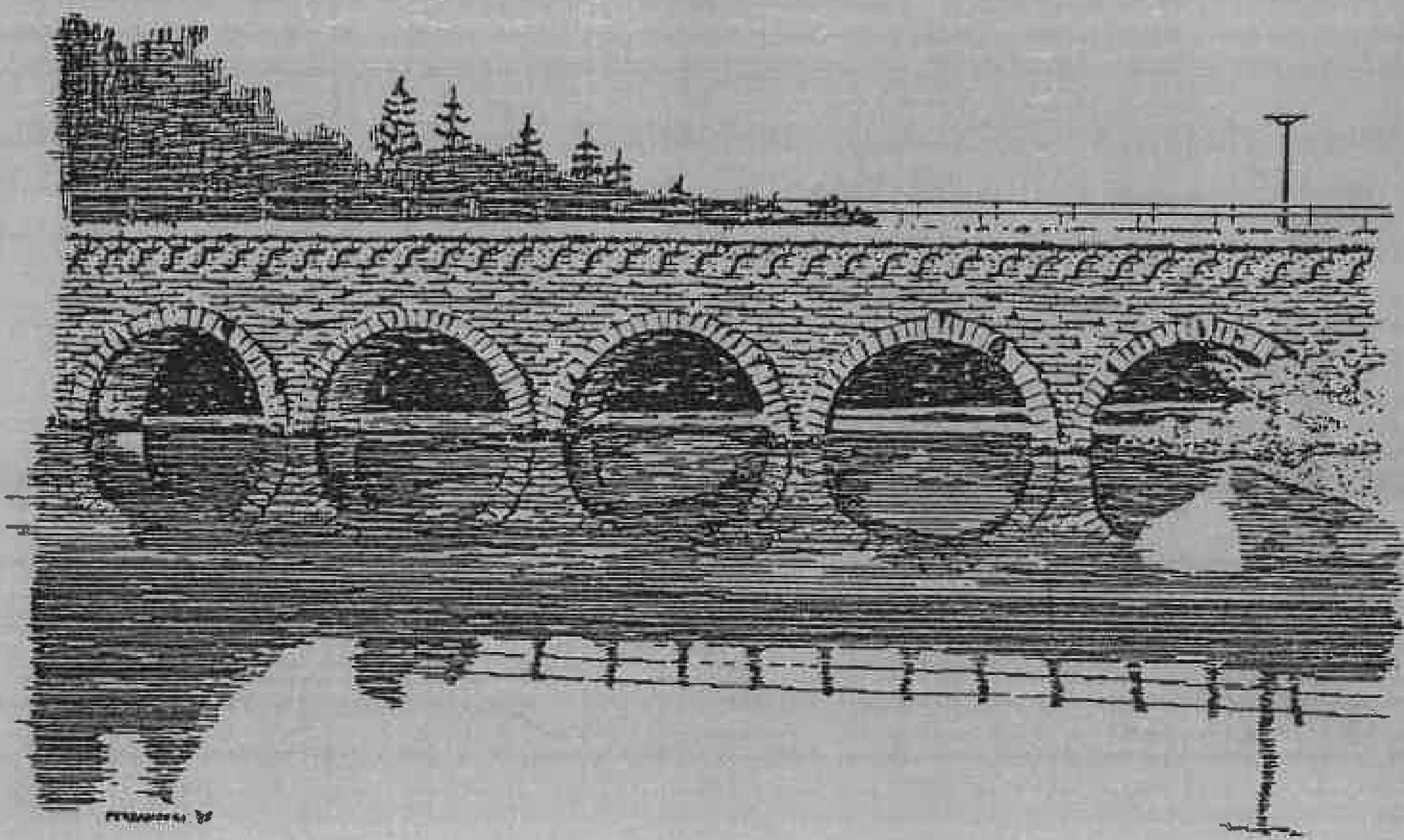
BOONS POND



DIAGNOSTIC/FEASIBILITY STUDY April '79 – July '80

massachusetts department of environmental quality engineering
DIVISION OF WATER POLLUTION CONTROL
thomas c. mcmahon, director

BOONS POND
DIAGNOSTIC/FEASIBILITY STUDY
APRIL 1979 - JULY 1980

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MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL QUALITY ENGINEERING
DIVISION OF WATER POLLUTION CONTROL
WATER QUALITY AND RESEARCH SECTION
WESTBOROUGH, MASSACHUSETTS

APRIL 1981

Cover

Metropolitan District Commission's Aqueduct Over
The Assabet River
Northborough, Massachusetts

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TABLE OF CONTENTS

ITEM	PAGE
ACKNOWLEDGMENTS	2
LIST OF TABLES	4
LIST OF FIGURES	6
OBJECTIVES OF THE DIAGNOSTIC/FEASIBILITY STUDY	7
WATERSHED CHARACTERISTICS	9
Physical Description	9
Watershed Development	20
LAKE CHARACTERISTICS	24
Physical Description	24
Lake Uses	28
PREVIOUS REPORTS AND MANAGEMENT PRACTICES	29
LIMNOLOGICAL DATA	31
Methods	31
Results	34
CONCLUSIONS	78
Lake	78
Watershed	78
GENERAL RECOMMENDATIONS	80
FEASIBILITY OF RESTORATION/PRESERVATION	81
Introduction	81
Alternative Watershed Preservation Techniques	81
Alternative Watershed Restoration Techniques	85
In-Lake Restoration Alternatives	92
RECOMMENDED RESTORATION/PRESERVATION PROGRAM	97

LIST OF TABLES

NUMBER		PAGE
1	Precipitation Data and Temperature Data, Gates Pond, Berlin	11
2	Boons Pond Watershed Limitations/Potentials of Soils for Septic Systems	17
3	Boons Pond Morphometric Data for the Lake and Watershed	27
4	Station 1 - Temperature and Dissolved Oxygen Data	36
5	Station 2 - Temperature and Dissolved Oxygen Data	37
6	Stations 3, 4, 4A, 5, 6 Temperature and Dissolved Oxygen Data	38
7	Secchi Disc Transparency, General Meteorological Conditions	39
8	Boons Pond - pH	41
9	Boons Pond - Conductivity	42
10	Boons Pond - Chloride	44
11	Boons Pond - Hardness	45
12	Boons Pond - Alkalinity	46
13	Boons Pond - Total Solids	47
14	Boons Pond - Suspended Solids	49
15	Boons Pond - Iron	50
16	Boons Pond - Manganese	51
17	Boons Pond - Total Phosphorus	52
18	Boons Pond - Total Kjeldahl-Nitrogen	53
19	Boons Pond - Nitrate-Nitrogen	54
20	Boons Pond - Ammonia-Nitrogen	55
21	Boons Pond - Ammonia-Nitrogen and Nitrate-Nitrogen	56
22	Boons Pond - Organic Nitrogen	57
23	Boons Pond - Bacteriological Analysis	59
24	Boons Pond - Chlorophyll a Data	62
25	Boons Pond - Silica Data	63
26	Microscopic Examination - Station 1	64
27	Microscopic Examination - Station 2	66

LIST OF TABLES (CONTINUED)

NUMBER		PAGE
28	Boons Pond - Sediment Samples, Chemical Analyses	68
29	Septic Snooper Survey - Chemical Data	71
30	Boons Pond - Discharge from Outlet	73
31	Boons Pond - Water Budget	74
32	Boons Pond - Instantaneous Discharge Measurements	74
33	Boons Pond - Total Nitrogen Budget	76
34	Boons Pond - Total Phosphorus Budget	77
35	Boons Pond - Proposed Lake Restoration Techniques	82

LIST OF FIGURES

NUMBER		PAGE
1	Sudbury-Assabet-Concord River Basin	8
2	Boons Pond Watershed	10
3	Surficial Geology - Boons Pond Watershed	12
4	Watershed Soils Map - Boons Pond	14
5	Watershed Limitation/Potential of Soils for Septic System Use	16
6	Town of Stow - Groundwater Significance Boons Pond Area	19
7	Land Use - Boons Pond Watershed	22
8	Bathymetric Map and Location of Sampling Stations - Boons Pond	25
9	Tributary Drainage Areas - Boons Pond	26
10	Zoning Regulations - Boons Pond	30
11	Dissolved Oxygen Profiles - Station 1	35
12	Macrophyte Map - Boons Pond	60
13	Septic Snooper Survey and Seepage Meters - Location of Sampling Stations	70

OBJECTIVES OF THE DIAGNOSTIC/FEASIBILITY REPORT

This report follows an intensive water quality study of Boons Pond and its watershed by the Water Quality and Research Section of the Massachusetts Division of Water Pollution Control. The data-gathering period extended from April 1979 to July 1980.

The objectives of this Division in the present study were several:

1. Data collection for the Commonwealth's lake classification and restoration/preservation program in fulfillment of the requirements of Section 314 (Clean Lakes Program) of the 1977 Amendments to the Federal Water Pollution Control Act (PL95-217);

2. To complete a lake and watershed diagnostic study consisting of hydrological information, geological descriptions, public use and benefit descriptions, land use information, a historical lake and watershed summary, and a discussion of historical and baseline data;

3. To complete a feasibility study consisting of the alternatives considered for pollution control or lake restoration and an identification and justification of the selected alternative; and

4. To satisfy the public's demand for attention to the existing and potential water quality impacts resulting from increased development and use of lake watershed areas.

SUASCO RIVER BASIN

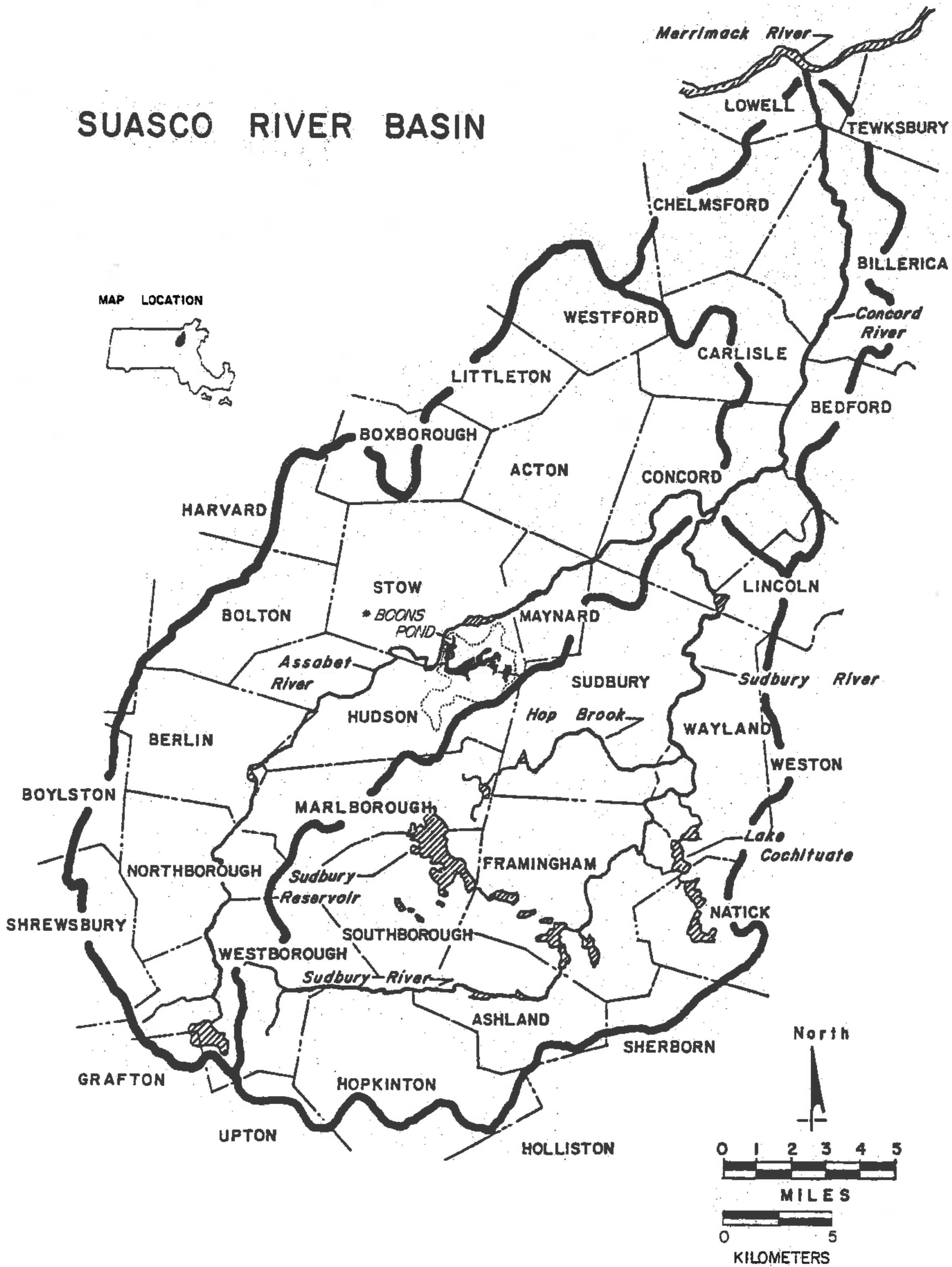


FIGURE 1

WATERSHED CHARACTERISTICS

Physical Description

Location

The Boons Pond Watershed in the Assabet River Drainage Basin is located in the planning area known as the "SuAsCo Basin" (Figure 1). The term SuAsCo refers to the area drained by the Sudbury, Assabet, and Concord rivers. The SuAsCo drainage area is a sub-basin of the Merrimack River Basin.

A map of the Boons Pond watershed is presented in Figure 2. The watershed covers an area of 621 hectares (1,535 acres), and is contained within the town limits of Stow and Hudson.

Climatology

The towns of Hudson and Stow are within the central Massachusetts climatological division. This division, covering more than 50 percent of the state, has a humid, temperate climate characteristic of the North Temperate Zone.

The average annual temperature in this region is about 9.4°C (49°F). Temperatures have been recorded as low as -34.4°C (-30°F) to as high as 40.6°C (105°F). The growing season, described as being the frost-free period above a threshold temperature of 0°C (32°F), averages from 140-160 days.

The mean annual precipitation about 112 cm (44 inches), is fairly evenly distributed throughout the year, so that droughts or severe floods seldom occur. Snowfall averages from 127-152.4 cm (50-60 inches), having much variation in short distances due to topographical influences. The average annual runoff is about one-half of the annual precipitation (U.S. Department of Agriculture 1978, U.S. Department of Commerce 1959). Local temperature and precipitation data for the Boons Pond area were provided by the Hudson Department of Public Works (Table 1).

Topography

The elevation of Boons Pond is about 60 m (190 ft.) above mean sea level (MSL). At the northwest corner of the watershed, the land rises to a height of 85 m MSL (280 ft.). The northeastern region of the watershed is a level plain. However, this drops off as a steep slope to the northeast lakeshore. The eastern end of the watershed is characterized by low wetland areas and low hills. At the southeast end of the area, Boons Hill

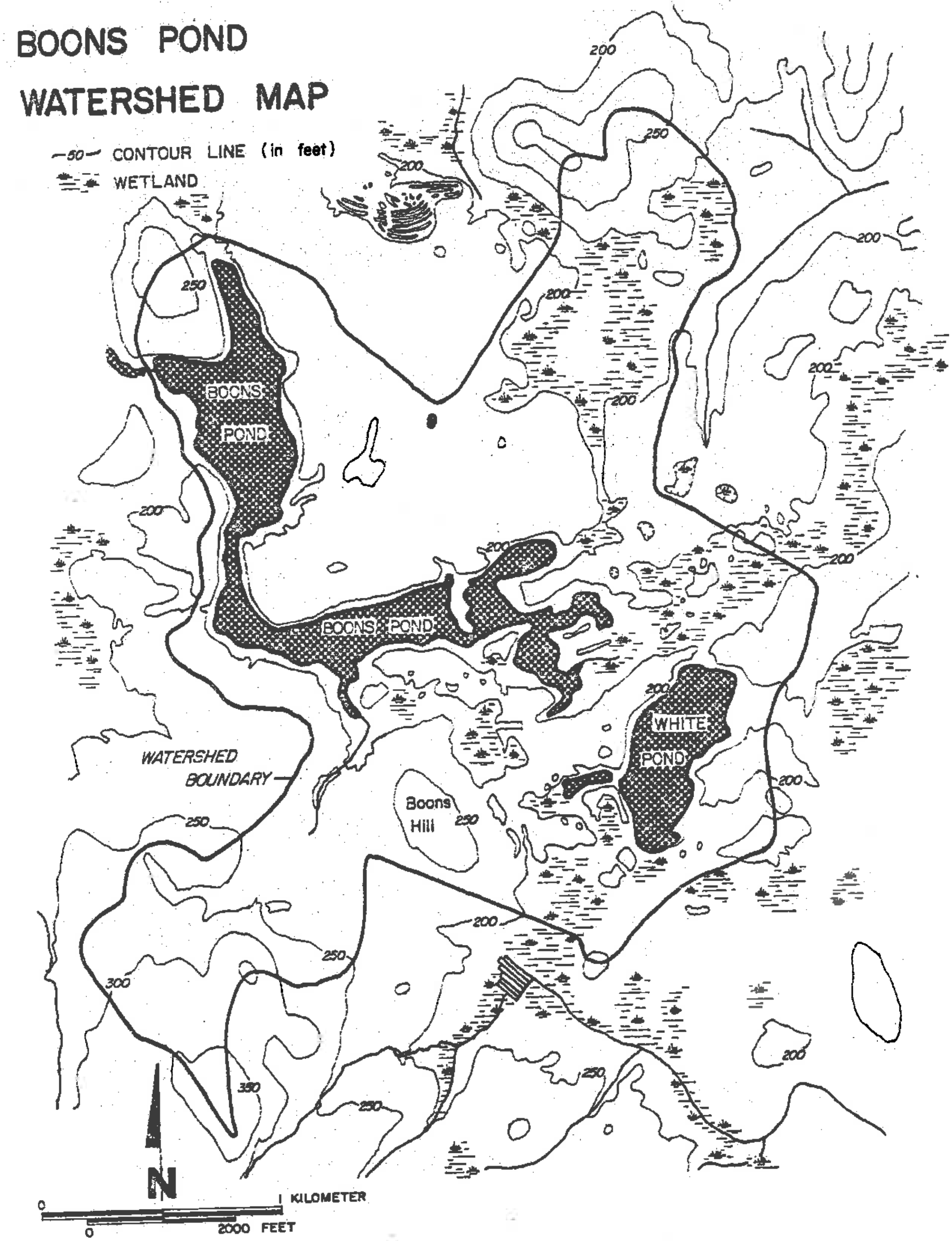


FIGURE 2

SOURCE: USGS (1965) topographic maps, Hudson and Maynard, Mass. quadrangles (7.5 minute series)

TABLE 1

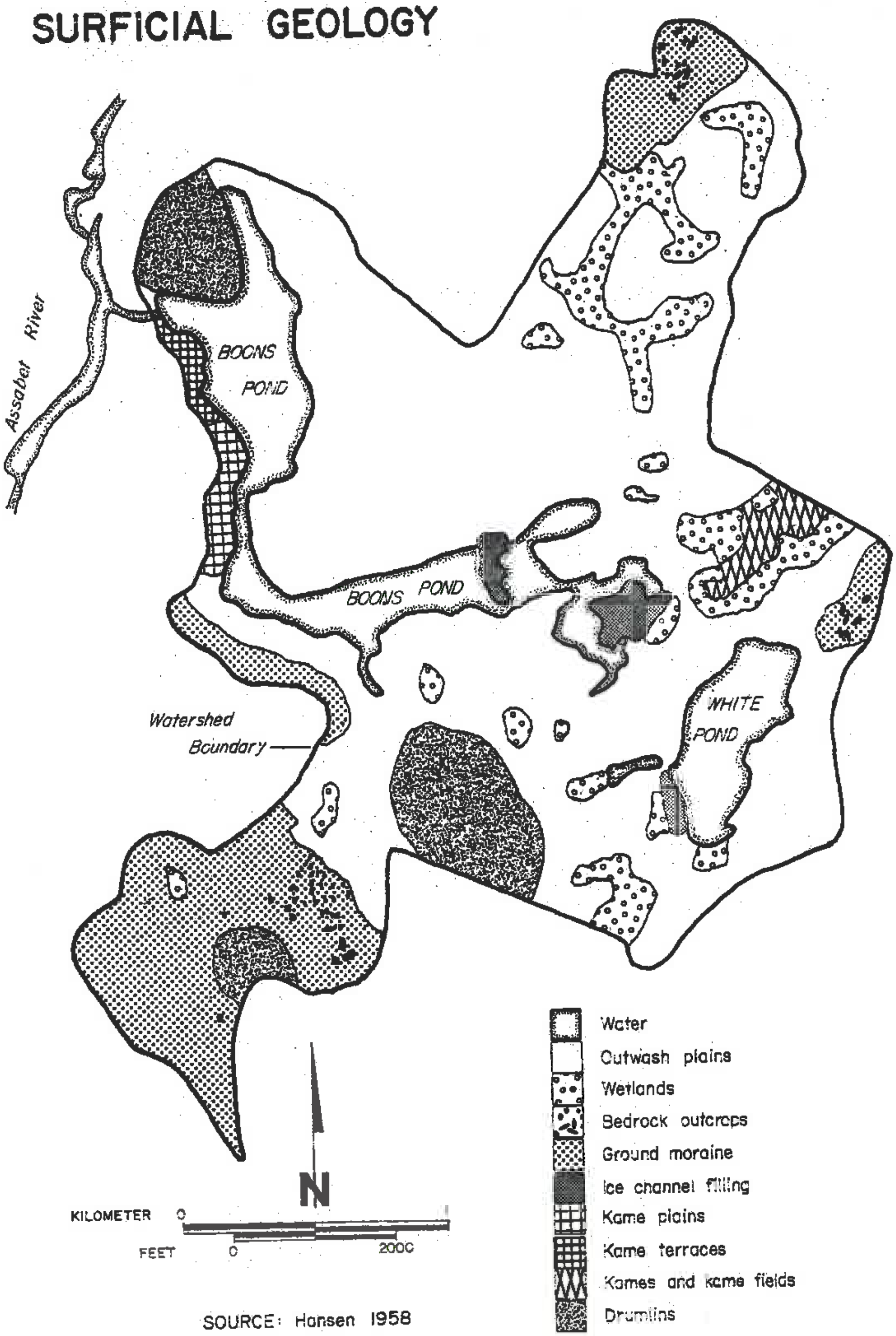
PRECIPITATION DATA AND TEMPERATURE DATA*

GATES POND BERLIN

DATE	TOTAL PRECIPITATION (cm)	*High Temperature °C	*Low Temperature °C
April 1979	9.75	14	-4
May 1979	11.68	22	4
June 1979	2.87	24	10
July 1979	10.95	27	11
August 1979	15.54	28	10
September 1979	7.77	20	0
October 1979	9.40	16	-2
November 1979	10.52	20	-3
December 1979	3.45	8	-12
January 1980	1.90	7	-13
February 1980	2.70	1	-14
March 1980	13.97	13	-16
April 1980	12.83	16	0
May 1980	6.88	18	6
June 1980	7.75	21	7
July 1980	7.98	24	13

*This information was provided by the Hudson Department of Public Works. Temperature and rainfall taken at Gates Pond, Berlin, Mass. at 7:00 A.M. each day.

BOONS POND
SURFICIAL GEOLOGY



SOURCE: Hansen 1958

FIGURE 3

rises to a height of about 91 m MSL (300 ft.). The southwest corner of the watershed is a rolling, hilly area which drains to a small, low wetland area (Figure 2).

Geology

The surficial geology of the Boons Pond watershed (Figure 3) is a result of the pleistocene glaciation. Glacier movement over the area left ground moraines which consist of broad relatively thin accumulations of till, characterized by gentle, undulatory relief that reflects the shape of the underlying bedrock surface. As the ice sheets receded meltwater streams scoured channels which became filled with coarse sand and gravel. Also, deposited by glacial meltwater were drumlins, oval or elongated rounded hills of till. Kame formations were deposited against the edge of the decaying ice sheet and include: kame terraces consisting of well stratified sands and gravel; kame plains consisting of flat-topped deposits of well stratified sands and gravel; kames and kame fields, irregular mounds or hillocks of mixed sands and gravel, commonly poorly sorted.

The Assabet River roughly marks the position in the area where the ice front stagnated. Many detached ice masses stood south of the main ice front. When the stranded ice blocks melted, they left depressions in the outwash which resulted in pond and wetland formation.

Soil Types

The towns of Hudson and Stow are in a region where the general soils associations are classified as Paxton-Hollis-Canton and Hinckley-Windsor-Muck (USGS, SCS, 1980). The Paxton-Hollis-Canton association soils were formed in the glacial till deposits. They occupy gently sloping to steep land forms of drumlins and ridges. These soils have fine, sandy loam surfaces. On the steeper slopes, bedrock outcrops are common. These soils are well drained to excessively drained and are free of problems associated with soil wetness. This association is dominated by three major soils. The Paxton soils have loamy, slowly permeable substrata. They make up about 50 percent of the association. The shallow Hollis soils overlaying bedrock make up about 15 percent. The Canton soils have permeable, sandy substrata and make up about 10 percent of the association. The remaining 25 percent of the association consists of numerous minor soils (AppendixB).

The Hinckley-Windsor-Muck association soils were formed in water-sorted materials, primarily glacial outwash. These soils are generally found in the valleys on nearly level to rolling terraces, deltas, kames, and eskers. There are many areas of this association that are suited for agriculture. The soils in this association are generally free from water table problems, although the Muck soils are too wet for most crops, unless they are drained.

BOONS POND
WATERSHED SOIL TYPES

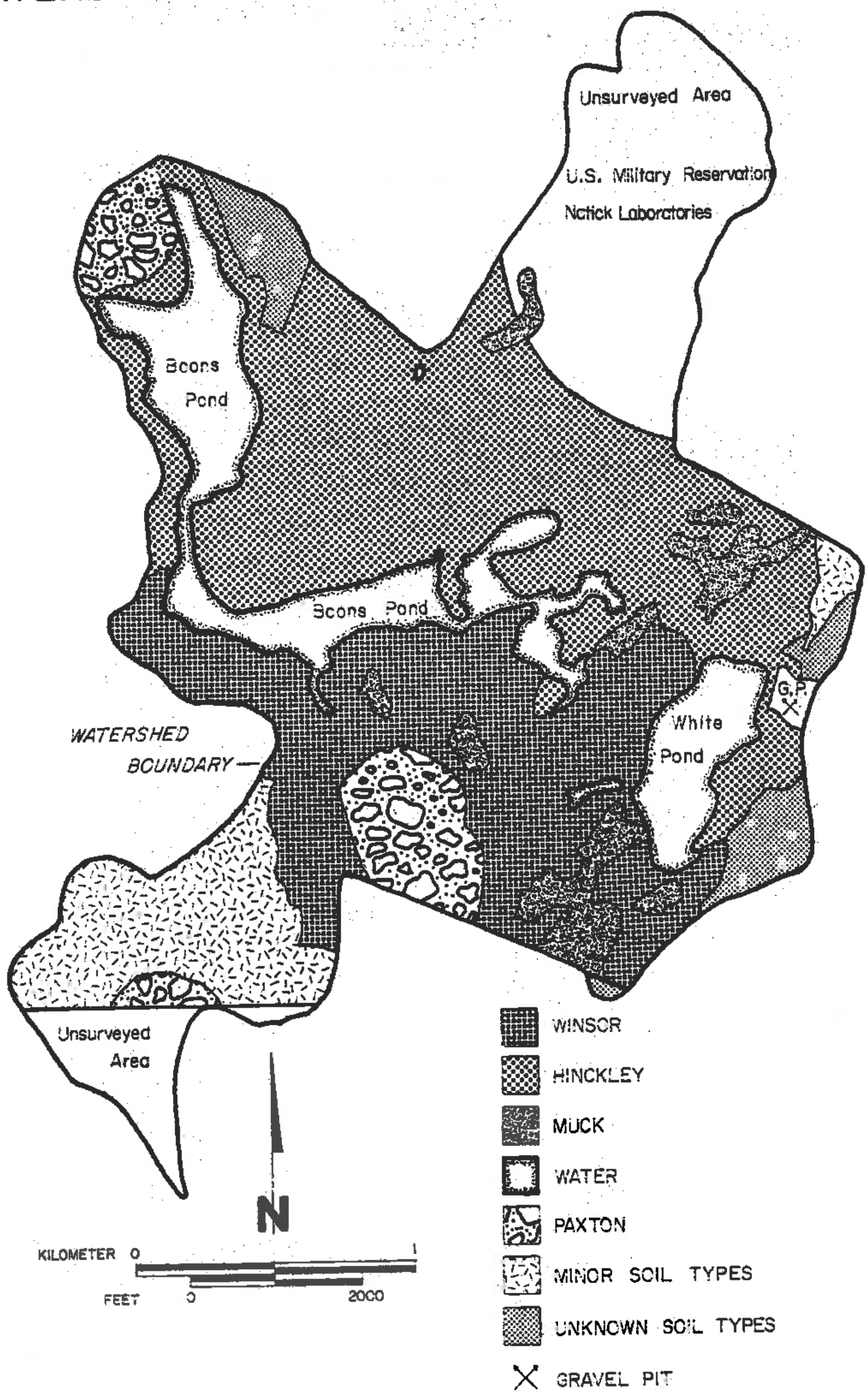


FIGURE 4

Making up about 40 percent of this soil association the Hinckley soils have sandy or sand/gravelly substrata and are permeable. The Windsor soils which have sandy subsoils are also permeable, and represent about 30 percent of the group. The Muck soils constitute about 10 percent. The remainder of this association is made up of other minor soil types (Appendix B).

Limitation/Potential of Soils for Septic System Use

The population within the Boons Pond watershed relies on septic tanks with leachfields or cesspools to dispose of household wastes. Many of the soils within the watershed have properties which limit the effectiveness of these systems for wastewater disposal.

Figure 5 locates the different soils in the watershed and their slope characteristics. In Table 2 the soils are rated according to their limitations for septic system use and the limiting feature of the soil for this use is identified. Possible management practices that can be employed to overcome limitations are identified in Appendix C and in the feasibility portion of the report. The potential for septic system use in the soil type is rated based on the cost of the prescribed management practice and the efficiency of the technique (See Appendix C for further explanation). In general, the soils within the Boons Pond watershed show severe limitation for septic system use and very low to medium potential use.

Soil Losses

Soil loss from the watershed area to the lake basin area is the result of erosion and runoff. According to the U.S. Soil Conservation Service field technicians, the following types of areas are thought to represent major erosional potential: farmland in cultivation, logging roads and skid trails, road banks, unpaved roads, gravel pits, construction areas, stream banks, and utility right-of-ways (U.S.D.A., 1978). Currently, there are many private unpaved roads in the watershed and potential construction sites associated with housing development and home conversion.

Hydrology

Boons Pond receives its supply of water from small streams draining wetland and residential areas, groundwater flow and overland runoff from lake shore areas, and direct precipitation onto the surface of the lake. The outlet flow from Boons Pond empties into Bailey Brook which drains to the Assabet River.

A buried groundwater aquifer in the Town of Stow is source of water recharge to the lake. The U.S. Geological Survey in 1964 showed various well sites in the watershed to be located in outwash sands which yield small to moderate quantities of water to wells, but store large amounts of groundwater (Pollack and Fleck 1964).

BOONS POND WATERSHED SOILS LIMITATION POTENTIAL FOR SEPTIC SYSTEMS

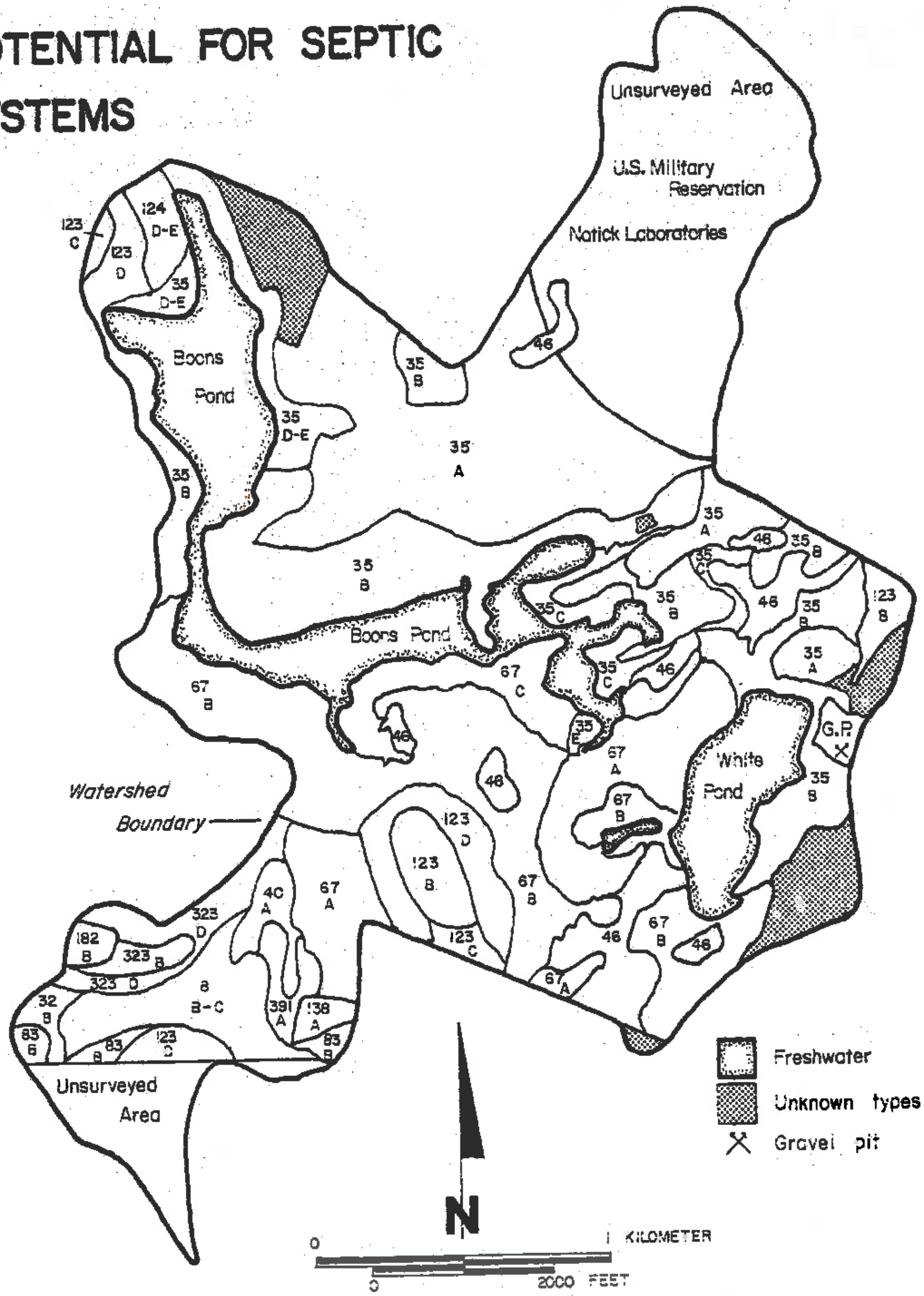


FIGURE 5

TABLE 2

KEY TO FIGURE 5

LAKE BOON WATERSHED LIMITATION/POTENTIALS

OF SOILS FOR SEPTIC SYSTEMS

	SOIL DESCRIPTION	SLOPE OF LAND	LIMITATION OF SOIL FOR SEPTIC SYSTEM USE	REASON FOR LIMITATION RATING	POSSIBLE MANAGEMENT PRACTICES	POTENTIAL FOR SEPTIC SYSTEM USE WITH MANAGEMENT PRACTICES
35A	Hinckley	0-3%	severe	poor filter capacity	control housing density	low
35B	Hinckley	3-8%	severe	poor filter capacity	control housing density	low
35C	Hinckley	8-15%	severe	poor filter capacity	control housing density	low
35D-E	Hinckley	15-35%	severe	poor filter capacity	control housing density	low
123B	Paxton	3-8%	severe	slow percolation rate, soil will smear	interceptor drains over hardpan, sand filter or mound system - avoid construction when wet	medium
123C	Paxton	8-15%	severe	slow percolation rate, soil will smear	interceptor drains over hardpan, sand filter or mound system - avoid construction when wet	medium
123D	Paxton	15-25%	severe	slow percolation rate, soil will smear	interceptor drains over hardpan, sand filter or mound system - avoid construction when wet	medium
124D-E	Paxton	15-35%	severe	slow percolation rate, soil will smear	interceptor drains over hardpan, sand filter or mound system - avoid construction when wet	medium
67A	Windsor	0-3%	severe	poor filter capacity	control housing density	low

TABLE 2 (CONTINUED)

	DESCRIPTION	SLOPE OF LAND	LIMITATION OF SOIL FOR SEPTIC SYSTEM USE	REASON FOR LIMITATION RATING	POSSIBLE MANAGEMENT PRACTICES	POTENTIAL FOR SEPTIC SYSTEM USE WITH MANAGEMENT PRACTICES
67B	Windsor	3–8%	severe	poor filter capacity	control housing density	low
67C	Windsor	8–15%	severe	poor filter capacity	control housing density	low
46	Muck	--	--	--	--	--
40A	Scarboro	0–3%	severe	wetness of soil	least suitable for use	very low
391A	AuGres	0–3%	--	--	--	--
138A	Deerfield	0–3%	severe	wetness of soil poor filter capacity	regional drainage, control housing density	low
83B	Woodbridge	3–8%	severe	slow percolation rate wetness of soil	sandfilter or mound system, interceptor drains over hardpan	medium
81B–C	Hollis	3–15%	severe	shallow depth of soil to bedrock	least suitable for use	very low
182B	Birchwood	3–8%	severe	slow percolation rate wetness	sand filter or mound system - interceptor drains over hardpan	medium
323B	Poquonock	3–8%	severe	slow percolation rate	sand filter or mound system	medium
323D	Poquonock	15–25%	severe	slow percolation rate extreme slope	sand filter or mound system - serial tile distribution	low
32B	Ridgebury	3–8%	severe	wetness - slow percolation	addition of fill, regional drainage, interceptor drain over hardpan - sand filter or mound system	low

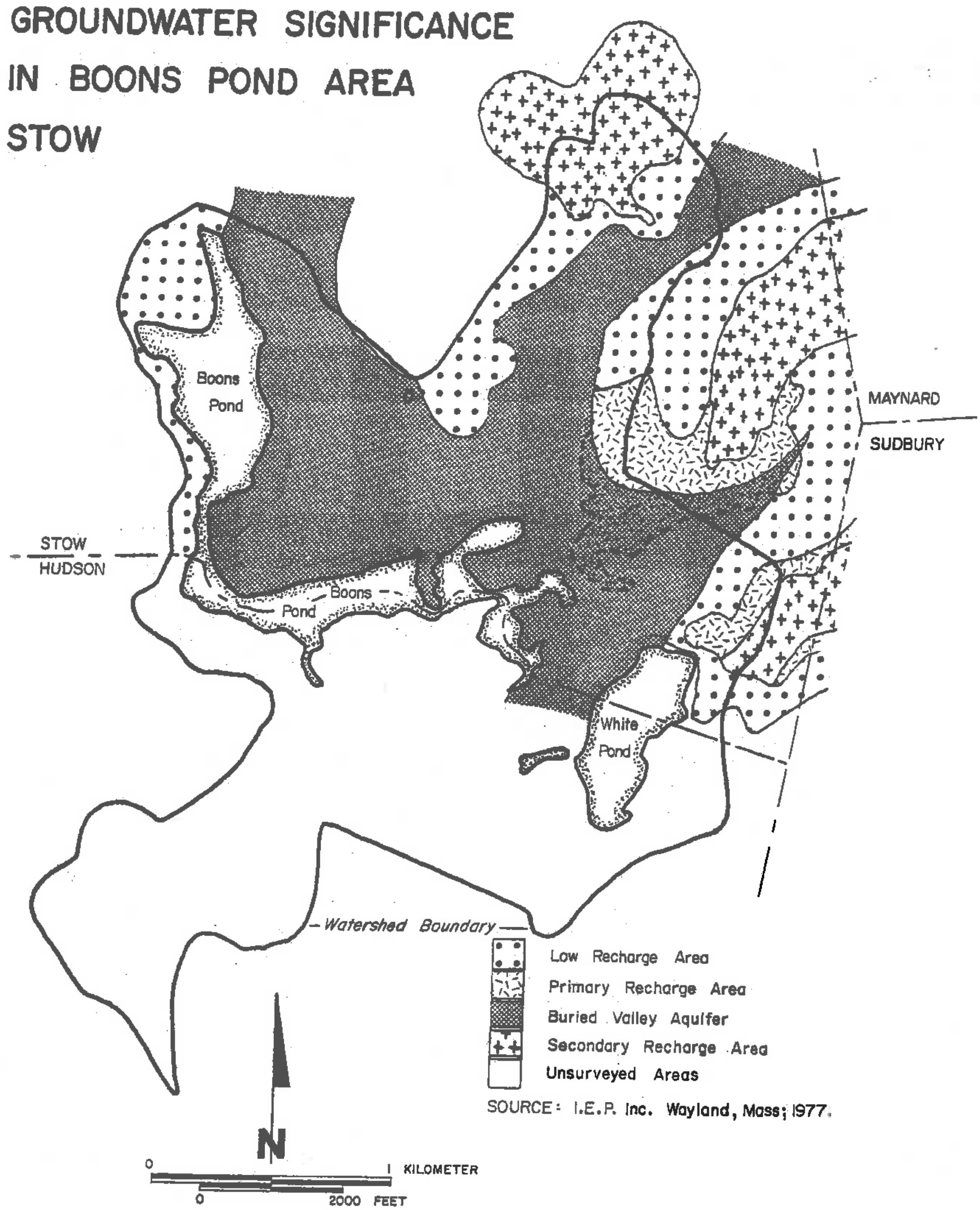

GROUNDWATER SIGNIFICANCE
IN BOONS POND AREA
STOW
Boons
Pond
Boons
Pond
White
Pond
STOW
HUDSON
MAYNARD
SUDBURY
Watershed Boundary
Low Recharge Area
Primary Recharge Area
Buried Valley Aquifer
Secondary Recharge Area
Unsurveyed Areas
SOURCE: I.E.P. Inc. Wayland, Mass; 1977.
N
0
1 KILOMETER
0
2000 FEET

FIGURE 6

The aquifer was identified in a Ground Water Study of the Town of Stow by IEP, 1979 (Figure 6). IEP recommended that buried valley aquifers adjacent to the lake be protected as a future source for a municipal water supply.

Watershed Development

History

Boons Pond was named after Matthew Boon, who came to the area around 1660. Boon settled on lands he purchased from the Indians. "Tradition hath it that Boon purchased this land, which extends over a vast surface of hills, plains, and ponds, from the Indians for a jackknife" (Crowell 1933). Many arrowheads have been found at the north end of the lake giving evidence of Indian canoeing spots in this section. Boon situated his family on the westerly side of what is now known as Boon's Hill. Boon lived here until 1676, when King Phillip's War forced him to move his family to Sudbury. Boon was killed near the pond at "Red Slough" when he returned for some household goods.

The next reference made to Boons Pond in the historical literature is in relation to the enterprises of Amory Maynard. Maynard purchased land on the Assabet River and built a saw-mill. Successful, he continued to purchase land along the river. In 1846 he controlled water rights up the river to Boons Pond and Fort Meadow. In 1847, Boston needed a larger supply of water and Mr. Maynard was deprived of his water power--Fort Meadow Pond in Marlborough (Crowell 1933).

"To make good the damage the State had done to Maynard's mill, they built two dams on the stream; one at Fort Pond, in Marlborough; the other on Boon's Pond." These dams greatly enlarged both of these ponds. "Boon's Pond was very small before this was done, but is now a most beautiful and attractive lake with many cottages on its banks" (Crowell 1933).

Both Hudson and Stow are rural communities, Hudson being more developed than Stow. Hudson was incorporated as a town on March 19, 1866 and has a Town Meeting type of government. It is located in eastern Massachusetts, bordered by Berlin on the southwest and west, Bolton and Stow on the north, Sudbury on the east, and Marlborough on the south. It is 18 miles from Worcester and 28 miles from Boston (MDCD 1971).

Stow was established as a town on May 16, 1683 and also has a Town Meeting type of government. Located to the north of Hudson, Stow is bordered on the west by Bolton and Harvard, on the north by Boxborough and Acton, and on the east by Maynard and Sudbury. It is about 25 miles from Boston and 28 miles from Worcester (MDCD 1973).

Population

The towns of Hudson and Stow experienced a period of rapid population growth from 1950 to 1970. Stow, with a land area of 45.79 square kilometers (17.68 square miles), had a 1950 population of 1,700; 96 persons per square mile. In 1970 the population had increased to 3,984; 225 persons per square mile, (MDCD 1973). The present population of the town is 5,190 (January 1980)*. Stow has maintained a low population density. Hudson, on the other hand, has not. It has a land area of 30.20 square kilometers (11.66 square miles). The town had a 1950 population of 8,211; 704 persons per square mile. In 1970 the population had increased to 16,084; 1,379 persons per square mile (MDCD 1971). The present population of the town is 16,620 (January 1980)*.

The projected 1995 populations for Hudson and Stow are 22,000 and 6,400 respectively. This increase for the period of 1970 to 1995 represents a 36.8 percent change for Hudson and a 60.6 percent change for Stow (MAPC 1977).

Land Use

The SuAsCo Basin can be characterized as a fast-growing group of communities undergoing land-intensive, suburban development, for low to moderate density, residential use. The abundance of developable land and good accessibility via Route 2, Route 8, I-90, and I-495 make the basin a highly attractive place in which to live.

In the Boons Pond watershed land development is predominantly residential with some small store commercial activity. A few industrial areas--electronics and automotive-related firms--can be found along and off of Main Street, Hudson. To the east of Boons Pond is the U.S. Military Reservation, Natick Laboratory. The Marlborough State Forest is located to the south (MAPC 1979)(Figure 2).

Both Hudson and Stow have almost doubled in population in the past twenty years, resulting in the conversion of forest and agricultural land to residential, commercial, and industrial land uses. Apparent in the lakeshore area are conversions of summer cottages to year-round homes. Without adequate controls, construction to increase residential area, summer cottage conversions, industrial discharges, and increased travel in the watershed area can all negatively affect water quality.

Current watershed land use was estimated, using the MacConnell Map Down Series, the Hudson and Maynard quadrangles, 1971 and the MAPC report, A Management Program for Lake Boon, 1979. Percentages of the various land uses were computed using the entire Boons Pond watershed, including the lake area (Figure 7). The largest area of land is occupied by mixed wood forest

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*Offices of the Town Clerk - Hudson and Stow.

BOONS POND
WATERSHED LAND USE MAP

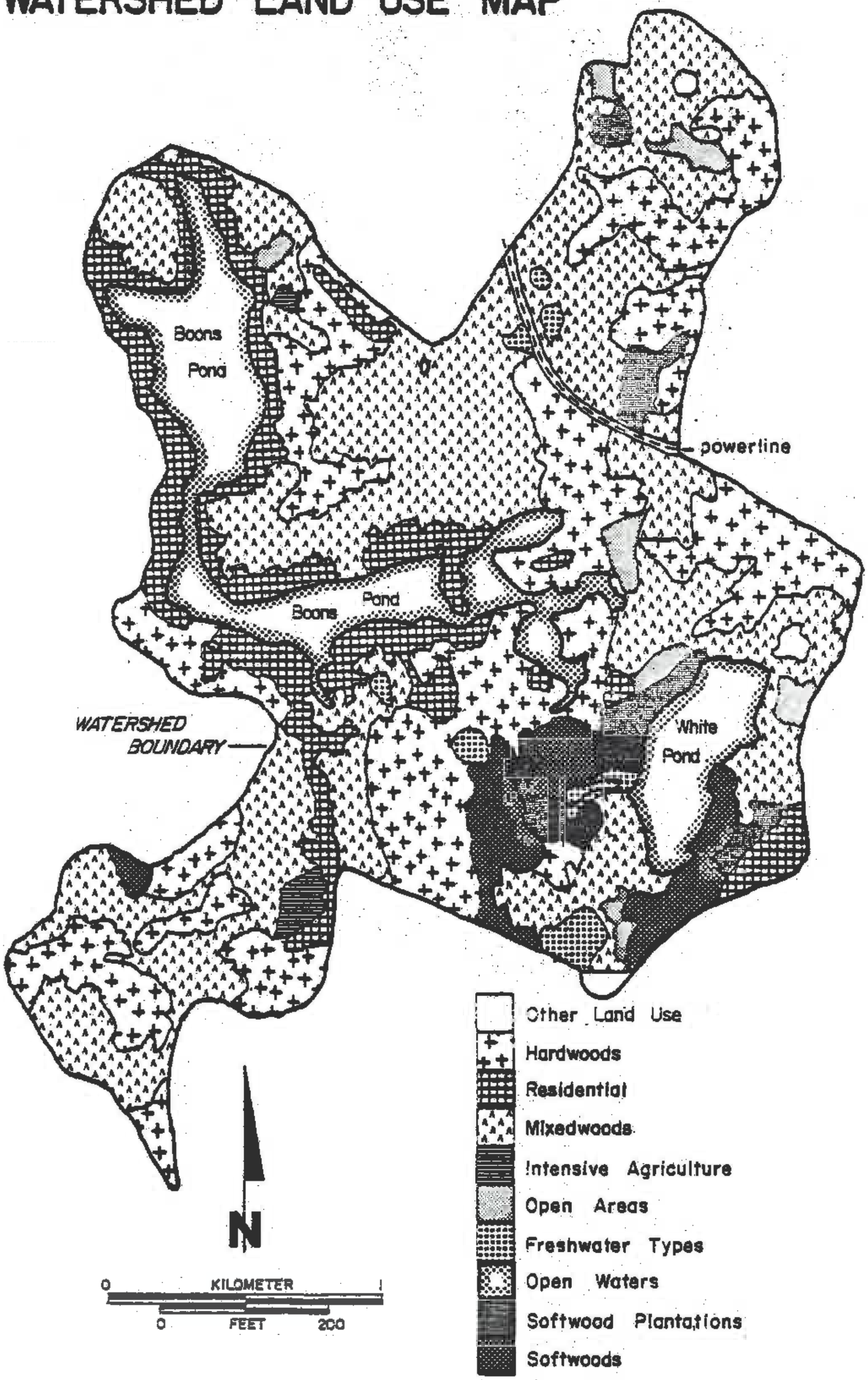

FIGURE 7

SOURCE: MacConnel Land Use Maps, Hudson and Maynard quadrangle, 1971.

thirty-eight percent. Twenty-six percent is in hardwood forest. Seven percent is in softwood forest. Ten percent of the total area is residential; one percent is in intensive agriculture. Open areas make up two percent. The lake is 11 percent of the total area. White Pond accounts for the remaining three percent of the total watershed area.

LAKE CHARACTERISTICS

Physical Description

Location

Boons Pond is an enhanced Great Pond.* The total area of the lake is 162.5 acres. Approximately 75 percent of the pond is located in Stow, Middlesex County, Massachusetts. The remaining 25 percent of the pond is located in Hudson, Middlesex County, Massachusetts. The approximate center of the pond is located at a north latitude of 42° 23' 30" and a west longitude of 71° 30' 0".

Lake Formation

Boons Pond was formed in a glacial outwash plain (see the geology section of this report. At one time, the lake was smaller than its present size. In the 1840s the pond was dammed up, flooding a wetland area. The current dam is formed by the Barton Road highway embankment. The spillway is a 4' X 4' concrete box culvert with a drop inlet. The Town of Stow controls the flowage rights of the pond. The dam is managed by the Stow Superintendent of Streets. There has been no change in the size of the lake since the enlargement in the 1840s.

Morphometry

The morphometric data for Boons Pond and its watershed are presented in Table 3. The data were computed using the topographic maps--Hudson and Maynard, Massachusetts Quadrangles (7.5 minute series, 1965) produced by the U.S. Geological Survey and a bathymetric map prepared by the Division of Fisheries and Wildlife. Boons Pond is a shallow, 162.5 acre lake (Figure 8). The major water volume of the lake is held in the first basin. The value for the development of volume index describes the variance of the shape of the basin from that of a cone. Boons Pond exhibits a normal basin shape, index >D.33 (Wetzel 1975). The value for the development of shoreline, 3.2, indicates a potential for development of littoral communities, such as aquatic weed beds. Definitions for the other morphological parameters include in Table 3 are found under "Description of Terms".

The watershed area for the lake was divided into subdrainage basins based on tributary drainage. These areas are defined in Figure 9 and the data is included in Table 3. Subdrainage Basin 7 is an area of direct overland runoff and groundwater flow to the lake.

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*Great Ponds as defined by the Commonwealth of Massachusetts General Laws are those over 10 acres and are naturally created.

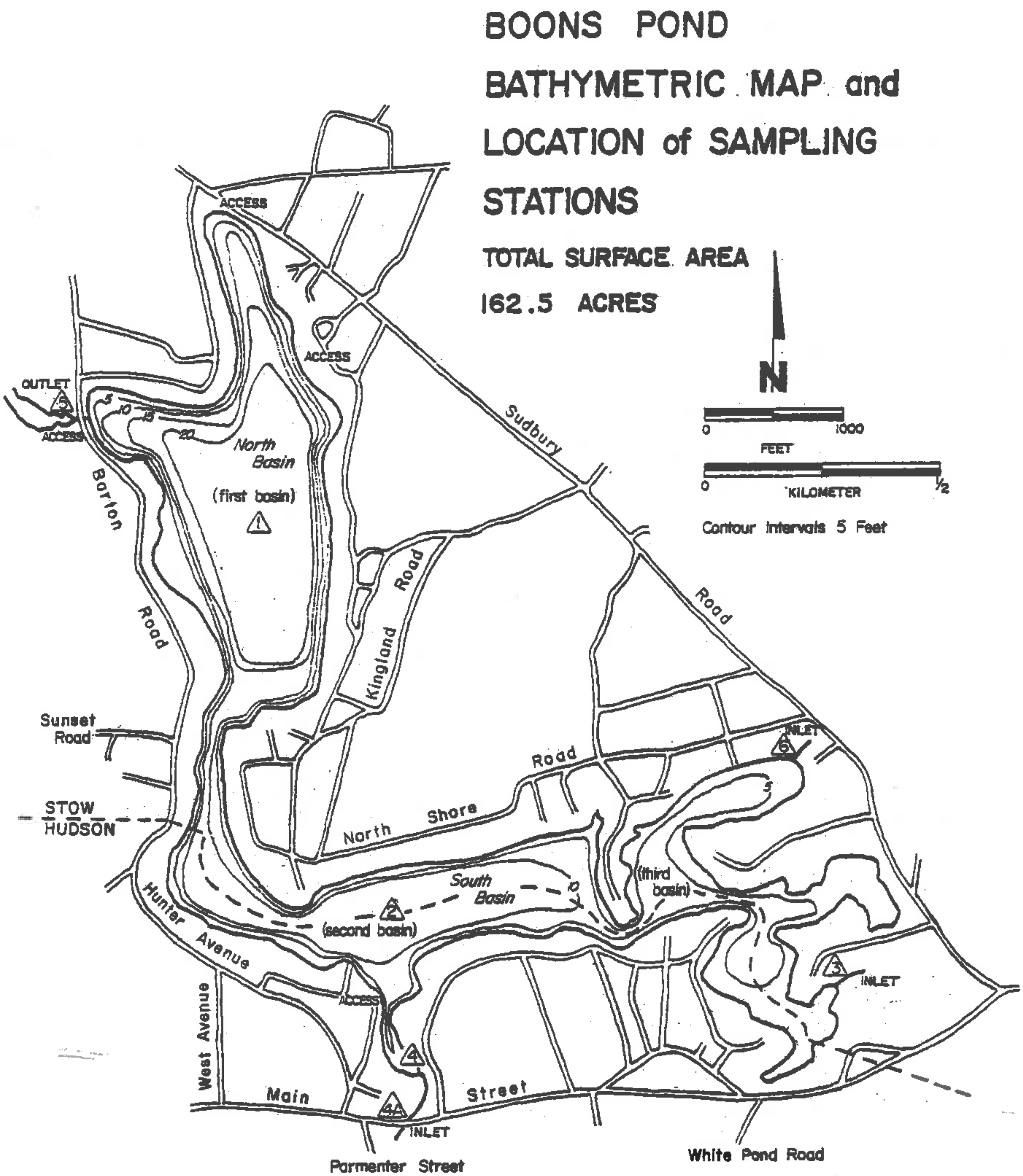

BOONS POND
BATHYMETRIC MAP and
LOCATION of SAMPLING
STATIONS
TOTAL SURFACE AREA
162.5 ACRES
N
FEET
KILOMETER
Contour Intervals 5 Feet
ACCESS
OUTLET
North Basin
(first basin)
South Basin
(second basin)
(third basin)
INLET
Sudbury Road
Barton Road
Kingland Road
North Shore Road
Sunset Road
STOW
HUDSON
Hunter Avenue
West Avenue
Main Street
Parmenter Street
White Pond Road

FIGURE 8

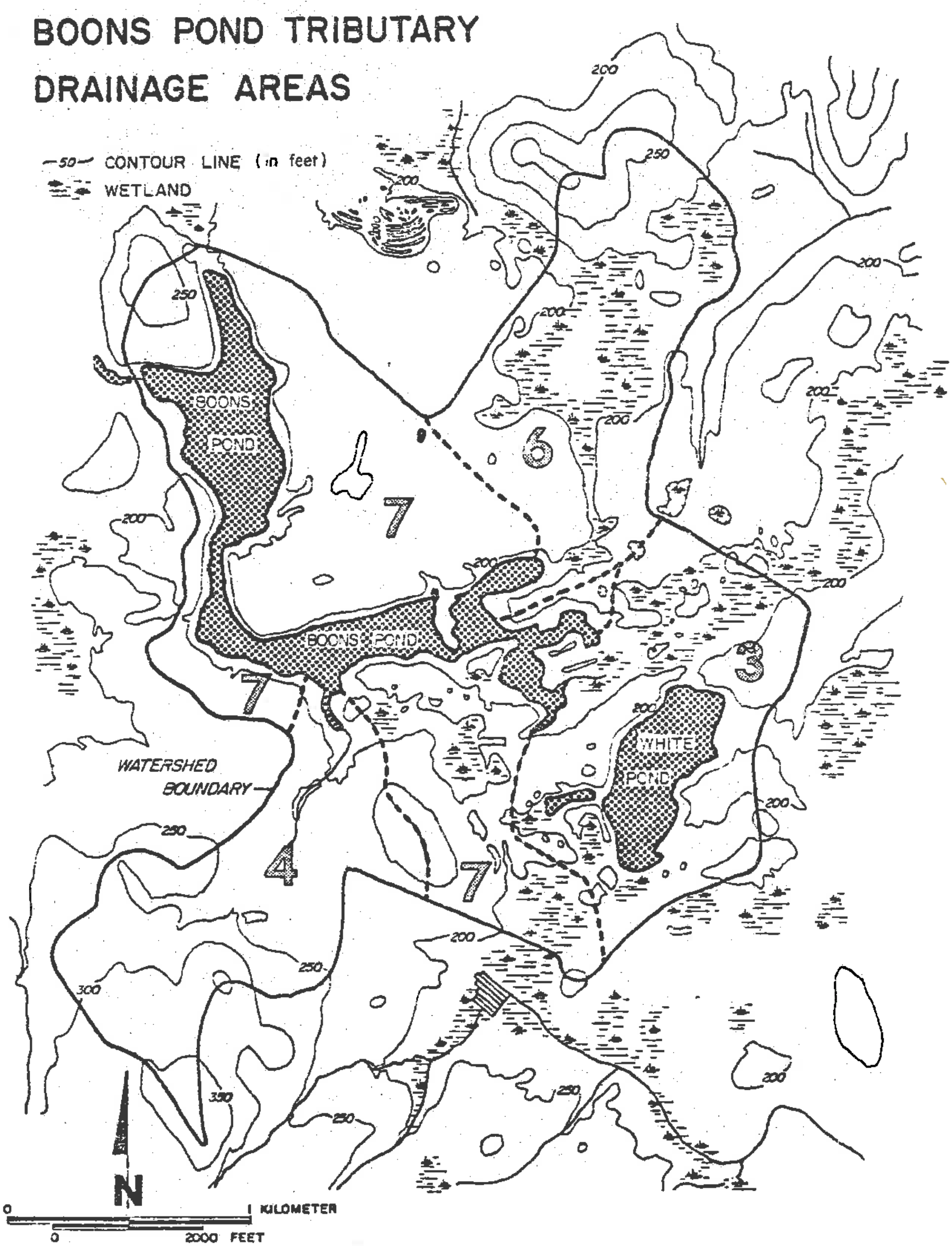


FIGURE 9

SOURCE: USGS (1965) topographic maps, Hudson and Maynard, Mass. quadrangles, (7.5 minute series)

TABLE 3

BOONS POND MORPHOMETRIC DATA FOR THE LAKE AND WATERSHED

Total Surface Area	658 X 10^3 m^2	(162.5 acres)
First Basin Surface Area	318 X 10^3 m^2	(78.5 acres)
Second and Third Basin Surface Area	340 X 10^3 m^2	(84.0 acres)
Total Volume	1,978 X 10^3 m^3	(69,800,000 ft^3)
First Basin Volume	1,326 X 10^3 m^3	(46,800,000 ft^3)
Second and Third Basin Volume	652 X 10^3 m^3	(23,000,000 ft^3)
Development of Volume		
First Basin	0.68	--
Second and Third Basin	0.61	--
Maximum Depth		
First Basin	6.1 m	(20 ft)
Second and Third Basin	3.1 m	(10 ft)
Mean Depth		
First Basin	4.2 m	(13.8 ft)
Second and Third Basin	1.9 m	(6.3 ft)
Total Lake Area Maximum Length	3,048 m	(10,000 ft)
Total Lake Area Maximum Width	536 m	(1,760 ft)
First Basin Maximum Effective Length	1,146 m	(3,760 ft)
First Basin Maximum Effective Width	536 m	(1,760 ft)
Total Lake Area Mean Width	216 m	(708 ft)
Shoreline Length	9,193 m	(30,160 ft)
Development of Shoreline	3.2	--
Mean to Maximum Depth Ratio	0.5	--
Total Watershed Area	6,211 X 10^3 m^2	(1,535 acres)
Subdrainage Basin #4	1,074 X 10^3 m^2	(265 acres)
Subdrainage Basin #3	1,208 X 10^3 m^2	(298 acres)
Subdrainage Basin #6	1,349 X 10^3 m^2	(333 acres)
Subdrainage Basin #7	1,922 X 10^3 m^2	(477 acres)

Lake Uses

Boons Pond and its watershed provide the public with enjoyment through recreational and residential assets. The shores of the lake are lined with dwellings. Primary contact recreation, swimming and secondary contact recreation, boating are the major lake use activities. Water skiing is a popular sport. Public boat access is available at Monahan's, off Main Street in Hudson, and at the dam off of Barton Road. There is a public beach for Stow residents located on the east side of the lake off Sudbury Road. There is a private beach club at the northern tip of the lake on Sudbury Road. During the warmer seasons fishermen enjoy bass and pickerel fishing from their docks, canoes, and prams. In the winter season the lake is used for ice fishing and by those who don their skates.

The lake was always a popular resort. In 1912 there were two public boat houses, an ice-house, and approximately 200 cottages on the lake's shores. Seasonal use of the lake continued through the 1930s. In the 1950s and 1960s human activity on the lake and in the watershed reached a greater intensity. Presently, watershed development has changed from seasonal housing to year-round housing.

Boons Pond is classified as Class B water in accordance with the Massachusetts Division of Water Pollution Control's Water Quality Standards (1978). These waters "are designated for the uses of protection and propagation of fish, other aquatic life and wildlife; and for primary and secondary contact recreation." Unfortunately, the massive weed problems have started to limit the use of the lake for recreational purposes. The areal coverage of aquatic weeds in the third basin and east part of the second basin is 75-100%.

The recreational and residential uses of Boons Pond and its watershed are similar to other lakes within a 50-mile radius. Transportation to the access areas must be provided by private car or bicycle. There is no public transportation to the area. The major roads in the watershed are publicly-owned. The smaller roads around the lake are privately-owned.

PREVIOUS REPORTS AND MANAGEMENT PRACTICES

Two reports were prepared by the Metropolitan Area Planning Council (MAPC) on Boons Pond and its watershed. The document, A Management Program for Lake Boon: Interim Report published in January 1979, outlined land use planning alternatives in the watershed. The Lake Boon Summary Report, issued in October 1979, outlined MAPC's activities and recommended a lake management program.

The Massachusetts Division of Water Pollution Control (MDWPC) has published a number of reports identifying water quality problems in the SuAsCo River Basin (Cooperman 1971, Hogan 1975). The SuAsCo River Basin Water Quality Management Plan describes the pathway toward the attainment of goals of pollution abatement and desired water quality for the Assabet River (MDWPC 1975). The Division has and will continue to monitor the water quality in the Assabet River (MDWPC 1979, 1980).

The private consulting firm of Whitman and Howard, Inc. 1977, prepared the Wastewater Treatment Facilities Plan Report under the Federal construction grants program 201, for the Town of Hudson. Included is a cost analysis for sewering in Hudson's Boons Pond area. However, there are no current plans for sewer construction in this area. The Town of Stow has no 201 facilities Plan and will continue to rely on septic systems for disposal of their sewage. They also must truck all pumped septage out of town for handling.

Hudson's zoning by-law as amended through 1974 divides the Hudson's Boons Pond watershed into four districts (Figure 10). A general residential area is defined adjacent to the lake. A single-family residential district is defined south of Main Street. Some of the land lying within these districts has a minimum lot size range between 20,000 to 40,000 square-feet. The other two districts are industrially zoned, one of which has no restrictions on types of industry and manufacturing (MAPC 1979), (Figure 10).

Stow's zoning by-law as amended through 1978 restricts the Stow's Boons Pond watershed to a single-family residential district with a minimum lot size of 65,340 square-feet. Stow has delineated an overlying floodplains/wetlands district for the protection of flood-prone areas, wetlands and other critical areas, as well as maintenance of groundwater (Figure 10). Stow has also delineated an overlying conservation district north of Sudbury Road (MAPC 1979).

Besides restricting development of new areas with zoning requirements as outlined above, a town can adopt a zoning by-law which restricts the conversions of existing dwellings. Hudson has recently adopted a by-law which restricts the conversion of non-conforming seasonal dwellings to year-round dwellings based on adequate provision for water supply, sewage disposal, drainage, and protection of natural resources from pollution (May Town Meeting 1980).

BOONS POND
ZONING REGULATIONS

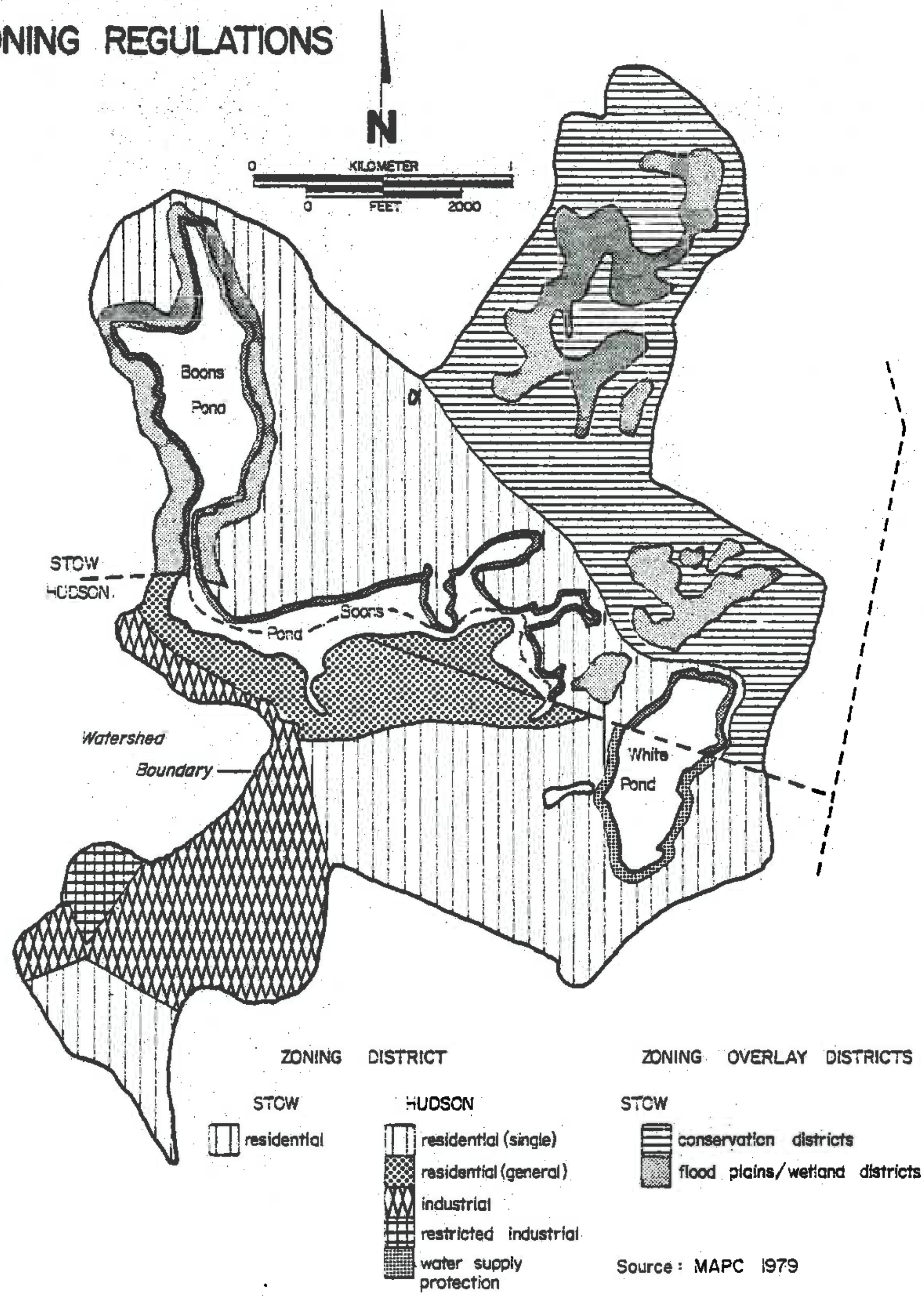


FIGURE 10

LIMNOLOGICAL DATA

Methods

Sampling Station Locations

Seven separate sampling stations were established on Boons Pond during the intensive study, April 1979-July 1980. The location of sampling stations can be seen in Figure 8.

Station 1 - The first basin "deep hole" station on the lake;

Station 2 - The second basin "deep hole" station on the lake;

Station 3 - Southeast inlet stream, subdrainage basin 3, sampled at the confluence with the lake;

Station 4 - South inlet stream, subdrainage basin 4, sampled at the confluence with the lake;

Station 4A- South inlet stream, subdrainage basin 4, sampled at Main Street;

Station 5 - The outlet, sampled at the dam; and

Station 6 - Northeast inlet stream, subdrainage basin 6, sample at the confluence with the lake.

Morphometry

A bathymetric map of Boons Pond was prepared using an original from the Massachusetts Division of Fisheries and Wildlife as confirmed in the field with a fathometer (Ray Jefferson Model 6006). Morphometric parameters were measured with a planimeter and rotometer according to Hutchinson (1957) and Welch (1948).

Physical and Chemical Data Collection

Temperature profiles were made in the field with a Tele-Thermometer (YSI Model 42SC). Transparency measurements were made with a standard 20 cm Secchi disc. Field pH tests were taken with a Hach Model 17N Wide Range pH Test Kit. Open water samples from the "deep hole" stations were collected with a brass Kemmerer water sampler. The inlet and outlet samples were generally collected below the surface by hand after thoroughly rinsing the sample bottle. Dissolved oxygen samples were collected in the manner prescribed by Welch (1948). Dissolved oxygen concentrations were measured by the azide modification of the Winkler technique (Standard Methods for the Examination of Water and Wastewater, 14th ed. APHA 1976). Titrations were made within several hours after fixing in the field with manganese sulfate and alkali-azide-iodide reagents. The sulfuric acid was added just prior to the titrations in the laboratory. Samples for chemical analyses were transported as soon as possible to the Lawrence Experiment Station of the Department of Environmental Quality Engineering, Division of Laboratories, and analyzed according to Standard Methods (APHA 1976), and Methods for Chemical Analysis of Water and Wastes (EPA 1979).

Phytoplankton and Chlorophyll *a*

Samples were collected by a standard procedure described by the Maine Department of Environmental Protection, Division of Lakes and Biological Studies. When the lake was unstratified, samples were collected by holding a clean and rinsed sample bottle several inches under the surface of the water. If stratification was evident, a composite sample of the water column above the thermocline was taken. Each sample consisted of a composite core taken with a 1/4-inch I.D. plastic tube with a weight attached to one end. The tube was lowered at the deep station to an appropriate point above the thermocline, pinched below the meniscus, and raised into the boat. The sample was allowed to drain into a clean and rinsed sample bottle. This procedure was repeated several times.

The phytoplankton samples were normally analyzed on the day of collection using a Whipple micrometer and Sedgewick-Rafter cell. Algal counts were reported as cells per ml, according to Standard Methods (APHA 1976).

Chlorophyll *a* analysis (Appendix D) was based on methodology from a modified EPA fluorometric procedure developed by the Division of Water Pollution Control at Westborough (Kimball 1979). Filtered samples were refrigerated for 24 hours after being ground and extracted in 90 percent acetone. Fluorometer readings were taken at 750 and 630 nannometers before and after treatment with 1N Hydrochloric acid (HCl) to correct for pheophytin.

Aquatic Weeds

The aquatic weed community in Boons Pond was located and mapped by slowly examining the entire littoral zone and cove areas. All habitats were sampled and the relative abundance of each plant type noted. Representative weeds were collected by hand and, in deeper water, by dragging a simple grappling hook with a weight attached to the shaft. When possible, entire plants were generally taken for analysis. Identification of the plant specimens was made using a stereoscopic microscope and various taxonomic keys (Fassett 1972, Hotchkiss 1972).

Bottom Sediment Sample

A representative sample of bottom sediments from Station 1 and Station 2 were collected using a standard 6X6-inch Ekman dredge. The sediment samples were placed in plastic one-quart containers, packed in ice, and transported to the Lawrence Experiment Station for analysis of heavy metals according to Standard Methods (APHA 1976).

Flow Measurements

The outlet flow was monitored using the coordinate method outlined in U.S. EPA (1973) Handbook for Monitoring Industrial Wastewater. Inlet flow was monitored using time of travel measurements (U.S.D.I. 1957, 1975).

Groundwater Seepage Meters

The following procedure was adapted from Lee and Cherry (1978):

> Seepage flux between the groundwater and the overlying surface water can be measured directly by covering an area of sediment with an open-bottomed container and then measuring the time and change of water volume in a polyethylene bag connected to the container. Two of these devices, known as seepage meters can be made by cutting end-sections from a 0.208 m^3 (55 gallon) steel drum. Seepage meters can detect flux as low as 0.001 cm^3/m^2 (about 0.1 mm/day) if the bag is left connected for a day or longer. In water over 20 cm deep, a single tube through the top of the seepage meter serves both as a vent for any gas released from the sediment and as a connection for the measuring bag.
>
> In use, the seepage meter is pushed slowly into the sediment and tilted slightly so that the vent will function properly. Time is then allowed (one-two weeks) for flushing of lake water from the drum. The stopper with tube and bag is then twisted into cylinder hole for sampling. Where flow is upward, it is unnecessary to add a known volume of water to the measuring bag before connecting it to the seepage meter.

Septic Leachate Detector System

The septic leachate survey was conducted by the Environmental Devices Corp., Marion Mass., during midweek, August 1979. The survey was funded by the Metropolitan Area Planning Council. The type 2100 Septic Snooper system is a portable field instrument used to pinpoint septic leachate pollution.

The technique employed was as follows:

1. The operator walked along the shoreline pulling the boat and holding the submersible pump in about one foot of water, or as close to the shoreline as possible.

2. As the pump was moved slowly along the shoreline, the fluorescence/ conductivity meter was monitored by a technician. Additionally a continuous monitoring of the conductivity/fluorescence is recorded on a paper tape.

3. When both fluorescence and conductivity levels rise simultaneously, the pump was held at the location of the rise. This location may be a few feet back from where it was when the rise was first observed as a result of the lag time inherent in the instrument. This resulted in the necessity of backtracking.

4. When the fluorescence and conductivity values remain steadily elevated, a bacteria and a chemical sample were taken.

The plume location was photographed and noted on a map of the shoreline. Additionally, the paper tape recording of the conductivity/fluorescence was coordinated with location.

Results

Physical

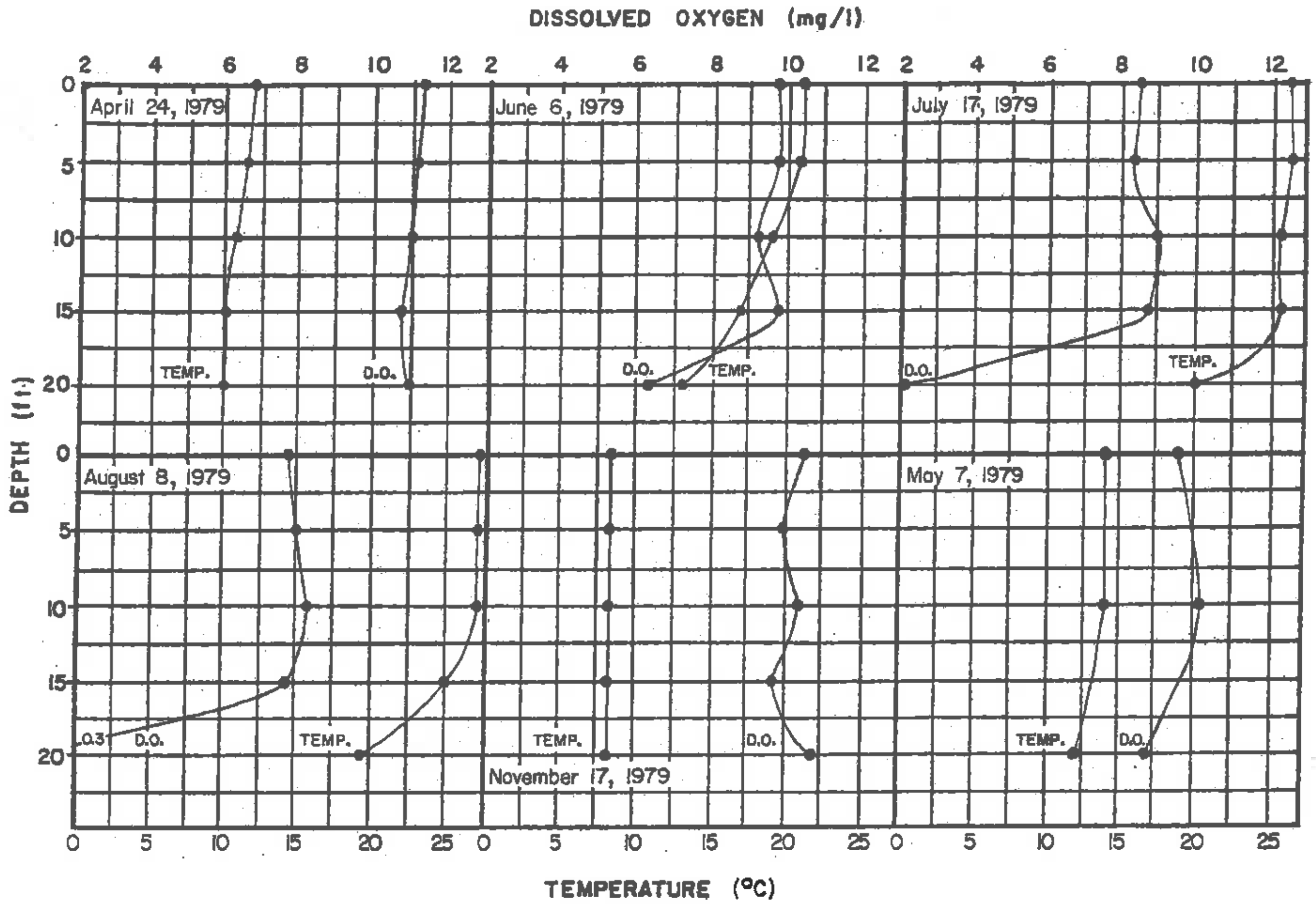
Temperature

Temperature data for the deep water station, first basin (Station 1) of Boons Pond appear in Table 4. The lake was circulating on the first sampling date, 24 April 1979. Thermal stratification was apparent on 6 June 1979. The lake remained stratified at Station 1 throughout the summer. On 19 November 1979 the lake had mixed throughout the water column. In the spring, 7 May 1980, the lake was starting to stratify as in the previous year. Throughout the summer of 1979 the thermal gradient was apparent between a depth of 3 m (10 ft.) and 6 m (20 ft.) (Figure 11). The range of surface temperatures recorded at Station 1 were 8.3°C to 27.0°C, while the range of bottom temperatures were 8.3°C to 20.0°C.

A temperature profile over time was also generated at Station 2 (Table 5). However, due to the shallowness of the basin, 10 ft. (3 m), no thermocline developed. Temperature data were also collected at the inlets and outlet stations to provide a reference point for determining the percent oxygen saturation at these stations.

Secchi Disc Transparency

The Secchi disc is used to measure the visibility of the water in terms of the depth one may see into the water. The readings for Boons Pond are presented in Table 7. The average Secchi disc readings were 2.6 m (8.5 ft.) and 2.0 m (6.5 ft.) at Station 1 and Station 2, respectively. The lowest values at the two stations occurred on 8 August 1979. The months of July and August are times of heavy motor boat use and high biological productivity. Both these factors influence the visibility of the water. The minimum visibility required by the Massachusetts Department of Public Health (1966) for swimming at public beaches is 1.2 m (4 ft.).



TEMPERATURE (°C) and DISSOLVED OXYGEN (mg/l) DATA STATION I

FIGURE II

TABLE 4

BOONS POND

DISSOLVED OXYGEN, TEMPERATURE AND PERCENT SATURATION DATA

STATION 1

Depth ft. (meters)	Temp. (°C)	D.O. (mg/l)	% Sat.	Temp. (°C)	D.O. (mg/l)	% Sat.
	April 24, 1979			June 6, 1979		
Surface	12.0	11.3	108	21.0	9.7	112
5' (1.5)	11.5	11.2	107	21.0	9.7	112
10' (3.0)	11.0	11.0	103	19.0	9.3	103
15' (4.6)	10.0	10.6	97	17.0	9.7	103
20' (6.1)	10.0	10.9	100	13.0	6.3	62
	July 17, 1979			August 8, 1979		
Surface	26.4	8.6	108	27.0	7.8	99
5' (1.5)	26.7	8.4	107	27.0	8.0	102
10' (3.0)	25.6	9.0	109	27.0	8.3	106
15' (4.6)	25.6	8.7	109	25.0	7.7	95
20' (6.1)	20.0	2.1	24	19.5	0.3	.03
	November 19, 1979			May 7, 1980		
Surface	8.3	10.5	91	14.0	9.6	96
5' (1.5)	8.3	9.9	86	--	--	--
10' (3.0)	8.3	10.4	91	14.0	10.2	102
15' (4.6)	8.3	9.7	84	--	--	--
20' (6.1)	8.3	10.8	94	12.0	8.8	84

TABLE 5

BOONS POND

DISSOLVED OXYGEN, TEMPERATURE AND PERCENT SATURATION DATA

STATION 2

Depth ft. (meters)	Temp. (°C)	D.O. (mg/1)	% Sat.	Temp. (°C)	D.O. (mg/1)	% Sat.
	June 6, 1979			July 17, 1979		
Surface	21.0	9.6	111	26.4	8.3	104
5' (1.5)	20.5	9.6	110	26.4	8.5	106
7.5' (2.3)	20.0	--	--	--	--	--
10' (3.0)	18.5	9.7	106	25.6	7.7	96
	August 8, 1979			November 19, 1979		
Surface	27.0	7.8	99	6.6	9.4	56
5' (1.5)	27.0	6.3	80	6.1	9.6	80
10' (3.0)	26.5	8.3	103	6.6	8.9	76
	May 7, 1980					
Surface	7.8	10.0	87			

TABLE 6

BOONS POND

DISSOLVED OXYGEN, TEMPERATURE AND PERCENT SATURATION DATA

STATIONS 3, 4, 4A, 5, 6

Station	Temp. (°C)	D.O. (mg/1)	% Sat.	Temp. (°C)	D.O. (mg/1)	% Sat.
	June 6, 1979			July 17, 1979		
3	--	--	--	19.5	1.0	11
4	15.0	8.8	90	17.2	7.7	82
5	22.0	9.7	114	--	--	--
6	--	--	--	17.2	1.8	19
	August 8, 1979			November 19, 1979		
3	N O F L O W			N O F L O W		
4	N O F L O W			5.0	10.3	120
5	27.8	8.1	92	7.8	9.9	84
6	N O F L O W			4.4	2.8	22
	February 27, 1980			March 27, 1980		
3	--	--	--	N O F L O W		
4A	3.3	10.5	73	3.5	11.9	92
5	3.3	12.5	86	4.5	12.1	97
6	N O F L O W			N O F L O W		
	May 7, 1980			May 20, 1980		
3	N O F L O W			N O F L O W		
4	7.8	9.0	78	--	--	--
4A	7.8	9.8	85	12.0	9.2	88
5	11.0	10.0	94	16.0	10.5	110
6	N O F L O W			N O F L O W		
	June 18, 1980					
3	N O F L O W					
4A	14.0	7.5	75			
5	21.0	8.9	98			
6	N O F L O W					

TABLE 7

BOONS POND

SECCHI DISC TRANSPARENCY READINGS

GENERAL METEOROLOGICAL CONDITIONS

DATE	STATION	READING		
		Meters	Feet	Weather Conditions & General Observations
4/24/79	1	3.4	11.0	Cloud cover 20%, water surface calm, wind 5-10 mph, time - 1100
	2	--	--	
6/6/79	1	2.9	9.5	Cloud cover 0%, water surface small waves wind - light, time - 1335
	2	2.1	7.0	Time - 1250
7/17/79	1	2.4	8.0	Cloud cover 75%, wind 10 mph, time - 1155
	2	1.4	4.5	Time - 1105
8/8/79	1	1.5	5.0	Cloud cover 25%, water surface 4 inch waves, wind moderate, time -1240
	2	1.5	5.0	Time - 1215
11/19/79	1	2.9	9.5	Cloud cover 0%, water surface calm, wind none, time - 1120
	2	3.0	10.0	Time - 1100

Chemical Data

Dissolved Oxygen Data

Seasonal fluctuations in epilimnetic dissolved oxygen, surface to 3 m (10 ft.), Station 1 and, surface to 1.5 m (5 ft.), Station 2 followed the temperature related solubility properties of water. Colder winter water held more oxygen than warm summer water. The supersaturated values of the epilimnetic waters observed during the spring and summer are in part a result of algal oxygen production.

In the hypolimnion Station 1, 6 m (20 ft.), when the summer thermal density gradient created a barrier to lake mixing and chemical/biological processes consumed oxygen, there was a dramatic decrease in dissolved oxygen content from 62 percent saturated to 0.03 percent saturated. Because of the well mixed condition of surface waters and bottom waters, Station 2 did not show the dissolved oxygen depletion observed in the first basin.

Dissolved oxygen percent saturation values at the inlets, Station 3 and Station 6, were low (Table 6) reflecting the high oxygen demand of the streams and the sluggish flow through the inlet. At the inlet stream Station 4 and Station 4A showed high dissolved oxygen saturation values throughout the study. When there was rapid flow through the inlet 7 May 1980, Station 4A and 4 had observed saturation values of 85 percent and 78 percent, respectively. Dissolved oxygen saturation values at the outlet, Station 5, were high throughout the study (Table 6).

pH

Generally, the pH values observed at the in-lake stations, inlet stations, and outlet station of Boons Pond, (Table 8) were within the range of values found in natural waters, pH 6.0-8.5 (Hem 1970). The range of pH values observed with depth at Station 1 during the summer are probably due to respiratory processes in or near the sediments decreasing the pH and, to photosynthetic processes in the surface waters, increasing the pH. Station 1 on 17 July 1979 had a surface pH of 7.5 and pH of 6.7 at 6 m (20 ft.). On 8 August 1979 a surface pH of 8.6 and at 6 m (20 ft.) pH of 6.6 was observed. The low pH value of 4.3 observed at inlet 3 on 17 July 1979 is typical of wetland drainage.

Conductivity and Chloride

Conductivity, or specific conductance, of natural waters measures the relative content of ionized salts. The major ionized salts contributing to conductivity are: calcium, magnesium, sodium, potassium, carbonate, sulfate, and chloride. In soft water systems the natural chloride concentration is greater than the sulfate concentration and the sulfate concentration is greater than the carbonate concentration. Increases in concentrations of any of the ionized salts would result in increased conductivity values. Conductivity values did not vary significantly throughout the water column at Station 1 and Station 2 (Table 9). The highest observed conductivity

TABLE 8

BOONS POND

pH (Standard Units)

STATION NUMBER	DEPTH (ft)	1979 4/24	6/6	7/17	8/8	11/19	1980 2/27	3/27	5/7	5/20	6/18
1	0	6.4	6.7*	7.5	8.6	7.2	-	-	6.7	-	-
	10	-	6.9	-	-	-	-	-	-	-	-
	20	6.6	6.6	6.7	6.6	7.2	-	-	6.6	-	-
2	0	6.3	6.9*	7.4	7.2	7.1	-	-	6.7	-	-
	10	-	7.0	6.9	7.6**	7.0	-	-	-	-	-
3	-	6.0	-	4.3	***	***	-	***	***	***	***
4	-	5.6	6.9	5.9	***	6.8	-	-	6.1	-	-
4A	-	-	-	-	-	-	6.3	5.7	6.1	6.1	6.7
5	-	6.3	6.9	-	8.2	7.1	6.7	6.8	6.7	6.9	7.2
6	-	-	-	6.6	***	7.1	***	***	***	***	***

*Sampled at 5 feet
**Sampled at 9 feet
***No flow
-Not sampled

TABLE 9

BOONS POND

CONDUCTIVITY (μmhos/cm)

STATION	DEPTH (ft.)	DEPTH (m)	1979 4/24	1979 6/6	1979 7/17	1979 8/8	1979 11/19	1980 2/27	1980 3/27	1980 5/7	1980 5/20	1980 6/18
1	0	0	85	100[1]	104	100	94	--	--	96	--	--
	10	3	--	100	--	--	--	--	--	--	--	--
	20	6	78	100	106	100	94	--	--	96	--	--
2	0	0	87	100[1]	102	100	92	--	--	92	--	--
	10	3	--	100	106	100[2]	92	--	--	--	--	--
3	--	--	280	--	99	*	*	--	*	*	*	*
4A	--	--	--	--	--	--	--	110	50	54	55	--
4	--	--	60	82	86	*	66	--	--	66	--	--
5	--	--	88	100	--	100	92	100	94	96	92	--
6	--	--	--	--	64	*	58	*	*	*	*	*

*No flow

[1]Sampled at 5 ft. (1.5 m)

[2]Sampled at 9 ft. (2.7 m)

values occurred at Station 3 on 24 April 1979, 280 umhos/cm, and at Station 4A on 27 February 1980, 110 umhos/cm. These peaks correspond to elevated chloride values. Low conductivity values at Station 4A on 27 March, 7 May 1980, and 20 May 1980 correspond to lower chloride concentrations (Table 10).

The average concentration of chloride in natural fresh waters is 8.3 mg/1, but this value varies widely (Wetzel 1975). Chloride is supplied to Boons Pond from the weathering of topsoil and geological formations, and seasonal road de-icing operations. The highest values observed at Stations 1, 2, 3, and 4 occurred on 24 April 1979 (Table 10). The highest value observed at Station 4A occurred on 27 February 1980. None of the other inlet or lake stations were sampled on this date. Although there appears to be a seasonal trend in conductivity and chloride these values do not represent a public health problem.

Total Hardness

Hardness is caused by the presence of calcium, magnesium, strontium, ferrous ions, and manganous ions in the water. The hardness of water is due to the local rock formations. Boons Pond is located in an area of glacial outwash and alluvium derived from bedrock low in limestone ($CACO_3$) (Reference cited in Chesebrough and Cooperman 1979). This area has characteristically low hardness values. Hardness values (Table 11) for Boons Pond ranged over the observed epilimnetic values of 14 mg/1 as $CaCO_3$ to 20 mg/1 as $CaCO_3$. These values fall within the range of values that characterize the lake as a soft water system, 0-75 mg/1 as $CaCO_3$ (Sawyer 1960). In comparison, Lake Buel located in an area of the state having limestone-bearing strata had an average hardness value of 124 mg/1 as $CaCO_3$ (Chesebrough et al. 1976).

Total Alkalinity

Total alkalinity represents the buffering capacity of the lake water to pH change (Table 12). Boons Pond is a weakly-buffered lake. The range of values observed at Station 1 were 7.0 mg/1 as $CaCO_3$ to 15.0 mg/1 as $CaCO_3$. The range of values at Station 2 were 8.0 mg/1 as $CaCO_3$ to 12.0 mg/1 as $CaCO_3$. The Environmental Protection Agency recommends a total alkalinity value of 20 mg/1 as $CaCO_3$, or more for maintenance and propagation of freshwater aquatic life, except where natural concentrations are less (U.S. EPA 1976).

Total Solids and Suspended Solids

The quantity total solids is an estimation of materials in water. This total is divided into two parts, suspended inorganic and organic material, and dissolved inorganic and organic residue. North basin total solids values and south basin total solids values ranged from 54 mg/1 to 186 mg/1, and 44 mg/1 to 170 mg/1, respectively. Inlet total solids values at Station 4, Station 4A, and Station 6 ranged from 28 mg/1 to 98 mg/1 (Table 13).

TABLE 10

BOONS POND

CHLORIDE (mg/1)

STATION	DEPTH (ft.)	DEPTH (m)	1979 4/24	1979 6/6	1979 7/17	1979 8/8	1979 11/19	1980 2/27	1980 3/27	1980 5/7	1980 5/20	1980 6/18
1	0	0	20	20[1]	18	21	19	--	--	18	--	--
	10	3	--	19	--	--	--	--	--	--	--	--
	20	6	31	20	19	20	19	--	--	18	--	--
2	0	0	31	20	19	21	19	--	--	8.0	--	--
	10	3	--	20	19	22[2]	19	--	--	--	--	--
3	--	--	106	--	17	*	*	--	*	*	*	*
4A	--	--	--	--	--	--	--	17	6.0	7.0	10	13
4	--	--	13	11	11	*	10	--	--	7.0	--	--
5	--	--	20	20	--	20	19	19	19	19	21	20
6	--	--	--	--	8	*	7	*	*	*	*	*

*No flow

[1]Sampled at 5 ft. (1.5 m)

[2]Sampled at 9 ft. (2.7 m)

TABLE 11

BOONS POND

TOTAL HARDNESS (mg/l as $CaCO_3$)

STATION	DEPTH (ft.)	DEPTH (m)	1979 4/24	1979 6/6	1979 7/17	1979 8/8	1979 11/19	1980 2/27	1980 3/27	1980 5/7	1980 5/20	1980 6/18
1	0	0	16	15[1]	15	17	16	--	--	14	--	--
	10	3	--	16	--	--	--	--	--	--	--	--
	20	6	16	15	17	20	16	--	--	14	--	--
2	0	0	17	16[1]	15	17	16	--	--	14	--	--
	10	3	--	15	15	17[2]	17	--	--	--	--	--
3	--	--	18	--	16	*	*	*	*	*	*	*
4A	--	--	--	--	--	--	--	15	9	10	10	12
4	--	--	14	13	15	*	11	--	--	11	--	--
5	--	--	16	15	--	17	15	16	13	14	14	15
6	--	--	--	--	10	*	9	*	*	*	*	*

*No flow

[1]Sampled at 5 ft. (1.5 m)

[2]Sampled at 9 ft. (2.7 m)

TABLE 12

BOONS POND

TOTAL ALKALINITY (mg/1 as $CaCO_3$)

STATION	DEPTH (ft.)	DEPTH (m)	1979 4/24	1979 6/6	1979 7/17	1979 8/8	1979 11/19	1980 2/27	1980 3/27	1980 5/7	1980 5/20	1980 6/18
1	0	0	8.0	7.0[1]	8.0	12.0	11.0	--	--	9.0	--	
	10	3	--	8.0	--	--	--	--	--	--	--	--
	20	6	9.0	11.0	14.0	15.0	12.0	--	--	9.0	--	--
2	0	0	8.0	11.0[1]	10.0	12.0	10.0	--	--	10.0	--	--
	10	3	--	9.0	9.0	12.0[2]	11.0	--	--	--	--	--
3	--	--	5.0	--	16.0	*	*	--	*	*	*	*
4A	--	--	--	--	--	--	--	9.0	4.0	4.0	4.0	7.0
4	--	--	3.0	6.0	15.0	*	5.0	--	--	5.0	--	--
5	--	--	7.0	13.0	--	10.0	11.0	10.0	9.0	9.0	9.0	10.0
6	--	--	--	--	9.0	*	12.0	*	*	*	*	*

*No flow

[1]Sampled at 5 ft. (1.5 m)

[2]Sampled at 9 ft. (2.7 m)

TABLE 13

BOONS POND

TOTAL SOLIDS (mg/1)

STATION	DEPTH (ft.)	DEPTH (m)	1979 4/24	1979 6/6	1979 7/17	1979 8/8	1979 11/19	1980 2/27	1980 3/27	1980 5/7	1980 5/20	1980 6/18
1	0	0	68	80[1]	62	70	54	--	--	186	--	--
	10	3	--	74	--	--	--	--	--	--	--	--
	20	6	68	82	54	68	60	--	--	180	--	--
2	0	0	70	82[1]	44	82	84	--	--	170	--	--
	10	3	--	76	54	64[2]	76	--	--	--	--	--
3	--	--	208	--	20	*	*	--	*	*	*	*
4A	--	--	--	--	--	--	--	62	28	52	64	78
4	--	--	62	82	4	*	98	--	--	64	--	--
5	--	--	64	82	--	52	78	68	50	192	--	150
6	--	--	--	--	70	*	80	*	*	*	*	*

*No flow

[1]Sampled at 5 ft. (1.5 m)

[2]Sampled at 9 ft. (2.7 m)

Suspended solids in the lake are considered to be settleable solids. These materials will eventually add to the sediment of the lake unless they are lost in outlet flow. Suspended solids values at the inlet stations varied throughout the study (Table 14). The average suspended solids values were: 2.7 mg/l (Station 3); 11.1 mg/l (Station 4A); and 10.5 mg/l (Station 6).

Total Iron and Total Manganese

Iron and manganese data for Boons Pond are presented in Tables 15 and 16. The typical range of iron and manganese concentrations found in oxygenated waters of pH 5 to 8 is about 0.05 to 0.20 mg/l and 0.001 to 0.850 mg/l, respectively (Wetzel 1975). Concentrations at Station 1 and Station 2 usually fell within this range. On 17 July 1979 the bottom sample from Station 1 showed elevated iron and manganese concentrations; 0.25 and 0.49 mg/l, respectively. The higher concentrations of these elements may indicate a release from the sediments with decreased oxygen concentration. On 19 November 1979, Station 2 showed elevated iron and manganese concentrations. Iron levels at Station 4 were also high on this date. Iron concentration was high at Station 4A on 18 June 1980. Station 6 and Station 3 had consistently high values. Higher iron concentrations are a common occurrence in stream water draining wetlands (McVoy et al. in press).

Total Phosphorus and Total Nitrogen

Total phosphorus data for Boons Pond Station 1 and Station 2, showed seasonal fluctuation (Table 17). The average total phosphorus concentration in the epilimnion and hypolimnion at Station 1 (April 79-May 80) was 0.07 mg/l. The average total phosphorus concentration at the surface and at a depth of 3 m (10 ft.) for Station 2 was 0.07 mg/l and 0.05 mg/l, respectively. Boons Pond had an average total phosphorus concentration at inlet 3 of 0.10 mg/l. The average total phosphorus concentration at inlet 4 was 0.06 mg/l. The average total phosphorus concentration at inlet 6 was 0.04 mg/l. The average total phosphorus concentration at the outlet Station 5 was 0.05 mg/l. These values are used to develop the nutrient budget for Boons Pond.

Nitrogen is present in freshwater as ammonia-nitrogen, nitrate-nitrogen, and organic nitrogen. Nitrogen data for Boons Pond are presented in Tables 18, 19, 20, 21, and 22. Total Kjeldahl-nitrogen includes ammonia-nitrogen and organic-nitrogen. Total nitrogen values are used in calculating the nutrient budget for Boons Pond and are the sum of total Kjeldahl-nitrogen and nitrate-nitrogen values.

Both nitrogen and phosphorus are present in sufficient supply to encourage biological activity. Because phosphorus concentration is more easily defined than the various forms of nitrogen and directly related to productivity this is the parameter that is usually modeled for.

Nitrate concentrations at the in-lake Stations 1 and 2 varied seasonally over the study period. Concentrations of nitrate measured at the outlet

TABLE 14

BOONS POND

SUSPENDED SOLIDS (mg/l)

STATION	DEPTH (ft.)	DEPTH (m)	1979 4/24	6/6	7/17	8/8	11/19	1980 2/27	3/27	5/7	5/20	6/18
1	0	0	0.8	1.0[1]	2.0	1.0	0	--	--	1.5	--	--
	10	3	--	1.5	--	--	--	--	--	--	--	--
	20	6	0.8	2.5	10.0	0	0.5	--	--	5.5	--	--
2	0	0	1.2	4.0[1]	1.5	0	1.0	--	--	3.0	--	--
	10	3	--	1.5	4.5	0[2]	0.5	--	--	--	--	--
3	--	--	2.8	--	2.5	*	*	*	*	*	*	*
4A	--	--	--	--	--	--	--	0.5	0.5	0	14.5	29.0
4	--	--	0.4	4.0	2.5	*	0	--	--	3.0	--	--
5	--	--	0.8	2.5	--	0	1.0	1.0	1.0	0.5	--	2.0
6	--	--	--	--	14.0	*	7.0	*	*	*	*	*

*No flow

[1] Sampled at 5 ft. (1.5 m)

[2] Sampled at 9 ft. (2.7 m)

TABLE 15

BOONS POND

TOTAL IRON (mg/1)

STATION	DEPTH (ft.)	DEPTH (m)	1979 4/24	6/6	7/17	8/8	11/19	1980 2/27	3/27	5/7	5/20	6/18
1	0	0	0.09	0.08[1]	0.02	0.05	0.10	--	--	0.00	--	--
	10	3	--	--	--	--	--	--	--	0.09	--	--
	20	6	0.05	0.00	0.25	0.05	0.06	--	--	--	--	--
2	0	0	0.15	0.07[1]	0.12	0.07	0.69	--	--	0.06	--	--
	10	3	--	0.04	0.20	0.10[2]	0.35	--	--	--	--	--
3	--	--	0.90	--	1.4	*	*	--	*	*	*	*
4A	--	--	--	--	--	--	--	0.08	0.02	0.10	--	0.25
4	--	--	0.05	0.08	0.22	*	0.29	--	--	0.11	--	--
5	--	--	0.08	0.00	--	0.00	0.05	0.13	0.07	0.00	--	0.12
6	--	--	--	--	6.1	*	3.1	*	*	*	*	*

*No flow

[1]Sampled at 5 ft. (1.5 m)

[2]Sampled at 9 ft. (2.7 m)

TABLE 16

BOONS POND

TOTAL MANGANESE (mg/1)

STATION	DEPTH (ft.)	DEPTH (m)	1979 4/24	1979 6/6	1979 7/17	1979 8/8	1979 11/19	1980 2/27	1980 3/27	1980 5/7	1980 5/20	1980 6/18
1	0	0	0.04	0.00[1]	0.02	0.01	0.00	--	--	--	--	--
	10	3	--	0.00	--	--	--	--	--	--	--	--
	20	6	0.01	0.03	0.49	0.18	0.04	--	--	--	--	--
2	0	0	0.05	0.00[1]	0.02	0.01	0.06	--	--	--	--	--
	10	3	--	0.00	0.02	0.07[2]	0.12	--	--	--	--	--
3	--	--	0.18	--	0.18	*	*	*	*	*	*	*
4A	--	--	--	--	--	--	--	0.02	0.10	--	--	0.06
4	--	--	0.05	0.06	0.10	*	0.24	--	--	--	--	--
5	--	--	0.01	0.00	--	0.02	0.02	0.00	0.04	--	--	0.03
6	--	--	--	--	0.40	*	0.82	*	*	*	*	*

*No flow

[1]Sampled at 5 ft. (1.5 m)

[2]Sampled at 9 ft. (2.7 m)

TABLE 17

BOONS POND

TOTAL PHOSPHORUS (mg/l)

STATION	DEPTH (ft.)	DEPTH (m)	1979 4/24	6/6	7/17	8/8	11/19	1980 2/27	3/27	5/7	5/20	6/18
1	0	0	0.09	0.10[1]	0.06	0.04	0.08	--	--	0.03	--	--
	10	3	--	0.08	--	--	--	--	--	--	--	--
	20	6	0.09	0.08	0.06	0.05	0.08	--	--	0.00	--	--
2	0	0	0.15	0.07[1]	0.03	0.03	0.08	--	--	0.03	--	--
	10	3	--	0.07	0.04	0.04[2]	0.05	--	--	--	--	--
3	--	--	0.12	--	0.08	*	*	*	*	*	*	*
4A	--	--	--	--	--	--	--	0.05	0.02	0.04	0.05	0.09
4	--	--	0.11	0.09	0.04	*	0.04	--	--	0.02	--	--
5	--	--	0.15	0.09	--	0.03	0.03	0.08	0.01	0.03	0.03	0.03
6	--	--	--	--	0.04	*	0.03	*	*	*	*	*

*No flow

[1] Sampled at 5 ft. (1.5 m)

[2] Sampled at 9 ft. (2.7 m)

TABLE 18

BOONS POND

TOTAL KJELDAHL-N (mg/l)

STATION	DEPTH (ft.)	DEPTH (m)	1979 4/24	1979 6/6	1979 7/17	1979 8/8	1979 11/19	1980 2/27	1980 3/27	1980 5/7	1980 5/20	1980 6/18
1	0	0	0.72	0.84[1]	0.88	0.87	0.65	--	--	0.65	--	--
	10	3	--	0.58	--	--	--	--	--	--	--	--
	20	6	1.3	0.65	0.96	0.59	0.67	--	--	0.73	--	--
2	0	0	0.80	0.55[1]	0.70	0.65	0.68	--	--	0.48	--	--
	10	3	--	0.43	0.81	0.56	0.61	--	--	--	--	--
3	--	--	1.4	--	1.5	*	*	*	*	*	--	*
4A	--	--	--	--	--	--	--	0.58	0.39	0.66	0.38	0.43
4	--	--	0.60	0.29	0.74	*	0.33	--	--	0.66	--	--
5	--	--	0.91	0.47	--	0.69	0.56	0.70	0.45	0.66	0.43	0.37
6	--	--	--	--	0.78	*	0.79	*	*	*	*	*

*No flow

[1]Sampled at 5 ft. (1.5 m)

[2]Sampled at 9 ft. (2.7 m)

TABLE 19

BOONS POND

NITRATE-N (mg/1)

STATION	DEPTH (ft.)	DEPTH (m)	1979 4/24	1979 6/6	1979 7/17	1979 8/8	1979 11/19	1980 2/27	1980 3/27	1980 5/7	1980 5/20	1980 6/18
1	0	0	0.2	0.1[1]	0.0	0.1	0.1	--	--	0.1	--	--
	10	3	--	0.1	--	--	--	--	--	--	--	--
	20	6	0.1	0.1	0.0	0.0	0.1	--	--	0.1	--	--
2	0	0	0.1	0.1[1]	0.0	0.0	0.1	--	--	0.1	--	--
	10	3	--	0.1	0.0	0.0[2]	0.1	--	--	--	--	--
3	--	--	0.0	--	0.0	*	*	*	*	*	*	*
4A	--	--	--	--	--	--	--	1.1	0.1	0.2	0.2	0.5
4	--	--	0.2	0.5	0.3	*	0.4	--	--	0.5	--	--
5	--	--	0.6	0.1	--	0.0	0.1	0.2	0.1	0.1	0.1	0.1
6	--	--	--	--	0.0	*	0.0	*	*	*	*	*

*No flow

[1] Sampled at 5 ft. (1.5 m)

[2] Sampled at 9 ft. (2.7 m)

TABLE 20

BOONS POND

AMMONIA-N (mg/1)

STATION	DEPTH (ft.)	DEPTH (m)	1979 4/24	1979 6/6	1979 7/17	1979 8/8	1979 11/19	1980 2/27	1980 3/27	1980 5/7	1980 5/20	1980 6/18
1	0	0	0.06	0.01[1]	0.01	0.12	0.12	--	--	0.05	--	--
	10	3	--	0.00	--	--	--	--	--	--	--	--
	20	6	0.03	0.00	0.01	0.13	0.09	--	--	0.05	--	--
2	0	0	0.05	0.00[1]	0.02	0.09	0.12	--	--	0.06	--	--
	10	3	--	0.20	0.01	0.14[2]	0.11	--	--	--	--	--
3	--	--	0.08	--	0.06	*	*	*	*	*	*	*
4A	--	--	--	--	--	--	--	0.06	0.06	0.02	0.00	0.04
4	--	--	0.02	0.00	0.01	*	0.03	--	--	0.01	--	--
5	--	--	0.07	0.00	--	0.14	0.09	0.06	0.01	0.06	0.01	0.04
6	--	--	--	--	0.09	*	0.15	*	*	*	*	*

*No flow

[1]Sampled at 5 ft. (1.5 m)

[2]Sampled at 9 ft. (2.7 m)

TABLE 21

BOONS POND

AMMONIA-N and NITRATE-N (mg/l)

STATION	DEPTH (ft.)	DEPTH (m)	1979 4/24	6/6	7/17	8/8	11/19	1980 2/27	3/27	5/7	5/20	6/18
1	0	0	0.26	0.11[1]	0.01	0.22	0.22	--	--	0.15	--	--
	10	3	--	0.10	--	--	--	--	--	--	--	--
	20	6	0.13	0.10	0.01	0.13	0.19	--	--	0.15	--	--
2	0	0	0.15	0.10[1]	0.02	0.09	0.22	--	--	0.16	--	--
	10	3	--	0.30	0.01	0.14[2]	0.12	--	--	--	--	--
3	--	--	0.08	--	0.06	*	*	*	*	*	*	*
4A	--	--	--	--	--	--	--	1.16	0.16	0.22	0.20	0.54
4	--	--	0.22	0.50	0.31	*	0.43	--	--	0.51	--	--
5	--	--	0.67	0.10	--	0.14	0.19	0.26	0.11	0.16	0.13	0.14
6	--	--	--	--	0.09	*	0.15	*	*	*	*	*

*No flow

[1]Sampled at 5 ft. (1.5 m)

[2]Sampled at 9 ft. (2.7 m)

TABLE 22

BOONS POND

ORGANIC-N (mg/l)

STATION	DEPTH (ft.)	DEPTH (m)	1979 4/24	1979 6/6	1979 7/17	1979 8/8	1979 11/19	1980 2/27	1980 3/27	1980 5/7	1980 5/20	1980 6/18
1	0	0	0.66	0.83[1]	0.87	0.75	0.53	--	--	0.60	--	--
	10	3	--	0.58	--	--	--	--	--	--	--	--
	20	6	1.27	0.65	0.95	0.46	0.58	--	--	0.68	--	--
2	0	0	0.75	0.55[1]	0.68	0.56	0.56	--	--	0.42	--	--
	10	3	--	0.23	0.80	0.42[2]	0.50	--	--	--	--	--
3	--	--	1.32	--	1.44	*	*	*	*	*	*	*
4A	--	--	--	--	--	--	--	0.52	0.35	0.64	0.38	0.39
4	--	--	0.58	0.29	0.73	*	0.30	--	--	0.65	--	--
5	--	--	0.84	0.47	--	0.55	0.47	0.63	0.29	0.54	0.42	0.33
6	--	--	--	--	0.69	*	0.64	*	*	*	*	*

*No flow

[1] Sampled at 5 ft. (1.5 m)

[2] Sampled at 9 ft. (2.7 m)

reflected in-lake concentrations. However, nitrate values observed at inlet 4 were often above in-lake values. On 27 February 1980 inlet 4 (Station 4A) showed nitrate concentrations of 1.1 mg/l. These measurements suggest a higher input rate of nitrate from this inlet.

By comparing the sum of ammonia-nitrogen values and nitrate-nitrogen values (Table 21) to nitrate-nitrogen values, or to ammonia-nitrogen values, a trend in the dominant form of inorganic-nitrogen is observed.

In August at the in-lake Stations 1 and 2, and at the outlet, Station 5, ammonia was the dominant form of inorganic nitrogen. This is probably due to the plant uptake of nitrate and increased decomposition rates producing ammonia. During July and November the relative proportions of each form were fairly equal. During February, March, May, and June nitrate was the dominant inorganic nitrogen form at the in-lake and outlet stations.

At Stations 3 and 6 ammonia-nitrogen was the more abundant inorganic form. At inlet 4 (Stations 4 and 4A) nitrate was the more important inorganic form of nitrogen.

Throughout the study at the in-lake Stations 1 and 2, at the outlet Station 5, at the inlets Stations 3 and 6 organic-nitrogen concentrations were greater than inorganic-nitrogen concentrations. However, at Station 4 and 4A inorganic-nitrogen values were greater than organic nitrogen values during the months of June 1979, November 1979, February 1980 and June 1980.

Biological

Bacteriological Analyses

Bacteria of the coliform group are considered the primary indicators of fecal contamination and are one of the most frequently applied indicators of water quality. The fecal coliform bacteria, which comprise a portion of the total coliform group, are restricted to the intestinal tract of warm-blooded animals. The total coliform group includes soil bacteria. Bacteriological analysis for Boons Pond is presented in Table 23. Total and fecal coliform values on 17 July 1979 at Station 2, Station 3, and Station 4 were high, indicating a summer water quality problem. A heavy rainfall the day before sampling may have washed contaminants into the lake. Values at Station 1 and Station 5 were low throughout the study. State water quality standards set the criteria for fecal coliform bacteria at less than 200/100 ml. (CMWRC 1978)

Phytoplankton - Chlorophyll a - Silica

The biomass of phytoplankton in Boons Pond rose to a maximum level in the summer. This is evidenced by both the chlorophyll a values (Table 24) and total cell counts (Table 26 and Table 27). Peak chlorophyll a values were observed at Station 1 and Station 2 on 17 July 1979 and 8 August 1979.

TABLE 23

BOONS POND

TOTAL & FECAL COLIFORM (counts/100 ml)

STATION	COLIFORM GROUP	1979 4/24	1979 6/6	1979 7/17	1979 8/8	1979 11/11	1980 2/27	1980 3/27	1980 5/7	1980 5/20	1980 6/18
1	Total	<5	10	20	10	90	--	--	5	--	--
	Fecal	<5	<5	<5	<5	<5	--	--	<5	--	--
2	Total	<5	10	1600	10	5	--	--	10	--	--
	Fecal	<5	<5	900	<10	<5	--	--	<5	--	--
3	Total	20	2000	1500	*	*	*	*	*	*	*
	Fecal	<5	20	600	*	*	*	*	*	*	*
4	Total	420	--	3000	*	220	--	--	300	--	--
	Fecal	5	--	880	*	<5	--	--	<5	--	--
4A	Total	--	--	--	*	--	30	<10	350	150	20
	Fecal	--	--	--	*	--	15	<5	<5	<5	<5
5	Total	20	10	--	10	10	<10	<10	<5	20	740
	Fecal	<5	<5	--	<10	<5	<5	<5	<5	5	30
6	Total	--	--	1400	*	30	*	*	*	*	*
	Fecal	--	--	430	*	<5	*	*	*	*	*

* No Flow

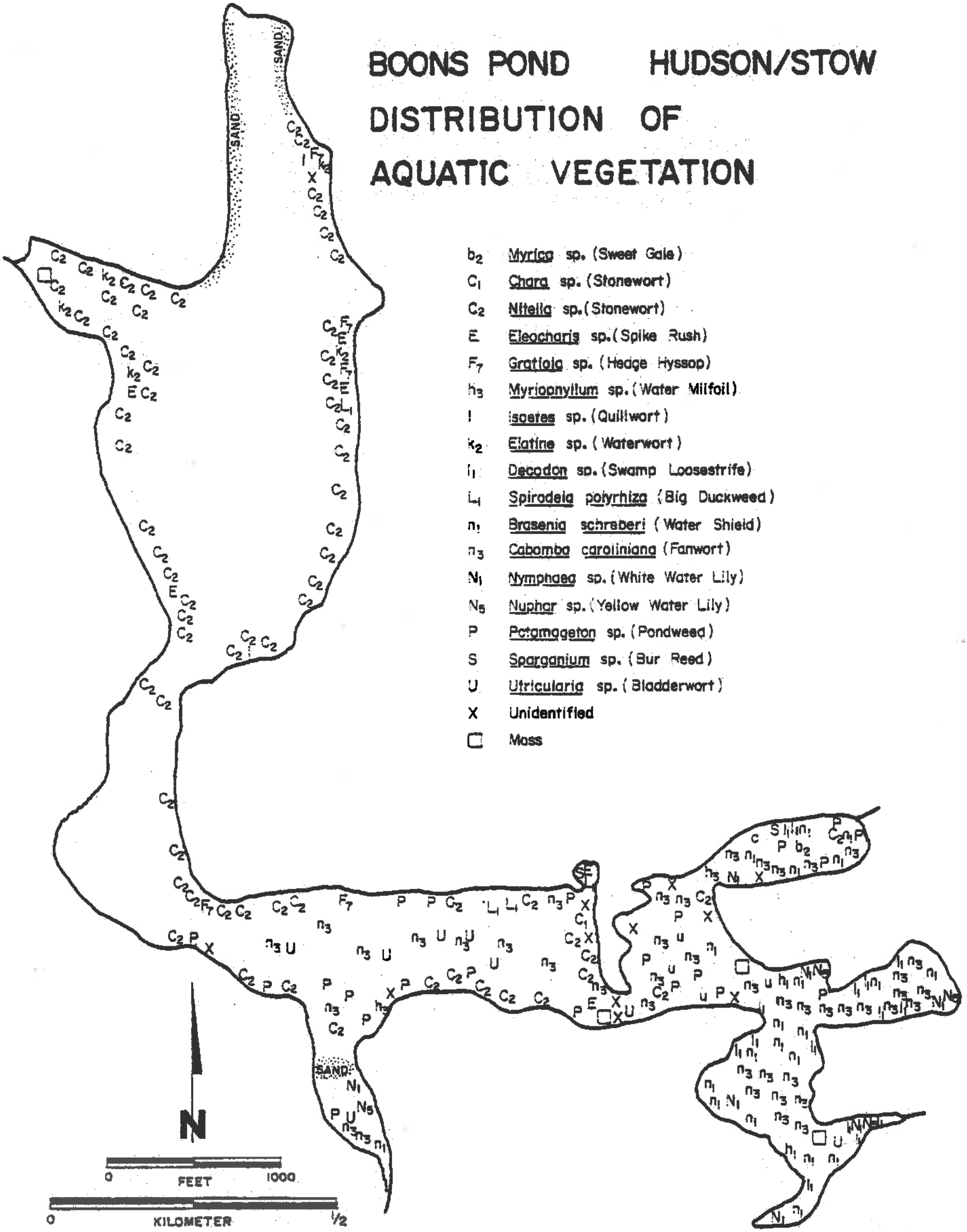

BOONS POND HUDSON/STOW
DISTRIBUTION OF
AQUATIC VEGETATION
b2 Myrica sp. (Sweet Gale)
C1 Chara sp. (Stonewort)
C2 Nitella sp. (Stonewort)
E Eleocharis sp. (Spike Rush)
F7 Gratiola sp. (Hedge Hyssop)
h3 Myriophyllum sp. (Water Milfoil)
I Isoetes sp. (Quillwort)
k2 Elatine sp. (Waterwort)
l1 Decodon sp. (Swamp Loosestrife)
L1 Spirodela polyrhiza (Big Duckweed)
n1 Brasenia schreberi (Water Shield)
n3 Cabomba caroliniana (Fanwort)
N1 Nymphaea sp. (White Water Lily)
N5 Nuphar sp. (Yellow Water Lily)
P Potamogeton sp. (Pondweed)
S Sparganium sp. (Bur Reed)
U Utricularia sp. (Bladderwort)
X Unidentified
Moss
SAND
N
0 FEET 1000
0 KILOMETER 1/2

FIGURE 12

Chlorophyll a values of 7.92 mg/m^3 and 7.47 mg/m^3 are indicative of a mesotrophic system (Weber 1974). A range of 0 to 3 mg/m^3 for the chlorophyll a parameter is indicative of an oligotrophic system.

Microscopic examination of water samples collected from Boons Pond are presented in Table 26 and Table 27. On 24 April 1979 the dominant phytoplankton at Station 2 were the diatoms. They require silica for frustule formation and thus deplete the supply of silica from the water column (Table 25). At Station 1 the flagellates were the dominant population. Chlamydomonas sp. and Uroglenopsis sp. were responsible for the flagellate dominance at Station 1. They produce a fishy odor when present in large numbers (Palmer, 1977).

On 6 June 1979 the flagellates were dominant at both Station 1 and Station 2. Mallomonas sp. was present at both sites and is commonly found in lake water (Palmer, 1977).

On 17 July 1979 the bluegreens were dominant at Station 2. At Station 1 there was an observed dominance of both bluegreens and greens. There was abundant diversity of species in both groups.

By 8 August 1977 the bluegreens were the dominant group at both Station 1 and Station 2. Oscillatoria sp. outnumbered the other species. This organism present in abundant numbers produces a musky odor, water coloration, and slime.

Silica concentrations increased throughout the lake in the late summer, allowing the diatoms to gain dominance in the fall at both Station 2 and Station 1. Tabelleria sp. was present in these samples, and when abundant, can result in a fishy odor.

The following spring, at Station 1, the diatoms and greens were competing for summer dominance. The flagellates were dominant at Station 2 with Uroglenopsis sp. present in large numbers.

Macrophytes

The dense aquatic weed growth in Boons Pond is the most serious symptom of lake pollution (Figure 12). Cabomba caroliniana (fanwort) is frequently found in ponds in Massachusetts. It is generally rooted in water one to three meters deep, but may continue to grow after it breaks away from the anchorage. The third basin of the lake is completely choked with this species. The weed is beginning to move out into the second basin. Associated with the fanwort growth is water shield, yellow water lily, white water lily, and pondweed. Decondon sp. (swamp loosestrife) is common in the wetland areas, the "stumps", adjacent to the third basin. Sparganium sp. (bur reed) is also present in the southern cove shore area.

In the first basin the dominant species is Nitella sp. which is actually an alga which grows among flowering plants. In Boons Pond, they attain a height of one foot or more, grow attached to the sediments, but have no roots.

TABLE 24

BOONS POND

CHLOROPHYLL a (mg/m^3)

DATE	STATION 1	STATION 2
4/24/79	1.22	2.98
6/6/79	4.57	4.15
7/17/79	7.92	7.47
8/8/79	7.06	8.30
11/19/79	5.81	4.15
5/7/80	1.49	2.08

TABLE 25

SILICA (mg/l)

BOONS POND

STATION	DEPTH (ft.)	SILICA (mg/l)
	4/24/79	
1	Surface	1.7
1	20	1.0
2	Surface	1.0
3	Surface	5.8
4	Surface	6.6
5	Surface	1.0
	6/6/79	
1	5	0.0
1	10	0.0
1	20	0.1
2	5	0.0
2	10	1.5
4	Surface	10.0
5	Surface	0.1
	7/7/79	
1	10	-
1	20	0.5
2	Surface	0.4
2	10	0.5
3	Surface	5.1
4	Surface	10.0
6	Surface	9.4
	8/8/79	
1	Surface	4.2
1	20	2.5
2	Surface	1.8
2	9	2.7
5	Surface	2.8

TABLE 26

BOONS POND

MICROSCOPIC EXAMINATION (cells/ml)

STATION 1

GENERA	1979					1980
DIATOMS	4/24	6/6	7/17	8/8	11/19	5/7
Cyclotella	343	--	29	57	--	266
Centronella	--	114	--	--	--	--
Stephanodiscus	--	--	29	--	--	198
Unknown Centric	--	--	143	--	--	--
Asterionella	372	--	57	--	29	14
Synedra	57	86	29	86	29	--
Unknown Pennate	29	14	--	--	---	--
Navicula	--	--	86	--	--	14
Cymbella	--	--	29	--	--	--
Fragilaria	--	--	--	86	--	--
Tabellaria	--	--	--	--	1,401	--
SUBTOTAL	801	214	402	229	1,459	492
BLUE-GREEN						
Chroococcus	229	--	--	--	--	--
Anacystis	--	29	--	--	--	--
Microcystis	--	--	686	--	--	--
Coelosphaerium	--	--	57	29	--	--
Chroococcus	--	--	915	429	--	--
Aphanocapsa	--	--	143	--	--	--
Gleocapsa	--	--	200	--	--	--
Gomphosphaeria	--	--	57	--	--	--
Nostoc	--	--	29	343	--	--
Aulosira	--	--	343	--	--	--
Gleocystis	--	--	29	--	--	--
Golenkinia	--	--	29	--	--	--
Oscillatoria	--	--	--	5,661	--	--
Spirulina	--	--	--	86	--	--
Nodularia	--	--	--	86	--	--
Anabaena	--	--	--	29	--	--
SUBTOTAL	229	29	2,488	6,663	0	0

TABLE 26 (CONTINUED)

GENERA	1979 4/24	1979 6/6	1979 7/17	1979 8/8	1979 11/19	1980 5/7
GREEN						
Kirchneriella	200	--	--	--	--	--
Sphaerocystis	--	29	--	114	29	--
Unidentified	--	200	--	--	--	--
Chlorella	--	--	114	--	--	--
Elakatothrix	--	--	29	--	--	--
Sphaerocystis	--	--	801	--	--	--
Oocystis	--	--	172	29	--	--
Chlorococcum	--	--	486	--	--	--
Unidentified	--	--	515	--	--	560
Scenedesmus	--	--	114	--	--	--
Cosmarium	--	--	29	--	--	--
Pediastrum	--	--	57	--	--	--
Arthrodesmus	--	--	172	29	--	--
Crucigenia	--	--	114	--	--	--
Staurastrum	--	--	29	--	--	--
Closterium	--	--	--	29	29	--
Ankistrodesmus	--	--	--	29	--	--
SUBTOTAL	200	229	2,632	230	58	560
FLAGELLATES						
Chlamydomonas	229	--	--	--	--	--
Volvox	86	--	--	--	--	--
Unidentified	601	429	--	--	--	--
Mallomonas	172	114	29	--	--	--
Uroglenopsis	372	--	29	--	200	--
Dinobyron	29	--	--	--	--	--
Gymnodinium	57	--	--	--	--	--
Pandorina	--	--	57	--	--	--
Unidentified	--	--	57	--	143	--
Pyrobutry	--	--	57	--	--	--
Chlorangium	--	--	--	--	29	--
SUBTOTAL	1,546	543	229	0	372	0
TOTAL	2,776	1,015	5,751	7,122	1,889	1,052

TABLE 27

BOONS POND

MICROSCOPIC EXAMINATION (cells/ml)

STATION 2

GENERA	1979					1980
DIATOMS	4/24	6/6	7/17	8/8	11/19	5/7
Cyclotella	157	--	--	--	--	112
Asterionella	57	--	114	--	114	84
Navicula	57	--	--	--	--	--
Fragilaria	29	--	--	29	--	--
Synedra	57	29	--	229	--	--
Unknown	--	114	57	--	--	--
Stephanodiscus	--	--	57	--	--	--
Cyclotella	--	--	200	--	--	225
Cocconeis	--	--	--	29	--	--
Merismopedia	--	--	--	57	--	--
Nitzschia	--	--	--	29	--	--
Tabellaria	--	--	--	--	543	--
SUBTOTAL	357	143	428	373	657	421
BLUE-GREEN						
Coelosphaerum	--	--	29	172	29	--
Unidentified	14	286	--	172	--	--
Anabeniopsis	--	57	--	--	--	--
Chroococcus	--	--	715	458	--	--
Microcystis	--	--	543	257	--	--
Aphanocapsa	--	--	114	--	--	--
Nostoc	--	--	14	372	--	--
Anabaena	--	--	29	--	--	--
Aulosira	--	--	743	--	--	--
Oscillatoria	--	--	--	3,861	--	--
Calothrix	--	--	--	372	--	--
Cylindrosperum	--	--	--	29	--	--
Spirulina	--	--	--	114	--	--
SUBTOTAL	14	343	2,187	5,807	29	0

TABLE 27 (CONTINUED)

GENERA	1979 4/24	1979 6/6	1979 7/17	1979 8/8	1979 11/19	1980 5/7
GREEN						
Kirchneriella	114	—	—	—	—	—
Unidentified	29	200	229	—	—	—
Arthrodesmus	14	—	—	—	—	—
Sphaerocystis	—	315	257	—	—	—
Scenedesmus	—	29	—	—	—	—
Closterum	—	29	—	—	—	—
Elakatothrix	—	—	29	—	—	—
Gloeocystis	—	—	14	—	—	225
Chlorella	—	—	57	—	—	—
Scenedesmus	—	—	29	—	—	—
Sphaerocystis	—	—	—	29	—	—
Oocystis	—	—	—	86	—	—
Unknown	—	—	—	29	—	—
SUBTOTAL	157	573	615	144	0	225
FLAGELLATES						
Unidentified	86	543	—	—	—	57
Gymnodinium	14	—	—	—	—	—
Mallomonas	29	486	—	114	29	—
Synura	29	—	—	—	—	—
Dinobryon	—	57	—	—	—	—
Peridinium	—	29	—	—	—	—
Hematococcus	—	—	29	—	—	—
Lepocinclis	—	—	—	57	—	—
Uroglenopsis	—	—	—	—	29	1,144
Pyrobotrys	—	—	—	—	—	28
Cryptomonas	—	—	—	—	—	143
SUBTOTAL	158	1,115	29	171	58	1,372
TOTAL	686	2,174	3,259	6,495	744	2,018

Mats of these are found in the first, second and third basin associated with the small aquatic waterwort, pondweed, and bladderwort. A potential pest present in the pond is *Myriophyllum* sp. (milfoil). Given the proper conditions this plant could colonize the cove areas and suitable shore areas in a few years.

Fish Populations

The lake was first stocked in 1912 by the Division of Fisheries and Wildlife with 750,000 white perch. Since then, it has been stocked periodically with such fish as smallmouth black bass, horned pout, pickerel, bluegills, yellow perch, crappie, and white perch. The lake is recognized as a bass and pickerel pond by the Division of Fisheries and Wildlife. Its last stocking took place in 1955 as part of a reclamation project (MDFW 1980). On July 16, 1955 approximately 60 acres were treated with rotenone. Over 10,700 pounds of fish were killed. About 70 percent were bluegills while game fish amounted to about five percent. In August and September of the same year the lake was stocked with 2,800 two to seven-inch largemouth bass. There is no record of fish management at Boons Pond since the 1950s.

Sediments

Grab samples of bottom sediments from Station 1 and Station 2 were collected on 18 June 1980 (Table 28). Observed values fell within the range of values for other Massachusetts lakes. The sediments throughout the lake were a rich organic mud.

TABLE 28

BOONS POND, SEDIMENT SAMPLES, CHEMICAL ANALYSES (mg/kg)

18 June 1980

PARAMETER	STATION 1	STATION 2	RANGE OF VALUES FOR OTHER MASSACHUSETTS LAKES*
Manganese	620	640	118-3,100
Iron	42,000	14,000	3,500-88,200
Chromium	27	19	4.7-65
Copper	56	5	36-130
Lead	330	320	116-720
Zinc	240	350	143-570
Cadmium	2	4	0-4.9
Arsenic	9.3	10.0	0.7-26

*The lakes included in this range of values were: Fort Pond, Indian Lake, Lake Mattawa, Pontoosuc Lake, Waushakum Pond, White Island Pond, and Lake Winthrop. Lake Winthrop, Fort Pond, Indian Lake were not included in the range of copper concentrations because of copper sulfate treatment. Data for arsenic concentrations were only available for White Island Pond, Fort Pond, and Lake Winthrop.

Sanitary Survey

A septic snooper survey was conducted on 7-9 August 1979 by Environmental Devices Corporation, Marion, Mass. Septic leachate plume locations were identified by an increase in the specific conductance parameter or an increase in the fluoresence parameter, or both (Figure 13). Chemical and bacteriological data were collected at plume locations to further qualify the plumes (Table 29). The chemical data from the sampling plume locations marked with an asterisk have high total Kjeldahl-nitrogen and total phosphorus values. Those sample sites marked with a question mark have high nutrient values, but may be contaminated by bottom sediments. Sample sites C-3, D-1, P-2 showed high total fecal coliform values. Values observed at Station 1 and Station 2 on 8 August 1979 are presented for comparison purposes.

Seepage Meters

Chemical samples were collected and flow measurements were made using seepage meters placed in Boons Pond on 15 July 1980. Each of the eleven sample stations (C-1, C-3, D-1, F-1, I-1, M-1, P-1, P-2, Q-2, Q-6, and U-1) were located in the area of an identified septic snooper plume (Figure 13).

The chemical data obtained (Appendix E) could not be used to quantify nutrient input because of incomplete flushing of the sampling devices by the groundwater.

The average observed groundwater flow into the lake at the eleven sample stations on 15 July 1980 was 1.3×10^{-7} $m^3/m^2/sec$. The estimated area for groundwater flow in the lake basin was $172 \times 10^3 m^2$ ($1{,}851 \times 10^3$ ft^2). This estimate was based on the assumption that groundwater flow occurs between the lake shore and the 1.5 m (5 ft.) contour. The calculated groundwater flow into the lake basin was 0.02 m^3/sec (0.7 cfs). At this time, none of the inlets exhibited flow, although flow was occurring at the outlet. Data obtained from USGS for this month estimated the average discharge from Boons Pond at 0.02 m^3/sec (0.7 cfs).

These measurements indicate that groundwater continues to flow to the lake in the summer months when the inlets are not flowing.

Water Budget

Two methods were used to calculate the discharge at the Boons Pond outlet, a desk top model (Carter 1964) based on precipitation falling into the watershed, and an area discharge relationship model based on USGS flow measurements. Precipitation data was obtained for local Gates Pond, Berlin, Mass. (Table 1). USGS data was obtained from the gaging station on the Assabet River at Maynard (Station number 01097000). The average annual outlet discharge values determined by the models were reasonably comparable (Table 30). However, the Carter model did not show a true

BOONS POND
LOCATION OF SAMPLING STATIONS
SEPTIC SNOOPER SURVEY
SEEPAGE METERS

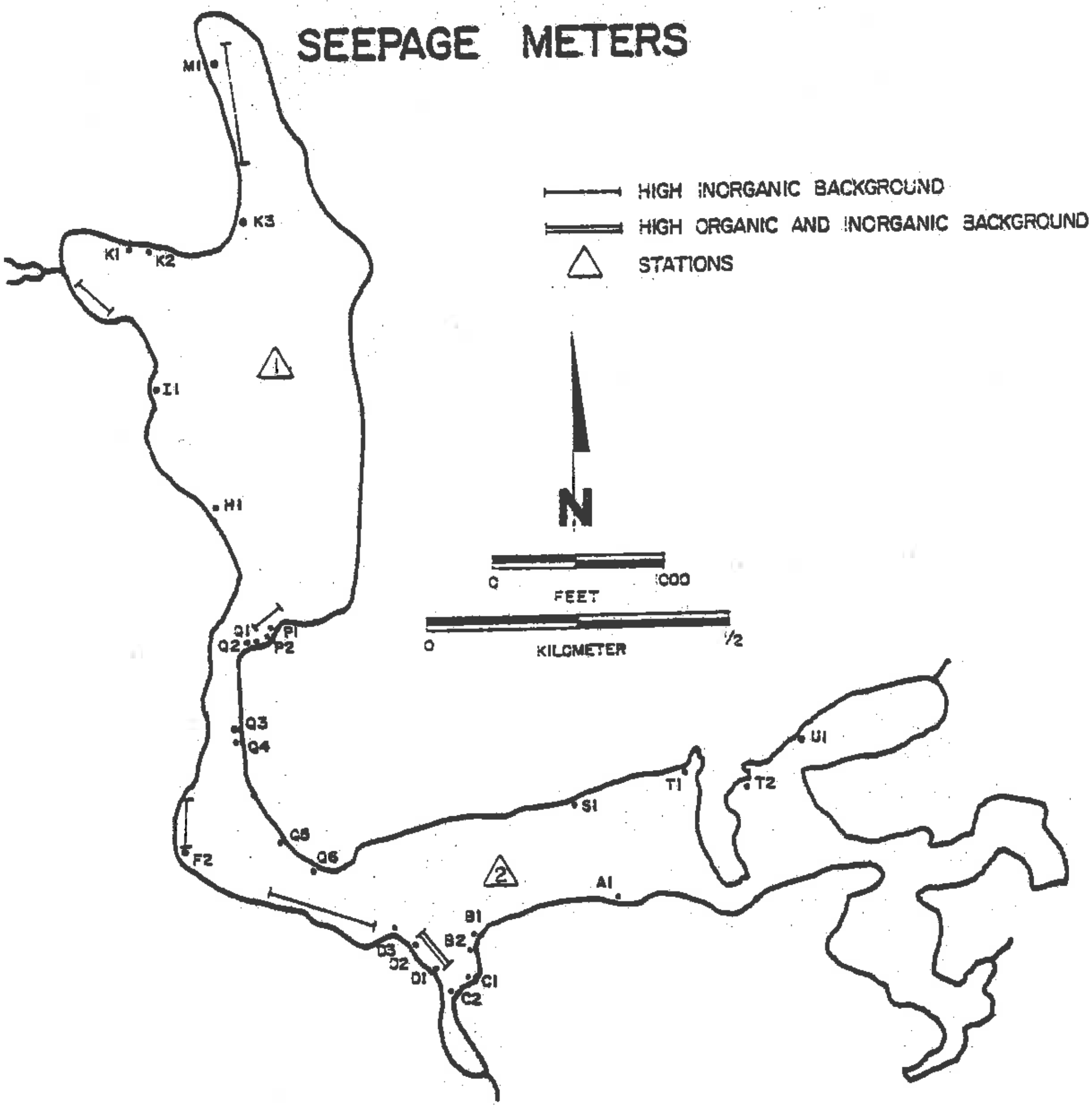


FIGURE 13

TABLE 29

BOONS POND

SEPTIC SNOOPER SURVEY DATA (mg/1)

(all values in mg/1, conductivity, μmhos/cm, coliform cells/100 ml)

8/7/79

STATIONS	A-1(?)	B-1	B-2	C-1	C-2	C-3(?)	D-1(?)	D-2(?)	D-3	F-1
PARAMETERS										
Suspended Solids	49	12	15	10	35	0.0	17	1.0	0.0	0.0
Total Solids	72	70	60	70	72	78	66	74	64	78
Total Kjeldahl-Nitrogen	1.3	0.98	0.86	0.65	0.72	1.6	1.2	1.2	0.75	0.51
Ammonia-Nitrogen	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Nitrate-Nitrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Phosphorus	0.09	0.03	0.03	0.02	0.07	0.14	0.10	0.16	0.04	0.03
Conductivity (μmhos/cm)	110	100	100	100	100	100	100	140	100	100
Chloride	20	20	20	22	21	22	23	10	20	20
Total Coliform/100 ml	40	200	300	200	20	600	800	140	80	140
Fecal Coliform/100 ml	10	10	20	<10	10	350	600	10	<10	20
Elevated	C	F+C	F+C	F	C+F	C+F	C+F	C+F	F	F+C

*High nutrient values
F - Fluorescence
C - Specific Conductance
? - High nutrient values, possible contamination

TABLE 29 (CONTINUED)

STATIONS	8/7/79 H-1	I-1(?)	K-1	K-2	8/8/79 K-3	M-1(?)	P-1*	P-2*	Q-1(?)	8/9/79 Q-2(?)
PARAMETERS										
Suspended Solids	1.0	1.5	4.5	2.5	0.5	3	11.5	5	0	0.0
Total Solids	86	150	82	96	80	130	516	1,038	70	352
Total Kjeldahl-Nitrogen	0.86	1.8	0.80	0.94	0.98	1.7	2.3	3.2	1.1	1.3
Ammonia-Nitrogen	0.00	0.05	0.12	0.25	0.10	0.08	0.11	0.05	0.13	0.01
Nitrate-Nitrogen	0.0	0.2	0.0	0.0	0.0	0.2	0.9	0.2	0.0	0.0
Total Phosphorus	0.05	0.20	0.11	0.10	0.08	0.17	0.38	0.64	0.07	0.08
Conductivity (µmhos/cm)	100	105	100	100	100	100	105	100	100	98
Chloride	20	--	--	--	--	--	--	21	21	20
Total Coliform/100 ml	120	200	180	120	60	240	200	800	180	600
Fecal Coliform/100 ml	10	20	10	20	<10	10	40	120	10	80
Elevated	C+F	C+F	C+F	C+F	C+F	F	C+F	C+F	C+F	C+F

STATIONS	Q-3	Q-4	Q-5	8/9/79 Q-6	S-1	T-1	U-1*	8/8/79 1-Surface	2 Surface
PARAMETERS									
Suspended Solids	3.5	0.0	1.5	1.5	0.0	2.0	6.5	1.0	0.0
Total Solids	142	80	76	86	76	70	244	70	82
Total Kjeldahl-Nitrogen	0.79	0.81	0.58	0.73	0.82	0.56	2.82	0.87	0.65
Ammonia-Nitrogen	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.12	0.09
Nitrate-Nitrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Total Phosphorus	0.05	0.06	0.06	0.10	0.08	0.06	0.46	0.04	0.03
Conductivity (µmhos)	98	100	105	100	100	100	100	100	100
Chloride	20	22	21	21	21	21	21	21	21
Total Coliform/100 ml	440	120	280	140	80	100	40	10	10
Fecal Coliform/100 ml	10	10	10	110	20	40	40	<5	<10
Elevated	C+F	C+F	C+F	C+F	C+F	C+F	C+F		

TABLE 30

BOONS POND

DISCHARGE FROM OUTLET

DATE	USGS DATA Average Monthly Flow* m^3/sec	CARTER MODEL Average Monthly Flow** m^3/sec
July 1979	0.037	0.0
August 1979	0.059	0.0
September 1979	0.065	0.0
October 1979	0.118	0.0
November 1979	0.148	0.180
December 1979	0.097	0.080
January 1980	0.028	0.044
February 1980	0.042	0.067
March 1980	0.180	0.325
April 1980	0.255	0.218
May 1980	0.166	0.0
June 1980	0.060	0.0
Average Annual Discharge	0.104 (3.7 cfs)	0.076 (2.7 cfs)

* Calculated for total watershed area based on average monthly flows measured at the USGS gage on the Assabet River at Maynard. Means supplied for October 1979 to June 1980 are provisional until reviewed and published by USGS (Station Number 01097000).

**Calculated based on Carter D. (1964). Basic Data and Water Budget Computation. The Earth Science Curriculum Project Reference Series, RS-8, and precipitation data from Gates Pond, Berlin, Massachusetts.

picture of seasonal flow. When the Carter model predicted no flow there was observed flow at the outlet. This discrepancy results from the assumed soil storage factor in the model. Based on the calculated annual average discharge at the outlet the retention time for Boons Pond is between 0.6 years to 0.8 years.

The water budget for Boons Pond presented in Table 31 defines the inputs and discharges of water volume. Average annual discharges to the lake from the subdrainage basins depicted in Figure 9 were calculated by the area discharge relationship model based on USGS flow data obtained on the Assabet River at Maynard, Massachusetts. It is assumed that the calculated average annual discharges to the lake from the subdrainage basins includes both groundwater flow and overland runoff.

TABLE 31

BOONS POND

WATER BUDGET

SOURCE	Average Annual Discharge M^3/sec	CFS
Subdrainage Basin #3	0.019	0.67
Subdrainage Basin #4	0.018	0.64
Subdrainage Basin #6	0.022	0.78
Subdrainage Basin #7	0.037	1.31
Precipitation to Lake Surface	0.022	0.78
Potential Evapotranspiration from Lake Surface	0.015	0.53
Boons Pond Outlet	0.104	3.7

Instantaneous discharge measurements made in the field for subdrainage Basin 4 and the outlet were used to verify calculated discharge values (Table 32).

TABLE 32

BOONS POND

INSTANTANEOUS DISCHARGE MEASUREMENTS

STATION	DATE	INSTANTANEOUS DISCHARGE FIELD MEASUREMENTS	CALCULATED DISCHARGE USGS DATA
Station 5 Outlet	20 May 1980	0.12 m^3/sec (4.2 cfs)	0.14 m^3/sec (4.9 cfs)
	18 June 1880	0.02 m^3/sec (0.7 cfs)	0.05 m^3/sec (1.7 cfs)
Station 4A Inlet	20 May 1980	0.017 m^3/sec (0.60 cfs)	0.022 m^3/sec (0.78 cfs)
	18 June 1980	0.002 m^3/sec (0.07 cfs)	0.008 m^3/sec (0.28 cfs)

Nutrient Budget

The nutrient budgets for Boons Pond (Tables 33 & 34) estimate the loading of phosphorus and nitrogen to the lake from diffuse sources within the watershed (see Appendix F for calculation and assumptions).

Calculated lake loading of total phosphorus based on land use types was 105-759 kg/yr. Observed lake loading was 198 kg/yr. Calculated lake loading of total nitrogen based on land use types was 2,026-4,233 kg/yr. Total observed lake loading of total nitrogen was 2,988 kg/yr. The observed loading may be underestimated because of the lack of adequate data on average annual nutrient concentrations in groundwater and annual groundwater flow rates.

Investigators have modeled the permissible loading of phosphorus to a lake to maintain a system of low productivity/low nutrients. For Boons Pond the estimated permissible loading of total phosphorus is 66 kg/yr (Vollenweider 1975) and/or 122 kg/yr (Dillon and Rigler 1975). Comparison of the permissible loading of phosphorus to the calculated loading (212 kg/yr) shows that reduced phosphorus loading to the lake would have to be accomplished to decrease lake productivity.

Examining the ranges of loading from the different land uses in the subdrainage basins, from precipitation onto the lake surface, and from nearshore septic systems one can assess the relative importance of the nonpoint source contributions. Specifically, reduction in the loading of nutrients from intensive agriculture and open waters does not currently need to be undertaken. Loading of nutrients from precipitation, forestland, and wetlands are uncontrollable and considered part of the natural background input. Runoff of nutrients from residential land and loading of nutrients from nearshore septic systems require control. These nonpoint sources will be difficult to control if control is defined as the ability to establish and enforce effluent standards. However, if the control is approached by using appropriate management practices, the sources will be reduced.

Lake Trophic Status

Boons Pond is characterized as a mesotrophic to eutrophic lake (12 severity points out of a possible 18) using the lakes classification system developed by the Commonwealth of Massachusetts Division of Water Pollution Control (1979) (Appendix G). Summer dissolved oxygen depletion near the bottom sediments contributed three severity points. Macrophyte growth and phytoplankton populations contributed two and three severity points, respectively. Limited Secchi disc transparency contributed two severity points. Nutrient concentrations contributed two severity points.

TABLE 33

BOONS POND

TOTAL NITROGEN BUDGET (kg/yr)

	Estimated Loading From Non-Point Sources						Observed Loading From Field Data
	FORESTLAND	RESIDENTIAL LAND	INTENSIVE AGRICULTURE	WETLANDS	OPEN WATERS	TOTAL	TOTAL
Subdrainage Basin #3	13-76	126	-	0	101-109	240-311	869
Subdrainage Basin #4	151-908	136	153	-	-	440-1197	516
Subdrainage Basin #6	20-119	21	-	-	-	41-140	541
Subdrainage Basin #7	255-1535	840	210	0	-	1305-2585	1062
Lake Loading	439-2638	1123	363	0	101-109	2026-4233	2988
Precipitation to Lake Surface	-	-	-	-	832-901	832-901	832-901*
Estimated Loading From Near Shore Septic Leachates	-	0-1047	-	-	-	0-1047	
Total Input to Lake	439-2638	1123-2170	363	0	933-1010	2858-6181	3820
Total Discharge at Outlet	-	-	-	-	-	-	2197

*Calculated value used because no field data available

TABLE 34

BOONS POND

TOTAL PHOSPHORUS BUDGET (kg/yr)

	Estimated Loading From Non-Point Sources						Observed Loading From Field Data
	FORESTLAND	RESIDENTIAL LAND	INTENSIVE AGRICULTURE	WETLANDS	OPEN WATERS	TOTAL	TOTAL
Subdrainage Basin #3	5-51	8-46	-	0	2-3	15-100	60
Subdrainage Basin #4	9-56	9-50	0-27	-	-	18-133	34
Subdrainage Basin #6	7-76	1-8	-	-	-	8-84	35
Subdrainage Basin #7	8-94	56-308	0-40	0	-	64-442	69
Lake Loading	29-277	74-412	0-67	0	2-3	105-759	198
Precipitation to Lake Surface	-	-	-	-	14	14	14*
Estimated Loading from Neashore Septic Leachates	-	0-123	-	-	-	0-123	-
Total Input to Lake	29-277	74-535	0-67	0	16-17	119-896	212
Total Discharge at Outlet	-	-	-	-	-	-	162

*Calculated value used because no field data available

CONCLUSIONS

Lake

1. Boons Pond is characterized as a shallow, softwater, weakly buffered, mesotrophic to eutrophic lake. The trophic state indicates a highly productive and nutrient rich system.

2. The first basin of Boons Pond is thermally stratified during the summer months resulting in oxygen reduction at the bottom. However, there was no nutrient loading of phosphorus from the sediments as a result of this stratification.

3. The transparency of the lake decreased to near the minimum visibility required by the Massachusetts Department of Public Health (1966) for swimming at public beaches during August, a time of heavy motor boat use and high productivity.

4. On 17 July 1979 fecal coliform bacteria levels exceeded state water quality standards for water designated for primary and secondary contact.

5. Summer phytoplankton populations were of moderate productivity and high diversity. These populations would present a problem in terms of visibility and odor if their productivity were to increase.

6. Dense growth of the aquatic plant *Cabomba caroliniana* (fanwort) represents a severe problem restricting the recreational use of the lake. These are aquatic perennials rooted in the sediments of the pond.

Watershed

1. The calculated loading of phosphorus to the lake (212 kg/yr) exceeds the recommended rate of lake loading (122 kg/yr). A high influx of nutrients from the watershed to Boons Pond results in a nutrient rich system of high productivity.

2. Runoff of nutrients from residential land and loading of nutrients from septic systems are the two controllable sources of nutrients to the lake. Loading of total phosphorus from residential land contributes from 74-412 kg/yr. Loading of total phosphorus from septic tank leachate contributes from 0-123 kg/yr.

3. The results of the sanitary survey pinpointed the locations of some of the septic leachate plumes. Sampling at these sites showed nutrient concentrations elevated over in-lake values.

4. In general the sandy, gravelly soils in the Boons Pond watershed show severe limitation for septic system use and very low to medium potential use because of poor filter capacity.

5. Pressure for new housing and locations for industry siting continue to mount in the watershed. Currently, 71% of the watershed is forested and susceptible to future development. Seasonal cottages surrounding the lake are continually being converted to year-round residences. These uses present potential nutrient loading problems for the lake from runoff and septic system leachate.

GENERAL RECOMMENDATIONS

The Boons Pond diagnostic/feasibility study was undertaken by the Commonwealth of Massachusetts Division of Water Pollution Control at the request of the Metropolitan Area Planning Agency, town officials in Hudson and Stow, the Lake Boon Association and concerned citizens. Now, it is up to you to implement the recommendations of this report and to develop an effective watershed and lake management program.

In lake management it is difficult to pinpoint one parameter as the causative agent in promoting lake eutrophication. The best possible approach for the restoration and preservation of the water quality of Boons Pond is to control the identified sources of nutrients to the lake from the watershed. This should result in decreased nutrient content of the water, thus limiting algae density. The effect of limited loading of nutrients from the watershed on the aquatic weed population is impossible to predict. The lake is suited for aquatic weed growth because of the shallowness of the lake and the nature of the sediment. The second basin, third basin, and "stumps" area are actually a flooded meadow. The best possible control of weed growth can be accomplished by removal of the weeds or by habitat alterations.

The alternatives to be considered to implement the above recommendations are discussed in the following section, Feasibility of Restoration/Preservation.

FEASIBILITY OF RESTORATION/PRESERVATION

Introduction

The alternatives to be considered for Boons Pond restoration/preservation can be defined as watershed techniques or in-lake techniques. Watershed techniques address the current and future problem of nutrient loading from groundwater and overland runoff. In-lake techniques address the current aquatic weed problem. An effective restoration/preservation program for the pond must encompass a combination of both approaches. Table 35 lists various alternatives considered for a lake restoration/preservation effort, and identifies those which will be considered for Boons Pond. Each option was reviewed to define the viability of a given alternative considering the implementation constraints and anticipated effectiveness in the Boons Pond Watershed. At the end of the discussion there is a listing of those alternatives which the Division recommends that the towns and residents of the watershed implement.

Alternative Watershed Preservation Techniques

"Lake Theme" Watershed Development Plan

Although some would like to turn the clock back so that the watershed maintained the characteristics of the 1920s. Future demand for housing will pressure much of the land in the Boons Pond watershed into residential use and small store commercial activity. High density development will result in increased pollutant runoff and septage disposal problems.

To protect the area a development plan should be drawn up by an engineering firm or by the planning boards with the main focus on the lake and recreational potential. Lake access areas could be improved to increase use of the lake by those not living on the lake shore. Signs indicating entrance to the Boons Pond Watershed could be placed on roads crossing the boundary. Shopping area design could be aesthetically pleasing. Nature walkways could be developed in wetland areas.

Alternatively, increasing minimum lot size would control residential development without a master plan. Stow presently requires a minimum lot size of one and one-half acres. Hudson could rezone their land-area to also require a minimum lot size of one and one-half acres.

Cost for the above involves either hiring a consultant to draw up a master "lake theme" plan or revamp zoning ordinances, at an approximate rate of $4,000 to $8,000. Cost for the master plan would be increased by construction work on the park theme. To decrease expected costs the town

TABLE 35.

BOONS POND

PROPOSED LAKE RESTORATION TECHNIQUES

	ESTIMATED COST[1]	CONSIDERED FOR BOONS POND
WATERSHED TECHNIQUES		
Non-Structural		
Lake Theme Watershed Development Plan	\$4,000-\$8,000	X
Establish Watershed Protection District	\$4,000-\$8,000	X
Protect Wetland Areas from Development by Purchasing	---	-
Watershed Road Sweeping Program	\$1.25/capita/day[3]	X
Establish Septic Tank Maintenance and Inspection Program	\$50,250/year	X
Regulate Conversion of Seasonal Homes	\$500	X
Establish and Conduct a Public Awareness Program	\$29,000	X
Watershed Housekeeping Practices	minimum cost	X
Structural		
Stormwater Management	---	-
ON-SITE SEWAGE DISPOSAL		
Engineering Design of Units for Watershed	\$20,000-\$50,000	X
Reduce Wastewater Flow	minimum cost	X
Composting Toilets	\$750-1,200[2]	X
Digesting Toilets	\$250-\$750[2]	X
Recirculating Systems	\$300[2]	
Incinerator Toilet	\$350-\$850[2]	X
Aerobic Systems	\$3,000[2]	X
Chemical Toilets	\$200[2]	X
Sliding Valve Toilets	\$125-\$200[2]	X
Grey Water Disposal by Septic Tank/Leach Field	\$750-\$1,200[2]	X

TABLE 35 (CONTINUED)

	ESTIMATED COST[1]	CONSIDERED FOR BOONS POND
ON-SITE SEWAGE DISPOSAL (continued)		
Grey Water Disposal by Storage for Central Treatment	\$1,000[2]	X
Holding Tank	\$3,000-\$5,000[2]	X
Conventional Septic Tank - Soil Absorption System	\$1,000-\$2,500[2]	X
Mound Systems	\$3,000-\$7,500[2]	X
Sewage Collection and Conventional Central Treatment for for Hudson Watershed Area	---	-
IN-LAKE TECHNIQUES		
Non-Structural		
Power Boat Restrictions	minimal	X
Biological Control	---	-
Structural		
Herbicides and Algicide	---	-
Nutrient Inactivation	---	-
Hypolimnetic Aeration and Artificial Destratification	---	-
Dilution	---	-
Bottom Screening	\$495,055	X
Harvesting	\$57,000	X
Hydraulic Dredging	\$381,900	X
Diver Operated Suction Dredge	\$136,975	X
Drawdown	engineering design and construction of new outlet	X
Dry Dredging	drawdown cost and minimum \$1,000,000	X

[1]Estimated costs were taken from EPA 1977 and MAPC 1977. For operation and maintenance costs see discussion

[2]Cost per system

[3]Included in town DPW budget

could elect to establish an ad hoc committee to develop the "lake theme" plan or to suggest lot size requirements. The final plan would be reviewed by town council and passed through town meetings.

Establishing a Watershed Protection District

Establishing an overlay district will serve to preserve and protect Boons Pond from the detrimental use and development of the land and waters within the protection district. The definition of the district and permitted uses would be defined in a bylaw passed through town government processes. Stow has overlayed a flood plains/wetland district on a portion of the watershed adjacent to the lake. They should continue this in the remaining area adjacent to the lake. Hudson should overlay a watershed protection district on their portion of the watershed.

Cost to create a bylaw would include town government processes, gathering together of land use information supplied in this report and the MAPC report (1979), and production of overlay maps. Cost for a consultant to accomplish this task is $4,000 to $8,000. The town could elect to establish an ad hoc committe to develop the draft.

Protect Wetland Areas from Development

Wetlands function as important nutrient and sediment traps. Enforcing protecting laws and purchasing areas, can regulate activities involving filling, dredging or otherwise altering wetlands. The towns through the conservation commissions could purchase wetlands around Boons Pond, but the cost would be prohibitive (greater than $1,000 per acre). The town conservation commission can also regulate activities in wetland areas through the authority granted under the Commonwealth of Massachusetts Wetlands Protection Act (MGL C 133,S40).

Regulate Conversion of Seasonal Homes

Boons Pond has a high density development of lakefront cottages with greater than five dwelling units per acre. Many of these seasonal residences are being converted to year-round dwellings without conversion of their septic systems. The soils around the lake have poor filter capacity and are not suited for conventional septic tank/leach field system. The result is a short-circuiting of the septic leachate to the groundwater of the lake. The towns of Hudson and Stow can regulate these conversions through amendments to the zoning bylaw, or through Board of Health regulations. Hudson has recently adopted amendments to the protective zoning bylaws of the town which restrict conversion of non-conforming seasonal dwellings to year-round dwellings. The cost for this procedure involves hiring a consultant to draft the amendment ($500). The Metropolitan Area Planning Commission could perform this task at minimum cost, or the town could elect a committee to draw up the document.

Establish and Conduct a Public Awareness Program

This strategy would address the problems of nutrient runoff from the watershed and nutrient input from failing septic systems through public education. The success of the proposed program depends on the participation of the residents of the watershed. Residents in the watershed would be asked to change their life style to conform to "Watershed Housekeeping Practices." Residents would have to commit substantial funds to pay for new septage disposal systems and/or sewage hook-up with user charge. Posters, flyers, and pamphlets would be distributed to explain the restoration effort. Meetings would be held to explain the proposed program and to discuss septage disposal problems with individual homeowners. A slide program would be developed for use in public meetings and discussions with town officials. The approximate cost for preparation of public participation and educational materials would be $12,000 (Lycott Environmental Company 1979, Big Alum Pond Cost Allocation).

The man-power cost for technical experts and local officials to attend public informational meetings would be approximately $17,000 (Lycott Environmental Co., 1979, Big Alum Pond Cost Allocation). The cost to develop an educational slide show would vary depending on photographic supply cost.

Alternative Watershed Restoration Activities

Clean Road Maintenance Program

The towns could develop a comprehensive plan for street sweeping, catch basin cleaning, and road de-icing activities--this would help to control the runoff of pollutants to the lake. The plan could be developed by the street department of the towns and reviewed by the Lake Boon Association. The towns should consider updating their sweeping equipment. Sweepers available range in an approximate cost of $25,000 for a three-wheeled sweeper; $35,000 for a four-wheeled sweeper; and $60,000 for a vacuum type sweeper. The operation and maintenance costs for sweeping are estimated at about $1.25 per capita per year (Central Massachusetts Regional Planning Commission 1977).

Stormwater Management

Construction of filter dams or desilting basins downstream from large cleared areas and other sources of silt can trap sediment. The structures would not be necessary at Boons Pond because: 1) the inlets do not carry a heavy sediment load, and 2) it would be difficult to treat overland runoff throughout the watershed as a point source. However, if any construction were to take place in the watershed, the appropriate protective measures to control erosion should be implemented at the site.

Watershed Housekeeping Practices

The practices are to be carried out by the individuals living in the area. They are necessary to control nutrient runoff from residences within the watershed. These issues were discussed in the MAPC 1979, Lake Boon Summary Report. Included were recommendations to eliminate or reduce use of phosphate detergents, to optimize use of lawn fertilizers, to remove lawn clippings and dead leaves from the area, and to collect pet droppings for disposal. The cost to enact these practices would be minimal since compliance with these suggestions would be voluntary.

Establish Septic Tank Maintenance and Inspection Program

The leaching of nutrients to the groundwater from failing or inadequate septic systems in the Boons Pond Watershed is a controllable pollutant input. An inspection program on a house-to-house basis could be set up to provide accurate information on systems.

There is clear authority in Title 5 of the state enviromental code to carry out cleaning and repairing of septic systems. A municipal inspector team for each town would cost $50,250/year (MAPC 1979). Alternatively, the lake association could conduct the house-to-house survey and the towns could hire an engineering firm to supply the technical expertise. The investigation could begin at trouble spots indentified by the septic snooper study.

Hudson and Stow could adopt, through the Board of Health, a mandatory septic tank and maintenance program requiring registration and periodic inspection.

Engineering Design of Units for Watershed

The major lake restoration activity for the watershed is to correct failing or inadequate septic systems. Inadequate systems are providing nutrient-rich groundwaters to the lake and tributary areas. Choosing the most effective sewage disposal method for inadequate systems depends on public opinion, engineering design, and availability of funding. The towns could subcontract to an engineering firm to sit down with homeowners to advise them on which sewage disposal option would best suit their needs. The engineering design phase for the individual septic systems could run from $20,000 to $50,000.

Innovative/Alternative Methods for Subsurface Disposal of Sewage

Introduction

The following discussion list both various subsurface disposal systems and methods of modifying wastewater characteristics that could be recommended to correct individual problems. Various alternatives to the subsurface sewage disposal systems are now available commercially. They are essentially non-discharge units, which means no portable water is used to carry off the wastes. Use of these systems would eliminate the need for large septic tanks and reduce the size of the leach area needed.

Composting Toilets - This system, used extensively in Europe, relies on microorganisms to decompose toilet wastes and garbage within a sealed bin vented to the atmosphere. Additional organic wastes, from the garden and kitchen, improve the decomposition process. The heat of natural decomposition creates sufficient draft to prevent odors. The final product from these toilets is an inert humus material, requiring occasional removal.

A composting toilet can cost from $750 to $1,200. The variation in cost is due mainly to the accessories available to the system (MVPC 1979).

Digesting Toilets (Biological) - Digesting toilets are similar to composting units, but require less space. The units use electricity to heat waste for optimal biological decomposition by microorganisms. These produce a small amount of liquid effluent and small quantities of humus.

There are a wide variety of biological systems available. The cost can vary from $250 to $750, depending on the anticipated level of use (MVPC 1979). The monthly cost of electricity and microorganism cultures must be considered.

Recirculating Systems - The recycle system is a closed circuit wastewater treatment system that recirculates a low volume of clean water (or an oil transport fluid). Solids are settled or filtered from the transport fluid and stored in a holding tank which must be periodically pumped.

The cost of this system runs about $300. In addition, there are installation fees as well as professional maintenance costs (MVPC 1979).

Incinerator Toilet - Using electricity or gas, this system burns the solid waste and evaporates the liquid wastes, leaving a sterile ash. Some odor is given off from the smoke. The relatively high operating costs limits its applicability.

The cost range for this type of system is about $300-$850. The cost will vary depending on the complexity of the system and its degree of refinement. Operating costs are a consideration, due to the use of electric or gas power.

Aerobic Systems - Aerobic systems operate on the principle of an aerobic environment. These systems treat household sewage and greywater through aerobic digestion and filtration. The system has a number of moving parts which can result in increase operation and maintenance costs. Depending on the size, aerobic systems can cost up to $3,000.

Chemical Toilets - This system is easily installed, requires no running water or electricity. The waste is disposed of in a chemical solution.

Some odors are produced and the unit must be dumped, cleaned and refilled frequently. This system is usually used in isolated recreation areas and in isolated locations. The cost ranges from $50-$75 for a portable model. A permanent chemical recirculating toilet costs about $200.

Sliding Valve Toilets - These are low water use systems that can handle black water. Since only one pint of water is used for each flush, a family of five would use about 100 gallons per month with this system as compared to 4,500 gallons for a standard flush toilet. This toilet discharges into a holding tank, septic system or sewer system.

Costs range from $125-$200. Depending on the method of discharging from the toilet (holding tank or septic system) there will be maintenance costs for pumping.

There are pros and cons for each system described above. In general, the reduction in the amount of drinking water consumed in a household can be significant (on an average of 40 percent) if a flush toilet is replaced with a non-discharge system.

The use of a dry system can prove to be cost-effective in many instances. If a dry system is used in a household with recurrent septic system problems, the reduction in hydraulic loading may let the septic system function properly. This could save the homeowner several thousand dollars in redesigning, rebuilding, or expansion costs. For a group of homes in the area, installation of dry systems would be less costly than creating a sewer district (MVPC 1979).

In the construction of new homes, the installation of a dry system can often be cheaper than installing septic tank systems. In addition, the savings realized from reduced water use and elimination of regular septic tank maintenance can be substantial.

The use of a non-discharge system eliminates the need of disposing of the "blackwater". However, there are other sources of wastewater in the household. Water from sinks, baths and washing machines, referred to as "greywater," must be disposed of. Techniques for handling greywater include disposal by conventional septic tank leach field and disposal by storage for central treatment.

Holding Tank - A holding tank or similar structure can be a temporary means of sewage collecting where a septic system has failed, and there is no land suitable or available for rebuilding or relocating a subsurface system. Its use would discontinue if sewers became accessible or if suitable land became available for expansion or relocation of the failed system. This alternative is very expensive, as the tank must be pumped every one or two weeks for a single family residence, depending on the capacity of the structure. The tank must be easily accessible to the pumper and, hopefully, an approved septage disposal site is located in the area. For these reasons, this alternative can be utilized only in extreme cases where no other is available.

The initial costs and installation fees may range from \$3,000-\$5,000. There are generally no other costs associated with the system, other than pumping fees. The average pumping fee in the region is from \$50-\$110/pump.

Conventional Septic Tank - Soil Absorption System - Local overloading of septic tank effluent onto the soil often occurs because of poor distribution. This may result in poor purification of the effluent in highly permeable soils and accelerate clogging in slowly permeable soils. Uniform application of the wastewater over the infiltrative surface is usually beneficial.

Absorption systems with uniform distribution and dosing are not necessary in all soil types to eliminate poor purification and soil clogging. Sands and weakly structured sandy loams and loams benefit most. After a system is put into service in natural sands, local overloading may cause groundwater contamination, which goes unnoticed until clogging develops. Development of a clogged zone may take several years. Excessive clogging caused by poor distribution tends to occur in weakly structured soils. Uniform distribution aids in reducing the clogging because the liquid is applied simultaneously to the entire infiltrative surface at rates no greater than the soil is able to accept (U.S.EPA 1977).

Liquid flow by gravity is the most common method of distributing waste effluent over the infiltrative surface of the soil absorption field. Perforated, 4-inch diameter pipe is laid level or at a uniform slope of two to four inches per 100 feet, with the holes downward. Such a system does not provide uniform distribution. The liquid trickles out the holes nearest the inlet and at points of lowest elevation.

Periodic dosing of large volumes of effluent onto the field improves distribution and allows the soil to drain between applications. Drainage exposes the infiltrative surface to air, reducing clogging. Even with dosing, however, the effluent is not distributed over the entire infiltrative surface if a four-inch pipe is used (U.S. EPA 1979).

Proper loading of permeable soils to prevent saturated flow is vital to ensure purification of the waste effluent. Pressure distribution systems provide this loading control. Conventional gravity distribution is ineffective.

Pressure distribution systems also retard clogging. Because the network is designed to apply no more liquid than an area of the bed can absorb each day, the soil remains well aerated. The aerobic environment maintained by pressure systems promotes the growth of microorganisms that destroy clogging materials; it also appears to attract larger fauna, such as worms, which consume nutrients accumulating at the infiltrative surface.

Installation of conventional septic tank-soil absorption system costs from \$1,000 to \$2,500 depending on the length of the leach field required, the length of the pipe required for proper location of the field and the need for pumping (Lycott Environmental Research Corp., 1979).

Mound Systems - The conventional septic tank-soil absorption field is not a suitable system of wastewater disposal in many areas, such as those with excessively permeable soils, or soils over shallow bedrock or high groundwater. Mound systems are alternatives, however, than can be used and that use the soils' ability to absorb and purify wastewater.

Homes should not be built in areas with permanently high groundwater tables. In some areas, however, homes are built where the water table is only occasionally high during the year. During high water table periods, a conventional septic tank-leach field cannot function properly because of flooding of the system and improper purification. A properly designed and constructed mound system provides sufficient unsaturated distance for purification before the effluent reaches the goundwater.

The design of the mound is based on the expected daily wastewater volume it will receive and the natural soil's characteristics. The mound must be large enough to accept the daily wastewater flow without surface seepage in the spring and fall when perched water exists in the natural soil, as well as during the summer and winter when the water table is lower. Size and spacing of the seepage trenches is important to prevent liquid from rising into the fill below the trenches when the water table is high. In addition, the total effective basal area of the mound must be large enough to conduct the effluent into the underlying soil.

To distribute the wastewater to each of the trenches, a pressure distribution network is used. This provides uniform application, which is necessary to prevent local overloading and eventual surface seepage. Normally the permeability of the natural soil is not a limiting factor, but the mound must prevent the perched water table from entering the base of the mound.

The cost for a mound system depends on the size of the mound required, piping needed for proper location of mound and whether fill and/or loam must be trucked. The construction cost ranges from $3,000 to $7,500. Operation costs depend on whether a power pump or a siphon is used (Lycott Environmental Research Corp. 1979).

Modifying the Treated Wastewater Characteristics - Although the search for improved methods of on-site disposal has centered on the soil absorption system, more emphasis recently has been on altering the characteristics of the effluent discharged to the soil. Improving effluent quality has been said to enhance soil infiltration, reduce dependence on soils for final treatment, and eliminate the need for soil in the system.

One of the simplest ways to improve the effluent discharged to the soil is to make changes at the source, either by reducing the total volume of waste discharged or by preventing pollutants from entering the waste stream.

Flow reduction to produce lower wastewater volumes can be accomplished through water conservation and recycling. Reductions can be achieved by improving water-use habits or by simple modifications in water use appliances and plumbing fixtures. With less wastewater to treat and dispose of, the life of the on-site disposal system would increase.

Nearly 70 percent of the total household wastewater generated is derived from toilet, laundry, and bath. Using low-flow toilets, "sudsaver" washing machines, and restricted-flow shower heads and recycling bath and laundry wastes for toilet flushing are four commonly mentioned ways to save water (U.S. EPA 1977).

Waste flows from homes are intermittent and subject to wide variation. A study of 11 rural homes showed the average per capita flow from a single household to be approximately 43 gallons per day per capita (U.S. EPA 1977).

By reducing the toilet flushing volume to three gallons, clothes washing to 28 gallons by using a sudsaver, and baths and showers to 15 gallons, average water use could be reduced 17 percent in rural homes. Recycling bath and laundry wastes to flush toilets could increase the savings to 33 percent.

Waste segregation to eliminate pollutants from the waste stream improves the quality of the wastewater. Analysis of wastewaters generated from household suggests which water-use events should be modified for the most beneficial results (U.S. EPA 1977).

Segregating black water from other household wastewater by using a non-water carrying toilet could conserve water resources and reduce the volume and pollutant load discharged to on-site disposal systems. The effect of toilet waste segregation on household wastewater could result in a 22 to 31 percent reduction in flow, a 14 to 42 percent reduction in total phosphorus concentration, and a 68 to 99 percent reduction in total nitrogen concentration.

Sewage Collection and Conventional Central Treatment

Sewers can alleviate septic system failures by replacing on-site waste treatment with controlled centralized treatment.

Sewer planning and construction are funded under Section 201 of the Federal Water Pollution Control Act (1977 Amendments). Sewer construction in Hudson's portion of the Boons Pond watershed is discussed in the 201 report prepared by Whitman and Howard Inc.,1971. Pertinent costs from the report are presented as estimates. The cost for the East Hudson Interceptor would be $650,000. The construction cost for the Hudson shoreline of Lake Boon would be $557,000. A pumping station would also be required at a cost of $94,000. These figures come from a proposed plan. Currently there are no construction plans for the area. The Hudson wastewater facility 20-year planning does not include wastewater flows from the Boons Pond area. The Town of Stow has elected to continue dependence on sub-surface disposal of sewage.

In-Lake Restoration Alternatives

Power Boat Regulations

Previous studies have indicated that a power boat equipped with a 50-horsepower outboard will effectively disturb a lake's water column to a depth of about 4.5 meters (U.S. EPA 1974). Given the mean depth of Boons Pond (4.2 meters) and the organic nature of the sediment, motor boat activity could reduce water clarity on a short-term basis. Also, motor boating in weed infested areas can cause fragmentation of the weeds which results in spreading of the population throughout the lake. Size of the motors should be limited on a voluntary basis. When trading in a current motor, it is suggested that a lower horsepower engine be purchased. The Lake Boon Commission should limit boating in areas infested with *Cabomba caroliniana*.

Cost for this control measure would be minimal, requiring voluntary compliance.

Biological Control

A variety of organisms which consume or are parasitic on aquatic weeds have been considered as agents for control of weed growth. The major symptom of eutrophication in Boons Pond is the dense growth of rooted aquatic weeds. Research has been and is being carried out using herbivorous fish, snails, crayfish, waterfowl, insects, and plants as bi-controls. The main disadvantage of biological control is the concern about introducing a foreign organism to control the pest species. There exists the possibility of releasing an organism as potentially disruptive as the pest itself (Province of British Columbia 1979).

The white amur, alias grass carp, is one of the most controversial topics in the field. Several authorities consider the white amur an effective and relatively inexpensive method of weed control. Work is being done in Arkansas to develop monosexed white amurs to prevent the spread of the introduced fish throughout a river basin. Currently, the Massachusetts Board of Fisheries and Wildlife will not allow the white amur into state waters.

Herbicides and Algaecides

There are several different chemicals available for weed control and algal control in lakes. Usually these applications have limited effectiveness, must be applied more than once during a growing season, and accumulate in the sediments over time. The following observations show chemical treatment not to be an effective restoration activity. Inadequate information exists concerning algicide and herbicide residues, breakdown rates, and longer-term effects on other organisms. When plants are killed chemically, dissolved oxygen levels quickly decline, often to levels detrimental to other organisms. Plant-bound nutrients are released into the water. Some herbicides, such as endothal may damage crops if the water is subsequently used for irrigation (U.S. EPA 1973). Lake Lashaway in Brookfield, Massachusetts has heavy growth of Cabomba caroliniana. In 1972, 2-4-D was used for control and appeared to have measurable beneficial effects (Lycott Environmental Research , Inc. 1979). However, this weed still flourishes in the lake. The use of herbicides is not recommended for control of Cabomba caroliniana in Boens Pond.

Cutrine-Plus Granular is an algacide which controls Chara sp., Nitella sp., and other bottom-growing algae. It is formulated to release copper over an extended period. Two or three applications per season are required, depending on the length of the growing season. These chemicals could be used to control the growth of Nitella sp. in Boons Pond, but present population density and algacide hazards do not warrant implementation of this control strategy.

Nutrient Inactivation

This technique involves addition of chemical compounds to lake waters in order to convert nutrients released from the sediments to a chemical form in which they are not usable by algae or macrophytes. Aluminum sulfates, and fly ash are among the materials that have been used in attempts to inactivate phosphorus in lake waters. Several lakes that had had significant algae bloom problems have reported reductions in total phosphorus levels and algal populations, and increases in dissolved oxygen and transparency, following application of this technique (U.S. EPA 1973). This is not considered to be a feasible restoration technique for Boons Pond because there was no apparent release of nutrients from the sediments.

Hypolimnetic Aeration and Artificial Destratification

These methods are of value for improving water quality of lakes in which the bottom layer (hypolimnion) is devoid of oxygen. Aeration devices such as Limno, Atlas Corporation, oxygenate the bottom layer of the lake without mixing the lake. This is an expensive technique and is used on lakes of depth greater than 8 m-10 m. The maximum depth of Boons Pond is 6.1 m.

Artificial destratification involves injecting air into bottom water. As the bubbles rise, currents are generated and the colder, denser bottom water mixes with the warmer surface water. As a result of mixing, the anoxic bottom waters absorb oxygen. Neither of these technqiues would serve as a restoration alternative for Boons Pond because the bottom waters do not go anaerobic.

Dilution

Dilute or replace existing pond water with water from another source. For this technique to be effective there must be available an inexpensive source of high quality water. There is no such source of water for dilution at Boons Pond.

Hydraulic Dredging

Dredging could be used to remove macrophytes and their root systems from Boons Pond. Normally a dredging operation includes setting up the dredge and setting up the disposal site. Mud Cat has a dredge available MC-915 which cuts an area 2.7 m X 0.45 m (9 ft. X 18 in.) at a maximum operating depth of 4.5 m (15 ft.). This system could be used to remove 127,300 m^3 (166,508 yds) of the weed and root systems to a sediment depth of 1 m^3 (3.2 ft.) for the shore to five-foot contour area in the second and third basins. The procedure would be more effective if dredging was also accomplished to the ten-foot contour area, 226,300 m^3 (296,000 yd^3).

There is an ongoing hydraulic dredging project being conducted at Nutting Lake, Massachusetts. The cost for dredge acquisition was $150,097. Projected operation and maintenance cost for a 26 month period of operation is $208,000. The cost for construction of necessary containment area was $186,700. The proposed volume to be dredged is 273,600 m^3 (360,000 yd^3). The cost breaks down to $1.50 yd^3 or $2.00/$m^3$. The project will last over a period of three and one-half years (Purcell and Taylor 1980). Based on the estimates from the Nutting Lake report it would cost $381,900 to dredge the littoral area up to the five-foot contour. A report prepared by Purcell Associates estimates that a Mud Cat can dredge at a rate of 76,464 m^3 of lake bottom per year. This estimate is based on a forty-hour work week and an eight-month dredge season. It would take approximately two years to dredge the above mentioned portion of Boons Pond.

It might be possible to sell the dewatered dredge spoils at a rate of $1.00/$yd^3$ or $1.00/0.76 m^3, thus recovering some of the cost of the dredging operation.

Diver-Operated Suction Dredge

This method entails intensive labor. It involves a diver who operates a suction device that removes stems, roots, and sediments. The material is transported by hose to a floating barge. Later it must be removed to a containment area onshore. One diver equipped with this device can handle 465 m^2/day (5,000 ft^2/day) at a cost of $500/day. This technique is useful for small weed populations. Both cost and time would prohibit employing this method at Boons Pond. The rate of weed removal will vary depending on weed density.

Lake Drawdown

Exposure of bottom muds during winter has been identified as a means of increasing winter kill of nuisance vegetation. There is little doubt the fluctuating water levels place stress on aquatic plants. There is no data available documenting the effect of over winter drawdown on _Cabomba caroliniana_. However, other rooted aquatics _Potamogeton robbinsii_ and _Myriophyllum_ sp. appear to be susceptible to exposure (Nicholas 1975; Wile and Hitchin 1977).

The review article on over winter drawdown by Wile and Hitchin states lowering of the water levels over the winter months appear to be an effective method of plant control resulting in the eradication of water milfoil in the dewatered zone, except in areas which remain damp. Studies suggest a minimum drying period of twenty-one days to kill water milfoil and suggest that drying of the root system is more important than freezing.

Nicholas (1975) suggests that the rapid re-invasion of vegetation would dictate repeated drawdowns, since subsequent drawdowns would diminish in effectiveness as tolerant species replace the susceptible plants.

Drawdown on Boons Pond could be accomplished by changing the outlet structure. With the present structure at the outlet the lake can be lowered about 0.6 m (2 ft.) (Telephone conversation with Stow Superintendent of Streets). A new outlet structure should allow for drawdown of the lake to a depth of 1.8 m (6 ft.). Exposing the shore to five foot contour area, a flashboard system could be incorporated in the new structure to allow for drawdown by gravity flow. The cost of the drawdown would involve engineering design plans and costs of construction. The area of the lake that would be affected by a drop of 1.8 m (6 ft.) is mainly in the second and third basin where *Cabomba caroliniana* represents a major problem. The first basin would be affected very little because of the rapid drop-off in the near shore area.

The potential disadvantage of drawdown at Boons Pond is that the organic mud that would be exposed would not dry out because of ground water recharge. Shallow wells on the lake might also be affected. The effect on hydrology downstream of the lake would have to be investigated as well as the impact to upstream/shoreland wetlands.

Dry Dredging

Dry dredging could be accomplished in Boons Pond by lowering the level of the lake 1.8 m (6 ft.), then bringing in heavy construction equipment to excavate the exposed area.

The lake level would have to be dropped as described under "drawdown", and the mud would have to dry out sufficiently so that heavy equipment could operate. The morphometry of the south basin is very irregular. As a result, there would have to be several construction access points. The major cost factors would be for dredging and disposal areas.

Fields Memorial Lake, Wisconsin, was excavated in the dry form during 1965 and 1966. Excavation was performed with scrapers, dozers, and other land-based excavation equipment. The cost at that time was 0.62 ¢/m^3. Excavation contracts are usually cost-estimated for the overall job. Recently, the Pontoosuc Lake Restoration Project cost \$7.80 to \$16.25/m^3 (Personal communication, Enser 1980). To excavate 127,300 m^3 of Boons Pond would cost about \$11,000,000.

Bottom Screening

The most effective bottom screening material available at present appears to be Aquascreen (Perkins et al 1980). Aquascreen is made of closely woven, coated fiberglass material. Aquascreen applications work by compressing weed communities into a stressed configuration and by screening sunlight at critical wavelengths. Natural bacterial decomposition of submerged weeds then takes place. The screen is weighted or pinned into place at the end of each strip. The screening is available in 100' X 7' rolls at a cost of $140/roll. The screen is installed by wading, or use of a small boat. Optimum coverage time is two months (Perkins et al 1980). This lake restoration technique is applicable for small beach-front areas such as public beaches and boat landings. It would be impossible to cover the five-foot contour area of the south basin with this material. The minimum area of coverage is 127,300 m^2. The cost of the screening, including installation, is approximately 0.35 ¢/.09 m^2 (Purcell Associates 1980). The screening could be used by individual homeowners to alleviate the weed problem.

Weed Harvesting

Cabomba caroliniana presents a major problem in Boons Pond shore to five-foot contour area of the second and third basin (127,300 m^2/32 acres). Cabomba caroliniana is also becoming a problem in the five-foot contour area to the ten-foot contour area of the second basin, (99,300 m^2/24 acres).

The most efficient method of weed removal consists of a harvester which cuts the weeds with a sickle bar and gathers them; a barge which transports them to the shore; and finally a conveyor unit that will unload the weeds into the truck for ultimate disposal. Cutting is limited to the season between growth and die-off. Harvesting is a short-term measure. Rooted aquatics such as Cabomba caroliniana tend to grow back within the season. Expected nutrient removal associated with submersed macrophyte harvest from an area 127,300 m^2 (32 acres) would by 19 kg TP/harvest (King 1980). Harvesting would have to be done twice during the growing season and this would have to be done every year.

This is one of the best possible ways to handle the weed problem on Boons Pond. The towns could develop a yearly comprehensive weed cutting program for the pond in conjunction with residents of the watershed. The towns could choose to buy a harvester at an approximate cost of $50,000. Harvesting units are available from Mud Cat, Fort Lee, New Jersey and from Aquamarine, Waukeska, Wisconsin. The units that would be effective on Boons Pond would have to cut to a depth of 1.5 m (5 ft.). The Aquamarine's harvester, H-650, and the Mud Cat's H9-650 would accomplish the harvesting of weeds in Boons Pond up to 1.5 m (5 ft.).

Alternatively, there are companies in New England offering mechanical harvesting services at about $300/acre. During the summer of 1980 ACT, Wayland harvested 30-35 acres on Lake Winthrop, in Holliston, Massachusetts, at a cost of $10,000. Harvesting costs can range from $60/acre to $600/acre. (Smith 1979). The towns could contract with a firm to do the harvesting. The cost over three years would be approximately $57,000 (approximately $300/acre).

RECOMMENDED RESTORATION/PRESERVATION PROGRAM

A lead agency, one for each town, should volunteer to coordinate the restoration/preservation effort. This agency would take the responsibility of appointing tasks and locating funding sources. Based on the preceding discussion of technical reliability, anticipated improvement of water quality, and cost estimates, the restoration/preservation program for Boons Pond should include the following:

A. Control of Future Nutrient Loading to Lake

1. "Lake theme" watershed development plan
2. Establish a watershed protection district
3. Regulate conversion of seasonal homes
4. Establish and conduct a public awareness program

B. Control of Present Nutrient Loading to Lake

1. Initiate watershed housekeeping practices
2. Develop and carry out a road maintenance program
3. Establish a septic tank maintenance and inspection program
4. Develop engineering designs for on-site sewage disposal units
5. Construct and remodel on-site sewage disposal units

C. Control of Aquatic Weed Growth

1. Investigate possibility of and carry out overwinter drawdown
2. Design and carry out a multiple harvesting program for weed beds in areas not affected by drawdown

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DESCRIPTION OF TERMS

The terms related to limnology and other limnological entities, as used in this report, are defined below the assist the reader in interpreting some of the data presented:

AREA of a lake refers to the size of the surface, exclusive of islands, measured in square units by planimetry.

AQUATIC PLANTS or aquatic macrophyton can be defined as those vascular plants which germinate and grow with at least their base in water and are large enough to be seen with the naked eye. The following three broad categories are recognized:

1. Emergent types are those plants rooted at the bottom and projecting out of the water for part of their length. Examples: arrowhead (*Sagittaria* spp.), pickerelweed (*Pontederia* spp.)

2. Floating types are those which wholly or in part float on the surface of the water and ususally do not project above it. Examples: water shield (*Brasenia* spp.), yellow water lily (*Nuphar* spp.).

3. Submerged types are those which are continuously submerged (except for possible floating or emergent influorescences). Examples: bladderwort (*Utricularia* spp.), pondweed (*Potamogeton* spp.).

BATHYMETRIC MAP - a map of the lake showing changing depth of the water.

BEDROCK - the solid rock underlaying unconsolidated surface materials (as soils).

CLINOGRADE is a stratification curve of temperature or of a chemical substance in a lake that exhibits a uniform slope from the surface into deep water.

CULTURAL EUTROPHICATION refers to the enrichment or rapid increase in productivity of a body of water caused by man. It is an accelerated process as opposed to natural, slow aging of a body of water. Visual effects include nuisance algal blooms, low transparency, extensive aquatic plant growth, and loss of cold-water fisheries due to oxygen depletion. It is caused by the rapid increase in nutrient additions to a lake.

DELTA is an alluvial deposit, usually triangular, at the mouth of a river.

DEVELOPMENT OF SHORELINE is the degree of regularity or irregularity of a shoreline expressed as an index figure. It is the ratio of the length of the shoreline to the length of the circumference of a circle of an area equal to that of the lake. It cannot be less than unity. The quantity can be regarded as a measure of the potential effect of littoral processes on the lake.

DEVELOPMENT OF VOLUME is defined as the ratio of the volume of the lake to that of a cone of basal area equal to the lake's area and height equal to the maximum depth.

DIMICTIC LAKE is one with spring and fall turnovers (temperate lakes).

DISSOLVED OXYGEN (D.O.) refers to the uncombined oxygen in water which is available to aquatic life; D.O. is therefore the critical parameter for fish propagation. Numerous factors influence D.O., including organic wastes, bottom depostis, hydrologic characteristics, nutrients, and aquatic organisms. Saturation D.O. or the theoretical maximum value, is primarily a function of temperature. D.O. values in excess of saturation are usually the result of algal blooms and therefore, indicate an upset in the ecological balance. Optimum D.O. values range from 6.0 mg/1 (minimum allowable for cold water fisheries) to saturation values. The latter range from 14.6 mg/1 at $0^{o}C$ ($32^{o}F$) to 6.6 mg/1 at $40^{o}C$ ($104^{o}F$).

DRUMLIN is a gravel hill, with an elongated form, are generally steepest toward one side, and rise more gently in all other directions.

EPILIMNION refers to the circulating, superficial layer of a lake or pond lying above the metalimnion which does not usually exhibit thermal stratification.

ESKER is a serpentine ridge of gravel and sand.

HETEROGRADE is a stratification curve for temperature or a chemical substrate in a lake which exhibits a non-uniform slope from top to bottom. It can be positive (metalimnetic maximum) or negative (metalimnetic minimum.

KAMES are conical hills or short irregular ridges of gravel or sand deposited in contact with glacier ice.

LENTIC refers to still or calm water, such as lakes or ponds.

LITTORAL refers to growing on or near a shore

LOTIC refers to moving water, such as rivers or streams.

MAXIMUM DEPTH is the maximum depth known for a lake.

MAXIMUM EFFECTIVE LENGTH is the length of a straight line connecting the most remote extremities of a lake along which wind and wave action occur without any kind of land interruption. It is often identical with maximum length.

MAXIMUM EFFECTIVE WIDTH is similar to maximum effective length but at right angles to it.

MAXIMUM LENGTH is the length of a line connecting the two most remote extremities of a lake. It represents the true open-water length and does not cross any land other than islands.

MAXIMUM WIDTH is the length of a straight line connecting the most remote transverse extremities over the water at right angles to the maximum length axis.

MEAN DEPTH is the volume of a lake divided by its surface area.

MEAN DEPTH - MAXIMUM DEPTH RATIO is the mean depth divided by the maximum depth. It serves as an index figure which indicates in general the character of the approach of basin shape to conical form.

MEAN WIDTH is the area of a lake divided by its maximum length

METALIMNION is the layer of water in a lake between the epilimnion and the hypolimnion in which the temperature exhibits the greatest difference in a vertical direction.

MILLIGRAMS PER LITER (mg/1) is used to express concentrations in water chemistry because it allows simpler calculations than the English system. The basis of the metric system is the unit weight and volume of water at standard conditions ($20^{o}C$). At these conditions, one milliliter of water equals one cubic centimeter and weighs one gram. One milligram per liter is therefore essentially equal to one part per million by weight or volume.

MUCK is a dark-colored soil, commonly in wet places which has a high level of decomposed or finely laminated organic matter.

NON-POINT SOURCE POLLUTION can be defined as any pollutant which reaches a water body by means other than through a pipe. Examples of non-point sources include leachate from dumps and agricultural runoff from dairy farms.

NUTRIENTS are basically organic compounds made up of carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulfur. Small amounts are vital to the ecological balance of a water body. Larger amounts can lead to an upset of the balance by allowing one type of organism, such as algae, to proliferate. The most significant nutrients in water bodies are those of carbon, nitrogen, and phosphorus. Nutrients of carbon are measured indirectly in the BOD test; separate tests are run to measure nutrients of nitrogen and phosphorus.

ORTHOGRADE is a stratification curve for temperature or a chemical substance in a lake which has a straight, uniform course.

PERCOLATION RATE the speed of water trickling through the soil.

pH is the measure of the hydrogen ion concentration of a solution on an inverse logarithmic scale ranging from 0 to 14. Values from 0 to 6.9 indicates acidic solutions, while values from 7.1 to 14 indicate alkaline solutions. A pH of 7.0 indicates a neutral solution. Natural streams usually show pH values between 6.5 and 7.5, although higher and lower values may be caused by natural conditions. Low pH values may result from the presence of heavy metals from acid mine drainage or metal-finishing waste. High pH values may result from detergents or photosynthetic activities of phytoplankton.

POINT SOURCE OF POLLUTION refers to continuous discharge of pollutants through a pipe or similar conduit. Primarily included are sewage and industrial waste, whether treated or untreated.

SESTON refers to all the particulate matter suspended in the water.

SHORELINE is the length of a lake's perimeter, measured from a map with a rotometer (map measurer).

SILICA DIOXIDE is necessary for diatom growth. The concentration of silica is often closely linked with the diatom population's growth. The limiting concentration is usually considered to be 0.5 mg/l.

TERRACES are relatively flat or horizontal surfaces which are bounded by a steeper ascending slope on one side and by a steep descending slope on the other side.

THERMAL STRATIFICATION is a layering of the lake in which the water column is divided by temperature dependent density gradient into a lower region and an upper region with a boundary layer between.

THERMOCLINE is coincident with the metalimnion and relates to the lake zone with the greatest temperature change in a vertical direction.

TITLE 5 of the State Environmental Code on Requirements for the Subsurface Disposal of Sanitary Sewage.

VOLUME is determined by computing the volume of each horizontal stratum as limited by the several submerged contours on the bathymetric (hydrographic) map and taking the sum of the volumes of all such strata.

WATERSHED-land area that is drained by a stream or river or lake system.

APPENDIX A

A NOTE ON LIMNOLOGY AND LAKE RESTORATION PROJECTS

Limnology is the study of inland fresh waters, especially lakes and ponds (lentic water vs. lotic water for streams and rivers). The science encompasses the geological, physical, chemical, and biological events that operate together in a lake basin and are dependent on each other (Hutchinson, 1957). It is the study of both biotic and abiotic features that make up a lake's ecosystem. As pointed out by Dillon (1974) and others before him, in order to understand lake conditions, one must realize that the entire watershed and not just the lake, or the lake and its shoreline, is the basic ecosystem. A very important factor, and one on which the life of the lake depends, is the gravitational movement of minerals from the watershed to the lake. Admittedly the report contained herein concentrates mainly on the lake itself. Yet the foremost problem affecting the lakes and ponds today is accelerated cultural eutrophication, which originates in the watershed and is translated into various and sundry non-point sources of pollution. A great deal of lake restoration projects will have to focus on shoreland and lake watershed management.

Hynes sums up the science well in stating..."The conclusions...are therefore that any interference with the normal condition of a lake or a stream is almost certain to have some adverse biological effect, even if, from an engineering point of view, the interference results in considerable improvement. At present it would seem that this is little realized and that often much unnecessary damage is done to river and lake communities simply because of ignorance. It is of course manifest that sometimes engineering or water-supply projects have over-riding importance; and even if they have not, the question of balancing one interest against another must often arise. But, regrettably, even the possibility of biological consequences is often ignored. It cannot be emphasized too strongly that when it is proposed to alter an aquatic environment the project should be considered from the biological as well as the engineering viewpoint. Only then can the full implications of the proposed alteration be assessed properly, and a reasonable decision be taken. Obviously this will vary with the circumstances and the relative importance of the various consequences involved, but, as present, unnecessary and sometimes costly mistakes are often made because the importance of biological study is unknown to many administrators. Often, as for instance in drainage operations, it would be possible to work out compromises which would satisfy both engineering and biological interests".*

* Hynes, H.B.N. 1974. The Biology of Polluted Waters. University of Toronto Press, Toronto, Canada.

EUTROPHICATION

The term "eutrophic" means well-nourished; thus, "eutrophication" refers to natural or artificial addition of nutrients to bodies of water and to the effects of added nutrients (Eutrophication: Causes, Consequences, and Correctives, 1969). The process of eutrophication is nothing new or invented by man. It is the process whereby a lake ages and eventually disappears. An undisturbed lake will slowly undergo a natural succession of stages, the end product usually being a bog and, finally, dry land (see Figure A). These stages can be identified by measuring various physical, chemical, and biological aspects of the lake's ecosystem. Man can and often does affect the rate of eutrophication. From a pollutional point of view, these effects are caused by increased population, industrial growth, agricultural practices, watershed development, recreational use of land and waters, and other forms of watershed exploitation.

It might also be mentioned that some forms of water pollution are natural. Streams and ponds located in densely wooded regions may experience such heavy leaf fall as to cause asphyxiation of some organisms. Discoloration of many waters in Massachusetts is caused by purely natural processes. As pointed out by Hynes (1974), it is extremely difficult to define just what is meant by "natural waters", which is not necessarily synonomous with "clean waters".

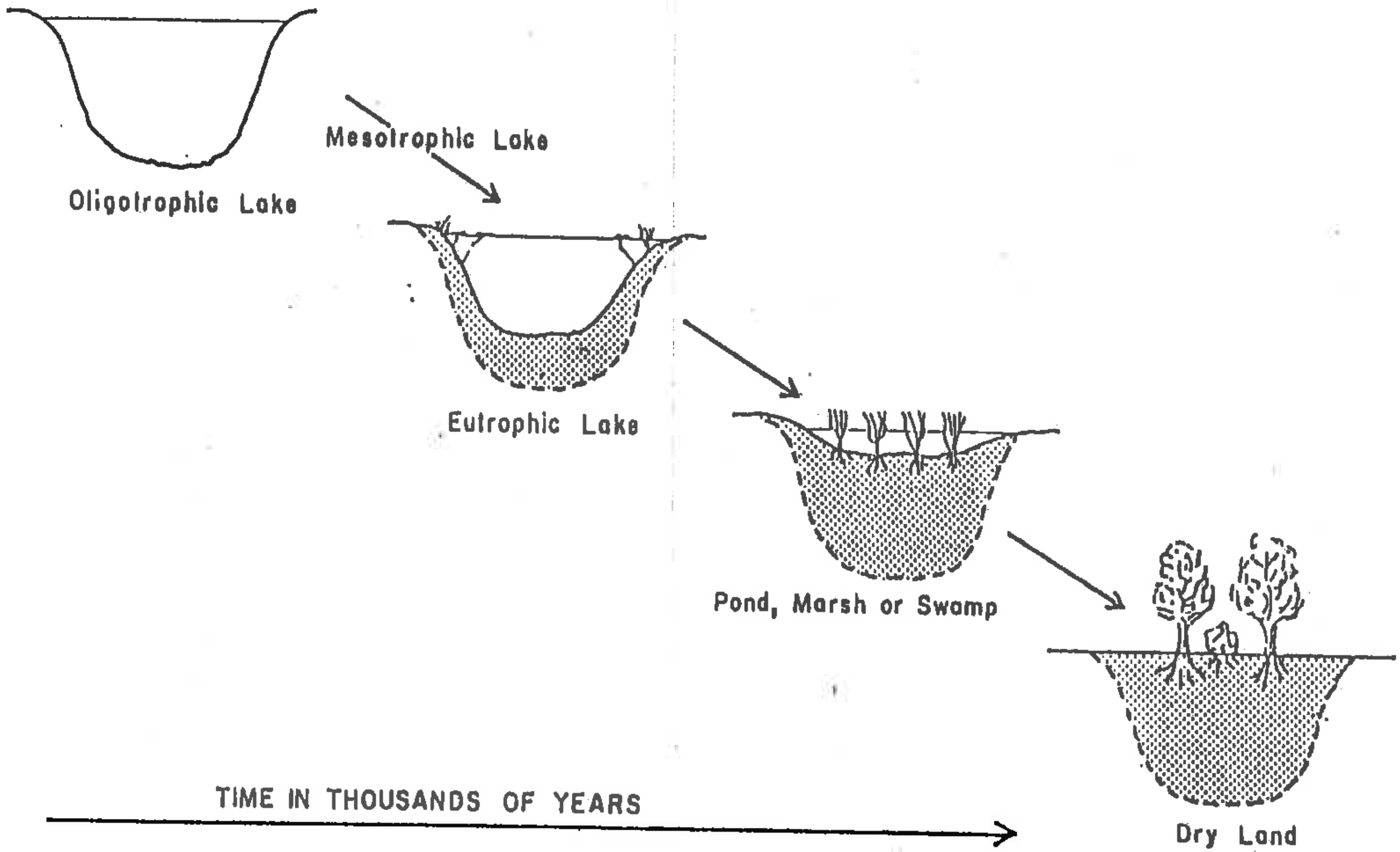
For restorative or preservative purposes of a lake and its watershed, it is important to identify both a lake's problem and the cause of the problem. Problems associated with eutrophication include nuisance algal blooms (especially blue-green algae), excessive aquatic plant growth, low dissolved oxygen content, degradation of sport fisheries, low transparency, mucky bottoms, changes in species type and diversity, and others. The pollutional cause is identified as either point or non-point in origin. A point source of pollution may be an inlet to the lake carrying some waste discharge from upstream. Or it may be an industrial, agricultural, or domestic (e.g., washing machine pipe) waste discharge which can be easily identified, quantified, and evaluated.

Non-point sources of pollution, which are the more common type affecting a lake, are more difficult to identify. They include agricultural runoff, urban runoff, fertilizers, septic or cesspool leakage, land clearing, and many more. They are often difficult to quantify and, thus, evaluate.

An objective of a lake survey is to measure a lake's trophic state; that is, to describe the point at which the lake is in the aging process. The measure most widely used is a lake's productivity. Technically, this involves finding out the amount of carbon fixed per meter per day by the primary producers. Since it is a rather involved procedure to determine the energy flow through a lake system, the lake survey attempts to indirectly describe the lake's trophic state or level of biological productivity.

Nitrogen and phosphorus have assumed prominance in nearly every lake investigation in relating nutrients to productivity (eutrophication). Some investigators (Odum, 1959) use the maximum nitrogen and phosphorus concentrations found during the winter as the basis of nutrient productivity correlation due to the biological minimum caused by environmental conditions. Others use data following the spring overturn as a more reliable basis for nutrient productivity correlation. In any event, considerable caution must be used in transporting nutrient concentration limits found in other lakes to the present situation.

Table B depicts concentrations of various substances and other data for two hypothetical lakes, one eutrophic, the other oligotrophic. It is intended as a guide for comparison to the data presented in this report. Each lake, of course, is different from all others. There is no hard and fast rule as to critical concentrations for each lake. The morphology of a lake (e.g., mean depth) plays an important part in its general well-being. A small, deep lake will react differently to nutrient loadings than a large, shallow lake. In the final analysis, each lake is found unique and must be evaluated on an individual basis.



EUTROPHICATION – the process of aging by ecological succession.

Source: _Measures for the Restoration and Enhancement of Quality of Freshwater Lakes._ Washington, D.C.: United States Environmental Protection Agency, 1973.

FIGURE A

TABLE A

LAKE TROPHIC CHARACTERISTICS

1. Oligotrophic Lakes:

   a. Very deep, thermocline high; volume of hypolimnion large; water of hypolimnion cold.

   b. Organic materials on bottom and in suspension very low.

   c. Electrolytes low, or variable; calcium, phosphorus, and nitrogen relatively poor; humic materials very low or absent.

   d. Dissolved oxygen content high at all depths and throughout year.

   e. Larger aquatic plants scanty.

   f. Plankton quantitatively restricted; species many; algal blooms rare; Chlorophyceae dominant.

   g. Profundal fauna relatively rich in species and quantity; Tanytarsus type; Corethra usually absent.

   h. Deep-dwelling, cold-water fishes (salmon, cisco, trout) common to abundant.

   i. Succession into eutrophic type.

2. Eutrophic Lakes:

   a. Relatively shallow; deep, cold water minimal or absent.

   b. Organic materials on bottom and in suspension abundant.

   c. Electrolytes variable, often high; calcium, phosphorus, and nitrogen abundant; humic materials slight.

   d. Dissolved oxygen, in deeper stratified lakes of this type, minimal or absent in hypolimnion.

   e. Larger aquatic plants abundant.

   f. Plankton quantitatively abundant; quality variable; water blooms common; Myxophyceae and diatoms predominant.

   g. Profundal fauna, in deeper stratified lakes of this type, poor in species and quantity in hypolimnion; Chironomus type; Corethra present.

   h. Deep-dwelling, cold-water fishes usually absent; suitable for perch, pike, bass, and other warm-water fishes.

   i. Succession into pond, swamp, or marsh.

TABLE A (CONTINUED)

3. Dystrophic Lakes:

   a. Usually shallow; temperature variable; in bog surroundings or in old mountains.

   b. Organic materials in bottom and in suspension abundant.

   c. Electrolytes low; calcium, phosphorus, and nitrogen very scanty; humic materials abundant.

   d. Dissolved oxygen almost or entirely absent in deeper water.

   e. Larger aquatic plants scanty.

   f. Plankton variable; commonly low in species and quantity; Myxophyceae may be very rich quantitatively.

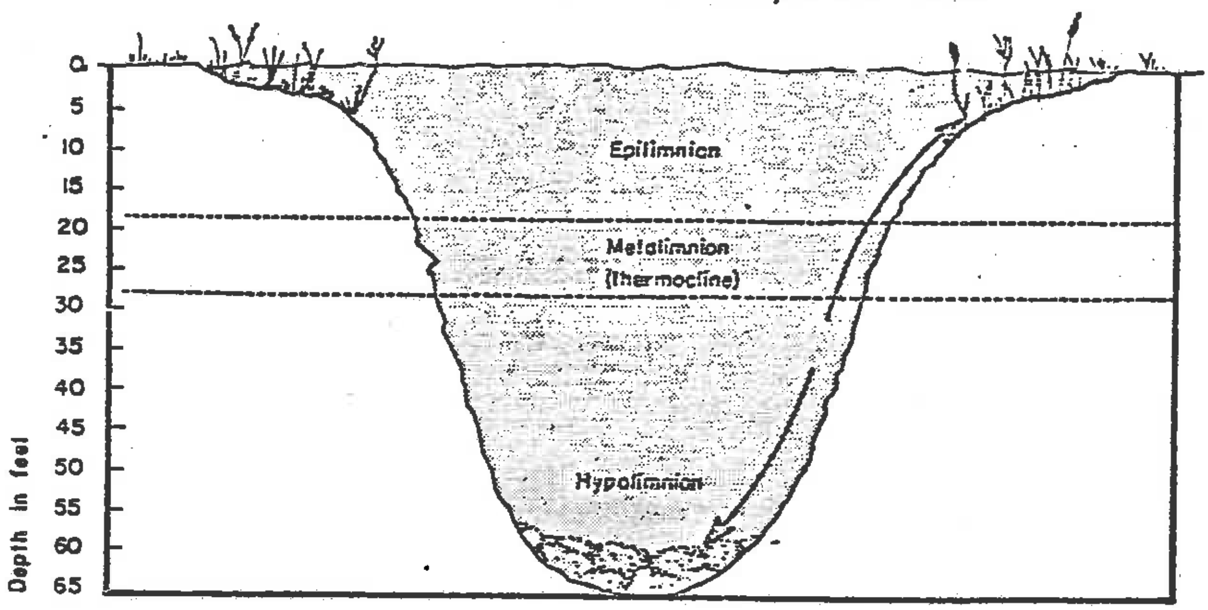
   g. Profundal macrofauna poor to absent; all bottom deposits with very scant fauna; Chironomus sometimes present; Corethra present.

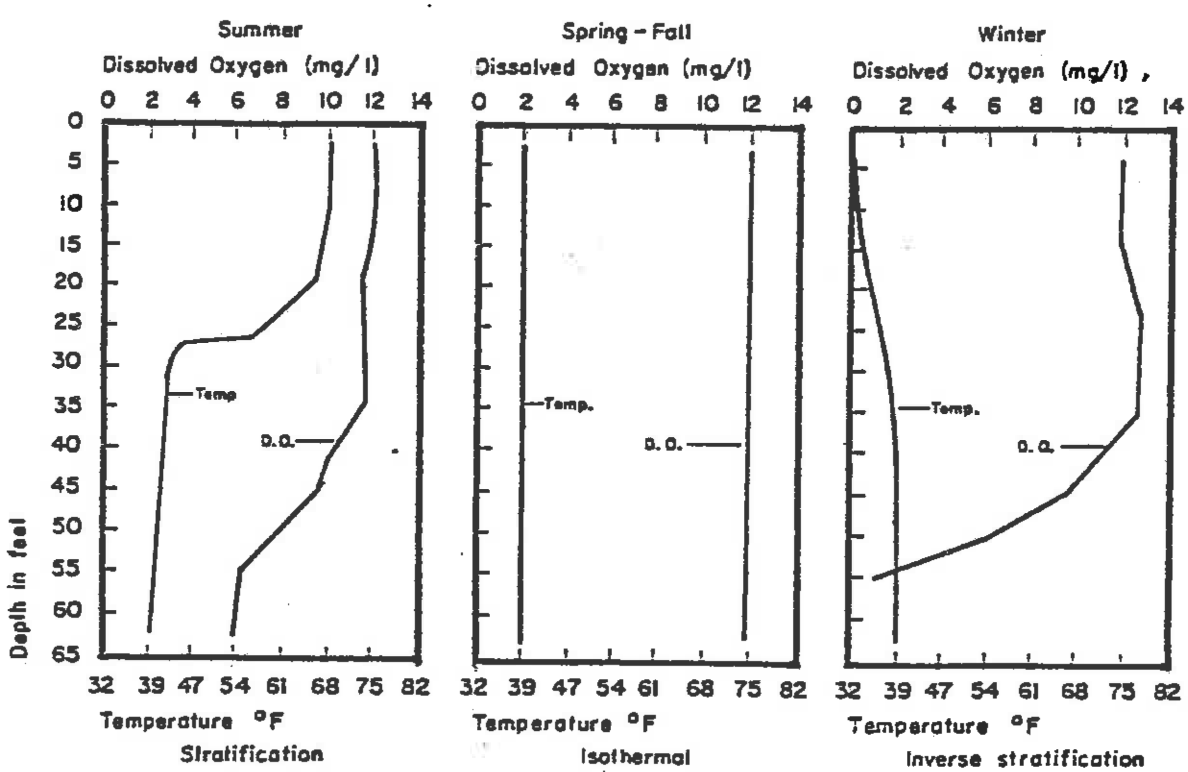
   h. Deep-dwelling cold-water fishes always absent in advanced dystrophic lakes; sometimes devoid of fish fauna; when present, fish production usually poor.

   i. Succession into peat bog.

SOURCE: Welch, P.S., Limnology, McGraw Hill Book Co., New York, 1952. (Reprinted with permission from the publisher.)

Diagrammatic sketch showing thermal characteristics of temperate lakes





Source: Measures for the Restoration and Enhancement of Quality of Freshwater Lakes. Washington, D.C.: United States Environmental Protection Agency, 1973.

FIGURE B

TABLE B

SELECTED DATA FOR TWO HYPOTHETICAL LAKES[1]

CONCENTRATIONS IN (mg/1)

TROPHIC STATUS[2]	DISSOLVED OXYGEN AT BOTTOM	TRANSPARENCY (Secchi Level)	NH_3-N	NO_3-N	TOTAL-P	PHYTOPLANKTON ASSEMBLAGES	AQUATIC VEGETATION	CHARACTERISTIC FISHERIES
Lake A (Oligotrophic)	High >5.0	High	Low <0.3	Low <0.3	Low <0.01	High diversity, low numbers, nearly complete absence of blue-greens	Sparse	Cold Water types
Lake B (Eutrophic)	Low <5.0	Low	High >0.3	High >0.3	High >0.01	Low diversity high numbers, abundance of blue-greens	Abundant	Warm Water types

[1] Not established as State standards.

[2] Oligotrophic = nutrient poor

Eutrophic = high concentrations of nutrients

APPENDIX B

Soil Descriptions*

Hinckley - Soils that are excessively drained, developed in deep deposits of sand and gravel, chiefly from granite and gneiss. These sandy, gravelly soils ususally have a gravelly, loamy, sand surface soil and a sandy and gravelly subsoil underlain by stratified sands and gravel. Water moves fast through these soils. They occur on level to very steep slopes.

Paxton- These well drained soils developed in stony, compact glacial till derived mostly from schist and gneiss. The surface soil, subsoil, and substratum are generally a fine, sandy loam--the first two of these having moderately rapid to rapid permeability and the third having a slowly permeable hardpan at about two feet. The surface of these soils is stony. They occur in level to very steep slopes.

Windsor - These soils are excessively drained that have formed in deep sand deposits. They have a loamy sand surface soil and subsoil and are commonly free of gravel to a depth of four feet from the surface. The soils have rapid permeability and low moisture-holding capacity. The water table is generally many feet below the surface. They occur on level to very steep slopes.

Muck - These are poorly drained bog soils formed in accumulations of organic deposits that are underlain by mineral soil materials. The water table is at or near the surface most of the year.

Scarboro - These are poorly drained soils that have formed in deep deposits of sands and gravel derived mostly from granite, gneiss, and quartz. These soils are wet most of the year by a high water table. They have rapid permeability and are usually free of stones and boulders.

Millis - These soils are well drained and have developed in a fine, sandy loam mantle about 20 to 30 inches thick over a compact loamy sand glacial till being from granite and gneiss. The surface soil and subsoil is a crumbly, fine sandy loam. The underlying glacial till is hard, compact, and is slowly permeable and the surface soil and subsoil is moderately rapid or rapid. These soils occur on nearly level to very steep slopes.

Au Gres - Developed in deep deposits of sand or sand and gravel, these soils are poorly drained. For seven to nine months of the year the water table is at or near the surface. They have rapid permeability, but because they are saturated most of the time, they can absorb little additional water. These soils occur on level to gentle slopes.

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*Soils and Their Interpretations For Various Land Uses. Central Mass. Planning District. U.S. Dept. of Agri. SCS. May 1967 (Soil Descriptions Section)

Deerfield - These moderately well drained soils have formed in deep deposits of sand. The surface soil and subsoil are loamy. Having a seasonal high water table, these soils are usually saturated with water in the winter, early spring, and when there are long periods of rain. They occur on level to gentle slopes.

Woodbridge - These moderately well drained soils have developed in compact, stony, glacial till. The surface soil and subsurface is a fine, sandy loam and has moderate or moderately rapid permeability. The sub-soil is underlain by hardpan that is slowly permeable. During the spring and the fall, seepage water from adjacent land, or by a high water table, causes the soil to be wet. During these times or long periods of rain the water table is within one and one-half to two feet of the surface.

Hollis - These somewhat excessively drained, shallow to bedrock soils are formed in thin deposits of glacial till from schistose and granitic material. The bedrock is usually within two feet of the surface, but is deeper in places. These soils occur on gentle to very steep slopes.

Birchwood - These soils developed in a sandy mantle over compact glacial till and are moderately well drained. A rapidly permeable, loamy sand makes up the surface soil and subsoil. The subsoil is underlain by hard-pan. A seasonal high water table or water from adjacent land may cause the soil to be wet. During this time the water table is within one and one-half to two feet of the surface. They occur on level to moderate slopes.

APPENDIX C

SOIL INTERPRETATIONS FOR SEPTIC SYSTM USE

Limitations

The concept of rating soils according to their limitations for various uses was developed in the 1960s by the National Cooperative Soil Survey. The ratings "slight," "moderate," and "severe" are based on such internal characteristics as texture, structure, drainage, permeability, and depth to bedrock; and such external characteristics as surface stoniness, rockiness, slope, and flood hazard. The system identifies the limiting feature of a soil that is to be used for a specific purpose and the degree to which that limitation will affect its use if uncorrected. The more severe the limitations, the more complex the engineering design and the higher the cost of overcoming the limitation. However, rating soils by their limitations does not identify specific corrective measures, estimate their relative cost, or judge their effectiveness in overcoming the limitations. The interpretative ratings for soil limitations are defined as follows:

Slight - The few limitations are easily overcome by engineering design. The expense of correction is usually below the average cost of preparing the site for the intended use.

Moderate - The limitations require more intensive on-site observation and testing to determine proper design. Moderate limitations can be corrected at average to above average costs of preparing the site for the intended use.

Severe - This rating indicates that the use of the soil is seriously limited by one or more factors. Intensive testing of the site is necessary to develop design features to overcome the limitations. Preparing the site for the intended use would be costly, and in some cases may be prohibitive.

Potentials

The concept of rating soils according to their potentials is intended to convey to the user the kinds of management practices that can be employed to overcome the limitations identified with each kind of soil. It also provides the relative cost of specific practices and the degree to which these practices have been successful by past experience. Rating soils by their limitations alone has caused some misunderstandings in their interpretation. A rating of "severe" for septic tank drainfields has, at times, been interpreted to mean that the soil should not be used for drainfields. However, the "severe" rating only implies that the limitations imposed by nature are formidable, that proper design must be based on intensive on-site testing and that these tests, design, and installation may add considerable cost to development. In some cases these costs may prove to be impractical.

Thus, the concept of soil potential ratings is intended to provide the broadest amount of information to soil survey users, landowners, developers, design engineers, and those charged with regulating land use in the public interest. Soil potential is a positive approach that allows the user to compare corrective designs as well as positive alternative uses for the soils

In developing potential ratings, the limitations that a soil imposes upon a specific use must first be identified. For example, a seasonal high water table that rises to within 18" below a septic tank drainfield is a specific limitation. Bedrock at shallow depths not only limits the installation of a septic tank drainfield but the thin soil layer above the bedrock limits proper renovation of the effluent. To overcome these limitations, specific management practices are available (i.e., land drainage, addition of fill, installation of sewers). Some corrective measures cost more than others and the results may not meet with expectations. Therefore, we have rated soil potentials as "high,""medium," "low," and "very low." The ratings are broadly defined as follows:

High potential - Few limitations exist and costs of overcoming them are a fraction of the average costs of site preparation. Once the corrective practices have been employed, performance is usually satisfactory according to local experience. Continuing limitations are rare, and environmental quality is maintained.

Medium potential - Individual limitations are more severe or more numerous. Costs of practices to overcome the limitations are average to 10-fold above average. The performance of the soil usually will be improved but continuing limitations may require additional modification of design or other practices. If the practices are successful, environmental quality may be maintained or it may be slightly lowered by continuing limitations.

Low potential - Limitations may be severe, requiring intensive and expensive management practices. Performance of the soil may be significantly below acceptable standards if limitations are not overcome. Costs of management practices may be up to 100-fold above average. Continuing limitations may reduce enviromental quality, even after corrective management practices have been employed.

Very low potential - Limitations are very severe and performance of the soil may be much below acceptable standards even after management practices have been employed. The costs of corrective measures may be greater than 100-fold above average costs and may be economically unsound. Continuing limitations are common and may seriously affect the maintenance of environmental quality. In many cases the decrease in environmental quality may be judged to be locally unacceptable.

The most common practices used in overcoming soil limitations are listed in Table C1 and are ranked according to increasing costs. Their relative position in the list for each use may vary among counties and regions within the state. Some practices imply regulatory action and their relative costs are not easily predicted. Regulatory practices were placed in the list according to the anticipated severity of impact upon the user. For example, controlling housing density to prevent pollution of a proven underlying aquifer is a more severe regulatory action than the restriction of percolation tests in certain soils to the normally wet spring months.

TABLE C1

MANAGEMENT PRACTICES ASSOCIATED WITH OVERCOMING SOIL LIMITATIONS

SEPTIC TANKS

- Serial distribution of title lines.
- Increase square feet of leaching system if percolation test rate is faster than 5 min/in and silt + clay content exceeds 30%. Square feet determined by percolation test x factor of 1.2.
- Avoid construction when soils are excessively wet.
- Percolation testing and deep pit observation when seasonal water tables and soil moisture are near maximum.
- Addition of suitable fill material. Compaction or natural stabilization.
- Curtain drain or other interceptor drains to cut off lateral flow of groundwater over compact till.
- Maximum size leaching system and/or graded sand filter system or mound system.
- Extensive land shaping and/or stone removal.
- Drainage system to lower water table.
- Flood control structures.
- Sewage collection as alternative system of choice if area is underlain by a major aquifer.
- Control of housing density.
- Least suitable for use.

Source: Hill, D. 1979. Soils Interpretation for Waste Disposal. The Connecticut Agricultural Experiment Station Bulletin 776, New Haven, Connecticut.

APPENDIX D

CHLOROPHYLL a PROCEDURES

I. Reagents and apparatus

A. Fluorometer

1. "Blue lamp" Turner No. 110-853
2. Excitation Filter: Corning CS-5-60, #5543, 2 in^2, 4.9 mm polished
3. Emmission Filter: Corning CS-2-64, #2408 2 in^2, 3.0 mm polished
4. R-136 photo multiplier tube

B. Tissue grinder and tube

C. Vacuum flask and pump

D. Millipore filter holder

E. Glass fiber filters: Reeve Angel, grade 934AH, 2.1 cm

F. Centrifuge (Fisher Scientific Safety Centrifuge)

G. 15 ml graduated conical end centrifuge tubes with rubber stoppers

H. 90% acetone

I. 1 N HCl (11:1 dilution of distilled water to conc. HCl)

J. Saturated Magnesium Carbonate solution in distilled H_2O

II. Procedure

A. Filter 50 ml (or less if necessary) of sample through glass fiber filter under vacuum

B. Push the filter to the bottom of tissue grinding tube

C. Add about 3 ml of 90% acetone and 0.2 ml of the $MgCO_3$ solution

D. Grind contents for 3 minutes

E. The contents of the grinding tube are carefully washed into a 15 ml graduated centrifuge tube

F. Q.S. to 10 ml with 90% acetone

G. Tubes are then centrifuged for 20 minutes and the supernatent decanted immediately into stoppered test tubes

I. Test tubes are wrapped with aluminum foil and stored in the refrigerator for 24 hours

J. The tubes are allowed to come to room temperature, the temperature recorded, the samples poured into cuvettes, and then the samples are read on the fluorometer. (The fluorometer must be warmed up for at least 1/2 hr. before taking a reading.)

K. 0.2 ml of the 1 N HCl solution is added to the sample in the cuvette, the cuvette stoppered and inverted and righted 4 times to mix thoroughly, and the sample is read again

L. Both values are recorded, along with the window orifice size and whether the high-sensitivity or the regular door was used

APPENDIX E

BOONS POND

SEEPAGE METERS

CHEMICAL DATA (mg/1)*

SAMPLE STATION	C-1	C-3	D-1	F-1	I-1	M-1
Total Kjeldahl-Nitrogen	1.1	1.0	1.3	1.5	1.3	1.1
Ammonia-Nitrogen	0.00	0.00	0.12	0.10	0.02	0.11
Nitrate-Nitrogen	0.0	0.0	0.1	0.1	0.0	0.0
Total Phosphorus	0.05	0.09	0.09	0.13	0.07	0.08

SAMPLE STATION	P-1	P-2	Q-2	Q-6	U-1	OUTLET
Total Kjeldahl-Nitrogen	1.2	1.6	1.7	0.92	1.3	0.60
Ammonia-Nitrogen	0.00	0.49	0.25	0.00	0.01	0.01
Nitrate-Nitrogen	0.0	0.0	0.0	0.0	0.0	0.0
Total Phosphorus	0.06	0.10	0.17	0.06	0.14	0.02

*Samples represent a mixture of lake water and groundwater.

APPENDIX F

NUTRIENT BUDGET CALCULATIONS

For loading purposes the watershed was divided into the subdrainage basins 3, 4, and 6 (see Figure 9), as defined by tributary streams. The area of direct overland runoff and groundwater flow to the lake was defined as subdrainage basin 7. Average annual discharges from the subdrainage basins were calculated in the Water Budget Section. Total observed input of phosphorus and nitrogen to the lake from the subdrainage basins were calculated by multiplying the average annual discharge by the average total phosphorus or total nitrogen concentration observed at that inlet.

Data on average total phosphorus and total nitrogen concentrations entering the lake was available for subdrainage basins 3, 4, and 6. Subdrainage basin 4 and subdrainage basin 7 had the most comparable land use of the four. Thus, the subdrainage basin 4 average total phosphorus and total nitrogen values were used for calculating the loading from subdrainage basin 7 (See Phosphorus/Nitrogen Section).

Loading of total phosphorus and total nitrogen from the various land uses in the subdrainage basins were calculated by multiplying the percent of the land use in the subdrainage basin by the average annual discharge in the subdrainage basin, by the range of nutrient concentrations from literature. Literature nutrient concentrations are presented below.

Literature Nutrient Values

	Total Nitrogen (mg/l)	Total Phosphorus (mg/l)	Source
Precipitation	1.2-1.3	0.02-0.04	Loehr 1974
Forested Land	0.3-1.8	0.01-0.11	Loehr 1974
Residential Land	3	0.2-1.1	Loehr 1974
Wetlands	0	0	Uttormark et al.(1974)
Intensive Agriculture	9	0.02-1.7	Loehr 1974
Open Waters*	1.2-1.3	0.02-0.04	Loehr 1974

*Considered to be the same as precipitation

To estimate loading from nearshore septic systems it was assumed that 25 percent of the nitrogen and 10 percent of the household wastewater effluent was exported to the lake (Shannon and Brezonick 1972).

In household wastewater effluent total phosphorus concentrations range from 3-5 g/capita/day and total nitrogen concentrations range from 6-17 g/capita/day (U.S. EPA 1980). Given that there are 211 homes adjacent to the lake (taxpayer lists, towns of Hudson and Stow), assuming an average of 3.2 persons/dwelling, and that the homes are occupied year-round; the total input of nutrients from septic systems was estimated.

APPENDIX G**

LAKE CLASSIFICATION SYSTEM

The Division of Water Pollution Control has developed a lake classification system as an aid to setting priorities for the Lake Restoration Program (Section 314 of PL 95-217) in Massachusetts. This system is generally applied only to those lakes and ponds for which the Division has collected water quality data. Although a host of physical, chemical, and biological parameters are measured during the normal lake survey, only six critical parameters are employed in the lake classification priority system. The six parameters are hypolimnetic dissolved oxygen, secchi disc reading, phytoplankton count, total ammonia- and nitrate-nitrogen, total phosphorus, and aquatic macrophyton. The most recent survey data are used and the priority listing is updated annually. The optimum season for collecting lake data is mid- to late summer, or during peak biological production. Unfortunately, this cannot always be achieved, thus spring or autumnal data have to be used in the lake classification system.

The limits used for awarding severity points for the six parameters have been based on several considerations and information sources. These include lake classifications of other states, the natural range of parameters in Massachusetts, limnological texts, and accepted indices of eutrophication reported in the literature. The severity point system has been formulated as follows:

PARAMETER	CONCENTRATION OR DEGREE OF SEVERITY	POINTS
Hypolimnetic dissolved oxygen	≥5.0 mg/l	0
	<5.0-3.0 mg/l	1
	<3.0-1.0 mg/l	2
	<1.0 mg/l	3
Transparency (secchi disc reading)	≥15 feet	0
	<15-10 feet	1
	<10-4 feet	2
	<4 feet*	3
Phytoplankton	0-500 ASU or natural cells/ml	0
	>500-1000 ASU or natural cells/ml	1
	>1000-1500 ASU or natural cells/ml	2
	>1500 ASU or summer "blooms"	3
Epilimnetic NH_3 + NO_3-N	0-<0.15 mg/l	0
	≥0.15-0.3 mg/l	1
	>0.3-0.5 mg/l	2
	>0.5 mg/l	3
Epilimnetic total phosphorus	0-0.01 mg/l	0
	>0.01-0.05 mg/l	1
	>0.05-0.10 mg/l	2
	>0.10 mg/l	3

* Four feet is the minimum allowable transparency at bathing beaches, as stated in Article VII of the State Sanitary Code.

**Commonwealth of Massachusetts Division of Water Pollution Control. 1980. Massachusetts Lake Classification Program. Westborough, Massachusetts.

PARAMETER	CONCENTRATION OR DEGREE OF SEVERITY	POINTS
Aquatic Vegetation	Sparse	0
	Medium	1
	Dense	2
	Very dense	3

It is expected that chlorophyll-a data will soon augment or replace the phytoplankton data as they become part of the routine lake survey. The severity points may be interpreted as follows:

0 = No problem. Considered to be representative of clean water quality.

1 = Slight problem; borderline case considered to be potentially degrading.

2 = Definite problem. Considered unacceptable for lake water quality..

3 = Severe problem, undoubtedly causing degradation of the lake's water quality or some recreational uses.

Lakes, ponds, and reservoirs are first divided into two major categories:

1. Those which stratify during the summer;
2. Those which do not stratify during the summer.

Next, severity points are assigned to each of the above critical parameters. On the basis of the severity point system, a priority listing can be maintained. This listing, in conjunction with other available data, can then be used for a trophic level classification system. On the basis of a possible 18 severity points, the trophic level index would be as follows:

0 - 6	oligotrophic
6 - 12	mesotrophic
12 - 18	eutrophic

The overlap of severity points is intentional and meant to underscore the system's flexibility. The general range of severity points is considered more important than the absolute total for a given lake.

Although the system is not 100% equitable, it does appear to give a fair representation of lake trophic conditions for the vast majority of Massachusetts' lakes. River impoundments below point waste discharges present special cases. Personal knowledge of these situations helps explain anomalies in the data. By its very nature, the system cannot be static but will be under constant reevaluation as new data become available.

APPENDIX H

Copies of the Boons Pond Preliminary report were made available for federal, state, and local review at the locations listed on the following page. The comment letters are enclosed on the following pages. All of the comments and corrections have been addressed in the final draft of the Boons Pond Diagnostic/Feasibility Report. The review period extended from December 1, 1981 to January 12, 1981.

Linda Moulton
Wastewater Disposal Committee
47 Marlboro Road
Stow, MA 01775
Home: 562-3764
Office: 897-7163

Richard Gelpke
Lake Boon Commission
53 Lakeside Avenue
Hudson, MA 01749
562-3535

Town of Hudson
Board of Selectmen
Hudson, MA 01749
Attn: Clayton R. Carlisle
562-9963

Town of Stow
Board of Selectmen
Stow, MA 01775
Attn: Kay Desmond
897-4514

John McGrath
Lake Boon Association
51 Hunter Avenue
Hudson, MA 01749
562-3970

Randall Library
Crescent Street
Stow, MA 01775
897-8572

Hudson Public Library
Wood Square
Hudson, MA 01749
(Available at main desk)
562-7521

Ronald G. Manfredonia
Clean Lakes Coordinator
U.S. Environmental Protection Agency
Region 1
J.F.K. Federal Building
Boston, MA 02203
223-5137

OFFICE OF THE

BOARD OF HEALTH

TOWN HALL, HUDSON, MASSACHUSETTS

01749

January 14, 1981

Barbara Notini
Division of Water Control
Box 545
Westboro, Ma.

Dear Ms. Notini:

This B oard has completed its' review of your Divion's report on the Lake Boone Study. We wish to express our thanks for this extensive, in depth study which offers us a great deal of assistance in this area. If we can be of assistance to you in any possible way in the future, please let us know.

Sincerely,

Hudson Board of Health

RG/k

January 15,1980

To: Barbara Notini
Mass. D.E.Q.E.
Division of Water Pollution Control
Water Quality and Research Section, P.O. Box 545
Westborough, Mass 01581

From: Stow Wastewater Disposal Committee (SWDC)
c/o Moulton
47 Marlboro Road
Stow, MA 01775

Re: Boons Pond Diagnostic Feasibility Study

All members of the SWDC have individually reviewed your study and the following is our concluding comments on a page by page basis. We then summarize by describing some broad concerns and posing some additional questions.

<u>page 19</u>
The management practices to overcome soil limitations, especially numbers 4 & 5 should be brought to the attention of the Planning Board and the ~~Building Inspector~~ Board of Health. This the committee will do.

<u>page 20</u>
SWDC will recommend that the Conservation and Planning groups should jointly work out by-laws to comply with the protection suggested by the IEP report. Comments on p.25 & 33 also referred.

<u>page 27</u>
Stow does not have a Department of Public Works. The corresponding agency for the dam management might be the superintendent of Streets.

<u>pages 30,67,74</u>
We recommend that the Recreation Commission be apprised of this situation and that we solicit their assistance in developing our public awareness program.

<u>page 76</u>
Correct "Figure 12" to read "Figure 13"

<u>page 87</u>
Re-zoning is supported and referred to the Stow Planning Board.

Establishment of a Watershed Protection District is supported by the SWDC and referred to the Conservation Commission. This will not be a recommendation to act solely on the Boons area but will also encompass the other important areas identified in the 1977 IEP ~~201~~ study which should be protected through Watershed Protection or re-zoning.

page 90

If road sweeping is to be considered it must be part of a town wide program. There don't appear to be any studies to support effectiveness in reducing salt pollutants. Are the sediments which would be removed that serious a contaminant that such a costly program should be undertaken.

The establishment of a septic tank maintenance program is strongly supported. The SWDC/B. of Health should try to earmark some money to establish and administer such a program. We do not agree that the program must be as expensive as that proposed here. State and federal funding might be considered, or residents in the Boons area may be legislated to assume such an expense. SWDC should investigatecmethods of handling the problem.

page 91

Conversion of seasonal homes by-law is desirable and will be referred to the Planning and Health Boards. With the assistance of the SWDC a by-law may be ready for this town meeting.

A public awareness program will be pursued by the SWDC with meetings and through our newsletter; if necessary we may contact residents on a house to house basis.(223 households). May call for assistance of other town commissions and boards.

page 92

Recommend that watershed housekeeping be addressed by us and handled along with the public awareness program.

page 95

A/I systems must be considered long-term measures and each should be presented in our communications with Lake residents. Final conclusions should be deferred until all those involved have the opportunity to understand the problem and make efforts to correct it using methods of their own choice with what resources they have. If,after a reasonable time,the effort is not made collectively or individually a determined campaign by the interested outsiders may be instituted to bring systems up to an acceptable standard using A/I systems.

Your report should deal with the State's regulatory attitude toward such systems. Our understanding is that the government's attitude is less than favorable.

page 99

The ideal situation would be to restore the tranquil atmosphere of many years ago, allowing nothing greater than a one and a half HP motor for very light boats for trolling. That not accomplished, the next solution is to ban all motors over 40HP.

page 103

Harvesting or dredging should definately be deferred until the pollutants are under control.

The SWDC further wondered if any studies have been done that relate the quality of lake water to that of residents' well water. Is there evidence that the same phosphorous and coliforms are present in high concentrations in wells? Residents in the Lake Boon area would certainly respond to such information. Appendix D (Excerpts from "Lake Boon Summary Report," MAPC, 1980) notes that "A well identification and on-going monitoring program should be established.""A well location and monitoring process could be incorporated into the septic maintenance and inspection program or organized as a separate municipal program." SWDC strongly agrees with this suggestion and should initiate interest for such well testing through a campaign aimed directly at the Lake homeowners.

A further concern is the philosphical issue in recommending that we go "all out" to slow down eutrophication. The Lake still has a finite life as a lake. How can we interest those in the community,with no direct interest in the Lake,in spending large sums of tax payers dollars to delay the inevitable. This is certainly not the time to add staff to the town for tackling this problem. It is completely unrealistic to think that any of these arguments for this lake would influence the majority of Stow's voters. The people who may be able to effect change are those directly involved in the Lake, recreational users, homeowners and interested town officials who will support reasonable legislation and reasonable, if limited,expense.

As in wastewater management for the rest of Stow we have to temper our enthusiasm for that which seems aesthically desirable and ultimately most pleasant, due to the economic and political realities of the situation. Our pragmatism extends to recommending and working for solutions which can help ease the problems and for which we are certain of gaining town-wide support, rather than pushing for causes which have no hope of passage thus leaving the whole situation unchanged.

As a sub-committee of the Board of Health, SWDC has no direct powers, instead it seeks to inform the residents of proper septic practices and functions as an advocacy group for the protection of Stow's water resources. Consistent with this role, it will draw the attention of the appropriate boards (Health, Conservation, Planning, Recreation) to relevent recommendations made in this report and seek in any way to assist in their implementation.

John Gotthardt
Barbara Jones
Lynda Moulton, Chairman
Robert Mong
Aaron Taub(B. of Health)

THE LAKE BOON COMMISSION

HUDSON AND STOW, MASSACHUSETTS

LAKE BOON

COMMISSIONERS: Stow: G. Horne
D. Powers
Hudson: R. Gelpke

December 22, 1980

Barbara Notini
Divisionof Water Pollution Control
Westboro, Mass 01581

Dear Barbara,

In response to the draft study of the Diagnostic/Feasibility study of "Boons Pond", dated November, 1980, I would like to offer the following comments.

First, I want to congratulate you and the staff of the DWPC, Westboro, for a comprehensive document containing a great deal of information. It obviously represents a great deal of effort on your part and I am especially appreciative of this. It is with this overall impression that I would make the following points:

1. I am sure many will disagree and I recognize the authority of the USGS (topographic maps) but most local residents will insist on "Lake Boon" (with or without the final 'e') as in the Commissions' name. An initial disclaimer might help.
2. (p. 17-19) Figure 5 & Table 2. I think needs more introduction to tie both together. Explanation of "percs" needed in table perhaps (footnote? glossary?) A statement that the numbers in last column go with management practices. How does the material relate?
3. (p. 22) Either here or later (p. 30?), the history section on lake uses. There needs to be discussion of the intensive housing development along the shore on small lots for seasonal use (with minimal septic facilites and water use). This is a crucial problem and was emphasized in the MAPC report and needs to be reiterated.
4. (p. 27) "north and south basins"--local use would call for First and Second basins (and third). I would recommend this to avoid confusion here.
5. (p. 31, map) Subdrainage "7" on map needs to be added as referred to on p. 81. (drainage from Cranberry Well to the south)
6. (p. 33) Regarding the W & H 201 Facilities Plan: Just 3 years ago I wrote a lengthy letter on the Suasco 208 plan (see MAPC, "Results of the Suasco Basin Review Process Preliminary Report, March, 1978, p. 87-93), a good part of which relates to this question. In brief, I would not support town sewering of the lakeshore and then exporting the groundwater to the river and out of the system.

THE LAKE BOON COMMISSION

HUDSON AND STOW, MASSACHUSETTS

LAKE BOON

COMMISSIONERS:

Dec. 22, 1980

Response to DWPC "Diagnostic/Feasibility" Boons Pond Study, p. 2

last paragraph (p. 33); by-law adoption during the May, 1980 Town Meeting.

7. (p. 34, fig 10) Map needs revision on zoning districts with Town Line change. Ex, State Forest, watershed district around White Pond, and south of 2nd & 3rd basins into residential, general. I believe Hudson has clause in zoning statute which allocates all land not otherwise classified is then classified as ...

8. p. 38) I would add the following after #4, continuing the sentence: "and the location noted on a detailed map and a photo taken directly on shore. Additionally a continuous monitoring of the conductivity/florescence and location is recorded on a tape and coordinated with location."

9. (p. 50 top) Might more be made of the road salt into the lake via runoff? This will appear later as well, but there are a number of areas where the street drainage is direct into the lake and there is no filtration at all.

10. (p. 50 & 55) Regarding the solids; suspended and dissolved. On dissolved--how derived or eliminated? will settle or remove? A paragraph on this, related to lake activity? (for us non-chemists) Iron & manganese? any implications?

11. (p. 65) 2nd paragraph: what is nitrate more typical of?

12. (p. 74) End of phytoplankton section; more needs to be said on why. Natural or induced? control? What it looks like during a "bloom" (p. 67).

13. (p. p. 75, fig 12) Why such confusing notations on the map to identify the plant species?

14. (p. 76) Under "septic snooper..", line 8: Figure 12 should be figure 13. What are the implications of incoming groundwater with higher nutrients? Needs to be drawn out more.

15. (p. 81) A paragraph or so on how water budget is derived and the importance would, I think, be helpful.

16. (p. 85-86, Conclusions)

- #2. What is the basis for the eutrophic point system? meaning of severity points here? no basis for this.
- #11. Is this typical? Important? Any implications for control?
- #12. Results from Hudson/Stow BofH dye tests?

I would add the following additional conclusions if you think that may be appropriate:

- #21. That the lake is shallow and there is a relationship between depth and prop wash and turbidity.
- #22. The small size of the watershed in relation to the lake. The implications for the lake are immediate, (severe?), short resident time of water (or long?), flushing time, etc.

THE LAKE BOON COMMISSION

HUDSON AND STOW, MASSACHUSETTS
LAKE BOON

COMMISSIONERS:

Dec. 22, 1980

Response to DWPC "Diagnostic/Feasibility" Boons Pond Study, p. 3

#23. Deciduous v. evergreen trees lining the shoreline. Altho much is now pine there is some oak, birch, etc. Impact of needles v. leaves in decay?

#24. High biomass content, potential for further growth? other impacts of this?

#25. Fundamentally, the lake is a plain shallow, enlarged, dammed lake that is warm due to sunlite penetration, and was never oligotrophic.

17. Under "Watershed Road Sweeping Program"--berming and installing catch basins (with good size sumps) for sediment detention. Will filtration adsorb/absorb any dissolved material? Help in delay of surface coliform in runoff? especially where boat ramps and other roads where surface flow is direct into the lake. Again (p. 90)--"Establishing Septic Tank..." major pollutant input because, as noted, groundwater inflow especially during dry weather is high; needs emphasis.

18. (p. 91) Conversion; Hudson has bylaw (altho it needs better definition), Stow is 1½ acres. This really needed then?
Public Awareness Program: How about signs ("now entering Lake Boon Watershed") on the 7 town roads that cross the watershed? To emphasize its existence. This may bring home the watershed concept. Cost shouldn't be that much, via public works depts of towns. Also, literature available at business and groups in the watershed would be helpful.

19. (p. 99-100) Boat Regulations: The Commission needs to hear about experiences elsewhere where boats have been controlled for pollution reasons; and current research results on prop wash, depths, and impacts on suspended solids and sediment release. Voluntary compliance will be hard to achieve without this data.

20. Conclusions: I would add, somewhere around #'s 7 & 8, perhaps some comments on the feasibility of some small communal systems for several of the severely overloaded septic areas (if the social, political, legal and economic realities permitted this). I don't think that lot by lot "improvements" will make all that much impact. Anyway, this is only an alternative recommendation. Waterless toilets?

Again, as noted at the outset, I appreciate all the work that you and the Division have done and thanx for the opportunity to comment on this. I hope the above are useful in preparing the final document.

Sincerely,

Dick

Richard Gelpke

Metropolitan Area Planning Council 44 School St. Boston MA 02108 Tele. 617/523-2454

January 13, 1981

Ms. Barbara Notini
Division of Water Pollution Control
Water Quality and Research Section
P.O. Box 545
Westview Bldg., Lyman School
Westboro, Mass. 01581

RE: Lake Boon Diagnostic Feasibility Preliminary Report

Dear Ms. Notini:

At the request of the Lake Boon Commission, I have reviewed the Lake Boon Preliminary Report and have the following comments to offer:

Watershed Management Techniques

1. Implementation of zoning recommendations was estimated to cost between $4,000.00 and $8,000.00 for consultant services. The report should also include less costly means of instituting zoning changes, such as the use of town personnel, committees, or assistance from regional and state agencies.

2. Elevated chloride levels were cited as one of Lake Boon's water quality problems, however, reduction in the use of road de-icing salt within the watershed was not recommended.

3. The term "septage" was misused throughout the watershed management section of the report. Septage refers to the solids that accumulate at the bottom of the septic tank as a result of settling from the wastewater. Septage disposal, therefore, does not usually involve on-site treatment, but rather disposal at a septage facility, lagoon, or wastewater treatment plant.

4. In addition to purchase of wetland areas, there are other wetland protection techniques that should be considered for inclusion in the report. For instance, current wetlands zoning in Stow might be expanded to include all of the wetlands within the watershed and the wetlands zoning bylaw might be revised to impose stricter standards on development occurring in wetland areas. Non-zoning wetlands bylaws can also be implemented to restrict wetlands from alteration.

5. Discussion of the proposed septic system inspection and maintenance program should include a comparative cost estimate for periodic pumping at the owner's expense.

6. The Board of Health may adopt a variety of regulations pertaining to rehabilitation of septic systems, increasing the setback distance from

surface water bodies, or imposing a minimum as well as a maximum percolation rate. These options should be mentioned in the report.

7. Sewage hook-ups were suggested as a possible future consideration for wastewater disposal. According to MAPC's Lake Boon Report, the towns of Hudson and Stow have no plans to sewer the watershed area. If the Diagnostic Feasibility Study considers sewering a viable option for Lake Boon, then a summary of environmental impacts commonly associated with sewer extentions should be included in the report.

8. Cost estimates for alternative on-site sewage disposal systems were given in the report for economic comparison of the various systems. It would be helpful to desceibe the advantages and disadvantages of the systems in environmental terms so that the most appropriate alternatives for Lake Boon can be determined.

In-Lake Techniques

1. Discussion of power boat impacts on Lake Boon was limited to resuspension of bottom sediments. Other impacts associated with power boats, such as pollution from fuel, algicides, fungicides, and wastewater should also be mentioned. The report should consider recommending a mandatory 10 horsepower limit on all boats. During lake restoration procedures, a total ban on all power boats should also be considered.

2. The use of algicides and herbicides was included as an in-lake management technique for control fo aquatic plant growth. Silvex was cautioned against due to possible crop damage if the water is subsequently used for irrigation. Recently, research on silvex has linked the chemical to genetic disorders and high incidence of miscarriages in women. In fact, as of February 1979, EPA has suspended all uses of silvex except for certain industrial and silvicultural applications. It is recommended, therefore, that silvex be omitted from the report as a possible herbicide for aquatic plant control at Lake Boon.

3. Nutrient inactivation techniques should include an explanation of the limiting nutrient in Lake Boon and the rationale behind the suggested nutrient inactivation techniques. The relative significance of nitrogen and micronutrients such as iron should also be discussed.

4. The discussion of macrophytic growth removal should mention biological substitution as a possible method of encouraging the establishment of macrophytes that cause less interference with recreational activities than Cabomba.

5. In view of the fact that Lake Boon is recharged by groundwater, the lake drawdown technique may not be as effective as other restoration techniques. The possibility of groundwater counteracting drawdown should be discussed.

Conclusions

1. The conclusions should include more information on the lake's recharge characteristics. Specifically, the turnover rate (flushing period) of the lake should be stated, as it is the primary indicator of the lake's ability to renew itself. Groundwater was mentioned as an important source of recharge, however,

the watershed area should also be included as a measure of surface water recharge to the lake.

2. A conclusion should be made with respect to Lake Boon's limiting nutrient. The report discusses the control of phosphorus quite extensively, but does not assess nitrogenous pollutant inputs. The N/P ratio should be stated along with an explanation of the ratio, to justify the report's emphasis on phosphorus control.

3. The lakes classification system, developed by the Division of Water Pollution Control, should be explained. The point range of each trophic status should be given to indicate Lake Boon's relative degree of eutrophication.

In general, the report was very informative and compliments MAPC's Lake Boon report very well. The joint effort of MAPC and DEQE should provide the towns of Hudson and Stow with the information needed to implement an effective watershed and lake restoration program.

I hope these comments can be useful for the final drafting of the Diagnostic Feasibility Report. If I may be of further assistance, please do not hesitate to contact me.

Very truly yours,

Arleen C. O'Donnell
Water Quality Planner

ACO/cem

cc: Mr. Richard Gelpe,
Commissioner, Lake Boon Commission
Allison Harper,
Director, Land Use and Environmental Quality

BARBARA NETINI
DWPC

BARBARA

THANK YOU FOR THE PRELIMINARY REPORT OF THE "BOONS POND" DIAGNOSTIC FEASIBILITY STUDY. IT PROVED TO BE VERY INTERRESTING AND INFORMATIVE.

OUR BIGGEST TASK AT HAND AT THIS TIME IS INFORMING OR RATHER CONVINCING THE LAKE BOON RESIDENTS THAT A POTENTIAL PROBLEM EXISTS, ESPECIALLY IF WE DO SOMETHING NOW TO STOP IT. UNFORTUNATELY A VERY LARGE SEGMENT OF OUR LAKESIDE POPULATION BELIEVES THE SAYING "EAT DRINK AND BE MERRY ---". SOME MEETINGS HAVE BEEN HELD, HOWEVER, SINCE YOU WERE LAST HERE AND WE HAVE BEEN GATHERING SOME MOMENTUM.

FROM THE HUDSON POINT OF VIEW, FUNDS FROM THE TOWN WILL BE NON EXISTENT. THIS IS THE OPINION EXPRESSED BY A TOWN SELECTMAN WHO ATTENDED OUR LAST MEETING, SO WE WILL BE ON OUR OWN MONETARILY SO INITIALLY WE WILL HAVE TO WORK ON INEXPENSIVE PROJECTS.

IN DEALING WITH THE TOWN COMMITTIES AND LAKE RESIDENTS I FIND THAT PEOPLE ARE LOOKING FOR SPECIFICS, SOMETHING THEY CAN POINT A FINGER AT. FOR EXAMPLE IS ROAD RUNOFF A REAL PROBLEM, IS SEPTIC A PROBLEM, ARE MOTOR BOATS A PROBLEM. PERHAPS THE FINAL REPORT CAN DEFINE DIRECTLY THESE PROBLEMS. BOTH HUDSON AND STOW DID DYE TESTS FOR SEPTIC SYSTEMS (MINIMALLY) AND CAME UP WITH NOTHING. PERHAPS YOU CAN DEFINE PROPER PROCEDURES FOR TOWNS TO RUN THESE TESTS.

ZONING, OF COURSE IS AN ISSUE THAT WE WILL PURSUE IN HUDSON. IT SHOULD BE INEXPENSIVE BUT AGAIN WE NEED SPECIFICS AND PERHAPS EXTRA EMPHASIS ON ZONING IN YOUR FINAL REPORT

HUDSON HAS A PROBLEM WITH INSUFFICIENT DRINKING WATER SUPPLY SO PERHAPS WE COULD CONVINCE THE TOWN OF HUDSON TO HELP EDUCATE THE RESIDENTS ON RECYCLING BATH AND LAUNDRY WASTE WATER FOR FLUSHING. "KILL TWO BIRDS WITH ONE STONE" PERHAPS YOU CAN MENTION THAT?

ONE MODERATELY EASY SOLUTION WOULD BE TO LOWER THE LAKE LEVEL SEVERAL FEET IN ORDER TO "DRY KILL" THE WEEDS. PERHAPS ONE METHOD OF LOWERING THE LAKE BELOW TWO FEET WITHOUT DAMAGING AND RE BUILDING THE BARTON ROAD DAM WOULD BE TO USE SEVERAL WIDE HOSES AND USE THEM AS A SIPHON AS THE RIVER LEVEL IS MUCH LOWER THAN THE LAKE

THANK YOU

John M McGrath

JOHN McGRATH
PRES. LAKE BOON ASST.
51 HUNTER AVE
HUDSON MA
01749

P20 ¶2 l1

Predominant soil type is identified as Paxton, in some contrast to information in Fig 4 and text identifying Hinkley-Windsor-Muck types.

P85 ff Conclusions + recommendations

Despite the enormous (seeming) data base and accompanying descriptions, it is nowhere demonstrated what the quantitative division of nutrient budget is — that is, what the effect of human habitation is on the lake's development.

The ~~[illegible]~~ only figure of interest is found on P93 ¶3, where an estimate of phosphorous loading due to homes is given as larger than 18% of the estimated nutrient budget (divided how, between phosphorous & nitrogen?)

The conclusion to be drawn from this data is that total elimination of sewage run-off would not necessarily have much effect on the lake. Either I'm real dumb, and I've missed something important, or the report is missing some vital analysis.

Therefore, the recommendations are ~~[illegible]~~ vague — after 100 pages of quantitative stuff, the recommendations are non-quantitative. There is no estimate of the magnitude of restoration resulting from any of the recommended measures. I think this causes some confusion. Perhaps a shallow lake is supposed to be weedy!

Dr. Richard Stein
19 Hale Rd
568-1310

1/18/81

COMMENTS ON THE LAKE BOON DIAGNOSTIC/FEASIBILITY STUDY.

1) I believe that the watershed area should be rezoned in Hudson to require a minimum of 1 acre lots.

2) I believe that no salt should be used on the roads within the watershed.

3) I think that Septic tanks should be inspected where it has been established that there is leakage into the lake. This would not require additional personnel, as would a general (total) inspection program.

4) The conversion of Seasonal Homes (in Hudson) has already been regulated.

5) I think that the Lake Boon Association should establish a publicity chairman, part of whose job should be to provide a steady stream of publicity about the lake in order to assure a high level of public awareness.

6) If it can be established that there are concentrated areas which would benefit from a common septic system (a mini-public system) then this avenue of approach should be investigated. This should be co-ordinated by the DPW of each town with a committee of concerned citizens from the affected areas.

7) I think that the lake should be drawn down as low as possible next winter in order to kill as many weeds as possible by exposure. At that time each homeowner that has both the desire and the ability will have the opportunity to clear out as far into the lake as feasible.

8) Dry dredging seems to be a potentially cost-effective way to clear the lake. It is entirely possible that it could be paid for by assessment of people who live in the confines of the watershed. Example, $80,000 ÷ 400 homes = 200 $/HOME

9) I believe the introduction of the [illegible] Carp should be studied as quickly as possible. It was not given much exposure in this report.

There have been many alternative toilet system costs mentioned in this report. Could the price of these be substantially reduced by pooling of purchasing power? It is possible that many people on the lake would be interested in conversion at a ~~reasonable~~ cost (which presumably could be obtained by mass purchasing of these units.)

I would be against introduction of chemical destruction of the weeds.

CARL BENANDER
21 WORCESTER AVE
HUDSON, MA. 01749
562-7681

Comments on the Preliminary Diagnostic/Feasibility Study

Being a new resident, I am basing much of my comments on certain assumptions.

It should be noted that there is one apparent error that I found in the report. In table 31(page 85), the average yearly discharge is computed as the mean of fifteen values. Although it was stated that precipitation was constant, or fairly so, during the year, I would suspect this mean to be biased. If computed on a seasonal basis, it would be .099 m^3/sec, or about 825 million gallons/year.

I have heard that the town of Hudson uses the White Pond Reservoir for its water supply. If this is the case, if 500,000 gallons per day were withdrawn from the reservoir, this would represent 18% of the available water. There appears to be no mention in the report of the impact of this abortive removal of the water. With continued town growth(my figures show a 23% growth rate from 1965 to 1975) would the increased consumption only thwart any efforts we take to improve the condition of the lake?

Mention has been made of the lack of funds available to any effort. If the above is true, would it not seem reasonable to expect that some of the revenues received for the water should be used to improve the condition of the watershed? Thus, the utility would be operated at an apparent profit, as much as it may hurt politically, with the "profit" being used to"return to the land,what is being taken from it."

Richard Snashall
25-27 Lakeside Ave.

50 Old County Rd. ,Hudson, MA 01749

Jan 22, 1981

Miss Barbara R. Notini
Department of Environmental Quality Engineering
Divixion of Water Pollution Control
Water Quality and Research Section
Westborough, Massachusetts

Dear Barbara,

Herewith my comments on the "Boons Pond" Preliminary report, numbered in accordance with your Recommended Restoration Program on page 106 of the report.

1. Rezoning should certainly be urged, altho it may be contrary to the interests of some property owners. As to a Watershed Protection District, since the same sort of ecological problems exist for all bodies of water, whether lentic or lotic, which lie within or partly within the Town, do we then need a protection district for each such body of water?

2. What effect, if any, does NaCl have on eutrophication?

3. Septic tank maintenance and inspection is presumably the most serious problem facing the concerned residents on the lake, yet the report only states: "Septic leachate appears to be reaching the lake", and "High bacterial levels - may represent a summer water quality problem." Septic system inspection will be met with hostility by many, and cannot be accomplished without town action. Such action seems highly unlikely unless there exists, or the Town is convinced there exists, a "clear and present danger" to the public health, and this the report does not prove, in my estimation. The two sampling procedures that were supposed to detect and quantify septic leachate, namely the septic snooper survey and the seepage meter tests, were both subject to procedural errors, which casts some doubt on the validity of the results. Total and fecal coliform counts at three locations on one date are reported as "fairly high", yet no acceptable level for this 'parameter' is given.

7. and 8. Few residents of the lake watershed will lay out any substantial amount of money to modify his septic system unless he is required to do so by law. Such legislation is unlikely unless there is a clear danger to health as mentioned above, or it can be shown that a valuable resource is being destroyed, and that the legislation will restore the resource. I think the report would be greatly strengthened if examples could be cited of lakes where eutrophication has been halted.

(continued)

General comments:

The report might be more meaningful to the general reader if each technical section were preceded by a brief summary telling what property of the water was tested, what the results were, and what significance the results have to the general well being of the lake.

Along the same line, much of the technical terminology could be replaced with everyday words, with no detriment to the scientific standing of the report. Words like macrophytes, phytoplankton, bathymetric, etc, discourage the general reader, particularly when they are not included in the glossary.

Despite all the foregoing, Barbara, I think you have put together a fine report, representing a lot of hard work, and a great service to the residents of the Lake area. I look forward to meeting you again, and to reading the final report when published.

Sincerely,
Alan D Kattelle
Alan D. Kattelle