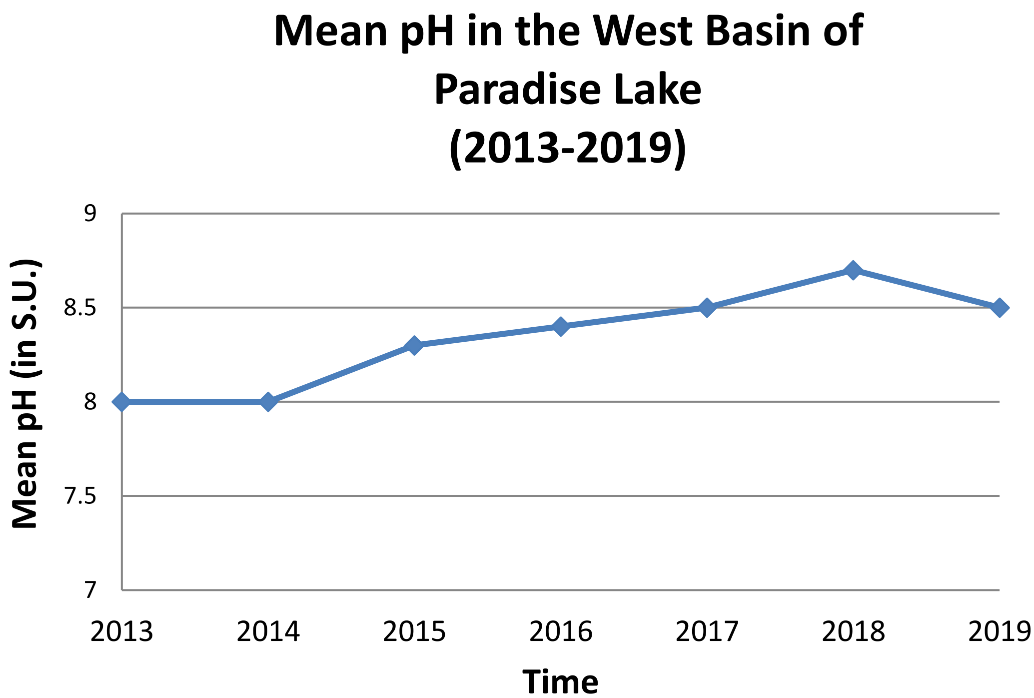

Figure 19. Mean pH in the West Basin of Paradise Lake (2013-2019).

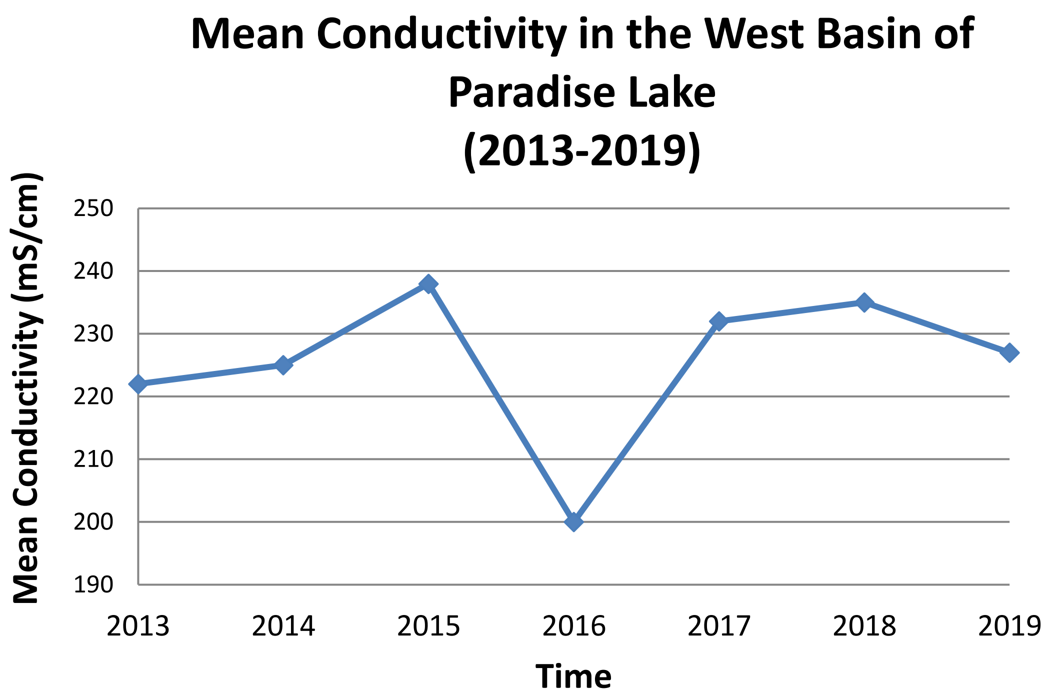

Figure 20. Mean conductivity in the West Basin of Paradise Lake (2013-2019).

5.2 Paradise Lake Chemical Water Quality Data Trends:

The following graphs display means of each water chemical quality parameter collected by RLS with time in the West Basin. They allow us to determine how individual water quality parameters are changing with time, presumably relative to the operation of the LFA system.

The mean TP (Figure 21) in the West Basin increased for a few years and then decreased in 2018 but increased slightly in 2019. The TP concentrations in the West Basin remain quite low and favorable below the eutrophic threshold. It also indicates that the aquatic plants obtain the majority of their nutrients from the sediments and sediment pore water.

The mean chlorophyll-a (Figure 22) in the West Basin has declined and is likely due to grazing by Zebra Mussels or due to the LFA system. These concentrations are highly favorable.

The mean TKN (Figure 23) in the West Basin has also declined to historical levels during the past two years despite a sharp increase in 2017. Although the TKN remains low, the ammonia concentrations in the lake are much higher and more bio-available for milfoil growth.

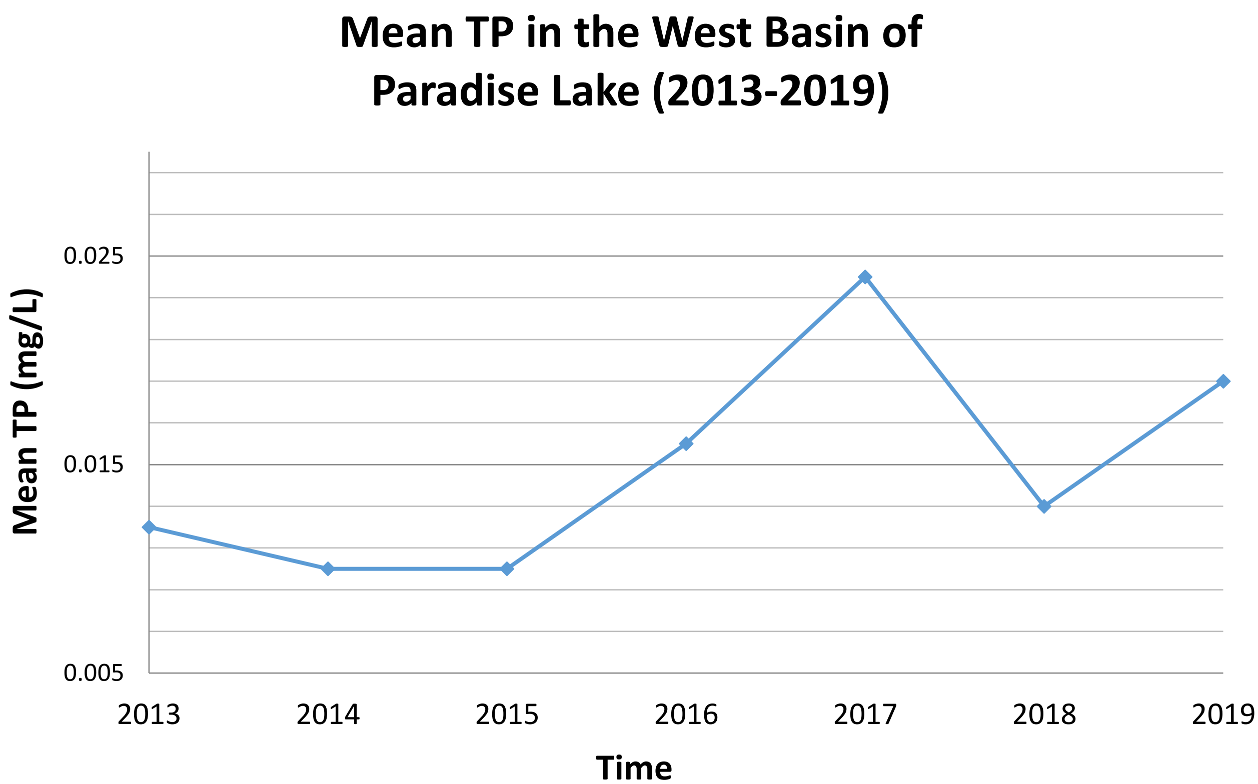

Figure 21. Mean TP in the West Basin of Paradise Lake (2013-2019).

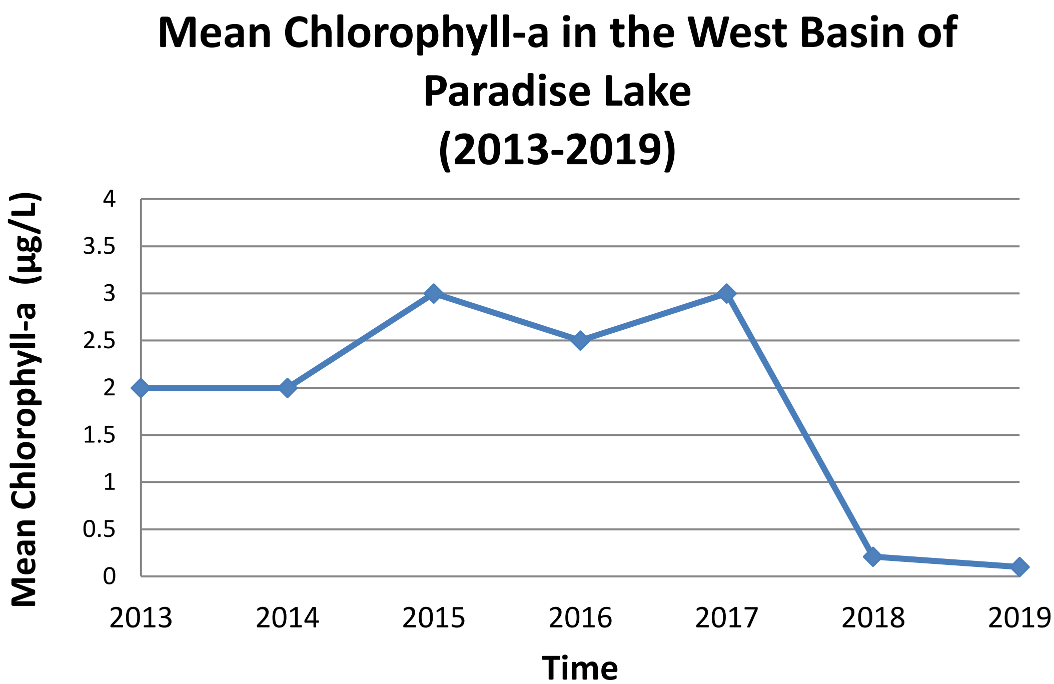

Figure 22. Mean chlorophyll-a in the West Basin of Paradise Lake (2013-2019).

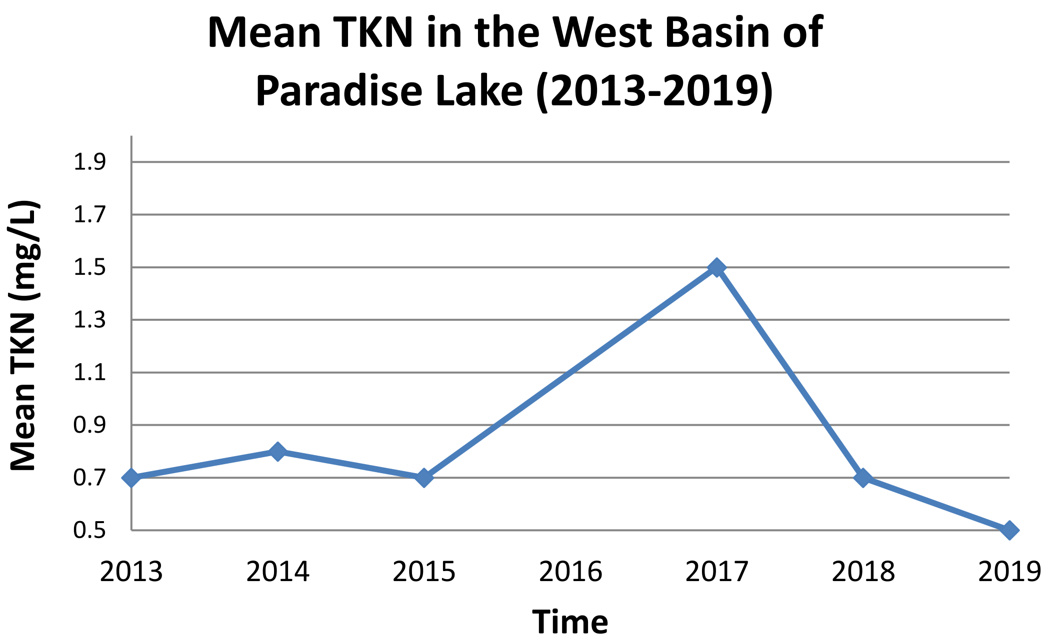

Figure 23. Mean TKN in the West Basin of Paradise Lake (2013-2019).

5.3 Paradise Lake Algal Community Data Trends:

In reference to Table 10 above, the proportion of green algae and diatoms to blue-green algae is favorable. Blue-green algae are the less desirable algae as they contribute to water quality degradation when in excess. The 2013 data set (RLS, 2013 report) showed more diatoms relative to green algae and the 2018 data set shows the same result in mid-September but more green algae in early July. This may be due to increased water temperatures that have occurred due to increasing air temperatures. Green algae need warm water temperatures and light to thrive in addition to nutrients. The blue-green algae in both years was quite low. The diatoms and green algae dominated in 2019 with fewer blue-green algae noted in the slide samples.

Chlorophyll-*a* has declined rapidly over the past two years and is likely related to the increasing Zebra Mussel population and their food preference of green algae. This parameter may also be declining due to LFA as that has been observed in other aerated lakes.

5.4 Paradise Lake Aquatic Vegetation Data Trends:

Earlier analyses (RLS 2014-2017 reports) demonstrated that the large canopy in the West Basin had segmented and was reduced in size. The amount of total cover in 2018 is similar to that observed in 2014. However, the EWM canopy remained below the lake surface until 2018-2019.

The overall native aquatic plant biodiversity remains high with 15 submersed, 2 floating-leaved, and 2 emergent aquatic plant species in the West Basin alone. The latest lack of EWM reduction was likely due to the high ammonia concentrations that would be used by the plant quickly and efficiently for accelerated growth. The EWM declined in 2019 only to be replaced by native pondweeds and other low-growing vegetation as is evidenced by the biovolume map.

5.5 Paradise Lake Sediment Data Trends:

In reference to sediment hardness, there has been a loss of moderate sediment hardness from 2014 to 2018 (58.44% to 34.69%) but a measurable increase in firmer bottom from 2014 to 2018 (33.18% to 48.46% and 6.47% to 14.41%) and again in 2019. This means that the LFA system is reducing sediment organic matter overall by reducing the soft bottom. The composition still consists of primarily sand with fibrous muck. The latter forms as a result of both decaying aquatic vegetation and also local mucky soils that originate on lake and may enter the lake with runoff and through erosion.

6.0 DISCUSSION OF POSSIBLE CONFOUNDING VARIABLES ON EFFICACY OF LFA SYSTEM RESULTS AND RECOMMENDATIONS

A confounding variable is one that may or may not be measured in a given experiment but may complicate the actual measured results because it can affect the outcome and may not be obvious. In this case, we are looking for data that may indicate confounding variables on the parameters in question for the efficacy of the LFA system in the West Basin. We know that making "cause and effect" statements in science is not usually possible but rather we look for evidence-based explanations of an observed outcome. The EWM in the LFA region was very dense in 2018 but that was also the case for other areas of the lake that remain non-aerated. RLS was able to determine that the majority of the nitrogen in the West Basin exists in the ammonia form which is the preferred food source for EWM. Thus, it is important to determine the possible source(s) of this ammonia. A likely origin of ammonia in lakes is from failing septic systems. With the higher frequency of heavy downpours occurring in the state and nationally (due to climate change), the ground around many septic systems becomes over-saturated and the nutrients (mostly ammonia) enter the lake water column and may result in exacerbated EWM growth. More data on ammonia is needed for other areas of the lake to determine additional areas of loading and potentially target septic areas that need improvements.

The application of the BioBlast® enzyme/bacteria formula to the West Basin of the lake in July 2018 was conducted to drop the EWM canopy by creating a competitive environment for nutrient uptake by the bacteria. This was somewhat successful with the canopy disappearing below the surface when other areas of the lake that were not treated remained emergent as a canopy (North shore). The canopy remained below the surface in 2019 when an additional BioBlast® treatment was conducted.

In addition to MDEQ permit required measurements for LFA, RLS recommends additional ammonia sampling throughout the lake basin to determine possible sources of ammonia which will further stimulate aquatic vegetation growth. The dense EWM noted throughout all of Paradise Lake during the 2018 season may have been due to sustained ammonia concentrations and elevated nitrate levels were noted in 2019. Over time, ammonia and nitrate enters the sediment pore water. However, if there are not adequate bacterial communities to oxidize ammonia (i.e. due to a lack of bio augmentation), then it will persist in that form and couple between the water column and sediment pore water where it is used as the primary nutrient source for EWM. Septic tanks may be a significant contributor to the total nitrogen in the lake and thus a lake-wide septic tank and drain field maintenance program should be pursued to reduce those sources.

RLS recommends that additional EWM reduction methods be on hand in case the EWM continues to be prevalent again throughout the Paradise Lake basin. This could include further bio augmentation in the West Basin and beyond, the use of a mechanical harvester to remove dense beds (NOTE: this has a high risk of fragmentation), and consideration of application of a fungal pathogen to attack the EWM. The use of DASH could be considered for individual homes but would be impractical on the large-lake scale. The PLIB should also discuss the benefits and risks of a possible one-time aquatic herbicide treatment which could be conducted prior to LFA re-starting in future years.