

HIGHLAND LAKE MACROPHYTE MAP

Performed for: Highland Lake Commission
Town of Winchester/City of Winsted
Town Hall
338 Main Street

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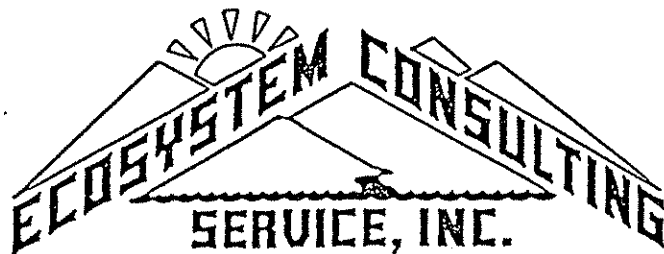


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EXECUTIVE SUMMARY/ABSTRACT

The primary objective of this study was to update the information requested by the Department of Environmental Protection regarding macrophyte populations at Highland Lake and the effectiveness of winter drawdown for the control of nuisance weed growth. During the performance of this work the weed beds were studied and described in qualitative (dense, moderate, sparse) and quantitative (wet weight) methods. In general, we found the littoral community at Highland Lake to be relatively diverse, healthy, and not problematic at this time. (Most weed beds are well below the water surface and offer diverse aquatic habitat. The species which offers the greatest potential to become a nuisance is water milfoil. The results of this study indicate that, although not eliminated, the spread and increased dominance of water milfoil appears to have been controlled by the winter drawdown program.) (The implementation of a regular schedule of winter drawdown will be important in avoiding the increasing dominance and nuisance growth of water milfoil. The frequency of drawdown should be determined by watching water milfoil populations following occasional drawdown. We would suggest that a "winter drawdown for weed control" be used every two to three years. Because of the volume represented by the surface of Highland Lake and the inflow hydrology from its watershed, we would recommend utilizing upstream systems (Crystal Lake, flood control structures) to the greatest extent possible for a rapid drawdown and refill of Highland Lake. A drawdown procedure is outlined.

In addition to the original scope of work (weed surveys), the water column was studied in order to define trophic status and to determine symptoms of future problems. It was noted that the 1.0% light level (compensation point), which represents the depth at which photosynthetic oxygen production and decomposition oxygen consumption are balanced, was at the depth of the anoxic boundary (where oxygen becomes depleted). This depth was found in the lower half of the metalimnion in August, 1985. Because of the location of the anoxic boundary within the metalimnion, the cold water fishery habitat becomes restricted to a 1-1.5 m layer during late summer. However, significant accumulations of redox compounds such as iron, manganese and hydrogen sulfide were only found in deeper water of the hypolimnion. (The algae found in Highland lake were primarily small forms of green algae. The dominance by desmids indicates that the waters are soft, slightly acidic and not problematic with respect to phytoplankton productivity.) The zooplankton (small organisms which graze on algae) were primarily small species. This suggests that the Highland Lake Commission may want to consider enhancing the piscivorous population of the lake (fish eating fish). This would tend to favor larger zooplankton forms which are more effective grazers of algae. Because of the depth of oxygen loss within the metalimnion and because this depth may become more shallow in future years, we would recommend that Highland Lake be monitored annually to keep track of production and decomposition rates in order to detect future eutrophication problems at a very early stage. A layer aeration system may become appropriate if oxygen consumption processes become more intense or if an extended cold water fishery habitat is desired. (However, at present there appears to be no imminent need for in-lake management for algal bloom avoidance.)

The longterm chronic condition of Highland Lake will be a function of both in-lake events and events within the watershed of the lake. (Although watershed nutrient loading does not appear to be problematic at this time we would recommend an on-going effort to manage the watershed in order to preserve the quality of Highland Lake. Small sedimentation basins at the mouth of major tributaries could be used effectively to manage incoming sediment loads. Small basins could be excavated at the mouth of these tributaries and accumulated sediments could be removed during the regular drawdown period by conventional equipment.) Appropriate locations for such small in-lake sedimentation basins would be major culvert outfalls, Sucker Brook (although the upstream flood control structure already provides a sedimentation function), and Taylor Brook. (It should be noted that the wetland associated with Taylor Brook may be very important to the longterm quality of Highland Lake and should be the focus of regulatory permissions in that part of the watershed.) A septic system management program would help to preserve the future quality of the lake, not only from a eutrophication view point but from a public health viewpoint. Systems suspected of failure should be tested and corrected. Although nutrient contribution from septic systems can be significant due to the nutrient budget of a lake, it appears that at Highland Lake the public health aspects are more important. This is because of the relatively small contribution from septic systems relative to the size of the lake and its watershed.)

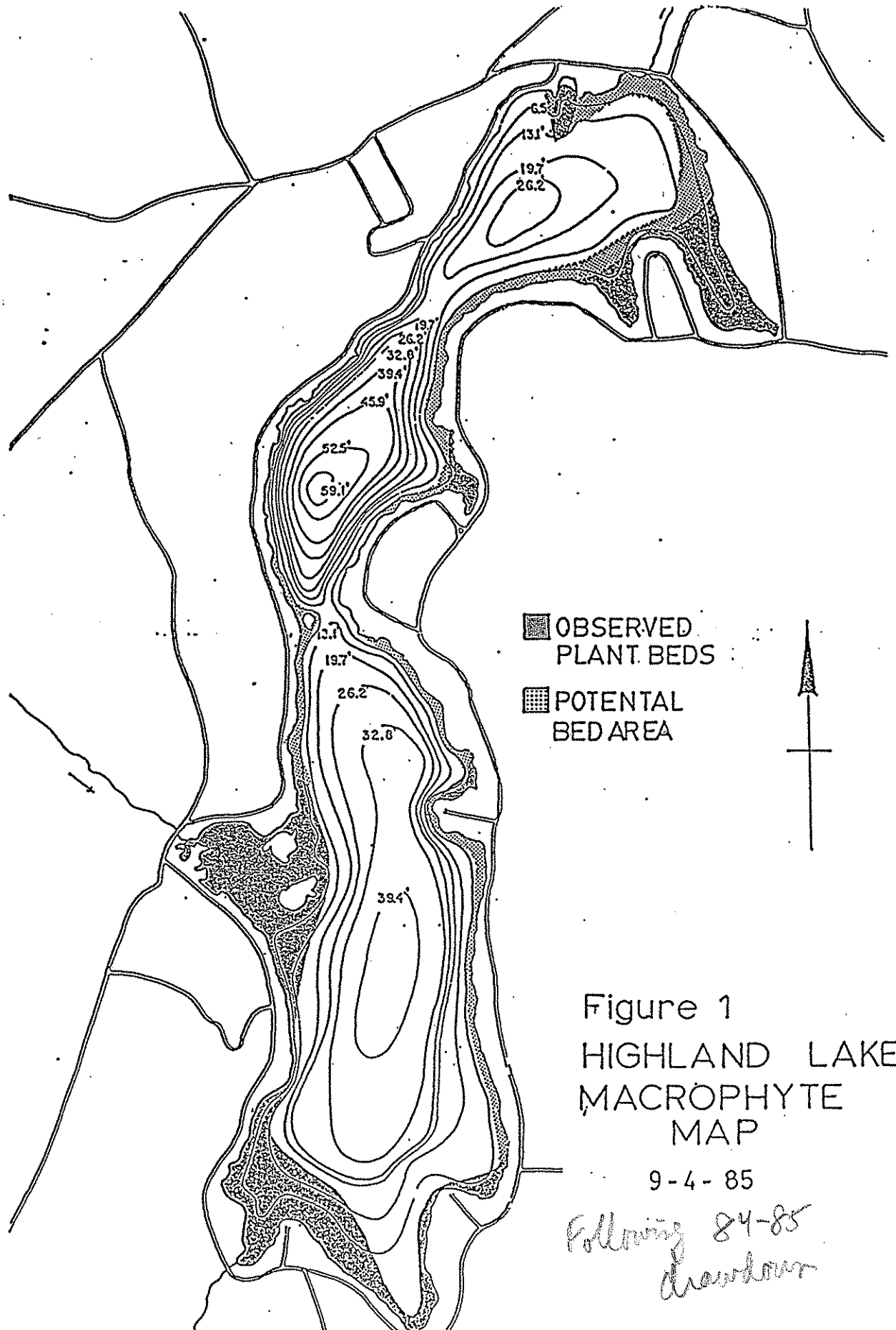
Part I. Weed Map Update:

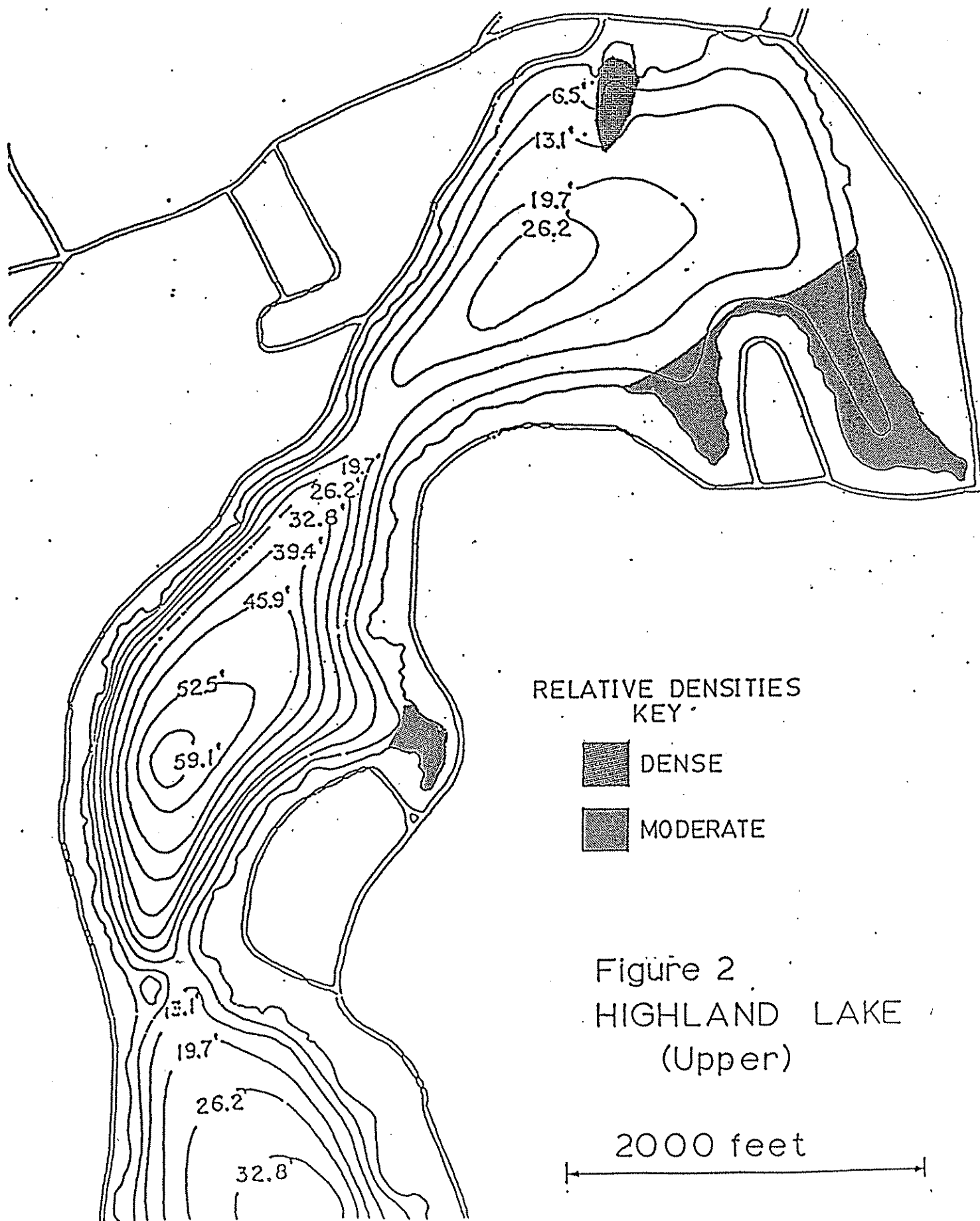
The aquatic plants of Highland Lake were observed and sampled on two different dates in order to update the map originally prepared by the Department of Environmental Protection in 1980. The map showing the location of the plants found is presented in Figure 1. The entire littoral area of the lake was not observed, steep banked areas were not visited, instead extra time was spent in the problem bays in order to map these areas more fully. This is presented on Figure 1 as 'observed plant beds' and 'potential bed' areas. The observed beds are areas that were visited, while the potential beds are areas that are littoral and capable of supporting plant beds but were not visited. In general plants were observed at all inspection points, usually no deeper than 4 meters (13 feet), and of moderate density.

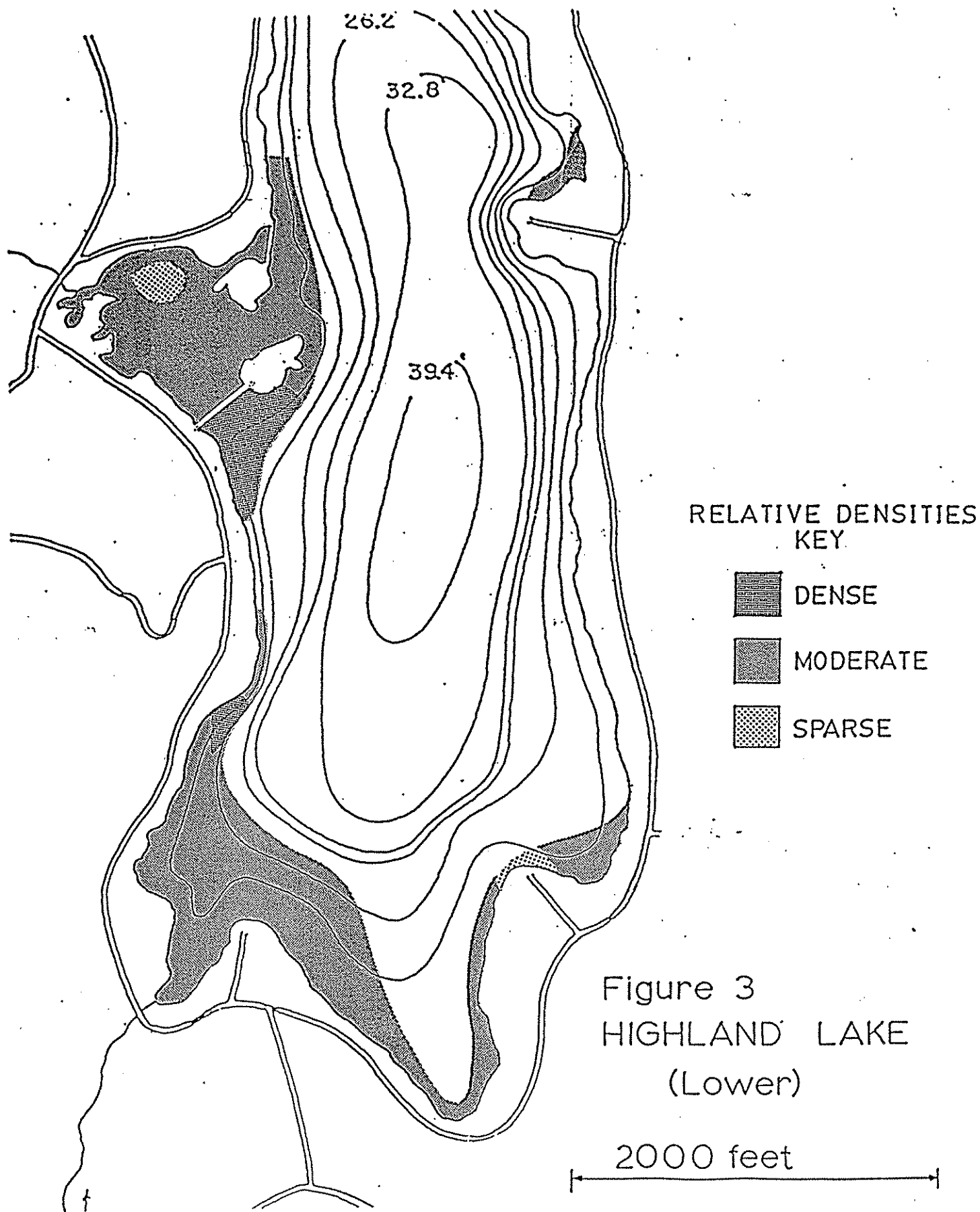
Table 1 lists the species found during the collection of biomass samples on 9-4-85. The list contains several new species but these species were not observed in dominant conditions, with the exception of Potamogeton obtusifolius which occurred at 100% cover in the D2 sample. The same species shown on the 1980 map as being dominant still compose a majority of the biomass present.

The density maps (Fig. 2 & 3) show the location of the three densities used to describe the macrophyte community of Highland Lake. Density areas were found by weight of collected samples for areas that were sampled, for areas not sampled but only observed the density was determined by comparing to a similar site that was sampled. Figure 4 shows the location of the biomass samples. Samples were collected with a circle of known internal area. this ring was placed on the bottom randomly, all plants in the ring were removed and brought to the surface. The information from the collection is presented in Table 2.

The depth of the water was measured at each sampling point. During this it was determined that certain contours were not correctly placed on the bathymetric map. Using the data that we collected from our sampling the contours for the south half of the lake were redrawn and are here presented in Figure 4.







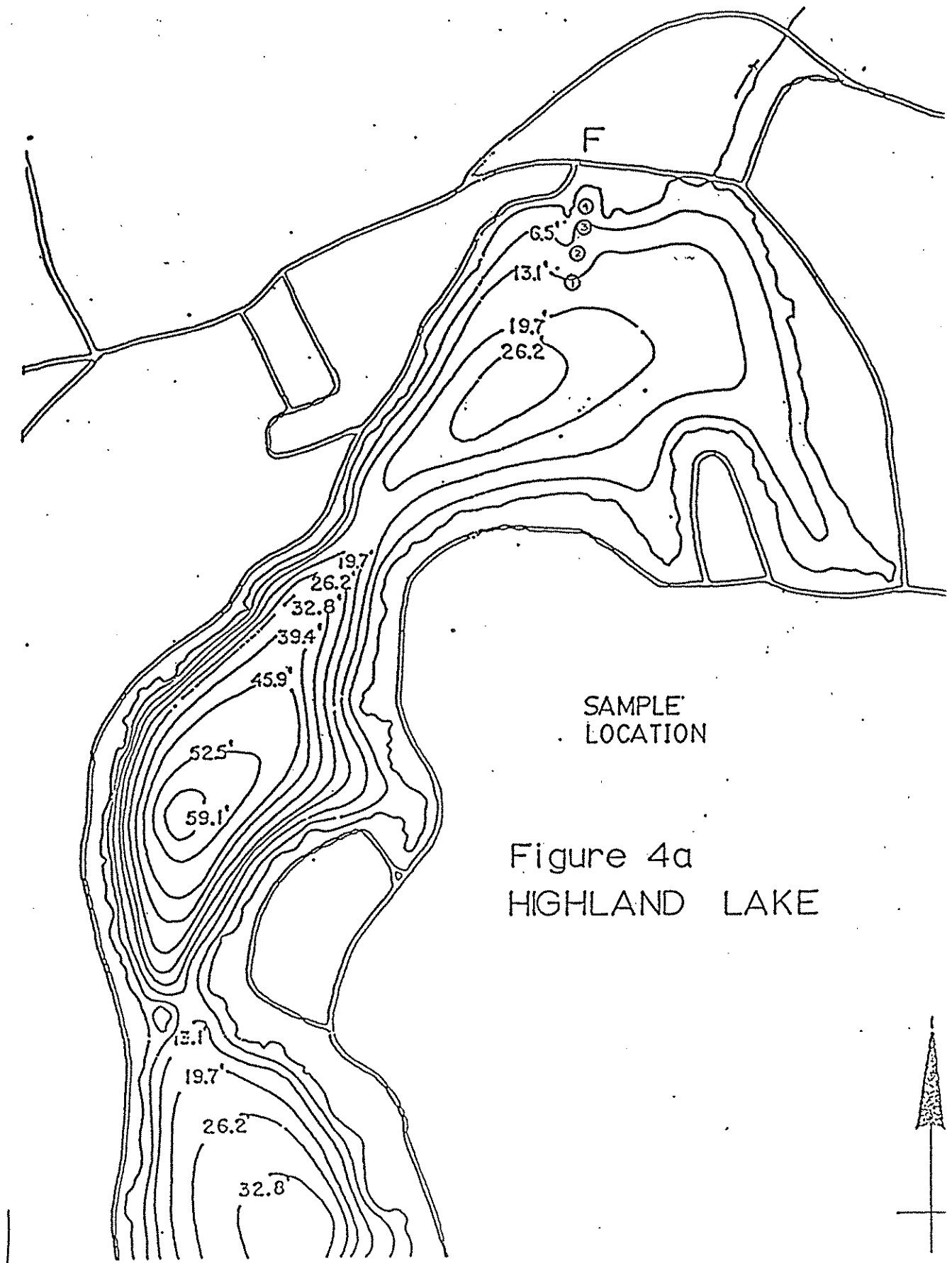


Figure 4a
HIGHLAND LAKE

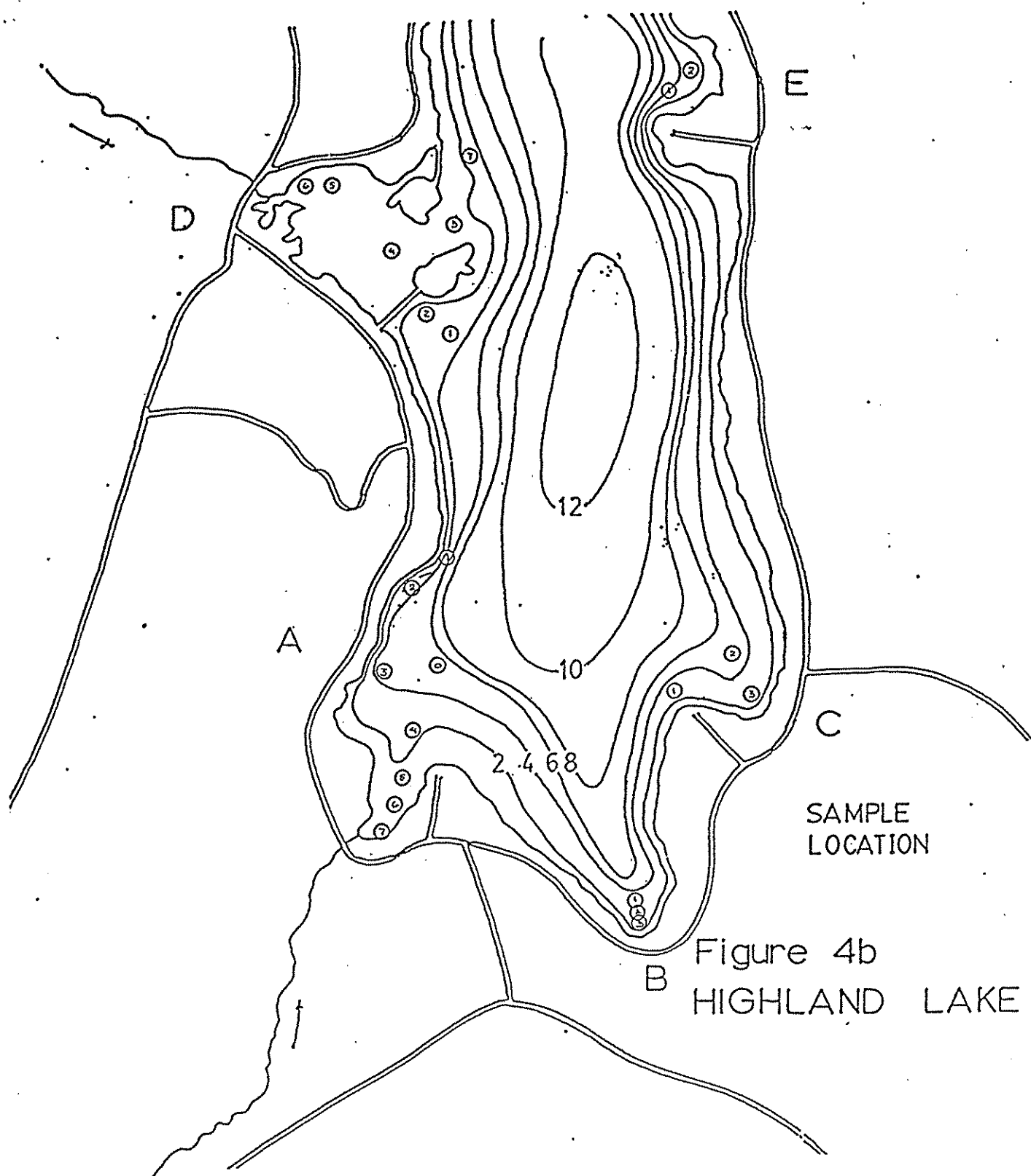


TABLE 1. SPECIES LIST FOR HIGHLAND LAKE

Myriophyllum verticillatum

Potamogeton richardsonii

Potamogeton robbinsii

Potamogeton amplifolius

Potamogeton obtusifolius

Vallisneria americana

Nitella sp

Chara sp.

Elodea canadensis

Isoetes spp.

Ceratophyllum demersum

found on shore at ramp but not in samples

TABLE 2. BIOMASS OF VEGETATION COLLECTED IN SAMPLES
(grams wet weight per 0.05 m2)

SAMPLE (Feet)	M.v.	P.R.	P.r.	P.a.	P.o.	V.a.	N.	C.	E.c.	I.
A0 (18)	0	0	0.4	0	0	0	7.4	0	5.7	0
A1 (15)	0	0	0	0	0	0	18.4	0	0	0
A2 (12)	89.4	0	0	0	0	0	0	0	0	0
A3 (14)	13.7	0	0	0	0	0	0	0	0	0
A4 (9)	0	3.2	1.6	0	0	28.2	3.5	0	8.5	0
A5 (6)	0	0	0	0	0	14.6	0	0	0	0
A6 (5)	0	1.7	0	0	0	0	0	18.3	0	3.2
A7 (2)	9.6	0	0	0	0	13.9	0	0	0	5.6
B1 (15)	34.3	0	0	0	0	0	0	0	0	0
B2 (12)	1.6	16.8	0	0	0	0	0	0	0	0
B3 (10)	34.6	7.6	0	0	0	0	0	0	0	0
C1 (9)	0	0	0	0	0	0	0	2.7	0	0
C2 (23)	0	0	0	0	0	0	0	0	0	0
C3 (11)	8.7	3.2	7.8	0	0	4.2	0	0	0	0
D1 (9)	74.6	0	0	0	0	7.3	22	0	0	0
D2 (8)	0	0	0	0	20.6	10.6	12	0	0	0
D3 (6)	0	5.3	0	0	0	0	0	9.8	0	3.2
D4 (5)	0	0	0	0	10.2	0	0	7.2	0	0
D5 (4)	0	0	0	0	0	0	0	0.5	0	1.1
D6 (5)	0	10.9	0	0	0	26.6	0	0	0	3.0
D7 (7)	0	8.9	0	0	1.5	4.6	9.2	0	1.2	0

TABLE 2 Continued.

SAMPLE	M.v.	P.R.	P.r.	P.a.	P.o.	V.a.	N.	C.	E.c.	I.
E1 (14)	17.1	0	0	0	0	6.2	13.6	0	1.2	0
E2 (9)	403.7	0	0	0	0	0	0	0	0	0
F1 (13)	23.5	22.9	0	0	0	5.3	0	0	0	0
F2 (10)	7.1	0	0	72.2	0	9.5	0	0	0	0
F3 (13)	0	0	0	0	0	0	84.3	0	0	0
F4 (9)	0	0	0	0	0	0	0	0	0	0
TOTAL= (rounded)	718	81	8	72	32	131	170	39	17	16

Part II. Discussion:

The macrophytes of Highland Lake were observed on August 28, & September 4 1985. Biomass and density of the plants present were mapped. This information was collected partially in order to evaluate the effectiveness of a drawdown of lake level over the winter of 1984 - 1985. Maximum drop in lake level attained during drawdown was 86 inches below the spillway elevation. This was maintained for 11 days after which the level gradually increased until it was again full on May 9, 1985. This drawdown would then affect plants growing above the 2 meter contour of the lake. Plants below this depth were not effected by the the drawdown. A general finding of the research is that plant beds above the 2 meter contour are more diverse in species composition. While those below the 2 meter contour are mainly milfoil or pondweed.

When the new map is compared to the Department of Environmental Protection map produced in 1980 it is clear that the plants have not become more dense then reported. The target species 'milfoil' has not spread into all available locations. This is significant because within five years the plant has the potential to colonize large areas of the littoral zone. The data in table 2 suggest that milfoil still is present below 7 feet, and in some cases, growing in dense beds. Above 7 feet the plant was found only occasionally and in sparse beds. The littoral zone above 7 feet now supports a healthy diverse macrophyte community that is beneficial to both the fish and wildlife component and the chemistry of the lake itself. No milfoil was encountered that grew to the surface of the water. It was always several feet below the water. The only plant found to grow to the surface was Vallisneria spiralis, however this was restricted to the shallow water at the rear of some of the bays.

Drawdown at Highland Lake can be said to have been successful in that the target species Myriophyllum verticillatum has been contained below the 2 meter contour while allowing the formation of healthy community of macrophytes above this depth.

HIGHLAND LAKE WEED MAP

Digitized Areas from 8 1/2" X 11" ECS Macrophyte Map.
(Bathymetry lines from Fink & Norvell may be inaccurate)

	<u>ft²</u>	<u>acres</u>
TOTAL LAKE AREA	18,342,720	421.09
Area Without Weeds	13,476,940	309.39
Area With Weeds	4,865,780	111.70
	(26.5%)	

Lake edge islands 18,342,720 - 129,122 = 18,123,598
 12,642 54,623 61,857 = 129,122

Contours:	6.5' - 2m	13,977,280		
	13.1' - 4m	6,443,319	= 4,449,025	
	19.7' - 6m	4,982,755	+ 2,018,224	+ 858,153
	26.2' - 8m	4,066,394	+ 1,738,483	+ 229,715
	32.8' - 10m	2,652,746	+ 1,431,294	
	39.4' - 12m	599,099	+ 1,065,019	
	45.9' - 14m		729,774	
	52.5' - 16m		280,620	
	59.1' - 18m		54,961	
		<u> </u>	<u> </u>	<u> </u>
		lower basin	middle basin	upper basin

Total Areas	<u>below depth</u>	
0m	18,213,598	ft ²
2m	13,977,280	
4m	10,892,344	
6m	7,859,132	
8m	6,034,592	
10m	4,084,040	
12m	1,664,118	
14m	729,774	
16m	280,620	
18m	54,961	

HIGHLAND LAKE

In-Lake Physical/Chemical/Biological Structure

The structure of the Highland Lake water column is defined by Figure 5, and Tables 3 and 4. Figure 5 illustrates that the epilimnion extends to about 5 meters and hypolimnion occurs below 9 meters. The "compensation depth" was observed at about 8 meters, below which Oxygen production by photosynthesis does not balance decomposition. It is important to note that this depth is the point where oxygen saturation drops from 21% to 4% and that it occurs just below the thermocline. If some event were to reduce transparency, oxygen loss would occur above the thermocline and algal bloom conditions could result. It is therefore essential to avoid turbidity, watershed nutrient enrichment and aquashade applications if the lake is to remain in its present trophic condition. Aquashade should not be used at Highland Lake!

Although the hypolimnion becomes anoxic and accumulates reduced compounds, the late summer concentrations are relatively deep and do not appear to be problematic at this time. This condition could change through time, however, and it would be wise to monitor the lake in order to detect problems very early.

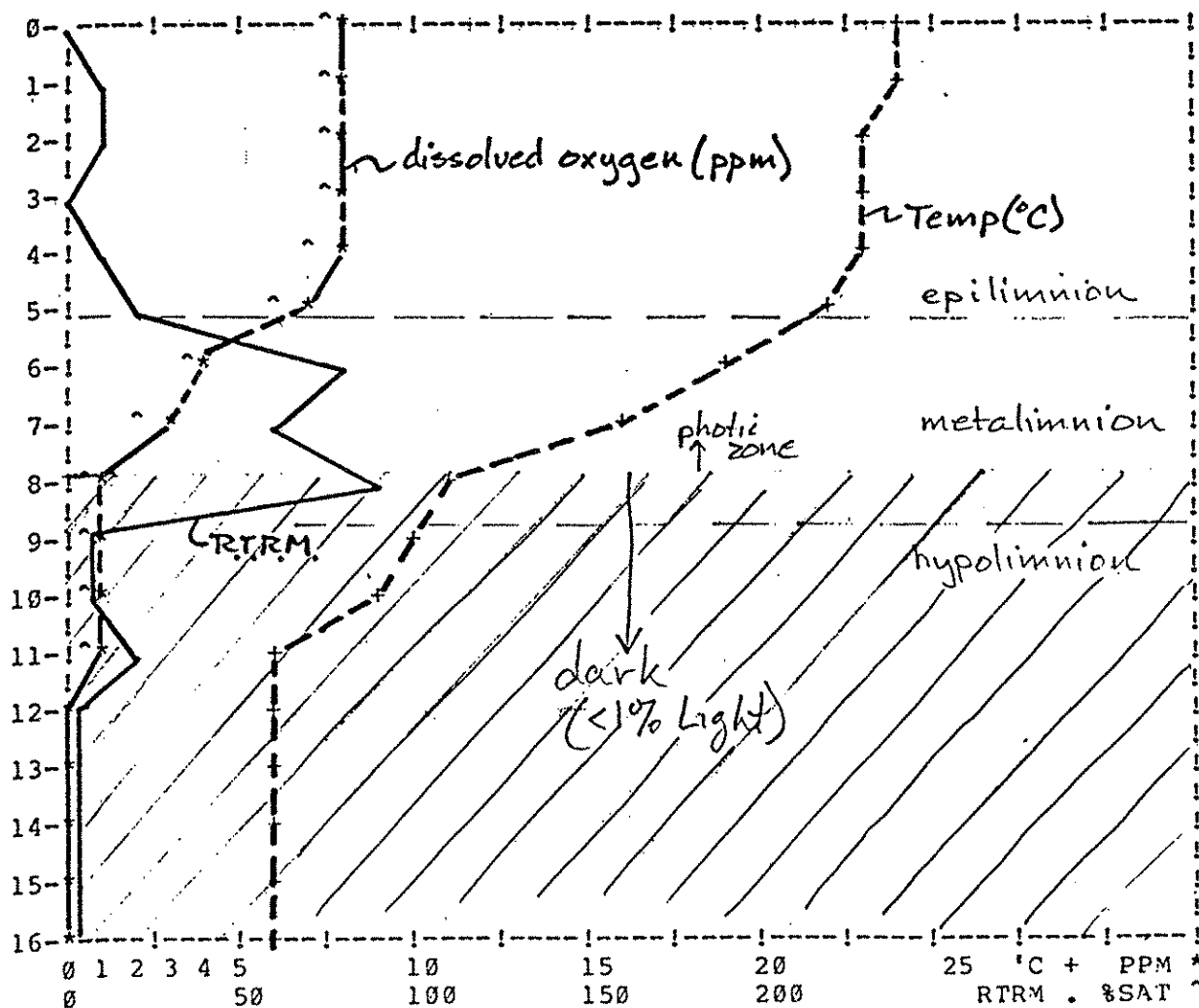
Table 4 is a morphometric summary of the lake which gives volume and area at each 2 meter depth increment. This will be useful for computing mass balances, etc., in future monitoring efforts.

Figure 5.

LAKE : HIGHLAND
August 28, 1985
STATION 1

SECCHI DEPTH 4.5 METERS
ANOXIC BOUNDARY 7.8 METERS

DEPTH M	TEMP °C	DO mg/L	%SAT	RTRM
0.0	23.8	8.3	73	0
1.0	23.5	8.3	73	9
2.0	23.2	8.4	74	9
3.0	23.2	8.3	73	0
4.0	22.8	7.8	68	12
5.0	22.1	7.0	60	20
6.0	19.0	4.2	33	81
7.0	16.3	2.7	21	60
8.0	10.7	0.6	4	91
9.0	9.6	0.5	4	12
10.0	9.1	0.6	4	5
11.0	6.3	0.5	4	19
12.0	6.3	0.0	0	0
13.0	6.1	0.0	0	1
14.0	6.0	0.0	0	0
15.0	6.0	0.0	0	0
16.0	6.0	0.0	0	0



HIGHLAND LAKE

8/28/95 Sampling

ALGAE (straw sample from upper 4.5 meters)

Very sparse - total numbers less than 200 cells/ml

Dominant: Ankistrodesmus spp Green - Desmid

Common: Tabellaria spp

Also found: Synedra Diatoms
Asterionella
Fragellaria
Dinobryon Chrysophyte (colonial protozoan)
Ceratium Dinoflagellate
Staurostrum Green - Desmid
unidentified small cells - few

Low numbers and dominance by Desmids & Diatoms
(relatively clean - water taxa) indicate that excessive
algae growth was not a problem in the lake at the time
of sampling.

No nuisance blue-green algae was found.

Desmids indicate soft water

Low numbers may reflect cropping by healthy zooplankton
community

ZOOPLANKTON (vertical tow - 15 m)

Approximately 12.5 animals/l - high population of small spp.

Healthy diverse population, although large types (Calanoid
copepods, Lg Cladocera, (Chaborous) not found.

Community dominated by cyclopoid copeopods and rotifers
(mostly Keratella spp) Bosmina and small forms (<1 mm) of
Daphnia and Ceriodaphnia very common. No large Daphnia
or copeopods found.

High diversity reflects healthy algae community.

Lack of large individuals may be due to size-selective
predators in fishery.

Table 3.

WATER CHEMISTRY
Highland Lake, Winchester, Ct.

Sample Date		8/28/85		8/28/85	
pH	1 m	6.80	Iron	1 m	0.000
	5 m	6.80	(Reduced)	5 m	0.000
	9 m	6.80	(mg/l)	9 m	0.000
	13 m	6.45		13 m	0.097
	15 m	6.35		15 m	6.040
Alkalinity (mg/l CaCO ₃)	1 m	18	Manganese	1 m	0.000
	5 m	18	(Reduced)	5 m	0.000
	9 m	16	(mg/l)	9 m	0.000
	13 m	22		13 m	0.303
	15 m	26		15 m	1.367
Turbidity (NU)	1 m	1.1	Hydrogen	1 m	0
	5 m	1.1	Sulfide	5 m	0
	9 m	1.6	(ppb)	9 m	0
	13 m	2.0		13 m	0
	15 m	32.0		15 m	81
Conductivity (umhos/cm)	1 m	85	Total In-	1 m	4.87
	5 m	82	organic	5 m	5.13
	9 m	80	Carbon	9 m	9.40
	13 m	83	(mg/l)	13 m	10.44
	15 m	82		15 m	14.25
Total	1 m	0.008			
Phosphorus	15 m	0.034			
(mg P/l)					

NOTE: Data collected by Ecosystem Consulting Service, Inc.

TABLE 4.

MORPHOMETRY : HIGHLAND LAKE (from bathymetric map in Frink and Norvell 1964)									
Max depth :		52.0 feet		Mean Depth :		23.9 feet			
DEPTH (feet)	SURFACE AREA AT DEPTH (acres)	SURFACE AREA OF STRATUM (acres)	SURFACE AREA AT DEPTH (percent)	SURFACE AREA OF STRATUM (percent)	VOLUME BELOW DEPTH (acre-ft)	VOLUME OF STRATUM (acre-ft)	VOLUME BELOW DEPTH (percent)	VOLUME OF STRATUM (percent)	
0.0	418.184	97.27	100.00	23.26	9598.20	2718.20	100.00	29.32	
6.5	320.918	70.83	76.74	16.94	6880.00	2110.66	71.63	22.07	
13.1	250.398	59.64	59.80	16.65	4751.94	1550.53	49.51	17.20	
19.7	182.446	41.89	43.15	10.02	3111.35	1172.90	32.42	12.22	
26.2	138.554	44.78	33.13	10.71	1938.45	914.45	20.20	9.53	
32.8	93.770	55.56	22.42	13.29	1024.00	618.00	10.57	6.45	
39.4	38.208	21.45	9.14	5.13	435.12	249.35	4.22	2.59	
45.9	15.756	19.31	4.91	2.47	156.77	110.53	1.53	1.15	
52.5	6.443	5.18	1.54	1.24	46.12	42.52	0.43	0.44	
59.1	1.292	1.26	0.30	0.30	3.55	3.55	0.04	0.34	
TOTAL		418.18		100.00		9598.20		100.00	
Max depth :		10.9 meters		Mean Depth :		7.0 meters			
DEPTH (meters)	SURFACE AREA AT DEPTH (10*3 sq. m.) (10*3 sq. m.)	SURFACE AREA OF STRATUM (10*3 sq. m.)	SURFACE AREA AT DEPTH (percent)	SURFACE AREA OF STRATUM (percent)	VOLUME BELOW DEPTH (cu. meters)	VOLUME OF STRATUM (cu. meters)	VOLUME BELOW DEPTH (percent)	VOLUME OF STRATUM (percent)	
0.0	1692.37	393.63	100.00	23.26	1103083.19	3352756.49	100.00	28.32	
2.0	1298.74	285.65	76.74	16.94	8486125.70	2612519.31	71.58	22.07	
4.0	1012.09	231.94	59.80	15.55	5073607.39	2035900.20	49.51	17.20	
6.0	730.25	159.53	43.15	10.02	3237599.19	1446737.39	32.42	12.22	
8.0	550.72	101.24	33.13	10.71	2300991.31	1127935.77	20.20	9.53	
10.0	379.48	224.95	22.42	13.29	1253054.53	753355.43	10.57	6.45	
12.0	154.53	85.92	9.14	5.13	499599.85	306330.63	4.22	2.59	
14.0	57.91	41.73	4.91	2.47	193350.45	135403.41	1.53	1.15	
16.0	26.07	20.97	1.54	1.24	59955.04	52451.20	0.43	0.44	
18.0	5.11	5.11	0.30	0.30	4513.33	4513.33	0.04	0.34	
TOTAL		1692.37		100.00		11030831.19		100.00	

HIGHLAND LAKE
Weed Control Alternatives

Winter Drawdown - appropriate for management at Highland Lake especially to control the spread of milfoil (See Drawdown Recommendations).

Chemical Applications - not recommended.

Aqua Shade - to be avoided - will cause serious problems at this lake if used!

Dartex Bottom Liner - can be effective in selected high use areas (swimming areas, marinas, etc.). "Mobile Application" can improve cost-effectiveness by a 3x factor (in development at ECS, Inc.)

Screen Type Liners - can be effective as permanent installation in selected high use areas.

Harvesting - may become appropriate in future years. At present, this technique does not appear to be warranted.

Dredging - Hydraulic - not recommended.

Conventional - may be very effective in selected areas coupled with a drawdown program.

Algal Control

Although not problematic at present, it would be wise to monitor lake conditions in order to detect developing problems early. "Lake Preservation" is far more cost-effective than "Lake Restoration".

Watershed Management

Techniques described by D.E.P. should be utilized including:

1. Regulatory enforcement -
 Inland Wetlands Act
 Erosion & Sedimentation Control Act
 Zoning Regulations
2. Septic System Management
3. Fertilization practices

and other methods described in the 1980 DEP report.

Road sand management should be implemented using catch basins and a regular early-spring clean out schedule.

HIGHLAND LAKE

Drawdown Recommendations

The maximum drop in lake level attained during the winter of 1984-1985 was 86 inches (7.16 ft) and required three months of discharge. The lake took 4 1/2 months to refill. It should be noted that a drought condition persisted during the draw-down and refill operation. This is an important observation for two reasons. First, drawdown was accomplished more rapidly than in a year with greater fall runoff volumes. Secondly, refill was delayed due to very low spring runoff amounts. Although the lake would refill more rapidly during a normal spring runoff, it would drawdown less rapidly during a normal fall runoff season.

The inflow from Sucker Brook is controlled by an Army Corps of Engineers flood control dam which would be utilized to facilitate an effective drawdown program. The following general operational format for drawdown is suggested:

1. Weed Control Drawdown (September - December) approximately 2-4 year interval depending on effectiveness.
2. Fully open Highland Lake gate as soon after the recreation season as possible - (e.g., September 1).
3. Upon Total Leaf-fall in the watershed, begin to store as much runoff as possible upstream of Highland Lake.

This can be accomplished by lowering the upper basins (flood control structure, Crystal Lake) prior to beginning Highland Lake Drawdown and using the top volume to retain runoff between leaf-fall and the end of December. In this manner, Crystal Lake (several feet on top) and the flood control dam will "refill" while Highland Lake continues to drain without large fall inputs. Water volumes stored in the watershed can then be used in January to refill Highland Lake more rapidly.

It should be noted that this procedure will not effect flood potential because were a large design storm to occur, sufficient storage volume would be available in the draw-down of Highland Lake.

4. Once a maximum safe drawdown (approximately 10 feet below spillway) has been accomplished, the lake should remain down for about 1-2 weeks. The gates should be closed on or before January 15 and stored watershed water allowed to flow to Highland Lake.

Fire Protection - Dry Hydrants

If dry hydrants must be available for fire protection during drawdown, the intake should be 10 ft. plus ice-cover thickness below spillway elevation. This is about:

Spillway Elevation	=	881 ft
Drawdown	-	10 ft (max)
Ice Cover	-	<u>2 ft</u>
Dry Hydrant Intakes		869 ft. M.S.L.
below		