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INTRODUCTION

General Introduction

Rogers Lake is a 260-acre waterbody located in the Towns of Lyme and Old Lyme (See **Appendix 1 - Map 1**). Although an essentially natural waterbody, the water level was raised four feet by the construction of a masonry dam across the outlet. The dam is equipped with a low-level outlet, which provides limited ability to lower the lake level. Drainage from the roughly 4,800 acre watershed enters the lake from numerous streams, most notably Grassy Hill Brook from the north. The outlet of Rogers Lake becomes Mill Brook, which is a tributary of the Lieutenant River.

As a popular recreational resource, the lake is heavily used for fishing and contact recreation throughout the summer months. It is also home to relatively dense, year-round residential development around a majority of the shoreline. Reportedly, all of these homes are on private water and wastewater systems. There is a State owned public boat ramp along the inlet from Grassy Hill Brook, which accommodates public access to the lake as well as numerous fishing tournaments throughout the year. There is also a public park on the south end of the lake.

Rogers Lake is listed as a Trophy Trout Lake. The state currently stocks 10,200 brown and rainbow trout annually. Reportedly, some of the brown trout hold over to the following year.

The State had also been stocking walleye, however this was discontinued in 1999. Overall the fishery for trout and largemouth bass in Rogers Lake is considered excellent.

In the 1970's, the Rogers Lake Authority was formed to assist the Towns in making decisions about the Lake. The authority consists of three members from each of the two towns and reports directly to the Selectmen. The Authority also facilitates communication between the Towns and the lake residents and works with the Marine Patrol to enforce the various ordinances on the lake. Currently, there is no speed limit on the lake except between sundown and 10AM, which is 6 or 12 MPH depending in the time of year. There is a restriction on motors over 135 HP.

The overall productivity of Rogers Lake is listed as moderate (mesotrophic) in the most recent "Fisheries Guide to Lakes and Ponds of Connecticut" (2002). For the most part, water quality is favorable with good water clarity and minimal problems with algae. The most notable impairment at Rogers Lake is localized growth of nuisance aquatic vegetation. The Towns of Lyme and Old Lyme in cooperation with the Rogers Lake Authority applied for and received a grant from the CT DEP Bureau of Water Management, Lakes Grant Program, to conduct a Diagnostic/Feasibility Study of the Lake in 2002.

Aquatic Control Technology, Inc. in association with Northeast Aquatic Research, LLC was selected to perform this work. This report is the culmination of a year-long study of Rogers Lake. The study involved the evaluation of water quality parameters in the lake and the major tributary streams feeding the lake. Samples were collected from as many as four in-lake stations with multiple sampling depths at each station, and 6 inlet stream stations (see **Appendix 1 - Map 2** for locations of lake sampling stations, **Appendix 1 - Map 3** for regular drainage basin stations and **Appendix 1 - Map 4** for the storm water stations). Water quality data collected included nutrient chemistry, temperature and oxygen measurements, water clarity, and basic phytoplankton and zooplankton population estimates. In addition, storm water discharge to the lake was investigated by sampling the 6 established stream stations and 8 extra inlets during one storm event in December of 2002. Also included in this study was a four day evaluation of water turbidity changes due to higher weekend boat use.

In addition to water quality sampling, the aquatic vegetation of Rogers Lake was surveyed over the course of two days in the late summer of 2002. Working with a Differential Geographic Positioning System (DGPS), data was collected on the distribution and density of vegetation along with sampling of unconsolidated soft sediment. A more detailed examination of sediment depths, including some limited characterization of the types of sediment, was conducted in several coves of the lake.

Historical Reports

The earliest record of limnological information for Rogers Lake was Edward Deevey's survey of Connecticut lakes conducted between 1937 and 1939 (Deevey 1940). He collected chlorophyll, nutrients, transparency, and alkalinity from 48 Connecticut lakes of which Rogers Lake was one that he described as located in the eastern highlands. The Connecticut State

Board of Fisheries and Game published a bathymetric map of Rogers Lake and briefly discussed the fisheries in the lake but didn't include any water quality data (CT State Board of Fisheries and Game 1959). The next set of data on the lake was collected by Frink and Norvell (1984) during a statewide survey of 70 lakes conducted in 1978. They measured the Secchi depth phosphorus, nitrogen, chlorophyll, alkalinity, and the major cations and anions.

The Connecticut Department of Environmental Protection included Rogers Lake in the "Trophic Classifications of Seventy Connecticut Lakes" (DEP 1982), where they gave the water chemistry results from the Frink and Norvell (1984) survey of 1978. The CT DEP listed the lake as having an oligo-mesotrophic classification, or as having moderate productivity not prone to algae blooms.

Data that is more recent was collected as part of a statewide survey of Connecticut lakes published in Canavan and Siver's "Connecticut Lakes, A Study of the Chemical and Physical Properties of Fifty-six Connecticut Lakes" (1995). They collected some limited water quality samples from Rogers Lake on two dates in 1991, two dates in 1992 and two dates in 1993. Lake data collected included Secchi disk transparency, Chlorophyll a, total phosphorus, pH, alkalinity, conductivity, and major cations and annions, no nitrogen samples were collected.

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

Author	Title	Dates of Data

		Collection
Deevey	A Contribution to Regional Limnology	1937-1939
Frink and Norvell	Chemical and Physical Properties of CT Lakes	1978
CT DEP	Trophic Classifications of Seventy Connecticut Lakes	Referenced 1978 data
Canavan and Siver	Connecticut Lakes, A Study of the Chemical and Physical Properties of Fifty-six Connecticut Lakes	1991 - 1993

Lake and Drainage Basin Characteristics

Lake Basin

Rogers Lake is located in the towns of Lyme and Old Lyme in New London County, Connecticut. Rogers Lake is a 260 acre lake (Jacobs and O' Donnell 2002) composed of three separate basins connected by shallower water. Two large basins, the North Central Basin and the South Basin are connected by a wide shallow area, and a third smaller basin, the North West Basin is located to the west of the North Central basin.

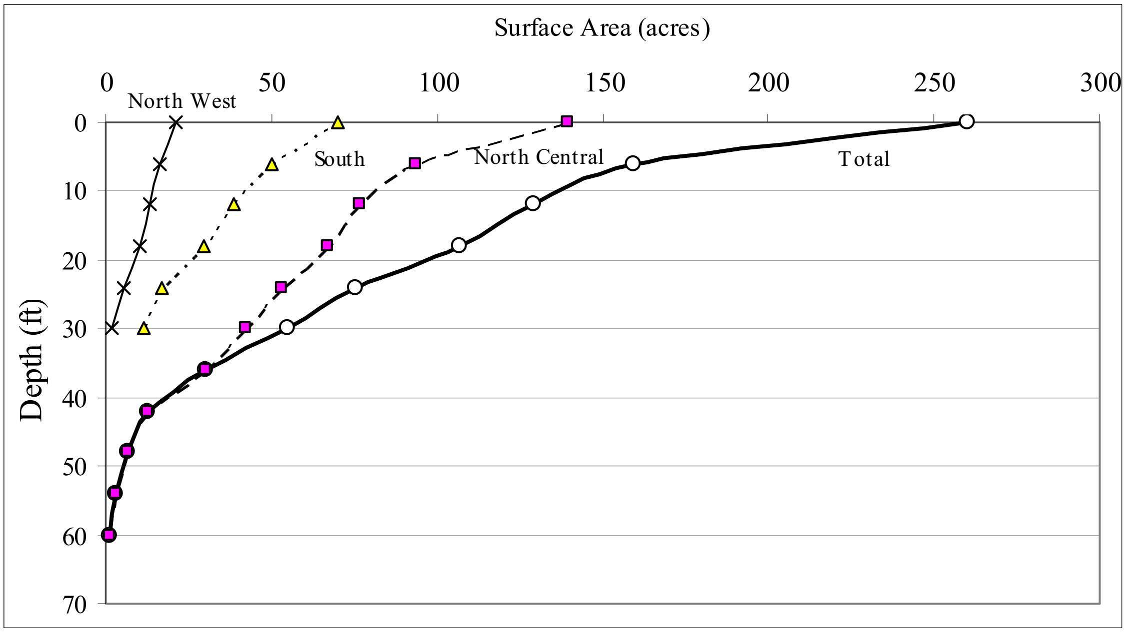
The maximum depth of the lake occurs in the middle of the North Central basin. The maximum water depth was reported by Deevey and by the CT Fisheries, Frink and Norvell, and Canavan and Siver as 20 meters (66 feet). Jacobs and O' Donnell give the maximum depth as 63 feet. The deepest water found during this study was 19.2 meters (62 feet) in the north central basin.

The hypsographic curve for Rogers Lake is shown in **Figure 1**. This is a graphic representation of the surface area at each depth and shows the general proportion of bottom area and depth. For instance, the curve starts at the top of graph at 250+ acres or the total surface area of the lake, while the surface area of the lake at the 30-ft depth is closer to 50 acres. From this type of relationship, it is possible to determine the approximate surface area within each interval of water depth.

The graph in **Figure 1** also shows the depth-area curves for the three individual basins, North Central, South, and North West. These relationships show that the North Central is the largest, followed by the South and finally by the North West. The North West Basin was essentially a bowl with steep sides that showed progressively smaller areas with depth. The South Basin had somewhat less steep sides with larger areas in the shallower water, less than 10 feet. The North Central Basin also had less steep sides but had a large area of shallow water. The graph does not isolate the large central shallow area of the lake but it is shown as the inflection of the curve of Total lake area between the surface and 10 feet.

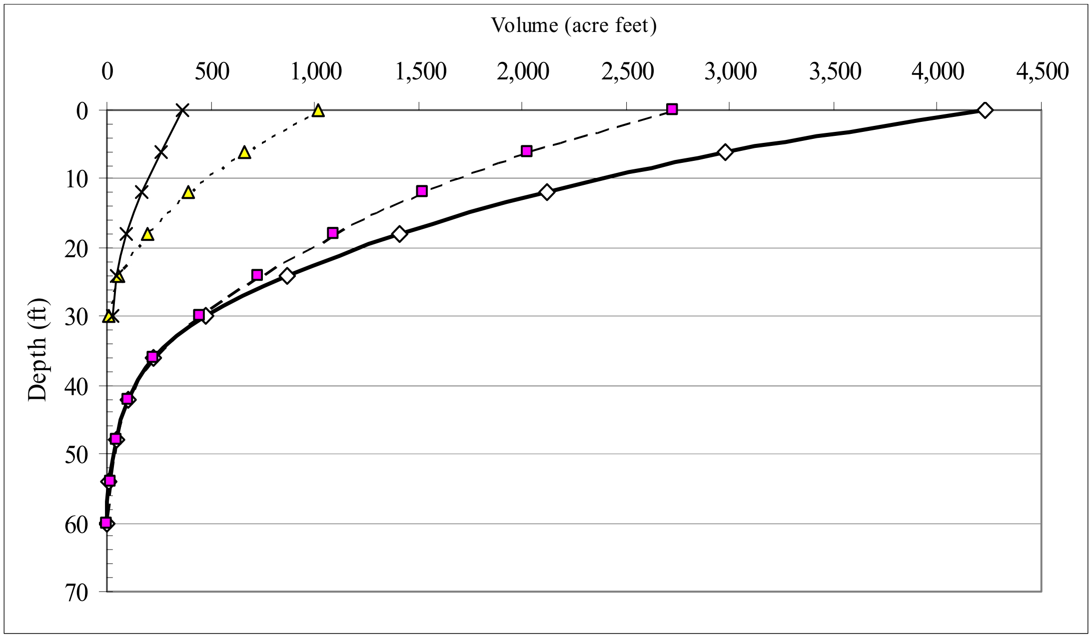
The graph also shows the sizes of the different basins relative to the total surface of the lake. The North Central basin had an area of about 140 acres, the South basin was about 70 acres, and the North West basin was about 20 acres. The surface area of the central shallows was about 50 acres.

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



The volume of water in the lake was approximately 4,231 acre-feet or about 5.2 million cubic meters (m^3). The volume below each depth is shown in **Figure 2.** The curve shows the volume of water contained in the lake below each depth such that the line for the total starts at the top of graph at 4,000+ acre-feet and gradually decreases with depth. Each of the individual basins are also shown for comparison. The North Central Basin contained the largest volume of water, with about 2,700 acre feet. Both the South Basin and the North West basins contained smaller volumes, 1,000, acre-feet and 340 acre-feet respectively. The graph also shows that about half the lake volume was contained in the water layer between 0 and 12 feet. There was less than 500 acre-feet below 30 feet deep.

Figure 2. Depth - Volume Curve for Rogers Lake. Individual Basins Are Marked As In Figure 1.



The mean depth of Rogers Lake was 4.96 meters (16.3 feet). The mean depth is determined by dividing the volume by the surface area and represents the water depth if the basin was smoothed to one uniform depth.

Table 2. Morphometric Characteristics of the Different Basins in Rogers Lake.

	Total	South	North (NC+NW)	Central Shallows	North Central	North West
Surface Area (acres)	260	70	139	51	118	21
Total Volume (Ac-ft)	4,231	1,019	3,005	137	2,723	338
Maximum Depth (ft)	63	36	63	6	63	30
Mean Depth (ft)	16.3	14.5	21.6	2.7	19.6	16.1
Mean Depth (m)	5.0	4.4	6.6	0.8	6.0	4.9

Drainage Basin

The drainage basin of Rogers Lake is approximately 4,834 acres and is located in the Towns of Lyme, East Lyme and Old Lyme. For the purposes of this study, the watershed has been broken down into 8 sub-basins (See Appendix 1 - Map 5) Table 3 lists the sub-basins description along with the approximate surface acreage.

Table 3 - Watershed Subbasins

Sub-Watershed	Basin #	Acreage
Grassy Hill Brook	1	1193
Gamel Ledge	2	582
Broad Swamp Brook	3	612
South Brook	4	1141
Rogers Lake	5	902
West Brook	6	315
North Brook West	7	33
North Brook East	8	56
Total		**4,834**

Land use in each of the 8 sub-watersheds, as taken from 1990 GIS Data, is described in Table 4. A map of the land-use in the watershed is provided in Appendix 1 – Map 6. Overall the land use from 1990 data can be summarized as 4.5% urban, 1.9% agricultural and 93.6% wooded/wetland. These numbers have not changed significantly since the last land use data issued by the CT DEP in 1982. The land-use data will be used later to conduct nutrient loading analysis.

Table 4 - Land-Use for the Rogers Lake Watershed Sub-basins

LAND USE CODE	TYPE	1	2	3	4	5	6	7	8	Land Use Totals
1	Surface - Impervious	0			1					1
2	Residential - High Density	0			0	13				14
3	Residential - Medium Density	11			15	52	8	1	1	89
6	Turf/Grass	0			3		0			3
7	Soil/Grass/Hay	21			20	1	11			52
8	Grass/Hay/Pasture	6			5	2	25			38
9	Soil/Corn	0			0		1			1
10	Grass/Corn	0			0	0	0			0
13	Forest - Deciduous	1058	481	563	1000	418	228	11	54	3814
14	Forest - Conifer	1	1		1	25	1	6		35
15	Water - Deep	0			1	260		0		261
16	Water - Shallow	2		6	11	58	1	1	0	80
17	Wetland - Non-Forested	17	1		1	1				20
18	Wetland - Forest	36	98	39	45	43	20	12	0	292
19	Land - Barren	5			8	1	1			14
20	Soil - Bare	0		1	9					10
25	Road - Major	36	1	3	20	28	19	2	2	110
Total Acreage		1193	582	612	1140	902	315	33	56	4834

WATER QUALITY RESULTS

In-lake Results

Methods

The lake was visited once each month beginning in April and ending in October. During each of the monthly visits sampling was conducted at Station 1, in the north central basin, and Station 2 in the south basin. At those two stations water samples were collected from the water column and temperature and oxygen measurements were taken at each 1 meter depth. The northwest basin, Station 4, was visited only in July, August, and September. And finally, during one weekend in July (July 12, 13, 14, and 15th) an additional Station 3 was established to monitor changes in water clarity. The sampling dates are given in Table 5.

Table 5 - Lake Sampling Dates At Rogers Lake, 2002.

	4-27	5-30	6-22	7-12	8-25	9-19	10-24

Lake Stations	St. 1 & 2	St. 1 & 2	St. 1 &2	St. 1 - 4	St. 1, 2 & 4	St. 1, 2 & 4	St. 1 & 2

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

Temperature and oxygen measurements were collected at each one-meter depth beginning at the surface and ending at the sediment surface using a YSI Model 58 oxygen meter. These data were tabulated on profile sheets that show the vertically arranged measurements and plot the data graphically. The profile data are summarized in Appendix 3. The temperature information was used to determine the depth in the lake were the thermal boundary existed and estimate its strength. The oxygen measurements were used to define the part of the lake that became devoid of oxygen, and whether the lakes upper water layers became super saturated with oxygen. The oxygen values were also used to assess whether any deep-water algae layers existed.

Water samples were collected from several depths; 1, 6, 11, and 18 meters at Station 1, at 1, 5, and 10 meters from Station 2, and 1 and 9 meters from Station 4. Water samples were collected using a non-metallic foot pump fitted with intake and outlet tubes of 1/2" ID Tygon tubing. The inlet tube has an attached brass orifice opening horizontally. The volume of water in the tube was flushed twice before depth-discrete samples were collected. Each sample bottle was then flushed 2 times before stoppering. No samples were collected unless the sampling tube line hung vertically in the water column.

Water samples collected monthly were analyzed for the following parameters, total phosphorus, ammonia, nitrate and organic nitrogen, turbidity, conductivity, alkalinity, total iron, and pH.

Once each month samples were collected from Station 1 for phytoplankton and zooplankton enumeration. In addition, algae samples were also collected from Station 2 in July, and September, while zooplankton samples were collected from Station 2 in August, September, and October, and from Station 4 in July and August. The phytoplankton samples were collected using a 5-meter ½ inch internal diameter latex tube that was lowered vertically into the water column, closed, brought to the surface and emptied into a 500 mL bottle. A 15 mL aliquot was removed and preserved with Lugols iodide solution. The zooplankton sample was collected with a 153 micron (0.153 mm) mesh net that was lowered to 0.5 meters from the bottom than raised back up through the water column. Captured organisms were rinsed into a 15 mL vial and preserved with Lugols iodide solution.

The Station 3 was used exclusively during the weekend turbidity survey in July. Testing was limited to Secchi disk, and light transmission, at each one meter depth to the bottom or 4 meter depth and turbidity testing. See **Appendix 1 - Map 2** for the locations of all the lake sampling stations.

Secchi Disk Depth

The Secchi disk depth was measured on 7 dates at Stations 1, & 2, and three dates at Station 4 during the 2002 season presented in **Table 6**. The Secchi disk depth was also measured at the 4 Station 3 locations used for the weekend clarity investigation. The Secchi disk measurements taken at those sites were made with the aid of a viewing tube which allowed for a more resolved reading. In most cases these readings were slightly better than measurements made without the view tube.

Table 6 - Secchi Disk Depths (meters) At Rogers Lake during 2002.

	April	May	June	July	August	Sept.	Oct.
St. 1	3.1	3.0	3.6	3.6	3.7	4.5	3.6
St. 2	3.2	2.5	3.2	3.3	3.8	4.0	3.2
St. 4	~	~	~	3.2	3.2	4.3	~

The Secchi disk depth at Rogers Lake was between 3.0 and 4.5 meters during the 2002 season for an annual average of 3.6 meters. The water clarity remained fairly constant during the season with no major decreases or increases. There was no significant difference between the two stations, although Station 2 had generally lower disk readings. Station 4 had similar readings to those taken at the other two stations. Water clarity readings were in the mesotrophic category, see Appendix 8.

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

The compensation depth or depth of 1% light at Rogers Lake is given in Table 7. The value of 1% is calculated from the best-fit logarithmic curve. The depth of the 1% light level averaged 5.2 meters for the season, less than twice the Secchi disk depth.

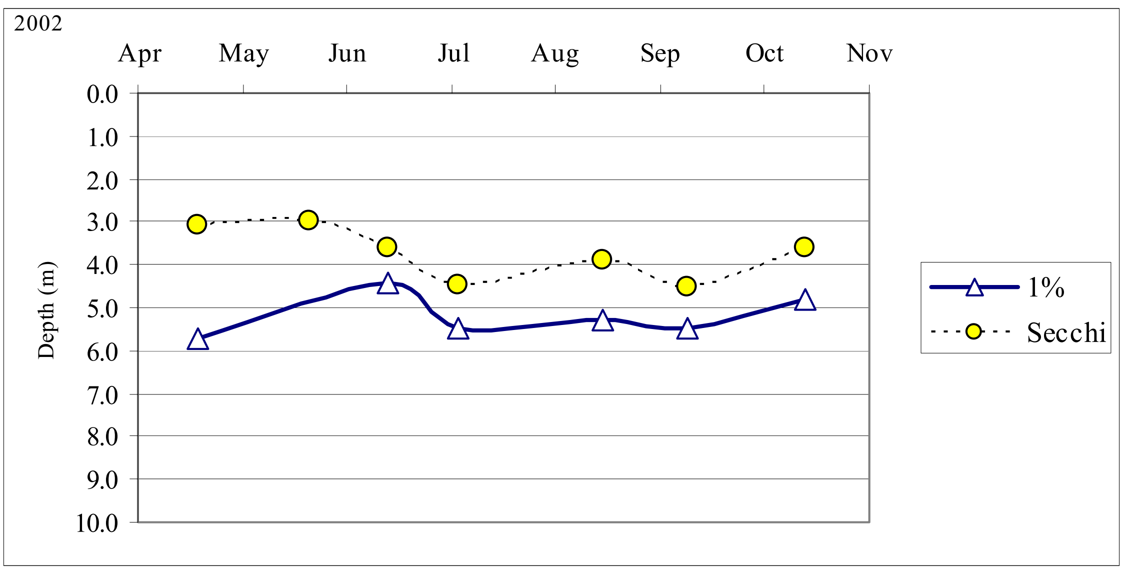
Table 7 - Depth of 1% Light (meters) At Rogers Lake during 2002.

	April	May	June	July	August	Sept.	Oct.
St. 1	5.7	~ *	4.4	5.5	5.3	5.5	4.8

* = equipment malfunction

When the two sets of data are plotted together as shown in **Figure 3** the similarity between both can be seen. The depth of 1% light defines the depth of the euphotic zone, or the depth into the water that light penetrates with sufficient intensity to fuel photosynthesis. In the case of Rogers Lake the euphotic zone is between the surface and 5.5 meters making it likely that no photosynthesis occurs below 5.5 (18 feet) meters. This also suggests that no aquatic rooted plants can grow in water depths deeper than that depth and are probably growth limited deeper than about 12 feet (or about the depth of the average summer Secchi disk depth).

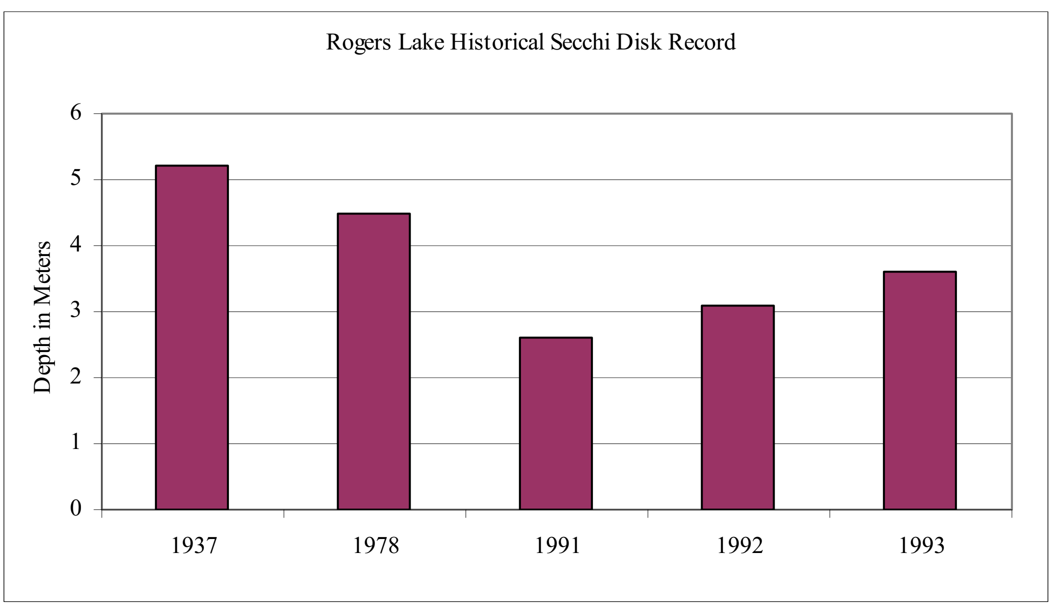
Figure 3. Rogers Lake Secchi Disk and 1% Light Depths at Station 1, 2002



The historical record of Secchi disk depth measurements at Rogers Lake is limited to a handful of values spread over the last 25 years, and one value from 1937. Two measurements were made in each of the four years, 1978 (April and July), 1991(June and September), 1992 (June and September), and 1993 (June and July). The mean of each of the two seasonal measurements has been graphed in **Figure 4**. Those data show that the Secchi disk depths at

Rogers Lake were in the range of 4.5 meters in 1978 or about 1 meter better than the average value from 2002. In 1991 the Secchi disk depth was about 2.5 meters or about 1 meter poorer than the 2002 data, however, in 1992 the Secchi disk depth was similar to the 2002 data. It should be noted that these comparisons are weak because not all the disk depth reading were made at the same time of the year. Although the 2002 season did not show large fluctuations in the water clarity this may not have been the case during those prior years. In 2002 there were some differences between spring and summer disk readings with the spring having slightly poorer readings than the summer. The two earlier data points, 1937 and 1978 show historically better water clarity than the present with clarity readings that represented oligo-mesotrophic conditions as opposed to the mesotrophic conditions exhibited during the 2002 season.

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



Temperature and Oxygen

Temperature

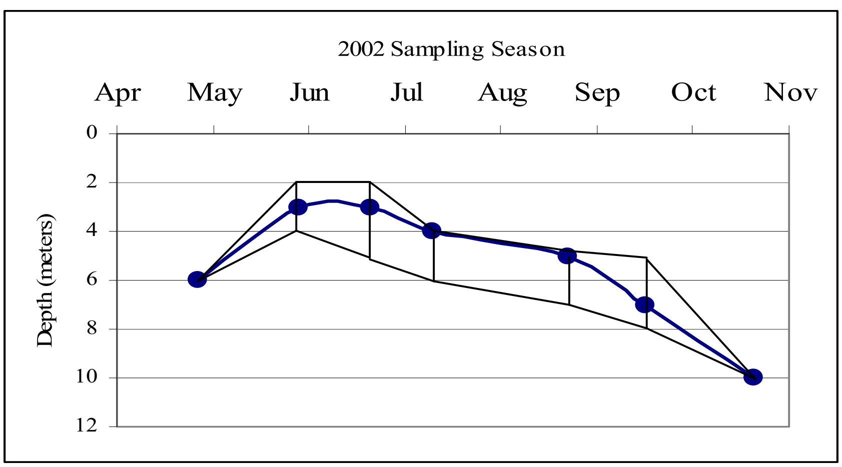
The water temperature of Rogers Lake was measured by taking vertical profiles, which consisted of recording the temperature (and oxygen) at the surface and each 1-meter depth to the bottom. Profiles of temperature were taken at Station 1 and Station 2 once each month between April and October, and at Station 4 during the summer months of July, August, and September.

The profiles were then used to determine the depth at which thermal stratification occurred. Thermal stratification is the boundary that is caused when water on the top of the lake is warmer than the water at the bottom of the lake. This generally occurs during the summer months, somewhere in the middle depth of the water column. When warm water sits on top of cooler water, the two layers will not mix, becoming stratified with the upper layer freely mixing due to wind action on the lake surface and the bottom layer remaining isolated and stagnant. The degree or strength of the stratification can be calculated by the rate of temperature change between each meter water depth. Stronger stratification means greater stagnation of the water below but also means that there will be less diffusion of materials upward across the boundary, specifically dissolved phosphorus that may be leached from the bottom sediments.

The temperature measurements at Rogers Lake showed that the lake stratified during the summer of 2002. The stratification started in April with a very weak boundary at 6 meters and persisted until October when a very weak boundary existed at 10 meters (Figure 5). During the months of June through September a strong boundary existed between 3 to 5 meters. The data in **Figure 5** shows the depth at which the greatest temperature difference occurred, the heavy center line, and the upper and lower boundaries of the metalimnion, thinner skeleton lines. The metalimnion is defined as the layers of water in the lake were water temperatures change rapidly with depth.

Rogers Lake had a shallow thermocline during most of the year. The thermocline was above 4 meters between May and July and only deepened slightly during August. Cooling water in September forced the thermocline to deepen during that month and the trend continued into October such that by then the thermocline was at 10 meters.

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



Oxygen

The dissolved oxygen in Rogers Lake was measured at the same time and location as was temperature. The two important aspects of the oxygen data are the depths of the lake where the concentration of oxygen exceeded 100 % of the amount of oxygen that can be dissolved in the water, and where it is less than 1 mg/L. The former is super saturated while the latter is anoxic. Super saturation occurs when algae are very abundant, typically happening in the upper layer of the water during the summer or fall. Anoxic water occurs during the summer below the thermal boundary.

The lake had rare periods were the water in the upper layers was super-saturated with oxygen during 2002. Data from May showed the only super saturation and then only by a slight degree, while the other dates of the season showed less than 100% saturation with oxygen (Table 8). The fact that oxygen was almost always below 100% saturation indicates that algae did not become very productive in the water column because oxygen is produced by algae photosynthesis, and high algae production usually leads to super-saturated conditions. This is a good indication of a healthy lake with good water quality. The lowest value of oxygen in the upper waters occurred in October and may have been due to lake overturn that was taking place at that time.

Table 8 - Average % Oxygen Saturation in Upper 3 Meters of Rogers Lake, 2002.

April	May	June	July	August	September	October
94	101	90	97	93	98	80

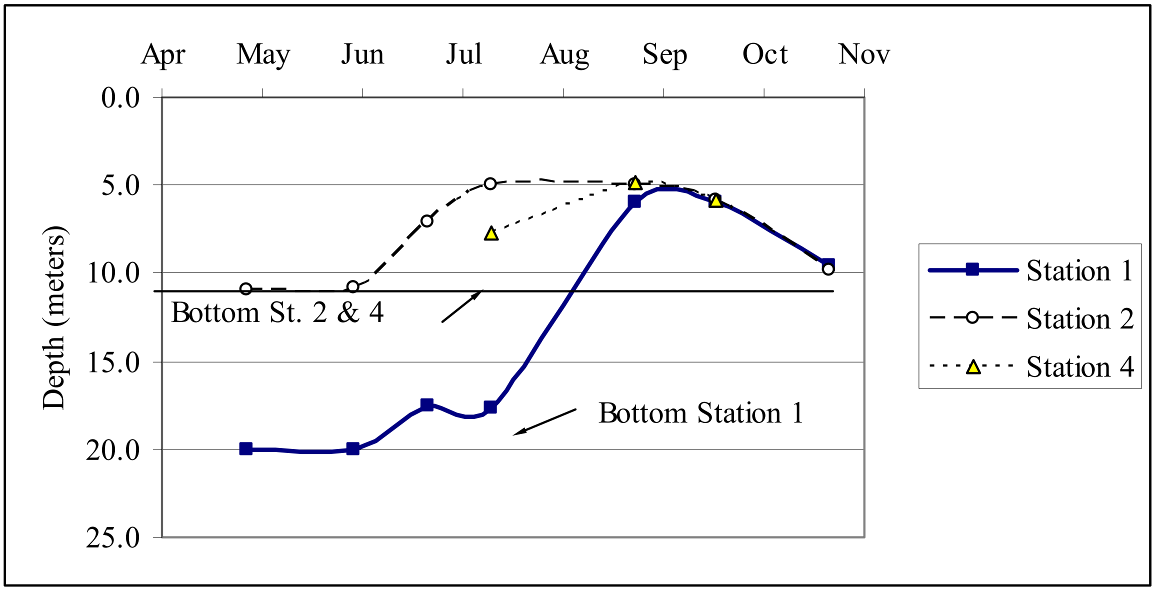
The deep waters in a lake become isolated from the atmosphere once the temperature boundaries are set up. In Rogers Lake this occurred as early as April at Station 1, and persisted until October. The waters below the thermocline become stagnant without a source of oxygen to it. Decomposition occurs because in lakes everything eventually sinks to the bottom.

All the algae, and zooplankton that die and settle to the bottom are decomposed by bacteria which use oxygen in the process. This consumption of oxygen proceeds until either all the dead material has been decomposed or all the oxygen is gone. Oxygen concentrations less than 1 mg/L or about 10% saturation, are too low to support any aerobic organism. Water with 1 mg/L and less dissolved oxygen is termed anoxic.

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

An anoxic boundary developed between the May and June sampling dates at both Station 1, & 2, and reached a maximum ascent depth of 5 meters in July at Station 2 and in August at Stations 1 and 4 (**Figure 6**). The boundary showed slow development at Station 1 during June and July remaining below 17 meters during those months. In August the water between 6 and 12 meters contained between 1.0 and 1.3 mg/L of oxygen, essentially an anoxic boundary that was 6 meters wide. Generally the boundary is abrupt implying that the water in the central basin had either low oxygen consumption rates or there was a subsidy of oxygen rich ground water entering the lake deep under water.

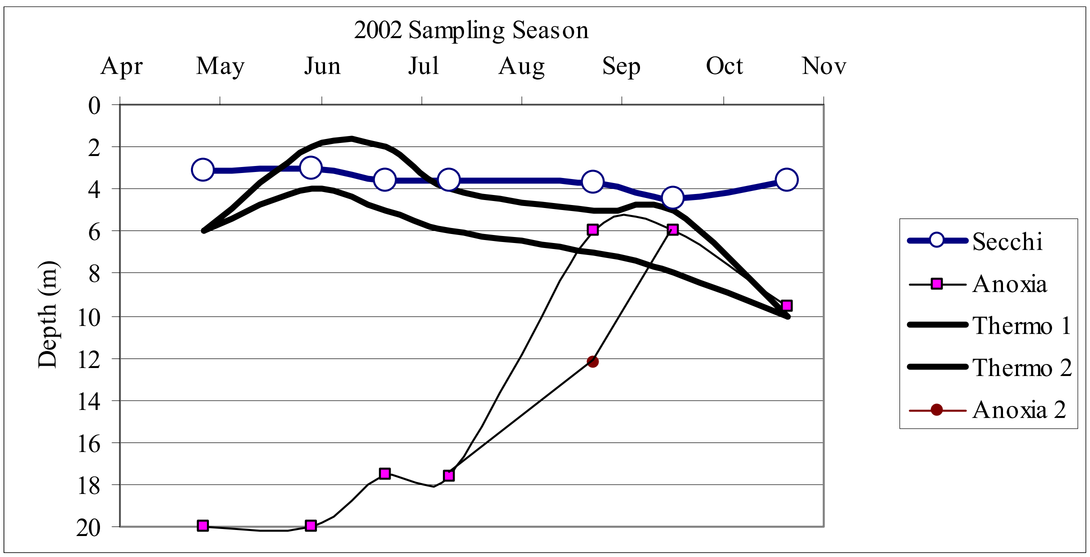
Figure 6. Anoxic Boundaries In Rogers Lake, 2002.



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

The graph shows the interaction between the thermocline and the Secchi disk depth during the season. The thermocline was at or near the Secchi disk depth during most of the early part of the season but below the Secchi disk depth starting in July. This indicates that light penetration dictated the location of the thermocline during the first few months but wind action on the surface and overall warming of the lake dictated the location of the thermocline in the late summer and into the fall. The anoxic boundary can be seen to reach into the middle of the metalimnion by the end of the season in September after which it follows the plunging thermocline in October. The lines for Anoxia 1 and Anoxia 2 on the graph show the strata of the lake that had 1.3 and 1.0 mg/L of dissolved oxygen respectively. The lines for Thermo 1 and Thermo 2 represent the upper and lower boundaries of the metalimnion.

Figure 7. Physical Boundaries at Rogers Lake, 2002.



In-Lake Water Quality Analysis

The testing of water samples from Rogers Lake including the primary plant nutrients, phosphorus and nitrogen. The forms of nitrogen tested were nitrate, ammonia, and organic nitrogen. Results are also presented for conductivity, turbidity, alkalinity, pH and total iron.

Total Phosphorus

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

Phosphorus was measured at 1, 6, 11, and 18 meters at Station 1; at Station 2 samples were collected from 1, 5, and 10 meters and at Station 4 from both 1 and 8 meters, the results are shown in Table 9. In general, the phosphorus concentrations in the lake were very low, with almost all values representative of oligotrophic waters (i.e. below 10 ppb, see Appendix 8). The only samples with phosphorus concentrations above 10 ppb were from the 1 meter depth at Stations 2 and 4 and most of the bottom water samples. But in each case no samples had phosphorus concentrations higher than 22 ppb. There was no statistical difference between the concentrations at Station 1 (1, 6, & 11 m), Station 2 (1, 5 m), and Station 4 (1 m), essentially these were the upper water samples. There was also no significant difference between Station 1 (18 m), and Station 2 (10 m), essentially these were the bottom water samples. The two groups of samples (upper and bottom waters) were statistically different.

Table 9 - Rogers Lake Total Phosphorus Concentrations (ppb), 2002.

Station 1

Depth (m)	April 27	May 30	June 22	July 12	August 25	Sept.19	Oct. 24
1	7	8	7	7	9	4	4
6	9	5	7	8	5	5	4

11	7	6	5	8	9	4	5
18	10	12	10	13	20	11	11
Mean	*8*	*8*	*7*	*9*	*11*	*7*	*6*

Station 2

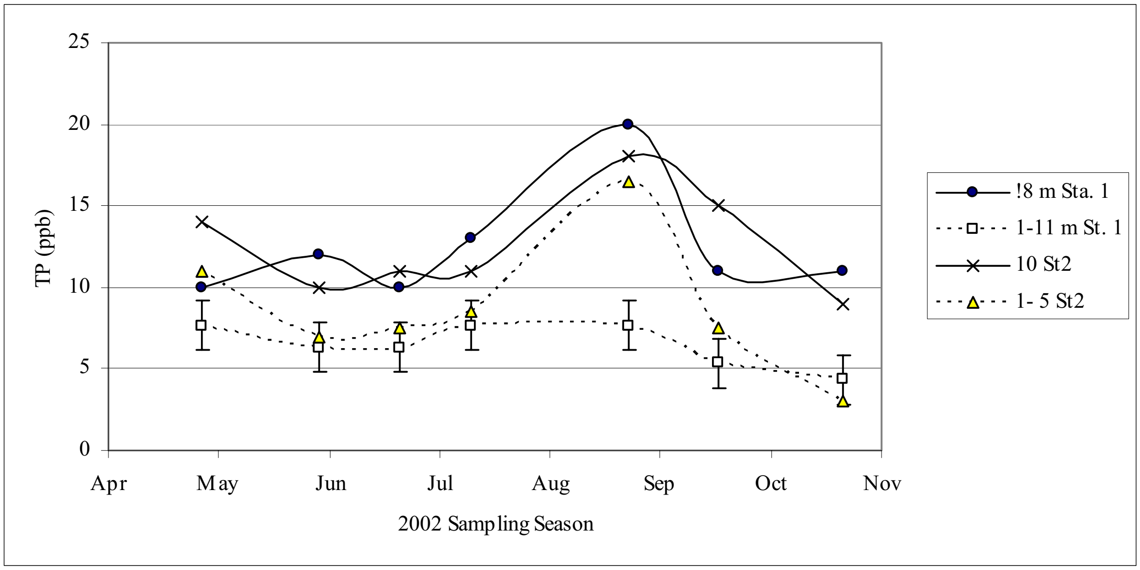
Depth (m)	April	May	June	July	August	September	October
1	11	8	9	8	10	7	2
5	11	6	6	9	23	8	4
10	14	10	11	11	18	15	9
Mean	*12*	*8*	*9*	*9*	*17*	*10*	*5*

Station 4

Depth (m)	April	May	June	July	August	September	October
1				8	12	6	
8				17	19	22	
Mean				*13*	*16*	*14*	

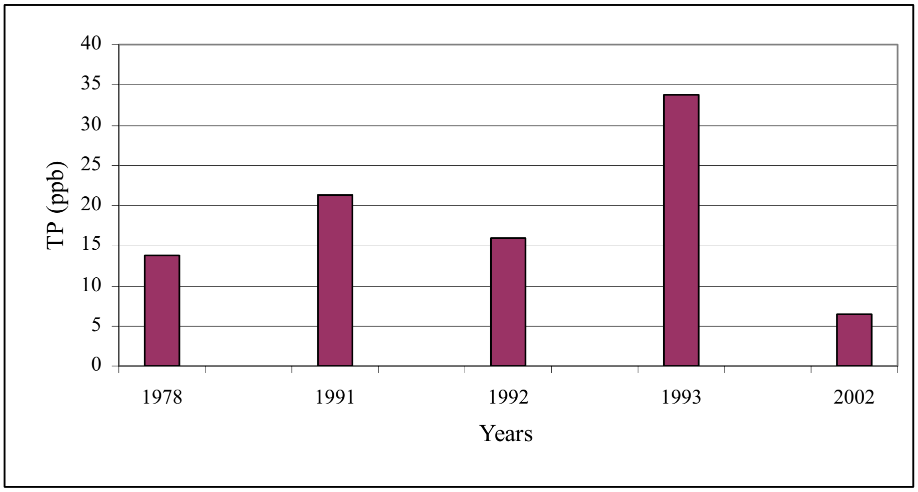
The trend in total phosphorus concentrations at Rogers Lake during the 2002 season are also presented graphically in **Figure 8**. The values from each of the top three sampling depths at Station 1 and top two depths at Station 2 have been pooled with the average shown in **Figure 8**, together with the corresponding deep water sample from each of the two stations. The graph shows how similar the values were between the two stations in the two lake strata, although it appears like the values from Station 2 (1-5m) were higher than Station 1 (1-11m) there was no significant difference between the two. The graph also shows the increase in phosphorus concentration that occurred in August.

Figure 8. Trends of Total Phosphorus in Rogers Lake, 2002.



The historical record for phosphorus at Rogers Lake contains data from the surface water of the lake. The average phosphorus value from each of the years that surface water data was available is given in Figure 9. The results show that surface phosphorus concentrations observed in 2002 were the lowest on record. Prior years had average surface water values between 10 and 20 ppb, data from 1993 appears high and may have been aberrant. Deevey (1940) reported total phosphorus at 8 ppb for Rogers Lake, consistent with data obtained during this survey.

Figure 9. Average Surface Water Total Phosphorus Concentrations at Rogers Lake.

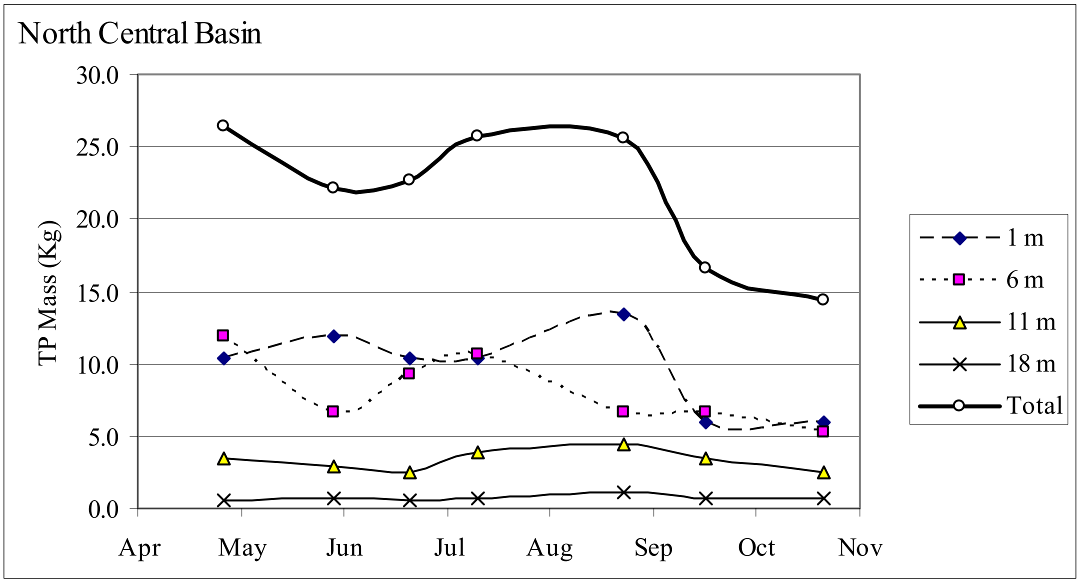


The total mass of phosphorus in the lake was determined by multiplying the concentration times the volume of each layer of water represented by the water sample depth. For example, since water was collected from 1, 6, 11, and 18 meters the volume of water between the surface and about 3.5 meter was apportioned to the 1 meter sample. The water between 3.5 and 9 meters was apportioned to the 6 meter sample and so on.

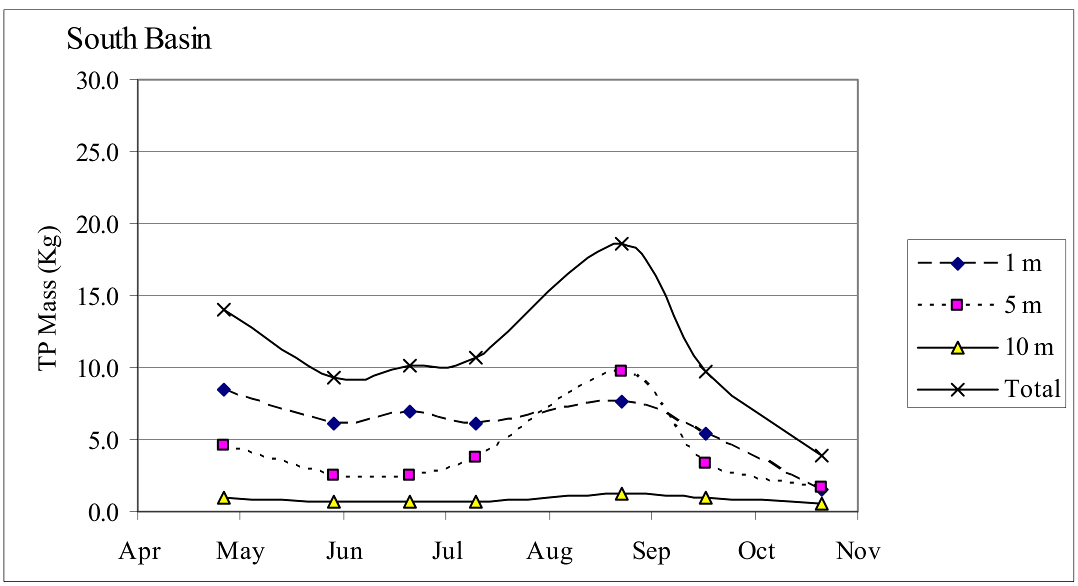
The change in phosphorus mass between the sampling dates (intervals) at each of the layers at Station 1 and Station 2 is shown for each station separately in **Figure 10**. The graph shows that the smallest mass of phosphorus occurred at the 18, and 11 m sampling depths due to the smaller volumes of water in that part of the lake. The largest mass of phosphorus was contained in the upper two layers, 1, and 6 meters because that is where most of the water in the lake is. The lake alternatively, gained and lost phosphorus at 1 and 6 meters during the season but had an overall decreasing trend of phosphorus at Station 1 such that the mass of phosphorus in October was about 10 Kg less than in April. At Station 2 a similar trend occurred with the exception of a spike in phosphorus at 5 meters in August.

Figure 10. Total Phosphorus Mass in Rogers Lake, 2002.

Station 1



Station 2



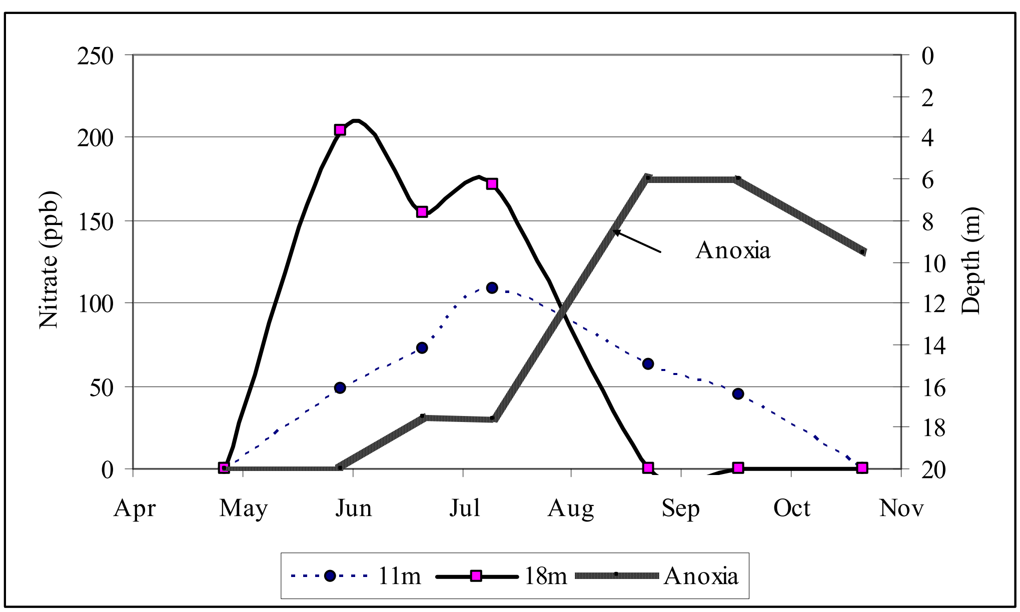
Total Nitrogen

The nitrogen in lake water occurs in two basic forms, inorganic (nitrate, nitrite, and ammonia) and organic.

Nitrate (including Nitrite)

Nitrate was below the detection limit of 20 ppb in all the samples collected from the top two sampling depths at Station 1 and 2. Nitrate was present in both the 11 meter and 18 meter sampling depths at Station 1 and only once at the 10 m depth at Station 2 (**Figure 11**). Nitrate was present at 18 meters in May, June, and July, at levels of between 150 and 200 ppb, but was below detection after that date. At 11 meters, nitrate was present between May and September, reaching a peak of 100 ppb in July. The accumulation of nitrate may have been due to nitrification of ammonia in the water column below the euphotic zone. The process requires oxygen to be present in the water so no nitrate accumulated after anoxia conditions dominated. The graph in **Figure 12** shows that the location of the anoxic boundary at Station 1 was at 18 when nitrate was present at that depth. Once anoxia reached above that depth nitrate disappeared at 18 meters. Nitrate continued to be present at 11m after the water became anoxic although the concentration declined.

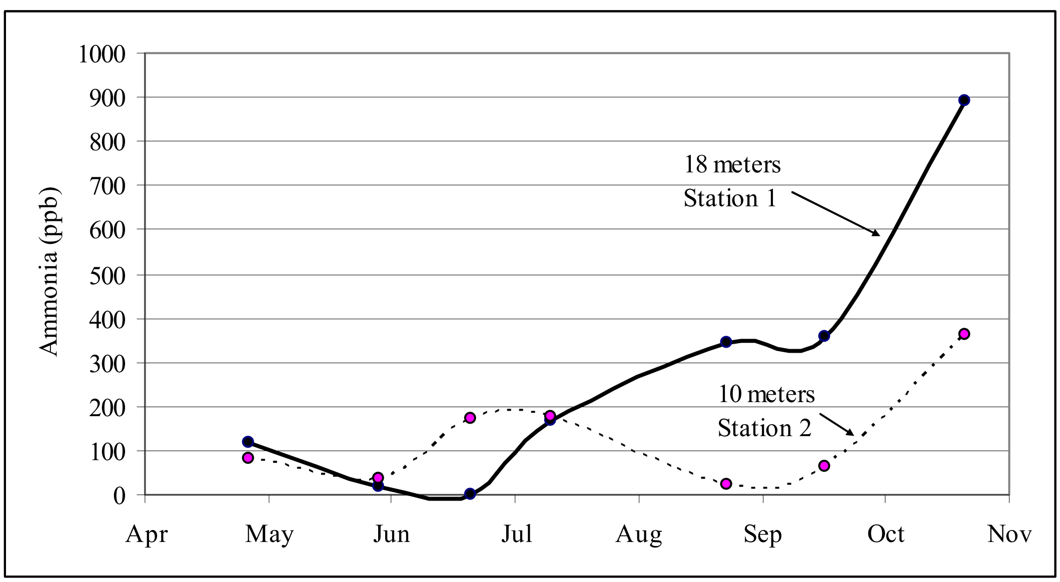
Figure 11. Nitrate Concentration Trends at 11 and 18 meters at Station 1, 2002.



Ammonia

Ammonia is a by-product of the decomposition process and is liberated from sediments during anoxic conditions. Ammonia accumulated at 18 meters during the season to reach a peak concentration of 890 ppb in October (**Figure 12**). Ammonia disappeared from the 18 meter depth in June when nitrification was probably occurring at peak rates (see **Figure 11**), however when anoxic conditions dominated ammonia began to accumulate. Ammonia was present at the other three depths (1, 6 and 11 meters) during the season with highest concentrations occurring in April and May. Ammonia in the upper water tended to decrease in concentration during the season with very low levels during occurring the late summer and fall. Similar trends were observed at Station 2, with ammonia accumulating at the bottom in late summer, and upper waters having highest levels in the May and June with a gradual decline during the remainder of the season.

Figure 12. Ammonia Nitrogen Concentration at 18 meters Station 1 in Rogers Lake, 2002.



Total Organic Nitrogen

The organic nitrogen in lake water is mostly in the form of re-mineralization remains of plant and animal material. The organic nitrogen is associated with complex combinations of carbon and hydrogen molecules. These types of molecules are the same that are responsible for staining the water brown when you brew tea. They are not immediately reactive so cannot be used as a growth nutrient for algae. However, this nitrogen is often associated with equal amounts of carbon which can be respired freeing the nitrogen as mineralized ammonia.

Organic nitrogen provides an estimate of total potential nitrogen stored in the lake water when nitrate and ammonia are at very low levels. Total nitrogen is another of the parameters used to identify trophic level in a lake. There is always a background of organic nitrogen in aquatic systems so that the levels in oligotrophic lakes range from 0 to 200 ppb, see the table in Appendix 8. The organic nitrogen concentration of lake can fluctuate widely from year to year such that oligotophic lakes can have peaks of 300+ during either spring or summer months. In general however, as the overall organic nitrogen level in a lake goes up the degree of water quality impairment goes up.

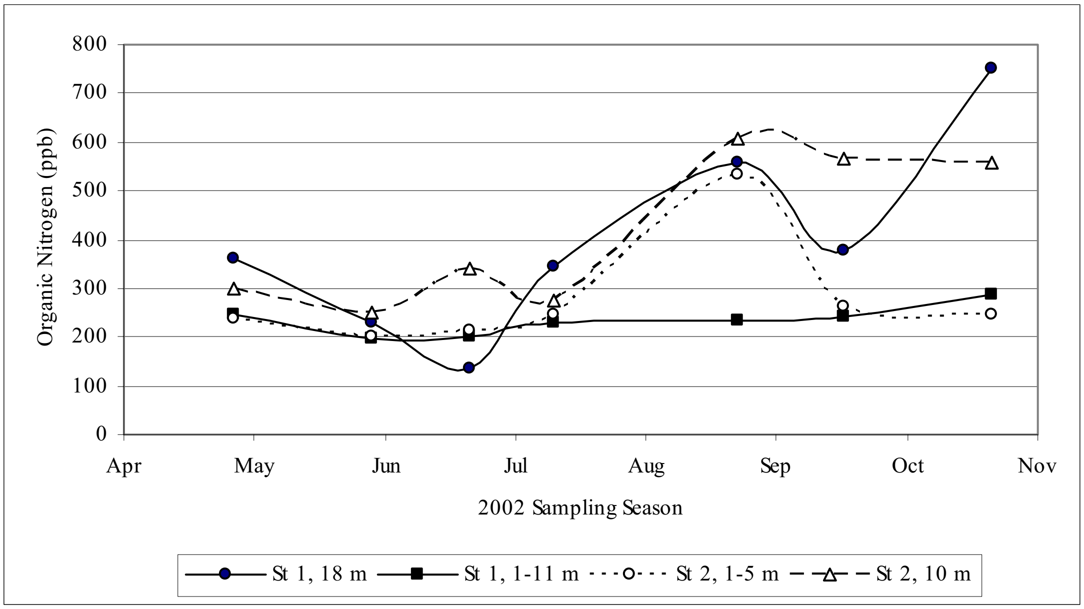
The organic nitrogen levels in Rogers Lake are shown in Figure 13. The graph shows data from both Station 1 and Station 2. The results are shown as were the phosphorus results, one line for the averaged 1, 6, and 11 meter samples, and, one line for 18 meters and a similar set of two lines for Station 2. There was no significant difference between the deep water samples at the two stations. There were significant differences between these bottom water samples and the upper water samples at each station. There was no significant difference between any of the upper 5 sampling depths, such that organic nitrogen was essentially the same across the lake down to the mid depth in the water column.

The concentration of organic nitrogen was generally low in the upper half of the lake, with Station 1 seasonal average of 233 ppb for the three sampling depths (1, 6, and 11m), and 277 ppb from Station 2. The higher mean at Station 2 was attributable to the small spike in organic nitrogen that occurred in August similar to the spike in phosphorus that occurred at 5 meters in August. Like that spike the organic nitrogen appeared to accumulate at 5 meters.

In deep water at Station 1 the organic nitrogen level first showed a decrease in May and June but than showed a gradual increase until reaching a peak value of 750 in October. Data from Station 2 showed a similar trend except that instead of decreasing in June it increased, and the peak value in October was 560 ppb.

The organic nitrogen levels observed in Rogers Lake represent one part of the total nitrogen quantity and must be added to both nitrate and ammonia concentrations. The total quantity of nitrogen in the lake water and can be used to infer trophic status of the lake. The average value of total nitrogen in the upper 11 meters from Station 1, was 266 ppb during the 2002 season, factoring in the 1, and 5 meter data from Station 2 increases that average to 282 ppb. The table in Appendix 8 gives Oligo-mesotrophic lakes a total nitrogen range of between 200 and 300 ppb. According to the total nitrogen observed in 2002 the lake was in the Oligo-mesotrophic category.

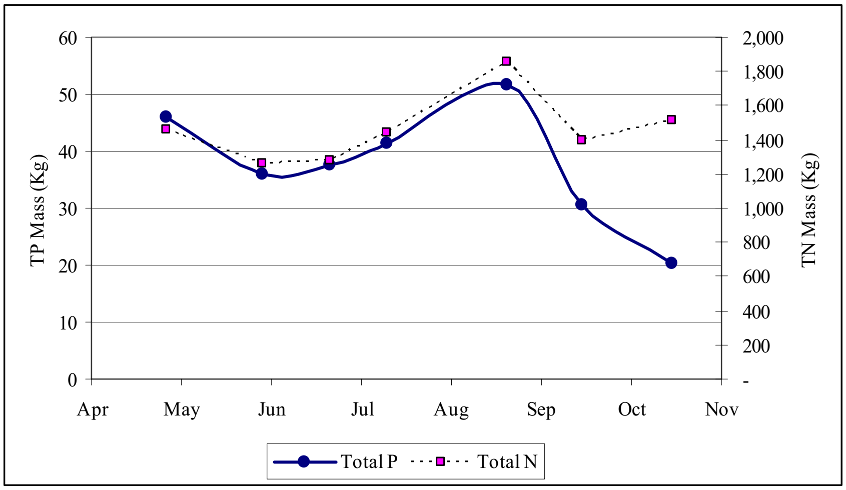
Figure 13. Organic Nitrogen Concentrations in Rogers Lake, 2002.



Organic nitrogen at 6 and 11 meters appeared to decrease during May and June and possibly in July being lower than both the surface and bottom water samples. This was followed by a dramatic decrease in the surface water concentration in August. The organic nitrogen decrease at 6 and 11 meters in May and June occurred simultaneously with the observed decreases in ammonia and increases in nitrate at those depths. It is possible that the middle and upper layers of the lake act as a de-nitrification sink during different periods of the year

The trends of total mass of phosphorus and nitrogen in Rogers Lake during the 2002 season are shown in **Figure 14**. The graph shows the content of phosphorus and total nitrogen in the lake at the time of each sampling event. Both phosphorus and nitrogen showed decreases in mass after April, followed by a slow increase in mass between June and August with peak content occurring in August. The mass of phosphorus decreased in September and October, while nitrogen mass decreased in September but stayed relativity constant into October.

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



The historical data record for the lake has total nitrogen values from two dates in 1978. A composite sample collected in April 1978 had 340 ppb organic nitrogen, while depth discreet samples collected in July 1978 showed 410 ppb from 1 meter, 330 ppm from 14 meters, and 770 ppb from 18 meters. The observed levels are consistent with results from this study.

Conductivity, Turbidity.

Conductance

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

The conductivity of the Rogers Lake waters was similar over the two stations with no significant differences between the two stations for the upper sampling depths. Conductivity in Rogers Lake had a range from 61 to 66 μmhos/cm, the samples from 1, 6, and 11 meters had a mean of 64 μmhos/cm. However there were differences between upper waters (1-11 meters) and deep waters (18 meters) with the deeper water having a mean of 70 μmhos/cm. The highest conductivity reading was 80 μmhos/cm, at 18 meters in October.

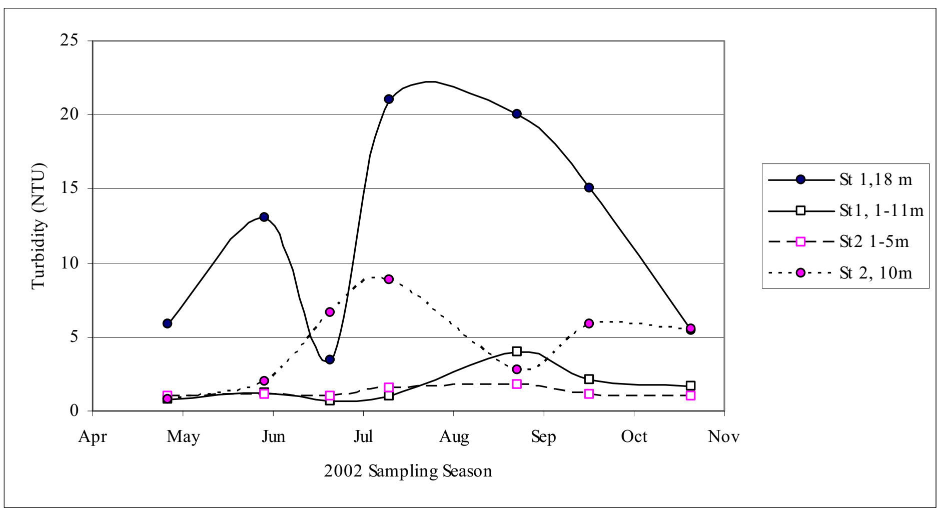
Turbidity

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

The turbidity of Rogers Lake water during the 2002 season is shown in Figure 15. The data is again presented for the upper and lower lake water from the two stations. The upper water samples (1-11 m at Station 1 and 1, & 5 meters at Station 2) are shown as averages for Station

1 and Station 2. The upper water layer at each station show generally low levels during the season. One small increase was detected at Station 1 in August but otherwise there was no significant difference between the two stations in upper water samples. The deep water samples showed increases in turbidity during the summer. Maximum turbidity occurred at Station 1 in July with 21 NTU, after that time the turbidity declined at 18 meters. A similar turbidity peak was measured at Station 2 when the July reading was 8.9 NTU. Turbidity at the bottom of Station 2 actually decreased to a low level similar to the surface water value observed in August.

Figure 15. Turbidity in Rogers Lake, 2002.



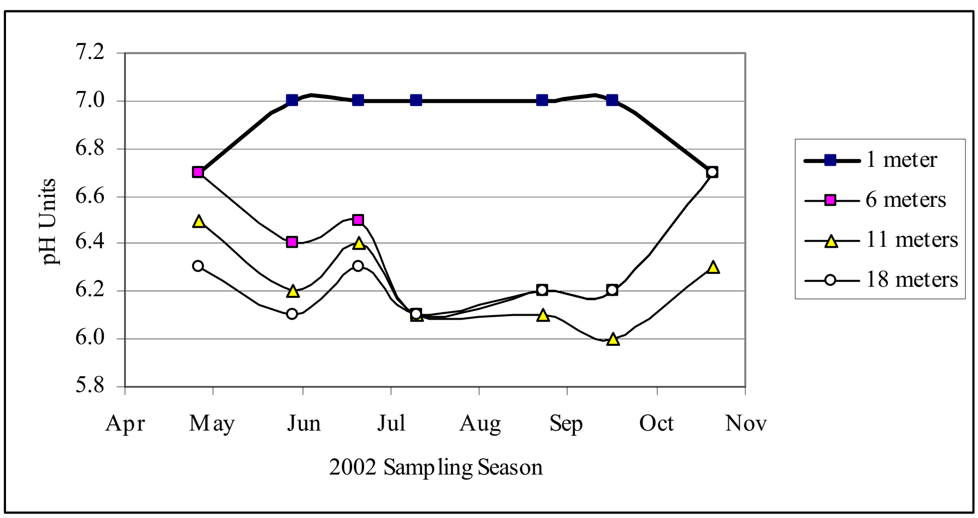
Alkalinity, and pH.

The alkalinity of the water is a measure of the acid buffering capacity or its neutralizing ability. The higher the alkalinity the more acid can be neutralized without any change in pH. The pH of the water is the log of the hydrogen ion concentration. The hydrogen ions are responsible for a liquid having an acidity characteristic such as citrus juice or vinegar.

The alkalinity of Rogers Lake varied between a low of 8 mg $CaCO_3$/L and a high of 12 mg $CaCO_3$/L in upper lake waters. The alkalinity increased slightly in deepest water reaching a peak of 20 mg $CaCO_3$/L in October. Most other bottom water samples had alkalinities similar to the upper lake water i.e. between 8 and 12 mg $CaCO_3$/L

The pH of the lake water is presented in **Figure 16**. The pH of the 1 meter sample increased in the spring to pH 7.0 and remained at that level during the summer, decreasing in October to the same level observed in April. The opposite trend occurred at the other depths where the pH decreased in the spring to about pH 6.1 and remained at that level for the summer returning to a pre-summer level in October.

Figure 16. pH Trends For Each Sampling Depth From Station 1, at Rogers Lake, 2002.

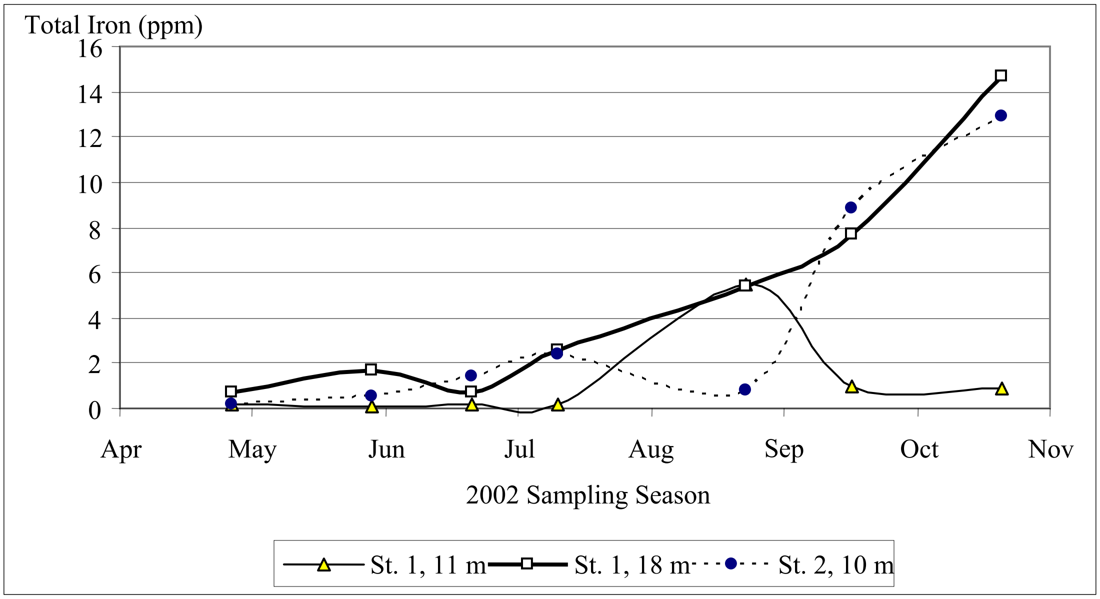


Iron

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

The total iron concentrations observed in Rogers Lake in 2002 are shown in **Figure 17**. The iron concentration in the two upper water samples at each station (1 & 6 at Station 1 and 1 & 5 at Station 2) had low levels of iron during the season ranging between 0.25 and 0.5 mg/L. The bottom water iron concentrations increased during the season to reach maximum levels of between 13 and 15 mg/L in October. An increase in total iron occurred at 11 meters at Station 1 in August but otherwise the concentration of iron at 11 meters was similar to the levels observed at 1 and 6 meters.

Figure 17. Total Iron Concentration From Station 1 (11 and 18 meters), and Station 2 (10 meters), Rogers Lake, 2002.



Weekend Clarity

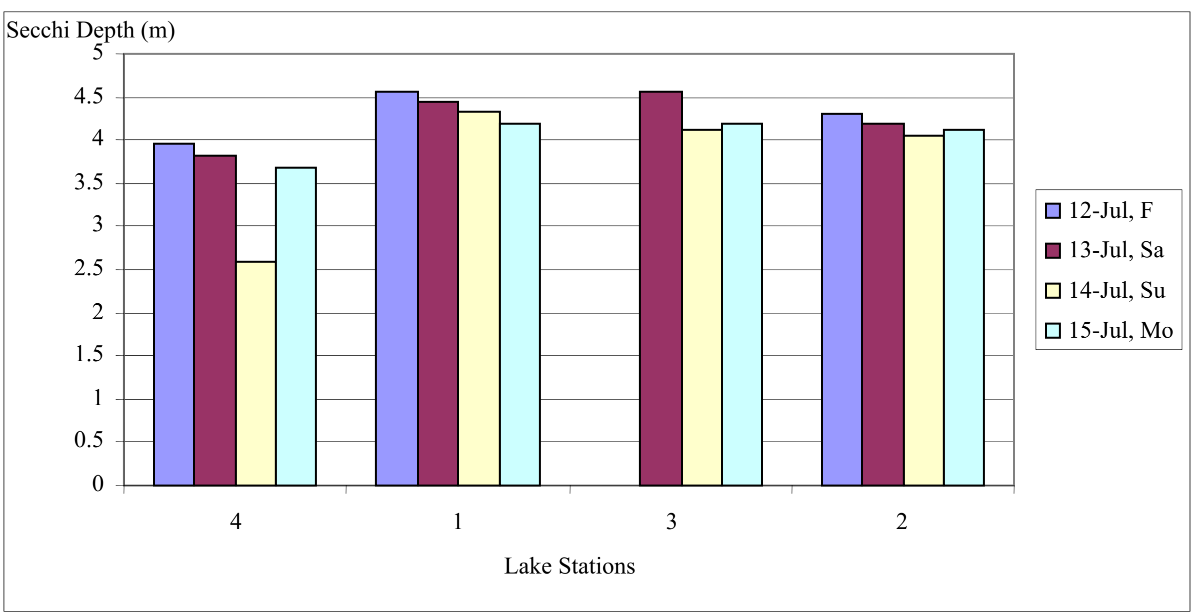
A four day investigation into the relationship between weekend boat use of Rogers Lake and water clarity was conducted over a Friday to Monday period, July 12 to July 15, 2002. The investigation involved measuring key parameters at four stations, the three regular lake stations (1, 2, and 4) and an additional station centered in the wide shallow area (lake Station 3). At each station the Secchi disk depth was measured and a sample for surface water turbidity was collected. The location of these stations is shown in Appendix 1 - Map 2. The weather over the week end was beautiful with clear skies, warm temperatures, and light winds.

The two sets of data from these stations, Secchi disk, and turbidity measurements are presented in the following three charts, Figure 18 shows Secchi Disk Depth, and Figure 19 shows the turbidity readings from surface samples.

Secchi Depth Results

The results from the Secchi disk measurements are presented in **Figure 18.** The data was collected from stations 1, 2, 3 and 4. Station 3 was used to represent the center shallow area. The Secchi disk depth was very similar between all dates and stations. Station 4, the northwest corner basin, had the poorest Secchi depth of the 4 stations, while Station 1 had the best readings. The mean from Station 4 was significantly lower than the other stations. The data showed a slight declining trend between Friday and Monday, however there was no statistical difference between the dates.

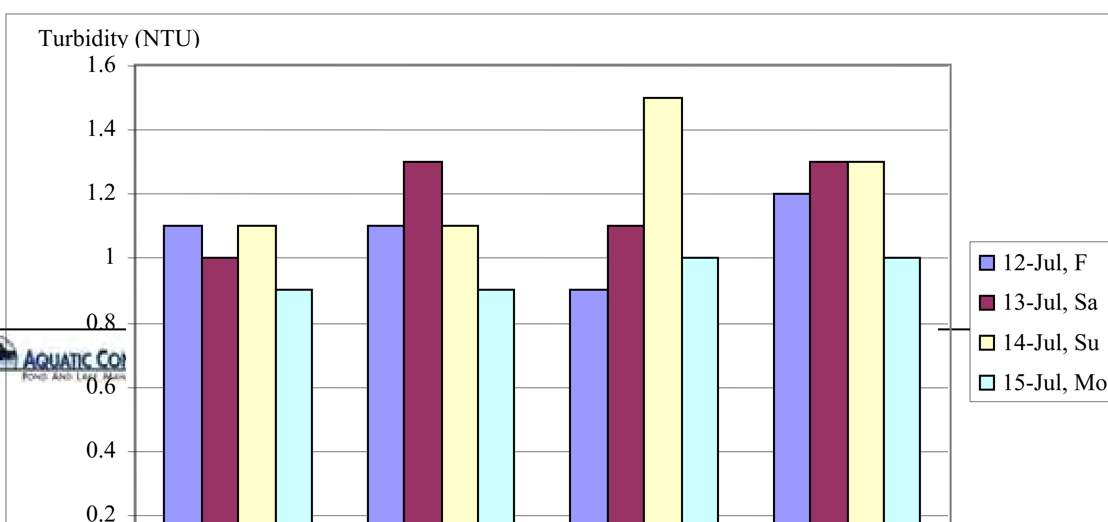
Figure 18. Secchi Disk Measurements At Lake Stations Over A Four Day Period in July.



Turbidity Results

The data shows that turbidity was slightly higher at stations, 1, 2, and 3 during the Saturday and Sunday than it was during the preceding Friday or the following Monday. The readings from Station 3 showed the largest change in turbidity with Sunday having the highest reading of each of the stations and dates. These data indicate that some increase in turbidity occurred during the weekend but that the change occurred principally in the shallow water area. One turbidity sample was collected 10 feet off the shore directly east of Station 3 on Sunday and Monday to determine if turbidity was different in the shallower water near the boat docks than it was in the deeper water in the center of the lake. The turbidity at that near shore site was 2.5 NTU on Sunday, and 1.6 NTU on Monday, as opposed to 1.5 NTU and 1.0 NTU for Station 3 on Sunday and Monday respectively, indicating that higher turbidity water was present along the shore on Sunday and that it decreased by Monday. The turbidity data does suggest that some water clarity decreases occur in the lake due to increased boat traffic but that these changes may happen more along the shore than in the open water of the lake.

Figure 19. Turbidity Readings At Different Lake Stations Over A Four Day Period in July.



Algae and Zooplankton

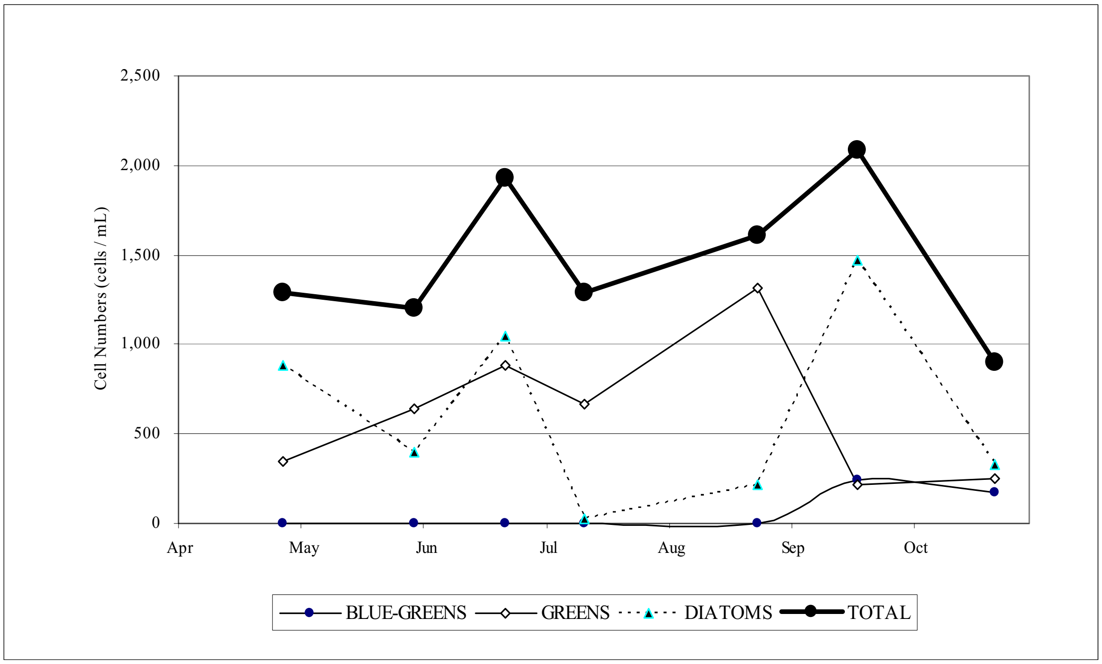
The algae that were sampled in Rogers Lake were the microscopic free-floating types that can color the water with a green hue. These types are responsible for the surface blooms in eutrophic lakes that reduce the water clarity during the summer and fall. The loss of Secchi depth is usually directly attributable to the increases in the number of cells in the water. The zooplankton in a lake are free swimming crustaceans that range in size between 0.4 and 2.0 mm. They graze on populations of algae and other small organisms in the lake. They, in turn, are prey items for juvenile and adult fish species, specifically alewife.

Phytoplankton

The phytoplankton results are presented in Figure 20. The data in the chart show algae cells per milliliter for the three major groups and the totals from Station 1 on each of the sampling dates in 2002. On each of the dates algae cell numbers were low, with totals mostly all below 2,000 cells/mL. The dominant group tended to be the green algae reaching a peak in August. The diatoms were present in most all samples except in July when they were not observed.

Bluegreen algae, the group that tend to form blooms, was not present in samples until September and October and only then in low numbers.

Figure 20. Planktonic Algae in Rogers Lake, 2002.



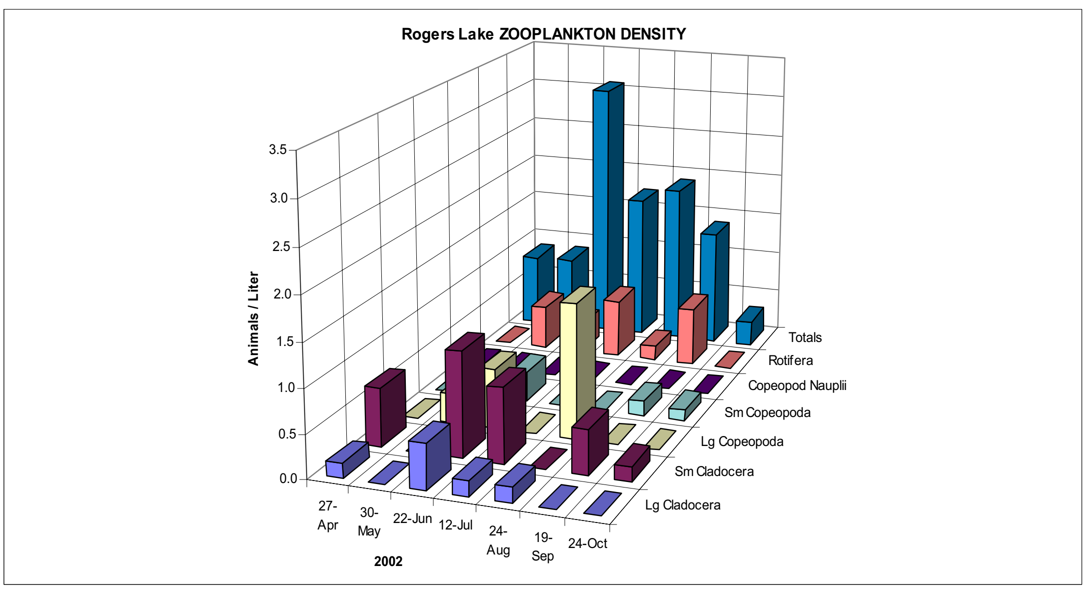
Zooplankton

The zooplankton in Rogers Lake was sampled using a vertically towed plankton net with a mesh size of 153 microns (0.153 mm). The net is lowered to the bottom than brought back to the surface. Organisms that are collected are preserved for counting later.

The zooplankton in a fresh water lake typically ranges in size between 0.2 and 3.0 mm and consist of two groups of animals the rotifers and the micro-crustaceans. The rotifers are small simple animals that feed by filter feeding in the water column. Micro-crustaceans consist of cladocerians and copepods. The copepods are represented by three separate groups, the calanoids, the cyclopoids, and the harpacticoids. The cladocerians are considered the most important group of zooplanktors because they are very efficient grazers of algae in the water column. The larger sized cladocera can filter a milliliter or more of water every hour. Copepods can be either carnivorous or filter feeders.

The zooplankton in Rogers Lake were found to be at very low numbers and of mostly small size. The data shown in **Figure 21** gives the animals per liter for each of the sample dates from Station 1. Data are reported in two size classes, small organisms are less than 0.8 mm, large organisms are greater than 0.8 mm. Generally animals were scarce in the tows, with typically only a few cladocera present. The low numbers of cladocera and other taxa of zooplankton suggest that predation is significant by zooplanktiverious fish, such as alewife and perch. CT DEP Fisheries data show (see table 10) that alewife have been observed during each of the elecroshocking surveys with some years having relatively high numbers suggesting that the population of alewife in the lake is abundant.

Figure 21. Zooplankton Density (Animals/L) at Station 1 in Rogers Lake, 2002.



Summary of CT DEP Fisheries Electroshocking Surveys

The Connecticut Department of Environmental Protection has conducted electroshocking surveys of Rogers Lake 11 times within the last 15 years, 1988, 1990, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, and 2002. With the exception of the 1990 survey which was done in October, all surveys were conducted in the spring months of April or May. The species that were observed during each of the 11 surveys is given in Table 8. Survey totals for the number of species observed ranged between 12 and 20 species of a mean per trip species count of 16. Several species were seen only once, smallmouth bass, brook trout, carp, spottail shiner, and redbreast sunfish. A couple of the species listed in the table were in an uncertain category, sunfish Young Of Year, and the hybrid pumpkinseed/bluegill.

Table 10 also shows the catch per unit effort or the number of fish each species observed per hour during the survey. The most abundant game fish was largemouth bass with several surveys showing fair numbers of rainbow trout, and chain pickerel. The numbers of bass and trout indicate that Rogers Lake has a good two tiered fishery with bass in the warm shallow water and trout in cooler deeper water. The lake is stocked annually with brown and rainbow trout with the brown trout successfully surviving each year in low numbers, suggesting that oxygen levels in the lake are sufficient during the summer. The anoxic boundary reached 6 meters during the mid-summer months of August and September suggesting that fish might be limited to a narrow band of water between the upper warm water and the deep anoxic water. The light limit may play a role in keeping the 5 meter water cool enough for the brown trout to survive during August.

Walleye was stocked in Rogers Lake between 1994 and 1999 but low survival prompted the stocking to be discontinued. White perch was stocked as a forage fish for the walleye.

Table 10. Fish Species Observed and Catch per Unit Effort (Fish/hr) During CT DEP Electroshocking Surveys.

	1988	1990	1992	1993	1994	1995	1996	1997	1998	1999	2002
Largemouth bass	57	56	94	64	79	101	83	98	71	75	77
Smallmouth bass					0.4						
Brook trout								0.4			
Brown trout			3	4	0.6	0.4	2	15	4	0.9	0.9
Rainbow trout	11		9	2	7	38	8	36	20	8	1.8
Walleye					23	12	14	21	7	4	
Chain pickerel	9	18	19	8	13	29	17	22	22	16	29
Black crappie	9		4		2	1.3	0.9	0.9	7	5	4
White perch					0.6	0.9	0.5	0.4	0.7	0.9	4
Yellow perch	99	45	130	103	131	105	69	209	137	137	70
Brown bullhead	7	2	11	14	9	11	18	33	13	19	19
Bluegill sunfish	253	190	330	210	351	396	272	317	298	447	505
Pumpkinseed	108	49	75	66	95	88	85	61	50	69	37
Redbreast sunfish							3				
American eel	80	45	53	42	34	22	24	14	6	11	8
Alewife	56	66	54	70	206	35	74	26	67	70	36
Golden shiner	15	1.2	37	8	31	20	13	21	30	15	5
Spottail shiner						0.4					
Bridle shiner	0.8	1.2	1.6	0.8	2	2		1.7	3	2	5
Banded killifish	0.8	0.6	0.8		1.1	0.4	1.0	0.4	2		1.8
Tessellated darter	0.8			0.3	0.4		3	3	1.1	0.9	
Four sp. stickleback				0.3	0.6			0.9			
Creek chubsucker				0.3	0.6		0.5				
Carp			0.4								

Summary of Lake Data

The Lake had relatively constant water clarity during the 2002 season, with an average Secchi disk depth of 3.6 meters for all dates and sites. There were no apparent algae blooms during the season. The depth of the 1% light averaged 5.3 meters during the season with very little variation. The lake thermally stratified in May with a thermocline at about 3 meters. The thermocline remained high in the water column for another month before beginning to migrate downward to the 4 to 5 meter range where it remained until the end of August. The thermocline descended to 7 meters in September and finally 10 meters in October. The lake lost oxygen in deep water during the 2002 season with an anoxic boundary developing over the sediment at the deepest depths in June. The water column below the thermocline showed gradual oxygen loss beginning in May the anoxic boundary stayed at 17 meters until August. This meant that there were several meters of water, between 6 and 12 meters, where oxygen was low, below 5 ppb, but not anoxic.

The nutrient levels in Rogers Lake were low in most regards except perhaps the organic nitrogen content. Phosphorus was below the threshold of 10 ppb for oliogtrophic lakes in upper waters, 11 meters and above. The deep water sample (18 m) showed very slight phosphorus accumulation either due to leaching from the anoxic sediments or from decomposition and mineralization of dead algae sinking from above. The maximum phosphorus concentration observed at the bottom of Station 1 was 20 ppb, at the bottom of Station 2 it was 18, although at the 5 meter depth one reading of 23 ppb was obtained. That increase at 5 meters at Station 2 was of interest because several other parameters also increased there at that time.

The ammonia levels were low except for the deepest waters of the central and south basins. In both of these, ammonia accumulation occurred during the summer with maximum concentrations occurred in October. Nitrate was generally below detection except for the 11 and 18 meter samples at Station 1 where nitrate was present in May, June, and July, coincident with the time that oxygen levels were low but not anoxic. Nitrate continued to be presence at 11 meters in August and September. The organic nitrogen levels in the lake were also generally low; the mean of all samples collected at 1, 5, and 11 meters from Station 1 was 260 ppb. The maximum organic nitrogen value at those three depths was 370 ppb. The maximum concentration at 18 meters was 1,640 ppb. Using the upper water samples as indicators or trophic state the lake had organic nitrogen levels within the Oligotrophic range, between 200 and 300 ppb. Station 2 had slightly higher levels with an average of 300 for 1 and 5 meters. Deep water samples at Station 2 were lower than the deep water samples at Station 1. At Station 2 a peak in organic nitrogen occurred in August at the 5 meter depth sample. This was the same time and place that phosphorus increased.

Conductivity was relatively constant during the sampling period. Turbidity was usually low in the upper waters but showed increased levels in the deep water samples at each of the two stations. PH increased at the surface to a pH of 7 during the summer while all other depths showed a decrease to the low 6s. The alkalinity remained relatively constant during the season.

The concentration of iron increased at the 18 meter depth during the season such that maximum concentration occurred in October, a similar increasing trend occurred at Station 2 at 10 meters such that the maximum concentration also occurred in October.

The algae and zooplankton counts both showed that generally low numbers of both algae and zooplankton existed in the lake during the 2002 season.

The trophic category of the lake appeared to be oligotrophic with regard to phosphorus, oligo-mesotrophic with regard to nitrogen and mesotrophic with regard to clarity. The poorer clarity may be due, in part, to high water color because the algae cell counts were consistently low indicating that productivity was low. Although the color of the water was not measured visual observation of inlet streams #5 and #6 was that these streams were of a brownish coloration.

Drainage Basin Sampling Results

Sampling Stations

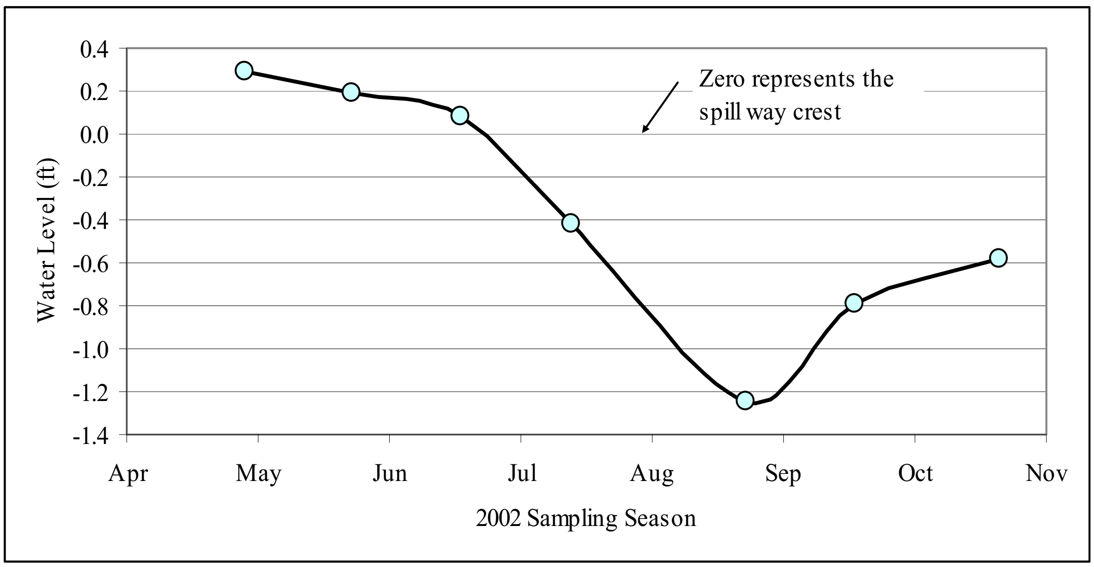
There were 6 stream sites identified for monthly monitoring around the lake with the locations of the sampling stations shown in **Appendix 1 - Map 3.** Locating and accessing stream #2 was hampered by posted private property signs until June, when the stream was visited for the first time. In April and May, 5 streams were sampled (1, 3-6). In June all 6 streams were sampled, but beginning in July all inlet streams were either dry or for the case of Stream #5 had no flow (**Table 11**). In September and October the three larger streams had begun to flow again although the flow levels were low at each.

Table 11. Tributary Stream Sampling Dates.

	4-29	5-24	6-19	7-15	8-25	9-20	10-24
# of Inlets sampled	5	5	6	0 (all dry)	0 (all dry)	3	3

The outlet of the lake was also sampled on the dates of the watershed inlet sampling. In addition the lake level was measured. The lake water level decreased during the season, slowly at first but then more rapidly (Figure 22). The lake stopped discharging over the spillway in June and did not again crest the dam spillway for the remainder of the study period. Instead the lake discharged through a 3 foot diameter culvert in the dam. There was also some leakage through the dam face such that water was constantly leaving the lake during the study period. The lake level reached a minimum of 1.3 feet (15 inches) below the spillway in August.

Figure 22. Rogers Lake Water Level As Measured At The Dam, 2002.



Stream #1 was a small seep located on the lake side of Rogers Lake Trail on the west side of the lake. Streams #2, #3, and #4 were located on the north side of the lake and appeared to be natural streams, having either rocky or wetland channels with unaltered stream beds, and vegetated banks. Stream #5 had the highest flow to the lake and drained a large series of wetlands to the northeast of the lake. The Stream #5 channel entered the lake via a narrow cove on the lakes east side. During low flow periods in the summer, the cove and lower reach of the stream contained standing water but no flow was detected. Stream #6 was the second largest of the lakes inlets, and was located at the south east corner of the lake. The stream discharged from a manmade pond over a concrete spillway and traversed a wide channel to the lake.

The water flow at each inlet and the outlet were measured during each of the monthly sampling visits and during the stormwater runoff event in December. The estimated discharge volumes are given in **Table 12**. Water flow was high in April, with the lake discharging about twice the volume as it received via overland flow at the 6 monitored tributaries. However, the April and May flow estimates do not include the volume contributed from the inaccessible inlet Stream #2. Stormwater flow measurements suggest that discharge from Stream #2 was very similar to the discharge from Streams #5, and #6. Discharge from those two streams was about 32 cfs in April; a similar discharge reading of 31 cfs could be assigned to Stream #2 for April. That would bring the total inlet discharge to 99.6 cfs. In addition, storm water monitoring identified inlet S7 as a high discharge stream with flows comparable to Streams #2, #5, and #6. Adding a discharge similar to those streams to the total would bring the total April discharge to over the 121 cfs outflow measured at the dam.

Table 12. Measured Water Flows (cfs) at 6 Tributary Inlets and the Outlet, Rogers Lake, 2002.

Inlet Sta.	29-Apr	24-May	19-Jun	15-Jul	25-Aug	20-Sep	24-Oct
1	0.042	0.003	0.003				
2			0.2			0.05	0.05

3	1.1	3.0	0.1				
4	1.1	0.7	0.1				
5	31.5	10.4	0.6			0.1	0.1
6	33.9	11.7	1.4			0.4	0.3
Total In	67.6	25.7	2.3	0.0	0.0	0.55	0.45
Outlet	121	32	4	0.1	0.1	0.1	0.06

Table 13. Measured Water Flows at 6 Regular Inlets and 7 Storm Water Inlets, 12-20-02.

Station	Flow (cfs)
1	0.0
2	11.0
3	1.4
4	1.9
5	11.4
6	10.4
Total	36.2

Station	Flow (cfs)
S1	0.4
S2	2.5
S3	0.3
S4	0.0
S5	0.4
S6	0.1
S7	12.2
Total	15.9

Total = 52.1

Figure 23. Total of Measured Flows Into (dashed line) and Out of (solid) Rogers Lake, 2002.

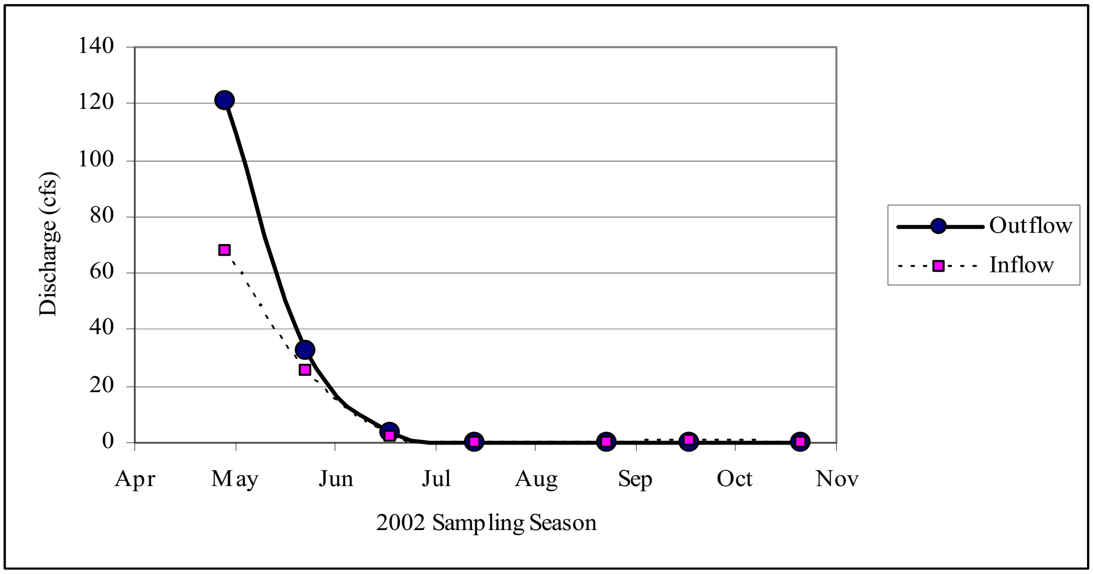
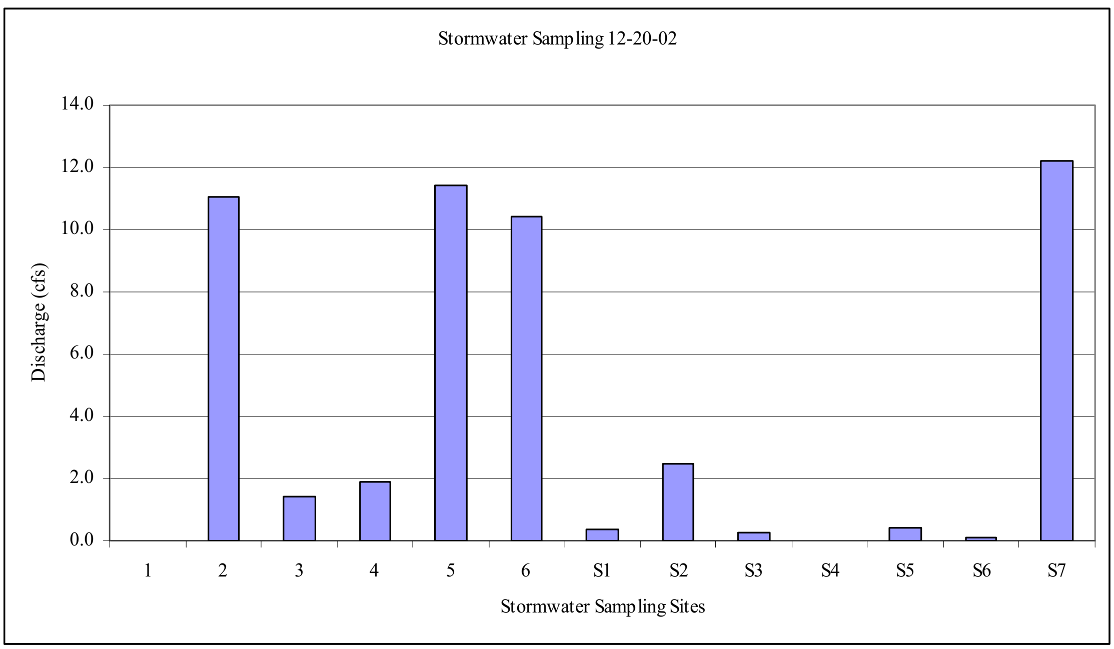


Figure 24. Discharge At Inlets Sampled During Storm Event, 12-20-02.



Drainage Basin Water Quality Results

The 6 inlet streams were sampled monthly from April to October to determine baseline water quality conditions of the drainage basin flows into Rogers Lake. In addition, storm water samples were collected in December from the 6 monitored inlets and 7 additional sites (**Map 4**). The water testing included total phosphorus, ammonia nitrogen, nitrate nitrogen, TKN or organic nitrogen, conductivity, alkalinity, turbidity, pH. The water flow as well as temperature and oxygen were measured in the field.

In each of the following water quality discussions, the seasonal average from each stream is shown. It should be noted that not all streams had flows during each of the months. This means that the average values calculated for each stream represent different numbers of samples. Refer back to **Table 10** to see the number of samples that were collected each month.

Phosphorus

The levels of phosphorus in the inlet streams were low in all cases (**Figure 25**). Mean stream phosphorus values ranged from 5 ppb to 13 ppb. Streams #2 and #6 tended to have higher levels but there was no statistically significant difference between any of the streams.

The storm water sampling showed higher phosphorus concentrations at the inlets but not by much, the average for the regular inlets was 24 ppb with streams #2 and #4 having the highest values, 46 ppb and 38 ppb respectively. The storm water sites showed slightly higher levels of phosphorus with an average of 37 ppb, storm site S1 had the highest phosphorus concentration at 104 ppb.

Figure 25. Average Stream Phosphorus Concentrations For Rogers Lake Inlets, 2002.

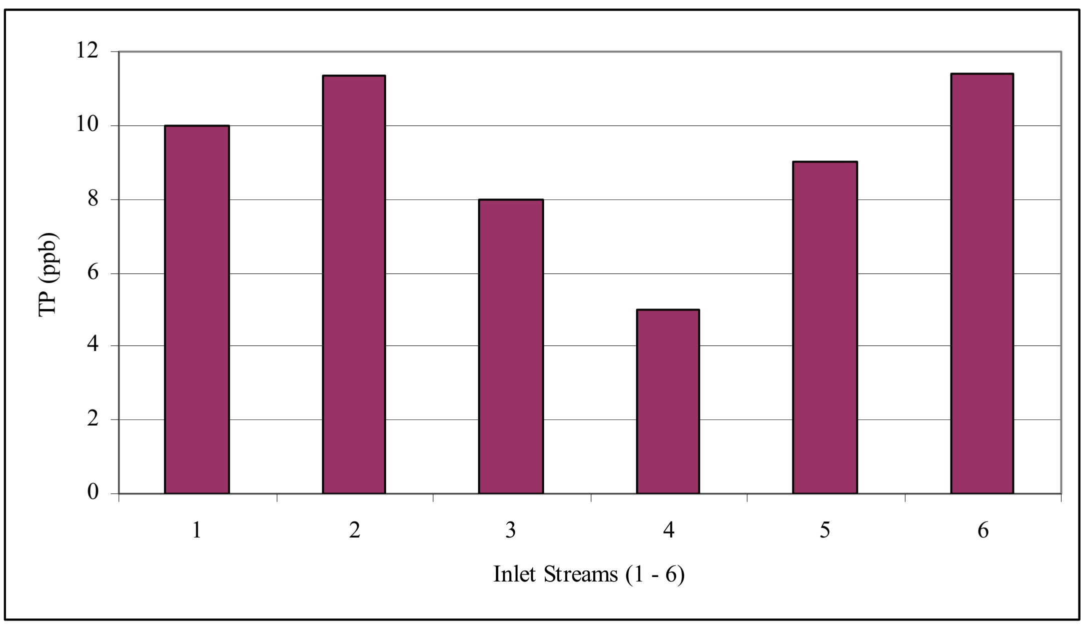
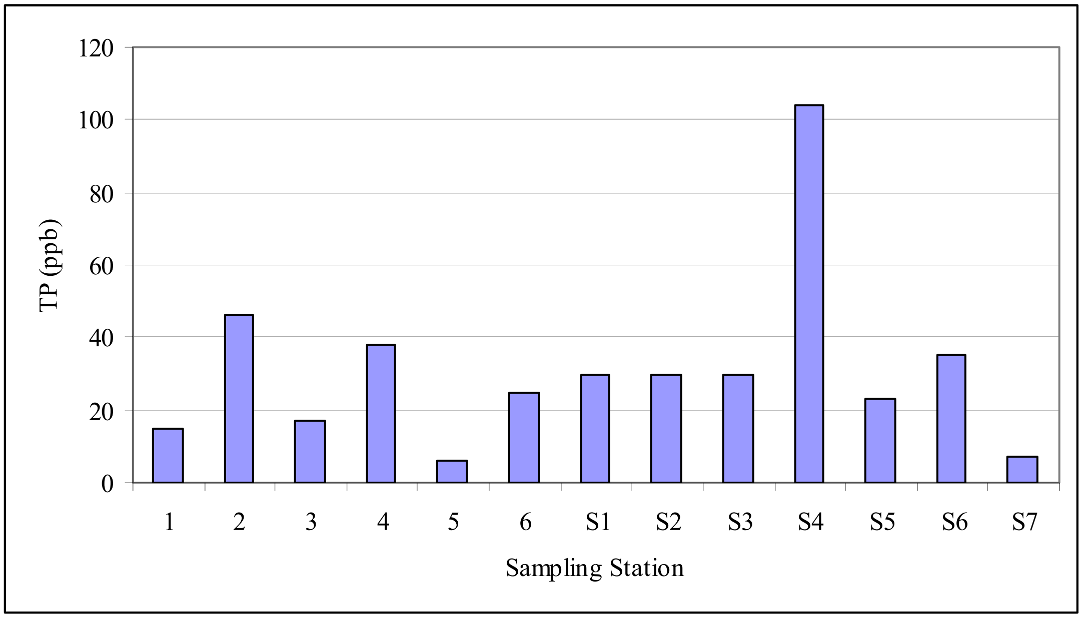


Figure 26. Storm Water Phosphorus Concentrations, 12-20-02, Rogers Lake, 2002.

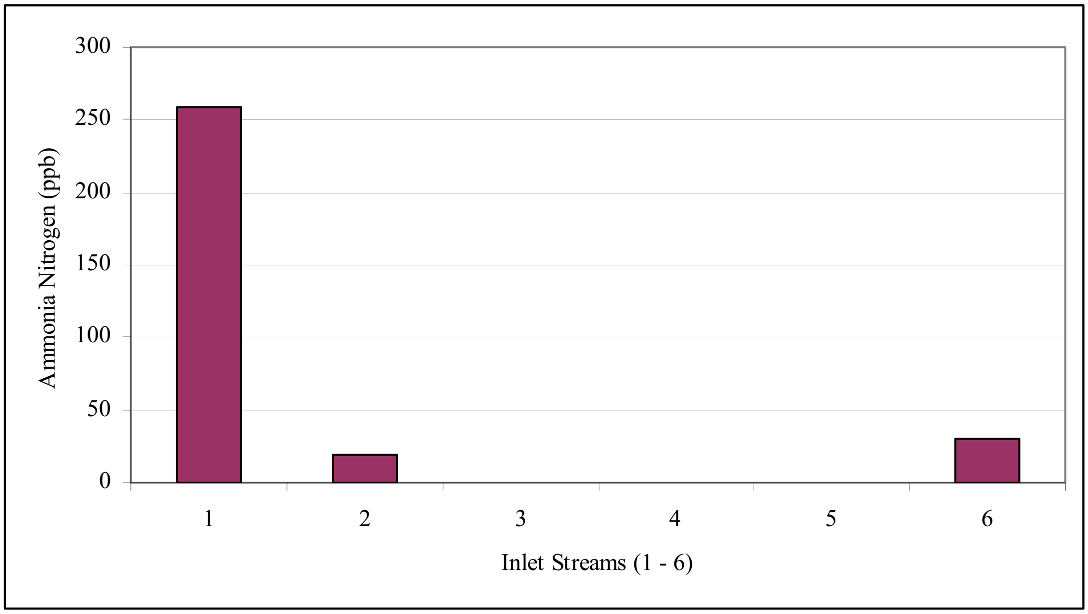


Ammonia Nitrogen

The ammonia nitrogen concentrations in the streams was below detection at streams #3, #4, and #5, and streams #2 and #6 had levels close to the detection limit of <10 ppb. Stream #1 was the only one to show significant levels of ammonia nitrogen, with an average of about 250 ppb.

The storm water sampling detected ammonia at only three sites, Stream #1 with 109 ppb, stream #6 with 29 ppb and storm station S2 with 66 ppb, all other sites had values below the detection limit of < 10 ppb.

Figure 27. Average Stream Ammonia Concentrations For Rogers Lake Inlets, 2002



Nitrate Nitrogen

The nitrate concentrations in the 6 regular streams were generally low, below 50 ppb, except for stream #1 which had an average of 350 ppb. Detectable levels of nitrate were also observed at streams #2, #4, and #6, although these levels were low. The storm sampling revealed a similar high level of nitrate at Stream #1, most other streams and storm sites had low nitrate levels. Storm water sites S5 and S6 showed slightly higher levels.

Figure 28. Average Stream Nitrate Concentrations For Rogers Lake Inlets, 2002

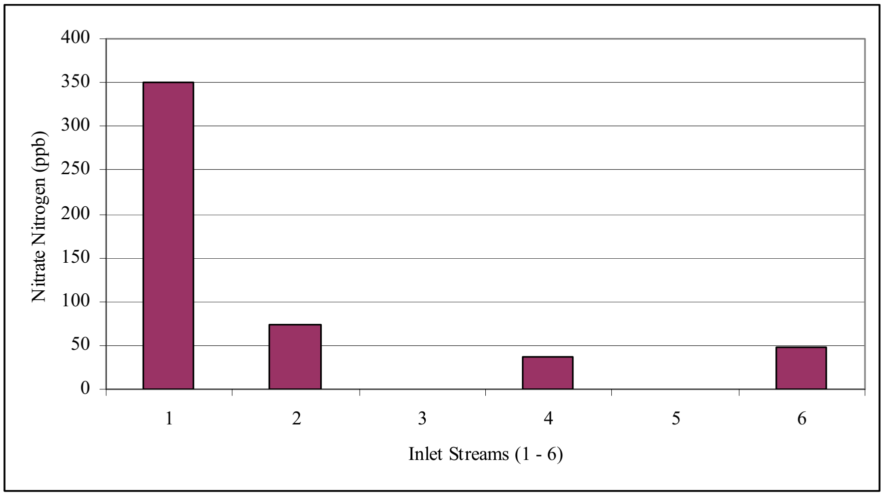
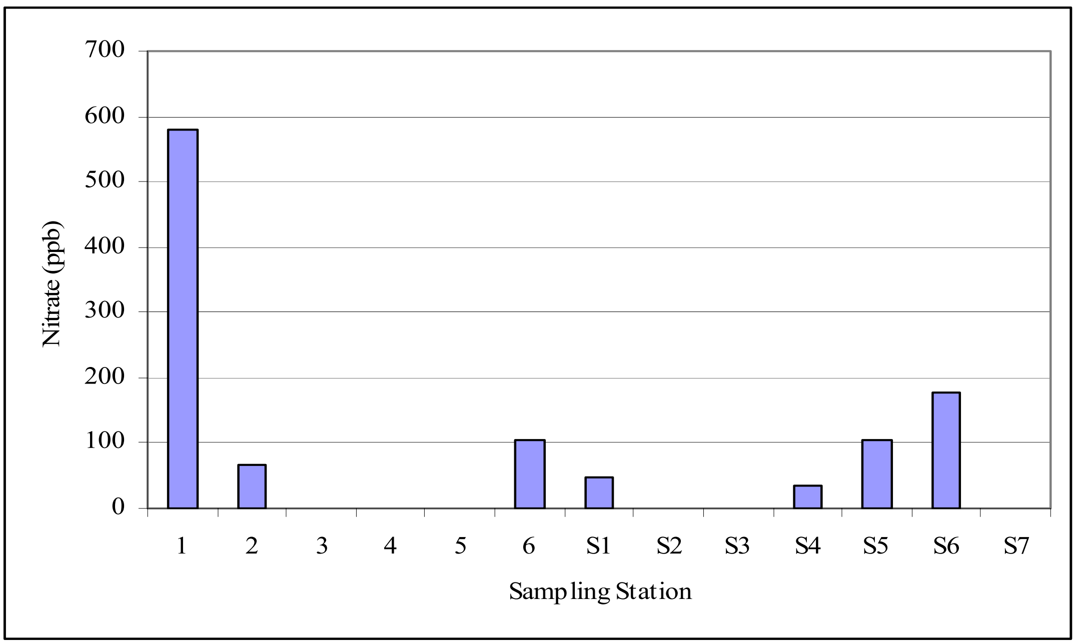


Figure 29. Storm Water Nitrate Concentrations, 12-20-02, Rogers Lake, 2002



Organic Nitrogen

The organic nitrogen levels in the inlet streams varied between a low of 73 to a high of 350 ppb (Figure 30). The highest average organic nitrogen was in Stream #1, but the levels in streams #2, #5 and #6 were each above 200 ppb. These data suggest that loading from these streams especially streams #5 and #6 are high in organic nitrogen due to the large water volumes in those streams. Stream #2 may also present a large source of organic nitrogen to the lake as storm water sampling also showed high nitrogen levels in Stream #2. The storm water data (**Figure 34**) was generally higher than the base flow concentrations to the lake which is to be expected. Interestingly however was that Stream #5 had the lowest organic nitrogen value of all the storm samples collected but had relatively high organic nitrogen in the base flow data.

Figure 30. Average Stream Organic Nitrogen Concentrations For Rogers Lake Inlets, 2002

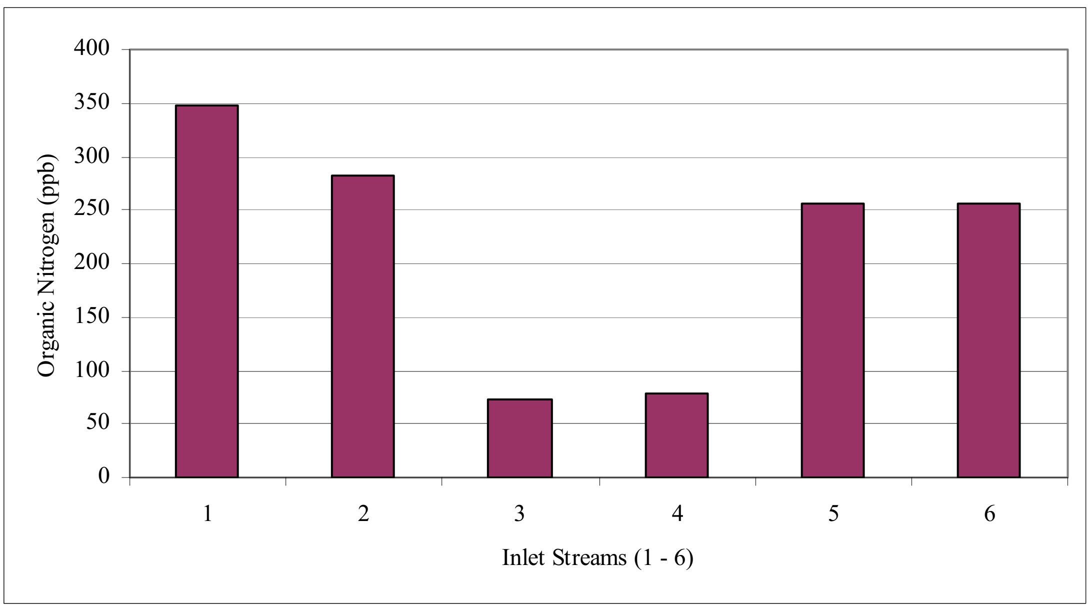
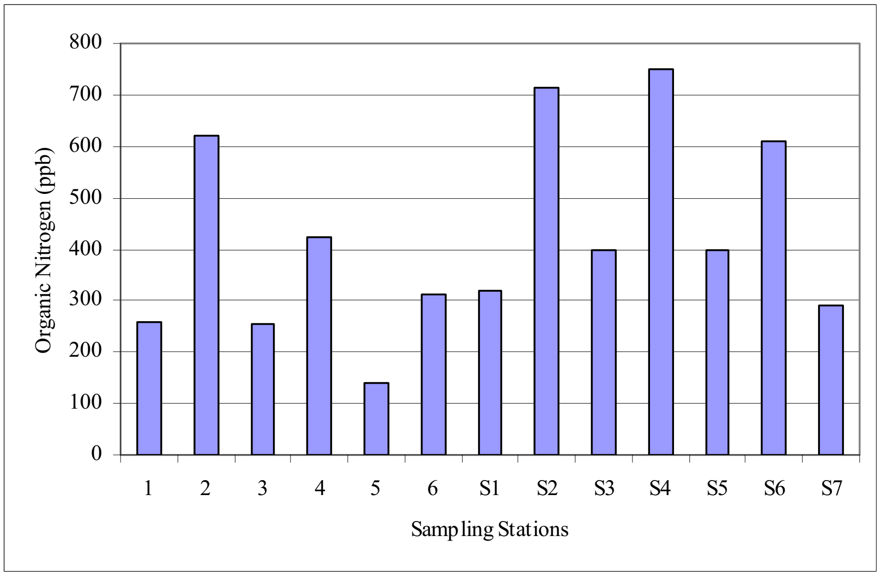


Figure 31. Storm Water Organic Nitrogen Concentrations, 12-20-02, Rogers Lake, 2002



Conductivity, Alkalinity, Turbidity, pH.

The conductivity of the inlet stream water varied between a low of 60 and a high of 160 µmohs/cm (**Figure 32**). The lake conductivity ranged between 61 and 66 µmohs/cm during the year so the baseline inlet water conductivity should remain close to that value. The mean values reported for Stream #5 and Stream #6 were inflated due to higher conductivity levels recorded in September after the streams started flowing again. It is possible that during the dry period salts accumulated in the watershed and were washed off during the rains in September causing slightly higher conductivity readings. The Stream #1 readings were high in each of the samples representing poorer water quality conditions at that site.

The alkalinity of the inlet streams were mostly all within the range of the lake alkalinity values recorded during the 2002 sampling (**Figure 33**). Only Stream #1 had higher than average values. All other streams had alkalinity levels that were consistent with lake values.

Turbidity measurements of the inlet streams showed that most streams were clear with little turbidity in the water (**Figure 34**). Stream #1 had the highest turbidity values due in part to oxidized iron that was present in the stream channel.

Figure 32. Average Conductivity of Streams Entering Rogers Lake, 2002.

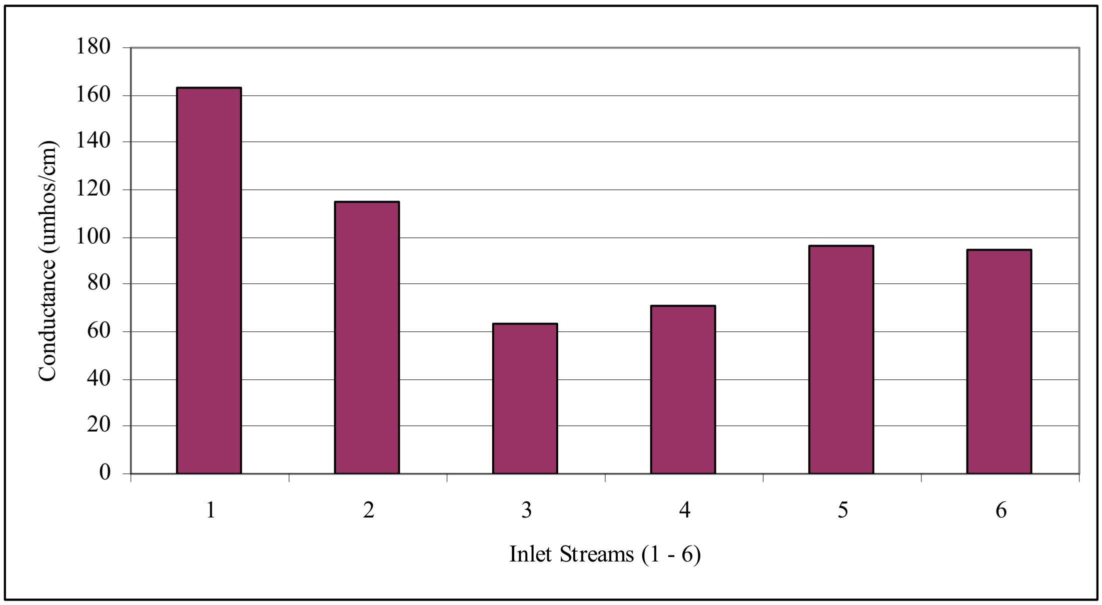


Figure 33. Average Alkalinity of Tributary Streams to Rogers Lake, 2002.

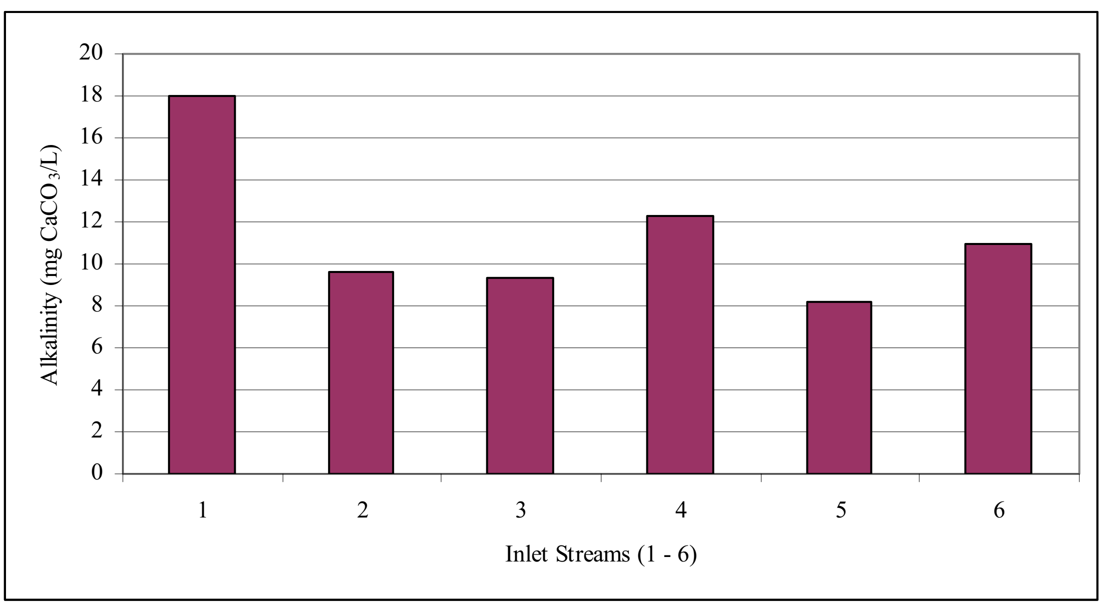
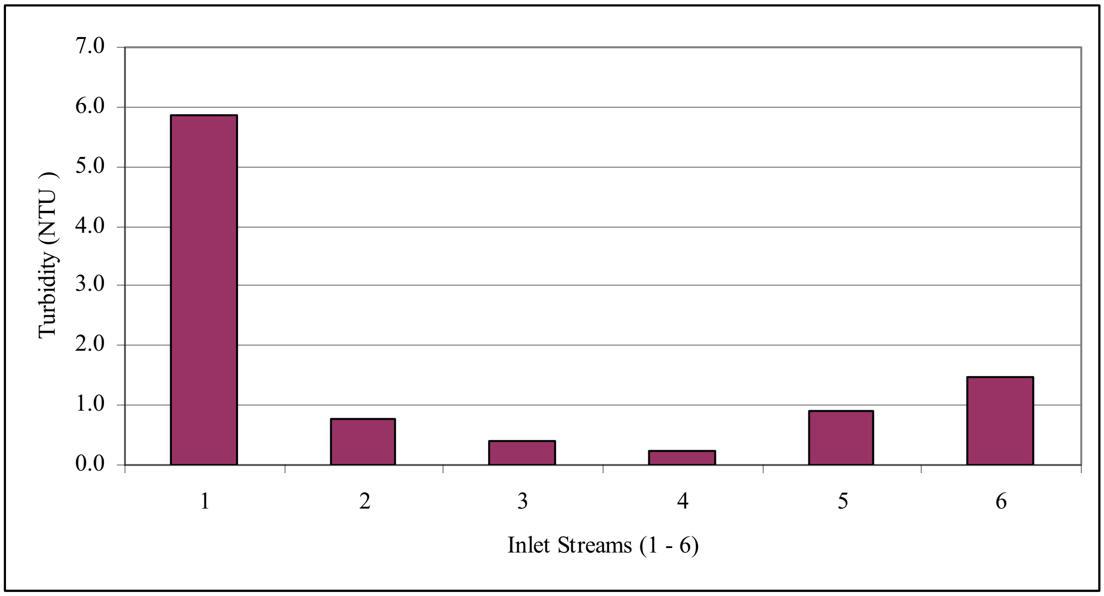


Figure 34. Average Turbidity of Streams Entering Rogers Lake, 2002.



Nutrient Loading

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

In this report, the phosphorus loading to the lake is reviewed using three different methods. The first is the land-use method where the existing land-use is evaluated and phosphorus export coefficients are applied to those uses to estimate an annual phosphorus budget. The second way that phosphorus loading to the lake is estimated is using the spring phosphorus concentration in the lake. This method utilizes the empirical lake relationships derived from studying many different lakes over several regions. Finally, the actual phosphorus runoff data will be used to estimate the total annual load to the lake.

Land Use

The CT DEP (1982) reported the land use of the Rogers Lake drainage basin according to 7 different categories. Frink and Norvell (1984) gave the percentages of the total drainage basin in only three categories; 5.9% urban, 1.3% agricultural, and 92.8% wooded or wet, which were numerically the same percentages as given in CT DEP (1982). The land use fractions were reviewed using the 1990 CT DEP aerial photograph of the Rogers Lake drainage basin and compared to the prior information (**Table 14**).

Table 14. Areas for Different Land Use Categories In Rogers Lake Drainage Basin.

Categories	Area (acres)	%	Area (acres)	%
	DEP 1982		This Study 1990	
Low Density Residential	161	3.3	13	0.3
Moderate Density Residential	126	2.6	38	0.8
Roads and other	~	~	114	2.3
Urban Total	**287**	**5.9**	**217**	**4.5**
Crop Land	63	1.3	91	1.9
Agricultural Total	**63**	**1.3**	**91**	**1.9**
Open land	290	6.0	24	0.5
Wetland	608	12.6	312	6.4
Water	282	5.8	340	7.0
Woodland	3,289	68.2	3,848	79.6
Wooded/Open Total	**4,469**	**92.6**	**4,524**	**93.6**

The percentages of the total drainage basin in the three categories are 5.9% urban, 1.3% agricultural, and 92.6% wooded or wet (using DEP 1982 values). Using the phosphorus runoff coefficients given in Frink and Norvell (1984) for these three land use categories the watershed loading can be estimated. The phosphorus export coefficient from urban land was given as

1.52 lb/acre, for agricultural land 0.48 lb/acre, and for wooded land 0.09 lb/acre. Multiplying through gives; 436 lbs from urban, 30 lbs from agricultural, and 402 lbs for the wooded/open/wet land. Together these sum to 869 lbs per year, or about 394 Kg / year. Using the updated values from the 1990 aerial photography the total load is slightly less at 354 Kg / year. The reason for the decrease between the two years was due to a lower value for the urban land use which went from 287 acres in 1982 to 217 acres in 1990. This may have been a function of better estimation methods employed with GIS mapping today and not due to actual lessening of the urban areas.

Empirical Phosphorus Models

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

Four empirical models were used to estimate the annual phosphorus loading to the lake. These models were: 1) Kirchner and Dillon (1975), 2) Vollenweider (1975), 3) Jones and Bachmann (1976), and 4) Chapra (1975). Each model uses the mean depth, the flushing rate, and a retention coefficient for the fraction of phosphorus that stays in the lake and settles to the bottom. Using a spring phosphorus concentration of 8 ppb from the 2002 data, the results of the models are given in **Table 15**.

Table 15. Results of Empirical Phosphorus Loading Models For Rogers Lake.

Model	**Kg Phosphorus / year**	**Grams P /m²/yr**
	2002 (8 ppb)	
Kirchner and Dillon	205	0.19
Vollenweider	178	0.17
Jones and Bachmann	121	0.11
Chapra	228	0.22
Mean	**183**	**0.17**

The results of the empirical modeling suggest that much less phosphorus is entering the lake than is predicted by the land use estimate. The land use estimate was between 394 and 354 kg/yr (depending on which years land use data is considered). The empirical modeling yielded an average estimate of 183 kg/yr plus or minus 50 kg/yr. Using an empirical model predicts about half the phosphorus load to the lake as does the land-use coefficient method.

The empirical method uses actual data, the spring phosphorus value and calculates the probable load to the lake based on that spring observation. The land use method uses state wide regressions determined by sampling many lakes across the state and developing relationships between the observed lake conditions and the types and quantity of land uses. The land use method may be a good planning tool to compare lakes in Connecticut but it may not be safe to use its estimates of loading as reliable lake specific values. The correlation between phosphorus predicted by land use and that actually observed had an r^2 value of 0.41 which accounts for only 41 percent of the variation (Frink and Norvell 1984). The uncertainty inherent in this model could be assumed to represent a mean value around which year to year variable would fluctuate however, it should not be used to predict the specific loading to Rogers Lake.

Direct Loading Estimates

The inlet phosphorus data collected during this study was also used to estimate the total annual load of phosphorus to the lake. The flow estimates for the period of study were used to calculate the potential load of phosphorus over the same intervals assuming that the average of the two data points represents the average phosphorus and flow during that interval. The total estimated phosphorus runoff during the period of study for each stream is shown in Figure 35, and the total nitrogen runoff is shown in Figure 36. Estimates for load from Stream #1 were close to zero because of the very low flow at that station.

Figure 35. Total Estimated Phosphorus Loading from Tributary Streams During the Period of Study, April – October, 2002.

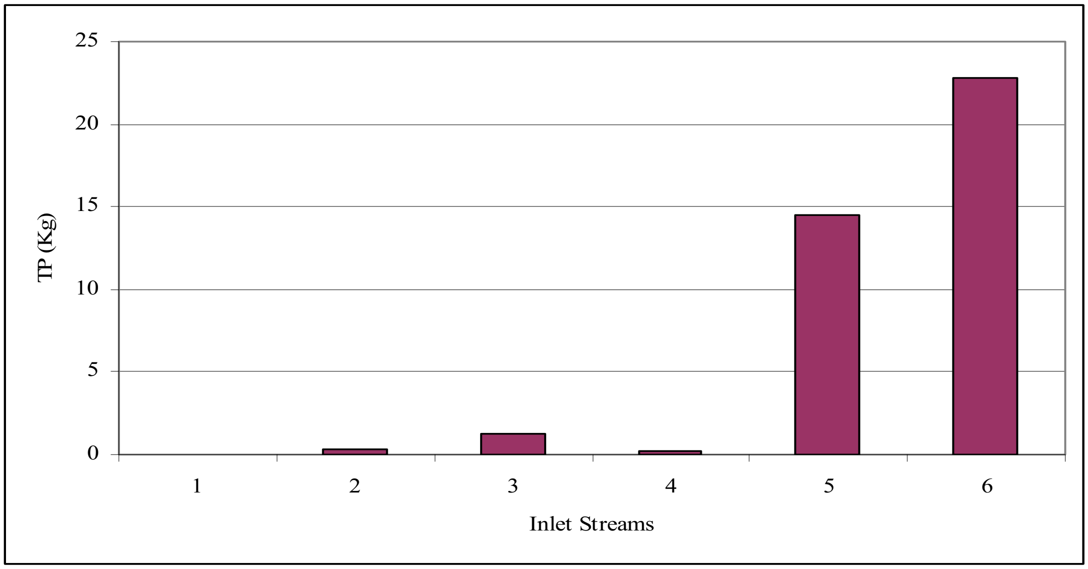
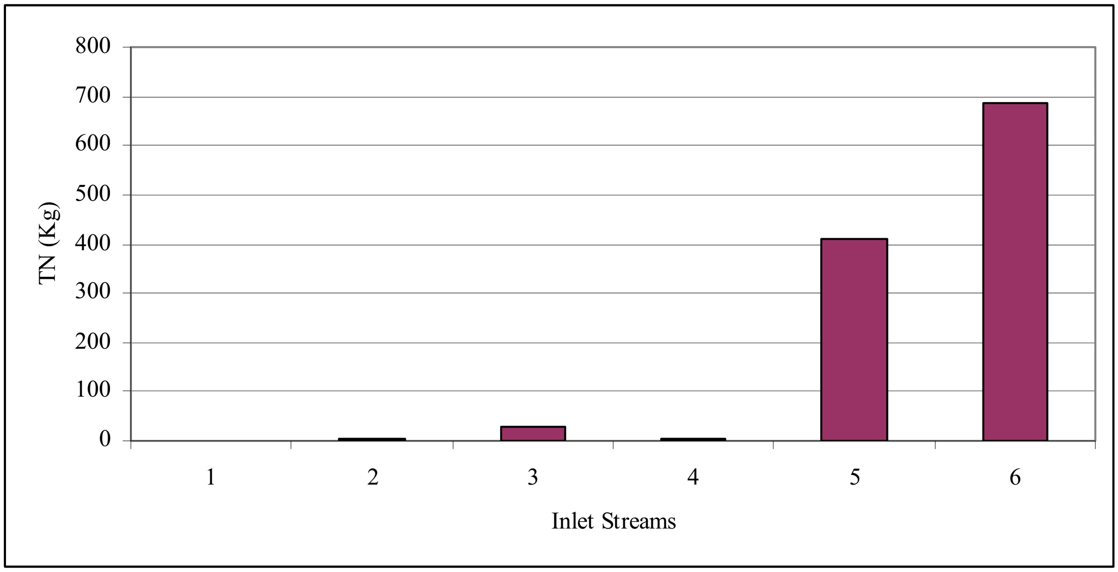


Figure 36. Total Estimated Nitrogen Loading from Tributary Streams During Period of Study, April – October, 2002



The total amount of phosphorus that entered the lake during the study period is estimated at about 40 Kg. The study period was 178 days in length, or about six months in duration. The measured flow during that time was about 3,143 acre-feet or about one third of the total estimated inflow volume of 9,480 acre-feet per year. If these estimates are true estimates of an average year the remaining 6 months of the year would produce a runoff volume of 6,337 acre-feet. The phosphorus load during that period can be estimated using the average phosphorus concentration from the April 2002 and October 2002 data. The average phosphorus concentration of inlet stream water during those two months was 8.5 ppb, if this number is applied to all 6,337 acre feet the resulting load is an additional 66 Kg of phosphorus. Summing the two estimates gives an annual loading to Rogers Lake of about 106 Kg.

Using the same method for nitrogen about 1,140 Kg was discharged to Rogers Lake during the study period. The average stream total nitrogen concentration during the months of April and October was 322 Kg, which would yield about 2,520 Kg of nitrogen during the winter months or about 3,660 Kg for the year. The phosphorus and nitrogen loading estimates are summarized in **Table 16**.

Table 16. Estimates of Annual Phosphorus and Nitrogen Loading To Rogers Lake.

Method	Phosphorus Kg/yr	Grams P /m^2/yr
Land-use 1982	394	0.37
Land-use 1990	354	0.34
Empirical	183	0.17
Direct	106	0.10

The loading of phosphorus can be compared to the both the mean depth of the lake and the combined mean depth and flushing rate to determine whether it exceeds the lakes capacity for that nutrient. In the following two graphs the estimated load of phosphorus to the lake is fit on plots of lake loading thresholds developed by Vollenweider in the 1960s and 1970s. These graphs show oligotrophic and eutrophic thresholds for lakes given their mean depth (**Figure 37**) and water load (**Figure 38**). The first graph shows the three estimates of phosphorus loading to Rogers Lake based on the mean depth alone. In that case the direct loading to the lake was above the oligotrophic level but both the empirical and land use estimates were above the eutrophic threshold. The second graph incorporates the lakes flushing rate into the model which results in a much larger capacity for the lake to absorb nutrients. The graph shows that the direct and empirical loading estimates are below the oligrotrophic threshold and the land use estimate is slightly above the oligrotrophic thershold. This indicates that the high flushing rater may be a critical factor in maintaining the lake in its current high water quality condition. Because the phosphorus concentration of the inlet streams was generally low the drainage basin contributes relatively low amounts of that nutrient to the lake. However, this also suggests that if the levels of phosphorus were to increase in the inlet streams the lake would probably respond by an increase in productivity rather quickly because the lake already receives excess phosphorus based on mean depth only. In other words the lake retains its good qualities because it is flushed twice a year with low phosphorus water. If that were no longer to occur, i.e. if the phosphorus level in the inlet streams were to increase, the lake trophic state would probably be shifted. The model suggests that doubling the phosphorus concentration in the streams to 18 ppb would increase the total annual load to about 200 kg/yr or 0.19 grams $P/m^2/yr$, shifting Rogers Lake to a position above the eutrophic threshold.

Figure 37. Phosphorus Loading To Rogers Lake Fit To Vollenweider's Total Phosphorus and Mean Depth Relationship.

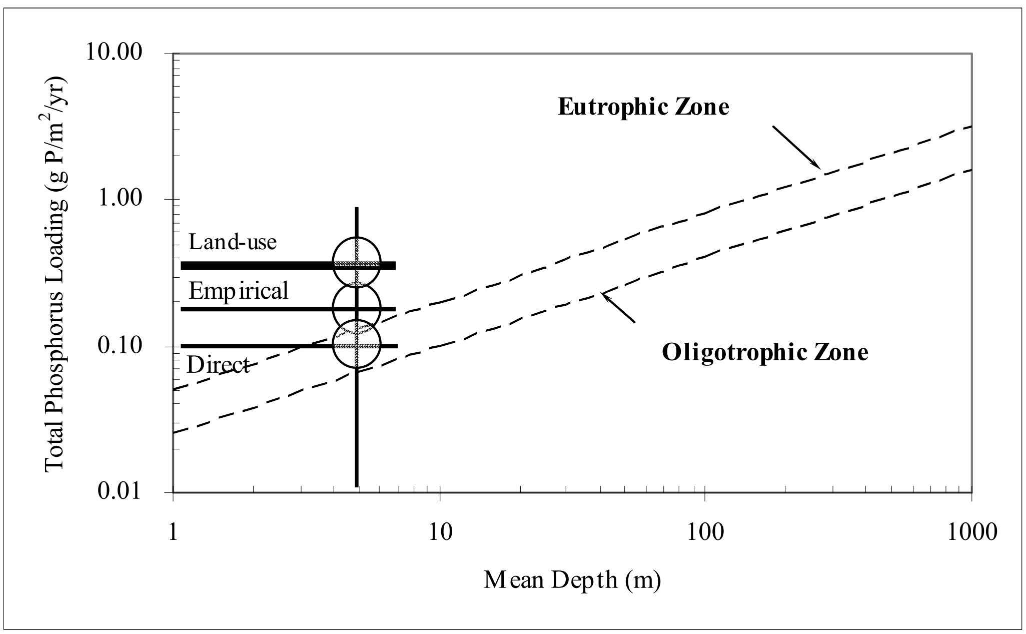
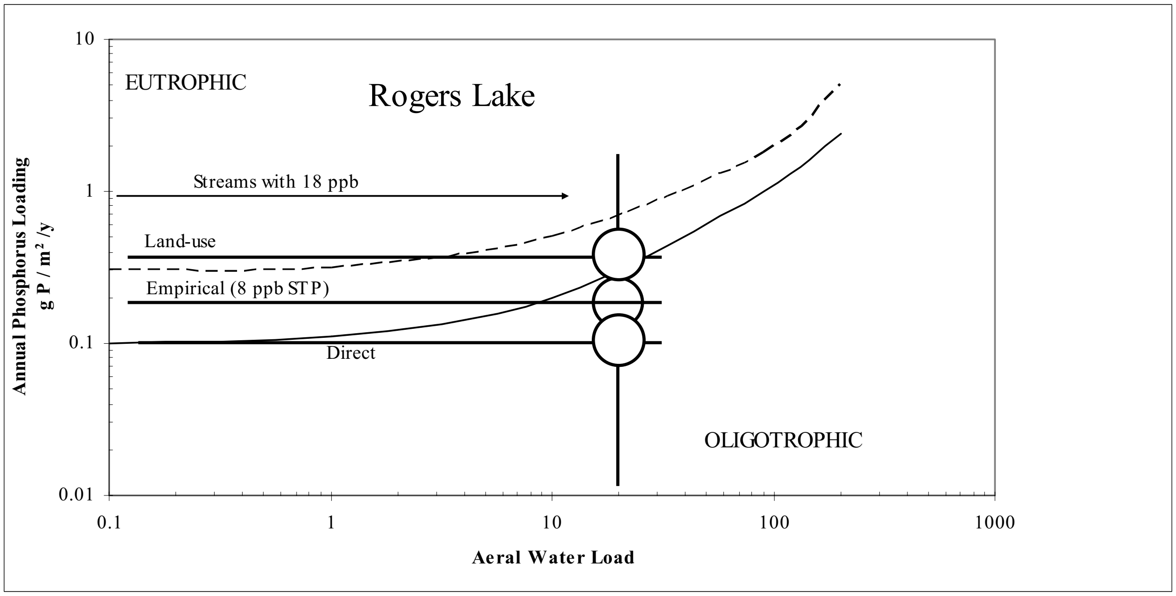


Figure 38. Comparison of the Estimated Total Phosphorus Loading To Rogers Lake and Vollenweider's Permissible and Dangerous Loading Thresholds.


Rogers Lake
EUTROPHIC
OLIGOTROPHIC
Streams with 18 ppb
Land-use
Empirical (8 ppb STP)
Direct
Annual Phosphorus Loading
g P / m2 /y
Aeral Water Load
10
1
0.1
0.01
0.1
1
10
100
1000

Aquatic Vegetation

The aquatic vegetation in Rogers Lake was surveyed on July 25 and September 24, 2002. Aside from general observations and map notations recorded during the survey, most of the data was collected along a series of 16 transects and 90 data points as shown on Appendix 1 – Map 7. The survey was conducted from a 16-foot jonboat equipped with a depth finder and DGPS system. The geographical location of the transect points was recorded with the aid of the DGPS system. At each data point, the water depth, soft sediment depth (in water less than 10-feet), plant density, plant biomass, and observed plant species was recorded. Plant density (cover of plant growth per unit area) was recorded on a scale of 0-4 where, 0 = no plants, 1 = 1-25% cover, 2 = 26-50% cover, 3 = 51-75% and 4 = 76-100% cover. Plant biomass is an index of the overall plant height in the water column and was also recorded on a scale of 0-4 where 0 = no plants, 1 = plants within 1-2 feet of the bottom, 2 = plants about mid-way through the water column, 3 = plants with 1-2 feet of the surface, 4 = plant at the surface.

The following is a list of the plant species found in Rogers Lake during our survey, including species that have been listed in past state inventories at the Lake.

Table 17 - Rogers Lake Vegetation Species List

Species	Symbol	Found in Lake	State List
Watershield (Brasenia schreberi)	B	Y	Y
Water purslane (Ludwigia palustris)	Wp	Y	N

(Ludwigia lacustrus)		N	Y
Coontail (Ceratophyllum demersum)	Cd	Y	N
Muskgrass (Chara echinatum)	Ch	Y	N
Elodea (Elodea canadensis)	E1	Y	N
Waterweed (Elodea nuttallii)	E2	Y	N
Filamentous algae	Fa	Y	N
Variable watermilfoil (Myriophyllum heterophyllum)	Mh	Y	Y
Leafless Milfoil (Myriophyllum tenellum)	Mt	Y	N
Stonewort (Nitella sp.)	Ni	Y	N
Naiad (Najas guadalupensis)	Nj	Y	Y
White waterlilies (Nymphaea odorata)	Ny	Y	Y
Yellow waterlilies (Nuphar variegatum)	Nu	Y	Y
Spotted Pondweed (Potamogeton pulcher)	P1	N	Y
Curlyleaf pondweed (Potamogeton crispus)	Pc	Y	N
Leafy Pondweed (Potamogeton epihydrus)	P2	Y	N
Thinleaf pondweed (Potamogeton bicupulatus)	P3	Y	N
Largeleaf pondweed (Potamogeton amplifolius)	Pa	Y	N
Floating-leaf pondweed (Potamogeton natans)	Pn	Y	Y
Robbins pondweed (Potamogeton robbinsii)	Pr	Y	Y
Burreed (Sparganium sp.)	Sg	Y	Y
Bladderwort (Utricularia gemiscarpa)	U1	Y	N
Bladderwort (Utricularia minor)	U2	Y	N
Bladderwort (Utricularia radiata)	U3	Y	Y

Bladderwort (Utricularia gibba)	U4	Y	N
Bladderwort (Utricularia purpurea)	U5	Y	N
Tapegrass (Vallisneria americana)	V	Y	Y
Pickerelweed (Pontedaria cordata)	Pw	N	Y
Water crowfoot (Ranunculus sp.)		N	Y
Water starwort (Callitriche sp.)		N	Y
Spike-rush (Eleocharis robbinsii)	Er	Y	N
Arrowhead (Sagittaria cristata)	Sc	Y	N
Water-willow (Decadon verticillatus)	D	Y	N

A map of the vegetation assemblage in Rogers Lake is shown in Appendix 1 – Map 8. The following is a narrative description of the different areas and types of vegetation found in the lake. For a more detailed inventory of the vegetation data, refer to Appendix 4 for the survey data sheets.

Area A – These areas exhibit nearly 100% cover of floating leafed plants including white & yellow waterlilies and watershield. Submersed plants were present in sparse to common densities dominated by bladderwort. There were also scattered occurrences of pondweeds, milfoil, and coontail especially in the boat launch cove.

Area B – Generally scattered growth of bladderwort, stonewort, vallisneria and an occasional pondweed. The littoral zone in these areas is generally narrow and steeply sloping. The substrate in a majority of these areas consists of sand and or sand/gravel with a minimal amount of accumulated soft sediment.

Area C – More dense growth (30-60% cover) of varied plant species including bladderwort, pondweeds, waterweed and milfoil. Growth in these areas was generally within 50-100 feet of the shoreline (or 8-10 feet of water depth) with scattered patches of waterlilies. Accumulated soft sediments were more significant than in Area B, with sediment depths ranging from 6-inches to 4-feet.

Area D – Generally sparse growth consisting mostly of stonewort and bladderwort. Substrates in this area exhibited more sand and gravel.

Area E – Common growth (30-60% cover) of a variety of submersed weeds including pondweeds, bladderwort, and milfoil. These areas bordered the " more shallow" waters dividing the two northern deep basins of the lake. Plant growth reached further from the shore, especially along the northern shoreline where there was a sizeable shoal or ridge extending out from the shore.

Area F – A sizeable cove area with water depths generally 8-feet or less. Vegetation was dominated by naiad and bladderwort with lesser amounts of milfoil and pondweeds. Scattered waterlilies were evident around the perimeter of the cove with some " pioneering" areas in deeper waters. Soft sediment was minimal in shallow waters but more significant in the middle of the cove.

Area G – An area of deeper water bordering Area F, which exhibited a sparse growth of bladderwort and naiad.

Area H – More shallow water bordering the southern end of the lake's deepest basin. Water depths in this areas ranged from 5-10 feet with varying amounts of soft sediment. Plant cover was generally in the range of 25-50% cover and consisted of a mixed variety of plants including pondweeds, naiad, milfoil, bladderwort, nitella, tapegrass, and scattered filamentous algae.

Area I - Clearly the most widespread shallow area in the lake, water depths generally ranged from 3-6 feet here. Plant growth was dense (50-100%) cover was dominated by variable milfoil and large-leaf pondweed. Growth of these plants was with in 1-2 feet of the surface in a majority of this area. Along the bottom in most of this area was a heavy growth of naiad and bladderwort. Scattered pondweeds were also observed here.

Area J – Dense growth similar to Area I, but dominated by naiad, nitella, and bladderwort with only scattered occurrences of milfoil and pondweed. Sediment depths in this area were significant and ranged from 1 to greater than 10-feet.

Vegetation Summary

There existed a wide variety of aquatic and emergent vegetation in Rogers Lake. For the most part, dense vegetation was located in water depths of 6-8 feet or less. The most abundant vegetation was located in cove areas and in the extensive shallow " zone" in the center of the lake near the islands adjacent to the Grassy Hill Brook inlet. Much of the shoreline around the deep basins is steeply sloped and usually contained fairly inhospitable growing substrate. As shown in the map, there were sizeable areas in between the deep basins where the littoral zone (the shallow water areas of the lake were plants grow) extended further from the shoreline.

Undoubtedly, the most problematic area and the one which is reportedly most bothersome to the users of the lake, is the extensive central shallow area. Water depths in this area were mostly 6 feet or less and stretch across the entire width of the lake. Organic deposits were also heavy in many of these areas.

Aside from a single occurrence of curly-leaf pondweed (Potamogeton crispus) the only other non-native species of plant found in the lake is variable watermilfoil (Myriophyllum heterophyllum). Although this plant is very invasive, it seems to co-exist well with native plants in the lake at this time. Fortunately, other invasive like fanwort (Cabomba caroliniana) and Eurasian watermilfoil (Myriophyllum spicatum) have not found their way into the lake, despite the heavy recreational usage and public access. When looking at vegetation management, it will be important to initiate some level of management for the variable watermilfoil and increase the level of protection against other potentially invasive species.

Some areas of floating leaf plants (mostly waterlilies and watershield) appear to be problematic in terms of access to the lake for homeowners. Some management of these areas is warranted and discussed in the following sections.

Sediment Survey

A survey of three cove areas (west inlet cove, south inlet cove and Grassy Pond Brook inlet cove) was conducted on November 20, 2002. A map of the data points is shown in Appendix 1 – Map 9. At each data point, which was located using a DGPS system, the water and soft sediment depth was measured. The sediment type was also described.

Using the sediment depth data and overall surface areas investigated, we came up with an approximate sediment volume in each area. Samples were also collected from each area and tested for Total organic carbon, % solids, and grain size. The following table shows the approximate soft sediment volumes in each of the areas.

Table 18 - Approximate Calculated Sediment Volumes

Area	Area (acres)	Sediment Volume (yd^3)
West Inlet (Area #1)	0.75	2,662
Grassy Hill Brook Inlet (Area #3)	4.3	15,262
South Inlet (Area #2)	0.7	2,484

The following is the results of the lab analysis conducted on the samples collected at each of the coves. Each sample was a composite from at least three " grabs" using an Eckman dredge sampling device.

Table 19 - Sediment Analysis Results

Area	Total Organic Carbon	% Solids	Grain Size							Silt/Clay Fraction	
			#10	#20	#40	#70	#100	#200	All	% Silt	% clay
1	16.1	10.7	0	0	3	18	29	27	23	0	23
2	1.18	67	0	0	27	23	22	21	6	0	6
3	6.48	42	0	0	40	32	16	8	3	0	3

FEASIBILTY ASSESSMENT

Existing Problems & Management Objectives

Rogers Lake is a heavily used recreational waterbody with fairly dense residential development along its shoreline. The results of the diagnostic assessment show that although there are a number of noticeable deficiencies in the condition of the lake, there is no one major problem facing the Town and lake residents at this time. The water quality of the lake stands in fairly good condition, with levels of phosphorus in the oligotrophic range and levels of nitrogen in the meso-oligotrophic range. Modeling shows the lake is potentially susceptible to changes in water quality if land use and other factors change the loading of nutrients to the lake. Given the large proportion of forested land cover in the watershed, protection should be a paramount concern to the Town' s residents.

Even with the favorable water quality, rooted plant growth is a problem in some areas of the lake. Most noticeable is the shallow area in the center of the lake, but several other cove areas also exhibit nuisance levels of weed growth. Rogers Lake currently has an excellent fishery and special care should be made to maintain suitable levels of residential growth while reducing weed growth in high-use residential areas of the lake.

This feasibility assessment begins with a discussion of watershed management. As mentioned above, the focus of watershed management should be on protection, but care should also be taken to reduce loading from existing sources as well. The watershed management options are broken down into *Source Reduction* and *Transport Mitigation*.

Watershed Management Options

Many of these watershed management options rely on a working knowledge of the current Town(s) regulations pertaining to development, planning, conservation and health standards.

We would encourage the Lake Association to meet with the various boards and commissions in both Towns to begin a dialogue regarding the management of Rogers Lake. A review of the current regulations and by-laws in each town will be important to ascertain where improvements can be made and to ensure consistency between the various municipalities in the lake's watershed.

Source Reduction

Agricultural Best Management Practices

Agricultural Best Management Practices (BMPs) incorporate techniques in forestry, animal science, and crop science to minimize adverse impacts to water resources. This management approach actually relies upon a combination of techniques in source reduction and transport mitigation. Such practices include manure management, fertilizer management, use of cover crops, and use of buffer zones. The use of agricultural BMP's is recommended in the Rogers Lake watershed. However, the extent of agricultural activities in this watershed is small at this time. This is a protective measure to be encouraged, but not a major factor in current lake condition. A more extensive inventory and review of the current agricultural uses in the watershed with the assistance of the UCONN Extension Service and the CT Agricultural Station should be considered.

Bank and Slope Stabilization

Erosion control is an important component of an overall management plan designed to decrease pollutant loading to aquatic ecosystems. This is especially important in areas of new development, where soils are both exposed and susceptible to erosion. Other critical areas include riparian zones and stream banks. This is a recommended management technique in the Rogers Lake watershed, as a matter of protection, but there are no known areas of severe erosion at this time. Specifically, a review of the current Towns' regulations regarding erosion control measures should be reviewed and improved where appropriate to

Behavioral Modifications

Behavioral modifications involve changing the actions of watershed residents and lake users to improve water quality. Such changes may include elimination of garbage grinders, limits on lawn fertilization, and eliminating illegal dumping in roadways and watercourses. Behavioral modifications can be brought about in two principal ways, through public education and/or the implementation of local bylaws and bans. Education is a critical first step and should precede any attempt at regulation.

Public education can be accomplished by mailing an informative brochure on watershed management to all residents in the watershed, through the use of video programs on local access television, by placing informative billboards in high access areas, or by holding public meetings for watershed residents. Public education relies heavily upon cooperation from residents and other lake users, and is not likely to result in major improvements in water quality by itself. However, some level of improvement has been noted in other studies and the education process sets the stage for community involvement and cooperation. Public education is a recommended management technique for Rogers Lake.

The focus of education and behavioral modifications in this watershed should be on fertilizer use everywhere and on septic system management in the direct drainage areas around the lake. It would be wise to emphasize the role of development and associated water quality controls in affecting lake quality as well. Some example educational handouts and an example brochure are included as Appendix 5.

Waste Water Management

A properly functioning on-site waste disposal system (e.g., septic system) can be an effective means of reducing pollutant loading to an aquatic ecosystem. Of particular concern are those systems where septic effluent is breaking-out above ground and is transported to the lake or a tributary during storm events. All of the homes around Rogers Lake are on private waste disposal systems. No detailed wastewater inventory was conducted during this investigation, but further evaluation is warranted, possibly including a septic survey.

Maintenance and inspection of on-site waste disposal systems is a recommended management technique for the Rogers Lake watershed. Education is the first step in alerting residents to this need. The Town of Lyme currently monitors pumping frequency for properties around the Lake and such an ordinance should be considered lake-wide (if not already in effect). Further monitoring and evaluation, including a review of the local health regulations regarding private systems should be performed.

Zoning and Land Use Planning

This is a very important component in controlling watershed inputs to aquatic resources. A strong relationship exists between land use type and pollutant generation, with developed lands (including agriculture) typically generating greater pollutant loads than non-developed lands. Preserving undeveloped land in the Rogers Lake watershed is highly recommended, with particular emphasis on preserving areas of land that form buffer zones along the lake and its tributaries. The zoning laws of all towns within the watershed should be reviewed with maintenance of buffer strips in mind. While current conditions in Rogers Lake are not optimal, water quality is certainly acceptable for most uses and increased pollutant loading could lead to much more severe degradation.

Transport Mitigation

To fully establish the applicability of the following transport mitigation measures, a more detailed stormwater drainage survey should be conducted to identify specific problem areas in the watershed where nutrients are entering the lake.

Buffer Strips

Buffer strips (or vegetated filter strips or grassed buffers) are areas of grass or other dense vegetation that separate a waterway from an intensive land use. These vegetated strips allow overland flow to pass through vegetation that filters out some percentage of the particulates and decreases the velocity of the storm water. Particulate settling and infiltration of water often occurs as the stormwater passes through the vegetation. Buffer strips need to be at least 25 ft wide before any appreciable benefit is derived, and superior removal requires a width >100 ft.

This can create land use conflicts, but creative planting and use of buffer strips can be a low cost, low impact means to minimize inputs to the aquatic environment. This management technique is highly recommended for the Rogers Lake watershed.

Catch Basins with Sumps and Hoods

Deep sump catch basins equipped with hooded outlets can be installed as part of a storm water conveyance system. Deep sumps provide capacity for sediment accumulation and hooded outlets prevent discharge of floatables (including non-aqueous phase hydrocarbons). Catch basins are usually installed as pre-treatment for other BMP' s and are not generally considered adequate storm water treatment as a sole system. Volume and outlet configuration are key features which maximize particle capture, but it is rare that more than the coarsest fraction of the sediment/pollutant load is removed by these devices. This management technique is recommended for Rogers Lake, where applicable. The fairly good stormwater quality does not warrant serious consideration of upgrading current basins, but rather for the installations of new systems.

Created Wetlands

Created wetlands are shallow pools that create conditions suitable for the growth of marsh or wetland plants. These systems maximize pollutant removal through vegetative filtration, nutrient uptake, soil binding, bacterial decomposition, and enhanced settling. Alternatively, a treatment system may combine created wetlands with detention ponds. Created wetlands are suitable for on-line or off-line treatment (assuming maintenance of adequate hydrology with off-line systems to support the wetland). This technique is recommended for the watershed of Rogers Lake in association with any new development. Natural wetlands already fulfill this function in some areas, but the capacity of existing wetlands should not be assigned to new development projects.

Detention

Detention ponds are essentially basins that are designed to hold a portion of storm water runoff for at least 12-24 hours. Pollutant removal is accomplished mainly through settling and biological uptake. Wet detention ponds are more effective than dry detention ponds as the latter have a greater risk of sediment re-suspension and generally do not provide adequate soluble pollutant removal. Although effective, the land requirement is typically large. If adequate parcels can be acquired, this is a desirable approach. The area should be at least 2% of the drainage area it serves, and preferably as much as 10% of that area.

Infiltration Systems

Infiltration systems may include trenches, basins or dry wells, and involve the passage of water into the soil or an artificial medium. Particles are filtered by the soil matrix and many soluble compounds are adsorbed to soil particles. Such systems require sufficient storage capacity to permit the gradual infiltration of runoff. Pre-treatment of the runoff allows larger particles to be removed, thereby aiding in the prevention of infiltration system failure due to clogging and sediment accumulation.

Site constraints such as shallow depth to groundwater table or bedrock and poorly drained soils often limit the effective use of infiltration. In sites with suitable conditions, off-line infiltration systems are generally preferred. The key to successful infiltration is providing adequate pre-infiltration settling time or other treatment to remove particles which could clog the interface at which infiltration occurs. This is a recommended management technique for new development in the Rogers Lake watershed in areas with appropriate soils and ground water elevations.

Each chosen site must be carefully evaluated for soil strata and permeability, much the way one would evaluate an area for a septic system. As residences in the area have functioning septic systems, it may indeed be possible to infiltrate a significant fraction of the runoff now discharged directly to the lake. The key will be isolating the first flush, the portion with which most pollutants are associated, and providing adequate infiltration capacity over a reasonable time period (a day or two). As infiltration can occur in subsurface chambers, no major impact to surface uses is necessary.

Oil/Grit Chambers

A number of oil/grit chamber designs are currently on the market. These self-contained units include an initial settling chamber for sediment removal, typically have hooded internal passages to remove oil and other floatables, and often incorporate some form of outlet pool to control exit velocity. Several rely on a vortex design to enhance sediment removal (e.g., Vortechnics, Storm Defender). Such systems are most applicable as pre-treatment for other

BMPs, and are generally well suited as retrofits for relatively small areas in developed watersheds. Installing these devices as off-line systems may enhance pollutant removal, but their more common use as on-line pre-treatment devices can be very beneficial. This is a recommended management technique for the Rogers Lake watershed in combination with infiltration technologies.

Street Sweeping/Catch Basin Cleaning

Removal of pollutants before they are washed into Rogers Lake could be accomplished by frequent street sweeping and catch basin cleaning. Both techniques provide only limited benefits by themselves, but could be effective tools in combination with other Best Management Practices. Truly effective street sweeping is accomplished with vacuum equipment, which costs in excess of $100,000/vehicular unit. Maintenance costs can also be substantial. Catch basin cleaning should be a semi-annual activity in any developed area, but rarely is; restoration of catch basin capacity is essential to the proper function of storm-water drainage systems, and costs about $50/catch basin per year when basins are cleaned on a bulk basis. Street sweeping and catch basin cleaning are recommended management techniques for the Rogers Lake watershed, as part of normal road maintenance and storm water drainage system management, but neither can be counted on as a primary pollutant control technique.

In-Lake Management Options

There are a number of different in-lake management techniques that can be used address problems like nuisance weed growth identified in the diagnostic assessment. Generally, these methods are broken down into mechanical, physical, chemical and biological techniques. The selection of appropriate techniques is based on the severity of the problem and the potential benefit to be provided, taking into account cost, permitting and disruption to the lake and its users.

Over the years, several different management techniques have been applied at Rogers Lake, but without the benefit of an overall plan to guide and monitor the activities. Reportedly some harvesting has been conducted, both with and without cut plant collection, as well as some limited hydro-raking. The lake has also undergone periodic winter drawdown to a depth of 18" , however there has been some difficulty with reduction of nearby well yields.

The following is a discussion of the available in-lake management options as they will (or will not) apply to Rogers Lake. Naturally, due to past experience and through the course of the diagnostic assessment, several management techniques have been identified as being likely to provide the most benefit to Rogers Lake.

Mechanical Methods

Mechanical methods include harvesting, hydro-raking and dredging. Removal of the targeted plants is achieved by mechanically cutting the plant foliage, or in the case of hydro-raking, by raking the bottom and removing the plants by their root systems. In both cases, the plant material is collected and deposited at designated off-loading areas for permanent disposal in an upland location.

Given the extent and location of the infestation at Rogers Lake, any mechanical harvesting/hydro-raking program targeting the majority of nuisance weed growth would be a sizeable and costly undertaking. Additionally, given the invasive nature of the non-native species of variable milfoil and the fact that milfoil propagates primarily through vegetative fragmentation, any such undertaking could potentially exacerbate the spread of this plant while only achieving short-term control (potentially as little as 1 month). Mechanical methods, conducted on a smaller scale, however do provide a viable alternative to chemical treatment and, if performed in a timely manner, could provide reasonable control of the targeted weeds in priority areas.

Harvesting

Cutting and removing the nuisance vegetation would be one way to maintain open-water conditions in selected areas of Rogers Lake. Mechanical harvesters are paddle wheel driven barges equipped with a depth-adjustable cutting head and a conveyor-mesh storage area. Weeds are cut near the sediment water interface (typically a maximum of 6-7 feet beneath the water surface) and collected on the barge for transport to a temporary on-shore disposal or transfer location. From the harvester, weeds can either be loaded directly into dump trucks or onto trailers with a shore or trailer-conveyor, or the weeds can be temporarily deposited on shore and then loaded into trucks with a backhoe or loader. While mechanical harvesting does not often carry some of the negative stigmas associated with chemicals, its cost-effectiveness does not often compare favorably with herbicide use. Harvesting submersed, perennial plants can be likened to " mowing the lawn," with some plant re-growth expected in the same season (requiring a second cutting) and a return to pre-harvesting conditions by the following year. Waterlilies generally re-grow to the surface within a few weeks of being harvested. Largeleaf pondweed, which is present in considerable density in the center of the lake, responds fairly well to harvesting because it is a seed bearing plant.

Harvesting is often discouraged in waterbodies that have non-native submersed plants like milfoil that can be spread through vegetative fragmentation. Milfoil is fairly well distributed throughout the lake, however density is fairly low except for the shallow center of the lake. Another benefit of harvesting is the removal of tons of organic material from the pond. Nutrient removal via harvesting, however, is rarely sufficient to overcome annual watershed nutrient inputs or the vast nutrient reserves contained in the lake sediment.

Harvester efficiency is largely dependent upon the travel distance to the temporary shoreline disposal/transfer sites. The State Boat Launch on the eastern shoreline of the lake is the most accessible site for launching and retrieval of the machine, and one good location to stockpile or transfer harvested vegetation. Other suitable locations should be found at different points around the shoreline. If a suitable off-loading site cannot be identified in each major area of harvesting, the efficiency of the operation will be significantly reduced which may, in the extreme case, require a second machine to act as a transport barge. For a moderate to large harvesting machine (e.g. Aquamarine H7-400), harvesting productivity at Rogers Lake should average about 0.3-acres/hour or roughly 2.0 acres per day, assuming 6-8 hours each workday are actual operating hours. While two separate cuttings might be required to maintain desirable open-water conditions for the entire summer; one mid-summer harvest should greatly improve conditions for a good portion of the season.

The central portion of the lake, where weed growth is greatest, totals about 50-acres. Based on this acreage, estimated costs to have a private contractor perform the work would be $600/acre per cutting including or $30,000. If one of the Towns were to handle the loading and trucking/disposal operation, this cost would be reduced by about 25-33%. Again, harvesting of this area, would not be the preferred method of control, however the above costs provide a good comparison to other techniques like chemical treatment.

Hydro-Raking

A mechanical hydro-rake removes plants by digging through the sediments and pulling plants out by their root structures. It is very effective for controlling emergent or floating-leafed plants with well-defined root systems. It is less effective on submersed plants; especially ones that reproduce vegetatively like milfoil. Hydro-raking may be suitable at Rogers Lake to clear shoreline access areas or for area-selective removal of waterlilies and their root mats. Hydro-raking would not be a cost-effective alternative to maintain open water conditions throughout large portions of the Lake.

The machine is best described as a floating backhoe equipped with a York rake attachment. The barge is propelled by paddle wheels to facilitate its operation into shallow water (2 feet) areas. There is no on-board storage on the hydro-rake, which requires each rake full of material to be deposited directly on shore or onto an awaiting transport barge. Hydro-raking work is usually contracted out hourly, plus an equipment mobilization change and costs to remove raked material from the temporary on-shore disposal site to a permanent upland location. Approximate unit costs run $2,500-$6,000 per acre, depending upon the type of vegetation, equipment requirements and the size of the area being cleared.

Hydro-raking is recommended at Rogers Lake, for two different applications. First, the Hydro-Rake can be used to remove waterlilies and clean waterfront areas in selected portions of the lake. The machine can be contracted by the Town and/or private residents. The Town could coordinate raking in common areas of the lake, including public parks and the boat ramp. The Town would also be the logical choice to coordinate work to open up channels in cove areas such as the Grassy Hill Brook inlet. Individual homeowners also contract for hydro-raking on an hourly basis and split the lump sum equipment mobilization cost amongst the participants. Depending on the size of the overall project, the hourly rate for the Hydro-Rake and operator will be in the range of $150-175/hour. The mobilization charge is generally $800-$1,000.

Contracting is typically handled with a " Sign-Up Form" (See Appendix 6) in which the homeowner can sign-up for a certain number of hours and provide a description of their waterfront and where they would like the work performed. Generally, the rake can effectively clean a 75 x 50 foot area in 1-2 hours. The raked material is deposited along each shore, unless arrangements can be made to establish a centralized disposal location. If such a location is chosen away from the work area, a transport barge may be required to maintain the productivity of the operation, as the Hydro-Rake has no onboard storage itself. Additionally, fragment barriers may need to be deployed around some or all of the work areas to prevent fragmentation and spread of floating plant material.

Physical Methods

Most physical methods attempt an alteration of the growing environment to achieve control of nuisance plant growth. Among the techniques available are water-level manipulation (drawdown), dredging, bottom barriers, dyes and aeration.

Drawdown

The ability to perform drawdown successfully is a factor of the lake morphology, hydrology, outlet structure and plant composition. The key to a successful drawdown is a prolonged and sustained drying and freezing of the lake bottom that supports nuisance plant growth. A minimum time interval for a sustained drawdown of 6-8 weeks is recommended. Drawdown should commence in early October with the refill to commence during sometime before the end of January. In northern lakes, both of these conditions can occur as long as there is not either an early snow to provide insulation or significant groundwater seepage to prevent drying. Even under the best conditions, significant re-infestation may occur from existing seed beds and areas of growth not reached or effected by the drawdown.

Some of the undesirable effects of drawdown include loss of desirable species of plants and infestation of drawdown resistant non-desirable plants. One way to reduce the re-infestation from undesirable species is to conduct drawdown only once every 2-3 years. There are also potential impacts to fish and other non-target organisms including reduced cover and food sources for waterfowl, loss of dissolved oxygen and possible fishkills, altered littoral habitat for fish and invertebrates and mortality of hibernating amphibians and reptiles. Other factors to consider are impacts to adjacent wetlands, shoreline erosion, adverse effects on nearby water supplies (i.e. shallow wells) and downstream flow impacts. Many of these impacts require further study and some could possibly be minimized by proper planning.

In terms of plant composition, not all species are susceptible to drawdown. Table 20 shows the effect of drawdown on some common aquatic plants. Generally, plants that grow from seed, like largeleaf pondweed are only marginally susceptible if at all. Plants with significant root structures, like waterlilies and perennial plants like milfoil are controlled fairly well with drawdown.

Drawdown has been used to some degree on Rogers Lake for rooted plant control, to prevent ice damage and to allow for repair of docks and shoreline areas. Reportedly, the lake has only been taken down 18" in the recent past, because of private water supply concerns. Most of the homes around Rogers Lake are serviced by relatively shallow wells near the shoreline and are therefore under the influence of surface water from Rogers Lake. For this reason alone, drawdown is unlikely to be a useful tool for nuisance weeds management at Rogers Lake.

The outlet structure at Rogers Lake also limits the amount of drawdown based on the change in elevation over the dam, and the location of the low-level outlet. The spillway itself is formed from concrete and stone and there is no board control apparatus. The low-level outlet pipe allows for only a 3-4 foot drawdown without a considerable amount of re-design. The Town of Old Lyme owns the dam and we have not seen any detailed plans for the structure. Given the limitations to drawdown, we do not recommend pursuing a more extensive drawdown of Rogers Lake at this time. We do however recommend that the limited drawdown of 18" be continued as long as effects on private water supplies are minimal. Such a limited drawdown will serve well to minimize plant growth right along the shoreline and allow residents to perform limited clean-up of their waterfronts and dock repairs.

Table 20 - Effects of Drawdown on 19 Common Aquatic Plants*

Species that usually increase	alligator weed (*Alternanthera philoxerides*)
	hydrilla (*Hydrilla verticillata*)
	cutgrass (*Leersia oryzoides*)
	bushy pondweed (*Najas flexilis*)
	smartweed (*Polygonum coccineum*)
	leafy pondweed (*Potamogeton epihydrous*)
	softstem bullrush (*Scirpus validus*)
Species that usually decrease	watershield (*Brasenia schreberi*)

	fanwort (*Cabomba caroliniana*)
	coontail (*Ceratophyllum demersum*)
	Brazilian elodea (*Elodea densa)*
	milfoil (*Myriophyllum spp.*)
	southern naiad (*Najas guadalupensis*)
	yellow water lily (*Nuphar spp.*)
	water lily (*Nymphaea odorata*)
	Robbins's pondweed (*Potamogeton robbinsii*)
Species that do not change or have variable response	water hyacinth (*Eichhornia crassipes*)
	elodea (*Elodea canadensis*)
	cattail (*Typha latifolia*)
	Largeleaf pondweed (Potamogeton amplifolius)

* Based on Table from "Restoration and Management of Lakes and Reservoirs" by Cooke et.al. (See references for bibliographic information)

Bottom Barriers

Bottom weed barriers are only beneficial for small applications around beach, swim or dock areas. Larger scale applications become cost prohibitive (>$25,000 per acre for material alone) and would prevent necessary interactions with the bottom sediments by benthic macroinvertebrates and other aquatic organisms. Individual lakefront owners may want to consider bottom barriers, but their widespread use is not recommended at Rogers Lake.

There are several types of weed barrier available for use. The two most common types are a PVC coated screening (Aquascreen) and a more traditional non-pourous PVC sheeting. Small apertures in the material allow for benthic gases to escape through the material and prevent billowing. Unit costs for the screening barrier type can be nearly twice the cost of traditional screening, which is in the range of $0.40-0.60 per square foot. Installation typically involves laying and weighing down the material. Deeper applications may require trained divers to install. Installation, if performed by profession can add 33-50% to the material cost.

Dredging

Removing nutrient rich sediments and deepening waterbodies is sometimes used to control nuisance aquatic vegetation. This would be a major undertaking at Rogers Lake, when considering both the associated permitting issues and project expense. Additionally, much of the littoral area has relatively little collected sediment.

The dredging of large portions of Rogers Lake is unlikely to provide much benefit, especially against plants like milfoil that naturally require a small amount of nutrients and can grow fairly well in a minimum layer of soft sediment. If any dredging were to be considered, it would likely be localized in cove areas particularly where inlet streams enter into the lake basin. Deepening of these areas would provide improved water flow and, if partitioned off in some fashion, may provide improved removal of suspended solids and nutrients. A more extensive drawdown could allow for dry-dredging selected shoreline and other shallow areas providing that the proper permits have been obtained.

The actual operation costs would ultimately depend upon the approach and amount of material being dredged. Reasonable unit cost estimates for a limited dredging project at Rogers Lake may run between $10 and $15 per cubic yard removed. Removing 4 feet of sediment from a one-acre area yields approximately 6,400 cubic yards of material. If a partial dredging project targeting the removal 4 feet over 20 acres is considered at Rogers Lake, the total amount of material to be removed would be 128,000 cu. yds., which translates into $1,280,000-$1,920,000 in operation costs. Costs may also run higher, depending upon certain permit conditions or other complicating factors. It should also be noted that dredging does not always eliminate nuisance aquatic vegetation problems, and other in-lake management activities may be required in order to maintain desired conditions.

Dyes/Shading

Dyes and other means of shading submersed plants are not likely to provide much benefit at Rogers Lake. Their benefit would be short-lived given the rapid flushing of the lake. Most dyes cannot legally be applied to ponds or lakes that have an outflow.

Hand-Pulling

Hand-pulling works best on small-localized infestations of weeds, thereby limiting its use in most areas of Rogers Lake, however the usefulness of hand-pulling may increase as other management techniques begin to reduce the size and severity of nuisance infestations. Hand-Pulling is usually the first round of defense against pioneering infestations of new non-native weeds. An active monitoring program is vital to identify any new infestations, so that hand-pulling can be initiated in a timely manner.

Hand-pulling should be conducted by trained individuals and care should be taken to remove the plants with their roots, as well as minimize fragmentation. Residents can be trained to perform these functions.

Aeration

Aeration is commonly used to improve water circulation and increase the amount of dissolved oxygen. More specifically, in larger lakes aeration is used to prevent hypolimetic oxygen loss and the accompanying release of phosphorus from the sediment. In severely eutrophic lakes or small ponds, aeration may be necessary required to prevent fish mortality and help to process organic matter through aerobic decomposition.

Based on the information collected on the temperature and dissolved oxygen in Rogers Lake, there appears a moderate loss of oxygen in the hypolimnion, but not severe anoxia as seen in many eutrophic lakes. Under current conditions, there is layer of water beneath the thermocline where temperature and oxygen levels are suitable for coldwater fish species. At this time, there does not appear to be a need to consider aeration in Rogers Lake.

Chemical Methods

Chemical treatment using USEPA / CT DEP registered herbicides & algaecides is a common management technique to control rooted plant and algae growth. Prudent herbicide treatment can provide at least complete seasonal control of target weeds often at a significantly lower cost that harvesting. If conducted properly by licensed professionals in accordance with the product' s USPEA label, the use of chemical treatment as a management technique poses a negligible risk to the environment and non-target organisms.

Herbicides

Herbicides often provide for area and species selective plant control. Typically a late spring or early summer treatment will provide season long control of the nuisance vegetation. With systemic herbicides like 2,4-D (Navigate) and fluridone (Sonar) two or more years of good plant control are the norm. Contact herbicides such as diquat (Reward) and endothall (Aquathol-K) provide effective seasonal control. Plant regrowth in subsequent seasons is often reduced, allowing reductions in the frequency and amounts of chemical required. In fact, none of the currently registered products have any restrictions on swimming in treated waters, but prudent practice calls for closure of the treated area on the day of treatment. In most cases, the only temporary water use restrictions following a treatment are associated with the use of treated water for irrigation or domestic purposes. Most of the herbicides are either rapidly broken down or irreversibly bound to the sediment, becoming biologically inactivated within a matter of days. Thousands of lakes across the country are treated with aquatic herbicides each year, including well over 400 lakes and ponds in Connecticut each year.

Given the area-selective abilities of most aquatic herbicides, certain areas of Rogers Lake can be treated to control nuisance weed growth while leaving other low-use areas for fish and wildlife habitat. The area of largest concern in Rogers Lake is the shallow central portion, which is infested with predominately milfoil, largeleaf pondweed and naiad. Treatment with herbicides is likely to provide the most effective control in this area of excessive plant growth.

Given the species of plants in this area, a combination of herbicides will be most effective. The two herbicides that will target the milfoil, largeleaf pondweed and naiad are Reward (diquat) and

Aquathol-K (endothall). These products, if applied in the early summer as part of a complete Aquatic Treatment Program, will provide at least seasonal control of the target plant. Some carry-over benefit may be seen in subsequent years, however some level of spot-treatment will likely be required on an annual basis. Unfortunately, none of the more systemic herbicides will work effectively on the mix of plants in the most problematic areas. Other areas of lake can also be treated as desired by the Lake Authority. The treatment program should be accompanied with detailed pre & post treatment inspections, which are used to designate and monitor the treatment areas.

Treatment of the 50-acre central region of the lake with the above mentioned herbicides would cost in the range of $20,000. This would include permitting, pre & post treatment inspection all required labor and material. Additional acreage could be added for a similar unit cost.

Temporary water-use restrictions associated with the use of these products includes up to a 14-day restriction on irrigation, livestock watering and drinking & a three-day restriction on fishing. Restrictions on swimming and boating are on the day of treatment only.

Management of certain areas of floating leaf waterlilies herbicides is also recommended. This can be completed in conjunction with or as a complement to hydro-raking for large of dense areas. The herbicide of choice for treatment of waterlilies is Rodeo (glyphosate). Rodeo is a systemic, topical herbicide that is applied directly to the floating leaf of the plant. It is extremely area-selective and very effective, providing up to several years of control. There are no restrictions on the use of the Rodeo herbicide, however it is prudent to restrict the area of treatment for recreation on the day of application to prevent the herbicide from being washed from the plants.

Treatment cost is dependent on the size and distribution of the treatment area, but generally runs in the range of $400-$600 per acre, with a minimum of 5-acres. Treatment areas can be established with the Lake Authority, but would likely focus on individual homefronts with significant infestations and in and around access points and boat channels.

The use of these herbicides requires a permit with the CT DEP, Pesticide Bureau as well as extensive notification procedure. A notice of the treatment date and subsequent water-use restrictions must be placed in a local newspaper. Additionally, signs warning of the temporary restrictions must be placed around the affected shoreline. The Authority may also want to consider distributing a newsletter to the residents notifying them of the treatment plan. We understand there are numerous residents who may use the lake water for irrigation. These people especially, should be aware of the 5-30 irrigation restriction post-treatment depending on the herbicide applied. There are generally no restrictions on any wells in the vicinity of the lake with the recommended products, other than for 2,4-D. Shallow wells in close (50-75 feet) proximity of the water' s edge may lead DEP to not issue a permit or possibly temporarily restrict drinking from such shallow wells. The only herbicide currently available for use in the aquatics industry that may require well restrictions is 2,4-D.

Algaecides

Copper based-algaecides like copper sulfate or K-Tea® are commonly used to control microscopic and/or filamentous algae blooms. Algaecide treatments are not preventative and are conducted only in response to a decrease in water clarity. Algal density is typically monitored with either a standard Seechi disk or through microscopic examination/cell counting. A water clarity under 4-feet or a rapid decline in clarity are common "triggers" for algaecide treatments. Based on historical conditions, a lake-wide algaecide treatment is not likely to be required at Rogers Lake.

Nutrient Removal/Inactivation

Nutrient Removal/inactivation treatment is usually reserved for lakes with severe algae problems. Treatment is performed with a specific chemical compound, usually aluminum sulfate (alum) or other metal salt, with the intent to chemically remove phosphorus (the prime nutrient for algae) from the water column. The aluminum forms an insoluble precipitate that chemically binds with the phosphorus and settles to the bottom of the lake. In many cases, the dose is increased so as to create a blanket of this aluminum "floc" on the sediment of lake able to trap any additional phosphorus which could be released under anoxic conditions. The typical cost of an alum treatment can range from $300-$1,000 per acre with the higher costs due to the addition of a buffer compound needed to balance the increase in acidity created from the alum reaction. The effectiveness of such treatments is dependent on several variables most important of which is the retention time of the lake and the level of nutrient loading from the watershed. Given the minimal problems with algae at Rogers Lake, alum treatment is unlikely to provide any benefit, especially against rooted weed growth.

Biological Controls

There are no known biological control agents that are specific to variable watermilfoil. Some promising research with various herbivorous insects is being conducted for plants like Eurasian watermilfoil (*Myriophyllum spicatum*) and purple loosestrife (*Lythrum salicaria*) but for most submersed plants the only approved and tested method is to stock the lake with sterile grass carp. There are numerous drawbacks to using grass carp and, given the importance of Rogers Lake as a valued fishery, it is highly unlikely that CT DEP Inland Fisheries will permit their use anytime soon. Grass carp are not selective and would forage on the native plant species before getting to the milfoil.

Impacts of Alewife Management

Rodgers Lake has been targeted by Connecticut Department of Environmental Protection Inland Fisheries Division as one of 15 lakes (larger than 40 acres) for restoration of anadromous alewife population. The sea-run alewives are currently excluded from spawning habitats in these lakes and their tributaries because they cannot pass the dams used to impound and form the lakes. The restoration of the sea-run alewife to these lakes will require the construction and operation of a fish passage structures at the dams.

The sea-run alewife, (*Alosa pseudoharengus*), is an anadromous fish that lives as an adult in the ocean, but spawns in fresh water. The adults return to fresh water rivers between March and June to spawn in lakes and streams. The sea-run alewife is approximately 11 inches long and a little over half a pound. Eggs are deposited in nests or broadcast freely in the water. Juvenile, or young of year, alewives spend the summer in the spawning areas then exit the lake during the fall to return to the ocean where they mature to adults.

The migration of alewives from Long Island Sound during the spring represents a source of nutrients to the lake. Because the adult alewives accumulate food storage reserves in the ocean and do not feed while in the lake, their upstream migration represents a source of nutrients to lakes. These migrating adult alewives will release nutrients into the lake by three different ways, excretion, release of gametes (eggs and roe), and mortality of the adult alewife. This last way may be the most significant, because after spawning a percentage of the adults will die from post spawning mortality with their carcasses remaining to decompose in the lake.

A study of alewife spawning migrations conducted in Rhode Island (Durbin et. al. 1979) measured the nutrients associated with each of the three inputs. They estimated excretion and release of gametes to be about 0.2 grams/fish for phosphorus, and 1.15 g/fish for nitrogen. The input from carcasses was an order of magnitude more, with 1.1 grams/fish for phosphorus and

6.5 g/fish for nitrogen. The alewife run into Bride Lake, Connecticut, was monitored in 1966 and 1967 (Kissil 1969) and found to consist of 140,000 and 187,000 adult alewife for each year respectively. Out of these adults that entered the Bride Lake 48% and 57% died and remained in the lake during each of the two years. Using the estimates from Durbin et. al. 1979, a run of this magnitude with roughly half of the fish dying in the lake would contribute a total phosphorus input of about 145 Kg during the months of the spawning period, March to July. The existing phosphorus loading to Rogers Lake was estimated as part of this study. The total annual phosphorus load to Rogers Lake was found to be between 100 and 200 Kg depending on the method used in the estimate, see pages 52-59. An alewife run of that magnitude could potentially double the annual load of phosphorus to the lake with the new contribution of phosphorus being loaded to the lake over a few month period in the spring when the lake is the most susceptible to additional phosphorus.

Alewife carcasses also represent a source of additional biological and chemical oxygen demand in the water that can further push oxygen levels toward hypoxia. The increase in oxygen demand materials in the lake may result in combination of factors that are all deleterious to the water quality of Rogers Lake. The increased oxygen demand will lower bottom water oxygen concentrations. Currently, the south bay looses oxygen over the bottom during the summer but internal loading of phosphorus was minor. The central basin looses oxygen very slowly during the summer, eventually reaching anoxic conditions by late summer, again with only minor internal loading of phosphorus. The increased oxygen demand represented by alewife mortality may accelerate the oxygen loss rates in both these basins causing anoxic to occur sooner then is currently the case. A longer period of anoxic could increase the likely hood that phosphorus will be released from the sediments during the summer contributing to summer algae blooms.

An alewife run into Rogers Lake will be smaller at first, probably only a few tens of thousands of fish. However, there is no way to predict how large the run will become over time as juveniles successful leave the lake to become adults at sea that are capable of returning to spawn again. Although it may be possible to count the fish that enter the lake during any one run, the estimated maximum load from these increasing fish runs would have to be determined so that an allowable limit could be set on the total number fish let into the lake.

In order for the fish to use the fish way an adequate supply of discharge water is needed. During the spring migration of adults into the lake it is expected that Rogers Lake will be discharge plenty of water out the outlet to allow for the usage of the fish ladder. However, during the late summer and early fall when juvenile fish will be ready to leave the lake the water flows necessary for fall release of fish may not be adequate. During this diagnostic feasibility study conducted during the 2002 season, the lake stopped spilling water over the spillway in July and did not again discharge for the remainder of the study period which ended in October. To allow for the juvenile fish to leave the lake the discharge might have to be subsidized by lake level drawdown. This may not be possible either if the lake level has already decreased due to summer dry period when the lake typically experiences some degree of water level lowering.

The young-of-the-year alewife that leave the lake may represent a loss of nutrients from the lake. The young fish leave between July and October, and can be between 2 and 4 inches long and about 0.06 ounces in weight. These fish are considerably smaller than the entering adults. The number of juvenile fish that successfully leave the lake is hard to predict but will be some fraction of the total number of adult fish that enter the lake. These exiting juvenile fish will export phosphorus but at only a fraction of the rate of the entering fish during the spring.

The young-of-year alewives will be supported by the existing food chain in the lake. Alewives are planktivorous, that is, they feed exclusively on large zooplankton in the water column. Rogers Lake currently has a large population of landlocked alewife that prey on zooplankton. It is unclear what affect the combination of sea-run and landlocked alewives will have on the existing zooplankton population. The affects of depleting the large bodied zooplankton stocks in lakes are varied and unpredictable. A strong case has been made in the literature for the loss of zooplankton to cause a shift to higher phytoplankton numbers and dominance by blue-green algae types. A combination of sea-run and landlocked alewife populations may have a drastic affect on remaining zooplankton numbers in Rogers Lake. However, it is also likely that the landlocked alewife will leave the lake as soon as the ladder is in place.

Summary and Recommended Management Plan

Rogers Lake appears to have stable water quality conditions at this time. All of the eutrophication indicators showed generally low levels of productivity, with the exception of aquatic plant distribution and abundance. Phosphorus, nitrogen, and clarity were between oligotrophic and mesotrophic, the water color probably contributing to the mesotrophic category for clarity.

Nutrient loading estimates and eutrophication modeling suggest that the high water quality of the lake is preserved by the high flushing rate and low levels of phosphorus in the inlet streams. In addition, internal nutrient loading from the sediments in the lake was also low. Modeling also suggests that the lake would not be able to tolerate much of an increase in nutrients from the drainage basin.

The relationship between water clarity, thermocline depth, and oxygen loss suggest that at present a balance exists between the development of a thermocline and the upper limit of the anoxic boundary. The boundary reaches the thermocline in September although hypoxic (oxygen below 4 mg/L but above 1 mg/L) existed just below the thermocline in August at Station 1. The north central basin, where station 1 was located, probably has a large capacity of oxygen and low consumption rates at present. These factors combine to provide that basin with longer lasting oxygen reserves in the summer. This combination of conditions may be the reason why brown trout can survive or hold over to the next year.

However, the existing situation may be vulnerable to perturbations that increase oxygen consumption rates, decrease Secchi disk depth, or increase productivity of blue green algae.

Any of these changes might result in an anoxic boundary that reaches the thermocline quicker in the year, while decreased water transparency would cause the thermocline to occur higher in the water column. If any changes occur to either the rate of oxygen loss or the depth of light penetration it could possibly increase the rate of recycling of phosphorus from bottom sediments. At present there appears to be a good balance between the sources and sinks of phosphorus in the lake. Changes in the rate of internal recycling would shift this balance toward greater accumulation of phosphorus in the lake leading to higher rates of productivity.

Recommendations for future actions at Rogers Lake for water quality reasons are limited to preservation of existing conditions. There did not appear to be any need to initiate any lake restoration actions at this time. However, the future management efforts at Rogers Lake should include a comprehensive plan of development of the drainage basin that addresses two things, first the inclusion of best management practices for any new development and second, a careful review of the existing storm water routing to lake especially on the west side of the lake that includes implementation of source controls and eventual retrofitting of structural components. It is imperative that increased levels of phosphorus in the inlet streams do not occur.

Watershed Management Techniques

Based upon the current conditions at Rogers Lake, watershed management issues will become increasingly important in the years ahead. Present nutrient loading of phosphorus and nitrogen from the watershed is at a critical turning point between the permissible and critical levels. This is the time to improve management of current sources of nutrients and plan ahead for future development in the watershed. The following specific items are recommended for Rogers Lake.

Table 21 - Recommended Watershed Management Techniques

Recommendation	Priority	Description
• Behavioral Modification (Public Education)	1	Involves the production and dissemination of educational brochures, public meetings and possibly the implementation of local bylaws and/or bans. Education sets the stage for public involvement and cooperation that is vital for the success of a watershed management plan. Focus should be on fertilizer use, septic system and protection of watercourses.
• Waste Water Management (septic system inspections, maintenance and pumping)	1	Inspection, maintenance and pumping of septic systems. The Town may want to consider a local bylaw to require proof of septic system maintenance. Public education is a vital part of this technique.
• Zoning and Land Use Planning	1	Protection of undeveloped land, especially those that form buffer zones to Rogers Lake and its tributaries. Enact superior water quality & stormwater management regulations for new development. Requires cooperation between all towns in the watershed.
• Buffer Strips	1	Where possible, especially for new development, use education and regulations to maintain sufficient vegetated buffer strips adjacent to the lake and its tributaries.
• Street Sweeping/Catch Basin Cleaning	1	Regular street sweeping and catch basin cleaning is recommended to pollutant and solids before they enter the lake or stormwater systems. Regular cleaning (at lease semi-annual) is essential to keep systems functioning properly.
• Catch Basins with Hoods	2	Promote the use of deep sump catch basins with hoods to prevent the discharge of floatables including oil/grease.

• Created Wetlands	3	Promote the use of created wetlands for treatment of stormwater, especially in new development. Created wetlands maximize nutrient uptake as opposed to simple detention basins
• Detention	3	Promote the use of detention pond for stormwater treatment, especially in new development. Wet detention ponds or a combination of detention ponds and created wetlands would be preferable.
• Oil/Grit Chambers	3	Self contained units for stormwater treatment where space is at a premium. Also can be used as retrofits for existing systems or as a pre-treatment for infiltration systems.

In-Lake Management Techniques

Nuisance weed growth is interfering with the intended uses of Rogers Lake. To most, the management of these plants is a top priority, especially given the invasive nature of the plants involved. Aside from management of the nuisance vegetation, there does not appear to be a need at this time to address any additional issues. The management plan at Rogers Lake should continue to be evaluated based on continued monitoring.

The following in-lake techniques appear to be the most appropriate and feasible for Rogers Lake.

Table 22 - Recommended In-Lake Management Techniques

Recommendation	Description	Cost

• Chemical Treatment	Treatment of approximately 50-acres in the central section of the lake with the Reward (diquat) and Aquathol-K (endothall) herbicide to control milfoil, largeleaf pondweed and naiad.	~$20,000
• Harvesting	As an alternative to chemical treatment, harvesting can be used to provide seasonal control of nuisance vegetation in the 50-acre central portion of the lake.	~$30,000
• Hydro-Raking	Recommended in high use areas of the lake and in front of individual shorefronts to remove waterlilies, clean swimming areas and open/maintain boating channels.	$160-$175/hr. plus $800-$1000 mobilization
• Drawdown	Drawdown at Rogers Lake is unlikely to provide effective control of nuisance vegetation, however the continuation of the current practice of 18" drawdown in recommended to provide near-shore plant control and allow for dock repair and shoreline maintenance.	ND

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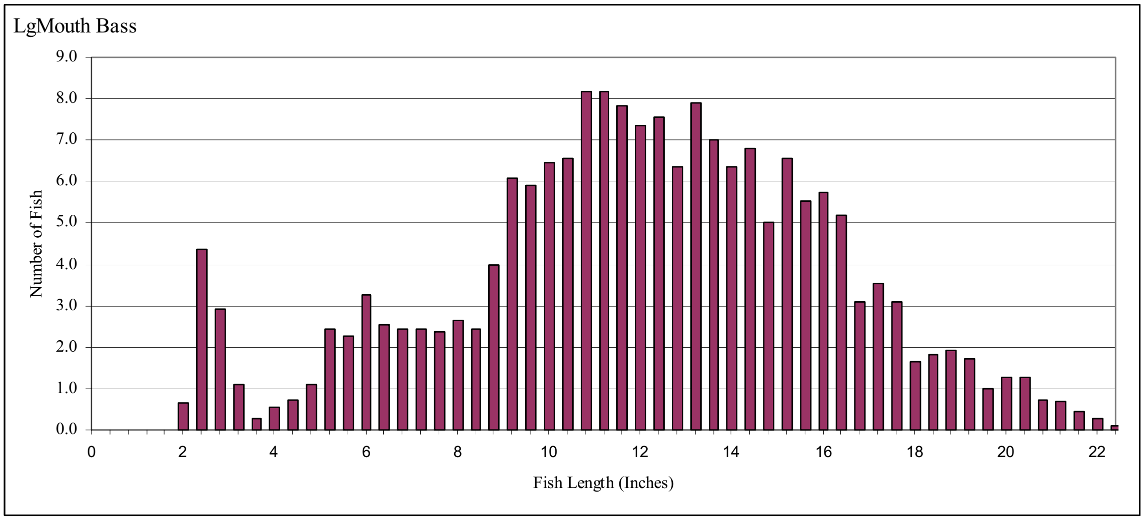
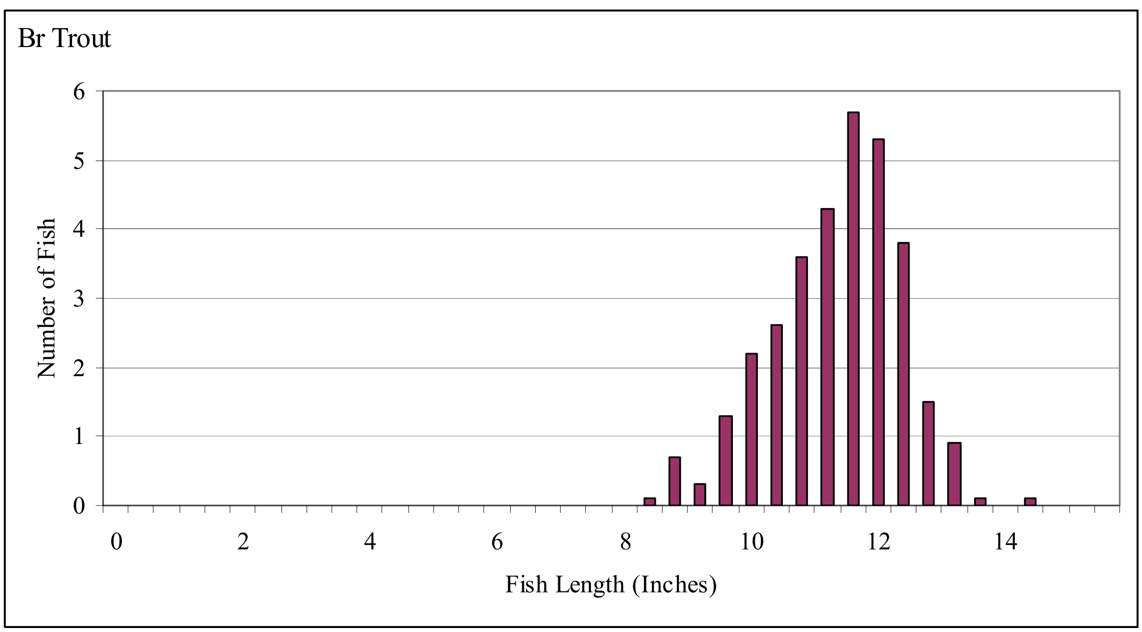
Appendix 1 - Maps

The follow charts show the average frequency of fish of different lengths caught during DEP electroshocking at Rogers Lake.

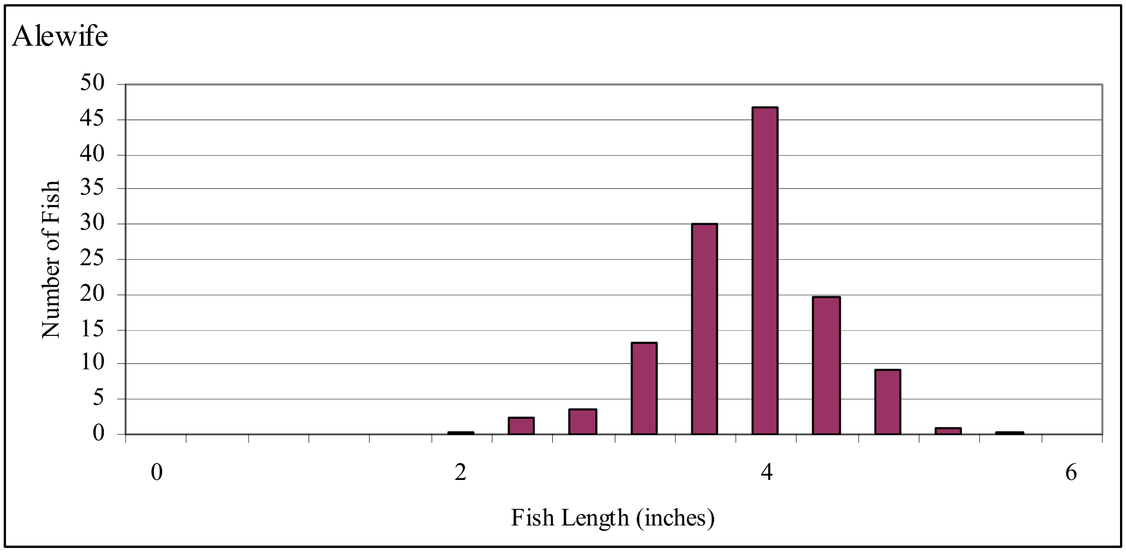
Largemouth Bass



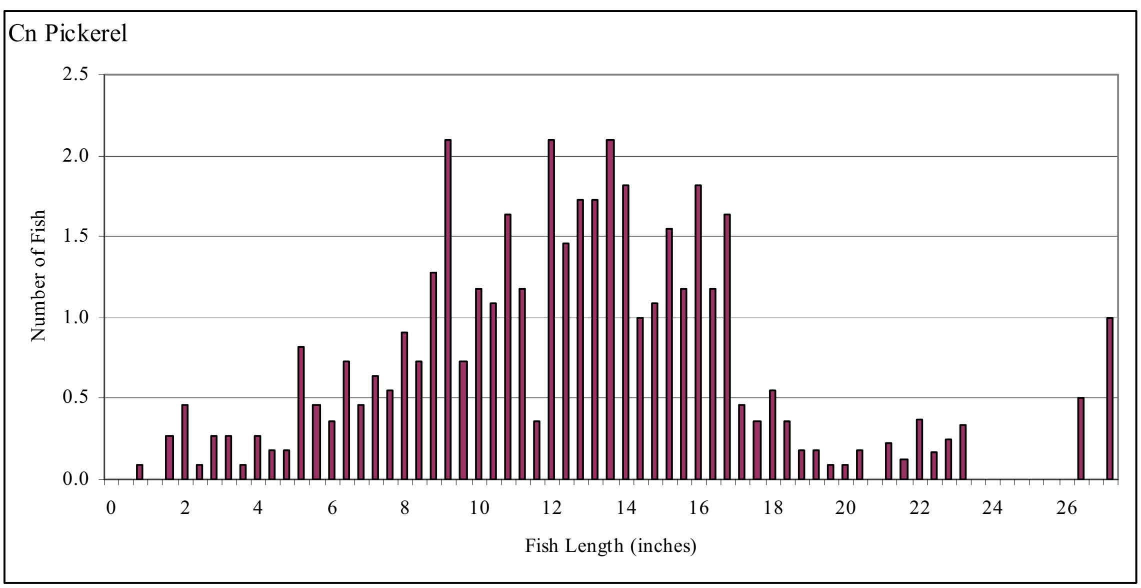
Brown Trout

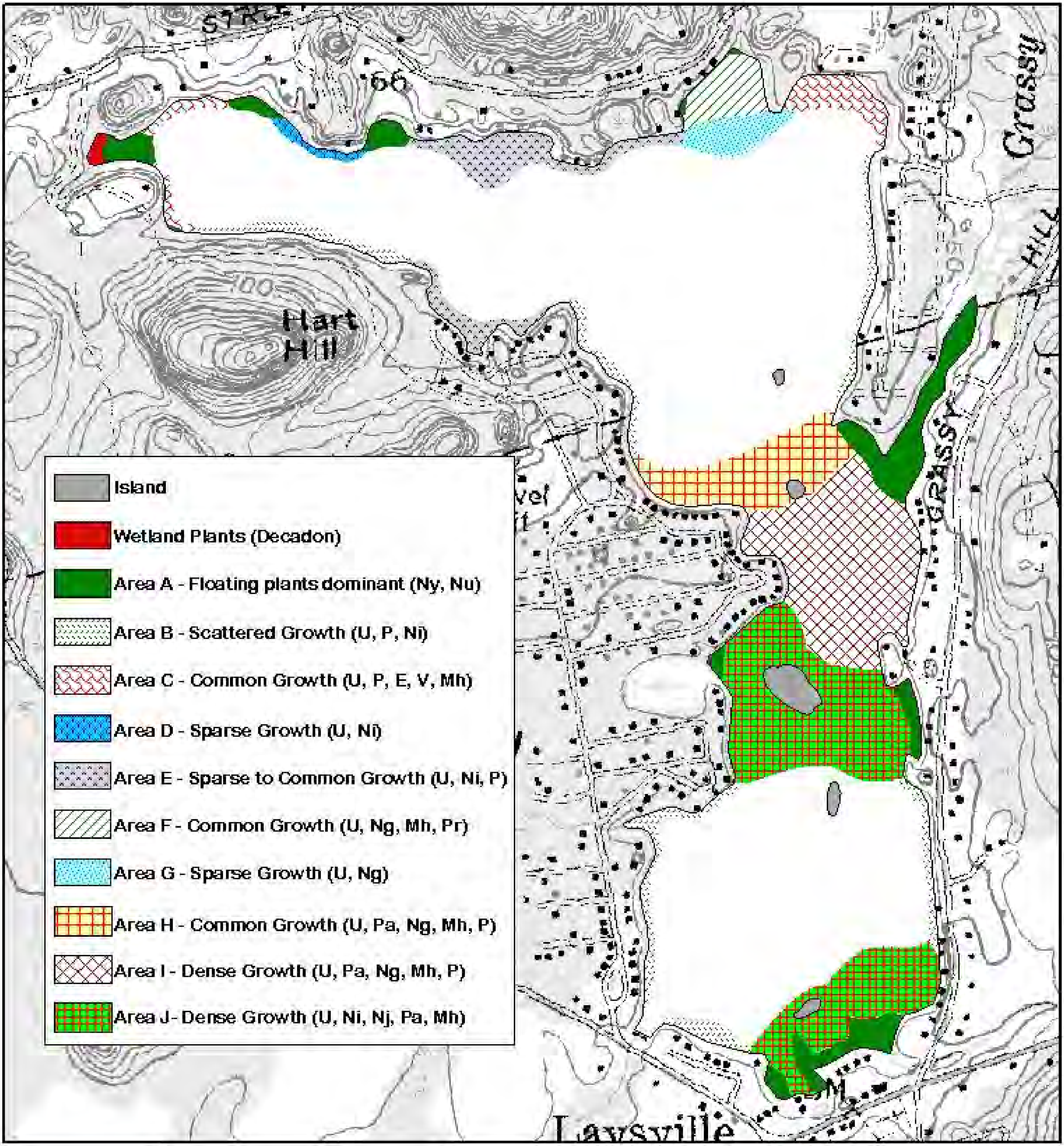


Alewife



Chain Pickerel





Rogers Lake

Diagnostic Feasibility Study

Vegetation Distribution

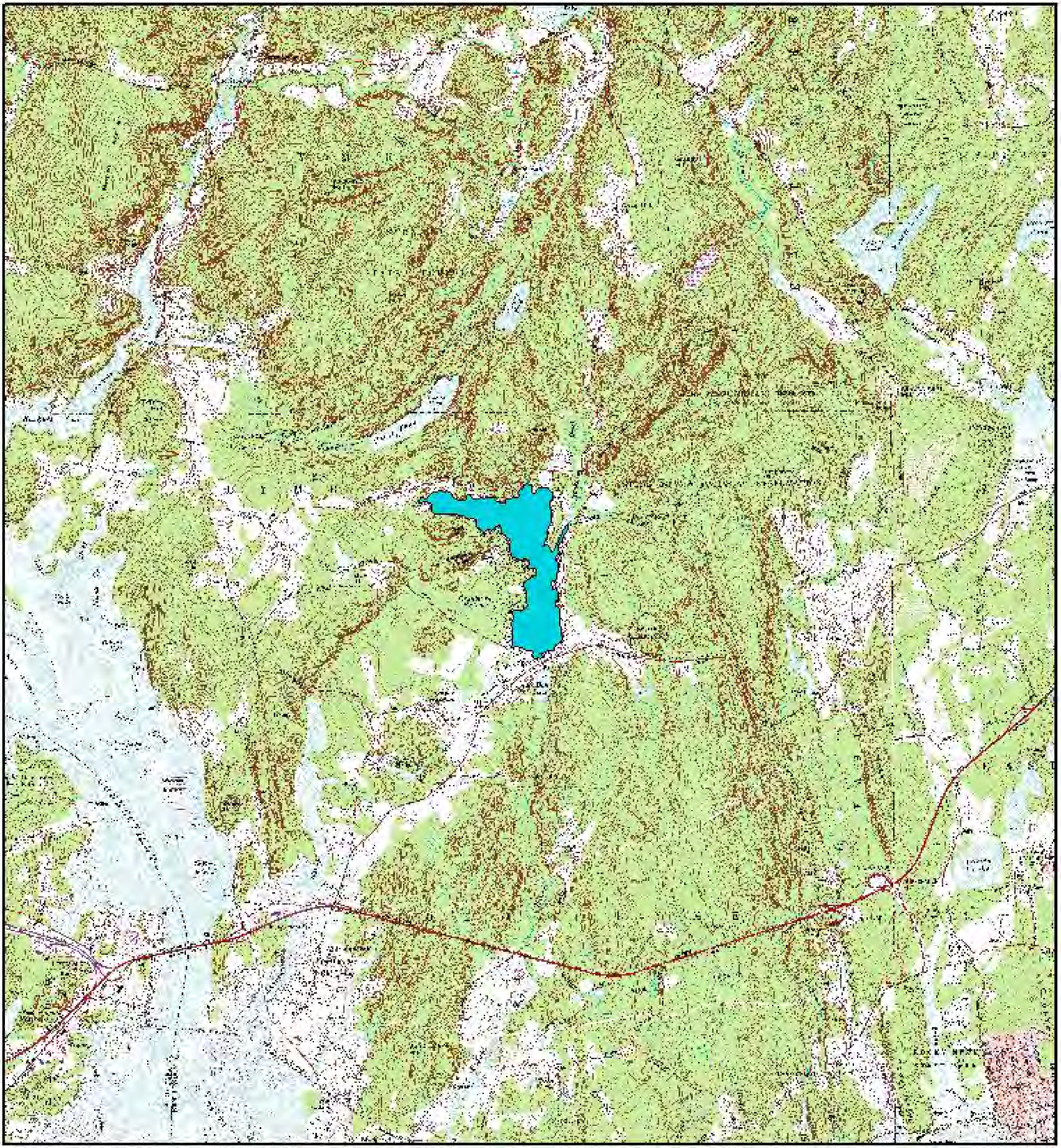
FIGURE	SURVEY DATE	MAP DATE
8		2/18/03

LEGEND

400 0 400 800 1200 Feet

Aquatic Control Technology, Inc.

11 John Road
Sutton, Massachusetts 01590



Rogers Lake

Diagnostic Feasibility Study

Locus Map

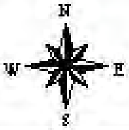
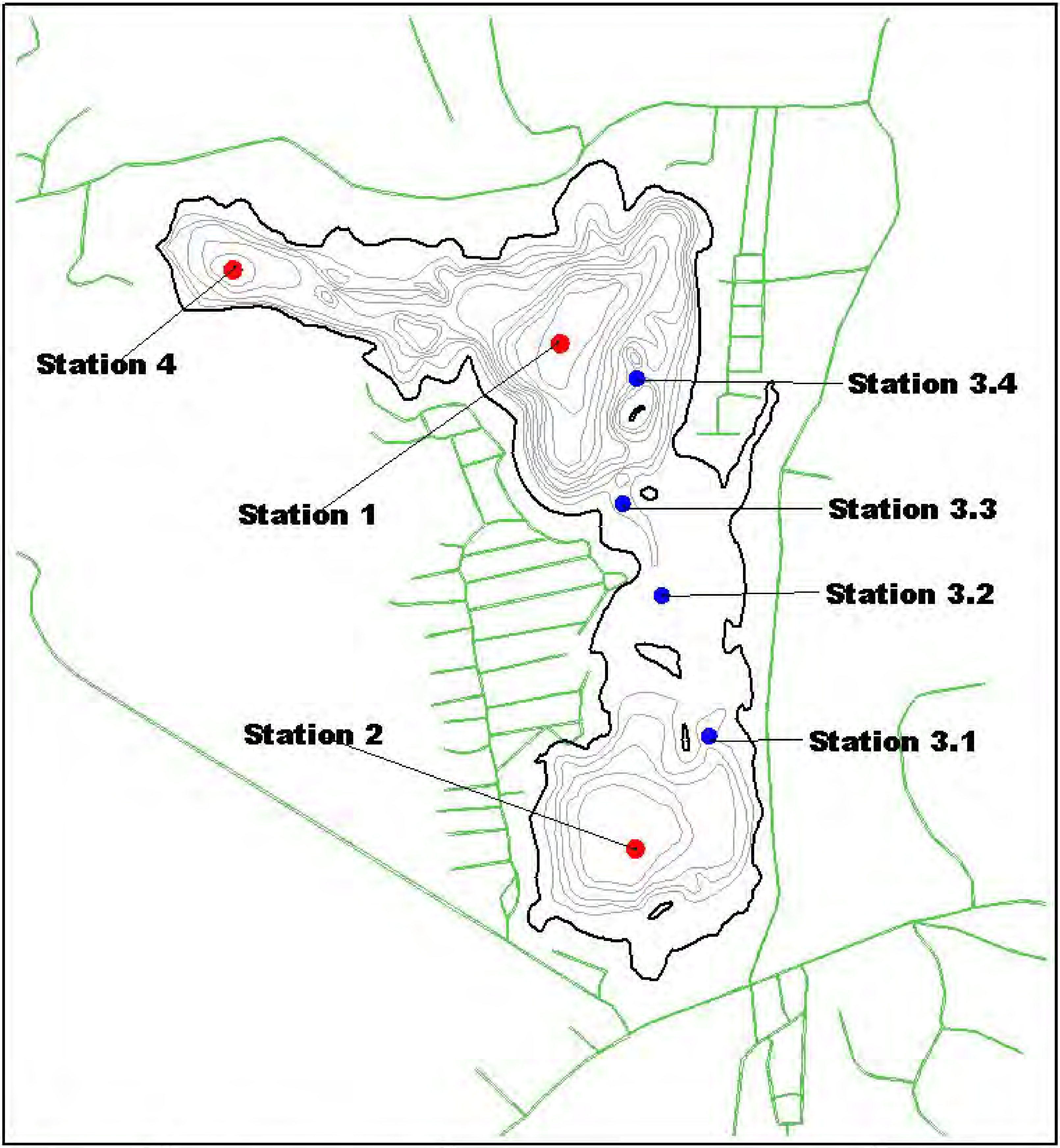


FIGURE	SURVEY DATE	MAP DATE
1		2/18/03

LEGEND

3000 0 3000 6000 Feet

AQUATIC CONTROL TECHNOLOGY, INC.
POND AND LAKE MANAGEMENT SPECIALISTS
11 John Road
Sutton, Massachusetts 01590
EMAIL. info@aquaticcontroltech.com
WEB. www.aquaticcontroltech.com



Rogers Lake Diagnostic Feasibility Study

In-Lake Sampling Stations

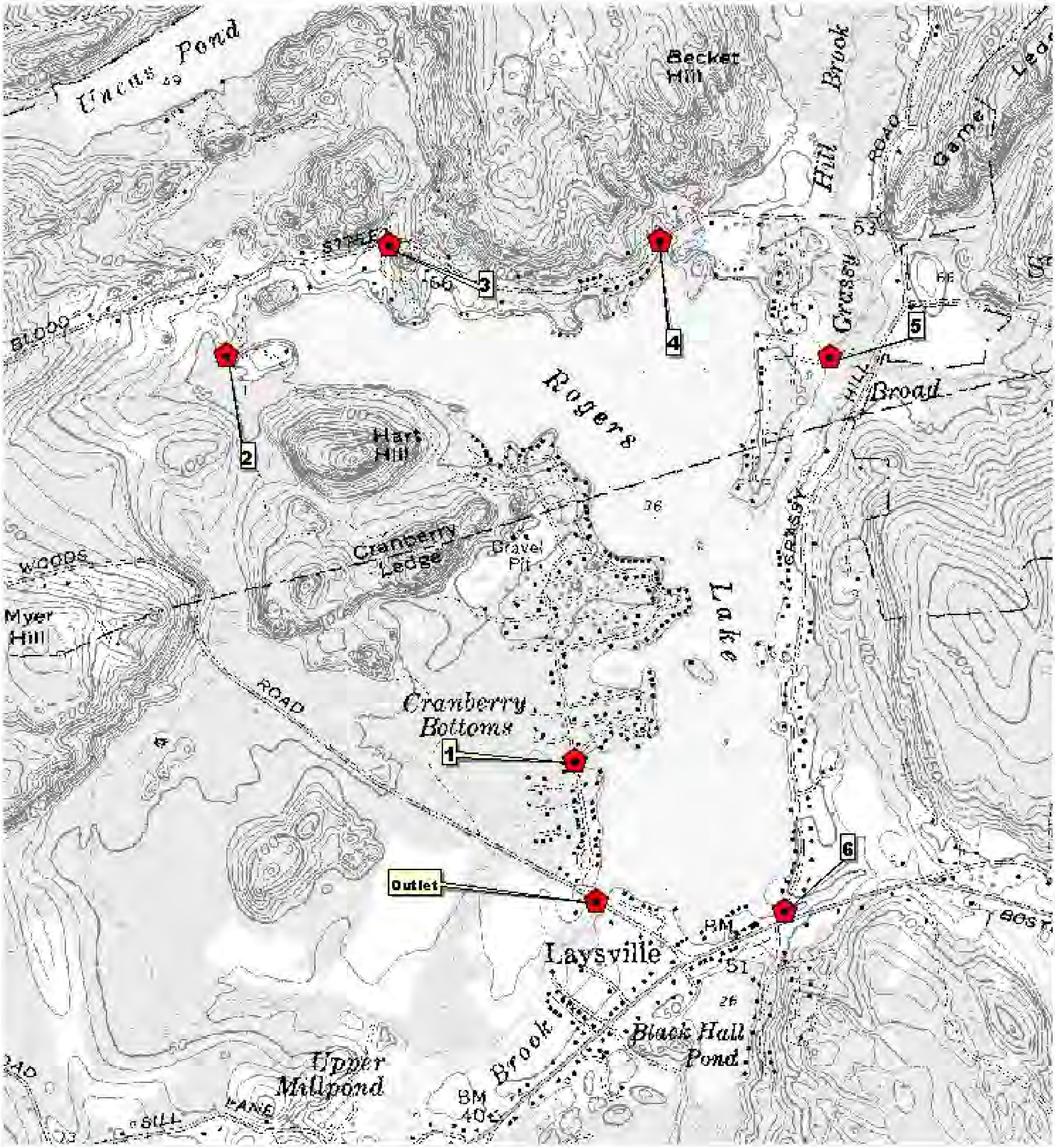
FIGURE	SURVEY DATE	MAP DATE
2		2/18/03

LEGEND

- Primary In-Lake Station
- Secondary In-Lake Station

700 0 700 1400 Feet

Aquatic Control Technology, Inc.
11 John Road



Rogers Lake

Diagnostic Feasibility Study

Watershed Sampling Stations

FIGURE	SURVEY DATE	MAP DATE
3		2/18/03

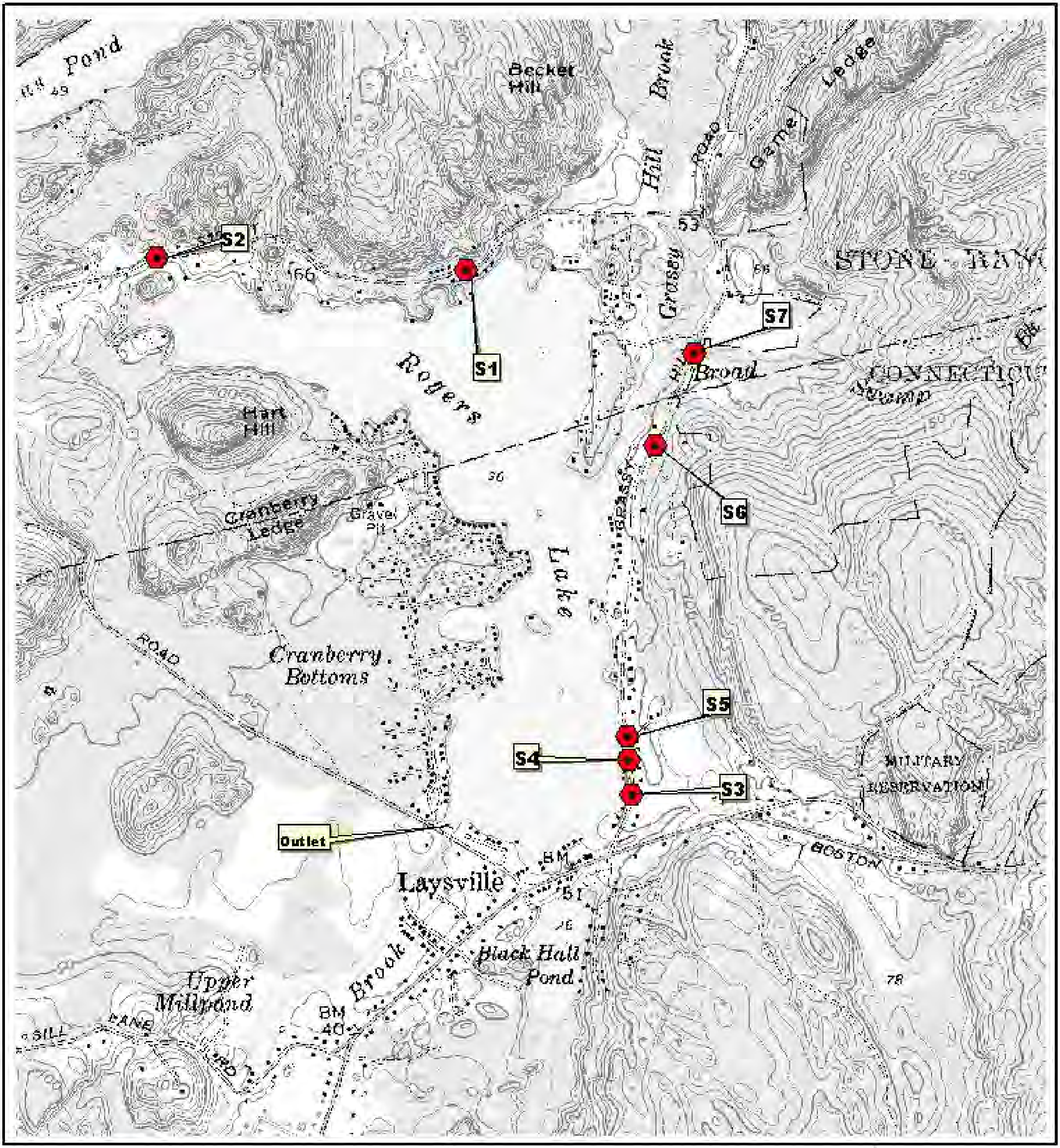
LEGEND

Sampling Station

900 0 900 1800 Feet

AQUATIC CONTROL TECHNOLOGY, INC.

11 John Road
Sutton, Massachusetts 01590



Rogers Lake

Diagnostic Feasibility Study

Stormwater Sampling Stations

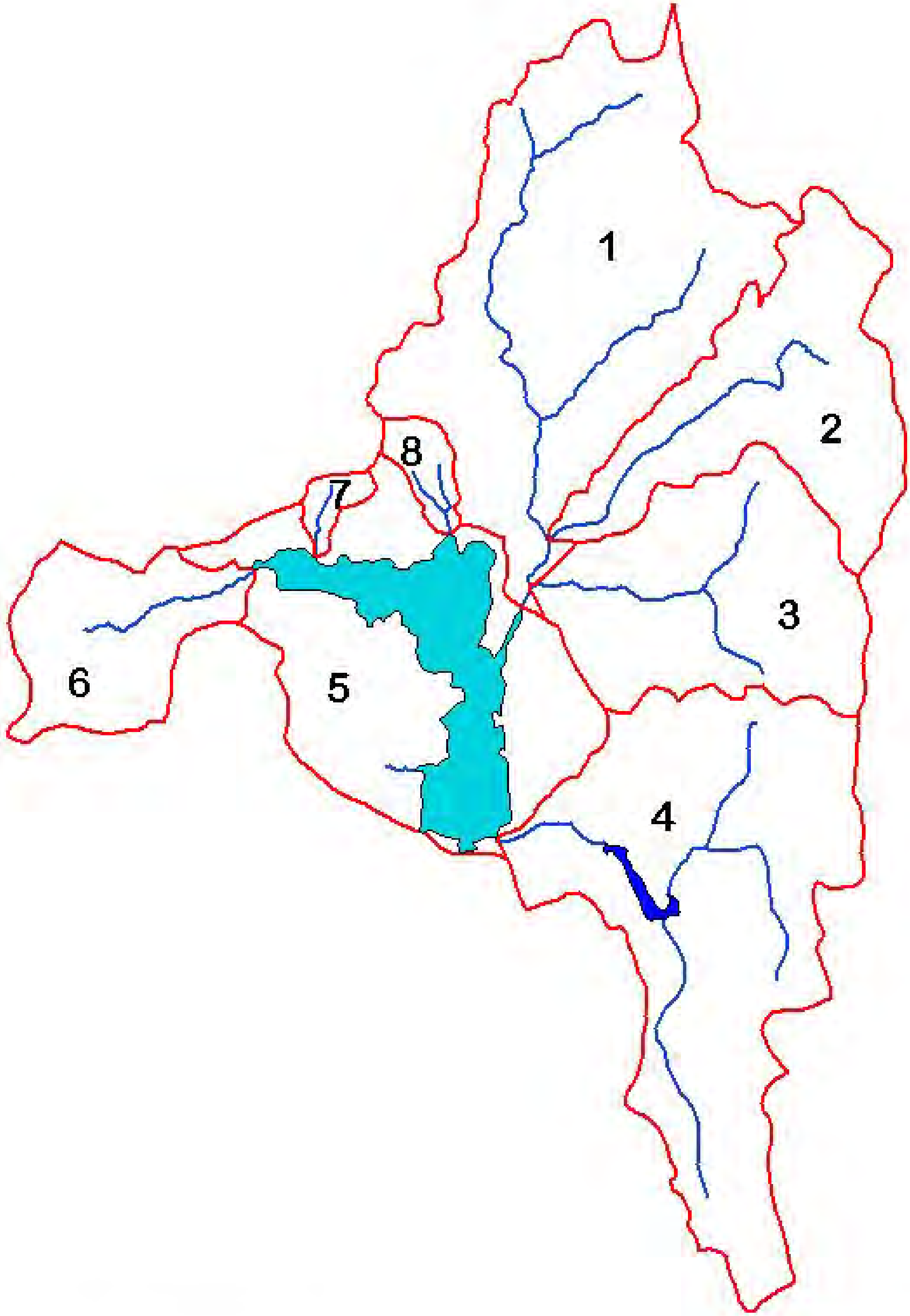
FIGURE	SURVEY DATE	MAP DATE
4		2/18/03

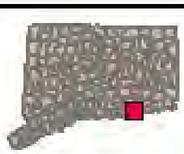
LEGEND

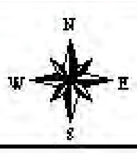
Sampling Station

1000 0 1000 2000 Feet

Aquatic Control Technology, Inc.
11 John Road







Rogers Lake

Diagnostic Feasibility Study

Watershed Map

FIGURE	SURVEY DATE	MAP DATE
5		2/18/03

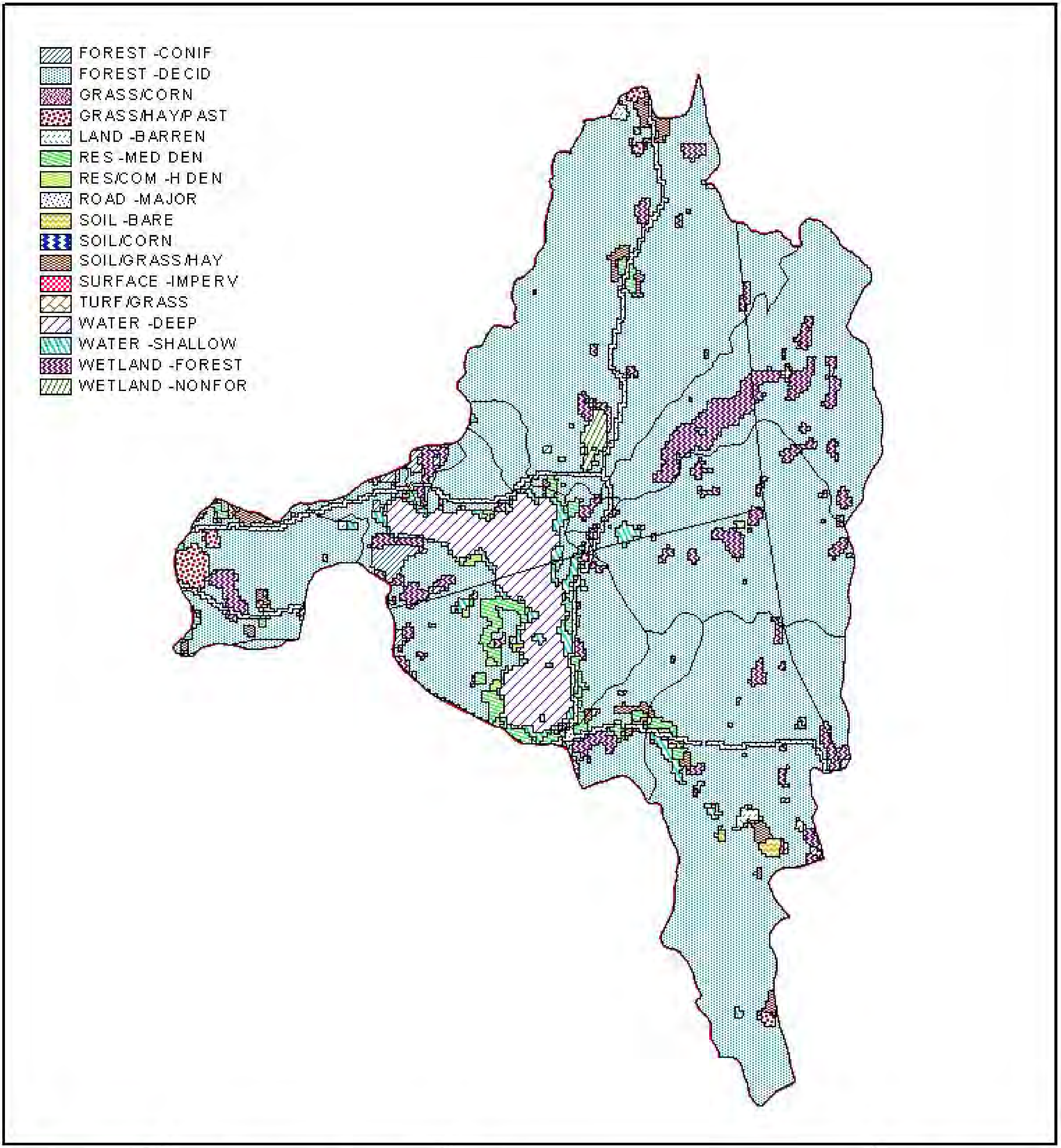
LEGEND

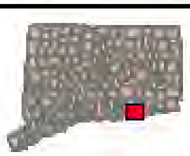
Watershed Boundary

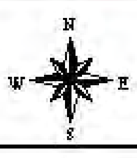
1 Basin ID #

2000 0 2000 4000 6000 Feet

Aquatic Control Technology, Inc.
11 John Road
Sutton, Massachusetts 01590







Rogers Lake

Diagnostic Feasibility Study

Land-Use

FIGURE	SURVEY DATE	MAP DATE
6		2/18/03

LEGEND

2000 0 2000 4000 Feet

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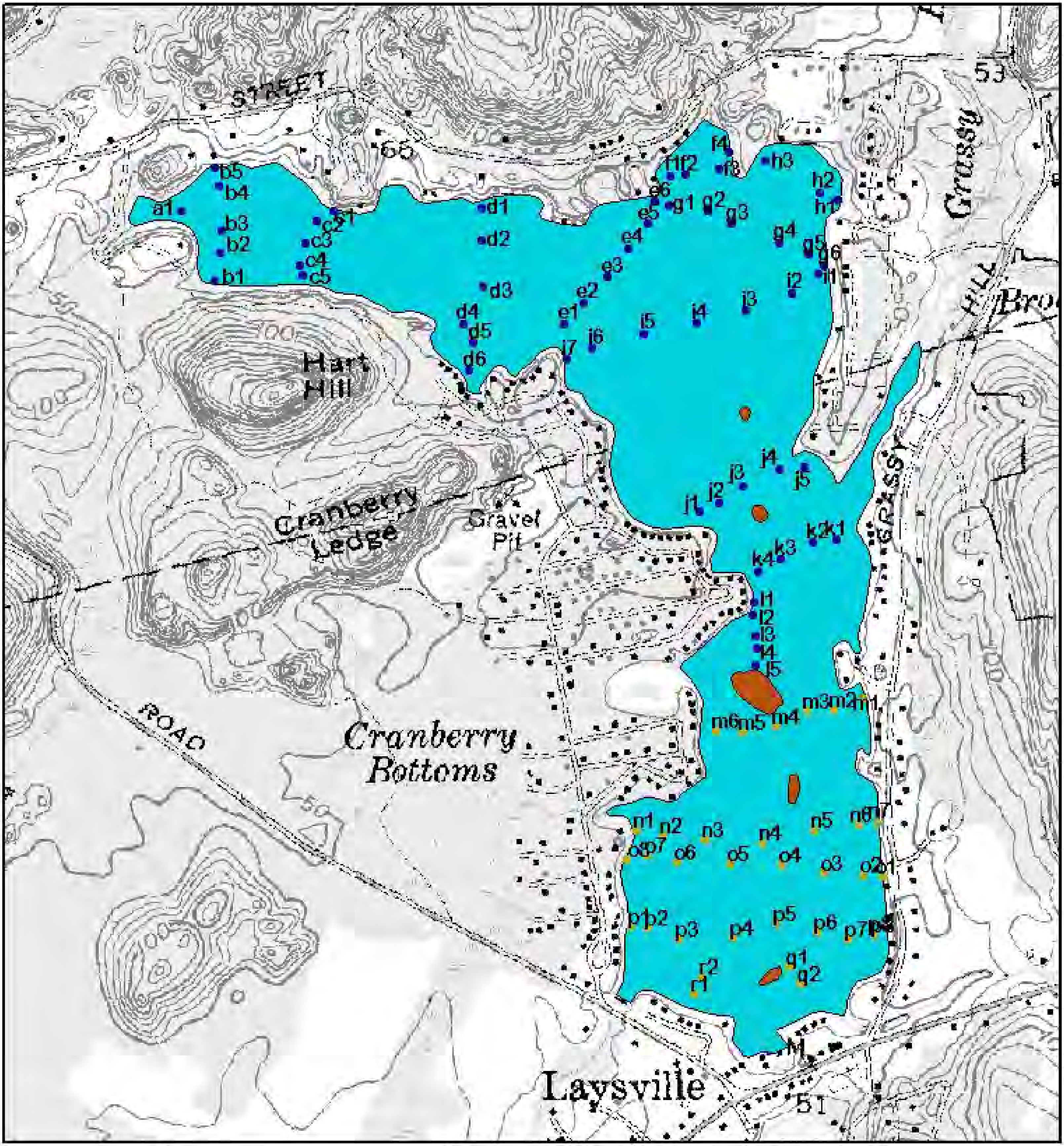
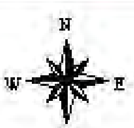




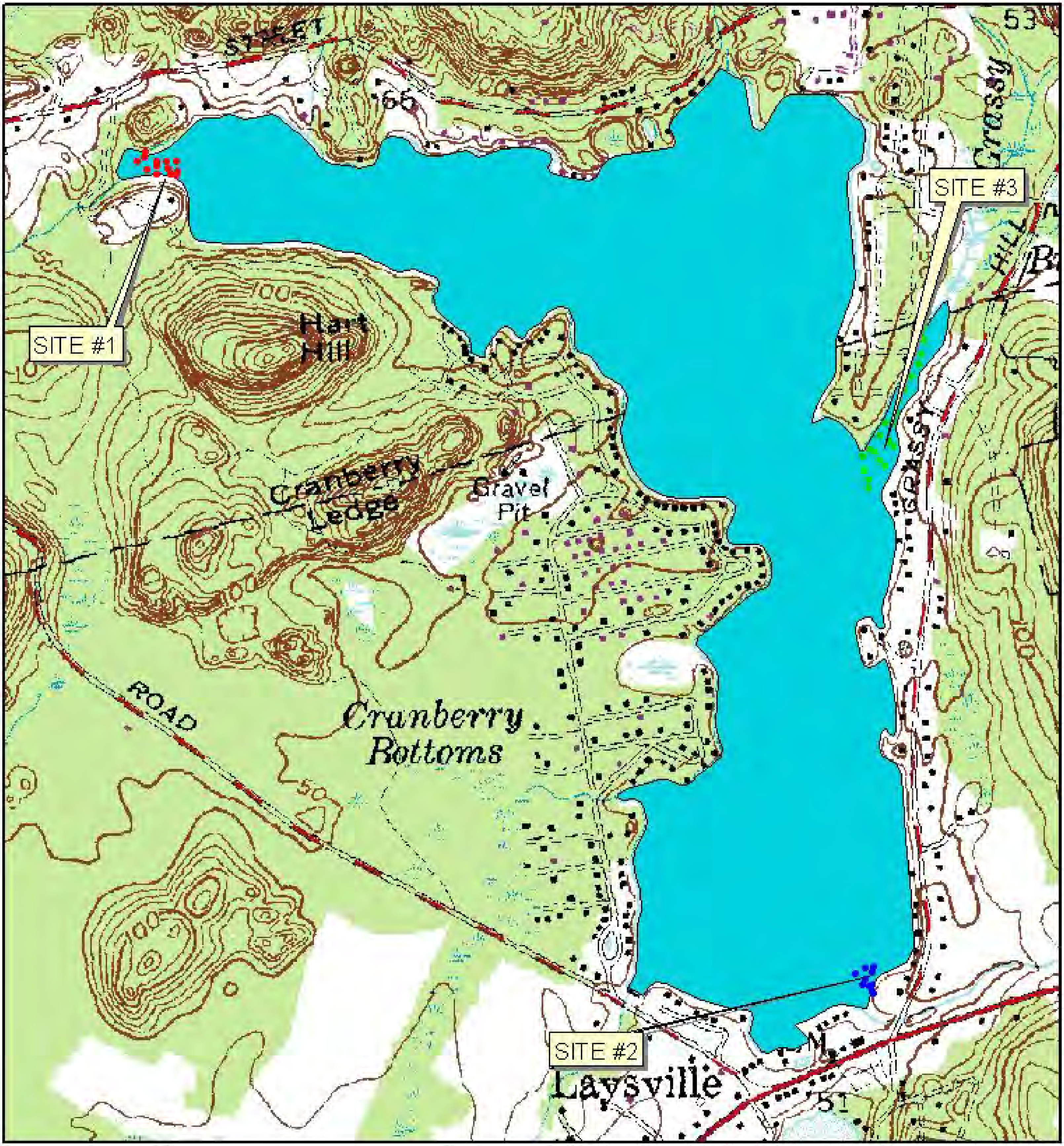
Rogers Lake
Diagnostic
Feasibility Study
Transect
Data Points

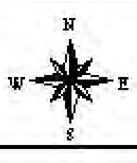
FIGURE	SURVEY DATE	MAP DATE
7		2/18/03

LEGEND
- Transect Data Point (July)
- Transect Data Point (September)

500 0 500 1000 1500 Feet

Aquatic Control Technology, Inc.





Rogers Lake

Diagnostic Feasibility Study

Sediment Sampling Points

FIGURE	SURVEY DATE	MAP DATE
9		2/18/03

LEGEND

500 0 500 1000 1500 Feet

AQUATIC CONTROL TECHNOLOGY, INC.