ESS

ENVIRONMENTAL SCIENCE SERVICES, INC.

ENVIRONMENTAL SCIENTISTS, ENGINEERS, AND PLANNERS

A NUTRIENT AND LIMNOLOGICAL INVESTIGATION OF LAKE BOON
Hudson/Stow, Massachusetts

Prepared For: **Lake Boon Commission**
16 Gately Avenue
Hudson, Massachusetts 01749

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Project No.: **L090**

Date: **March 31, 1999**

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A NUTRIENT AND LIMNOLOGICAL INVESTIGATION OF LAKE BOON HUDSON/STOW, MASSACHUSETTS EXECUTIVE SUMMARY

Environmental Science Services, Inc. (ESS) conducted a nutrient and limnological investigation of Lake Boon and the watershed draining into the lake during the summer and fall of 1998. The primary goal of this investigation was to determine the relative contribution of various nutrient sources to the lake. A second goal was to accurately assess Lake Boon's current water quality for the purpose of comparison to previous studies that were conducted during the past 20 years. The most recent data consists of limited water quality information gathered in 1997; the last full study of the lake was conducted in 1987. The information gathered was used to provide viable management alternatives and associated costs for improving the quality of the lake. A lake and watershed management plan has been prepared for the Lake Boon Commission.

The physical, chemical, and biological characteristics of the lake were assessed and the hydrologic and pollutant contributions from the watershed were monitored. The lake is comprised of three main basins that are physically distinct but hydrologically interconnected by narrow passageways. Portions of Lake Boon are deep and relatively free of aquatic plants while other areas of the lake are very shallow, full of organic sediments and dominated by invasive plant species at nuisance levels. The lake has no permanent tributaries; however, three small intermittently flowing tributaries deliver surface water to the lake during wetter periods and following larger storm events. These tributaries drain a mixture of primarily forest, wetland, and residential land. In addition to these main tributaries, Lake Boon also receives a significant amount of storm water runoff as sheet flow and from storm drains serving roads and residential areas adjacent to the lake. Surface water inputs in response to storms comprise nearly 50 percent of the annual water load, while surface water inputs during dry weather account for less than 12 percent of annual water input.

Phosphorus is believed to be the nutrient that controls primary productivity in this system. Phosphorus concentrations in the main tributary (the only tributary that flowed during the study) are relatively low during dry weather but high to extremely high during storms. This tributary is believed to be representative of other wet weather contributions, underscoring the importance of runoff to total nutrient loading. Phosphorus contributions from groundwater represent an additional source of nutrients to Lake Boon. Groundwater flow to the lake was determined to be approximately 23 percent of total water input on an annual basis. Groundwater sources were determined to be delivering nearly 10 percent of the total phosphorus load to the lake. These and other nutrient sources to the lake were modeled to predict a total phosphorus load to the lake of 186 kg/yr. This phosphorus load is above the permissible phosphorus load of 151 kg/yr and indicates that water quality impacts are likely to occur on a regular basis, particularly during extended dry periods when the effect of these nutrients will be fully expressed.

In addition, particularly high levels of nitrogen found in the organic bottom sediments in this relatively shallow system appear capable of supporting a dense rooted plant community, and nuisance growths are severe throughout a significant portion of the lake. Both native and non-native plant species achieve excessively high densities throughout the southern and eastern basins of the lake. The rooted species, fanwort and water milfoil, and the small floating species, duckweed and watermeal, are the primary problem plants, achieving great densities over more than 50 percent of the total lake area and impairing both habitat value and recreational use of the lake. Growths of these plants accelerate the sedimentation process, thereby increasing buildup of sediment and associated nutrient reserves in the lake. The buildup, in turn, facilitates further plant growth and can negatively impact water quality as these nutrients are released to the water column. This cycle of productivity cannot be broken by watershed management alone. Management will also need to include some form of in-lake remediation to address the existing plant growth and the accumulation of soft sediment.

Although, management goals should be discussed further among Town officials, the Lake Boon Commission, and members of the community, to date, perceived needs have been developed into the following four objectives:

1. Reduce aquatic plant growths to levels appropriate for habitat, recreational use, and safety considerations.

2. Minimize impacts from watershed activities with the goal of improving in-lake water quality and protecting future water quality.

3. Curtail excessive sediment, nutrient and related pollutant inputs associated with storm events, thereby improving aquatic conditions and maintaining acceptable water quality.

4. Establish a cost-effective monitoring program that provides early warning of potential problems and that tracks the progress of any implemented management measures in achieving stated goals.

Lake and watershed management options have been reviewed in light of these objectives. The vascular plant community of the lake would best be managed through chemical treatment with the herbicide fluridone. Chemical treatment is not the best option for long-term control but may be the most cost effective and appropriate means by which to achieve the goal of reducing aquatic weed biomass in Lake Boon over the short term. The results of this treatment could be maximized with a limited (2-4 foot) annual drawdown to maintain open areas in shallow coves and along shorelines. Water level control hinges on the status of the outlet structure, and further inspection of this structure is needed. Education of watershed residents regarding their influence on water quality and implementation of simple management practices that could be developed and distributed as a brochure may sufficiently reduce pollutant loading to Lake

Boon. These behavioral modifications could be enough to lower phosphorus loading below the permissible load of 151 kg/yr.

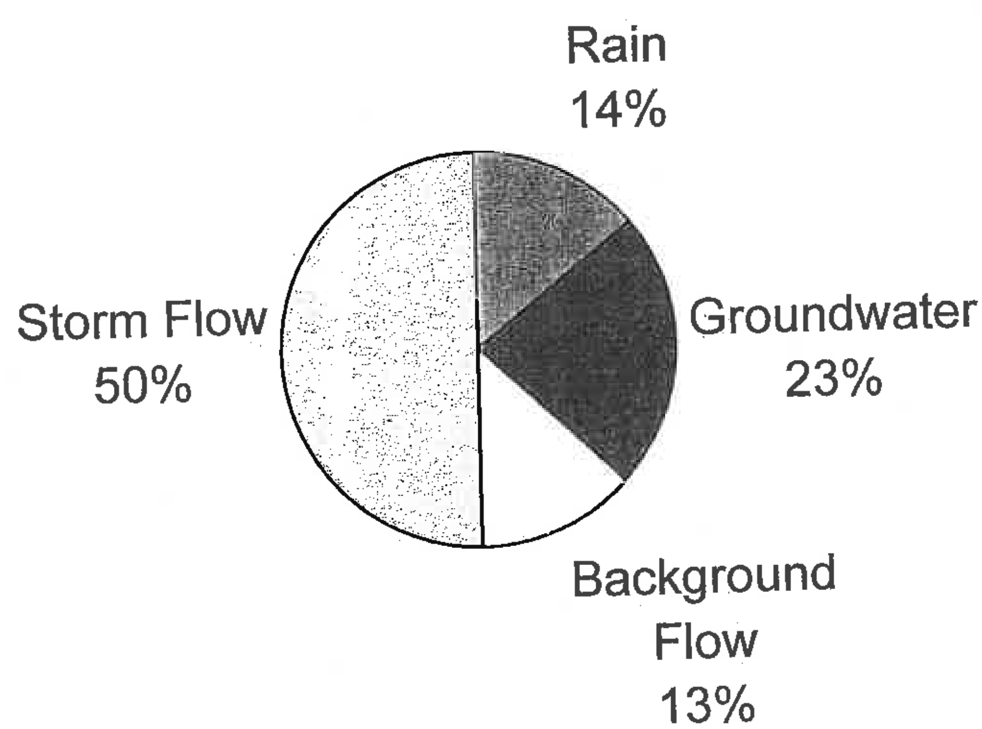
Costs for these management program elements will depend upon their level of application. Chemical treatment of Lake Boon with fluridone could cost as much as $40,000 and would need to be repeated at least every three years. An additional $2,000 is likely for permitting this action. Drawdown costs are likely to be negligible once initiated and could be performed as maintenance on an annual basis. An initial investigation of a 2 foot trial drawdown is recommended ($10,000) to determine the impact on shallow wells near the lake shore. Initial permitting costs for the drawdown would be on the order of $4,000. Watershed management actions will carry highly variable costs ranging from relatively small out-of-pocket costs by homeowners for increased treatment system pumping, to over $5,000,000 to construct sewer lines. An educational brochure for watershed residents could be prepared for approximately $3,000 describing actions that should be taken at the local level.

At this time, a short-term program is recommended to meet the stated objectives. The short-term program addresses all of the above-described objectives for the lowest overall cost. An overall cost for the short-term program on the order of $60,000 is envisioned. In addition, the short-term program could be initiated immediately. The program would focus on the control of plant growth through herbicide application and drawdown. At this time only minor improvements in water quality are required and these may be achieved through the distribution and implementation of actions described in an educational brochure.

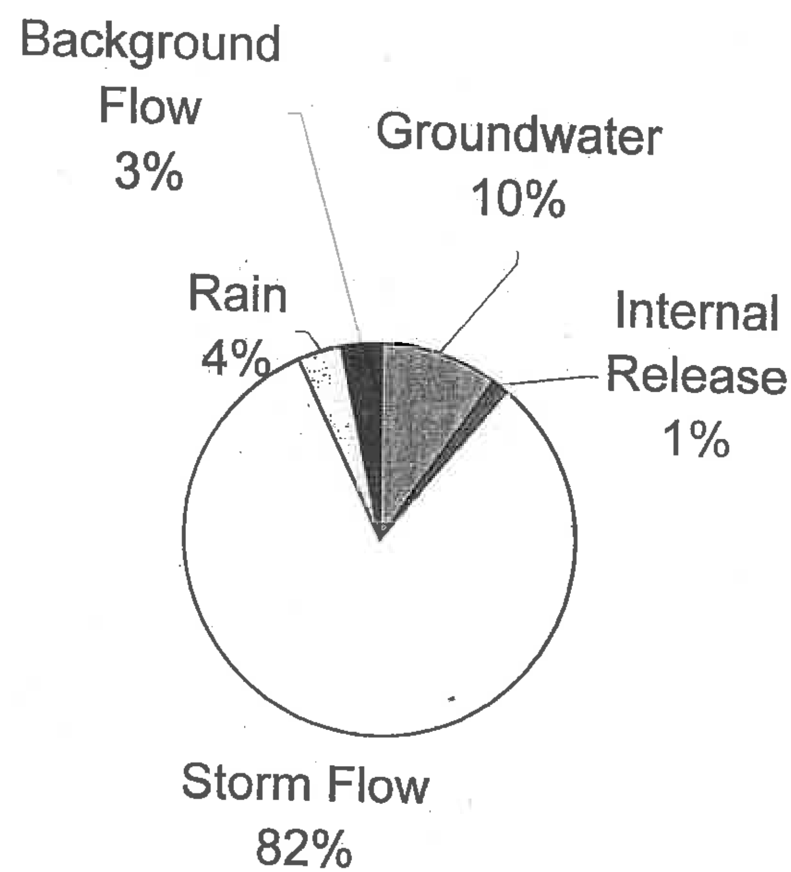
Once the short-term program has been implemented, it will be beneficial to establish some form of annual monitoring to assess its effectiveness and to establish a database for the lake and incoming waters. This will allow tracking of management progress and provide warning of potential problems. The associated expense is minimal ($6,000/yr) by comparison with management costs.

Chemical treatments and annual drawdowns may be the most efficient means for reducing plant densities in Lake Boon; however, dredging of selected portions of the lake would be beneficial over the long-term. Similarly, if annual monitoring indicate that the pollutant load to the lake has not been sufficiently reduced through the behavioral modifications outlined in the educational brochure, additional actions will be required. Although not warranted at this time, these additional actions (the long-term program) may include the creation of storm water detention facilities to intercept storm water runoff from the tributaries and any future development in the watershed, and could potentially include the installation of sewer lines. Costs for this long-term program would be on the order of $7,000,000, but could be implemented incrementally, as funding becomes available.

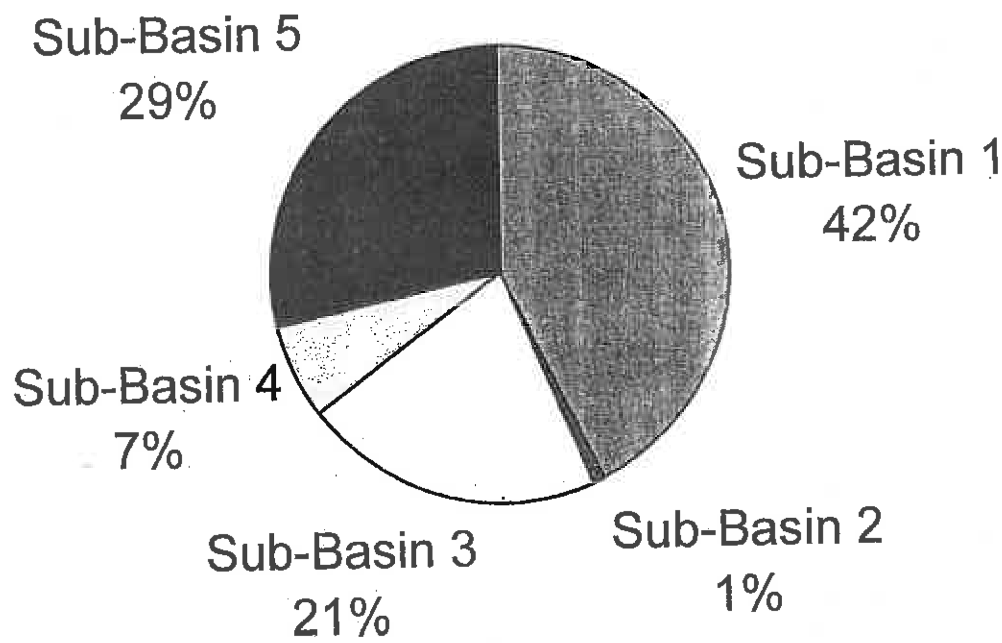
Annual Hydrologic Load to Lake Boon



Annual Phosphorus Load to Lake Boon



Expected Phosphorus Load to Lake Boon by Sub-Basin



A NUTRIENT AND LIMNOLOGICAL INVESTIGATION OF LAKE BOON HUDSON/STOW, MASSACHUSETTS

1.0 INTRODUCTION

Concern over plant nuisances and a perceived decrease in water clarity prompted the initiation of a nutrient and limnological investigation of Lake Boon. Environmental Science Services, Inc. (ESS) conducted the study of Lake Boon during the summer and fall of 1998. This investigation included an evaluation of watershed features as well as physical, chemical and biological features of the lake. The purpose of this investigation was to accurately assess Lake Boon's hydrologic and nutrient budgets, water clarity, and aquatic plant growth in order to provide viable management alternatives and approximate cost estimates for improving the quality of the lake. A lake and watershed management plan has been prepared for the Lake Boon Commission.

2.0 STUDY APPROACH

Background data and general lake and watershed information were compiled from existing sources and reviewed. Water depth was measured along transects to enable depth contours within each basin to be drawn. In-lake surface water quality monitoring stations were chosen and water quality was monitored in July, August, and September to assess differences in the chemical (alkalinity, total phosphorus, nitrate nitrogen, total Kjeldahl nitrogen, fecal coliform, turbidity, pH, conductivity, dissolved oxygen, and temperature) quality of water during dry and wet weather situations. Quantitative and qualitative ground water seepage characteristics were also assessed by the methods of Mitchell et al. (1988, 1989). Water quality information provides insight into potential sources and the degree of pollutant loading to the system. While longer- term (multiple years) measurement is desirable, this brief investigation provides sufficient data to make reasonable assumptions regarding pollutant inputs and in-lake water quality.

Hydrologic loading was determined using estimated values based upon watershed and lake features. Nutrient budgets were determined using a minimum load calculation as well as by using several models based upon system hydrology and in-lake nutrient concentrations. Nutrient loading was further categorized by itemizing various inputs to the lake from available data.

Diversity, distribution and abundance of the aquatic plant community were measured by surveying along lines transecting the lake. The information compiled during the survey was used to generate maps depicting area, location and species composition of major weed beds.

The fish and wildlife community occurring in and around the lake was documented throughout the course of the study to assess the potential impacts that may occur as a result of any proposed management options.

An evaluation of human impacts to Lake Boon was made through the use of questionnaires distributed to watershed residents and through boat activity monitoring during the summer months. Much of the information collected was due to the efforts of the Friends of Lake Boon organization.

3.0 STUDY RESULTS

3.1 Historical Background

A review of management actions and previous investigations performed at Lake Boon was conducted by ESS. Literature reviewed included records from the Massachusetts Division of Fish and Wildlife and studies performed by the Massachusetts Division of Water Pollution Control (DWPC) and various environmental consultants. These investigations characterized Lake Boon as a mesotrophic to eutrophic lake (CDM 1987, Notini and Morrison 1980) mainly due to summer dissolved oxygen depletion at the bottom of the deeper basin (Basin 1), extensive macrophyte growth and algal densities, and high nutrient concentrations. Throughout its history, Lake Boon has served an important recreational role in the community, consequently the lake has been subject to extensive residential development along its shoreline. As a result of its value to the community, the lake has been studied extensively over the years. Reports of deteriorating water clarity and increasing plant growth, particularly fanwort (*Cabomba caroliniana)*, were documented in the lower basins in the 1950's. A more recent concern has been the frequent occurrence of algal blooms, most notably the persistent bloom that occurred during the summer of 1989. Previous reports have cited septic systems, stormwater runoff, lawn fertilization, and increased recreational use as sources of nutrients to the lake.

3.2 Watershed Features

A United States Geological Survey (USGS) topographical map was used to identify the watershed of Lake Boon (Figure 1). The watershed map was further divided into watershed sub-basins to allow management to be targeted to specific areas of concern.

Lake Boon and its watershed are located within the Towns of Stow and Hudson. Previous studies have included White Lake within the Lake Boon watershed; however, with respect to hydrologic and nutrient loading it is unlikely that this lake has a significant influence on water quality in Lake Boon. This study has focused on five major sub-basins encompassing a total watershed area of approximately 1,076 acres (Table 1). The watershed of Lake Boon is approximately 6 ½ times the size of the lake's three basins (161 acres).

Watershed sub-basin 1 is the largest sub-basin, draining approximately 320 acres via sheet flow and groundwater infiltration. Sub-basin 4 is the second largest sub-basin draining nearly approximately 267 acres via the unnamed tributary flowing into the southern cove of the lake. The remaining three sub-basins drain to Lake Boon predominantly through small intermittent tributaries, sheet flow, and groundwater infiltration. Sub-basin 5 is the largest of these sub-basins (132 acres) and is located along the western shore of the lake. Sub-basins 2 and 3 are approximately 84 and 112 acres respectively.

Major land uses within the watershed were identified using Massachusetts state databases presented in Graphical Information System (GIS) format (Figure 2) which were field checked to ensure reliability. Nearly 64 percent of the watershed land is forested, while roughly 28 percent of the watershed is allocated to residential development. Other major land uses in the Lake Boon watershed include industrial (4 percent), commercial (3 percent), and agricultural (1.6 percent). The residential development is heavily concentrated along the lake's shoreline and is distributed fairly evenly among all five sub-basins. Industrial and commercial development is located mainly within sub-basins 4 and 5, and agricultural land is predominantly located in sub-basins 1 and 2.

Information on the distribution and classification of soils within the Lake Boon watershed has been discussed in previous reports (CDM 1987, Notini and Morrison 1980). Generally, this region consists of fine, sandy loam soils at the surface of gently sloping land with bedrock outcrops common on steeper slopes. These soils are well-drained to excessively drained (Notini and Morrison 1980). Also common are sandy or gravelly soils, which tend to be found in valleys, and level or rolling terraces (Notini and Morrison 1980). The last dominant soil is best described as mucks consisting of nearly level, deep, very poorly drained organic soils in depressions of uplands and glacial outwash plains and terraces. These deep, black, highly decomposed materials have moderate permeability with the water table at or near the surface most of the year.

Increases in the percentage of the developed land in a watershed are likely to increase the potential for significant impacts on lake water quality, although the nature of the associated soils and drainage systems will temper this effect. As a significant portion of the watershed is not fully developed there is potential for further development of the watershed into residential, commercial and/or industrial areas.

3.3 Lake Features

3.3.1 Physical Characteristics

Lake Boon can be divided into three basins for discussion purposes (Figure 3). Basin 1 is the deepest and northernmost of the basins. Basin 2 commences where Basin 1 begins to narrow and continues until the next major constriction in the lake. Basin 2 is of intermediate depth and is located centrally in the lake. Basin 3 is located on the easternmost part of the lake and consists of three major branches that are extremely shallow. The third basin reportedly was not part of the original lake, but was created by flooding wetlands when the water level was raised in the 1800's (CDM 1987). Lake Boon has an area of approximately 161 acres and receives its supply of water from small inlet streams, groundwater, overland runoff from lakeshore areas, piped storm drainage, and direct precipitation. The main tributary enters the lake on the south side of Basin 2. Two other intermittent tributaries enter the lake at the east end of Basin 3 (Figure 3). Lake Boon has one main outlet at the western most part of Basin 1. The outlet empties into Bailey Brook which in turn empties into the Assabet River.

Flows to the lake from the tributary in Basin 2 were measured during both wet weather and dry weather conditions. Flows to the lake from this tributary (LB-T) ranged between 0.01 and 1.0 cfs with an average flow rate of approximately 0.4 cfs during the period of this study. Storm drains located within Lake Boon's watershed discharge directly into the lake; however, the outlet pipes for most of these drains were not readily accessible for direct monitoring. Several storm drains discharge into the two minor tributary systems prior to discharging to the lake. This discharge did not enter Lake Boon since these tributaries were not flowing during the study period.

Water and soft sediment depth were measured throughout the lake along 18 transects (Figure 4, Table 2). Lake Boon had a maximum water depth of over 21 feet in Basin 1 (Table 2) with a mean water depth of nearly 10.8 feet (Table 3). Moderately to steeply sloped bottom contours occur throughout the lake, with maximum depth achieved in the northern portion of the lake (Basin 1) (Figure 5). The lake has been determined to have a total volume of over 75 million cu. ft. of water (Table 3). Most sediment was comprised of sand and gravel substrate. Soft sediment depth was measured in Basin 3 where it reached a maximum of approximately 5.5 feet (Table 2), with an average soft sediment depth of over 3.2 feet.

3.3.2 Chemical Characteristics

3.3.2.1 Surface Water Analysis

Water quality was monitored at two in-lake stations (LB-1 and LB-2) and in the main tributary to the lake (LB-T), (Figure 6). In-lake samples were collected during July, August, and September. The main tributary was sampled during July, August, September, and October three times during dry weather and twice during storm flow conditions. Parameters examined included, total phosphorus, dissolved phosphorus, nitrate nitrogen, ammonium nitrogen, total Kjeldahl nitrogen, total alkalinity, total suspended solids, fecal coliform, turbidity, pH, conductivity, dissolved oxygen, percent oxygen saturation, secchi depth, and temperature (Tables 4 and 5).

Stormwater sampling of the tributary was conducted to capture first flush storm water conditions. Samples were collected on August 24, 1998 when a rainfall event of 0.36 inches followed a 6 day dry period and on October 8, 1998 when a rainfall event of 2.70 inches followed a 7 day dry period. These samples were analyzed for the parameters described above (Tables 4 and 5).

Results and major trends from the current water quality monitoring program are summarized below for each parameter. Comparisons were made between this study and historical data by calculating the average for each parameter over similar seasonal time periods and from similar sampling locations.

Dissolved oxygen and temperature
Dissolved oxygen is the amount of molecular oxygen (O_2) dissolved in water. Dissolved oxygen below 5 mg/L is generally considered unsuitable for many forms of aquatic life. Additionally, release of phosphorus from bottom sediments can often be a problem under anoxic (no oxygen) or very low oxygen (<1.0 mg/L) conditions. Dissolved oxygen at the surface for the in-lake monitoring stations (LB-1 and LB-2) ranged between 7.2 mg/L and 8.8 mg/L (Table 4) indicating well-oxygenated conditions. However, low levels of dissolved oxygen were documented in the deeper portions of Lake Boon in July, August and September (Table 4). It is unlikely that a significant release of phosphorus was actually occurring since the phosphorus content of the deeper lake sediments was not at a detectable level (see Section 3.3.2.2).

Dissolved oxygen and temperature profile data for the two in-lake stations are presented in Table 6a and 6b. Dissolved oxygen levels in Basin 1 decrease between the depths of 4 and 5 meters during July and August and between 6 and 6.5 meters below the surface in September. The thermocline (zone where temperature dramatically changes) occurs between 3 and 4 meters below the surface in July and between 4 and 5 meters below the surface in August. In September, the water column was completely mixed and no thermocline was present. Summer temperature stratification and low levels of oxygen do not occur in Basin 2 because it is shallower and therefore fairly well mixed (Table 6a and 6B). Previous studies of Lake Boon also reported low levels of oxygen in the deeper portions of Basin 1 during the summer (CDM 1987, Notini and Morrison 1980) (Appendix A).

Conductivity
Conductivity measures the resistance of a solution to electrical flow and can be used as an indirect measure of dissolved solids in water. Conductivity values in Lake

Boon ranged from 72 to 151 μmhos at the two in-lake stations and from 16 to 147 μmhos in the major tributary. These values are low to moderate and are in a similar range to those levels measured in previous studies (CDM 1987, Notini and Morrison 1980) (Appendix A). The conductivity levels measured in 1998 and historically in Lake Boon are low compared to other Massachusetts lakes (CDM 1987).

Turbidity

Turbidity is an indirect measure of the quantity and size of particles in a water sample. Turbidity values less than 10 NTU are generally assumed to have minimal impact on habitat and biota. Turbidity values observed at the two in-lake monitoring stations averaged 2.0 NTU while turbidity values recorded at the tributary monitoring stations averaged nearly 0.3 NTU during dry weather sampling and 14.7 NTU during wet weather sampling. The high average turbidity values in the tributary during wet weather sampling are mainly due to the August 24, 1998 sampling that yielded a turbidity value of 26.4 NTU. In contrast, on October 8, 1998 turbidity was measured as 3.0 NTU in the tributary during storm flow conditions. These wet weather turbidity results are significantly higher than previous measurements of turbidity (CDM 1987, GSC 1997a) (Appendix A); however, the historical studies may not have sampled turbidity during wet weather storm flow conditions. Results from this study indicate that under some storm flow conditions, turbidity values can exceed the critical value of 10 NTU.

Fecal coliform

Fecal coliform was measured as <10 colonies/100 mL at both in-lake stations for all sample dates and ranged from 30 colonies/100 mL to 680 colonies/100 mL at the tributary station (LB-T). Fecal coliform values averaging less than 200 colonies/100 mL is the state standard set for contact recreation. Consequently, water quality in Lake Boon is capable of supporting the desired forms of recreation. Although the tributary seems to contribute high concentrations of fecal coliform especially during storm flow events, fecal coliform concentrations are most likely rapidly diluted once the storm flow reaches the lake. Historic water quality data from 1979 reported higher fecal coliform concentrations in the lake and tributary compared to values measured during this study (Appendix A). It is not possible to determine whether fecal coliform values are truly lower than was historically observed based on the limited data set and wide variations in fecal coliform values.

Alkalinity

Alkalinity is a measure of the ability of water to neutralize acids. Waters with an alkalinity >25 mg/L are generally not susceptible to acid precipitation. In addition, the Environmental Protection Agency recommends a total alkalinity value of 20 mg/L as CaCO3, or more for maintenance and propagation of freshwater aquatic life, except where natural concentrations are less (U.S. EPA 1976). Alkalinity values at both of the in-lake monitoring stations were low, ranging between 10 mg/L and 20 mg/L. These values are generally in the same range as alkalinity values reported in previous studies (CDM 1987, Notini and Morrison 1980) (Appendix A). Values measured at the tributary monitoring station were also low, ranging from 3 mg/L to 7 mg/L. These low alkalinity values measured at the in-lake and tributary stations indicate that Lake Boon and its major tributary have relatively low buffering capacity (ability to withstand acid inputs). Therefore, Lake Boon and its tributary cannot easily resist changes in pH and may be susceptible to pH changes over time. The alkalinity levels in the lake and tributary are most likely a natural result of soil and bedrock characteristics within the watershed.

Water Transparency and Total Suspended Solids

Water transparency in Lake Boon was measured in the field with a Secchi disk at both in-lake stations (LB-1 and LB-2). Secchi disk transparency is a measure of the clarity of water. Factors such as plankton concentration, water color, and suspended particles within the water column directly impact Secchi depth. Secchi depth ranged from 1.5 meters to 3.7 meters at the in-lake stations with the greater Secchi depths recorded in the upper basin (Basin 1). Basin 1 had an average Secchi depth of 3.0 meters while Basin 3 had an average Secchi depth of 1.5 meters. The lower values observed in Basin 3 are most likely a result of the basin's shallow depth. Wind and boat activity can suspend soft bottom materials and associated nutrients. The nutrients can in turn contribute to increased phytoplankton growth in the water column. Previous studies reported similar Secchi depth results ranging from 1.4 meters to 3.0 meters (CDM 1987, GSC 1997a, GSC 1997b, Notini and Morrison 1980) (Appendix A).

pH

The pH value is a measure of acids and bases dissolved in water. In general, pH values for most lakes and streams in central Massachusetts range from 5.5 to 7.5 SU, with only the more urban lakes having values in excess of 7.0 SU. The pH values for Lake Boon ranged from 6.2 to 8.1 SU which is higher than the typical range for lakes in Massachusetts but within the range of values found in natural waters (pH 6.0-8.5 SU) (Hem 1970). pH values at the tributary station ranged from 5.5 to 6.3 SU, slightly more acidic than the in-lake samples. Although alkalinity values discussed above indicate low buffering capacity, pH measurements in the lake fluctuate within the expected natural range and therefore suggest that acidification is not currently a threat to Lake Boon.

Phosphorus and nitrogen

Phosphorus and nitrogen are essential plant nutrients. Excessive concentrations of these nutrients can often fuel undesirable growths of algae in the water column and accumulations in the shallower bottom sediments (within the euphotic zone) can promote rooted plant growths. Total phosphorus ranged from 0.01 to 0.06 mg/L for water samples collected from the in-lake stations (LB-1 and LB-2), while concentrations as high as 0.52 mg/L were recorded from the tributary station (LB-T) during storm flow. Typically, values no greater than 0.02 mg/L are desirable for maintaining low algal biomass and high water clarity, while concentrations above 0.05 mg/L are considered excessive. An examination of the historical data (CDM 1987, Notini and Morrison 1980, GSC 1997a) indicate that concentrations of total phosphorus in the main tributary (LB-T) measured in this study are substantially higher than those measured in previous studies (Appendix A). No clear trend in total phosphorus concentration was observed for the in-lake samples.

Values for nitrate-nitrogen ranged from <0.01 to 0.01 mg/L for the in-lake stations (LB-1 and LB-2) which is well below the normal background level (0.05 mg/L) for central and eastern Massachusetts (MAPC 1983). Tributary nitrate-nitrogen values ranged from 1.04 to 1.31 mg/L with a mean value of 1.17 mg/L during dry weather and 1.0 mg/L during storm flow. Despite the higher nitrogen inputs from the tributary, in-lake values did not exceed 0.01 mg/L suggesting rapid uptake within the lake. These nitrate-nitrogen concentrations are lower than values measured in previous studies (CDM 1987, Notini and Morrison 1980, GSC 1997a, GSC 1997b) indicating a possible trend of decreasing nitrate-nitrogen levels in the lake. No clear trend was observed for nitrate-nitrogen concentrations in the main tributary; historical data report both higher and lower concentrations (Appendix A).

Total Kjeldahl nitrogen (TKN, a combination of ammonium and organic nitrogen forms) values for the tributary were low during dry weather, with a mean value of 0.09 mg/L and high during storm flow conditions, with a mean value of 1.8 mg/L. The mean value for the in-lake stations was 0.79 mg/L over the three sampling months. The in-lake and tributary concentrations of TKN measured in this study exhibit an increase compared to historical values of TKN (CDM, 1987; Notini and Morrison, 1980; GSC, 1997a; GSC, 1997b) (Appendix A).

Ammonium nitrogen has a similar range of possible values as nitrate, as the sources are the same. However, ammonium is converted to nitrite then nitrate under oxygenated conditions, so the persistence of larger concentrations of ammonium indicates not only a significant source, but also a lack of oxygen. Additionally, un-ionized ammonium is more toxic at lower concentrations than nitrate; aquatic life is affected at 0.02 mg/L of free ammonia, which is a fraction of the ammonium level (dependent on pH, conductivity, and temperature) necessary to create toxicity. Ammonium concentrations >1 mg/L would be necessary to create toxicity in a waterbody with the features of Lake Boon. Measured ammonium nitrogen concentrations ranged from <0.01 to 0.13 mg/L for the in-lake stations (LB-1 and LB-2). Tributary ammonium nitrogen values ranged from 0.02 to 0.58 mg/L with a mean value of 0.02 mg/L during dry weather and 0.31 mg/L during storm flow. These results suggest that ammonium nitrogen does not pose a toxicity threat to Lake Boon at this time.

3.3.2.2 Sediment Analysis

Sediment sampling results are presented in Table 7. Cores of the soft sediment and organic bottom material were composited from four locations within Basins 1 and 2 (Figure 7). Cores were collected from the deepest portions of the lake in order to determine the likelihood of internal nutrient recycling which typically occurs in the anoxic hypolimnion (deep portion below the thermocline) of lakes. Sediment cores were representative of the soft sediment within the lake that may be contributing to nutrient recycling within the lake's water column. Consequently, cores were not collected from the shallower Basin 3 since these shallower sediments would not be expected to experience anoxic conditions. Sediment samples were analyzed for the following parameters: moisture, total solids, total volatile solids, total Kjeldahl nitrogen, total phosphorus, oil and grease, particle size, and total metals.

Moisture, expressed as a percentage, is the amount of water contained in the sediment's interstitial spaces. The composite sediment sample from Lake Boon has a very high percent moisture content (90 percent), typical of lake sediments.

Total volatile solids, a measure of the percent organic content of the sediment, was relatively low in the composite sediment sample (Table 7) and would be classified as non-polluted by the USEPA (USEPA 1977). The value measured was well below the mean value of 20.9 percent calculated for Massachusetts lakes and ponds.

Total Kjeldahl nitrogen (TKN) and total phosphorus were measured to determine the amount of nutrients that are contained in Lake Boon's sediments. TKN was excessively high in Lake Boon, measuring 8,500 mg/kg. Total phosphorus was not detected at a detection limit of 40 mg/kg. TKN values greater than 2,000 mg/kg are considered heavily polluted by the USEPA (U.S.EPA 1977). There is a high likelihood that the elevated TKN levels are influencing water quality through nutrient recycling and are likely to enhance aquatic plant growth.

Particle size refers to the relative quantity of sediment sizes that are present in a sediment sample. Samples collected from Basins 1 and 2 of Lake Boon consisted of primarily fine silt and clay sized particles, with these two fractions accounting for 100 percent of the material present. These small particle sizes are most likely being transported to the lake during storm flow conditions.

Total metals in a sediment sample are measured to determine whether the level of a particular metal found in the sediment exceeds normal background levels, and if so, to what degree contamination has occurred. Of the metals tested, Lake Boon's sediment exceeded the Massachusetts Division of Water Pollution Control (MDWPC) Category III concentrations for arsenic (Table 7). The concentration of lead was within the Category II classification. All other metals were below the

Category I concentrations. Category I sediments have the least restrictions for dredging, handling, and disposal; whereas, Category III sediments are the most restrictive. It should be noted that the arsenic value was 28 mg/kg, just over the Category III cut-off value of 20 mg/kg. Also, the value was well below the mean values calculated for the sediments of Massachusetts' lakes and well below the maximum allowable contaminant level of 40 mg/kg established for sediment reuse at landfills in Massachusetts.

Based on the chemical and physical data collected, the Lake Boon sediment would currently be classified as Category III, Type C dredge material (as per MDWPC) based primarily on the high levels of arsenic and the high fraction of silt and clay. Dredging of the deep sediments of the lake is not a recommended management goal for Lake Boon at this time.

3.3.2.3 Ground Water Analysis

The shoreline of Lake Boon was divided into 7 segments (Figure 8) based on topography and housing features (density). Shoreline length was measured from a USGS 7.5 Minute Series Quadrangle Map in a straight or curving line, but did not follow all details of shoreline contour; the object was to establish the long axis of a rectangle which would represent each seepage segment. Fieldwork was conducted on 13 August and 7 October 1998.

The seepage surveys were conducted according to the methods outlined in Mitchell et al. (1988 and 1989). Seepage quantity was estimated by installing two seepage meters per defined shoreline segment and measuring the change in volume in the attached bag. Change in volume multiplied by a conversion factor relating the allotted seepage time to an entire day and another conversion factor relating the seepage meter area to a square meter, yields the liters of inseepage (positive value) or outseepage (negative value) per square meter per day (Table 8). Seepage meters occupied approximately one quarter of a square meter and were left in place for 3.0-4.7 hours. Most seepage values were positive, indicating that at the time of sampling, inseepage was occurring. Three seepage values from the August sampling were negative and one seepage value from the October sampling was negative (Table 8).

During spring, precipitation will typically raise the lake level faster than the ground water elevation, resulting in net outflow around the sandy edge of the lake. During dry periods, the lake elevation will decline in response to surface water outflow and evaporation, while the ground water elevation will decline more slowly in response mainly to well withdrawal. Ground water will seep into the lake when lake elevation drops below the ground water elevation. Local variation is possible, allowing water to flow into one part of the lake and out of another. Negative seepage typically occurred near the outlet of Lake Boon, while inseepage occurred throughout most of the lake and was typically greatest closer to shore.

Ground water flow may change direction throughout the summer, as precipitation changes the lake level more rapidly than the ground water level, and greater evaporation and surface outflow draw the lake down again. The generally sandy substrate on the lake bottom allows ground water to enter or exit most parts of the lake fairly easily.

At the time of measurement, the relatively wet summer had left the groundwater table higher than the level of the lake. This allowed the groundwater to flow to the lake. Groundwater seepage into the lake averaged 4.8 $L/m^2/D$ during August and 3.8 $L/m^2/D$ during October for a combined average of 4.3 $L/m^2/D$.

Groundwater seepage quality was assessed through sampling with a Littoral Interstitial Porewater (LIP) sampler. Porewater extracted from several locations in each segment was tested in the field for conductivity and pH, and then sent to a laboratory for the remaining analyses.

Porewater conductivity was variable (36-497 µmhos/cm) at each of the seven segments, the highest values occurred in segments 6 and 7 (Table 9). The average conductivity was higher in October (274 µmhos/cm) than in August (201 µmhos/cm). The highest conductivity value was measured in October, 1998 (497 µmhos/cm). Conductivity at these levels can be detrimental to water quality and is often indicative of human influences, typically faulty or poorly maintained septic systems.

Total dissolved phosphorus (TDP) is the concentration of all forms of dissolved phosphorus. "Dissolved" in this case is defined as passing through the 1.0 μm filter. By using a slightly more porous filter we were certain not to underestimate the dissolved forms that could potentially be reaching the lake (usually 0.45 or 0.2 μm is the cutoff). Particles <1.0 μm may move with the ground water in porous soils; however, and it was intended that phosphorus inputs not be underestimated. In ground water, dissolved phosphorus values in excess of 0.05 mg/L are of concern in terms of eutrophication, and values in excess of 0.10 mg/L can cause serious deterioration of conditions if the phosphorus is biologically available. However, larger values in porewater do not necessarily translate into lake water column values of the same magnitude. High iron levels are known to promote complexing of iron phosphates, which are highly insoluble in oxygenated water. For phosphorus to become available in the water column at a significant level, it must therefore enter at an elevated concentration with concurrent iron levels at less than five times the phosphorus level.

Total dissolved phosphorus in Lake Boon porewater ranged from <0.01 to 0.1 mg/L, with a mean of 0.03 mg/L (Table 9). Total dissolved iron levels ranged from <0.02 to 6.0 mg/L. Ten of the fourteen samples had an iron:phosphorus ratio of <5:1, indicating that there was not always a sufficient iron level to counteract the elevated phosphorus values and render them biologically inert. However, phosphorus levels were generally low in these samples (≤ 0.03 mg/L); therefore, it is not as important to have the levels of iron required to sequester the phosphorus.

Nitrate nitrogen values in Lake Boon porewater ranged from <0.01 to 10.7 mg/L with an average value of 2.4 mg/L (Table 9); this greatly exceeds the likely range of 0.01-0.5 mg/L which would be expected under most "pristine" conditions. Values over 1.0 mg/L are unusual without some form of urban or agricultural influence, while values over 10 mg/L or more are considered a health hazard for human consumption. Stations S4 and S5 had the greatest levels of nitrate nitrogen reaching levels of 8.59 and 10.7 mg/L respectively. Based upon the limited number of samples (twice over a single year), these high levels of nitrate nitrogen indicate that there is likely a significant influence by septic systems on Lake Boon's water quality along some portions of the lake shore.

Ammonium nitrogen has a similar range of possible values as nitrate, as the sources are the same. As stated in Section 3.3.2.1, ammonium concentrations >1 mg/L would be necessary to create toxicity in a waterbody with the features of Lake Boon. Measured ammonium nitrogen concentrations ranged from <0.01 to 0.4 mg/L in Lake Boon porewater (Table 9), suggesting that ammonium nitrogen does not pose a toxicity problem for Lake Boon at this time.

The sum of nitrate and ammonium nitrogen, or soluble inorganic nitrogen (SIN), could be expected to reach up to approximately 1.0 mg/L under natural conditions. Values much over that concentration raise suspicions of septic leachate contamination. SIN values ranged from 0.02 mg/L to 10.7 mg/L with an average value of 2.48 mg/L. SIN values greater than 1.0 mg/L were measured in 5 out of the 7 segments, with the highest values of SIN occurring in Basin 2. These high SIN values indicate that there is likely septic leachate contamination occurring throughout the lake.

The Friends of Lake Boon conducted a voluntary survey of homeowners around the lake during the summer of 1998. Survey results indicated that the setback of houses from the lake ranged between 16 and 300 feet with an average distance of only 62.8 feet. These homes had an average treatment system age of 15 years with a maximum of 60 years. In light of the present data, it would be beneficial to increase the pumping frequency of these systems. It is recommended that pumping occur at least annually for newer systems that are used year round. The pumping frequency should be increased to twice per year for older systems. In the case of summer homes, it would be preferable to pump the systems at the end of the summer season so that leaching is minimized throughout the off season.

3.3.3 Hydrologic and Nutrient Loading

It is possible to estimate the amount (load) of phosphorus and nitrogen being contributed to Lake Boon by its watershed when an estimate of water flowing into the lake and the concentration of each nutrient in this water is known. Water flowing into a lake comes from three primary sources: surface water, ground water, and from direct precipitation. Surface water flows can be estimated from actual flow data or from known relationships for water yield from similar watersheds. Ground water inputs can be estimated or measured directly through the use of seepage meters, while, inputs from direct precipitation can be estimated from long-term climatological data and the surface area of the lake.

Estimated average water input to Lake Boon from surface water, ground water and direct precipitation is 2.48, 0.91, and 0.56 cfs, respectively, for a total annual flow of 3.95 cfs (Table 10). This flow will vary appreciably among seasons and weather conditions, but is relatively small in comparison to the total lake volume. Surface water is by far the dominant component of inflow (62.7 percent), and can be further divided into dry weather (background) flows and wet weather (storm) flows. Wet weather flow to Lake Boon averages approximately 4 times the background flow (2.00 cfs vs. 0.48 cfs) on an annual average basis. However, background flow at the tributary monitoring station was consistently low, ranging between 0.01 cfs to 0.18 cfs. Storm flows occur only about 20 percent of the time and could exceed 35 cfs as a 24-hour average of a storm that occurs once every two years. Peak flows to the lake could be in excess of 70 cfs.

Based on total lake volume and the flow through the lake, average detention time was calculated to be 219 days. Detention time represents the duration of time necessary to exchange the volume of water in the lake one time. Flushing rate is the inverse of detention time, and represents the number of times per year the lake volume is replaced; for Lake Boon, the flushing rate is about 1.67 times/yr. This flushing rate is similar to rates estimated during previous studies. This is a low flushing rate and the implications on management efforts are the same.

When detention time is known, a calculation can be made to determine response time (time needed for a lake to fully realize nutrient inputs), which for Lake Boon ranges between 160 days and 266 days. Since Lake Boon's detention time is within its response time, the effect of any nutrient entering the lake is likely to be fully expressed before passing through the system. This is especially true for storm events, during which a majority of the pollutant load occurs.

The nutrient data, presented in Table 11, can be placed into perspective once the values are interpreted as a measurement of the nutrient load to Lake Boon. A calculation of minimum nutrient load was made by multiplying the volume of the lake by its flushing rate and the mean concentration of the nutrient. The minimum phosphorus and nitrogen loads delivered to Lake Boon were determined to be 0.14 $g/m^2/yr$ (92 kg/yr) and 4.31 $g/m^2/yr$ (4,359 kg/yr), respectively, based on the in-lake concentration data collected during this study (Table 11). The actual load of phosphorus or nitrogen will exceed the estimated minimum load as a consequence of loss processes that reduce the in-lake concentration over time. Since phosphorus is viewed as the nutrient that controls productivity in this lake, emphasis is placed on a more detailed modeling analysis of its loading to Lake Boon.

A more detailed and realistic estimate of nutrient loading can be obtained by using a combination of actual field data and in-lake modeling theory. Nutrient loads are calculated based on nutrient values measured within the lake and hydraulic features of the lake. The predicted phosphorus load necessary to achieve the values found in Lake Boon ranges between 0.15 $g/m^2/yr$ (100 kg/yr) and 0.47 $g/m^2/yr$ (307 kg/yr) (Reckhow 1977, Kirchner-Dillon 1975, Vollenweider 1975, Larsen and Mercier 1976, Jones and Bachmann 1976) based on this approach (Table 11). The mean predicted phosphorus load for all six models was 0.28 g/m2/yr (186 kg/yr). The nitrogen load necessary to achieve the observed in-lake concentrations was estimated to be 6.69 g/m2/yr (4,359 kg/yr) (Bachmann 1980) in this manner (Table 11).

Vollenweider (1968) established criteria for calculating the phosphorus load below which no productivity problems were expected (permissible load) and above which productivity problems were almost certain to occur (critical load). These loading limits are also based on the hydraulic properties of the lake and depend upon mean depth and detention time. The average of phosphorus loads estimated for the lake by in-lake modeling (186 kg/yr) is above the permissible level of 151 kg/yr but below the critical level of 303 kg/yr (Table 11).

Lake Boon is currently within the transition range, where an increase in the rate of phosphorus input to the system is likely to result in a drastic decrease in water quality. Similarly, any significant reductions in phosphorus load to the lake could greatly enhance water clarity by reducing the duration and intensity of many algal blooms. This knowledge is useful for determining the value of the various management alternatives, and can be particularly helpful when prioritizing their order of implementation under fiscal constraints.

It should be noted that the concentrations measured during this study were measured over a relatively short period of time and during a particularly wet summer. It is very likely that in-lake phosphorus concentrations would be higher during periods when less surface runoff is entering and flushing the lake. Groundwater flow represented more than 23% of Lake Boon's hydrologic budget on an annual basis. Groundwater contributions could represent nearly 100% of the hydrologic budget in Lake Boon during extended periods of dry weather, increasing the groundwater's influence on in-lake nutrient concentrations. The average nutrient concentration in the groundwater was slightly higher than concentrations measured at the in-lake monitoring stations. Several individual groundwater sampling sites were much higher.

Similar loading limits for nitrogen have not been established, owing to the less predictable relationship between nitrogen, lake hydrology, and primary productivity. Although nitrogen data are very useful in understanding lake conditions and processes, phosphorus is the logical target of management actions aimed at controlling algal biomass and plant growth.

The actual in-lake concentrations of phosphorus and nitrogen are moderate to slightly high, and indicate an immediate threat to water quality. Water clarity was better during the summer months when a thermocline was well established. A significant decrease in water clarity was measured during the 24 September 1998 sampling. The decrease in water clarity was likely a result of increased algal production occurring as the nutrient rich hypolimnion (water from below the thermocline) circulated throughout the lake's water column. Algal productivity during the July and August sampling periods was not a problem (low algal biomass). However, September samples showed a significant increase in algal abundance.

Itemized load estimates for the different sources of phosphorus (Table 12) can be a useful alternative for evaluating nutrient loads. An itemized phosphorus load can be developed when phosphorus data from each of the various sources has been determined. Annual phosphorus loading itemized by sources to Lake Boon suggests that the actual load of phosphorus may be much higher than indicated by the in-lake models or concentration. The wet weather surface flow inputs stand out as the dominant influence, at over 203 kg/yr and over 81 percent of the estimated phosphorus load. These estimates are based on the relatively limited number of samples collected over a very short period of time (one summer) and could be greatly influenced by the conditions prior to the commencement of the sampling or by the size of the particular storm events sampled. More than half of the phosphorus load to Lake Boon during the study was in dissolved form rather than in particulate form. Dissolved phosphorus is more readily available for uptake by aquatic plants and algae within the water column. Particulates that enter the lake are likely to settle in shallow portions of the lake near the mouth of each tributary, becoming part of the shallow, soft-sediment layer and not strongly influencing water column phosphorus levels through internal recycling. Use of this phosphorus supply by rooted plants is undoubtedly important in shallower areas of the lake, particularly throughout Basins 2 and 3. In summary, the "effective" phosphorus load to the lake may be somewhat higher than the actual load, resulting in a somewhat increased overall impact on water quality.

A third approach for estimating the nutrient load to Lake Boon that may be the most insightful method when long term data are not available would be to calculate the nutrient load generated by each acre of land in the watershed based on its use (Table 13 and 14). Attenuation coefficients are used to calculate the total load that actually would be expected to reach the lake based on the structure of the particular drainage basin and its relative distance from the lake. Sub-basins 1, 3, and 5 are close to the lake, relatively small and are primarily residential areas served by storm drain systems; roughly 80 percent of the load generated would be expected to reach Lake Boon. Conversely, Sub-basins 2 and 4 are more heavily forested and more removed from the lake. The distance of travel in these sub-basins, particularly through wetland areas, would be expected to limit the nutrient load reaching the lake to roughly 20 percent of that generated.

Tables 13 and 14 summarize the above calculations, by sub-basin, for the entire Lake Boon watershed. Phosphorus and nitrogen generation from the Lake Boon watershed would be expected to fall within the range of a typical Massachusetts watershed. The expected mean phosphorus load to Lake Boon using these calculations would be roughly 201 kg/yr and the expected mean nitrogen load to the lake would be roughly 1,247 kg/yr. The phosphorus load, of primary interest, is only slightly higher than the effective load suggested by in-lake models. It appears likely that much of this load is quickly sequestered in the shallower sediment at the mouths of the tributaries where it can fuel rooted plant growth, but has yet to severely impact water quality.

A loading trend analysis for phosphorus was calculated using the same modeling techniques and assumptions made during this study (described in the above sections). Historical data was analyzed and the calculated phosphorus loads are included as Appendix A. Data used from each study for the modeling was selected to correspond to the seasons sampled during this investigation for consistency and to focus comparisons on the critical summer growing season. Loading to Lake Boon is not consistent among the three studies analyzed (CDM 1987 - 123kg/yr, DWPC 1979 - 458 kg/yr, and ESS 1998 186 kg/yr). The two previous studies had loads calculated to be both less than and greater than the load calculated for the current study. Year to year variability would be expected and the range of values is not beyond what would be expected.

3.3.4 Biological Community

3.3.4.1 Zooplankton

The floating microscopic animals or zooplankton are of interest because they represent the linkage between the bottom of the food base and higher trophic levels, namely planktiverous fish. Zooplankton were collected from Lake Boon on each of the three dry weather sampling dates from both in-lake monitoring stations (LB-1 and LB-2). Lake Boon had moderate to high zooplankton density and biomass. Zooplankton samples included a range of types and sizes, however no one species was dominant during all sampling dates (Table 15 and Appendix B). Taxonomic composition was appropriate for establishing desirable algal grazing potential and food supply for small fish.

3.3.4.2 Phytoplankton

Phytoplankton, or microscopic algae suspended in the water column, are an important component of aquatic food webs, but may also impart detectable color and odor to lake water as well as a reduction in water clarity. Knowledge of the phytoplankton community can provide insight into a lake's water quality that may not be gained through limited water quality sampling. Phytoplankton were collected from Lake Boon on each of the dry weather sampling dates at water quality monitoring stations LB-1 and LB-2. Phytoplankton samples contained 7 of 8 freshwater algal divisions and an average of over 30 taxa per sample (Table 16 and Appendix B).

The average phytoplankton concentration over the sampling period was 26,838 cells/ml, which is typically considered a high count. However, this number may be misleading due to the dominance of the small blue green cells in many of the samples. Average phytoplankton biomass over the sampling period was 1.7 mg/L which falls between low and high algal biomass with low biomass generally considered to be <1 mg/L and high biomass generally considered to be >10 mg/L.

Phytoplankton cell concentrations and taxa composition indicate that Lake Boon is a borderline mesotrophic/eutrophic system. However, samples at both stations were often dominated by heterotrophic blue-greens which indicate a more productive system with a reasonable amount of nutrients available. Water quality could easily degrade and become more dominated by these opportunistic blue-greens. The presence of the taxa *Euglena*, *Trachelomonas*, and *Gonyostomum* confirm the presence of organic compounds in the water column. Later in the summer season, Chrysophytes increase dramatically in abundance, another indication of a borderline mesotrophic/eutrophic system with relatively high concentrations of organic compounds available (e.g. organic carbon, humic/tannic compounds).

Of the most common species, blue-greens are not particularly valuable to the food web, however, many of the diatom taxa are excellent food for grazing zooplankton. Although the algal community in Lake Boon is composed of species typical of moderately eutrophic systems, some species are capable of forming blooms at nuisance levels. In-lake phosphorus concentrations indicate a definite potential for algal blooms, continued monitoring of nutrient levels in the lake would be beneficial.

3.3.4.3 Macrophytes

Macrophytes refer to the more complex aquatic plants found within or on the margins of aquatic environments. These plants may or may not have roots and can be broadly grouped into three categories based on their habits: the emergent plants, the floating-leaved plants, and submerged plants. Macrophytes are critical elements of the littoral zone (shallow water areas), providing structure and habitat for fish and invertebrate communities, and helping to mediate some of the nutrient interactions between land and water.

Aquatic plants in and around Lake Boon were mapped on 14 August 1998. A description of the location and size (amount of area covered) of various plant beds was noted along with an estimate of plant biomass (expressed as the portion of water column filled by plants). Data from the plant survey are presented in Figures 9 through 11. A list of the plant species identified in Lake Boon is provided as Table 17 and a list of dominant plant species identified in the lake is provided with the transect data in Table 2. The plant coverage and biomass estimates are presented in Tables 18 and 19 respectively.

The aquatic plant community in Lake Boon was dominated by fanwort (*Cabomba caroliniana*) and water milfoil (*Myriophyllum heterophyllum*) with some dense patches of white water lily (*Nymphaea odorata*) and watershield (*Brasenia schrieberi*). Lake Boon's perimeter was occupied in several areas by purple loosestrife (*Lythrum salicaria*), smartweed (*Polygonum* sp.), cattail (*Typha* sp.), and bur-reed (*Sparganium* sp.). Other commonly observed aquatic plants included various species of lakeweed (*Potamogeton* spp.), yellow waterlily (*Nuphar variegatum*), bladderwort (*Utricularia* spp.), bushy lakeweed (*Najas flexilis*), coontail (*Ceratophyllum demersum*), watermeal (*Wolffia columbiana*), and duckweed (*Lemna minor*). In addition to these more common species, filamentous green algae and blue green algae were found at several locations in Basin 3. Blue green algae was also observed floating along the shoreline in Basin 2 on several occasions.

Plant coverage was greater than 75 percent in most areas of Basins 2 and 3 (Figure 10). Plant biomass (volume of water column filled) was greater than 75 percent in most areas of Basin 3 (Figure 11). The only portion of Lake Boon that consists partially or wholly of open water (0 percent plant cover or plant biomass) is Basin 1, while 71 acres (83 percent) of Basins 2 and 3 have plant coverage exceeding 75 percent (Figure 10).

The plants that represent the most immediate threat to recreational use of Lake Boon are fanwort and water milfoil. Fanwort is a highly invasive and non-native species that can grow to the exclusion of other, often native, plant species. The water milfoil species present in Lake Boon is native to New England; however, it too can grow to nuisance levels under certain conditions. The majority of the lower two basins (Basins 2 and 3) are completely covered with these plants (Figure 10). Fanwort and water milfoil are rooted species with relatively large and finely dissected leaves that grow as tufts off of the plant's main stem. These plants root in the lake bottom but can derive their nutrients from both the soft bottom sediments and directly from the water column. These plants can grow to entirely fill the water column in shallow areas (less than 10 feet). These plants typically spread vegetatively whereby small pieces of plant can float to uncolonized areas and rapidly root.

The other aquatic plants observed in Lake Boon all have some degree of nuisance potential as well, but are less of a threat than those described above and are at least native species. In the right combination and density, they could establish valuable fish and wildlife habitat without major impairment of most human uses of the lake.

The peripheral emergent plant community was predominantly purple loosestrife (*Lythrum salicaria*), smartweed (*Polygonum* sp.), cattail (*Typha* sp.), and bur-reed (*Sparganium* sp.), which occupied roughly 10 percent of Lake Boon's perimeter. Densities were greatest along the shoreline of Basin 3. Purple loosestrife is a non-native and extremely invasive species. When allowed to grow unchecked, purple loosestrife will encircle a lake and rapidly expand into shallow areas. The remaining species are native species and have considerable habitat value. Cattail can become a problem in shallow lakes or lakes, as it can expand out into a waterbody and choke out other vegetation. This is not currently an issue at Lake Boon.

3.3.4.4 Fish and Wildlife

ESS conducted a fisheries data review at the Massachusetts Division of Fish and Wildlife's Westborough office. Data available on Lake Boon was limited and covered a period from 1913 to 1960. Wildlife data specific to Lake Boon was available but very limited and outdated. ESS was able to document fish and wildlife species during each of the visits to the lake. Efforts were made to collect and describe both fish and aquatic invertebrates. Data gathered on the biological community allows informed management recommendations to be made that are tailored toward achieving realistic management goals.

Fish are an integral part of the aquatic community at Lake Boon and fishing is an important activity at the lake, particularly in areas where plant densities are not excessive. The Massachusetts Division of Fish and Wildlife has published no reports about Lake Boon, but reports that a typical warmwater assemblage exists. Species included: large-mouth bass (*Micropterus salmoides*), chain pickerel (*Esox niger*), bluegill (*Lepomis macrochirus*), yellow perch (*Perca flavescens*) white sucker (*Catastomous commersoni*), brown bullhead (*Ictalurus punctatus*), and golden shiner (*Notemigonus crysoleucas*). Bass and pickerel fishing are reported to be quite productive. The growth rate of fish in Lake Boon are expected to be at the state average.

The invertebrate population of the lake is dominated by dragonflies (Odonata), beetles (Coleoptera), flies (Diptera), and worms (Oligochaeta). In addition to these taxonomic groups, mayflies (Ephemeroptera) and caddisflies (Trichoptera) were observed in the main tributary to the lake. The invertebrate community appeared to be relatively diverse; however, there were a disproportionate number of aquatic flies and worms, which typically dominate nutrient enriched waters.

The wildlife community observed to be directly interacting with the lake and its surrounding wetland habit included: painted turtle, snapping turtle, green frog, bull frog, several types of duck, Canada geese, great blue heron, green heron, and muskrat. Observations were made directly or by observing animal sign and tracks.

3.3.4.5 Recreational Value

Recreational activity in and around the lake was recorded during most visits to Lake Boon. In-lake activities include fishing, swimming, boating and water skiing. These activities occur throughout the summer despite the aquatic plant growth that is reported to diminish the experience as the growing season progresses. Winter activities are reported to include both ice-fishing and skating.

Boating: Motorized craft have been demonstrated to disturb bottom sediments in shallow waterbodies (Wagner 1996). Disturbing sediments can cloud the water column directly through increased turbidity or indirectly through the resuspension of nutrients which in turn fuel phytoplankton growth (Yousef et al. 1980). The effect is more pronounced in lakes with highly organic, nutrient rich muck, this may be the case in Lake Boon's Basin 3, but is not the case in either Basin 1 or Basin 2.

Boat activity was monitored by ESS personnel and by local volunteers for the purpose of documenting the extent and pattern of the recreational pressure placed on Lake Boon. Observations were conducted throughout the summer for a total of 19 hours of observation. During mid-day on weekdays boat activity was rare or non-existent, this was typically the case when ESS was collecting water quality samples. As is the case with most lakes in Massachusetts, evening hours and weekends were significantly busier. Based on the viewpoints of many boaters, one boat per 25 acres (25 acres/boat) of water surface is considered sufficient for all recreational activities (e.g. skiing, fishing, etc.) (Wagner 1996). Densities observed in Lake Boon over the summer of 1998 ranged between 18 acres/boat to 160 acres/boat. Waterskiiers feel restricted at less than 10 acres/boat, and nearly all motorized watercraft users feel crowded at less than 5 acres/boat. The current use patterns observed at Lake Boon suggest that there is not yet a density problem with respect to recreational use.

It is very likely that boating densities in the narrower portions of the lake are potentially contributing to water clarity problems during certain periods. Observations made within "the narrows" of Lake Boon revealed an average (during the study period) of more than 7 passes per hour. Although this number does not seem excessive, it is possible that as a result of this area's shallow depth, sediment suspension could be greater than desirable. Adhering to the existing lake rules (no wake zones, minimum distances to shore, etc.) should minimize this impact for all but the busiest weekends.

Wildlife Viewing: A recreational activity that should be discontinued at Lake Boon relates to wildlife viewing, or more specifically wildlife feeding. Several residents around the lake were observed to be feeding flocks of ducks and geese that frequent the lake. Waterfowl, particularly geese, are of particular concern as they contribute a significant load of phosphorus rich fecal matter to the lake. Each goose contributes an average of 1kg of phosphorus per year to a system that is already above its permissible load. The feeding activity should be discouraged.

4.0 MANAGEMENT FEASIBILITY ASSESSMENT FOR LAKE BOON LAKE

4.1 Management Objectives

Just how a lake is managed will depend upon its intended uses, which are decided partly based on environmental law (e.g., protection of certain habitats or species) and partly on human needs and desires. Lake Boon serves a variety of human purposes, including boating, fishing, skating, and passive aesthetic enjoyment. Such uses are greatly impaired during the growing season. Lake Boon also serves as habitat for a variety of aquatic and semi-aquatic life forms, both plant and animal. This lake is not a potable water supply, although it interacts with ground water, and is indirectly used by several residents with shallow wells along its shoreline. The priority of uses has not been completely defined, but enjoyment of the lake has decreased dramatically in recent years as a result of elevated plant densities and increased frequency of algal blooms. In recent years there has been a need to resolve potential use conflicts as a result of increased recreational pressure. Currently the use of the lake is restricted to swimming and non-motorized craft during designated "quiet hours". If plant growth is allowed to progress unchecked, the effective open water area of the lake may be reduced as plant densities increase. The Lake Boon Commission may wish to consider what other uses Lake Boon might serve, now or in the future, and should set priorities before making management decisions, as not all aspects of all uses are compatible.

The selection of management actions should be driven by long-term management objectives of the Lake Boon community. Management for water supplies is not the same as management for fish yield, which is dissimilar than management for diverse recreational opportunity. Although Lake Boon may have been conceived as a water supply facility for mill operations, the recreational goal is believed to be appropriate for Lake Boon at this time, as this water body is intended to provide recreational opportunity to a wide variety of users, human and non-human alike. From public discussion, it appears that management goals for Lake Boon include: providing adequate habitat for waterfowl, fish, reptiles and amphibians, unhindered opportunity for non-motorized and motorized watercraft, and aesthetic appeal for passive users. Maintenance of water quality sufficient for swimming is also a priority.

As we understand it, the general goal of any management plan for Lake Boon is to enhance habitat quality and maintain and perhaps restore human use potential. More specifically, water quality is to be managed to maintain sufficient water clarity to promote safe use by humans and support an aquatic biological community indicative of a healthy environment. Physical features of the lake are to be managed to provide appropriate fish habitat, provide adequate but limited access, maximize safety for human users, minimize shoreline erosion, and prevent excessive plant growths or other abnormal biological nuisances. Short-term management effort is clearly needed with regard to rooted and floating aquatic plant nuisances, while long-term management should be directed toward protecting water quality.

With the preferred uses in mind, the following specific management objectives are suggested:

1. Limit aquatic plant growths to levels appropriate for habitat enhancement, recreational use, and safety considerations.

2. Minimize impact from watershed activities with the goal of improving water quality and protecting future water quality.

3. Curtail excessive sediment, nutrient and related pollutant inputs associated with storm events, thereby improving aquatic conditions and maintaining acceptable water quality.

4. Establish a cost-effective monitoring program that provides early warning of potential problems and that tracks the progress of any implemented management measures in achieving stated goals.

4.2 Management Options

As shown in Table 20, the range of options for managing Lake Boon is not especially large. Management methodologies can be subdivided in a number of ways, but those subdivisions tend to deal with the details of application, not the fundamental approach. With a specific management objective in mind, management methodologies can be examined to determine the applicability and feasibility of options for meeting that objective. A review of these management options for the four suggested management objectives is presented below.

4.2.1 Limit Aquatic Plant Growths

Excessive phosphorus in the water column, relatively shallow water depths, and an expansive, organically-rich soft substrate in the shallower portions of the lake contribute to excessive growths of rooted and floating aquatic plants, predominantly fanwort, milfoil, duckweed, and watermeal. These growths primarily occur in the shallower basins (2 and 3). Infestations of these plants severely impede use of the lake, particularly for residents located along the shoreline of these shallower basins. When fanwort grows to the densities observed in Lake Boon, it has limited cover and food value to fish and waterfowl. Other plant species were far less common, suggesting that this infestation in Lake Boon is severe.

Fanwort, or *Cabomba caroliniana*, is a perennial plant with stems arising from short rhizomes with fibrous roots. Fanwort appears to be native to parts of the southern United States, and was first reported in the Northeast in Cranston, Rhode Island in 1933. It is suspected to have been transported north as part of the aquarium trade, but migrating waterfowl could also be responsible. It thrives in acidic waters of muck-bottom lakes or ponds in the sandy outwash plains in southern New England. This plant flowers and may produce viable seeds, but seems to depend mainly on vegetative reproduction (plant fragmentation) for propagation.

Control of this plant has been extremely difficult. Among the available herbicides, only fluridone provides any hope of eradication, and its use may not be feasible for this lake if there are negative public perceptions about possible influence on well water. Benthic barriers or dredging could also provide complete control, but at an astronomical price. Harvesting, which has rarely been capable of eradicating any species, could be enhanced through supplemental hand pulling of fanwort, but complete eradication will be difficult.

Although other species may become nuisances in Lake Boon in the future, fanwort is the only non-native species currently presenting such a threat. Vigilance through monitoring is recommended to avoid other problems in the future.

Since fanwort thrives in waters with sandy to mucky bottoms, it is likely that this species will be a member of the plant community of Lake Boon without extreme and continued management measures. It does not have to be the primary component of the plant community, however, and should not exist where any substantive recreational and habitat value are desired. Control methods for fanwort are similar to those of many rooted aquatic plants, falling into seven categories (Table 21). One or more of these methods will be essential to control fanwort or any other plant nuisance that may arise in Lake Boon.

The milfoil species currently present in Lake Boon is *Myriophylum heterophylum*, which is a native species. Although this species can grow to dominate a lake, this species is currently being out competed by the more aggressively growing fanwort. There are certain areas of Basin 3 in which this plant is abundant, but not dominant.

Duckweed and watermeal thrive in nutrient rich water, particularly systems with abundant nitrogen. Control methods for these plants are limited to reducing nutrient inputs to the system and chemical treatment. Due to the low flushing rate of Lake Boon, chemical treatment could be an effective long-term solution. However, control of these forms of aquatic plants will best be achieved through improved overall water quality, discussed further under the section addressing water quality.

4.2.1.1 Drawdown

Drawdown involves lowering the water level of a lake to expose bottom sediments and associated plants to drying and/or freezing. It can be effective against species which reproduce mainly by vegetative means, but is generally ineffective against annual plants which depend on seeds for regrowth each year, as the seeds are often stimulated by the drawdown instead of killed. Drawdown can be conducted at any time, but the interaction of drying and freezing is preferred suggesting that late autumn and winter drawdown will be most effective. Although most of the species in Lake Boon can produce seeds, most do overwinter in some vegetative form and could be greatly reduced in density by an effective drawdown. Performing an effective drawdown depends on the ability to control the water level and the configuration and type of bottom sediments, which must at least partially dewater.

The outlet of Lake Boon incorporates flashboards that could be withdrawn to initiate the drawdown. Although the area in front of the outlet may not be the deepest point in the lake, and the potential maximum drop in water level is unknown, it does appear that the water level could be lowered sufficiently to expose at least all areas currently <2 ft deep. This would be the initial target drawdown depth to be used as a test of this method in the lake. Maintaining the reduced water level appears possible with the existing outlet configuration during typical autumn and winter conditions. Larger flows associated with major storms could not be passed, however, without some storage of water in the lake and a concurrent rise in water level.

Because the lake has a relatively steep morphometry, the potential to dewater exposed areas is fairly high. Areas where pools of water become isolated may exist; however, no obvious areas were encountered in this investigation. Since the sediments are permeable, they should dewater adequately with prolonged exposure. Obligate aquatic plants would be dried and frozen during the late autumn and winter if weather conditions are suitable.

The likelihood that drawdown would be successful is highly dependent upon conditions that cannot be readily predicted, and generally depends upon interactions between physical features and weather. A dry, cold December would provide maximum results; while a mild winter, early cover by insulating snowfall, or especially wet conditions would decrease the effectiveness of the drawdown. Given the unpredictability of those conditions, it may be necessary to perform a drawdown annually to obtain the desired conditions at least once every few years. This can be sufficient to control many species, but does introduce an element of uncertainty into the process.

The eventual target level for drawdown will depend upon its impacts to non-target species and shallow wells. The two-foot drawdown suggested as a test would not be expected to cause appreciable negative impacts to peripheral emergent vegetation, fish, or water supplies, the most commonly cited concerns. Impacts to hibernating amphibians are sometimes raised as a concern, but many lakes subjected to drawdown have thriving amphibian communities. Timing of the drawdown may be an issue in this regard, but would be easily adjusted in Lake Boon. A more detailed discussion of drawdown and its impacts is provided in Appendix C.

Plants grow to nuisance densities over roughly one half of the lake area; therefore, a complete drawdown would be needed to attempt actual eradication of fanwort. This is not practical or permitted under current environmental regulations, limiting the value of drawdown. Lesser drawdowns are expected to provide some temporary level of control, however, and could do so at minimal cost. The proposed test drawdown would expose approximately 11% (18 acres) of the bottom area. The maximum likely drawdown would lower the water level by 4 ft, exposing approximately 23% (37 acres). Just how far a drawdown can go in this system is not clear at this time, and will depend on any measured effects on fish, non-target plant species, and the nearby wells.

Drawdown is clearly not the ideal management measure for Lake Boon, as it is unlikely to eradicate fanwort, will require repeated application, will provide varying results dependent upon weather conditions, and does have a variety of possible adverse impacts. This approach is very inexpensive, however, which makes it attractive in times of budgetary constraints. The primary costs are associated with permitting and monitoring.

Permitting could become a problem, although the recommended test level should not pose any major risks. Drawdown has been the subject of some controversy in Massachusetts in recent years; mostly involving alleged impacts to protected resources. An Order of Conditions under the Wetlands Protection Act would be required. Approval under Chapter 91 of the Massachusetts General Laws, dealing with alteration of a Great Pond, would also be necessary since Lake Boon is officially listed as a Great Pond. The history of its creation and inclusion on the list must be researched. A cost of $4,000 is expected to be adequate for handling these approval processes. Substantial additional costs could be experienced if the MEPA process is invoked or other regulatory complications arise.

Monitoring would consist of water level tracking and assessment of any impacts to non-target aquatic species or water supplies. Most of this monitoring would be precautionary for a 2 foot drawdown, but would provide data which would allow assessment of likely impacts of a 4 ft drawdown. Studies of drawdown impacts have typically been mandated by the permitting process, often without clear goals or at an impractical level, and sometimes with a substantial pre-drawdown component. In light of uncertainty about what would be required, a cost of up to $10,000 is suggested as an estimate for a "drawdown module" to be added to any regular monitoring proposed in response to objective #4 (monitoring for early warning and tracking of progress).

4.2.1.2 Dyes

Dyes are used to limit light penetration and therefore restrict the depth at which rooted plants can grow. In essence, they mimic the effect of light inhibition that might be expected during periods of high turbidity or prolonged ice and snow cover. Natural periods of low light are an important variable in determining plant composition and abundance, and use of dyes can produce similar effects. Dyes tend to reduce the maximum depth of plant growth, but have little effect in shallow water (<6 ft or 1.8 m deep). They are only selective in the sense that they favor species tolerant of low light or with sufficient food reserves to support an extended growth period (during which a stem could reach the lighted zone). Due to the large volume of Lake Boon, the amount of dye that would be required to produce effective results makes dye an inappropriate tool in this case.

4.2.1.3 Biological Controls

Biological controls for fanwort are almost unknown. A herbivorous fish (*Ctenopharyngodon idella*, the grass carp) has been used for general macrophyte control in smaller lakes in Connecticut and New York, but has not shown a preference for fanwort. Given little choice, it might reduce fanwort densities in Lake Boon, but the stocking of this non-native fish is illegal in Massachusetts.

4.2.1.4 Dredging Approaches

Dredging works as a plant control technique when either a light limitation is imposed through increased water depth or when enough soft sediment is removed to reveal a less hospitable substrate (typically rock or gravel). The only exception may be suction dredging, whereby a target species can be reduced or possibly eliminated by removing whole plants and any associated seed banks. Suction dredging might more appropriately be considered a form of harvesting, however, as plants are extracted from the bottom by SCUBA divers, and most sediment is returned to the lake.

Since light limitation through increased depth is unlikely to be achieved, control will depend on excavation to a hard bottom (coarse sand or gravel in this case). This means that any dredging to control rooted plants must remove all soft sediment in the target area. It may not be necessary to dredge the entire lake to achieve a satisfactory level of plant control, but it would be necessary to do a thorough job in any area where control is to be achieved.

Dredging in Lake Boon could be an effective rooted aquatic plant control technique, but would be quite expensive. With a soft sediment volume approaching 200,000 cy in Basin 3 alone, the cost is estimated at between $500,000 and $2,000,000, depending upon how much sediment is removed and a variety of other factors. In light of these costs and associated environmental considerations, dredging is recommended as a long-term goal for managing Lake Boon but may not be the most appropriate solution in the short-term.

4.2.1.5 Harvesting Approaches

Harvesting includes a wide range of plant removal techniques; the simplest form is hand pulling of selected plants. Successively more complicated approaches include manual cutting, mechanical cutting and collection, aquatilling (underwater rototilling), suction dredging, and hydroraking (mechanical whole plant harvesting with some collection). Harvesting can be an effective longer-term control technique when the target plants reproduce by seed and harvesting is timed properly to eliminate annual seed production. Usually several successive years of effort are necessary, as seeds deposited prior to management can be expected to germinate over more than one year. There is some evidence that intense harvesting of plants reproducing by vegetative propagation limits survival over the winter, but the effect varies by species and location. Harvesting can be an effective short-term control strategy for any aquatic plant nuisance, analogous to mowing the lawn.

Harvesting techniques which present the opportunity for plant fragments to escape are generally not suited for longer-term control of species which reproduce vegetatively, and may actually be counterproductive to control. While short-term control may be achieved in the target area, long-term control is rare and the escape of fragments often results in colonization of new sites. Any of the cutting techniques without collection, and often even with collection effort, can be expected to result in the spread of vegetatively reproducing species. For that reason, only harvesting approaches with a very low probability of fragments being left in the water are appropriate for longer-term control of fanwort. The exception may exist where fanwort has already become the dominant plant in the system, and spreading by natural means will greatly exceed any harvester-induced dissemination.

In Lake Boon, fanwort has not become established to the point where mechanical harvesting would be unlikely to foster further spread of this nuisance species. Small scale harvesting, such as hand harvesting or smaller harvesting equipment, might be possible but would not provide the degree of control with any reasonable level of efficiency. Except on a small scale by individual property owners, harvesting holds little potential for achieving the plant control objective for Lake Boon.

4.2.1.6 Benthic Barriers

Benthic barriers are negatively buoyant materials, usually in sheet form, which can be applied on top of plants to limit light, physically disrupt growth, and allow unfavorable chemical reactions to interfere with further development of plants. A variety of solid and porous materials have been used. Commercial production of effective materials has occurred since the late 1970's, although creative lake managers found ways to cover plants long before then. In theory, benthic barriers should be a highly effective plant control technique, at least on a localized scale. In practice, however, there have been many difficulties in the deployment and maintenance of benthic barriers, limiting their utility in the broad range of field conditions.

Benthic barrier problems of prime concern have been long-term integrity of the barrier, billowing caused by trapped gases, accumulation of sediment on top of barriers, and growth of plants on porous barriers. An additional concern is the non-selective nature of benthic barriers, which kill all plants over which they are applied. One final problem is the tendency of products to come and go without much stability in the market. Few of the barrier materials on the market at any time continue to be available for more than 5-10 years; most need to be made in bulk to keep costs down, yet cost remains high enough to hinder demand and reduce bulk use.

The ability of vegetative fragments to recolonize porous (mesh) benthic barriers has made porous barriers less useful for combating infestations by fanwort on any but the smallest scale, as sheets must be removed and cleaned at least yearly. Solid barriers have been more useful, although gas entrapment has been troublesome; billowing occurs without venting and anchoring, yet appropriate venting and anchoring creates problems for eventual maintenance or redeployment. Expense dictates that only limited areas can be treated without re-use of a deployed barrier. Nevertheless, benthic barriers are capable of providing control of fanwort on at least a localized basis, and have such desirable side benefits as creating more edge habitat within dense plant assemblages and minimizing turbidity generation from fine bottom sediments.

Plants under the barrier will usually die completely after about a month, with solid barriers more effective than porous ones in killing the whole plant. Barriers of sufficient tensile strength can then be moved to a new location, although continued presence of at least solid barriers restricts recolonization.

Cost and labor are the main factors limiting the use of benthic barriers in most lakes, and would be prime deterrents in Lake Boon. Cost per installed square foot is on the order of $1.00 (Table 22), leading to an expense of about $40,000 per acre. Bulk purchase and use of volunteer labor can greatly decrease costs, but use over the entire area infested with fanwort is highly unlikely, even if permittable.

The application of solid barriers such as Palco Pond Liner is useful in controlling small (<1 acre) beds of rooted aquatic plants where the material is left in place and where effort is expended on removing any peripheral growths. Redeployment of barriers will reduce the overall cost of this approach and is consistent with the goal of restoring a native plant assemblage to areas infested with fanwort, but is likely to require additional effort at the original application site to prevent recolonization by fanwort. Such effort might include hand harvesting of fanwort for at least two growing seasons after removal of the barrier, or might involve augmentation of the native population in the formerly covered area.

Benthic barriers offer some potential for localized control of fanwort in Lake Boon. If a more comprehensive lake management plan incorporating fanwort control does not gain adequate funding or approval by regulatory agencies, use of benthic barriers by individuals or small groups would seem to be a logical, if sub-optimal, approach to fanwort control on a patchwork basis. This approach, however, will not satisfy the objectives for management of Lake Boon as originally designed.

4.2.1.7 Chemical Control

There are few aspects of plant control that breed more controversy than chemical control through the use of herbicides, which are a subset of all chemicals known as pesticides. Part of the problem stems from pesticides which have come on the market, enjoyed widespread use, been linked to environmental or human health problems, and been banned from further use. Many pesticides in use even 20 years ago are not commonly used or even approved for use today.

Yet as chemicals are an integral part of life and the environment, it is logical to seek chemical solutions to problems such as plant species which grow to nuisance proportions, just as we seek physical and biological solutions. Current pesticide registration procedures are far more rigorous than in the past. While no pesticide is considered unequivocally "safe," a premise of federal pesticide regulation is that the potential benefits derived from use outweigh the risks when the chemical is used according to label restrictions.

Among the variety of herbicides available today, only one has potential applicability for the nuisance plant species found in Lake Boon. This is fluridone, a systemic chemical that affects target plants by inhibiting critical metabolic pathways after uptake through roots, leaves or shoots. Fluridone (1-methyl-3-phenyl-5-[3-(trifluoromethyl)phenyl]-4[1H]-pyridinone) is the only approved herbicide capable of controlling fanwort, the most abundant nuisance species in Lake Boon. It would have some effect on the other species as well, but is unlikely to eradicate them. It may be possible to use fluridone to selectively remove fanwort, if so desired, based on experience in the Charles River and elsewhere.

Fluridone, which is the active ingredient in Sonar, obtained Federal registration in 1986 and has been in widespread use since the late 1980's. It currently comes in two formulations, an aqueous suspension (Sonar AS) and a slow release pellet (Sonar SRP), although an even slower release pellet is in the development stage. This chemical inhibits carotene synthesis, which in turn exposes the chlorophyll (active photosynthetic pigment) to photodegradation. Most plants are negatively sensitive to sunlight in the absence of protective carotenes, resulting in chlorosis of tissue and death of the entire plant with prolonged exposure to a sufficient concentration of fluridone. Fluridone has been used to control fanwort and certain other species in the Charles River system with up to three years of success from a single treatment.

For susceptible plants, lethal effects are expressed slowly in response to treatment with fluridone. Existing carotenes must degrade and chlorosis must set in before plants die off; this takes several weeks to several months, with 30-90 days given as the observed range of time for die off to occur after treatment. Fluridone concentrations should be maintained in the lethal range for the target species for at least three weeks, and preferably for six weeks. This presents some difficulty for treatment in areas of substantial water exchange, but the slow rate of die off minimizes the risk of oxygen depletion. The need for prolonged exposure to an adequate Sonar concentration also creates a potential conflict with use of waters for irrigation or other agricultural purposes.

We are told that Lake Boon water is drawn from many shallow wells along its shoreline for consumptive purposes. Consequently, some concern may be expressed over use of an herbicide within an aquifer zone, but Sonar has been used directly in water supplies in the past. Appendix E has been provided as reference material with regard to Sonar.

Sonar is considered to have low toxicity to invertebrates, fish, other aquatic wildlife, and humans. It is not known to be a carcinogen, oncogen, mutagen or teratogen. Research on its degradation products initially suggested some possible effects, but further testing indicated no significant threat. Substantial bioaccumulation has been noted in certain plant species, but not to any great extent in animals. The USEPA has designated a tolerance level of 0.5 ppm (mg/l or mg/kg) for fluridone residues or those of its degradation products in fish or crayfish. The USEPA has set a tolerance limit of 0.15 ppm for fluridone or its degradation products in potable water. The recommended dose in Lake Boon would be no more than 0.05 ppm.

Label restrictions for Sonar AS include maintenance of a distance of one quarter mile (1,320 ft) between treatment locations and potable water intakes, although there are no federal restrictions on the use of treated water at concentrations <0.02 mg/l (20 ppb); the required distance is assumed to allow sufficient dilution to eliminate all possible effects from water collected by intakes.

It would be necessary to hold water in Lake Boon for several weeks to ensure effectiveness and limit downstream impacts, but this could be accomplished by the removal of one or two flashboards at the dam, allowing the water level to be lowered prior to treatment, at which time the board(s) would be replaced. Pelletized Sonar SRP could be used, but the nature of the organic mucks in the pond may cause incomplete release of fluridone from the pellets through "plugging." Consequently, use of the liquid Sonar AS is preferred in this case. It may be appropriate to apply sequential treatments in Basin 3 of the lake to minimize downstream transport and maintain the desired concentration.

Given the species present in Lake Boon, treatment with the systemic herbicide Sonar, which has fluridone as its active ingredient, would be likely to provide the desired range and longevity of control over the plant species present with the least number of adverse side effects. Costs would range from about $300-500 per treated acre. Assuming an 84 acre treatment of Lake Boon's two plant infested basins (Basins 2 and 3), an initial treatment cost of $25,200-42,000 would be expected with repeat treatments on at least a 2- to 4-year cycle. In addition, about $2,000 in permitting costs are expected if the process went smoothly. However, issues with respect to use in an aquifer zone, downstream uses of water, and possible downstream impacts (either from Sonar residuals or from withholding water for several weeks) will have to be thoroughly investigated before permitting can be undertaken. This may add another $3,000 to the cost, but will determine whether or not the treatment can be performed. Although some measure of plant control may be achievable in Lake Boon with this herbicide, the logistics of such a treatment are complicated and the expense would be substantial.

Costs in the permitting process could escalate if there is any significant opposition to the treatment. Permits could be denied, appealed, or rigorously conditioned, the last of which could add cost both through constraints on the treatment process and monitoring expense. Costs cannot be precisely estimated, but the cost of the treatment could rise as much as 25%, and a rough estimate of $8,000 in monitoring costs is postulated as an addition to any monitoring proposed in response to objective #4 (monitoring for early warning and tracking of progress).

There is one other herbicide that may have some potential to control fanwort; however, it is still experimental and we know of no data regarding its use against fanwort. This herbicide, Garlon 3A with triclopyr as its active ingredient, is currently experimental for aquatic habitats. If successfully registered for aquatic use, it will be marketed under the tradename Renovate. Its mode of action is to prevent synthesis of plant-specific enzymes, resulting in disruption of growth processes. Like Sonar, this herbicide is most effective when applied during the active growth phase of young plants. It represents a possible future tool.

4.2.2 Minimize Impact from Watershed Activities, Improve Water Quality and Protect Future Water Quality

Existing water quality within Lake Boon is generally acceptable for most intended uses of the lake. Concentrations of phosphorus and nitrogen, considered to be the most important plant nutrients, are moderate. Dense algal blooms are reported to occur and the coverage of Basin 3 by floating aquatic plants is a direct result of these somewhat elevated nutrient values. Also, the fertile particulate accumulations (organic bottom sediment) fuel rooted plant growths and algal mat development.

The estimated annual load of phosphorus from models employing in-lake values and hydrologic variables (Table 11) is well above the calculated permissible load, the load above which algal blooms and related water quality impairment are considered likely. The load predicted from those models, however, is below the critical load, above which frequent problems would be expected. Estimation from itemized sources and water quality data collected during this study also suggests a phosphorus load well above the permissible loading limit (Table 12), although some of that phosphorus is believed to be entering in particulate form not immediately available to algae or plants. Therefore, current land uses (particularly, a high residential density in close proximity to the lake) are considered to have a detrimental effect on Lake Boon. Management should take the form of prevention in this regard, which translates into either source reduction or pollutant trapping. Phosphorus concentrations in Lake Boon are at a level that is very sensitive to changes in the phosphorus loading to the lake. Any management efforts that reduce phosphorus loading are likely to exhibit immediate benefits to in-lake water quality. Rooted plant growth, however, will not change appreciably in response to decreases in phosphorus loading since plants will continue to draw their nutrients from the lake sediments.

Due to the watershed's highly residential usage, sources of contaminants are numerous in this watershed. Lawn fertilizers and other maintenance chemicals, pet and urban wildlife wastes, car washing, road sanding and salting, erosion from new construction, and a variety of routine activities within the watershed generate pollutants that are washed with runoff into the storm water drainage system and eventually enter Lake Boon. Additionally, "dryfall" (particulates which fall from the sky) can contain substantial pollutants that originated outside the watershed and are deposited continuously. These substances would become part of the soil base in a forested system, but are easily washed from pavement and packed lawns in a residential watershed with each storm event.

Available lake and watershed management options are summarized in Table 20. The list is not especially long, although it is possible to greatly expand this list by subdividing the functional categories of management options based on a number of details. Additionally, the combination and level of application of techniques for a given lake or watershed can vary greatly, making each lake a unique situation to some extent. Techniques, as listed in Table 20, are essentially "taken off the rack" and tailored to meet specific lake management needs. With regard to Lake Boon's watershed, the applicable techniques would include behavioral modifications, detention or infiltration of runoff, increased street sweeping and catch basin cleaning, stormwater diversion, and chemical treatment of runoff. The in-lake techniques that should be considered would be dredging of bottom sediments and possibly nutrient inactivation, although these represent mitigation of unavoidable inputs, not input remediation.

4.2.2.1 Minimize Internal Nutrient Recycling

Although there are few data to support a projection of impact, oxygen depletion as a function of sediment-water interaction is a possibility in Lake Boon's hypolimnion. Sediment oxygen demand is normally encountered within inches of the sediment-water interface, but can cause unhealthy loss of oxygen in a greater portion of the water column in the presence of thermal stratification. Oxygen plays an important role in controlling the rate of phosphorus release from the sediments. When the sediment-water interface becomes anoxic (dissolved oxygen concentration at 0 mg/L), phosphate passes rapidly into the water above. The phosphorus can then be mixed throughout the lake once the stratification period ends (typically during spring and fall). In Lake Boon, phosphorus was not detected in the composite sediment samples at an elevated level. However, it is possible that much of the phosphorus was released from the sediment at the time of sampling. Elevated phosphorus concentrations in the water column of the hypolimnion supports this assumption.

Four possible alternatives exist for the remediation of this problem: aeration, nutrient inactivation, sequestration, and sediment removal. None of these management alternatives are warranted at this time. In addition, each of these alternatives for controlling phosphorus release from sediment are relatively expensive, while the phosphorus released through internal recycling was determined to be only 3.4 kg/yr. This represents less than 3% of Lake Boon's entire phosphorus load. Funds would be better spent toward the management of more significant sources.

4.2.3 Curtail Excessive Contaminant Loading

The loading of sediment, phosphorus, nitrogen, bacteria, salt and a variety of other contaminants to Lake Boon is most likely erratic and largely a function of episodic storm events. The tributaries deliver high contaminant concentrations but do not appear to deliver excessive loads since they represent a very small portion of the total hydrologic budget. Sediment loads over time are sufficient to cause some build-up, but total loads of most contaminants are not beyond the assimilative capacity of this system. The effect of these impacts is likely to be fully expressed under long detention times. When storms are followed by longer periods of dry weather, the potential for water quality impacts is greatly increased.

Loading analysis indicates that the permissible load for phosphorus in Lake Boon is exceeded, suggesting that eutrophic conditions should exist on a relatively frequent basis. However, in-lake water quality in a wet year such as 1998 is more a function of instantaneous input concentrations and detention time than any in-lake processes. The relatively higher rate of flushing during 1998 appears to have minimized any algal biomass accumulations or visual water quality impairment during this investigation, other than moderate turbidity following storm events. Yet such conditions may not prevail during a dry year. Flushing will still be an important factor, but intermittent problems might be expected. Watershed management actions would be necessary to minimize in-lake water quality problems that could be induced under detention time increases that result during dry years.

Although actions within the drainage basins of the main tributaries may be justified, primary concentration should focus on managing nutrient inputs (especially phosphorus) from residential areas surrounding the lake. The high density and close proximity of many homes to Lake Boon is responsible for a major fraction of the phosphorus load. Elimination or major reduction of inputs from these drainage areas might satisfy the management objective without requiring implementation of more drastic in-lake management alternatives. Possible actions include behavioral modifications, increased detention, increased street sweeping, maintenance and upgrade of on-site disposal systems, installation of sewer lines, and land use planning (Table 20).

Behavioral Modifications: Behavioral modifications include alteration of individual or group practices that lead to increased runoff or pollutant loading. Actions relating to lawn care, yard waste disposal, automotive cleaning and maintenance, and deicing would be likely targets for this approach. Lawn fertilization, particularly with phosphorus, is only a necessity when trying to establish a new lawn, and the desirability of lawns in close proximity to a lake should be questioned in any case. Where storm drainage systems are extensive, even lawns distant from the lake can have a distinct impact. Enough green lawns usually translate into a green lake. Chemicals used outdoors should be used only as needed and in a manner consistent with minimizing transport from the property. Lawn wastes should be properly composted or bagged for hauling to an approved disposal area. Pet wastes should be collected and processed with other solid waste. Residences served by septic systems should avoid garbage grinders, as they unnecessarily load the system with solids and increase the frequency of pump-out necessary to maintain efficient function. The ban on the sale of phosphate laden detergents in Massachusetts is an example of legislated behavioral change. Illegal dumping does not appear to be a problem in this case, although no study of what is placed in storm drains has been conducted. Although not exhaustive, Appendix D has been provided to give examples of information that should be included in an educational program for watershed residents.

Modifications are usually attained by a combination of education and regulation, but there are practical limits in a heavily residential environment. Most behavioral controls are best implemented on a voluntary basis, and are likely to provide up to a 10 percent reduction in loads. It very unlikely that more than a 10% reduction could be achieved through behavioral controls as much of the nutrients entering the lake are from natural sources and the watershed is already heavily developed. Mandatory controls are better suited to situations of clear non-compliance, as with illegal hook-ups to the storm drainage system or faulty septic systems. These are not expected to be a major problem in this system, but further study would be necessary. Such a study might involve dye testing individual septic systems with monitoring of discharges at key locations to define any "hotspots". Funding on the order of $12,000 is estimated for this monitoring.

There are typically no permits or tangible costs associated with behavioral modifications, but compliance is difficult to measure and major changes in water quality are rarely observed as a result. It would be beneficial, however, to encourage appropriate residential property management through a brochure aimed at informing watershed residents of their link to water quality and role in protecting it. Such a brochure could be produced and distributed for a cost of under $3,000.

Increased Detention: Detention approaches suffer from limits on land availability and treatment efficiency. The runoff produced from a 1-inch storm would occupy over 2 million cubic feet, probably the minimum detention volume for a system with detectable benefit to Lake Boon. As an acre-foot equates to 43,560 cubic feet of water, somewhere between 30 and 50 acre-feet of detention area would be needed to hold the runoff now entering Lake Boon during storms of sub-two year frequency.

Treatment efficiency for detention systems varies by parameter and system design, but typical systems can be expected to remove 30%-40% for phosphorus without auxiliary treatment of some kind (Schueler 1987). Removal rates may be higher for particulate phosphorus, but the average is lowered by the inability of the system to remove most of the dissolved phosphorus. Both dissolved and particulate forms are important in this watershed, and an overall reduction of 20% is needed to reach the permissible load. Storm water represents a significant input source, constituting over 50% of the total phosphorus load. Elimination of storm water inputs may be sufficient by itself to reach the permissible loading limit. Effectiveness would be dependent upon the design, location, and capacity of the detention system(s).

Assuming land could be made available (a total of roughly 10 acres), design and permitting of an appropriately designed system or series of systems could cost up to $100,000. In addition, at a rough cost of $5/cubic yard of detention capacity gained (based on a minimum excavation rate), the construction of suitable detention facilities (totaling 30-50 acre-feet) would cost between $242,000 and $403,000. While any detention would represent an improvement, substantial detention is needed to make a noticeable difference. If watershed development continues, particularly in the relatively undeveloped watershed sub-basins 1 and 4, detention facilities should be considered.

Increased Street Sweeping and Catch Basin Maintenance: By increasing the frequency of street sweeping and catch basin cleaning, the towns could remove some potential runoff pollutants. Catch basins should be cleaned once or twice per year, although this does not happen in many municipalities. Street sweeping would have to be performed far more frequently than in even the most actively managed watersheds, as particulates should be removed from the street between storms. A frequency of at least monthly would be necessary, perhaps even more often. Additionally, vacuum equipment is far more effective than conventional brush technology, which picks up less than half the load in most cases.

A program which provides monthly vacuuming of all streets and semi-annual cleaning of all catch basins in the Lake Boon watershed would carry a capital cost of over $200,000 and an operational cost of at least $35,000/yr, and would address only those pollutants on roadways or trapped by catch basins. While roadway pollutants could be an important source of contamination, contaminants on lawns are likely to be at least equally important, and would not be appropriately addressed by a street-sweeping program. Beyond normal street and catch basin maintenance, this approach has only limited merit for the Lake Boon watershed.

Maintenance and Upgrade of On-Site Disposal Systems: Contaminant loading from groundwater was a significant source of Lake Boon's total contaminant load. The phosphorus load from groundwater as measured during this study represented nearly 10% of the lake's total phosphorus load. This source becomes even more significant during periods of low surface water inputs (late summer and early fall). Proper septic system management involves exercising caution with regard to what is put into the system and calls for periodic tank inspection and pump out. Septic systems will not control nitrogen inputs to any appreciable extent, but can be an effective phosphorus removal system. It is essential that homeowners understand that wastes are being processed and that an effluent is being discharged into the environment, even though it cannot be seen. Antiquated systems should be replaced, as it is unreasonable to expect the environment and its users to pay for any individual homeowner's failure to properly treat wastes. A septic system pumping program was recommended as part of the CDM study (CDM 1987). The existing study points toward specific shoreline areas that should be investigated further for faulty treatment systems.

Sewering: Installation of sewer lines within the Lake Boon watershed would be somewhat beneficial towards improving water quality since nearly 10% of the phosphorus load to the lake can be attributed to groundwater. Costs of sewering could exceed 5 million dollars (CDM 1987). As there are many issues associated with development of a sewer system within the watershed, in addition to the capital costs, it is unlikely that this alternative can bring relief in the near future. Improvements achieved through increased maintenance of existing treatment systems may be sufficient to improve water quality in timely manner and at a much reduced cost. Implementation of this alternative is not warranted at this time.

Land Use Planning: The lake is a reflection of its watershed, which is currently heavily developed around the lake's perimeter but much less developed throughout the entire watershed. It is recommended that efforts are made to preserve natural areas not subject to protection (as with wetlands), especially along stream corridors and encourage best management practices for agriculture and construction. Costs for such actions are highly variable and unpredictable, but could be minimal with thoughtful use of existing regulations and programs. Additionally, performing a build-out analysis (about $4,000) for the Lake Boon watershed would be beneficial toward determining how water quality would change if all available sites were developed. A build-out analysis would also discuss how such impacts might be mitigated for any future development.

4.2.4 Long-term Annual Monitoring of Lake Boon

In addition to the five objectives discussed above, it would be of great benefit to the future management of Lake Boon to implement a cost efficient long-term annual monitoring program. This would provide continuous background data for the purpose of tracking the effectiveness of future management practices that may be implemented. Since water quality can be unacceptable during some years, the monitoring program for water quality should center on tracking in-lake conditions during the peak growing season each year. This will allow quantification of the normal range of parameter values and recognition of any potentially detrimental shifts or trends. Water clarity and phosphorus levels would be the key variables in this regard. Also, assessment of easily measured field parameters (pH, oxygen, temperature, conductivity, turbidity and flow) would be beneficial. Evaluation of plant species density and distribution should be the focus of biological monitoring.

Evaluating water quality trends truly requires several years of continuous data, with multiple samples collected in each year. Evaluation of management techniques would be more immediate, allowing comparisons between pre- and post-management periods. It would seem most appropriate to collect a single sample from a central area of the lake's main basin (Basin 1) once in the early spring to assess conditions at the start of the growing season. Additional samples should be collected again in June and August to represent the period of greatest usage and potential impact. It would be useful to include investigative sampling to further characterize storm water inputs over time. Annual plant mapping should also be conducted, with particular attention to the growth and spread of invasive species such as fanwort (*Cabomba caroliniana*).

A proposed monitoring plan is outlined in Table 23. This program would cost approximately $6,000 per year. Most of the tasks could be carried out through a volunteer monitoring program at a reduced cost after some initial training and equipment purchases. The value of the long-term data that could be collected through such a simple program should not be underestimated.

5.0 RECOMMENDED MANAGEMENT PROGRAM

Based on the previous discussion and consideration of options, the recommended program for achieving the stated objectives would include three distinct phases: aquatic weed control, nutrient source control through public education, and annual monitoring.

1. Control rooted aquatic plants, with emphasis on fanwort, by one of the following means:

   a) Perform a treatment with the aquatic herbicide Sonar AS, a liquid formulation of fluridone, to reduce plant densities, with effort directed toward the eradication of fanwort. Actual treatment costs are expected to range from about $20,000 to $30,000, with permitting and monitoring costs estimated at up to $15,000, depending upon constraints imposed by regulatory agencies.

b) Conduct a drawdown of the pond to a test level of 2 feet below the normal water level; monitor the results in the 11% of the lake which would be exposed, and attempt a 4 ft drawdown (23% exposure) if results are encouraging. Determine impacts to shallow wells. Monitoring and permitting costs are estimated at up to $14,000. No initial engineering or construction costs are expected, although some outlet modification may be desirable if this approach proves satisfactory.

c) Implement a dredging feasibility investigation to determine if it is possible to dredge Basin 3 of Lake Boon: The study should include an assessment of the sediment quality as per the MADEP guidelines for dredge material disposal, total sediment volume to be dredged, and potential sites for dewatering and disposal. Although dredging is proposed here only as a long-term solution, it would be wise to continue to aggressively work toward this goal. Dredging is the only means for eliminating the soft, organically rich sediment that is fueling plant growth in the lake. This will also restore the original depth to this portion of the lake. Approximately $8,000 will be needed for a feasibility assessment, with a commitment of between $500,000 and $2,000,000 in total project costs if the project proves feasible.

2. Nutrient source control with emphasis on septic system maintenance and behavioral modifications by watershed residents:

   a) Implement a program for identifying and correcting faulty wastewater treatment systems located within 300 feet of the tributaries or lake shoreline (Section 4.2.3). Costs for identifying problems would be approximately $12,000, but the burden of repair would likely fall on the individual homeowner.

   b) Develop and distribute an educational brochure for watershed residents. This could be prepared by an outside consultant at a cost of approximately $3,000, or with some research, by a motivated group of volunteers for substantially less. If there is enough interest, a workshop could also be conducted as part of the educational program for very little additional expense.

   c) Further investigate the possibility of minimizing stormwater runoff to the lake through increased detention/infiltration capabilities. Investigations would focus on identifying areas that might be used based on strategic location and availability.

3. Establish a monitoring program to provide early warning of future problems and to track the progress of management efforts. An annual cost of $6,000 is expected, exclusive of any special monitoring costs associated with plant control techniques.

Table 23 summarizes these recommended management techniques, the suggested order of implementation, and the associated costs for each. The most cost effective and appropriate means by which to achieve the goal of reducing aquatic weed biomass in Lake Boon over the short term would be chemical treatment. The herbicide fluridone (Sonar) would be safe and extremely effective but would not be the best option for long-term control due to costs associated with reapplication. Lake drawdown alone may potentially reduce plant growth along the perimeter of the lake to a level that would be satisfactory. Otherwise, drawdown could be used to maximize the effects of any chemical treatment. Drawdown would need to be conducted on an annual basis to maintain open areas in shallow coves and along shorelines. Water level control hinges on the status of the outlet structure, and further inspection of this structure may be needed. Education of watershed residents regarding their influence on water quality is recommended. Due to the densely populated nature of the majority of the watershed this could substantially lower pollutant loads. Creation of larger detention and or infiltration facilities in association with the primary tributaries would enhance water quality during periods of storm flow.

Costs for these management program elements will depend upon their level of application. Chemical treatment of Lake Boon with fluridone could cost as much as $40,000 and would need to be repeated every 2 to 4 years. An additional $2,000 is likely to be required for permitting this action. Drawdown costs are likely to be negligible once initiated and could be performed as maintenance on an annual basis. Investigation of a 2 foot trial drawdown is recommended ($10,000) to determine the impact on shallow wells near the lake shore. Initial permitting costs for the drawdown would be on the order of $4,000. Watershed management actions will carry highly variable costs ranging from relatively small out of pocket costs by homeowners for increased treatment system pumping to over $5,000,000 to construct sewer lines. An educational brochure for watershed residents could be prepared for approximately $3,000 describing actions that should be taken at the local level.

At this time, a short-term program is recommended to meet the stated objectives. An overall cost for the short-term program on the order of $60,000 is envisioned. The program would focus on the control of plant growth through herbicide application and drawdown. At this time, only minor improvements in water quality are required and these may be achieved through the distribution and implementation of an educational brochure.

Although not warranted at this time, the long-term program that would include the dredging of Basin 3, the creation of stormwater detention facilities, and the installation of sewer lines. Costs for this program would likely exceed $7,000,000 and could be implemented incrementally, as funding becomes available.

Finally, it would be beneficial to establish some form of monitoring to assess annual plant distribution and density, along with water quality monitoring to establish a database for the lake and incoming waters. This would allow tracking of management progress and provide warning of potential problems. The associated expense is minimal ($6,000/yr) by comparison with management costs.

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TABLES

Table 1. Land use within each of the five watershed sub-basins within the Lake Boon watershed.

Land Use	Lake Boon (acres)	Sub-Basin 1 (acres)	Sub-Basin 2 (acres)	Sub-Basin 3 (acres)	Sub-Basin 4 (acres)	Sub-Basin 5 (acres)	Total acres for Watershed
Industrial	0.0	0.0	0.0	0.0	16.4	20.0	**36.4**
Commercial	0.0	0.0	0.0	0.0	20.5	6.7	**27.2**
Residential	0.0	109.3	0.0	56.9	25.1	61.8	**253.1**
Agriculture	0.0	5.1	4.6	5.1	0.0	0.0	**14.8**
Forest	0.0	205.2	79.5	50.3	205.2	43.3	**583.5**
Water	161.0	0.0	0.0	0.0	0.0	0.0	**161.0**
Total Acres	161.0	319.6	84.1	112.3	267.2	131.8	**1076.0**

Table 2. Transect data collected from Lake Boon (corresponds with locations on Figure 4)

Survey Point ID	Water Depth (feet)	Sediment Depth (feet)	Sediment Type	Plant Cover	Plant Biomass	Plant Species
T1 (Basin 1)						
1	7	-	Sand	0	0	
2	12.9	-	Sand	0	0	
3	15.1	-	Sand	0	0	
4	15.5	-	Sand	0	0	
5	15.1	-	Sand	0	0	
6	14	-	Sand	0	0	
7	13	-	Sand	0	0	
8	10	-	Sand	0	0	
T2 (Basin 1)						
1	11.7	-	Sand	0	0	
2	20	-	Sand	0	0	
3	20	-	Sand	0	0	
4	20	-	Sand	0	0	
5	21	-	Sand	0	0	
6	21	-	Sand	0	0	
7	17.1	-	Sand	0	0	
8	8.2	-	Sand	0	0	
T3 (Basin 1)						
1	4.1	-	Sand	0	0	
2	8.2	-	Sand	0	0	
3	13.4	-	Sand	0	0	
4	14.2	-	Sand	0	0	
5	15.5	-	Sand	0	0	
6	15.5	-	Sand	0	0	
7	14	-	Sand	0	0	
8	12.5	-	Sand	0	0	
9	5.8	-	Sand	0	0	
T4 (Basin 1)						
1	13	-	Sand	0	0	
2	15.5	-	Sand	0	0	
3	19.6	-	Sand	0	0	
4	20	-	Sand	0	0	
5	21	-	Sand	0	0	
6	21	-	Sand	0	0	
7	21	-	Sand	0	0	
8	22	-	Sand	0	0	
9	19.2	-	Sand	0	0	
10	8.8	-	Sand	0	0	
T5 (Basin 1)						
1	3.8	-	Sand	0	0	
2	17.5	-	Sand	0	0	
3	20	-	Sand	0	0	
4	20	-	Sand	0	0	
5	20	-	Sand	0	0	
6	20	-	Sand	0	0	
7	20	-	Sand	0	0	
8	15.5	-	Sand	0	0	
9	6.7	-	Sand	0	0	
T6 (Basin 1)						
1	5	-	Sand	1	1	Cc
2	13.2	-	Sand	1	1	Cc
3	11	-	Sand	1	1	Cc
T7 (Basin 2)						
1	6.1	-	Sand	2	1	Cc, Nf, Mh
2	12.7	-	Sand	2	1	Cc
3	8.6	-	Sand	4	1	Cc
T8 (Basin 2)						
1	6.5	-	Sand	3	1	Cc, Nf, Mh
2	6.7	-	Sand	3	1	Cc
3	8.2	-	Sand	3	1	Cc
4	7.4	-	Sand	4	1	Cc
5	7.1	-	Sand	4	1	Cc
6	6.1	-	Sand	3	1	Cc

Key to Species
Cc - Cabomba caroliniana, Usp - Utricularia sp., Pa - Potamogeton amplifolius, Pr - Potamogeton robinsii,
Pp - Potamogeton pusillus var. gemmiparus, No - Nymphaea odorata, Cd - Ceratophyllum demersum, BG - blue green alga
Mh - Myriophyium heterophyium, Bs - Brasenia schieberi, Ssp - Sagittaria sp., Po - Polygenum, FG - filamentous green alg
Nv - Nuphur variagatum, Wc - Wolffia columbiana, Lm - Lemna minor, Nf - Najas flexilis

Key to Plant Cover and Plant Biomass
0 = No Plants, 1 = 1-25%, 2= 26-50%, 3 = 51-75%, 4 = 76-100%

Table 2. Continued

Survey Point ID	Water Depth (feet)	Sediment Depth (feet)	Sediment Type	Plant Cover	Plant Biomass	Macrophyte Species
T9 (Basin 2)						
1	4	-	Sand	4	1	Cc
2	6.2	-	Sand	4	1	Cc
3	7.2	-	Sand	4	1	Cc
4	12	-	Sand	4	1	Cc
5	10.7	-	Sand	4	1	Cc
6	6.6	-	Sand	4	1	Cc
7	6.9	-	Sand	4	2	Cc
8	6.6	-	Sand	4	2	Cc
9	5	-	Sand	4	2	Cc
T10 (Basin 2)						
1	3.8	-	Sand	4	1	Cc
2	5.7	-	Sand	4	1	Cc
3	10.7	-	Sand	4	1	Cc
4	10.9	-	Sand	4	1	Cc
5	5.5	-	Sand	4	1	Cc
6	6.3	-	Sand	4	2	Cc
7	4.8	-	Sand	4	2	Cc
T11 (Basin 2)						
1	6.7	2.5	Sand	1	1	Cc
2	10.0	0.0	Sand	1	1	Cc
3	8.0	3.0	Sand	4	1	Nf, Cc
T12 (Basin 3)						
1	7.8	1.3	Sand	4	3	Cc, No, Mh
2	7.5	4.0	Sand	4	2	Cc, Pa
3	8.5	3.5	Sand	4	1	Cc
4	8.8	3.2	Sand	4	2	Cc, No
T13 (Basin 3)						
1	4.0	1.3	Sand	4	2	Cc, No, Pa, Bs, Mh, Ssp, Po
2	7.2	3.1	Sand	4	3	Cc, Usp, Pa
3	7.4	4.6	Sand	4	2	Cc, Pa
4	5.1	1.0	Sand	4	3	Cc, No, Pa, FG, Mh, Nv
T14 (Basin 3)						
1	2.4	0.0	Sand	4	3	Cc, Usp, Pa, Pr, Pp
2	6.0	0.5	Sand	4	3	Cc, Pa, No, Usp
3	5.8	3.2	Sand	4	2	Cc, Cd, Usp, Pa
4	6.2	4.8	Sand (fine)	4	4	Cc, No, Pa, Pr, Usp, BG
5	6.5	4.0	Sand	4	3	Cc, No, Cd, Pa
6	6.0	1.2	Sand	4	4	Cc, No, Pa, Mh, Usp
T15 (Basin 3)	3.8	5.5	Hard	4	4	Cc, Bs, No, Nv, Mh
T16 (Basin 3)						
1	6.2	0.6	Gravel	4	4	No, Bs, Cc, Pa, Usp
2	9.2	4.8	Gravel	3	2	Cc, Pa, BG
3	6.6	3.7	Hard	4	4	Cc, BG
T17 (Basin 3)						
1	5.2	2.1	Hard	4	3	Cc, Bs, No, Nv, Pa, Mh
2	7.7	3.3	Sand	4	3	Cc, BG
3	7.3	4.7	Hard	4	4	Cc, No, BG
4	6.0	3.5	Hard	4	4	Mh/Cc, Pa, Bs
T18 (Basin 3)						
1	4.5	3.5	Hard	4	4	Bs, Wc, Lm, Usp, Mh, Nv, Cc
2	4.9	4.6	Hard	4	4	Mh, Bs, No, Cc, Pa
3	4.3	5.2	Hard	4	4	Mh, Bs, No, Cc, Pa, Wc, Lm
4	4.5	5.5	Hard	4	4	Mh, Bs, No, Cc, Wc, Lm
5	4.5	4.3	Sand	4	3	Cc, Bs, Wc, No, Mh

Key to Plant Species
Cc - Cabomba caroliniana, **Usp** - Utricularia sp., **Pa** - Potamogeton amplifolius, **Pr** - Potamogeton robinsii,
Pp - Potamogeton pusillus var. gemiparus, **No** - Nymphaea odorata, **Cd** - Ceratophyllum demersum, **BG** - blue green algae,
Mh - Myriophylum heterophylum, **Bs** - Brasenia schieberi, **Ssp** - Sagittaria sp., **Po** - Polygenum, **FG** - filamentous green alga
Nv - Nuphur variagatum, **Wc** - Wolffia columbiana, **Lm** - Lemna minor, **Nf** - Najas flexilis

Key to Plant Cover and Plant Biomass
0 = No Plants, 1 = 1-25%, 2= 26-50%, 3 = 51-75%, 4 = 76-100%

Table 3. Area and volume calculations from bathymetric contours of Lake Boon.

Depth Contour (feet below water level)	Area (sq. ft.)	Avg. Area (sq. ft.)	Incremental Volume (cu. ft.)	Cumulative Volume (cu. ft.)
22.0	-			
20.0	1,301,355	650,678	1,301,355	1,301,355
15.0	2,108,522	1,704,938	8,524,692	9,826,047
10.0	3,368,364	2,738,443	13,692,215	23,518,262
5.0	5,201,064	4,284,714	21,423,570	44,941,832
0.0	7,013,160	6,107,112	30,535,560	75,477,392

Total water volume in Lake Boon 75,477,392 cu. ft.
Mean water depth in Lake Boon 10.76 feet

Table 4. Water quality data for Lake Boon, Stow/Hudson, Massachusetts

Site	Date	Sample Type (Dry or Wet)	Temp. (Celsius)	Dissolved Oxygen (mg/L)	Saturation (%)	Turbidity (NTU)	pH (SU)	Conductivity (umhos)	Secchi Depth (meters)	Flow (cfs)
LB-1s	7/22/98	Dry	27.1	8.8	111	1.1	7.2	79	3.1	NA
	8/20/98	Dry	25.2	7.2	88	0.8	6.6	111	3.7	NA
	9/24/98	Dry	20.7	7.2	80	4.7	6.3	151	2.3	NA
LB-1b	7/22/98	Dry	17.7	0.1	1.4	2.5	8.1	72	NA	NA
	8/20/98	Dry	16.5	0.2	2	3.4	6.2	113	NA	NA
	9/24/98	Dry	18.4	0.2	2.5	2.8	6.3	143	NA	NA
LB-2s	7/22/98	Dry	27.8	8.7	111	1.2	8.1	72	1.5	NA
	8/20/98	Dry	24.5	7.3	89	1.0	6.4	115	1.5	NA
	9/24/98	Dry	19.9	7.4	81	0.8	6.3	136	1.5	NA
LB-T	7/22/98	Dry	14.3	NA	NA	0.3	-	16	NA	0.15
	8/20/98	Dry	13.8	NA	NA	0.2	6.3	129	NA	0.01
	9/24/98	Dry	12.4	NA	NA	0.3	5.9	147	NA	0.18
	8/24/98	Wet	13.0	NA	NA	26.4	5.5	83	NA	1.0
	10/8/98	Wet	15.5	NA	NA	3.0	5.8	130	NA	0.67

NA = Not Applicable to Sampling Station

LB-1s = Lake Boon Water Quality Sampling Station 1 at Surface (Figure 6)
LB-1b = Lake Boon Water Quality Sampling Station 1 at Bottom (Figure 6)
LB-2S = Lake Boon Water Quality Sampling Station 2 at Surface (Figure 6)
LB-T = Lake Boon at the Main Tributary (Figure 6)

Table 5. Water quality data for Lake Boon, Stow/Hudson, Massachusetts

Site	Date	Sample Type (Dry or Wet)	Total Alkalinity (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Ammonium Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Total Phosphorus (mg/L)	Dissolved Phosphorus (mg/L)	Total Suspended Solids (mg/L)	Fecal Coliform (MF) (per 100 ml)
LB-1s	7/22/98	Dry	11	0.75	0.01	<0.01	0.01	<0.01	NA	<10
	8/20/98	Dry	12	0.6	<0.01	<0.01	0.02	0.02	NA	<10
	9/24/98	Dry	16	0.84	0.13	<0.01	0.02	0.01	NA	<10
LB-1b	7/22/98	Dry	11	0.95	0.03	<0.01	0.04	0.03	NA	NA
	8/20/98	Dry	20	1.18	0.05	0.01	0.06	0.04	NA	NA
	9/24/98	Dry	NA	NA	NA	NA	NA	NA	NA	NA
LB-2s	7/22/98	Dry	11	0.74	<0.01	<0.01	0.02	0.01	NA	<10
	8/20/98	Dry	10	0.66	<0.01	< 0.01	0.02	0.01	NA	<10
	9/24/98	Dry	10	0.58	0.01	<0.01	0.02	<0.01	NA	<10
LB-T	7/22/98	Dry	5	0.1	0.02	1.31	<0.01	<0.01	1	70
	8/20/98	Dry	7	0.08	0.02	1.16	0.01	<0.01	1	40
	9/24/98	Dry	7	<0.2	0.02	1.04	0.02	0.02	2	30
	8/24/98	Wet	3	3.3	0.58	1.06	0.52	0.16	230	-
	10/8/98	Wet	-	0.35	0.04	0.95	<0.01	<0.01	4	680

NA = Not Applicable to Sampling Station

LB-1s = Lake Boon Water Quality Sampling Station 1 at Surface (Figure 6)
LB-1b = Lake Boon Water Quality Sampling Station 1 at Bottom (Figure 6)
LB-2S = Lake Boon Water Quality Sampling Station 2 at Surface (Figure 6)
LB-T = Lake Boon at the Main Tributary (Figure 6)

Table 6a. Dissolved Oxygen and Temperature Profiles for Lake Boon - Upper Basin (LB-1)

	Jul-98			*Aug-98*			*Sep-98*		
Water Depth (meters)	Dissolved Oxygen (mg/L)	Saturation (%)	Temperature (°C)	Dissolved Oxygen (mg/L)	Saturation (%)	Temperature (°C)	Dissolved Oxygen (mg/L)	Saturation (%)	Temperature (°C)
0.0	8.75	110.6	27.1	7.2	87.5	25.2	7.2	80	20.7
0.5	---	---	---	7.1	86.2	25.1	7.2	80	20.7
1.0	8.8	110.4	27.1	7.2	86.6	24.6	7.3	81	20.5
1.5	---	---	---	7.1	85.5	24.5	7.2	80	20.5
2.0	8.7	109.8	27.1	7.1	84.7	24.4	7.1	79	20.5
2.5	---	---	---	7	83.4	24.3	7.1	79	20.5
3.0	9.1	113.1	26.5	6.8	87.7	24.3	7	78	20.5
3.5	8.6	100.2	24.6	6.4	76.8	24.2	6.9	77	20.5
4.0	6.5	81.5	23.7	6.1	72.7	24.2	6.9	76	20.4
4.5	---	---	---	5.9	68	23.4	6.9	76	20.4
5.0	0.2	1.6	19.0	0.4	4.4	22.2	6.7	75	20.3
5.5	0.1	1.4	17.7	0.2	2	16.5	6.3	70	20.2
6.0							5.4	62	20
6.5							0.2	2.5	18.4

Table 6b. Dissolved Oxygen and Temperature Profiles for Lake Boon - Lower Basin (LB-2)

	Jul-98			*Aug-98*			*Sep-98*		
Water Depth (meters)	Dissolved Oxygen (mg/L)	Saturation (%)	Temperature (°C)	Dissolved Oxygen (mg/L)	Saturation (%)	Temperature (°C)	Dissolved Oxygen (mg/L)	Saturation (%)	Temperature (°C)
0.0	8.7	111.1	27.8	7.25	88.6	24.5	7.4	81	19.9
0.5	---	---	---	9.3	111.2	23.9	7.1	77	19.3
1.0	8.8	110.5	26.9	8.1	98	23.5	7.1	78	19.2
1.5	---	---	---	6.6	76.3	23.1	5.9	63	18.9
2.0	---	---	---	---	---	---	5.6	59	18.9

Table 7. Results of sediment sampling in Lake Boon conducted on August 20, 1998
Samples were collected from locations corresponding to Figure 7

Parameter	Units	Results	Detection Limit
Solids, Total	%	10	NA
Solids, Total Volatile	%	6	NA
Moisture	%	90	NA
Nitrogen, Total Kjeldal	mg/kg	8,500	1,250
Phosphorus, Total	mg/kg	<40	40
Oil and Grease	mg/kg	518	313
Particle Size			
Sand + (>53 um)	%	0	NA
Coarse Silt (20-53 um)	%	0	NA
Medium Silt (5-20 um)	%	0	NA
Fine Silt (2-5 um)	%	6.1	NA
Clay (<2 um)	%	93.9	NA
Metals, Total			
Arsenic	mg/kg	28	13
Cadmium	mg/kg	<3	3
Chromium	mg/kg	17	13
Copper	mg/kg	30	13
Lead	mg/kg	145	32
Mercury	mg/kg	<0.08	0.08
Nickel	mg/kg	17	13
Zinc	mg/kg	158	32

NA = not applicable

Table 8. Seepage data (water quantity inflow or outflow) for Lake Boon
Station locations correspond to Figure 8

Station	Date	Seepage Time *min*	Seepage Time *hr*	Volume Change *liters*	Seepage *L/m² /D*
S1A	8/13/98	234	3.9	-0.088	-3.0
	10/7/98	210	3.5	0.062	2.4
S1B	8/13/98	232	3.9	0.020	0.7
	10/7/98	214	3.6	0.000	0.0
S2A	8/13/98	211	3.5	-0.138	-3.9
	10/7/98	217	3.6	0.260	7.2
S2B	8/13/98	212	3.5	0.008	0.2
	10/7/98	219	3.7	0.100	2.7
S3A	8/13/98	177	3.0	0.428	14.5
	10/7/98	226	3.8	0.275	7.3
S3B	8/13/98	179	3.0	0.454	15.2
	10/7/98	226	3.8	0.365	9.7
S4A	8/13/98	277	4.6	0.224	6.5
	10/7/98	224	3.7	-0.015	-0.5
S4B	8/13/98	282	4.7	0.084	2.4
	10/7/98	226	3.8	0.215	7.6
S5A	8/13/98	263	4.4	0.170	5.2
	10/7/98	232	3.9	0.095	3.3
S5B	8/13/98	263	4.4	0.358	10.9
	10/7/98	234	3.9	0.208	7.1
S6A	8/13/98	256	4.3	0.390	9.1
	10/7/98	242	4.0	0.058	1.4
S6B	8/13/98	257	4.3	0.264	6.2
	10/7/98	242	4.0	0.060	1.5
S7A	8/13/98	251	4.2	0.140	3.3
	10/7/98	240	4.0	0.010	0.3
S7B	8/13/98	251	4.2	-0.030	-0.7
Average	**8/13/98**	**239**	**4.0**	**0.163**	**4.8**
Average	**10/7/98**	**227**	**3.8**	**0.130**	**3.8**
Combined Average		233	3.9	**0.147**	**4.3**

Table 9. Litoral Interstitial Porewater data (groundwater quality) from Lake Boon Station identification corresponds with Figure 8

Station	Date	pH (SU)	Conductivity (umhos)	Dissolved Phosphorous (mg/L)	Nitrate (as N) (mg/L)	Ammonia (as N) (mg/L)	Total Kjeldahl (as N) (mg/L)	Dissolved Iron (mg/L)
S1	8/13/98	6.6	179	0.10	0.14	0.4	-	0.71
	10/7/98	5.9	148	0.07	<0.01	0.14	0.4	2.5
S2	8/13/98	6.2	164	0.10	0.31	0.08		1.4
	10/7/98	5.6	221	0.01	3.28	<0.01	<0.2	<0.02
S3	8/13/98	5.9	98	0.03	0.01	0.01		0.02
	10/7/98	5.7	170	0.01	<0.01	<0.01	<0.2	<0.02
S4	8/13/98	5.9	36	0.02	0.04	0.01		0.02
	10/7/98	4.75	234	0.02	8.59	<0.01	<0.2	<0.02
S5	8/13/98	5.9	203	0.02	3.12	0.01		0.02
	10/7/98	5.5	280	<0.01	10.7	<0.01	<0.2	<0.02
S6	8/13/98	6.0	464	0.03	3.19	0.4		0.11
	10/7/98	6.2	370	<0.01	1.59	0.21	0.2	6
S7	8/13/98	6.0	265	0.02	1.63	0.01		0.02
	10/7/98	5.5	497	<0.01	0.74	<0.01	<0.2	0.02
Average		**5.83**	**238**	**0.03**	**2.38**	**0.09**	**0.23**	**0.78**

Table 10. Annual hydrologic (water) loading to Lake Boon determined through modeling

Source	(cfs)	Load (m3/min.)	(%)	Notes
Direct Precipitation	0.56	0.95	14.1	
Ground Water Inseepage	0.91	1.55	23.1	
Surface Water	2.48	4.21	62.7	Peak of 35 cfs likely for 2-year storm
Dry Weather*	0.48	0.86	12.8	
Wet Weather*	2.00	3.35	49.9	
Total Annual	3.95	6.71	100.0	

* Subset of surface water total

Watershed Area	4,354,572 square meters
Lake Boon Area	651,567 square meters
Volume	2,114,010 cubic meters
Mean Depth	3.24 meters
Maximum Depth	6.70 meters
Detention Time	219 days (0.600 years)
Flushing Rate	1.67 times/year
Response Time	160 - 266 days

Table 11. In-Lake predictive nutrient loads determined through modeling for Lake Boon

Variable	Total Phosphorus	Total Nitrogen
In-lake concentration *(mg/L)*	0.026	0.797
Min. load *g/m2/yr*	0.14	4.31
In-lake Predictive Models		
Bachmann (N) *g/m2/yr*		6.69
Bachmann (N) *kg/yr*		4,359
Kirchner-Dillon (P) *g/m2/yr*	0.32	
Vollenweider (P) *g/m2/yr*	0.15	
Reckhow (General P) *g/m2/yr*	0.47	
Larsen and Mercier (P) *g/m2/yr*	0.25	
Jones and Bachmann (P) *g/m2/yr*	0.23	
Average of all phosphorus models *g/m2/yr*	0.28	
Average of all phosphorus models *kg/yr*	186	
Vollenweider's permissible		
load *g/m2/yr*	0.23	
load *kg/yr*	151	
concentration *mg/L*	0.043	
Vollenweider's critical		
load g/m2/yr	0.46	
load *kg/yr*	303	
concentration *mg/L*	0.086	

Table 12. Annual phosphorus loads (kg/yr) for Lake Boon listed by source as derived from both field measurements and modeling.

Source	Phosphorus Loads (kg/yr)	Phosphorus Loads (%)
Direct Precipitation	9.99	4.0%
Ground Water Inseepage	24.44	9.8%
Surface Water		
Dry Weather	7.59	3.0%
Wet Weather	203.60	81.8%
Internal Release (from sediments)	3.39	1.4%
Total Annual	249.01	100.0%

Table 13. Maximum, mean and minimum expected phosphorus loading to Lake Boon listed by sub-basin as determined from land use modeling within each of the watershed's sub-basins

Maximum	Sub-Basin 1	Sub-Basin 2	Sub-Basin 3	Sub-Basin 4	Sub-Basin 5	Total for Watershed
Industrial	0.0	0.0	0.0	41.3	50.4	91.8
Commercial	0.0	0.0	0.0	51.7	16.9	68.6
Residential	275.6	0.0	143.5	63.3	155.8	638.1
Agriculture	10.1	9.1	10.1	0.0	0.0	29.3
Forest	68.9	26.7	16.9	68.9	14.5	196.0
Total Load	354.6	35.8	170.5	225.2	237.7	1,023.8
Attenuation Coefficient	0.8	0.2	0.8	0.2	0.8	
Adjusted Total Load	**283.7**	**7.2**	**136.4**	**45.0**	**190.1**	**662.4**

Mean	Sub-Basin 1	Sub-Basin 2	Sub-Basin 3	Sub-Basin 4	Sub-Basin 5	Total for Watershed
Industrial	0.0	0.0	0.0	12.7	15.5	28.1
Commercial	0.0	0.0	0.0	15.8	5.2	21.0
Residential	84.5	0.0	44.0	19.4	47.8	195.6
Agriculture	3.1	2.8	3.1	0.0	0.0	9.0
Forest	19.9	7.7	4.9	19.9	4.2	56.7
Total Load	107.5	10.5	52.0	67.9	72.6	310.5
Attenuation Coefficient	0.8	0.2	0.8	0.2	0.8	
Adjusted Total Load	**86.0**	**2.1**	**41.6**	**13.6**	**58.1**	**201.3**

Minimum	Sub-Basin 1	Sub-Basin 2	Sub-Basin 3	Sub-Basin 4	Sub-Basin 5	Total for Watershed
Industrial	0.0	0.0	0.0	1.3	1.5	2.8
Commercial	0.0	0.0	0.0	1.6	0.5	2.1
Residential	8.4	0.0	4.4	1.9	4.8	19.5
Agriculture	0.3	0.3	0.3	0.0	0.0	0.8
Forest	1.7	0.6	0.4	1.7	0.4	4.7
Total Load	10.4	0.9	5.1	6.4	7.2	29.9
Attenuation Coefficient	0.8	0.2	0.8	0.2	0.8	
Adjusted Total Load	**8.3**	**0.2**	**4.1**	**1.3**	**5.7**	**19.5**

Table 14. Maximum, mean and minimum expected nitrogen loading to Lake Boon listed by sub-basin as determined from land use modeling within each of the watershed's sub-basins

Maximum	Sub-Basin 1	Sub-Basin 2	Sub-Basin 3	Sub-Basin 4	Sub-Basin 5	Total for Watershed
Industrial	0.0	0.0	0.0	255.3	311.4	566.7
Commercial	0.0	0.0	0.0	319.2	104.3	423.5
Residential	1,701.7	0.0	885.9	390.8	962.2	3,940.5
Agriculture	63.7	57.4	63.7	0.0	0.0	184.8
Forest	519.9	201.4	127.4	519.9	109.7	1,478.3
Total Load	2,285.2	258.8	1,077.0	1,485.1	1,487.5	6,593.7
Attenuation Coefficient	0.8	0.2	0.8	0.2	0.8	
Adjusted Total Load	1,828.2	51.8	861.6	297.0	1,190.0	4,228.6

Mean	Sub-Basin 1	Sub-Basin 2	Sub-Basin 3	Sub-Basin 4	Sub-Basin 5	Total for Watershed
Industrial	0.0	0.0	0.0	66.2	80.7	146.9
Commercial	0.0	0.0	0.0	82.7	27.0	109.7
Residential	441.0	0.0	229.6	101.3	249.4	1,021.2
Agriculture	17.9	16.1	17.9	0.0	0.0	51.8
Forest	237.5	92.0	58.2	237.5	50.1	675.4
Total Load	696.4	108.1	305.7	487.7	407.2	2,005.0
Attenuation Coefficient	0.8	0.2	0.8	0.2	0.8	
Adjusted Total Load	557.1	21.6	244.5	97.5	325.8	1,246.5

Minimum	Sub-Basin 1	Sub-Basin 2	Sub-Basin 3	Sub-Basin 4	Sub-Basin 5	Total for Watershed
Industrial	0.0	0.0	0.0	9.8	12.0	21.8
Commercial	0.0	0.0	0.0	12.3	4.0	16.3
Residential	65.5	0.0	34.1	15.0	37.0	151.6
Agriculture	3.1	2.8	3.1	0.0	0.0	8.9
Forest	114.6	44.4	28.1	114.6	24.2	325.9
Total Load	183.1	47.2	65.2	151.7	77.2	524.4
Attenuation Coefficient	0.8	0.2	0.8	0.2	0.8	
Adjusted Total Load	146.5	9.4	52.2	30.3	61.8	300.2

Table 15. Zooplankton concentration and biomass as measured at the two in-lake monitoring stations (LB-1 and LB-2) in Lake Boo

Sample I.D.	Date	Concentration (#/L)	Biomass (ug/L)
LB-1	7/22/98	21.88	37.73
LB-2	7/22/98	18.03	4.74
LB-1	8/20/98	20.27	40.04
LB-2	8/20/98	4.65	2.51
LB-1	9/24/98	22.53	111.99
LB-2	9/24/98	17.3	27.66
Mean		17.44	37.45

Table 16. Phytoplankton concentration and biomass as measured at the two in-lake monitoring stations (LB-1 and LB-2) in Lake Boo

Sample I.D.	Date	Concentration (#/ml)	Biomass* (ug/L)
LB-1	7/22/98	6,458	1,800
LB-2	7/22/98	100,000	2,800
LB-1	8/20/98	14,599	840
LB-2	8/20/98	11,025	2,500
LB-1	9/24/98	15,734	1,500
LB-2	9/24/98	13,213	1,042
Mean		26,838	1,747

* Biomass estimate assumes a specific gravity of 1.0

Table 17. Aquatic and semi-aquatic plants observed in Lake Boon during the summer of 1998 (dominant species are in bold)

Common Name	Scientific Name	Symbol
Arrowhead	*Sagittaria sp.*	Ssp
Bladderwort	*Utricularia radiata*	Ur
Bladderwort	*Utricularia sp.*	Usp
Bladderwort	*Utricularia vulgaris*	Uv
Blue green algae	*Cyanobacteria*	BG
Bur reed	*Sparganium sp.*	Sp
Bushy pondweed	***Najas flexilis***	Nf
Cattail	*Typha sp.*	Ty
Coontail	*Ceratophyllum demersum*	Cd
Duckweed	***Lemna minor***	Lm
Eurasian milfoil	*Myriophyllum spicatum*	Ms
Fanwort	***Cabomba caroliniana***	Cc
Filamentous green algae	*Various species*	FG
Pondweed	*Potamogeton amplifolius*	Pa
Pondweed	*Potamogeton epihydrus*	Pe
Pondweed	*Potamogeton pusillus var. germiparus*	Pp
Purple loosestrife	*Lythrum salicaria*	Ls
Robinson's Pondweed	*Potamogeton robbinsii*	Pr
Smartweed	*Polygonum sp.*	Po
Sphagnum moss	*Sphagnum sp.*	Sh
Stonewort	*Nitella sp.*	Ni
Tapegrass	*Vallisneria americana*	Va
Variable milfoil	***Myriophyllum heterophyllum***	Mh
Water starwort	*Callitriche sp.*	Ca
Watermeal	***Wolffia columbiana***	Wc
Watershield	*Brasenia schrieberi*	Bs
Waterweed	*Elodea canadensis*	Ec
Waterweed	*Elodea nuttallii*	En
White water lily	*Nymphaea odorata*	No
Yellow water lily	*Nuphar variegatum*	Nv
Yellow-eyed grass	*Xyris difformis*	Xd

Table 18. Area (acres) of plant coverage within each of Lake Boon's three basins listed by the corresponding plant coverage densities (0%, 1-25%, 25-50%, 51-75%, and 76-100%)

Percentage of Lake Bottom Covered by Plants (density)	Basin 1 (*acres*)	Basin 2 (*acres*)	Basin 3 (*acres*)	Total Area (*acres*)	Percent of Lake
76-100%	0.0	29.0	42.1	71.2	44.2
51-75%	0.0	9.9	1.9	11.8	7.3
26-50%	0.0	2.2	0.0	2.2	1.4
1-25%	0.7	0.0	0.0	0.7	0.5
0%	75.1	0.0	0.0	75.1	46.7
Basin Totals	75.9	41.2	44.0	161.0	100.0

Table 19. Area (acres) of plant biomass within each of Lake Boon's three basins

Percentage of Water Column Filled by Plant Biomass	Basin 1 (*acres*)	Basin 2 (*acres*)	Basin 3 (*acres*)	Total Area (*acres*)	Percent of Lake
76-100%	0.0	0.0	18.7	18.7	11.6
51-75%	0.0	2.4	10.5	12.9	8.0
26-50%	0.0	9.1	6.7	15.8	9.8
1-25%	1.5	36.3	1.1	38.9	24.1
0%	74.7	0.0	0.0	74.7	46.4
Basin Totals	76.2	47.8	37.1	161.0	100.0

TABLE 20. LAKE RESTORATION AND MANAGEMENT OPTIONS

Technique	Descriptive Notes
Watershed Level	**Approaches applied to the drainage area of a water body.**
1. Agricultural Best Management Practices	Application of techniques in forestry, animal, and crop science intended to minimize adverse impacts.
2. Bank and Slope Stabilization	Erosion control to reduce inputs of sediment and related substances.
3. Behavioral Modifications	Actions by individuals.
a. Use of Non-Phosphate Detergents	Elimination of a major wastewater phosphorus source.
b. Eliminate Garbage Grinders	Reduce load to treatment system.
c. Limit Lawn Fertilization	Reduce potential for nutrient loading to water body.
d. Limit Motorboat Activity	Reduce wave action, vertical mixing, and sediment resuspension.
e. Eliminate Illegal Dumping	Reduce organic pollution, sediment loads and potentially toxic inputs to a water body.
4. Detention or Infiltration Basin Use and Maintenance	Lengthening of time of travel for pollutant flows and facilitation of natural purification processes.
5. Increased Street Sweeping and Catch Basin Cleaning	Removal of potential runoff pollutants from roads and drainage systems.
6. Maintenance and Upgrade of On-site Disposal Systems	Proper operation of localized systems and maximal treatment of waste water to remove pollutants.
7. Provision of Sanitary Sewers	Community level collection and treatment of waste water to remove pollutants.
8. Storm Water or Waste Water Diversion	Routing of pollutant flows away from a target water body.
9. Zoning and Land Use Planning	Management of land to minimize deleterious impacts on water.
10. Treatment of Runoff or Stream Flows	Inactivation of nutrients or other treatments to chemically alter inflows.

TABLE 20 (continued). POND RESTORATION AND MANAGEMENT OPTIONS

Technique	Descriptive Notes
In -Pond Level	**Actions performed within a water body.**
1. Aeration and/or Destratification	Mechanical maintenance of oxygen levels and prevention of stagnation.
2. Biocidal Chemical Treatment	Addition of inhibitory substances intended to eliminate target species.
3. Biomanipulation or Habitat Management	Facilitation of biological interactions to alter ecosystem processes.
4. Bottom Sealing	Physical obstruction of rooted plant growths and/or sediment-water interaction.
5. Chemical Sediment Treatment	Addition of compounds which alter sediment features to limit plant growths or control chemical exchange reactions.
6. Dilution and/or Flushing	Increased flow to minimize retention of undesirable materials.
7. Dredging	Removal of sediments under wet or dry conditions.
8. Dye Addition	Introduction of suspended pigments to create light inhibition of plant growths.
9. Hydroraking and Rotovation	Disturbance of sediments, often with removal of plants, to disrupt growth.
10. Hypolimnetic Withdrawal	Removal of oxygen-poor, nutrient-rich bottom waters.
11. Macrophyte Harvesting	Removal of plants by mechanical means.
12. Nutrient Inactivation	Chemical complexing and precipitation of undesirable dissolved substances.
13. Water Level Control	Flooding or drying of target areas to aid or eliminate target species.

TABLE 21. MANAGEMENT OPTIONS FOR CONTROL OF ROOTED AQUATIC PLANTS

Option	Mode of Action	Positive Impacts	Negative Impacts
Drawdown	♦ Lowering of water over winter period allows desiccation, freezing, and physical disruption of plants, roots and seed beds ♦ Duration of exposure and degree of dewatering of exposed areas are important ♦ Variable species tolerance to drawdown; emergent species and seed-bearers are less affected ♦ Most effective on annual to once/3 yr. basis	♦ Control with some flexibility ♦ Opportunity for shoreline clean-up/structure repair. ♦ Flood control utility	♦ Possible impacts on contiguous emergent wetlands ♦ Possible impairment of well production ♦ Reduction in potential water supply and fire fighting capacity ♦ Alteration of downstream flows ♦ Possible overwinter water level variation ♦ Possible effects on overwintering reptiles or amphibians
Chemical treatment	♦ Liquid or pelletized herbicides applied to target area or to plants directly ♦ Contact or systemic poisons kill plants or limit growth ♦ Typically requires application every 1-5 yrs	♦ Wide range of control is possible ♦ May be able to selectively eliminate species ♦ May achieve some algae control as well	♦ Possible toxicity to non-target species of plants/animals ♦ Possible downstream impacts; may affect non-target areas within pond ♦ Restrictions of water use for varying time after treatment ♦ Increased oxygen demand from decaying vegetation ♦ Possible recycling of nutrients to allow other growths
Harvesting/ hydroraking/ rototilling	♦ Plants directly removed by mechanical means, possibly with disturbance of soils ♦ Collected plants placed on shore for composting or other disposal ♦ Wide range of techniques employed, from manual to highly mechanized ♦ Application once or twice/yr. usually needed	♦ Highly flexible control May remove other debris ♦ Can balance habitat and recreational needs	♦ Possible impacts on aquatic fauna ♦ Non-selective removal of plants in treated area ♦ Possible spread of undesirable species by fragmentation ♦ Possible generation of turbidity

TABLE 21 (continued). MANAGEMENT OPTIONS FOR CONTROL OF ROOTED AQUATIC PLANTS

Option	Mode of Action	Positive Impacts	Negative Impacts
Benthic barriers	♦ Mat of variable composition laid on bottom of target area, preventing plant growth ♦ Can cover area for as little as several months or permanently ♦ Maintenance improves effectiveness ♦ Not really intended for use in large areas, usually applied around docks, boating lanes, and in swimming areas	♦ Highly flexible control ♦ Reduces turbidity from soft bottoms ♦ Can cover undesirable substrate ♦ Often improves fish habitat	♦ May cause anoxia at sediment-water interface ♦ May limit benthic invertebrates ♦ Non-selective interference with plants in target area ♦ May inhibit spawning/feeding by some fish species
Dredging	♦ Sediment is physically removed by wet or dry excavation, with deposition in a containment area for dewatering ♦ Dredging can be applied on a limited basis, but is most often a major restructuring of a severely impacted system ♦ Plants are removed and regrowth can be limited by light and/or substrate limitation	♦ Plant removal with some flexibility ♦ Increases water depth ♦ Can reduce pollutant reserves ♦ Can reduce sediment oxygen demand ♦ Can improve spawning habitat for many fish species ♦ Allows complete renovation of aquatic ecosystem	♦ Temporarily removes benthic invertebrates ♦ May create turbidity ♦ May eliminate fish community (complete dry dredging only) ♦ Possible impacts from containment area discharge ♦ Possible impacts from dredged material disposal ♦ Interference with recreation or other uses during dredging
Dyes	♦ Water-soluble dye is mixed with pond water, thereby limiting light penetration and inhibiting plant growth ♦ Dyes remain in solution until washed out of system.	♦ Light limit on plant growth without high turbidity or great depth ♦ May achieve some control of algae as well ♦ May achieve some selectivity for species tolerant of low light	♦ May not control peripheral or shallow water rooted plants ♦ May cause thermal stratification in shallow ponds ♦ May facilitate anoxia at sediment interface with water
Biological controls	♦ Fish, insects or pathogens which feed on or parasitize plants are added to system to affect control ♦ The most commonly used organism is the grass carp, but the larvae of several insects have been used more recently, and viruses are being tested	♦ Provides potentially continuing control with one treatment ♦ Harnesses nature to produce desired conditions ♦ May produce potentially useful fish biomass as an end product	♦ Typically involves introduction of exotic species ♦ Effects may not be controllable ♦ Plant selectivity may not match desired target species ♦ May adversely affect indigenous species

Table 22. Current Costs[1] for Available Benthic Barriers

Type of Material	Material Cost ($/sq. ft.)	Anchoring & Installation ($/sq. Ft.)	Total Cost ($/sq. ft.)
Aquatic Weed Net™ - PVC coated fiberglass	$0.60	$0.50	$1.10
Texel™ - Polyester geotextile (needle punched)	$0.30	$0.50	$0.80
Palco™ - PVC pond liner	$0.50	$0.50	$1.00

1 Retail costs assuming, professional diver installation. Costs may be substantially less for large installation or use of local, less costly labor.

Table 23. Proposed Long-Term Monitoring Program for Lake Boon

Parameter	Utility	Proposed Locations	Proposed Frequency
Secchi transparency	Water clarity	In-lake (1)	3/yr, April, June, August
Total phosphorus	Fertility	In-lake (1)	3/yr, April, June, August
		LBT (1)	3/yr, April, June, August
Temperature	Fish health	In-lake (1)	3/yr, April, June, August
Dissolved Oxygen	Fish health	In-lake (1)	3/yr, April, June, August
pH	Fish health	In-lake (1)	3/yr, April, June, August
Conductivity	Dissolved solids	In-lake (1)	3/yr, April, June, August
		LBT (1)	3/yr, April, June, August
Turbidity	Suspended solids	In-lake (1)	3/yr, April, June, August
		LBT (1)	3/yr, April, June, August
Plant density/distrib.	Plant nuisances	In-lake (all areas)	Annually, late June

Table 23. Summary of management techniques, order of priority, and associated cost for improving Lake Boon.

Management Activity	Order of Priority	Approximate Cost ($)
Lake drawdown for plant control	4	14,000
Herbicide treatment for plant control	3	25,000 to 40,000
Dredging of Basin 3 for plant control	6	500,000 to 2,000,000
Identify and repair faulty septic systems	5	12,000 plus owner expense
Prepare educational brochure	1	3,000
Implement annual monitoring program	2	6,000/year
Create detention/infiltration facilities	7*	242,000 to 403,000
Install sewer system	8*	5,000,000
Total for short-term program (Priorities 1-4)		48,000 to 63,000

Note: Costs include any additional investigation, permitting, design work, direct labor, and all other expenses.

"*" = Not recommended unless conditions continue to deteriorate as documented through the annual monitoring program

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FIGURES

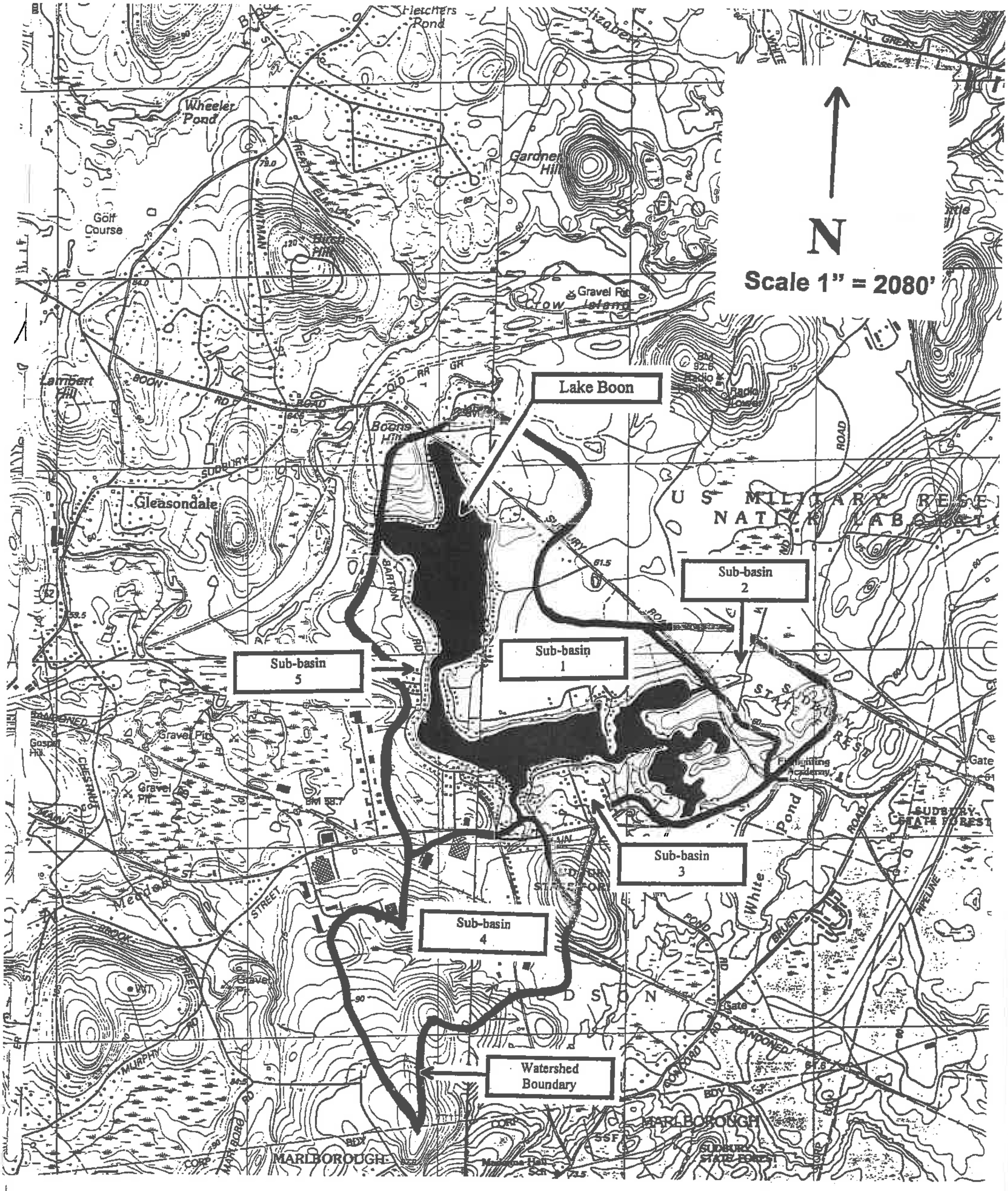

Figure 1. Watershed and watershed sub-basins for Lake Boon, Hudson/Stow, Massachusetts.

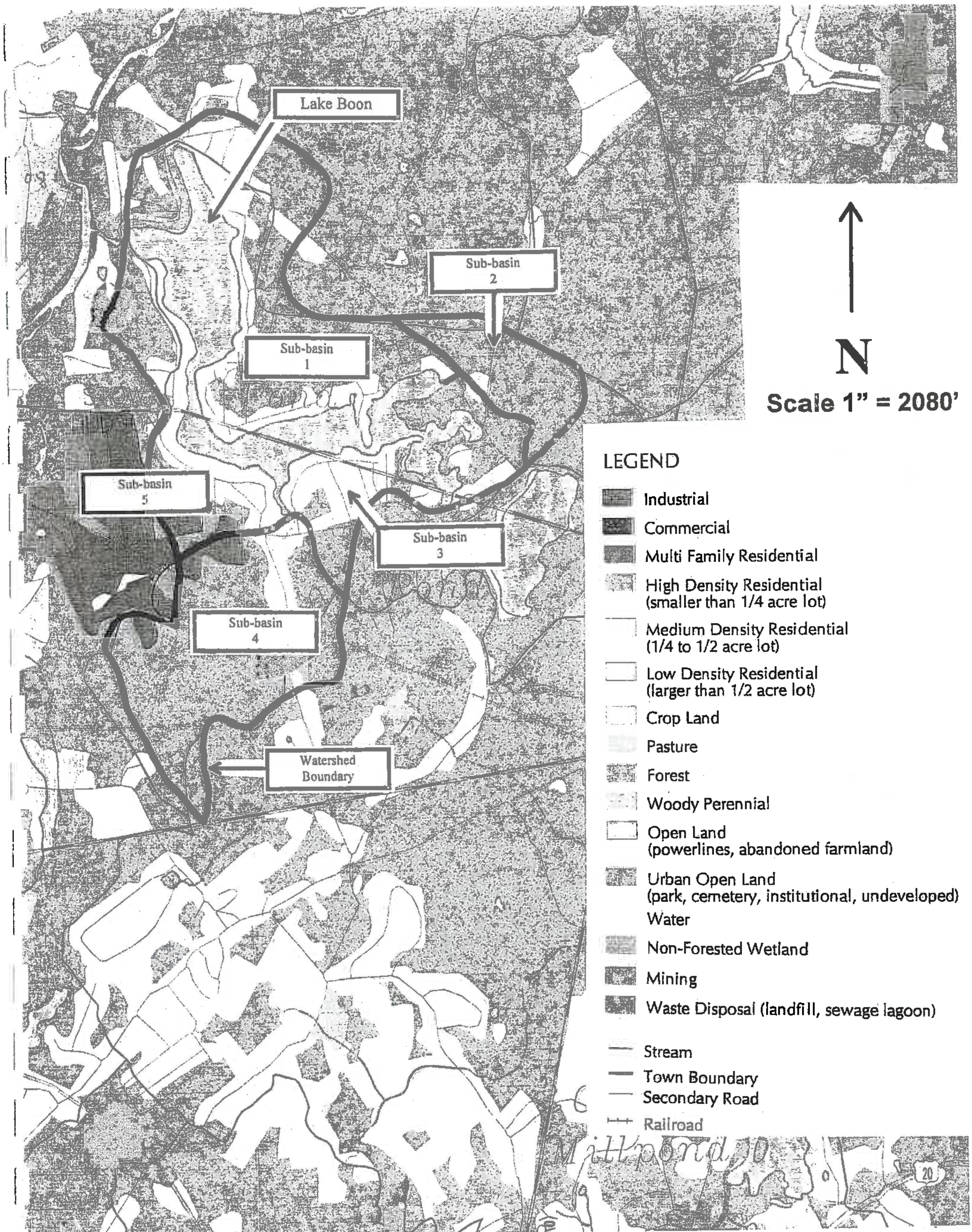

Figure 2. Land use in the Lake Boon watershed.

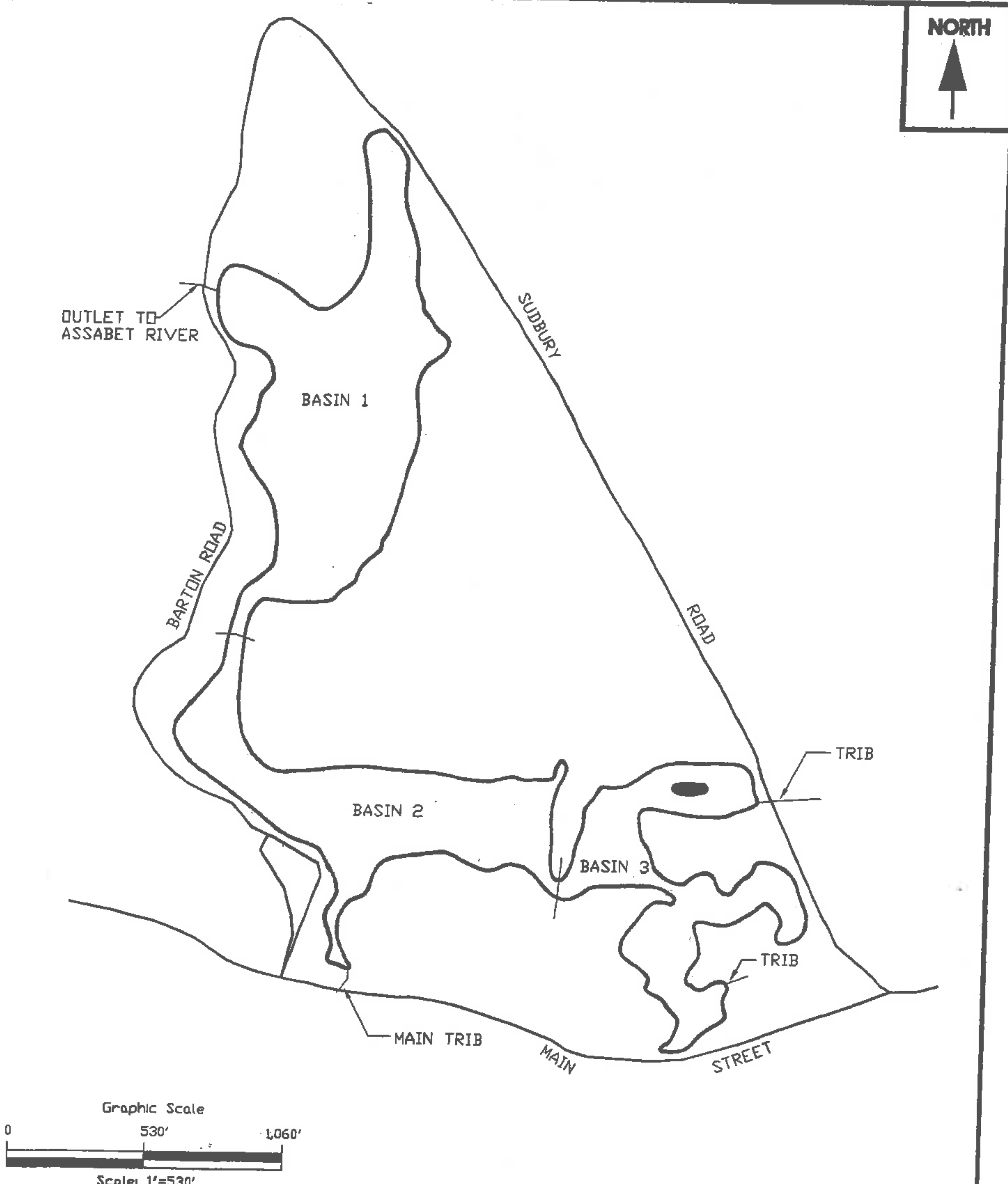

Figure:3

Basin Locations
Lake Boon
Hudson/Stow, Massachusetts

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SCALE: AS SHOWN
DATE: January, 1999
Dwg. # 1090-f3

1090_f3

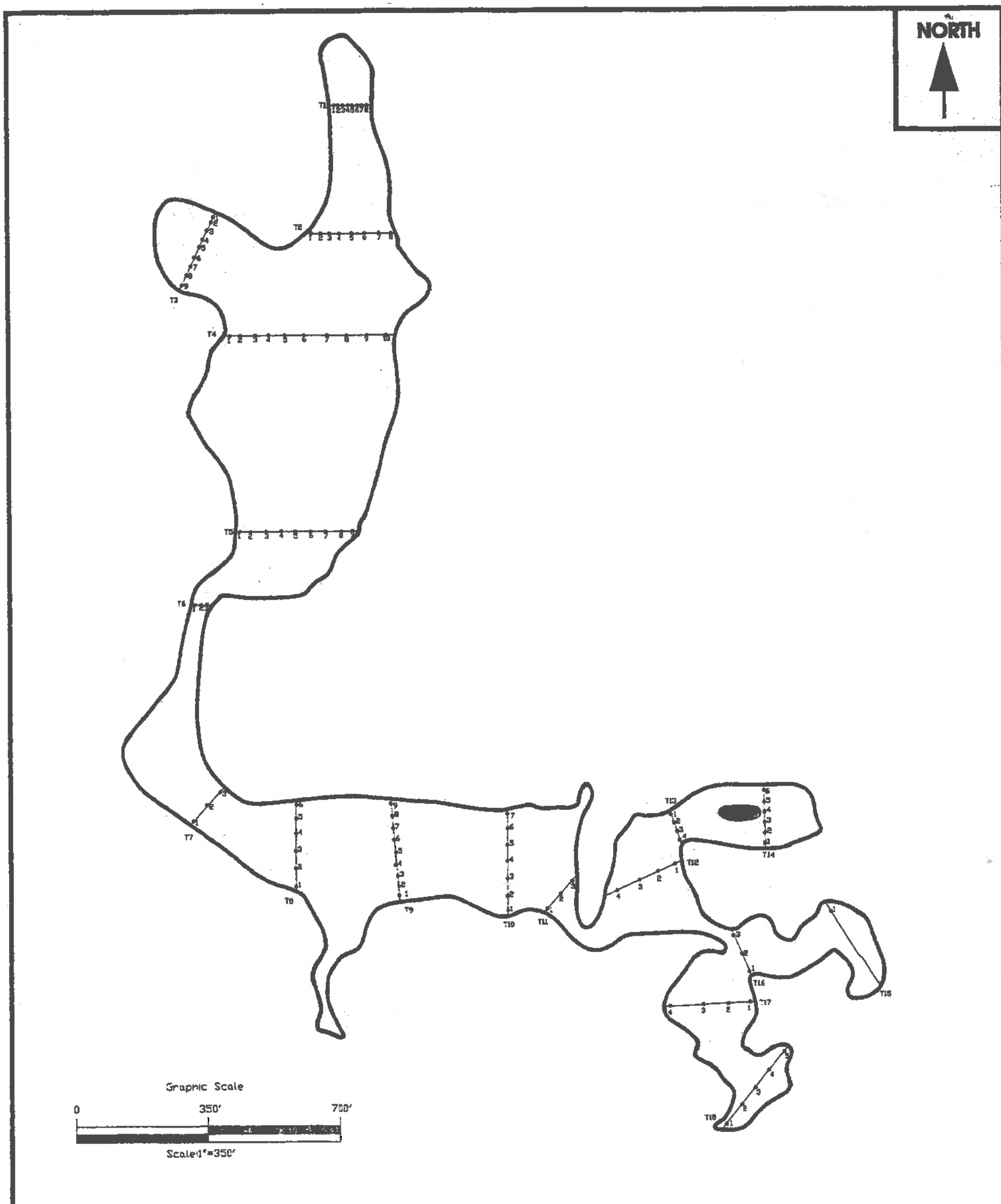

Figure:4

Transect and Sample Points
Lake Boon
Hudson/Stow, Massachusetts

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l090_f4.dwg

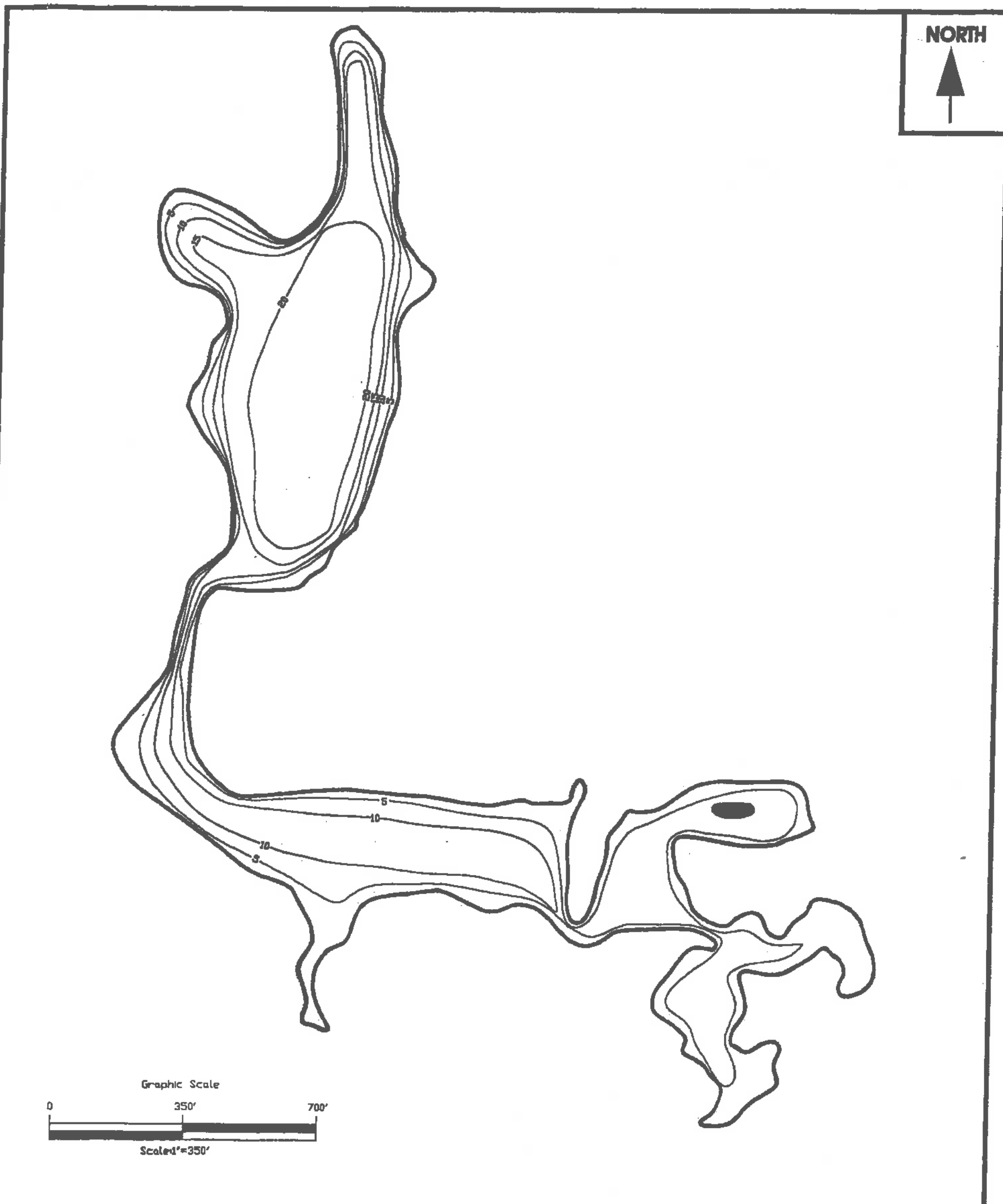

Figure:5

Bathymetric Contours
Lake Boon
Hudson/Stow, Massachusetts

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SCALE: AS SHOWN Dwg. # L090_f5
DATE: January, 1999

l090_f5.dwg

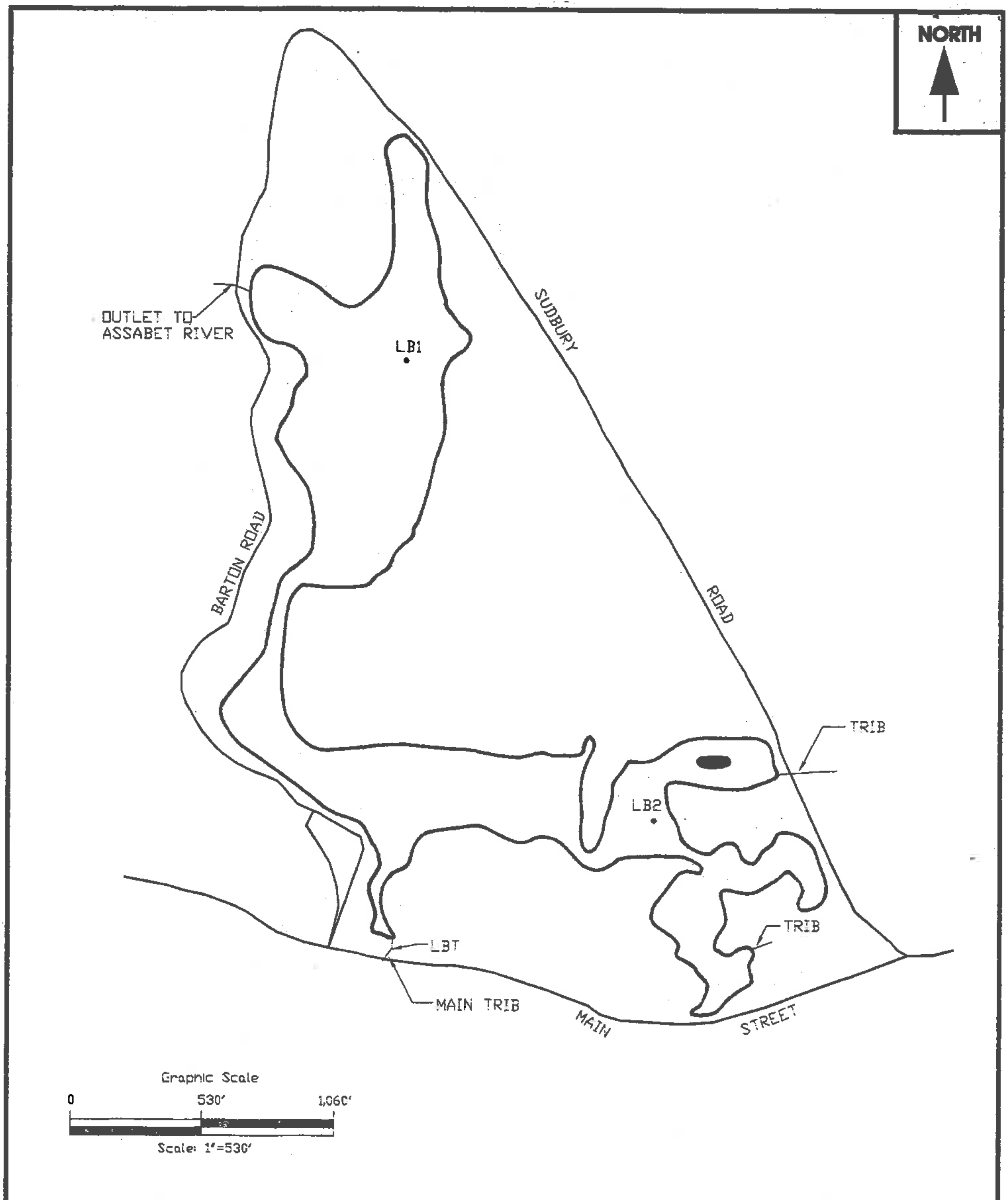

Figure:6

Water Quality Monitoring Sites
Lake Boon
Hudson/Stow, Massachusetts

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DATE: January, 1999

l090_f6

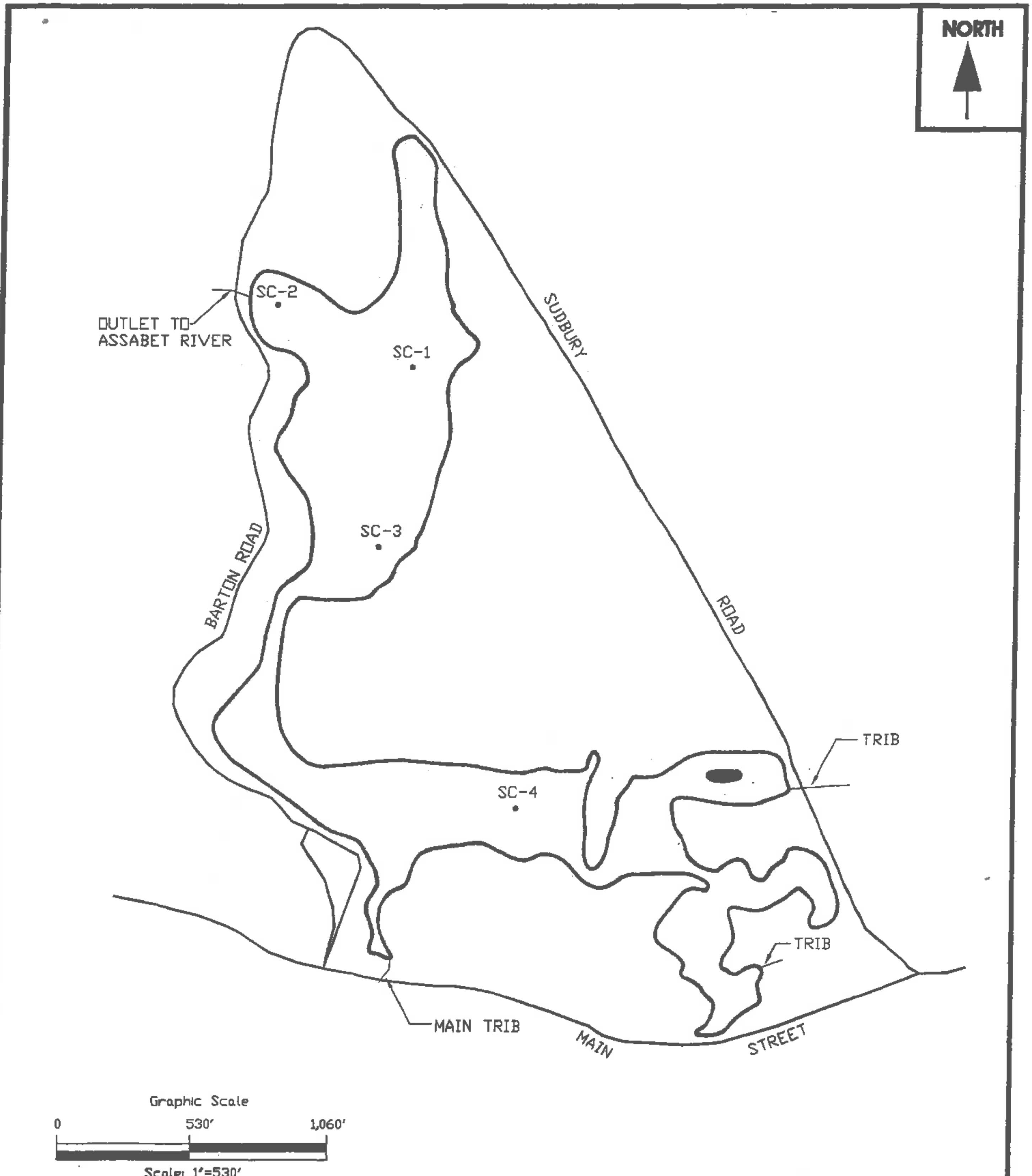

Figure:7

Sediment Core Location Map
Lake Boon
Hudson/Stow, Massachusetts

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Dwg. # L090-f7
DATE: January, 1999

l090_f7

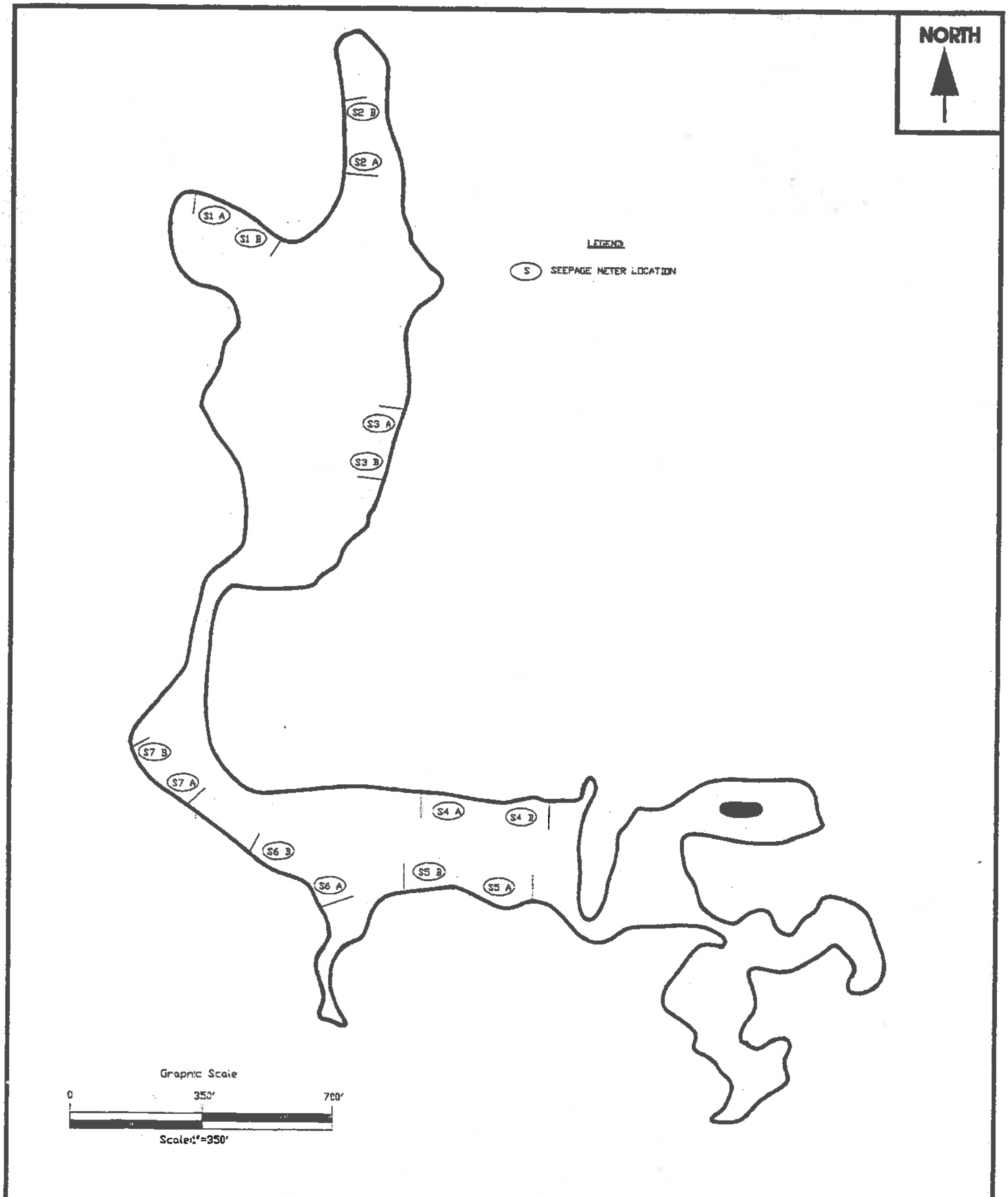

Figure:8

Seepage Meter Location Map
Lake Boon
Hudson/Stow, Massachusetts

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DATE: January, 1999
Dwg. # L090_f8

L090_f8.dwg

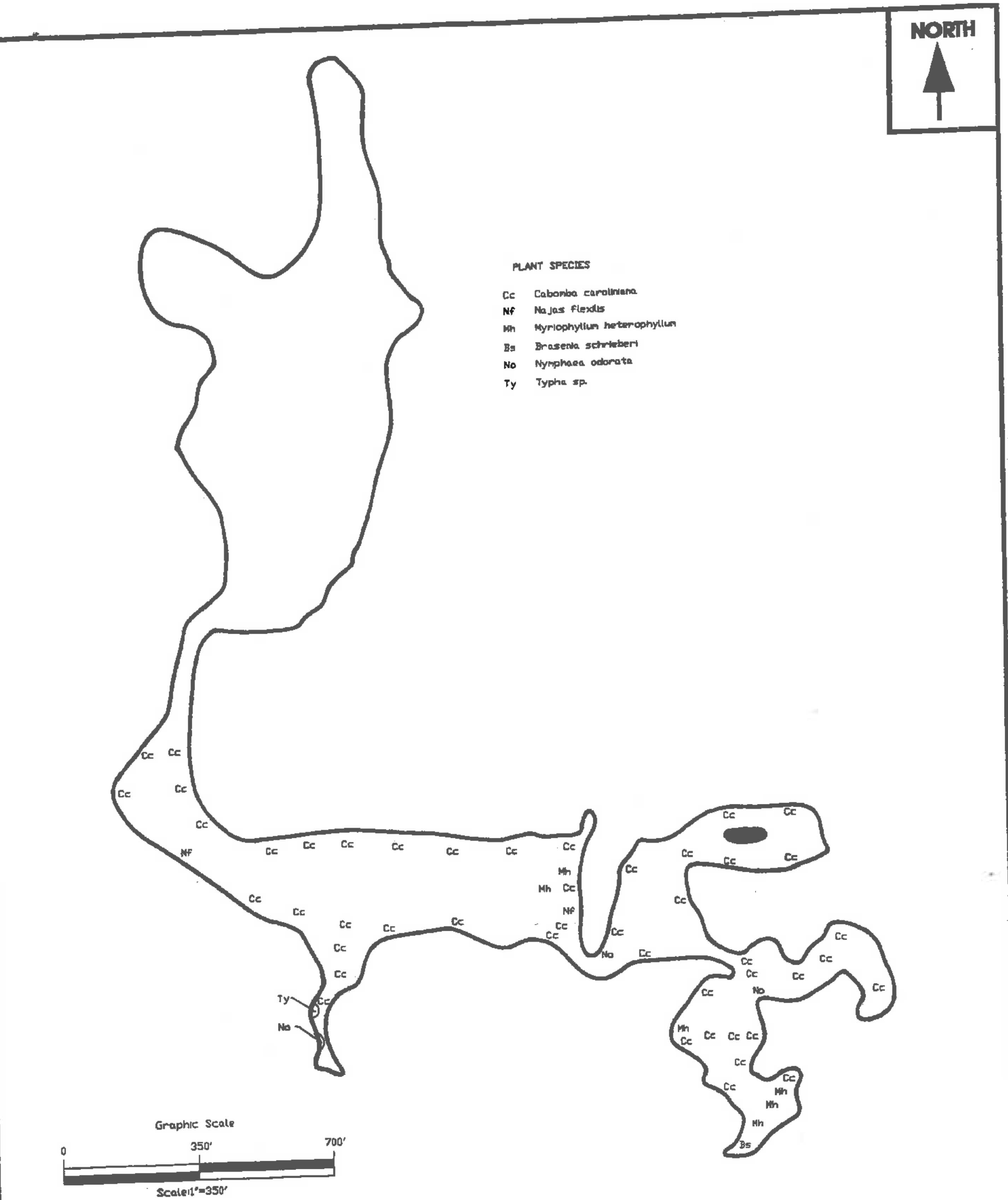

Figure:9

Dominant Aquatic Plant Distribution
Lake Boon
Hudson/Stow, Massachusetts

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SCALE: AS SHOWN
DATE: January, 1999
Dwg. # 1090_f9

1090_f9.dwg

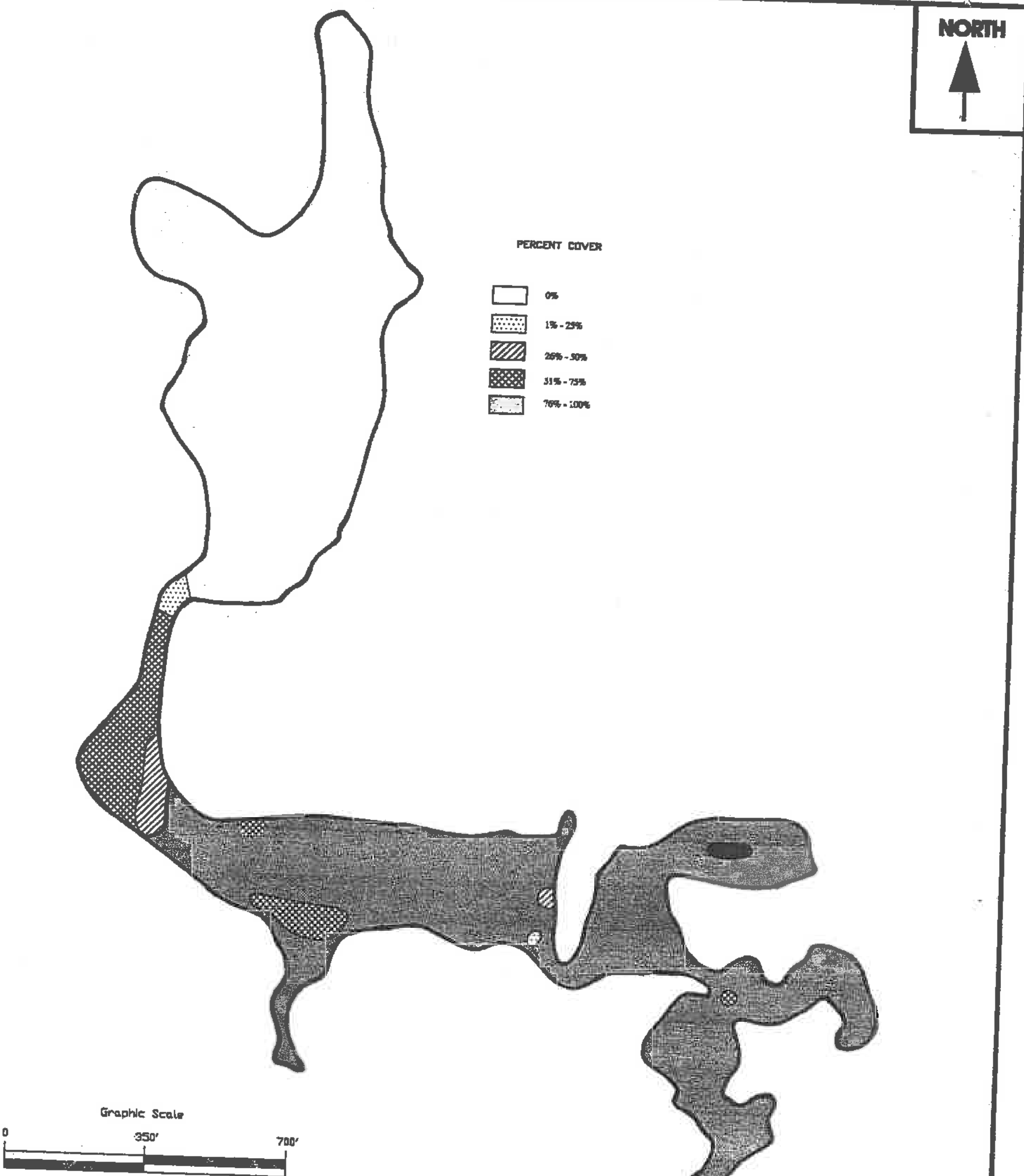

Figure:10

Percent Plant Cover
Lake Boon
Hudson/Stow, Massachusetts

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ENVIRONMENTAL SCIENCE SERVICES, INC.

SCALE: AS SHOWN

DATE: January, 1999

Dwg. # 1090_f10

1090_f10.dwg

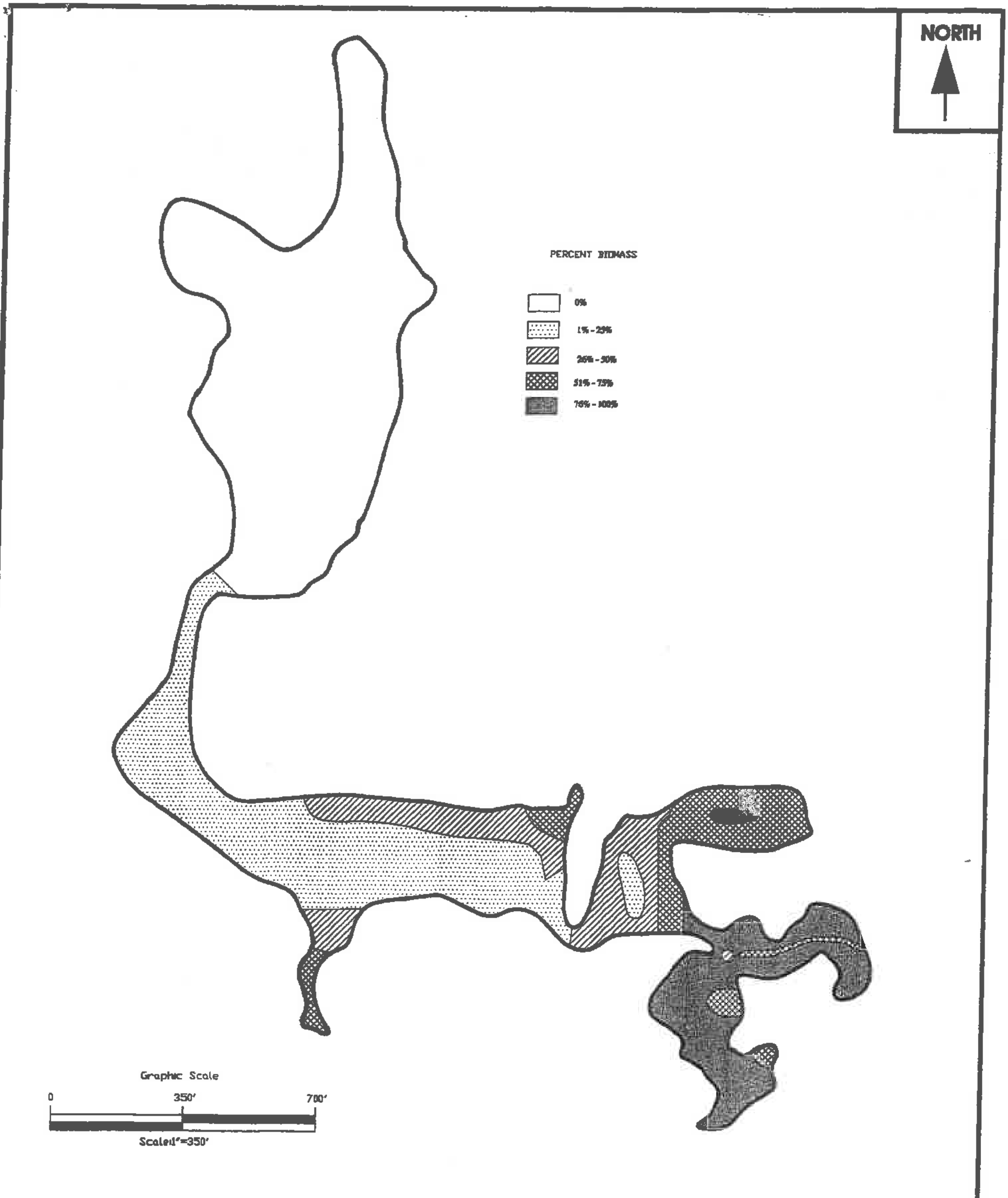

Figure:11

Percent Plant Biomass
Lake Boon
Hudson/Stow, Massachusetts

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SCALE: AS SHOWN — Dwg. # L090_f11
DATE: January, 1999

L090_f11.dwg

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APPENDIX A

Historical Water Quality Data

Historical Comparision of In-Lake Water Quality Data, Lake Boon

Parameter	Source of Data				
	Notini and Morrison (1980) [1]	CDM (1987) [2]	GSC (1997a) [3]	GSC (1997b) [4]	ESS (1998) [5]
Turbidity (NTU)					
maximum	NS	4	1	NS	4.7
minimum	NS	<2	1	NS	0.8
average	NS	2.3	1	NS	2.0
Secchi Depth (meters)					
maximum	2.9	3.0	1.95	2.95	3.7
minimum	1.4	1.7	1.73	2.3	1.5
average	2.0	2.4	1.84	2.6	2.3
TKN (mg/L)					
maximum	0.96	0.66	0.38	0.82	1.18
minimum	0.55	0.34	0.34	0.24	0.58
average	0.74	0.52	0.36	0.41	0.79
Ammonium Nitrogen (mg/L)					
maximum	0.13	0.21	ND	0.21	0.13
minimum	0.00	<0.01	ND	ND	<0.01
average	0.04	0.07	ND	NA	0.031
Nitrate Nitrogen (mg/L)					
maximum	0.10	0.14	0.2	ND	0.01
minimum	0.00	0.05	ND	ND	<0.01
average	0.04	0.095	NA	ND	0.006
Total Phosphorus (mg/L) [6]					
maximum	0.10	0.04	0.012	0.04	0.06
minimum	0.03	<0.01	0.007	ND	0.01
average	0.06	0.016	0.0095	0.03	0.026
Dissolved Phosphorus (mg/L)					
maximum	NS	NS	NS	NS	0.04
minimum	NS	NS	NS	NS	<0.01
average	NS	NS	NS	NS	0.016
Fecal Coliform (MF) (per 100 ml)					
maximum	900	3	NS	NS	<10
minimum	<5	0	NS	NS	<10
average	152.5	1.5	NS	NS	5

1 Data from Station 1 (surface and bottom) and Station 2 (surface only) sampled in June and July, 1979.
2 Data from Station 1 (surface and bottom) and Station 2 (surface only) sampled in October 1985 and July 1986.
3 Data from Station 1 and 2 sampled on November 27, 1996.
4 Sampled on July 2, 1997.
5 Data from Station LB-1s, LB-1b, and LB-2s sampled in July, August and September, 1998.
6 Laboratory methodology change occurred in 1983 allowing phosphorus to be detected at lower levels.

NA = Not Applicable
NS = Not sampled
ND = Non detectable

Historical Comparision of Major Tributary Water Quality Data

Parameter	Notini and Morrison (1980) [1]	CDM (1987) [2]	GSC (1997a) [3]	ESS (1998) [4]
	Source of Data			
Turbidity (NTU)				
maximum	NS	2.0	1 *	26.4
minimum	NS	<2.0	1 *	0.2
average	NS	1.5	NA	6.04
Total Suspended Solids (TSS)				
maximum	29	5.0	NS	230
minimum	2.5	2.0	NS	1
average	11.8	3.5	NS	47.6
TKN (mg/L)				
maximum	0.74	0.48	0.31 *	3.3
minimum	0.29	0.20	0.31 *	<0.2
average	0.49	0.34	NA	0.79
Ammonium Nitrogen (mg/L)				
maximum	0.04	0.019	ND *	0.58
minimum	0	<0.10	ND *	0.02
average	0.017	NA	NA	0.14
Nitrate Nitrogen (mg/L)				
maximum	0.5	1.4	0.23 *	1.31
minimum	0.3	0.88	0.23 *	0.95
average	0.43	1.14	NA	1.1
Total Phosphorus (mg/L)				
maximum	0.09	<0.01 *	0.021 *	0.52
minimum	0.04	<0.01 *	0.021 *	<0.01
average	0.073	NA	NA	0.11
Dissolved Phosphorus (mg/L)				
maximum	NS	NS	NS	0.16
minimum	NS	NS	NS	<0.01
average	NS	NS	NS	0.039
Fecal Coliform (MF) (per 100 ml)				
maximum	880	0 *	NS	680
minimum	<5	0 *	NS	30
average	441.25	NA	NS	205

1 Data from Station 4 and 4A sampled in June and July, 1979 and June, 1980.
2 Data from Station 4 sampled in October 1985 and July 1986.
3 Data from Station 4 sampled on November 27, 1996.
4 Data from Station LB-T sampled in July, August, September and October 1998.

* data based on one sample only
NA = Not Applicable
NS = Not sampled
ND = Non detectable

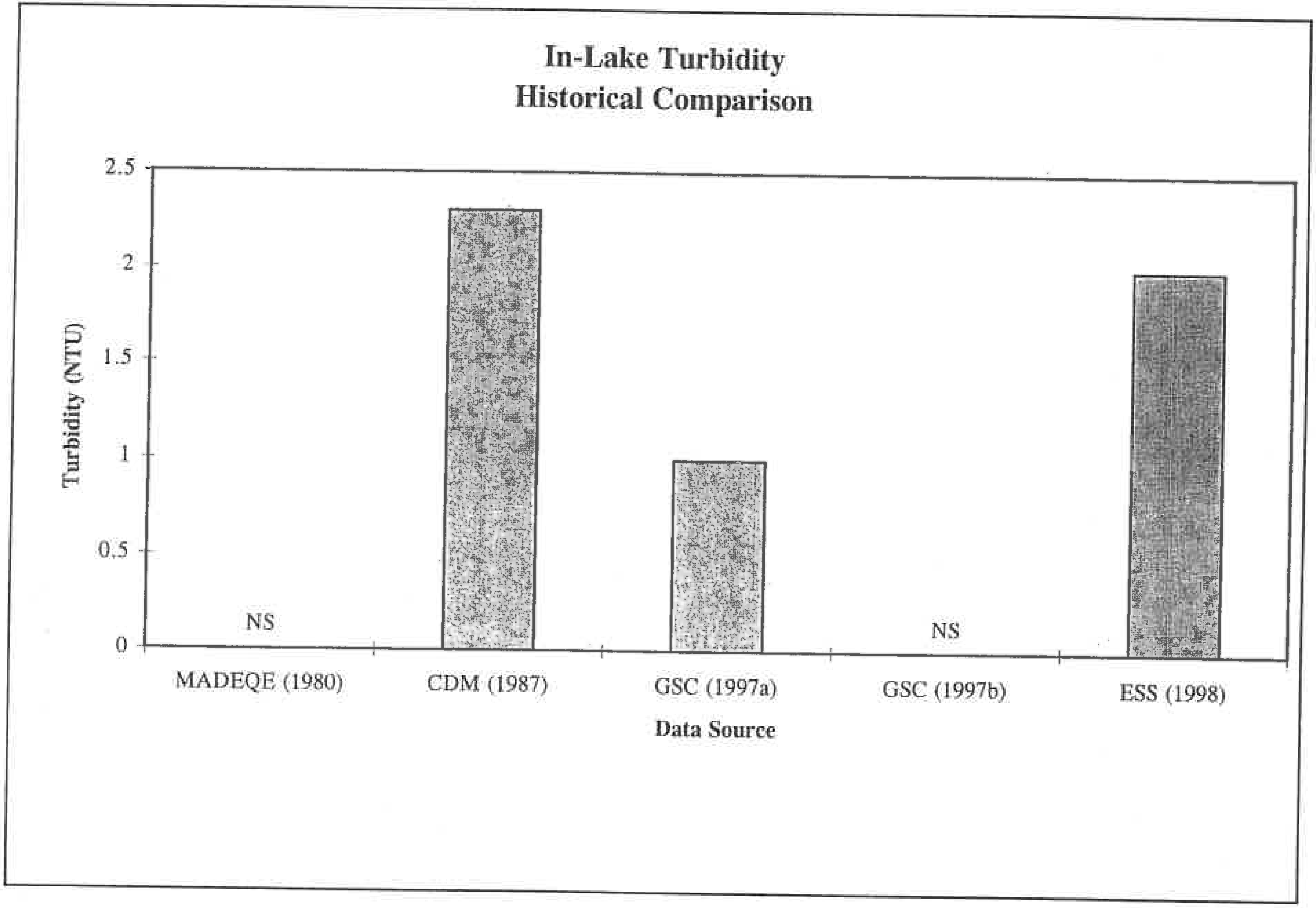
Phosphorus loading to Lake Boon calculated from historical data.

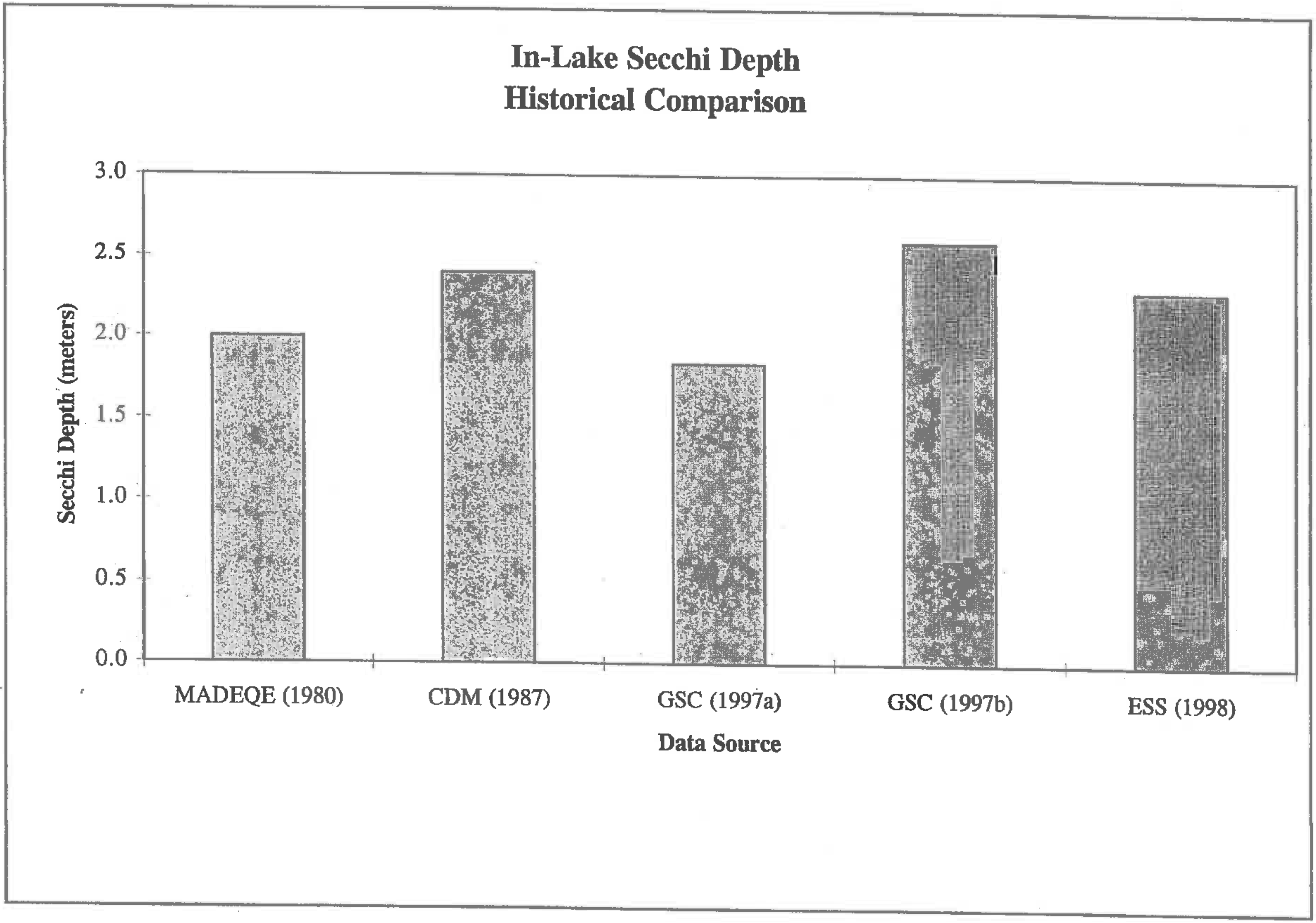
Source of Measurements	**CDM 1987**	**DWPC 1979**	**ESS 1998**
	Mean Phosphorus Concentration (mg/L)		
In-Lake	0.016	0.060	0.026
Tributary	0.010*	0.065*	0.114**
Outlet	0.010	0.060	0.017
Modeled Load *(kg/yr)*	123	458	186

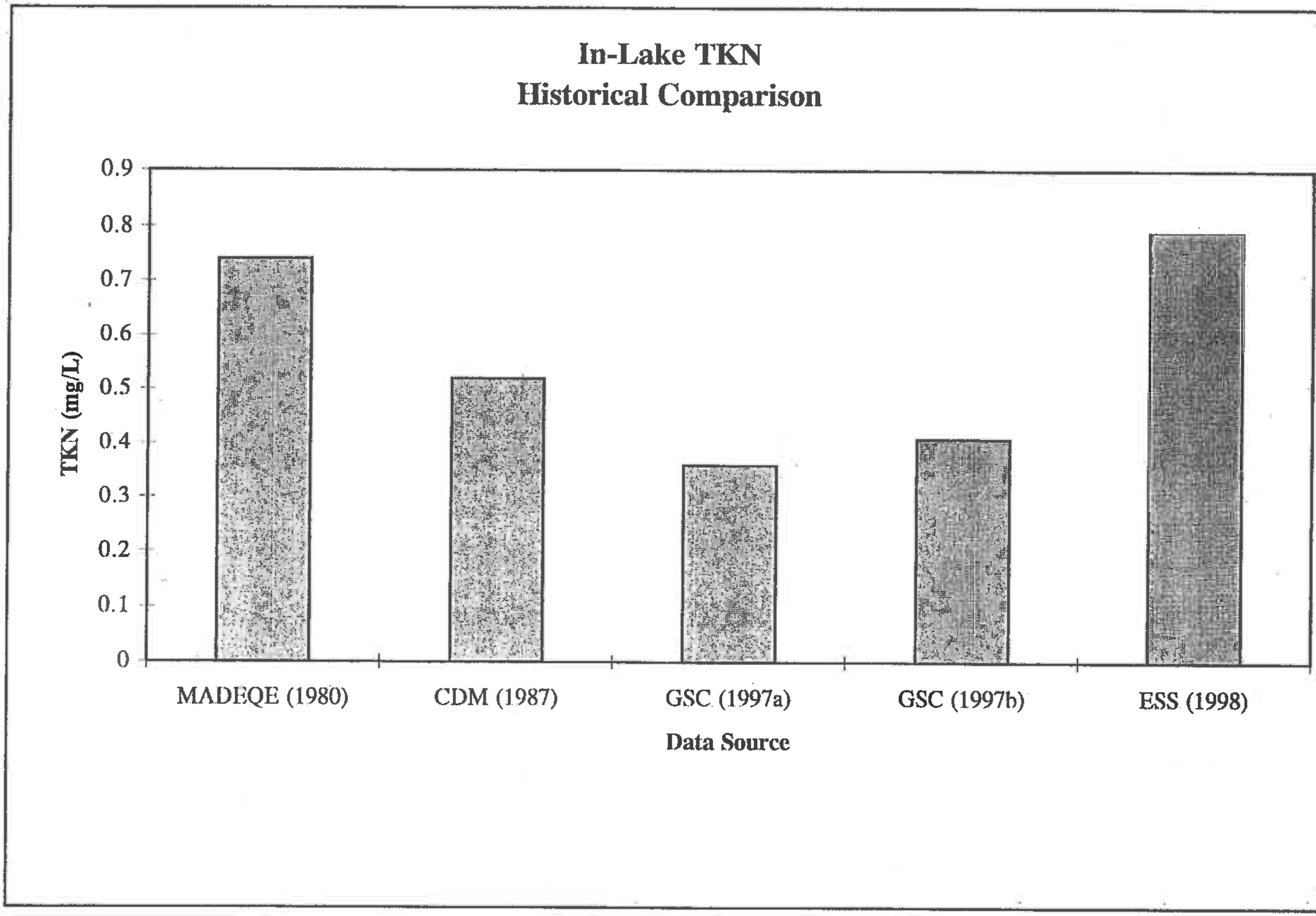
* Dry weather sampling only

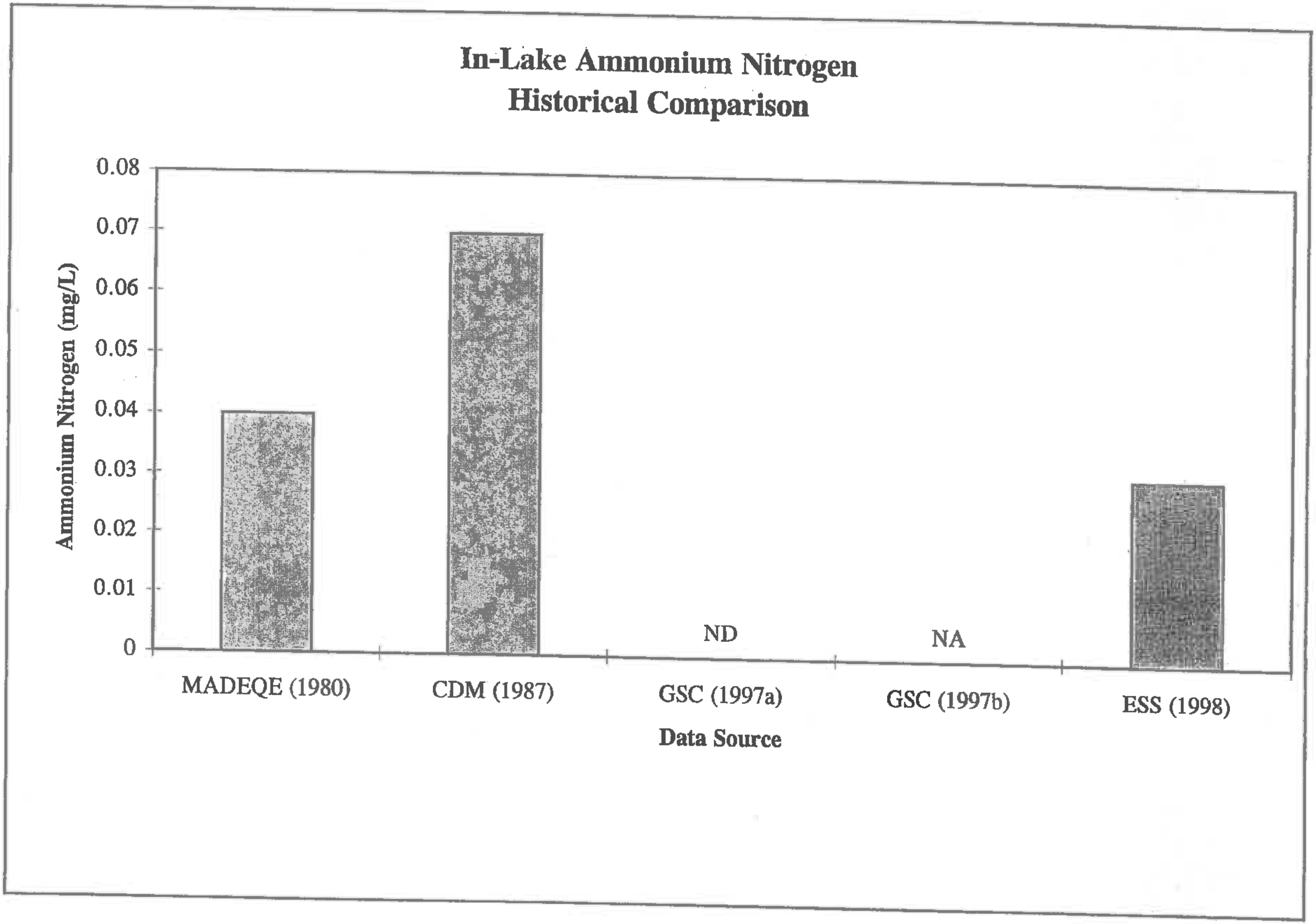
** Dry weather and wet weather sampling

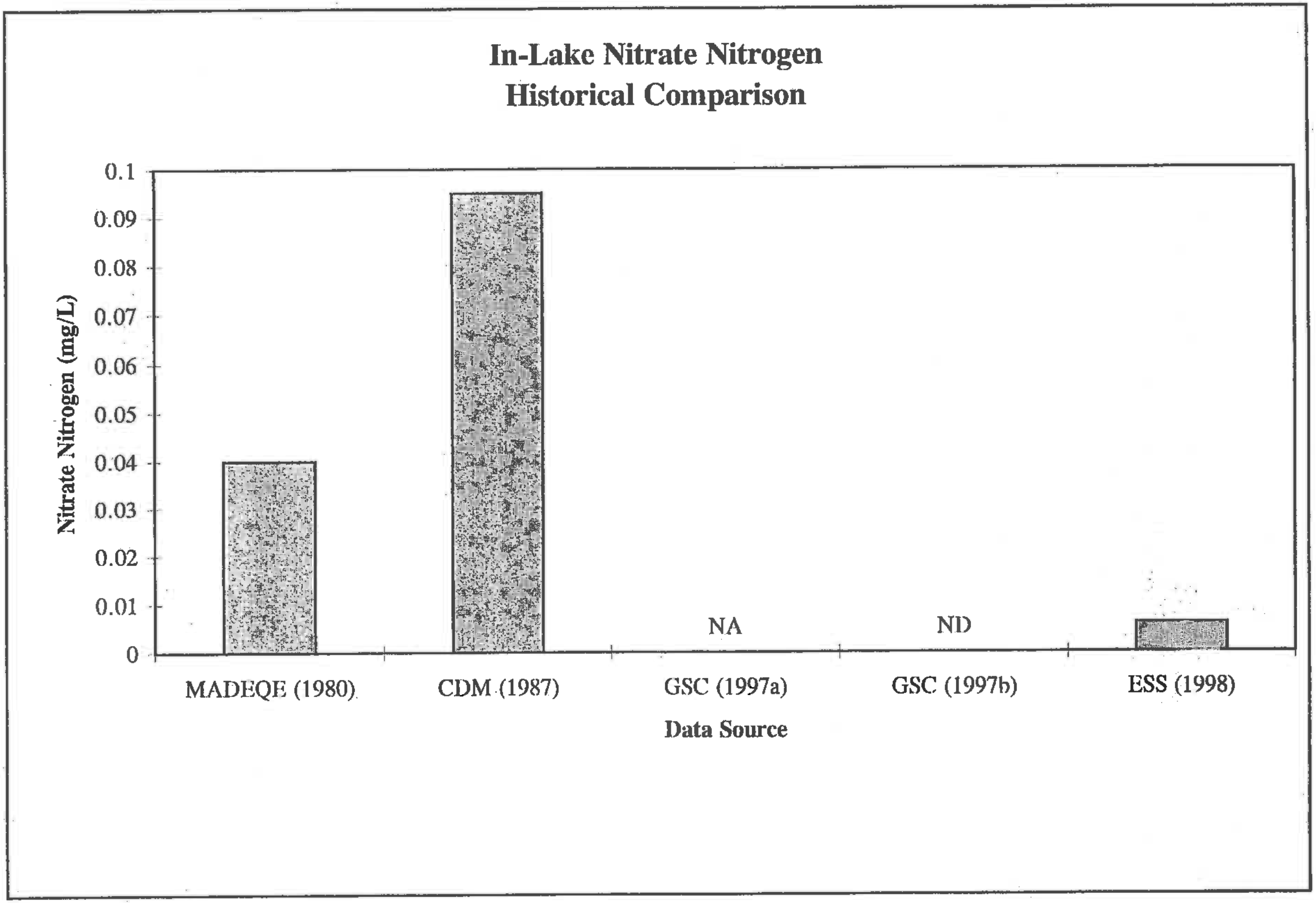
Note: Data used for comparisons were collected during the summer months only.

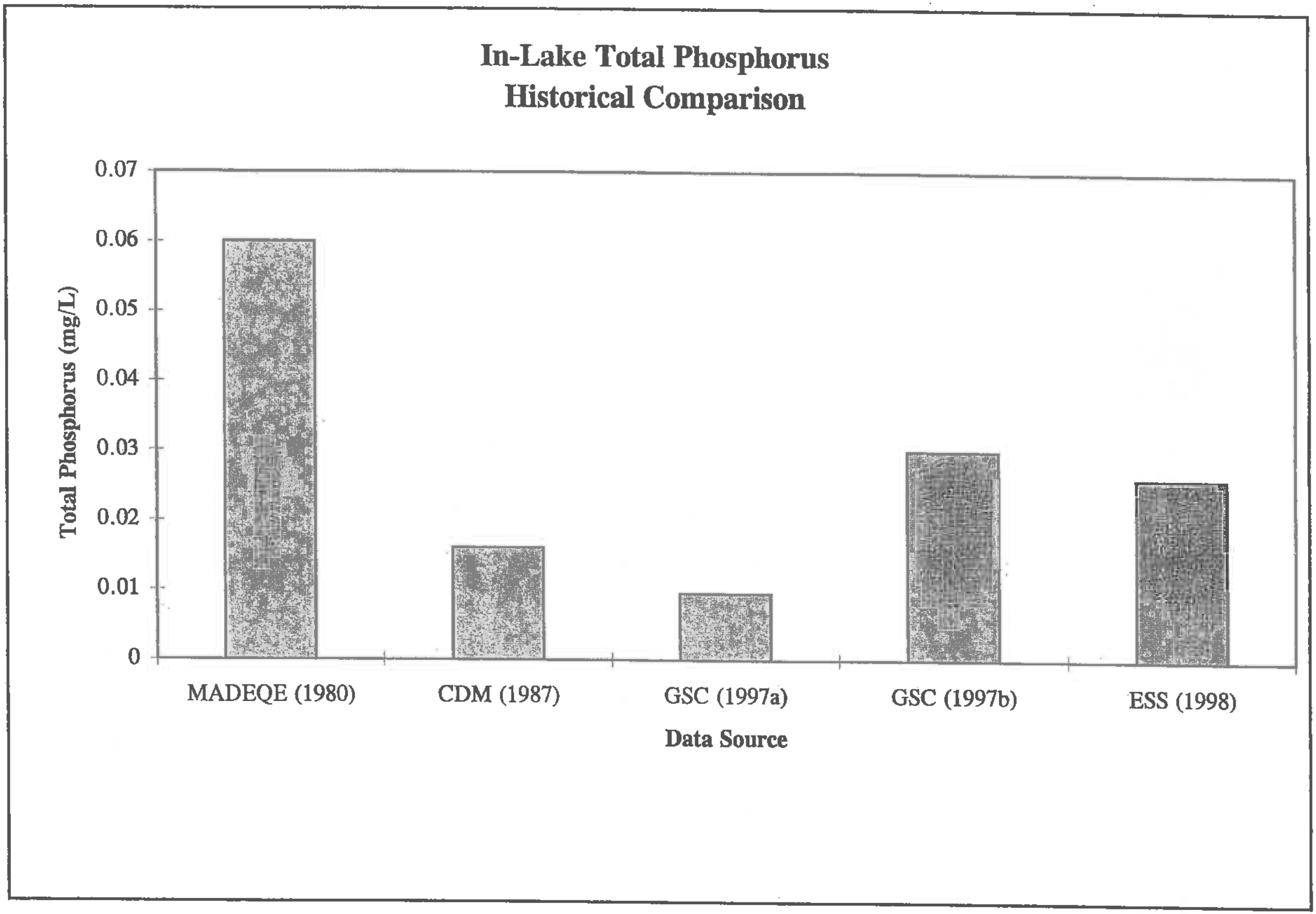

In-Lake Turbidity
Historical Comparison
Turbidity (NTU)
2.5
2
1.5
1
0.5
0
NS
NS
MADEQE (1980)
CDM (1987)
GSC (1997a)
GSC (1997b)
ESS (1998)
Data Source

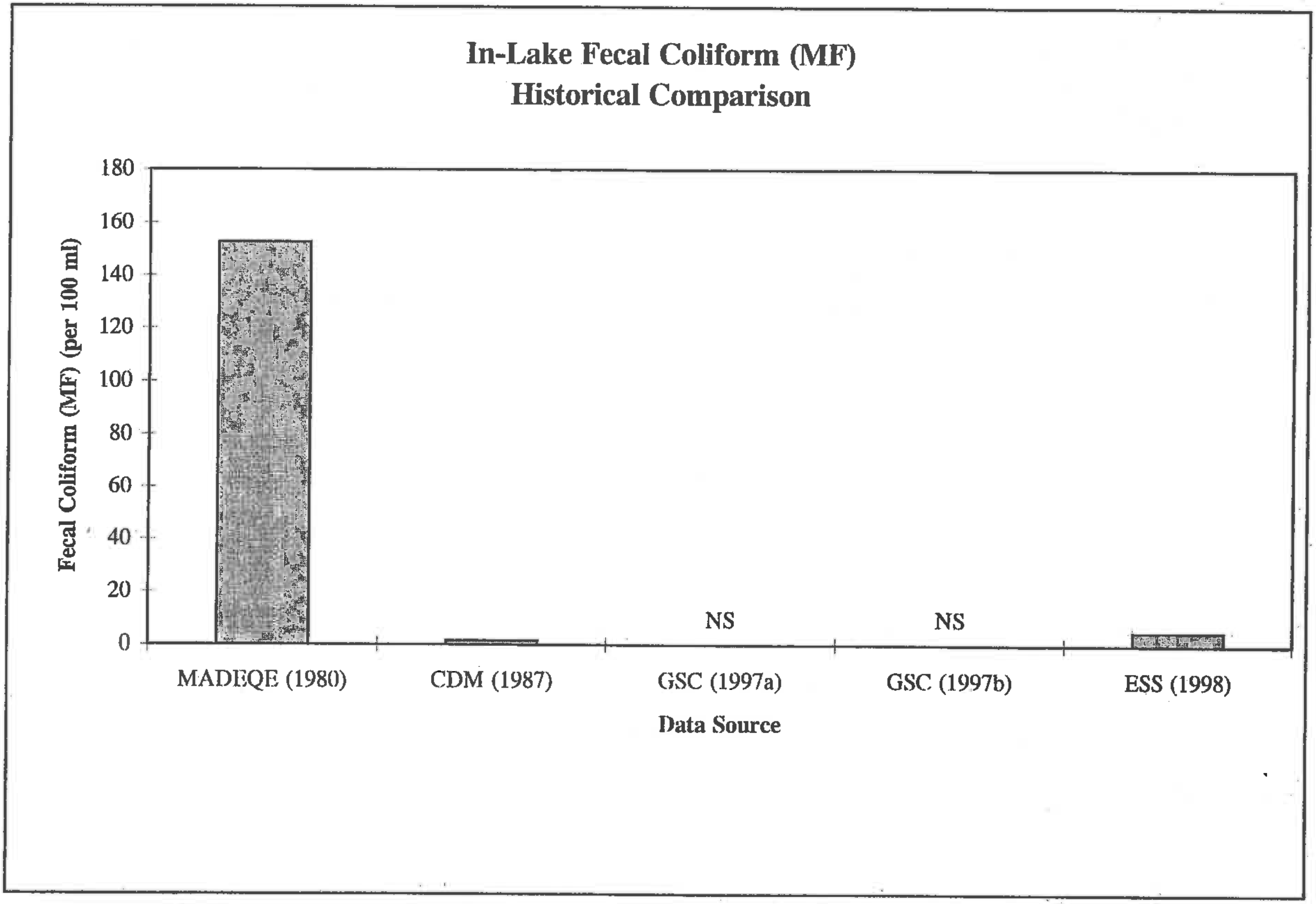

In-Lake Secchi Depth
Historical Comparison
Secchi Depth (meters)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
MADEQE (1980)
CDM (1987)
GSC (1997a)
GSC (1997b)
ESS (1998)
Data Source


In-Lake TKN
Historical Comparison
TKN (mg/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
MADEQE (1980)
CDM (1987)
GSC (1997a)
GSC (1997b)
ESS (1998)
Data Source

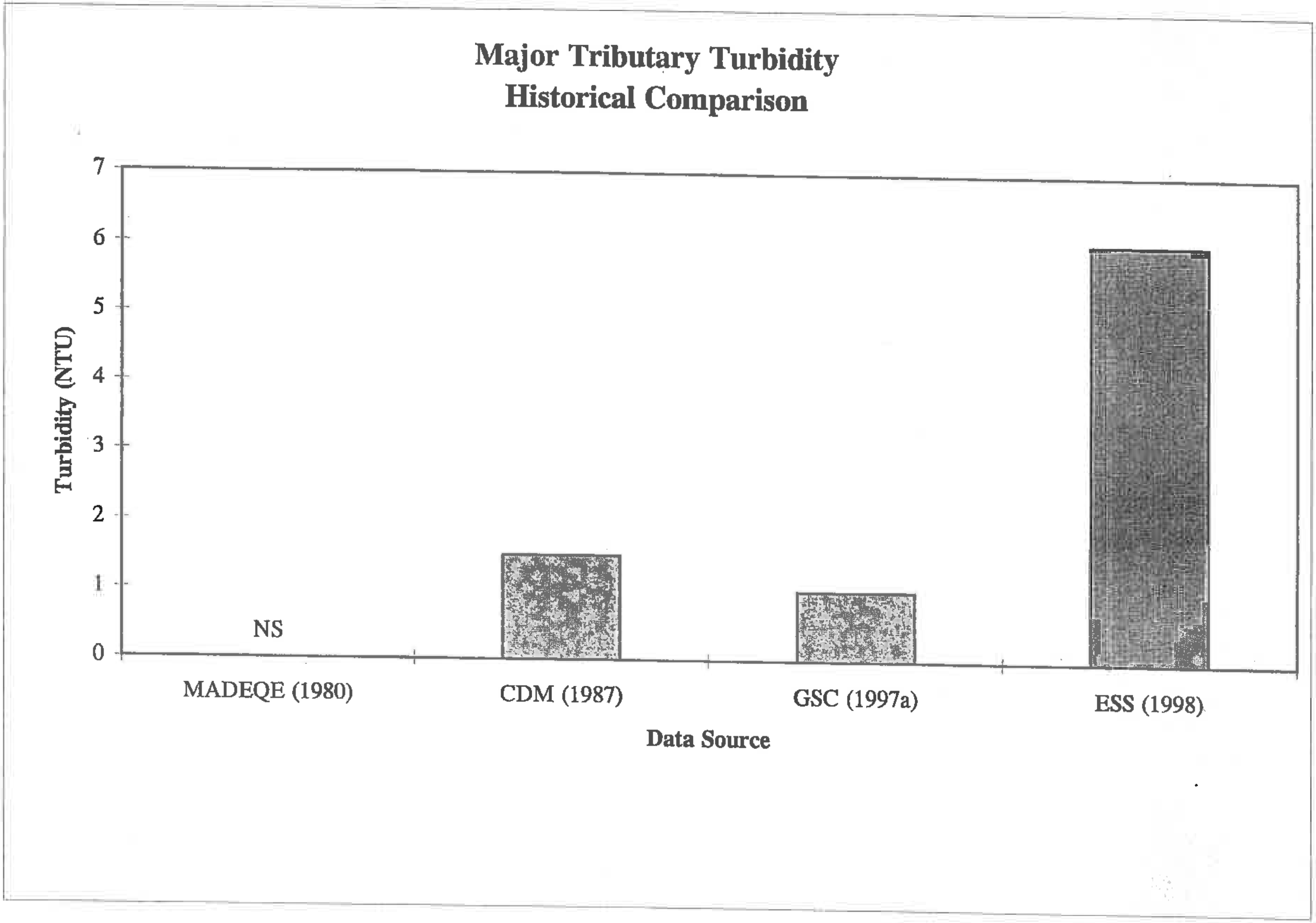

In-Lake Ammonium Nitrogen
Historical Comparison
Ammonium Nitrogen (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
ND
NA
MADEQE (1980)
CDM (1987)
GSC (1997a)
GSC (1997b)
ESS (1998)
Data Source


In-Lake Nitrate Nitrogen
Historical Comparison
Nitrate Nitrogen (mg/L)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
NA
ND
MADEQE (1980)
CDM (1987)
GSC (1997a)
GSC (1997b)
ESS (1998)
Data Source


In-Lake Total Phosphorus
Historical Comparison
Total Phosphorus (mg/L)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
MADEQE (1980)
CDM (1987)
GSC (1997a)
GSC (1997b)
ESS (1998)
Data Source

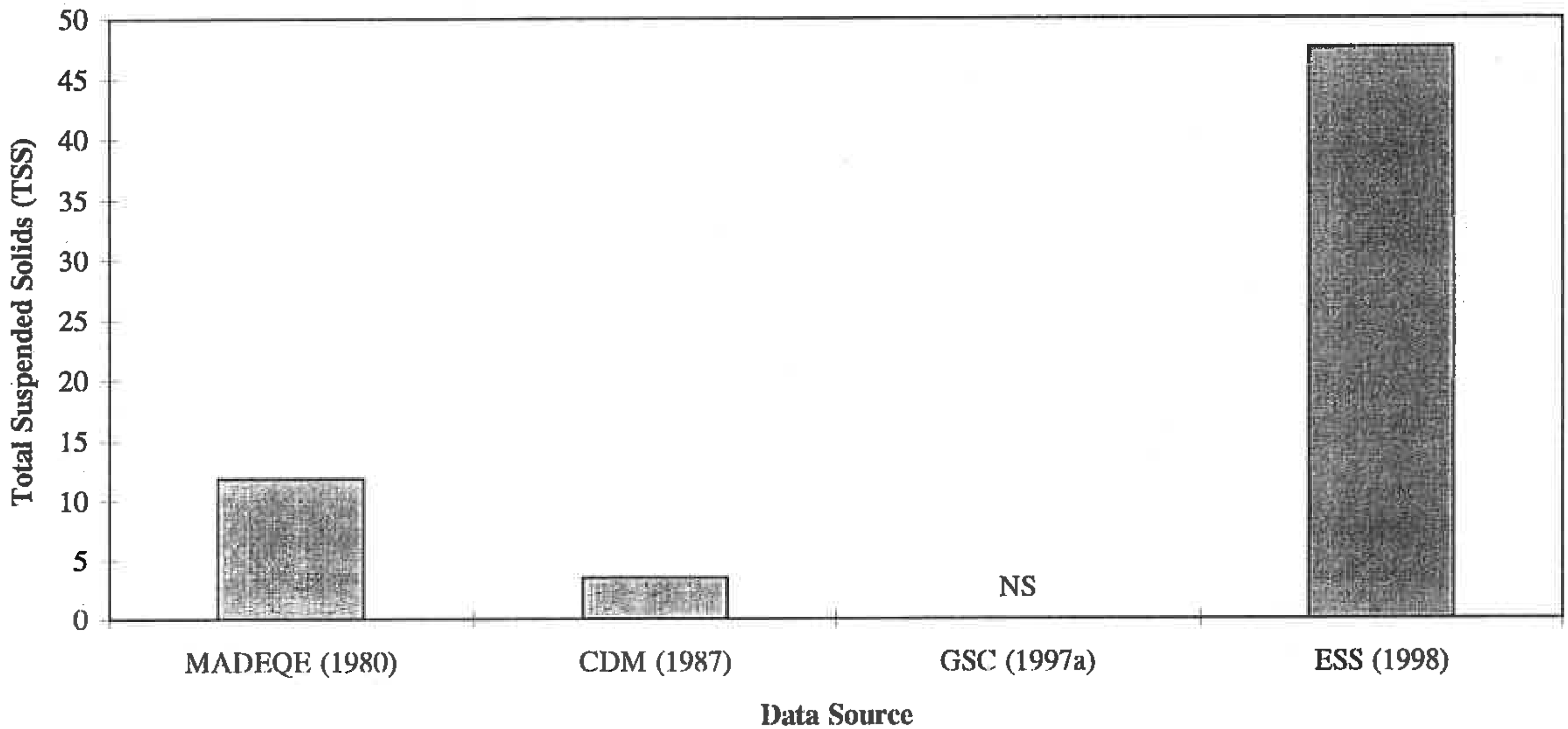


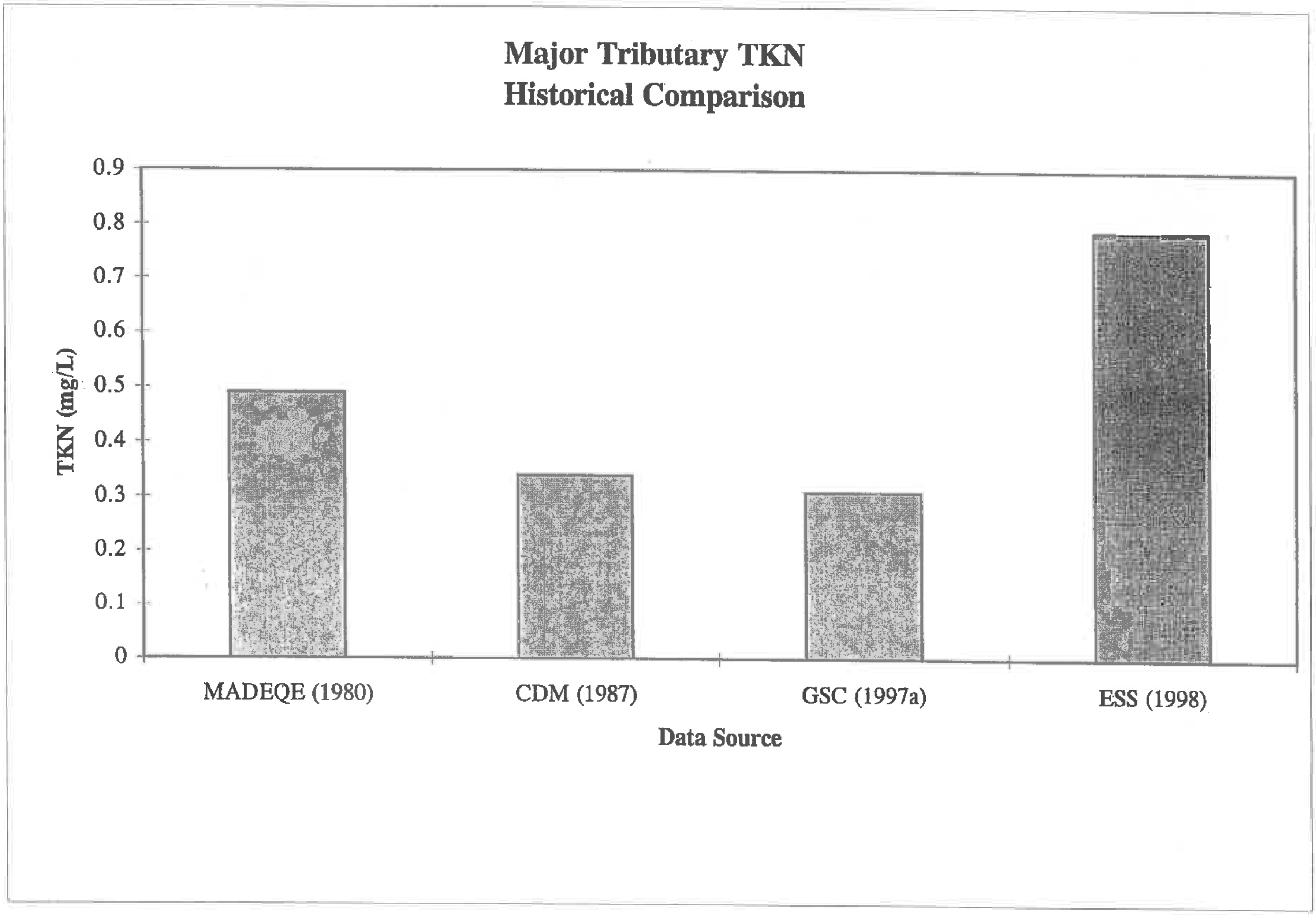
In-Lake Fecal Coliform (MF)
Historical Comparison
Fecal Coliform (MF) (per 100 ml)
180
160
140
120
100
80
60
40
20
0
NS
NS
MADEQE (1980)
CDM (1987)
GSC (1997a)
GSC (1997b)
ESS (1998)
Data Source



Major Tributary Turbidity
Historical Comparison
Turbidity (NTU)
0
1
2
3
4
5
6
7
NS
MADEQE (1980)
CDM (1987)
GSC (1997a)
ESS (1998)
Data Source

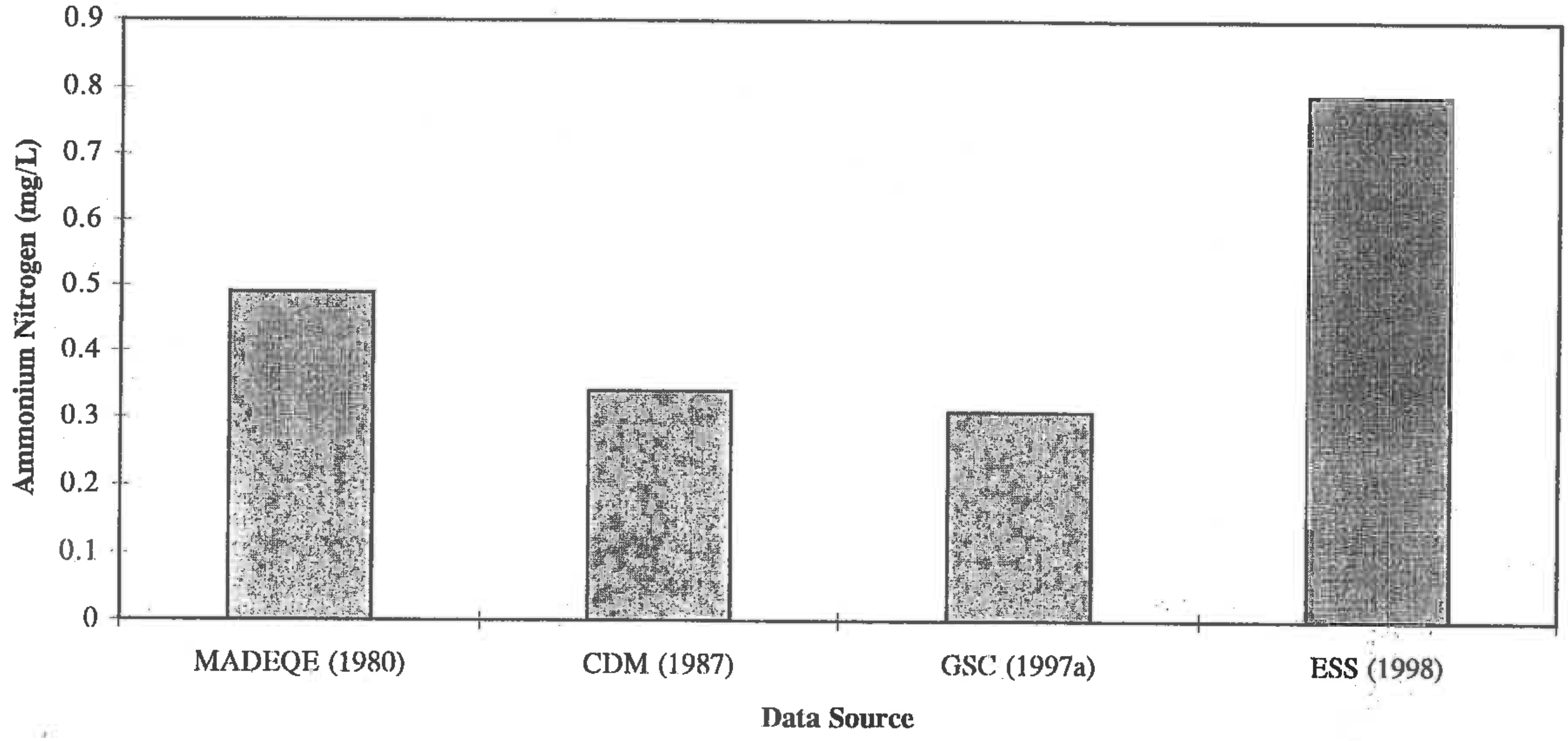
Major Tributary Total Suspended Solids Historical Comparison

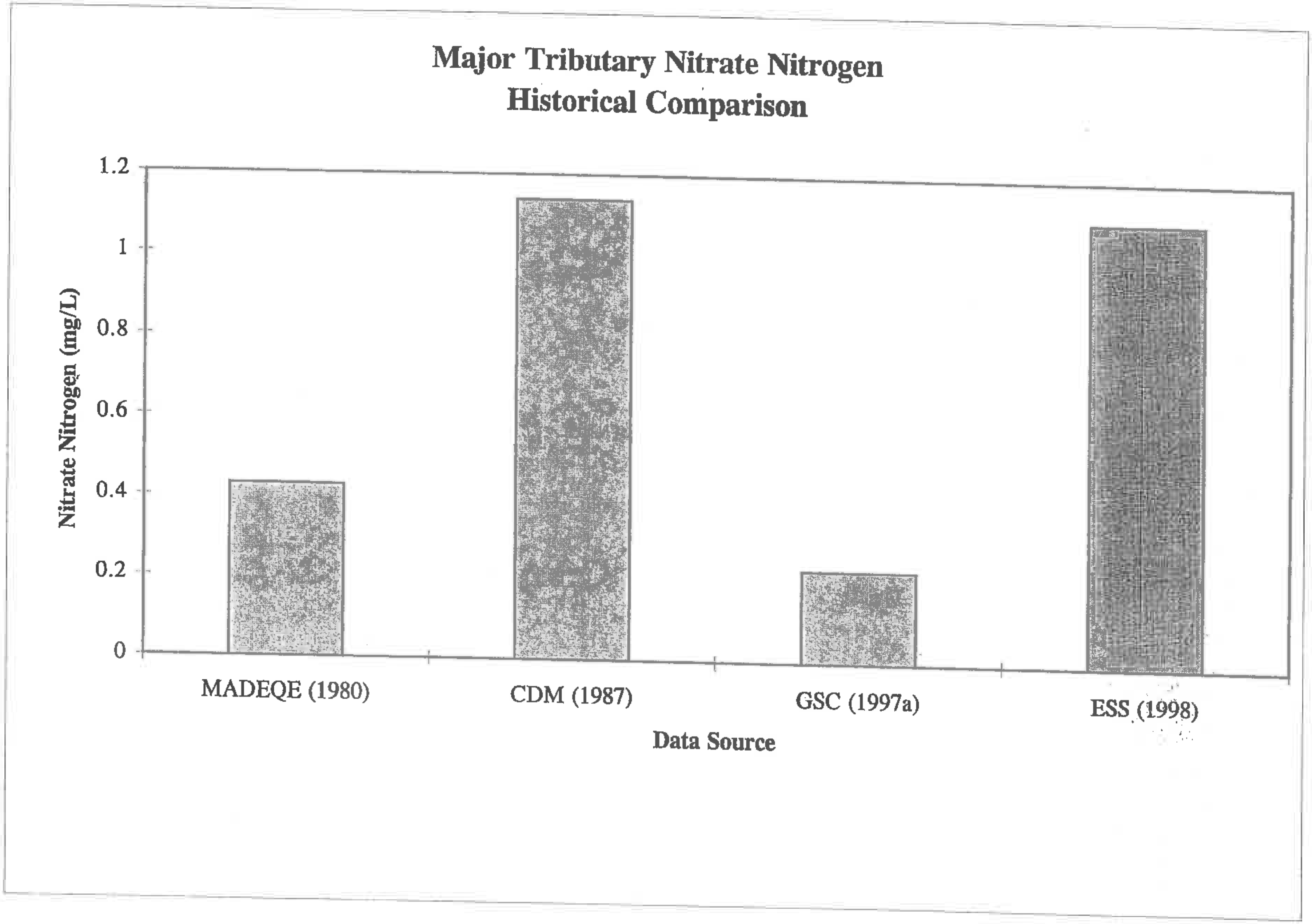


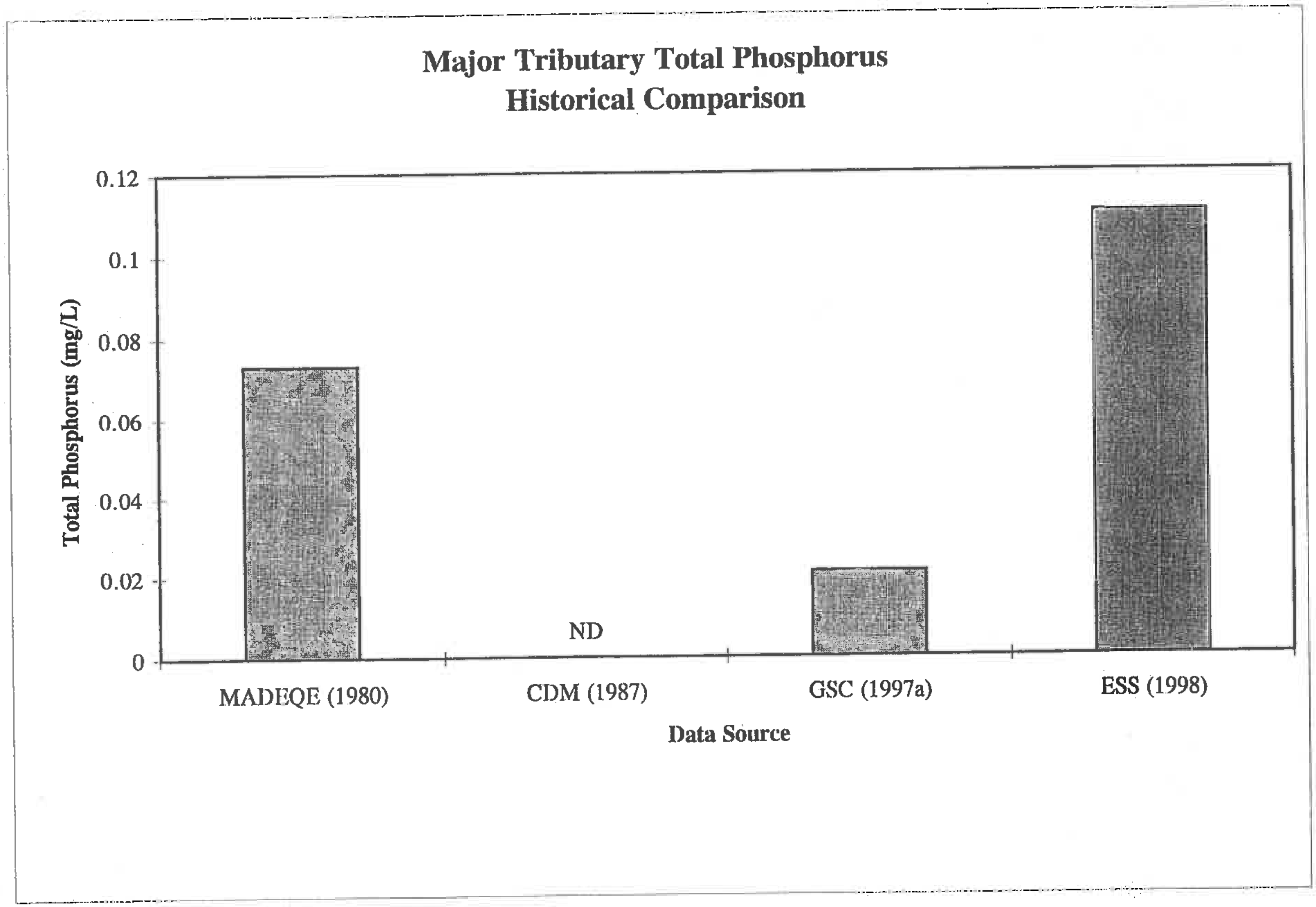


Major Tributary TKN
Historical Comparison
TKN (mg/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
MADEQE (1980)
CDM (1987)
GSC (1997a)
ESS (1998)
Data Source

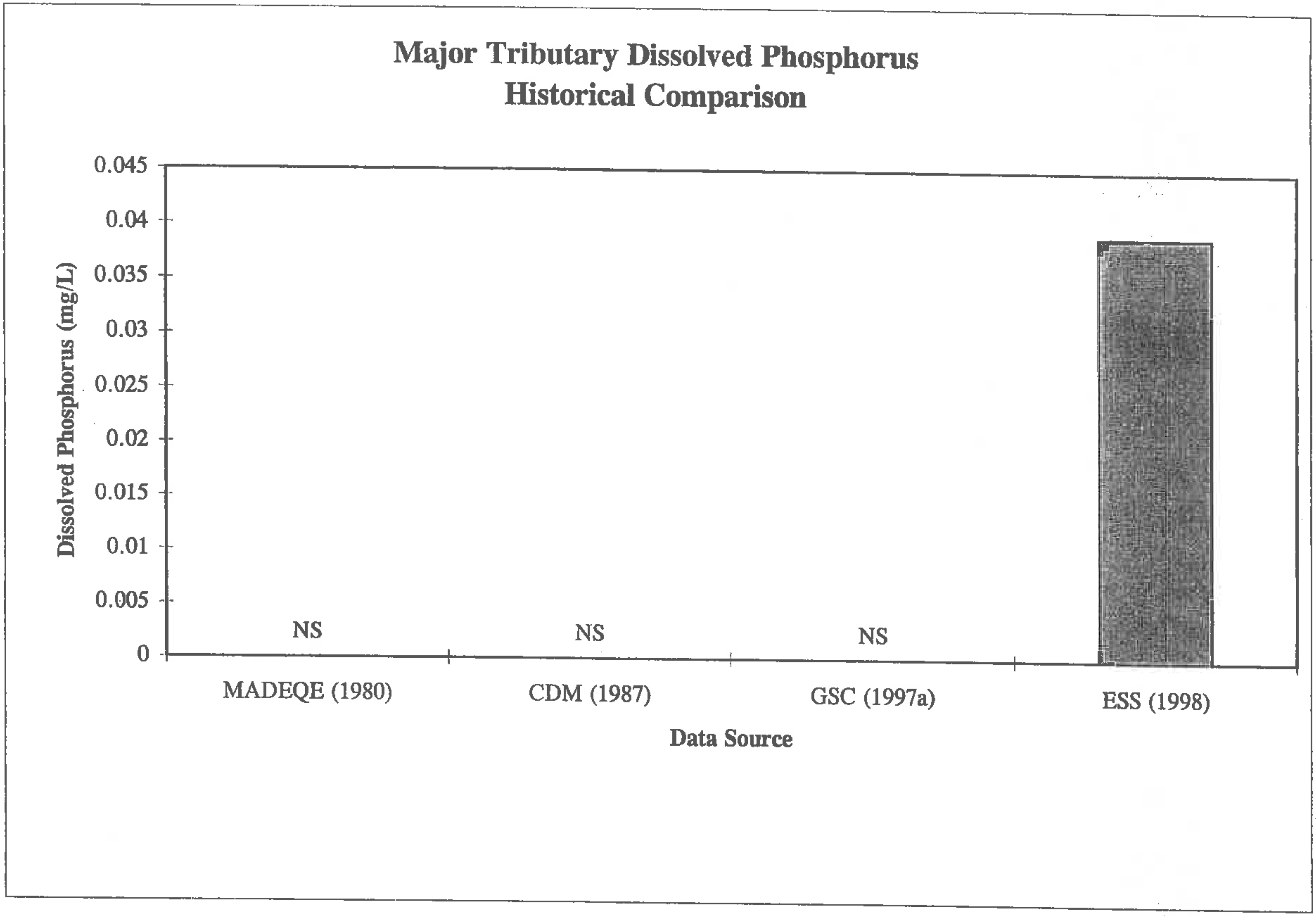
Major Tributary Ammonium Nitrogen Historical Comparison



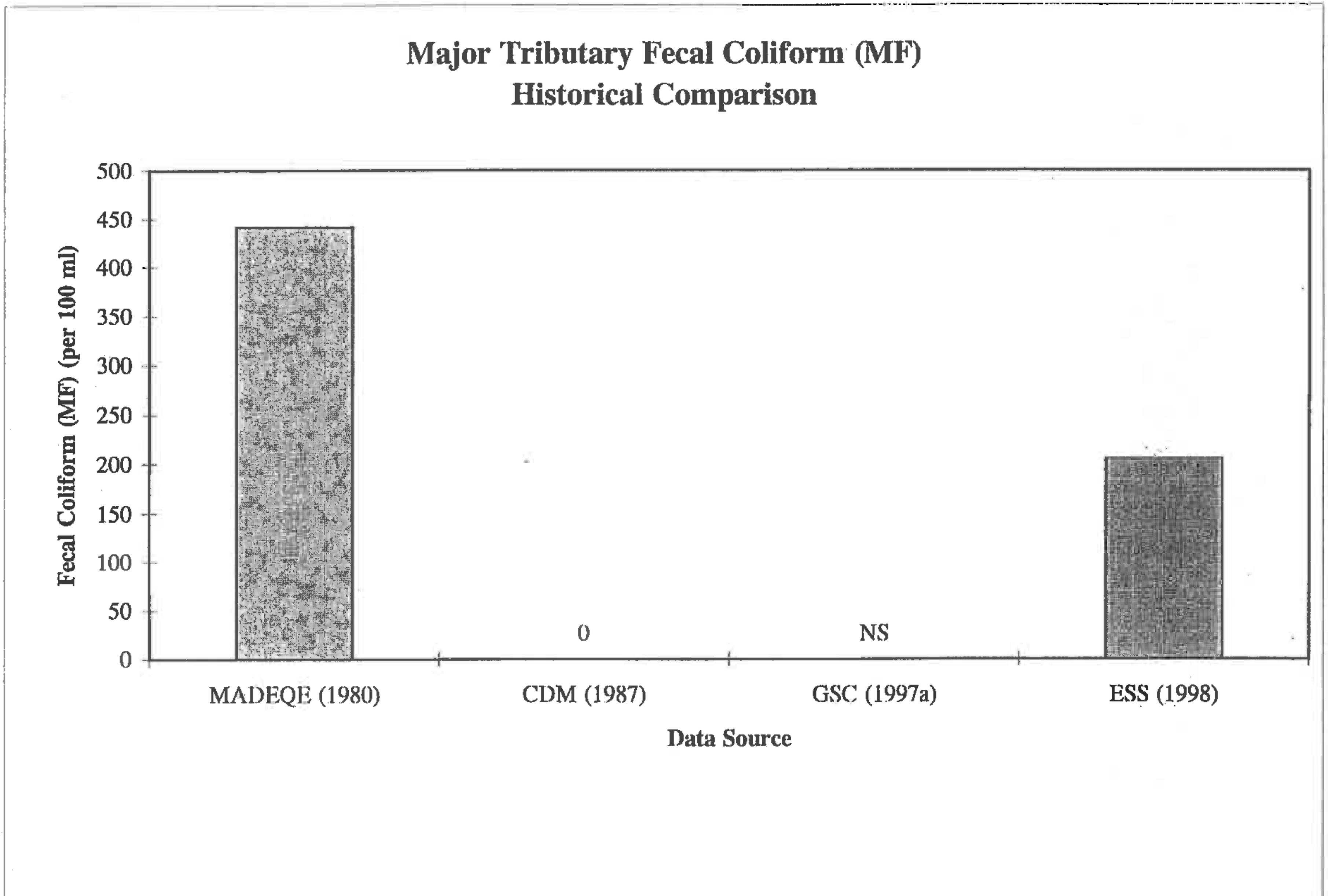

Major Tributary Nitrate Nitrogen
Historical Comparison
Nitrate Nitrogen (mg/L)
1.2
1
0.8
0.6
0.4
0.2
0
MADEQE (1980)
CDM (1987)
GSC (1997a)
ESS (1998)
Data Source



Major Tributary Total Phosphorus
Historical Comparison
Total Phosphorus (mg/L)
0.12
0.1
0.08
0.06
0.04
0.02
0
ND
MADEQE (1980)
CDM (1987)
GSC (1997a)
ESS (1998)
Data Source



Major Tributary Dissolved Phosphorus
Historical Comparison
Dissolved Phosphorus (mg/L)
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
NS
NS
NS
MADEQE (1980)
CDM (1987)
GSC (1997a)
ESS (1998)
Data Source


Major Tributary Fecal Coliform (MF)
Historical Comparison
Fecal Coliform (MF) (per 100 ml)
500
450
400
350
300
250
200
150
100
50
0
0
NS
MADEQE (1980)
CDM (1987)
GSC (1997a)
ESS (1998)
Data Source

ESS

APPENDIX B

Zooplankton and Phytoplankton Data for Lake Boon

DATE:			22-Jul-98	20-Aug-98	24-Sep-98	22-Jul-98	20-Aug-98	24-Sep-98
LAKE:			Boon	Boon	Boon	Boon	Boon	Boon
SITE:			LB-1	LB-1	LB-1	LB-2	LB-2	LB-2
Tracking #:			98000157	98000357	98000557	98000757	98000957	98001157
	BIOMASS(ug/L)							
CLADOCERANS	Bosmina	longirostris	0	0	8.008	0.018	0.062	1.19
	Ceriodaphnia	spp.	0	0	0.117	0	0	0
	Chydorus		0	0.052	0.735	0.022	0.027	0
	Daphnia		29.43	24.643	59.82	0.387	0	1.199
	Diaphanasoma		0	3.003	2.527	0	0.027	0.322
	Holopedium		0	0	14.819	0	0	0
	Immature		0	0	0.57	0	0	0
Copepods	Calanoid	copepodid	0	0.088	0.045	0	0.17	1.362
	Cyclopoid	copepodid	0.294	0.446	1.492	0.022	0	0.041
	Diacyclops		0.002	0	0	0.086	0	0
	Epischura		0	0	0	0	0	16.027
	Leptodiaptomus		6.211	8.023	7.122	1.592	0.86	0
	Mesocyclops		0.825	3.536	13.497	0	0	0
	Nauplii		0.302	0	3.235	1.529	0.721	7.314
Rotifers	Asplanchna		0	0.238	0	0.37	0.526	0.174
	Brachionus		0	0	0	0	0	0
	Conochilus		0.661	0.009	0.003	0.709	0.093	0.033
	Kellicottia	longispina	0	0	0.003	0	0	0
	Keratella	cochlearis	0	0	0	0	0	0
	Lecane	spp.	0	0	0	0	0	0
	Polyarthra	vulgaris	0	0	0	0	0	0
	Synchaeta		0	0	0	0	0	0
	Trichocerca		0	0	0	0	0.027	0
		TOTAL	37.73	40.04	111.99	4.74	2.51	27.66

DATE:			22-Jul-98	20-Aug-98	24-Sep-98	22-Jul-98	20-Aug-98	24-Sep-98
LAKE:			Boon	Boon	Boon	Boon	Boon	Boon
SITE:			LB-1	LB-1	LB-1	LB-2	LB-2	LB-2
Tracking #:			98000157	98000357	98000557	98000757	98000957	98001157
AUBUNDANCE (#/L)								
CLADOCERANS	Bosmina	longirostris	0	0	1.492	0.037	0.074	0.726
	Ceriodaphnia	spp.	0	0	0.079	0	0	0
	Chydorus		0	0.091	0.864	0.037	0.025	0
	Daphnia		3.688	3.168	6.673	0.037	0	0.121
	Diaphanasoma		0	0.815	0.785	0	0.049	0.182
	Holopedium		0	0	0.393	0	0	0
	Immature		0	0	0.707	0	0	0
Copepods	Calanoid	copepodid	0	0.181	0.157	0	0.32	3.993
	Cyclopoid	copepodid	0.688	0.996	4.004	0.075	0	0.121
	Diacyclops		0.25	0	0.157	0.075	0	0.061
	Epischura		0	0	0	0	0	0.726
	Leptodiaptomus		2.063	2.987	1.963	0.636	0.541	0
	Mesocyclops		0.25	0.453	0.628	0	0	0
	Nauplii		0.375	10.679	3.925	2.094	1.009	10.285
Rotifers	Asplanchna		0	0.181	0	0.112	0.517	0.061
	Brachionus		0	0	0	0	0	0
	Conochilus		14.563	0.634	0.236	14.923	2.091	1.029
	Kellicottia	longispina	0	0	0.471	0	0	0
	Keratella	cochlearis	0	0.091	0	0	0	0
	Lecane	spp.	0	0	0	0	0	0
	Polyarthra	vulgaris	0	0	0	0	0	0
	Synchaeta		0	0	0	0	0	0
	Trichocerca		0	0	0	0	0.025	0
		TOTAL ZOOPS	**21.88**	**20.27**	**22.53**	**18.03**	**4.65**	**17.3**

ALGAL SAMPLE ANALYSIS

Job: 57 Lake: LB Date: 07/22 Year: 98 Sample: n/a

Replicate #: 1 Station #: 2 Site: Lake Boone Tow Volume (ml): n/a

Depth: Epilimnion Level: None Fraction: None Calc. Type: Phyto-Grab

98000857

Code	Taxa	Division	GALD (µm)	Conc. Unit/ml	Rel% Conc.	Biov. (µm³/U)	TotBiov (µm³/ml)	Rel% Biov.
10[illegible]	*Cyclotella sp.*	Diatom	9.9	17.4	TR	513.4	8914.3	0.3
1[illegible]	*Dinobryon sp.*	Chryso	63.8	26.0	TR	189.0	4922.2	0.2
1[illegible]	*Fragilaria sp.*	Diatom	88.0	8.8	TR	7061.4	61912.1	2.2
12[illegible]	*Nitzschia sp.*	Diatom	44.0	8.7	TR	110.3	957.8	TR
13[illegible]	*Synedra sp.*	Diatom	50.9	34.7	TR	210.3	7303.5	0.3
14[illegible]	*Chlorocloster sp.*	Chryso	6.6	43.4	TR	27.1	1178.4	TR
15[illegible]	*Ochromonas sp.*	Chryso	6.6	112.9	0.1	122.5	13826.5	0.5
1651	*Non-motile Chrysophytes*	Chryso	8.8	8.7	TR	356.4	3094.0	0.1
1653	*Cyst (Chrysophyte)*	Chryso	6.6	26.0	TR	150.4	3915.9	0.1
1660	*Psephonema sp.*	Chryso	66.0	8.7	TR	153.1	1329.5	TR
1730	*Erkenia sp.*	Chryso	4.4	442.7	0.4	44.6	19724.5	0.7
2080	*Chlamydomonas sp.*	Chloro	8.8	8.7	TR	356.4	3094.0	0.1
2180	*Cosmarium sp.*	Chloro	11.0	8.7	TR	267.5	2322.2	0.1
2190	*Crucigenia sp.*	Chloro	6.6	17.4	TR	48.7	846.0	TR
2330	*Micractinium sp.*	Chloro	33.0	8.7	TR	37.6	326.3	TR
2360	*Oocystis sp.*	Chloro	6.6	17.4	TR	111.4	1933.8	0.1
2380	*Pediastrum sp.*	Chloro	4.4	8.7	TR	69.7	605.0	TR
2480	*Scenedesmus sp.*	Chloro	5.0	95.5	0.1	27.2	2594.1	0.1
2490	*Schroederia sp.*	Chloro	22.0	17.4	TR	25.1	435.7	TR
2550	*Tetraedron sp.*	Chloro	6.6	17.4	TR	75.3	1307.8	TR
2640	*Sphaerocystis sp.*	Chloro	24.8	147.6	0.1	171.2	25272.1	0.9
2683	*Non-motile Chlorococcales*	Chloro	4.4	104.2	0.1	44.6	4641.1	0.2
3010	*Cryptomonas sp.*	Crypto	16.5	52.1	0.1	507.0	26406.9	0.9
40[illegible]0	*Anabaena sp.*	Cyano	32[illegible].6	52.1	0.1	13187.2	6.9E+005	24.3
40[illegible]0	*Aphanizomenon sp.*	Cyano	34[illegible].7	295.2	0.3	5237.5	1.5E+006	54.6
40[illegible]6	*Aphanocapsa sp. (cells <2*	Cyano	[illegible].2	4505.7	4.4	3.1	13805.7	0.5

Code	Taxa	Division	GALD (µm)	Conc. Unit/ml	Rel% Conc.	Biov. (μm^3/U)	TotBiov (μm^3/ml)	Rel% Biov.
4060	*Aphanothece sp. (colony)*	Cyano	11.6	15448.2	15.2	7.6	1.2E+005	4.2
4094	*Coelosphaerium sp. (singl*	Cyano	5.5	69.4	0.1	31.3	2175.5	0.1
4260	*Microcystis sp. (colony)*	Cyano	29.3	26.0	TR	444.8	11584.5	0.4
4282	*Non-motile blue-greens (<*	Cyano	0.9	16735.5	16.5	0.4	6380.7	0.2
4285	*Non-motile blue-greens (>*	Cyano	3.3	26.0	TR	18.8	489.5	TR
4323	*Synechococcus sp. 1*	Cyano	1.8	57287.1	56.5	0.8	43683.3	1.5
5020	*Euglena sp.*	Euglen	38.5	8.7	TR	2340.4	20317.6	0.7
5040	*Trachelomonas sp.*	Euglen	16.0	52.1	0.1	1477.2	76940.2	2.7
6030	*Gymnodinium sp.*	Dinofl	6.6	60.8	0.1	53.5	3248.7	0.1
7140	*Misc. microflagellate*	Misc.	3.3	4062.8	4.0	21.9	89086.7	3.1
8040	*Monoraphidium sp.*	Chloro	3.6	1571.3	1.5	8.9	11959.2	0.5
9510	*Polygoniochloris sp.*	Chryso	8.8	17.4	TR	107.0	1858.5	0.1
	Totals.			1.0E+005			2.8E+006	

ALGAL SAMPLE ANALYSIS

Job: 57 Lake: LB Date: 07/22 Year: 98 Sample: n/a

Replicate #: 1 Station #: 1 Site: Lake Boone Tow Volume (ml): n/a

Depth: Epilimnion Level: None Fraction: None Calc. Type: Phyto-Grab

98000257

Code	Taxa	Division	GALD (µm)	Conc Unit/ml	Rel% Conc.	Biov. (µm³/U)	TotBiov (µm³/ml)	Rel% Biov.
1070	*Cyclotella sp.*	Diatom	17.6	3.7	0.1	1497.9	5572.6	0.3
1126	*Dinobryon cyst*	Chryso	12.1	7.4	0.1	949.5	7065.2	0.4
1560	*Kephyrion sp.*	Chryso	6.6	3.7	0.1	150.4	559.4	TR
1630	*Uroglena sp. (single)*	Chryso	4.4	11.2	0.2	44.6	498.2	TR
2030	*Ankistrodesmus sp.*	Chloro	27.5	7.4	0.1	46.0	342.4	TR
2080	*Chlamydomonas sp.*	Chloro	4.4	3.7	0.1	44.6	165.8	TR
2260	*Franceia sp.*	Chloro	33.0	3.7	0.1	1147.4	4268.9	0.2
2330	*Micractinium sp.*	Chloro	33.0	3.7	0.1	150.4	559.4	TR
2360	*Oocystis sp.*	Chloro	6.1	14.9	0.2	52.9	787.3	TR
2460	*Quadrigula sp.*	Chloro	24.8	29.8	0.5	202.0	6013.6	0.3
2490	*Schroederia sp.*	Chloro	33.0	3.7	0.1	16.7	62.2	TR
2530	*Staurastrum sp.*	Chloro	44.0	3.7	0.1	1706.1	6347.4	0.4
2640	*Sphaerocystis sp.*	Chloro	15.0	89.3	1.4	55.9	4993.3	0.3
2683	*Non-motile Chlorococcales*	Chloro	3.7	78.1	1.2	27.4	2139.2	0.1
3010	*Cryptomonas sp.*	Crypto	11.7	29.8	0.5	140.0	4167.0	0.2
3040	*Rhodomonas sp.*	Crypto	6.6	7.4	0.1	23.5	175.2	TR
4010	*Anabaena sp.*	Cyano	106.8	40.9	0.6	4421.7	1.8E+005	10.2
4040	*Aphanizomenon sp.*	Cyano	175.6	636.2	9.9	1502.2	9.6E+005	53.7
4050	*Aphanocapsa sp.*	Cyano	11.0	7.4	0.1	34.6	257.7	TR
4060	*Aphanothece sp. (colony)*	Cyano	33.0	3.7	0.1	188.0	699.3	TR
4080	*Chroococcus sp.*	Cyano	13.2	6.3	0.1	100.2	627.8	TR
4240	*Gomphosphaeria sp.*	Cyano	36.7	11.2	0.2	319.3	3563.7	0.2
4282	*Non-motile blue-greens (<*	Cyano	0.9	919.5	14.2	0.4	350.6	TR
4323	*Synechococcus sp. 1*	Cyano	1.8	1839.1	28.5	0.8	1402.4	0.1
5040	*Trachelomonas sp.*	Euglen	13.2	3.7	0.1	1202.9	4475.3	0.3
6010	*Ceratium sp.*	Dinofl	187.0	6.3	0.1	88501.5	5.5E+005	31.2

Code	Taxa	Division	GALD (µm)	Conc. Unit/ml	Rel% Conc.	Biov. (µm³/U)	TotBiov (µm³/ml)	Rel% Biov.
7140	*Misc. microflagellate*	Misc.	2.8	2678.8	41.5	11.7	31467.0	1.8
9140	*Anomoeoneis sp.*	Diatom	19.8	3.7	0.1	198.6	738.9	TR
	Totals.			6458.1			1.8E+006	

ALGAL SAMPLE ANALYSIS

Job: 57   Lake: LB   Date: 08/20   Year: 98   Sample: n/a

Replicate #: 1   Station #: 2   Site: Lake Boone   Tow Volume (ml): n/a

Depth: Epilimnion   Level: None   Fraction: None   Calc. Type: Phyto-Grab

98001057 - sm[illegible] particulates are assoc. with degrading [illegible] cells

Code	Taxa	Division	GALD (µm)	Conc. Unit/ml	Rel% Conc.	Biov. (µm³/U)	TotBiov (µm³/ml)	Rel% Biov.
1010	*Achnanthes sp.*	Diatom	9.9	26.0	0.2	35.2	91[illegible]9	TR
1070	*Cyclotella sp.*	Diatom	8.8	117.2	1.3	[illegible]87.2	2194[illegible].0	0.9
1210	*Navicula sp.*	Diatom	35.2	13.0	0.1	[illegible]94.4	1034[illegible]6	0.4
1220	*Nitzschia sp.*	Diatom	50.6	26.0	0.2	[illegible]90.3	49[illegible].8	0.2
1310	*Synedra sp.*	Diatom	66.0	26.0	0.2	165.5	431[illegible].2	0.2
1450	*Chlorocloster sp*	Chryso	6.6	13.0	0.1	37.6	48[illegible].5	TR
2030	*Ankistrodesmus sp.*	Chloro	55.0	13.0	0.1	111.5	145[illegible].4	0.1
2080	*Chlamydomonas sp.*	Chloro	11.0	13.0	0.1	696.1	9064.6	0.4
2190	*Crucigenia sp.*	Chloro	8.1	39.1	0.4	33.4	1305.3	0.1
2360	*Oocystis sp.*	Chloro	6.6	26.0	0.2	56.4	1468.5	0.1
2460	*Quadrigula sp.*	Chloro	44.0	13.0	0.1	209.0	2721.1	0.1
2480	*Scenedesmus sp.*	Chloro	5.0	78.1	0.7	30.3	2367.4	0.1
2550	*Tetraedron sp.*	Chloro	8.8	13.0	0.1	178.5	2325.0	0.1
2640	*Sphaerocystis sp.*	Chloro	11.0	26.0	0.2	59.9	1559.1	0.1
2682	*Colonial chlorophyta [illegible] ty*	Chloro	44.0	13.0	0.1	178.2	2320.5	0.1
2683	*Non-motile Chlorococcales*	Chloro	4.4	130.2	1.2	44.6	5801.3	0.2
3010	*Cryptomonas sp.*	Crypto	8.8	130.2	1.2	57.7	7511.3	0.3
4010	*Anabaena sp.*	Cyano	192.5	13.0	0.1	7805.4	1.0E+005	4.1
4090	*Coelosphaerium sp. (colon*	Cyano	55.0	13.0	0.1	2506.0	32632.5	1.3
4094	*Coelosphaerium sp. (singl*	Cyano	5.5	52.1	0.5	31.3	1631.6	0.1
4170	*Oscillatoria sp.*	Cyano	88.0	13.0	0.1	334.3	4353.8	0.2
4282	*Non-motile blue-greens (<*	Cyano	0.9	2574.7	23.4	0.4	981.6	TR
4285	*Non-motile blue-greens (>*	Cyano	4.4	963.6	8.7	44.[illegible]	42929.9	1.7
4323	*Synechococcus sp. 1*	Cyano	1.8	1931.0	17.5	0.[illegible]	1472.5	0.1
5020	*Euglena sp.*	Euglen	69.7	39.1	0.4	6680.[illegible]	2.6E+005	10.5
5030	*Phacus sp.*	Euglen	39.1	26.0	0.2	6125.[illegible]	1.6E+005	6.4

Code	Taxa	Division	GALD (µm)	Conc. Unit/ml	Rel% Conc.	Biov. (μm^3/U)	TotBiov (μm^3/ml)	Rel% Biov.
5040	*Trachelomonas sp.*	Euglen	18.2	39.1	0.4	3204.6	1.3E+005	5.0
6030	*Gymnodinium sp.*	Dinofl	11.0	13.0	0.1	247.5	3223.0	0.1
6040	*Peridinium sp.*	Dinofl	44.0	8.8	0.1	35195.5	3.1E+005	12.4
7110	*Gonyostomum sp.*	Misc.	22.0	1888.1	17.1	710.0	1.3E+006	53.8
7140	*Misc. microflagellate*	Misc.	5.5	156.3	1.4	41.1	6417.7	0.3
8040	*Monoraphidium sp.*	Chloro	3.6	2578.3	23.4	8.9	22905.4	0.9
	Totals.			11025.3			2.5E+006	

ALGAL SAMPLE ANALYSIS

Job: 57 Lake: LB Date: 08/20 Year: 98 Sample: n/a

Replicate #: 1 Station #: 1 Site: Lake Boone Tow Volume (ml): n/a

Depth: Epilimnion Level: None Fraction: None Calc. Type: Phyto-Grab

98000457

[illegible]	Taxa	Division	GALD (µm)	Conc. Unit/ml	Rel% Conc.	Biov. (µm³/U)	TotBiov (µm³/ml)	Rel% Biov.
0	*Cyclotella sp.*	Diatom	9.4	31.3	0.2	231.8	7245.8	0.9
0	*Mallomonas sp.*	Chryso	22.0	5.2	TR	3132.5	16316.2	1.9
0	*Nitzschia sp.*	Diatom	44.0	5.2	TR	110.3	574.7	0.3
[illegible]	*Chlorocloster sp.*	Chryso	6.6	10.4	0.1	16.7	174.0	TR
0	*Ochromonas sp.*	Chryso	6.6	5.2	TR	150.4	783.2	0.1
0	*Psephonema sp.*	Chryso	198.0	10.4	0.1	1185.3	12348.1	1.5
0	*Erkenia sp.*	Chryso	4.4	119.8	0.8	44.6	5337.2	0.6
[illegible]	*Ankistrodesmus sp.*	Chloro	28.9	20.8	0.1	43.9	915.0	0.1
[illegible]	*Oocystis sp.*	Chloro	4.7	41.7	0.3	16.2	674.4	0.1
2460	*Quadrigula sp.*	Chloro	26.4	15.6	0.1	183.9	2873.5	0.3
2490	*Schroederia sp.*	Chloro	24.8	36.5	0.2	28.2	1029.4	0.1
2530	*Staurastrum sp.*	Chloro	44.0	5.2	TR	714.2	3720.1	0.4
2550	*Tetraedron sp.*	Chloro	8.8	10.4	0.1	178.5	1860.0	0.2
2640	*Sphaerocystis sp.*	Chloro	14.9	83.3	0.6	136.4	11370.6	1.4
2683	*Non-motile Chlorococcales*	Chloro	3.9	130.2	0.9	31.7	4124.4	0.5
2840	*Lobomonas sp.*	Chloro	7.7	5.2	TR	238.8	1243.7	0.1
3010	*Cryptomonas sp.*	Crypto	15.4	72.9	0.5	328.1	23923.5	2.9
3040	*Rhodomonas sp.*	Crypto	6.6	10.4	0.1	23.5	245.2	TR
4010	*Anabaena sp.*	Cyano	148.7	26.0	0.2	6638.1	1.7E+005	20.6
4040	*Aphanizomenon sp.*	Cyano	140.6	140.6	1.0	2139.0	3.0E+005	35.9
4050	*Aphanocapsa sp.*	Cyano	44.0	5.2	TR	278.4	1450.3	0.2
4060	*Aphanothece sp. (colony)*	Cyano	30.3	31.3	0.2	47.5	1484.8	0.2
4090	*Coelosphaerium sp. (colon*	Cyano	44.0	5.2	TR	4134.9	21537.4	2.6
4094	*Coelosphaerium sp. (singl*	Cyano	6.3	57.3	0.4	44.6	2552.6	0.3
4170	*Oscillatoria sp.*	Cyano	1210.0	5.2	TR	10306.3	53682.0	6.4
4240	*Gomphosphaeria sp.*	Cyano	33.0	5.2	TR	167.1	870.2	0.1

Code	Taxa	Division	GALD (µm)	Conc. Unit/ml	Rel% Conc.	Biov. (µm³/U)	TotBiov (µm³/ml)	Rel% Biov.
4282	*Non-motile blue-greens (<*	Cyano	0.9	3218.4	22.0	0.4	1227.1	0.1
4285	*Non-motile blue-greens (>*	Cyano	3.3	57.3	0.4	21.9	1256.4	0.1
4323	*Synechococcus sp. 1*	Cyano	1.8	3218.4	22.0	0.8	2454.1	0.3
5040	*Trachelomonas sp.*	Euglen	20.2	15.6	0.1	4020.1	62817.6	7.5
7110	*Gonyostomum sp.*	Misc.	22.0	52.1	0.4	710.0	36983.5	4.4
7140	*Misc. microflagellate*	Misc.	2.8	6875.5	47.1	11.7	80765.4	9.6
8040	*Monoraphidium sp.*	Chloro	3.6	265.6	1.8	8.9	2360.0	0.3
	Totals.			14598.8			8.4E+005	

ALGAL SAMPLE ANALYSIS

Job: 57 Lake: LB Date: 09/24 Year: 98 Sample: n/a

Replicate #: 1 Station #: 2 Site: Lake Boone Tow Volume (ml): n/a

Depth: Epilimnion Level: None Fraction: None Calc. Type: Phyto-Grab

98001257

Code	Taxa	Division	GALD (µm)	Conc. Unit/ml	Rel% Conc	Biov. (µm³/U)	Tot Biov (µm³/ml)	Rel% Biov.
1010	*Achnanthes sp.*	Diatom	11.0	18.6	0.1	41.4	[illegible].7	0.1
1120	*Dinobryon sp.*	Chryso	63.3	130.2	1.0	283.5	[illegible].5	3.6
1123	*Dinobryon* monads	Chryso	8.8	1525.4	11.5	200.5	3.[illegible]005	29.6
1210	*Navicula sp.*	Diatom	35.2	12.4	0.1	353.1	[illegible].7	0.4
1220	*Nitzschia sp.*	Diatom	24.2	37.2	0.3	88.3	[illegible]284.0	0.3
1310	*Synedra sp.*	Diatom	66.0	6.2	TR	165.5	[illegible]026.2	0.1
1630	*Uroglena sp. (single)*	Chryso	4.4	508.5	3.8	44.6	22696.1	2.2
2180	*Cosmarium sp.*	Chloro	8.8	6.2	TR	137.0	849.3	0.1
2190	*Crucigenia sp.*	Chloro	4.4	6.2	TR	22.3	138.1	TR
2340	*Mougeotia sp.*	Chloro	132.0	6.2	TR	2006.1	12439.3	1.2
2380	*Pediastrum sp.*	Chloro	35.2	6.3	TR	1115.1	6983.7	0.7
2460	*Quadrigula sp.*	Chloro	33.0	12.5	0.1	125.4	1570.4	0.2
2480	*Scenedesmus sp.*	Chloro	8.3	24.8	0.2	65.8	1632.7	0.2
2490	*Schroederia sp.*	Chloro	22.0	6.2	TR	25.1	155.6	TR
2550	*Tetraedron sp.*	Chloro	6.6	12.4	0.1	100.4	1245.5	0.1
2640	*Sphaerocystis sp.*	Chloro	22.0	6.2	TR	356.4	2210.0	0.2
2683	*Non-motile Chlorococcales*	Chloro	4.4	12.4	0.1	44.6	552.5	0.1
2920	*Xanthidium sp.*	Chloro	6.6	6.2	TR	75.3	467.1	TR
3010	*Cryptomonas sp.*	Crypto	17.6	43.4	0.3	519.1	22533.9	2.2
3040	*Rhodomonas sp.*	Crypto	6.6	43.4	0.3	23.5	1021.7	0.1
4050	*Aphanocapsa sp.*	Cyano	16.5	12.4	0.1	105.8	1312.2	0.1
4060	*Aphanothece sp. (colony)*	Cyano	33.0	12.4	0.1	219.3	2719.4	0.3
4090	*Coelosphaerium sp. (colon*	Cyano	66.0	6.2	TR	4385.5	27193.7	2.6
4094	*Coelosphaerium sp. (ingl*	Cyano	5.5	55.8	0.4	31.2	1748.2	0.2
4160	*Merismopedia sp.*	Cyano	44.0	6.2	TR	178.2	1105.0	0.1
4170	*Oscillatoria sp.*	Cyano	36.7	18.8	0.1	139.3	2617.4	0.3

Code	Taxa	Division	GALD (µm)	Conc. Unit/ml	Rel% Conc.	Biov. (µm³/U)	TotBiov (µm³/ml)	Rel% Biov.
4260	*Microcystis sp. (colony)*	Cyano	11.0	12.4	0.1	65.8	815.8	0.1
4282	*Non-motile blue-greens (<*	Cyano	0.9	5977.0	45.2	0.4	2278.8	0.2
4285	*Non-motile blue-greens (>*	Cyano	3.6	155.0	1.2	28.4	4397.4	0.4
4323	*Synechococcus sp. 1*	Cyano	1.8	2758.6	20.9	0.8	2103.5	0.2
4460	*Pseudanabaena sp.*	Cyano	17.6	6.2	TR	25.1	155.4	TR
5040	*Trachelomonas sp.*	Euglen	16.5	6.2	TR	2349.4	[illegible]	1.4
6040	*Peridinium sp.*	Dinofl	55.0	6.2	TR	68741.2	[illegible]	41.2
7110	*Gonyostomum sp.*	Misc.	55.0	6.2	TR	11094.3	[illegible]	6.7
7140	*Misc. microflagellate*	Misc.	3.9	1562.6	11.8	31.7	[illegible]	4.8
8040	*Monoraphidium sp.*	Chloro	3.6	179.8	1.4	8.9	[illegible]	0.2
	Totals.			13212.9			[illegible] 0E+006	

ALGAL SAMPLE ANALYSIS

Job: 57 Lake: LB Date: 09/24 Year: 98 Sample: n/a

Replicate #: 1 Station #: 1 Site: Lake Boone Tow Volume (ml): n/a

Depth: Epilimnion Level: None Fraction: None Calc. Type: Phyto-Grab

98000[illegible]57

C[illegible]	Taxa	Division	[illegible]ALD µm)	Co[illegible] Unit/	Rel% Conc.	Bi[illegible] (µm³/[illegible])	TotBiov (µm³/ml)	R[illegible] Bi[illegible]v.
[illegible]	*Dinobry[illegible] [illegible]p.*	Chryso	[illegible]3.0	62[illegible]	4.0	24[illegible]	1.5E+005	1[illegible].3
1	*Dinobry[illegible] monads*	Chryso	8.8	423[illegible]	26.9	200.5	8.5E+005	5[illegible].1
1	*Synura sp. (colonial)*	Chryso	8.8	11	0.1	35[illegible].4	4125.4	[illegible].3
1	*Psephon[illegible] sp.*	Chryso	[illegible]1.6	11	0.1	300.7	3480.8	[illegible].2
2	*Oocysti[illegible] sp.*	Chloro	[illegible]3.2	11	0.1	55[illegible].9	6445.9	0.4
2[illegible]	*Quadrig[illegible]la sp.*	Chloro	44.0	11	0.1	167.2	1935.0	0.1
2[illegible]	*Schroederia sp.*	Chloro	27.5	81.0	0.5	13.9	1129.7	0.1
2530	*Staurastrum sp.*	Chloro	22.0	23.1	0.1	11139.2	2.6E+005	17.3
2640	*Sphaerocystis sp.*	Chloro	38.5	46.3	0.3	356.4	16501.6	1.1
3010	*Cryptomonas sp.*	Crypto	16.5	23.1	0.1	507.0	11736.4	0.8
3040	*Rhodomonas sp.*	Crypto	6.6	23.1	0.1	23.5	544.9	TR
4010	*Anabaena sp.*	Cyano	35.2	11.6	0.1	2255.4	26106.0	1.8
4060	*Aphanothece sp. (colony)*	Cyano	7.7	11.6	0.1	12.5	145.0	TR
4090	*Coelosphaerium sp. (colon*	Cyano	44.0	11.6	0.1	1782.0	20627.0	1.4
4094	*Coelosphaerium sp. (singl*	Cyano	6.1	277.8	1.8	43.9	12182.8	0.8
4160	*Merismopedia sp.*	Cyano	8.0	81.0	0.5	39.0	3158.5	0.2
4282	*Non-motile blue-greens (<*	Cyano	0.9	7080.4	45.0	0.4	2699.5	0.2
4285	*Non-motile blue-greens (>*	Cyano	3.3	46.3	0.3	18.8	870.2	0.1
4323	*Synechococcus sp. 1*	Cyano	1.8	1931.0	12.3	0.8	1472.5	0.1
5040	*Trachelomonas sp.*	Euglen	26.4	8.8	0.1	9623.1	84371.8	5.7
7110	*Gonyostomum sp.*	Misc.	22.0	23.1	0.1	710.0	16437.1	1.1
7140	*Misc. microflagellate*	Misc.	2.8	1145.9	7.3	11.7	13460.9	0.9
	[illegible]otals.			15733.6			1.5E+006	

Code	Taxa	Taxonomic Authority	Division
1010	*Achnanthes sp.*	Bory	Diatom
1070	*Cyclotella sp.*	(Kützing) de Brébisson	Diatom
1120	*Dinobryon sp.*	Ehrenberg	Chrysophyte
1123	*Dinobryon monads*	N/A	Chrysophyte
1126	*Dinobryon cyst*	N/A	Chrysophyte
1150	*Fragilaria sp.*	Lyngbye	Diatom
1180	*Mallomonas sp.*	Perty	Chrysophyte
1210	*Navicula sp.*	Bory	Diatom
1220	*Nitzschia sp.*	Hassall	Diatom
1310	*Synedra sp.*	Ehrenberg	Diatom
1320	*Synura sp. (colonial)*	Ehrenberg	Chrysophyte
1450	*Ch[illegible]ecloster sp*	Pascher	Chrysophyte
1560	*Kephyrion sp.*	Pascher	Chrysophyte
1570	*Ochromonas sp.*	Wyssotzki	Chrysophyte
1630	*Uroglena sp. (single)*	Ehrenberg	Chrysophyte
1651	*Non-motile Chrysophytes*	N/A	Chrysophyte
1653	*Cyst (Chrysophyte)*	N/A	Chrysophyte
1660	*Psephonema sp.*	Skuja	Chrysophyte
1730	*Erkenia sp.*	Skuja	Chrysophyte
2030	*Ankistrodesmus sp.*	Corda	Chlorophyte
2080	*Chlamydomonas sp.*	Ehrenberg	Chlorophyte
2180	*Cosmarium sp.*	Corda	Chlorophyte
2190	*Crucigenia sp.*	Morren	Chlorophyte
2260	*Franceia sp.*	Lemmermann	Chlorophyte
2330	*Micractinium sp.*	Fresenius	Chlorophyte
2340	*Mougeotia sp.*	Agardh	Chlorophyte
2360	*Oocystis sp.*	Nägeli	Chlorophyte
2380	*Pediastrum sp.*	Meyen	Chlorophyte
2460	*Quadrigula sp.*	Printz	Chlorophyte
2480	*Scenedesmus sp.*	Meyen	Chlorophyte
2490	*Schroederia sp.*	Lemmermann	Chlorophyte
2530	*Staurastrum sp.*	Meyen	Chlorophyte
2550	*Tetraedron sp.*	Kützing	Chlorophyte
2640	*Sphaerocystis sp.*	Chodat	Chlorophyte
2682	*Colonial chlorophyta - type 2*	N/A	Chlorophyte
2683	*Non-motile Chlorococcales-s[illegible]her*	N/A	Chlorophyte
2840	*Lobomonas sp.*	Dangeard	Chlorophyte
2920	*Xanthidium sp.*	Ehrenberg	Chlorophyte
3010	*Cryptomonas sp.*	Ehrenberg	Cryptophyte

Code	Taxa	Taxonomic Authority	Division
3040	*Rhodomonas sp.*	Karsten	Cryptophyte
4010	*Anabaena sp.*	Bory	Cyanophyte
4040	*Aphanizomenon sp.*	Morren	Cyanophyte
4050	*Aphanocapsa sp.*	Nägeli	Cyanophyte
40[illegible]	*Aphanocapsa sp. (cells <2um)*	Nägeli	Cyanophyte
40[illegible]	*Aphanothece sp. (colony)*	Nägeli	Cyanophyte
4[illegible]	*Chrooco[illegible]cus sp.*	Nägeli	Cyanophyte
4[illegible]	*Coelosp[illegible]aerium sp. (colony)*	Nägeli	Cyanophyte
4[illegible]	*Coelosp[illegible]erium sp. (single)*	Nägeli	Cyanophyte
4[illegible]	*Merismo[illegible]dia sp.*	Meyen	Cyanophyte
4[illegible]	*Oscill[illegible]ria sp.*	Vaucher	Cyanophyte
4[illegible]	*Gompho[illegible]aeria sp.*	Kützing	Cyanophyte
[illegible]	*Microc[illegible]is sp. (colony)*	Kützing	Cyanophyte
4[illegible]	*Non-mo[illegible]e blue-greens (<1.1 UM)*	N/A	Cyanophyte
4[illegible]	*Non-mo[illegible]e blue-greens (>2 UM)*	N/A	Cyanophyte
4[illegible]	*Synech[illegible]ccus sp. 1*	(Nägeli) Elenkin	Cyanophyte
4[illegible]	*Pseuda[illegible]aena sp.*	Lauterborn	Cyanophyte
5[illegible]	*Euglena [illegible]p.*	Ehrenberg	Euglenophyte
50[illegible]	*Phacus [illegible]p.*	Dujardin	Euglenophyte
50[illegible]	*Trachel[illegible]monas sp.*	Ehrenberg	Euglenophyte
60[illegible]	*Ceratium sp.*	Schrank	Dinoflagellate
60[illegible]0	*Gymnodinium sp.*	Stein	Dinoflagellate
60[illegible]0	*Peridinium sp.*	Ehrenberg	Dinoflagellate
7110	*Gonyostomum sp.*	Diesing	Miscellaneous
7140	*Misc. microflagellate*	N/A	Miscellaneous
8040	*Monoraphidium sp.*	Reinsch	Chlorophyte
9140	*Anomoeoneis sp.*	Pfitzer	Diatom
9510	*Polygoniochloris sp.*	Ettl	Chrysophyte

ESS

APPENDIX C

Drawdown Information

LITERATURE REVIEW OF DRAWDOWN IMPACTS

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General Information:

Historically, water level drawdown has been used in waterfowl impoundments and wetlands for periods of a year or more, including the growing season, to improve the quality of wetlands for waterfowl breeding and feeding habitat (Kadlek 1962, Harris and Marshall 1963). More recently lake drawdown has been successfully used to control submerged aquatic macrophytes, considered nuisance weeds in the littoral zone (Mitchell and Titlow 1989). Although drawdown is known to be a potentially effective tool for lake management, potential conflicts with other lake uses and functions are of concern.

For a lake, water depth is critical to aspects of the fish, benthic invertebrate and macrophyte communities and to water quality (Cooke et al. 1986). Water level is an important determinant of recreation through maintenance of depth of bathing areas, limiting the activity or size of boats, and affecting shoreline facilities (e.g., docks and retaining walls). Water level may also be critical at industrial intakes for processing or cooling water supply purposes. Water level in a lake is related to flood storage capacity and regulation of downstream flow variation. Outside of the lake, changing lake water level may affect water levels in nearby supply wells and the hydrology of hydraulically connected wetlands.

Water level in a lake may be kept relatively constant, fluctuate seasonally or vary in a rapid or seasonally unsynchronized fashion. Respective examples of these types of water level fluctuations would be: (1) an impoundment where the level is determined by the elevation of a large capacity control structure, (2) a natural lake where the level rises with the spring floods but eventually falls with declining summer water table, and (3) a hydroelectric reservoir where release rates are dictated by economic supply and demand. Conflicts with wetlands occur when water level is manipulated principally to the benefit of one purpose without regard to competing uses (O'Neil and Witmer 1988). Management conflicts between lake recreation and wetland protection are most likely to arise in the first category above, since the water level can be regulated for specific purposes. Disagreement over water use priorities or lack of a unified lake management plan (Wagner and Oglesby 1984) can easily result in such conflicts.

In-lake Considerations:

One of the common problems of recreational lakes is the overabundance of submerged macrophytes impacting recreational uses such as swimming, fishing and boating. Many lakes are pre-disposed to plant nuisances, but human activities have resulted in excess sedimentation and overfertilization which promote such growths. In the many cases these problems have been exacerbated by invasions of exotic species. To treat the problem, lake managers may resort to a water level drawdown. While this technique is not effective on all submerged species, it does decrease abundance of some of the chief nuisance species, particularly those which rely on vegetative propagules for expansion (Cooke et al. 1986). If there is an existing drawdown capability, lowering the water level provides an inexpensive means to control macrophytes. Additional benefits may include opportunities for shoreline maintenance and oxidation or removal of nutrient-rich sediments.

The desired depth of drawdown should be determined by lake morphometry and the location of target nuisance species, although many other factors will enter into determining the allowable or achievable depth of drawdown. From experiences with several Massachusetts Lakes, suggested drawdowns were generally restricted to less than six feet. More often than not, it is the elevation of the outlet structure, such as a spillway or bottom drain, which determines the practical limits of drawdown. The duration of drawdown should be determined by the time necessary to sufficiently desiccate or freeze vegetation to the point of the desired density reduction. As this cannot usually be determined during the drawdown, several years of experimentation in a given system are often needed. The actual period of drawdown is often determined by watershed size (tributary inflows), weather (storms) and size of the dam opening (maximum outflow).

The typically intended effects of a drawdown are to reduce the density of rooted aquatic plants in the exposed area and to provide an opportunity for clean-up and repairs by shoreline property owners. If the water level declines, there is little that will interfere with maintenance efforts, but several factors may affect the success of drawdown with respect to plant control. The presence of high levels of groundwater seepage into the lake may mitigate or negate destructive effects on both target submergents and adjoining emergents by keeping the area moist and unfrozen. The presence of extensive seed beds may result in rapid re-establishment of previously occurring or new and equally undesirable plant species. Recolonization from nearby areas may be rapid, and the response of some macrophyte species to drawdown is quite variable (Cooke et al. 1986, EPA 1988, Table 1).

Drawdowns of many lakes have controlled macrophyte growths to the satisfaction of users and managers, and have been employed for longer than most other lake management techniques (Dunst et al. 1974). Winter drawdowns of Candlewood Lake in Connecticut (Siver et al. 1986) reduced nuisance species by as much as 90% after initial drawdown. Reductions in plant biomass of 44 to 57% were observed in Blue Lake in Oregon (Geiger 1983) following drawdown. Certain species have been reduced or eliminated from shallow water in Richmond Pond in Massachusetts by annual winter drawdown (Enser, pers. comm.). Drawdown of Lake Bomoseen in Vermont (VANR 1990) caused a major reduction in many species, many of which were not targeted for biomass reductions. About a decade of experience with drawdown at Lake Lashaway in Massachusetts has resulted in the elimination of nuisance conditions without eliminating any species of plants (Munyon, pers. comm.). Drawdowns in Wisconsin lakes have resulted in from 40 to 92% reductions in plant coverage/biomass in targeted areas (Dunst et al. 1974). Reviewing drawdown effectiveness in a variety of lakes, Nichols and Shaw (1983) noted the species-specific effects of drawdown, with a number of possible benefits and drawbacks. A system-specific review is highly advisable prior to conducting a drawdown (Cooke et al. 1986, WDNR 1989).

TABLE 1
ANTICIPATED RESPONSES OF SOME WETLAND PLANTS TO WINTER WATER LEVEL DRAWDOWN

	Change in Relative Abundance		
	Increase	No Change	Decrease
Acorus calamus (sweet flag)	E		
Alternanthera philoxeroides (alligator weed)	E		
Asclepias incarnata (swamp milkweed)			E
Brasenia schreberi (watershield)			S
Cabomba caroliniana (fanwort)			S
Cephalanthus occidentalis (buttonbush)	E		
Ceratophyllum demersum (coontail)			S
Egeria densa (Brazilian Elodea)			S
Eichhornia crassipes (water hyacinth)		E/S	
Eleocharis acicularis (needle spikerush)	S	S	S
Elodea canadensis (waterweed)	S	S	S
Glyceria borealis (mannagrass)	E		
Hydrilla verticllata (hydrilla)	S		
Leersia oryzoides (rice cutgrass)	E		
Myrica gale (sweetgale)		E	
Myriophyllum spp. (milfoil)			S
Najas flexilis (bushy pondweed)	S		
Najas guadalupensis (southern naiad)			S
Nuphar spp. (yellow water lily)			E/S
Nymphaea odorata (water lily)			S
Polygonum amphibium (water smartweed)		E/S	
Polygonum coccineum (smartweed)	E		
Potamogeton epihydrus (leafy pondweed)	S		
Potamogeton robbinsii (Robbins' pondweed)			S
Potentilla palustris (marsh cinquefoil)			E/S
Scirpus americanus (three square rush)	E		
Scirpus cyperinus (wooly grass)	E		
Scirpus validus (great bulrush)	E		
Sium suave (water parsnip)	E		
Typha latifolia (common cattail)	E	E	
Zizania aquatic (wild rice)		E	

E=emergent growth form; S=submergent growth form; E/S=emergent and submergent growth forms

After Cooke et al., 1986

Desirable side effects associated with drawdowns include the opportunity to clean up the shoreline, repair previous erosion damage, repair docks and retaining walls, search for septic system breakout, and physically improve fish spawning areas (Nichols and Shaw 1983, Cooke et al. 1986, WDNR 1989). The attendant concentration of forage fish and game fish in the same areas is viewed (Cooke et al. 1986) as a benefit of most drawdowns. Since emergent shoreline vegetation tends to be favored by drawdowns, populations of furbearers are expected to benefit (WDNR 1989). The consolidation of loose sediments and sloughing of soft sediment deposits into deeper water is perceived as a benefit in many cases, at least by shoreline homeowners (Cooke et al. 1986, WDNR 1989).

Undesirable possible side effects of drawdown include loss or reduction of desirable plant species, facilitation of invasion by drawdown-resistant undesirable plants, reduced attractiveness to waterfowl (considered an advantage by some), possible fishkills if oxygen demand exceeds re-aeration during a prolonged drawdown, shoreline erosion during drawdown, loss of aesthetic appeal during drawdown, more frequent algal blooms after reflooding, reduction in water supply and impairment of recreational access during the drawdown (Nichols and Shaw 1983, Cooke et al. 1986). Inability to rapidly refill a drawn down lake is a standard concern in evaluating the efficacy of a drawdown. Winter drawdown can often avoid many of these negative side effects, but managers should be aware of the potential consequences of any management action (WDNR 1989).

Recolonization by resistant vegetation is sometimes a function of seed beds and sometimes the result of expansion of the shoreline vegetation fringe. *Najas* recolonized areas previously overgrown with *Myriophyllum* after the drawdown of Candlewood Lake in Connecticut (Siver et al. 1986), apparently from seeds that had been in those areas prior to milfoil dominance. Cattails and rushes are the most commonly expanding fringe species (Nichols and Shaw, WDNR 1989).

Effects of drawdown on amphibians and reptiles have not been well studied, but burrowing species might be expected to be below the zone of freezing or desiccation. The nature of the sediment and the dewatering potential of the drawdown will be key factors in determining impacts. The drawdown of Lake Bomoseen in Vermont was believed to have reduced the bullfrog population through desiccation and freezing of its burrowing areas (VANR 1990), although the evidence is scant.

Unintended effects within the littoral zone of a lake include loss of fish spawning areas and reduction of benthic invertebrate abundance and diversity. Few fish species spawn during winter in temperate climates (Scott and Crossman 1979), and spawning habitat improvement is more common than detrimental impacts (Cooke et al. 1986). Recolonization by invertebrates is usually rapid, although changes in species composition and diversity may occur and recolonization may be slow in large scale drawdowns (Cooke et al. 1986, WDNR 1989, VANR 1990).

Drawdown may affect water quality, particularly the parameters of clarity and dissolved oxygen concentration. Clarity will be a function of algal production and suspension of non-living particles. Algal production is most often related to phosphorus availability. By oxidizing exposed sediments, later release of phosphorus may be reduced through binding under oxic conditions, although post-drawdown algal blooms suggest that this mechanism may not be effective for all lakes. Some researchers have suggested that decomposition during drawdown makes nutrients more available for release, but there is little experimental evidence to support this mechanism (Cooke et al. 1986). It is likely that binding of iron and phosphorus influences phosphorus availability after drawdown, and the interplay between oxygen and levels of iron, sulfur and phosphorus is likely to vary among aquatic systems, resulting in variable nutrient availability.

Interaction between unexposed sediments and the lesser volume of water in the lake during drawdown can lead to depressed oxygen levels if oxygen demand exceeds aeration and sources of inflow are slight (Cooke et al. 1986, WDNR 1989). Compaction of sediment during drawdown varies with sediment type and dewatering potential, but any resulting compaction tends to last after refilling, reducing resuspension potential and post-drawdown turbidity (Kadlec 1962, Bay 1966, Cooke et al. 1986).

Recreational facilities and pursuits may be adversely impacted during a drawdown. Swimming areas will shrink and beach areas will enlarge during a drawdown. Boating may be restricted both by available lake area and by access to the lake. Again, winter drawdown will avoid most of these disadvantages, although lack of control over winter water levels can make ice conditions unsafe for fishing or skating.

Physical structures associated with the lake may be impacted by a drawdown. Outlet structures, docks and retaining walls may be subject to damage from freeze/thaw processes during overwinter drawdowns, if the water level is not lowered beyond all contact with the structure.

Downstream Considerations:
Desirable flood storage capacity will increase during a drawdown, but associated alteration of the downstream flow regime may have some negative impacts. Once the target drawdown level is achieved, there should be little alteration of downstream flow. However, downstream flows must necessarily be greater during the actual drawdown than they would be if no drawdown was conducted. The key to managing downstream impacts is to minimize erosion and keep flows within an acceptable natural range.

Water Supply Considerations:
Impairment of water supply during a drawdown is a primary concern of groups served by that supply. Processing or cooling water intakes may be exposed, reducing or eliminating intake capacity. The water level in wells with hydraulic connections to the lake will decline, with the potential for reduced yield, altered water quality and pumping difficulties. Drawdowns of Cedar Lake in Sturbridge, MA and Forge Pond in Westford, MA resulted in impairment of well water supplies, but there is little mention of impairment of well production in the reviewed literature.

Considerations for Hydraulically Connected Wetlands:
The impact of drawdowns on wetlands which are hydraulically connected to the lake is often a major concern of environmental agencies. Hydrology is generally considered the master variable of wetland ecosystems (Carter 1986), controlling recruitment, growth and succession of wetland species (Conner et al. 1984). It is apparent that the depth, timing, duration and frequency of water level fluctuations are critical with regard to severity of impacts to adjacent wetlands (Kusler and Brooks 1988). It is also apparent that the specific composition of a wetland plant community prior to drawdown plays an important role in determining impacts.

The naturally-occurring hydrologic regime is probably the single most important determinant for the establishment and maintenance of specific types of wetlands and wetland processes. Hydroperiod is the seasonal pattern of water levels in a wetland and is like a hydrologic signature of each wetland type. It is unique to each type of wetland and its constancy from year to year ensures reasonable stability for that wetland (Mitsch and Gosselink 1986).

The hydrologic regime of a specific wetland system can be permanently altered by a variety of techniques including: (1) constructing or removing berms or other containment devices, (2) water supply augmentation by wells or surface water diversion, (3) diffusing streamflow through the use of mechanical "spreaders" or by physically altering (e.g., braiding) the existing streamflow, and (4) by diverting surface or groundwater flow from the wetland. Significant changes in hydroperiod can produce rapid changes in vegetative species zonation in non-forested wetlands (Brinson et al. 1981). Most drawdowns for lake management purposes constitute only a temporary influence on hydrologic regime, however, and will not necessarily have a detectable, widespread effect.

Duration and timing of the drawdown are important factors in limiting impacts to associated wetlands. The duration of the drawdown must be at least several weeks (and preferably longer), if previously submergent vegetation is to be impacted (EPA 1988). Drawdown of the water level in summer, if more than a week or two in duration, leads to desiccation and stress of wetland species in most cases. In contrast, a similar drawdown practiced during late fall or early winter is expected to have little impact on dormant emergent plants, but should have a destructive effect on exposed littoral zone submergents and their rootstocks.

The frequency of drawdown can be as important as its duration or timing. Annual summer lake drawdowns provide a level of disturbance that often leads to a wetland interface which, while productive, is devoid of all but the most hardy vegetation (aquatic grasses) and lacking in a smooth transition into the littoral zone (Burt 1988). In some cases, annual drawdowns are conducted specifically to prevent emergent wetland encroachment into the lake. The rationale is that if emergent wetlands encroachment into the lake. The rationale is that if emergent wetlands are permitted to extend further into the lake, their ensuing protected legal status would dictate lake management policy.

Management drawdowns to control nuisance submergent vegetation are usually recommended for alternate years (Cooke et al. 1986), although they may be practiced at a higher frequency initially. The "every other year" approach tends to prevent domination by resistant submergent plants. This level of disturbance should also promote a degree of rejuvenation and diversity of the emergent wetland community, and should increase the area of ecotonal overlap between the fringing marshlands and the open water.

Although drawdowns may prevent expansion of emergent vegetation, the absence of water level fluctuations alone probably does not promote intrusion of emergent wetland plants. While emergent wetland species may expand in conjunction with other factors (e.g., increased sedimentation, eutrophication), a stable water level would normally be more encouraging to the expansion of the submergent plant population. However, just as with the emergent vegetation, an expansion of submergents cannot take place without accompanying favorable light, substrate and nutrient conditions.

Most wetland plants are very well adapted for existence during conditions of fluctuating water level. In fact, a prolonged stable water level is known to lead towards dominance by single species in emergent wetland communities; nearly pure stands of common cattail or sedges/grasses are the most common manifestations of this phenomenon (Van der Valk and Davis 1980). Some water level fluctuation is required for elevated species diversity.

The nature of the wetland soils will influence wetland response to a drawdown. Generally the water table in a peat or muck soil is within one or two feet of the average ground surface (Bay 1966). The upper layer of a peat soil has been termed the active layer, the layer in which plant roots exist and the layer with the greatest water level fluctuation (Romanov 1968). The total porosity of the undecomposed raw peat moss horizon exceeds 95%, but the porosity of decomposed peat is only 83%. While this may not seem to be a major difference, lowering the water table in loose, porous, undecomposed peat removes 60 to 80% of the water in a given horizon, but an equal lowering in a decomposed peat removes only approximately 10% of the water (Bay 1966).

The loss of nutrients from wetland organic soils may have an adverse affect on wetland plant growth, especially after repeated annual or biannual drawdowns, but this potential impact is not well understood at this point and needs additional research. Where replacement of lost nutrients is possible, nutrient losses from exposed soils may not have any detectable effect on wetland communities.

Although often viewed as separate entities, wetlands and lakes really constitute a continuum of hydrologic resources, habitat values and recreational opportunities. The interaction between lake and wetland is complex, and any attempt at co-management must accommodate the subtleties of the relationship. The need for integrated watershed management is clear, but a set of goals with corresponding priorities is needed to reach decisions where conflicts occur (Wagner and Oglesby 1984).

From a lake management perspective, wetlands do not always act as good neighbors. Among their common, less desirable exports to lakes are organic material, color, turbidity, odors, easily resuspended particulates, nuisance insects, animal wastes, larger floating debris, and floating macrophytes (e.g., *Utricularia, Lemna*). Yet, it is undeniable that wetlands are critical to promoting a healthy lake flora and fauna and maintenance of desirable recreational and aesthetic qualities of most lakes. Furthermore, the Wetlands Protection Act establishes certain priorities and considerations without regard to potentially conflicting management goals. Management activities must therefore be structured around existing regulations.

Carefully planned water level fluctuation can be a useful technique to check nuisance macrophytes and periodically rejuvenate wetland diversity. Planned disturbance is always a threshold phenomenon; a little is beneficial, too much leads to overall ecosystem decline. Therefore; the depth, length, timing and frequency of the disturbance are critical elements in devising the most mutually beneficial program. This type of management is compatible with the idea of a multi-purpose lake, with various recreational and conservation zones (Jones 1988).

Extreme variations in wetland hydrology directly influence wildlife presence and production, and affect habitat quality through modification of the plant substrate, food abundance and variety, and physical elements that modify spatial relationships (Weller 1988). Common parameters of change are water depth, areal extent of flooding, and length of the hydroperiod. Additionally, rate of change is also critical and may be the primary cause of impact on some species. Drawdowns may cause an extreme variation in wetland hydrology, but the timing and duration of drawdown will be the primary determinants of its impact.

ESS

APPENDIX D

Educational Information for Watershed Residents

TIPS FOR LOW IMPACT LAWN CARE

Have a soil test performed to determine if fertilizer is needed and the right ratio of primary components (nitrogen - phosphorus - potassium; the 3 number given on most fertilizer labels). Soil tests can be performed cheaply through the UMASS soils lab in Amherst. Only new lawns need any appreciable addition of phosphorus.
Do not overapply fertilizer. Using nitrogen as the guide, a maximum rate of 2 pounds per 1000 square feet of lawn per year is appropriate. Apply no more than 3 times per year. Slow release fertilizers are often appropriate, as long as the application rate does not have to be increased greatly for the same effect.
Lime before fertilizing. Elevated soil pH minimizes the mobility of phosphorus in runoff. Lowered pH will also help. but is not as desirable for plants.
Do not fertilize within two days prior to a predicted storm. Weather can be unpredictable, but try to fertilize shortly after a period of substantial rain, when dry weather is predicted for several days.
Water lawns properly. Apply water overnight, during periods of lower evapotranspiration, and at a rate of no more than 1 inch over the watered area. Avoid watering that creates runoff.
Maintain grass at a length of at least 3 inches. Close-cropped lawns hold less pollutants in response to rainfall and are more susceptible to water loss and related damage. Set mower height to avoid creating "putting greens" out of lawns.
Minimize pesticide use. Use pesticides only in response to an identified problem and then use the pesticide appropriate to the problem.
Be wary of lawn care services. Economy of scale for these companies tends to dictate overfertilization and standardized ratios of fertilizer and pesticide components. The guarantee of a green, monoculture lawn is secured at great risk to neighboring surface and ground water resources. If such a service is essential, have application rates and components spelled out in the contract.
Consider natural landscaping. Minimize exotic species which require extra fertilizer and/or watering. Plant species native to the area which are adapted to the range of likely conditions. Plant in a manner which impedes erosion and pollutant transport. Consider alternatives to monoculture lawns.
Create buffer strips along waterways or road interfaces. Buffer strips of dense vegetation with several vertical layers will impede transport of pollutants to waterways, ether directly or via storm drains.
Collect and compost vegetative wastes. Grass clippings, leaves and related yard wastes can be composted for later use as soil amendments. At least keep them from entering storm drainage systems or waterways. Mulching grass clippings in place on the lawn is appropriate as long as the lawn is not cut so short that runoff is encouraged.

OHIO STATE UNIVERSITY

Ohio Cooperative Extension Service
The Ohio State University

Agricultural Engineering

SEPTIC TANK MAINTENANCE

Karen M. Mancl
Water Quality Specialist

The most common wastewater treatment system used in rural areas is the septic tank-soil absorption system. The septic tank removes settleable and floatable solids from the wastewater, and the soil absorption field filters and treats the clarified septic tank effluent. Removing the solids from the wastewater protects the soil absorption system from clogging and premature failure. In addition to removing solids, the septic tank also permits digestion of a portion of the solids and stores the undigested portion.

The septic tank removes solids by holding wastewater in the tank, which allows the solids to settle and scum to rise to the top. To accomplish this, wastewater should be held in the tank for at least 24 hours. Up to 50 percent of the solids retained in the tank decompose. The remaining solids accumulate in the tank. **Biological and chemical additives are not needed to aid or accelerate decomposition.**

As the septic system is used, sludge continues to accumulate in the bottom of the septic tank. Properly designed tanks have enough space for up to three years safe accumulation of sludge. When the sludge level increases beyond this point, sewage has less time to settle properly before leaving the tank. As the sludge level increases, more solids escape into the absorption area. If sludge accumulates too long, no settling occurs before the sewage escapes directly to the soil absorption area. To prevent this, the tank must be pumped periodically. The material pumped out is known as "septage."

The frequency of pumping depends on several factors:

(1) capacity of septic tank
(2) flow of wastewater
(related to size of household)
(3) volume of solids in wastewater
(more solids if garbage disposal is used)

Table 1 gives the estimated pumping frequencies according to septic tank capacity and household size. The frequencies were calculated to provide a minimum of 24 hours of wastewater retention assuming 50 percent digestion of the retained solids.

Table 1. ESTIMATED SEPTIC TANK PUMPING FREQUENCIES IN YEARS (FOR YEAR-ROUND RESIDENCE)

Tank Size (gal)	Household Size (No. of People) 1	2	3	4	5	6	7	8	9	10
500	5.8	2.6	1.5	1.0	0.7	0.4	0.3	0.2	0.1	-
750	9.1	4.2	2.6	1.8	1.3	1.0	0.7	0.6	0.4	0.3
1000	12.4	5.9	3.7	2.6	2.0	1.5	1.2	1.0	0.8	0.7
1250	15.6	7.5	4.8	3.4	2.6	2.0	1.7	1.4	1.2	1.0
1500	18.9	9.1	5.9	4.2	3.3	2.6	2.1	1.8	1.5	1.3
1750	22.1	10.7	6.9	5.0	3.9	3.1	2.6	2.2	1.9	1.6
2000	25.4	12.4	8.0	5.9	4.5	3.7	3.1	2.6	2.2	2.0
2250	28.6	14.0	9.1	6.7	5.2	4.2	3.5	3.0	2.6	2.3
2500	31.9	15.6	10.2	7.5	5.9	4.8	4.0	4.0	3.0	2.6

Note: More frequent pumping needed if garbage disposal is used.

2/88 — 5M

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914 in cooperation with the U.S. Department of Agriculture, Frederick E. Hutchinson, Acting Director of Cooperative Extension Service, The Ohio State University.

In Ohio, a 1,500 gallon septic tank is used for a home with three bedrooms. If six people reside in a three-bedroom house, the tank should be pumped every 2.6 years. If the same system serves a family of two, the tank would be ready for pumping every 9.1 years. Systems installed before the current rules and regulations may have smaller septic tanks. As shown in Table 1, these tanks may need to be pumped more often than once a year.

It is important to note that the soil absorption field will not fail immediately when a full tank is not pumped. However, the septic tank is no longer protecting the soil absorption field from solids. Continued neglect may result in failure and the soil absorption field may need to be replaced. In some cases, replacement of the absorption area may not be possible due to site limitations.

Cleaning the Tank

Septic tank pump and haul contractors can clean your tank. It is a good idea to supervise cleaning to ensure that it is done properly. To extract all the material from the tank, the scum layer must be broken up and the sludge layer stirred up into the liquid portion of the tank (see Figure 1). This is usually done by alternately siphoning liquid from the tank and reinjecting it into the bottom of the tank. The septic tank should be pumped out through the large central manhole, not the baffle inspection ports. Pumping out a tank through the baffle inspection ports can damage the baffles.

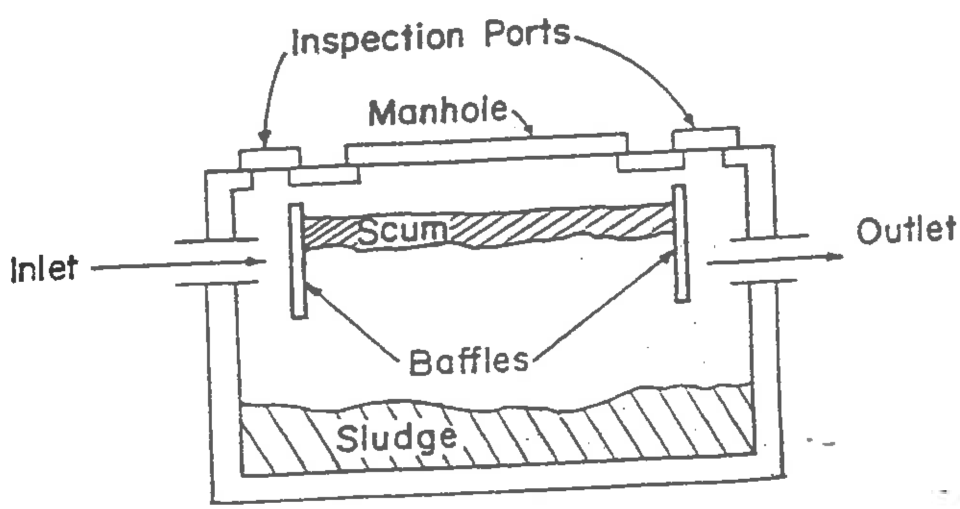
Before closing the tank, check the condition of the baffles. If they are missing or deteriorated, replace them with sanitary tees. It should **never be necessary to enter a septic tank**. Any work to replace the baffles or repair the tank should be made from the outside. The septic tank produces **toxic gases which can kill a person in a matter of minutes**. When working on a tank make sure the area is well ventilated and someone is standing by. **Never go into a septic tank to retrieve someone** who fell in and was overcome by toxic gases or the lack of oxygen without a self-contained breathing apparatus (SCBA). If a SCBA is not available the best thing to do is call for emergency services and put a fan at the top of the tank to blow in fresh air.

To facilitate future cleaning and inspection, install risers from the central manhole and inspection ports to the surface before burying the tank. Also mark the location of the tank so that it can be easily located.

Summary

The septic tank is only one part of an on-site wastewater system. It is designed to remove solids to protect the soil absorption system, provide for the digestion of a portion of those solids, and store the remaining solids. Biological and chemical additives are not needed to aid or accelerate decomposition. Garbage disposals are also not recommended, because they impose an additional solids load on the system. Solids must be removed periodically to keep them from entering the soil absorption system. For a properly designed septic system, the tank should be inspected and pumped every one to five years.

Figure 1. CROSS SECTION OF A SEPTIC TANK



Ohio Cooperative Extension Service
The Ohio State University

Maintaining Your Septic System

This file contains information on how to use and maintain your septic system. It also provides a convenient place for you to record vital information about your system. Keep this folder with other important documents about your home and property.

You would certainly never think of connecting the plumbing that carries wastewater from your house to the plumbing that carries fresh water to your drinking water tap. That's exactly what you might be doing. An improperly sited, overloaded, or poorly maintained septic system can add nutrients, bacteria, viruses, and hazardous chemicals to groundwater. Those pollutants can then be drawn into your well and come out the tap in your drinking, cooking and bathing water.

Even if you don't pollute your own or your neighbor's drinking water, improperly functioning septic systems can add pollutants to lakes and streams increasing weed and algae growth and, in extreme cases, killing fish.

These problems can be avoided if your septic system is:

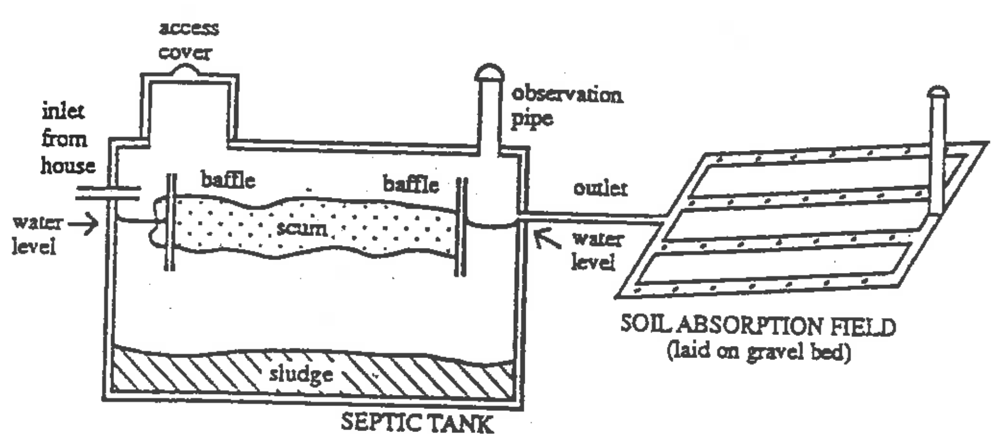
- correctly sited
- properly designed
- carefully installed
- correctly used
- regularly maintained.

Regular maintenance costs much less than repair or replacement of a failed system.

How Your Septic System Works

Whatever you put into your toilets and sinks flows into the septic tank. In the tank, most solids settle to the bottom and are partially decomposed by bacteria to form sludge. Some materials float and form a scum on top of the water (see illustration).

The liquid in the tank–carrying bacteria, viruses, compounds of nitrogen and other potentially harmful substances–is discharged into a soil absorption field. The soil is your last line of defense to prevent polluted water from entering lakes, streams, and groundwater. The wastewater is partially purified by the filtering action of the soil and the ability of microorganisms in the soil to decompose many of the remaining contaminants. However, the soil cannot remove dissolved solvents, drain cleaners, and other household chemicals that can easily percolate into the groundwater.



Septic System Maintenance

The most critical part of septic system management is the decisions you make about what to put into the system as noted later under "Household Hints."

The Septic Tank

The tank is the part of the system that requires regular maintenance. You must have the tank cleaned out regularly so that sludge and scum don't build up. If you do not clean your tank when needed, sludge or scum will clog the outlet pipe or move out into the soil absorption field. This will clog the field and lead to early and costly failure of the system.

How do you know when your septic tank needs to be pumped? You can have a commercial septic tank pumper give you an idea of how often you should have the tank pumped. It depends on the size of your family, the volume of water you use, whether you use a garbage disposal, and the capacity of the tank. Generally, for a family of four using a modern septic system, it's a good idea to have the tank pumped every two to three years. Pump annually if you use a garbage disposal. If you don't want to pay to have the tank pumped this often, you can make your own determination about the need for pumping by measuring the sludge and scum depth in the tank. Here's how you do it:

1. Find the tank. Sometimes this is tricky. The tank's cover will usually be within a couple of feet below the ground surface, but the depth can vary depending on how your land slopes. If you don't know where the tank is, you can probably find it by gently tapping a steel rod into the ground starting about ten feet from where the sewer drain leaves your house. If your tank has an observation pipe, the cover should be at the other end of the tank–a few feet toward the house. After you find the cover, you might want to mark its location so you can find it again the next time.

2. Remove sod and soil until you can lift the cover. Loose soil should be kept clear of the opening.

3. Find a pole or thin board long enough to reach the bottom of the tank (~8'). Wrap the bottom five feet with white rags.

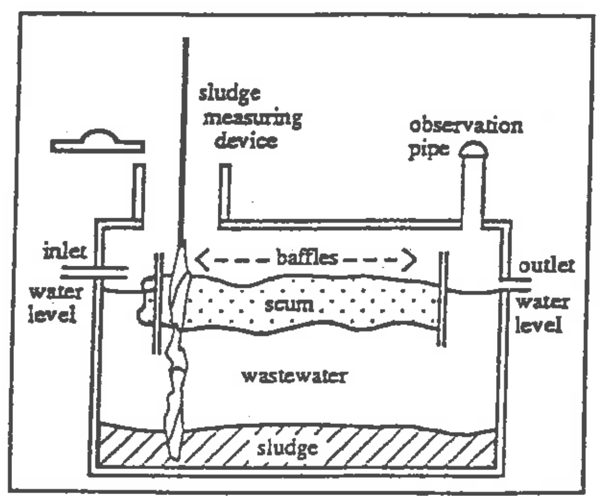
4. Lower the wrapped part of the pole. Note the thickness of the scum as the pole penetrates the floating layer. Then lower to the bottom of the tank (see illustration).

5. Hold the pole there for several minutes so that the sludge layer will get the rags filthy black.

6. Remove the pole and note the sludge line and the liquid line. The sludge line will be darker than the coloration caused by the liquid waste.

7. If the total depth of sludge plus the scum is more than one-third of the total wetted length of your pole, it's time to have the tank cleaned. For example, if the total length of your stick that is wet is 48 inches, the tank should be pumped if the dark sludge portion plus the scum portion is over 16 inches. Pump the tank immediately if the scum is more than 4 inches thick or appears to be escaping below the baffle.

If you have trouble measuring the sludge or scum or have trouble with the system, call a pumper or plumber. The gases generated in a septic tank are dangerous, and can kill. Never enter a septic tank. Only a trained person with life support equipment and a trained assistant should ever enter a septic tank.



Septic System Layout

If you do not have a sketch of your septic system to place in this file, draw one in the space provided. Show the location of your septic system components in relation to your house. Use the sketch to locate the tank for testing and cleaning, and to avoid the tank and drainfield when routing driveways, planting trees, or directing heavy trucks or trailers.

Maintenance Record

Keeping a record of your septic system maintenance activities will help you anticipate when the next cleaning is needed.

Date	Pumper	Address	Telephone #	Cost

Information Directory

Inside Plumber
Name____________
Address____________
Phone____________

Septic System Installer (Outside Plumber)
Name____________
Address____________
Phone____________

DILHR District Office
Name____________
Address____________
Phone____________

County Sanitarian (or Code Administrator)
Name____________
Address____________
Phone____________

DNR Lake Management Coordinator
Name____________
Address____________
Phone____________

Extension Resource Agent
Name____________
Address____________
Phone____________

For more general information on rural living obtain a copy of Country Acres: A Guide to Buying and Managing Rural Property G3309 available from your County Extension office. Lakeshore homeowners have a special responsibility to ensure that their septic systems are not polluting the lake. More general information on lake management can be obtained from the DNR and Extension staff shown above.

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May 1990

Wisconsin Department of Natural Resources
U.W. Extension
Department of Industry, Labor, and Human Relations

Laundry

Detergent. Use powdered, phosphate-free detergent. Indiana law prohibits the use of detergents containing phosphates. Liquid detergents generally contain no phosphates, but are sold in plastic bottles that may be recyclable in your community. Powders are available in boxes made from recycled paper. Even biodegradable phosphate-free detergents can add to water pollution. For extra whitening, use soap flakes and washing soda.

Detergent amount. Putting more detergent into the wash will not get the clothes cleaner; it only adds a surface film. Your conditions may vary above or below recommended amounts.

Perspiration stains. Weak water solutions of white vinegar, lemon juice or aspirin can be used as a presoak to remove perspiration stains, or soak clothes in a solution of corn meal and water.

Stain remover. Prewash and boosters often contain the same ingredients as detergents. Extra detergent applied to a stain will usually get it out. Many stains can be removed with water and vinegar. To remove tough stains, soak the spot in a mixture of 1/4 cup borax in 2 cups of cold water prior to washing. Rub corn meal and water into greasy stains and then rinse with lemon juice before machine washing.

Starch. Laundry starch is basically nontoxic. Purchase it in the spray pump bottle rather than the aerosol can.

White/bright. Chlorine bleach can be hazardous when combined with other elements in waste water. Use it sparingly or not at all. Washing soda achieves the same results.

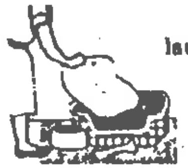
Hand Cleaner

To clean hands of paint or grease, massage them with baby oil, mineral oil, margarine or butter. Wipe them dry on paper towel, then wash your hands with soap and water.

Pest Control

Ant control. Ants will avoid lines of powder and sharp crystals. Sprinkle barriers of talcum powder, chalk, bone meal, cayenne pepper or boric acid across their trails. When ants appear, the first and best choice is to wipe them away with a soapy sponge.

Cockroach control. Try a light dusting of borax around the refrigerator, stove and duct work. You can combine sugar, flour and boric acid to poison roaches; they'll carry the powder back to their nests.



Fleas. Prevention is best. Keep the pet's bed laundered. Regular vacuuming will eliminate them. *Safer* brand products offer a full line of products that contain no pesticides.

Flies. Don't spray, swat. Non-insecticide flypaper still works.

Moths. Mothballs contain a chemical called p-dichlorobenzene, a known carcinogen. Cedar blocks or chips are a safe alternative. Sweaters should be stored in airtight containers or zipper bags.

Mice/rats. Traps are the non-toxic choice. Poison can be a problem if there are pets or toddlers in the home. Future infestation needs to be prevented by checking sanitation and rat-proofing potential entrances.

Published by the Office of External Affairs

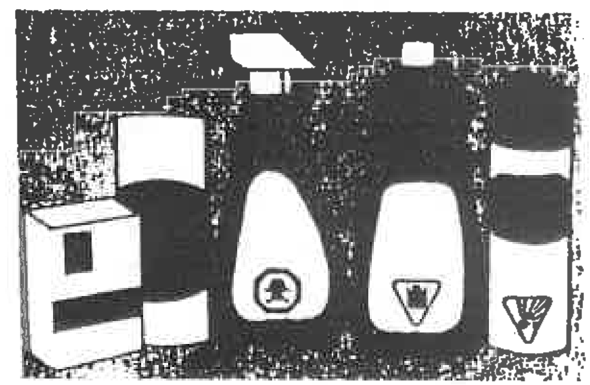
For more information about hazardous product substitutes, contact the:

Indiana Department of Environmental Management
Office of Pollution Prevention and Technical Assistance
105 South Meridian Street, P.O. Box 6015
Indianapolis, Indiana 46206-6015

Phone (317) 232-8172, or through the toll-free Environmental Helpline, 1-800-451-6027.

printed on recycled paper

Simple substitutes for hazardous household products



Housework

Laundry

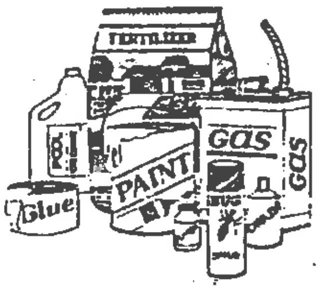
Pest Control

Simple substitutes for hazardous household products

Many household products that we use routinely in maintaining our homes and lifestyles are potential hazardous waste when simply tossed into the trash or washed down the drain.

While most of us have used many of these products for years and rarely thought about their environmental consequences when washed down the drain, they do pose a threat to the quality of the air we breathe and the water we drink.

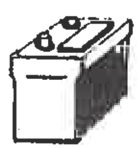
If washed into the sewer system, some product chemicals do not break down as well as others in the treatment process and can end up back in a drinking water source, such as a river. The chemicals thrown into the trash that end up in a landfill become part of the liquid runoff that can eventually seep into the ground water, where 60 percent of our drinking water comes from statewide.



To avoid this, we can use safer products and keep hazardous waste out of our trash. In many communities, household hazardous waste products and containers can be disposed of through local tox-away days. Community health agencies usually can identify where items can be taken and when.

The best way to avoid this problem is to avoid using the hazardous products in the first place. There are substitutes for products commonly used in routine household chores that are less costly, simple alternatives.

Batteries

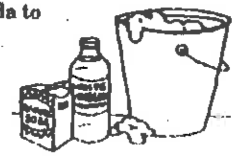


Disposable batteries. Closely evaluate the purchase of battery operated items. Consider rechargeable items and a battery eliminator for items being used where power is available. Use rechargeable batteries that over time save money and consumption of countless disposables.

Housework

Air freshener. Herbal potpourri or cotton balls soaked in vanilla are sweet smelling. Also try boiling cinnamon and cloves in a small amount of water. An open box of baking soda absorbs refrigerator odors. Borax sprinkled in the bottom of a garbage can control odors, too.

All-purpose cleaner. Most all-purpose cleaners contain ammonia or chlorine. A better choice is to mix 1 gallon hot water and 1/4 cup vinegar. This solution is safe for all surfaces and can be rinsed away with water. Scouring powders also contain chlorine and phosphorous; try Bon Ami, which contains neither.



Bathroom cleaner. Use baking soda to scrub surfaces clean and wipe surfaces with a solution of 1/4 cup vinegar in a gallon of warm water.

Blood stains. Club soda and cold water remove fresh blood stains. Blot up with a clean cloth.

Chocolate stains. Blot the stain with club soda.

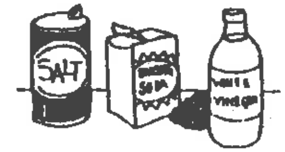
Copper cleaner. Dip the copper in warm vinegar, then sprinkle salt on the piece and scrub with a soft cloth. Rinse all with clean water.

Drain cleaners. The active chemical in drain cleaners is lye, which is extremely caustic and considered hazardous. Keep drains open and clean with a plunger or metal snake. As a preventative or if a drain becomes clogged, pour in 1/4 cup baking soda followed by 1/2 cup vinegar. After fizzing stops, flush well with boiling water.

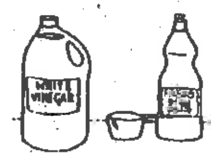
Floors/toilets. A mixture of 2-3 teaspoons each of borax and liquid dish soap in 2 quarts of hot water works well on tough jobs like floors and toilet bowls. Most toilet cleaners contain chlorine and hydrochloric acid.

Killing germs. Most disinfectants contain organic solvents that are flammable and poisonous. Make your own disinfectant by mixing 1/2 cup of borax with 1 gallon of hot water.

Mildew. Mildew cleaner for the tub and shower contains pesticides. Borax mixed with warm water usually works.



Oven cleaner. Dampen the spil and sprinkle salt on it while the oven is still warm. Scrape the sp away when cooled. Greasy spots can be removed with a vinegar soaked rag. Really tough spots can be removed by dampening the area with water and lightly scrubbing with baking soda ar steel wool pads.

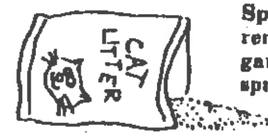


Pet stains/odors. Try a mixture of 1/4 cup vinegar in 1/4 cup liquid soap. Rub in the mixture, blot the stain and rinse with water.

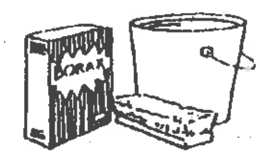
Rust remover. Vinegar's weak acid works well on rust stains. Warm vinegar and scrubbing will remove rust from dishes, sinks and teapots.

Silver cleaning. Baking soda and wate or buttermilk make fine silver-soaking solutions. The fine abrasives in toothpaste will also brighten silver jewelry with mild brushing. Also try boiling silver for 2-3 minutes in a mixture of 1 cup water, 1 teaspoon baking soda, 1 teaspoon salt and a piece of aluminum foil. Rins pieces well with water and dry with a soft cloth.

Sinks/counter tops. Use vinegar mixed with warm water and salt.



Spot removers. To remove grease from garage floors, sprinkle the spot with fresh cat litter. Let stand for a few hours, then sweep up.



Stains. General household stains can be cleaned and disinfected with borax solutions.

Windows. Glass cleaners are mostly water and alcohol. A better choice is made with a vinegar and water mixture that you can do easily yourself.

Wood furniture polish. Look for products containing pure oils like lemon oil, tung oil or almond oil without petroleum distillates. You can make furniture polish with a mixture of 1 part lemon juice to 2 parts mineral oil.

Wood cleaning. Try Murphy's Oil Soap.

Wood scratches. Mix 1 teaspoon each of lemon juice and mineral oil.

ESS

APPENDIX E

Herbicide (Sonar) Information

Sonar*

Humans who are exposed to Sonar-treated water are at negligible risk

Drinking Sonar-Treated Water

A 70-kg adult (about 154 pounds) would have to drink over 1,000 gallons (child - 285 gallons) of water daily, containing the maximum legally allowable concentration of Sonar in potable water (0.15 ppm), for a significant portion of their lifetime to receive a dose equivalent to the NOEL.

Swimming in Sonar-Treated Water

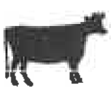
At the maximum allowable concentration of Sonar in water (0.15 ppm), an adult would have to swim for 24 hours every day for over 57 years to receive an amount equal to the NOEL.

Eating Fish from Sonar-Treated Water

Adults would have to consume 2,467 pounds (child - 705 pounds) of fish daily, at the maximum allowable tolerance limit in fish (0.5 ppm), for a significant portion of their lifetime to receive the dose equal to the NOEL.

Eating Food Crops Irrigated with Sonar-Treated Water

Adults would need to eat over 8,250 pounds (child - 2,300 pounds) of these foods daily, at the maximum allowable tolerance limit (0.1 - 0.15 ppm), for a significant portion of their lifetime to receive the dose equal to the NOEL.



Eating Livestock Exposed to Sonar from Drinking Treated Water

Adults would need to eat 25,000 pounds (child - 7,000 pounds) of these foods daily, at the maximum allowable tolerance limit in meat, poultry, eggs, and milk (0.05 ppm), for a significant portion of their lifetime to receive the dose equal to the NOEL.

WHAT IS NOEL?

No Observable Effect Level (NOEL) - the highest dose at which no adverse effects are observed in laboratory animals.

The maximum non-toxic dose is usually established by laboratory studies in animals and is reported as the NOEL.

The dietary NOEL for Sonar is approximately 8 milligrams per kilogram of body weight per day (8mg/kg/day). This NOEL was determined from a study in rats that were fed Sonar in their regular diets every day for their entire two-year lifetime.

WHAT IS NEGLIGIBLE RISK?

This term is used because it is beyond the capabilities of science to prove that a substance is absolutely safe, i.e., that the substance poses no risk whatsoever. Any substance, be it aspirin, table salt, caffeine, or household cleaning products, will cause adverse health effects at sufficiently high doses. Normal exposure to such substances in our daily lives, however, are well below those associated with adverse health effects. At some exposure, risks are so small that, for all practical purpose, no risk exists. We consider such risks to be negligible or insignificant.

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