Restorative Lake Sciences

Bear Lake: State of the Lake & 2013 Annual Report

Prepared for the Bear Lake Improvement Board, Bear Lake Township, Pleasanton Township, and the Village of Bear Lake

December, 2013

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MANISTEE COUNTY, MICHIGAN

December, 2013

1.0 EXECUTIVE SUMMARY

This report describes the current distribution of native and exotic submersed, floating-leaved, and emergent aquatic plants, including the exotic species, Eurasian Watermilfoil (*Myriophyllum spicatum;* EWM) within Bear Lake, Manistee County, Michigan. During the original lake improvement feasibility study in 2007, Bear Lake was infested with over 300 acres of invasive EWM that was widely distributed around the lake. Over the past five years, the EWM was successfully spot-treated and reduced. On June 18, 2013, approximately 3 acres of exotic milfoil were treated with triclopyr (Renovate OTF® at 150 lbs. per acre) near shore and 2,4-D (Navigate® at 160 lbs. per acre) offshore. Additionally, on August 13, 2013, approximately 5 acres of exotic milfoil were treated with triclopyr (Renovate OTF® at 100 lbs. per acre) near shore and 2,4-D (Navigate® at 100 lbs. per acre) offshore.

Continuous monitoring of Bear Lake for EWM, new invasives, and the changes in native aquatic plant community composition is highly recommended on an annual basis, preferably in mid to late spring and in late summer. Whole-lake grid surveys conducted on June 4 and September 17, 2013 revealed that the native pondweed and low-growing native aquatic plant communities have flourished throughout the lake. Currently, much of the lake remains unvegetated and the majority of the west region of the lake contains mixed pondweed and low-growing aquatic vegetation growth. In particular, native species such as Wild Celery (*Vallisneria americana*), Richardson's Pondweed (*Potamogeton richardsonii*), Northern Watermilfoil (*Myriophyllum *sibiricum*), Coontail (*Ceratophyllum demersum*), and the low-growing Southern Naiad (*Najas guadalupensis*) have expanded in areas previously dominated by the exotic EWM. This is favorable because these plants represent a high diversity in plant structures that house different macroinvertebrate communities which feed fish.

There are currently a total of 26 native aquatic plant species in and around Bear Lake, which includes 19 submersed, 3 floating-leaved, and 4 emergent aquatic plant species. The strategic management of EWM is critical to protect the native aquatic plant biodiversity and the fishery within Bear Lake.

The water clarity of the lake continues to be high and helps support abundant aquatic plant growth in many areas. The high Secchi transparency also supports aquatic plant growth to a depth of approximately 12 feet in Bear Lake. Levels of nutrients such as phosphorus and nitrogen have remained consistent over the past several years and are slightly lower than most lakes of similar depth. The alkalinity and pH of the lake water are indicative of a neutral chemistry lake and consistent with other Michigan inland lakes.

Phytoplankton communities within the lake appear to be balanced between the diatom and green-algae communities with little evidence of blue-green algae. Nutrient levels in the lake are still low enough to prevent excessive blue green algae blooms. Green algae and diatoms are the preferred food choices for zooplankton.

A timeline of all lake management activities performed in 2013 is shown below.

Bear Lake Timeline of Lake Management Events-2013

5-24-2013: Spring water quality sampling
6-4-2013: Initial GPS Point Intercept Survey and Lake Scan
6-18-2013: Initial aquatic plant treatment oversight with A&T Service, LLC
7-22-2013: Post-treatment survey
8-10-2013: RLS lake information booth at Bear Lake Days
8-13-2013: Second aquatic plant treatment oversight with A&T Service, LLC
9-30-2013: Post-treatment survey and Fall water quality sampling

In addition, RLS staff attended all Bear Lake Improvement Board meetings on April 18, May 16, June 13, July 18, August 15, September 19, October 17, and December 19, 2013.

2.0 AQUATIC PLANT SURVEY METHODS

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 following large-scale aquatic herbicide treatments to assess the changes in aquatic vegetation structure and to record the relative abundance and locations of native aquatic plant species. Due to the large size of Bear Lake a bi-seasonal GPS Point-Intercept grid matrix survey is conducted to assess all aquatic species, including submersed, floating-leaved species, and emergent aquatic plants.

2.1 The GPS Point-Intercept Survey Method

The Point-Intercept Grid Survey method is meant to assess vegetation throughout the entire surface area of a lake (Madsen et *al*. 1994; 1996). This method involves conducting measurements at Global Positioning Systems (GPS)-defined locations. The points should be placed together as closely and feasibly as possible to obtain adequate information of the aquatic vegetation communities throughout the entire lake. At each GPS Point location the aquatic vegetation species presence and abundance are estimated. In between the GPS points, any additional species and their relative abundance are also recorded using visual techniques. This is especially important to add to the Point-Intercept method, since EWM and other invasive plants may be present between GPS points. Once the aquatic vegetation communities throughout the lake have been recorded using the GPS points, the data can be placed into a Geographic Information System (GIS) software package to create maps showing the distribution and relative abundance of particular species. The GPS Point- Intercept method is particularly useful for monitoring aquatic vegetation communities through time and for identification of nuisance species that could potentially spread to other previously uninhabited areas of the lake.

The GPS Point-Intercept method surveys on June 4, 2013 and on September 30, 2013 consisted of 586 equidistantly-spaced grid points on Bear Lake, using a Lowrance® 50-satellite GPS WAAS-enabled unit (accuracy within 2 feet). A combination of rake tosses and visual data accounted for the observations in the survey. Areas that were deeper than 20 feet and not vegetated or that consisted of bare sand were not included in the data analysis. For additional verification of aquatic plant locations, a benthic scan using side-scan and bottom-scan sonar was conducted.

3.0 AQUATIC PLANT SURVEY RESULTS FOR 2013

Whole-lake grid surveys conducted in 2013 revealed that the native pondweed and native milfoil population has flourished throughout the lake.

3.1 Bear Lake Exotic Aquatic Plant Species (2013)

Eurasian Watermilfoil (EWM) continues to be the only submersed exotic invasive aquatic plant species in Bear Lake (Figures 1 and 2). The June 4, 2013 survey detected approximately 3 acres of invasive milfoil (Figure 3) distributed throughout the lake. A July 22, 2013 survey found an additional 5 acres of milfoil sparsely located throughout the lake in low density (Figure 4) By the end of the 2013 season, no viable EWM could be found in Bear Lake (Table 1).

Invasive Aquatic Macrophyte Species	***Common Name***	***% Coverage June, 2013***	***% Coverage August, 2013***	***% Coverage September, 2013***
Myriophyllum spicatum	Eurasian Watermilfoil	0.2%	0.3%	0%

Table 1. Changes in EWM present within Bear Lake through the season (2013).

Figure 1. Eurasian Watermilfoil
© RLS, 2006

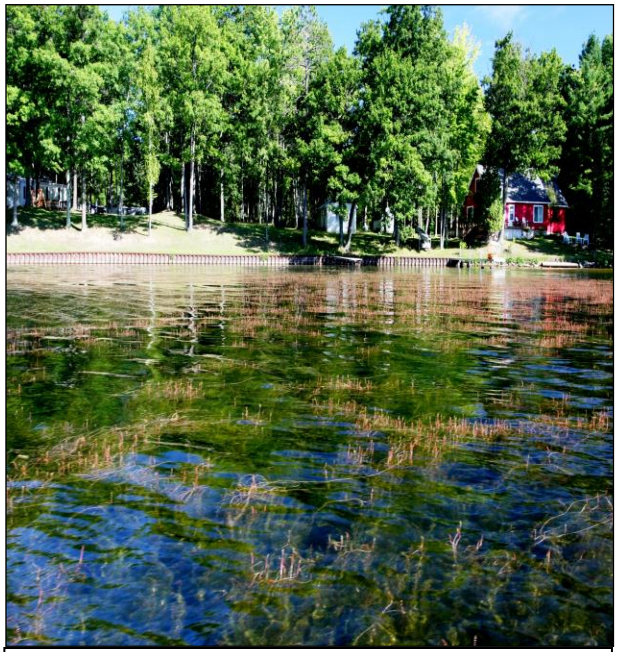


Figure 2. Eurasian Watermilfoil Canopy
© RLS, 2006

Figure 3. Aerial photo showing GPS locations of EWM patches (approximately 3 acres total) in June, 2013.

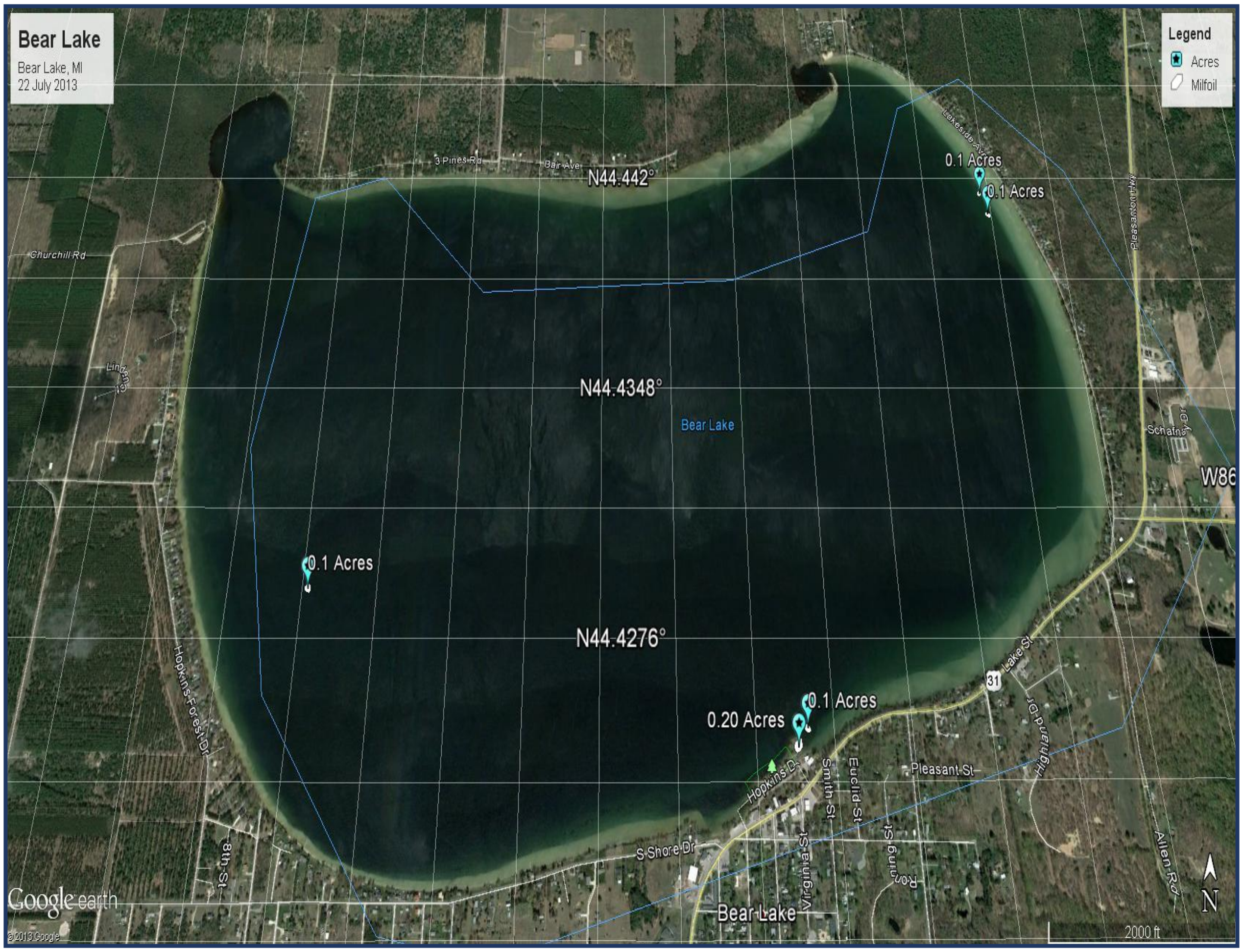


Figure 4. Aerial photo showing GPS locations of EWM patches (approximately 5 acres of total treatment area) in July, 2013.

3.3 Bear Lake Native Aquatic Plant Species (2013)

Based on the June and September 2013 aquatic vegetation surveys, Bear Lake contained 19 native submersed, 3 floating-leaved, and 4 emergent aquatic plant species (Table 2) for a total of 26 species. The Pondweeds were the most abundant submersed aquatic plant taxa, with Fernleaf Pondweed (*Potamogeton robbinsii*) as the most abundant throughout the lake, followed by Leafless Watermilfoil (*Myriophyllum tenellum*) and Variable-leaved Pondweed (*Potamogeton gramineus*). The Leafless Watermilfoil is very small and contains small leafless stems borne on a horizontal meristem that is rooted directly above the lake bottom. This tiny plant appears as a submersed sod and forms a dense low-growing carpet on the lake bottom. All of these species are low-lying in the water column and serve as excellent sediment stabilizers that reduce resuspension of sediment into the water column. In addition, the macroalga *Chara vulgaris* was found in over 200 of the sampling locations. This important non-vascular algae serves as excellent fish spawning habitat and also stabilizes sediments. It is most often found in near shore areas close to the lake bottom and has a strong “skunky” odor. The low-growing Southern Naiad (*Najas guadalupensis*) was also noted in many areas and appears as small green tufts on the lake bottom. Photographs of all native aquatic plant species found can been seen below in Figures 5-34.

Native Aquatic Plant Species	***Common Name***	***% cover in/around Bear Lake***	***Growth Habit***
Chara vulgaris	Muskgrass	0.0	Submersed, Rooted
Potamogeton illinoensis	Illinois Pondweed	2.3	Submersed, Rooted
Potamogeton pusillus	Small-leaved Pondweed	2.8	Submersed, Rooted
Potamogeton robbinsii	Fern-leaf Pondweed	13.5	Submersed, Rooted
Stuckenia pectinatus	Sago Pondweed	1.0	Submersed, Rooted
Potamogeton amplifolius	Large-leaf Pondweed	2.0	Submersed, Rooted
Potamogeton praelongus	White-stemmed Pondweed	1.7	Submersed, Rooted
Potamogeton gramineus	Variable-leaved Pondweed	12.1	Submersed, Rooted
Potamogeton natans	Floating-leaved Pondweed	1.2	Submersed, Rooted
Potamogeton zosteriformis	Flat-stemmed Pondweed	1.3	Submersed, Rooted
Vallisneria americana	Wild Celery	0.8	Submersed, Rooted
Najas guadalupensis	Southern Naiad	3.2	Submersed, Rooted
Najas flexilis	Slender Naiad	2.5	Submersed, Rooted
Myriophyllum tenellum	Leafless Watermilfoil	12.4	Submersed, Rooted
Megalodonta beckii	Water Marigold	1.7	Submersed, Rooted
Ceratophyllum demersum	Coontail	0.5	Submersed, Non-Rooted
Elodea canadensis	Common Elodea	1.4	Submersed, Non-Rooted
Utricularia vulgaris	Common Bladderwort	2.5	Submersed, Non-Rooted
Utricularia minor	Small Bladderwort	0.2	Submersed, Non-Rooted
Nymphaea odorata	White Water lily	0.2	Floating-Leaved, Rooted
Nuphar variegata	Yellow Water lily	0.1	Floating-Leaved, Rooted
Brasenia schreberi	Watershield	1.1	Floating-Leaved, Rooted
Typha latifolia	Cattails	0.5	Emergent
Scirpus acutus	Bulrushes	0.8	Emergent
Iris versicolor	Blueflag Iris	0.0	Emergent
Decodon verticillatus	Swamp Loosestrife	0.7	Emergent

Table 2. Native aquatic plant species found in and around Bear Lake during 2013 surveys.

Figure 5. A photograph of Muskgrass (*Chara* sp.)

Figure 6. A photograph of Thinleaf Pondweed (*Stuckenia pectinatus*) © *RLS*

Figure 7. A photograph of Flatstem Pondweed (*Potamogeton zosteriformis*) © *RLS*

Figure 8. A photograph of Fernleaf Pondweed (*Potamogeton robbinsii*) © *RLS*

Figure 9. A photograph of Variableleaf Pondweed (*Potamogeton gramineus*) © *RLS*

Figure 10. A photograph of Whitestem Pondweed (*Potamogeton praelongus*) © *RLS*

Figure 11. A photograph of Claspingleaf Pondweed (*Potamogeton richardsonii*) © *RLS*

Figure 12. A photograph of Illinois Pondweed (*Potamogeton illinoensis*) © *RLS*

Figure 13. A photograph of Largeleaf Pondweed (*Potamogeton amplifolius*) © *RLS*

Figure 14. A photograph of Floatingleaf Pondweed (*Potamogeton natans*)

Figure 15. A photograph of Waterstargrass (*Zosterella dubia*) © *RLS*

Figure 16. A photograph of Wild Celery (*Vallisneria americana*) © *RLS*

Figure 17. A photograph of Northern Watermilfoil (*Myriophyllum sibiricum*) *© RLS*

Figure 18. A photograph of Coontail (*Ceratophyllum demersum*) *© RLS*

Figure 19. A photograph of Elodea (*Elodea canadensis*) *© RLS*

Figure 20. A photograph of Large Bladderwort (*Utricularia vulgaris*) *© RLS*

Figure 21. A photograph of Small Bladderwort (*Utricularia minor*) *© RLS*

Figure 22. A photograph of Southern Naiad (*Najas guadaluensis*) *© RLS*

Figure 23. A photograph of Slender Naiad (*Najas flexilis*) *© RLS*

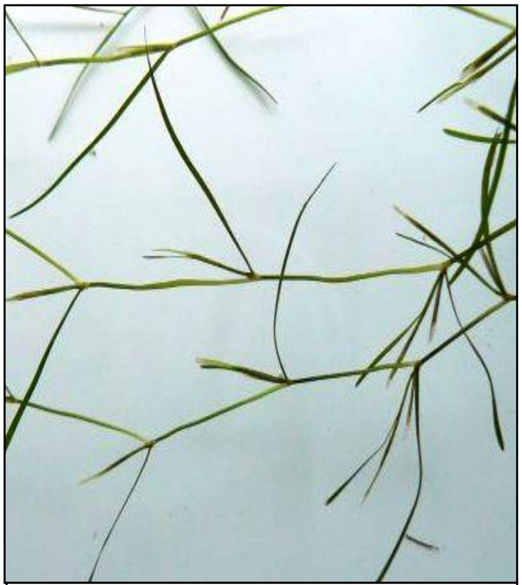


Figure 24. A photograph of Small-leaf Pondweed (*Potamogeton pusillus*) *© RLS*

Figure 25. A photograph of Leafless Watermilfoil (*Myriophyllum tenellum*) © *RLS*

Figure 26. A photograph of Water Marigold (*Megalodonta beckii*) © *RLS*

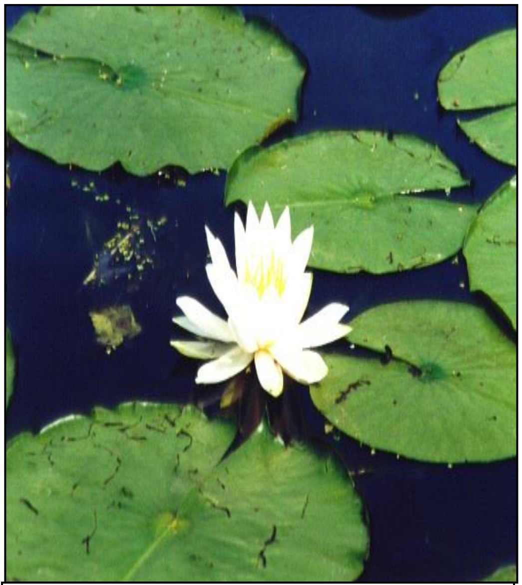


Figure 27. A photograph of White Waterlily (*Nymphaea odorata*) © *RLS*

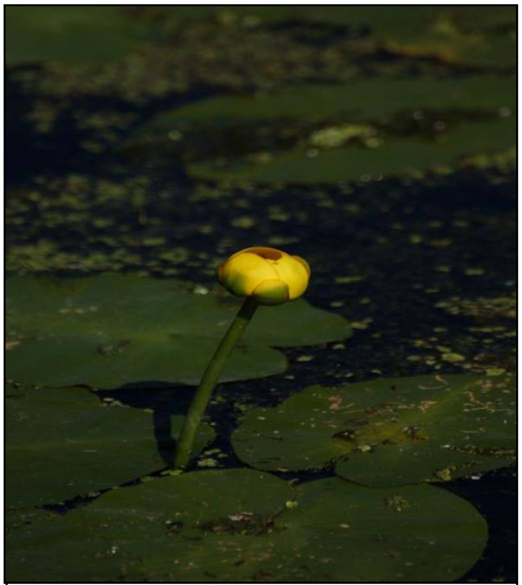


Figure 28. A photograph of Yellow Waterlily (*Nuphar* sp.) © *RLS*

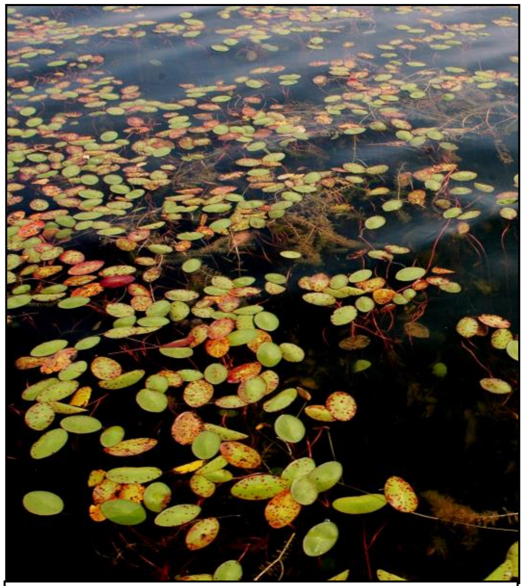


Figure 29. A photograph of Watershield (*Brasenia schreberi*) © *RLS*

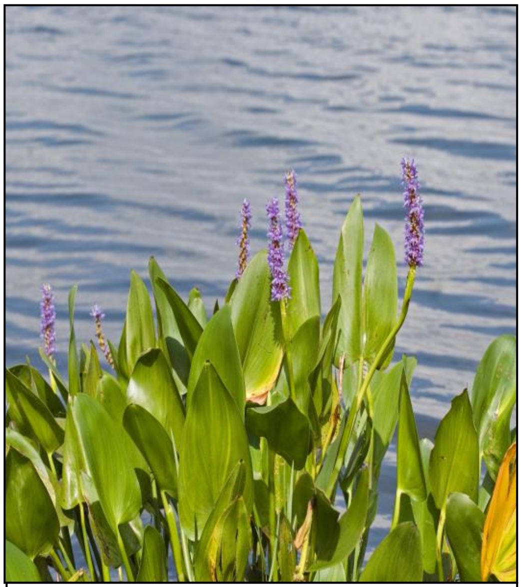


Figure 30. A photograph of Pickerelweed (*Pontedaria cordata*) © *RLS*

Figure 31. A photograph of Cattails (*Typha sp.*) © *RLS*

Figure 32. A photograph of Bulrushes (*Schoenoplectus sp.*) © *RLS*

Figure 33. A photograph of Yellow Iris (*Iris pseduacorus*) © *RLS Note: Blue Flag Iris is around Bear Lake, which is native.*

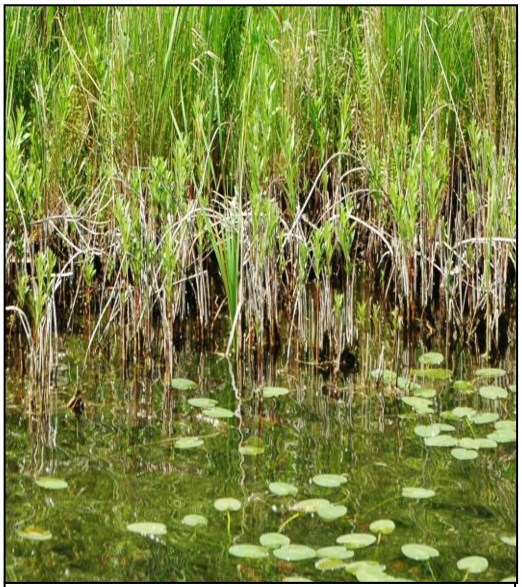


Figure 34. A photograph of Swamp Loosestrife (*Decodon verticillatus*) © *RLS*

4.0 BEAR LAKE 2013 AND HISTORICAL WATER QUALITY RESULTS

The quality of water is highly variable among Michigan inland lakes, although some characteristics are common among particular lake classification types. The water quality of Bear Lake is affected by both land use practices and climatic events. Climatic factors (i.e., spring runoff, heavy rainfall) may alter water quality in the short term; whereas, anthropogenic (man-induced) factors (i.e. shoreline development, lawn fertilizer use) alter water quality over longer time periods. Furthermore, lake water quality helps to determine the classification of particular lakes (Table 3). Lakes that are high in nutrients (such as phosphorus and nitrogen) and chlorophyll-*a*, and low in transparency are classified as **eutrophic**; whereas those that are low in nutrients and chlorophyll-*a*, and high in transparency are classified as **oligotrophic**. Lakes that fall in between these two categories are classified as **mesotrophic**. Bear Lake is classified as mesotrophic based on its high transparency and moderate nutrient and chlorophyll-*a* concentrations.

Lake Trophic Status	***Total Phosphorus ($\mu g\ L^{-1}$)***	***Chlorophyll-a ($\mu g\ L^{-1}$)***	***Secchi Transparency (feet)***
Oligotrophic	< 10.0	< 2.2	> 15.0
Mesotrophic	10.0 – 20.0	2.2 – 6.0	7.5 – 15.0
Eutrophic	> 20.0	> 6.0	< 7.5

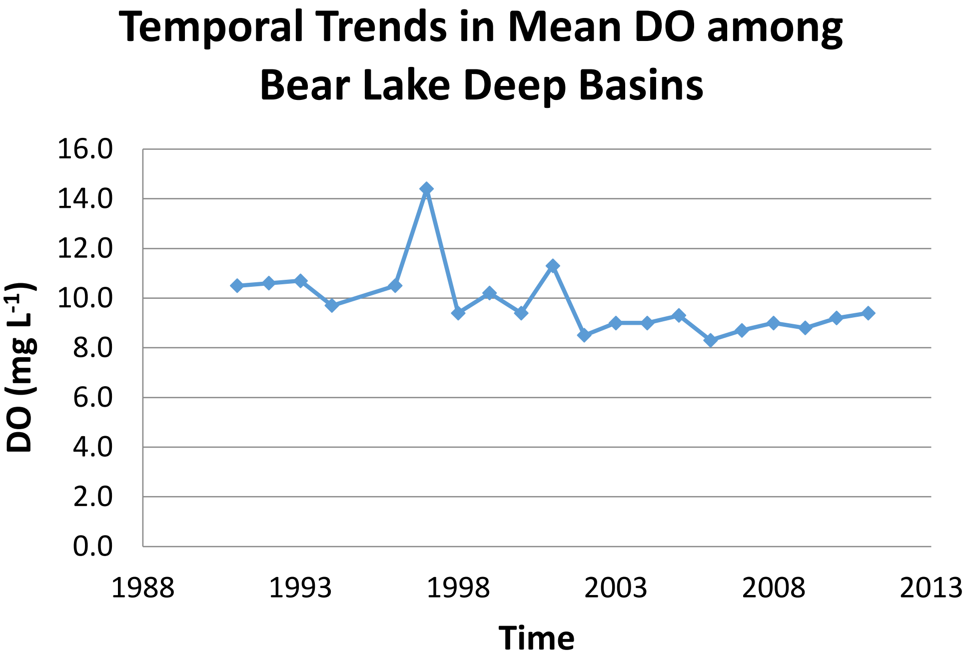
Table 3. Lake Trophic Status Classification Table (MDEQ)

4.1 Bear Lake Deep Basin Water Quality Data

Water quality parameters such as dissolved oxygen, water temperature, conductivity, turbidity, total dissolved solids, pH, total alkalinity, total phosphorus, total Kjeldahl nitrogen, and Secchi transparency, among others, all respond to changes in water quality and consequently serve as indicators of water quality change. Three deep basins were measured, with DB#1 located at the NW corner of the lake, DB#2 located at the central portion of the lake, and DB#3 located at the northeastern portion of the lake. These parameters are discussed below along with water quality data specific to Bear Lake which were collected in late May and late September of 2013 (Tables 4-9).

Dissolved Oxygen

Dissolved oxygen is a measure of the amount of oxygen that exists in the water column. In general, dissolved oxygen levels should be greater than 5 mg L^{-1} to sustain a healthy warm-water fishery. Dissolved oxygen concentrations in Bear Lake may decline if there is a high biochemical oxygen demand (BOD) where organismal consumption of oxygen is high due to respiration. Dissolved oxygen is generally higher in colder waters. Dissolved oxygen is measured in milligrams per liter (mg L^{-1}) with the use of a dissolved oxygen meter and/or through the use of Winkler titration methods. The dissolved oxygen concentrations in Bear Lake were normal and consistent with increased depth during spring ranged between 11.9 – 11.3 mg L^{-1} from the surface to the bottom, with concentrations relatively consistent among deep basin sampling sites. This may be due to near isothermic conditions during these seasonal periods. During summer months, dissolved oxygen at the surface is generally higher due to the exchange of oxygen from the atmosphere with the lake surface, whereas dissolved oxygen is lower at the lake bottom due to decreased contact with the atmosphere and increased biochemical oxygen demand (BOD) from microbial activity. A decline in dissolved oxygen may cause increased release rates of phosphorus (P) from Bear Lake bottom sediments if dissolved oxygen levels drop to near zero milligrams per liter. Late summer dissolved oxygen concentrations ranged from 9.2 mg L^{-1} at the surface to 6.7 mg L^{-1} at the bottom due to increased biochemical oxygen demand at the lake bottom.



Water Temperature

The water temperature of lakes varies within and among seasons and is nearly uniform with depth under winter ice cover because lake mixing is reduced when waters are not exposed to wind. When the upper layers of water begin to warm in the spring after ice-off, the colder, dense layers remain at the bottom. This process results in a "thermocline" that acts as a transition layer between warmer and colder water layers. During the fall season, the upper layers begin to cool and become denser than the warmer layers, causing an inversion known as "fall turnover". In general, lakes with deep basins will stratify and experience turnover cycles. Water temperature is measured in degrees Celsius (ºC) or degrees Fahrenheit (ºF) with the use of a submersible thermometer. The late May water temperatures of Bear Lake demonstrated the lack of a thermocline between the surface and a "middle depth", since the lake was sampled during a nearly isothermic period. However, late September water temperatures ranged between 68.5ºF at the surface and 60.4ºF at the lake bottom among both deep basin sampling locations.

Conductivity

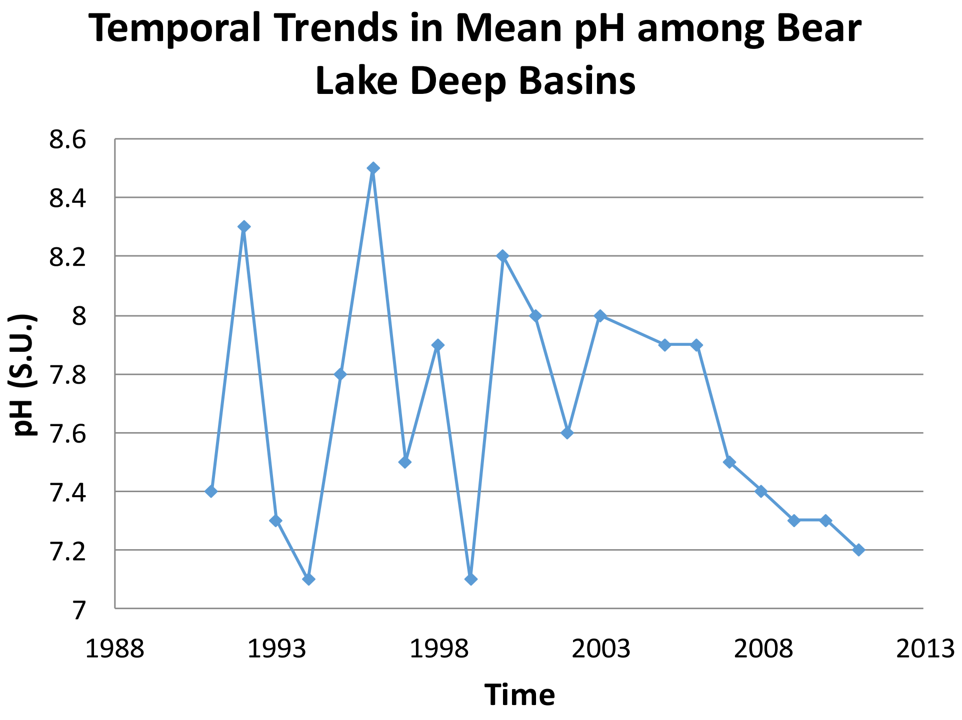
Conductivity is a measure of the amount of mineral ions present in the water, especially those of salts and other dissolved inorganic substances. Conductivity generally increases as the amount of dissolved minerals and salts in a lake increases, and also increases as water temperature increases. Conductivity is measured in microsiemens per centimeter ($\mu S\ cm^{-1}$) with the use of a conductivity probe and meter. Conductivity values for Bear Lake were low and consistent among sampling sites and seasons and similar to most healthy inland lakes in Michigan. Conductivity was consistent within and among sites and ranged between 223 $\mu S\ cm^{-1}$ and 231 $\mu S\ cm^{-1}$ for May and late September water samples among the three sites. Baseline parameter data such as conductivity are important to measure the possible influences of land use activities (i.e. road salt influences) on Bear Lake over a long period of time, or to trace the origin of a substance to the lake in an effort to reduce pollutant loading.

Turbidity

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 from erosion inputs, phytoplankton blooms, stormwater 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 the water temperature. Since higher water temperatures generally hold less oxygen, shallow turbid waters are usually lower in dissolved oxygen. Turbidity is measured in Nephelometric Turbidity Units (NTU's) with the use of a turbimeter. 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 turbidity of Bear Lake is low and ranged from 0.2 – 0.9 NTU's during the May sampling event and ranged from 0.4-1.7 NTU's during the late September sampling. The lake bottom is predominately sandy substrate with some silt, which increases the turbidity values near the lake bottom.

pH

pH is the measure of acidity or basicity of water. The standard pH scale ranges from 0 (acidic) to 14 (alkaline), with neutral values around 7. Most Michigan lakes have pH values that range from 6.5 to 9.5. Acidic lakes (pH < 7) are rare in Michigan and are most sensitive to inputs of acidic substances due to a low acid neutralizing capacity (ANC). pH is measured with a pH electrode and pH-meter in Standard Units (S.U). The pH of Bear Lake water ranged from 7.1 – 7.7 during the May and late September sampling. It is not uncommon for lakes in the northern region of Michigan to possess pH values slightly lower than those of southern lakes due to the underlying geological features which help determine pH. From a limnological perspective, Bear Lake is considered "slightly basic" on the pH scale.

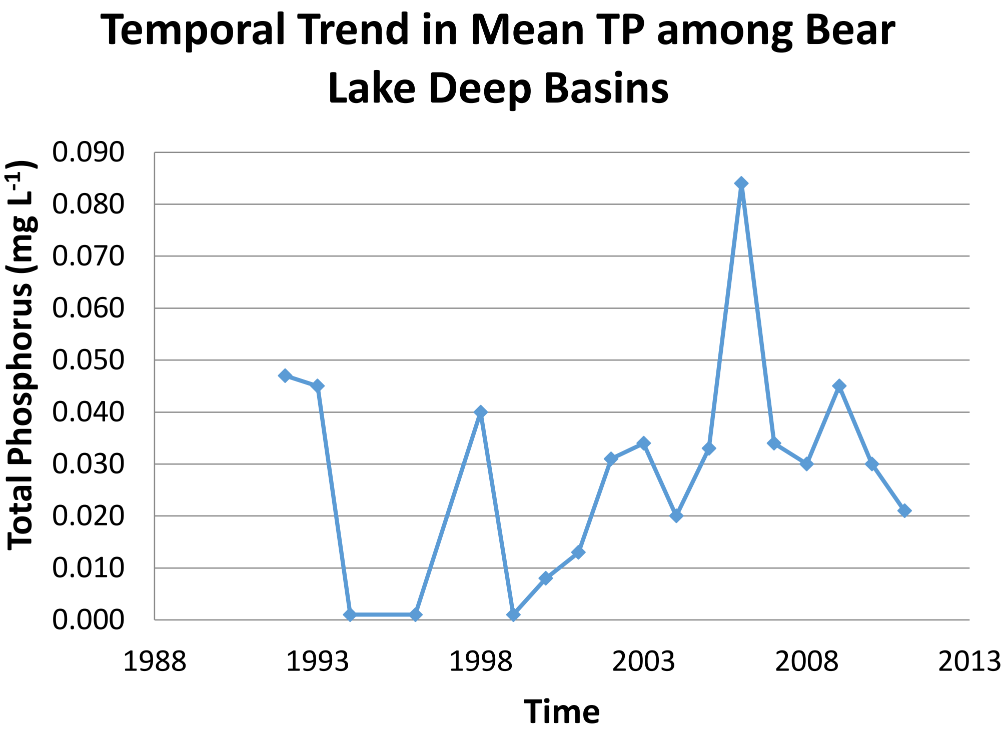


Total Alkalinity

Total alkalinity is the measure of the pH-buffering capacity of lake water. Lakes with high alkalinity (> 150 mg L^{-1} of $CaCO_3$) are able to tolerate larger acid inputs with less change in water column pH. Many Michigan lakes contain high concentrations of $CaCO_3$ and are categorized as having "hard" water. Total alkalinity is measured in milligrams per liter of $CaCO_3$ through an acid titration method. The total alkalinity of Bear Lake is considered "low" (< 150 mg L^{-1} of $CaCO_3$), and indicates that the water is not hard or highly alkaline. Total alkalinity ranged from 60-63 mg L^{-1} of $CaCO_3$ during the May and late September sampling. Total alkalinity may change on a daily basis due to the re-suspension of sedimentary deposits in the water and respond to seasonal changes due to the cyclic turnover of the lake water.

Total Phosphorus

Total phosphorus (TP) is a measure of the amount of phosphorus (P) present in the water column. Phosphorus is the primary nutrient necessary for abundant algae and aquatic plant growth. Lakes which contain greater than 20 $\mu g\ L^{-1}$ of TP are defined as eutrophic or nutrient-enriched. TP concentrations are usually higher at increased depths due to higher release rates of P from lake sediments under low oxygen (anoxic) conditions. Phosphorus may also be released from sediments as pH increases. Total phosphorus is measured in micrograms per liter ($\mu g\ L^{-1}$) with the use of a chemical auto analyzer. Mean surface total phosphorus (TP) concentrations for the Bear Lake Deep Basin sampling sites (based on the $n = 3$ Deep Basin sites) during spring were $< 0.010\ mg\ L^{-1}$. Middle depth (depth = 10.0 feet) total phosphorus concentrations among the three Deep Basin sites averaged $< 0.020\ mg\ L^{-1}$. Total phosphorus concentrations at the bottom depths (depths = 20.8 feet) among the three Deep Basin sites were $< 0.030\ mg\ L^{-1}$, with the highest value recorded at Deep Basin 2.



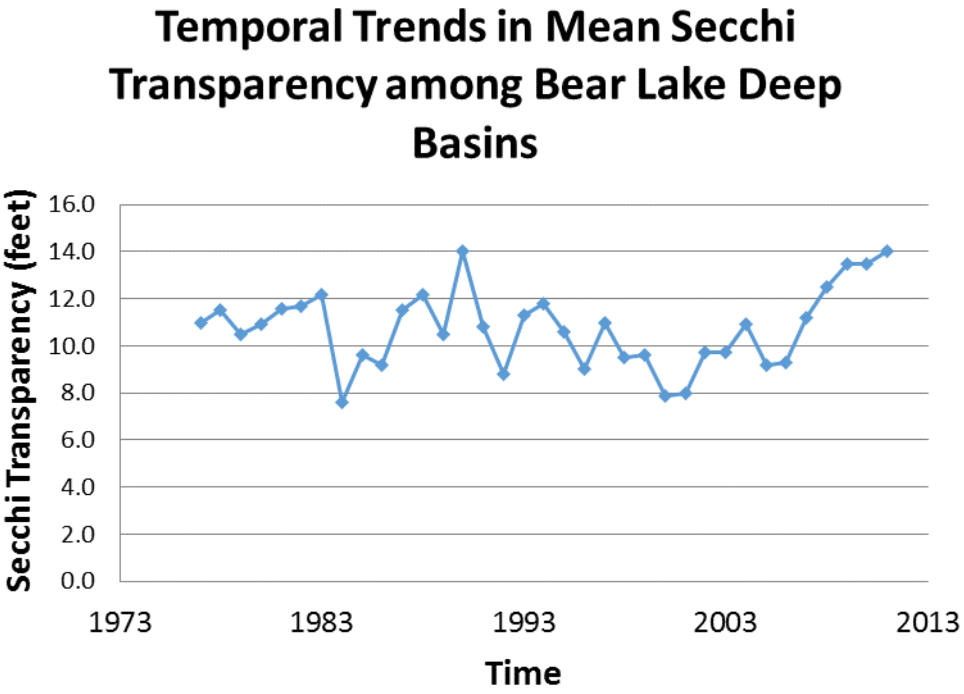
Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is the sum of nitrate (NO_3^-), nitrite (NO_2^-), ammonia (NH_4^+), and organic nitrogen forms in freshwater systems. Much nitrogen (amino acids and proteins) also comprises the bulk of living organisms in an aquatic ecosystem. Nitrogen originates from atmospheric inputs (i.e. burning of fossil fuels), wastewater sources from developed areas (i.e. runoff from fertilized lawns), agricultural lands, septic systems, and from waterfowl droppings. It also enters lakes through groundwater or surface drainage, drainage from marshes and wetlands, or from precipitation (Wetzel, 2001). In lakes with an abundance of nitrogen (N: P > 15), phosphorus may be the limiting nutrient for phytoplankton and aquatic macrophyte growth. Alternatively, in lakes with low nitrogen concentrations (and relatively high phosphorus), the blue-green algae populations may increase due to the ability to fix nitrogen gas from atmospheric inputs. Lakes with a mean TKN value of

0.66 mg L^{-1} may be classified as oligotrophic, those with a mean TKN value of 0.75 mg L^{-1} may be classified as mesotrophic, and those with a mean TKN value greater than 1.88 mg L^{-1} may be classified as eutrophic. Bear Lake contained highly variable values for TKN (= 0.3 – 1.8 mg L^{-1}). These values were lower than those measured in 2012.

Secchi Transparency

Secchi transparency is a measure of the clarity or transparency of lake water, and is measured with the use of an 8-inch diameter standardized Secchi disk. Secchi disk transparency is measured in feet (ft) or meters (m) by lowering the disk over the shaded side of a boat around noon and taking the mean of the measurements of disappearance and reappearance of the disk. Elevated Secchi transparency readings allow for more aquatic plant and algae growth. Eutrophic systems generally have Secchi disk transparency measurements less than 7.5 feet due to turbidity caused by excessive planktonic algae growth. The Secchi transparency of Bear Lake averaged 15.5 feet over the three deep basins during the 2013 spring and late September sampling periods, which meant that the water was much more clear than in 2012. This transparency is adequate to allow abundant growth of algae and aquatic plants in the majority of the littoral zone of the lake, which is observed to a depth of 12 feet. Secchi transparency is variable and depends on the amount of suspended particles in the water (often due to windy conditions of lake water mixing) and the amount of sunlight present at the time of measurement.



Total Dissolved Solids

Total Dissolved Solids (TDS) is the measure of the amount of dissolved organic and inorganic particles in the water column. Particles dissolved in the water column absorb heat from the sun and raise the water temperature and increase conductivity. Total dissolved solids are often measured with the use of a calibrated meter in mg L^{-1}. Spring values would likely be higher due to increased watershed inputs from spring runoff and/or increased planktonic algal communities. The concentration of TDS in Bear Lake during the spring and late summer sampling events ranged from < 100 mg L^{-1} to 121 mg L^{-1}. Total Suspended Solids were highest at the lake bottom in Deep Basin #2. These values were lower than those measured in 2012 and correspond with higher Secchi transparency.

Oxidative Reduction Potential

The oxidation-reduction potential (E_h) of lake water describes the effectiveness of certain atoms to serve as potential oxidizers and indicates the degree of reductants present within the water. In general, the Eh level (measured in millivolts) decreases in anoxic (low oxygen) waters. Low E_h values are therefore indicative of reducing environments where sulfates (if present in the lake water) may be reduced to hydrogen sulfide (H_2S). Decomposition by microorganisms in the hypolimnion may also cause the E_h value to decline with depth during periods of thermal stratification. The E_h (ORP) values for Bear Lake ranged between 145.2 mV and 67.1 mV from the surface to the bottom within the lake, and thus were within a normal range for meso-eutrophic lakes.

Depth ft	***Water Temp ºF***	***DO mg L^{-1}***	***pH S.U.***	***Cond. µS cm^{-1}***	***Turb. NTU***	***ORP mV***	***Total Kjeldahl Nitrogen mg L^{-1}***	***Total Alk. mgL^{-1} $CaCO_3$***	***Total Phos. mg L^{-1}***
0	54.7	11.9	7.1	223	0.2	145.2	0.4	63	0.010
10	51.0	11.7	7.5	227	0.8	124.9	0.4	61	0.010
21	49.1	11.3	7.7	230	0.9	122.1	0.4	60	0.015

Table 4. Bear Lake Water Quality Parameter Data Collected over Deep Basin 1 on May 24, 2013.

Depth ft	Water Temp ºF	DO mg L^{-1}	pH S.U.	Cond. µS cm^{-1}	Turb. NTU	ORP mV	Total Kjeldahl Nitrogen mg L^{-1}	Total Alk. mgL^{-1} $CaCO_3$	Total Phos. mg L^{-1}
0	54.4	11.8	7.4	227	0.2	147.1	0.4	62	0.010
10	51.2	11.8	7.6	227	0.7	151.7	0.4	62	0.010
22	50.6	11.2	7.5	231	0.7	155.8	0.4	61	0.020

Table 5. Bear Lake Water Quality Parameter Data Collected over Deep Basin 2 on May 24, 2013.

Depth ft	Water Temp ºF	DO mg L^{-1}	pH S.U.	Cond. µS cm^{-1}	Turb. NTU	ORP mV	Total Kjeldahl Nitrogen mg L^{-1}	Total Alk. mgL^{-1} $CaCO_3$	Total Phos. mg L^{-1}
0	53.9	11.9	7.7	228	0.2	146.1	0.3	62	0.010
10	51.8	11.7	7.7	227	0.6	141.9	0.4	61	0.010
21	50.5	11.3	7.3	229	0.9	140.0	0.4	60	0.010

Table 6. Bear Lake Water Quality Parameter Data Collected over Deep Basin 3 on May 24, 2013.

Depth ft	***Water Temp ºF***	***DO mg L^{-1}***	***pH S.U.***	***Cond. µS cm^{-1}***	***Turb. NTU***	***ORP mV***	***Total Kjeldahl Nitrogen mg L^{-1}***	***Total Alk. mgL^{-1} $CaCO_3$***	***Total Phos. mg L^{-1}***
0	68.5	9.2	7.6	230	0.4	147.8	0.5	61	0.010
10	62.1	8.8	7.5	227	0.9	127.1	0.5	61	0.020
21	61.2	7.0	7.2	223	1.7	88.7	1.5	62	0.020

Table 7. Bear Lake Water Quality Parameter Data Collected over Deep Basin 1 on September 30, 2013.

Depth ft	***Water Temp ºF***	***DO mg L^{-1}***	***pH S.U.***	***Cond. µS cm^{-1}***	***Turb. NTU***	***ORP mV***	***Total Kjeldahl Nitrogen mg L^{-1}***	***Total Alk. mgL^{-1} $CaCO_3$***	***Total Phos. mg L^{-1}***
0	68.9	9.0	7.5	229	0.4	149.1	0.4	63	0.010
10	63.6	7.5	7.5	229	0.9	110.3	0.4	63	0.020
22	60.4	6.1	7.7	231	1.7	67.1	1.8	63	0.030

Table 8. Bear Lake Water Quality Parameter Data Collected over Deep Basin 2 on September 30, 2013.

Depth ft	*Water Temp °F*	*DO mg L^{-1}*	*pH S.U.*	*Cond. μS cm^{-1}*	*Turb. NTU*	*ORP mV*	*Total Kjeldahl Nitrogen mg L^{-1}*	*Total Alk. mgL^{-1} $CaCO_3$*	*Total Phos. mg L^{-1}*
0	68.7	9.2	7.6	228	0.7	147.1	0.4	63	0.010
10	64.9	8.1	7.5	227	0.5	132.7	0.4	61	0.020
21	61.9	6.9	7.4	223	1.7	77.6	0.4	60	0.025

Table 9. Bear Lake Water Quality Parameter Data Collected over Deep Basin 3 on September 30, 2013.

5.0 BEAR LAKE 2014 MANAGEMENT RECOMMENDATIONS

5.1 Bear Lake Open water Improvements

The use of aquatic chemical herbicides is regulated by the MDEQ under Part 33 (Aquatic Nuisance) of the Natural Resources and Environmental Protection Act, P.A. 451 of 1994, and requires a permit. The permit contains a list of approved herbicides for a particular body of water, as well as dosage rates, treatment areas, and water use restrictions. Wherever possible, it is preferred to use a systemic aquatic herbicide for longer-lasting plant control. There are often restrictions with usage of some systemic herbicides around shoreline areas that contain shallow drinking wells (such as with 2,4-D).

In the past, systemic herbicides such as 2, 4-D and Triclopyr have been used to control EWM in Bear Lake and continued spot-treatments with both herbicides are recommended. The September 30, 2013 survey indicated that the 2013 treatments were successful and no viable EWM was found in the lake. The native aquatic plant communities such as Wild Celery, pondweeds, and naiads continue to thrive in areas once dominated by EWM.

Water quality parameters as noted above should be monitored during 2014.

Table 10 below shows the proposed budget for the continuation of the Bear Lake Improvement Program (2014).

Bear Lake Improvement Strategy	***Estimated Annual Cost***
Herbicides for Control of Invasive Aquatic Plants (approx. 50 acres)@ \$525 per acre	\$26,250
Professional Management Services[3] (water sampling, oversight of treatments, mapping, management)	\$12,500
Contingency Funds (necessary for additional costs that may arise due to unpredictable circumstances)	\$3,875
TOTAL ANNUAL ESTIMATED COST	\$42,625

Table 10. Proposed lake management budget for Bear Lake in 2014.

6.0 LITERATURE CITED

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