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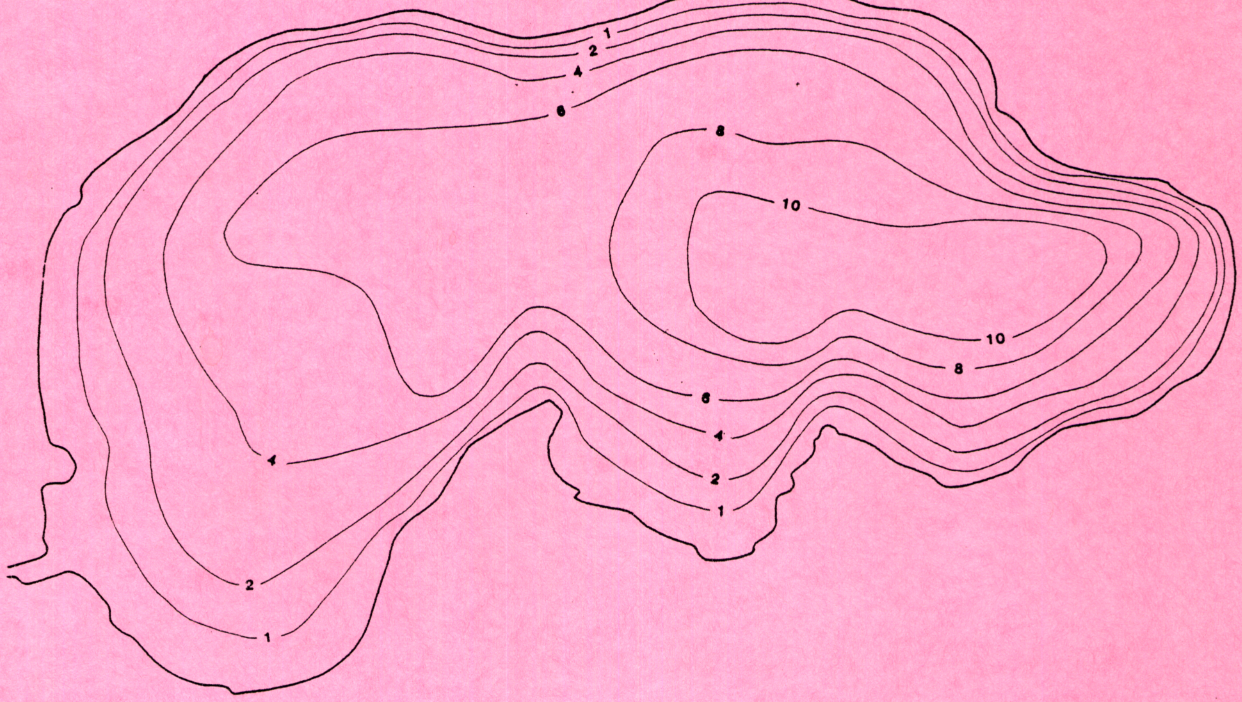
DIAGNOSTIC-FEASIBILITY STUDY
of Seven
Metropolitan Area Lakes

Part Two: *Spring Lake*



Metropolitan Council
of the Twin Cities Area

September 1983

DIAGNOSTIC-FEASIBILITY STUDY OF SEVEN METROPOLITAN AREA LAKES

Part Two: Spring Lake

by

Richard A. Osgood

Metropolitan Council of the Twin Cities Area
300 Metro Square Building, 7th and Robert Streets
St. Paul, Minnesota 55101
Telephone: (612) 291-6359

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ABOUT THIS REPORT

The Metropolitan Council collected water quality data in a limited number of the Area's lakes and streams during 1980 (Osgood 1981; Oberts 1982) in connection with its surface water management planning efforts mandated by Section 208 of the Clean Water Act. Fundamental differences between the character of runoff in mainstem streams and urban storm sewered watersheds and the watersheds of Area lakes were noted. Thus, assessing the impacts of nonpoint source pollution on lake water quality using extrapolations from differing watershed types was not satisfactory. The Council then proposed a follow-up study (September 1980) to better define these relationships in several Area lakes and their watersheds. As data collection was no longer eligible for 208 funding, a Phase I Diagnostic-Feasibility study grant under Section 314, Clean Water Act was obtained. The primary objective of this study is to diagnose problems in these lakes, identify their causes and define remedial programs. However, an equally important objective of this study is to obtain data that will be used with data obtained in 1980 in better defining a relationship between watershed characteristics and water quality.

The feasibility of protecting/restoring seven Metropolitan Area lakes is specifically examined in this series. Generalized runoff water quality relationships requiring data collected from this study and also from a previous study (Oberts 1982; Payne et al. 1982), the 1980 208 work, will be examined in a companion follow-up study.

INTRODUCTION

This report contains the detailed analyses, findings, conclusions and recommendations for the examination of feasible restoration/protection alternatives for Spring Lake, Minnesota.

A general approach to the methods employed is found in "Diagnostic-Feasibility Study of Seven Metropolitan Area Lakes: Part One." As such, this report is more or less an analysis worksheet containing summaries of the results, analysis and examination and discussion of alternative management methods specifically for Spring Lake. Only essential analytical summary and detail are found in this report with the general methods, raw data and literature cited found in Part One.

SUMMARY AND CONCLUSIONS

Spring Lake is located in a large, agricultural watershed. The lake itself is large, but relatively shallow. Spring Lake is very fertile, receiving nutrients from runoff and from internal sources. The great fertility causes legendary algal growths. The blue-green algae that normally blooms is an incredible nuisance, and has been toxic in the past (four dogs died after drinking lake water in 1980; Minneapolis Tribune, July 1, 1980).

The lake's dominant algae, Aphanizomenon, grows in flake form under the conditions found in Spring Lake. These flakes are unsightly, but also profoundly influences the lake's internal nutrient dynamics. Certain life-history characteristics of this alga act to transport phosphorus (and other nutrients) from their deposition site (lake sediments) back into the water. These algae will resist efforts at nutrient reduction in the lake; in fact, it appears theoretically possible that algae could increase in abundance with nutrient reductions! Improving the water quality of Spring Lake requires both that the character of the algal community be changed and that phosphorus in the lake be substantially reduced. Improvements in water quality may occur if phosphorus from all sources is reduced by greater than 1,500 kg/year. This minimum reduction is judged to be extremely difficult to attain, thus water quality improvement in Spring Lake would be extremely difficult to attain.

RECOMMENDATIONS

Prior Lake-Spring Lake Watershed District should:

A. Continue to monitor lake water quality as detailed in this plan in order to better understand the lake's ecology and to establish baseline data.

B. Continue to monitor the quantity and quality of water in the watershed as detailed in this plan and prepare annual phosphorus and water budgets.

C. Continue their efforts to improve the lake's water quality with the understanding that improvements are not likely to occur with annual phosphorus reductions of less than 1,500 kg. These efforts may include research to better understand the lake's biology and internal nutrient loading mechanisms or projects with unknown chances for success.

DIAGNOSTIC STUDY

Spring Lake is located in Scott County, Minnesota, about 22 kilometers southwest of Minneapolis (Minnesota Department of Natural Resources ö70-0054; Lat. 44:42.05, Long. 93:28.21). It is located in the Prior Lake-Spring Lake Watershed District. Spring Lake has two inlets, one is ephemeral and one outlet. The lake is classified by the Minnesota Pollution Control Agency (MPCA) as 2B, 2C, 3B, 3C, 4A, 4B, 5 and 6 in the classification system for intrastate waters of Minnesota, 6 MCAR sec. 4.8024.

The Spring Lake watershed lies in glacial till related to the Des Moines lobe of the Wisconsin glaciation, some lake deposits are associated with the till. Three soil associations occur in the watershed: Cordova-Lester-Clarion, Lester-Cordova-Hayden and Hayden-Lester-Caron. The first consists of poorly drained Cordova soils which are found in nearly level areas, well drained Lester soils found on gentle slopes and Clarion soils which are well drained and occur on gentle slopes. The second association has Lester and Cordova soils as well as the well drained Hayden soils found on undulating slopes and hills. The third association consists of Hayden and Lester soils and very poorly drained organic Caron soils found in depressions. Sediment production is about 5,589 kg/ha/yr; sediment production is defined as the amount of soil loss reaching a water body as an average annual volume (Oberts and Jouseau 1979).

The contributing land area within the Spring Lake watershed is 47.2 km^2. The population in that area is 1,706, thus population density is 36.1 persons per km^2. The major land use in the watershed is cropland with wetlands, grassland, woodland, pastureland and some residential. Other land uses are relatively minor. Details about land use are found in Results. There are 117 housing units within 91.5 meters (300 feet) of the lake that have septic systems. There have been no point source discharges to the lake for at least five years.

Census data for Spring Lake Township (1980), the town in which Spring Lake is located, provides an outline of the economic structure of the population residing near the lake:

Annual Income (dollars)	Number of Households in that Income Range	Percent of Total Households
Less than 2,500	12	2.2
2,500 - 9,999	40	7.3
10,000 - 19,999	148	27.1
20,000 - 29,999	141	25.8
30,000 - 39,999	105	19.2
40,000 - 49,999	61	11.1
50,000 - 74,999	31	5.7
75,000 +	9	1.6
	547	

The median income for Spring Lake Township is $24,906, the mean income is $27,204. There are 2,142 people residing in the township.

Spring Lake is one of 942 lakes located in the seven county Metropolitan Area. The population of the Region is about 2 million. Approximately 16.5 million water-related recreation occasions take place annually in the Region. A 162 ha regional park is under development to the north of Spring Lake. A boat launch is proposed for the park, as is a separate swimming area, campground, picnic area and trail system. No data exist to document historical use of the lake; projections for use of the park include 47,000 summer visits in the year 2000. There is no public transportation available to points within one mile of the lake.

Spring Lake is used principally for fishing, it has populations of northerns, crappies and walleyes. Swimming has not been popular in the lake for some time. Further lake degradation may adversely affect activities on the lakeshore and fishing.

Historical limnological data for Spring Lake are sparse. The MnDNR surveyed the lake in 1940, 1948, 1954, 1973 and 1982. MPCA measured total phosphorus in 1979. The Metropolitan Council conducted lake surveys in 1980, 1981 and 1982. There are too few data to indicate changes in lake trophic state. However, the past values of several trophic indicators are within the range of recent values. No change in trophic status since 1940 may be inferred from this information. Biological resources and ecological relationships in Spring Lake are discussed later in this paper.

RESULTS

A. WATERSHED AND BASIN CHARACTERISTICS

Spring Lake has a large watershed. Runoff monitoring stations and their subwatersheds are shown in Figure 1. Table 1 summarizes land use in Spring Lake's watershed. Other watershed characteristics are found in Table 2.

Spring Lake's watershed is largely agricultural; 57 percent (2,710 ha) crops and pastureland. Other significant land uses include natural areas (grassland and woodland, 17 percent) and wetlands (15 percent). These percentages are computed excluding non-contributing and open water areas. Residential accounts for less than six percent of the watershed area.

In-lake sample site locations are shown in Figure 2 with Spring Lake basin morphometry as follows:

Maximum Length = 2.57 km
Surface Area = 255.3 ha
Mean Breadth = 0.99 km
Shoreline Length = 8.1 km

Maximum Depth = 10.4 m
Volume = $14.4 \times 10^6 m^3$
Mean Depth = 5.63 m

Spring Lake is broad, particularly with respect to the prevailing wind direction (westerly). Due to its orientation and depth, Spring Lake mixes quite frequently during the summer (polymictic).

B. HYDROLOGIC/PHOSPHORUS BUDGETS

Runoff information was collected over a 15 month period. Annual and seasonal loading rates are summarized as follows:

Season	Inclusive Dates	Number of Days
Fall '81	12 October - 31 December 1981	80
Snowmelt	1 January - 22 April, 1982	112
Spring	23 April - 1 June, 1982	40
Early Summer	2 June - 17 July, 1982	46
Late Summer	18 July - 4 September, 1982	49
Fall '82	5 September - 31 December, 1982	118

Annual rates are computed as the water year 1982 (12 October 1981 to 4 September 1982; 327 days) and as the calendar year 1982 (365 days). Calendar year 1982 had about nine percent more precipitation than normal (Nelson and Brown 1983).

Loading (and export) of water and phosphorus to/from Spring Lake is shown in Figure 3. Seasonal loading budgets appear in Table 3. Water load to Spring Lake (precipitation, stream inflow and groundwater inflow) is $9.356/11.431 \times 10^6 m^3$/year (water/calendar year). Of this input, half (55/45 percent) enters during snowmelt. Phosphorus load to Spring lake is 2,181/ 2,645 kg/year. Of this load, the largest proportion (80/80 percent) is from stream inflow. Snowmelt accounts for the largest portion of stream inflow (77/64 percent). Phosphorus loading can also be significant in the fall (6/23 percent) and annual input from nearshore septic systems is small (5/5 percent).

Figure 1.
SPRING LAKE WATERSHED

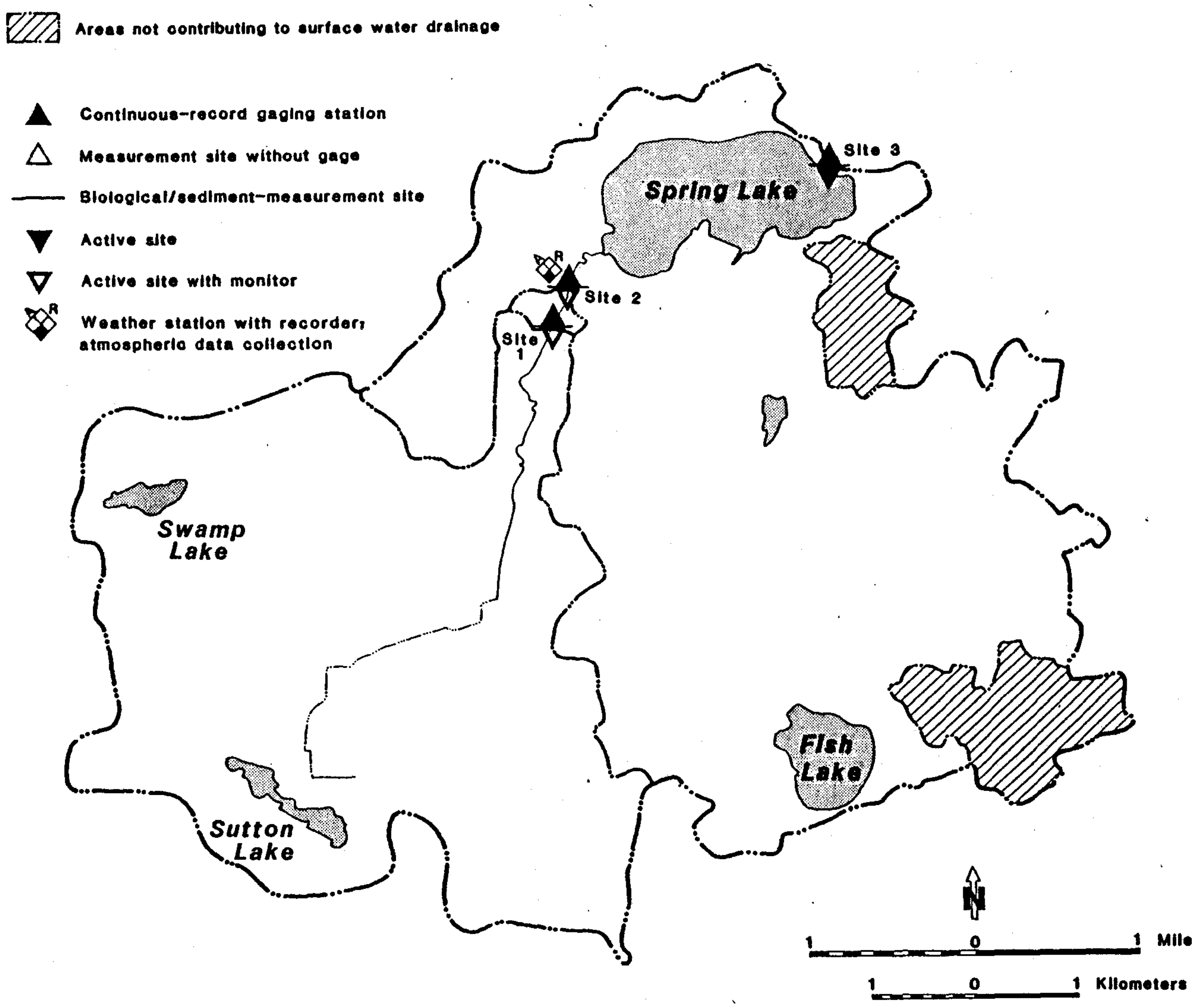


Table 1
LAND USES - SPRING LAKE

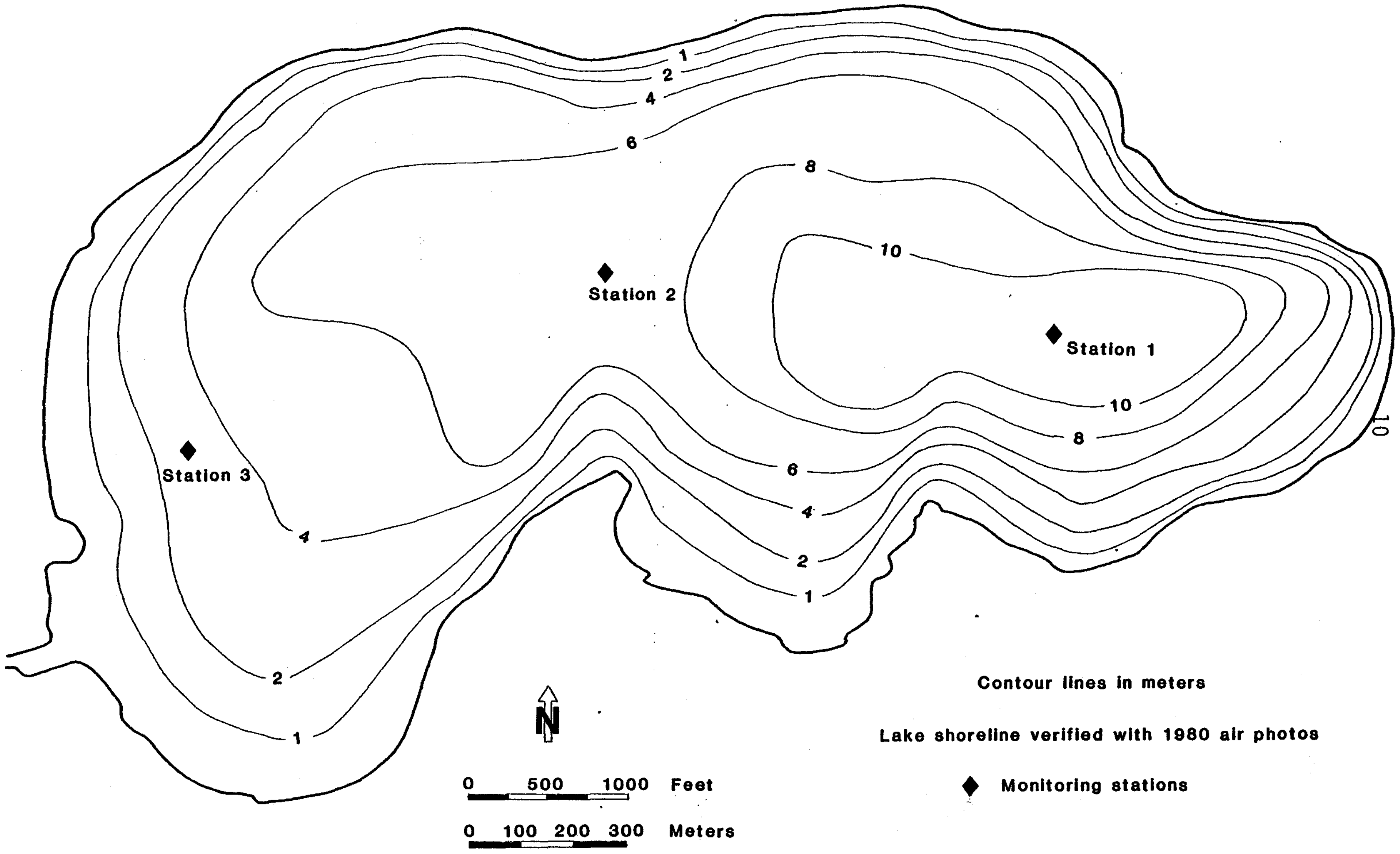
Land Use (ha)	Subwatershed Site 1	Subwatershed Site 2	Remaining Watershed	Total
Low-density residential	56.9	0.5	180.5	237.9
Medium-density residential	8.5	--	22.3	30.8
Multifamily	--	--	--	--
Wetlands	330.8	10.1	351.6	692.5
Open water	31.1	--	322.0*	363.1
Parks, Open Space	0.8	10.1	351.6	692.5
Commercial, Industrial, Institutional	1.6	--	0.5	2.1
Crops	1,270.6	8.7	1,107.4	2,386.7
Pastureland	143.8	--	179.2	323.0
Grassland	152.0	3.8	272.2	428.0
Woodland	121.5	1.7	248.4	371.6
Other	10.0	--	0.8	10.8
Miscellaneous, Error	128.5	-0.2	99.6	227.9
Total Contributing Area	2,256.0	24.6	2,803.9	5,084.5
Total Noncontributing Area	--	--	297.9	297.9
Total Watershed Area				5,382.4

* Includes Spring Lake (255.3 ha).

Table 2
WATERSHED CHARACTERISTICS - SPRING LAKE

	Subwatershed Site 1	Subwatershed Site 2	Remaining Watershed	Total
Area under construction (ha)	--	--	10.6	10.6
Population density (persons/ha)	0.15	0.15	0.54	0.37
Relief (m)	26	11	58	58
Drainage density (m/ha)	9.95	14.87	11.37	10.72
Main channel slope (m/km)	--	--	--	0.83
Impervious area (ha)	30.8	0.4	45.7	76.9
Ditch density (m/ha)	9.2	14.87	10.97	10.20
Animal units (number)	675	0	823	1498
Length of ditches (km)	20.66	0.37	27.13	48.16

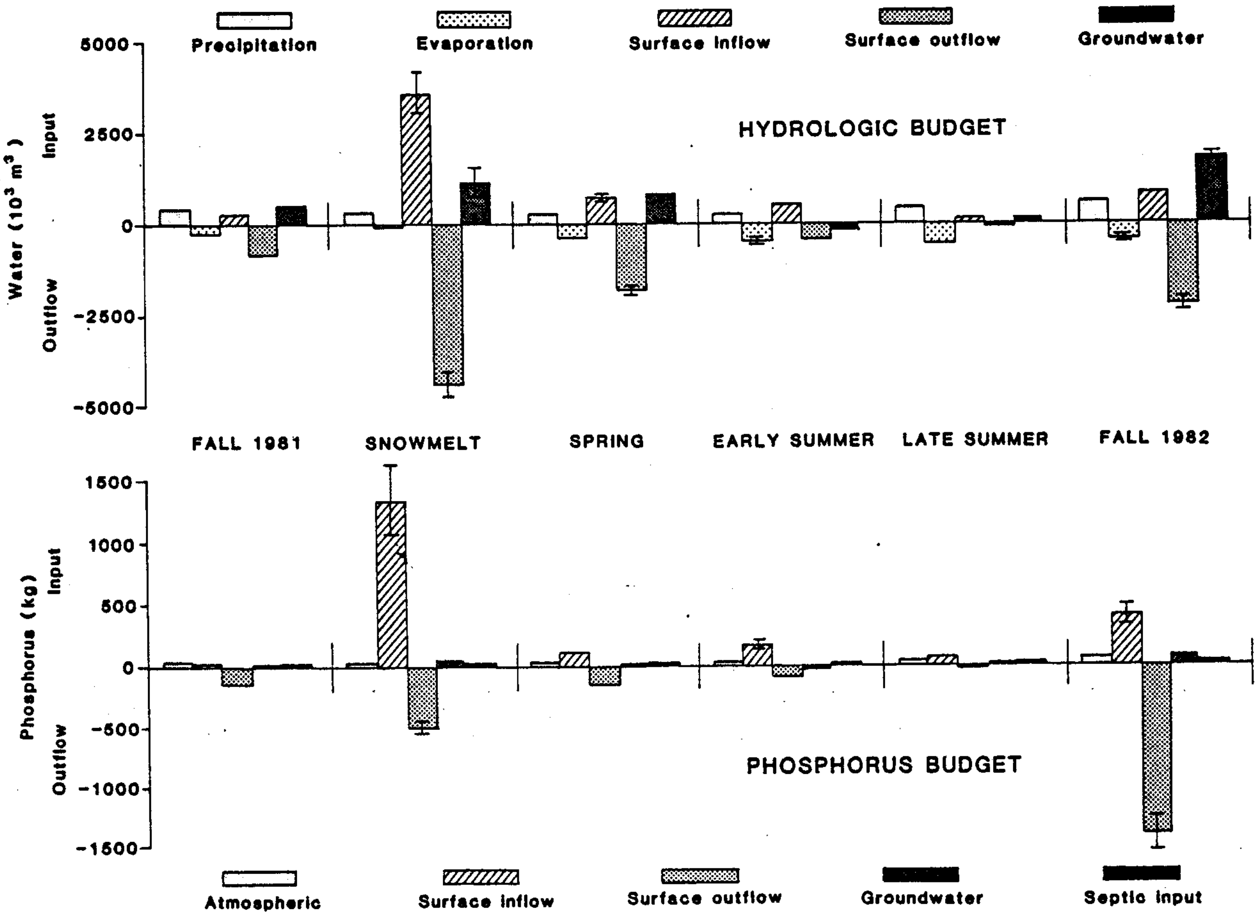
Figure 2. SPRING LAKE BASIN MORPHOLOGY



Contour lines in meters

Lake shoreline verified with 1980 air photos

◆ Monitoring stations



Note: Errors (denoted I) of less than 100,000 m^3 or 30 kg are not shown.

Figure 3. Hydrologic and Phosphorus Budgets - Spring Lake

Table 3.
HYDROLOGIC AND PHOSPHORUS BUDGETS- SPRING LAKE

	Fall 81	Snowmelt	Spring	Early Summer	Late Summer	Fall 82
HYDROLOGIC BUDGET ($10^3 m^3$)						
Precipitation	402(34)*	342(29)	261(22)	273(23)	442(37)	584(49)
Evaporation	265(62)	69(16)	405(95)	544(127)	557(13)	436(102)
Surface Inflow	250(48)	3632(625)	704(121)	522(90)	77(13)	840(144)
Surface Outflow	834(72)	4400(381)	1800(156)	470(41)	43(4)	2200(190)
Storage (Change)	+17(1)	+677(34)	-470(24)	-416(21)	-36(2)	+555(28)
Groundwater	+464(53)	+1172(468)	+770(84)	-197(68)	+45(35)	+1767(127)
PHOSPHORUS BUDGET (kg)						
Atmosphere	48(10)	34(7)	34(7)	45(10)	44(10)	61(13)
Surface Inflow	38(8)	1352(258)	122(26)	177(37)	62(13)	416(89)
Surface Outflow	135(41)	500(56)	150(17)	76(8)	4(0)	1400(156)
Groundwater	+22(6)	+54(15)	+36(10)	-26(9)	+2(1)	+82(22)
Septic Input	27(12)	38(17)	13(6)	16(7)	17(8)	40(18)

*Parameter value (+/- associated error).

C. IN-LAKE DATA

Phosphorus/Nitrogen

Spring Lake is enriched with phosphorus. Surface phosphorus concentration exceeds all accepted criteria for an eutrophic lake (Carlson 1977; Maloney 1979). Winter phosphorus concentrations, both TP and TDP (Figure 4), are 40-50 ugP/l. TP was greatly elevated by late April (123 ug/l). TDP was considerably lower, suggesting most phosphorus was particulate and associated with diatoms (Cyclotella). TP declined rapidly, to its lowest annual concentration, over the next couple of weeks. This decline corresponds to the demise of Cyclotella, which suggests removal of phosphorus from the surface by settling cells. Then, phosphorus is essentially all dissolved at this time. In mid-May, phosphorus, both TP and TDP, begin to steadily increase through the rest of the season to a maximum of 170 ug/l. This increase corresponds to bloom of blue-green algae, primarily Aphanizomenon, that persists into autumn. Aphanizomenon, which is present in "flake" form, may be bringing nutrients from the bottom waters to the surface according to the hypothesis of Lynch (1980).

Near bottom phosphorus generally follows surface values except following calm periods when the lake stratifies. During these times, hypolimnetic build-up of phosphorus exceeding 1,600 ug/l near the bottom is common. Subsequent re-circulation may partially account for the steady epilimnetic increases throughout the summer, particularly TDP (Stephan and Hanson 1981).

Nitrogen (TKN) ranges from 1.44 to 2.79 mg/l at the surface in Spring Lake (Figure 5). This relatively narrow range is common in Metropolitan Area lakes (Osgood 1981). TDKN exceeds TKN several times which suggests possible analytical difficulties. The largest proportion of particulate TKN (non-dissolved) co-occurs with Aphanizomenon flake blooms, suggesting that Aphanizomenon is not nitrogen limited. TDKN does not decline during the flake blooms (Figure 5), further sugesting that Aphanizomenon may be transporting N from the sediments (Lynch 1980). Also, the nitrogen: phosphorus ratio, which equals between 10 and 20 during the blue-green blooms (Figure 6), may influence species composition (Smith 1982) when the algal community is dominated by non-nitrogen fixing blue-greens. However, at the peak of a Chroococcus bloom (and a concurrent decline of Aphanizomenon) in mid-August, surface nitrogen (and phosphorus) was all dissolved (TDKN). Coupled with the extreme phosphorus concentrations, nitrogen may normally be non-limiting.

Except during mid-May, ammonia (NH3) and dissolved inorganic nitrogen (N/N) are at low levels (Figure 5). The elevated levels of NH3 and N/N in mid-May correspond to low chlorophyll levels and intense zooplankton grazing (indicated by high animal densities).

Temperature/Oxygen

Spring Lake is polymictic, that is, it mixes many times during the summer. Hypolimnetic (8 m) temperature increases throughout most of the summer (Figure 7). This indicates nearly complete mixing at regular intervals. The area below 8 m is thermally isolated during July and August, however, only 17 percent of the bottom surface area and 4.5 percent of the lake's volume is below this depth.

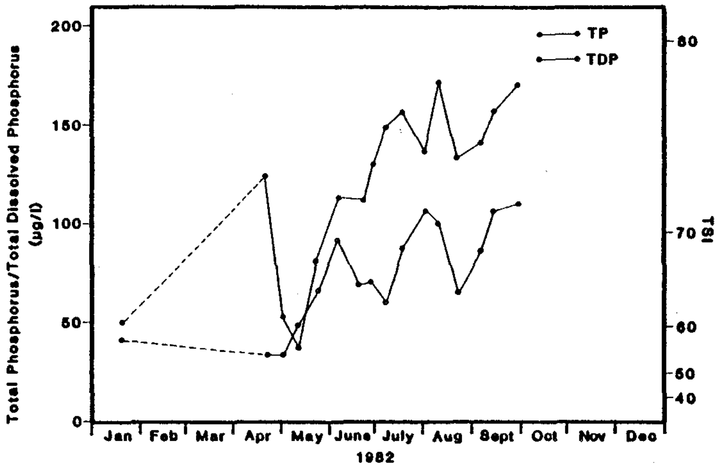


Figure 4. Surface Phosphorus - Spring Lake, Station 1. TSI from Carlson (1977)

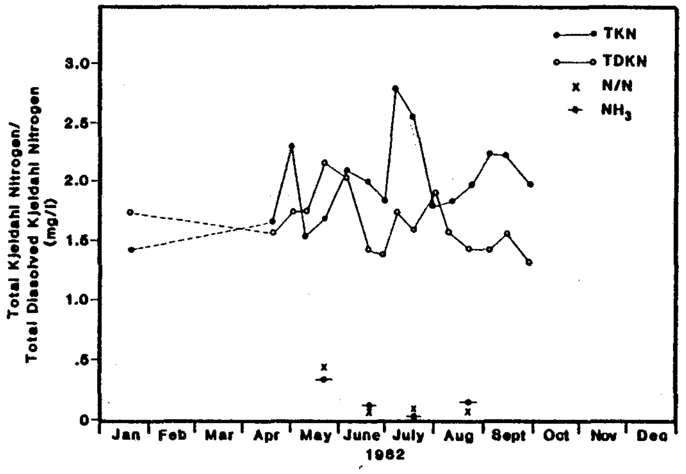


Figure 5. Surface Nitrogen (TKN, TDKN, NH_3, N/N) - Spring Lake, Station 1

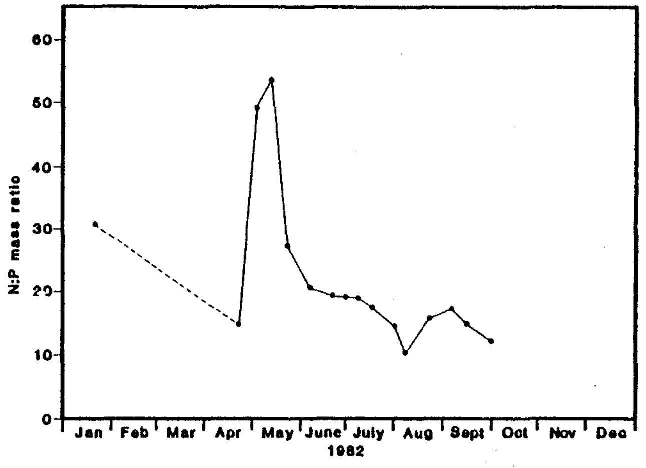


Figure 6. Nitrogen:Phosphorus Mass Ratio - Spring Lake, Surface, Station 1

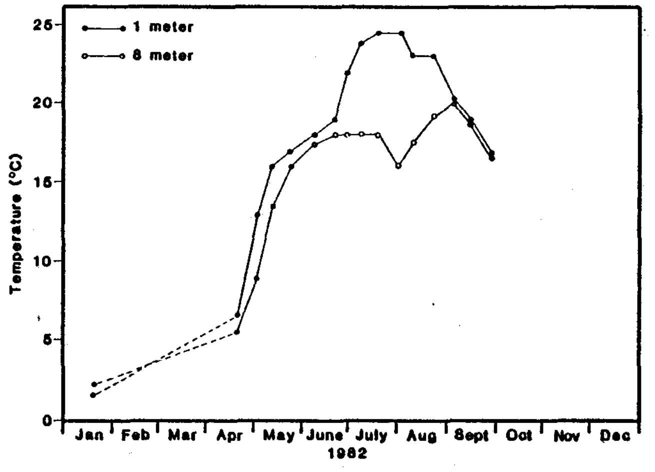


Figure 7. Surface (1 m) and Hypolimnetic (8 m) Temperature - Spring Lake, Station 1

Most of the lake is oxygenated (greater than 1 mgO_2/l above 8 m) during the year. Surface concentrations fluctuate, but commonly exceed 10 mgO_2/l. Due to deep and frequent mixing, an oxygenated sediment/water interface occurs regularly and over a large bottom area. This condition is apparently necessary for the generation of Aphanizomenon flakes (Lynch 1980; Lennon 1981; Lynch and Shapiro 1981).

Secchi Disc

Secchi disc values are normally moderate (1-2 m) throughout the summer (summer time average = 2.0 m), except during mid-May (Figure 8). These moderate values are common in the presence of populations of Aphanizomenon "flake" blooms which persist from mid-May until autumn (Lynch 1980; Osgood 1982b). The greatest transparency in mid-May (SD = 5.1 m) corresponds to the lowest standing crop of algae (as chlorophyll a).

Chlorophyll/Total Suspended Solids

Planktonic algae substantially constitute all suspended material in Spring Lake's surface waters. Chlorophyll a (Figure 9) mirrors total suspended solids (Figure 10) except on April 22 when TSS is quite low and CHL is high. This difference cannot be explained. Except during May, chlorophyll is quite high (up to 89 ug/l) during the growing season (seasonal average = 47 ug/l). The combination of a rapidly settling Cyclotella and intense grazing by Daphnia (Lynch 1980; Lennon 1981) likely accounts for the low chlorophyll levels in May. Another decline in chlorophyll is noted in early August. This is associated with a sharp decline Aphanizomenon flakes (see Phytoplankton). Finally, when Aphanizomenon flakes are present, they can be easily transported across the lake's surface. Wind re-distribution of flakes on Spring Lake is indicated by differing chlorophyll levels among the three surface sampling stations (Appendix A, Part I).

Fecal Coliform/Streptococci

Fecal coliforms and fecal streptococci are both at low levels in Spring Lake (1 m depth, Station 01). Fecal coliforms never exceed four colonies/100 ml and fecal streptococci only four times exceeded nine colonies/100 ml (max. = 45 in January). See Appendix B, Part I.

Phytoplankton

Spring Lake is characterized by Aphanizomenon flake blooms through most of the year. The dynamics of such blooms are not completely understood, but the descriptions of Lynch (1980), Lennon (1981) and Lynch and Shapiro (1981) seem to apply to Spring Lake. Briefly, they suggest that the colonialization of Aphanizomenon filaments into flakes occurs on an oxic sediment surface in the presence of large Daphnia (pulex).

The annual sequence of the phytoplankton community is illustrated by Figures 11, 12, 13 and 14 with further detail found in Appendix C, Part I. The winter community is relatively diverse (Figure 11) but sparse (200 cells/ml). Cyclotella blooms early and declines rapidly. The decline may be related to zooplankton grazing if these large cells are ingestable (Burns 1968). Settling may also account for the decline. Following the demise of Cyclotella (and substantially all other algae), the lake is quite

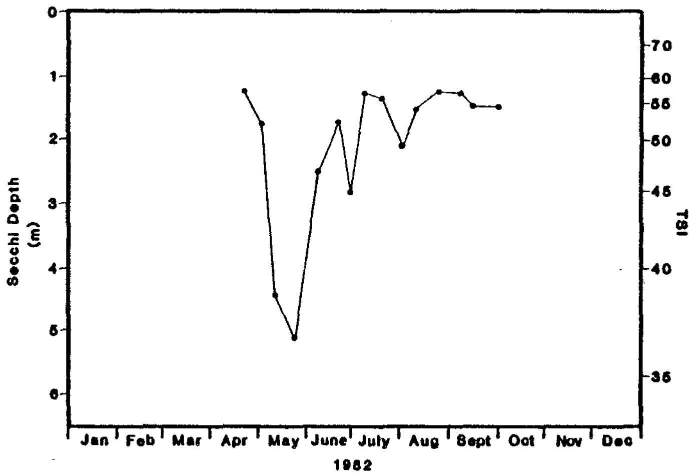


Figure 8. Secchi Disc Transparency – Spring Lake, Station 1. TSI from Carlson (1977)

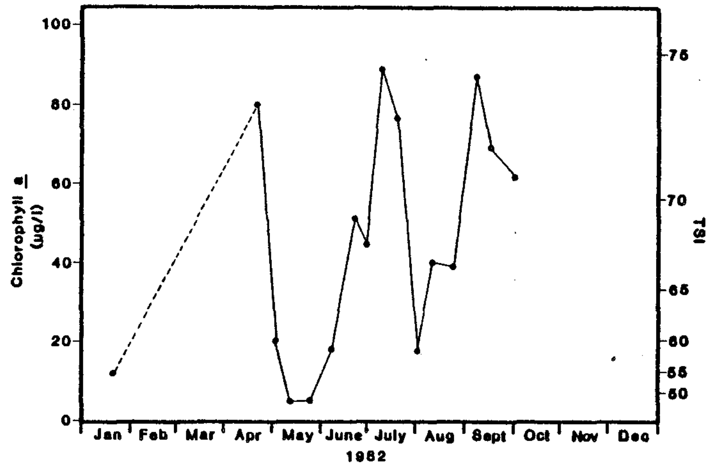


Figure 9. Surface Chlorophyll a – Spring Lake, Station 1. TSI from Carlson (1977)

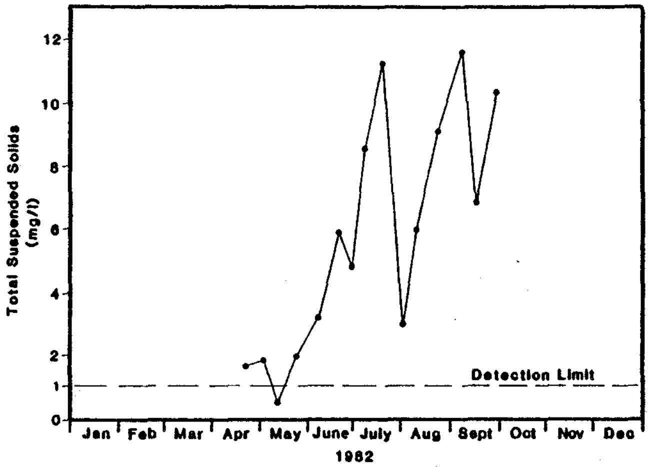


Figure 10. Surface Total Suspended Solids – Spring Lake, Station 1

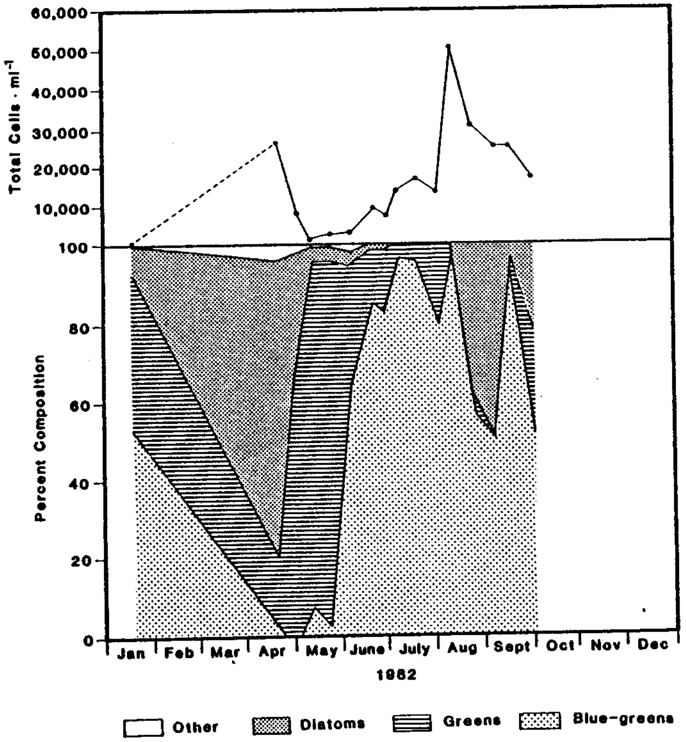


Figure 11. Phytoplankton Community Composition - Spring Lake, Station 1

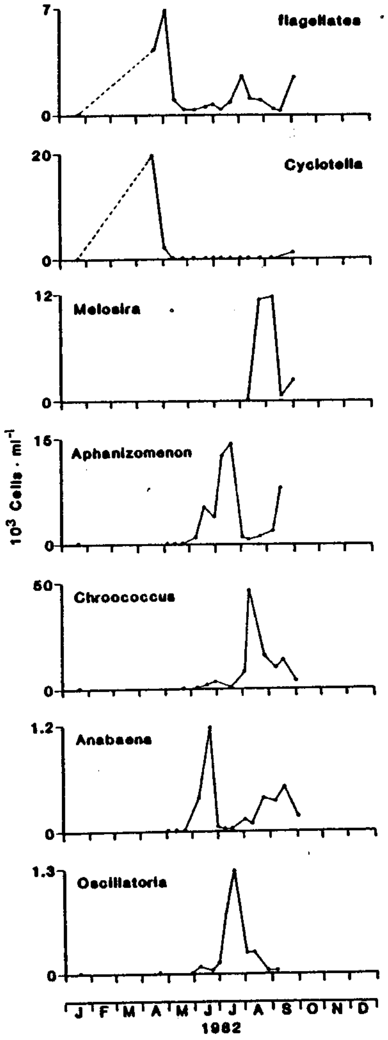


Figure 12. Seasonal Occurrence of Important Phytoplankters - Spring Lake. Flagellates include: Chlamydomonas, Chlorochromonas, and Cryptomonas.

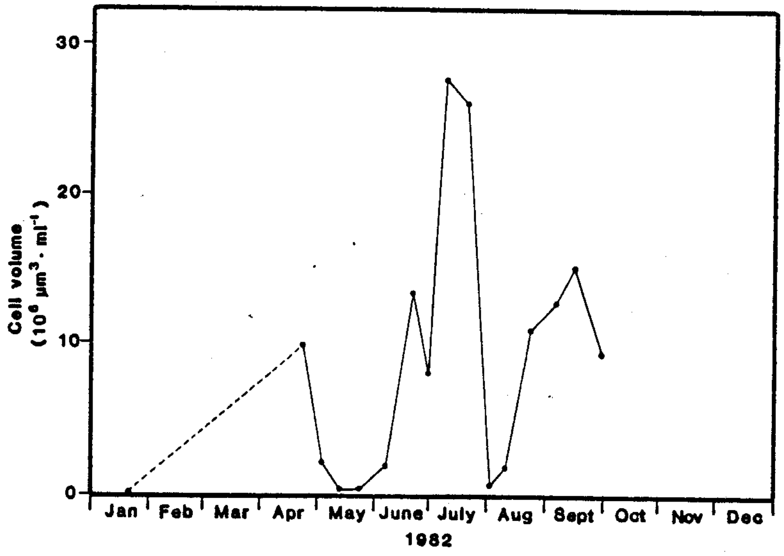


Figure 13. Phytoplankton Community Biovolume (for cells comprising at least 10 percent of community by number) - Spring Lake

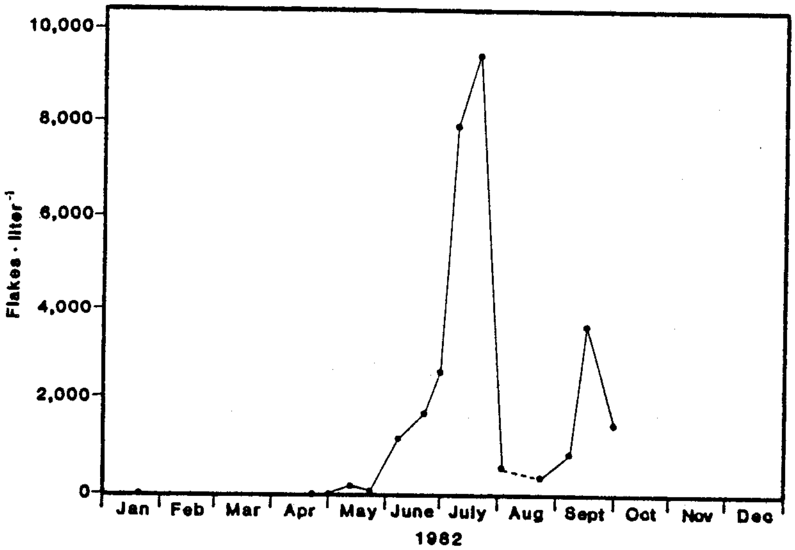


Figure 14. _Aphanizomenon_ Flake Density - Spring Lake, Station 1

clear (SD = 5.1 m) and low in phosphorus (all dissolved). Expanding zooplankton populations (see next section) efficiently graze the algae to low levels during May. This allows flake Aphanizomenon to be competitive (for nutrients) (Lynch 1980). Aphanizomenon flakes become abundant at the surface in early June and maintain dominance through most of the rest of the year (Figures 11 and 14). During a brief decline of Aphanizomenon in August, there is a dramatic increase in Chroococcus followed by a bloom of Melosira. Chroococcus expands to large numbers (about 50,000 cells/ml), but comprise a relatively small portion of community biomass. Melosira blooms briefly in late August and early September and is quickly succeeded by Aphanizomenon flakes which persist through the season. Other taxa of importance (cell numbers) include green flagellates, Anabaena and Oscillatoria; but these are seldom of great quantitative (biomass) significance.

Zooplankton

Figures 15, 16, 17 and 18 summarize the zooplankton community dynamics in Spring lake and further detail is found in Appendix D, Part I. The cladoceran community is dominated by Daphnia pulicaria, D. galeata mendotae and Chydorus (Figures 15 and 16). Other cladocerans include D. retrocurva, Diaphanosoma, Leydigia, Pleuroxus and Leptidora, but are unimportant (in terms of numbers).

The spring increase in D. pulicaria (Figure 15) is related to a rapid decline in chlorophyll (Figure 9). This increase is also related to the appearance of Aphanizomenon flakes (Figure 14) which is consistent with Lennon (1981). D. pulicaria declines to low levels in August with a concurrent reduction in CHL and Aphanizomenon flakes. D. pulicaria is replaced by D. galeata mendotae in September as the dominant Cladocera. The increase in D. galeata mendota spurs a second bloom of Aphanizomenon flakes (Figure 14).

Copepod community abundance seems to be related to the presence of high quality food (greens and diatoms) with pulses just following blooms of diatoms or flagellates (Figures 13 and 17). Dominance shifts in the community among Diaptomus, Cyclops and Mesocyclops.

Rotifers are abundant only briefly (July 19) in Spring Lake (Figure 18). This animal (Conochilus) is abundant when the filamentous blue-greens Aphanizomenon and Oscillatoria are maximum.

Trophic State

Spring Lake is eutrophic. Total phosphorus ranges from 37 to 170 ug/l at the surface, chlorophyll a (surface) ranges from 5.4 to 87 ug/l, Secchi disc ranges from 1.2 to 5.1 meters, there are intense blue-green blooms, and the hypolimnion (when present) becomes anoxic. All of these indicate eutrophy (Uttormark and Wall 1975; Carlson 1979; Shapiro 1979). Carlson's (1977) trophic state index also indicates that Spring Lake is eutrophic (Figures 4, 8 and 9). The TSI for chlorophyll and phosphorus always exceeds 50 and normally exceeds 70. TSI for Secchi disc is somewhat lower (about 35-65); but in lakes characterized by flake blooms of Aphanizomenon, it is a poor indicator of trophic state (Osgood 1982b).

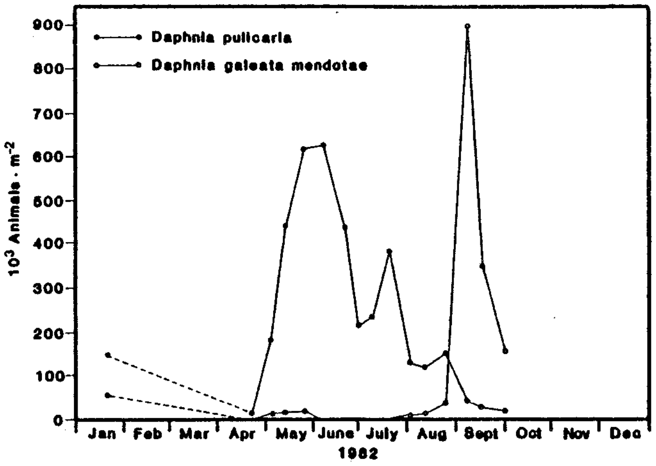


Figure 15. Seasonal Occurrence of D. pulicaria and D. galeata mendotae – Spring Lake

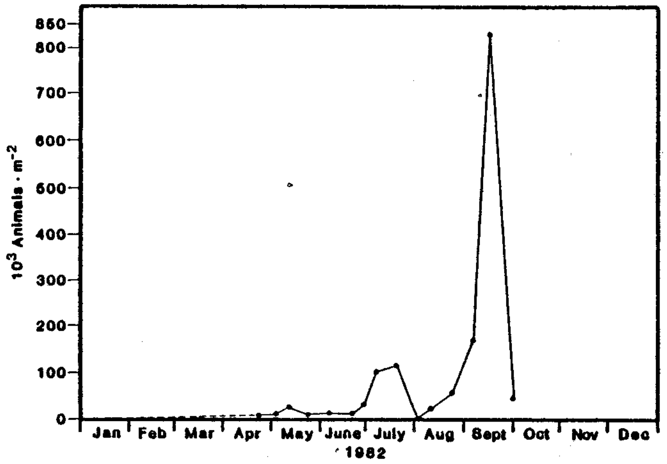


Figure 16. Seasonal Occurrence of Chydorus – Spring Lake

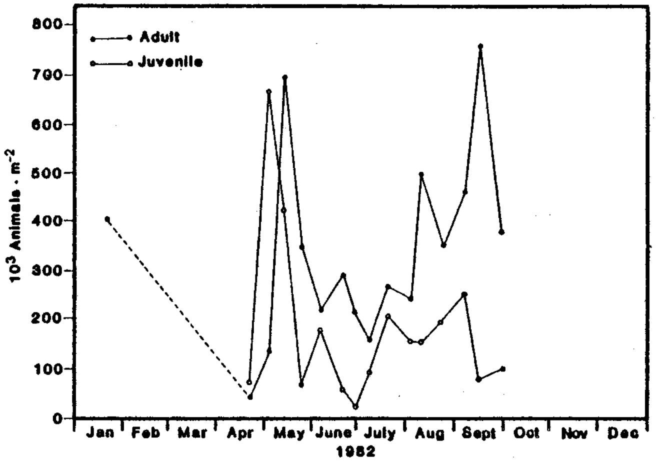


Figure 17. Seasonal Occurrence of Copepoda – Spring Lake

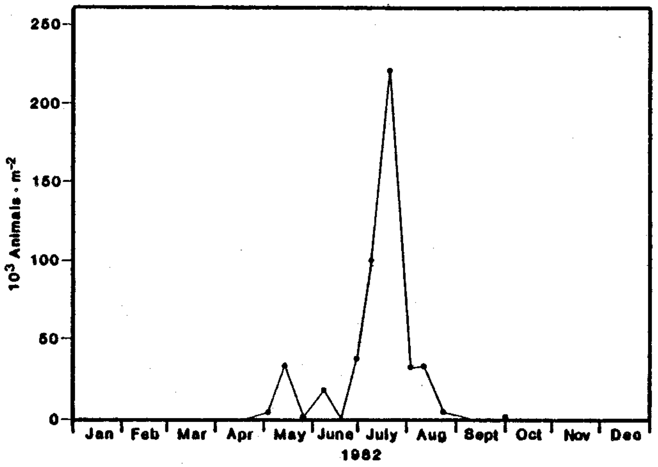


Figure 18. Seasonal Occurrence of Rotifers – Spring Lake

Macrophytes

Vascular plants do not grow to a depth greater than about three meters in Spring Lake which indicates potential areal coverage of about 34 percent of the lake (87 ha). Significant growths, however, are largely limited to the western portion of the lake and the central southern bay. The predominant taxa are *Potamogeton* (*filaformis*) and *Ceratophyllum demersum* with *Elodea* (*Anacharis*), *Heteranthera dubia*, and *Lemna trisulca* also found.

Fish

Spring lake is managed for walleyes by the Minnesota Department of Natural Resources. Recent surveys show that despite intensive stocking efforts (Table 4), walleyes are relatively sparse (Table 5). Planktivores such as perch, sunfish, bluegills and crappies are relatively abundant while predators are sparse. Absolute abundances of the perch and panfish exceed the local (Metro Area) median numbers.

Table 4
MINNESOTA DEPARTMENT OF NATURAL RESOURCES STOCKING SINCE 1970
SPRING LAKE

Year	Number Stocked	Size[1]	Rate (fish/lb)	Pounds	Type[2]
1970	82	Y	N/A	N/A	NP
1970	1,100	F	220	5	WA
1971	130	F	65	2	WA
1973	12,675	F	174	73	WA
1974	7,680	F	960	8	NP
1974	4,284	F	204	21	WA
1975	189,000	Fr	-	-	WA
1976	193,000	Fr	-	-	WA
1977	190,200	Fr	-	-	WA
1978	188,000	Fr	-	-	WA
1979	380,000	Fr	-	-	WA
1980	345,000	Fr	-	-	WA
1981	345,000	Fr	-	-	WA
1982	335,000	Fr	-	-	WA

1. F = fingerling; Y = yearling; Fr = fry.
2. NP = northern pike; WA = walleye.

Table 5
MINNESOTA DEPARTMENT OF NATURAL RESOURCES FISHERIES
LAKE SURVEY SUMMARY - SPRING LAKE*

	Percentages Captured						
	1973			1977		1982	
Fish Type	Seine	Gillnet	Trapnet	Gillnet	Trapnet	Gillnet	Trapnet
Largemouth Bass	1	-	-	-	-	-	0
Northern Pike	-	2	-	3	0	0	0
Walleye	-	-	-	2	-	1	-
Perch	0	53	1	56	0	84	2
Sunfish	8	-	1	-	0	0	9
Bluegill	-	-	51	-	8	0	23
Crappie	1	38	37	31	90	6	63
Sucker	-	1	0	1	0	4	0
Bullhead	-	5	9	5	0	4	1
Carp	-	0	1	-	0	-	0
Minnow	90	0	-	-	-	-	-
Mean Total Numbers per Net	408	131	96	141	121	319	126

*Summarized from surveys provided by the MN DNR Fisheries.

ANALYSIS

A. CHLOROPHYLL/SECCHI DISC RELATIONSHIP

Water clarity in Spring Lake generally depends on chlorophyll (see Figures 8 and 9). This CHL/SD relationship is different from Metropolitan lakes in general (Figure 19). The water is more transparent, particularly at high chlorophyll concentrations. This is related to the presence of *Aphanizomenon* flakes (Osgood 1982b; Lynch and Shapiro 1981). At low chlorophyll levels, the relationship is quite good. This occurs at times when *Aphanizomenon* is absent (Lennon 1981; Lynch 1980). Changes in the seasonal character of Spring Lake´s phytoplankton (ie., *Aphanizomenon* dominance) will likely change the character of the CHL/SD relationship (Figure 19).

B. PHOSPHORUS/CHLOROPHYLL RELATIONSHIP

Spring Lake has a lower yield of chlorophyll than predicted on the basis of phosphorus (Figure 20). This may be due (at least in part) to nitrogen limitation (Smith 1982; Smith and Shapiro 1981). Considering that nitrogen is relatively constant (Figure 5), Smith´s (1982) model (82) suggests that nitrogen limitation may occur at high phosphorus concentrations (TP greater than 100 ug/l). Indeed, at high phosphorus concentrations, N:P ratio is low (Figures 4 and 6). Another explanation may be *Aphanizomenon*´s "cost of coloniality" (Smith et al. 1982). They suggest that there is an ecological cost to *Aphanizomenon* in the flake form. This cost is reduced rates of nutrient uptake by colonial *Aphanizomenon*. Finally, the grazing pressure of abundant, large *Daphnia* may reduce algal abundance--at least in the spring. All three mechanisms, nitrogen limitation, cost of coloniality and grazing *Daphnia*, may account for reduced chlorophyll yield.

C. HYDROLOGIC/NUTRIENT INPUTS AND IN-LAKE PHOSPHORUS

In-lake phosphorus concentration is related to the input of nutrients to the lake. Parameters used to estimate in-lake phosphorus have been presented earlier (Table 3) and are used as follows:

$$P = \frac{L(1 - Rp)}{qs}$$

where P is predicted in-lake phosphorus concentration, L is areal phosphorus loading ($gm/m^2/year$), Rp is phosphorus retention coeffecient (Kirchner and Dillon 1975), and qs is areal water load (m/year). For further detail see Dillon and Rigler (1974b) and Reckhow (1979). The modelling exercise is summarized in Table 6. Predicted in-lake phosphorus is 67/75 with a range of 39/45 to 110/119 ugP/l. This significantly underestimates the observed level of phosphorus in Spring Lake (Figure 4). See the following section for an explanation of this difference.

D. INTERNAL NUTRIENT LOADING

The seasonal input of nutrients from within a lake (primarily from bottom sediments) is termed internal nutrient loading. Spring Lake´s phosphorus concentration exceeds the expected levels. The annual mean (volume-

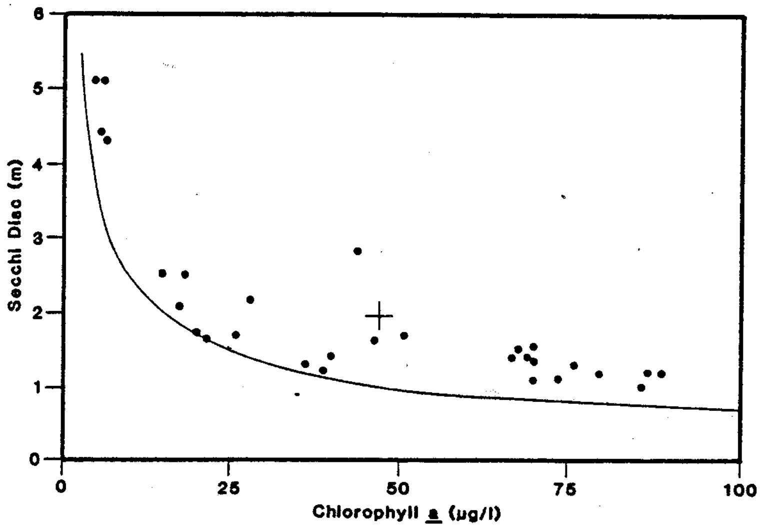


Figure 19. Chlorophyll/ Secchi Disc Relationship for Spring Lake. Line represents a generalized regional relationship from a past study (Osgood 1981, Figure 43). + indicates seasonal average values.

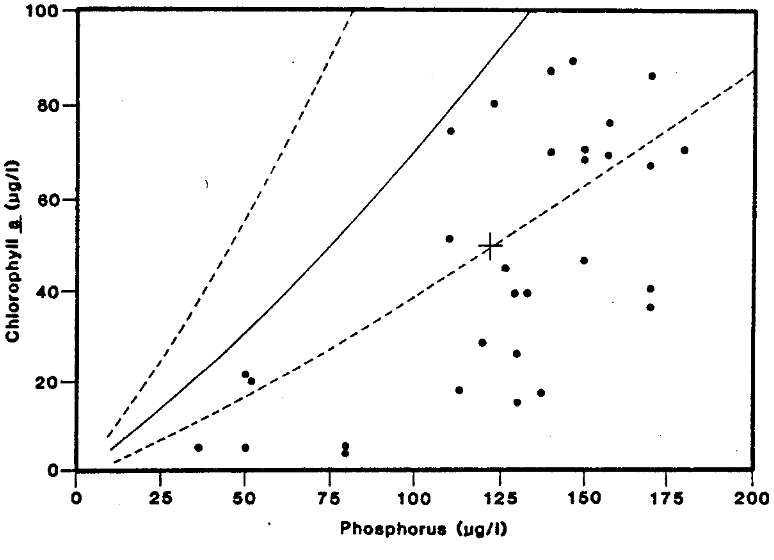


Figure 20. Phosphorus/Chlorophyll Relationship – Spring Lake. Lines represent a generalized regional relationship (+/- 90 percent confidence interval of predicted chlorophyll, from Osgood 1981, Figure 44). + indicates seasonal average values.

Table 6.
HYDROLOGIC/NUTRIENT MODEL[1] - SPRING LAKE

	Parameter Values[2]	
HYDROLOGIC PARAMETERS		
Water Input ($10^3 m^3$)	81:	9356 (7674 - 11,038)[3]
	82:	11,431 (9564 - 13,298)
Residence Time (years)	81:	1.54 (1.30 - 1.87)
	82:	1.26 (1.08 - 1.50)
Areal Water Load (m/year)	81:	3.66 (3.01 - 4.33)
	82:	4.47 (3.75 - 5.21)
P Retention Coefficient	81:	0.712 (0.683 - 0.746)
	82:	0.677 (0.650 - 0.708)
PHOSPHORUS LOAD		
Annual Input (kg)	81:	2181 (1686 - 2767)
	82:	2645 (2044 - 3246)
Areal Phosphorous Load (g/m^2/year)	81:	0.854 (0.660 - 1.048)
	82:	1.036 (0.801 - 1.271)
MODEL		
Predicted In-lake P (ug/l)	81:	67 (39 - 110)
	82:	75 (45 - 119)

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1. Dillon and Rigler (1974b); Kirchner and Dillon (1975).
2. 81 refers to water year 1982; 82 refers to calendar year 82.
3. Numbers in ( ) are the ranges from carrying associated errors through the computations.

weighted) phosphorus concentration of the lake is 118 ug/l. The magnitude of the internal nutrient source may be estimated. Visual examination of the lake's surface concentration indicates a nearly linear increase from May 13 to July 19 (Figure 21). This change applied to the lakes volume indicates an increase of 2,600 kgP. Internal phosphorus loading rate during this time may then be estimated by excluding the measured external load (406 kg) and assuming input occurs over the entire bottom area. This loading rate is 12.8 mgP/m^2/day. This is considered the maximum net loading rate since it occurs at a time of the greatest rate of increase of both surface phosphorus and Aphanizomenon flakes.

Circular

Phosphorus concentration in Spring Lake predicted on the basis of external phosphorus dynamics is 75 ug/liter (Table 6). Observed phosphorus concentration (volume-weighted, daily integrated) was 118 ug/liter, significantly greater than predicted. Assuming that the lake's phosphorus retention coefficient is 0.677 (Kirchner and Dillon 1975) and knowing the annual phosphorus input, the annual outflow of phosphorus would be 854 kg. This is much lower than the measured output. The difference (= 1,302 kg) is attributed to internal phosphorus sources. Adding this to the measured external load yields a new predicted phosphorus concentration of 112 ug/liter--very close to the observed concentration.

This internal loading of phosphorus in Spring Lake is significant, substantial and largely associated with the life history characteristics of Aphanizomenon flakes. Estimates of in-lake phosphorus that consider only external nutrient sources are significantly less than the observed concentration. This difference is large and is asociated with internal phosphorus sources. Both the estimated maximum areal loading rate (12.8 mgP/m^2/day) and the annual internal load (1,302 kgP) are substantial. Internal phosphorus loading may account for 33 percent of Spring Lake's total annual load and this source is entirely from the proposed mechanism: rising Aphanizomenon flakes. Other internal phosphorus sources in Spring Lake are probably insignificant. Benthivorous fish are not abundant, extensive growth of macrophytes are not noted and anaerobic release, though it does occur, is unimportant.

Anaerobic release may be estimated by applying the following rates: 9 +/- 4 mgP/m^2/day (Armstrong 1979; Larsen et al. 1981). Assuming a hypolimnetic area of 42.9 ha (8 m contour) becomes anaerobic on a regular basis (Figure 7) and further, that this area is anaerobic for the entire period indicated by Figure 7 (78 days), anaerobic release is 301 +/- 134 kg phosphorus. Though substantial, this is a small percentage of the estimated internal load.

Higher than expected internal phosphorus loading may be due to transport of phosphorus from the sediments to the euphotic zone by rising Aphanizomenon flakes. This mechanism of nutrient translocataion has not been considered in the past (as far as the author is aware). According to Lynch and Shapiro (1981), Lennon (1981) and Lynch (1980), Aphanizomenon flakes form on or closely associated with oxic sediments. Once these flakes reach ungrazeable size (about 1.5 mm), they float to the surface. Observations on Spring Lake are consistent with this hypothesized mechanism: no flakes observed in hypolimnetic water containing less than one mgO_2/l, with 2-3 mgO_2/l seemingly a transition zone. This mechanism could be the most important internal nutrient source in Spring Lake.

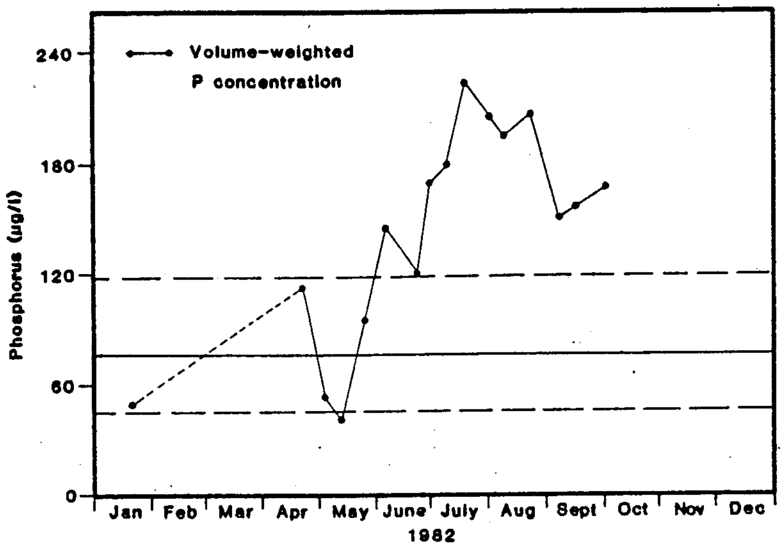


Figure 21. Volume-Weighted Phosphorus Concentration Compared to Predicted Phosphorus Considering only External Phosphorus Sources. Predicted phosphorus (solid line) is from Table 6 and dashed lines represent 90 percent confidence interval (Reckhow et al. 1980).

DISCUSSION

Spring Lake has a large (surface area), shallow basin (Figure 2) that is located in a very large agricultural watershed (Figure 1, Table 1). The watershed has a large number of wetlands (Figure 22a). A great deal of runoff is generated in this watershed with half the annual volume entering (the lake) during snowmelt (Table 3). Phosphorus load to the lake is also large, again over half entering the lake via stream inflow during snowmelt. Other sources of hydrologic and nutrient input are relatively minor (Table 3).

There is a detention basin on the primary stream inlet near the lake. Its small size and volume have rendered it ineffective in reducing phosphorus (and perhaps other pollutant) delivery to the lake. In addition, a large wetland downstream from the detention basin (Figure 22b) has had a channel constructed through it, thus eliminating potential treatment of the stream inflow.

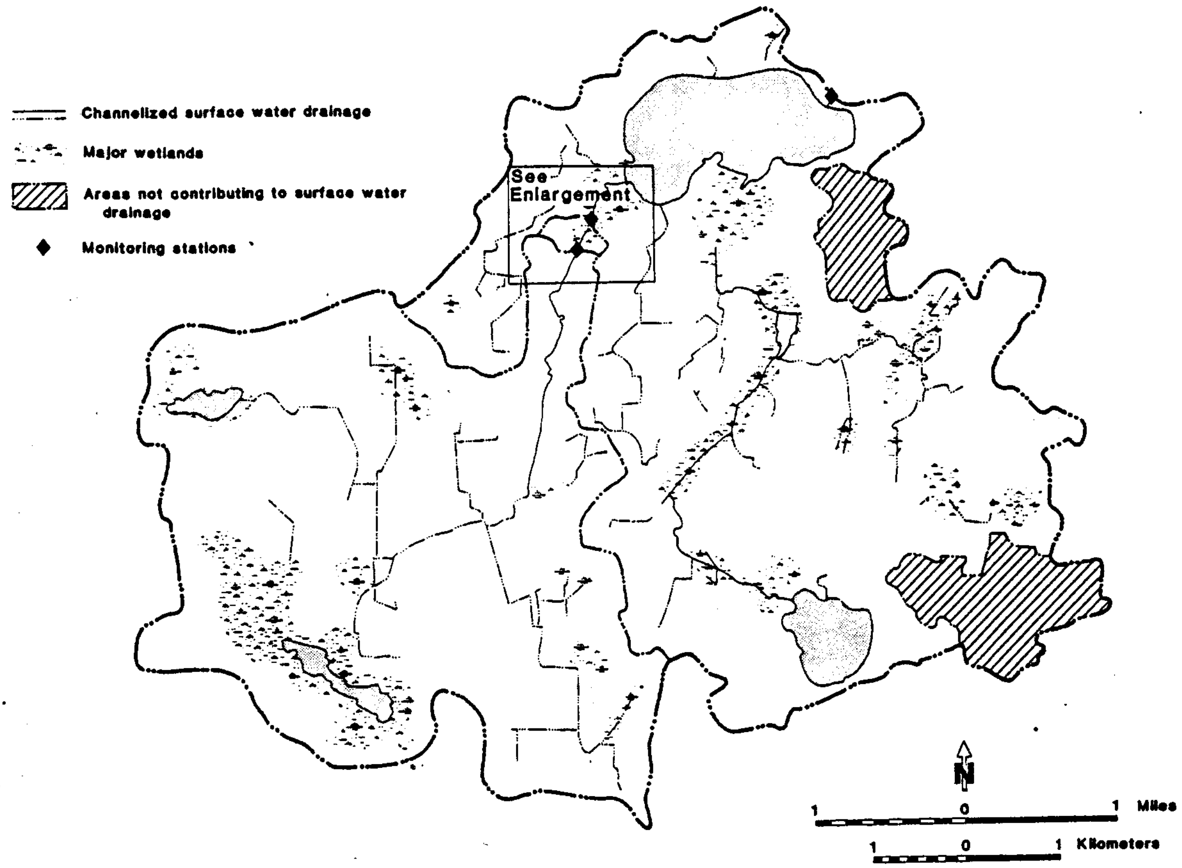
In-lake phosphorus concentration is high (Figure 4). However, phosphorus concentration is considerably underestimated on the basis of external hydrologic and phosphorus dynamics (Table 6). An internal phosphorus source is postulated where Aphanizomenon "flakes" rising from the lake´s bottom carry nutrients to the photic zone. This mechanism is consistent with an hypothesis of Lynch (1980).

This mechanism of internal phosphorus loading is supported by the following sequence of observations: First, prior to the presence of Aphanizomenon flakes, the ambient phosphorus concentration is high with very little dissolved phosphorus (Figure 4). This co-occurs with a Cyclotella bloom (Figure 12), suggesting that these cells have utilized nearly all the available phosphorus. With the demise of this diatom bloom, all particulate phosphorus disappears (Figure 6) and is not substantially replenished from external sources (Table 3). Phosphorus concentration begins to increase concurrent with the appearance of flakes (Figures 4 and 14). The dynamics of this season´s Aphanizomenon bloom have been discussed earlier (RESULTS) and is found to be consistent with descriptions of Lynch (1980), Lennon (1981) and Lynch and Shapiro (1981). The increase in total phosphorus has an increasing (with time) component of particulate (non-dissolved) phosphorus; again, associated with the Aphanizomenon flakes (Figures 4, 9, 12, 13 and 14).

Internal phosphorus loading rates are estimated with this mechanism in mind. Internal phosphorus loading was found to be 1302 kg/year with a maximum rate of 12.8 mgP/m^2/day. Such considerations of internal phosphorus loading in addition to external nutrient dynamics adequately explain the lake´s phosphorus dynamics.

Spring lake is unquestionably eutrophic. However, phosphorus considered alone, inadequately describes the overall algal biomass found in the lake (Figure 20): there is a lower yield of chlorophyll than predicted. Nitrogen limitation (Figure 6; Smith 1982), the "cost of coloniality" (Smith et al. 1982) or intensive grazing by Daphnia (Figure 15; Lynch 1980) may all play a role in reducing chlorophyll. Also, with the presence of flakes, the water is more transparent (SD) than expected (Figure 19), particularly at higher chlorophyll concentrations (Lynch 1980; Osgood 1982b).

Figure 22a. SPRING LAKE WATERSHED - SURFACE DRAINAGE FEATURES



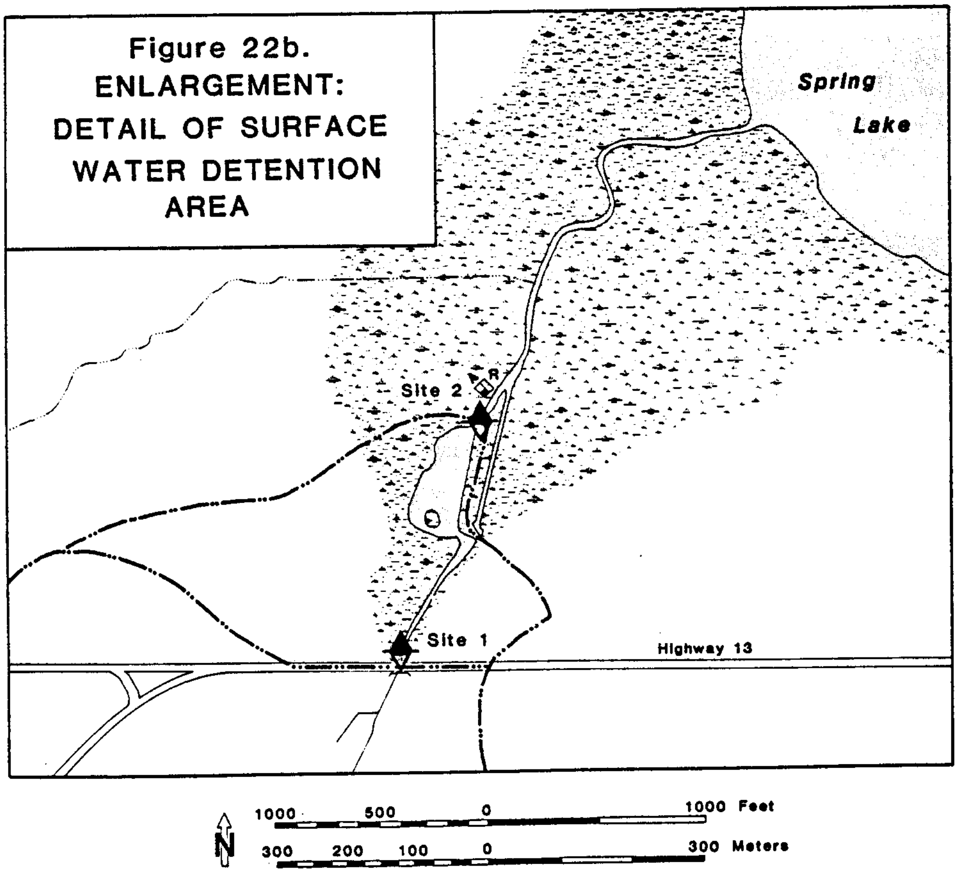


Figure 22b. ENLARGEMENT: DETAIL OF SURFACE WATER DETENTION AREA

The most dramatic and perhaps most ecologically significant component of Spring Lake's biotic community is *Aphanizomenon*. Its dynamics in Spring Lake have been detailed previously and its dynamics in general have been presented by others (Lynch 1980; Lennon 1981; Lynch and Shapiro 1981). *Aphanizomenon* is present in flake form seemingly only in association with large (body size) cladoceran herbivores, particularly *Daphnia pulex* (*pulicaria*). Large *Daphnia* require some sort of refuge (Lynch and Shapiro 1981; Lynch 1979; Dodson et al. 1976; Dodson 1974, 1970; Brooks and Dodson 1965) from their predators in order to maintain their populations. It is unclear where such a refuge may be in Spring Lake, perhaps the flakes themselves act as decoys and interfere with fish predation on *Daphnia* (T. Noonan and D. Wright, personal communications).

FEASIBILITY STUDY

A. POLLUTION CONTROL/RESTORATION ALTERNATIVES

Spring Lake is incredibly eutrophic. It has an annual phosphorus input of 3,947 kg (1982; 67 percent from the watershed, 33 percent from internal sources). The majority (56 percent) of the annual external phosphorus load comes from surface runoff during snowmelt and spring runoff (Table 3). While external phosphorus is generally considered controllable (Oberts 1982), in-lake improvements (reduced chlorophyll) may not be possible. The management strategy for Spring Lake will be to examine the practical extent of the preceding statement.

Prior to a detailed watershed analysis that examines the feasibility of managing nutrients, it will be instructive to look at Spring Lake's situation more generally. Spring Lake's external annual phosphorus load is primarily from surface runoff (80 percent) with atmospheric, groundwater and septic systems accounting for the remainder. It is generally not feasible to control any of the minor sources. The maximum possible reduction of phosphorus input from surface runoff in this type of watershed is 47 percent (Oberts 1982). Though substantial, this reduction would reduce the in-lake phosphorus concentration to about 84 ug/l; from about 112 ug/l. This in-lake reduction should reduce algal production (as chlorophyll, Figure 20), but not greatly. Also, if this reduction changes the character of the lake's plankton community, chlorophyll may actually increase! Flake blooms of Aphanizomenon have reduced the slope of the TP/CHL relationship (Figure 20). Elimination of the Aphanizomenon flakes should have the effect of raising the slope of the relationship causing a higher yield of chlorophyll for a given phosphorus concentration. As a result, chlorophyll would not change with the proposed phosphorus reduction (= 47 ug/l in 1982; = 57 ug/l with P reduction); indeed it may increase. If the flake blooms persisted, no significant reduction in chlorophyll could be expected since these algae are apparently obtaining nutrients that are associated with the lake's sediments. Therefore, improved water quality (reduced chlorophyll) of Spring Lake cannot be demonstrated by reducing external nutrient loading alone.

In-lake restoration measures for Spring Lake are also not feasible. Normal phosphorus control measures would be difficult or expensive in this large, shallow lake. Also, in-lake measures are ineffective without prior, substantial nutrient reductions. Biotic manipulations in the lake are not appropriate since the lake's zooplankton community already mimics the ideals of biomanipulation (Shapiro et al. 1982). In this case, however, Daphnia is providing Aphanizomenon a service (Lynch 1980) by reducing algal competitors (Smith et al. 1982). Disturbing Daphnia's community structure would actually lead to increased chlorophyll (see previous paragraph).

What phosphorus reductions would lead to improvements in Spring Lake? The annual phosphorus load to the lake is now 3,947 kg (2,645 external, 1302 internal). It is judged that a reduction of at least 1,500 kgP/year is required before significant changes in chlorophyll would occur. Eliminating the lake's internal phosphorus would nearly accomplish this objective. This may be possible by altering the lake's zooplankton community in a way contrary to the biomanipulation approach (Shapiro et al. 1982). This would control Aphanizomenon flakes (Lynch 1980), thus control a large portion of internal nutrients input (see ANALYSIS). The transparency, however, would likely decline with the alteration of the plankton community (Figure 19; Osgood 1982b).

As discussed earlier, agricultural management techniques could reduce surface input of phosphorus up to 47 percent (994 kg). This reduction has been estimated by assuming the combination of techniques applied on each agricultural site will yield the maximum possible reduction and that these techniques are currently not applied. Thus, this estimated reduction is probably high.

Finally, there is currently a small detention basin near the primary inlet to the lake (Figure 22b). This basin is largely ineffective in controlling phosphorus (Nelson and Brown 1983). The large wetland downstream could conceivably be fashioned to act as a retention area. Unfortunately, only 819 kg phosphorus per year flow through this area. Also, just retaining the snowmelt would raise the level over the wetland area by about 3 m. It is not feasible to utilize the wetland in this way. It would be generally beneficial, however, to allow the runoff to seep through the wetland rather than bypass it through the channel that now exists.

Water quality improvements in the lake (greater transparency or less chlorophyll) cannot be assured with an annual phosphorus reduction of less than 1,500 kg. No apparent way has been found to feasibly reduce phosphorus to Spring Lake by 1,500 kg.

Spring Lake is a valuable regional resource. It is a popular fishing lake and there is a large Regional Park planned near the lake. Even though substantial improvements in the lake's water quality are unlikely, the lake is worth maintaining at or near its present condition.

Is there any way Spring Lake can ever be clean? It appears that the only chance to significantly improve Spring Lake's water quality will require a monumental effort. The analyses thus far, suggests that even with great nutrient reductions, Spring Lake will likely not improve; however, there are still many questions. The likelihood for improvement in this non-typical biological system is unclear. Therefore, given the great recreational potential of Spring Lake and a willing public, management efforts of an experimental nature or with an unknown chance for success may be considered. Since such efforts have uncertain chances for success, they cannot be specifically recommended. However, discussing the direction future efforts based on the conclusions of this study would be a useful service. The following discussion will address research and monitoring, and pollution sources.

Research and Monitoring

Addressing the following research topics may help to direct future management in Spring Lake:

1. Specific internal loading mechanisms of phosphorus and nitrogen should be identified. Nutrient translocation by the *Aphanizomenon* flakes has been implicated as an important internal nutrient loading mechanism. The relative importance of this source compared to others should be assessed.

2. What is reducing the chlorophyll yield (with respect to phosphorus) in this lake? Nitrogen limitation, *Aphanizomenon*'s "cost of coloniality," or intensely grazing zooplankton may all be responsible.

3. Where is Daphnia's refuge? The presence of numerous, large body-sized Daphia implies the existence of a refuge for Daphnia. Does this refuge exist and, if so, where is it found?

4. If the Aphanizomenon flakes were prevented, would the Daphnia persist? If so, the Daphnia could be counted on to control other algal growth. If not, algal growth would be dictated by the nutrient conditions in the lake.

A monitoring program to back up this research effort is detailed in Part C of this feasibility study. In essence, data collection should continue in a manner similar to this study. Additional analysis may be required to address the particular research questions presented above.

Pollution Sources

The 1982 inputs of phosphorus to Spring Lake are broken down as follows:

Source	Percentage of Total Input
Atmosphere	6
Groundwater	4
Nearshore Septic System	3
Internal Loading	33
Surface Runoff	54

The total phosphorus load was 3,947 kg. Which of these sources can potentially be controlled? The atmospheric, groundwater and septic system inputs are all relatively small and not practically controlled. The greatest reduction in the remaining sources may be as follows: The main surface inflow contributes 819 kgP (1982) and, if diverted, could be eliminated. The remaining surface inflow (1,310 kgP) could possibly be reduced up to 47 percent (see earlier discussion). Internal phosphorus input is likely going to be very difficult to control. For this discussion, it will be assumed that internal phosphorus input can be reduced by 50 percent; although, considering the possible mechanisms, this may be optimistic.

These reductions will lead to a phosphorus reduction of 2,086 kgP per year (based on 1982). Considering these reductions in water and phosphorus loads, in-lake phosphorus concentration would be about 58 ug/l (Table 6). This is still substantial and the flakes may still be there. These possible phosphorus reductions may yield reductions in chlorophyll (Figure 20), but the behavior of the lake's plankton with reduced nutrients is unknown.

Finally, internal or external sources of phosphorus in 1982 may have been lower than in more normal years. Since the annual runoff volume was near normal, internal sources of phosphorus may have been greater in prior years. This is suggested by looking at the lake's phosphorus concentration during the two prior years. The average phosphorus concentrations in 1980 and 1981 were 237 and 141 ug/l, respectively (Osgood 1981, 1982a). This year's average concentration was 118 ug/l.

B. EXPECTED BENEFITS

No demonstrable improvements in Spring Lake's water quality are practically feasible, thus benefits related to improved water quality are not expected.

C. PHASE 2 IMPLEMENTATION AND MONITORING PROGRAM

There is no Phase 2 implementation program proposed for Spring Lake, however, water quality monitoring should continue. Annual water quality monitoring should include:

ANALYSIS	FREQUENCY	DEPTH
TP	Twice Monthly (May-Sept.) Monthly (Oct.-Apr.)	Profile
TDP, TKN, CHL	Twice Monthly (May-Sept.) Monthly (Oct.-Apr.)	Surface
ALK, N/N, NH3	Monthly	Surface
TEMP/DO	Twice Monthly (May-Sept.) Monthly (Oct.-Apr.)	Profile
SD	Twice Monthly (May-Sept.) Monthly (Oct.-Apr.)	Except under ice
Zooplankton Collection, Identification and Enumeration	Twice Monthly (May-Sept.) Monthly (Oct.-Apr.)	Vertical Tow
Algal Community: Identification and Enumeration	Twice Monthly (May-Sept.) Monthly (Oct.-Apr.)	Surface
Aphanizomenon Flake Counts	Twice Monthly (May-Sept.) Monthly (Oct.-Apr.)	Surface

This annual monitoring should be conducted at Station No. 1 from this study. Also, import and export of phosphorus to/from the lake should be estimated by monitoring the lake's inlets its outlet and precipitation volume (as in this study).

D. PHASE 2 SCHEDULE AND BUDGET

There is no Phase 2 implementation program proposed for Spring Lake, therefore, a schedule and budget is unnecessary.

E. FUNDING SOURCES

Recent legislation by the State of Minnesota (1982 Surface Water Management Law, Chapter 509) mandates efforts toward the formation of watershed management organizations (WMOs) in the Metropolitan Area by the end of 1983 (formation by mid-1984). Such agencies will prepare surface water management plans for their respective watersheds, then will be able to initiate and implement projects in their districts for water (quantity and quality) management. Funding for such projects will be from such things as property tax levies, and assessment is based on the degree of benefit realized by that property for the particular project. Benefitted properties are defined to include those properties found to contribute to the problems remedied by the proposed projects, as well as those that receive a direct benefit.

F. RELATION TO OTHER PROGRAMS

The Metropolitan Council´s Development Guide chapter: Water Resources Management consists of Part 1. Sewage Treatment and Handling and Part 2. Surface Water Management: Nonpoint Source Pollution and Storm Water Runoff. Part 1 of this development guide is the Council´s plan for managing sewage treatment in the Metropolitan Area. None of the Area´s sewage treatment facilities discharge effluents to this lake.

The Surface Water Management Act (see previous section) requires watersheds in the Metropolitan Area (through WMOs) to plan for the management of stormwater runoff volume and quality. Following approval of these plans, implementation funding may be obtained. Improved ability to manage the water resources in these watersheds should be a direct result of this process.

G. PUBLIC PARTICIPATION SUMMARY

The Metropolitan Council appointed a 17-member Water Quality Management Advisory Committee on December 23, 1982. The committee consists of representatives of private citizens, public interest groups, watershed districts, public officials, and private interests. This committee reviewed the preliminary findings, conclusions and recommendations of this report and recommended this report be adopted by the Metropolitan Council.

A technical advisory group was also formed to review the technical aspects of the study. This 17-member group was composed of technically trained representatives familiar with this lake as well as members trained in general aspects of lake ecology.

Finally, a draft of this report was made available to the public for their comments (written or oral) at a public meeting held near the lake. These comments were considered as they related to technical or practical aspects of this report. Appropriate changes were made in the final draft. These final changes were also reviewed by the Water Quality Advisory Committee.

H. OPERATION AND MAINTENANCE

No structural modifications are being proposed in this plan.

I. PERMITS

No activities requiring permits under Section 404 of the Clean Water Act are being proposed.

J. ENVIRONMENTAL EVALUATION

No project has been proposed for the management of Spring Lake´s water quality.

DEFINITIONS

Algae: Extremely small (microscopic) plants that live floating in lakes.

Algal bloom: A period of abundant algae.

Anaerobic (Anoxic): Lacking molecular oxygen.

Autochthonous: Originating from within the lake.

Biomass: The amount of living matter (plants and animals).

Biotic Community: The plants and animals occupying the lake.

Chlorophyll: The green pigment coloring plants; a measure of the amount of phytoplankton in the water.

Diurnal: Occurring on a daily basis.

Epilimnion: The upper, warmer layer in a stratified lake.

Epilimnetic: Referring to the upper layer in a stratified lake.

Eutrophic: Enrichment of nutrients which support dense growths of aquatic plants.

Eutrophication: The process of the nutrient enrichment or overfertilization of lakes.

Harvesting: Physically removing large plants growing in the lake.

Herbivore: Animal that eats plants.

Hypolimnion: The bottom, cooler water layer in a stratified lake.

Kg (Kilogram): 2.2 pounds.

Macrophytes: Large, visible plants that grow attached to the lake bottom.

Metalimnion: The transitional layer between the epilimnion and the hypolimnion (see also Thermocline).

Mesotrophic: A lake with intermediate nutrient levels.

mg/l: Milligrams per liter; also parts per million.

Nitrogen: A chemical (nutrient) necessary for plant growth.

Nutrient: A chemical required by plants for growth.

ODR: Oxygen depletion rate.

Oligotrophic: A nutrient-poor lake.

Oxic: Condition when there is oxygen present.

Phosphorus: The nutrient or chemical that normally controls algal growth.

Photic zone: Zone of the lake which is penetrated by light.

Phytoplankton: Very small plants that live floating in lakes (see also Algae). Includes algae such as Aphanizomenon, Cyclotella, flagellates and diatoms.

Piscivore: Fish that eat other fish.

Planktivore-Planktivorous: Animals that feed on very small aquatic animals (zooplankton).

Primary Productivity: The production of organic matter from light energy and inorganic chemicals.

Runoff: Water that flows on the land surface during and after a rain.

Taxa: A grouping of plants or animals which are alike for classification purpose.

TP and TN: Total phosphorus and total nitrogen.

Thermocline: The layer of water in a lake characterized by a very strong temperature change.

ug/l: Micrograms per liter: also parts per billion.

Watershed: The land area around a lake from which surface runoff flows to the lake.

Zooplankton-Zooplankter: Small animals that live floating in lakes. Includes Daphnia, cladocerans, copepods and rotifers.