Lake Level Drawdown Impacts on the Sediments, Benthos, Select Physical Properties, and Aquatic Vegetation of Maple and Ackley Lakes, Van Buren County, Michigan

August, 2019

Photo courtesy of Village of Paw

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Lake Level Drawdown Impact on the Sediments, Benthos, Select Physical Properties, and Aquatic Vegetation of Maple and Ackley Lakes, Van Buren County, Michigan

August, 2019

1.0 EXECUTIVE SUMMARY

Maple Lake is located in Sections 1,11,12,13, and 14 (T.3S, R.14W) of the Village of Paw Paw and Paw Paw Township in Van Buren County, Michigan. The lake surface area is approximately 192 acres (Michigan Department of Natural Resources, 2001) and the lake may be classified as a eutrophic riverine impoundment with a dam at the north end of the lake. Maple Lake has a maximum depth of 15.0 feet and an average depth of 7.0 feet (MDNR, 2005). Maple Lake has historically been infested with invasive exotic watermilfoil, exotic Curly-leaf pondweed, and dense nuisance native aquatic vegetation. The Village of Paw Paw spends approximately $60,000 annually on combined aquatic plant control efforts to maintain navigation and recreation activities in the lake. The drawdown process has significantly reduced these costs in previous years, especially in regards to hybrid watermilfoil reductions.

Ackley Lake is approximately 65 acres in surface area and is located in Sections 1, 6, 7 and 12 of (T.3S, R. 13, and R.14W) of the Village of Paw Paw and Paw Paw Township in Van Buren County, Michigan. Although Ackley Lake does not have the nuisance aquatic vegetation growth that Maple Lake does, some residents are concerned that the Maple Lake drawdown may have negative impacts on the health of Ackley Lake.

The principal objectives of this project under this QAPP were to: 1) document the changes in both exotic and native aquatic vegetation communities in both lakes; 2) determine if the lake drawdown had an effect on the total suspended solids (TSS) and turbidity on lake water as measured downstream of the Maple Lake dam; 3) determine if the lake drawdown had an effect on the dissolved oxygen (DO) throughout the deep basin of Ackley Lake in winter; and 4) evaluate if the lake drawdown had any impacts on biotic communities of macroinvertebrates or fish spawning habitat in Maple and Ackley Lakes. The data was evaluated both prior to and after the drawdown process as mandated by MDEQ Permit No. 15-80-0005-P. Thus, this study and QAPP plan can evaluate if the drawdown had any impacts on both lakes.

An unfortunate failure of the Briggs Pond dam occurred in 2017 and thus the drawdown was suspended. An estimate by Wightman & Associates of sediment mobilization due to this breach was around 11,982 cubic yards. Since drawdown did not occur again until September of 2018, the pre-drawdown dataset now includes 2015 and 2017 with the post-drawdown dataset consisting of 2016, 2018, and 2019.

Overall conclusions for the evaluation period of 2015-2019 were that: 1) the dissolved oxygen in Ackley Lake was not depleted during the winter months, 2) the TSS and Turbidity downstream of the Maple Lake dam was low during and after the lake drawdown, 3) The lake drawdown reduced invasive milfoil in Maple Lake by approximately 30% between 2015-2016 and sustained this in 2016 with reductions in some other nuisance native species, 4) Chara had a measurable increase post-drawdown in both Maple and Ackley Lakes, 5) the sediment macroinvertebrate IBI remained very good to excellent before and after lake drawdown in both lakes, 6) fishery spawning habitat changed slightly in both lakes due to changes in bottom hardness and associated substrate.

Future recommendations include continued lake level drawdowns in the fall of each year. Additional herbicide treatments or mechanical harvesting may also be used to reduce the high density of nuisance aquatic vegetation. The parameters mentioned above, especially those that could be influenced by seasonality (aquatic plant community growth and distribution, sediment hardness, aquatic plant biovolume, sediment macroinvertebrates, and fishery spawning habitat) were sampled in September of 2016 and May of 2017 and again in 2018-2019 to compare season effect to lake drawdown effect. This allowed for a more precise determination of cause of changes in the parameters measured.

2.0 PROJECT DESCRIPTION

This document reports the baseline and post-drawdown data as listed in the QAPP which was created in pursuance to Permit No. 15-80-0005-P (Michigan Department of Environmental Quality; MDEQ) which granted lake drawdown of Maple Lake in Van Buren County, Michigan beginning no sooner than October 1, 2015 with refilling of the lake no later than March 1, 2016 and the same dates in 2017-2018.

The purpose of this evaluation was to determine if the lake drawdown in Maple Lake and subsequently, Ackley Lake, would impact select physical parameters, fish spawning habitat, aquatic macroinvertebrate community structure, and aquatic vegetation of both lakes. A site location map showing both lakes is shown below in Figure 1.

Lake level drawdowns have been implemented in many waterbodies to reduce nuisance aquatic vegetation growth. Lake levels are commonly lowered in the fall/winter months to allow for exposure of the lake bed and inherent seed bank to freezing and desiccation conditions. Lake sediments exposed to freezing may result in damage to the seed bank from ice-scouring and uprooting of overwintering vegetation. It is critical that thorough aquatic vegetation/biota surveys be conducted prior to and after drawdown to assure that favorable native species of biota (plants, clams, etc.) are not being negatively impacted. In addition, this data is necessary to determine the efficacy of drawdown on the management of nuisance aquatic vegetation.

Figure 1. Aerial photo of Maple and Ackley Lakes, Van Buren County, Michigan.

3.0 PARAMETERS MEASURED, DATES, AND ASSOCIATED METHODS

3.1 Abiotic (non-living parameters)

Abiotic parameters include physical or chemical properties that are measured in an aquatic ecosystem. Three major abiotic parameters were measured before and after drawdown and include dissolved oxygen (in the deep basin of Ackley Lake), and total suspended solids, and turbidity (downstream of the Maple Lake Dam).

3.1.1 Dissolved Oxygen

Dissolved oxygen (DO) is a measure of the amount of oxygen that exists in the water column. In general, DO levels should be greater than 5 mg L^{-1} to sustain a healthy warm-water fishery. DO concentrations may decline if there is a high biochemical oxygen demand (BOD) where organismal consumption of oxygen is high due to respiration. DO is generally higher in colder waters. DO was measured in milligrams per liter (mg L^{-1}) with the use of a calibrated YSI meter. The DO meter was calibrated on March 10, 2016 and again on March 20, 2017 and again on February 4, 2019 using the calibration method specified in Section 7.3A of the QAPP document. During the summer months, DO at the surface is generally higher due to the exchange of oxygen from the atmosphere with the lake surface, whereas DO is lower at the lake bottom due to decreased contact with the atmosphere and increased biochemical oxygen demand (BOD) from microbial activity. Permit No. 15-80-0005-P required that DO concentrations be measured over the deep basin (N 42°13.899’, W 85° 52.627’) of Ackley Lake (Figure 2). The measurements were collected on March 11, 2016 and again on March 20, 2017 and February 4, 2019 in 1-foot intervals due to unsafe ice conditions in February of 2016 and early to mid-March of 2017. The MDEQ was notified and also invited to accompany Restorative Lake Sciences (RLS) during the sampling. The field data for DO is shown in Appendix A.

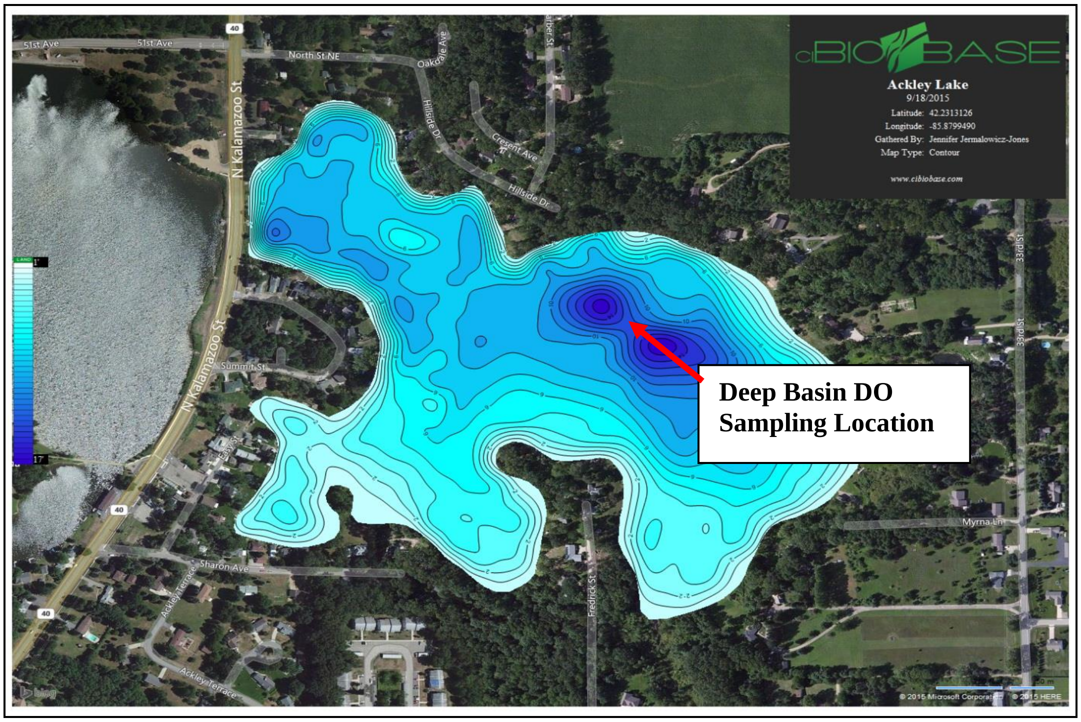


Figure 2. Ackley Lake deep basin DO sampling site
(March 11, 2016 and March 20, 2017 and February 4, 2019).

3.1.2 Total Suspended Solids and Turbidity

Total Suspended Solids (TSS) is the measure of the amount of suspended particles in the water column. Particles suspended in the water column absorb heat from the sun and raise the water temperature. Total suspended solids were measured in mg L^{-1} and analyzed in the laboratory. TSS grab samples were collected by RLS scientists with fresh non-used 250-ml sample bottles as supplied from TRACE Analytical Laboratories in Muskegon, Michigan.

TSS samples were collected pre-drawdown on September 27, 2015; during drawdown on October 13, 2015; and after drawdown on November 10, 2015 and December 16, 2015 downstream of the dam. In 2016, samples were collected on September 29, October 6, October 10, October 14, October 17, October 19, and October 24 at the locations shown below in Figure 3. In 2017, samples were not collected due to a lapse in drawdown due to the breach of Briggs Dam Pond into Maple Lake. In 2018, samples were collected on August 2, September 19, September 28, November 2, November 28, and December 14. All samples were kept on ice prior to analysis and taken to TRACE within 48 hours of collection for analysis of TSS using Method SM2540-D. TRACE is a NELAC certified laboratory (the highest level of QA QC). Fresh samples collected at the same time of the TSS samples were then transferred immediately to a Lutron® turbidity meter (Model No. TU-2016) and data was read and recorded. The meter was calibrated (as listed in the meter instructions listed in the QAPP) prior to taking these readings.

Data was then recorded onto an RLS field data sheet with the lake name, date, personnel taking the measurements, field conditions, and location (GPS coordinates) of each sample as required in the QAPP. Although it was intended to have TRACE analyze the TSS in 1 mg L^{-1} increments, the samples were analyzed based on lowest detection limit which was < 10 mg L^{-1}.

Turbidity is a measure of the loss of water transparency due to the presence of suspended particles. The turbidity of water increases as the number of total suspended particles increases. Turbidity may be caused by erosion inputs, phytoplankton blooms, storm water discharge, urban runoff, re-suspension of bottom sediments, and by large bottom-feeding fish such as carp. Particles suspended in the water column absorb heat from the sun and raise water temperatures. Since higher water temperatures generally hold less oxygen, shallow turbid waters are usually lower in dissolved oxygen. Turbidity was measured in Nephelometric Turbidity Units (NTU's) with the use of a turbidimeter. The World Health Organization (WHO) requires that drinking water be less than 5 NTU's; however, recreational waters may be significantly higher than that.

The field data sheets for all TSS and turbidity data can be found in Appendix A.

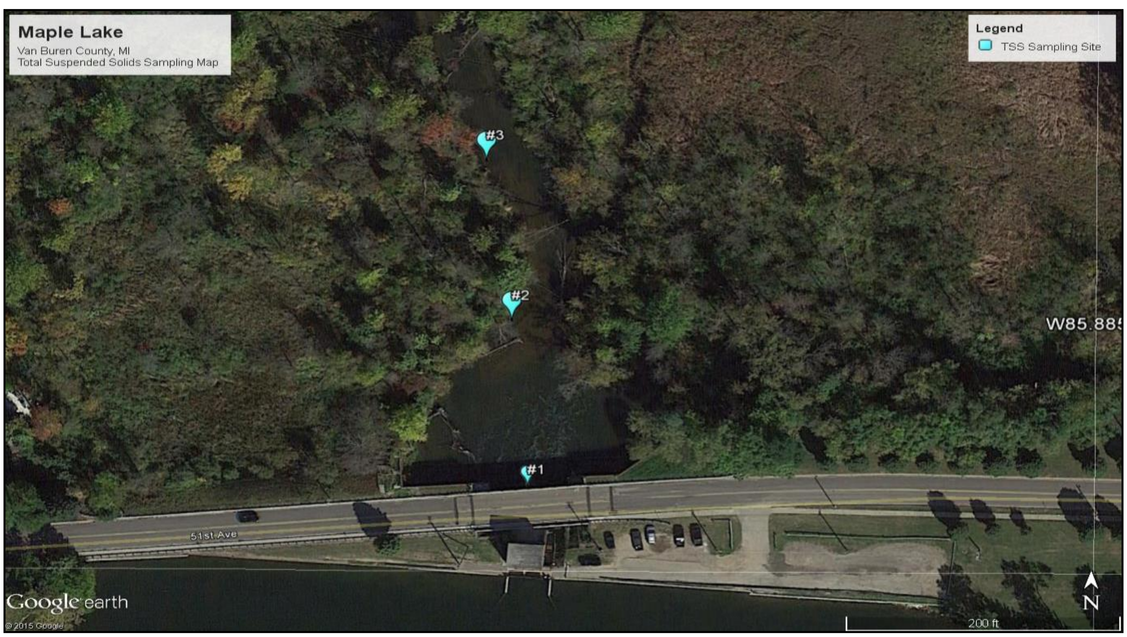


Figure 3. TSS and Turbidity sampling locations downstream of the Maple Lake dam (#1: N 42°14.125', W 85°53.208'; #2: N 42°14.150', W 85°53.211'; #3: N 42°14.174', W 85°53.215'). NOTE: An additional sample was collected in 2016 on the south side of the Michigan Ave bridge near the inlet to Maple Lake per the MDEQ request (42°13.060 N, 85° 53.745 W).

3.1.3 Sediment Composition Change

The procedure for scanning the lake bottoms for bottom composition are described in detail in Appendix D of the QAPP. On September 18, 2015, May 19, 2016, May 15, 2017, and September 19, 2018, and May 29, 2019 a benthic scan using a Lowrance® 50-satellite GPS HDS 8 WAAS-enabled unit (accuracy within 2 feet) was conducted to analyze the bottom of Maple and Ackley Lakes. On the sediment maps, the red and orange colors indicate firmer substrate types whereas the grey colors denote softer, organic substrate.

3.2 Biotic (living/biological parameters)

Biotic parameters include the biological properties that are measured in an aquatic ecosystem. Three major biotic parameters were measured before and after drawdown and include sediment macroinvertebrates, fisheries spawning habitat, and aquatic vegetation communities.

3.2.1 Sediment Macroinvertebrates

Freshwater macroinvertebrates are ubiquitous, as even the most impacted lake contains some representatives of this diverse and ecologically important group of organisms. Benthic macroinvertebrates are key components of lake food webs both in terms of total biomass and in the important ecological role that they play in processing of energy. Others are important predators, graze alga on rocks and logs, and are important food sources (biomass) for fish. The removal of macroinvertebrates has been shown to impact fish populations and total species richness of an entire lake or stream food web (Lenat and Barbour 1994). In the food webs of lakes, benthic macroinvertebrates have an intermediate position between primary producers and higher trophic levels (as fish) on the other side. Hence, they play an essential role in key ecosystem processes (food chain dynamics, productivity, nutrient cycling and decomposition). These may also include many rare species.

Pursuant to MDEQ permit No. 15-80-0005-P, the macroinvertebrate communities of both Ackley and Maple Lakes were assessed prior to and after lake drawdown of 10 sampling stations in Maple Lake and in Ackley Lake on September 18, 2015 (pre-drawdown) and again on May 19, 2016 and on May 15, 2017 (post-drawdown) and again on September 19, 2018 and May 29, 2019. Benthic samples were collected with an Ekman® hand dredge (9” x 9” square). As recommended, if any woody debris was present within the benthic area sampled, then the woody debris was also recorded and the macroinvertebrates were sampled from the woody debris. Samples were collected from aquatic macrophyte plant beds, and along the surface of the sediment/water interface, with the use of a Turtox® dip net (Model 425-T10) from Wildco®.

Macroinvertebrate samples were placed in small plastic buckets and analyzed in the RLS wet laboratory within 24 hours after collection using a hard plastic sorting tray, tweezers, and a Meiji® dissection microscope under 1X, 3X, and 10X power. Macroinvertebrates were taxonomically identified using a key from: "The Introduction to the Aquatic Insects of North America", by Merritt, Cummings, and Berg (2008) to at least the family level and genus level whenever possible. All macroinvertebrates were recorded including larval or nymph forms, crayfish, mussels, snails, worms, or other "macro" life forms. Data for the macroinvertebrate collections can be found in Appendix A. Figure 4 below shows the locations of all macroinvertebrate sampling areas on both Maple and Ackley Lakes.

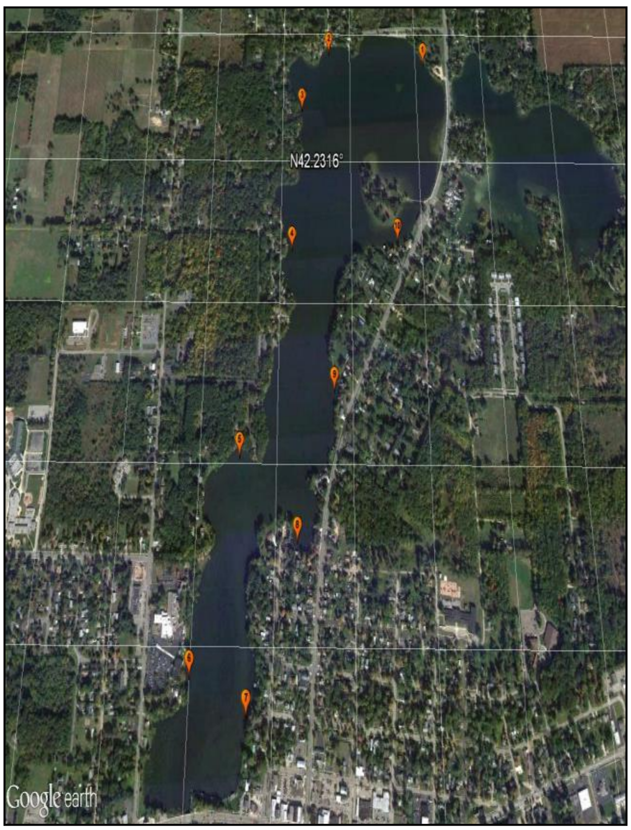


Figure 4. Macroinvertebrate sampling locations in Maple and Ackley Lakes (2015-2017 and 2018-2019).

3.2.2 Fisheries Spawning Habitat

Fishery spawning and nursery habitat sites in both lakes were sampled by RLS scientists by boat prior to and after drawdown of both lakes on September 18, 2015 (pre-drawdown) and again on May 19, 2016 and May 15, 2017, and May 29, 2019. Samples were not collected in 2018 due to the breach. Assessment of the entire shoreline occurred on both lakes. Assessment of active beds with fish on or very near to the beds was also assessed. Determination of the number of inactive beds with no viable fish and/or bare lake bottom were also made. In addition, nursery habitat with thick vegetation and woody debris that serves as excellent shelter from predators were also assessed.

A series of five classification groups were assigned to evaluate the integrity of fishery spawning habitat in the assessment survey: 1) nursery-type habitat, which is defined as shelter from predators including thick emergent vegetation or thick submersed vegetation and/or the presence of woody debris, 2) active beds, where fish are visible on or very near to those particular beds, 3) unsuitable habitat which is defined as areas poor in vegetation cover or woody debris, and 4) potential bedding areas, where vegetation is not too thick for bedding, yet non-vegetated lake bottom may be visible, and 5) in active beds where habitat is visible but the fish are not actively present.

Each spawning habitat site was marked by GPS and maps were made for both lakes that show the locations of the spawning habitat and the type of habitat classification (denoted by map legends). Existing knowledge of the type of fish species that currently utilizes the existing fish habitat was also taken into account and that data was also recorded both before and after drawdown.

3.2.3 Aquatic Vegetation Communities

The aquatic plant sampling methods used for lake surveys of macrophyte communities commonly consist of shoreline surveys, visual abundance surveys, transect surveys, AVAS surveys, and Point-Intercept Grid surveys. The Michigan Department of Environmental Quality (MDEQ) prefers that an Aquatic Vegetation Assessment Site (AVAS) Survey, or a GPS Point-Intercept survey (or both) be conducted on most inland lakes. This method is used to assess the changes in aquatic vegetation structure and to calculate the percent cumulative cover and locations of native aquatic plant species.

The MDEQ AVAS Survey Method to be used in the QAPP:

The MDEQ Aquatic Vegetation Assessment Site (AVAS) Survey method was developed by the MDEQ to assess the presence and percent cumulative cover of submersed, floating-leaved, and emergent aquatic vegetation within and around the littoral zones of Michigan lakes. With this survey method, the littoral zone areas of the lakes are divided into lakeshore sections approximately 100 - 300 feet in length. Each AVAS segment is sampled using visual observation, dependent on water clarity, and weighted rake tows to verify species identification. The species of aquatic macrophytes present and density of each macrophyte are recorded onto an MDEQ AVAS data sheet. Each separate plant species found in each AVAS segment is recorded along with an estimate of each plant density. Each macrophyte species corresponds to an assigned number designated by the MDEQ. The Michigan Department of Environmental Quality has 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). In addition to the particular species observed (via assigned numbers), density information above was used to estimate the percent cumulative coverage of each species within the AVAS site. If shallow areas were present in the open waters of the lakes, then individual AVAS segments were sampled at those locations to assess the macrophyte communities in offshore locations. This is particularly important since exotics often expand in shallow island areas located offshore in many lakes such as Maple Lake.

The MDEQ AVAS survey of both Maple and Ackley Lakes prior to and after lake drawdown on September 18, 2015 and again on May 19, 2016 and May 15, 2017 and September 19, 2018, and May 29, 2019 . The data was placed in a table showing the relative abundance of each aquatic plant species found and a resultant calculation showing the frequency of each plan, and cumulative cover. A map showing the locations of each species was also derived and was used to generate the tabular data. The procedure for the AVAS survey protocol was previously submitted for the QAPP.

The GPS Benthic Scanning Method to also be used in the QAPP:
While the MDEQ AVAS protocol considers sampling aquatic vegetation using visual observations in areas around the littoral zone, the GPS Benthic Scanning Survey method is meant to assess aquatic plant biovolume throughout the entire surface area both lakes. This method involved conducting a scan of the entire bottom of both Ackley and Maple Lakes on September 18, 2015 and again on May 19, 2016, and May 15, 2017 and again on September 19, 2018 and May 29, 2019. Once the aquatic vegetation communities throughout the lake were recorded using the GPS Lowrance® HDS 8 unit, the data was uploaded into a Geographic Information System (GIS) software package (BioBase®) to create maps showing the aquatic vegetation biovolume and bottom hardness and depth contours. The GPS Benthic Scanning method was particularly useful for monitoring aquatic vegetation communities through time and for determining the possible impacts of lake drawdown on overall aquatic plant biovolume. The benthic scans resulted in whole-lake aquatic vegetation biovolume maps. The procedure for conducting the GPS Benthic Scanning Survey was previously submitted for the QAPP.

4.0 PARAMETER RESULTS BEFORE AND AFTER DRAWDOWN

4.1 Abiotic (non-living parameters)

Abiotic parameters include physical or chemical properties that are measured in an aquatic ecosystem. Three major abiotic parameters were measured before and after drawdown and include dissolved oxygen (in the deep basin of Ackley Lake), and total suspended solids, and turbidity (downstream of the Maple Lake Dam).

4.1.1 Dissolved Oxygen

The DO in Ackley Lake on March 11, 2016 over the deepest basin ranged from 13.51 mg L^{-1} at the surface to 7.58 mg L^{-1} at the bottom (Table 1). These values were taken just a week after ice off due to unsafe ice conditions in February. Another profile of DO was collected in Ackley Lake on March 20, 2017 (Table 2) and the DO concentrations ranged from 11.40-13.68 mg L^{-1}. Lastly, another profile of DO was measured on February 4, 2019 (Table 3) and the concentrations ranged from 8.0-13.3 mg L^{-1}.

The results indicated that Ackley Lake had ample DO concentrations throughout the water column and near the lake bottom during these sampling periods and that drawdown does not appear to be decreasing

DO concentrations in Ackley Lake during later winter/early spring. The field data sheet for this DO data is shown in Appendix A of this report.

Sample Location	**Depth (ft.)**	**Temp (°C)**	**DO (mg L^{-1})**
Deep Basin	0	9.5	13.51
	1	9.3	13.64
	2	9.1	13.67
	3	9.1	13.69
	4	8.9	13.38
	5	8.9	13.33
	6	8.9	13.23
	7	8.8	13.21
	8	8.8	13.16
	9	8.7	13.10
	10	8.5	12.85
	11	8.5	12.80
	12	8.4	12.71
	13	8.3	12.51
	14	8.2	11.54
	15	8.2	7.58

Table 1. Ackley Lake DO concentrations on March 11, 2016 over the deepest basin.

Sample Location	**Depth (ft.)**	**Temp (°C)**	**DO (mg L^{-1})**
Deep Basin	0	9.9	13.60
	1	9.9	13.60
	2	9.8	13.68
	3	9.8	13.68
	4	9.7	13.68
	5	9.7	13.66
	6	9.5	13.66
	7	9.5	13.62
	8	9.5	13.59
	9	9.3	13.59
	10	9.0	13.45
	11	9.0	12.88
	12	9.0	12.80
	13	9.0	12.79
	14	8.9	12.21
	15	8.9	11.40

Table 2. Ackley Lake DO concentrations on March 20, 2017 over the deepest basin.

Sample Location	Depth (ft.)	Temp (°C)	DO (mg L^{-1})
Deep Basin	0	9.6	13.3
	1	9.5	13.3
	2	9.3	13.3
	3	9.3	13.3
	4	9.2	13.4
	5	9.1	13.3
	6	9.0	13.3
	7	8.9	13.3
	8	8.9	13.3
	9	8.9	13.2
	10	8.7	13.2
	11	8.7	12.9
	12	8.6	12.9
	13	8.5	12.6
	14	8.4	11.7
	15	8.4	8.0

Table 3. Ackley Lake DO concentrations on February 4, 2019 over the deepest basin.

4.1.2 Total Suspended Solids and Turbidity

Total suspended solids (TSS) and turbidity (Turb) sample data indicated that there was elevated TSS and turbidity prior to lake drawdown on September 27, 2015, which was likely due to heavy rainfall in the sampling area. TSS and turbidity samples collected during (October 13, 2015) and after drawdown (November 10, 2015 and December 16, 2015) and before and after drawdown in 2018, were all low and indicated no solids or elevated turbidity was resulting from the lake drawdown activity. For the 2016 samples, most of the 29 samples had TSS concentrations < 10 mg L^{-1}, except for location #2 on October 10 which was 40 mg L^{-1}; location #5 (mid-stream) on October 17 which was 12 mg L^{-1}; and location #1 on October 19 which was 12 mg L^{-1}. All of the Turbidity measurements ranged from 0.8-1.8 NTU's which is quite low. In 2018, all TSS samples were below 10 mg L^{-1} and turbidity ranged from 0.8-4.5 NTU's which is favorable.

Tables 4-6 below show the actual data and the field data sheets and lab reports can be found in Appendix A. An independent samples t-test (α=0.05) was applied to the TSS and turbidity data for both lakes. There was a significant decline in TSS and turbidity from pre-drawdown to post-drawdown and also a significant decline in TSS and turbidity from pre-drawdown to during draw-down (see Tables 7a and 7b and Table 8a and 8b below) and also from pre-drawdown to post-drawdown.

Sampling Date	Sample Location	Sample No.	TSS (mg L^{-1})	Turb. (NTU)
9-27-2015 (Pre drawdown)	1	1000	98	5.1
	2	1001	60	4.6
	3	1002	36	4.2
10-13-2015 (during drawdown)	1	1003	< 10	1.0
	2	1004	< 10	0.9
	3	1005	< 10	0.9
11-10-2015 (after drawdown)	1	1	< 10	0.6
	2	2	< 10	0.6
	3	3	< 10	0.5
12-16-2015 (after drawdown)	1	1	< 10	1.1
	2	2	< 10	0.6
	3	3	< 10	0.6

Table 4. TSS and Turbidity downstream of the Maple Lake dam prior to, during, and after drawdown (2015).

Sampling Date	Sample Location	Sample No.	TSS (mg L^{-1})	Turb. (NTU)
9-29-2016 (Pre drawdown)	1	6943	<10	1.1
	2	6944	<10	1.0
	3	6945	<10	0.9
10-6-2016 (during drawdown)	1	TSS #1	<10	1.2
	2	TSS #2	<10	1.0
	3	TSS #3	<10	1.0
10-10-2016 (during drawdown)	1	6955	<10	0.9
	2	6956	40	1.3
	3	6957	<10	1.3
10-14-16 (during drawdown)	1	6974	<10	1.4
	2	6975	<10	1.1
	3	6976	<10	1.4
	4	6977	<10	0.8
10-17-2016 (during drawdown)	1	7052	<10	0.9
	2	7053	<10	0.9
	3	7054	<10	1.3
	4	7055	<10	1.0
	5	7056	12	1.0
	6	7057	<10	1.3
	7	7058	<10	1.1
	8	7059	<10	0.9
10-19-2016 (during drawdown)	1	7060	12	1.8
	2	7061	<10	1.1
	3	7062	10	1.1
	4	7063	<10	0.9
10-24-16 (post-drawdown)	1	7064	<10	0.9
	2	7065	<10	0.9
	3	7066	<10	1.1
	4	7067	<10	0.9

Table 5. TSS and Turbidity downstream of the Maple Lake dam prior to, during, and after drawdown (2016).

Sampling Date	Sample Location	Sample No.	TSS (mg L^{-1})	Turb. (NTU)
8-2-2018 (Pre drawdown)	1	504	<10	1.0
	2	505	<10	1.0
	3	506	<10	1.0
	4	507	<10	1.5
9-19-2018 (Pre drawdown)	1	679	<10	0.9
	2	676	<10	0.9
	3	677	<10	1.7
	4	678	<10	1.0
9-28-2018 (During drawdown)	1	722	<10	2.0
	2	723	<10	0.8
	3	724	<10	1.0
	4	725	<10	1.0
11-2-2018 (Post drawdown)	1	848	<10	2.0
	2	849	<10	2.5
	3	850	<10	1.0
	4	851	<10	1.3
11-28-2018 (Post drawdown)	1	851	<10	2.0
	2	852	<10	0.8
	3	853	<10	0.8
	4	854	<10	1.0
12-14-2018 (Post drawdown)	1	876	<10	4.0
	2	877	<10	4.0
	3	878	<10	4.5
	4	879	<10	4.0

Table 6. TSS and Turbidity downstream of the Maple Lake dam prior to, during, and after drawdown (2018).

Group Statistics

	VAR00002	N	Mean	Std. Deviation	Std. Error Mean
VAR00001	1.00	3	4.6333	.45092	.26034
	2.00	35	1.0143	.26805	.04531

Table 7a. Descriptive statistics showing means of turbidity in 2015 (μ=4.6 NTUs) and 2016 (μ=1.0 NTUs).

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
VAR00001	Equal variances assumed	1.065	.309	21.383	36	.000	3.61905	.16925	3.27579	3.96231
	Equal variances not assumed			13.695	2.123	.004	3.61905	.26425	2.54284	4.69525

Table 7b. Statistical output for pre-drawdown to post-drawdown turbidity data downstream of the Maple Lake Dam (p=0.000). Turbidity was higher pre-drawdown in 2015 compared to post-drawdown in 2016.

Group Statistics

	VAR00002	N	Mean	Std. Deviation	Std. Error Mean
VAR00001	1.00	3	64.6667	31.26233	18.04932
	2.00	38	10.8947	4.87015	.79004

Table 8a. Descriptive statistics showing means of TSS in 2015 (μ=65 mg L^{-1}) and 2016 (μ=10.9 mg L^{-1}).

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
VAR00001	Equal variances assumed	36.794	.000	10.522	39	.000	53.77193	5.11061	43.43475	64.10911
	Equal variances not assumed			2.976	2.008	.096	53.77193	18.06660	-23.67845	131.22231

Table 8b. Statistical output for pre-drawdown to post-drawdown TSS data downstream of the Maple Lake Dam (p=0.000). TSS was higher pre-drawdown in 2015 compared to post-drawdown in 2016.

Group Statistics

	VAR00002	N	Mean	Std. Deviation	Std. Error Mean
VAR00001	1.00	12	1.1500	.37295	.10766
	2.00	12	2.3250	1.43345	.41380

Table 9a. Descriptive statistics showing means of turbidity in 2018 (pre drawdown μ=1.2 mg L^{-1}) and post-drawdown 2018 (μ=2.3 mg L^{-1}).

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
VAR00001	Equal variances assumed	23.289	.000	-2.748	22	.012	-1.17500	.42758	-2.06174	-.28826
	Equal variances not assumed			-2.748	12.482	.017	-1.17500	.42758	-2.10263	-.24737

Table 9b. Statistical output for pre-drawdown to post-drawdown turbidity data downstream of the Maple Lake Dam (p=0.012). TSS was higher pre-drawdown in 2018 compared to post-drawdown in 2018.

Note: All TSS values in 2018 both pre and post-drawdown were < 10 mg L^{-1} which is below detection. As a result of these similar numbers, further analyses were not needed.

Bottom Composition Change:

Figures 5a-5c show the sediment bottom hardness of Maple Lake in 2015 pre-drawdown and 2016-2017 post drawdown, respectively. Figures 6a-6c show the pre (2015) and post (2016-2017) drawdown sediment bottom hardness for Ackley Lake, respectively. Lastly, Figures 5d-e and 6d-e show the pre and post drawdown maps for 2018-2019.

The statistics generated for Maple and Ackley lakes pre and post-drawdown are shown in Tables 10 and 11 below, respectively. On the sediment maps, the red and orange colors indicate firmer substrate types whereas the grey colors denote softer, organic substrate. For Maple Lake, there was an increase in the two softest bottom type categories and the hardest bottom type but a measurable decline in the moderate bottom category. This indicates that fine, soft sediments are settling out on the bottom Maple Lake as

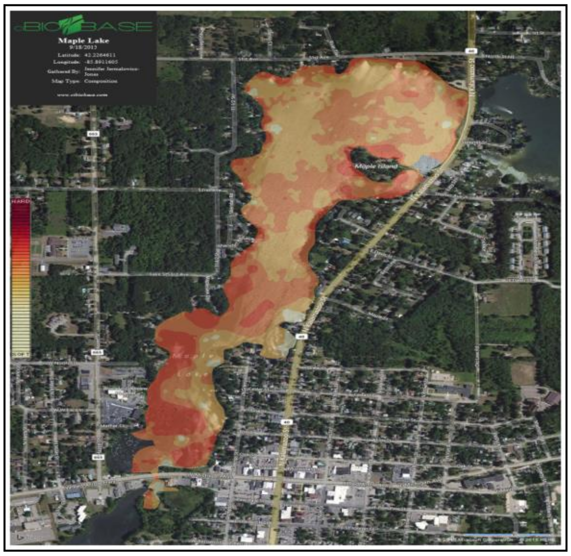
they enter the lake and do not migrate much downstream of the dam given the low TSS and turbidity readings. For Ackley Lake, there were also increases in the two softest bottom type categories and losses in the hardest bottom and moderate bottom categories. Since it is unlikely that sediment is being transported from Maple to Ackley Lake, the increase in soft bottom in Ackley Lake could be due to multiple aquatic vegetation treatments and the consequential accumulation of organic matter on the lake bottom.

Lake Bottom Composition	September, 2015 (%)	May, 2016 (%)	May, 2017 (%)	September, 2018 (%)	May, 2019 (%)	Net Loss(-) or Gain (+) (%)
<0.2 (softest)	0.15	0.47	1.39	0.9	0.15	0
0.2-0.3	39.38	50.46	60.71	27.12	39.28	-0.1
0.3-0.4	57.45	30.23	27.37	52.87	26.53	-30.92
>0.4 (hardest)	3.01	18.85	10.54	19.1	34.03	+31.02

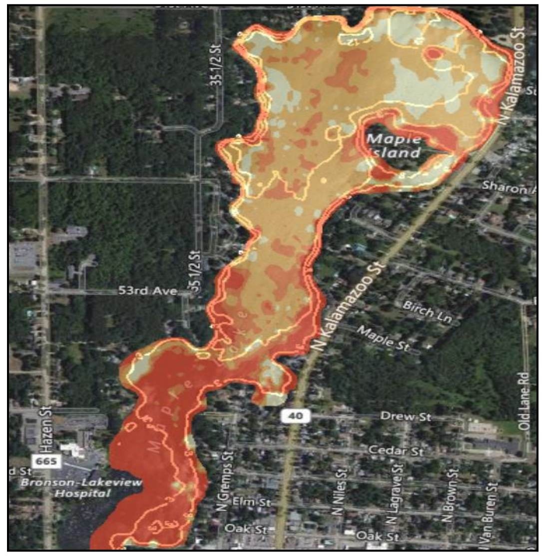
Table 10. Changes in sediment bottom hardness in Maple Lake before (September, 2015 and September, 2018) and after (May, 2016 and May, 2017 and May, 2019) and again pre (September 2018 and post May 2019) lake drawdown. This indicates that most of the soft sediments are settling out in Maple Lake rather than going downstream of the dam when the TSS and turbidity values are also considered.

Lake Bottom Composition	September, 2015 (%)	May, 2016 (%)	May, 2017 (%)	September, 2018 (%)	May, 2019 (%)	Net Loss(-) or Gain (+) (%)
<0.2 (softest)	2.36	0.74	8.34	0.72	0.24	-2.12
0.2-0.3	14.34	55.95	65.14	12.49	13.65	-0.69
0.3-0.4	53.63	21.29	18.73	49.75	50.50	-3.13
>0.4 (hardest)	29.67	22.02	7.77	37.04	33.80	+4.13

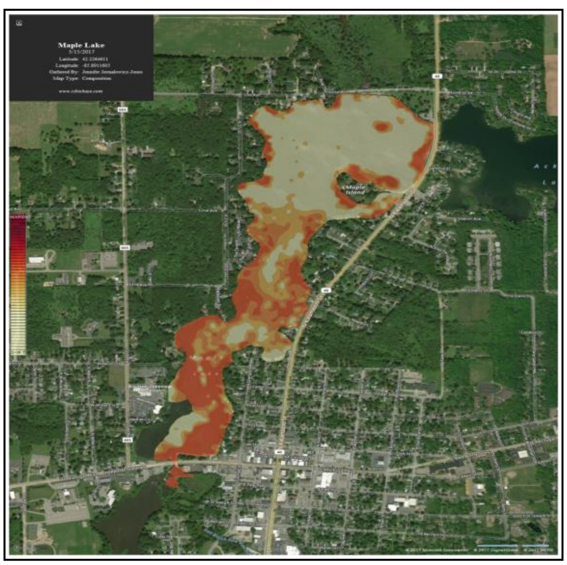
Table 11. Changes in sediment bottom hardness in Ackley Lake before (September, 2015) and after (May, 2016 and May 2017) and again before (September 2018) and after (May, 2019) lake drawdown.



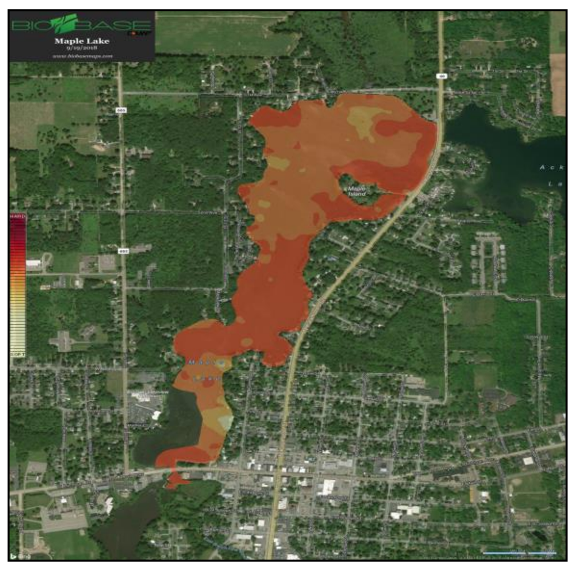
5a. Maple Lake pre-drawdown sediment Hardness map (September, 2015)



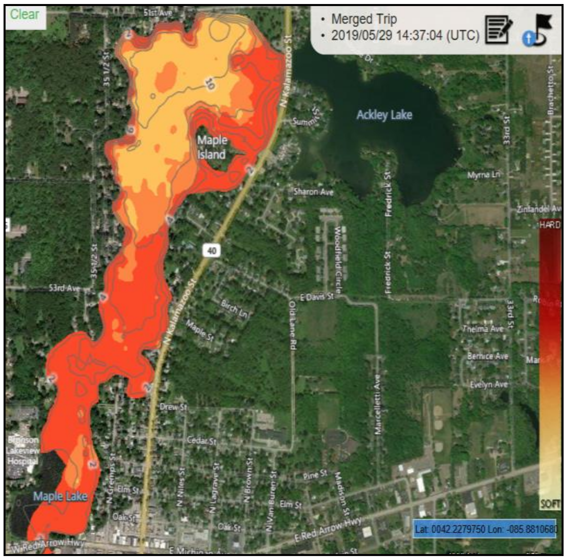
5b. Maple Lake post-drawdown sediment hardness map (May, 2016)



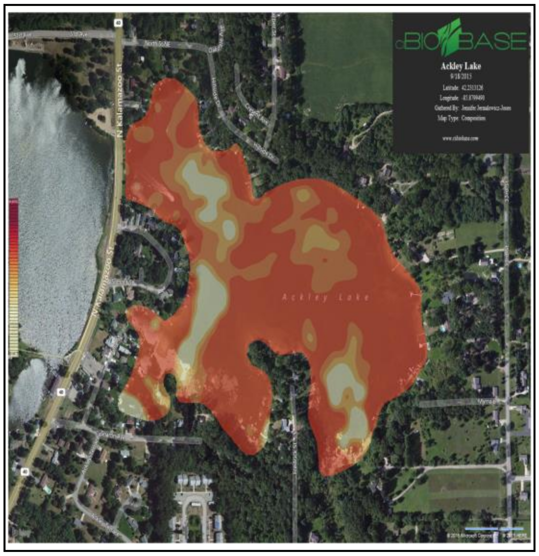
5c. Maple Lake post-drawdown sediment hardness map (May, 2017)



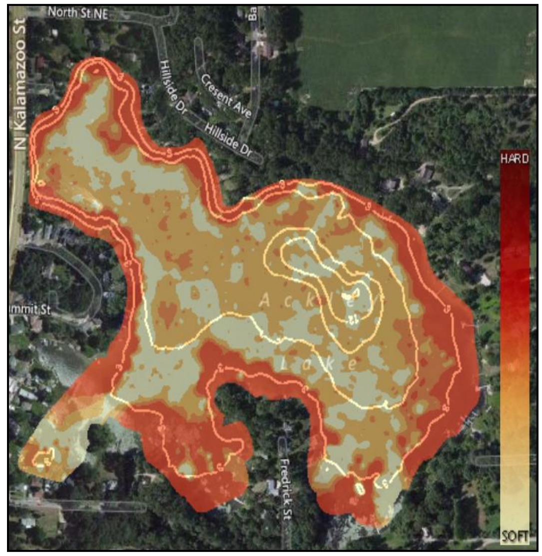
5d. Maple Lake pre-drawdown sediment hardness map (September, 2018).



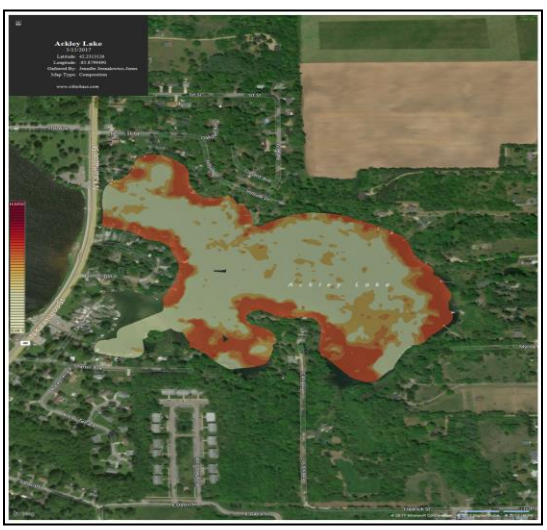
5e. Maple Lake pre-drawdown sediment Hardness map (May, 2019).



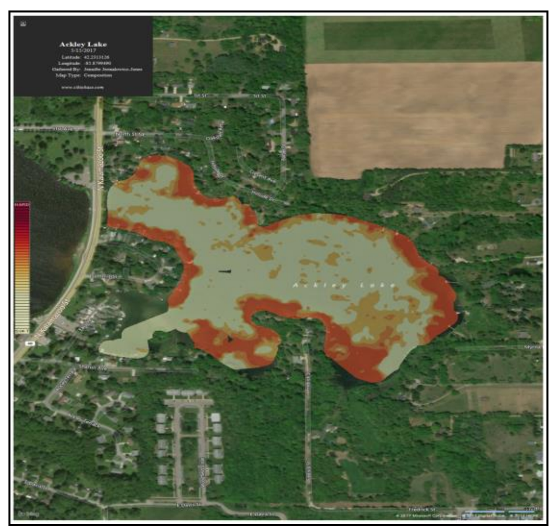
6a. Ackley Lake pre-drawdown sediment Hardness map (September, 2015)



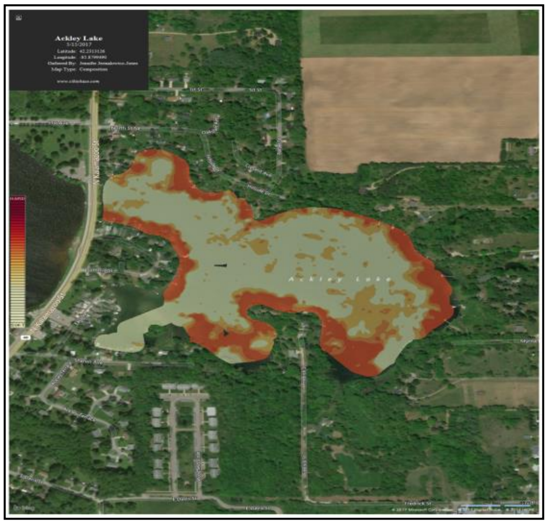
6b. Ackley Lake post-drawdown sediment hardness map (May, 2016)



6c. Ackley Lake post-drawdown sediment hardness map (May, 2017)



6d. Ackley Lake pre-drawdown sediment hardness map (September, 2018).



6e. Ackley Lake post-drawdown
Sediment hardness map (May, 2019).

4.2 Biotic (living parameters)

Biotic parameters include the biological properties that are measured in an aquatic ecosystem. Three major biotic parameters were measured before and after drawdown and include sediment macroinvertebrates, fisheries spawning habitat, and aquatic vegetation communities.

4.2.1 Sediment Macroinvertebrates

Sediment macroinvertebrates were samples were collected in Maple and Ackley Lakes on Sept 18, 2015 and May 19, 2016, May 15, 2017, September 19, 2018, and May 29, 2019, and the summary data is shown below in Table 12. There were no macroinvertebrates found during the surveys on the woody debris or aquatic vegetation.

Date	Lake Name	# Samples	# Total Macroinverts	# Different Taxa	IBI*
9-18-2015	Maple Lake	10	430	17	24-Excellent
5-19-2016	Maple Lake	10	295	15	25-Excellent
5-15-2017	Maple Lake	10	256	16	24-Excellent
9-19-2018	Maple Lake	10	261	10	22-Good
5-29-2019	Maple Lake	10	329	8	19-Fair
9-18-2015	Ackley Lake	10	300	16	24-Excellent
5-19-2016	Ackley Lake	10	201	17	20-Good
5-15-2017	Ackley Lake	10	329	14	24-Excellent
9-19-2018	Ackley Lake	10	315	12	22-Good
5-29-2019	Ackley Lake	10	350	11	22-Good

Table 12. Maple and Ackley Lakes pre and post drawdown macroinvertebrates and associated IBI's. *IBI's calculated using the online calculator based on Ohio EPA biota (website: http://kentschools.net/cooltechred/ibi). The actual parameters to create the IBI were inherent in the online software algorithm which is based on the Ohio EPA Stream Quality Assessment Form. The form specifies Groups 1-3 taxa that represent different water quality indicators. After each category is tallied on the software (using specific taxa from both Maple and Ackley Lakes, a cumulative index is computed

as shown above. The software also accounts for changes in taxa richness which are reflected in the IBI above. The Index of Biotic Integrity (IBI) was developed by Karr in 1981 as a need from the1972 Clean Water Act which required "restoration and maintenance of the chemical, physical, and biological integrity of the Nation's waters".

The IBI's for both lakes pre and post drawdown were good to excellent. The total number of macroinvertebrates sampled increased for Ackley Lake from 2015-2017 but declined in Maple Lake. However, in 2018-2019 the number of taxa declined for both lakes but abundance of macroinvertebrates increased. The number of different macroinvertebrate taxa ranged from 8-17 among the lakes for all years which is favorable and is represented by the IBI values.

4.2.2 Fisheries Spawning Habitat

The quality of fishery spawning habitat is dependent upon many variables such as water quality, lake bottom substrate, aquatic vegetation composition, and the overall health of the aquatic ecosystem. It is critical to evaluate all of these factors in an effort to create sound management strategies for the protection of spawning habitat and to facilitate improvements for existing habitats in need of mitigation efforts. There are over 8,000 freshwater fish species which live in freshwater lakes and rivers (Bone et *al*., 1995). Throughout geological time, freshwater fishes have evolved with morphological adaptations to tolerate low dissolved oxygen levels, turbid waters, and harsh environmental conditions. However, a prized warm-water fishery will consist of several diverse species found in a healthy lake with good water quality and high dissolved oxygen levels, moderate to high water clarity, and an abundance of food and spawning substrate. It is critical that fish spawning habitat be of high quality to sustain successful egg deposition and fertilization to assure adequate success of fishery population growth.

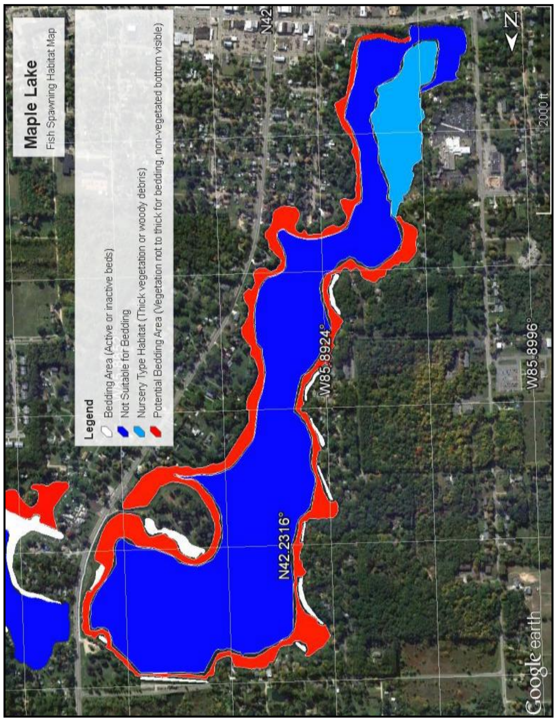
The fishery of Maple and Ackley Lakes may be defined as a diverse warm-water fishery due to the shallow depth of the lakes and the resultant warm water temperatures during the open-water season. Fish communities consist of 17 species (Michigan Department of Natural Resources) including Yellow Perch (*Perca flavescens*), Bluegill (*Lepomis macrochirus*), Pumpkinseed Sunfish (*Lepomis gibbosus*), Green Sunfish (*Lepomis cyanellus*), Largemouth Bass (*Micropterus salmoides*), Rock Bass (*Ambloplites rupestris*), Brown and Yellow Bullhead Catfish (*Ameiurus* sp.), Black Crappie (*Pomoxis nigromaculatus*), Common Carp (*Cyprinus carpio*), Bluntnose Minnows (*Pimephales notatus*), Blackside Darters (*Percina maculata*), Golden Shiners (*Notemigonus crysoleucas*), Shorthead Redhorse (*Moxostoma macrolepidotum*), Walleye (*Sander vitreus*), Warmouth (*Lepomis gulosus*), and the White Sucker (*Catostomus commersonii*). The lake fishery will benefit from a diverse (yet balanced) native aquatic plant community, ample supply of zooplankton, and abundance of submerged habitats (i.e. wood structures and native macrophyte beds). Fish stocking by the MDNR has occurred as recent as 2005 which included Walleye. A report by Dexter (2000) on the management direction for the management of fisheries in Maple Lake during a 1995 survey recommended that walleye fingerlings be continuously stocked at a rate of 50-100 per acre. Additionally, it was determined that lake drawdowns would not have a negative impacts on the fishery populations.

In accordance with the existing QAPP, a set of pre and post-drawdown spawning habitat surveys were conducted for both Maple and Ackley Lakes in September of 2015, May of 2016, and May of 2017 and September of 2018 and May of 2019. A series of four classification groups were assigned to evaluate the integrity of fishery spawning habitat in the assessment survey: 1) nursery-type habitat, which was defined as shelter from predators including thick emergent vegetation or thick submersed vegetation and/or the presence of woody debris, 2) active beds, where fish were visible on or very near to those particular beds, 3) unsuitable habitat which was defined as areas poor in vegetation cover or woody debris, and 4) potential bedding areas, where vegetation was not too thick for bedding, yet non-vegetated lake bottom was visible. Note: In the QAPP it was mentioned that five categories of habitat would be utilized; however, upon further review of previous data and for scientific consistency, the previously used four category analysis was again conducted.

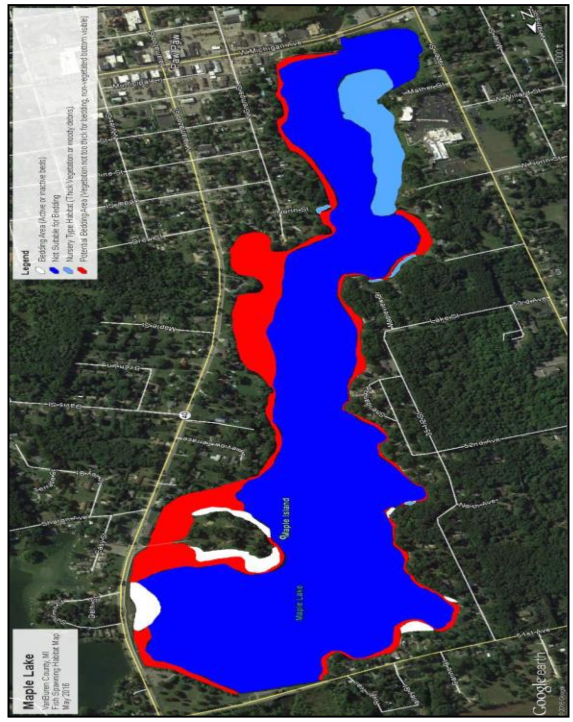
Figures 7a-7c show the fisheries habitat in Maple Lake on September 18, 2015, May 19, 2016, and May, 2017, respectively. Figures 8a-8c show the fisheries habitat in Ackley Lake on September 18, 2015, May 19, 2016, and May, 2017 respectively. Figures 7d-e show the pre and post conditions in Mapole Lake for 2018-2019. Figures 8d-e show the pre and post drawdown conditions for Ackley Lake in 2018-2019. Table 10 demonstrates the attempt to analyze the diagrams using statistics; however there are not enough degrees of freedom to conduct this type of analysis. Tables 14 and 15 show the changes in acreage of each of the four spawning habitat categories for both Maple and Ackley lakes, respectively.

In Maple Lake, there was a slight increase in nursery habitat and woody debris (1.61 acres) from 2015-2017. There was also a slight decline in inactive beds (0.26 acres) and also in the potential bedding areas (3.26 acres). There was a more measurable decline in areas not suitable for bedding (10 acres) from 2015-2017. Also, there was a slight decline in inactive beds from 2018-2019 and slight declines in the other categories. These declines were minimal however, given the standard of error likely associated with the polygon areas.

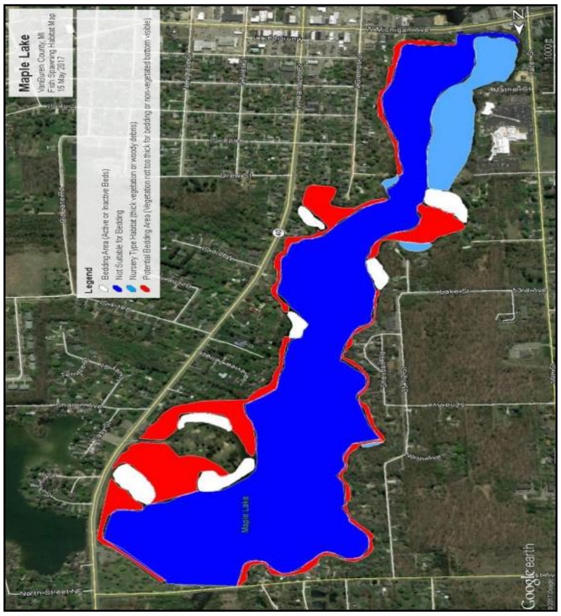
In Ackley Lake, there was a measurable increase in nursery habitat and woody debris (3.83 acres) form 2015-2017. There was a slight decline in active beds (0.70 acres) and also in areas not suitable for bedding (0.8 acres). There was a measurable increase in potential bedding areas (5.5 acres) as well. Also, there was a slight decline in inactive beds from 2018-2019 but minimal declines in the other areas. As noted above, these numbers are not likely significantly different given the polygon margins of error.



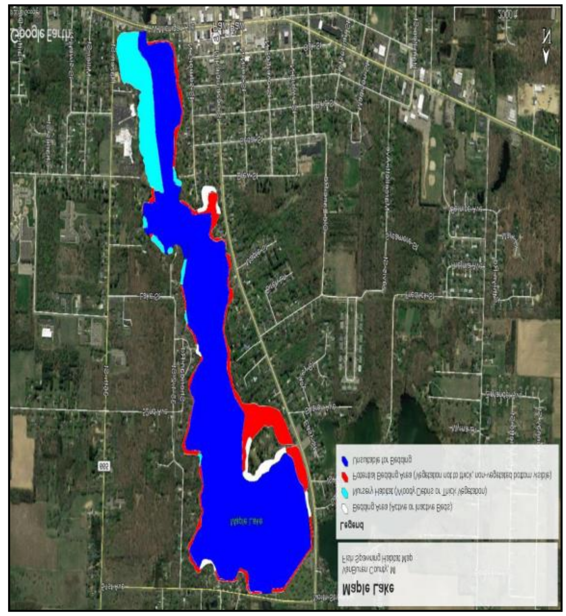
7a. Maple Lake Pre-Drawdown, September 2015



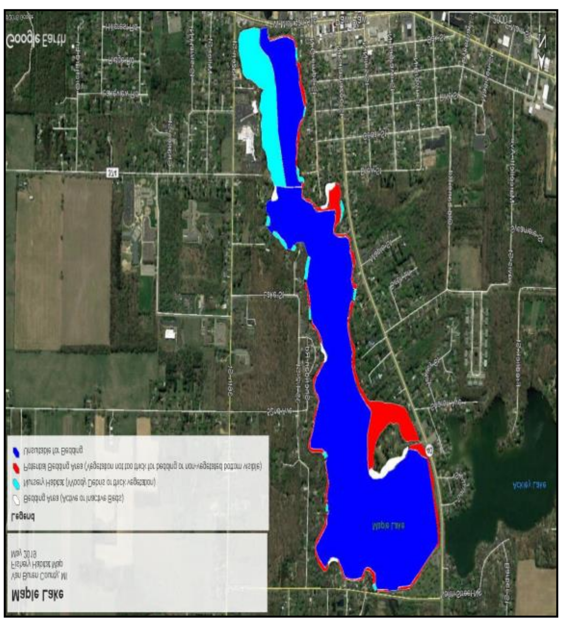
7b. Maple Lake Post-Drawdown, May 2016



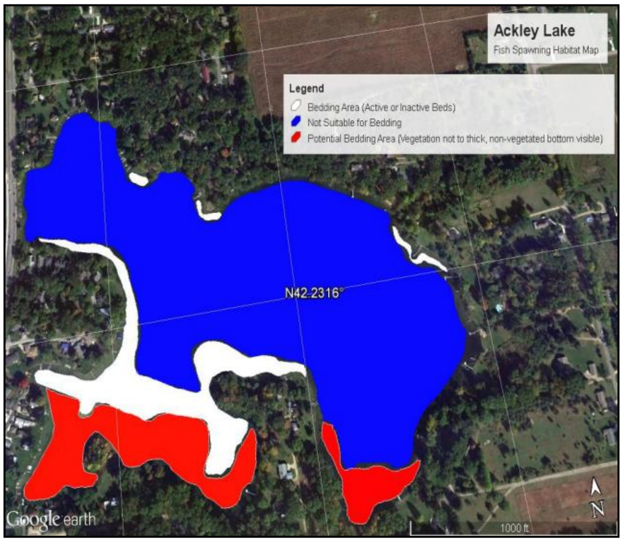
7c. Maple Post-Drawdown, May 2017



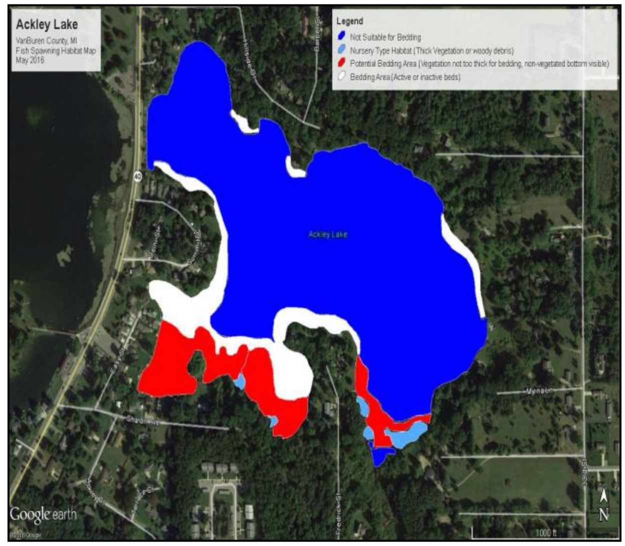
7d. Maple Lake Pre-Drawdown, September, 2018.



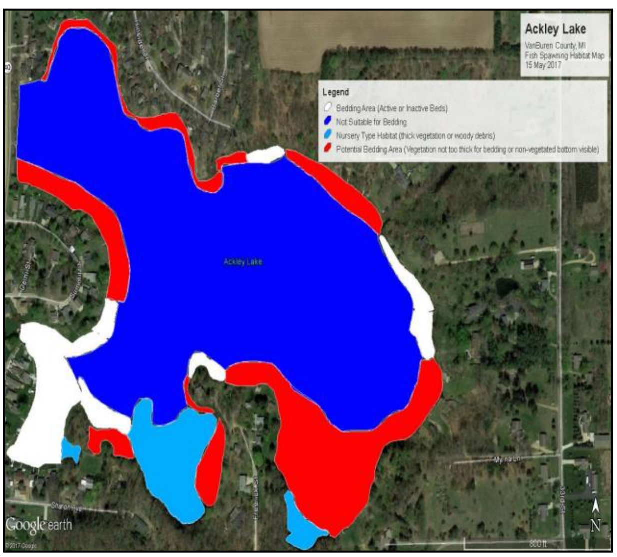
7e. Maple Lake Post-Drawdown, May, 2019



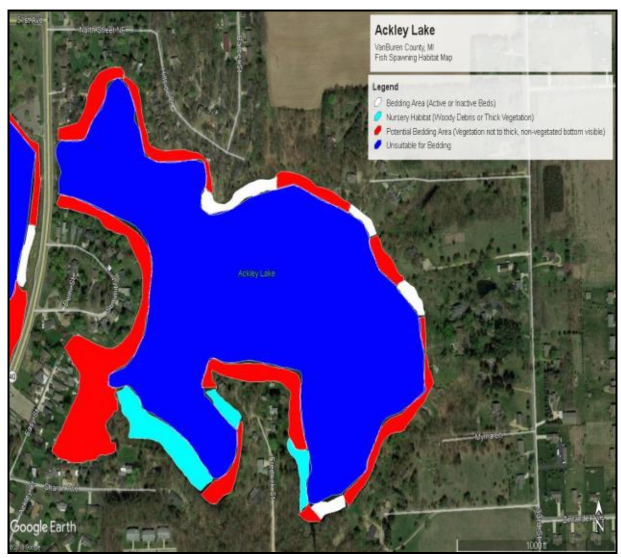
8a. Ackley Lake Pre-Drawdown, September, 2015



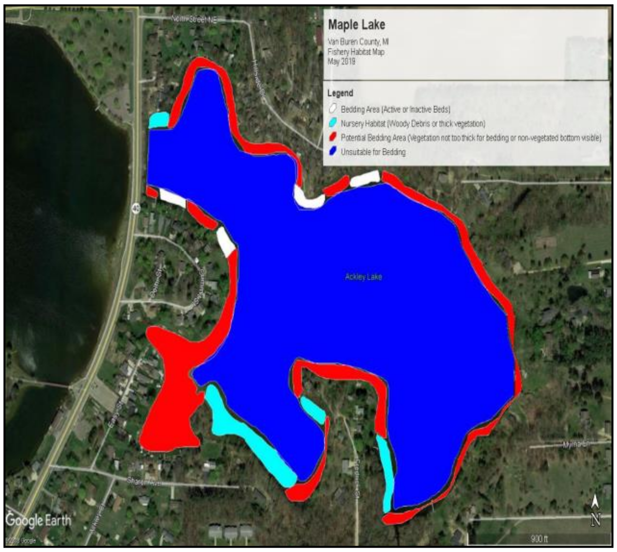
8b. Ackley Lake Post-Drawdown, May, 2016



8c. Ackley Lake Post-Drawdown, May, 2017



8d. Ackley Lake Pre-Drawdown, Sept 2018



8e. Ackley Lake, Post-Drawdown, May 2019

Group Statistics

	VAR00002	N	Mean	Std. Deviation	Std. Error Mean
VAR00001	1.00	1	6.3000	.	.
	2.00	1	7.5000	.	.

		t-test for Equality of Means							
								95% Confidence Interval of the Difference	
		F	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
VAR00001	Equal variances assumed	.	.	0	.	-1.20000	.	.	.
	Equal variances not assumed		.	.	.	-1.20000	.	.	.

Table 13. Statistical output showing too few degrees of freedom to compare each spawning habitat category for both Maple and Ackley Lakes.

Spawning Habitat Category	Maple Lake 2015	Maple Lake 2016	Maple Lake 2017	Maple Lake Pre-2018	Maple Lake Post-2019	Change in acres:
White: Active or Inactive Beds	9.4	4.6	9.14	4.2	2.6	-6.8
Light Blue: Nursery-type Habitat/Thick Vegetation or Woody Debris	12.1	8.9	13.71	16.3	16.2	+4.1
Red: Potential Bedding Area	32.7	27.1	29.44	20.1	15.3	-17.4
Dark Blue: Not Suitable for Bedding	103	128	113	129	132	+29

Table 14. Net changes in fishery spawning habitat acreage in Maple Lake (pre, 2015) and (post, 2016) and (post, 2017) and (pre, 2018) and (post, 2019) drawdown.

Spawning Habitat Category	Ackley Lake 2015	Ackley Lake 2016	Ackley Lake 2017	Ackley Lake Pre-2018	Ackley Lake Post-2019	Change in acres:
White: Active or Inactive Beds	6.3	7.5	5.6	1.4	0.9	-5.4
Light Blue: Nursery-type Habitat/Thick Vegetation or Woody Debris	0	0.9	3.83	2.6	2.2	+2.2
Red: Potential Bedding Area	7.1	7.1	12.6	11.7	9.5	+2.4
Dark Blue: Not Suitable for Bedding	41.7	47.4	40.9	46.6	47.7	+6.0

Table 15. Net changes in fishery spawning habitat acreage in Ackley Lake (pre, 2015) and (post, 2016), and (post, 2017) and (pre, 2018) and (post, 2019) drawdown.

4.2.3 Aquatic Vegetation Communities

A review of the scientific literature on individual weed species responses to lake level drawdown reveals variable responses. Cooke (1980) determined that the watermilfoils declined in abundance, along with native plants such as the floating-leaved Watershield (*Brasenia* sp.), Yellow Waterlily (*Nuphar* sp.), and White Waterlily (*Nymphaea* sp.), and even the emergent Spike Rush (Eleocharis sp.) and Pickerelweed (*Pontedaria* sp.). Furthermore, Cooke et al. (1986) found that Coontail (*Ceratophyllum demersum*), milfoils, Southern Naiad (*Najas guadalupensis*), Lilies, and Robbins Pondweed (*Potamogeton robbinsii*) all decreased following lake drawdowns. McGowan et *al*. (2005) noted a shift in aquatic species composition from abundant Coontail prior to drawdown to a system dominant in Sago Pondweed (*Stuckenia pectinatus*) after drawdown in lakes of the northern Great Plains. Doyle and Smart (2001) noted a substantial decline in *Hydrilla verticillata* (a highly invasive, submersed aquatic plant) tubers in the sediment of an experimental pond after six drawdown cycles.

Winter drawdown of the lake level of Tennessee Valley Authority lakes by 1.83 meters for a duration of 21-25 days resulted in a 90% reduction of Eurasian Watermilfoil acreage. Additionally, a winter drawdown of Wildwood Lake in Cheboygan County, Michigan during 2009-2010 resulted in a 35% reduction in hybrid watermilfoil and over a 30% reduction in the nuisance native Floating-leaf Pondweed (*Potamogeton natans*), and a 20% reduction in Coontail, all of which were all impeding navigation and displacing favorable native aquatic vegetation (Jermalowicz-Jones, 2010).

The sediments within a lake along with the seed bank buried within the sediments are generally heterogeneous throughout the lake and as a result the impacts of drawdown on individual species may vary around the lake. Lake drawdown has been shown by scholars such as Fox et *al*. (1977) to also contribute to water quality improvements such as increases in dissolved oxygen, decreases in turbidity and algae, and increases in macroinvertebrates over time.

The AVAS survey data sheets and calculation spreadsheets are available in Appendix A of this report. Tables 16-17 below show the changes from pre to post-drawdown (2015-2019) in aquatic plant species for both Maple and Ackley Lakes, respectively. Since the aquatic vegetation treatments were conducted well prior to September of 2015, the reduction of EWM from 31.5% of the littoral zone in 2015 to 0.2% of the littoral zone in 2017 in Maple Lake was likely due to the drawdown. This finding supports previous drawdown events on reservoirs studied by the Tennessee Valley Authority and on Wildwood Lake by RLS. Table 18 shows the changes pre to post in 2018-2019.

In Maple Lake, there were reductions in Flat-stem Pondweed, Large-leaf Pondweed, Thin-leaf Pondweed, Illinois Pondweed, Coontail, Elodea, Starry Stonewort (invasive), and some of the emergents such as Cattails. There were actual gains in Curly-leaf Pondweed and Chara. Curly-leaf Pondweed may be higher in spring (May) due to drawdown-resistant turions that can germinate. In 2018-2019, there was a slight reduction in milfoil and also Curly-leaf Pondweed as well as reductions in most species. There was a slight increase in Coontail and Yellow Waterlily.

In Ackley Lake there was also an increase in Chara and the floating-leaved White Waterlily. Most of the other species were reduced. In 2018-2019, no milfoil or Curly-leaf pondweed were found but there was a slight increase in Thin-leaf Pondweed and White Waterlily and Cattails.

Note: A comparison of the means was conducted for both data sets but could not yield significant results due to having too few degrees of freedom for each aquatic plant species (Tables 18 and 19). The AVAS method does however calculate changes in the littoral zone cover in percentages.

Aquatic Plant Name	Native (N) or Invasive (I)	September 18, 2015 (Pre-Drawdown) % littoral zone	May 19, 2016 (Post-Drawdown) % littoral zone	May 15, 2017 (Post-Drawdown) % littoral zone	September 19, 2018 (Pre-Drawdown) % littoral zone	May 29, 2019 (Post-Drawdown) % littoral zone
Eurasian Watermilfoil	I	31.5	0.0	0.2	10.5	9.0
Curly-Leaf Pondweed	I	0.5	9.3	9.9	6.5	0.3
Chara	N	0.8	0.0	28.4	10.0	10.6
Thin-leaf Pondweed	N	3.6	11.9	2.6	23.0	17.7
Flat-stem Pondweed	N	4.4	0.7	0	0.5	0.3
Robbins Pondweed	N	1.3	0.0	0	0	0
Variable-leaf Pondweed	N	0	0	0.1	0	0
White-stem Pondweed	N	0.0	0.0	0	0.5	0.3
Illinois Pondweed	N	1.0	0.0	0	1.4	0
Large-leaf Pondweed	N	4.4	0.4	0.2	0	0
Wild Celery	N	0	0	0.1	0	0
Coontail	N	11.4	2.7	0.2	13.0	14.6
Elodea	N	4.0	0.1	0.1	2.1	0.3
Bladderwort	N	0.0	0.0	0	0	0
Southern Naiad	N	0.7	0.0	0	4.4	0.5
Small-leaf Pondweed	N	0.0	0.0	0	0	0

White Waterlily	N	2.1	0.6	0	0	2.1
Yellow Waterlily	N	0	0	0.3	0	0.3
Duckweed	N	0.0	0.0	0.1	0	0
Cattails	N	0.4	0.3	0.1	0.2	0
Iris	N	0.4	0.0	0	0	0
Purple Loosestrife	I	0.0	0.0	0	0.0	0.3
Starry Stonewort	I	1.1	0.0	0	11.9	1.8

Table 16. Changes in aquatic plant relative abundance in the Maple Lake littoral zone before and after lake drawdown.

Aquatic Plant Name	Native (N) or Invasive (I)	September 18, 2015 (Pre-Drawdown) % littoral zone	May 19, 2016 (Post-Drawdown) % littoral zone	May 15, 2017 (Post-Drawdown) % Littoral Zone	September 19, 2018 (Pre-Drawdown) % Littoral Zone	May 29, 2019 (Post-Drawdown) % Littoral Zone
Eurasian Watermilfoil	I	0.1	0.0	0.1	0	0
Curly-leaf Pondweed	I	0.1	0.0	1.1	0	0
Chara	N	5.7	6.3	38.7	7.6	5.8
Thin-leaf Pondweed	N	4.4	5.7	1.7	5.1	6.7
Flat-stem Pondweed	N	1.1	0.9	0.2	1.0	0.7
Robbins Pondweed	N	0.0	0.0	0	0	0
Variable-leaf Pondweed	N	0.2	0.0	0.1	0	0
Illinois Pondweed	N	1.0	0.0	0.7	1.0	0.2
Northern Milfoil	N	0.0	0.0	0	0	0
Coontail	N	0.7	1.0	0.1	0.6	0.4
Elodea	N	0.1	0.0	0.2	0	0
Bladderwort	N	0.0	0.0	0	0	0
Southern Naiad	N	17.1	7.3	1.4	4.3	1.5
Slender Naiad	N	2.0	0.1	0	0	0
White Waterlily	N	2.8	1.9	6.2	1.7	2.0
Yellow Waterlily	N	5.4	2.4	1.1	1.8	0.9
Watershield	N	0.0	0.2	0	0	0.9
Duckweed	N	0.3	0.0	0	0	0
Arrowhead	N	0.0	0.0	0	0.2	0.4
Pickerelweed	N	0.0	0.2	0	0.2	0.4
Cattails	N	1.3	1.2	0	1.2	2.6

Bulrushes	N	0.1	1.0	0	0.4	0.7
Iris	N	0.1	0.1	0.4	0.4	0.7
Swamp Loosestrife	N	0.1	0.1	0	0.4	0.2
Purple Loosestrife	I	0.1	0.1	0	0.4	1.1
Starry Stonewort	I	1.4	0.0	0	0	0

Table 17. Changes in aquatic plant relative abundance in the Ackley Lake littoral zone before and after lake drawdown.

Group Statistics

	VAR00002	N	Mean	Std. Deviation	Std. Error Mean
VAR00001	1.00	1	31.5000	.	.
	2.00	1	.0000	.	.

		t-test for Equality of Means							
								95% Confidence Interval of the Difference	
		F	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
VAR00001	Equal variances assumed	.	.	0	.	31.50000	.	.	.
	Equal variances not assumed		.	.	.	31.50000	.	.	.

Table 18. Statistical output for Maple Lake AVAS data 2015-2019.

Group Statistics

	VAR00002	N	Mean	Std. Deviation	Std. Error Mean
VAR00001	1.00	1	.1000	.	.
	2.00	1	.0000	.	.

		t-test for Equality of Means							
								95% Confidence Interval of the Difference	
		F	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
VAR00001	Equal variances assumed	.	.	0	.	.10000	.	.	.
	Equal variances not assumed		.	.	.	.10000	.	.	.

Table 19. Statistical output for Ackley Lake AVAS data 2015-2019.

MAPLE LAKE & ACKLEY LAKE AQUATIC VEGETATION BIOVOLUME:

Since aquatic vegetation species was specifically studied as a component of this project, the aquatic vegetation biovolume is incidentally scanned as a component of the benthic scanning and adds considerable evidence that the drawdown affects aquatic plant biovolume. The maps in Figures 9a-c and 10a-c below show the changes from red (dense vegetation growth) to blue (no vegetation growth) pre and post drawdown for Maple and Ackley Lakes, respectively. Figures 9d-e and 10d-e demonstrate the changes in biovolume pre and post drawdown in 2018-2019. Additionally Tables 20 and 21 below quantifies the changes in aquatic vegetation biovolume in Maple and Ackley lakes pre and post-drawdown.

In Maple Lake, the lowest biovolume category (<20%) had the highest gain around 34.15% which indicates that more low-growing aquatic vegetation was present in 2017 compared to baseline conditions in 2015. There were losses in the 20-40%, 40-60%, 60-80%, and >80% categories which indicates that high biovolume was reduced between 2015-2017 due to the drawdown. Interestingly, there was a marked increase in the lowest-growing plant category from pre drawdown in 2018 to post in 2019 with an increase from 19.7% cover to 56.1% cover. The largest decrease was in the highest growth category with a decline from 38.8% cover to 2.5% cover. This was likely not a seasonal effect since most of the aquatic vegetation was fully grown by the May 29, 2019 survey date.

In Ackley Lake, the lowest biovolume category (<20%) had the highest gain around 10.2% which indicates that more low-growing aquatic vegetation was present in 2017 compared to baseline conditions in 2015. There was a loss in the 20-40% biovolume category of 12.16% but only slight (<1%) increases in the 40-60%, 60-80%, and > 80% biovolume categories. This indicates that the drawdown also reduced the nuisance vegetation in Ackley Lake as well. In 2018-2019, there was also an increase in the lower growing plant category from 60.3% cover to 78.5% cover and a corresponding decrease from 8.0% cover to 3.3% cover in the highest growing category.

The 2018-2019 results demonstrate a significant reduction in high-growing plants in both lakes which given the sampling times is most likely due to drawdown.

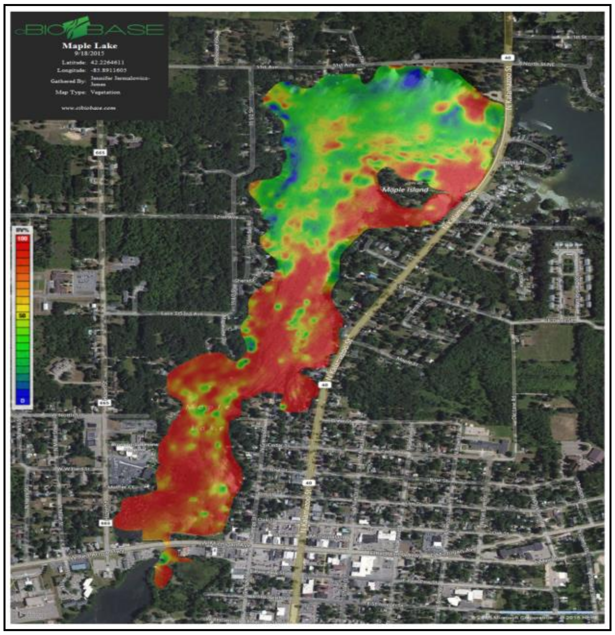


Figure 9a. Maple Lake Pre-drawdown aquatic vegetation biovolume (September, 2015)

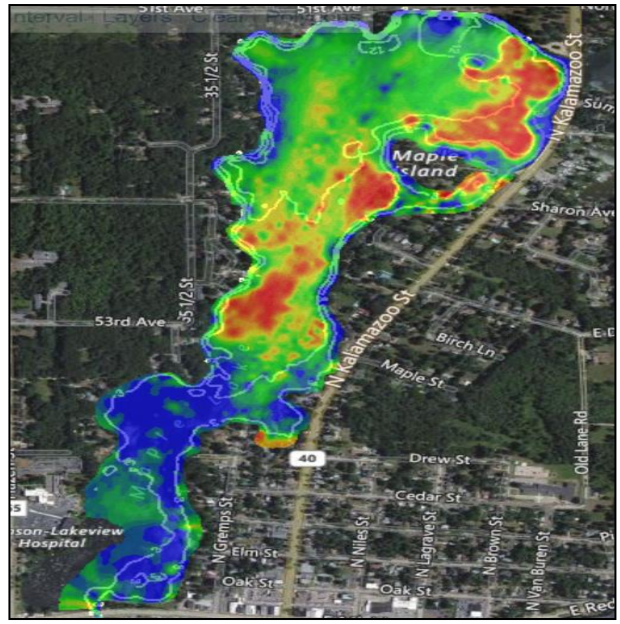


Figure 9b. Maple Lake post-drawdown aquatic vegetation biovolume (May, 2016)

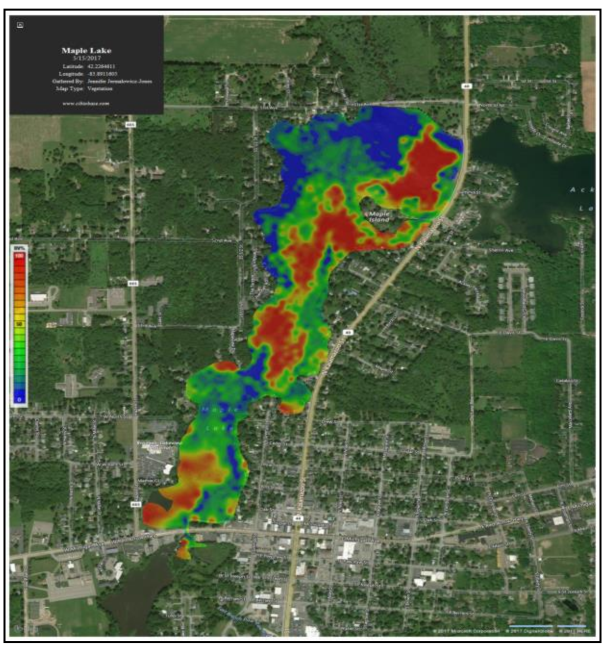


Figure 9c. Maple Lake post-drawdown aquatic vegetation biovolume (May, 2017)

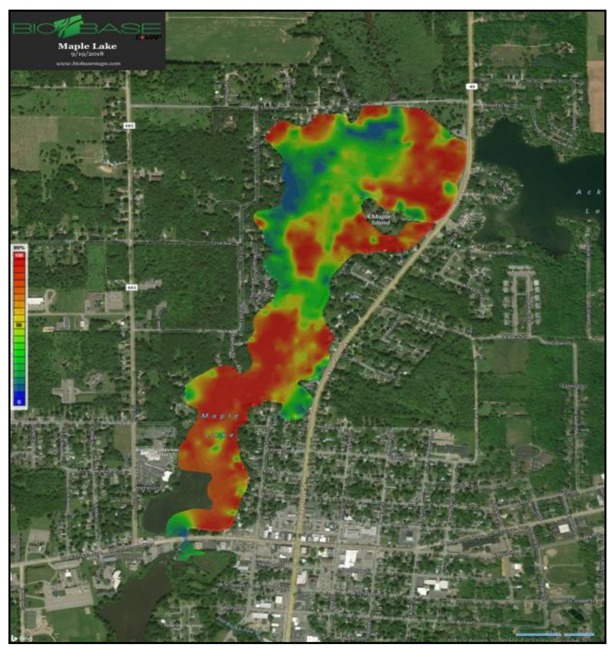


Figure 9d. Maple Lake pre-drawdown aquatic vegetation biovolume (September, 2018).

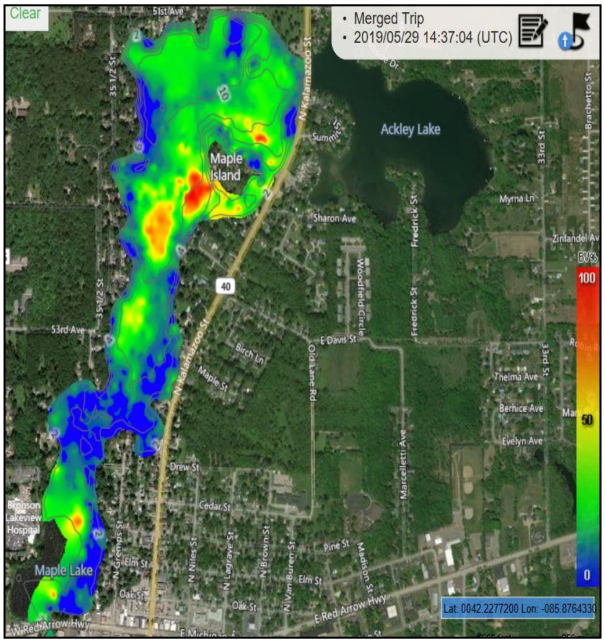
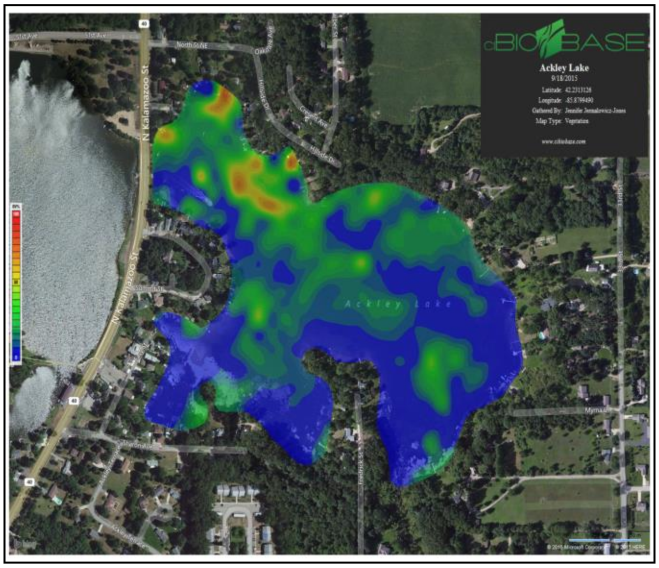


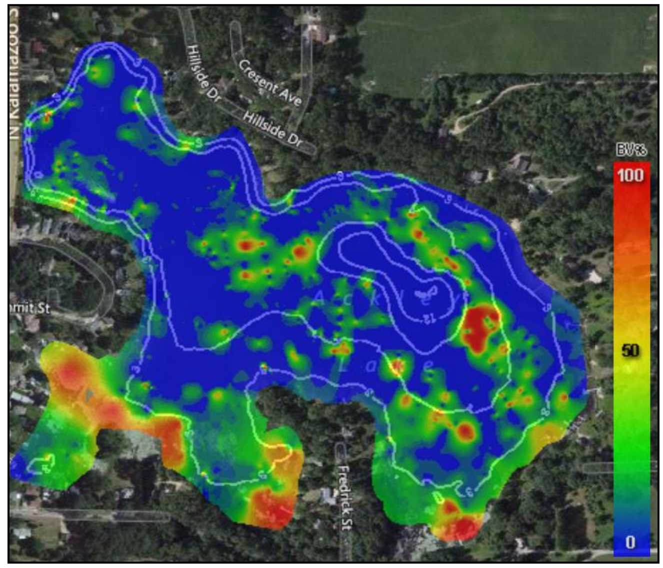
Figure 9e. Maple Lake post-drawdown aquatic vegetation biovolume map (May 29, 2019).

% Aquatic Plant Biovolume	September, 2015 (%)	May, 2016 (%)	May, 2017 (%)	September, 2018 (%)	May, 2019 (%)	Net Loss(-) or Gain (+) (%)
<20%	11.55	41.70	45.70	19.7	56.1	+44.6
20-40%	22.85	22.69	15.70	15.8	29.3	+6.5
40-60%	14.20	14.63	7.76	12.9	8.4	-5.8
60-80%	12.98	8.33	7.38	12.8	3.7	-9.3
>80%	38.42	12.65	23.46	38.8	2.5	-35.9

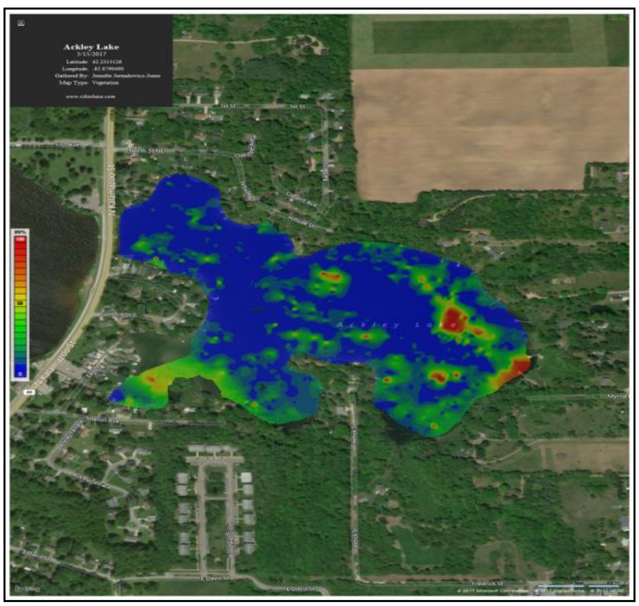
Table 20. Changes in aquatic vegetation biovolume in Maple Lake before (September, 2015) and after (May, 2016) and (May, 2017) and pre (2018) and post (2019) lake drawdown.



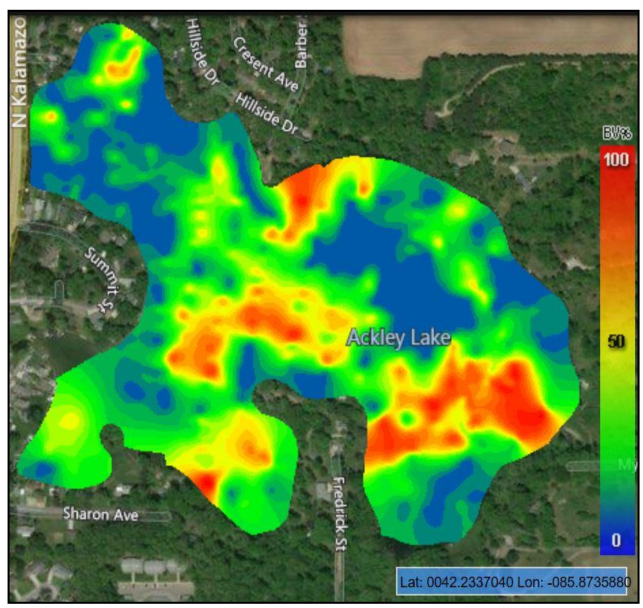
10a. Ackley Lake pre-drawdown aquatic vegetation biovolume (September, 2015)



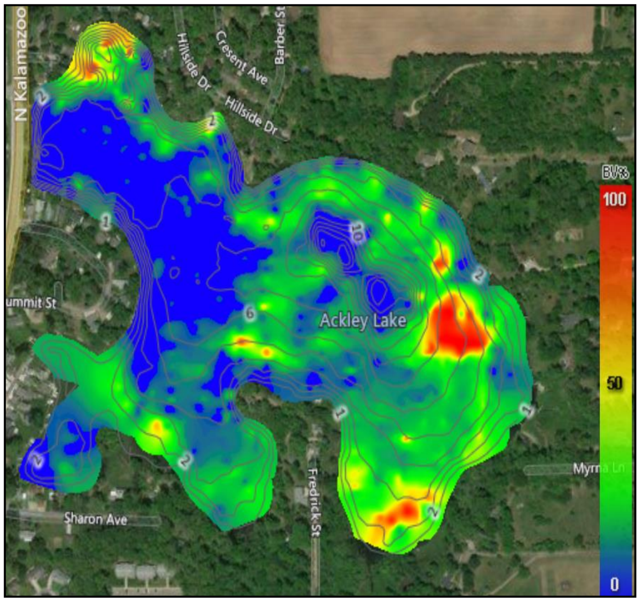
10b. Ackley Lake post-drawdown aquatic vegetation biovolume (May, 2016)



10c. Ackley Lake post-drawdown aquatic vegetation biovolume (May, 2017)



10d. Ackely Lake pre-drawdown aquatic vegetation biovolume (September, 2018)



10e. Ackely Lake post-drawdown aquatic vegetation biovolume map (May, 2019).

% Aquatic Plant Biovolume	September, 2015 (%)	May, 2016 (%)	May, 2017 (%)	September, 2018 (%)	May, 2019 (%)	Net Loss(-) or Gain (+) (%)
<20%	75.53	80.47	85.68	60.3	78.5	+2.97
20-40%	17.98	7.94	5.82	11.5	12.5	-5.48
40-60%	3.24	4.02	3.43	11.2	3.8	+0.56
60-80%	1.35	3.30	2.20	9.0	1.9	+0.55
>80%	1.90	4.27	2.87	8.0	3.3	+1.4

Table 21. Changes in aquatic vegetation biovolume in Ackley Lake before (September, 2015) and after (May, 2016) and (May, 2017) and pre (2018) and post (2019) lake drawdown.

5.0 CONCLUSIONS AND FURTHER RECOMMENDATIONS

Based on the data collected in Maple and Ackley Lakes from 2015-2019, lake drawdown did not have a negative effect on the dissolved oxygen concentrations of Ackley Lake. Additionally, the total suspended solids and turbidity of the lake water downstream of the Maple Lake dam were overall low and did not indicate that solids were exiting Maple Lake during and after the drawdown. In fact, the sediment bottom hardness scans show how the sediments are settling out in Maple Lake. The presence of organic soft bottom may be seasonal due to the presence of organic debris from the previous season (i.e. decaying aquatic vegetation). The aquatic vegetation data showed a 30% decline in milfoil in Maple Lake and a measureable increase in Chara in both lakes for 2015-2017. Chara is excellent for fishery spawning habitat. Sediment macroinvertebrates are also representative of healthy IBI's in both lakes prior to and after drawdown events. The overall quantity and biovolume of aquatic vegetation was however lower for 2018-2019 which was likely due to the drawdown combined with the hard winter of 2018.

Future drawdowns should not negatively impact the lake biota or fish spawning habitat. It is recommended that the drawdowns not exceed 5.0 feet in order to leave ample space for the lake fishery since much of the lake is at or below that depth. However, it is critical to continue to evaluate these biological parameters in future months to assure that the drawdown is not having a negative impact on the two lake ecosystems.

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APPENDIX A
2018-2019 FIELD AND LABORATORY DATA
SUPPLEMENTAL TO THIS REPORT AND ATTACHED SEPARATELY