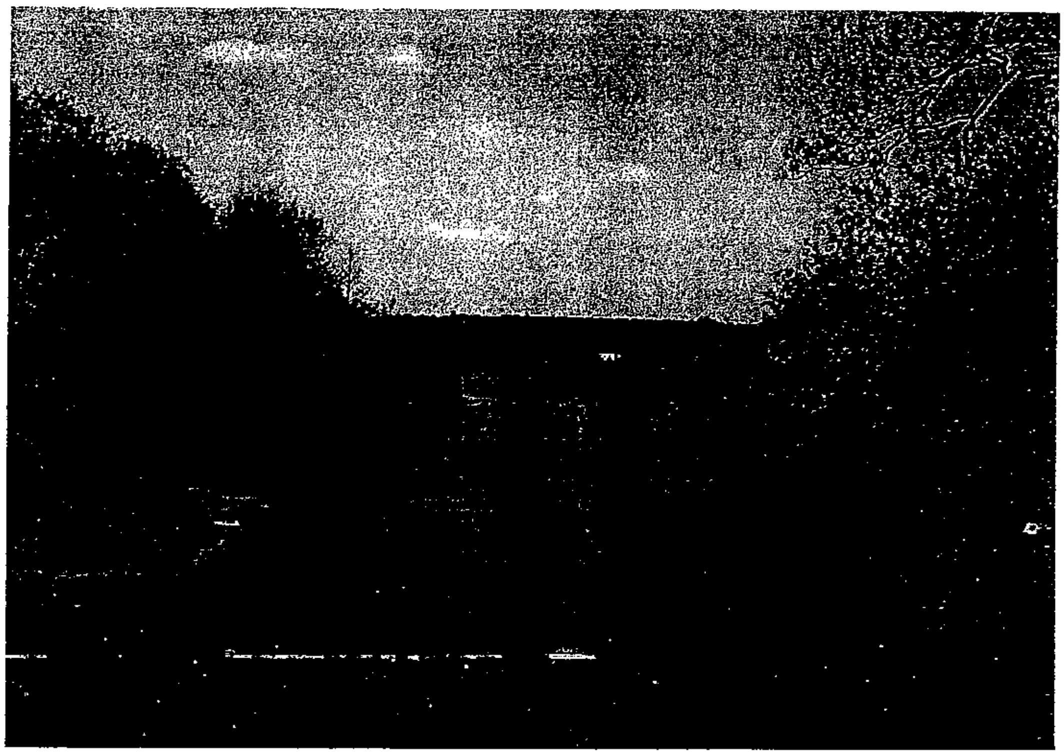
Prepared For:

Bashan Lake Association

Diagnostic/Feasibility Study of Bashan Lake East Haddam, Connecticut



July 2003

Prepared By:

Northeast Aquatic Research, LLC

Diagnostic Feasibility Study of Bashan Lake, East Haddam, Connecticut

Prepared For:

Town of East Haddam

Bashan Lake Association

CT Department of Environmental Protection

Prepared By:

Northeast Aquatic Research, LLC

George W. Knoecklein

74 Higgins Highway

Mansfield Center, CT 06250

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

This report represents the results and conclusions of a Diagnostic Feasibility study of Bashan Lake in East Haddam Connecticut. The study included both water quality sampling of the lake and inlets to the lake during the 2002 season, April through October. In addition the aquatic plants in the lake were surveyed during the summer of 2002 with a specific focus on the invasive plant variable leaved milfoil (*Myriophyllum heterophyllym*).

Water Clarity

The water clarity of Bashan Lake was stable during the 2002 season with an average Secchi disk depth of 7.6 meters (25 feet). There was very little fluctuation in water clarity during the season indicating that the lake had generally low algae productivity. The clarity of Bashan Lake was in the oligotrophic category.

Total Phosphorus

The phosphorus concentrations in Bashan Lake between May and October were all below the threshold for oligotrophic lakes (10 ppb). April samples showed slightly higher levels with an average concentration of 12 ppb. Samples from the bottom during anoxic conditions showed no increases in total phosphorus indicating no internal loading of phosphorus occurred in Bashan Lake during 2002. The estimated loading of phosphorus to the lake from the drainage basin was 22 Kg/yr, an extremely low value.

Total Nitrogen

The nitrogen levels in the lake were also generally low. Nitrate was present briefly at the bottom while ammonia accumulated at both 9 and 12 meters during the summer. Organic nitrogen levels were also generally low except for bottom water samples. Bashan Lake had meso-oligotrophic levels of nitrogen and an estimated loading from the drainage basin of 578 Kg/year.

Aquatic Plants

The lake had approximately 20 acres of dense variable-leaved milfoil coverage and numerous locations of isolated clumps of milfoil scattered around Bashan Lake.

INTRODUCTION

General Introduction

This report presents the results of a diagnostic feasibility study of Bashan Lake, located in the town East Haddam. The study involved the evaluation of water quality parameters in Bashan Lake and the major tributary streams feeding it. Samples were collected from one in-lake station shown in **Map 1**, and from 5 inlet stream stations, shown in **Map 2**. Water quality data collections included nutrient chemistry, temperature and oxygen measurements, water clarity, and basic phytoplankton and zooplankton population estimates. An examination of the aquatic plants in Bashan Lake was also conducted with emphasis on mapping the distribution of the invasive weed variable milfoil (*Myriophyllum heterophyllym*).

Report Organization

The data collection was started in April 2002 and progressed through to October of 2002. The lake was visited once each month during that time period to collect water samples and record measurements from the lake and inlet stations. The water samples were analyzed for total phosphorus, total nitrogen (nitrate, ammonia, and organic nitrogen), alkalinity, pH, conductivity, total iron.

The report presents the results of each of the different measurements and test results in the following order. The Secchi data collected during this study are reported first, followed by the historical Secchi disk depth collected from difference sources. The Secchi data are used to define the depth of light transparency in the lake as well as help classify the trophic status of the lake. The temperature and oxygen data are discussed next to define the location and strength of the thermocline, a temperature boundary, and the location of the anoxic boundary, the depth in the lake were oxygen is depleted. At this point, the three types of data will be presented together, Secchi, thermocline, and anoxic boundary as a way of defining the physical structure of the lake during the season.

The chemical test results are presented beginning with phosphorus and nitrogen, the two important nutrients in lakes, then in turn each of the other chemical parameters that have been analyzed with iron completing the chemical results section. The last section of the in-lake results is a review of some of the biological aspects, phytoplankton, zooplankton, and fisheries.

The next section treats the drainage basin of the lake by presenting the physical data such as the area and boundaries of the subbasins. The water chemistry results of the inlet samling follow. This section concludes with mass loading estimates for phosphorus and nitrogen.

A discussion section follows the results with information on storm water management, weed control techniques, and a review of the soils groups in the drainage basin with focus on septic system capabilities.

Historical Reports

The earliest record of limnological information for Bashan Lake is Edward Deevey's survey of Connecticut lakes conducted between 1937 and 1939 (Deevey 1940). He collected chlorophyll, nutrients, transparency, and alkalinity from 48 Connecticut lakes of which Bashan Lake was one that he described as located in the eastern highlands. The Connecticut State Board of Fisheries and Game published a bathymetric map of Bashan Lake and briefly discussed the fisheries in the lake but didn't include any water quality data (CT State Board of Fisheries and Game 1959). The next set of data on the lake was collected by the CT Agricultural Experiment Station by Charles Frink and William Norvell (1984) during a statewide survey of 70 lakes conducted between 1973 and 1980, with Bashan Lake visited twice in 1980. They measured the Secchi depth and had water samples analyzed for nutrients, chlorophyll, alkalinity, cations and anions.

The Connecticut Department of Environmental Protection included Bashan Lake in the Trophic Classifications of Seventy Connecticut Lakes (DEP 1982) which listed water chemistry results from the Frink and Norvell (1984) survey of 1980, giving the lake an oligotrophic classification.

Data that is more recent was collected as part of a statewide survey of Connecticut lakes published in Canavan and Siver's Connecticut Lakes, A Study of the Chemical and Physical Properties of Fifty-six Connecticut Lakes (1995). The survey collected water quality samples from Bashan Lake on two dates in 1992 and two dates in 1993. Lake data collected included Secchi disk transparency, Chlorophyll a, total phosphorus, pH, alkalinity, conductivity, and major cations and anions.

In 1993, Benson Environmental, Inc., conducted a survey for potential sources of nonpoint pollution in the drainage basin of Bashan Lake. The study focused on examining existing mapping of land-use, and soil capabilities to identify areas where practices and existing development of the drainage basin may be causing pollutants to enter Bashan Lake. The report entitled Nonpoint Source Pollution Watershed Survey of Bashan Lake, East Haddam, CT. was reviewed as part of this study.

The Connecticut Agricultural Experiment Station (CAES), with initial funds from CT DEP Lakes Grant Program, has been treating the variable-leaved milfoil infestation in Bashan Lake with the aquatic plant herbicide 2-4D since 1999; during their field visits they collected water quality data to support the treatments. In 2000 CAES measured alkalinity and pH, 11 times between June 11 and September 27, 2000 from 5 locations around the lake. In 2001 CAES tested the lake for total phosphorus, alkalinity, conductivity, pH, and Secchi disk depth, they also made oxygen and temperature readings with depth. Their data was collected between May 29, 2002 and August 9, 2002 from 4 locations around the lake with surface and bottom samples from each site. The CAES also conducted surveys of the milfoil population in the lake usually making 2 to 3 maps during each season that showed the target and treatment beds.

Finally, the CT DEP published the A Fisheries Guide to Lakes and Ponds in Connecticut, by Jacobs and O'Donnell in 2002, which included a new bathymetric map of the lake and other summary information including remarks about the fisheries in the lake.

Table 1. Summary of Sources of Lake Data For Bashan Lake.

Author	Title	Dates of Data Collection
Deevey	A Contribution to Regional Limnology	1937-1939
Frink and Norvell	Chemical and Physical Properties of CT Lakes	1980
CT DEP	Trophic Classifications of Seventy Lake Connecticut Lakes	Referenced 1978 data
Canavan and Siver	Connecticut Lakes, A Study of the Chemical and Physical Properties of Fifty-six Connecticut Lakes	1992 – 1993
Benson Environmental	Nonpoint Source Pollution Watershed Survey of Bashan Lake, East Haddam, CT	1993
Lake Residents	Monitoring, (no reports)	1997 - 2000
Ct. Agric. Exp. Station	Control of Milfoil in Bashan Lake	1999 - 2002
Jacobs and O'Donnell	A Fisheries Guide to Lakes and Ponds in Connecticut	2002

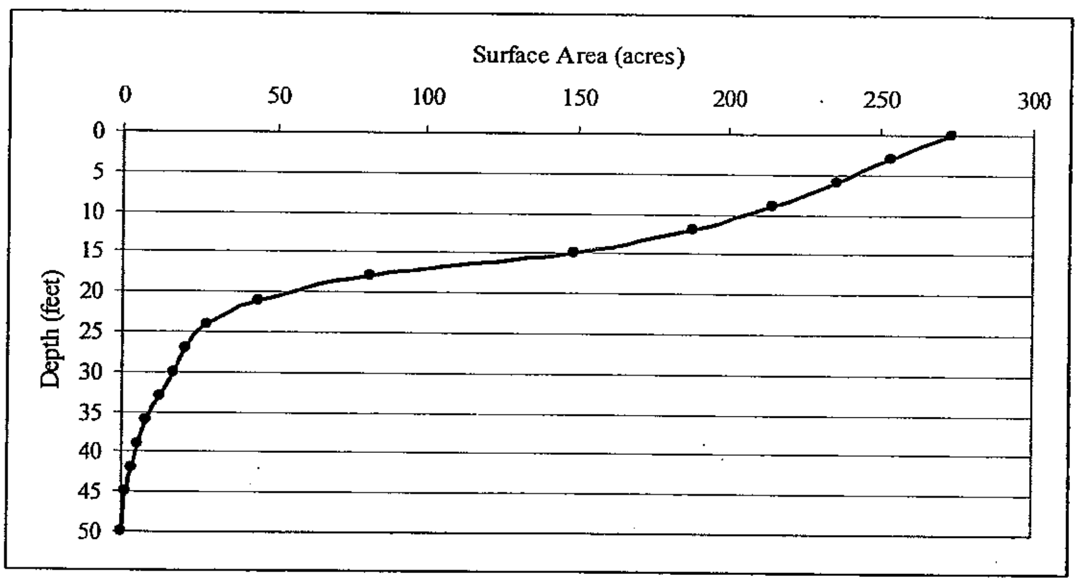
Lake and Drainage Basin Characteristics

Lake Basin

Bashan Lake is located in the town of East Haddam in Middlesex County, Connecticut. Bashan Lake has a surface area of 273 acres (Jacobs and O'Donnell 2002) composed of one central basin and several shallow coves. There are six islands in Bashan Lake the largest is 0.39 acres, located toward the southern end of the lake. The maximum depth, 50 feet occurred in the middle of the lake. The lake drains toward the north directly into Moodus Reservoir.

The hypsographic curve for Bashan Lake is shown in **Figure 1**. This is a graphic representation of the surface area at each depth and shows the general proportion of bottom area and depth. For instance, the curve starts at the top of the graph at 270+ acres or the total surface area of the lake, while the surface area of the lake at the 20 ft depth is closer to 50 acres. From this type of relationship, it is possible to determine the approximate surface area within each interval of water depth.

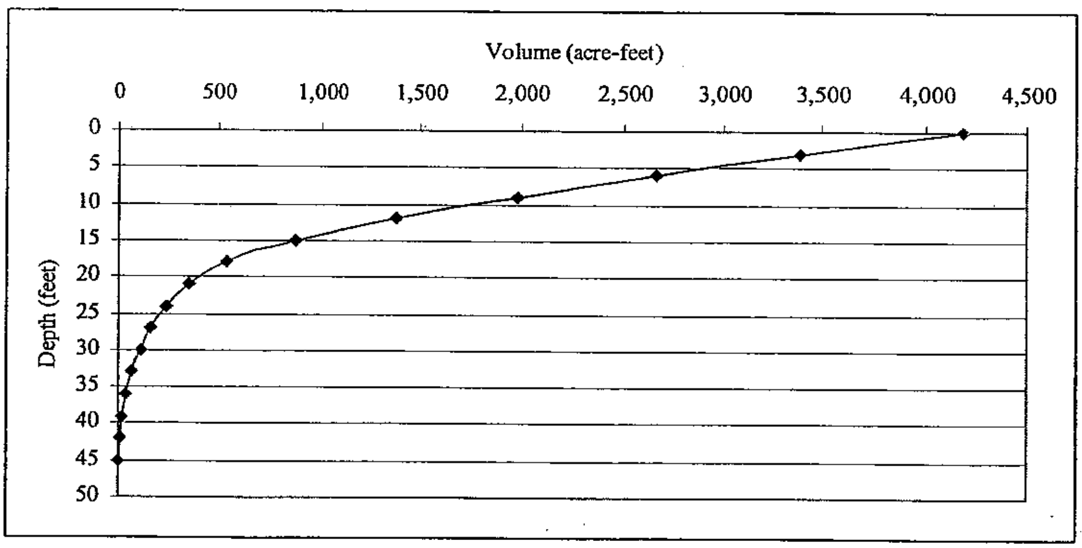
Figure 1. Hypsographic (Depth-Area) Curve for Bashan Lake.



The volume of water in the lake was determined to be approximately 4,231 acre-feet or about 5.2 million cubic meters (m^3). The surface area of each 3 foot depth contour was used to develop a volume by assuming the lake to be similar to a cone (bathymetric map given in Jacobs and O'Donnell 2002. The volume below each depth is shown in **Figure 2.** The curve shows the volume of water contained in the lake below each depth such that the line for the total starts at the top of graph at 4,000+ acre-feet and gradually decreases with depth until reaching about 18 feet below which the volume decreases rapidly with depth. The graph shows that about half the lake volume was contained between 0 and 9 feet and another quarter of the volume was contained between 9 and 15 feet. The graph also shows that there was only about 10% of the lake volume below 20 feet.

The mean depth of Bashan Lake was 4.66 meters (15.3 feet). The mean depth is determined by dividing the volume by the surface area and represents the water depth if the basin was smoothed to one uniform depth. The mean depth will be discussed during the nutrient loading section of the report because the mean depth provides a measure of the capacity of the lake to assimilate nutrients. Lakes with larger mean depths, i.e. the lake has more water of deeper depths than shallow water, have a higher capacity to store nutrients without showing signs of eutrophication. Shallower lakes have less capacity so are more sensitive to nutrient loading. Bashan Lake has a relatively large mean depth that suggests it would tend toward oligotrophic.

Figure 2. Depth - Volume Curve for Bashan Lake.



Drainage Basin

The watershed of Bashan Lake was located entirely within the town of East Haddam, CT. The size of the watershed was about 1,257 acres (Jacobs and O'Donnell 2002) with a slightly larger value given in DEP CT of 1,275 acres. Both these reported values are essentially the same; this report will make use of the more recent of the two values, 1,257 acres. The size of the watershed area minus the lake area equals the total drainage basin for the lake, 1,257 – 273

= 984 acres. This area is relatively small for the size of the lake and results in the lake having a long retention time. The retention time is a conceptual value that represents the time it takes to fully replace the water volume in the lake by inputs from the watershed. In the case of Bashan Lake the retention time is about 1.7 years. This suggests that the water and materials that are washed into the lake tend to remain in the lake for about that amount of time, although actual flushing will be different for different depths and areas of the lake. For example the water at the bottom of the deep area in the center may remain there for a longer period of time, while water in the outlet channel may move more rapidly.

The drainage basin could be subdivided into several smaller sub basins that are drained by streams that flow into the lake. The sub basins of Bashan Lake are shown in **Map 2**. Six sub basins were identified together representing about 631 acres or 64% of the total drainage area to the lake. The remaining 353 acres had either very small tributaries or drained to the lake via direct flow or ground water. Storm water discharges to the lake appeared to be minor except for the Sunset Lane area where catch basins and street drains intercept flows from an agricultural land use on the east side of Newberry Road.

WATER QUALITY RESULTS

In-lake Results

Methods

The lake was visited once each month beginning in April and ending in October. During each of the monthly visits between April and October sampling was conducted at Station 1 located in the deepest area of the lake, sampling dates are given in **Table 2.**

Table 2. Lake Sampling Dates At Bashan Lake, 2002.

Dates	4-5	5-28	6-25	7-26	8-22	9-20	10-18
Water Quality	St. 1	St. 1	St. 1	St. 1	St. 1	St. 1	St. 1

Dates	6-25	7-26	8-22	9-10	9-17	10-18
Plant Surveys	South End	North Shore	West Shore	Sunset Cove	Island Area	East Shore

The in-lake testing included several different kinds of data collection. The water clarity was measured using both a Secchi disk and a light meter. The Secchi disk is an 8 inch round disk with alternating white and black quadrants. It is gradually lowered into the water until it disappears, than slowly brought back up until it re-appears. The average of these two depths is recorded as the Secchi disk depth. A light meter records the actual quantity of incident solar radiation reaching any given depth. The light sensor of the meter (a Licor Model 185A light meter) was lowered into the water and readings were taken at each one-meter depth until either it reached the bottom or the values were less than 0.5% of the surface level.

Temperature and oxygen measurements were collected at each one-meter depth beginning at the surface and ending at the sediment surface using a YSI Model 58 oxygen meter. These data were tabulated on profile sheets that show the vertically arranged measurements and plot the data graphically. The profile sheets are included in **Appendix 1.** The temperature information was used to determine the depth in the lake were the thermal boundary existed and estimate its strength. The oxygen measurements were used to define the part of the lake that became devoid of oxygen, and whether the lakes upper water layers became super saturated with oxygen. The oxygen values were also used to assess whether any deep-water algae layers existed.

Water samples were collected from 6 depths; 1, 3, 5, 7, and 12 meters at Station 1. The testing results are given in **Appendix 2**. Water samples were collected using a non-metallic foot pump fitted with intake and outlet tubes of 1/2" ID Tygon tubing. The inlet tube has an attached brass orifice opening horizontally. The volume of water in the tube was flushed twice before depth-discrete samples were collected. Each sample bottle was then flushed 2 times before stoppering. No samples were collected unless the sampling tube line hung vertically in the water column.

Water samples collected monthly were analyzed for the following parameters, total phosphorus, ammonia, nitrate and organic nitrogen, turbidity, conductivity, alkalinity, total iron, and pH. Lake samples were also tested for redox potential (eH).

Once each month samples were collected from Station 1 for phytoplankton and zooplankton enumeration. The phytoplankton samples were collected using a 5-meter ½ inch internal diameter latex tube that was lowered vertically into the water column, closed, brought to the surface and emptied into a 500 mL bottle. A 15 mL aliquot was removed and preserved with Lugols iodide solution. The zooplankton sample was collected with a 153 micro mesh net that was lowered to 0.5 meters from the bottom than raised back up through the water column. Captured organisms were rinsed into a 15 mL vial and preserved with Lugols iodide solution.

Secchi Disk Depth

The Secchi disk depth was measured on 7 dates at Stations 1 during the 2002 season with data given in **Table 3**.

Table 3. Secchi Disk Depths (meters) At Bashan Lake during 2002.

	April	May	June	July	August	Sept.	Oct.
St. 1	8.0	8.1	7.0	5.5	8.5	8.5	7.6

The Secchi disk depth at Bashan Lake was between 5.5 and 8.5 meters during the 2002 season for an annual average of 7.6 meters. The water clarity remained fairly constant during the season with only one deviation when the Secchi disk transparency decreased to 5.5 meters in July. That reading was out of line from the other measurements taken at Bashan Lake during 2002 and it suggests that an increase in productivity did occur probably beginning in June and lasted until sometime in July but had ended prior to the sampling visit made in August.

The light meter was also used to measure the penetration of light into the water column. The depth in the lake were light has diminished to only 1% of that impinging the surface is considered to be the dividing point between photosynthesis and respiration. The two activities are regulated by the amount of light that is present. When light is sufficiently high photosynthesis can take place and oxygen is produced in excess of that required by respiration. When the amount of light is low, photosynthesis cannot take place and respiration dominates. The depth where these two processes are balanced is known as the compensation point because photosynthesis balances respiration. Below this depth there is no net oxygen production so oxygen is consumed through the various kinds of respiration.

The compensation depth or depth of 1% light at Bashan Lake is given in **Table 4**. The value of 1% is calculated from the best-fit logarithmic curve. The depth of the 1% light level averaged 11.7 meters for the season, or about 97% of the bottom area of the lake.

Table 4. Depth of 1% Light (meters) At Bashan Lake during 2002.

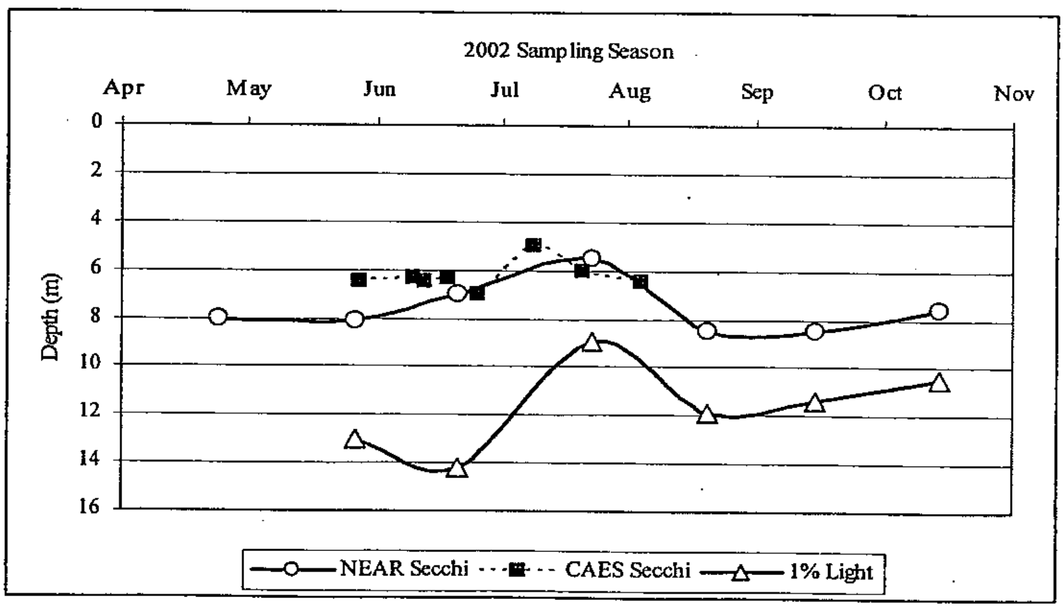
	April	May	June	July	August	Sept.	Oct.
St. 1	*	13	14.2	8.9	11.9	11.4	10.5

* = equipment malfunction

When the two sets of data are plotted together as shown in **Figure 3** the similarity between both can be seen. The depth of 1% light defines the depth of the euphotic zone, or the depth into the water that light penetrates with sufficient intensity to fuel photosynthesis. It also defines the depth in the lake were sunlight will warm the water. In the case of Bashan Lake the euphotic zone was between the surface and about 14 meters early in the season, but decreased as the season progressed, ranging between 12 and 11 meters during the late summer and fall. This also suggests that there was sufficient light for aquatic plants to grow in water depths of at least 26 feet and probably deeper.

The CAES measured Secchi disk Depth in Bashan Lake 8 times from the center of the lake corresponding to Station 1 in this study. The data is shown together with Secchi depths collected during this study in **Figure 3**. The time period of the CAES data spanned late May to early August. Their Secchi depths ranged from 7 meters to 5 meters. Their measurements taken in late May were lower than those obtained by Northeast Aquatic Research (NEAR) but measurements taken in June and July were comparable to those collected as part of this study. Both CAES and NEAR observed a decrease in transparency in July, although CAES noticed that the decline started earlier and reached a slightly poorer level having recorded a minimum Secchi disk depth of 5 meters on July 11, 2002. Their measurements taken in early August were identical to the observed trend of increasing Secchi disk depth predicted by readings taken as part of the study.

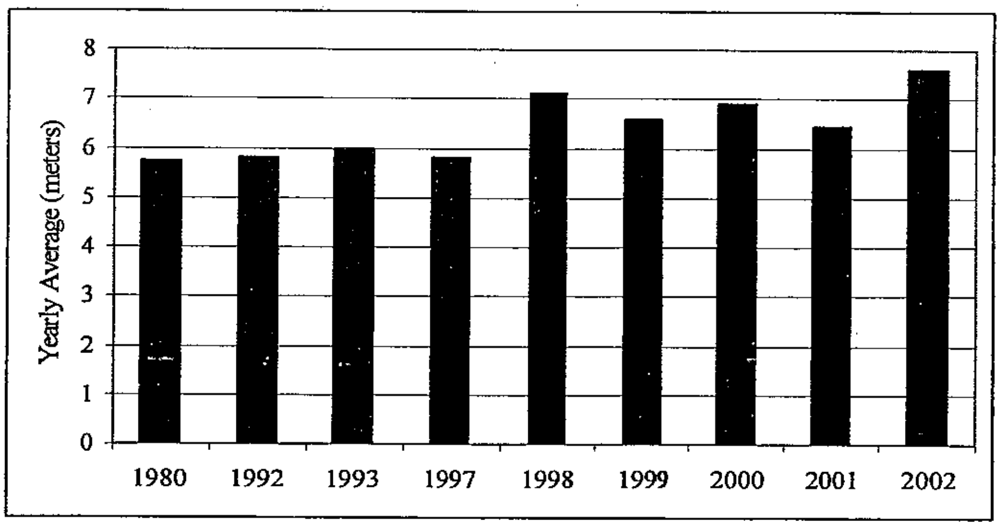
Figure 3. Bashan Lake Secchi Disk and 1% Light Depths at Station 1, 2002.



The historical record of Secchi disk depth measurements at Bashan Lake included values spread over the last 25 years, and one value from 1937. Two measurements were made in each of the three years, 1980, 1992, and 1993. Lake residents monitored Secchi disk at the lake between 1997 and 2000 with eleven measurements made in 1997, seven in 1998, four in 1999 and four in 2000. Northeast Aquatic Research made two measurements in 2001. The Connecticut Agricultural Experiment Station (CAES) measured the Secchi disk depth 12 times in 2001.

The mean of each set of seasonal readings is presented in **Figure 4**. The data show that the Secchi disk depths at Bashan Lake have remained within a range of 5.8 m to 7.5 m, with the highest average from 2002. The average of all readings taken between 1980 and 1997 is 5.8 meters while the average of all readings taken in 1998 and later is 7.1 meters. The two sets of data are statistically different, if all the readings between 1980 and 1997 are compared against all the readings from 1998 and later. This suggests that the clarity in the lake has been about 1.2 meters better in the years beginning in, and following 1998.

Figure 4. Historical Record of Secchi Disk Depth at Bashan Lake.



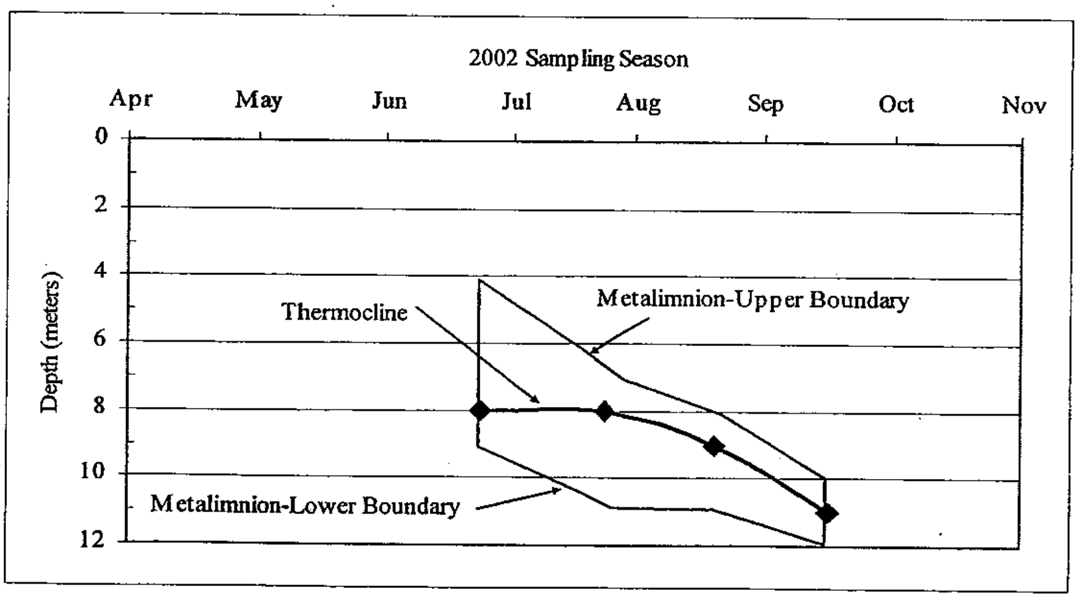
Temperature and Oxygen

Temperature

The water temperature of Bashan Lake was measured by taking vertical profiles of temperature (and oxygen) from the surface to the bottom at each 1-meter depth. Profiles of temperature were taken at Station 1, once each month between April and October. The profiles were than used to determine the depth at which thermal stratification occurred. Thermal stratification is the boundary that is caused when water on the top of the lake is warmer than the water at the bottom of the lake. Generally somewhere in the middle depth of the water column the temperature changes quickly in a couple of meters of depth. When warm water sits on top of cooler water, the two layers will not mix. When this happens the two layers are stratified with the upper layer freely mixing due to wind action on the lake surface and the bottom layer isolated and stagnant. The degree or strength of the stratification can be calculated by the rate of temperature change between each meter water depth. Stronger stratification means greater stagnation of the water below but also means that there will be less diffusion of materials across the boundary.

The temperature measurements at Bashan Lake showed that the lake stratified during the summer of 2002 (**Figure 5**). Bashan Lake had a deep thermocline during most of the year. The thermocline was at 8 meters in June and July deepened to 9 meters in August and 11 meters in September. There were no temperature boundaries in the water column in April, May and October. The data shows the depth at which the greatest temperature difference occurred, the heavy center line, and the upper and lower boundaries of the metalimnion, the thinner lines. The metalimnion is defined as the layers of water in the lake were water temperatures change rapidly with depth. Above and below the metalimnion the temperature changed very little with depth. Above the metalimnion the water temperature was warm below the metalimnion the water temperature was cold.

Figure 5. Bashan Lake Thermocline Depth at Station 1, 2002.



The upper boundary of the metalimninon, marks the bottom of the epilimnion. The epilimnion is the part of the lake that is uniformly warm, has plenty of sunlight shinning into it and is freely mixing due to wind blowing on the lake surface. It is this part of the lake where most of the algae and plants grow. The sediment surface in the epilimnion supports rooted aquatic plants because of the ample supple of light that reaches there. In Bashan Lake the epilimnion reached down to 4 meters in June but gradually deepened during the summer such that by September it reached down to 10 meters.

Below the metalimnion the water is stagnant, cold, and dark. The water under the metalimnion is termed the hypolimnion. Typically all mixing related to wind action on the surface is dissipated by the thermocline so there is no turbulence or mixing in the hypolimnion. The lack of mixing through the metalimnion also cuts off oxygen distribution to deeper waters. This means that oxygen can be depleted in the hypolimnion and typically lakes show oxygen completely exhausted there. A hypolimnion existed in Bashan Lake between 9 meters and bottom in June but was compressed as the season progressed such that by September it reached from 12 meters to the bottom. The maximum water depth at Bashan Lake is between 45 and 50 feet or about 15 meters so the hypolimnion in September was only about 3 meters thick.

Oxygen

The dissolved oxygen in Bashan Lake was measured at the same time and location as was temperature. In addition to knowing where in the lake the oxygen levels are adequate there area two other important aspects of the oxygen data, 1) the depths of the lake where the concentration of oxygen exceeds 100% and, 2) where it is less than 1 mg/L. The former is super saturated while the latter is anoxic. Super saturation occurs when algae are very abundant and typically happens in the upper layer of the water during the summer or fall. Anoxic water occurs during the summer below the thermal boundary.

Data from April showed to be the only time when super saturation occurred, and only by a slight degree, while the other dates of the season showed less than 100% saturation with oxygen (**Table 5**). The fact that oxygen was almost always below 100% saturation indicating that algae did not become very productive in the water column.

Table 5. Average % Oxygen Saturation in Upper 3 Meters of Bashan Lake, 2002.

April	May	June	July	August	September	October
103	97	93	98	94	92	89

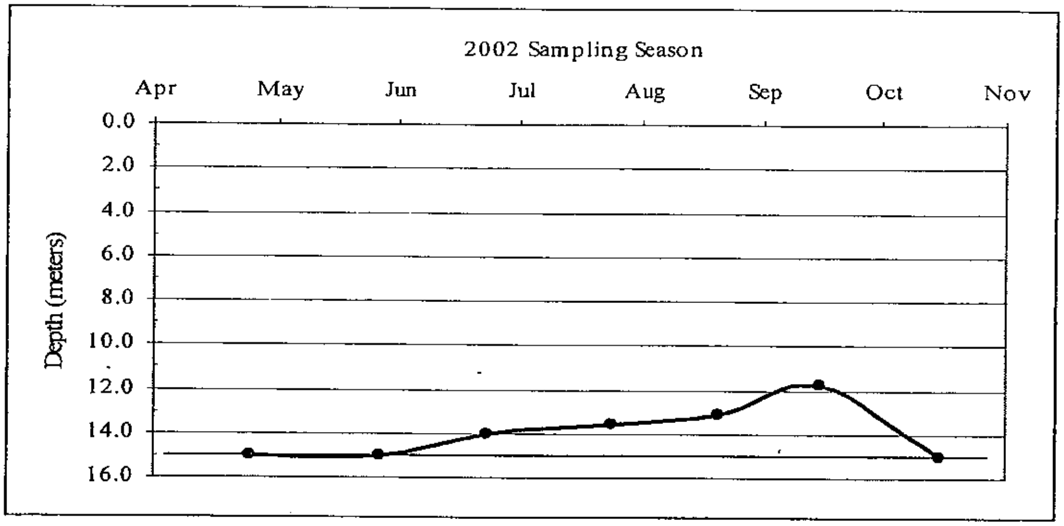
The deep water, or hypolimnion, of Bashan Lake became isolated from the atmosphere once the temperature boundaries of the metalimnion were in place. In Bashan Lake this occurred in June and persisted until September. The hypolimnion is the site were material sinks to the bottom eventually decomposes using up oxygen that is contained in the water. This consumption of oxygen proceeds until either all the dead material has been decomposed or all the oxygen is gone. Oxygen concentrations less than 1 mg/L are too low to support any oxygen breathing organisms. Water with dissolved oxygen of 1 mg/L or less is termed anoxic.

Usually what happens in lakes is that the oxygen is consumed first in the sediments of the very deepest water, then in the water just over the sediments, then in the water a little further away from the sediments and so on. The result is a zone of anoxic water that progressively expands from the bottom of the lake upward toward the surface. It never gets to the surface and in fact usually the zone of anoxia stops somewhere just below the thermocline. The zone of anoxia is demarcated by tracking the leading edge or where the water has a concentration of 1 mg/L. This leading edge is termed the anoxic boundary signifying the boundary between water with oxygen and water without oxygen.

An anoxic boundary developed between the May and June sampling dates at Station 1, and reached a maximum ascent depth of 12 meters in September (**Figure 6**). The boundary showed slow development during June, July, and August remaining below 13 meters during those months. The anoxic water did not cross the lower boundary of the metalimnion during the season, meaning that leakage of any anaerobic materials from the anoxic water into the rest of the lake did not occur.

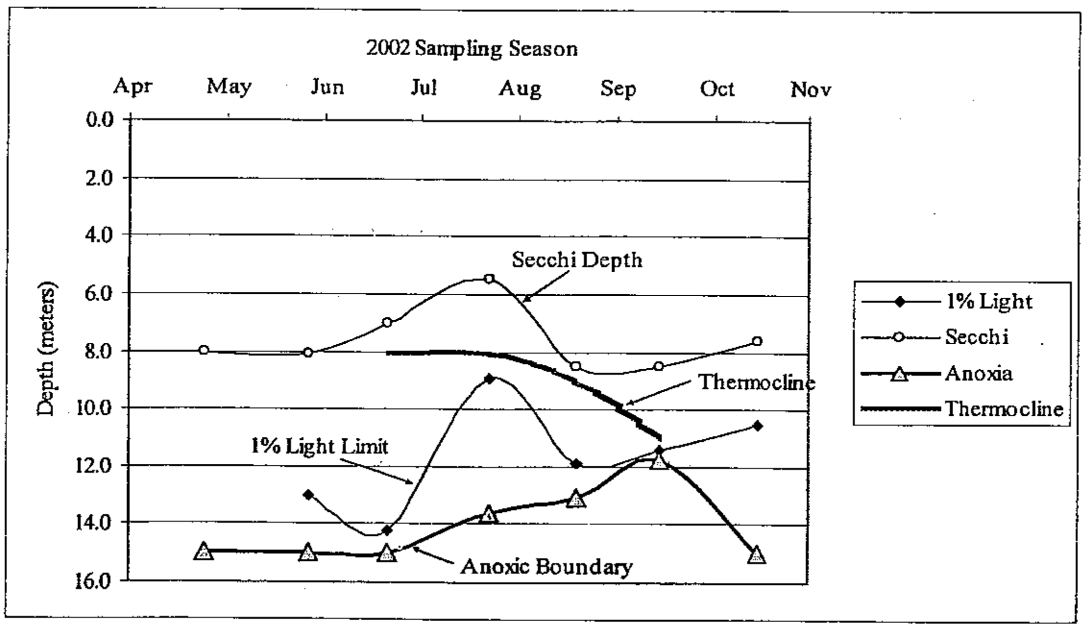
The volume of anoxic water and the area of the sediment surface affected by the oxygen loss remained very small in Bashan Lake. The total volume of anoxic water at the height of anoxia was about 20 acre-feet, with contact sediment area of about 5 acres. This is relatively small area compared to the total lake surface area.

Figure 6. Anoxic Boundary In Bashan Lake, 2002.



Now that each of the three physical boundaries has been presented separately, they can be combined on one graph to show how they may have interacted. The boundaries from 2002 are shown in **Figure** 7. The three boundaries are 1) the penetration of light as measured by the Secchi disk, and the compensation depth (1% light limit), 2) the thermocline, and 3) the depth of the anoxic boundary.

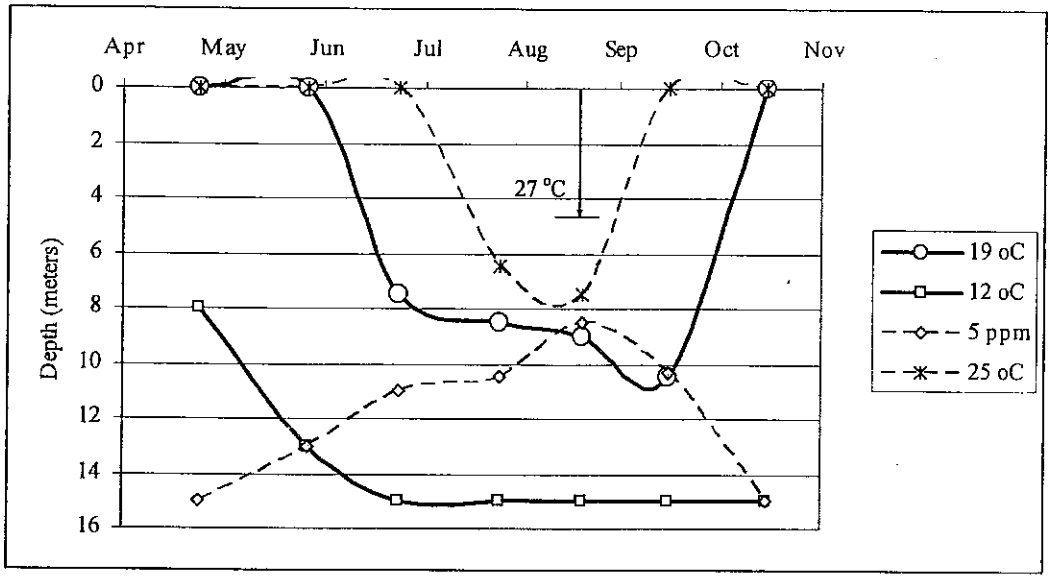
Figure 7. Physical Boundaries at Bashan Lake, 2002.



Using the thermocline as the boundary between the epilimnion and hypolimnion, it can be seen that the division depth in Bashan Lake was between 8 and 11 meters during the season, with April, May and October having no thermal boundaries. The Secchi depth appears to govern the location of the thermocline early in the season since the thermocline established at 8 meters, the same depth as April and May Secchi depth. The brief decline in the Secchi depth in July did not have any impact on the thermocline depth as the latter remained stable during the period. The location of the 1% light limit shows that just about the entire lake volume received some light during the spring months, probably responsible for maintaining good oxygen levels to the bottom. The period of Secchi decline in July caused a simultaneous decline in the 1% light limit which may have allowed the anoxic boundary to begin ascending up into the water column. During July anoxia moved up past 14 meters. Light transmission into the water column was less extensive in August, September, and October reaching depths of 12 meters in August and 10.5 meters in October. This is still quite deep, illuminating 97% of the bottom surface area. The penetration of light down to 12 meters in September probably was responsible for keeping the anoxic boundary from ascending higher into the water column at that time. This exceptional light penetration is also the reason why aquatic plants can grow to such extreme depths. During the weed surveys variable water milfoil was found growing down to water depths of 18, 19, and 20 feet, (6 meters) while the bottom carpet species mix was found to water depths of about 23 feet, 30 feet is the theoretical maximum depth for most vascular plants based on hydrostatic pressure. Musk Grass (*Nitella*), which is not a vascular plant, was found in water depths up to 33 feet.

The extremely clear water allows heat to be distributed to greater depths. Because sunlight is the heating agent, the further into the water light penetrates the deeper the water will be warmed. This has an impact on cold water fisheries. Trout, which require cool water with good oxygen levels, don't do well in Bashan because of that fact. Although the oxygen levels are good, the water becomes too warm too deep during the summer. The juxtaposition of oxygen and temperature optimums for Brown Trout are shown in **Figure 8** (using data from U.S. Fish & Wildl. Ser. 1986). The optimum temperatures for adult brown trout are between 12 and 19 °C. Trout can tolerate temperatures above 19 °C, up to 25 °C, if oxygen levels are at least 7 ppm, but cannot survive in water above 27 °C. **Figure 8** shows the location of the 12 °C, 19 °C, and 25 °C isotherms in Bashan Lake during the 2002 season. Also shown is the 5 ppm oxygen line where oxygen levels below that line were lower than 5 ppm. The two lines, 5 ppm oxygen and 19 °C are shown to cross in August and not re-cross until September meaning that nowhere in the lake was there water cooler than 19 °C that had more than 5 ppm of oxygen. In fact during August water temperatures of 25 °C existed down to 8 meters and of 27 °C down to 5 meters. These trends indicate that brown trout will have difficultly surviving during the summer in Bashan Lake.

Figure 8. Brown Trout Habitat Boundaries in Bashan Lake During 2002.



Total Phosphorus

Phosphorus was measured in total form, i.e. all the phosphorus in the sample was measured collectively. This test is referred to as total phosphorus, but for purposes of clarification all mention of phosphorus in this report will mean total phosphorus. Unless otherwise stated all phosphorus results will be presented as parts per billion (ppb). A ppb is equal to 1 thousandth of a milligram per liter (mg/L), or 1 ppb = 0.001 mg/L, 1 mg/L = 1,000 ppb.

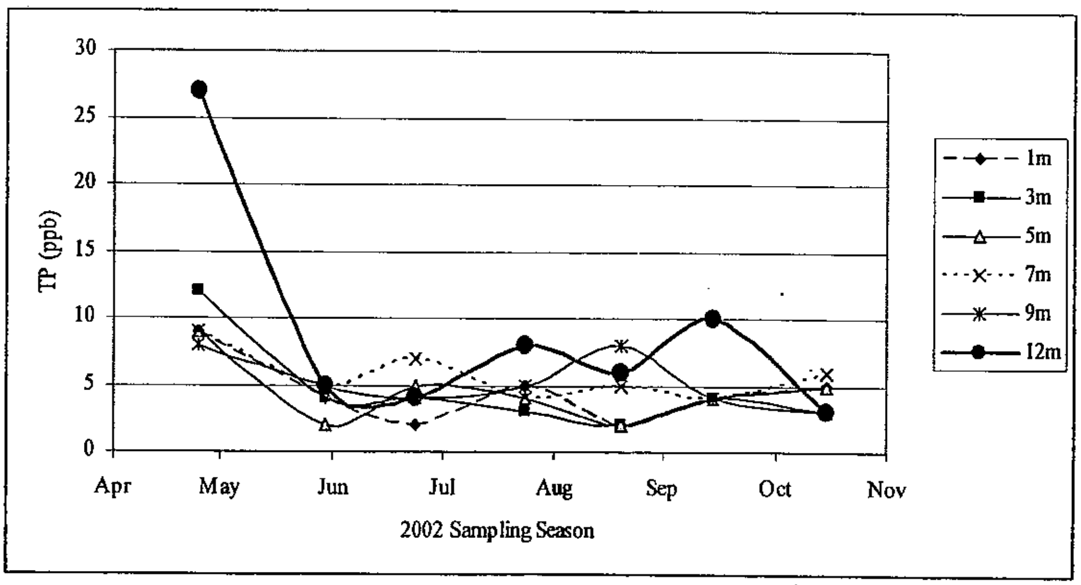
Phosphorus was measured at 1, 3, 5, 7, 9, and 12 meters at the deepest part of the lake with the results shown in **Table 6**. In general, the phosphorus concentrations in the lake were very low, with almost all values representative of oligotrophic waters (i.e. below 10 ppb, see **Appendix 3**). April was the only month that had phosphorus that exceeded the oligotrophic threshold of 10 ppb. During that month the average water column concentration of phosphorus was 12.3 ppb although the highest value was recorded from 12 meters so using the data from 1 – 9 meters the average was 9.4 ppb. In either case the April phosphorus concentration was about 3 times higher than any of the following months. During each of the remaining months, May through October, the average water column phosphorus concentration varied between 4 and 5 ppb.

Table 6. Bashan Lake Total Phosphorus Concentrations (ppb), 2002.

Depth	25-Apr	31-May	25-Jun	26-Jul	22-Aug	17-Sep	18-Oct
1	9	4	2	5	2	4	5
3	12	4	4	3	2	4	3
5	9	2	5	4	2	4	5
7	9	5	7	4	5	4	6
9	8	5	4	5	8	4	3
12	27	5	4	8	6	10	3

The trend in total phosphorus concentrations at Bashan Lake during the 2002 season are also presented graphically in **Figure 9**. The data in **Figure 9** shows the concentration trends for each of the 6 sampling depths. The graph shows the higher concentrations in April, especially the 12 meter sample. The remaining months show stable concentration levels that remained below 5 ppb for the 1 – 5 meter depths and below 10 ppb for the 7 – 12 meter depths.

Figure 9. Trends of Total Phosphorus in Bashan Lake, 2002.

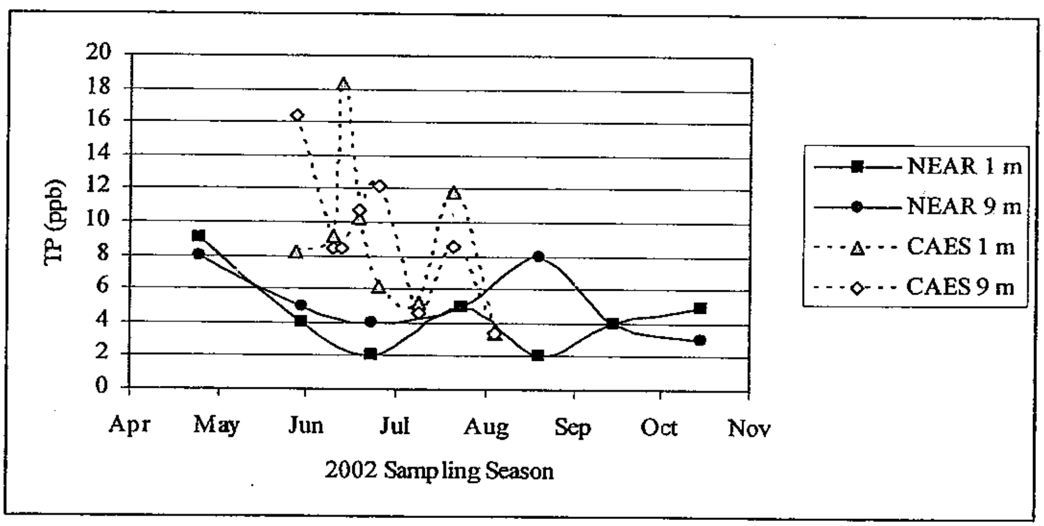


The lake showed no sign of internal phosphorus loading from deep water sediments during the 2002 season. When lakes lose oxygen at the bottom, phosphorus can become mobile and migrate out of the sediments in the deepest water first but at other anoxic depths later in the season. However, the data here indicate that phosphorus did increase at 12 meters depth from 5 ppb to about 10 ppb in September, not enough of an increase to call internal loading.

The CAES also collected total phosphorus samples from Bashan Lake during the 2002 season. The two sets of data are shown in **Figure 10**. CAES collected data from the surface and 9 meters at the central deep water station. Their data spans the period from May 29, 2002 to August 9, 2002. The CAES data was generally higher than the NEAR data by about 10 ppb. The surface water phosphorus concentrations reported by CAES varied between 3 ppb and 18 ppb, while the samples from the 9 meter depth varied between 3 ppb and 16 ppb. There was a trend in decreasing phosphorus concentration in the CAES data with higher concentrations early in the season and minimums in August.

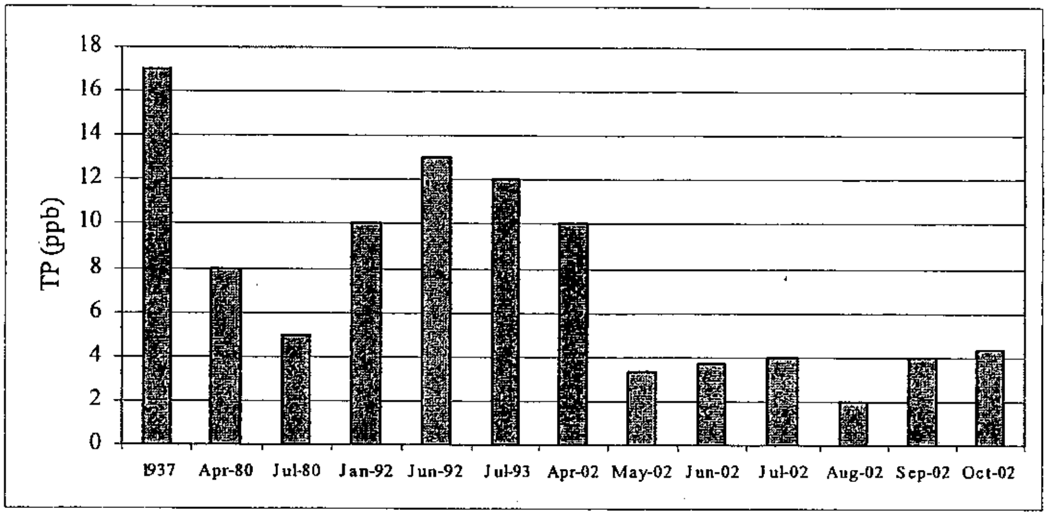
The two sets of data were different with CAES data being higher by as much as 12 ppb. Although the CAES data was higher than the NEAR data there were still only two CAES total phosphorus surface values that exceeded the 10 ppb threshold for oligotrophic lakes with all other values coming in lower than that. The differences between the two sets of data could have been due to differences in laboratory procedures.

Figure 10. Comparison of NEAR and CAES Phosphorus Concentration Results From Bashan Lake 2002.



The historical record for phosphorus at Bashan Lake contains mostly data from the surface water and a one value of 15 ppb taken from 9 meters in July of 1980. The average phosphorus value from each of the years that upper water data was available is given in **Figure 11**. The results show that surface phosphorus concentrations observed in 2002 were the lowest on record. Prior years had average surface water values between 10 and 20 ppb. The first value in the chart is from 1937 and appears high. The values observed between 1992 and 1993 showed the lake to have average concentrations above 10 ppb. The higher phosphorus levels reported from the lake in the early 1990's may have been responsible for the lower Secchi disk depths recorded at that time.

Figure 11. Average Surface Water Total Phosphorus Concentrations at Bashan Lake.

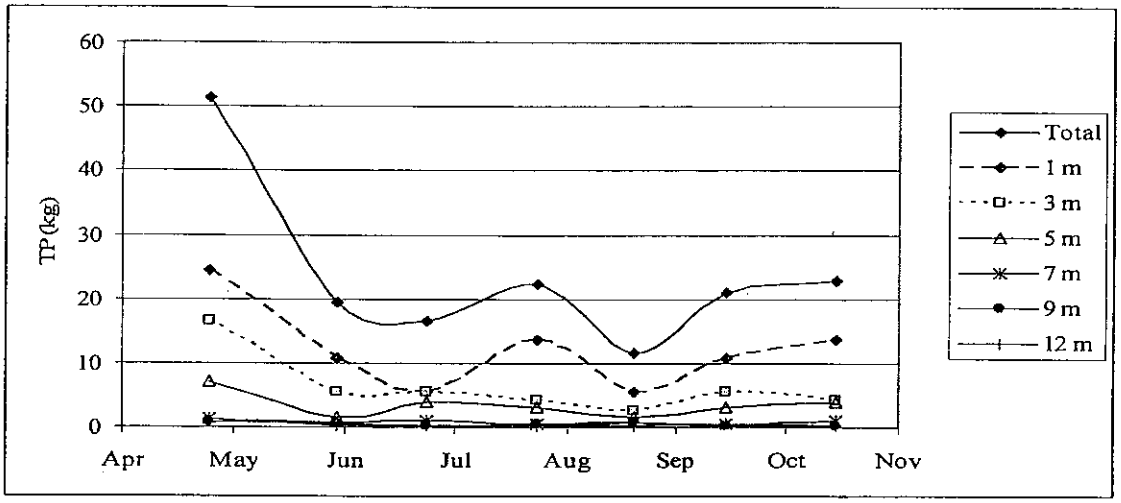


The total mass of phosphorus in the lake was determined by multiplying the concentration times the volume of each layer of water represented by the water sample depth. For example, since water was collected from 1, 3, 5, 7, 9, and 12 meters the volume of water between the surface and 2 meters was apportioned to the 1 meter sample. The water between 2 and 4 meters was apportioned to the 3 meter sample and so on.

The change in phosphorus mass between the sampling dates (intervals) at each of the sampling depths is shown for each station separately in **Figure 12.** The graph shows that the smallest mass of phosphorus occurred in water 7 meters and deeper. This was due to the very small volume of deep water. The largest mass of phosphorus was contained in the upper two layers, 1, and 3 meters, because that is where most of the water in the lake is contained. The lake first lost phosphorus at both the 1 and 3 meter depths but then gained phosphorus in July at 1 meter while the 3 meter depth did not show any increase in mass. The total mass in the lake was initially about 50 Kg but decreased to below 20 Kg by May. The phosphorus content remained at that level for the remainder of the season.

The pulse of phosphorus at 1 meter in July resulted in an increase of about 10 Kg of phosphorus in the top couple of meters of the lake. It was at this time that the Secchi disk depth decreased to its lowest level for the season of 5 to 5.5 meters. At that time there was no water flowing into the lake from any of the monitored streams. However, the increase appears to have occurred at the surface only with the 3 meter depth showing very little change in mass. Mass of phosphorus increased again at 1 meter in September and October while the deeper waters again showed very little change.

Figure 12. Total Phosphorus Mass in Bashan Lake, 2002.



Total Nitrogen

The nitrogen in lake water occurs in two basic forms, inorganic and organic. The inorganic form is commonly represented by nitrate, ammonia and to lesser extent by nitrite. The organic form consists of organic nitrogen. All three forms were tested for in Bashan Lake.

Nitrate

Nitrate was below the detection limit of 20 ppb in all the samples collected from the top 5 sampling depths. Nitrate was present in only the May, June and July samples from 12 meters. The maximum concentration of nitrate was 79 ppb with an average of 51 ppb. The presence of nitrate at the bottom was probably due to the low oxygen concentration at that depth. Once fully anoxic conditions existed at 12 meters the nitrate disappeared.

Ammonia

Ammonia is a by-product of the decomposition process and is also liberated from sediments during anoxic conditions. The lake had ammonia concentrations between < 20 and 40 ppb throughout most of the season. Ammonia accumulated at the 9 and 12 meter depths during the summer but began to disperse in September. The maximum concentration was 190 ppb in August occurring at 12 meters.

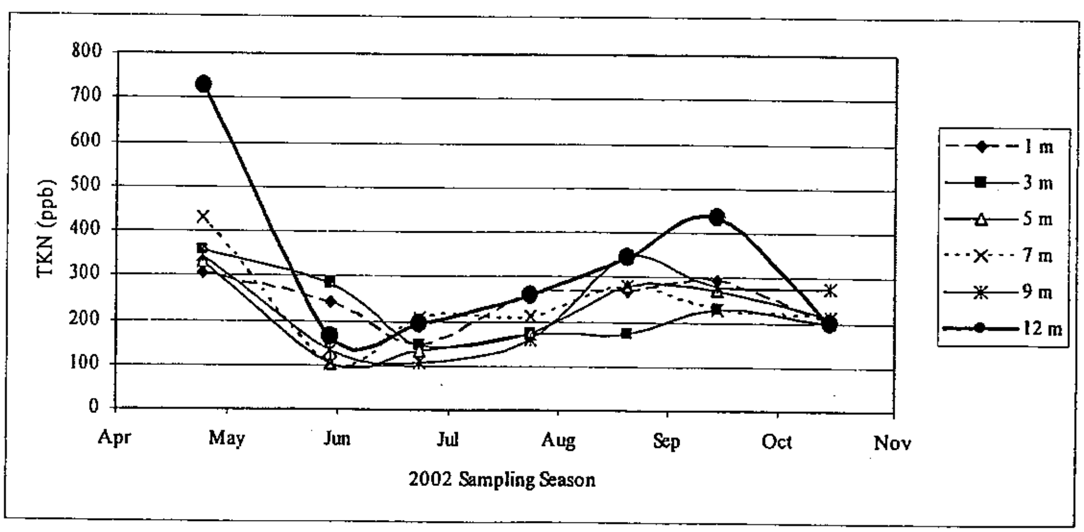
Total Organic Nitrogen

The organic nitrogen in lake water is mostly in the form of mineralized remains of plant and animal material. Organic nitrogen is obtained using a test called the Kjeldahl Nitrogen Procedure, which tests for ammonia and organic nitrogen together. The total Kjeldahl nitrogen result represents the total amount of nitrogen that can consume oxygen (other than nitrite which generally occurs at very low concentrations in lakes). Together, Kjeldahl and nitrate (and nitrite) represent the total nitrogen in the water. Total nitrogen is another of the parameters used to identify the trophic level in a lake.

There is always a background of organic nitrogen in aquatic systems so that the levels of total nitrogen in oligotrophic lakes range from 0 to 200 ppb, see the table in **Appendix 3**. The organic nitrogen concentration of lake can fluctuate widely from year to year such that oligotophic lakes can have peaks of 300+ during either spring or summer months. In general however, as the overall organic nitrogen level in a lake goes up the degree of water quality impairment goes up.

The total Kjeldahl nitrogen is useful because it represents potential oxygen consumption both in the water and at the sediment surface **Figure 13**. The graph shows data from Station 1. The concentration of TKN was high in April, between 300 and 750 ppb with the highest levels occurring at the bottom (12 meters). Levels decreased during May and June to reach a seasonal low level of between 100 and 200 ppb. At that time all depths had similar TKN concentrations indicating that lake wide mixing was probably occurring.

Figure 13. Total Kjeldahl Nitrogen Concentrations in Bashan Lake, 2002.



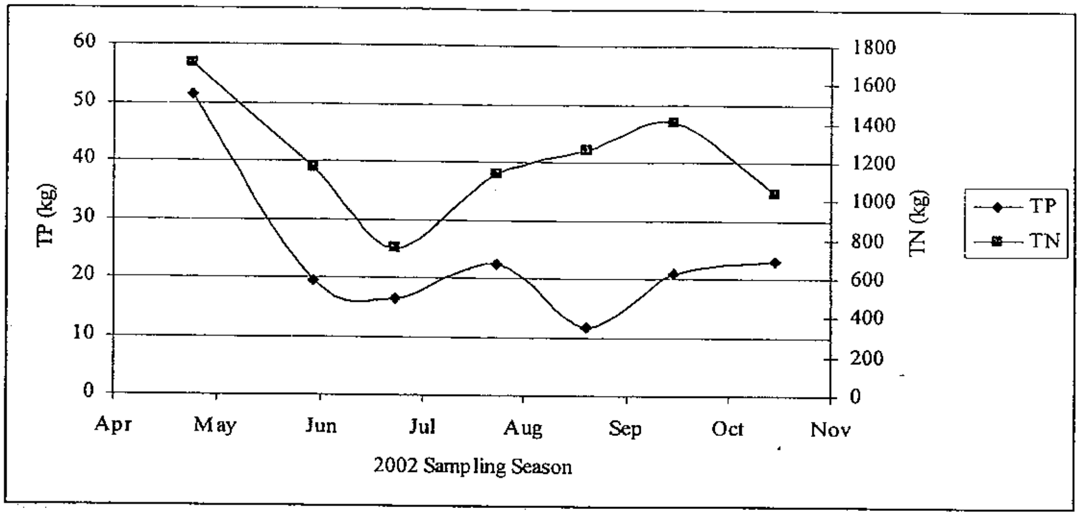
Between June and September the concentration of organic nitrogen slowly increased at all depths although the deepest water depth increased at the highest rate. September marked another period of peak organic nitrogen concentrations with about 420 ppb at 12 meters and between 200 and 300 ppb at the other depths. Deep water organic nitrogen decreased at 12 meters in October when once again all depths had similar concentrations of around 200 ppb.

The organic nitrogen levels observed in Bashan Lake represent the total quantity of nitrogen in the lake water and are another way to infer trophic status of the lake. The only time that nitrate was present, the other component of total nitrogen other then the TKN value, was at 12 meters during a few months in the spring. The average total nitrogen concentration in the lake was 247 ppb during the 2002 season. The average water column concentration in April was 330 ppb while the average water column concentration for the remaining months was 220 ppb. The table in **Appendix 3** gives lakes with a total nitrogen concentration range of between 200 and 300 ppb a Oligo-mesotrophic classification. Bashan Lake had total nitrogen concentrations that were mostly within this category, although sometimes just barely over the threshold of 200 ppb.

The trends of total mass of phosphorus and nitrogen in Bashan Lake during the 2002 season are shown in **Figure 14.** The graph shows the content of phosphorus and total nitrogen in the lake at the time of each sampling event. Both phosphorus and nitrogen showed peak mass in April, followed by decreases between May and June. The mass of phosphorus decreased from 50 Kg to about 18 Kg and appeared to remain at that level for the remainder of the season. The lake contained about 51 Kg of phosphorus in April but had only about 22 Kg in October. Typically lakes have lowest levels of phosphorus during the winter, with similar values observed in April and October, providing a baseline condition. It is surprising that Bashan Lake had such a large disparity between the two months and it suggests that either the April data is spurious or something is happing in the drainage basin or in the lake during the early spring months. Nitrogen decreased from almost 1,700 Kg in April to 800 Kg in June but then slowly increased over the next several months to reach another peak of 1,400 Kg in September. The lake contained about 1,700 Kg of nitrogen in April and 1,000 Kg in October again a large difference between the beginning and end of the season.

The difference between the mass of phosphorus and nitrogen in the lake in spring and fall suggests that some watershed loading is occurring during the winter or early spring months, but that summer and fall loading is minimal.

Figure 14. Whole Lake Mass of Phosphorus and Nitrogen in Bashan Lake, 2002.



Conductivity, Turbidity.

The specific conductance of water is the capacity to carry an electrical current and is directly proportional to the amount of salts dissolved in the water. There are a number of ions that are commonly found in lake water, road salts used for winter deicing are examples. Typically, the salts are found in very low quantities hence our waters in the state are considered soft.

Conductance

The conductivity of the Bashan Lake waters had a range from 70 to 77 µmhos/cm during the 2002 sampling season. The lowest values were from the early months of April and May, highest values were recorded during July and August. The conductivity measured by CAES during the 2002 season ranged from 47 to 67 µmhos/cm, with the conductivity increasing during the season. The lowest values were recorded in May and highest values were recorded in late July and August.

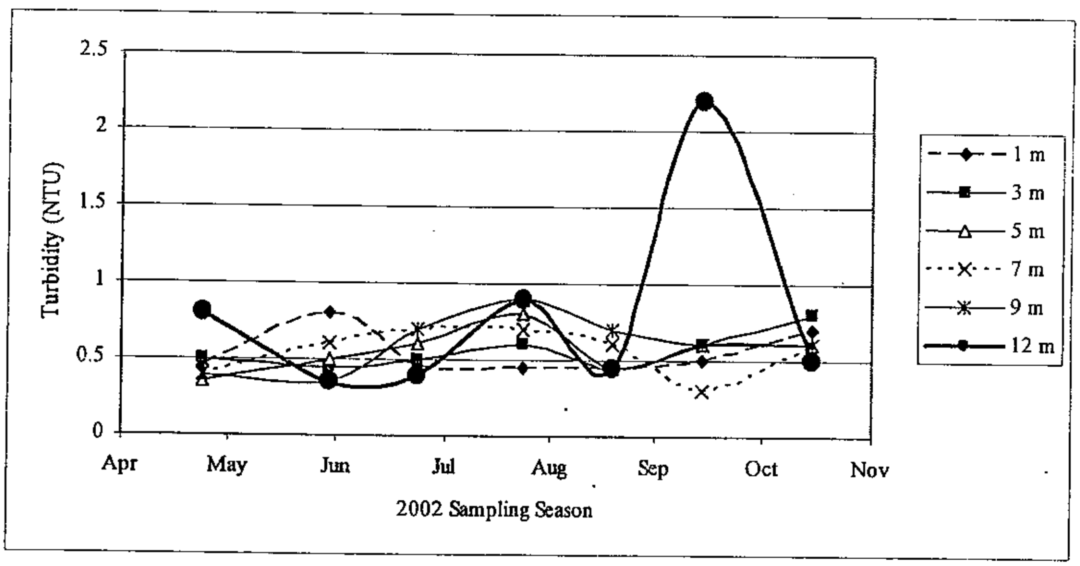
Conductivity data from prior lake surveys (1980 – 1993, see Canavan and Siver 1995) showed the lake to have between 37 and 44 µS/cm or about half the value observed during this survey. These two units µmhos/cm and µS/cm are identical only different names for the same thing. These data show that conductivity of Bashan Lake water has increased from 40 µmhos/cm (1980 to 1993) and 74 µmhos/cm seen during this study. The Bashan Lake data collected by CAES during 2002 was lower then the NEAR data but still higher than any of the values reported between the period from 1980 to 1993. This suggests that conductivity of Bashan Lake water has increased within the last 10 years.

Turbidity

The turbidity of the water is a measure of how cloudy the water is. The measurement is taken by passing a beam of light through the sample with a sensor the measures how much of the light gets through. The cloudiness of the water is measured against known standards of arbitrary levels Nephalmetric Turbidity Units (NTU).

The turbidity of Bashan Lake water during the 2002 season was generally very low **Figure 15**. All samples except one were below 1 NTU. The one exception was from 12 meters in September, when the turbidity reached a maximum level of just over 2 NTU. The increase in turbidity was due to changes in bottom water due to anoxic water and was probably associated with the increase in total iron concentration at that time.

Figure 15. Turbidity in Bashan Lake, 2002.



Alkalinity, and pH.

The alkalinity of the water is a measure of the acid buffering capacity or its neutralizing ability. The higher the alkalinity the more acid can be neutralized with any change in pH. The pH of the water is the log of the hydrogen ion concentration. The hydrogen ions are responsible for a liquid having an acidity characteristic such a citrus juice or vinegar.

The alkalinity of Bashan Lake varied between a low of 2 mg $CaCO_3$/L and a high of 6 mg $CaCO_3$/L. There did not appear to be any depth related increase in the lake. These are low alkalinities and suggest that the lake has low calcium inputs from the drainage basin.

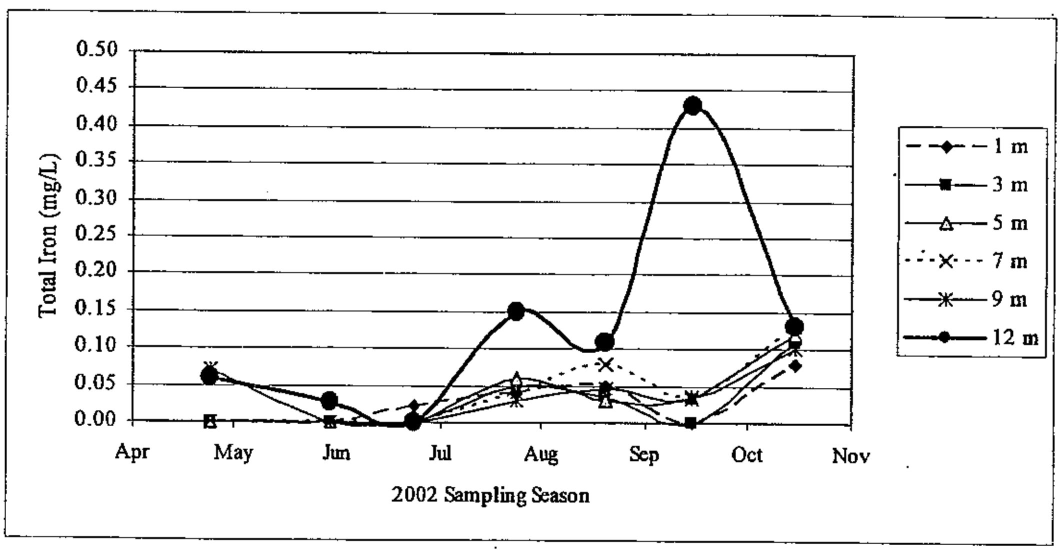
The pH of Bashan Lake water varied between 6.1 and 6.8 pH units.

Iron

Iron is a very common element in the landscape and soils of Connecticut. Iron can accumulate in the sediments of lakes, were it remains unless released by a change in the concentration of oxygen. In the presence of oxygen iron will rust to form oxides that are not soluble in water. Normal lake water has very little iron in solution but this can change when the water over the sediments loses oxygen. Typically lakes show an increase in the concentration of iron in water at the bottom as oxygen is exhausted and iron is no longer oxidized.

The total iron concentrations observed in Bashan Lake in 2002 are shown in **Figure 16.** The iron concentration in the lake was very low during the season ranging between 0.0 and 0.1 mg/L for all depths except the bottom. The bottom water iron concentration increased to a maximum of 0.43 mg/L in September, the same time that anoxic levels reached the peak ascent depth.

Figure 16. Total Iron Concentration From Station 1, Bashan Lake 2002.



Redox Potential

The redox potential is a measure of how reducing the anoxic water has become. Typically in well oxygenated water the potential, measured in units of millivolts, is positive and high, above 100 mV and usually between 200 and 500 mV. Once the oxygen is depleted in the deep water of a lake bacterial decomposition of organic matter continues by becoming anaerobic. The process of anaerobic decomposition releases electrons into the water which accumulate causing the redox potential to decrease. It typically decreases in stages that correspond to the different electron acceptors that are used by the bacteria. It is not unusual to find negative potentials in anoxic water and in some cases the potential can decrease to the theoretical limit of -350 mV. Measuring the redox potential is a good indicator of when the anoxic water has progressed to the point of liberating phosphorus from the mud so can be an index of internal loading. In Bashan Lake the redox potential never dropped below 100 mV, even in the anoxic bottom water.

Algae and Zooplankton Results

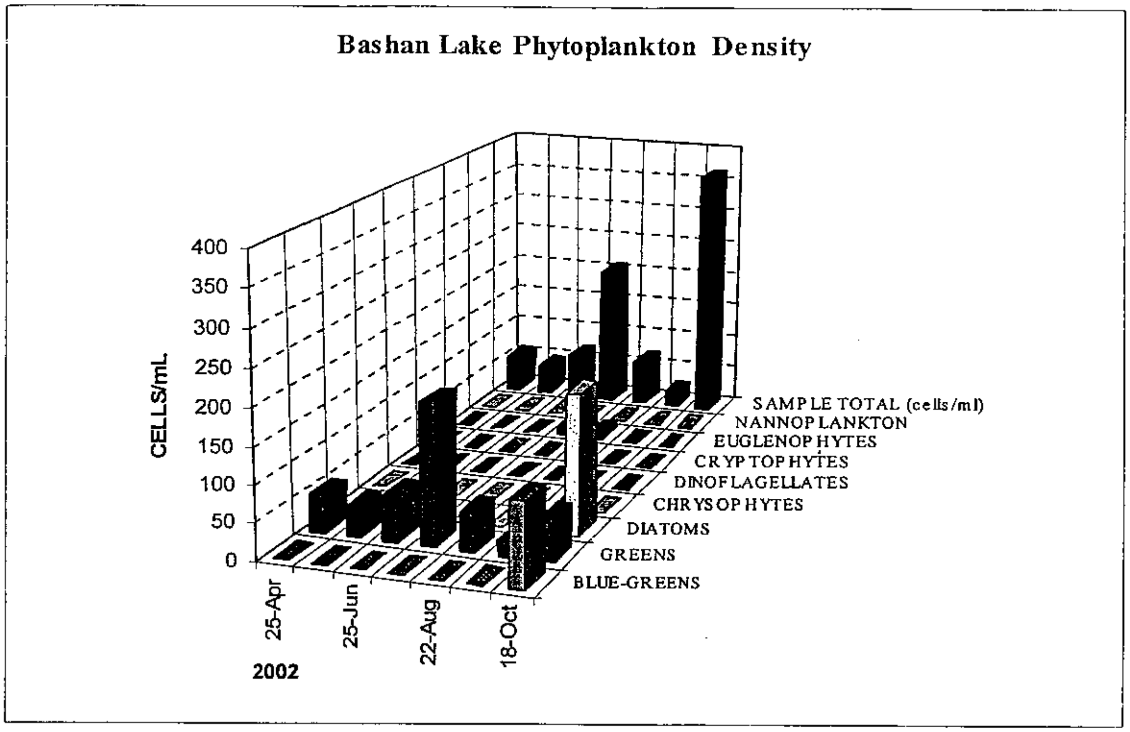
The algae that were sampled in Bashan Lake were the microscopic free-floating types. Algae in Connecticut fresh water lakes are of three types, phytoplankton, which are usually tiny single cell plants that float in the water, filamentous algae which form billowy cotton candy like green clouds in shallow water, and the last type resembles a rooted aquatic plant. The data reported here are the phytoplankton from the open water area of the lake. The other two types of algae are reported in aquatic plant survey section.

The zooplankton are free swimming crustaceans that range in size between 0.4 and 3.0 mm (3 mm is slightly more than a ¼ of an inch). They graze on populations of algae and other small organisms in the lake. They, in turn, are prey items for juvenile and adult fish species.

Phytoplankton

There was very few phytoplankton in the samples collected during 2002. Only green algae were observed in the samples except in October when a few diatoms and bluegreens were also observed. The cell count densities are shown in **Figure 17**. The maximum cell count was 350 cells per mL in October, these numbers are very low and indicate that very low numbers of phytoplankton existed in Bashan Lake during the 2002 season. There was only a slight indication from the cell counts as to why the Secchi disk decreased in July to 5.5 meters, suggesting that transparency was decreased due to either non-algae turbidities, or algae number increases deeper in the water column. The algae sample was collected from the water column between 0 and 5 meters.

Figure 17. Phytoplankton Count Densities for Bashan Lake, 2002.



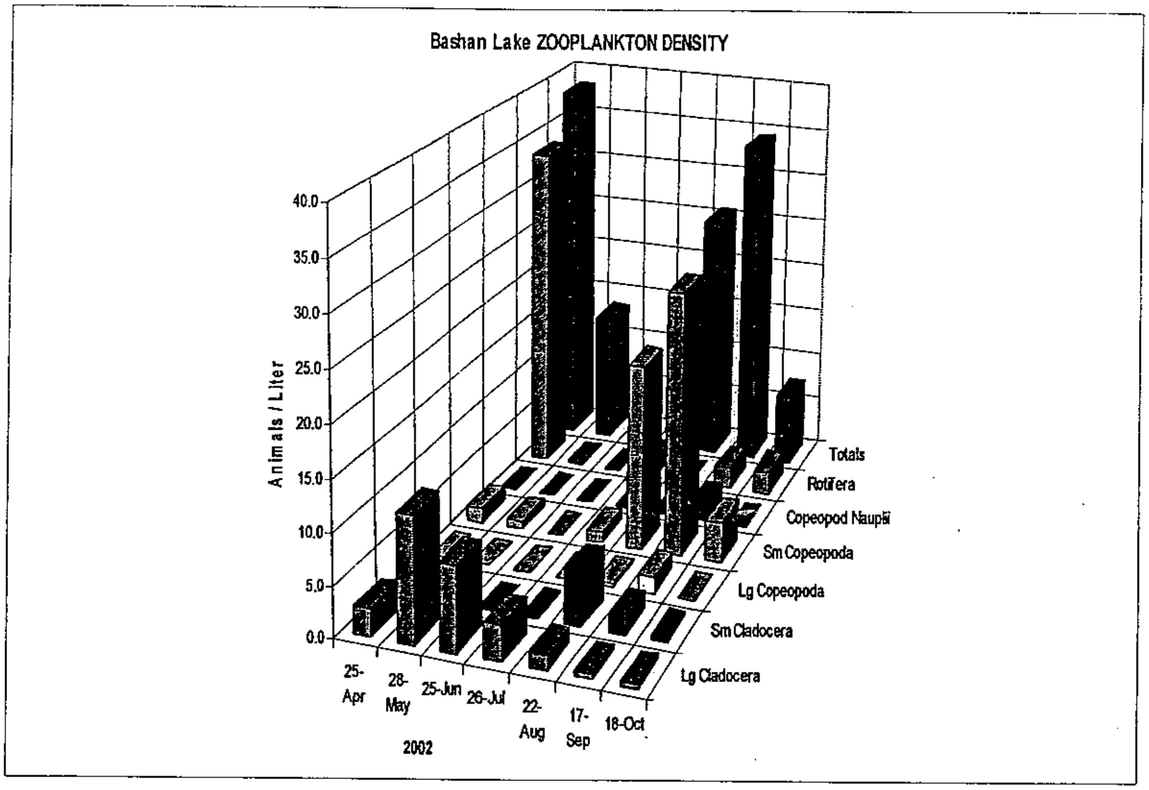
Zooplankton

The zooplankton in Bashan Lake were sampled using a vertically towed plankton net with a mesh size of 153 microns. A micron is 1000th of a mm or there are 1000 microns in a mm. The zooplankton in a fresh water lake typically range in size between 0.2 and 3.0 mm or between 200 and 3,000 microns so the net size is small enough the catch most small organisms. The net is lowered to the bottom than brought back to the surface so vertical tow is collected one meter less than the total water depth. Organisms that are collected are preserved for counting later.

Zooplantkon consist of mostly two groups of animals the rotifers and the micro-crustaceans. The rotifers are small (usually between 0.2 and 0.4 mm) simple animals that feed by filter feeding in the water column. Micro-crustaceans consist of cladocerians and copepods. The copepods are represented by three separate groups, the calanoids, the cyclopoids, and the harpacticoids. The cladocerians are considered the most important group of zooplanktors because they are very efficient grazers of algae in the water column. The larger sized cladocera can filter a milliliter or more of water every hour. Copepods can be either carnivorous or filter feeders.

The dominant zooplankton community in Bashan Lake fluctuated during the season. Large cladocera (larger than 0.8 mm) were the principle organisms in the spring and early summer, while in August and September small sized copepods (0.4 to 1.0 mm) were dominant The data shown in **Figure 18** gives the animals per liter for each of the sample dates. Large cladoceria, the first set of bars were present in the samples in April, May, June and July with high numbers observed in May and June. There was a population increase of small copepods in August and September with peak densities reaching about 25 organisms per mL. The copepods appeared to increase in numbers after the population of cladoceria decreased. Rotifers were plentiful in April. Overall the zooplankton community in Bashan Lake appeared very healthy.

Figure 18. Zooplankton Density (Animals/L) in Bashan Lake, 2002.



Summary of CT DEP Fisheries Electroshocking Surveys

The Connecticut Department of Environmental Protection has conducted electroshocking surveys of Bashan Lake 8 times within the last 15 years, 1988, 1990, 1992, 1997, 1998, 1999, 2000, and 2001. With the exception of the 1988 survey which was done in October, all surveys were conducted in the spring months of April or May. The species that were observed during each of the 8 surveys is given in **Table** 7. Between 11 and 14 species were recorded with a mean number species count of 12 per trip. Two species were seen only once, white catfish, and American eel.

Table 7 also shows the catch per unit effort or the number of fish caught per hour for each species on each of the trips. There were several game fish that appeared in consistently high numbers, largemouth bass, smallmouth bass, and chain pickerel and yellow perch. Both rainbow and brown trout black crappie were found in low numbers. The numbers of bass and trout indicate that Bashan Lake has a good two tiered fishery with bass in the warm shallow water and trout in cooler deep water. The lake is stocked annually with 4,000 catchable brown and rainbow trout with the trout holdover considered to be rare because of limited deep water habitat. The oxygen and temperature thresholds for brown trout in Bashan Lake were given earlier in the text see **Figure 9** (page 24).

Table 7. Fish Species Observed and Catch per Unit Effort (Fish/hr) During CT DEP Electroshocking Surveys.

Species	1988	1990	1992	1997	1998	1999	2000	2001
Largemouth	17	72	46	31	77	35	139	26
Smallmouth	19	15	50	50	55	54	68	45
Brown trout		3	9	3	6	3	1	5
Rainbow trout	51	10	15	12	4	9	3	3
Chain Pickerel	13	21	7	11	22	16	21	5
Black Crappie	3	3				1	2	
Yellow Perch	144	279	283	105	188	158	348	105
Brown bullhead		4	2		6	5	5	2
White Catfish					1			
Bluegill	135	133	120	216	405	373	510	333
Pumpkinseed	8	7	10	5	63	50	56	18
Redbreast	14	0.95	13	73	72	35	62	50
Golden shiner	0.6	0.7	1			4	2	
Bridled Shiner	6			1		2	1	
Banded Killifish	4	1.5	2	9	19	8	3	3
American Eel								1

Aquatic Plant Distribution

The aquatic plants in Bashan Lake were surveyed to determine the different species that were present, which ones were dominant, their approximate distribution throughout the lake with including estimated abundance. Surveys to visually record aquatic plant species presence were made on June 25, July 26, August 22, September 10, September 17, and October 18, 2002.

The plants found during the survey and those observed by the CT DEP Environmental & Geographic Information Center are listed in **Table 8.** A total of 25 species of aquatic plants have been recorded from Bashan Lake.

Table 8. Aquatic Plant Species List.

Scientific Name Common Name	Abundance	Status
Brasenia schreberi Watershield	Rare	Floating leaved plant similar to water lily, found in northern cove.
Eleocharis acicularis Spikerush	Rare	Tiny plant growing in very shallow water not a problem.
Eleocharis robbinsis *Spikerush*	Common	Rush that grows in shallow water, produces a shoot that protrudes out of the water. Can be several inches high.
Elodea Canadensis Waterweed	Uncommon	Innocuous plant that was a minor part of the community.
Eriocaulon septangulare Pipewort	Rare	A slender plant that sends a stalk out of the water topped with a small white button. Can grow in sheltered water up to 4 or 5 feet deep.
Gratiola aurea Golden-pert	Rare	Tiny shoreline plant in protected cove areas.
Heteranthera dubia	Rare	Localized and innocuous not a problem.
Myriophyllum heterophyllum Variable Milfoil	Abundant	Non native invasive, found in most areas some very dense. **This plant is represents a serious threat.**
Myriophyllum humile Low Milfoil	Rare	Observed by DEP in 1998, not observed during this study.
Najas flexilis Water naiad	Common	Abundant bottom carpet plant.
Nitella Muskgrass	Very Common	Mostly in greater then 10 feet deep not a problem. This was one of plants that literally carpet the bottom of the lake.
Nymphaea odorata White Waterlily	Common	White water lily. Shallow water with a maximum depth of about 5 feet. Mostly found in sheltered coves and area with rich organic muds.
Potamogeton bicupulatus Pondweed	Rare	A few areas around the lake in shallow water.
P. epihydrus Pondweed	Common	Localized and innocuous.
P.pusillus ssp. gemmiparus * Pondweed	Common	Found in only one location, small cove at north end of the lake
Pontederia cordata Pickerel Weed	Common	A shore line plant.
Sagittaria cristata Water Arrowhead	Common	A small bottom plant of sandy shallow water.
Sparganium sp. Burr Reed	Uncommon	Another shoreline plant.

Callitriche sp. *Starwort*	Rare	Localized and innocuous.
Utricularia gemiscapa *Bladderwort*	Very Common	Bladderwort is very dense along the bottom, one of the bottom carpet plants.
Utricularia gibba *Bladderwort*	Very Common	Another bladderwort found mostly on the bottom.
Utricularia purpurea Bladderwort	Very Common	Bladderwort is very dense along the bottom, one of the bottom carpet plants.
Utricularia radiata Bladderwort	Common	Shallow water in coves.
Utricularia vulgaris *Bladderwort*	Very Common	Bladderwort is very dense along the bottom, one of the bottom carpet plants.
Vallisneria americana Tapegrass	Common	This plant can send small spaghetti like strands to the surface which can become a nuisance, however it does not form dense beds so it is probably not be a problem.

Underlined plants are non natives
* = indicates a state listed plant of concern

The lake had large a coverage of variable leaved milfoil (*Myriophyllum heterophyllum*) as shown in **Map 3** (pg 71). The plant was very dense along the east side of the lake between the southern island and the mainland and into Sunset Cove. There were also dense stands in the outlet channel and around the base of the two islands that flank the outlet channel. The plant was found growing in water depths up to 20 feet with many very dense stands of the plant in 15 to 18 feet of water. The plants observed at those depths were large clumps and dense mono-colonies consisting of plants with shoots up 10 feet tall. Large isolated clumps of plants were also noted in most all other areas of the lake

The milfoil has been spot treated with granular 2, 4-D (Navigate) in 2000, 2001 and 2002. In 1999 another formulation of 2.4-D called Aquacide was used with only marginal success. Several areas where treatments have been made were clear of the plant, especially the northwestern cove, the boat launch cove and in shallow water in Sunset Cove. However there appears to be significant areas of plant dominance in the lake. Between Sunset Cove and the southern island there was about 19 acres of dense milfoil, with another 2 acres of dense coverage in the outlet channel and around the two islands. Between these two areas approximately 21 acres of the lake surface area have dense milfoil. Milfoil clumps could be found in most areas around the lake. These clumps typically were individual plants that generally occurred isolated from other plants. The large area of the lake north of the deep hole that is between 15 and 21 feet was not completely surveyed for milfoil clumps, although some were found this area appeared mostly free of milfoil. However, it is within the depth limit of the plant which appears to grow to depths of 20 feet, so is an area where milfoil could colonize. If the plant is moving northward from the boat ramp this area might be next. It has filled in the area west of the island south island and Sunset Cove. The east shore around the island group had a dense coverage of the plant that was removed by 2,4-D treatments in 2002. It appears that milfoil is dominating areas of the lake down to a depth of 20 feet. Currently dense beds have reported from Sunset Cove, around the south island, the east side in and around the islands, the outlet channel, the two north coves, and along the west side. Only sporadic isolated plants were found in the large north basin. That area of the lake had a dense coverage of bladderwort and water naiad.

The treatment program has had significant affect on reducing the prevalence of the plant in the lake. At no time during the plant surveys conducted as part of the study was variable leaved milfoil found breaking the surface with aerial shoots. This had been a common occurrence for the plant in the past prior to treatments (personal communication with Greg Bugbee). Although the treatments don't appear to be reducing the coverage, as new plant appear in areas that had been treated in prior years, the treatments are keeping the plant from completely over-running the lake. It is likely that without treatments the plant would infest each of the coves with shoots that would break the surface, and cover the bottom with dense stands of large plants.

The lake had a relatively low diversity plant community. A very large area of the bottom of the lake, about 97 acres, was completely covered by a mix of three plants, bladderwort, water naiad, and muskgrass (**Map 4**). Even in areas with milfoil these plants, mostly bladderwort, were present. Typically the coverage started at about 10 feet deep and extended out to about 22 – 24 feet. Although in some of the sheltered coves the bladderwort extended into the coves to about 6 feet deep. Within this community called the Bottom Carpet Mix very few other species were found.

The locations of the aquatic rush *Eleocharis robbinsii*.have also been mapped and are shown in **Map 5**. This slender plant grew in water a couple of feet deep and sends a shoot above the water surface. Under water the plant produces a mass of grassy strands about a foot long. There were several beds of the plant located around the lake.

A majority of the species noted in the lake were found in the four sheltered coves, two at the north end, one on the west side and the boat launch cove. The two northern coves, the larger contained a few of the very small shallow water species, golden pert, and *Eleocharis acicularis* along the extreme northern edge. The second of the northern coves, directly east of the larger cove just mentioned, had several species within the sheltered sand bar. The two floating leaved plants, water shield, and white water lily, the three pondweeds including *Potamotegon pusillus*, spp. *gemmiparus* and starwort were found within the sheltered part of the cove (see **Map 5**). Immediately outside of the sand bar but within the cove area were small beds of pipewort and tape grass.

Summary of Lake Data

The lake had exceptional water clarity, generally between 7 and 8 meter transparency as measured by the Secchi disk. Only briefly in July did the water clarity decrease to 5 meters. The phosphorus concentrations in the lake were higher in April, but then decreased to very low levels for the remainder of the season. The April values may be a reason for concern because phosphorus is typically lowest in the spring increasing usually later in the summer months. However, the water clarity and the phosphorus levels were both indicative of an oligotrophic lake. The nitrogen levels were between 200 and 300 ppb during the season with some slightly higher readings at the bottom and in April. Overall the nitrogen levels were indicative of meso-oligotrophic lakes.

The lake lost oxygen at the very bottom with an anoxic boundary that remained below 12 meters during June, July, and August. In September the anoxic boundary ascended to just over the 12 meter depth, (11.8 meters). There was no indication of internal phosphorus release from anoxic sediments. There were some changes in 12 meter water quality associated with the anoxia, as ammonia, iron and turbidity increased to modest levels in September. The redox potential did not drop below zero.

There was aquatic plant coverage of almost the entire bottom to water depths of about 33 feet. Most of the bottom had coverage of a combination of plants with bladderwort being dominant. There was also about 22 acres of dense milfoil coverage but many individual plants were noted around most of the lake area.

The lake has a good bass fishery with both largemouth and smallmouth bass plentiful. Trout are stocked in the lake but the combination of oxygen loss and extent of warm water limits the holdover success of trout.

Algae were found at very low cell numbers, while zooplankton appeared to be at strong population levels.

Overall the lake appears stable and of high water quality. The spring phosphorus levels are of some concern as they appeared to be out of line with readings taken during the rest of the season. The aquatic invasive plant milfoil has appeared to have infested large areas of the lake with the potential to spread to all areas shallower than 20 feet.

Drainage Basin Sampling Results

Sampling Stations

There were 6 stream sites identified for monthly monitoring around the lake, the locations of the sampling stations are shown in **Map 2.** The number of stream samples collected each month is shown in **Table 9**. Locating and accessing the streams was hampered by posted private property during April when only one stream was sampled. In May, 5 inlet streams and the outlet were sampled. Also sampled in May, was a small seep located on Sunset Lane. Each of the 5 inlets and the outlet were again sampled in June, although the seep was dry. In July and August all inlet streams were dry and the lake level had lowered below the spillway. In September and October streams began to flow again although the flow levels were low. During the October sampling visit, runoff was noticed coming from the farm on the eastern side of the drainage basin, this flow was sampled as it entered a catch basin on Newberry Road.

Table 9. Tributary Stream Sampling Dates.

	4-29	5-31	6-20	7-25	8-22	9-20	10-15
# of Inlets sampled	1	5 (& seep)	5	0 (all dry)	0 (all dry)	1	3 (& farm)

Water was sampled at the outlet from the lake during May and June. The lake stopped discharging water over the spillway in June and did not again crest the dam spillway for the remainder of the study period.

The streams that were sampled during the study were given identification names by the author, the names are shown in **Map 3**. Launch Brook was located at the south end of the lake and discharged directly into the cove with the state boat launch. This stream had the largest sub basin area at 325 acres. Hidden Brook drains the southwest side of the watershed with an area of 123 acres. The next two streams, Laurel Brook and Cove Brook were located on the western side and drained into the cove on the western side of the lake. Each had small drainage areas at 50 and 35 acres for Laurel and Cove Brooks respectively. North Brook was located at the north end of the lake and drained into the northern most cove. North Brook had a drainage area of 46 acres. The last of the identified natural stream inlets was Sunset Brook on the eastern side of the lake. This brook had a drainage area of 52 acres. Together the drainage basin area for these streams totaled 631 acres or about 64% of the total drainage basin of Bashan Lake. The total drainage area of each of the sampled streams is given in **Table 10**.

Table 10. Bashan Lake Tributary Subbasin Areas.

Basin Identifier	Area (acres)
Launch	325
Hidden	123
Laurel	50
Cove	35
North	46
Sunset	52

The water flow at each inlet and the outlet was measured during each of the monthly sampling visits. The estimated discharge volumes are given in **Table 11**. Water flow was measured at only one stream in April but flow was measured at all of the identified streams and the outlet in May and monthly afterward. In May and June the only two months when the lake discharged over the dam, the lake had significantly more water outflow than inflow from the 5 flowing streams. This suggests that the lake receives a portion of its water from ground water flows. All streams were dry in July and August, only one had flow in September and two had measurable flow in October.

In addition to these regular sampling sites, two other samples were collected from drainage basin flows. One from a small seep located on the eastern side of Sunset Lane, the second from a stream draining the farm on the eastern side of Newberry Road.

Table 11. Measured Water Flows (cfs) at 6 Inlets and the Outlet, Bashan Lake, 2002.

Inlet Sta.	29-Apr	24-May	19-Jun	15-Jul	25-Aug	20-Sep	16-Oct
Launch	2.8	0.853	0.292	0.0	0.0	0.004	0.011
Sunset	~	0.154	0.004	0.0	0.0	0.0	0.0
North	~	0.4	0.1	0.0	0.0	0.0	0.0
Laurel	~	0.156	0.078	0.0	0.0	0.0	0.029
Hidden	~	0.1	0.1	0.0	0.0	0.0	0.0
Total In	2.8	1.6	0.6	0	0	0.004	0.04
Outlet	~	9.0	4.0	0	0	0	0

Drainage Basin Water Quality Results

The 5 inlet streams were visited monthly beginning in May to determine baseline water quality conditions of the drainage basin flows into Bashan Lake. The water testing included total phosphorus, ammonia nitrogen, nitrate nitrogen, TKN or organic nitrogen, conductivity, alkalinity, turbidity, pH. The water flow as well as temperature and oxygen were measured in the field.

In each of the following water quality discussions, the seasonal average from each stream is shown except for the pasture runoff and the Sunset Lane seep values which were both from isolated samples. It should be noted that not all streams had flows during each of the months. This means that the average values calculated for each stream represent different numbers of samples. Refer back to **Table 9** to see the number of samples that were collected each month.

Phosphorus

The levels of phosphorus in the inlet streams were low in each of the natural stream inlet sites but the two incidental sites had high levels (**Table 12**). Mean stream phosphorus values ranged from 2 ppb to 8 ppb while the pasture and the seep had 500 and 630 ppb respectively.

Table 12. Average Stream Phosphorus Concentrations For Bashan Lake Inlets, 2002.

Site	TP (ppb)
Launch	6
Sunset	8
North	3
Laurel	2
Hidden	5
Pasture*	500
Sunset seep*	630

*= one sample

Ammonia Nitrogen

The ammonia levels in the inlet streams were generally low ranging from 0 to 82 ppb for the natural streams and 65 and 5,700 ppb for the seep and pasture respectively. The pasture sample showed a significant level of ammonia in the runoff from that site.

Table 13. Average Stream Ammonia Concentrations For Bashan Lake Inlets, 2002

Site	Ammonia (ppb)
Launch	17
Sunset	82
North	13
Laurel	0
Hidden	0
Pasture	5,700
Sunset seep	65

Nitrate Nitrogen

The average nitrate concentrations in the 5 monitored streams and the two additionally sampled sites are given in **Table 14**. Both the seep and pasture samples had high nitrate levels with 685 and 800 ppb respectively. Detectable levels of nitrate were also observed at the Launch and Sunset inlets while the other streams had no detectable nitrate concentrations.

Table 14. Average Stream Nitrate Concentrations For Bashan Lake Inlets, 2002

Site	Nitrate (ppb)
Launch	52
Sunset	122
North	0
Laurel	0
Hidden	0
Pasture	800
Sunset seep	685

Organic Nitrogen

The organic nitrogen concentrations were highest in the pasture and seep samples, with 3,300 ppb and 5,555 ppb respectively. The regularly monitored streams had between 0 and 240 ppb (**Table 15**).

Table 15. Average Stream Organic Nitrogen Concentrations For Bashan Lake Inlets, 2002

Site	TKN (ppb)
Launch	240
Sunset	75
North	0
Laurel	74
Hidden	65
Pasture	3,300
Sunset seep	5,555

The seep and pasture sample each had high levels of phosphorus and nitrogen, the following **Table 16** summarizes the results from those two samples.

Table 16. Summary of Phosphorus and Nitrogen Concentrations From Seep and Pasture Sampling Sites.

Site	Phosphorus	Nitrate	Ammonia	Organic Nitrogen	Total Nitrogen
Pasture	500	800	5,700	3,300	9,800
Seep	630	685	65	5,555	6,305

Conductivity, Alkalinity, Turbidity.

The conductivity, alkalinity and turbidity data from the stream sampling appears in **Tables 17, 18, 19.** The conductivity (**Table 17**) from the streams shows that all but 2 sites had average conductivities that were higher than the lake conductivity (mean of 74 µmohs/cm). Hidden Brook had an average conductivity or 32 µmohs/cm, and Laurel Brook had a conductivity of 66 µmohs/cm. The alkalinity of the inlet streams were within the range of the lake alkalinity values except for the seep and the pasture samples which had higher values (**Table 18**). The turbidity measurements of the inlet streams showed that most streams were clear with little turbidity in the water. Pasture and seep samples were high as each contained sediments. The pasture sample was storm runoff from exposed soils and was visibly muddy (**Table 19**).

Table 17. Average Conductivity of Streams Entering Bashan Lake, 2002.

Site	Conductance (µmhos/cm)
Launch	94
Sunset	130
North	95
Laurel	66
Hidden	32
Pasture	292
Sunset seep	152

Table 18. Average Alkalinity of Streams Entering Bashan Lake, 2002.

Site	Alkalinity (mg CaCO3/L)
Launch	3
Sunset	6
North	2
Laurel	1
Hidden	2
Pasture	59
Sunset seep	26

Table 19. Average Turbidity of Streams Entering Bashan Lake, 2002.

Site	Turbidity (NTU)
Launch	1.0
Sunset	0.4
North	0.3
Laurel	0.4
Hidden	0.195
Pasture	43
Sunset seep	41

Nutrient Loading

The concept of estimating nutrient loading to a lake is based on the premise that phosphorus is the nutrient in shortest supply, or the limiting nutrient to algae growth, and that the principal source of phosphorus is from the drainage basin. The primary ways that phosphorus is transported to lakes is through the hydrology of the basin as direct runoff that occurs in streams and culverts. The amount of phosphorus that is carried by the inlet tributaries can be estimated either by the existing land-use in the drainage basin, by the spring phosphorus concentration in the lake or by directly measuring phosphorus in the stream water.

In this report, the phosphorus loading to the lake was reviewed using three different methods. The first was the land-use method where the existing land-use was tallied and phosphorus export coefficients were applied to three different uses. The second way was by applying the spring phosphorus concentration to existing empirical lake models. Finally, the third method was to use actual phosphorus runoff data collected from streams during the study interval.

Land Use

The CT DEP (1982) gave estimates of 6 different land use categories in the Bashan Lake drainage basin. Later Frink and Norvell (1984) gave the percentages of only three categories; 23% urban, 9% agricultural, and 68% wooded or wet which were numerically the same percentages as given in CT DEP (1982). After examining the watershed and reviewing Benson (1993) the land-use fractions were revised downward in the case of the urban/residential and agricultural lands and upward for the wooded and open land. The revised numbers are 18.4% urban/residential, 3.3% agricultural, and 78.3% wooded. The area estimates from both studies are shown in **Map 6** and listed here in **Table 20.**

Table 20. Areas for Different Land Use Categories In Bashan Lake Drainage Basin.

Categories	Area (acres)	%	Area (acres)	%
	DEP 1982		This Study	
Low Density Residential	154	12.1	182	14.5
Moderate Density Residential	143	11.2	50	4.0
Urban Total	**297**	**23.3**	**232**	**18.4**
Crop Land	120	9.4	41	3.3
Agricultural Total	**120**	**9.4**	**41**	**3.3**
Open land	0	0	13	1.0
Wetland	80	6.3	105	8.3
Water	273	21.4	273	21.4
Woodland	507	39.7	593	47.2
Wooded/Open Total	**860**	**67.3**	**984**	**78.3**

Using the phosphorus runoff coefficients given in Frink and Norvell (1984) for these three land use categories the watershed loading can be estimated by multiplying by the phosphorus export coefficient from urban land, 1.52 lb/acre, for agricultural land, 0.48 lb/acre, and for wooded land, 0.09 lb/acre. Multiplying through gives; 451.4 lbs from urban, 57.6 lbs from agricultural, and 77.4 lbs for the wooded/open/wet land. Together these sum to 586.4 lbs per year, or about **265.9** Kg / year. Using the new estimates there would be 352.6 lbs from urban, 19.7 lbs from agricultural, 88.6 lbs from wooded or about **209.1** Kg/yr. The total amount of phosphorus runoff that would be generated from an entirely wooded drainage basin would be 113 lbs or **51** Kg/yr.

Empirical Phosphorus Models

Empirical modeling uses the relationships derived from studying a large group of similar lakes over several seasons. The phosphorus supplied to the lake during the winter and spring typically comprises a large percentage of the total annual input. That phosphorus is then mixed uniformly in the whole lake by the time of ice out. That supply of phosphorus is considered the initial growing condition, because once leaf-out occurs in the drainage basin the input of phosphorus decreases as water flows decline. Empirical studies of lakes have shown that the concentration of phosphorus in the lake at ice-out, or shortly after, is related to the annual input of phosphorus and the summer chlorophyll level or the summer Secchi depth.

Four empirical models were used to estimate the annual phosphorus loading to the lake. These models were: 1) Kirchner and Dillon (1975), 2) Vollenweider (1975), 3) Jones and Bachmann (1976), and 4) Chapra (1975) (See **Appendix** 4). Each model uses the mean depth, the flushing rate, and a retention coefficient for the phosphorus that stays in the lake and settles to the bottom. Using a spring phosphorus concentration of 9 ppb, collected in April 2002, the results of the models are given in **Table 21**.

Table 21. Results of Empirical Phosphorus Loading Models For Bashan Lake.

Model	Kg Phosphorus / year
	2002 (9 ppb)
Kirchner and Dillon	156
Vollenweider	127
Jones and Bachmann	58
Chapra	187
Mean	**132**

The results of the empirical modeling suggest that much less phosphorus is entering the lake than predicted by the land use estimate. The land use estimate was between 209 Kg/yr and 266 Kg/yr while the empirical modeling yielded an average estimate of 132 Kg/yr or about half the land-use predicted load. The land use estimate is based on the runoff from many Connecticut watersheds so has an inherent variability. The relationship that was used to derive the coefficient values given above (1.52 lb/acre, 0.48 lb/acre, and 0.09 lb/acre) had large variation when used to predict phosphorus in lakes, accounting for only about 40% of the difference between observed and predicted spring phosphorus concentrations. This implies that the land use method is not very accurate at estimating phosphorus runoff.

Direct Loading Estimates

The inlet phosphorus data collected during this study was also used to estimate the total annual load of phosphorus to the lake. The flow estimates for the period of study were used to calculate the potential load of phosphorus over the same intervals assuming that the average of the two data points represents the average phosphorus and flow during that interval. The total estimated phosphorus runoff during the period of study, April to October 2002, for all the streams was 2.3 Kg.

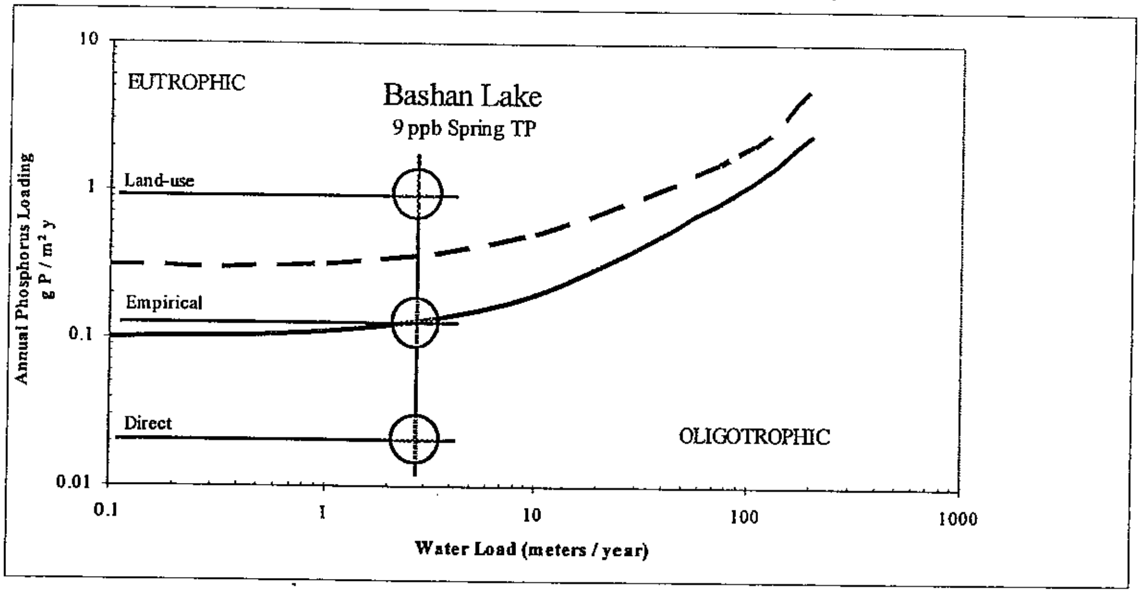
The study period was 174 days in length or about just about half the year. Typically the highest flows of the year occur during the late winter and early spring. The total discharge to the lake during the study period was about 182 acre-feet or about 7% of the estimated total of 2,472 acre-feet (see **Appendix 4**). The remaining runoff volume that occurred during the months between October and April would be by difference about 2,290 acre-feet. Given an average phosphorus concentration of 7 ppb for the inlet streams during the period between April and in October the loading of phosphorus during the winter can be estimated to be 19.7 Kg. Summing the two estimates gives an annual loading of phosphorus to Bashan Lake of about 22 Kg. Using the same method for nitrogen about 578 Kg was discharged to Bashan Lake during the year. The estimates of phosphorus loading to the lake are summarized in **Table 22.**

Table 22. Estimates of Annual Phosphorus and Nitrogen Loading To Bashan Lake.

	Kg / Year		Grams P / m^2 /yr
	Phosphorus	Nitrogen	Annual Load
Direct Measurement	22	578	0.02
Land-use	209		0.19
Empirical	132		0.12

A lake can absorb a certain amount of phosphorus based on its total volume and its flushing rate. Larger volume lakes tend to be able to absorb more nutrients than smaller volume lakes, and lakes tend to be able to absorb more nutrients with increasing flushing rates. The following graph shows the estimated load of phosphorus from each of the three methods fit to theoretical lake loading thresholds developed by Vollenweider in the 1960s and 1970s. The graph shows the thresholds of each of the three trophic categories (**Figure 19**). The solid curving line divides oligotophic and mesotrophic while the dashed curved line divides mesotrophic and eutrophic

Figure 19. Comparison of the Estimated Total Phosphorus Loading To Bashan Lake and Trophic Thresholds.



The land-use estimate for phosphorus load to Bashan Lake is well above the eutrophic loading threshold for phosphorus. This value should be considered an over estimate of phosphorus load to the lake because clearly the lake had oligotrophic characteristics during the year. The value from the empirical models showed that the estimated loading would place the lake on the threshold between oligotrophic and mesotrophic loading, more in line with observed lake characteristics. The direct loading estimate however was far below the threshold for oligotrophic loading.

The empirical loading estimate may be on the higher side because the phosphorus values observed in April were about three times higher than any other month of the study. Phosphorus concentrations averaged about 5 ppb between the period of May to October. But the direct estimate was almost certainly an underestimate because of; 1) only 7% of the estimated average annual water load to the was actually sampled, 2) during the months when all 5 streams were visited the outflow was still much larger than the measured inflow, implying additional water inputs from groundwater, 3) only one of the streams was sampled in April, and 4) Connecticut was experiencing a severe drought at the time of the study which probably significantly decreased the flow from all inflows. The actual loading of phosphorus to Bashan Lake probably falls somewhere between the direct estimate and the empirical estimate or in the range of 0.02 and 0.1 mg P / m^2 / year.

CONCLUSIONS AND RECOMMENDATIONS

Bashan Lake appears to have excellent and stable water quality conditions at this time. All of the trophic indicators showed low levels of productivity, with the exception of aquatic plant distribution and abundance due to the infestation of milfoil. Phosphorus and water clarity both indicate that the lake is oligotrophic, while total nitrogen was slightly higher indicating a meso-oligotrophic category.

Nutrient loading estimates and trophic modeling suggest that the lake has low nutrient input from the drainage basin and although the flushing rate is low the lake is not receiving excess phosphorus. In addition, internal nutrient loading from the sediments in the lake was also very low to non-existent. However, phosphorus concentrations observed in April were higher than all other months indicating that there was increased loading during that time of the year.

The relationship between water clarity, thermocline depth, and oxygen loss suggest that at present the extreme clarity of the water causes the metalimnion to form deep in the water column and keep the anoxic boundary from ascending up past 12 meters. However, due to the high clarity the water warms deeper into the water column limiting the summer habitat for trout.

The existing lake condition may be vulnerable to perturbations that decrease the water clarity of the lake. The clarity appears to determine the deep mixing depth and limit anoxia to the deepest water. A change in clarity would probably cause the thermocline to form higher in the water column which in turn would probably limit deep water mixing possibly leading to a higher ascent depth of anoxia. If any changes occur to either the rate of oxygen loss or the depth of light penetration it could possibly increase the rate of recycling of phosphorus from bottom sediments. Changes in the rate of internal recycling would shift this balance toward greater accumulation of phosphorus in the lake leading to higher rates of productivity.

Recommendations

The lake showed excellent water quality conditions during the period covered by this study. Historical data suggests that the lake has had similar excellent water quality in the past. However, the lake does have a serious infestation of variable-leaved milfoil that is likely to continuing spreading. This infestation represents the only in-lake management necessary at this time. Both water quality monitoring and focused surveys of the milfoil should be continued into the future.

The future management efforts in Bashan Lake should include:

1) annual surveys of aquatic plant distribution,

2) a comprehensive weed management plan to treat the threat of variable-leaved milfoil,

3) a water quality monitoring program to maintain a long term data base on the lake condition.

The drainage basin, although mostly in good shape, showed evidence of nutrient contributions to the lake. The seep and farm runoff sites both had high nutrient levels in water discharged toward the lake suggesting that further investigations are warranted. Based on these examples the following drainage basin actions are recommended:

1) a thorough sanitary survey of all homes in the drainage basin, and,

2) a review of exiting storm water conveyance to the lake, including existing runoff from agricultural practices in the drainage basin.

Feasibility Assessment And Management Options

In this section detailed information is presented about management options for each of the three primary recommendations, milfoil control, domestic on-site waste water control, and stormwater/runoff control.

Milfoil Control

The lake at this time has only one problem plant, variable-leaved milfoil. However, fanwort another very invasive rooted aquatic plant occurs in two neighboring lakes and poses a threat to Bashan Lake. An active monitoring program should be initiated that involves frequent surveys of the boat launch area for the presence of shoots of fanwort.

The current treatment method for the milfoil using spot treatments of 2-4D is probably the only method that will prove affective at controlling the milfoil long term. Although there may be utility in suction harvesting of deepwater beds. A milfoil management plan should be developed that provides a course of action for the next 5 to years. This plan should identify the goals of a herbicide treatment program. Suggested goals may be to limit the spread of milfoil into new areas, maintain milfoil free shallow water coves, and eliminate isolated clumps and patches of milfoil. The plan should also address such factors as frequency of treatments and methods to be used for early detection and distribution surveys. Other actions that could be considered to remove milfoil are hand pulling with SCUBA, and suction harvesting.

Control of Rooted Aquatic Plants

This section provides a comprehensive review of all available rooted aquatic plant control techniques available to control aquatic plant nuisances in Connecticut. Each has a different approach varying from large-scale methods that affect the entire lake to small-localized methods. Each of the methods is listed here with a brief description of how it works and compares the advantages and disadvantages of each method.

Benthic Barriers

The term benthic refers to the sediment surface so a benthic barrier is a bottom cover or liner that is placed over the plants on the lake bottom. The goal of the barrier is to cut off the light to the plant as well as provide a barrier through which the plant cannot grow. In theory, these barriers work very well, but in practice, a number of shortcomings that have limited their use to specific situations. The materials tended to trap gases under them causing them to billow up, or the material did not hold up to long-term exposure to light. Accumulated sediments on top of the barriers allowed for rooting of plants essentially burying the barrier. New porous materials have solved the billowing problem by allowing gases to pass through the barrier but accumulated sediment must still be removed annually.

Benthic barriers are effective in small areas such as dock spaces and swimming beaches to completely terminate plant growth. They are also useful in creating access lanes through areas of dense plant growth. Large areas are not often controlled because the of the high cost of the material (approximately $1/sq. foot) and an additional installation and maintenance costs. Covering large areas of the littoral zone the most productive part of the lake with a barrier also impacts native or non-target species and can significantly limit habitat for aquatic organisms.

Benthic barriers may provide some limited use at Bashan Lake where boating lanes are required through either water lily beds or pondweed. A benthic barrier may also be useful around the outside edge of beaches where weeds can interfere with swimming lanes.

Dredging

Dredging works as a plant control technique when either light limitation on growth is imposed through increased water depth or when enough soft sediment is removed to expose less hospitable substrates such as gravel or coarse sand. Another form of dredging using suction hoses and SCUBA can be used to remove a target weed species by extracting the whole plant, rootstocks, and seeds. The sediment however is usually returned to the lake. This method may be of merit to consider at Bashan Lake. Because large areas of the lake can be treated and all loose sediments and plants are moved this type of dredging might be affective at totally removing milfoil.

In order to make the lake deep enough to limit the amount of light reaching the plants sediments have to be removed such that the new depth is greater than the associated light penetration. This limits the use of dredging to areas away from shore because some slope is still necessary at the lake edge. In addition, if water clarity is already very good than the depth required to induce light limitation may be too excessive to be practical which is indeed the case at Bashan Lake.

If the soft sediments that are supporting the nuisance plants are not especially thick it may be possible to create a substrate limitation instead. In this situation the organic mucks are removed leaving coarser material that don't support plant growth. It is usually impossible to remove all the muck so some re-growth occurs.

There are a number of disadvantages to dredging that limit its use. In each case, a site is necessary to contain the sediments that are to be removed. If no local site is available next to the lake, than sediments need to be trucked to an off-site disposal area, usually at great expense. Local sediment containment basins need some type of capability to allow dewatering flows to get back to the lake. Since these flows are turbid and contain nutrients the flows need to either pass through a settling basin or have a flocculent added to remove the turbidity. Those flows would have to be monitored and may need treatment so as to not impact the lake. Dredging itself causes turbidity in the lake and may impact invertebrate populations, non-target species of plants and fish habitats. But in areas were milfoil existing in massive dense stands dredging of a shallow layer of sediment that includes the plants and most of its roots may be a very effective way of removing large scale areas of milfoil.

Light Limitation Dyes

Blue dyes are used to limit the light transmission into water and therefore restrict the depth at which rooted plants can grow. These dyes tend to reduce the maximum depth that plants will grow but usually have limit affect in shallow water (< 4 ft deep). The dye has to be replenished based on the flushing rate of the water body to retain its effectiveness. The low light tolerant plants are favored and those that can reach the surface. Because the dyes limit light penetration there may be some decrease algae photosynthesis in deeper water causing a subsequent increase in deep water oxygen loss. These types of plant controls are not suitable for controlling weeds at Bashan Lake because in order to limit the light reaching 20 feet the clarity would have to be reduced to point where the lake would be deleterious affected.

Mechanical Removal

There are several methods of mechanical removal. These are, hand pulling, cutting without collection, harvesting with collection, rototilling, and hydroraking. Hand pulling is done by a diver who pulls out the target plants individually. This can be very time consuming but because it is highly selective and is done using a visual operator it can be very effective at controlling target plants in a specific location. Although hand pulling leaves little doubt about whether an individual plant has been removed once the operation is underway it is difficult to keep the area from becoming too turbid to see more plants. Hand pullers have to move to an alternate site until the sediments settle out and the plants can be seen again. Often the site has to be revisited several times in order to insure that all the plants have been removed.

Both cutting and harvesting involve a specialized barge that is fitted with a cutter bar and a in the case of a harvester also a conveyor assemble that retrieves the cut plant material and loads it on the barge. A cutter boat only cuts the plants and leaves the fragments in the lake to be removed by another means or not at all. A harvester collects the cut fragments and transports the material to an off loading site on the shore. In either case, the plant root system and lower shoots are left intake so re-growth is possible and in some case can be so rapid that the area needs re-cutting in a week or two. Cutting or harvesting aggressive colonialist plants such as milfoil is a particularly bad idea because it greatly promotes the spread of these plants into other areas of the lake.

Hydroraking involves the equivalent of a floating backhoe outfitted with a York rake, which looks like a large pitchfork. The tines of the rake are moved through the sediment to rip out thick root masses and associated sediment and debris. A hydrorake can be very effective at removing submerged stumps, water lily root masses, or floating islands. The raking process is not a clean process causing considerable turbidity of the water as well as releasing plant fragments and other debris.

Hydroraking does not have any application at Bashan because it would be ineffective at controlling milfoil and there are no beds of lilies which currently cause any problems. Harvesting usually results in spreading fragments of milfoil which causes more growth so it is also not recommended.

Water Level Control

Lake drawdown has been used in Connecticut for many years as a standard cure-all. It is inexpensive costing virtually nothing, all that is necessary is to open the dam and release water in the fall and close it in the spring. The lower water level in the winter allows for access to shoreline structures for maintenance, a side benefit that has value on its own. The ability of this method to control rooted aquatic plants is dependent on several factors. Only those plants that grow in the exposed area will be impacted by the lower water level. Plants that live below the water level will not be impacted and may instead increase in range by expanding into the areas cleared by the drawdown. Plants that are exposed by the drawdown are subject to both drying and freezing if down during the winter. However, freezing is not always guaranteed, heavy snowfall can insulate the sediments, while areas with steady groundwater input can remain unfrozen. Drawdown is non-selective as it will affect all the plants growing within the exposed areas, good and bad. There is also the problem of refilling the lake during the spring. A deep drawdown will require more water for refilling once the dam is closed. Timing the closing of the valve is important because generally runoff of the drainage basin decreases dramatically after leaf-out in May. The ability of the drainage basin to provide enough water during a refill window needs to be estimated prior to deep drawdowns. Bashan Lake has a small watershed so refill may be a problem.

Drawdowns may also impact the other organisms living the exposed area. Sometimes this may cause significant harm to the food webs by eliminating invertebrates, insects, mussels, reptiles, amphibians, and snails. The littoral zone is a very productive part of a lake ecosystem that would take several years to recover from one winter of freezing and drying. If the sediments are organic or mucky a drawdown that eliminates rooted plants on those substrates may cause the proliferation of filamentous algae the following spring due to the abundant nutrients in the muds. Drawdown also exposes sediments to rain causing erosion during the drawdown period that can wash minerals into the lake causing nutrient increases.

Drawdown would not be affective at controlling milfoil at Bashan Lake because the plant was found growing in water as deep as 20 feet. In order to impact the deeper plants a draw down of 20 feet would have to be accomplished. That would almost be the same as draining the lake.

Herbicides

Chemicals to control weeds and algae have been used for many years, and other than drawdown is probably the most widely used of all weed control methods. It has only been recently that the other techniques have gained acceptance.

There are only seven active ingredients currently approved for use in aquatic herbicides in USA today.

- COPPER products are not usually used for control of rooted plants, instead being used as a herbicide against algae both filamentous and planktonic. Copper can be used in conjunction with other herbicides to render them more affective if the plants have a dense growth of attached algae on their surfaces. The copper kills the attached algae so the herbicide can be affective against the plants.
- ENDOTHALL is a contact herbicide, attacking plants at the point of contact. Only the part of the plant that it contacts with will be affected. The roots will not be impacted so re-growth and recovery can be expected. The herbicide acts quickly against the leaves and shoots causing accumulation of large amounts of dead plant material on the sediment surface, which in turn can cause oxygen loss. There are use restrictions on the label against using it in drinking water supply reservoirs, although there shouldn't be toxicity impacts to other lake fauna.
- DIQUAT is another fast acting contact herbicide. Again, there is a domestic water use restriction and it is not used in water supplies. This herbicide can be toxic to invertebrates, fish, and other animals. Because contact herbicides do not affect the roots and buried seeds re-growth is probably certain.
- GLYPHOSATE is another contact herbicide. It is typically used against emergents and floating leaved plants but not against submersed species.
- 2,4-D is a systemic herbicide meaning that it is absorbed by the roots and incorporated into the whole plant. This herbicide has been in use for over 30 years, and has shown to be very effective against Eurasian Milfoil and Variable Milfoil. The herbicide can be used in either liquid or solid form so the area of treatment can be very well controlled. 2,4-D has variable toxicity to fish, and the label restricts its use in water used for drinking water supply or other domestic

uses, or for irrigation or watering of livestock. This appears to be the only herbicide that is affective against variable leaved milfoil.

- <u>FLURIDONE</u> is another systemic herbicide introduced in 1979 becoming widespread since the mid 1980's. Fluridone has proven to be very affective against milfoil and some of the other invasive aquatic plants. The herbicide comes in both a liquid and a slow release pellet allowing for both spot treatments and whole lake treatments. The herbicide has low toxicity to other organisms. The use of the liquid fluridone does require a 40 day contact period during which lake outflow should be minimized. Sometimes the required level of fluridone has to be bumped up because of dilution and flushing out of the lake.
- <u>TRICLOPYR</u> is a new systemic herbicide similar to 2,4-D in that it is absorbed into the plant and causes metabolic changes in growth process. It is not as yet approved for use in CT. It targets dicots such as milfoil.

<u>Biological Introductions</u>

The biological controls most often used today are herbivorous fish such as grass carp and the aquatic weevil. The goal of using these organisms is that they will graze on the desired target plant and affect some control without using herbicides. The grass carp has been used since the 1960's because of its high grazing rates on aquatic plants. It has a very high growth rate so it can consume large quantities of plant material in a season. The fish usually avoid the floating leaved species like lilies and go after the submersed plants like pondweed, elodea, and coontail. Although it is impossible to predict which plant the carp will feed on, overstocking grass carp can eradicate all the plants in a lake. There is also a possibility that grass carp increase the nutrient cycling in a lake by passing digested plant material out as excrement faster than the natural decay of the senescing plants in the fall. Grass carp are approved for use in Connecticut under special conditions. The lake outlet must be fitted with a grate structure to insure that the fish will not leave the lake, and only sterile fish can be stocked.

The weevil feeds exclusively on Eurasian milfoil not the variable-leaved species that is in Bashan Lake. The presence of the weevils is often difficult to determine but there is documentation of the existence of native populations of these organisms. Natural crashes of milfoil due to the grazing of these insects have been reported from a few lakes but the evidence is still preliminary that it will become a widespread control method. Some lakes with dense milfoil beds have stocked weevils in an attempt to establish a population at a dollar per weevil but again there is little information that these introductions are working on the long term.

Summary Of Applicable Aquatic Weed Management Options At Bashan Lake

The herbicide 2,4-D appears to be the only method of controlling the milfoil in Bashan Lake. All other methods benthic barriers, dredging, and hydroraking remaining herbicides, grass carp, drawdown, and light limiting dyes do not appear to have applicability at Bashan Lake at this time. Hand pulling using SCUBA and suction harvesting may prove to be applicable at Bashan Lake

Domestic Waste Water Control

This study did not include either a sanitary survey or water sampling for indicator bacteria. However, the drainage basin to Bashan Lake is small relative to the size of the lake and the existing development is already at the threshold for contributing to trophic changes in the lake. Some areas of development are both dense i.e. high number of year round houses on small lots in a small area and are within the direct drainage area to the lake. Because of these factors combined with poor soil suitability for domestic sanitary waste water renovation some areas of the drainage basin are probably leaching nutrients to the lake.

In this section the soils in the watershed will be reviewed for their suitability to function as renovation for domestic waste water from leach fields. The soils have been grouped into 5 categories following work done by Benson (1993). The soils designations are taken from the Soil Survey of Middlesex County, Connecticut. The area of each of the 5 groups is shown on **Map 7** the areas of each of the 5 groups are summarized in **Table 23**.

GROUP 1: These soils are well suited for individual domestic waste water systems. The soils in this group are of the Canton and Charlton fine sandy loam series and have map symbols of Cd, Cc, Cd, and Cr. These soils are well drained with gentle slopes.

GROUP 2: These soils are classified as wetlands. They are poorly drained with a water table located 0.0 to 1.5 feet below grade from November to May. Activities within 75 feet of wetlands are regulated by the East Haddam Inland Wetland and Watercourses Commission. In the Bashan Lake watershed the wetlands are predominantly Leicester/Ridgebury/Whitman soils with a map symbol of Lg. There are also a few isolated pockets of Adrian peat and muck soils with a map symbol of Aa.

GROUP 3: These soils have a perched water table within 1.5 to 3.0 feet below the soil surface between November and March. These soils have very slow percolation rates due to low permeability of substratum layers. Septic systems within these soils need to be engineered in order to prevent breakouts of effluent to the surface. These soils are Paxton and Woodbridge and have the map symbols Pb, Pd, Pe, Wx, Wy, and Wz.

GROUP 4: These soils are excessively drained glacial drift sandy soils. Because of the sand and gravel composite of these soils groundwater flow is rapid allowing easy permeability. Septic systems need to be designed specifically to prevent quick drainage. Leachate from leach fields in these soils and move thought the soils without renovation. These soils are Agawam and Hinckley with the map symbols Af, Hk, and Hm.

GROUP 5: These soils have shallow depth to bedrock and slopes that exceed 20%. Bedrock is commonly encountered within 15 to 20 inches from the surface with out crops throughout the areas of these soils. The prevalence of bedrock causes these soils to present significant limitations to excavation and percolation. Groundwater flows can become trapped on top of the bedrock and travel quickly without renovation often breaking out to the surface. Septic systems located in these soils need to be engineered systems and carefully designed to avoid groundwater and surface water pollution. These soils are Hollis with map symbols Hr, Hp, and Hs.

Table 23. Summary of Soils Groups in Bashan Lake Drainage Basin.

Soil Group	Type	Acres	Percent	Notes
Group 1	Canton/Charlton	296.0	30.0 %	Well drained and suitable
Group 2	Leicester	105.2	10.7 %	Wetlands-
Group 3	Woodbridge/Paxton	488.4	49.6 %	Perched water table
Group 4	Agawam/Hinckley	34.8	3.5 %	Excessively drained
Group 5	Hollis	69.6	7.1 %	Shallow to bedrock

Only soils in the first group present moderate limitations for septic system leach fields. All other groups have severe limitations to functioning septic system leach fields. The majority of the drainage basin consists of soils that present potential problems with the renovation of waste waters. About half the drainage basin has soils with a perched water table; this includes the high density residential area of Sunset Lane. Another 10 % of drainage basin has soils that have either excessive percolation or are shallow to bedrock. Problems with septic systems and leach fields will not show up in areas where the percolations rates are high.

The high density of homes on marginal soils indicates that septic systems in the watershed are probably contributing nutrients to the lake in the form of dissolved phosphorus, ammonia, nitrate, and organic nitrogen. The area where nutrient loading is probably going to be most prevalent is the Sunset Lane area where seasonal cottages have been converted to year-round dwellings; the soils in that portion of the drainage basin have either a perched water table or are shallow to bedrock. One seep was sampled, located on the east side of Sunset Lane about

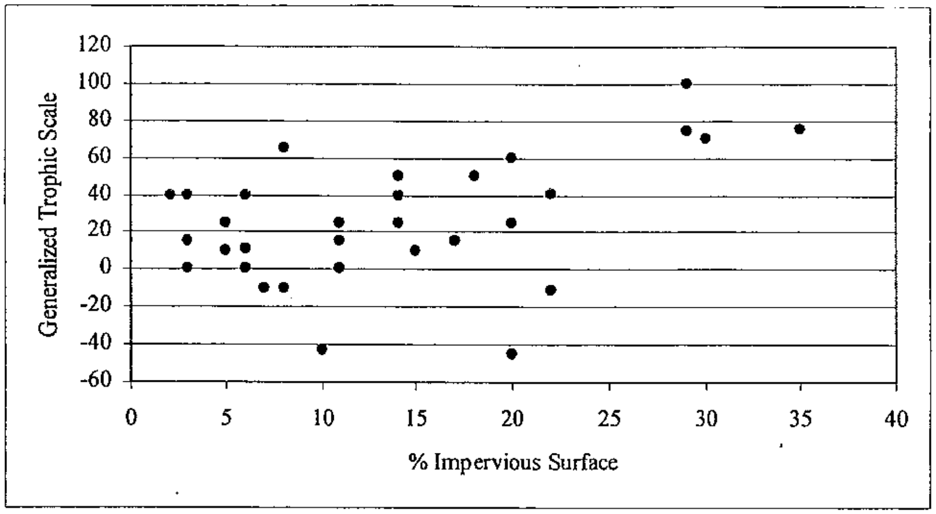
A full sanitary survey is warranted for the Bashan Lake watershed with the higher density residential areas targeted for more immediate investigation. A sanitary survey consists of an on site review of each dwellings waste disposal system to determine the presence of soil wetness or evidence of breakouts. Also included in a sanitary survey is cataloging of the type size and location of each dwellings waste water disposal system. Regular pump-outs of septic tanks is highly recommended. The frequency of pump out depends on tank size and number of occupants of the dwelling that the tank services. The Town of Old Saybrook recently adopted an ordnance (Old Saybrook Ordinance #75) that calls for regular pump-out and inspection of all on-site waste water disposal systems once every 5 years. However, it is important to note that smaller size tanks that may be undersized for the number of occupants would need more frequent attention.

Storm Water Control

In general urbanization increases the amount of impervious land surface area, which in turn leads to increases in storm water runoff. There is about 232 acres of developed residential area in the Bashan Lake watershed. The eastern side, along Sunset Lane has about 50 acres of densely developed residential area mostly within a short distance of the lake shore. The rest of the lake drainage basin has about 182 acres of moderately or seasonal residential land-use that drain to the lake. The total drainage basin size was given to be 984 acres meaning that 232 acres is about 23.6% of the drainage basin area is currently developed with semi or totally impervious surfaces. The data in **Table 20** give percentages for the entire watershed including the lake area.

As the percentage of impervious surfaces in a drainage basin increase the general trophic category of a lake also increases. Trophic indices have been shown to be linked to change in land-use from undeveloped wood land to urban impervious surfaces by Siver *et al.* (1999). The data in **Figure 20** shows that trophic measures, such as a decrease in Secchi disk transparency, or increase in nitrogen phosphorus levels, begin to increase as the percent of the drainage basin that is imperious reaches 10%, with dramatic increases after the percentage reaches 20%. The existing condition of the Bashan Lake drainage basin is that about 23.6% is impervious land-use.

Figure 20. Trophic Index Changes Due To Increasing Impervious Surface.



The implication here is two fold, first storm water runoff may be a problem especially on the east side of the lake and is likely responsible for pollutants entering the lake, and second any additional development of the drainage basin could possibly result in increased trophic levels of the lake if the development is not storm water runoff is not controlled. There are several methods to reduce storm water impacts to a lake. Non point source and urban storm water controls fall into three basic categories:

- Regulatory Controls
- Source Controls
- Structural Controls.

Regulatory Controls

LAND-USE REGULATIONS

There are at least three goals of changes in zoning, 1) preservation of open space, 2) control of future new developments and 3) control of changes made to existing development. The east and north sections of the drainage basin have large areas of undeveloped land that may at some time in the future become developed. Increases in the percentage of impervious surface over the existing level will result in further degradation of the lake water quality. It is important that future new developments be performed in way that reduces the load of pollutants to the storm water not increases it. Changes in existing homes on the east side along Sunset Lane and on the northwest shore where the density of development is already high can also lead to increased pollutant loads. Where ever possible important natural features should be purchased so that they remain in an undeveloped condition.

A comprehensive review of zoning regulations within the drainage basin should be conducted to determine 1) where future development is possible, 2) the potential build out capacity, 3) the kinds of development that are permitted, 4) the level of upgrade to existing houses such as seasonal to year round, and 5) the controls that are currently required for new developments such as erosion control features.

PROTECTION OF NATURAL RESOURCES

Protection of water quality can also be accomplished by restricting development in land that serves important water quality enhancement and restorative functions. These areas include floodplains, wetlands, stream buffers, steep slopes, groundwater recharge areas, and undeveloped lake frontage. A land-use review of the basin shows that several significant wetlands and water corridors exist in the drainage basin of the lake. Contained in the review of zoning regulations in the drainage basin should be an overlay of the important natural features that are critical to the protection of water quality. The listing of these features should not be limited to those that are in a natural condition now but also include stream corridors that could be targeted for improvement with a goal of returning them to a more natural condition. Streams on the east side of the lake are examples where stream bed restoration could be initiated so that the water course can perform water quality regeneration functions. The watercourse associated with the Sunset sampling site could be inspected to determine if sediment has accumulated in the channel, if the banks are stable or show evidence of eroding. There were other sites along Sunset Lane where water flows from storm may be washing out the slope above the road. These flows need be assessed for their capacity and appropriate natural channels created to prevent further erosion.

LAND ACQUISITION

The municipalities or organizations can purchase land or seek conservation easements so that important water features are preserved.

Source Controls

The methods identified in this section are nonstructural practices that can reduce the load of pollutants that get into either storm water flows or into streams. In all cases the use of these practices requires diligence and a long term commitment or change in behavior. It is not enough to perform one or more of these actions once and than forget or lapse back to negligence. Instead a plan or program needs to be installed such that a schedule of activities is set in place and adhered to each year. It may be that in order to follow through with these methods a person or committee would need to be given responsibility of overseeing the completion each year. A paid position of Lake Manager or Watershed Protection Committee are examples.

STREET SWEEPING

Street sweeping is the cleaning of road surfaces of accumulated sand, debris, dirt, and their associated pollutants. By regularly sweeping streets these materials don't get washed into storm drain systems and into the lake. Street sweeping can be affective only if conducted at regular intervals and if done consistently. In most cases sand and salts that are applied in the winter are washed into catch basins and culverts during the first rain events. Only a progressive program of early year street sweeping would remove these sediments prior to the first rain storm. Streets should be cleaned at least twice per year, once in the spring to remove the sands from winter and once in late summer or early fall to remove dry fall and accumulated dirt and silts.

CATCH BASIN CLEANING

A storm water study should be conducted to include a review of all existing conveyances and repair and replacement program. The catch basins around the lake should be cleaned periodically such that the sump does not reach two thirds full. Often these sumps are the only interception between the impervious surface and the lake. It is the only site where sediments and solids can be trapped. Any cleaning program should also include an annual inspection to insure that sumps have been cleaned. Of course this assumes that all the catch basins have sumps. This is not always a safe assumption as many of the basins don't have sumps meaning that materials carried by the storm water flows are passed directly through the basin and into the lake.

FERTILIZER AND PESTICIDE CONTROLS

The use of fertilizers on residential lawns and gardens can result in over saturation of phosphorus and nitrogen in soils. Once these levels have been reached excess nutrients are either washed off or carried by groundwater flows. Public education is probably the only way that limitations can affectively be reached.

ANIMAL WASTE REMOVAL

Domestic animal waste represents a source of both bacteria and nutrients that can be washed directly into storm drains. Pet clean up ordinances is one way but general education about the affects of these kinds of practices is probably better because it will really depend on a voluntary action and commitment by private citizens.

SOLID WASTE MANAGEMENT

A municipal program should be set up to collect solid waste like yard trash, leaves, and brush help prevent these materials from getting into the storm water system and clogging pipes and catch basins. When these systems back up storm water will travel directly down street surfaces seeking its way to the lake in other ways. A program to collect this type of material helps discourage dumping into lake shore areas where it can cause deterioration of the lake.

REDUCED SANDING AND SALTING

The use of sands and salts in the winter on snow and ice covered roads is not likely to be stopped. Also there may not be any feasible ways to reduce the use of these materials given the steepness of many of the roads around lake. However it should be realized that without controls the sand will be transported directly into the lake. If the streets are not cleaned soon after spring in April or May most of the sands will be moved into catch basins, and discharged to the lake.

Because it is much easier to apply the sand than it is to retrieve it in most cases sand collection is performed much later in the season when it becomes convenient. A survey should be conducted that maps each of the storm water discharge sites to Bashan Lake and includes observations of sand bar formation in the lake at the outfall point. The drainage area of each outfall should be mapped and an assessment made of the relative contribution of each drain.

Structural Controls

When existing storm water conveyance systems are inadequate to remove pollutants from the water these systems have to be retrofitted to improve the effectiveness. In places were there is already significant development this process is often very complicated due to the limitation of space to install new features, existing structures such roads, bridges, bulkhead, and the lack of easements over private property.

The function of new structural control devices seeks to remove pollutants from runoff through the actions of settling, filtration, microbial decay, and vegetation uptake. Often the use of all types is necessary in areas where existing systems are inadequate and retrofitting is complicated by extensive existing development.

DETENTION BASINS

These systems are features that seek to detain the water in a constructed pond or wetland. Once collected the water is retained long enough to allow settling of sands and silts and their associated nutrients and metals. The water is released in a controlled way after sufficient time. There are three general types of detention basins. Dry Ponds, Wet Ponds and Constructed Wetlands. Dry Ponds are used to collect and detain peak runoff such that velocity and volumes are reduced prior to discharge to receiving bodies. Dry Ponds are constructed to allow all of the contained water to eventually drain out of the basin such that it becomes dry. Dry Ponds are effective at removing heavy sediments and some fraction of nutrient load especially if the basin of the pond contains vegetation. They are not very good at removing dissolved nutrients and bacteria. Wet Ponds are designed to remain permanent pools of water. Storm water enters the pool and once it fills to spillway level water is discharged to receiving streams of the lake. The concept behind a Wet Pond is to design it to have a flushing rate that accommodates the intended water and pollutant loads. Essentially it becomes a mitigation lake that absorbs the nutrients and sediment so that the resource lake doesn't have to. Created Wetlands are basins that contain established wetland plant communities. These systems filter and trap constituents in the storm water. They are effect at removing a wide range of different pollutants. However, as in wet ponds they need to be designed to fit the intended flushing rate of the water load, water volumes in excess of its capacity will simply channelize the wetland and pass through.

INFILTRATION STRUCTURES

The concept behind infiltration is to provide a means for storm water to be discharged to the groundwater. This allows the soils to act as a filter and remove sediments and other solid and solid adsorbed nutrients from the storm water. Infiltration does not remove dissolved nutrients like nitrate. Infiltration requires the correct soils for proper functioning for example clays soils are not suitable. The installation of infiltration structures can be of any size and located in most any area were water is piped or culverted. Parking lots, road side ditches, house lots can all have infiltration trenches or dry wells. These systems can only accommodate a limited amount of water but if enough are placed in series they become very affective in reducing the quantity of storm water and the pollutant load.

VEGETATIVE PRACTICES

The use of vegetation to remove nutrients can be used in conjunction with other systems as pretreatment in absorption of dissolved nutrients. Promote infiltration, capture solids and decreases velocity. There is a growing body of literature on the use of vegetated buffer strips and vegetation shorefronts in reducing nutrients entering a lake.

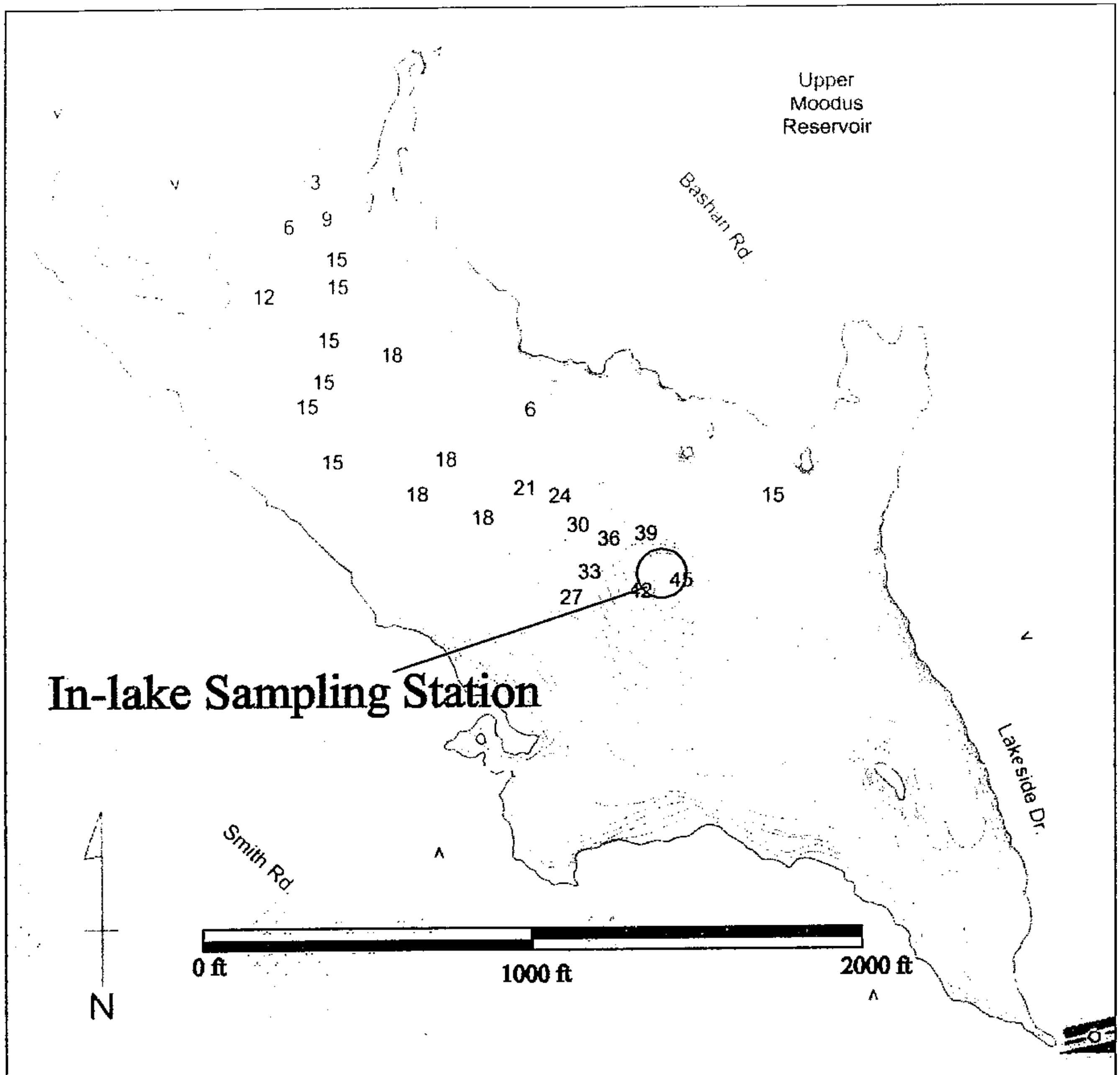
FILTRATION PRACTICES

Filtration is the use of some filtration medium, such as sand, to remove constituents from the water. Water is passed through a bed of filtration medium than passed back to a stream or culvert.

WATER QUALITY INLETS

These are specific devices that separate oil and grease or gross particles from the storm water. They usually are installed in conjunction with other removal systems and can reduce the maintenance required to keep them free of sediments, debris and trash.

[lap 1. Bashan Lake Bathymetric Map Showing Location of In-lake Sampling Station



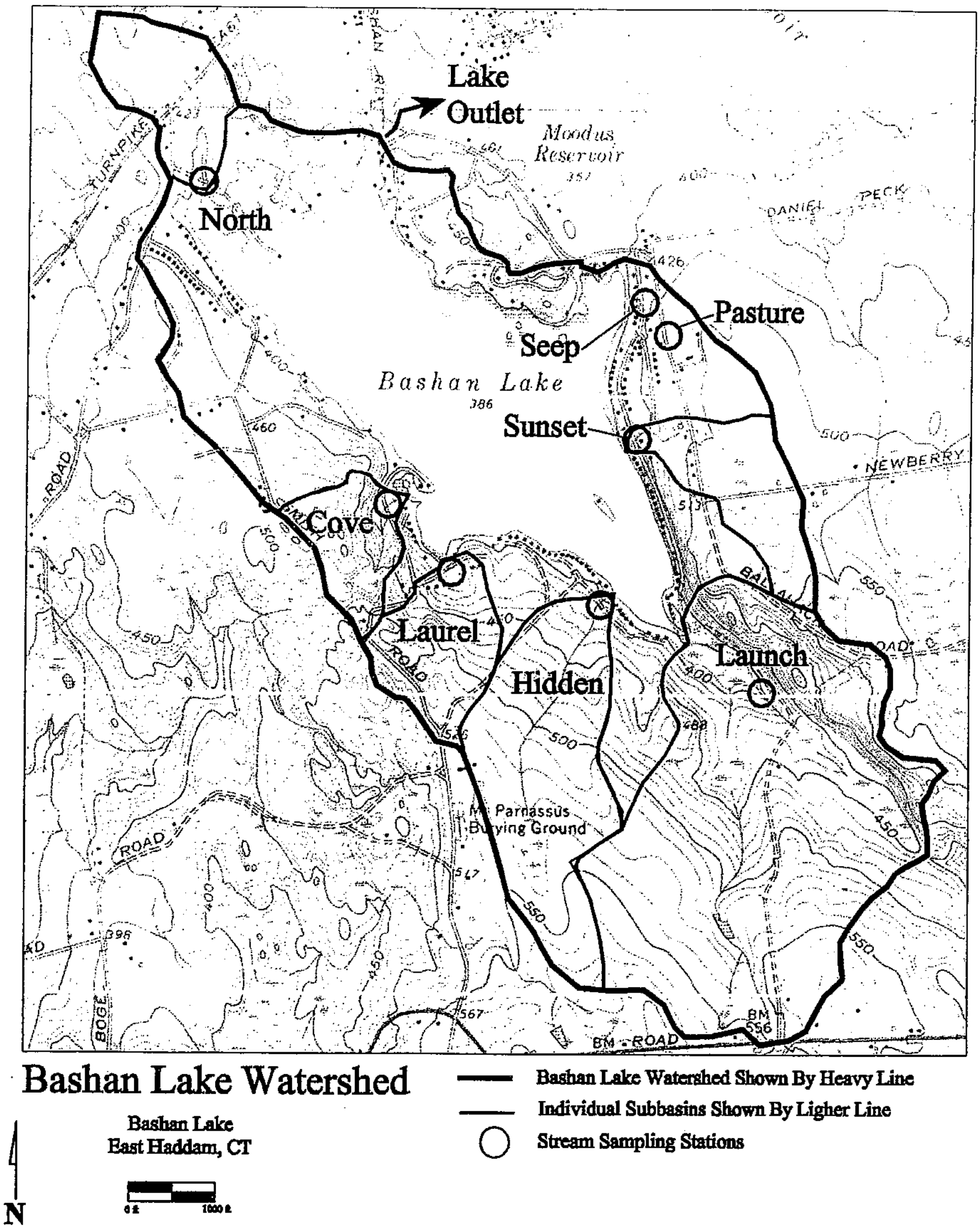
Bathymetric Map from
Jacobs and O'Donnell, 2002
CT DEP Bulletin #35

Bashan Lake
East Haddam, CT

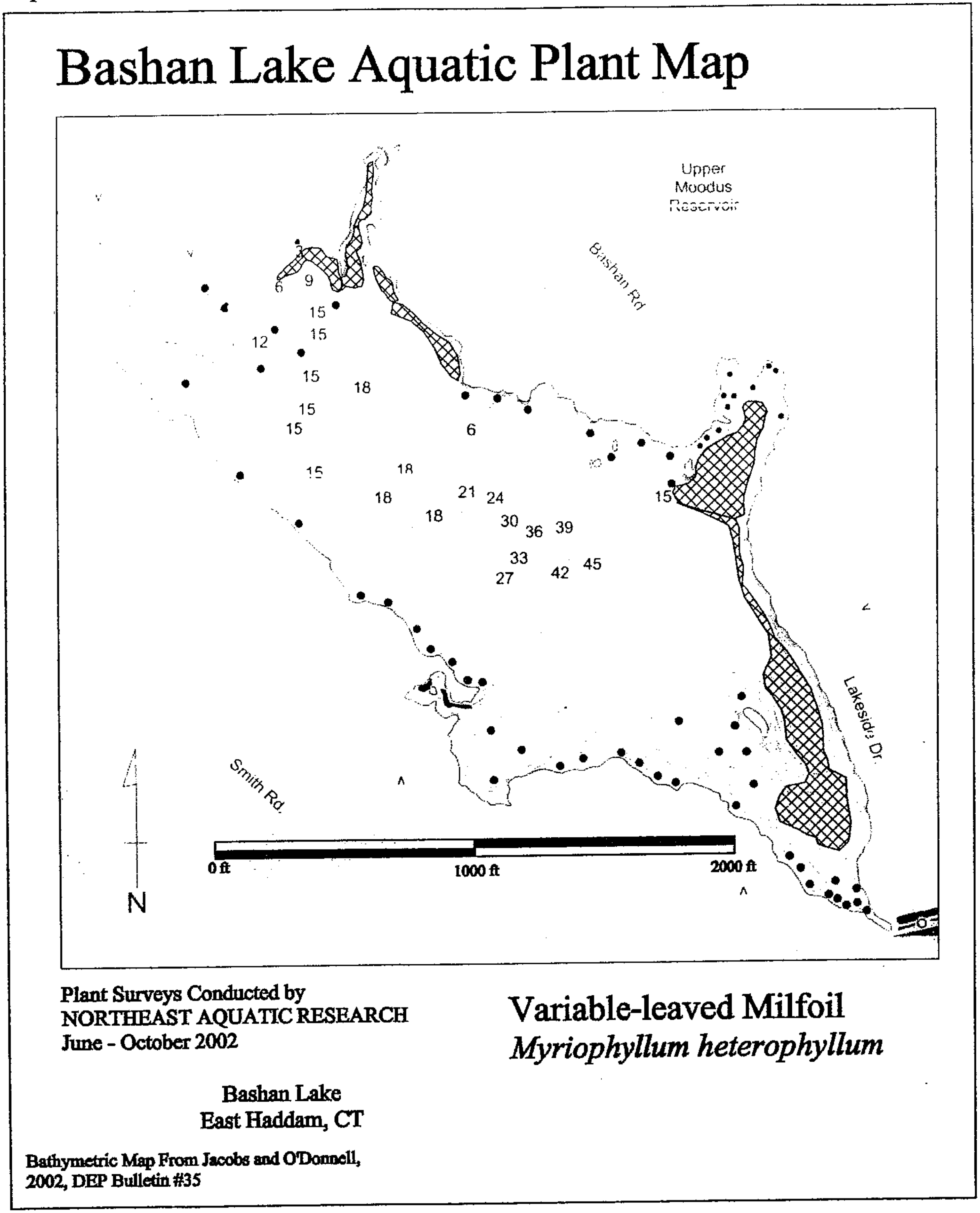
Bashan Lake Bathymetric Map

Contour Interval is 3 feet

Map 2. Bashan Lake Watershed and Subbasin Boundaries, and Locations of Stream Sampling Stations

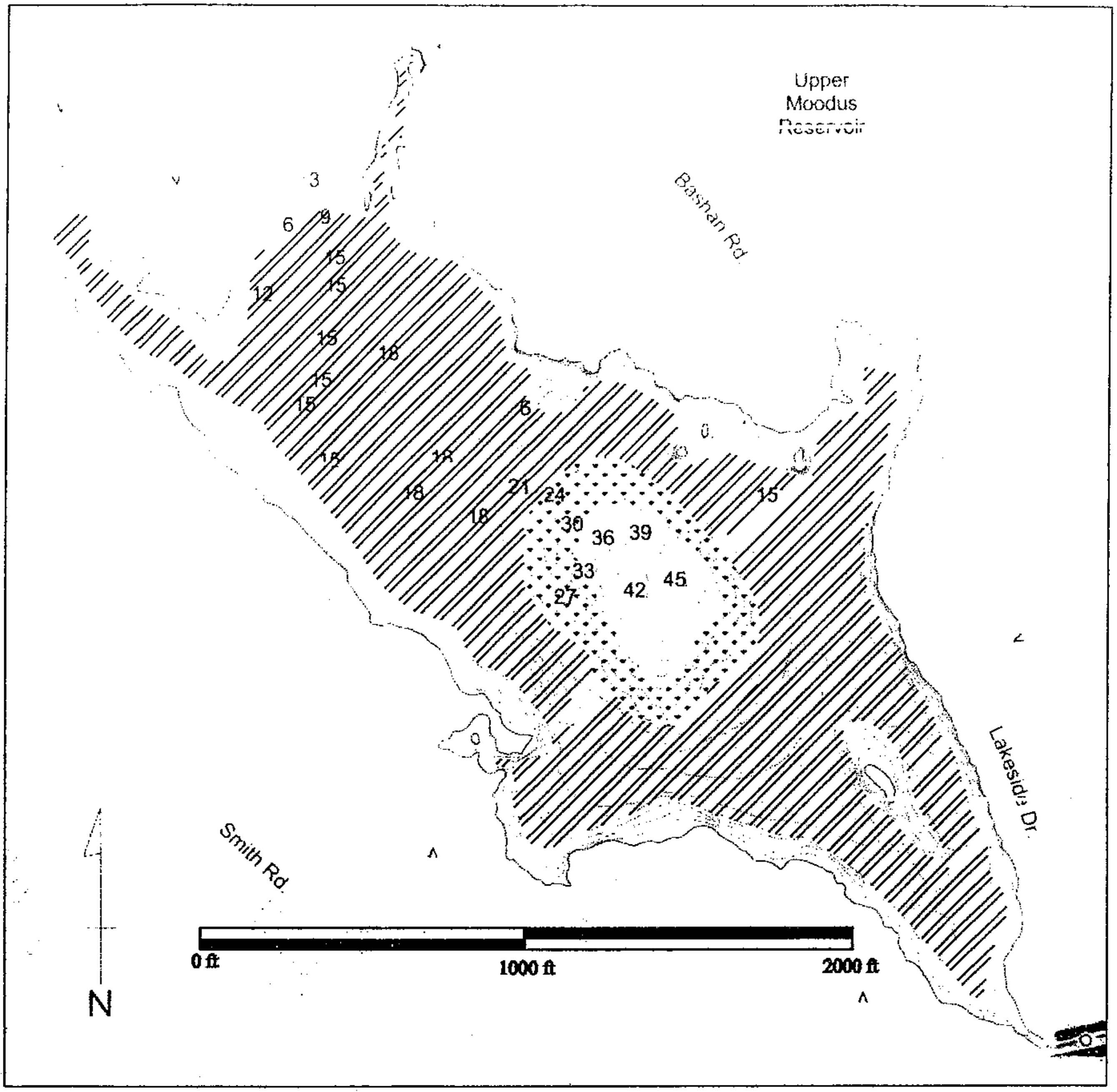


Map 3. Distribution of Variable-leaved Milfoil (Myriophyllum heterophyllum in Bashan Lake, Summer 2002.



Map 4. Distribution of Bladderwort/Nitella Bottom Carpet Mix in Bashan Lake, Summer 2002.

Bashan Lake Aquatic Plant Map



Plant Surveys Conducted by
NORTHEAST AQUATIC RESEARCH
June - October 2002

Bashan Lake
East Haddam, CT

Bathymetric Map From Jacobs and O'Donnell, 2002, DEP Bulletin #35

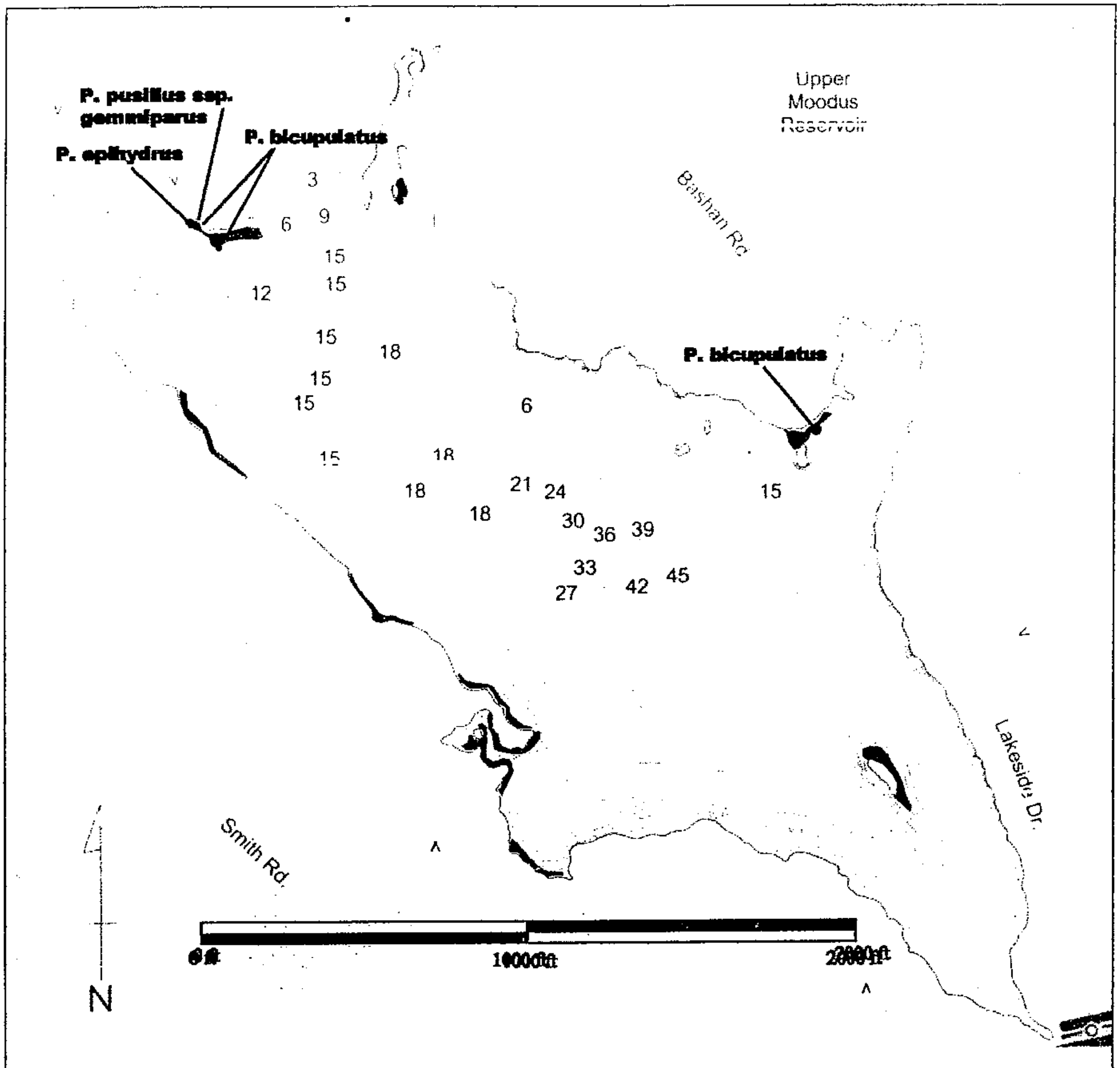
Bladderwort, Nitella

Nitella only

Bottom Carpet Mix

Map 5. Distribution of Eleocharis robbinsii and Potamogeton Species in Bashan Lake, Summer 2002.

Bashan Lake Aquatic Plant Map



Plant Surveys Conducted by
NORTHEAST AQUATIC RESEARCH
June - October 2002

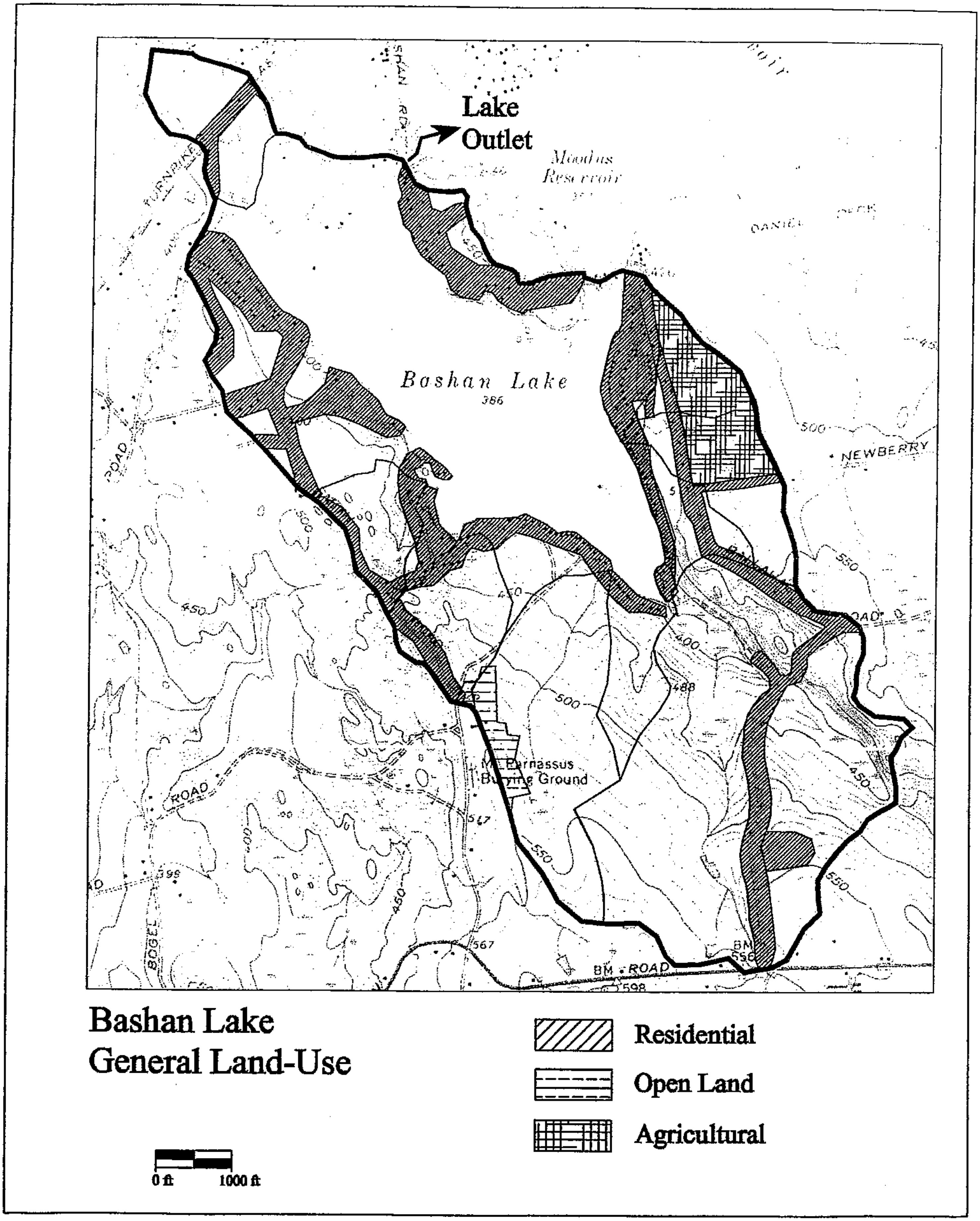
Bashan Lake
East Haddam, CT

Eleocharis robbinsii

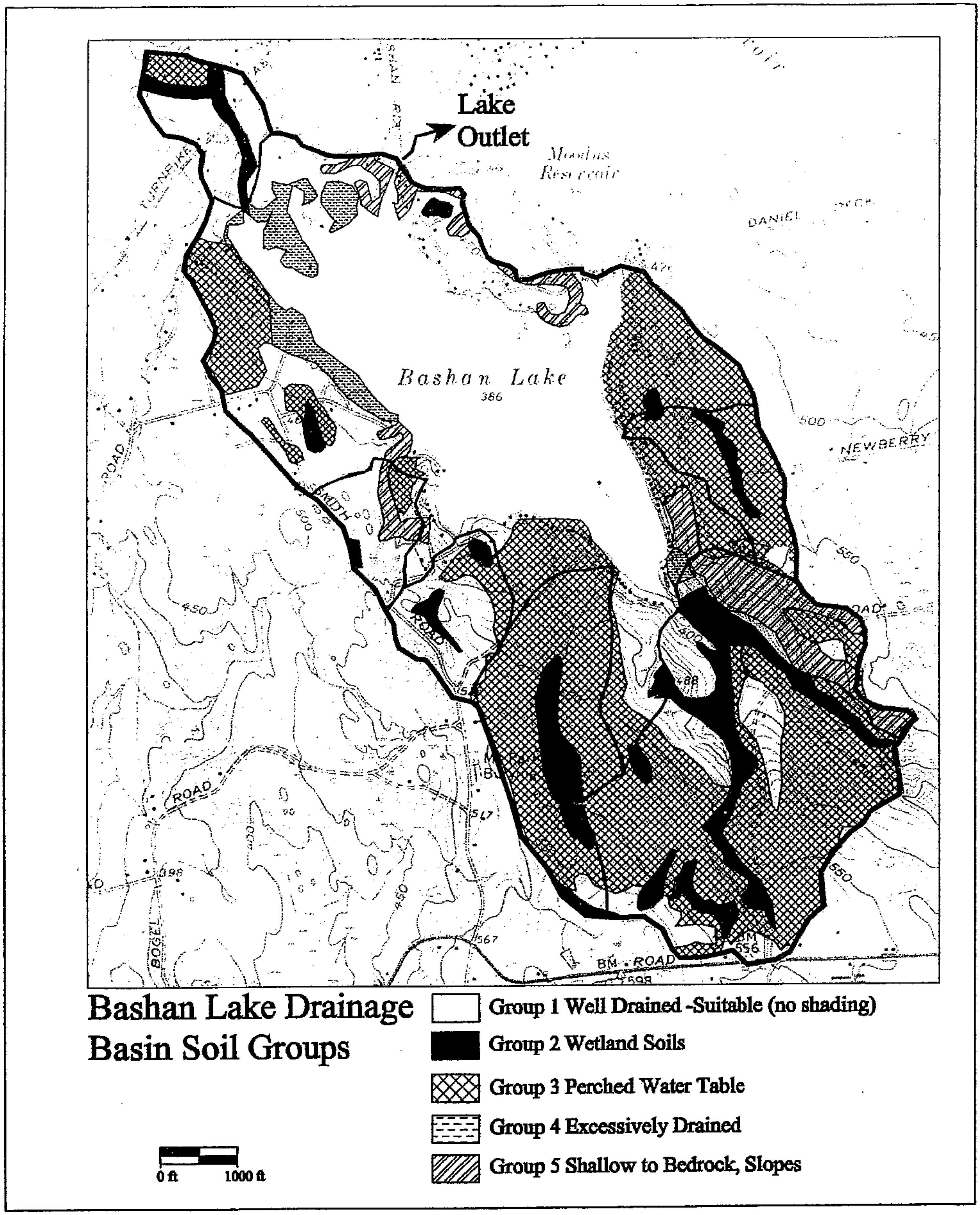
Sand Bars

Bathymetric Map From Jacobs and O'Donnell, 2002, DEP Bulletin #35

Map 6. General Land-use of Bashan Lake Drainage Basin



Map 7. General Soil Groups in Bashan Lake Drainage Basin.



LITERATURE CITED

Benson Environmental Inc. 1993. Nonpoint Source Pollution Watershed Study of Bashan Lake, East Haddam, CT. Clean Water Act Section 319, Connecticut Watershed Project. Newtown. CT.

Bugbee, G.J. and J. C. White. Control of Milfoil in Bashan Lake 2001, Connecticut Agricultural Experiment Station. New Haven. CT.

Bugbee, G.J. and J. C. White. Control of Milfoil in Bashan Lake 2002, Connecticut Agricultural Experiment Station. New Haven. CT.

Canavan, R.W.IV and P.A. Siver. 1995. Connecticut Lakes: A Study of the Chemical and Physical Properties of Fifty-six Connecticut Lakes. Connecticut College Arboretum. New London. CT

Chapra. S.C. 1975. Comment on 'An Empirical Method of Estimating the Retention of Phosphorus in Lakes' by W.B. Kirchner and P.J. Dillon. Water Resources Res. 2(6): 1033-1034

Connecticut Board of Fisheries and Game Lake and Pond Survey Unit. 1959. A Fishery Survey of the Lakes and Ponds of Connecticut. Hartford

Connecticut Department of Environmental Protection, 1982. A Trophic Classification of Seventy Lakes. CT DEP Bureau of Water Management. Planning and Standards Division. Hartford. CT

Connecticut Department of Environmental Protection, 1991. A Trophic Classification of Forty-nine Lakes. CT DEP Bureau of Water Management. Planning and Standards Division. Hartford. CT

Connecticut Department of Environmental Protection, 1991B. Lake Bashan Inflow Stream Water Quality Survey Data. CT DEP Bureau of Water Management. Planning and Standards Division. Hartford. CT

Deevey, E. S. Jr. 1940. Limnological Studies in Connecticut. Part V. A Contribution to Regional Limnology. Am Jour. Sc. Vol. 238. 717-741.

Frink, C.R. and W.A. Norvell. 1984. Chemical and Physical Properties of Connecticut Lakes. The Connecticut Agricultural Experiment Station. Bulletin 817. New Haven.

Kirchner, W.B. and P.J. Dillon. (1975). An Empirical Method of Estimating the Retention of Phosphorus in Lakes. Water Resources Res. 11: 182-183.

Jacobs, Robert P., and Eileen B. O'Donnell. 2002. A Fisheries Guide To Lakes And Ponds Of Connecticut. CT. Department of Environmental Protection. Bulletin #35.

Jones, J.R. and R.W. Bachmann. (1976). Prediction of Phosphorus and Chlorophyll levels in Lakes. J. Water Poll. Control Fed. 48: 2176-2182.

Siver, Peter A., Anne Marie Lott, Ethan Cash, Jamal Moss, and Laurence J Mariscano. 1999. Century Changes In Connecticut, U.S.A. Lakes As Inferred From Siliceous Algal Remains And Their Relationships To Land-Use Change. Limno. Oceanogr. 44:1928-1935.

U.S.D.A. Soil Survey of Middlesex County, Connecticut. Soil Conservation Service.

U.S. Fish and Wildlife Service. 1986. Habitat Suitability Index Models and Instream Flow Suitability Curves: Brown Trout. U.S. Dept. of the Interior. Biological Report #82 (10.124).

Vollenweider. R. A. (1975) Input-output Models, With Special Reference To The Phosphorus Loading Concept in Limnology. Schweiz. Zeit. Hydrol. 37: 53-84.

Appendix 1

Oxygen / Temperature Profiles

Each of the sheets shows the temperature and oxygen values recorded at each one-meter depth beginning at the surface, 0 meters, and ending at the bottom. The third column gives the calculated percent oxygen saturation value, based on the measured temperature and oxygen values at that depth. The fourth column shows the difference in the water density between each meter as calculated in Relative Thermal Resistance to Mixing a unit less number. The RTRM value is calculated using the following formula:

Water density at depth X – water density at depth X-1 (with depth in meters)/(1-0.9999919). Theses final values are the density of water at 4°C and 5°C respectively.

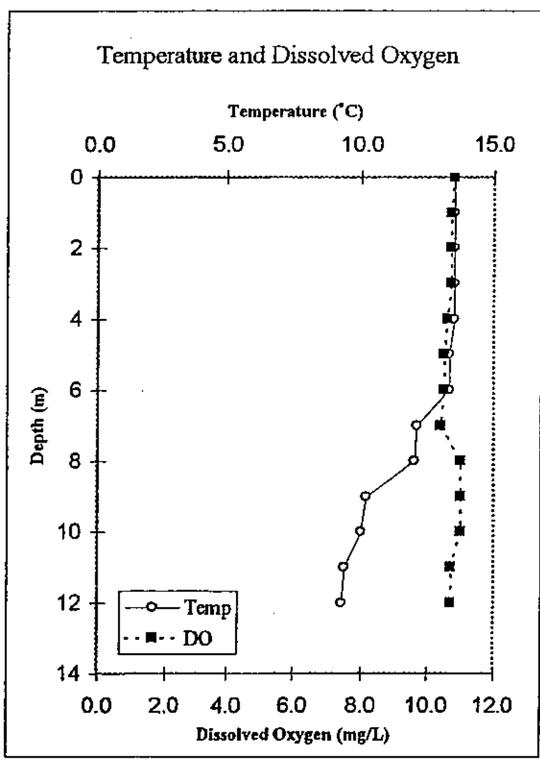
WATER COLUMN PROFILE DATA

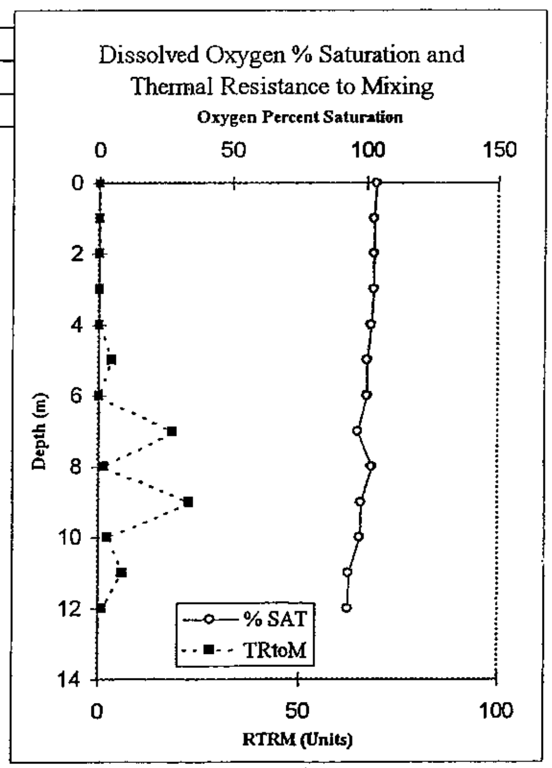
Bashan Lake *April 25, 2002*

Station #	Anoxic Boundary Location
1	none

Secchi Disk Depth (m)	Total Mixing Resistance
8.0	55

Water Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)	% Oxygen Saturation	Mixing Resistance
0	13.5	10.8	104	0
1	13.5	10.7	103	0
2	13.5	10.7	103	0
3	13.5	10.7	103	0
4	13.5	10.6	102	0
5	13.3	10.5	100	3
6	13.3	10.5	100	0
7	12.1	10.4	97	18
8	12.0	11.0	102	1
9	10.2	11.0	98	23
10	10.0	11.0	97	2
11	9.4	10.7	93	6
12	9.3	10.7	93	1





WATER COLUMN PROFILE DATA

Bashan Lake *May 28, 2002*

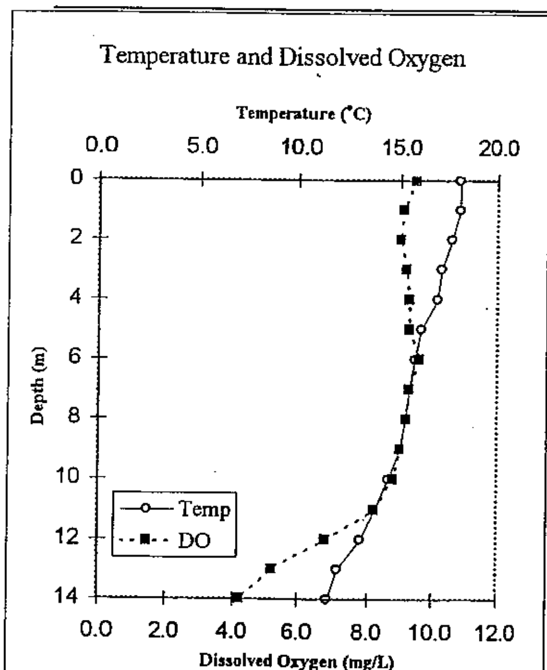
Station #
1

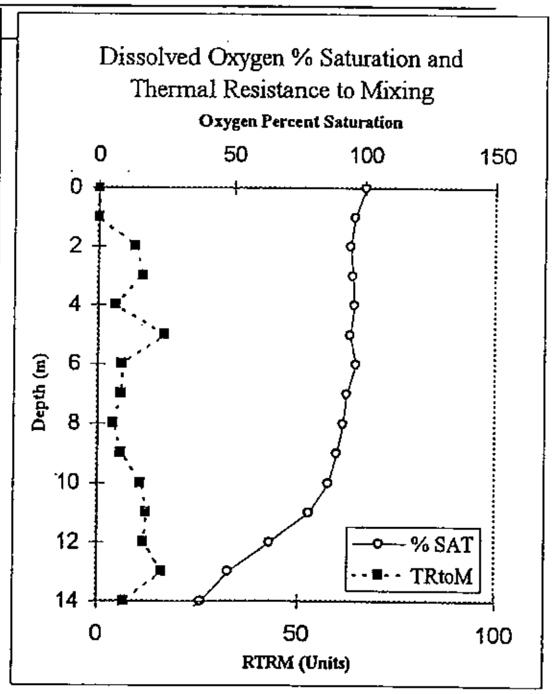
Anoxic Boundary Location
none

Secchi Disk Depth (m)
8.1

Total Mixing Resistance
122

Water Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)	% Oxygen Saturation	Mixing Resistance
0	18.0	9.5	100	0
1	18.0	9.1	96	0
2	17.6	9.0	94	9
3	17.1	9.2	95	11
4	16.9	9.3	96	4
5	16.1	9.3	94	17
6	15.8	9.6	97	6
7	15.5	9.3	93	6
8	15.3	9.2	92	4
9	15.0	9.0	89	6
10	14.4	8.8	86	11
11	13.7	8.2	79	12
12	13.0	6.8	65	11
13	11.9	5.2	48	16
14	11.4	4.2	38	7
14.5	11.2	3.5	32	3





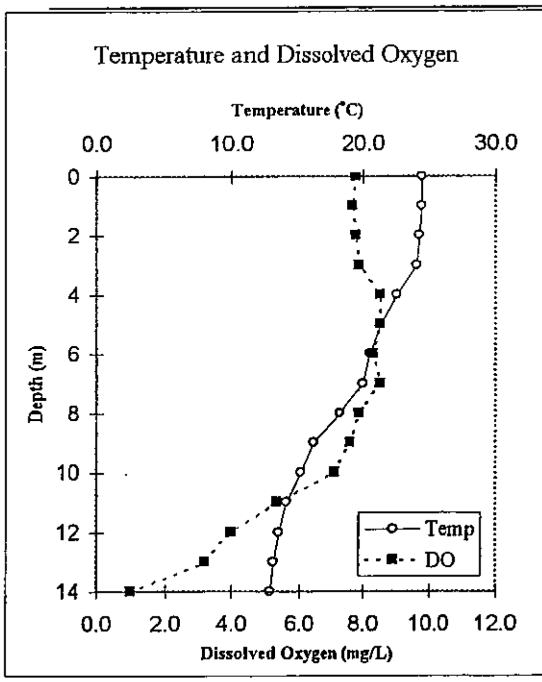
WATER COLUMN PROFILE DATA

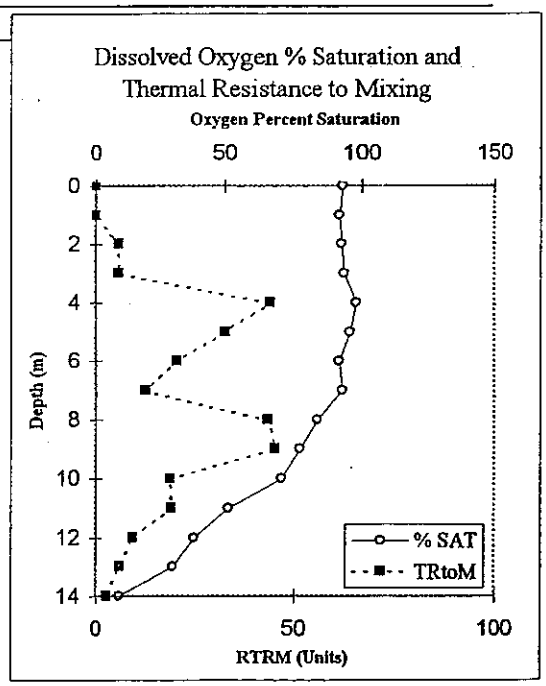
Bashan Lake *June 25, 2002*

Station #	Anoxic Boundary Location
1	14.0 meters

Secchi Disk Depth (m)	Total Mixing Resistance
7.0	272

Water Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)	% Oxygen Saturation	Mixing Resistance
0	24.4	7.8	93	0
1	24.4	7.7	92	0
2	24.2	7.8	93	6
3	24.0	7.9	94	6
4	22.5	8.5	98	44
5	21.3	8.5	96	33
6	20.5	8.3	92	21
7	20.0	8.5	93	13
8	18.2	7.9	84	44
9	16.1	7.6	77	45
10	15.1	7.1	71	19
11	14.0	5.3	51	20
12	13.4	4.0	38	10
13	13.0	3.2	30	7
14	12.8	1.0	9	3





WATER COLUMN PROFILE DATA

Bashan Lake *July 26, 2002*

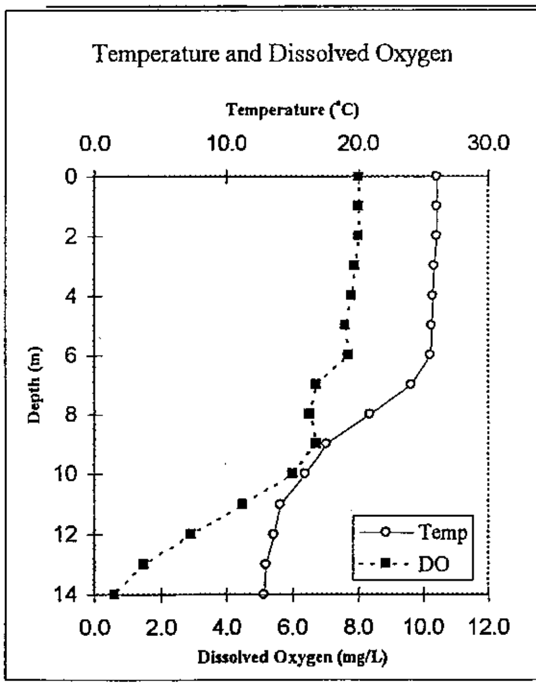
Station #
1

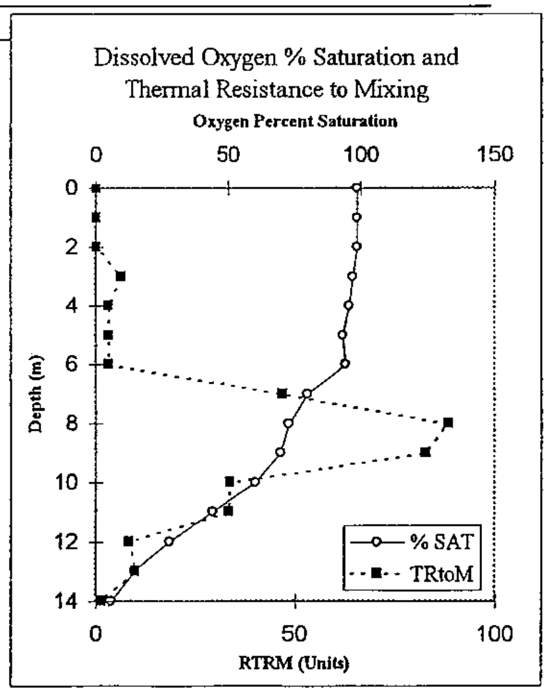
Anoxic Boundary Location
13.6 meters

Secchi Disk Depth (m)
5.5

Total Mixing Resistance
326

Water Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)	% Oxygen Saturation	Mixing Resistance
0	26.0	8.0	99	0
1	26.0	8.0	99	0
2	26.0	8.0	99	0
3	25.8	7.9	97	6
4	25.7	7.8	96	3
5	25.6	7.6	93	3
6	25.5	7.7	94	3
7	24.0	6.7	80	47
8	20.9	6.5	73	88
9	17.5	6.7	70	83
10	15.9	6.0	61	34
11	14.1	4.5	44	33
12	13.6	2.9	28	8
13	13.0	1.5	14	10
14	12.9	0.6	6	1
14.5	12.6	0.3	3	4





WATER COLUMN PROFILE DATA

Bashan Lake *August 22, 2002*

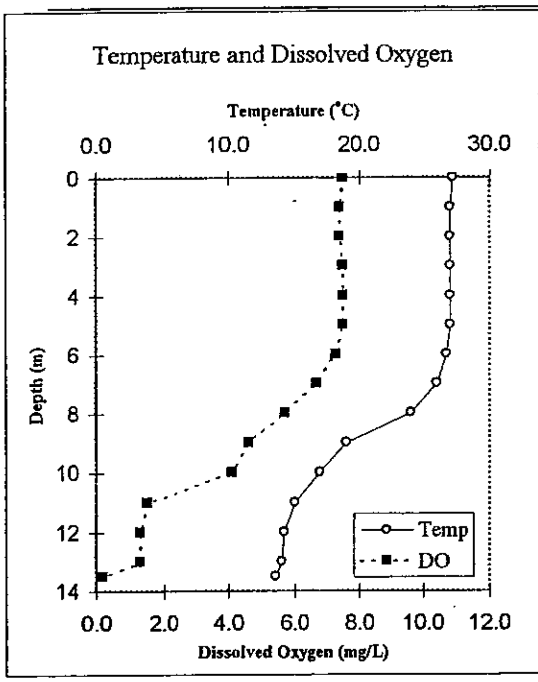
Station #
1

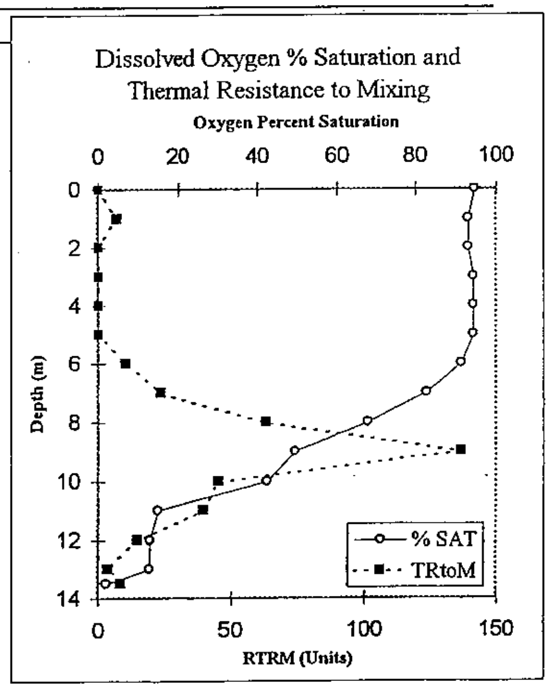
Anoxic Boundary Location
13.1 meters

Secchi Disk Depth (m)
8.5

Total Mixing Resistance
352

Water Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)	% Oxygen Saturation	Mixing Resistance
0	27.2	7.5	94	0
1	27.0	7.4	93	7
2	27.0	7.4	93	0
3	27.0	7.5	94	0
4	27.0	7.5	94	0
5	27.0	7.5	94	0
6	26.7	7.3	91	10
7	26.0	6.7	83	23
8	24.0	5.7	68	63
9	19.0	4.6	50	137
10	17.0	4.1	42	46
11	15.0	1.5	15	40
12	14.2	1.3	13	14
13	14.0	1.3	13	4
13.5	13.5	0.2	2	8





WATER COLUMN PROFILE DATA

Bashan Lake — *September 17, 2002*

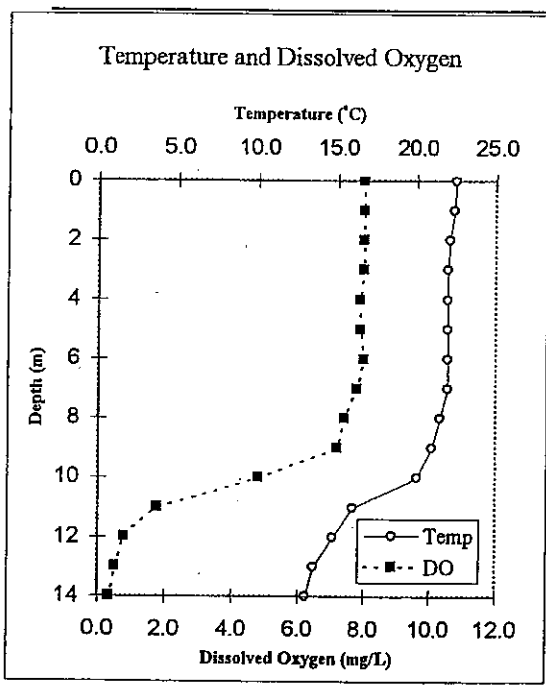
Station #
1

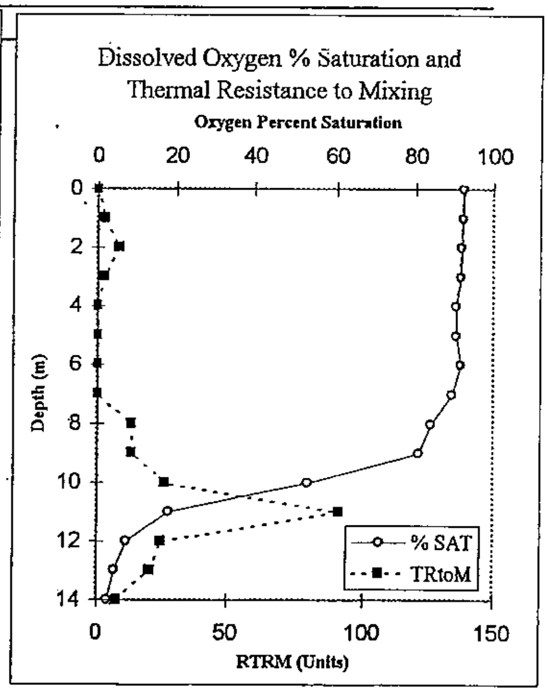
Anoxic Boundary Location
11.8 meters

Secchi Disk Depth (m)
8.5

Total Mixing Resistance
212

Water Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)	% Oxygen Saturation	Mixing Resistance
0	22.5	8.0	92	0
1	22.4	8.0	92	3
2	22.1	8.0	92	9
3	22.0	8.0	92	3
4	22.0	7.9	90	0
5	22.0	7.9	90	0
6	22.0	8.0	92	0
7	22.0	7.8	89	0
8	21.5	7.4	84	14
9	21.0	7.2	81	14
10	20.0	4.8	53	26
11	16.0	1.8	18	91
12	14.7	0.8	8	25
13	13.5	0.5	5	21
14	13.0	0.3	3	8
14.5	13.0	0.3	3	0





WATER COLUMN PROFILE DATA

Bashan Lake — *October 18, 2002*

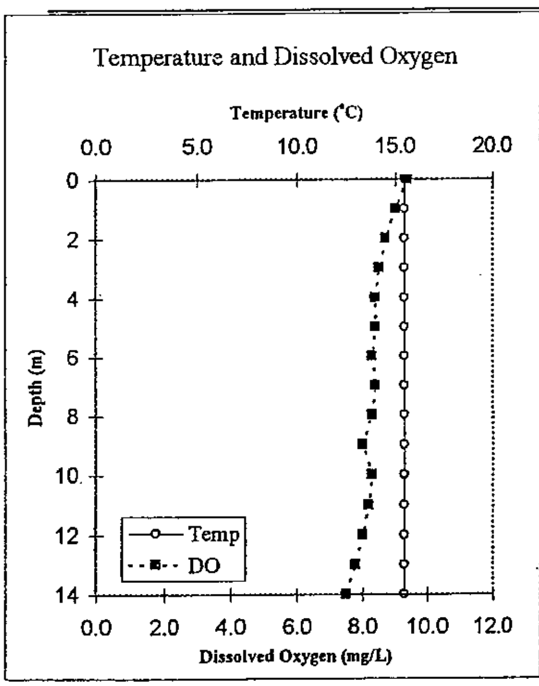
Station #
1

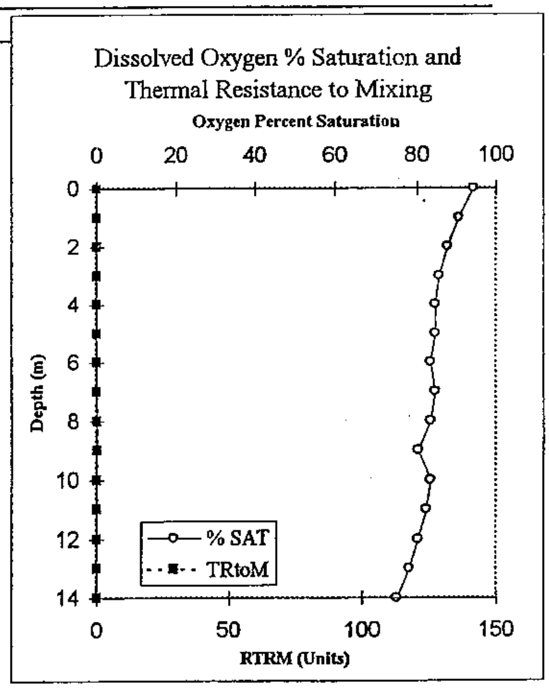
Anoxic Boundary Location
none

Secchi Disk Depth (m)
7.6

Total Mixing Resistance
0

Water Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)	% Oxygen Saturation	Mixing Resistance
0	15.5	9.4	94	0
1	15.5	9.0	90	0
2	15.5	8.7	87	0
3	15.5	8.5	85	0
4	15.5	8.4	84	0
5	15.5	8.4	84	0
6	15.5	8.3	83	0
7	15.5	8.4	84	0
8	15.5	8.3	83	0
9	15.5	8.0	80	0
10	15.5	8.3	83	0
11	15.5	8.2	82	0
12	15.5	8.0	80	0
13	15.5	7.8	78	0
14	15.5	7.5	75	0





Appendix 2

Water Testing Data

Total Phosphorus (ppb)							
Depth (m)	25-Apr	31-May	25-Jun	26-Jul	22-Aug	17-Sep	18-Oct
1	9	4	2	5	2	4	5
3	12	4	4	3	2	4	3
5	9	2	5	4	2	4	5
7	9	5	7	4	5	4	6
9	8	5	4	5	8	4	3
12	27	5	4	8	6	10	3

Ammonia Nitrogen (ppb)							
Depth (m)	25-Apr	31-May	25-Jun	26-Jul	22-Aug	17-Sep	18-Oct
1	16	15	0	0	0	10	24
3	24	18	0	0	0	11	18
5	18	17	0	0	0	12	19
7	17	26	0	43	0	12	24
9	13	27	19	101	102	21	24
12	62	44	60	120	190	177	24

Nitrate / Nitrite - Nitrogen (ppb)							
Depth (m)	25-Apr	31-May	25-Jun	26-Jul	22-Aug	17-Sep	18-Oct
1	< 20	< 20	< 20	< 20	< 20	< 20	< 10
3	< 20	< 20	< 20	< 20	< 20	< 20	< 20
5	< 20	< 20	< 20	< 20	< 20	< 20	< 20
7	< 20	< 20	< 20	< 20	< 20	< 20	< 20
9	< 20	< 20	< 20	< 20	< 20	< 20	< 20
12	< 20	40	79	34	< 20	< 20	< 20

TKN Nitrogen (ppb)							
Depth (m)	25-Apr	31-May	25-Jun	26-Jul	22-Aug	17-Sep	18-Oct
1	305	240	145	260	265	293	198
3	355	285	145	173	172	230	198
5	330	105	133	173	278	270	210
7	430	105	206	210	278	230	210
9	345	135	109	161	345	280	275
12	725	165	194	260	345	435	198

2002 Water Testing Data
IN-LAKE

Specific Conductance (umhos/cm)							
Depth (m)	25-Apr	31-May	25-Jun	26-Jul	22-Aug	17-Sep	18-Oct
1	72	73	73	75	77	70	74
3	73	73	74	76	77	73	75
5	73	73	73	76	77	73	75
7	73	73	72	76	77	73	75
9	73	73	72	73	75	74	75
12	73	74	74	75	77	75	76

Alkalinity (mg/L)							
Depth (m)	25-Apr	31-May	25-Jun	26-Jul	22-Aug	17-Sep	18-Oct
1	2	6	2	2	4	3	4
3	2	6	4	4	4	3	4
5	4	6	3	4	4	3	2
7	3	6	4	4	4	2	4
9	2	5	3	4	5	3	2
12	3	5	4	4	5	4	4

Turbidity (NTU)							
Depth (m)	25-Apr	31-May	25-Jun	26-Jul	22-Aug	17-Sep	18-Oct
1	0.45	0.8	0.46	0.45	0.45	0.5	0.7
3	0.5	0.45	0.5	0.6	0.45	0.6	0.8
5	0.35	0.5	0.6	0.8	0.45	0.6	0.6
7	0.4	0.6	0.7	0.7	0.6	0.3	0.6
9	0.4	0.35	0.7	0.9	0.7	0.6	0.6
12	0.8	0.35	0.4	0.9	0.45	2.2	0.5

Total Iron (mg/L)							
Depth (m)	25-Apr	31-May	25-Jun	26-Jul	22-Aug	17-Sep	18-Oct
1	< .05	< .02	0.021	0.04	0.05	< .02	0.08
3	< .05	< .02	< .02	0.05	0.035	< .02	0.11
5	< .05	< .02	< .02	0.06	0.029	0.035	0.12
7	< .05	< .02	< .02	0.04	0.08	0.034	0.13
9	0.07	< .02	< .02	0.03	0.046	0.032	0.1
12	0.06	0.027	< .02	0.15	0.11	0.43	0.13

pH							
Depth (m)	25-Apr	31-May	25-Jun	26-Jul	22-Aug	17-Sep	18-Oct
1				6.6	6.8	6.4	6.4
3				6.6	6.8	6.5	6.5
5				6.6	6.8	6.6	6.5
7				6.6	6.6	6.5	6.5
9				6.3	6.3	6.5	6.5
12				6.1	6.2	6.1	6.5

Hydrogen Sulfide (mg/L)							
Depth (m)	25-Apr	31-May	25-Jun	26-Jul	22-Aug	17-Sep	18-Oct
14				< .01		< .01	

Redox Potential (eH)							
Depth (m)	25-Apr	31-May	25-Jun	26-Jul	22-Aug	17-Sep	18-Oct
1	474	309	172	246	~	330	195
3	464	325	155	238	325	270	204
5	524	320	145	150	300	310	205
7	512	351	146	155	325	303	200
9	487	288	150	134	315	305	204
12	445	290	170	178	210	313	205

2002 Water Testing Data
STREAMS

Total Phosphorus (ppb)							
Depth	25-Apr	31-May	20-Jun	20-Jul	24-Aug	20-Sep	16-Oct
Launch	13	8	9			5	6
Sunset		8	13				7
North		1	4				
Laurel		1	1				2
Hidden		1	9				
Pasture							500
Sunset s		630					
Outlet		5	5				

Ammonia Nitrogen (ppb)							
Depth	25-Apr	31-May	20-Jun	20-Jul	24-Aug	20-Sep	16-Oct
Launch	< 10	13	20			<10	< 10
Sunset		< 10	82				< 10
North		< 10	13				
Laurel		< 10	< 10				< 10
Hidden		< 10	< 10				
Pasture							5,700
Sunset s		65					
Outlet		37	21				

Nitrate / Nitrite Nitrogen (ppb)							
Depth	25-Apr	31-May	20-Jun	20-Jul	24-Aug	20-Sep	16-Oct
Launch	< 20	46	58			< 20	< 20
Sunset		46	130				190
North		< 20	< 20				
Laurel		< 20	< 20				< 20
Hidden		< 20	< 20				
Pasture							800
Sunset s		685					
Outlet		< 20	< 20				

TKN Nitrogen (ppb)							
Depth	25-Apr	31-May	20-Jun	20-Jul	24-Aug	20-Sep	16-Oct
Launch	133	275	176			320	380
Sunset		131	176				163
North		52	88				
Laurel		52	< 50				81
Hidden		65	< 50				
Pasture							9,000
Sunset s		5,620					
Outlet		249	88				

Specific Conductance (umhos/cm)							
Depth	25-Apr	31-May	20-Jun	20-Jul	24-Aug	20-Sep	16-Oct
Launch	73	86	84			128	100
Sunset		103	111				176
North		94	95				
Laurel		102	96				50
Hidden		33	31				
Pasture							292
Sunset s		152					
Outlet		73	73				

Alkalinity (mg/L)							
Depth	25-Apr	31-May	20-Jun	20-Jul	24-Aug	20-Sep	16-Oct
Launch	3	6	1.5			3	2
Sunset		9	5				4
North		3	0				
Laurel		3	0				1
Hidden		4	0				
Pasture							59
Sunset s		26					
Outlet		4	0				

Turbidity (NTU)							
Depth	25-Apr	31-May	20-Jun	20-Jul	24-Aug	20-Sep	16-Oct
Launch	1.3	0.8	1.2			1.2	1.2
Sunset		0.45	0.2				0.6
North		0.17	0.35				
Laurel		0.22	0.25				0.45
Hidden		0.14	0.25				
Pasture							43
Sunset s		41					
Outlet		0.5	0.45				

pH							
Depth	25-Apr	31-May	20-Jun	20-Jul	24-Aug	20-Sep	16-Oct
Launch						5.7	5.6
Sunset							6
North							
Laurel							5.1
Hidden							
Pasture							7.2
Sunset s							
Outlet							

Temperature							
	25-Apr	31-May	20-Jun	20-Jul	24-Aug	20-Sep	16-Oct
Launch	8.0	17.3	19.2			18.2	11.0
Sunset		15.1	16.3				11.0
North		15.5	17.0				
Laurel		13.0	14.1				11.5
Hidden		14.2	15.5				
Outlet		19.1	24				

Dissolved Oxygen							
	25-Apr	31-May	20-Jun	20-Jul	24-Aug	20-Sep	16-Oct
Launch	10	7.0	8			6.9	7.2
Sunset		7.0	6.4				8.0
North		7.5	6.8				
Laurel		7.4	7				7.6
Hidden		8	8				
Outlet		8.8	7.8				

Appendix 3

CT DEP Lake Trophic Categories.

Category	T.P. (ppb)	T. Nitrogen (ppb)	Chlorophyll (ppb)	Secchi Depth (m)
Oligotrophic	0 - 10	0 - 200	0 - 2	6+
Oligo-mesotrophic	10 - 15	200- 300	2 - 5	4 - 6
Mesotrophic	15 - 25	300 - 500	5 - 10	3 - 4
Meso-eutrophic	25 - 30	500 - 600	10 - 15	2 - 3
Eutrophic	30 - 50	600 - 1000	15 - 30	1 - 2
Highly Eutrophic	50+	1000+	30+	0 - 1

Appendix 4

Phosphorus Loading Models

PHOSPHORUS LOADING INFORMATION

Bashan Lake

Existing Conditions

PARAMETER	English Units		Metric Units	
Lake Surface Area	**273**	**acres**	1,104,793	m^2
Littoral Area	**173**	**acres**	700,107	m^2
Profundal Area *(Too deep for weeds < 10 ft)*	**100**	**acres**	404,686	m^2
Lake Volume	**4,178**	**acre-ft**	5,155,652	m^3
Mean Depth	**15.3**	**feet**	4.67	m
Maximum Depth	**50.0**	**feet**	15.2	m
Watershed Area *(Total)*	**1,257**	**acres**	5,086,903	m^2
Epilimnion Sediment Area (A_e)	**80.0**	**acres**	323,749	m^2
Epilimnion Volume (V_e)	**1,217**	**acre-ft**	1,501,145	
$(A_e) / (V_e)$	**0.22**			
Watershed Area/Lake Area	**5**			
Lake/Watershed Area	**17.8**	**%**		
Mean Depth/Maximum Depth	**0.31**	**Ratio**		
Residence Time	**1.690**	**years**		
Depth / Residence Time	**3**	**m/yr**		
Flushing Rate	**0.59**	**times / year**	617	Days
Areal Water Load	**9**	**feet / year**	2.8	m / year
Inflow Rate	**2,472**	**acre-ft / year**	3,049,286	m^3 / year
Total Precipitation =	**47.2**	**inches**		
Effective Precipitation =	**23.6**	**inches**		
Outflow Rate =	**2,693**	**acre-ft / year**		
Total Precipitation on Lake Surface =	**1,074**	**acre-ft / year**		
Net Precipitation on Lake Surface =	**221**	**acre-ft / year**		
Spring Total Phosphorus Concentration (STP)			**9.0**	**ppb**
Predicted Load from Observed STP			**0.12**	**g P m^{-2} yr^{-1}**
Areal Water Load			**2.8**	**m / yr**
Morphometry Data From: Jacob and O'Donnell 2002				
Total Precipitation =	47.20	inches		ASSUMED
Effective Precipitation =	23.60	inches		ASSUMED
Average Evaporation =	37.50	inches		ASSUMED

EUTROPHICATION MODELS

Bashan Lake — Existing Conditions

Variables and Constants	Value	Symbol	Units
Spring Total Phosphorus Concentration	**9.0**	**TP**	**mgP/m^{-3}**
Mean Depth	4.67	-z-	m
Flushing Rate	0.59	F	times/year
Areal Water Load (-z- * F)	2.76	qs	m/year
Retention Coefficient (Kirchner Dillon)	0.83	Rp	
Retention Coefficient (Vollenweider)	2.14	S	
Retention Coefficient (Chapra)	0.85	R	

MODEL 1 Kirchner and Dillon 1975 (Water Resources Res. 2(1): 182-183)

Prediction of annual phosphorus load from; Spring Total Phosphorus Concentration (TP), Mean Depth (-z-), Flushing Rate (F), and Retention Coefficient (Rp)

L = TP (-z-) (F) / (1-Rp) ... where TP is Obs 9 mg P / m^3.

Predicted L = **0.14** g P / square meter / year

Predicted TP Load 159 kg/year

MODEL 2 Vollenweider 1975 (Sch. Zeit. Hydrol. 37: 53-84)

Prediction of annual phosphorus load from; Spring Total Phosphorus Concentration (TP), Mean Depth (-z-), Flushing Rate (F), and Retention Coefficient (S)

L= TP * (-z-(S+F))

Predicted L= **0.11** g P / square meter / year

Predicted TP Load= 127 kg/year

MODEL 3 Jones and Bachmann 1976

Prediction of L from TP, -z-, F, and S:

L= TP * (-z-(S+F)) S=0.65

Predicted L= **0.05** mg P/square meter / year

Predicted TP Load= 58 kg/year

MODEL 4 Chapra 1975 (Water Resources Res. 2(6): 1033-1034)

Retention Coefficent (R), Mean Depth (-z-) and Retention Coefficent (S)

L = (TP)(-z-)(F) / (1-R)

Observed TP= 9 mg P / m^3

Predicted L= **0.17** mg P/square meter/year

Predicted TP Load= 187 kg/year

SUMMARY OF EMPIRICAL MODEL RESULTS

	Load from Observed Spring TP	
	gp/m^{2}yr^{-1}	kg/year
Model 1	0.144	159
Model 2	0.115	127
Model 3	0.052	58
Model 4	0.169	187
MEAN	**0.120**	**132**