hydraulic conductivity between 0.042 - 0.141 m sec^{-1}. Fourth, the Lumley-Makinen complex with 0 - 8% slopes range between 0 - 80 inches in thickness, are comprised of approximately 0% clay, are very high in organic matter (55 - 100%), and possess a hydraulic conductivity of between 0.001 - 0.042 m sec^{-1}. Fifth, the Pipestone sands with a 0 - 6% slope range between 0 – 80 inches in thickness, are comprised of approximately 0 - 9% clay, are low in organic matter (0 - 5%), and possess a hydraulic conductivity of between 0.042 - 0.141 m sec^{-1}. Sixth, the Benona sands with 0 - 6% slope range between 0 - 80 inches in thickness, are comprised of approximately 0 - 5% clay, are low in organic matter (0 - 5%), and possess a hydraulic conductivity of between 0.042 - 0.141 m sec^{-1}. Lastly, the Brethren sands with 0 - 6% slope range between 0 - 80 inches in thickness, are comprised of approximately 0 - 5% clay, are low in organic matter (0 - 5%), and possess a hydraulic conductivity of between 0.042 - 0.141 m sec^{-1}. Soils from the Lumley-Makinen Complex (West and East Bays) are very poorly drained, highly organic, and are associated with frequent ponding. Ponding is the accumulation of water on the soil surface and may thus contribute to flooding. Also, nutrients may enter the lake via surface runoff since these soils do not promote adequate drainage.

3.0 BEAR LAKE WATER QUALITY

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 every 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. Since many lakes have a fairly long hydraulic residence time, the water may remain in the lake for years and is therefore sensitive to nutrient loading and pollutants.

Furthermore, lake water quality helps to determine the classification of particular lakes (Table 2). Lakes that are high in nutrients (such as phosphorus) 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**.

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 2. Lake trophic status classification table (MDNR)

3.1 Water Quality Parameters

Water quality parameters such as dissolved oxygen, water temperature, conductivity, turbidity, pH, total alkalinity, total phosphorus, total Kjeldahl nitrogen, chlorophyll-*a*, algal species, and Secchi transparency, among others, all respond to changes in water quality and consequently serve as indicators of water quality change.

These parameters are discussed below along with water quality data specific to Bear Lake. Historical water quality data from previous studies are summarized in Figures 7a-e and may also be found in Appendix A.

3.1.1 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 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 concentration in Bear Lake was plentiful and consistent with increased depth. This may be due to increased lake mixing from wind and wave action over the shallow depths of the lake. Dissolved oxygen at the surface is generally higher due to the exchange of oxygen from the atmosphere with the lake surface. Low dissolved oxygen levels at the lake bottom may lead to the increased release rates of phosphorus (P) from bottom sediments if dissolved oxygen levels drop to near zero milligrams per liter. Historical reviews of Bear Lake dissolved oxygen levels indicate that the lake contains a healthy and uniform concentration of oxygen during all seasons.

3.1.2 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, shallow lakes will not stratify and deeper lakes may experience single or multiple turnover cycles. Water temperature is measured in degrees Celsius (ºC) or degrees Fahrenheit (ºF) with the use of a submersible thermometer. The early October water temperature of Bear Lake demonstrated a lack of a thermocline between the surface and a depth of approximately 21.0 feet. It is not uncommon for wind-driven lakes such as Bear Lake to warm or cool quickly in response to air temperatures at the surface-water interface. Due to its relatively shallow "deep" basin depth, Bear Lake water is fairly warm at the lake bottom during warm periods such as the summer.

3.1.3 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 similar to most healthy inland lakes in Michigan. Baseline parameter data such as conductivity are important to measure the possible influences of land use activities on a lake over a long period of time.

3.1.4 Turbidity

Turbidity is a measure of the loss of transparency of water 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 Heath 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 relatively low and slightly higher at the lake bottom than at the surface. The lake bottom is predominately a silty peat and therefore is easily perturbed from water turbulence. Many of the fine silt particles may enter into the water column and decrease water transparency, thereby increasing the turbidity of the water. The turbidity readings at the surface and mid-depth are also low.

3.1.5 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 acid rain 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 declined only slightly with increased depth. The lake is considered above "neutral" on the pH scale and indicates that the lake is slightly alkaline.

3.1.6 Total Alkalinity

Total alkalinity is the measure of the pH-buffering capacity of lake water. Lakes with high alkalinity (> 100 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 moderate (< 100 mg L^{-1} of $CaCO_3$), and indicates that the water is moderately buffered against acidic inputs. 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.

3.1.7 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 autoanalyzer. The total phosphorus (TP) concentration of Bear Lake is equal to the "eutrophic threshold" of 20 $\mu g\ L^{-1}$ in the East Bay, yet was undetectable at the surface and middle depths of the West Bay and Central Deep Basin during the time of sampling. Analysis of the historical total phosphorus concentrations demonstrates that the mean is approximately to 40 $\mu g\ L^{-1}$, which indicates that the lake has overall eutrophic levels of phosphorus. This means that the lake contains ample nutrients in some areas but may be overall classified as meso-eutrophic.

The bottom depth TP concentration is 150 $\mu g\ L^{-1}$ which indicated that some TP loading is occurring in the hypolimnion (deeper portion of the lake). This is common since particulate P from decaying aquatic plants and organisms settles to the lake bottom.

3.1.8 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 contains oligotrophic values for TKN (= 0.0 - 0.6 mg L^{-1}) in the surface waters (epilimnetic layer) and middle depths of the lake. The bottom TKN sample was 3.8 mg L^{-1} indicating the presence of nitrogen loading at the lake bottom. Similar nitrogen values from groundwater were found for Lawrence Lake, which is a small calcareous glacial-till lake in southwestern Michigan (Manny and Wetzel, 1982). Analysis of the historical nitrate nitrogen data suggests a mean nitrate concentration of approximately 0.619 mg L^{-1}. The N:P = 25 in Bear Lake benthic waters, and N:P = 15.5 in the open water, and thus the lake is phosphorus limited and contains between 15.5-25 times more nitrogen than phosphorus.

3.1.9 Chlorophyll-a and Algae

Chlorophyll-*a* is a measure of the amount of green plant pigment present in the water, often in the form of planktonic algae. High chlorophyll-*a* concentrations are indicative of nutrient-enriched lakes. Chlorophyll-*a* concentrations greater than 6 µg L^{-1} are found in eutrophic or nutrient-enriched aquatic systems, whereas chlorophyll-*a* concentrations less than 2.2 µg L^{-1} are found in nutrient-poor or oligotrophic lakes. Chlorophyll-*a* is measured in micrograms per liter (µg L^{-1}) with the use of an acetone extraction method and a spectrometer. The chlorophyll-*a* concentrations in Bear Lake were determined by collecting a composite sample of the algae throughout the water column at each of the three sampling sites from just above the lake bottom to the lake surface. The chlorophyll-*a* concentration in the West Bay was 10.7 µg L^{-1}, which is eutrophic, and the East Bay had a value of

1.1 μg L^{-1} which is oligotrophic. Values in the West Bay may be higher than in other areas of the lake, since the bay is almost entirely surrounded by a bog that likely contributes nutrients which promote algal growth in the bay. The chlorophyll-*a* concentration over the deep basin was 0.6 μg L^{-1} and also falls in the oligotrophic range. These values are likely higher in the spring after spring runoff or in late summer when water temperatures increase and lead to the growth of algae in the water column (planktonic form) or on the surface (filamentous form).

Algal genera from a composite water sample collected over the deep basin of Bear Lake were analyzed under a compound microscope. The genera present included the green algae: *Chlorella* sp., *Lyngbya* sp., *Scenedesmus* sp., *Radiococcus* sp., *Protococcus* sp., *Haematococcus* sp., *Pediastrum* sp., *Cladophora* sp., *Spirogyra* sp., and *Gleocapsa* sp. Blue-green algal (cyanobacteria) genera included *Microcystis* sp., *Anabaena* sp., and *Oscillatoria* sp. Diatom genera include *Navicula* sp., *Synedra* sp., *Stauroneis* sp., *Cymbella* sp., *Fragilaria* sp., *Diatomella*, and *Gomphonema* sp. These genera indicate a favorable balance of green algae, diatoms and blue-green algae to serve as the autotrophic base of the Bear Lake aquatic ecosystem food chain.

3.1.10 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. 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. 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. The Secchi transparency of Bear Lake was approximately 15.5 feet over the deep basin on the day of sampling, yet is likely higher during calmer wind conditions as evidenced by the inherent color and clarity of the water. The Secchi transparency of the two shallow bays went beyond the available water depth. This transparency is adequate to allow abundant growth of algae and aquatic plants in the littoral zone of the lake and throughout the bays. 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.

Depth (ft)	***Water Temp (°F)***	***DO ($mg\ L^{-1}$)***	***pH (SU)***	***Cond. ($\mu S\ cm^{-1}$)***	***Turb. (NTU)***	***Total Alk. ($mg\ L^{-1}$ $CaCO_3$)***	***Total Kjeldahl Nitr. ($mg\ L^{-1}$)***	***Total Phos. ($\mu g\ L^{-1}$)***
0	64.2	11.3	8.3	0.222	2.5	88	0.6	0
10	64.1	11.1	8.2	0.223	2.3	87	0.6	0
20	64.0	10.9	8.1	0.223	2.8	84	3.8	150

Table 3. Bear Lake water quality parameter data taken over the Central Deep Basin on 3 October, 2007.

Depth (ft)	***Water Temp (°F)***	***DO ($mg\ L^{-1}$)***	***pH (SU)***	***Cond. ($\mu S\ cm^{-1}$)***	***Turb. (NTU)***	***Total Alk. ($mg\ L^{-1}$ $CaCO_3$)***	***Total Kjeldahl Nitr. ($mg\ L^{-1}$)***	***Total Phos. ($\mu g\ L^{-1}$)***
0	63.9	10.9	8.3	0.223	1.8	83	0.6	0
5	63.9	10.9	8.3	0.225	1.8	83	0.6	0

Table 4. Bear Lake water quality parameter data taken from the West Bay on 3 October, 2007.

Depth (ft)	***Water Temp (°F)***	***DO (mg L^{-1})***	***pH (SU)***	***Cond. (µS cm^{-1})***	***Turb. (NTU)***	***Total Alk. (mg L^{-1} $CaCO_3$)***	***Total Kjeldahl Nitr. (µg L^{-1})***	***Total Phos. (µg L^{-1})***
0	63.8	10.3	8.0	0.228	1.6	86	0.6	20
5	63.7	10.3	8.0	0.230	1.8	86	0.6	20

Table 5. Bear Lake water quality parameter data taken from the East Bay on 3 October, 2007.

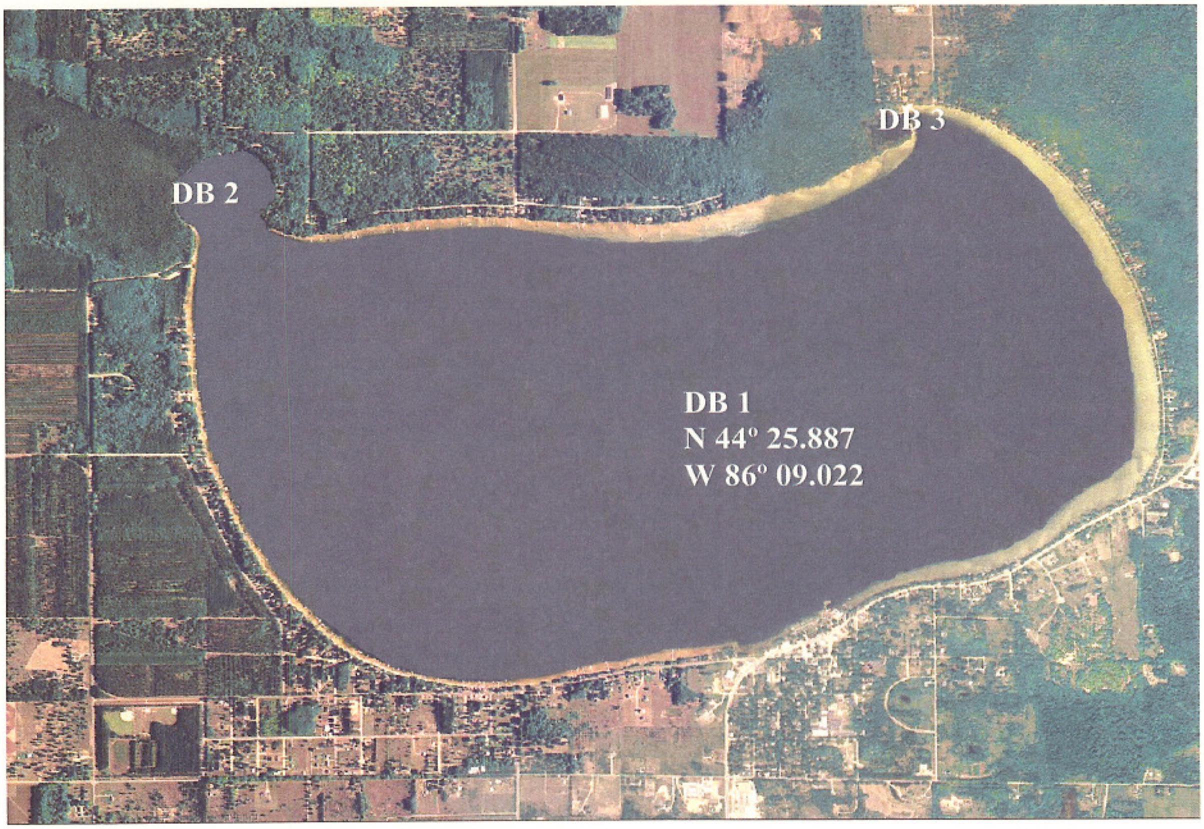

Figure 6. Water quality sampling locations over the three major "deep" basins (DB) of Bear Lake, October, 2007.

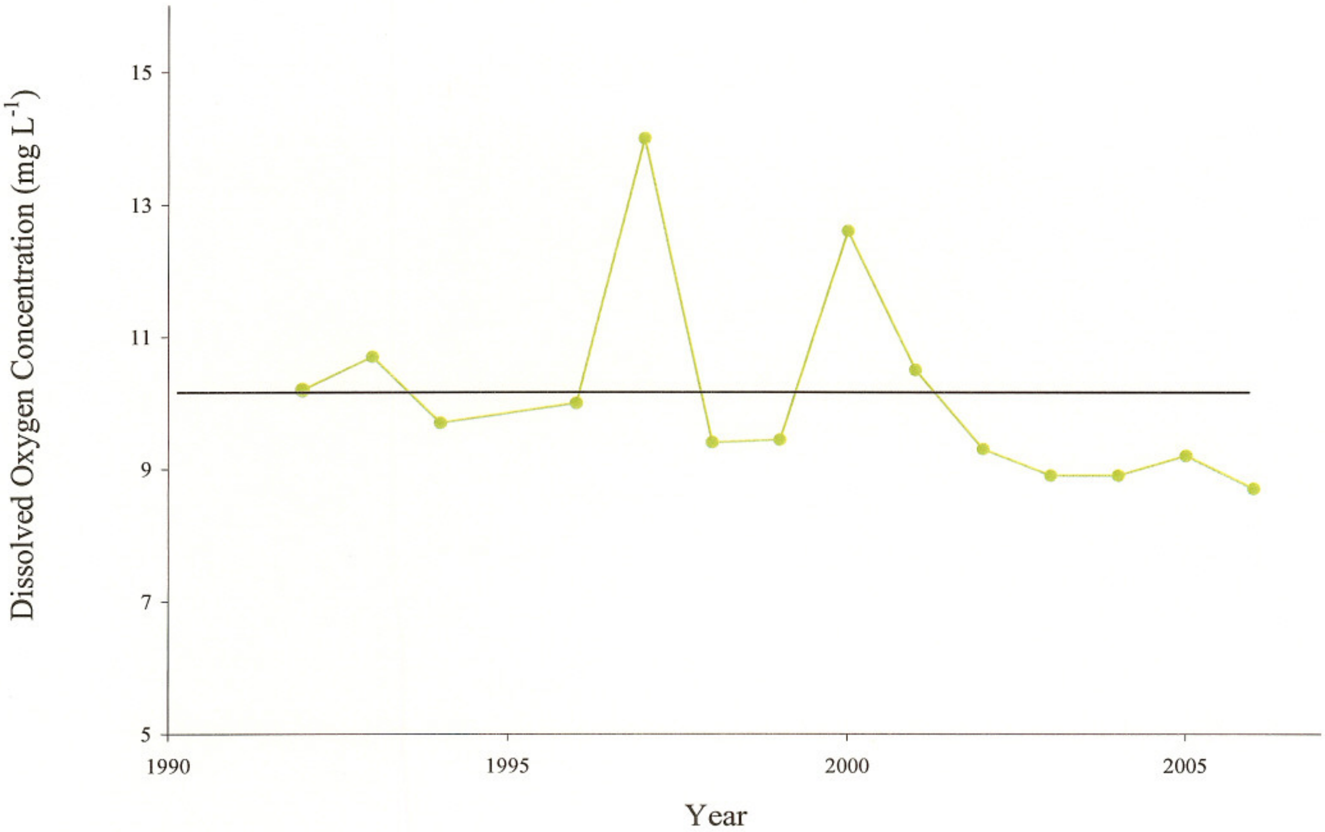

Figure 7a. Annual mean dissolved oxygen values for Bear Lake (1991-2006; data courtesy of BLPOA taken from means of n = 10 lake sampling stations). *Overall mean (~10.1 mg L^{-1}) is denoted by the line bisecting the data on the graph.

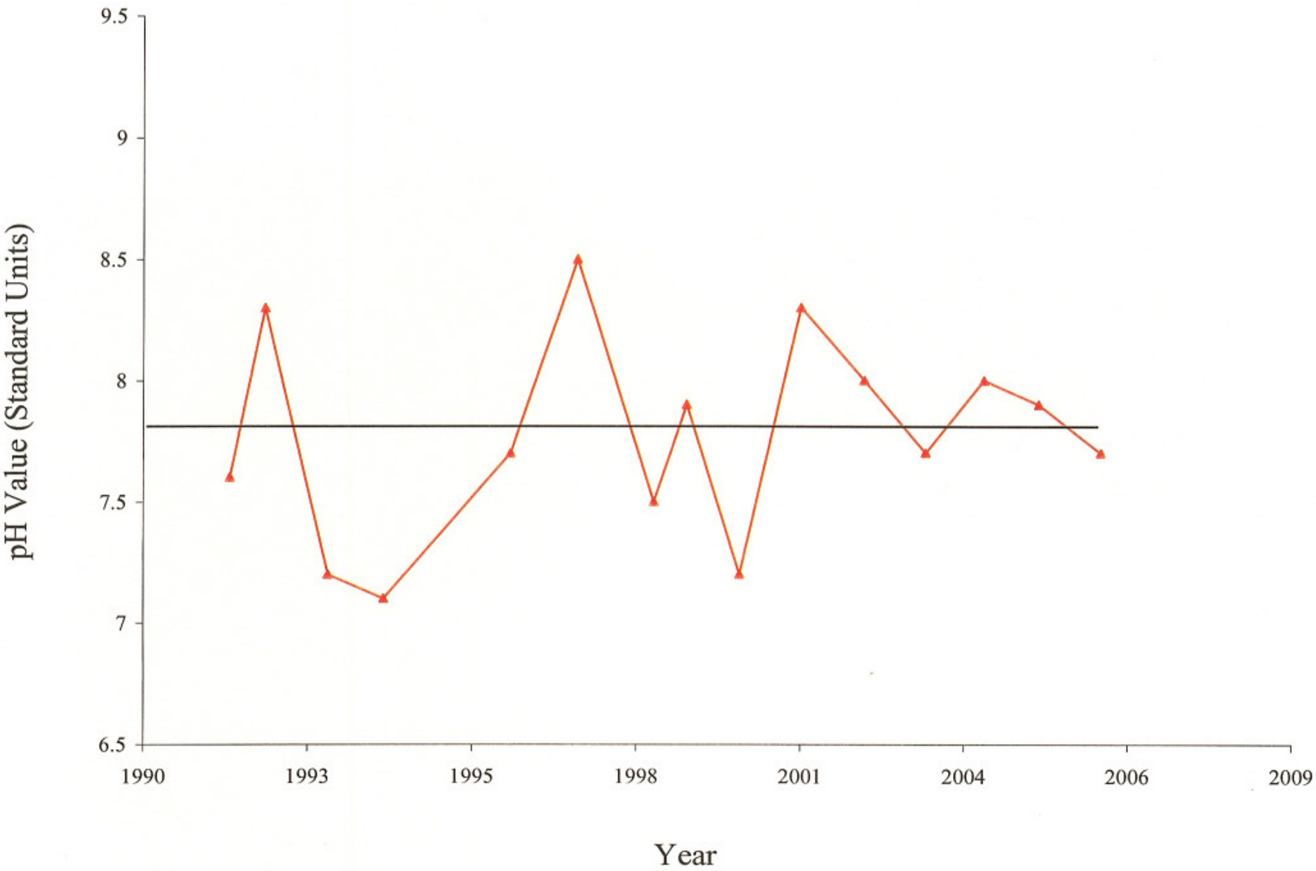

Figure 7b. Annual mean pH values for Bear Lake (1991-2006; data courtesy of BLPOA taken from means of n = 10 lake sampling stations). *Overall mean (~7.8) is denoted by the line bisecting the data on the graph.

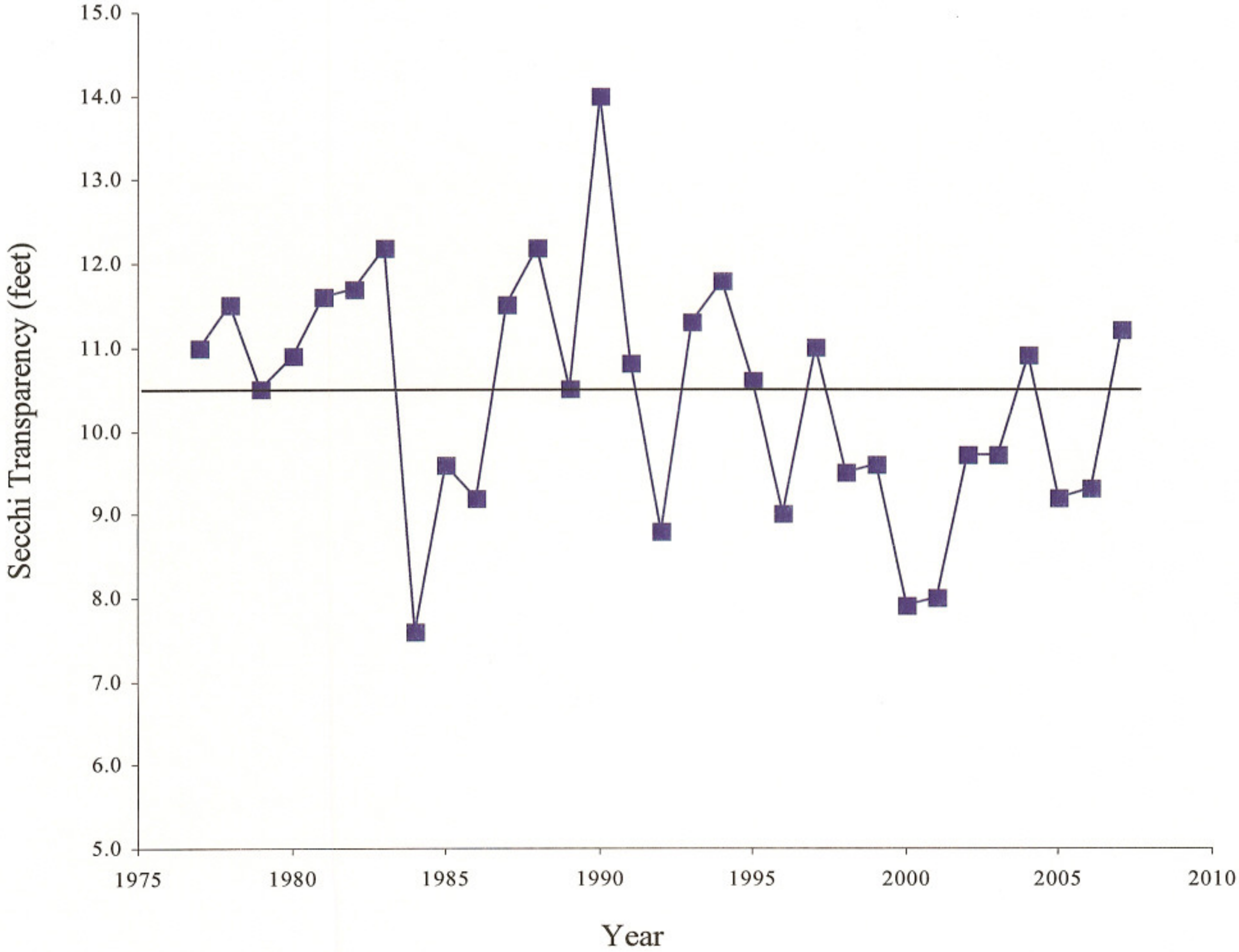

Figure 7c. Summer mean Secchi transparency values for Bear Lake (1977-2007; data courtesy of CLMP and Micorps). *Overall mean (~10.4 feet) is denoted by the line bisecting the data on the graph.

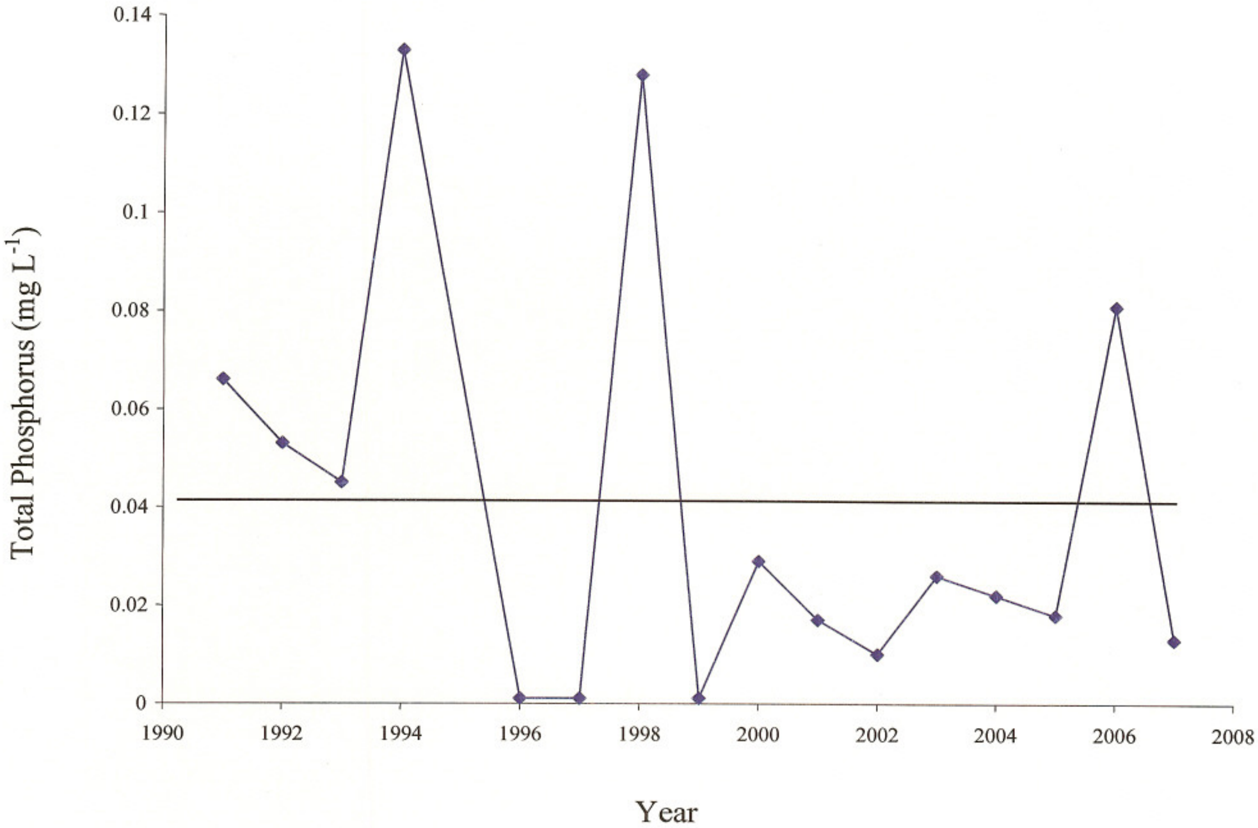

Figure 7d. Annual mean total phosphorus values for Bear Lake (1991-2007; data courtesy of BLPOA taken from means of n = 10 lake sampling stations). *Overall mean (~0.040 mg L^{-1}) is denoted by the line bisecting the data on the graph.

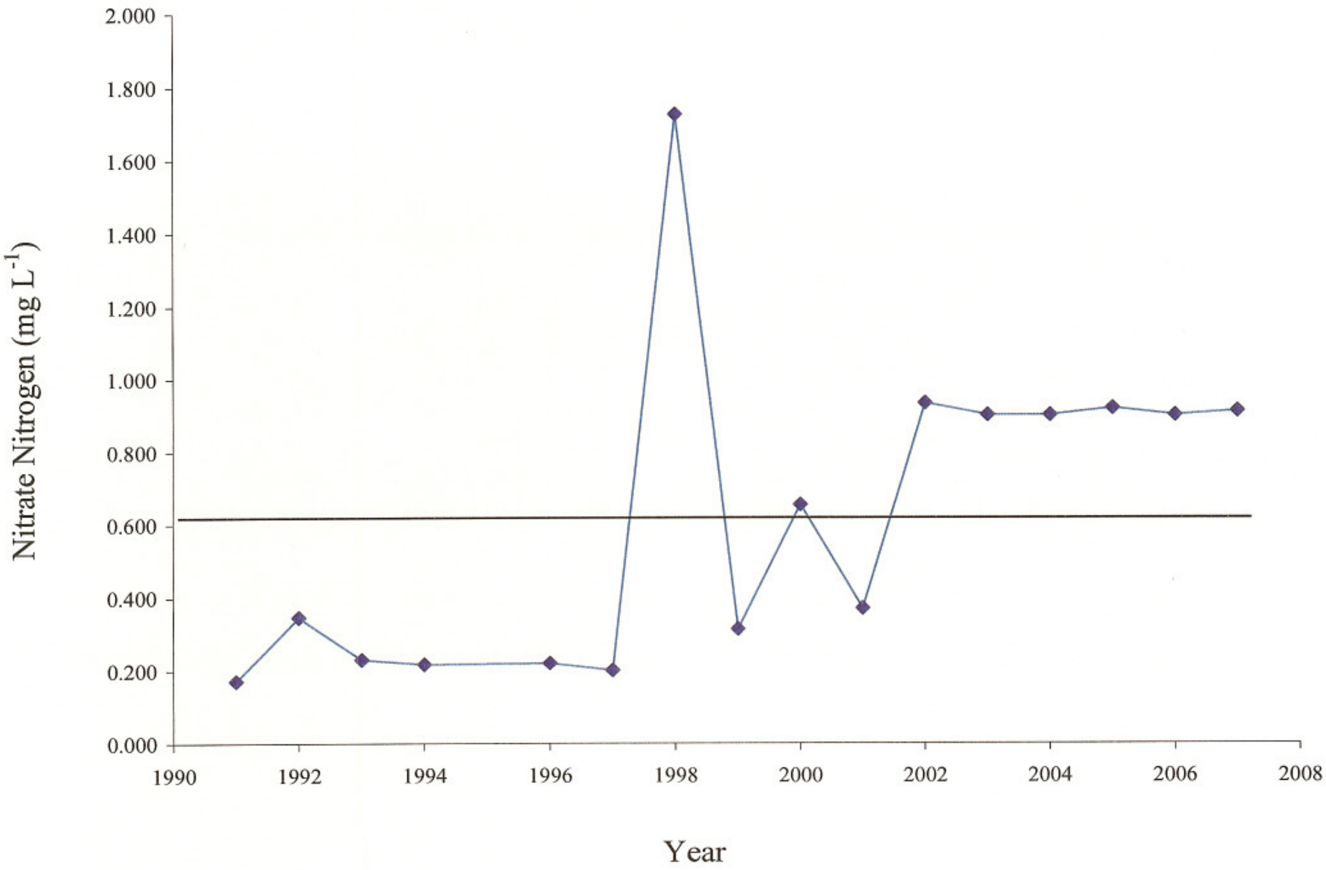

Figure 7e. Annual mean nitrate nitrogen values for Bear Lake (1991-2007; data courtesy of BLPOA taken from means of n = 10 lake sampling stations). *Overall mean (~0.619 mg L^{-1}) is denoted by the line bisecting the data on the graph.

3.1.11 E. coli Bacteria

Escherichia coli (*E. coli*) is a rod-shaped bacterium that constitutes fecal coliform, which is the dominant bacterium present in the feces of warm-blooded animals. *E. coli* bacteria are useful indicators of bacteriological contamination in aquatic ecosystems. *E. coli* may be contributed from fecal matter from warm-blooded animals directly, or from leaking septic seepage. The state of

Michigan adopted *E. coli* concentration threshold limits for surface waters in May of 1994 to protect human health. If three or more samples are collected over a 30-day period and average over 130 *E. coli* Colony Forming Units (CFU's) per 100 milliliters (ml), then local health officials are required to close public beaches. In addition, if any one sample detects an *E. coli* concentration of 300 CFU's per 100 ml, then the beaches will be closed. Other (non-body contact) activities (such as fishing and boating will be halted if concentrations exceed 1,000 CFU's per 100 ml. Additionally, soils with adequate moisture such as loams and peats, allow for a longer survival time of fecal bacteria such as *E. coli* (Peavy 1978). Historical annual mean *E. coli* concentration data for Bear Lake (1991-2007 data courtesy of the BLPOA) was analyzed for the ten lake sampling stations and determined to range between 13.5 and 66.8 CFU's per 100 ml. Values were highest among the Bear Lake Creek sites and the main central deep basin, along with the East Bay. It is recommended that *E. coli* concentrations be measured around the shoreline of Bear Lake in mid-summer to assess the abundance and distribution of bacterial populations that could impact the water quality of Bear Lake.

3.2 Bear Lake Fish Community

The fishery of Bear Lake may be defined as a diverse warm-water fishery due to the shallow depth of the lake and the resultant warm water temperatures during the summer season. Fish communities consist of 15 species (Tonello 1999) including Yellow Perch (*Perca flavescens*), Bluegill (*Lepomis macrochirus*), Pumpkinseed Sunfish (*Lepomis gibbosus*), Black Crappie (*Pomoxis nigromaculatus*), Largemouth Bass (*Micropterus salmoides*), Smallmouth Bass (*Micropterus dolomieu*), Northern Pike (*Esox lucius*), Rock Bass (*Ambloplites rupestris*), Bluntnose Minnows (*Pimephales notatus*), Bowfin (*Amia calva*), Brown Bullhead (*Ameiurus nebulosus*), White Sucker (*Catostomus commersonii*), Green Sunfish (*Lepomis cyanellus*), Walleye (*Sander vitreus vitreus*), and Yellow Bullhead (*Ameiurus natalis*). There are also reports that sturgeon (*Acipenser fulvescens*) also reside in the lake (Jaquish, 1992; Little River Band of Ottawa Indians, Inland Fisheries Division, personal communication). A detailed fishery survey was conducted by the Michigan Department of Natural Resources (MDNR; Tonello) in 1999 using a combination of fyke nets and inland gillnets. The most abundant species found during that survey were bluegill, yellow perch, and rock bass. Walleye (both Bay De Noc and Muskegon species strains) have been repeatedly stocked in Bear Lake during 1984-86, 1989-91, 1993, 1995, 1999, 2000, and 2003. The fishery community is thus quite diverse and will benefit from a diverse native aquatic plant community, ample supply of zooplankton, and abundance of submerged habitats (i.e wood structures and weed beds).

3.3 Bear Lake Aquatic Vegetation Communities

Aquatic plants (macrophytes) are an essential component in the littoral zones of most lakes in that they serve as suitable habitat and food for macroinvertebrates, contribute oxygen to the surrounding waters through photosynthesis, stabilize bottom sediments (if in the rooted growth form), and contribute to the cycling of nutrients such as phosphorus and nitrogen upon decay. In addition, decaying aquatic plants contribute organic matter to lake sediments which further supports healthy growth of successive aquatic plant communities that are necessary for a balanced aquatic ecosystem. An overabundance of aquatic vegetation may cause organic matter to accumulate on the lake bottom faster than it can break down. Aquatic plants generally consist of rooted submersed, free-floating submersed, floating-leaved, and emergent growth forms. The emergent growth form (i.e. Cattails, Native Loosestrife) is critical for the diversity of insects onshore and for the health of nearby wetlands. Submersed aquatic plants can be rooted in the lake sediment (i.e. Milfoils, Pondweeds), or free-floating in the water column (i.e. Coontail).

There is evidence that the diversity of submersed aquatic macrophytes can greatly influence the diversity of macroinvertebrates associated with aquatic plants of different structural morphologies (Parsons and Matthews, 1995). Therefore, it is possible that declines in the biodiversity and abundance of submersed aquatic plant species and associated macroinvertebrates, could negatively impact the fisheries of inland lakes. Alternatively, the overabundance of aquatic vegetation can compromise recreational activities, aesthetics, and property values. Different management options are needed to control exotic and native nuisance aquatic vegetation growth. Such management options are thoroughly discussed in the management recommendations section of this lake management plan report.

3.3.1 Bear Lake Exotic Aquatic Macrophytes

Exotic aquatic plants are not native to a particular site, but are introduced by some biotic (living) or abiotic (non-living) vector. Such vectors include the transfer of aquatic plant seeds and fragments by boats and trailers (especially if the lake has public access sites), waterfowl, or by wind dispersal. In addition, exotic species may be introduced into aquatic systems through the release of aquarium or water garden plants into a water body. An aquatic exotic species may have profound impacts on the aquatic ecosystem. Eurasian Watermilfoil (*Myriophyllum spicatum*; Figure 8) is an exotic aquatic macrophyte first documented in the United States in the 1880's (Reed 1997), although other reports (Couch and Nelson 1985) suggest it was first found in the 1940's. *M. spicatum* has since spread to thousands of inland lakes in various states through the use of boats and trailers, waterfowl, seed dispersal, and intentional introduction for fish habitat. *M. spicatum* is a major threat to the ecological balance of an aquatic ecosystem through causation of significant declines in favorable native vegetation within lakes (Madsen et al. 1991), and may limit light from reaching native aquatic plant species (Newroth 1985; Aiken et al. 1979). Additionally, *M. spicatum* can alter the macroinvertebrate populations associated with particular native plants of certain structural architecture (Newroth 1985).

Since the introduction of Eurasian Watermilfoil, many nuisance aquatic plant management techniques such as chemical herbicides, mechanical harvesting, and biological control have been implemented. Some individual plants of *M. spicatum* were found at depths of approximately 18-21 feet. Furthermore, the West and East Bays contain sparse yet patchy distributions of *M. spicatum*. *M. spicatum* growth may be limited in deeper areas due to decreased available light and intense competition from other deeper-growing native aquatic plants. However, growth of

M. spicatum in Bear Lake is also suppressed near shore due to the presence of a shallow littoral zone shelf that exhibits high wave energy and prevents many *M. spicatum* plants from rooting in the relatively turbulent waters. *M. spicatum* growth in Bear Lake is very robust and forms a dense canopy in shallow areas (Figure 9). The results of a detailed GPS-guided Point-Intercept aquatic vegetation survey of Bear Lake (ASI Environmental Technologies, Inc, April, 2007; Figure 10; Appendix B) demonstrated that approximately 300 acres of *M. spicatum* infested the lake. A slight increase (approximately 13) acres of *M. spicatum* was found in the lake during a fall survey (ASI Environmental Technologies, Inc, 2007). The majority of the *M. spicatum* growth found during both surveys was noted near the 8-13 foot depth contours at the west side of the lake and in small areas throughout the south and east shores, and in the bays.

Figure 8. A photograph showing the seed structures (a), dissected leaves (b), and lateral branches (c) of Eurasian Watermilfoil (*Myriophyllum spicatum*).

Figure 9. Eurasian Watermilfoil infestation and canopy in Bear Lake (July, 2007).

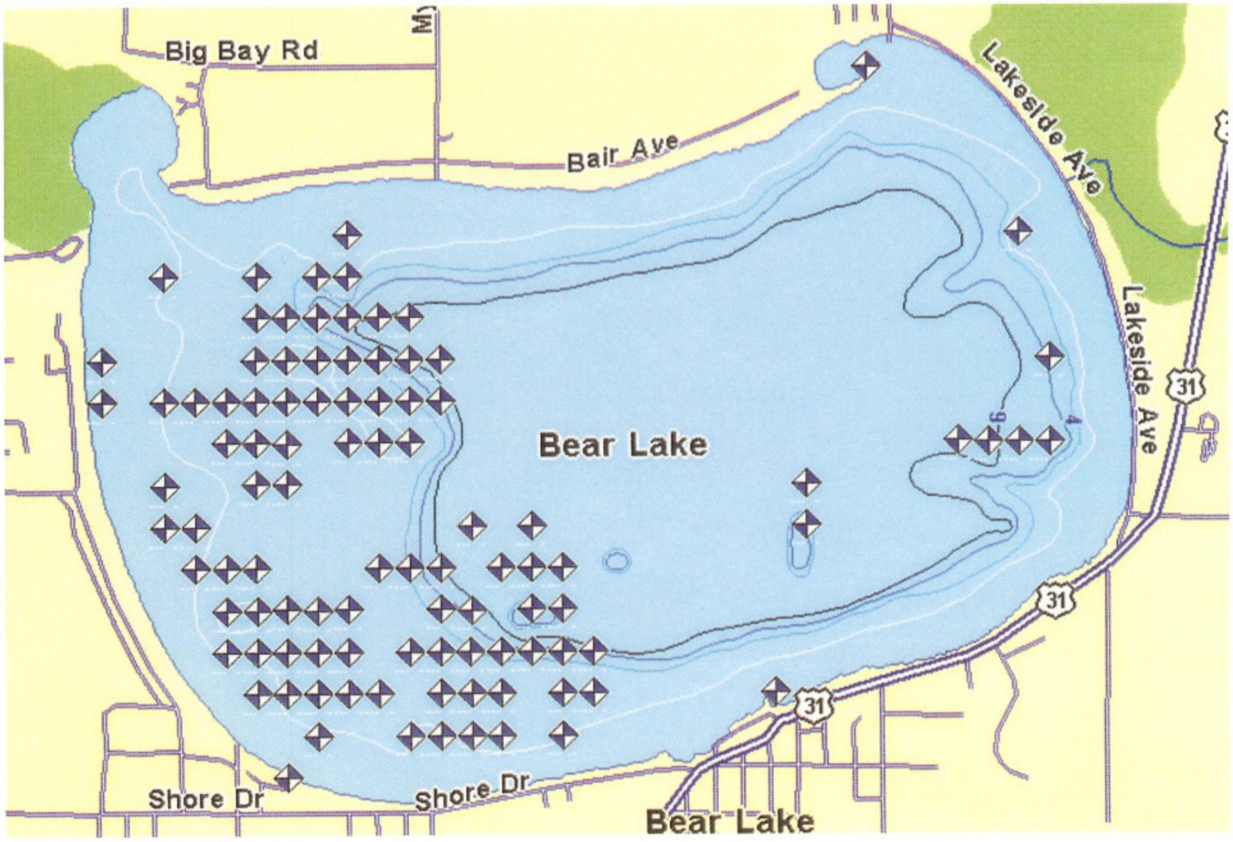

Figure 10. Distribution of Eurasian Watermilfoil in Bear Lake (April, 2007). *Note: The Eurasian Watermilfoil distribution during the October 2007 survey was identical to the April 2007 survey, except for an additional 13 acres located just east of the Hopkins Park access site in the Village of Bear Lake.

Figure 11. Purple loosestrife (*Lythrum salicaria*) invading a wetland bordering a lake.

Purple loosestrife (*Lythrum salicaria*; Figure 11) is an invasive (i.e. exotic) emergent aquatic plant that inhabits wetlands and shoreline areas. *L. salicaria* has showy magenta-colored flowers that bloom in mid-July and terminate in late September. The seeds are highly resistant to tough environmental conditions and may reside in the ground for extended periods of time. It exhibits rigorous growth and may out-compete other favorable native emergents such as cattails (*Typha latifolia*) or native swamp loosestrife (*Decodon verticillatus*) and thus reduce the biological diversity of localized ecosystems. The plant is spreading rapidly across the United States and is converting diverse wetland habitats to monocultures with substantially lower biological diversity. Although only a few individual plants of the genus were located during the October 2007 survey, residents should be educated about its invasiveness and threat to the health of the

Bear Lake ecosystem. Management options for the plant are provided in the management recommendations section of the report.

An Aquatic Vegetation Assessment Site (AVAS; Appendix B) survey was conducted on Bear Lake on 2 October, 2007 using the method as defined by the Michigan Department of Environmental Quality (MDEQ). The Aquatic Vegetation Assessment Site (AVAS) Survey method was developed by the MDEQ to quickly assess the presence and relative abundance 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 lake are divided into lakeshore sections approximately 100 - 300 feet in length. The species of aquatic macrophytes present and relative abundance of each macrophyte are recorded onto an MDEQ AVAS data sheet. Each macrophyte species corresponds to an assigned number designated by the MDEQ. In addition to the particular species observed (via assigned numbers), a relative abundance scale is used to estimate the percent coverage of each species within the AVAS site. If shallow areas are present in the open waters of the lake, then individual AVAS segments can be sampled at those locations to assess the macrophyte communities in offshore locations. This is particularly important since *M. spicatum* and other exotics often expand in shallow island areas located offshore in many lakes. Exotic aquatic plant species in all studied regions of Bear Lake are shown in Table 6.

Exotic Aquatic Plant Species	***Common Name***	***Abundance in or around Bear Lake***
Lythrum salicaria	Purple Loosestrife	Found
Myriophyllum spicatum	Eurasian Watermilfoil	Common

Table 6. Bear Lake exotic aquatic macrophyte species (October, 2007).

3.3.2 Bear Lake Native Aquatic Macrophytes

There are hundreds of native aquatic plant species in the waters of the United States. The most diverse native genera include the Potamogetonaceae (pondweeds) and the Haloragaceae (milfoils). Native aquatic plants may grow to nuisance levels in lakes with abundant nutrients (both water column and sediment) such as phosphorus, and in sites with high water transparency. The diversity of native aquatic plants is essential for the balance of aquatic ecosystems, because each plant harbors different macroinvertebrate communities and varies in fish habitat structure.

Bear Lake contains 13 submersed, 3 floating-leaved, and 3 emergent aquatic plant species (Table 7), for a total of 19 native aquatic macrophyte species. The majority of the emergent macrophytes may be found along the shoreline of the lake, and especially along the West and East Bay shorelines. Additionally, the majority of the floating-leaved macrophyte species can be found in the two shallow bays. The two bays in Bear Lake currently contain the greatest biodiversity of aquatic plant species, likely due to enriched sediments, shallower water depth with reduced wave energy, and the presence of many different habitats including open-water and wetlands. The dominant aquatic plants in each location were Variable-leaved and Robbin's Pondweeds which cover a large portion of the lake bottom. The Pondweeds (Family: Potamogetonaceae) are critical foraging habitat for the fishery of Bear Lake. In addition, Robbin's Pondweed creates a thick "carpet-like" layer on the lake bottom that helps to inhibit the rooting of Eurasian Watermilfoil fragments in some areas. The relative abundance of rooted aquatic plants (relative to non-rooted plants) in the lake suggests that the lake sediments are rich in nutrients, since these plants obtain most of their nutrition from the sediments. Floating-leaved vegetation such as the waterlilies is critical for snail and macroinvertebrate habitat and should be encouraged in shoreline areas and in the shallow bays.

Native Aquatic Plant Species	***Common Name***	***Abundance in Bear Lake***	***Growth Habit***
Chara vulgaris	Muskgrass	Common	Submersed, Rooted
Potamogeton pectinatus	Sago Pondweed	Sparse	Submersed, Rooted
Potamogeton illinoensis	Illinois Pondweed	Common	Submersed, Rooted
Potamogeton zosteriformis	Flat-stem Pondweed	Found	Submersed, Rooted
Potamogeton gramineus	Variable-leaved Pondweed	Common	Submersed, Rooted
Potamogeton robbinsii	Robbin's Pondweed	Common	Submersed, Rooted
Potamogeton amplifolius	Large-leaf Pondweed	Sparse	Submersed, Rooted
Potamogeton richardsonii	Richardson's Pondweed	Found	Submersed, Rooted
Bidens beckii	Beck's Water-Marigold	Found	Submersed, Rooted
Vallisneria americana	Wild Celery	Found	Submersed, Rooted
Najas guadalupensis	Southern Naiad	Sparse	Submersed, Rooted
Elodea canadensis	Common Waterweed	Sparse	Submersed, Rooted
Myriophyllum tenellum	Leafless Watermilfoil	Sparse	Submersed, Rooted
Nymphaea odorata	White Waterlily	Sparse	Floating-Leaved, Rooted
Nuphar variegata	Yellow Waterlily	Found	Floating-Leaved, Rooted
Brasenia schreberi	Watershield	Found	Floating-Leaved, Rooted
Typha latifolia	Cattails	Sparse	Emergent, Rooted
Scirpus sp.	Bulrushes	Sparse	Emergent, Rooted
Decodon verticillatus	Swamp Loosestrife	Common	Emergent, Rooted

Table 7. Bear Lake AVAS survey of native aquatic plants found in Bear Lake, October, 2007.