ECOLOGICAL STUDY

HIDDEN LAKE, HADDAM, CT

1995

Prepared by

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For

Hidden Lake Association
Haddam, CT

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PREFACE

This report is intended to serve as a source of information for both technical and non-technical readers. It can be used for future comparisons should lake management efforts be undertaken or should changes in the lake warrant further investigation. It is necessarily detailed and descriptive. A glossary of terms has been provided and the table of contents will serve as an outline.

I would like to thank Mr. Lloyd Pearson for his support of the study and for valuable data and background information. I also thank Mr. William Carson for making his boat available for the field work.

INTRODUCTION

Hidden Lake is a shallow 39 acre lake located on Hidden Lake Road, west of Route 81 in Haddam, CT (Figure 1). The lake is privately owned and is managed by the Hidden Lake Association, a group of about 110 property owners. Residents use the lake for swimming, fishing, canoeing and boating. However, recreational activities are limited by the extensive growth of aquatic plants across the entire breadth of the lake.

There is very little information available concerning the ecology of Hidden Lake. The lake has no public access and therefore was not included in Connecticut Department of Environmental Protection (DEP) studies of 106 lakes (Frink and Norvell, 1984; DEP, 1991). A bathymetric map showing the contours of the bottom was included in an early fishery survey (State Board of Fisheries and Game, 1959), but there is no current information available concerning water quality or aquatic plant and algal communities. In particular, the level of nutrient enrichment has not been systematically quantified.

The purpose of this study is to provide baseline data describing the ecology of the lake during the summer of 1995. These data constitute a scientific documentation of conditions during the aquatic plant growing season. The report will give information needed to develop a lake management program and will

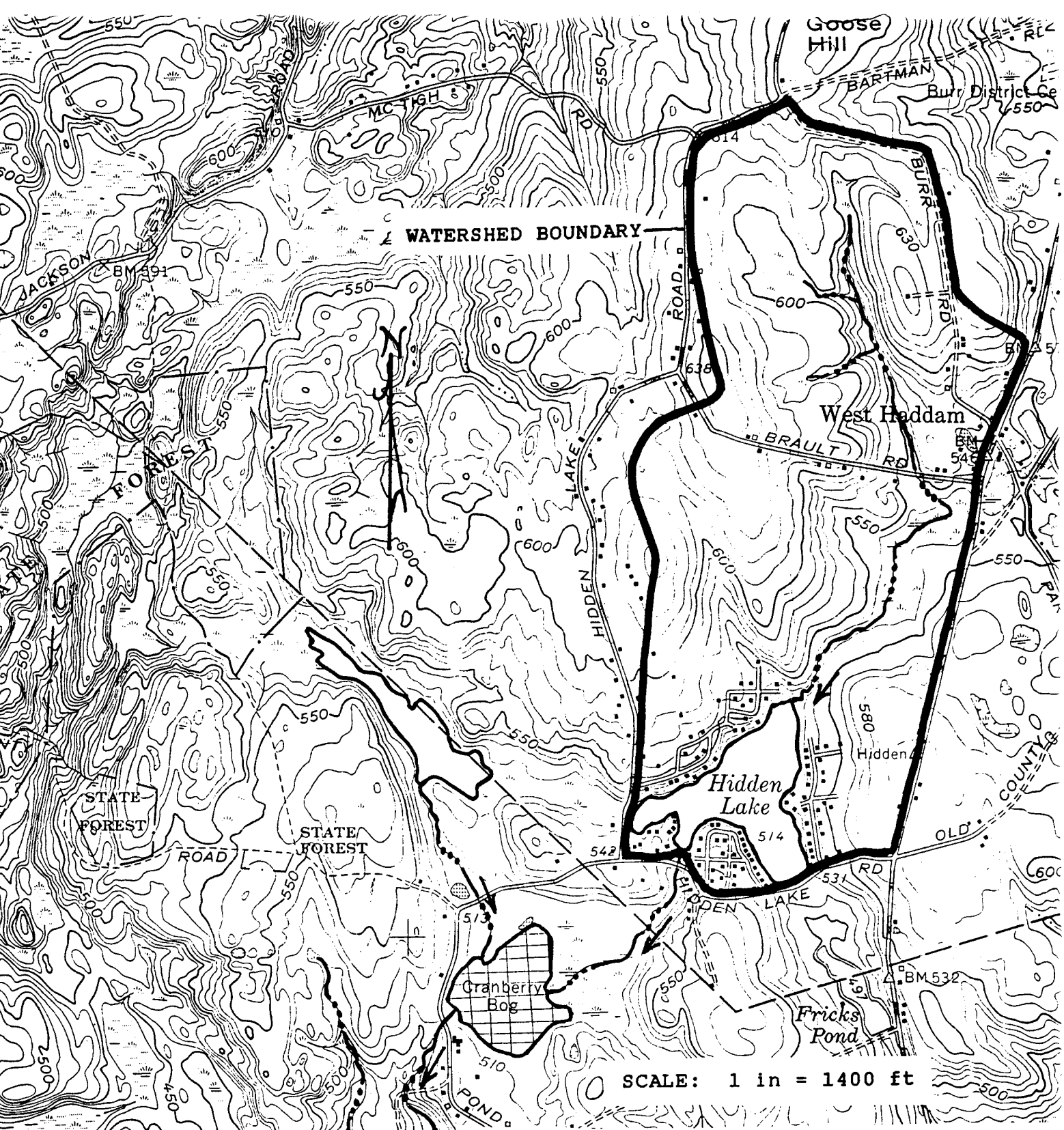

Figure 1
HIDDEN LAKE WATERSHED
HADDAM, CT

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From
U.S.G.S. Topographical Map
Haddam Quadrangle

include recommendations for various management techniques. The study will allow future comparisons to determine the response of the lake to management efforts.

FIELD METHODS

The lake was sampled by boat once a month from May through August, 1995. Three sampling stations were established (Figure 2). Station 1 (average depth 1.77 m, 5.8 ft) was located in the southwest arm of the lake off the peninsula between West Cove and Mill Bay. Station 2, the shallowest station (average depth 1.18 m, 3.9 ft), was located in South Cove, and Station 3 (average depth 1.56 m, 5.1 ft) was located in the center of North Cove.

At each station, measurements of water temperature, oxygen concentrations and conductivity (see Glossary for definition of unfamiliar terms) were taken at 0.5 m intervals from surface to the bottom. Water clarity was measured at Station 1 by lowering a white disk into the water (Secchi disk) and recording the depth at which it disappeared from view. Water samples were collected (0.35 m depth) and analyzed for pH, alkalinity, and the plant nutrients nitrate and total phosphorus. Phytoplankton (microscopic algae floating in the water) were counted and identified. Phytoplankton biomass was quantified as the concentration of chlorophyll a using a Turner fluorometer and the

HIDDEN LAKE SAMPLING STATIONS
HADDAM, CT

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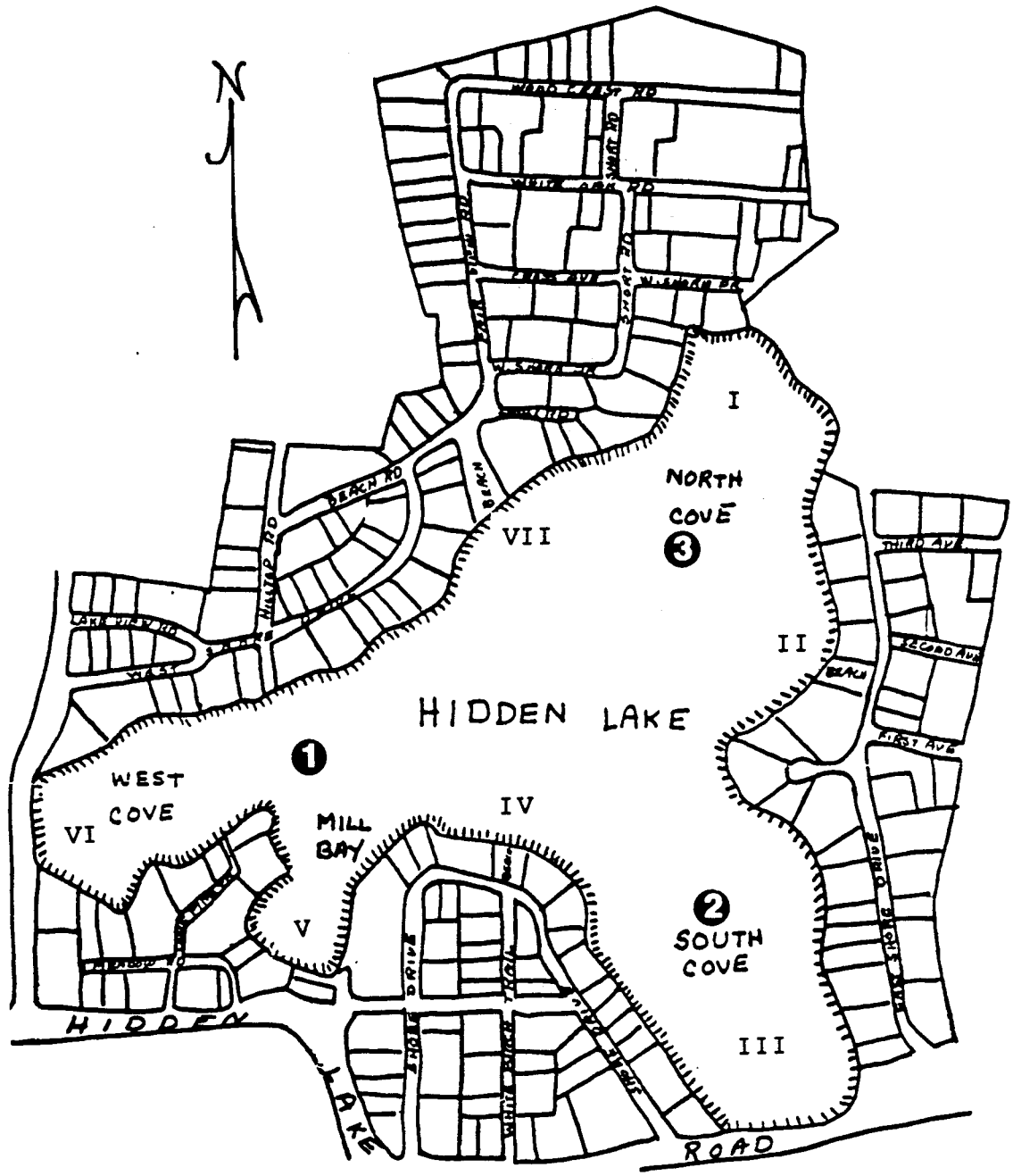
From
Hidden Lake Association Map



Circles = Study Stations
Roman Numerals = Lake Association Stations

SCALE: 1 in = 500 ft

methods of Axler and Owen (1994). Locations of aquatic plants were noted. Technical details of field and laboratory methods are presented in Appendix A.

It should be noted that the lake has also been sampled in the past by the Hidden Lake Association for total coliform and total phosphorus. Association sampling stations are shown as I through VII on Figure 2. Stations II, IV and VII represent the three beaches on the lake: East Shore Beach, Shore Drive Beach and West Shore Beach, respectively.

The major inflow stream, designated Inflow A (Figure 3), at the north end of the lake was sampled in May, June and July, but was not flowing in August. A second smaller stream, Inflow B, was sampled in May but was not running throughout the rest of the study; the summer of 1995 was remarkably dry. The stream samples were analyzed for all variables except phytoplankton and chlorophyll a.

A bathymetric survey was carried out to map the approximate shape of the lake basin. Depths were measured during calm conditions at 23 locations using a weighted plumb line. Depths were plotted on a tracing of an enlarged aerial photograph (#CT DEP 8-51-1693, March 29, 1990) and bottom contours were estimated from the data (Figure 3). The surface area of the lake was found using the grid enumeration method (Lind, 1985) and the length of

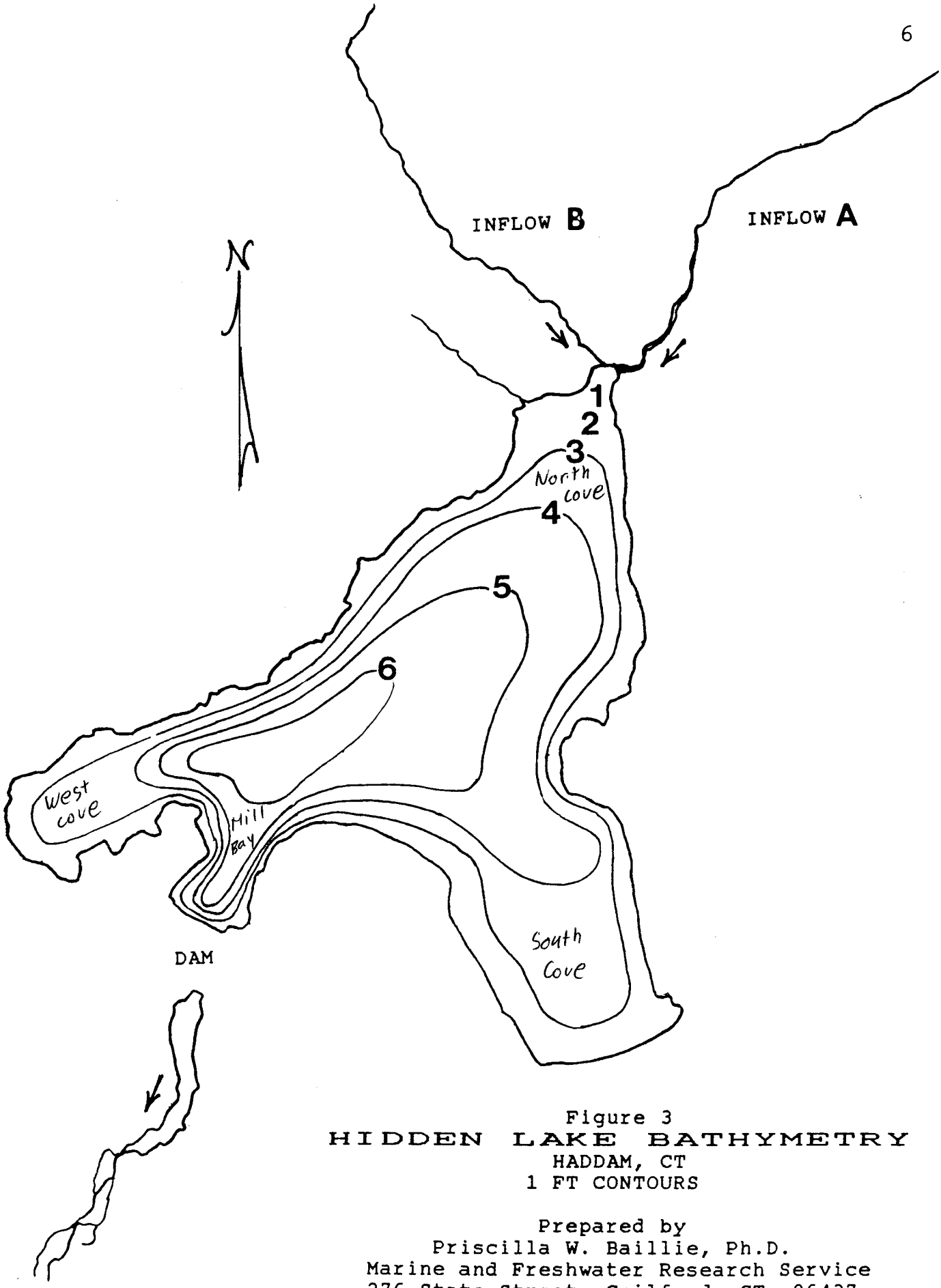


Figure 3
HIDDEN LAKE BATHYMETRY
HADDAM, CT
1 FT CONTOURS

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From
D.E.P. Aerial Photograph Enlargement

SCALE: 1 in = 400 ft

the shoreline was determined by means of a curvilinear map measurer. Maximum depth was measured in the field and mean depth was calculated as the average of the 23 depth readings.

DIMENSIONS

The dimensions of a lake (i.e. its area, mean depth, volume and length of shoreline) have important effects on many aspects of its ecology (Wetzel, 1983; Cole, 1979; Lind, 1985). Also, the nature of the land draining into a lake, termed the watershed, has a profound effect on the condition of the system. Important first steps in a lake study are determinations of the size, shape and depth of the basin, as well as the size and characteristics of its watershed.

THE WATERSHED

The watershed of Hidden Lake lies within the Chatfield Hollow Brook Drainage Basin No. 5105 (DEP, 1982). The lake, together with its inflow and outflow streams, is a tributary of Pond Meadow Brook (DEP, 1972). The lake watershed is 0.89 mi^2 in area and is largely undeveloped forest. The U.S. Geological Survey topographical map for the Haddam Quadrangle (1961, photo-revised 1971) shows the surface of the lake at elevation 514 ft above sea level (Figure 1). Slopes around the lake and within the watershed rise to a maximum elevation of about 640 ft. There

are virtually no wetlands associated with the lake shore. Homes and lawns occupy most of the shoreline, although some areas support natural wooded vegetation (Figure 4). According to the topographical map, most of the houses around the lake were built prior to 1961. At present, there are 80 year-round homes and 30 seasonal homes comprising the lake-side community.

The main feeder stream (Inflow A) and a second intermittent stream (Inflow B) enter the lake from the north (Figure 3). The lake is also fed by groundwater, surface runoff and several small intermittent brooks and road drainage ditches. The lake outflow traverses a recently reconstructed masonry dam at the southwestern end. It is piped under Hidden Lake Road and then flows through a cranberry bog, eventually discharging into Pond Meadow Brook about 2.5 miles downstream. The fact that the inflow and outflow are at opposite ends of the lake ensures good water circulation during periods of high flow.

THE LAKE

Many physical, chemical and biological characteristics of a lake are affected by its dimensions (Wetzel, 1983). For example, the length of the shoreline and the type of bordering vegetation affect the quantity of leaves and debris entering a lake each season, thereby influencing nutrient input. The orientation of the lake with respect to the prevailing wind, and

Figure 4

Laser copy of DEP Aerial Photograph

3/29/90, CT-DEP-8-51-1693

The photograph shows the degree of development around the shoreline of Hidden Lake. The main inflow brook enters at the top right corner of the photograph. The outflow is at the bottom left. North is at the top of the photograph. The scale is 1 in = 400 ft.

the shelter provided by surrounding hills and vegetation, determine the degree of wind mixing. The overall depth of a lake affects the rate at which it ages. All lakes tend to fill gradually with accumulated organic matter and thus shallow lakes, such as Hidden Lake, tend to be shorter lived than deeper systems.

As earlier noted, the surface area of Hidden Lake is 39 acres. The maximum depth measured during this study (under severe drought conditions) was 6.10 ft and the mean depth was 4.48 ft. The lake level was approximately 9 inches below the spillway during the latter part of the study, meaning that the average depth is about 5.23 ft when the lake is filled to the height of the spillway. The lake volume therefore varies from about 7,620,000 to 8,895,000 ft^3 (175 to 204 ac ft). Using the above low water volume and a published "driest year" flow rate for Hidden Lake of 0.72 ft^3/sec (U.S. Geological Survey, 1982), the turnover time during drought conditions would be 123 days. Using the volume at the spillway and a "median" flow rate of 1.29 ft^3/sec, the turnover time would be 80 days. These turnover times mean that water is moving through the lake rather rapidly compared to other deeper systems. As long as good water quality is maintained in the inflow stream, this circumstance benefits the ecology of the lake.

The lake is generally triangular in shape. It is composed of three major bays and several peninsulas (Figure 4). The

shoreline is about 4.28 mi in length. Shoreline irregularity is of interest because the amount of leaves, other terrestrial debris and overland runoff containing nutrients and sediments entering a lake increases with the length of its shore. A lake with numerous bays and indentations is more subject to impacts emanating from the watershed than a lake with a simple circular or oval shape.

The Shoreline Development Index (SDI) is a measure of shoreline irregularity. This index is the ratio of the length of shoreline to the circumference of a circle with an area equal to that of the lake (Wetzel, 1983). The index is calculated using the equation shown in Appendix B. A perfectly circular lake would have an SDI of 1.0. The relatively complex shoreline of Hidden Lake is reflected in a high SDI value of 4.89. This means that the ecology of the lake is highly impacted by disturbances in the land immediately adjacent to its shoreline.

A comparison of the bathymetric map (Figure 3) with an earlier map (Appendix C) developed in 1959 by the State Board of Fisheries and Game, indicates the extent to which the lake has filled in over a period of 36 years. The area enclosed within the 6 ft contour in Figure 3 is considerably reduced compared to the 6 ft contour developed in 1959. This represents a significant loss of depth in a shallow system.

PHYSICAL and CHEMICAL CHARACTERISTICS

LAKE WATER QUALITY

Temperature and Dissolved Oxygen

There was little difference in temperature between surface and bottom at any of the stations throughout the study (Table 1). Because the lake is shallow, wind action on the surface causes the lake to be well mixed, and measurements of lake characteristics from the surface down tended to be fairly uniform. For example, the lake was well oxygenated from surface to bottom throughout the summer. Dissolved oxygen levels ranged from 7.0 to 9.2 mg/l at the surface (Figure 5). Near the bottom, oxygen levels were more variable, ranging from 3.8 to 8.4 mg/l. Generally, however, even the sediments were quite well oxygenated. Dissolved oxygen concentrations in all areas of the lake were adequate to support fish and other aquatic organisms.

Alkalinity, pH and Conductivity

Alkalinity is a measure of the concentration of calcium carbonate in a lake and is related to water hardness. Since certain kinds of pollution (leakage from septic systems, for example) can increase alkalinity levels, this variable is routinely measured in water quality studies. In unpolluted lakes

HIDDEN LAKE
Haddam, CT

Table 1.
PHYSICAL CHEMICAL CHARACTERISTICS

MAY 22, 1995

Weather: Full sun, cool, light breeze
Secchi: 1.80 m

Location	Depth meters	Temp. oC	D.O. mg/l	Conduct. umhos/cm	pH	Alkal. mg/l	Chlo.a ug/l	Pheo.a ug/l	NO3-N mg/l	T.P. mg/l
Station 1										
Depth: 1.92 m										
Time: 0850										
	Surface	18.6	9.2	55	6.91	15	5.99	1.17	0.030	0.023
	0.5	18.5	9.0	54						
	1.0	18.1	9.0	54						
	1.5	17.5	9.9	54						
	Bottom	16.8	6.3	54						
Station 2										
Depth: 1.29 m										
Time: 0935										
	Surface	18.2	8.9	55	6.84	15	5.38	1.08	0.024	0.025
	0.5	18.1	8.7	55						
	1.0	18.0	8.8	56						
	Bottom	18.0	8.2	56						
Station 3										
Depth: 1.65 m										
Time: 1005										
	Surface	19.0	9.1	54	6.85	15	3.52	0.61	0.023	0.025
	0.5	18.8	9.0	55						
	1.0	18.2	8.8	55						
	1.5	18.1	9.3	55						
	Bottom	17.9	8.1	58						
Inflow A		14.5	9.3	47	6.68	15			0.055	0.015
Time: 1205										
Inflow B		14.9	9.7	29	6.75	15			0.062	0.053
Time 1215										

ABBREVIATIONS:

Temp. =	Temperature	m =	Meters
D.O. =	Dissolved oxygen	oC =	Degrees celsius
Conduct. =	Conductivity	umhos/cm =	Micromhos per centimeter
Alkal. =	Alkalinity	mg/l =	Milligrams per liter
Chlo.a =	Chlorophyll a	ug/l =	Micrograms per liter
Pheo.a =	Pheopigments a	BDL =	Below detectable level
NO3-N =	Nitrate nitrogen		(0.010 mg/l)
T.P. =	Total phosphorus		

HIDDEN LAKE
Haddam, CT

Table 1.
PHYSICAL CHEMICAL CHARACTERISTICS

JUNE 27, 1995

Weather: Bright sun, very windy
Secchi: 1.68 m

Location	Depth meters	Temp. oC	D.O. mg/l	Conduct. umhos/cm	pH	Alkal. mg/l	Chlo.a ug/l	Pheo.a ug/l	NO3-N mg/l	T.P. mg/l
Station 1										
Depth: 1.80 m										
Time: 0855										
	Surface	22.8	7.0	63	6.93	15	14.89	3.74	BDL	0.013
	0.5	22.8	6.9	63						
	1.0	22.8	6.9	63						
	1.5	22.8	6.9	63						
	Bottom	22.8	4.5	75						
Station 2										
Depth: 1.24 m										
Time: 0925										
	Surface	23.0	7.4	66	7.02	15	8.24	3.31	BDL	0.015
	0.5	23.0	7.3	65						
	1.0	22.9	7.3	66						
	Bottom	22.9	6.5	65						
Station 3										
Depth: 1.61 m										
Time: 1000										
	Surface	23.2	8.0	64	7.00	15	9.04	2.75	BDL	0.015
	0.5	23.0	7.8	63						
	1.0	22.9	7.8	65						
	Bottom	22.9	7.8	66						
Inflow A		17.00	8.3	66	7.02	25			0.252	BDL
Inflow B		Not Running								

ABBREVIATIONS:

Temp. =	Temperature	m =	Meters
D.O. =	Dissolved oxygen	oC =	Degrees celsius
Conduct. =	Conductivity	umhos/cm =	Micromhos per centimeter
Alkal. =	Alkalinity	mg/l =	Milligrams per liter
Chlo.a =	Chlorophyll a	ug/l =	Micrograms per liter
Pheo.a =	Pheopigments a	BDL =	Below detectable level
NO3-N =	Nitrate nitrogen		(0.010 mg/l)
T.P. =	Total phosphorus		

HIDDEN LAKE
Haddam, CT

Table 1.
PHYSICAL CHEMICAL CHARACTERISTICS

JULY 20, 1995

Weather: Clear, scattered clouds, surface calm
Secchi: To bottom

Location	Depth meters	Temp. oC	D.O. mg/l	Conduct. umhos/cm	pH	Alkal. mg/l	Chlo.a ug/l	Pheo.a ug/l	NO3-N mg/l	T.P. mg/l
Station 1										
Depth: 1.66 m										
Time: 0820										
	Surface	25.8	8.2	68	7.20	15	5.05	2.78	BDL	0.016
	0.5	25.8	8.2	69						
	1.0	25.8	8.2	69						
	1.5	25.1	6.4	69						
	Bottom	25.1	3.8	72						
Station 2										
Time: 0915										
	Surface	26.2	7.3	69	7.00	15	7.60	2.25	BDL	0.020
	0.5	26.1	7.3	69						
	1.0	26.0	7.3	69						
	Bottom	26.0	4.6	71						
Station 3										
Depth: 1.49 m										
Time:0955										
	Surface	26.5	8.8	69	7.34	15	5.37	0.29	BDL	0.019
	0.5	26.3	8.7	69						
	1.0	26.0	8.6	69						
	Bottom	26.0	8.4	70						
Inflow A		18.9	7.9	122	6.68	15			0.263	0.012
Time: 1200										
Inflow B		Not Running								

ABBREVIATIONS:

Temp. =	Temperature	m =	Meters
D.O. =	Dissolved oxygen	oC =	Degrees celsius
Conduct. =	Conductivity	umhos/cm =	Micromhos per centimeter
Alkal. =	Alkalinity	mg/l =	Milligrams per liter
Chlo.a =	Chlorophyll a	ug/l =	Micrograms per liter
Pheo.a =	Pheopigments a	BDL =	Below detectable level
NO3-N =	Nitrate nitrogen		(0.010 mg/l)
T.P. =	Total phosphorus		

HIDDEN LAKE
Haddam, CT

Table 1.
PHYSICAL CHEMICAL CHARACTERISTICS

AUGUST 26, 1995

Weather: Full sun, mild, calm
Secchi: To bottom

Location	Depth meters	Temp. oC	D.O. mg/l	Conduct. umhos/cm	pH	Alkal. mg/l	Chlo.a ug/l	Pheo.a ug/l	NO3-N mg/l	T.P. mg/l
Station 1										
Depth: 1.70 m										
Time: 0840										
	Surface	22.0	7.4	69	7.19	15	2.18	1.62	BDL	BDL
	0.5	22.0	7.4	69						
	1.0	22.0	7.6	69						
	1.5	22.0	7.5	69						
	Bottom	22.0	6.9	70						
Station 2										
Depth: 1.00 m										
Time: 0908										
	Surface	21.2	8.0	68	7.09	15	2.50	1.27	BDL	0.012
	0.5	21.0	7.7	68						
	Bottom	21.0	7.7	68						
Station 3										
Depth: 1.49 m										
Time: 0935										
	Surface	22.0	7.7	69	7.04	15	2.55	0.23	BDL	0.012
	0.5	21.9	7.7	69						
	1.0	21.9	7.9	68						
	Bottom	21.9	6.6	70						
Inflow A		Not running								
Inflow B		Not Running								

ABBREVIATIONS:

Temp. = Temperature
D.O. = Dissolved oxygen
Conduct. = Conductivity
Alkal. = Alkalinity
Chlo.a = Chlorophyll a
Pheo.a = Pheopigments a
NO3-N = Nitrate nitrogen
T.P. = Total phosphorus

m = Meters
oC = Degrees celsius
umhos/cm = Micromhos per centimeter
mg/l = Milligrams per liter
ug/l = Micrograms per liter
BDL = Below detectable level (0.010 mg/l)

and ponds, alkalinity is primarily regulated by the geology of the watershed; levels are higher in areas of sedimentary rock and lower in areas of igneous rock. The eastern regions of Connecticut are dominated by schist, gneiss and granite (Bell, 1985). Therefore, eastern lakes tend to be softwater systems with low alkalinity. Alkalinity in Hidden Lake was consistently very low (15 mg/l) at all stations and on all sampling occasions, and the lake is thus classified as a softwater system.

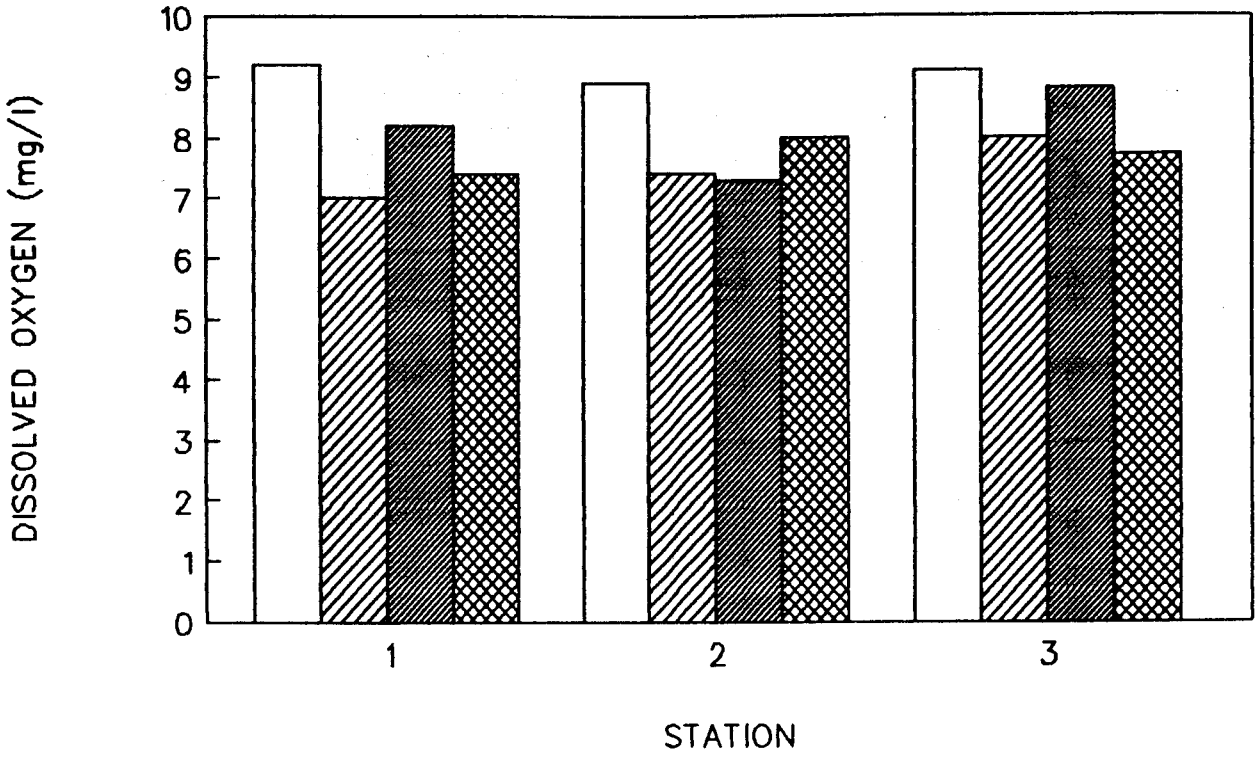
PH is a measure of the acidity of lake water. On a scale of 1 to 14, a pH of 7 is neutral, below 7 is acidic and above 7 is basic. In natural waters, pH usually ranges between 6 and 9. In Hidden Lake, pH was close to neutrality, ranging from 6.84 to 7.34. There was no significant difference in pH between stations or between sampling dates (Figure 6).

Conductivity reflects the overall concentration of ions in the water and is a non-specific pollution indicator. It is directly related to the concentration of total dissolved solids but does not indicate the type of ions in solution. Again, the geology of the watershed affects conductivity. Levels less than 100 umhos/cm are typical of unpolluted softwater systems. In Hidden Lake, conductivity fell within the expected range, varying from 54 to 75 umhos/cm. There was no significant difference in conductivity between the three stations (Figure 7).

DISSOLVED OXYGEN
HIDDEN LAKE, HADDAM, CT

MAY JUN JUL AUG

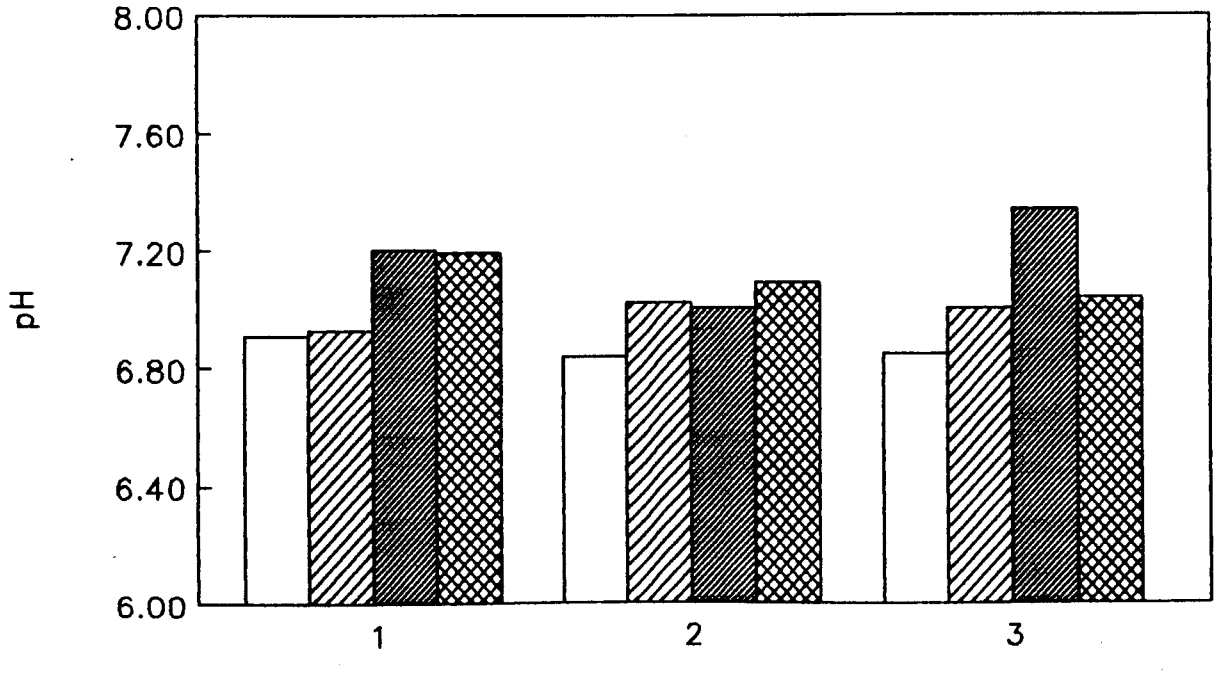
Fig.5



pH
HIDDEN LAKE, HADDAM, CT

MAY JUN JUL AUG

Fig.6



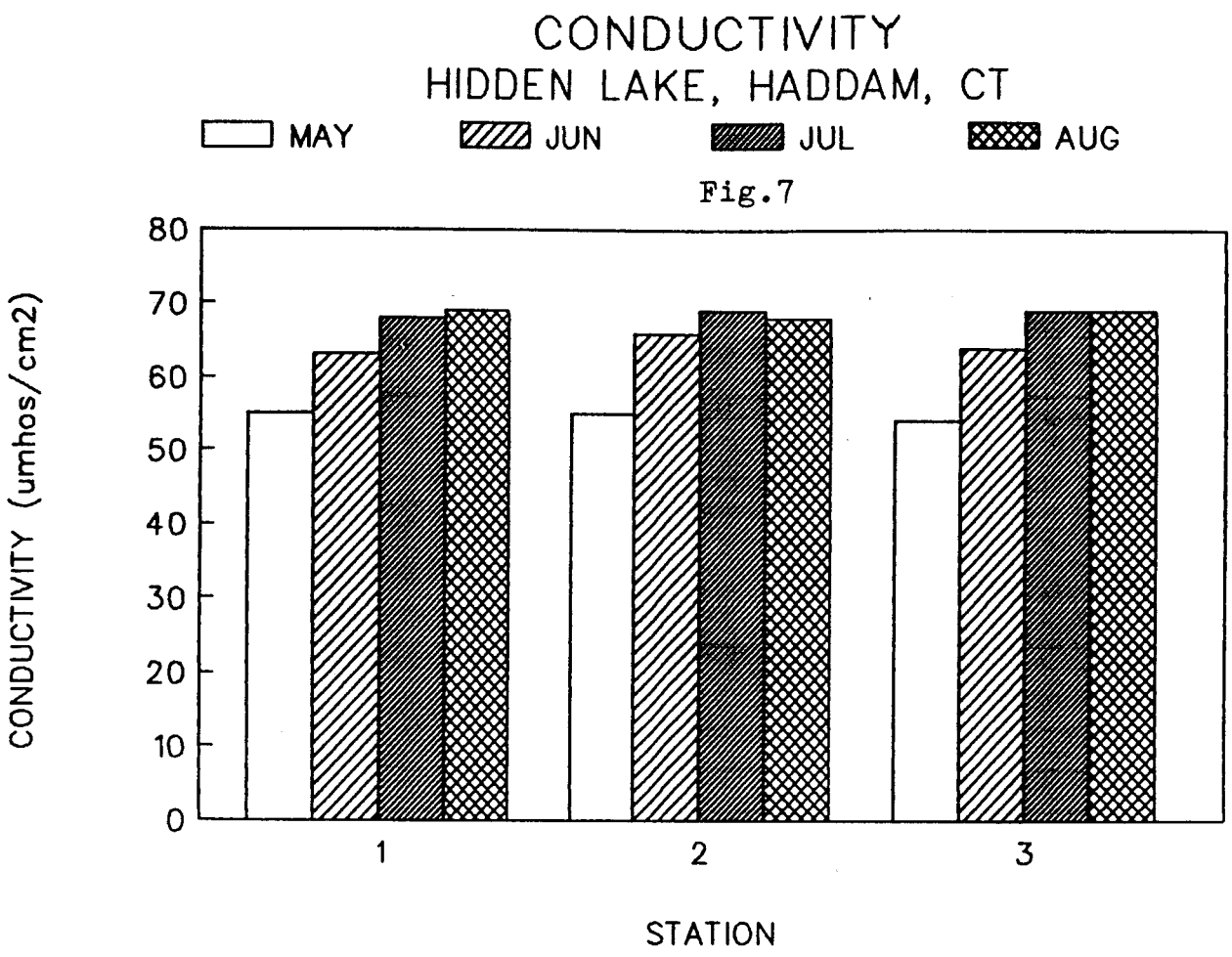

CONDUCTIVITY
HIDDEN LAKE, HADDAM, CT
MAY
JUN
JUL
AUG
CONDUCTIVITY (umhos/cm2)
80
70
60
50
40
30
20
10
0
1
2
3
STATION

Fig.7

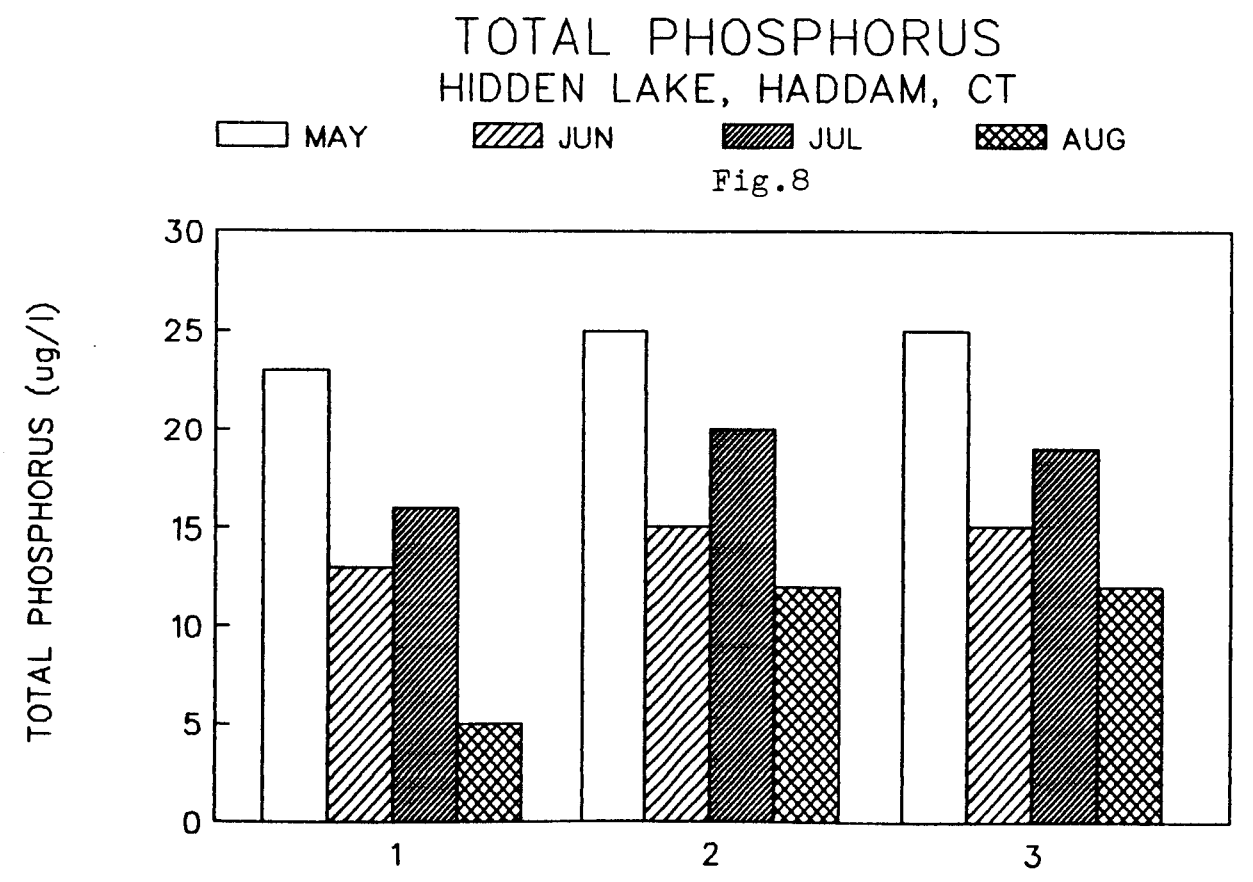

TOTAL PHOSPHORUS
HIDDEN LAKE, HADDAM, CT
MAY
JUN
JUL
AUG
TOTAL PHOSPHORUS (ug/l)
30
25
20
15
10
5
0
1
2
3

Fig.8

During the May and June sampling trips, the conductivity probe was trolled around the entire shoreline of the lake in an effort to detect pulses of elevated conductivity which might indicate septic input. No peaks were detected. On those two occasions, conductivity ranged within expected limits, between 55 and 68 umhos/cm.

Nitrate and Total Phosphorus

The two most important plant nutrients in ecosystems are nitrogen and phosphorus. Nutrients entering Connecticut lakes have increased in recent years as the result of man's activities. Nutrients are plentiful in septic waste, fertilizers and road runoff. Soil erosion, originating in areas of construction, is also a major source of nutrients, especially phosphorus.

Nitrogen occurs naturally in the environment in greater quantities than phosphorus. It is present in several dissolved and particulate forms (nitrate, nitrite, ammonia and organic nitrogen). The form of nitrogen measured in this study was nitrate-N, which is the form most readily used by plants and algae. In Connecticut lakes and ponds, nitrate-N levels generally range between 0.50 and 1.00 mg/l. In Hidden Lake, nitrate-N levels were very low in May, ranging from 0.023 to 0.030 mg/l, and were undetectable throughout the rest of the study.

Phosphorus is normally less plentiful in the natural environment than nitrogen. It is derived from rock and is associated with soil particles. Therefore, when eroded sediments reach a lake they not only increase turbidity and decrease depth, but they also carry large amounts of phosphorus into the system. Levels below 0.030 mg/l are considered acceptable for lakes and ponds (Frink and Norvell, 1983). Total phosphorus levels in Hidden Lake were generally low, ranging from 0.025 mg/l to undetectable (Figure 8). Phosphorus enters a lake primarily in streams or overland runoff. Severe drought conditions during the summer of 1995 (with the resulting lack of stream flow and runoff) prevented phosphorus from reaching the lake.

Lake Association Data

Total phosphorus levels and total coliform counts have been monitored by the Hidden Lake Association for several years (Table 2). The data indicated that there may have been a sporadic problem with septic input at the western end of the lake. The State of Connecticut standard is 500 total coliform bacteria per 100 ml of water (DEP, 1992). This standard was greatly exceeded at the West Cove and West Shore stations in 1993, and again at West Cove in 1995 (Figure 9).

Total phosphorus levels ranged from 0.05 to 0.14 mg/l at the Mill Bay and West Cove stations in 1993 and 1994 (Figure 10).

Table 2

HIDDEN LAKE
Haddam, CT

HIDDEN LAKE
ASSOCIATION DATA

Date	Station Number	Station Name		Total Coliform /100 ml	Total Phosphorus mg/l
JUNE 9, 1993	I	NORTH COVE		30	0.03
	II	EAST SHORE		70	0.03
	III	SOUTH COVE		10	0.04
	IV	SHORE DRIVE		30	0.03
	V	MILL BAY		90	0.05
	VI	WEST COVE		955	0.06
	VII	WEST SHORE		1210	0.03
AUGUST 8, 1994	I	NORTH COVE		38	0.03
	II	EAST SHORE		42	0.03
	III	SOUTH COVE		30	0.03
	IV	SHORE DRIVE		40	0.04
	V	MILL BAY		30	0.14
	VI	WEST COVE		120	0.05
	VII	WEST SHORE		22	0.03
JULY 17, 1995	I	NORTH COVE		138	0.01
	II	EAST SHORE		34	0.01
	III	SOUTH COVE		40	0.01
	IV	SHORE DRIVE		34	0.01
	V	MILL BAY		48	0.04
	VI	WEST COVE	*	1600	0.01
	VII	WEST SHORE		90	0.01

* Bacteria re-tested August 4, 1995
Range: 42 - 270 /100ml; Mean 138 /100ml