DRAFT

DIAGNOSTIC-FEASIBILITY STUDY
OF
STRAWBRIDGE LAKE

February 1993

Presented to:

Township of Moorestown
Burlington County, New Jersey

Prepared by:

F. X. Browne, Inc.
220 South Broad Street
Lansdale, Pennsylvania 19446
(800) 220-2022

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FXB Project No. NJ1246-01

Table of Contents

Table of Contents (con't)

Table of Contents (con't)

Section **Page**

Executive Summary

Overview

This Phase I Diagnostic-Feasibility Study of Strawbridge Lake was conducted under section 314 of the Clean Water Act. A Diagnostic-Feasibility Study is typically conducted in two stages. The Diagnostic portion of the study is conducted to determine the lake's water quality condition, to identify existing problems, and to determine the pollutant sources that are causing the problem. The feasibility part of the study involves the development of a restoration program based on the results of the diagnostic study. Alternatives for restoration programs include both in-lake and watershed management options.

Strawbridge Lake is located in Moorestown Township, approximately 8 miles to the east of the City of Camden in Burlington County, New Jersey. Strawbridge Lake consists of three basins formed by the impoundment of Hooten Creek between 1931 to 1937. Surface water enters Strawbridge Lake primarily through Hooten Creek and the North Branch of Pennsauken Creek. The discharge from the lake retains the name of North Branch Pennsauken Creek and flows into the Delaware River approximately 10 miles below the dam of the lower basin. Morphometic and Hydrologic characteristics are given on the following table.

Characteristics of Strawbridge Lake	
Lake Surface Area	32.9 acres (13.3 hectares)
Lake Volume	26 million gallons (98000 m^3)
Average Depth	2.4 feet (0.74 meters)
Maximum Depth	8.0 feet (2.4 meters)
Hydraulic Retention Time	1.5 days
Average Discharge	26.3 cubic feet per second (0.75 m^3/sec)
Drainage Basin Area	8086.8 acres (3272.7 hectares, 12.6 square miles)

The lake has extensive public access through Strawbridge Lake Park which borders its entire northern shore. Strawbridge Lake is primarily used by the residents of Burlington and Camden Counties which has a combined population of over 898,000 people. There is a strong regional desire to restore this lake. There are few areas in this densely populated area which possess the recreational potential of Strawbridge Lake.

The Strawbridge Lake watershed is approximately 12.6 square miles and covers parts of three Burlington County townships: Moorestown, Mt. Laurel and Evesham (and the border of Maple Shade). The ratio of watershed to lake area is approximately 245 to 1. The major land use categories are cropland-pasture, residential, industrial, commercial, and other urban land uses.

Samples for water quality analyses were collected from each of Strawbridge Lake's basins and tributaries. Each station was sampled monthly during March and April and bi-monthly May through August, 1992. Water quality samples for a total of three storms events were sampled at these stations and at the major culverts entering Strawbridge Lake. In addition, surveys of lake bathymetry (lake depth) and macrophyte (aquatic weed) distribution were conducted.

Conclusions

Strawbridge Lake is eutrophic. Nutrient concentrations are high, water transparency is extremely low and nearly all of the lake bottom is colonized by macrophytes (aquatic weeds). It appears algae and weed growth are limited by low light levels due to the large amount of suspended sediment in the water column.

Sediment accumulation is the primary problem in Strawbridge Lake. The lake's mean depth has been reduced from 4.9 to 2.4 feet. There are approximately 37,000, 20,000, and 72,000 cubic yards of unconsolidated sediment in the upper, middle and lower basins, respectively. This has reduced the aesthetic and recreational value for the lake users.

Overall, the conditions within Strawbridge Lake are determined by erosion and stormwater runoff (nonpoint source pollution) from the watershed, rather than by in-lake processes. The majority of nutrients and sediment entering Strawbridge Lake appears to be caused by erosion from agricultural and residential land. The importance of pollution from waterfowl and septic systems are insignificant compared to the impact of erosion and stormwater runoff.

Recommended Management Plan

A. Implement Watershed Management Plan

1. Establishment of a Watershed Management Committee to evaluate and coordinate watershed management activities in the Strawbridge Watershed.

2. Establishment of a "Watershed Watch" program to ensure that erosion and stormwater management controls are installed properly during construction activities and ensure that long-term stormwater controls are properly operated and maintained.

3. Implementation of Best Management Practices (BMPs) on agricultural lands within the watershed. All farms should have an approved Conservation Plan.

4. Implementation of urban Best Management Practices throughout the watershed on areas that have severe erosion or stormwater runoff problems.

5. Installation of erosion protection measures on eroding areas of streams and on the shoreline of Strawbridge Lake.

6. Evaluation of the creation of biofilters and the enhancement of existing wetlands in the Strawbridge Lake watershed to reduce the silt and nutrients entering Strawbridge Lake.

B. Implement In-Lake Management and Restoration

1. Deepen Strawbridge Lake by dredging the three basins in a phased program.

2. Install shoreline stabilization controls and enhance existing wetlands depending on the availability of local, state, and federal funds.

3. Implement a macrophyte (aquatic weed) control program by stocking grass carp in the upper and middle basins of Strawbridge Lake. Consider weed harvesting and the application of herbicides if aquatic weed problems continue to occur.

C. Perform Limited Water Quality Monitoring Program.

D. Implement Public Education Program.

1.0 Project Description

1.1 Background

Strawbridge Lake is a relatively small lake in Moorestown Township, Burlington County, New Jersey. Strawbridge Lake consists of three separate impoundments with a surface area totaling 32.9 acres. Strawbridge Lake is situated in a park, though much of the surrounding land use is residential, commercial and industrial. Despite its size, Strawbridge Lake is a highly visible and valued part of the environment in Moorestown and surrounding area. There is free and open public access along its entire northern shoreline. The lake represents one of the few natural areas that remain, and there is a strong community and regional desire to restore and preserve it.

Strawbridge Lake watershed lies in Moorestown, Mount Laurel and Evesham Townships and is approximately 3272.7 acres in size. The approximate coordinates of Strawbridge Lake are 39° 57' 00" north latitude and 74° 57' 30" west longitude.

Construction of Strawbridge Lake began in 1931 by dredging and damming Hooten Creek. For at least four decades Strawbridge Lake was the recreational centerpiece of the region, providing a natural, scenic area for fishing, swimming, picnicking and outdoor relaxation. In recent years, the aesthetics and recreational uses of Strawbridge Lake have been severely impacted by pollution. Siltation has reduced the mean water depth to approximately 2.4 feet; siltation continues at an estimated rate of nearly an inch of sediment per year. Investigation into chlordane contamination led to the posting of the waters in 1978 by the New Jersey Department of Environmental Protection and the New Jersey Department of Health.

Application for funding to conduct an EPA Phase I Diagnostic/ Feasibility Study of Strawbridge Lake under Section 314 of the Clean Water Act was made to the U.S. EPA in September of 1990. A work plan was developed and approved by NJDEPE in February 1992, and work started on the project in March, 1992.

1.2 Project Objectives

A diagnostic-feasibility study is typically conducted in two stages. The diagnostic portion of the study is conducted to determine current water quality conditions, identify existing problems, and determine the pollutant sources that are responsible for the observed problems. The feasibility aspect of the study involves the evaluation of various lake and watershed restoration alternatives based on the results of the diagnostic study. These alternatives usually include watershed management practices and in-lake restoration methods.

The primary objectives of the Phase I Diagnostic-Feasibility Study of Strawbridge Lake were:

1. To evaluate existing water quality conditions in Strawbridge Lake and to determine their impacts on recreational uses of the lake and its surrounding area,

2. To identify the sources and magnitude of pollutants entering Strawbridge Lake,

3. To evaluate feasible management and restoration alternatives, and

4. To develop and recommend lake and watershed management plan that is cost-effective, environmentally sound and acceptable to the public.

2.0 Lake and Watershed Characteristics

2.1 Lake Morphology

Strawbridge Lake is located approximately 8 miles to the east of the City of Camden in Burlington County, New Jersey. Strawbridge Lake consists of three basins formed by the impoundment of Hooten Creek between 1931 to 1937.

The Strawbridge Lake watershed is approximately 12.6 square miles and covers parts of three Burlington County townships: Moorestown, Mt. Laurel and Evesham (and the border of Maple Shade). Surface water enters Strawbridge Lake primarily through Hooten Creek and the North Branch of Pennsauken Creek. The discharge from the lake retains the name of North Branch Pennsauken Creek and flows into the Delaware River approximately 10 miles below the dam of the lower basin. The Delaware River flows into the Atlantic Ocean at Delaware Bay. Morphometric and hydrologic characteristics of Strawbridge Lake are summarized in Table 1.

Table 1
Morphometric and Hydrologic Characteristics of Strawbridge Lake

Lake Surface Area	32.9 acres (13.3 hectares)
Lake Volume	26 million gallons (98000 m^3)
Average Depth	2.4 feet (0.74 meters)
Maximum Depth	8.0 feet (2.4 meters)
Hydraulic Retention Time	1.5 days
Average Discharge	26.3 cubic feet per second (0.75 m^3/sec)
Drainage Basin Area	8086.8 acres (3272.7 hectares, 12.6 square miles)

2.2 Benefits and Recreational Use of Strawbridge Lake

2.2.1 Present Lake Uses

The three basins of Strawbridge Lake are situated within Strawbridge Lake Park. There is free and open public access along its entire northern shoreline of the lakes. The 77 acre Strawbridge Lake Park is maintained by the Township of Moorestown. The lake within the park provides a natural, scenic area for bird watching, nature appreciation and outdoor relaxation for area residents. The park has both playground equipment and picnic tables. Walking, biking, picnicking are popular activities in Strawbridge Lake Park. Recreational activities for the park are coordinated by the Moorestown Department of Parks and Recreation. Although the quality of the fishery has deteriorated and the lake is no longer stocked, Strawbridge Lake is still a popular recreational fishing spot for local residents.

2.2.2 Public Access

Strawbridge Lake is uniquely situated within Strawbridge Lake Park to provide a quiet setting within a relatively densely populated region. Strawbridge Lake is located within eight miles of the City of Camden and 12 miles of Philadelphia, Pennsylvania. Lake front access is provided along Haines Drive and Route 38. Haines Drive parallels the northern border of the lake inside the Strawbridge Lake Park boundaries. Parking spaces are available for lake users along Haines Drive and additional access and parking can be found along the southern border of the lake on Route 38. Strawbridge Lake is within two miles of both interstate 295 and the New Jersey Turnpike.

2.2.3 Other Area Lakes

Public lakes within an 80 km (50 mile) radius of Strawbridge Lake are listed in Table 2.

TABLE 2
PUBLIC LAKES WITHIN 50 MILES (80 km) OF STRAWBRIDGE LAKE

Lake	Owner	Nearest Town	County	Acres	Recreational Facilities			
					Boating	Fishing	Swimming	Picnicking
			Atlantic					
Corbin City Impoundment	S	Corbin City		631	Y	Y	N	N
Hammonton Lake	SM&P	Hammonton		75	N	Y	Y	Y
			Burlington					
Atsion Lake	S	Atsion		62	Y	Y	N	N
Batsto Lake	S	Batsto		40	Y	Y	N	N
Harrisville Lake	S	Martha		40	Y	Y	N	N
Lake Oswego	S	Jenkins Neck		92	Y	Y	Y	Y
Lake Absegami	S	Leektown		63	Y	Y	N	N
Mirrow Lake	M&P	Browns Mills		250	Y	Y	N	Y
Swedes Lake	M	Riverside		45	Y	Y	N	N
Whitebog Pond	S	Whitebog		39	Y	Y	N	Y
			Camden					
Cooper River Park Lake	C	Collingswood		150	Y	Y	N	Y
New Brooklyn Lake	C	Sicklerville		40	Y	Y	N	Y
Newton Lake	C	Collingswood		40	N	Y	N	Y
			Cap May					
East Creek Pond	S	Eldora		62	Y	Y	Y	Y
Tuckahoe Lake	S	Middletown		10	Y	Y	N	N
Tuckahoe Impoundment	S	Middletown		337	Y	Y	N	N

TABLE 2
PUBLIC LAKES WITHIN 50 MILES (80 km) OF
STRAWBRIDGE LAKE (Continued)

Lake	Owner	Nearest Town	County	Acres	Recreational Facilities			
					Boating	Fishing	Swimming	Picnicking
			Cumberland					
Bostwick Lake	M	Friesburg		32	Y	Y	Y	Y
Cedar Lake	M	Cedarville		57	Y	Y	N	N
Clarks Ponds	S	Fairton		43	Y	Y	N	N
Laurel Lake	M&P	Laurel Lake		135	N	Y	N	N
Menantico Sand Ponds	S	Millville		62	Y	Y	N	N
Sunset Lake	M&P	Bridgeton		88	Y	Y	Y	Y
Union Lake	SM&P	Millville		898	Y	Y	N	N
			Gloucester					
Iona Lake	M	Porchtown		36	Y	Y	N	N
Stewarts Lake	M	Woodbury		45	Y	Y	Y	Y
			Hunterdon					
Spruce Run Reservoir	S	Clinton		1290	Y	Y	Y	Y
			Mercer					
Carnegie Lake	S&P	Princeton		237	Y	Y	N	Y
Lake Mercer	C	Edinburg		275	Y	Y	N	Y
			Middlesex					
Carnegie Lake	S&P	Princeton		237	Y	Y	N	Y
DeVoe Lake	M	Spotswood		59	Y	Y	Y	Y
E. Brunswick Park Lake	M	E. Brunswick		40	Y	Y	Y	Y

TABLE 2
PUBLIC LAKES WITHIN 50 MILES (80 km) OF STRAWBRIDGE LAKE
(Continued)

Lake	Owner	Nearest Town	County	Acres	Recreational Facilities			
					Boating	Fishing	Swimming	Picnicking
Farrington Lake	C&P	Milltown		290	Y	Y	N	Y
Manalapan Lake	C	Jamesburg		40	Y	Y	Y	Y
Westons Mill Pond	C&P	New Brunswick		92	N	Y	N	N
			Monmouth					
Allentown Pond	M&P	Allentown		35	N	Y	N	Y
Assunpink Lake	S	Roosevelt		225	N	Y	N	N
Lefferts Lake	M&P	Matawan		69	Y	Y	Y	Y
Rising Sun Lake	S	Roosevelt		38	N	Y	N	N
Shadow Lake	M&P	Red Bank		88	N	Y	N	N
Stone Tavern Lake	S	Roosevelt		52	N	Y	N	N
			Ocean					
Deerhead Lake	M&P	Forked River		37	N	Y	N	Y
Horicon Lake	M	Lakehurst		50	N	Y	N	Y
Lake Barnegat	M&P	Forked River		50	N	Y	N	Y
Lake Carasaljo	M&P	Lakewood		67	N	Y	N	Y
Lake Manahawkin	C&P	Manahawkin		70	N	Y	Y	Y
Manahawkin Impoundments	S	Manahawkin		80	N	Y	N	N
Oakford Lake	M&P	New Egypt		35	N	Y	N	N
Pohatcong Lake	M&P	Tuckerton		33	N	Y	Y	Y
Prospertown Lake	S	Hornerstown		80	N	Y	Y	Y
Shenandoah Lake	C	Lakewood		100	N	Y	N	Y

TABLE 2.3
PUBLIC LAKES WITHIN 50 MILES (80 km) OF STRAWBRIDGE LAKE
(Continued)

Lake	Owner	Nearest Town	County	Acres	Recreational Facilities			
					Boating	Fishing	Swimming	Picnicking
Stafford Forge Reservoir	S	Stafford Forge		68	N	Y	N	N
Stafford Forge Main Line	S	Stafford Forge		73	N	Y	N	N
Stafford Forge Ponds	S	Stafford Forge		70	N	Y	N	N
Success Lake	S	Colliers Mills		40	N	Y	N	N
Turn Mill Pond	S	Colliers Mills		100	Y	Y	N	N
Whitesbog Pond	S	Whitesbog		53	N	Y	N	N
			Salem					
Maskells Mills Lake	S	Canton		33	N		Y	Y
Parvin Lake	S	Centerton		95	N	Y	Y	Y

Legend
<u>Ownership</u>

F - Federal
S - State
C - County
M - Municipal
P - Private

* - reported swimming availability
P - pool
B - beach

2.2.4 Impairment of Recreational Uses

In recent years, the aesthetics and recreational uses of Strawbridge Lake have been severely impacted by pollution. Siltation has reduced the average water depth to approximately 2.4 feet, and siltation continues at an estimated rate of nearly 1 inch of sediment per year. Chlordane contamination led to the posting of the waters in 1978 by the New Jersey Department of Environmental Protection and the New Jersey Department of Health. Runoff from a 1978 fire at a Burlington County garden supply center is believed to be partly responsible for the high chlordane concentrations. Water quality has been impacted by the stormwater runoff of oil, fertilizers and pesticides. A fish-kill which occurred during the summer of 1989 was attributed to pesticide runoff from residential lawns. Additionally, geese and duck wastes litter the Strawbridge Lake shoreline.

There have been a number of studies of Strawbridge Lake and the vicinity, including a 1980 New Jersey Department of Environmental Protection Intensive Lake Survey (NJDEP, 1980), a chlordane fisheries contamination study (Suchow, et al., 1980), and a Master's Thesis (Moser, 1985). The NJDEP Intensive Lake Survey concluded that Strawbridge Lake was eutrophic and in overall poor ecological condition. The report recommended that a watershed management program be implemented, along with in-lake restoration measures such as bank stabilization and dredging.

Restoration of the lake will result in many positive benefits that could be enjoyed by the public. Besides enhancing the general aesthetic condition of the lake, restoration will improve the aquatic ecosystem, which will in turn improve the fishery. Deepening the lake will increase recreational options by allowing people to use small boats and canoes.

2.3 Lake Bathymetry and Sediment Thickness

A bathymetric survey was conducted by members of the Strawbridge Lake Restoration Association during the summer of 1990. A second bathymetric survey was performed in the spring of 1992 using a survey rod along selected transects across the lake to verify the existing bathymetric survey. Moorestown Township provided a boat and assistant as an in-kind service for the bathymetric field work. Water depth and sediment thickness of the existing maps were supplemented with data from the 1992 survey. Lake and unconsolidated sediment volumes were calculated. Sediment volume estimates were used to evaluate dredging needs and costs. Predictions of sedimentation rates and impacts were also made.

Maps showing current water depth, unconsolidated sediment, and sediment thickness contours were prepared.

Results of the bathymetric survey indicate that Strawbridge Lake has been heavily impacted by siltation. The lake currently has an estimated volume of 29 million gallons (98,000 m^3). This is nearly 50% less than the lake's estimated potential volume of 52 million gallons, if it were completely dredged. The average sediment thickness measured in May 1992 was 2.5 feet (0.76 m), and the estimated volume of unconsolidated sediments was 129,000 cubic yards (98,800 m^3). Sediment characteristics are discussed in Section 3.5.

2.4 Watershed Characteristics

The Strawbridge Lake watershed encompasses an area of 8086.8 acres (3272.7 hectares) in Burlington County, New Jersey. The boundaries of the Strawbridge Lake watershed are shown in Figure 1. Various watershed characteristics are discussed in the following subsections.

2.4.1 Topography

The watershed of the Strawbridge Lake watershed lies in the inner lowland of the Atlantic Coastal Plain of New Jersey (Markley, 1971). The inner Coastal Plain is characterized by low relief and altitudes typical under 100 feet. The highest point in the watershed is along the extreme northern border of the watershed along the Marne Highway in Moorestown Township with an elevation of 107 feet mean sea level (MSL). Slopes in the Strawbridge Lake watershed ranges from 0 to 2 percent to over 15 percent, with slopes of 2 to 5 percent predominating. The dam site at an elevation of 13 feet MSL is the lowest point in the watershed.

2.4.2 Geology

The surface geology of the Strawbridge Lake watershed is composed of mostly sand, gravel and clay from the Cretaceous geologic period with sections along Hooten Creek and Pennsauken Creek overlain by gravel deposits of the Quaternary period (Johnson, 1950). The basement rock beneath the surficial unconsolidated sediments is Precambrian Wissahickon Formation. The Northwestern section of the watershed including the lower basin of Strawbridge Lake is underlain by Woodbury Clay. This Cretaceous clay is characterized as containing mica, sand and pyrite and is the only bedrock in the watershed that is not characterized by glauconitic sands. Glauconite (also known as Green Earth) is the material of the New Jersey marl or Green Sand of the Cretaceous and other rocks. It is a soft, dark of light green silicate of alumina, iron, and potash with water (Dana, 1980). The middle and upper basin along with a large portion of the watershed are underlain with Englishtown Sand and Marshalltown formations. Englishtown Sand is white and yellow sand with little mica and glauconite and thin layers of clay. Marshalltown Formation consists of black sandy clay to clayey glauconitic marl. Excavations over three feet deep in Woodbury or Marshalltown clays may encounter extremely acid soil conditions (IEC, 1977). The bedrock beneath the southern section of the watershed is

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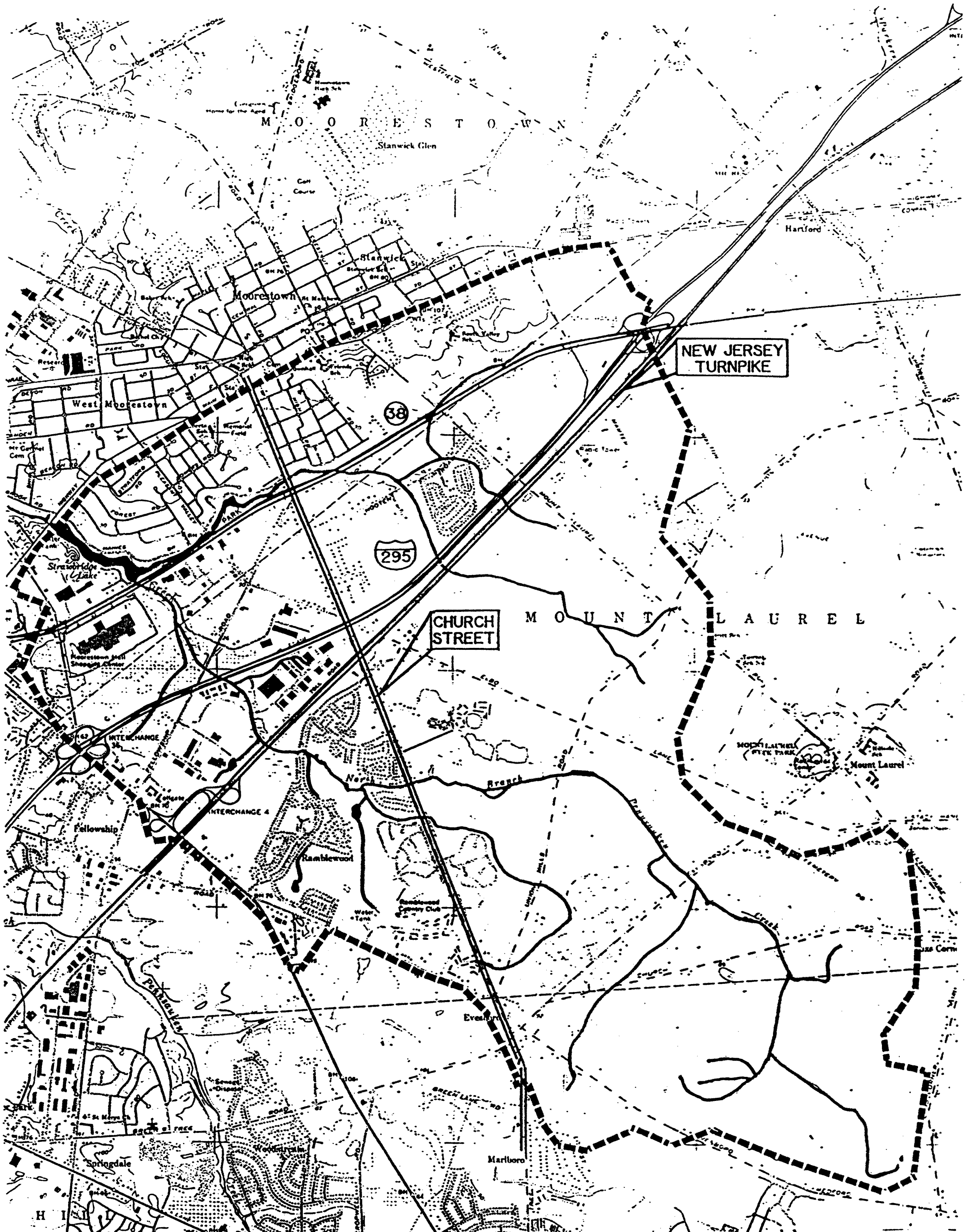


FIGURE 1	STRAWBRIDGE LAKE WATERSHED BOUNDARY

Mount Laurel Sand/Wenonah Sand and Navesink Marl. Mount Laurel Sand and Wenonah Sand are dark grey silts to medium quartz sands with varying amounts of glauconite, mica and lignite (IEC, 1977). Navesink Marl is glauconitic marl (Johnson, 1950). Marl is a clay containing a large portion of carbonate lime and is often used as a fertilizer due to the presence of potash and phosphates (Dana, 1980).

2.4.3 Soils

Soil characteristics are derived from the parent bedrock. The soils of northern Burlington County in the inner Coastal Plain were formed in marine deposits. Physical and chemical processes interact to break down bedrock to form unconsolidated mineral soils on the surface of the earth. Soils formed from marine deposits in this region are characteristically high in glauconite. Although Pleistocine (Ice age) glaciers did not extend as far south as Burlington County, glacial meltwater deposited silt, sand and gravel along Coastal Plain stream beds throughout the county (Markley, 1971).

A soil association is a categorization of soils based on similar characteristics. The predominant soil association in the Strawbridge Lake watershed is the Freehold-Holmdel-Adelphia association. The other two soil associations found in the watershed are the Woodstown-Sassafras association and the Colemantown-Kresson-Marlton association. Water passes slowly through soils in the Woodstown-Sassafras association which are underlain by clay beds. The Colemantown-Kresson-Marlton association soils also have slow permeability due to clay loam or sandy clay in the upper two to three feet. All of the lake front soils around Strawbridge Lake, Woodstown, Sassafras, Holmdel, and Donlonton are listed as fine sandy loams (Markley, 1971).

2.4.4 Groundwater

The Potomac-Raritan-Magothy Aquifer System overlays the basement Wissahickon Formation in Burlington County. The Raritan and Magothy formations each have layers of almost impermeable clay and hold local confined aquifers. Except for reports of high iron concentrations in some areas, there is generally good water quality in the these formations. In the northwest section of the watershed, the Englishtown Formation is used as a domestic water supply where clay content is low. Water quality is good from this formation but water is generally hard and may contain high concentrations of iron (Rush, 1968). Despite the high clay content of the Marshalltown Formation, resulting in a confining layer, ample recharge of the Englishtown Formation is possible. The Mount Laurel Sand and Wenonah Formations contain a productive aquifer of hard water of good water quality (Rush, 1968).

2.4.5 Land Use

Land use in the Strawbridge Lake drainage basin was determined with information supplied by the county planning offices, aerial photographs, and USGS topographic quadrangles, New Jersey Wetlands Inventory, and the New Jersey Land Use Overlay (sheet #31). Estimated land use is summarized in Table 3.

Table 3
Land Use in the Strawbridge Lake Drainage Basin

Land Use Category	Acres	Percent of Drainage Basin
Cropland-Pasture	3007.7	37.2
Residential	2408.7	29.8
Lakes and Ponds	56.8	0.7
Industrial, Commercial and Other Urban	1528.3	18.9
Mixed Forest	1020.5	12.6
Forested Wetland	64.5	0.8
Total	**8086.8**	**100**

2.5 Population and Socio-Economic Structure

Strawbridge Lake is used primarily by residents of Burlington and Camden Counties. Population census data and future projections for the two counties are presented in Table 4. Population by age for the counties is given in Tables 5 and 6.

Table 4 Population Data for Burlington and Camden Counties, NJ			
Year	**1980**	**1990**	**2000**
		Population	
Burlington County*	362,542*	395,066**	457,400*
Camden County	471,650***	502,824**	537,234***

* Source: New Jersey Department of Labor Demographic Information for Burlington County

** Source: New Jersey State Data Center, New Jersey Department of Labor, May 1991

*** Delaware Valley Regional Planning Commission, 1990 Census Data.

Table 5 Burlington County Population by age:1980*		
Age	**Number**	**Percent**
Total	362,542	100.0
0-9	52,475	14.5
10-19	70,488	19.4
20-29	63,218	17.4
30-39	55,683	15.4
40-49	39,986	11.0
50-59	38,006	10.5
60-69	24,306	6.7
≥70	18,380	5.1

*Source: New Jersey Department of Labor Demographic Information for Burlington County

Table 6 Camden County Population by age:1990*		
Age	**Number**	**Percent**
Total	502,824	100.0
0-9	78,385	15.4
10-19	69,105	13.7
20-29	79,817	15.9
30-39	85,624	17.0
40-49	64,069	12.7
50-59	43,584	8.7
60-69	42,938	8.5
≥70	40,302	8.0

* Source: New Jersey State Data Center, New Jersey Department of Labor, May 1991

In 1990 minorities comprised approximately 17.8 percent and 23.4 percent of the populations of Burlington and Camden Counties, respectively (New Jersey State Data Center, New Jersey Department of Labor, May 1991). Per capita income for Burlington County residents in 1989 was $ 16,985 (Source: New Jersey Department of Labor Demographic Information for Burlington County). The per capita income for Camden County in 1987 was $ 12,859. In 1990, the average annual unemployment for Burlington County was 4.1%. A total of 3.1 percent of the families in Burlington County and 8.0 percent in Camden County had incomes below the poverty level in 1990 (Source: Delaware Valley Regional Planning Commission, 1990 Census Data).

Although both the amount of land devoted to farming is declining in Burlington County, approximately 20% percent of the land is still devoted to agriculture and annual agricultural sales were approximately $58 million in 1988 (Burlington County Cooperative Extension, 1992). Important crops are corn and soybeans, garden vegetables, cranberries, blueberries and sod and nursery farms, dairy and tree fruits.

Table 7 Employed persons by occupation in Burlington and Camden Counties		
Occupation	**Burlington***	**Camden****
Manufacturing	23,161	36,800
Wholesale & Retail Trade	41,204	53,100
Services	37,226	49,300
Other Private	25,377	30,900
Government	27,002	33,600
Total	**153,970**	**203,700**

* Source: Employment Data, 1990, New Jersey Department of Labor Demographic Information for Burlington County

** Source: Occupations by Work Location, 1986, New Jersey Department of Labor, Camden County Profile, 1989

2.6 History

Construction of the Strawbridge Lake impoundments began in the late 1920's. Initial funding for the project was provided by the Moorestown Improvement Association, the Works Progress Administration and private donors. The lake bears the name of the Strawbridge family, one of the original benefactors during the construction of the lake basins. Recreational stocking of the lakes began in 1939 and continued annually. The stocking program was interrupted during World War II, and for a short period during 1976 and 1977 trout stocking was replaced with the warm water channel catfish. In 1978, the NJDEP and the Burlington County Health Department posted the two lower basins of Strawbridge Lake due to high levels of Chlordane. A 1978 fire at a Mt. Laurel garden center contaminated Pennsauken Creek and Strawbridge Lake. After the fire, fish tissue from Pennsauken Creek and Strawbridge Lake had chlordane levels above the U.S. Food and Drug Administration action level of 300 parts per billion (ppb). However, a joint study by the New Jersey Department of Environmental Protection (NJDEP) and the New Jersey Department of Health (NJDOH) found that fish and sediments from five other western New Jersey waterways, in addition to Pennsauken Creek, were also contaminated with organochlorine pesticides (Suchow et al., 1980). Seven of nine resident fish species in these six waterways were found to have average chlordane levels exceeding 300 ppb. By comparison, fish tissue from twenty eight sites outside of the Camden area had mean chlordane concentrations below 300 ppb. The report by Suchow et al. suggests that the Strawbridge Lake's urban watershed places the lake at risk from homeowner pesticide use.

Community members have demonstrated their commitment to restoring Strawbridge Lake. Local citizens united to form the Strawbridge Lake Restoration Association (SLRA) and in June 1990, they collected 700 signatures in support of their lake restoration efforts. Members of the SLRA and local volunteers donated their time and expertise to perform a bathymetric survey of the three basins, and inspection the lakeshore and watershed during July and August of 1990.

Restoration of the lake will result in many positive benefits that could be enjoyed by the public. Besides enhancing the general aesthetic condition of the lake, restoration will improve the aquatic ecosystem, which will in turn improve the fishery. Deepening the lake will increase recreational options by allowing people to use small boats and canoes. Today, few areas in the Camden and Burlington County region can offer a the natural recreational setting equal to Strawbridge Lake Park.

3.0 Lake Water Quality

A glossary of lake and watershed terms is provided in Appendix A as an aid to understanding the following discussion.

3.1 Monitoring Program

A sampling program was designed to assess existing water quality in Strawbridge Lake. The lake and watershed monitoring program began in March 1992 and continued through August 1992. The monitoring program examined lake water quality, sediment chemistry, lake bathymetry (water depth and sediment thickness), and macrophyte (aquatic plant) distribution.

3.1.1 Lake Monitoring

Water quality stations were established on each of the three Strawbridge Lake basins as shown in Figure 2. Each station was sampled monthly during March and April 1992, and twice per month from May through August 1992. On each sampling date, water quality samples were collected one meter below the lake's surface. On each sampling date, Secchi depth transparency, temperature profiles and dissolved oxygen profiles were determined in the field for each station. Table 8 describes the chemical and biological data that were gathered during the study, along with the sampling period for each. Integrated composite samples from the photic (surface) zone were collected and analyzed for chlorophyll a and phytoplankton (to genera). Lake samples were collected with the asssistance of a boat and an operator provided by the Township of Moorestown. Water samples were stored in a cooler at 4 degrees Celsius and brought back to the F. X. Browne, Inc. laboratory for analysis. Samples for phytoplankton analyses were preserved in the field with 7.0 mL of Lugol's solution per liter. Another 3 mL of Lugol's solution was added before shipping to Baystate Labs for identification. Counts and identifications were made using a Sedgewick-Rafter counting chamber and a microscope equipped with a Whipple Grid. Water quality data for the project are provided in Appendix B.

Laboratory analyses were performed with procedures established in *Methods for Chemical Analysis of Water and Wastes* (EPA 600/4-79-020, 1979) and *Standard Methods for the Analysis of Water and Wastewater, 17th Edition* (1989).

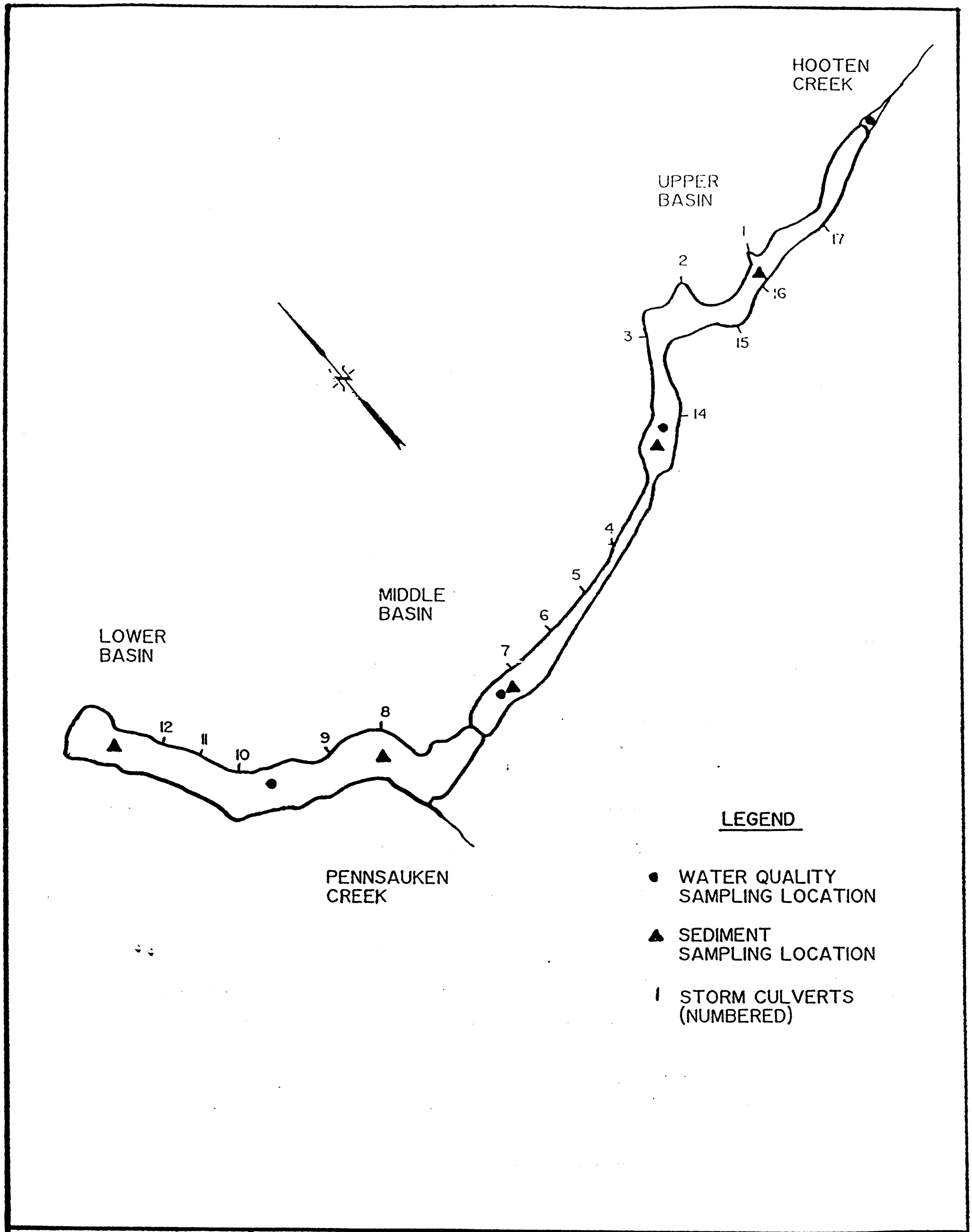


FIGURE 2

STRAWBRIDGE LAKE SAMPLING LOCATIONS

Table 8 Parameters Analyzed in Strawbridge Lake Water Samples	
Parameter	**Monitoring Period**
Secchi Disk transparency	March 1992 - August 1992
Dissolved Oxygen & Temperature	March 1992 - August 1992
Soluble Orthophosphorus	April 1992 - August 1992
Total Phosphorus	April 1992 - August 1992
Nitrate-Nitrite Nitrogen	April 1992 - August 1992
Ammonia Nitrogen	April 1992 - August 1992
Total Kjeldahl Nitrogen	April 1992 - August 1992
Total Suspended Solids	March 1992 - August 1992
Conductivity	March 1992 - August 1992
Fecal Coliform Bacteria	April 1992 - August 1992
Fecal Streptococcus Bacteria	April 1992 - August 1992
Alkalinity	March 1992 - August 1992
Phytoplankton	April 1992 - August 1992
Chlorophyll a	April 1992 - August 1992
pH	March 1992 - August 1992

3.1.2 Watershed Monitoring Program

Stream water quality stations were established on the two major inlets and the lake outlet as shown in Figure 2. The North Branch of Pennsauken Creek, Hooten Creek and the lake outlet were sampled once in March and April 1992 and twice per month from May 1992 through August 1992. Gages were installed with the assistance of the Township of Moorestown Public Works Department at all three stream stations. Baseflow was determined from gage readings taken by Strawbridge Lake Restoration Association volunteers and readings and flow measurements made at the time of sample collection by F. X. Browne, Inc. personnel. Table 9 describes the schedule and parameters analyzed in stream samples.

Table 9 Parameters Analyzed in Strawbridge Lake Stream Samples	
Parameter	**Monitoring Period**
Dissolved Oxygen & Temperature	March 1992 - August 1992
Soluble Orthophosphorus	April 1992 - August 1992
Total Phosphorus	April 1992 - August 1992
Nitrate-Nitrite Nitrogen	April 1992 - August 1992
Ammonia Nitrogen	April 1992 - August 1992
Total Kjeldahl Nitrogen	April 1992 - August 1992
Total Suspended Solids	March 1992 - August 1992
Conductivity	March 1992 - August 1992
Fecal Coliform Bacteria	April 1992 - August 1992
Fecal Streptococcus Bacteria	April 1992 - August 1992
Alkalinity	March 1992 - August 1992
pH	March 1992 - August 1992
Particle Size Distribution	One dry and one wet weather event at inlets, June 1992 - August 1992

Samples from the two inlet stations and the lake outlet were collected during three storm events. Storm samples were analyzed for the parameters listed in Table 9. Storm flow samples were collected by SLRA volunteers in containers provided by F. X. Browne, Inc. Storm flow samples were shipped to F. X. Browne, Inc.'s laboratory for analysis. To assess pollutant loading from storm drains around Strawbridge Lake, wet weather samples were collected at major storm drains during three storm events. Storm sewer samples were analyzed for total phosphorus, total suspended solids and conductivity. Precipitation quantity was determined from precipitation data provided by SLRA volunteers and the Townships of Moorestown and Evesham. Precipitation from one of the sample locations was analyzed for pH, alkalinity, total phosphorus, total suspended solids, nitrate/nitrite, and total Kjeldahl nitrogen. The results of the precipitation analyses are presented in Appendix C.

There are no known point sources (i.e. wastewater treatment plant discharges) within the Strawbridge Lake watershed. The Ramblewood Wastewater Treatment Facility used to discharge to Pennsauken Creek. The Ramblewood Facility now serves as a pumping station and pumps wastes to another facility outside of the watershed.

3.2 Chemical and Biological Interactions

Water quality is determined by a complex system of chemical, physical and biological interactions. Lake water quality is dependent upon land use in the watershed. Nutrients (nitrogen and phosphorus) and suspended solids enter Strawbridge Lake from upstream tributaries, direct overland flow and from storm drains that collect runoff from the roadside areas adjacent to the lake. As water enters the lake its velocity decreases, resulting in sedimentation of suspended solids. A portion of the phosphorus entering the lake is bound to sediment particles (referred to as particulate phosphorus), and this portion gradually settles. Very small sediment particles, such as clays, resist sedimentation and may pass through the lake without settling.

Phytoplankton (algae) and attached plants adsorb available nutrients and convert them into plant material. The most readily-available form of phosphorus is dissolved orthophosphate, analytically determined as dissolved reactive phosphorus (DRP), which can also include hydrolyzable particulate and organic phosphorus. The inorganic forms of nitrogen, ammonia (NH_3-N) and nitrate (NO_3-N), are the forms most available to support the growth of aquatic life. Aquatic plants, or macrophytes, and algae can also affect concentrations of other chemical species in water. For example, in the photosynthetic process, carbon dioxide, a weak acid, is removed from the water and oxygen is produced, resulting in increased pH and dissolved oxygen levels.

Interactions among biological communities (the food web) greatly affect levels and cycling of nutrients, such as phosphorus, nitrogen and carbon in lakes. Energy from the sun is captured and converted to chemical energy via photosynthesis in aquatic plants, which forms the base of the food web. Energy and nutrients, now tied up in organic molecules, travel through the different levels of the food web. Small aquatic animals (zooplankton and invertebrates) graze upon algae and plants. Larger invertebrates and fish then consume the grazers. Energy at upper levels of the food web is derived from the breakdown of organic molecules in the process known as respiration. Respiration and decomposition processes consume oxygen in the water column and in lake sediments.

The larger organic waste products of the food web organisms, together with their remains after death, comprise detritus, which settles to the bottom of the lake and becomes part of the sediment. Bacteria and fungi (decomposers) utilize the energy in this material, converting organic molecules to inorganic nutrients which are once again available for use by plants and algae. Unused organic material accumulates in the sediments. Energy can become blocked in lower levels of the food web instead of flowing smoothly through it, because many of the algae and aquatic plants found in highly eutrophic lakes are also the ones least favored by grazers.

3.3 Strawbridge Lake Water Quality

Water quality data for the tributaries flowing into Strawbridge Lake, Hooten Creek and Pennsauken Creek, and the lake outlet were analyzed for a variety of chemical, physical and biological parameters, which are discussed in the following sections.

3.3.1 Temperature and Dissolved Oxygen

Usually in late spring or the beginning of summer, deep temperate lakes develop stratified layers of water, where warmer and colder waters are near the lake's surface (epilimnion) and the lake's bottom (hypolimnion), respectively. As temperature differences become greater between these two water layers, the resistance to mixing will also increase. Under these circumstances, the epilimnion is usually oxygen rich due to photosynthesis and direct inputs from the atmosphere, while the hypolimnion may become depleted of oxygen due to the decomposition of organic matter.

Temperature and dissolved oxygen profiles were measured at all three lake stations on each sampling date, and the data are presented in Appendix E. Strawbridge Lake showed only weak thermal stratification, mainly in the lower basin, and at no time were anoxic (zero dissolved oxygen) conditions found. Water quality information from 1979 and 1980 also indicates that there was no thermal stratification or oxygen depletion (NJDEP, 1980). The absence of thermal stratification is common in shallow water bodies, such as Strawbridge Lake, because the water column is able to completely mix.

In general, cold water fish, such as trout, function best at temperatures below 72 degrees Fahrenheit (22°C) and dissolved oxygen levels above 4.0 mg/L. Cold water fish species introduced into Strawbridge Lake would experience physiological stress during the summer when surface water temperatures are warm and dissolved oxygen concentrations are low. Therefore, a viable cold water fishery could not be supported in Strawbridge Lake.

3.3.2 Alkalinity and pH

The pH and alkalinity of water are interrelated. The intensity of the acid and base reactions in water is usually expressed as pH, which is the negative logarithm of the hydrogen ion concentration. The hydrogen ion concentration in water is determined by a number of complex interactions, and the pH observed is an overall measure of the intensity of the various acid/base interactions which are occurring. The pH of water ranges from 1 to 14 standard units. A pH of 7 is neutral, while pH values less than 7 are acidic and pH values greater than 7 are basic. Since pH is expressed on a logarithmic scale, each 1 unit change in pH represents ten-fold increase or decrease in hydrogen ion concentration. Therefore, a pH of 6 would be 10 times more acidic than a pH of 7 and 100 times more acidic than a pH of 8. The pH of normal rainwater (containing no pollutants) can be near 5.0 due to small amounts of weak and strong acids of natural origin (Schindler, 1988). As the rainwater travels over and through rocks and soil, chemical reactions with minerals affect the pH and buffering capacity of the water. The pH of water is important because most chemical and biological reactions are controlled or affected by pH.

Alkalinity is a measure of buffer capacity and provides an indication of the capacity of water to neutralize acids. The salts of weak acids, such as bicarbonates, carbonates, borates, silicates and phosphates, are the major source of alkalinity in most waters. In most cases, the bicarbonate ion represents the major form of alkalinity in natural waters at neutral pH levels.

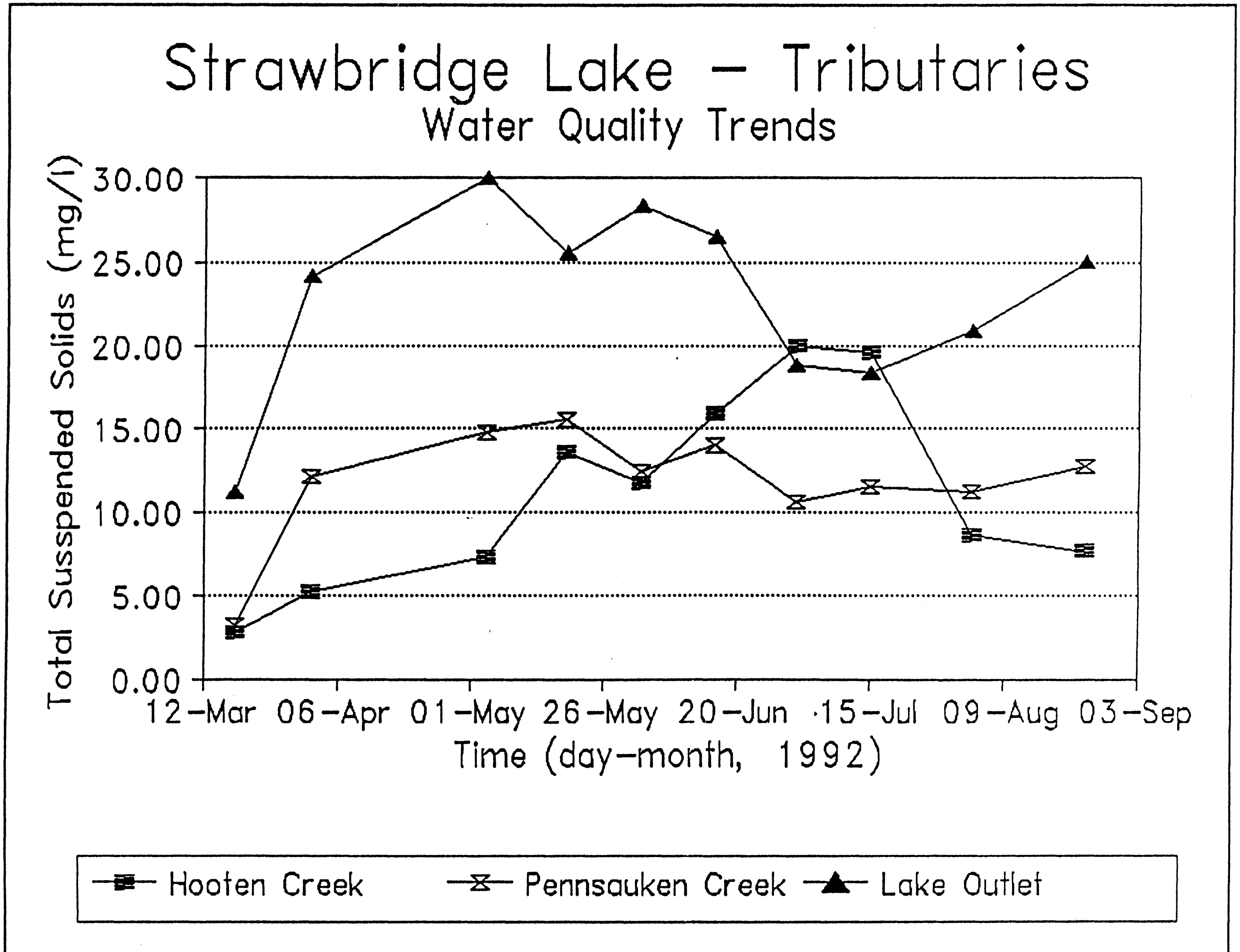
In lake ecosystems, interactions between pH and alkalinity occur when phytoplankton use carbon dioxide in their photosynthetic activity. The pH of the water increases as dissolved carbon dioxide in the water column is utilized as a carbon source for algal growth. As carbon dioxide is removed, $CaCO_3$ precipitates to maintain chemical equilibrium. Calcium carbonate will dissolve when pH decreases to maintain carbon dioxide and bicarbonate concentrations in the water column. As a result of the above interactions, the carbonate system is one of the most important factors affecting the chemical composition of natural waters.

In general, pH values recorded for Strawbridge Lake fall within the range of values typically reported for temperate lake systems, which is 6.0 to 9.0 standard units. For the inflowing tributaries, Hooten Creek and Pennsauken Creek, the pH values ranged from 6.4 to 7.1 and the average was 6.7 units. Lake pH values were a little higher than values reported for the inflowing tributaries. Average pH values for the Upper, Middle and Lower basins were 7.4, 7.0 and 6.9, respectively. The average pH for the outlet was 7.0.

The alkalinity values for this lake may be classified as "moderate", thereby providing a sufficient buffering capacity to acidic inputs such as acidic deposition ("acid rain" and dry fallout). Average alkalinity values for the three stations were 25.9, 24.8 and 25.4 mg/l (as mg $CaCO_3$) for the Upper, Middle and Lower Basins, respectively.

3.3.3 Total Suspended Solids

The concentration of total suspended solids in a lake is a measure of the amount of particulate matter in the water column. Suspended solids are comprised of both organic matter, such as algae, and inorganic material, including soil particles and clay minerals. The presence of large amounts are indicative of poor water quality, because these particles carry pollutants into the lake and decrease water depth through sedimentation.


Strawbridge Lake - Tributaries
Water Quality Trends
Total Susspended Solids (mg/l)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
12-Mar
06-Apr
01-May
26-May
20-Jun
15-Jul
09-Aug
03-Sep
Time (day-month, 1992)
Hooten Creek
Pennsauken Creek
Lake Outlet

Total suspended solids concentrations in the three main tributaries were monitored over the entire six month study period, and these data are presented in Figure 3. Additional samples were collected from the tributaries and the major storm culverts during three different storm events on May 8, June 5, and July 22. Excluding storm event samples, the average total suspended solids for Hooten Creek, Pennsauken Creek and the lake outlet were 11.2, 11.8 and 22.9 mg/L, respectively. The average suspended solids concentrations for the storm events were 44.5, 43.0, and 24.4 mg/L for Hooten Creek, Pennsauken Creek and the lake outlet, respectively.

As shown in Figure 3, total suspended solid concentrations were also high in each of the lake's basins. Upper Basin surface total suspended solids concentrations ranged from 1.0 to 16.4 mg/L with a mean of 6.7 mg/L. Middle Basin total suspended solids concentrations ranged from 3.2 to 11.2 mg/L with a mean of 7.1 mg/L. Lower Basin total suspended solids concentrations ranged from 8.0 to 36.0 mg/L with a mean of 21.4 mg/L.

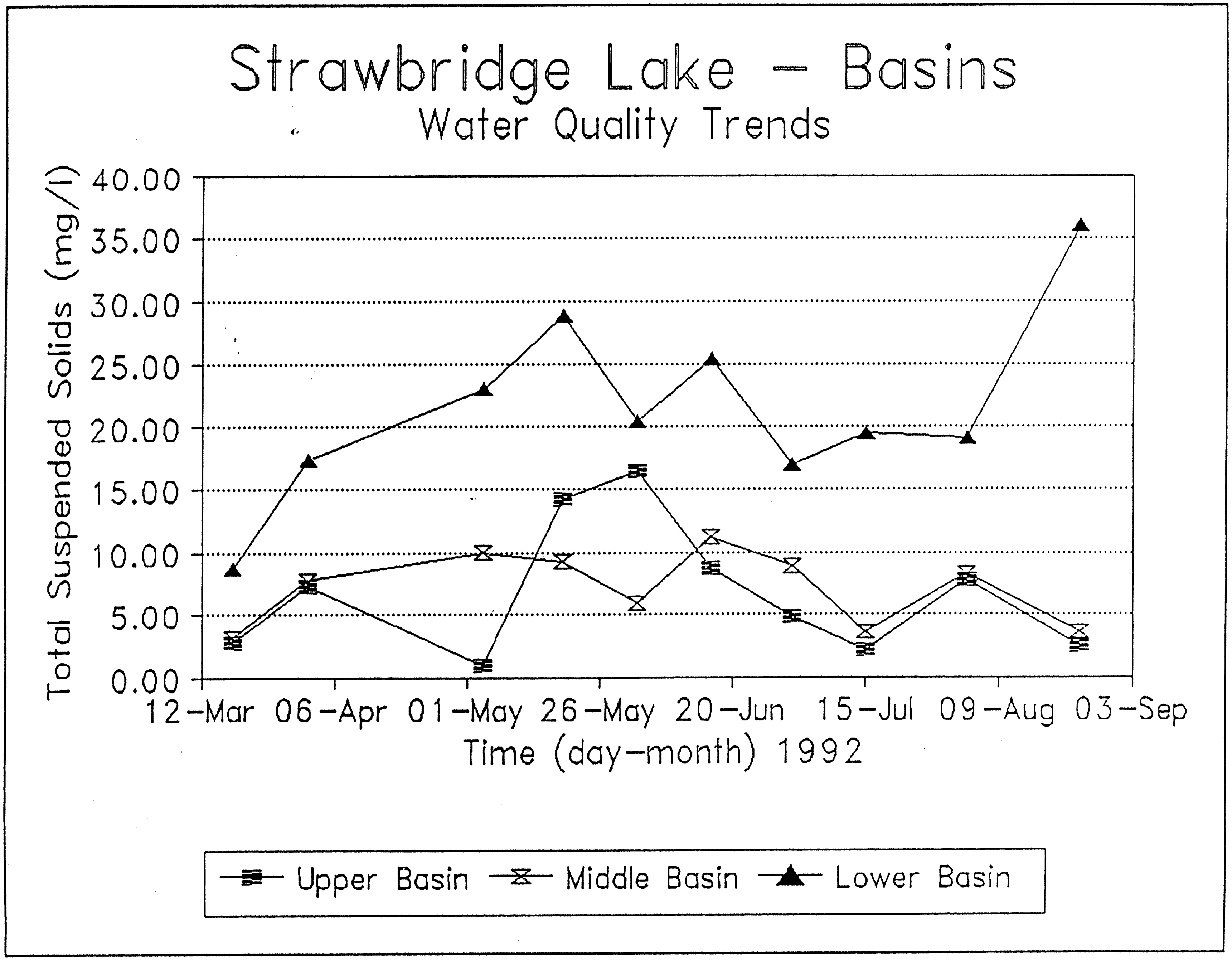
Total suspended solids concentrations were substantially higher in the lower basin relative to the upper two basins. This is because the lower basin receives drainage from Pennsauken Creek in addition to Hooten Creek. Also, the lower basin is more heavily impacted by storm culverts draining directly into the Lake. The impact of these storm culverts are discussed in Section 3.6.

Overall, total suspended solids concentrations in Strawbridge Lake are very high. In fact, these levels are more characteristic of streams. This is because the lake volume is so small relative to the amount of water flowing through the basins.

3.3.4 Transparency

The transparency, or clarity, of water is most often reported in lakes as the Secchi disk depth. This measurement is taken by lowering a circular white or black-and-white disk, 20 cm (8 inches) in diameter, into the water until it is no longer visible. Observed Secchi disk depths range from a few centimeters in very turbid lakes to over 40 meters in the clearest known lakes (Wetzel, 1975). Although somewhat simplistic and subjective, this testing method probably best represents the conditions which are most readily visible to the common lake user.

Secchi disk transparency is related to the transmission of light in water, and depends on both the absorption and scattering of light. The absorption of light in dark-colored waters reduces light transmission. Light scattering is usually a more important factor than absorption in determining Secchi depths. Scattering can be caused by color, by particulate organic matter, including algal cells, and by inorganic materials, such as suspended clay particles in water.



Strawbridge Lake - Basins
Water Quality Trends
Total Suspended Solids (mg/l)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
12-Mar 06-Apr 01-May 26-May 20-Jun 15-Jul 09-Aug 03-Sep
Time (day-month) 1992
Upper Basin
Middle Basin
Lower Basin

Figure 3

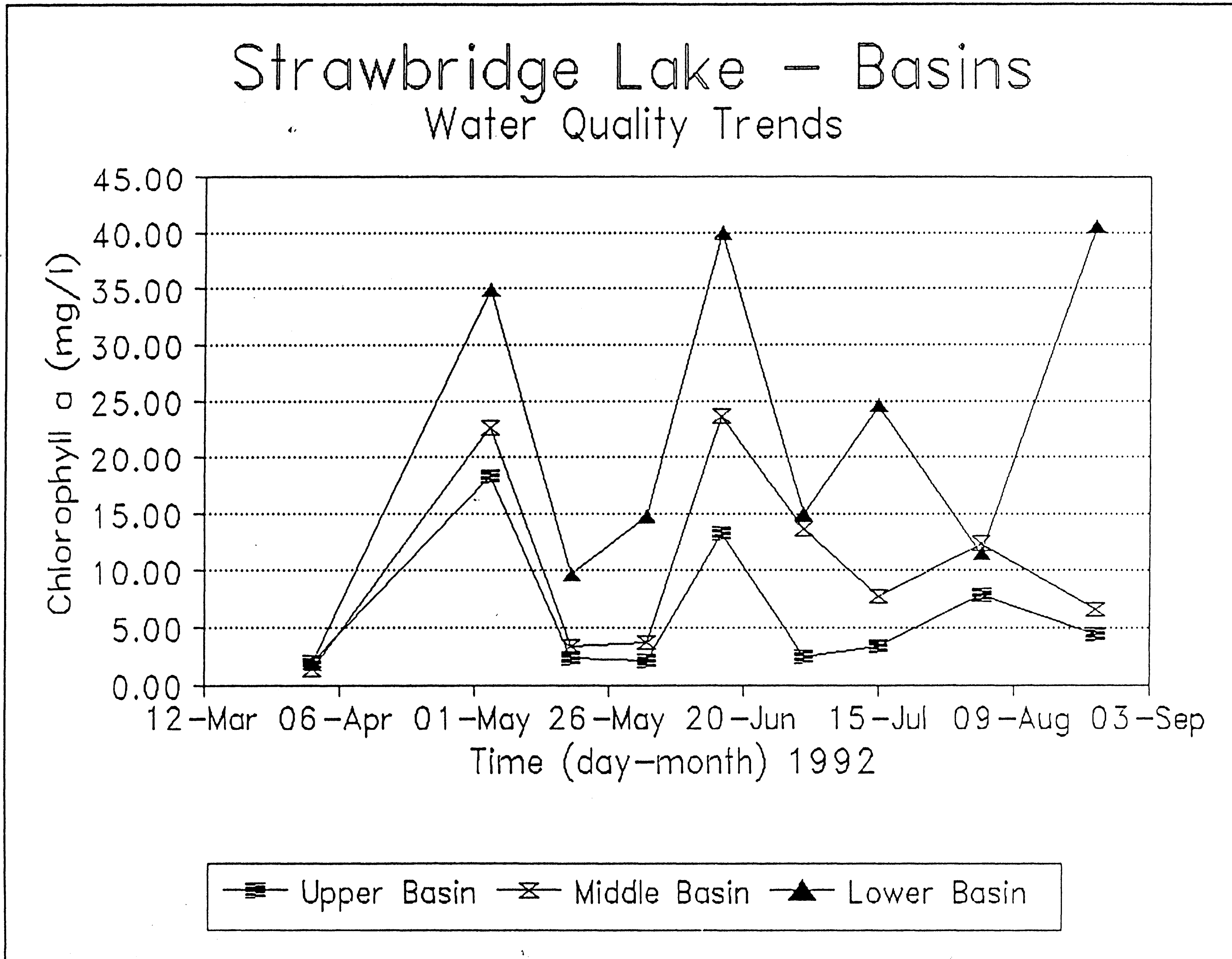


Figure 8
Chlorophyll a

Secchi disk transparencies for each basin are shown in Figure 4. Overall, water clarity is quite poor in Strawbridge Lake. Average Secchi depths were 0.83, 0.89, and 0.43 meters for the upper, middle, and lower basins, respectively. The lower basin showed the lowest transparency on all sampling dates.

Low lake transparencies can be related to both high levels of algal biomass and inorganic suspended solid. In general, transparency in Strawbridge Lake is affected to a greater extent by suspended inorganic particulates, such as clay particles. This conclusion is partly based on the simple observation that the water in Strawbridge Lake is more likely to appear brown rather than green. In addition, the period with the lowest transparency, the end of May thru the beginnignof of June, had high concentrations of suspended solids but low concentrations of chlorophyll a. A more detailed discussion regarding chlorophyll a (a measure of algal biomass) is found in Section 3.4.1 and the relationship between transparency, chlorophyll a, turbidity and lake trophic status is discussed in Section 3.6.

3.3.5 Nutrient Concentrations

Phosphorus and nitrogen compounds are major nutrients required for the growth of algae and macrophytes in lakes. The lake monitoring program that was developed for Strawbridge Lake included the analysis of lake samples for both total and dissolved inorganic forms of both nutrients. The dissolved inorganic nutrients, dissolved reactive phosphorus and nitrate and ammonia nitrogen, are regarded as the forms readily available to support aquatic growth, while the total nutrient amounts provide an indication of the maximum growth which could be achieved.

Phosphorus

Total phosphorus represents the sum of all phosphorus forms, and includes dissolved and particulate organic phosphates from algae and other organisms, inorganic particulate phosphorus from soil particles and other solids, polyphosphates from detergents, and dissolved orthophosphates. Soluble orthophosphate is the phosphorus form that is most readily available for algal uptake and is usually reported as dissolved reactive phosphorus because the analysis takes place under acid conditions which can result in some hydrolysis of other phosphorus forms. Once soluble orthophosphorus is taken up by algae it will be measured as part of the total phosphorus concenhtration.

Total phosphorus is the most commonly used chemical parameter to describe a lake's trophic state. The amount of total phosphorus found within the water column of a lake is equal to the amount that has entered the lake minus the amount that has flowed out and/or settled into the sediments. On the other hand, soluble orthophosphate levels are highly affected by algal consumption during the growing season.

Total phosphorus concentrations at all three tributaries for the study period are shown in Figure 5.

For the inflowing tributaries, the average total phosphorus levels were 0.052, and 0.105 mg/L for Hooten Creek and Pennsauken Creek, respectively. The average total phosphorus concentration of the lake outlet was 0.202 mg/L. The average total phosphorus concentrations for three storm events (May 8, June 5 and July 22) were 0.172, 0.297 and 0.152 mg/L for Hooten Creek, Pennsauken Creek, and the lake outlet, respectively. These high concentrations of total phosphorus concentrations during storm flows are caused by erosion and stormwater runoff in the watershed.

Total phosphorus concentrations in Strawbridge Lake are shown in Figure 6.

Total phosphorus levels were high in Strawbridge Lake, with concentrations for surface water samples being 0.052, 0.055 and 0.188 mg/L for the Upper, Middle and Lower Basins, respectively. Average total phosphorus concentrations were similiar between Hooten Creek and the Upper and Middle basins. The substantially higher concentrations in the lower basin were due to the influence of Pennsauken Creek and stormwater enterning the basin flow storm culverts.

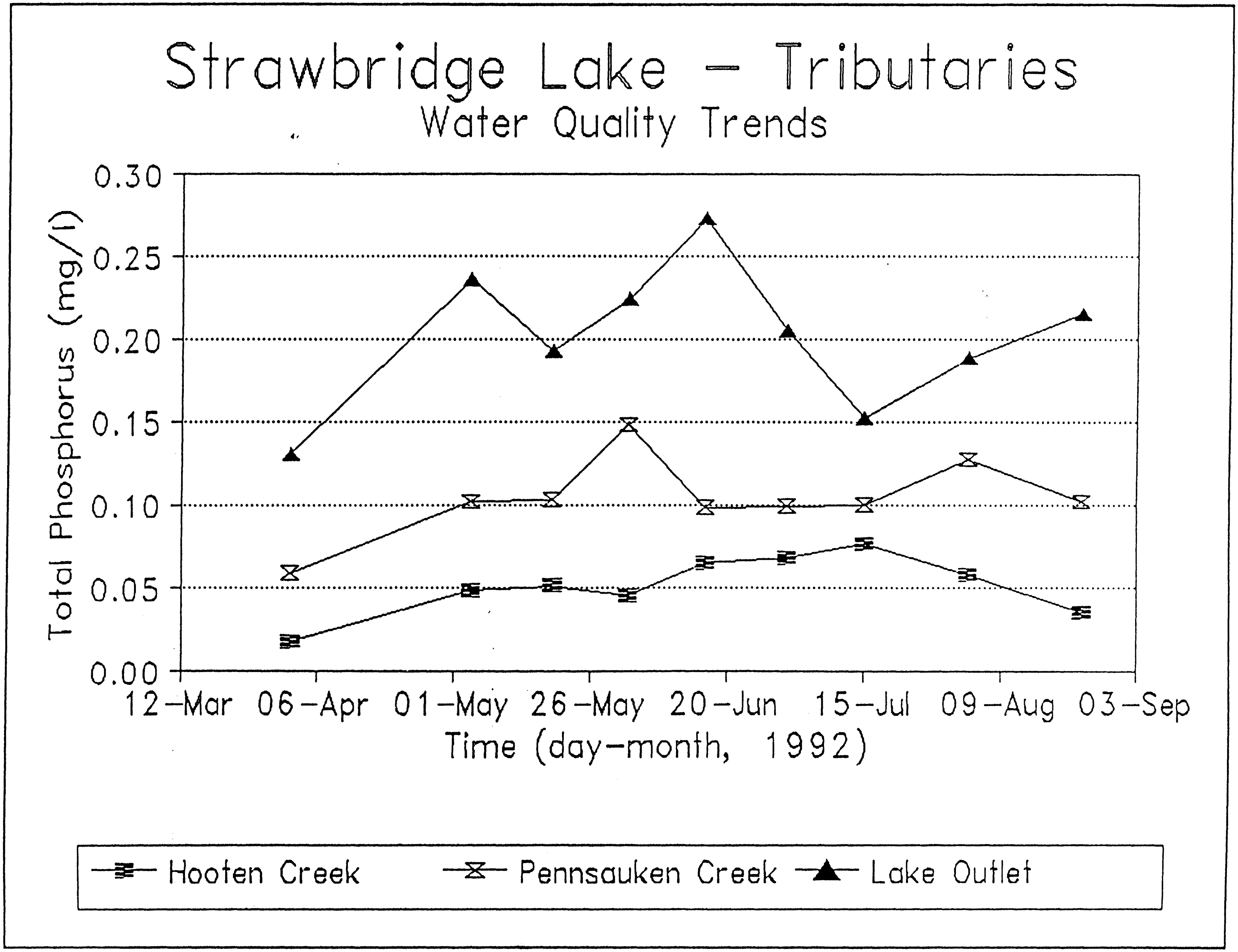
In contrast to total phosphorus, orthophosphate levels were relatively low in Strawbridge Lake. Average concentrations were 0.003, 0.003 and 0.007 mg/L at the Upper, Middle and Lower Basin stations, respectively.

It is not uncommon for lakes with high total phosphorus levels to have low orthophosphorus concentrations. For example, in many eutrophic (phosphorus rich) lakes summer orthophosphate levels are usually very low due to high algal uptake. However, chlorophyll a concentrations in Strawbridge Lake were substantially lower than would be expected based on its total phosphorus concentrations. This suggests that most of the total phosphorus appears to be inorganic phosphorus that is bound to sediment particles entering the lake through the tributaries. The interrelationships between total phosphorus, chlorophyll, Secchi transparncy, and the lake's trophic are will be discussed in further detail in Section 3.6.

Nitrogen

Nitrogen compounds are also important for algae and aquatic macrophyte growth. The common inorganic forms of nitrogen in water are nitrate (NO_3^-), nitrite (NO_2^-) and ammonia (NH_3). The form of inorganic nitrogen present depends largely on oxygen concentrations. Nitrate is the form usually found in surface waters, while ammonia is only stable under anaerobic (low oxygen) conditions. Nitrite is an intermediate form which is unstable in surface waters. Nitrate and nitrite (total oxidized nitrogen) are often analyzed together and reported as NO_3+NO_2-N, although nitrite concentrations are usually

Figure 5



Strawbridge Lake - Tributaries
Water Quality Trends
Total Phosphorus (mg/l)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
12-Mar
06-Apr
01-May
26-May
20-Jun
15-Jul
09-Aug
03-Sep
Time (day-month, 1992)
Hooten Creek
Pennsauken Creek
Lake Outlet

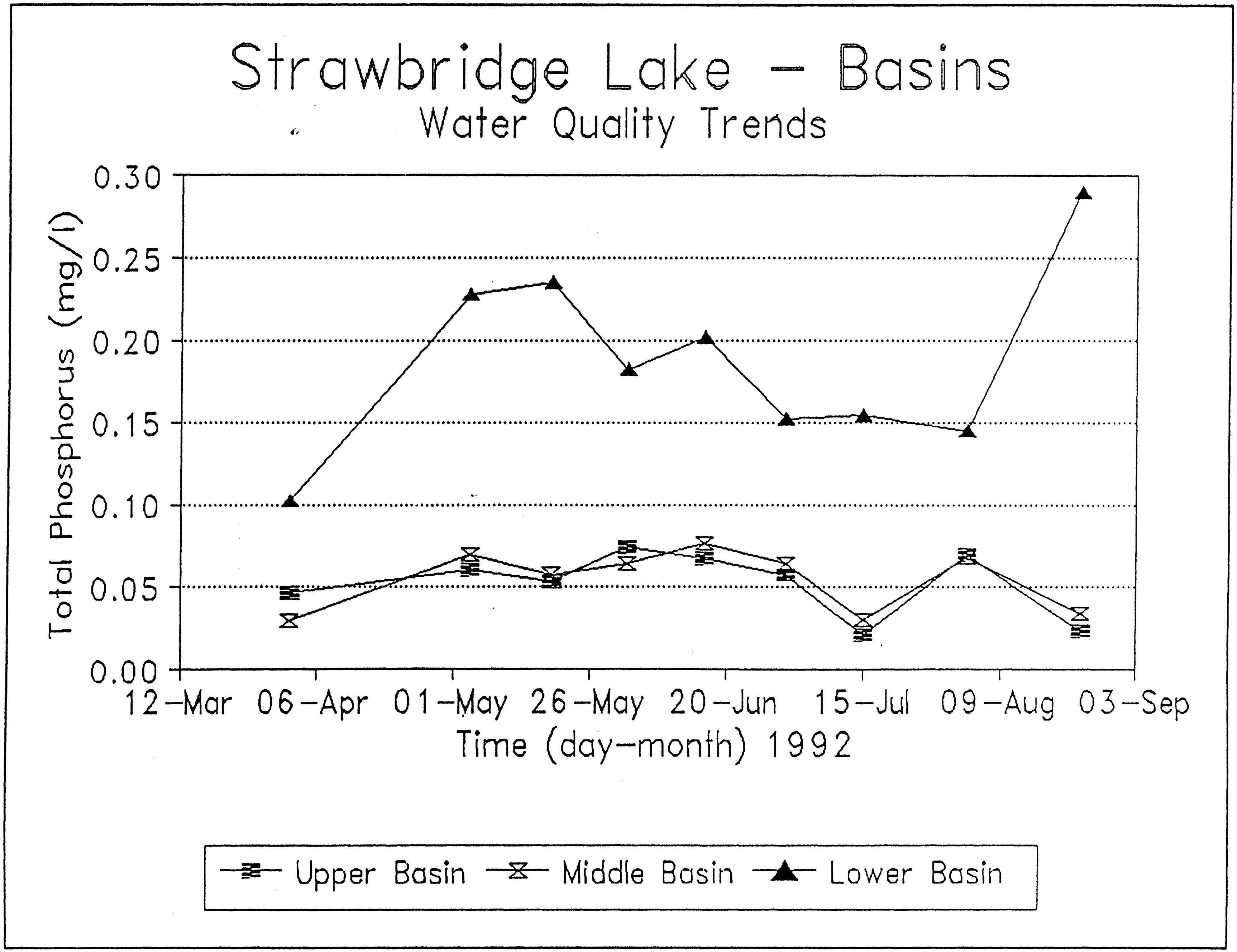

Strawbridge Lake - Basins
Water Quality Trends
Total Phosphorus (mg/l)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
12-Mar
06-Apr
01-May
26-May
20-Jun
15-Jul
09-Aug
03-Sep
Time (day-month) 1992
Upper Basin
Middle Basin
Lower Basin

Figure 6

insignificant. Total Kjeldahl nitrogen (TKN) concentrations include ammonia and organic nitrogen (both soluble and particulate forms).

Total oxidized nitrogen, total Kjeldahl nitrogen and ammonia were monitored at all lake and tributary stations. The average total Kjeldahl nitrogen concentrations were 0.45, 0.52 and 0.741 mg/L for Hooten Creek, Pennsauken Creek and the lake outlet, respectively. At all three monitoring stations at Strawbridge Lake, total Kjeldahl nitrogen concentrations were higher than inflow concentrations). The highest average total Kjeldahl nitrogen concentrations was recorded at the Lower Basin (0.76 mg/L). The average total Kjeldahl nitrogen concentration for the Middle and Upper Basins were 0.50 and 0.42 mg/L, respectively.

The average total oxidized nitrogen (NO_2 - NO_3) concentrations were 0.47, 0.25 and 0.24 mg/L for Hooten Creek, Pennsauken Creek and the lake outlet, respectively. The Upper, Middle and Lower Basin average total oxidized nitrogen concentrations were 0.27, 0.30 and 0.27 mg/L, respectively. Amonia concetration were nearly always below the detection limit, as would be expected in well oxygenated waters.

Limiting Nutrient

Phytoplankton growth depends on a variety of nutrients, including macronutrients such as phosphorus, nitrogen, and carbon, and trace nutrients, such as iron, manganese, and other trace minerals. According to the law of the minimum, biological growth is limited by the factor that is present in the minimum quantity with respect to the needs of the organism. In natural waters, phosphorus and nitrogen are nutrients which most commonly limit algal growth. Assuming one of these nutrients is the limiting algal and aquatic weed growth, the limiting nutrient can be calculated two ways: 1) calculating the ratio of total nitrogen to total phosporus (TN:TP), or 2) calculating the ratio of total inorganic nitrogen to dissolved reactive phosphorus (TIN:DRP).

Depending on the species, algae require approximately 15 to 26 atoms of nitrogen for every atom of phosphorus. This ratio converts to 7 to 12 mg of nitrogen per 1 mg of phosphorus on a mass basis. A ratio of total nitrogen to total phosphorus of 15:1 is generally regarded as the dividing point between nitrogen and phosphorus limitation (U.S. EPA, 1980). Identification of the limiting nutrient becomes more certain as the total nitrogen to total phosphorus ratio moves farther away from the dividing point, with ratios of 10:1 or less providing a strong indication of nitrogen limitation and ratios of 20:1 or more strongly indicating phosphorus limitation. TN:TP ratios for Strawbridge Lake are shown in Figure 7. This graph suggests algae are strongly limited by nitrogen in the lower basin, and no clear conclusion can be drawn in the upper two basins.

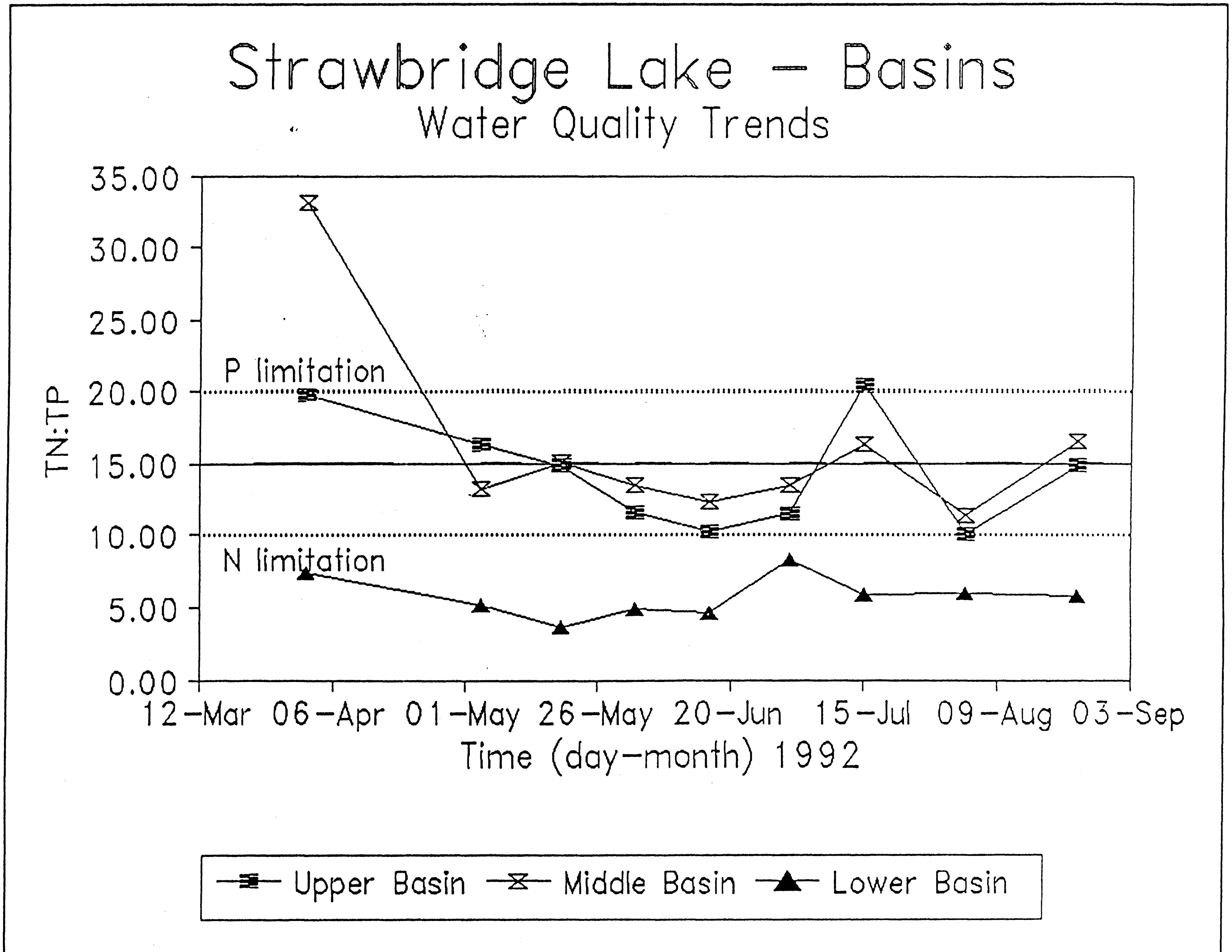


Figure 7
TN:TP

Ratios of total inorganic nitrogen (TIN = ammonia- and nitrate plus nitrite-nitrogen) to dissolved reactive phosphorus (DRP) greater than 12 are indicative of phosphorus limitation, ratios of TIN:DRP less than 8 are indicative of nitrogen limitation, and TIN:DRP ratios between 8 and 12 indicate either nutrient can be limiting (Weiss, 1976). The ratio of TIN:DRP for Strawbridge Lake never fell below 22, suggesting very strong phosphorus limitation.

It is important to realize when interpreting these data that factors other than nutrients can limit algal growth. As shown previously, Strawbridge Lake has high levels of suspended solids and low transparency. This means that light can be the overall limiting factor. This matter will be discussed further in Section 3.6.

3.4 Biological Interactions

The size of algal and plant populations, and chlorophyll a concentrations in water are primary biological indicators of lake trophic conditions. Identification of species within producer and consumer food web levels is also important in understanding dynamics causing lake conditions. Eutrophic lakes often support unbalanced communities characterized by large numbers of relatively few species.

3.4.1 Phytoplankton and Chlorophyll a

Phytoplankton

Phytoplankton are microscopic algae that have little or no resistance to currents and live free floating and suspended in open water. Their form may be unicellular, colonial or filamentous. As photosynthetic organisms (primary producers), they form the base of aquatic food chains and are grazed upon by zooplankton and herbivorous fish.

A healthy lake should support a diverse assemblage of phytoplankton, in which many algal species are represented. Excessive growth of a few species is usually undesirable. Such growths can cause oxygen depletion in the water at night, when the algae are respiring but not photosynthesizing. Oxygen depletion can also occur after an algal bloom when bacteria, using dead algal cells as a food source, grow and multiply. Excessive growths of some species of algae, particularly members of the blue-green group, may cause taste and odor problems, release toxic substances to the water, or give the water an unattractive green soupy or scummy appearance.

Phytoplankton samples were taken from Strawbridge Lake as part of the regular lake sampling program. Cells were identified to genus and counted. Biomass was determined for each genus, based on cell size. Phytoplankton data are included in Appendix D.

Overall phytoplankton abundances were highly variable both within and between basins. The overall densities ranged from 144 to 15300 individuals per ml. The highest densities were found in the lower basin and the lowest were found in the upper basin. The trend between basins was reversed for diversity, with the upper basin showing the greatest number of genera. In all basins the highest densities were generally associated with the lowest diversity and a dominance of either Chrysophyta (brown alage) or Cyanophyta (Blue-green algae). In all cases, high densities of these algae were followed by a sharp decline in the next sample collected.

The composition of the phytoplankton community in Strawbridge Lake appears influenced by the lake's high flushing rate and low light availability. The two most important genera of blue-green algae observed in Strawbridge Lake were *Oscillatoria* and *Anabaena*. Both of these genera form surface scums and are rather easy to flush out of a lake. Also, the alteration in dominance between blue-green algae (mainly *Oscillatoria*) and the filamentous brown algae ,*Dinobryon*, could also be a function of rapid fluctuations between nitrogen and phosphorus limitation.

Chlorophyll a

Chlorophyll a is a pigment which gives the green color to all green plants. Its function is to convert sunlight to chemical energy in the process known as photosynthesis. Because chlorophyll a constitutes about 1 to 2 percent of the dry weight of planktonic algae, the amount of chlorophyll a in a water sample is an indicator of phytoplankton biomass.

Chlorophyll a concentrations monitored at all lake stations from April to August, are presented in Figure 8. The average chlorophyll a concentrations were 6.2, 10.5 and 21.4 μg/L for the Upper, Middle and Lower Basins, respectively. In general, chlorophyll a concentrations were highly variable throughout the study period. This high variablity between sampling dates suggests algal biomass levels in Strawbridge Lake may be partly controlled by the flushing of the lake during storm events. Basically, this involves the development of large algae populations during low flow periods which are flushed out of the lake during high flows.

In general, chlorophyll a concentrations between 2.0 and 4.0 μg/L indicate oligotrophic conditions while concentrations greater than 6 μg/L indicate eutrophic conditions. Chlorophyll a concentrations in Strawbridge Lake were low relative to the observed phosphorus concentrations. In section 3.7, the relationship between chlorophyll a, total phosphorus and secchi depth is discussed.

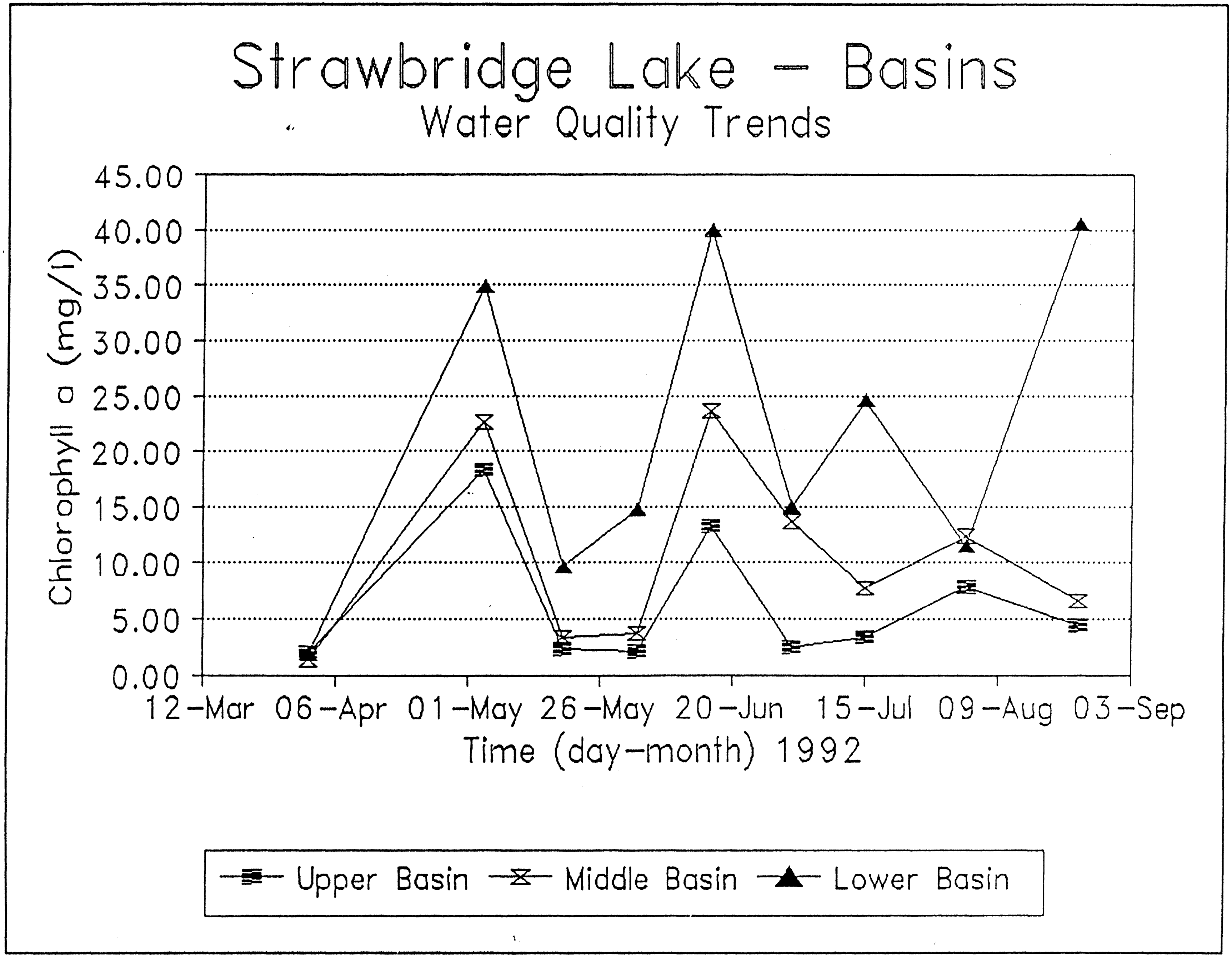


Figure 8
Chlorophyll a

3.4.2 Macrophyte Survey

A macrophyte (aquatic plant) survey of Strawbridge Lake was conducted in (July) 1992. Plants were collected, identified and mapped in order to show species distribution within the lake. A map showing the distribution of macrophytes in Strawbridge Lake was developed.

While macrophytes colonize nearly the entire bottom of the lake, areal biomass (mass of plants within a given area) was generally low. Also, they were only visable from the shore in relatively small areas where canopies at the water's surface formed. Overall, the presence of these plants do not severely diminish water quality, which is surprizing in such a shallow nutrient rich lake. It appears the high levels of suspended sediments in this lake have a shading effect on these plants, as well as the algae. Therefore, it is quite possible that the growth of these plants will increase drastically if water clarity improves.

The most common aquatic macrophyte in Strawbridge Lake is *Ceratophyllum demersum* (commonly called coontail). This plant is generally considered to be a nuisance by lake users, because it is unsightly and can inhibit boat travel and fishing.

Nuphar spp. (commonly called Spatterdock or Cow Lily) is the second most common aquatic plant in Strawbridge Lake. In contrast to *Ceratophyllum demersum*, this plant is commonly considered to be a "pretty" plant. It is likely the presence of this plant adds aesthetic appeal for most lake users.

3.4.3 Fecal Coliform Bacteria

The bacterial population in lakes is an essential part of a healthy aquatic biological community. Bacteria are decomposers and break down large organic molecules into inorganic nutrients which are released back into the water column. Many of the nutrient cycles and chemical interactions in lakes are dependent upon the activity of a diverse bacterial assemblage; however, there are few types of bacteria that may occur in lakes which may be harmful in and of themselves, or indicate the presence of harmful organisms.

When people use a water resource for primary contact purposes such as a drinking water supply or for swimming, the water must be tested frequently to make sure that no disease-causing organisms (pathogens) are present. Pathogenic types of bacteria, protozoa and viruses can be transmitted to humans via water. The source of many of these pathogens is intestinal wastes from warm-blooded animals including humans, domestic and wild animals and birds. Excreta contains a wide assemblage of organisms, some of which are pathogenic, some not. The non-pathogenic coliform bacteria have long been used to indicate presence of fecal material in water systems.

An ideal indicator organism should always be present in water when pathogenic fecal organisms are present, the survival time of the indicator should be greater than that of pathogens in the water, it should disappear rapidly after pathogens disappear and the indicator should always be absent in water which is free of pathogens. At present, there is no ideal indicator, but methods are constantly being revised to approach the ideal as research increases our understanding of bacterial dynamics in aquatic systems.

If the test for total coliforms (TC) is positive, the water source in question may contain fecal material. However, there are many different types of bacteria in the coliform group, some of which do not originate from warm-blooded animals, but are naturally occurring in vegetation, insects, fish and soils. Also, some strains of the coliform group (notably Aeromonas) are able to multiply in receiving waters if conditions such as temperature and nutrient content are favorable, making evaluation of actual fecal pollution difficult. Because of this problem, a test differentiating fecal coliforms (FC) from other coliforms is now widely used.

The presence of fecal coliforms definitely indicates fecal pollution; however, there are limitations to this test. A few species of fecal coliforms will not show up in the fecal coliform test. In addition, the relationship between pathogens and fecal coliforms in terms of their co-occurrence and survival times in aquatic systems has not been thoroughly established. There are tests available for measuring levels of pathogens themselves but these tests are not widely used because of sensitivity limitations and the number of tests necessary to assure safety of the water source.

Water samples from Strawbridge Lake and its tributaries were analyzed for fecal coliform bacteria. The average fecal coliform counts were 454, 469, and 198 colonies per 100 mL for Hooten Creek, Pennsauken Creek and the lake outlet, respectively. The average fecal coliform count for the Upper, Middle and Lower Basins were 184, 167 and 371 colonies per 100 mL, respectively. The highest counts were observed on June 2, 1992, for all three lake stations. In general, fecal bacteria concentrations greater than 200 colonies per 100 mL is considered unsafe for contact recreation, such as swimming.

The fecal bacteria in Strawbridge Lake appear to come from a mixture of animal and human sources. Septic systems near the intersection of Church Street and Route 38 may contribute to high bacterial counts. Waterfowl and farm animals are also sources.

3.5 Sediment Analyses

Sediment cores were collected from five locations in Strawbridge Lake in April, 1992. A KB coring device was used to collect two foot cores from two sites in the Upper and Lower Lake basins and one in the Middle Lake basin (see Figure 2). The samples from each basin were composited and analyzed for solids, particle size distribution, nutrients, heavy metals, pesticides and PCB's, and TCLP (Toxicity Characteristic Leaching Procedure). The TCLP replaced the Extraction Procedure (EP) toxicity leachate test in 1990 (55 FR 61, March 1990). The TCLP is a more aggressive leachate test than EP toxicity test for highly alkaline wastes and volatile organic compounds. The guidelines for determining how sediments can be disposed depend on TCLP leachate and bulk analysis results.

The results of the physical characteristics are presented in Table 10. The three samples ranged from 18.2 percent solids to 28.2 percent solids. Percent volatile solids ranged from 14.0 to 14.4. Particle size distribution tests characterize lake sediments according to grain size. The five categories are listed by decreasing grain size from gravel to clay. Sediments from the upper and middle basins of Strawbridge Lake consisted of mostly silt and clay. The Lower Basin was roughly 34 percent fine sand, 44 percent silt and 20 percent clay.

The results of the nutrient and metal analyses and TCLP toxicity analyses are presented in Tables 11 and 12. Total phosphorus and total nitrogen concentrations were relatively high for lake sediments indicating organic enrichment of the sediments. Several of the metals analyzed including barium, cadmium, chromium and silver were present in concentrations below detection limit. Total concentrations of all pesticides tested were also below detection limits. These sediments did not exceed the maximum allowable concentrations for the TCLP analysis. In the bulk analysis, only lead exceeded the regulatory limit for residential disposal. However, the non-residential lead standard was not exceeded.

The TCLP toxicity test simulates the leaching of contaminants from wastes disposed in a landfill. It is used on dredged material to determine if the sediment would be classified as a hazardous waste for disposal purposes. There is little correlation between sediment concentrations of pollutants and leachate test concentrations of those same pollutants (Kizlauskas and Homer, 1984). Concentrations of all parameters tested were below RCRA/NJDEPE regulatory concentrations for TCLP toxicity (Table 12).

Table 10 Sediment Results: pH and Physical Characteristics			
Parameter	**Upper Basin**	**Middle Basin**	**Lower Basin**
pH (standard units)	7.76	7.40	7.20
Percent Solids	18.16	24.97	28.23
Percent Volatile Solids	14.43	14.04	13.99
Percent Gravel	2.3	0.4	0.1
Percent Coarse Sand	2.1	1.2	2.3
Percent Fine Sand	4.2	10.0	33.7
Percent Silt	52.7	51.4	43.6
Percent Clay	38.7	37.0	20.3

Table 11
Sediment Results: Total Concentrations

Parameter	Upper Basin Concentration	Middle Basin Concentration	Lower Basin Concentration	Regulatory Limits for Residential Application*
Total Phosphorus (mg/kg)	1,526	97.2	669	NA
Total Nitrogen (mg/kg)	2,875	3,075	2,250	NA
Total Petroleum Hydrocarbons (mg/kg)	695	961	1,580	---
Arsenic (mg/kg)	9.0	12	10	20
Barium (mg/kg)	<20	<20	<20	600
Cadmium (mg/kg)	<0.05	<0.05	<0.05	1
Chromium (mg/kg)	<0.1	<0.1	<0.1	---
Lead (mg/kg)	190	200	145	100
Mercury (mg/kg)	0.28	0.25	0.25	14
Selenium (mg/kg)	3.0	1.8	0.025	1
Silver (mg/kg)	<0.1	<0.1	<0.1	40
PESTICIDES Chlordane (μg/kg)	<10	<10	<10	---
Endrin (μg/kg)	<10	<10	<10	17000
Heptachlor (μg/kg)	<10	<10	<10	150
Lindane (μg/kg)	<50	<50	<50	520
Methoxychlor (μg/kg)	<10	<10	<10	280000
Toxaphene (μg/kg)	<10	<10	<10	620
PCBs (μg/kg)	<50	<50	<50	450

* Regulatory limits for the land application of sludge material on residential lands (NJDEPE). Other required limits in mg/kg; copper 600, DDE 3, DDT 2, DDE 2, total phenol 10,000. Sulfate/sulfide, chlorides, and oil and grease must be measured but have no regulatory limit.

Table 12
Sediment Results: Toxicity Characteristic Leaching Procedure

Parameter	Upper Basin Concentration	Middle Basin Concentration	Lower Basin Concentration	Maximum Allowable Concentration
INORGANICS Arsenic (mg/L)	0.018	0.020	0.020	5.0
Barium (mg/L)	<0.2	<0.2	<0.2	100.0
Cadmium (mg/L)	<0.01	<0.01	<0.01	1.0
Chromium (mg/L)	<0.05	<0.05	<0.1	5.0
Lead (mg/L)	0.004	0.005	0.004	5.0
Mercury (mg/L)	<0.02	<0.02	<0.02	0.2
Selenium (mg/L)	0.018	0.023	0.017	1.0
Silver (mg/L)	<0.05	<0.05	<0.05	5.0
VOLATILE ORGANICS Benzene (μg/L)	<50	<100	<50	500
Carbon Tetrachloride (μg/L)	<50	<100	<50	500
Chlorobenzene (μg/L)	<50	<100	<50	100,000
Chloroform (THM) (μg/L)	<50	<100	<50	6,000
1,4-Dichlorobenzene (μg/L)	<50	<100	<50	7,500
1,2-Dichloroethane (μg/L)	<50	<100	<50	500
1,1-Dichloroethylene (μg/L)	<50	<100	<50	700
Methyl ethyl ketone (μg/L)	<500	<1000	<500	200,000
Tetrachloroethylene (μg/L)	<50	<100	<50	700
Trichloroethene (μg/L)	<50	<100	<50	500
Vinyl Chloride (μg/L)	<50	<100	<50	200
BASE NEUTRAL EXTRACTABLES 2,4-Dinitrotoluene (μg/L)	<10	<10	<10	130*
Hexachlorobenzene (μg/L)	<10	<10	<10	130*
Hexachlorobutadiene (μg/L)	<10	<10	<10	500
Hexachloroethane (μg/L)	<10	<10	<10	3,000
Nitrobenzene (μg/L)	<10	<10	<10	2,000
Pyridine (μg/L)	<100	<100	<100	5,000

Table 12 (continued)
Sediment Results: Toxicity Characteristic Leaching Procedure

Parameter	Upper Basin Concentration	Middle Basin Concentration	Lower Basin Concentration	Maximum Allowable Concentration
ACID EXTRACTABLES O-cresol (μg/L)	<10	<10	<10	200,000
m-Cresol (μg/L)	<10	<10	<10	200,000
p-cresol (μg/L)	<10	<10	<10	200,000
Pentachlorophenol (μg/L)	<10	<10	<10	100,000
2,4,5-Trichlorophenol (μg/L)	<10	<10	<10	400,000
2,4,6-Trichlorophenol (μg/L)	<10	<10	<10	2,000
PESTICIDES Chlordane (μg/L)	<10	<10	<10	30
Endrin (μg/L)	<10	<10	<10	20
Heptachlor (μg/L)	<10	<10	<10	8
Lindane (μg/L)	<50	<50	<50	400
Methoxychlor (μg/L)	<10	<10	<10	10,000
Toxaphene (μg/L)	<10	<10	<10	500
HERBICIDES 2-4-D (μg/L)	<10	<10	<10	10,000
2,4,5-TP Silvex (μg/L)	<10	<10	<10	1,000

* NJDEPE regulatory concentration differs from U.S. EPA standard

Previous Studies

Several studies have examined concentrations of pesticides in sediments and fish tissue from Pennsauken Creek and Strawbridge Lake. Although a garden center fire in 1978 drew attention to contaminated waters in the vicinity of Strawbridge Lake, pesticide contamination of Pennsauken Creek existed prior to garden center fire. In 1976, before the garden center fire, the NJDEP examined fish tissue for pesticide and PCB contamination. High concentrations of the pesticide chlordane were found in fish collected from Pennsauken Creek and adjacent Cooper River (Belton et al., 1982). Chlordane is an organochlorine pesticide used as a non-species specific garden pesticide and for termite control. After the fire, the NJDEP found contaminated sediments in Strawbridge Lake sediments in 1979 during their Intensive Lake Survey (NJDEP, 1980). A follow up study by the NJDEP and the New Jersey Department of Health (NJDOH) found that sediments from five other western New Jersey waterways were also contaminated with organochlorine pesticides (Suchow et al., 1982). The Belton et al. (1982) and the Suchow et al. (1982) indicate that the fire at the garden center was only partially responsible for high pesticide concentrations in Strawbridge Lake. Because pesticide contamination was detected in Pennsauken Creek fish before the fire and because other area tributaries also exhibit high pesticide concentrations, homeowner pesticide use in the urban watersheds may be the primary pollutor.

Comparison of 1992 sediment data with previous studies indicate a decline in Strawbridge Lake sediment concentrations of the pesticide chlordane. Sediment samples collected from Strawbridge Lake in 1979 yielded a chlordane level of 11,892.7 μg/kg (NJDEP, 1980). The follow up study by the NJDEP and the NJDOH found lower concentrations of chlordane (range 1,369 μg/kg to 2,594 μg/kg) in Strawbridge Lake (Suchow et al., 1982). Strawbridge Lake sediments were examined again as part of a thesis project in 1983 and 1984 by Moser (1985). Thirteen sediment samples collected from the three basins of Strawbridge Lake yielded concentrations of alpha and gamma chlordane from nondetectable to 568 μg/kg (Moser, 1985). Chlordane levels in sediment samples from all three basins in the 1992 study were below detection limits.

3.6 Trophic State Index

Eutrophication is a natural process whereby sediments and nutrients from the watershed accumulate in the lake. The eutrophication process is often accelerated by the activities of man. Contrary to the popular opinion that a eutrophic lake is "dead," it is actually suffering from an over-abundance of living organisms. The organisms in a eutrophic lake are abundant in number, but usually represent relatively few species. In contrast, an oligotrophic lake is one containing relatively small numbers of organisms representing many species. Mesotrophic lakes have conditions intermediate between eutrophic and oligotrophic lakes.

The Trophic State Index (TSI) developed by Carlson (1977) is among the most commonly used indicators of lake trophic state. This index is actually composed of three separate indices based on observations of total phosphorus concentrations, chlorophyll a concentrations, and Secchi disk depths from a variety of lakes. Total phosphorus was chosen for the index because phosphorus is often the nutrient limiting algal growth in lakes. Chlorophyll a is a plant pigment present in all algae and is used to provide an indication of the biomass of algae in a lake. Secchi disk depth, as discussed previously, is a common measure of the transparency of lake water.

This index is a highly valuable interpretive tool for evaluating lakes. For an individual lake, average summer values for total phosphorus, chlorophyll a, and Secchi depth are logarithmically converted to a scale of relative trophic state ranging from 1 to 100. Increasing values for the Trophic State Index are indicative of increasing trophic state, with an index of 50 being the dividing line between mesotrophic and eutrophic conditions. The index was designed such that an increase of ten index units represents a doubling in algal biomass. For example, a lake with a chlorophyll TSI value 60 has twice as much algae as a lake with a value of 50. Also, the index was designed so that under phosphorus limiting conditions, and where algae are the main factor affecting transparency, TSI values calulated from Secchi depth, total phosphorus, and chorophyll data should be very similiar. Therefore, when there is not a correspondence between TSI values one must look for other determinates of algal biomass and water transparency.

Trophic State Indices, based on total phosphorus, chlorophyll a, and Secchi depth, were determined for each basin of Strawbridge Lake. The Trophic State Indices for each basin are shown in Figure 9. For all three basins, trophic indices based on total phosphorus, lake transparency and chlorophyll a indicate that Strawbridge Lake is eutrophic. The Trophic State Index for chlorophyll a, however, is generally lower than the indices for phosphorus and transparency. The discrepancy between trophic indices calculated for chlorophyll a and both total phosphorus and lake transparency may be a result of low orthophosphate concentrations and high inorganic suspended solids loadings to Strawbridge Lake. Though total phosphorus values are high, only phosphorus in the form of orthophosphate can be utilized by phytoplankton. Since orthophosphate levels at strawbridge Lake were generally low, most of the phosphorus is probably bound to incoming sediment (inorganic suspended solids) and, therefore, unavailable to algae for growth and reproduction. In addition to low orthophosphate concentrations, high amounts of inorganic suspended solids reduce the net amount of sunlight in the water column.

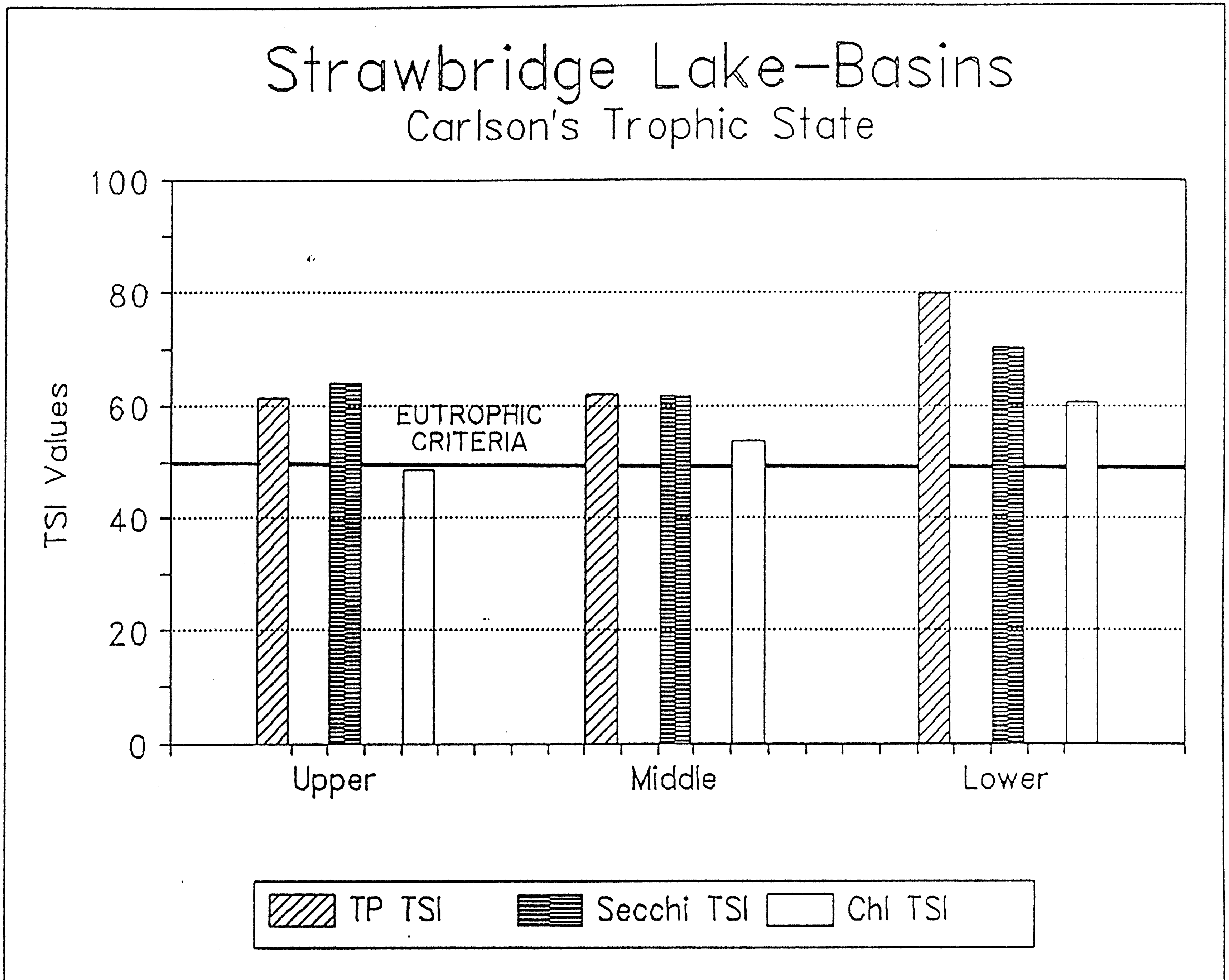


Figure 9
Trophic State Indices
for Strawbridge Lake

4.0 Pollutant Sources

Pollutants can enter a lake from both point and nonpoint sources. Point sources are defined as all waste-water effluent discharges within a watershed. At present, there are no known point sources of pollution in the Strawbridge Lake drainage basin. Until 1987, the Ramblewood Sewage Treatment Facility discharged into the North Branch of Pennsauken Creek approximately 1.25 miles upstream of the Lower Basin. The Ramblewood Facility now serves as a pumping station for Mount Laurel's Pike Road Interim Plant which discharges to Rancocas Creek (out of the Strawbridge Lake watershed).

All other pollutant sources within a watershed are classified as nonpoint sources. Nonpoint sources can contribute pollutants to a lake through inflow from tributaries, direct runoff, direct precipitation on the lake surface, or through internal loading and groundwater inputs. Both natural events, such as precipitation and runoff, and human activities, including agriculture, silviculture, septic systems, and construction, can contribute pollutants from nonpoint sources. Nonpoint sources can be difficult to quantify but are important because they often constitute the major source of pollutants to lakes.

Calculations of pollutant loads require information on the water quality of inlet streams, knowledge of lake and watershed interactions, and hydrology, and also require data analysis, modeling, and engineering assumptions. Many sources of error can be incorporated into the results because of the number of water quality samples which must be analyzed, the data analysis required, and the number of assumptions which must be made.

Errors resulting from the water quality analyses can be minimized through a good laboratory quality assurance/quality control program, but the other errors involved can only be reduced through the collection of large amounts of chemical and hydrologic data from the entire watershed. This in-depth monitoring approach was not performed due to the scope of work and limited resources. As a result, the pollutant loads presented in this report should be considered as best estimates rather than the actual pollutant loads.

4.1 Hydrologic Budget

The average annual precipitation for Moorestown, N.J. is 44.38 inches (National Climatic Data Center). According to Markley (1971), much of the precipitation in Burlington County comes in the summer in the form of thunderstorms. There is an average of 28 thunderstorms per year and rainfall may reach a maximum of 2.0 inches in an hour or 5.0 inches in 24 hours (Markley, 1971).

The precipitation recorded during the study period was lower than the reported average values. The average watershed precipitations between March and August, 1992 was only 23.4 inches. Also, not even the largest storm came close to delivering 5 inches of rain within a 24 hour period. The largest storms recorded during the study period delivered approximately 2.75 inches of rain within a 24 hour period. Based on recorded observations by SLRA volunteers, the bulk of storm flows passed through the lake during a day, but substantially affected water quality for a much longer period of time. The consideration of these hydrological conditions are of vital importance when considering the restoration alternatives for Strawbridge Lake.

Surface flow estimates during the study period were determined for the two major inlets, Hooten Creek and Pennsauken Creek, and the lake outlet. Staff gages were installed on both tributaries as well as below the spillway from the lower basin. Water levels at each of the gages were recorded at approximately daily intervals by SLRA volunteers. Flow measurements were made by F. X. Browne, Inc. personnel throughout the study period. A complete stream rating curve could not be developed because only small storms occurred during the study period. As an alternate means to represent flow during the study period, Figure 10 shows a hydrograph based on gage heights alone. These data are very reliable and are adequate to show the timing and relative magnitude of the storm events. These data also show that storm hydrographs (flow increases following a rain event) last less than one day.

Estimates of average annual discharges were based on readings from two USGS gaging stations in the vicinity of Strawbridge Lake. This method of estimating average flow rates has the advantage of being based on several years of record.

This methodology is commonly used and involves generation of areal flow rates from continuous hydrologic records collected at nearby USGS stations. The Cooper River gaging station in Haddenfield, N.J. (USGS number 01467081) has a drainage area of 17.0 square miles and an average discharge of 35.5 cubic feet per second (cfs). The gaging station located on the South Branch of Pennsauken Creek in Cherry Hill, N.J. (USGS number 01467150) has a drainage area of 8.98 square miles an average discharge of 18.75 cubic feet per second (cfs). The discharge per square mile for these two stations was similar, 2.08 cfs for the Cooper River and 2.09 cfs for the South Branch of Pennsauken Creek. These two gaging stations should provide a good basis for estimating annual flows in the Strawbridge Lake drainage basin. The estimated annual discharge for Strawbridge Lake was calculated by multiplying the average annual discharge per square mile at the two USGS gaging stations (2.085 cfs) by the entire Strawbridge Lake watershed area (12.6 square miles) and the Hooten Creek and Pennsauken Creek sub-watershed areas (4.48 and 8.15 square miles, respectively). Discharges calculated by this method are 26.33, 9.34, and 16.99 cfs for the entire watershed, the Hooten Creek watershed, and Pennsauken Creek watershed, respectively. The discharges calculated from the USGS data would include contributions from groundwater.

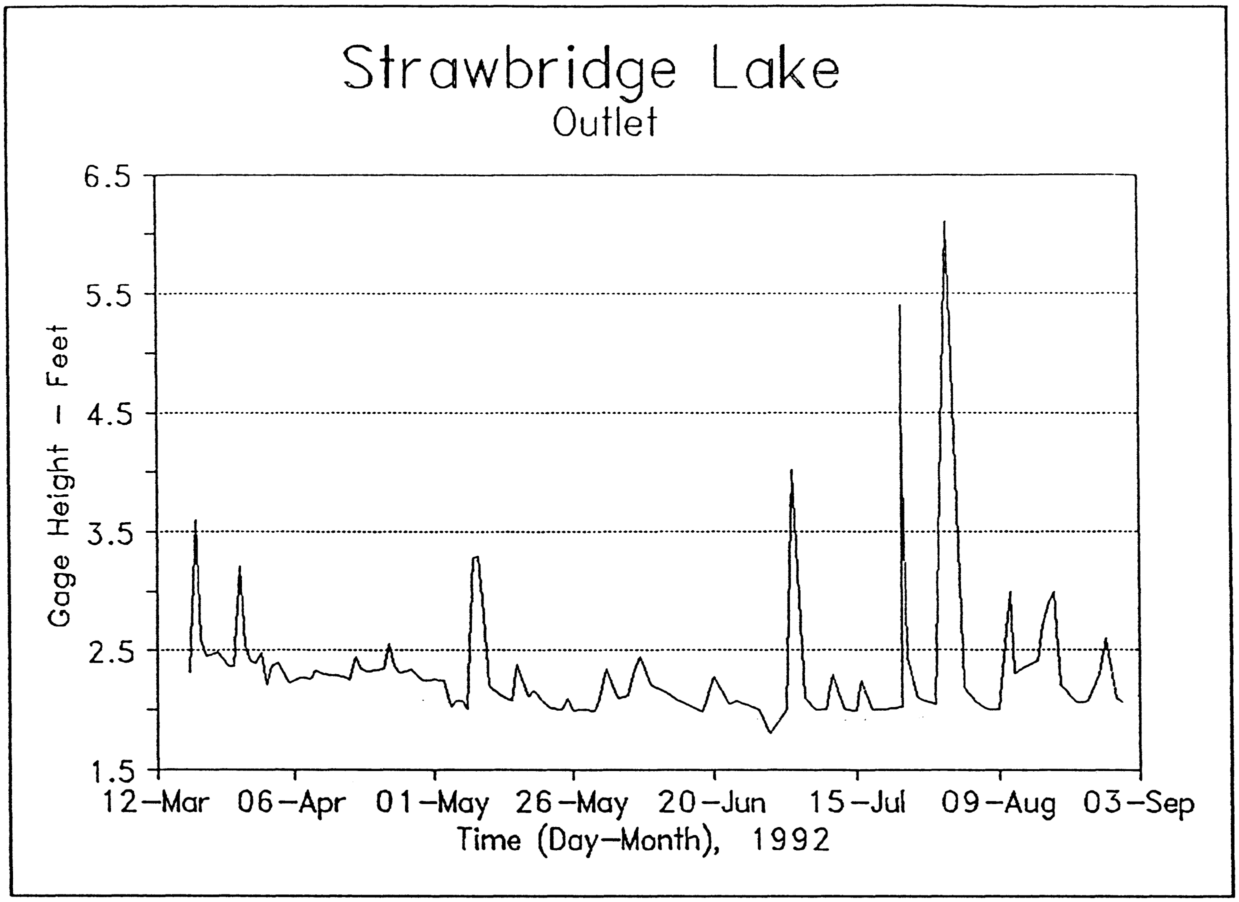


Figure 10
Stream Height vs. Time

4.2 Nonpoint Source Pollutant Loads

Nonpoint source pollutant loadings for lakes can be assessed through a lake and stream monitoring program or through the use of the unit areal loading (UAL) approach (U.S. EPA, 1980). The monitoring approach requires that inlet streams be analyzed for flow and pollutant concentrations during both wet and dry weather to determine average pollutant loadings. The unit areal loading approach is based on the fact that different types of land use contribute different quantities of pollutants through runoff.

4.2.1 Unit Areal Loadings

The unit areal loading (UAL) approach for the estimation of pollutant inputs from nonpoint sources has been widely-accepted for watersheds where extensive stream monitoring data are not available. A combination of limited watershed monitoring and unit areal loadings were used in this report for the calculation of nonpoint source nutrient and total suspended solids budgets for Strawbridge Lake. The actual data obtained by F. X. Browne, Inc. and by volunteers were used in selecting representative unit area loading concentrations.

Nutrient and suspended solids export coefficients compiled by Uttormark et al. (1974), Reckhow et al. (1980), Betz (1977) and the U.S. EPA (1980) were evaluated and specific coefficients were selected based on their applicability to the Strawbridge Lake watershed. The export coefficients describe the mass of pollutant loss per unit area and are usually given in the metric units of kilograms/hectare (kg/ha), which are approximately 10 percent greater than the corresponding English units of pounds/acre.

Since Strawbridge Lake consists of three separate basins which are fed by two major streams, it was necessary to consider the drainage pattern before using the unit areal loads. Hooten Creek (and an unnamed tributary) drains into Hooten Pond, which drains into the upper basin, which drains into the middle basin. The Lower basin receives its water from both the middle basin and Pennsauken Creek. Therefore, only the Hooten Creek sub-watershed and the area of direct runoff were used to calculate loadings for the middle and upper basins. Loadings for the lower basin were based on the area of direct runoff and drainage from the both the Hooten Creek and Pennsauken Creek sub-watersheds. Using the entire watershed to calculate loadings to the lower basin without actually measuring the discharge from the middle basin is valid, because nutrient concentrations were similar between Hooten Creek and the upper two basins.

4.2.2 Septic Tank Leachate

Pollutants originating as septic tank leachate are considered to be nonpoint source loadings but are not included in the pollutant budgets calculated using the UAL approach. Loadings from septic tanks are of significance in urban watersheds with large areas that are not serviced by sewers. Most of the Strawbridge Lake watershed is sewered. The only section of the watershed that is un-sewered and is close enough to Strawbridge Lake to significantly impact the lake is in Moorestown east of Church Street and south of Route 38 to the Township boundary. The land bounded by Hooten Pond, Route 38 and Church Street is also included in this area. SLRA volunteers estimate that there are 24 housing units in this small section of the watershed. Assuming that the average household and apartment contains 2.5 people and that the houses are occupied on a permanent basis, the population served by septic systems in this area is 60 people. Other areas in Moorestown, Maple Shade and Mount Laurel in close proximity to the lake are serviced by public sewer systems.

Typical septic leachate loadings developed by the North American Lake Management Society (U.S. EPA, 1988) were used to estimate nutrient inputs to the lake from septic tanks. Typical septic system loadings are 1.49 kg (3.28 pounds) of total phosphorus and 4.65 kg (10.2 pounds) of total nitrogen/capita/yr. The soils in this section of Moorestown are listed as "moderate" and "severe" for septic tank limitation. Loadings to Strawbridge Lake were calculated by assuming that 85 percent of the phosphorus and 10 percent of the nitrogen would be removed by absorption during infiltration or uptake before reaching the lake.

4.2.3 Resident Waterfowl

Waterfowl excrement is considered to be a nonpoint source load. Although these pollutant loadings may be significant to some lakes, they are not included in the pollutant budgets calculated using the UAL approach. Loadings from waterfowl are usually only significant in watersheds with small drainage areas. Strawbridge Lake Park has become home to a large number of ducks and geese attracted to the park by visitors who leave food for them. In order to quantify the impact of the resident waterfowl on the lake, loading values developed by Grimillion and Malone (1986) were used to estimate phosphorus inputs to Strawbridge Lake. Typical duck and geese loadings are 0.42 g/duck/day and 0.62 g/goose/day of total phosphorus. Waterfowl estimates were determined using maximum resident population estimates obtained by SLRA volunteers during 1992 and assuming the resident population inhabitants the area around the lake for 365 days a year.

4.2.4 Storm Culverts

Strawbridge Lakes has a large number of storm culverts which drain directly into the lake. SLRA volunteers located potential problem culverts, described relative flow rates, and collected water samples for pollutant concentration determinations during three storm events. Average concentrations during storm events ranged from 0.047 to 0.450 mg/l for total phosphorus and 2.0 to 67.3 mg/l for total suspended solids.

The amount of pollutants which enter the lake from this source is a function of amount of water the pipes carry and the concentration of pollutants in this water. The culverts which deliver the greatest pollutant loads are presented in Table 13, and the locations of these culverts are shown on Figure 2. Four out of six of these culverts drain into the Lower basin. Those culverts draining the Ramblewood-Forest Road area appear to contribute the most pollution.

Table 13

Pollutant Loads

Culvert #	Pipe Diameter (inches)	Average Conductivity (microhos)	Average Total Phosphorus (mg/l)	Average Total Suspended Solids (mg/l)	Basin
1	30	123.9	0.357	15.1	Upper
6	36	101.3	0.375	17.6	Middle
8	30	255.0	0.450	17.6	Lower
10	36	77.0	0.203	20.7	Lower
11	30	129.8	0.234	67.3	Lower
12	24	71.6	0.323	16.0	Lower

While these culverts adversely affect water quality in Strawbridge Lake to a certain degree (especially in the Lower Basin), the importance of their impact relative to the main tributaries is relatively small. The volume of water these culverts carry is substantially lower than the amount the tributaries carry. These culvert drain only about 13 percent of the watershed, and only have sizable flows during rain events (An SLRA volunteer reports one of the culverts in the lower basin has a small flow all the time). Also, pollutant concentrations within these culverts are similar to slightly higher than the tributaries' during storm events.

4.3 Pollutant Budgets for Strawbridge Lake

The selected runoff coefficients and resulting unit areal loadings for the entire Strawbridge Lake watershed and calculated septic system and water fowl nutrient loadings are summarized in Table 14. Tables 15 present the percentages for the specific land-uses and corresponding loading for the sub-watersheds of the lower basins. Table 16 presents the pollutant budget for the middle and upper basins. The upper and middle basins are affected by discharge from Hooten Creek and direct runoff from storm culverts. In addition to these pollutant sources, The lower basin is affected by discharge from Pennsauken Creek.

Table 14
Nonpoint Source Pollutant Loadings for the Strawbridge Lake Drainage Basin

Category	Area (hectares)	Parameter	Runoff Coefficient (kg/ha/yr)	Annual Load (kg/yr)
Cropland-pasture	1,217.2	Total Phosphorus	2.04	2483.2
		Total Nitrogen	11.62	14144.3
		Total Suspended Solids	1000.0	1217234.6
Residential	974.8	Total Phosphorus	0.71	692.1
		Total Nitrogen	4.11	4006.4
		Total Suspended Solids	300.00	292434.6
Lakes and Ponds	23.0	Total Phosphorus	0.75	17.3
		Total Nitrogen	22.14	510.2
		Total Suspended Solids	34.00	783.4
Industrial, Commercial and Other Urban	618.5	Total Phosphorus	0.77	476.3
		Total Nitrogen	4.27	2641.0
		Total Suspended Solids	350.00	216479.4
Mixed Forest	413.0	Total Phosphorus	.06	24.8
		Total Nitrogen	2.82	1164.5
		Total Suspended Solids	250.00	103240.1
Forested Wetland	26.1	Total Phosphorus	0.07	1.8
		Total Nitrogen	12.80	73.2
		Total Suspended Solids	75.00	1960.9
Total Watershed Area	3272.7	Runoff Phosphorus Load		3778.8
		Runoff Nitrogen Load		22789.9
		Runoff Suspended Solids Load		1832133.1

Table 14 (continued)
Nonpoint Source Pollutant Loadings for the Entire Strawbridge Lake Drainage Basin

Septic Tank Loadings

# of Housing Units	Number of People	Parameter	Annual Load (kg/yr)
24	60	Total Phosphorus	13.41
	60	Total Nitrogen	250.33
	60	Total Suspended Solids	0

Resident Waterfowl

Resident Population	Phosphorus Load/yr	Total Load (kg/yr)	Annual Load (kg/yr)
219 Ducks	0.153 kg/yr	33.57	70.01
161 Geese	0.2263 kg/yr	36.43	

Total Pollutant Loading

Total Phosphorus Load	3862.4
Total Nitrogen Load	23040.2
Total Suspended Solids Load	1832133.1

Table 15
Nonpoint Pollutant Loadings to the Lower Basin of Strawbridge Lake from Different Sources

Source (Land use % of Total)	Phosphorus Load (%)	Nitrogen Load (%)	Total Suspended Solids Load (%)
Cropland-Pasture (37.2)	65.7	62.1	66.4
Residential (29.8)	18.3	17.6	16.0
Lakes and Ponds (0.7)	0.5	2.2	0.0
Industrial, Commercial and Other Urban (18.9)	12.6	11.6	11.8
Mixed Forest (12.6)	0.7	5.1	5.6
Forested Wetland (0.8)	0.0	0.3	0.1
Septic Tanks (0)	0.4	1.1	0.0
Resident Ducks and Geese (0)	1.9	0.0	0.0
Total	100.0	100.0	100.0

Table 16 Nonpoint Pollutant Loadings to the Middle and Upper Basins of Strawbridge Lake from Different Sources			
Source (Land use % of Total)	**Phosphorus Load (%)**	**Nitrogen Load (%)**	**Total Suspended Solids Load (%)**
Cropland-Pasture (34.7)	64.3	58.8	64.5
Residential (34.6)	22.3	20.3	19.3
Lakes and Ponds (0.8)	0.5	2.5	0.0
Industrial, Commercial and Other Urban (11.7)	8.2	7.3	7.6
Mixed Forest (12.6)	1.0	7.5	8.5
Forested Wetland (18.3)	0.0	0.3	0.1
Septic Tanks (0)	1.0	3.1	0.0
Resident Ducks and Geese (0)	2.6	0.0	0.0
Total	100.0	100.0	100.0

4.4 Phosphorus Modeling

The use of phosphorus loading models for predictive purposes has been widely documented. Although there are several phosphorus models, they all have the same general form. For all models, lake concentration is dependent on the amount of phosphorus entering the lake minus the amount that leaves through the outlet and lost to the sediment. The main difference between these models is how they estimate the sedimentation term. Since this term cannot be practically measured, it is usually determined empirically as a function of a lake's hydrologic (flow) and morphometric (depth, volume, and surface area) characteristics

The empirical model developed by Dillon and Rigler (1975) gave the best predictive results for phosphorus concentrations in Strawbridge Lake. Furthermore, the hydrologic and morphometric characteristic of Strawbridge Lake fit the assumptions used to calculate the sedimentation term in this model.

The Dillon and Rigler model (1975) has the form:

$$TP = L(1-R)/pz \qquad (2)$$

where TP = annual average phosphorus concentration (g/m^3),
L = areal phosphorus loading ($g/m^2/yr$),
R = phosphorus retention coefficient
p = flushing rate (1/yr) = 1/Tw
z = average depth (m)
Tw = Hydraulic Residence Time

* the value for R was determined from an empirical equation developed by Kirchner and Dillon (1975)

The input variables and the modeled and observed total phosphorus concentrations for Strawbridge Lake are shown on Table 17. The modeled concentrations for the Lower basin and the combined Upper and Middle Basins are 0.155 and 0.047 mg/l, respectively. Both modeled concentrations are somewhat lower than the observed concentrations (0.188 and 0.054 mg/l, respectively), but these differences are not great enough to discount the application of this model when the inherent uncertainties are considered.

Table 17
Phosphorus Modeling of Strawbridge Lake

	Lower Basin	Combined Upper and Middle Basins
Mean Depth (m)	0.69	0.77
Volume (m^3)	27,264,241	323,500,000
L (g/m^2)	23.2	48.5
R Coefficient	0.05172	0.032826
Modeled Total Phosphorus (mg/l)	0.047	0.155
Observed Total Phosphorus (mg/l)	0.054	0.188

In order to determine the reduction in loading required to give the basins a phosphorus concentration which would be classified as mesotrophic, the above equation was rearranged to solve for L (areal phosphorus load). The Lower basin would require loading reductions of 82 and 88 percent in order to reduce lake total phosphorus concentrations to 0.03 and 0.02 mg/l, respectively. Reducing loading by this amount is not practical; therefore, it is unreasonable to expect the Lower basin to become mesotrophic, In contrast, loading to the Upper and Middle basins could be reduced by 36 and 57% in order to obtain lake concentrations of 0.03 and 0.02 mg/l, respectively. While reducing the pollutant loading by this magnitude would be difficult, it is possible. These differences between lake basins are illustrated in Figure 11. It is important to note, that reducing loading by any magnitude will benefit the lake, because it would decrease the rate of sediment accumulation.

4.5 Conlusions

Based on the results of the Phase I Diagnostic-Feasibility Study, the following conclusions are made:

1. Strawbridge Lake is eutrophic evidenced by high concentrations of nutrients and sediments and the presence of excessive siltation and aquatic weeds.

2. Siltation has reduced Strawbridge Lake's mean depth from 4.9 feet to 2.4 feet.

3. Algae and aquatic weeds appear to be limited by light availability, rather than by nutrients.

4. The majority of Strawbridge Lake's bottom is colonized by aquatic plants (mainly *Ceratophyllum demersum*), but most plants are not currently visible at the water's surface. Increased growth of aquatic weeds is possible if water clarity improves.

5. The problems in Strawbridge Lake are far more related to high pollutant loadings from its watershed rather than to in-lake processes. Excessive erosion and stormwater runoff is the primary problem that must be corrected.

6. The lower basin is in worse condition than the upper two basins and will be far more difficult to manage. The lower basin receives signficantly higher pollutant loadings than the upper and middle basins since a larger amount of the watershed drains to the lower basin.

7. A comprehensive lake and watershed management program should be implemented or Strawbridge Lake will continue to deteriorate.

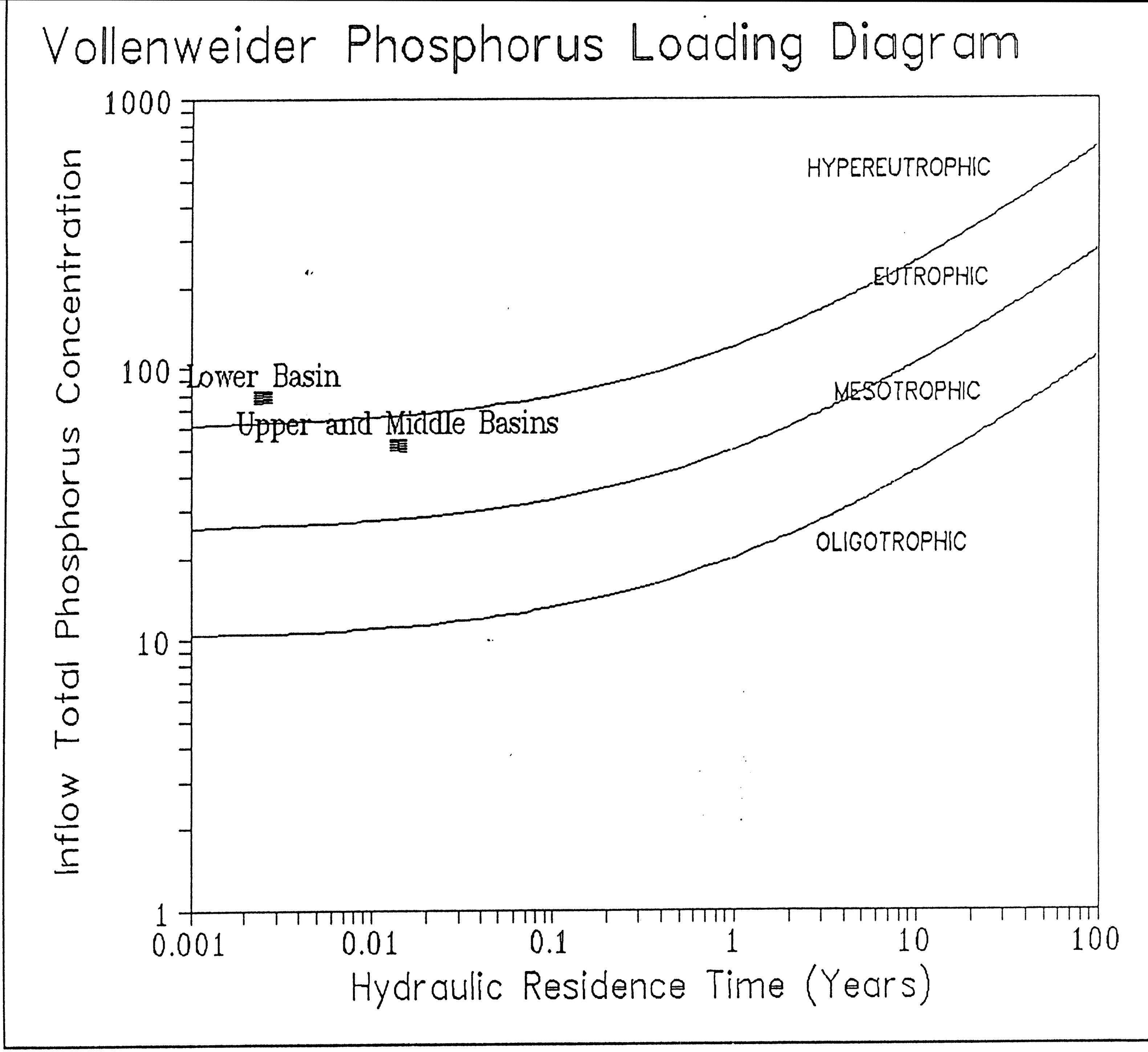


Figure 11
Phosphorus Modeling of Trophic State
of Strawbridge Lake

5.0 Evaluation of Lake Restoration Alternatives

Management alternatives for Strawbridge Lake were divided into two categories: watershed management alternatives and in-lake management alternatives. The first priority in all management programs is to determine whether watershed management practices can be implemented to reduce the pollutants entering the lake. Because nonpoint source pollutants account for a high percentage of the nutrient and sediment loading to Strawbridge Lake, it is critical that a watershed management plan be implemented. If adequate watershed controls are not put into practice, then the recommended in-lake management plan will have a diminished or shorter term of effectiveness.

The following is a list of the watershed and in-lake management alternatives that were evaluated for Strawbridge Lake.

A. Watershed Management Alternatives
   1. Watershed Management Practices
   2. Homeowner Management Practices
   3. Septic System Management Practices
   4. Development of Model Ordinances
   5. Stormwater Management
      a. Detention Basins
      b. Stormwater Diversion
      c. Solid Separators

B. In-lake Management Alternatives
   1. Lake Aeration
      a. Aeration
      b. Mechanical Circulation

   2. Lake Deepening
      a. Dredging
      b. Drawdown and Sediment Consolidation
      c. Raise Lake Surface Elevation

   3. Other Physical Controls
      a. Harvesting of Nuisance Aquatic Weeds
      b. Water Level Fluctuation
      c. Habitat Manipulation
      d. Covering Bottom Sediments to Control Macrophytes

4. Chemical Controls
    a. Algicides
    b. Herbicides
    c. Pesticides

5. Biological Controls
    a. Predator-prey relationships
    b. Grass Carp

6. In-lake Methods to Accelerate Nutrient Outflow or Prevent Recycling
    a. Dredging for nutrient control
    b. Nutrient Inactivation/Precipitation
    c. Dilution/flushing
    d. Biotic harvesting for nutrient removal
    e. Selective discharge from impoundments
    f. Sediment exposure and desiccation
    g. Sediment sealing

The following criteria were used in the evaluation of potential management alternatives:

Effectiveness	-	how well a specific management practice meets its goal
Longevity	-	reflects the duration of treatment effectiveness
Confidence	-	refers to the number and quality of reports and studies supporting the effectiveness rating given to a specific treatment
Applicability	-	refers to whether or not the treatment directly affects the cause of the problem and whether it is suitable for the region in which it is considered for application
Potential for Negative Impacts	-	an evaluation was made to insure that a proposed management practice does not cause a negative impact on the lake ecosystem
Capital Costs	-	standard approaches were used to evaluate the cost- effectiveness of various alternatives
Operation and Maintenance Costs	-	these costs were evaluated to help determine the cost-effectiveness of each management alternative

A summary of this evaluation is presented on the following tables.

Table 18
In Lake Management Evaluation Matrix

Practice	Effectiveness	Longevity	Confidence	Applicability	Probability of Negative Impacts	Capital Costs	O&M Costs
Dredging	H	M-H	H	H	L	H	V
Drawdown to Reduce Weeds	M	M	L	L	L	H	V
Weed Harvesting	H	L	H	M	L	M-H	M
Algicides/ Herbicides	M	L	L-M	M	H	L	H
Grass Carp to Control Weeds	M-H	H	H	M-H	H	L	V
Physical Barriers to Control Weeds	H	M	H	V	L	M-H	M-H
Alum Treatment to Precipitate and Inactivate Phosphorus	M	M-H	M	V	L-M	H	V
Dilution/Flushing	L	L-H	L	L	L	M-H	L-H
Food Chain Manipulation	M	?	L	V	?	L-H	L-H

H = High, M = Medium, L = Low, V = Very Low, ? = Unknown

Table 19
Watershed Management Evaluation Matrix

Practice	Effectiveness	Longevity	Confidence	Applicability	Probability for Negative Impacts	Capital Costs	O&M Costs
Conservation Tillage	M-H	M	M	H	L	M	M
Integrated Pest Management	M-H	M	M	H	L	L	L-M
Buffer Strip	H	H	M	H	V	L-M	V
Structural Shoreline Stabilization	H	H	H	H	V	M-H	L
Grass Waterways	H	H	M	H	V	L-M	L-M
Fencing	M-H	H	M-H	M-H	L	L-M	L
Animal Waste Management	H	H	H	M-H	L	M-H	L-M
Dynamic Solid Separator	?	?	V	L	L-M	H	H
Stormwater and Erosion Ordinance	H	H	H	H	L	V	L

H = High, M = Medium, L = Low, V = Very Low, ? = Unknown

5.1 Watershed Management Alternatives

Watershed Management alternatives evaluated in this study included:

1. Agricultural Best Management Practices (BMPs)
2. Homeowner Best Management Practices (BMPs)
3. Septic System Management
4. Shoreline Stabilization
5. Storm Sewer Modification
6. Biofilters and Wetland Enhancement

5.1.1 Agriculture Controls

Nonpoint source pollution from agricultural runoff is a significant source of nutrient (phosphorus and nitrogen) and sediment loadings to many lakes. To reduce pollutant loadings from agricultural land uses, a number of agricultural best management practices (BMP's), such as conservation tillage, cover cropping, critical area planting, terraces, farmland management, fencing, agricultural waste storage structures, filter strips, grassed waterways, and impoundment ponds can be implemented in these watersheds.

Cropland and Pasture accounts for 37.2 percent of the land use in the Strawbridge Lake watershed and 65.7 percent of the phosphorus loading. The following sections discuss various agricultural land use practices which should be used where applicable. Grassed waterways, buffer strips, farmland management, fencing and agricultural waste storage and management are most applicable to the type of agricultural land use in the Strawbridge Lake watershed. All farms in the watershed should be encouraged to develop up-dated conservation plans.

Conservation Tillage

Conservation tillage applies to crop tillage methods used to control the amount of erosion from crop fields. It is accomplished by leaving a certain percentage of the crop residue on the field at all times. Stormwater runoff can be reduced by retaining water on the fields and infiltration can be increased due to slower runoff velocities.

The most common conservation tillage practice is no-tillage or zero tillage. No-till farming involves soil preparation and planting that are accomplished in one operation with specialized farm equipment. This results in limited soil disturbance and leaves most crop residues on the soil surface. Planting is normally done in narrow slots opened by a fluted coulter or double-disk opener. Soil infiltration rates of the area are increased by maintaining a plant canopy or a mulch of plant residues on the surface for the entire year. However, soil compaction and reduction of evaporation from the surface due to the residues may lead to increases in runoff.

Other conservation tillage practices such as ridge planting, strip tillage, and plow planting are less common than no-tillage. Typically these methods require specialized soil and cropping conditions to be practical. Some of the conservation tillage methods may also decrease runoff volume by allowing significant amounts of runoff to infiltrate into the soil. The infiltration capacity is dependent on the amount of soil compaction in the undisturbed areas of the field and the amount of crop residues that are left exposed. High soil compaction inhibits infiltration whereas exposed crop residues absorb the water and retain it on site until it evaporates.

Additional benefits of conservation tillage include less labor per acre, lower equipment costs, and reduced fuel costs. Disadvantages of conservation tillage include increased use of herbicides, soil compaction, increased management requirements, and lower soil temperatures in spring caused by heavy mulch residue. Concentrations of nitrate in runoff water from conservation tilled fields are typically higher than concentrations from conventionally tilled fields. This is not necessarily a disadvantage since less runoff occurs from conservation tilled fields. The concentration of available phosphorus in eroded soils is higher with conservation tillage than with conventional tillage. Again, this is not necessarily a disadvantage since less soil erosion occurs when conservation tillage practices are employed.

The effectiveness of no-till farming is considerable. A comprehensive study performed in Georgia indicated that runoff can be reduced by 47 percent with the use of no-till farming. Soil loss can be reduced by 91 to 98 percent with the use of no-till farming compared to convention tillage (North Carolina Agricultural Extension Service, 1982). Conservation tillage can reduce pesticide and phosphorus transport by 40 to 90 percent for conservation tillage and 50 to 95 percent for no-till (EPA, 1987). Increased reliance on pesticides typically associated with conservation tillage can be avoided by implementing an integrated pest management program. Using conservation tillage without an appropriate pesticide and fertilizer management plan is not considered an acceptable BMP (EPA, 1987).

It is recommended that the use of conservation tillage, particularly no-till methods be implemented. As part of the conservation tillage practices, an integrated pesticide/fertilizer management plan should also implemented to reduce the off-site migration of these chemicals.

Integrated Pest Management

Integrated pest management is a combination of traditional pest control methods, such as crop rotation and pesticides, with a careful monitoring of the pests to improve the efficiency of the pesticides and other controls. The amount of pesticides applied at any one time can be minimized by targeting specific pests at vulnerable points in their life cycle. The EPA/USDA Rural Clean Water program is emphasizing the need for pesticide and fertilizer management to limit groundwater contamination. Reductions in pollutant loadings range from 20 percent up to 90 percent (EPA, 1987). Since pesticides and fertilizers are applied at their most effective times and quantities, this BMP can save money in both labor and materials.

It is strongly suggested that an integrated pest management should be implemented along with any conservation tillage activities within the Strawbridge Lake watershed.

Cover Cropping

Cover cropping involves planting and growing cover and green manure crops. Cover and green manure crops are crops of close-growing grasses, legumes (clover), or small grain planted in a fallow field and plowed into the ground before the next row of crop is planted. This technique is used to control erosion during periods when the major crops do not furnish cover. In addition to erosion control, residual nitrogen from legume cover crops enhances the soil for the major commercial crops and should be considered when calculating the nitrogen requirements of these crops planted later.

The cover crop can be seeded after harvesting the major crop by light plowing or it can be seeded prior to cultivation of the major crop without additional seedbed preparation. The cover crop should be protected from grazing until it is well established and from weeds by chemical or mechanical methods as needed. Cover crops are most beneficial to farm practices that leave bare soil following harvesting.

Critical Area Planting

Critical area planting involves planting vegetation on critical areas to stabilize the soil and promote stormwater infiltration, thereby reducing damage from sediment erosion and excessive runoff to downstream areas. Critical areas can be sediment-producing, highly erodible, or severely eroded areas where vegetation is difficult to establish with usual seeding or planting methods.

The selection of vegetation and the use of mulching materials immediately after seeding is of special concern. Jute and excelsior matting and mulching can be used to protect soil from erosion during the period of vegetative establishment when plants are most sensitive to environmental conditions. To reinforce areas designated for planting, bank stabilization structures can be used.

Maintenance of critical area planting includes periodic inspection of seeded areas for failures. Repairs should be made as needed. If the stand is more than sixty percent damaged, the planting area should be re-established using the original planting criteria.

It is strongly suggested that permanent vegetation should be established on all areas within the Strawbridge Lake watershed that are subject to severe erosion. In areas where the establishment of vegetation is impractical, structural methods should be used. By reducing soil erosion, both sediment and nutrient loadings to downstream watercourses will consequently decrease, thereby resulting in improved lake water quality.

Terraces

A terrace is an earth embankment, ridge or channel constructed across a slope at a suitable location to intercept runoff water and control erosion. Generally terraces are considered supporting practices to use in conjunction with contouring, stripcropping and reduced tillage methods. Terracing has been shown to be highly effective in trapping sediment and reducing erosion. The effectiveness of terracing is not as good for reducing the loss of nutrients and soil from surface runoff. Subsurface nitrogen losses may increase.

A terrace can be constructed across a slope with a supporting ridge on the lower side. The use of terraces is usually not applicable below high sediment producing areas without supplementary control measures. Any sediment build-up that does occur should be removed on an as-needed basis.

The effectiveness of terraces for reducing sediment loss ranges from 50 to 98 percent and costs are approximately $2/ft. For land that has very long steep slopes and is used for agricultural purposes, terracing may be useful in controlling various forms of soil erosion and under these circumstances, should be considered as a viable option.

While the slopes within the Strawbridge Lake watershed are not steep enough to warrant large scale terracing. Small scale use of this methodology should be considered for use along with other bank stabilization methods.

Grassed Waterways

Grassed waterways are designed to facilitate the safe disposal and transmission of surface runoff. Grassed waterways apply to both natural and constructed drainage channels. Grassed waterways may prevent 60 to 80 percent of the suspended particles in surface runoff from reaching nearby streams. Grassed waterways should be used in conjunction with other BMP's such as conservation tillage and terraces.

Constructed grassed waterways are generally shaped or graded by heavy equipment and are usually over ten feet wide at the top of the channel. Vegetation cover is usually a variety of grass or legume compatible with existing species in the area. These channels should be protected from grazing, fire and insects and should not be used as farm roads. Maintenance consists of mowing the grass and spraying if weed control is needed. If necessary, cuttings should be removed to prevent transport to nearby streams during storm events. All seeded areas should be inspected occasionally for needed repairs. Also, any sediment build-up that significantly reduces the capacity of the channel should be removed.

All drainage swales should be regraded and seeded with grasses that are tolerant of wet soil conditions. With proper maintenance, grassed waterways are highly effective in reducing gully erosion. These might be particularly applicable along roadsides which are currently ditched and left bare.

Grade Stabilization Structures

Soil in areas subject to heavy erosional forces, such as the outlet of a grassed waterway or a steep area which will not support vegetative cover, can be stabilized with a structure such as riprap. This is an effective method for treating small problem areas unsuitable for other stabilization methods. Construction cost for grade stabilization is approximately $500 per structure. Grade stabilization structures should be established where applicable to reduce gully erosion.

Farmland Management

Farmland management incorporates several practices which discourage accelerated erosion at the farm site. The first farmland management practice is commonly referred to as pasture and hayland planting. Pasture and hayland planting involves the proper techniques that are necessary in establishing long-term stands of adapted species of perennial and biennial forage plants. The primary purpose of pasture and hayland planting is erosion control. An additional benefit could be the production of a high quality forage crop. Proper planting measures involve the adequacy and timing of lime and fertilizer application; determination of a particular area's seedbed preparation needs, seed mixtures, seeding rates, and weed control.

After pasture and hayland plantings are established, the proper maintenance of these areas is as equally important. Pasture and hayland management involves the proper treatment and use of these areas. Proper management involves the use of adapted species of grasses, time of harvest, state of plant growth and height to which plants are cut or grazed, and the control of weeds, diseases and insects. Of particular importance is establishment of grazing plans. Grazing plans should be developed to include schedules for moving animals into and out of the pasture as well as for maintenance of the pasture. Uniform, complete cover, and vigorous pasture growth are essential for control of erosion and subsequent nutrient loss. Adequate pasture facilities should be provided, including waters, shade and mineral feeders. These facilities should be periodically moved to prevent overuse in any one area. Streams, ponds, and lakes should be fenced to limit animal access.

Another farmland management practice is the control of livestock watering facilities. The development and protection of springs can be used as water supply sources of farms. Spring development involves excavation, cleaning, and capping of waterways to convey and distribute water to livestock at several locations in the farmyard and pastures. This technique distributes grazing to several points rather than concentrating it in one area. Concentrated grazing can result in overgrazing which in turn leads to accelerated erosion. Developments should be confined to springs or seepage areas that are capable of providing a dependable supply of suitable water during the planned period of use. Maintenance includes the periodic removal of sediment from spring boxes.

These farmland management practices should be established within the Strawbridge Lake watershed. By properly establishing and maintaining pasture and hayland areas plus managing livestock watering facilities, soil erosion due to farmland practices can be minimized.

Fencing

Fencing involves enclosing and dividing an area of land with a permanent structure that serves as a barrier to animals and people. The primary purpose of fencing is to control erosion by protecting sensitive areas, particularly watercourses, from the disturbance of grazing or public access, by subdividing designated grazing areas for a planned grazing system and by protecting new seedlings and plantings from grazing until they are well established. Fencing may also be a source pollution control by preventing livestock from depositing their wastes in natural watercourses.

Fencing controls stream-bank erosion by preventing both the physical destruction of the bank and the denuding of stream-bank vegetation from grazing animals. The use of filter strips between fences and the watercourses can increase the effectiveness of fencing. Fences for this purpose are not to be temporary such as electric fences. Depending on the type of animal to be restricted, the permanent fence can be woven wire, barbed wire, or high tension wire. Fences should be periodically inspected to check for broken or disconnected wire, loose staples and loose or deteriorated post or brace members.

In the Strawbridge Lake watershed, fences should be maintained around surface waters, where livestock have direct access. By not allowing livestock direct access to a watercourse, both sediment and nutrient loadings to the watercourse will be drastically reduced. These loading reductions will be further enhanced by allowing buffer strips to be established between fences and nearby watercourses.

Agricultural Waste Storage Structures

An agricultural waste storage structure can be either an above-ground fabricated structure or an excavated pond. The above-ground fabricated structure can be either a holding tank or a manure stacking facility designed to temporarily store nontoxic agricultural and animal wastes. The primary purpose of agricultural waste storage structures is to reduce contamination of natural watercourses by source pollution control of liquid and solid wastes. Wastes can be disposed of by controlled application to cropland. Animal wastes supply soils with nutrients and soil tilth. Runoff rates are reduced and soil infiltration rates are increased with the application of animal wastes. Manure should not be applied when the ground is frozen or there is snow on the ground.

Manure stacking facilities are typically constructed of reinforced concrete, reinforced concrete block, pre-cast panels, or treated tongue and groove lumber, and may be opened or roofed. Holding tank facilities for liquid and slurry wastes may be open or covered. Holding tanks may be located indoors, beneath slotted floors. Holding tanks can be made of cast-in-place reinforced concrete or fabricated steel with fused glass or plastic coatings.

Both holding tanks and stacking facilities should be emptied in accordance with the overall waste management plan for land application. If the holding tanks are located outdoors and are not covered, a grass waterway should be constructed down slope of the tanks to prevent surface runoff from reaching a stream or drainage channel.

A waste storage pond is an impoundment constructed by excavation or earthfill for temporary storage of nontoxic agricultural and animal wastes. When polluted runoff is stored, accumulated liquids are removed from the pond promptly after settling to ensure that sufficient capacity is available to store runoff from subsequent storms. Extraneous surface runoff should be prevented from entering the pond. The pond should be located as near to the source of waste or polluted runoff as possible. Soils under the pond should be of low to moderate permeability. Where self-sealing is not probable, the pond should be sealed by mechanical treatment or by using an impermeable membrane. Accumulated wastes should be properly disposed of as discussed above for fabricated structures. Waste storage ponds should be properly maintained including periodic inspection and clearing of inlets.

Agricultural waste storage structures can result in significant nutrient reductions because the wastes treated by these structures contains nutrients in mobile forms. Construction costs can run from $5,000 to $15,000 depending on volume and treatment requirements.

Within the Strawbridge Lake watershed, agricultural waste storage structures are recommended at all livestock operations. As stated in the section below, land application of stored waste should be applied to the land under favorable soil conditions. By properly applying animal wastes to agricultural land, the majority of this waste will be retained by the underlying soils, which then allows farmers to operate in a more cost-effective manner and also protects the water quality of downstream watercourses.

Agricultural Waste Management

Manure is a resource that should be used and managed wisely to increase crop yields and control pollution. In normal farming operation manure application provides nutrients for plant growth, improves soil tilth, and helps develop beneficial soil organisms. The use of manure as a fertilizer also decreases the erosion potential of the soil and promotes infiltration and retention of water in soil. The use of manure can reduce soil loss from sloping land by 58 to 80 percent. (North Carolina Agricultural Extension Service, 1982)

A manure management plan should be adopted for individual farms. The plan should include methods to conserve nutrients in the manure while it is being stored, to determine appropriate application rates, to determine appropriate time of application, and to determine the method of application. Methods of application typically include daily spreading, storage and periodic spreading, and subsurface injection. A manure management plan should be established for each farm in the Strawbridge Lake watershed, thereby allowing farmers to fertilize their land in a cost-effective manner and protecting the water quality of nearby watercourses.

Buffer Strips

Buffer strips are vegetated areas which intercept storm runoff, reduce runoff velocities, and filter out runoff contaminants. Although filter strips are similar to grassed waterways, they are primarily used along surface waters which are adjacent to urban developments, agricultural fields, and logging areas.

Successful application of buffer strips to urban developments and agricultural fields requires consideration of natural drainage patterns, steepness of slopes, soil conditions, selection of proper grass cover, filter width, sediment size distribution, and proper maintenance. All of these factors affect pollutant removals, which can range from 30 to over 95%, depending on local conditions.

Water tolerant species of vegetative cover (reed canary grass, tall fescue, Kentucky bluegrass, and white clover) should be used to maintain high infiltration rates. The type of filter strip depends upon land capability, uses of the strip, types of adjacent land use, kinds of wildlife desired, personal preferences of the landowner, and availability of planting stock or seed. Filter strips should be established at the perimeter of disturbed or impervious areas to intercept sheet flows of surface runoff. These grass buffer strips will slow runoff flow to settle particulate contaminants and encourage infiltration. Periodic inspections are necessary and thatch should be periodically removed. A recent study has shown that vegetative buffer strips with established woody undergrowth may be more effective at reducing pollutants in runoff than grass buffer strips, but presents much lower removal efficiencies in all cases (Dennis, et al., 1989).

In the Strawbridge Lake watershed, buffer strips would be an effective method to use in agricultural areas suffering from turn row erosion and along streams and ditches. Runoff in a field can travel along individual rows, concentrating in the areas at the ends of the rows where the plow made a sharp turn. Approximately 10 feet of buffer may remove around 80 percent of the total solids from runoff (EPA, 1987).

5.1.2 Homeowner Best Management Practices

Within the ten lakes watershed, many homeowners can make a significant contribution in reducing the amounts of sediments and nutrients loadings to nearby watercourses, which may eventually affect the water quality of Strawbridge Lake. The following homeowner best management practices are strongly recommended and are listed below:

1. Routine maintenance of septic systems can not be over stressed. By properly maintaining septic systems, the nutrient loadings to downstream watercourses are greatly reduced. The county health departments may aid the watershed management district by performing on-site inspection of older septic systems. Failing systems should be repaired and where clusters of failing systems are identified, the installation of small community treatment systems may be required.

2. The use of pesticides and lawn fertilizers should be kept to a minimum and applied during the times when runoff is minimized. Homeowners should have their soils tested. Along with test results, the appropriate amount and type of fertilizer to be used are generally recommended. In many instances, homeowners often over fertilizes lawns.

3. All exposed soils should be reseeded, thereby reducing sediment loadings to nearby watercourses.

4. Homeowners' with lawns that are immediately adjacent to streams and lakes should consider establishing buffer strips. Buffer strips may consist of ornamental tree and shrub plantings. By allowing a small path through the buffer strip, the homeowner still retains access to the watercourse and reduces both sediment and nutrients loadings to lakes and streams.

5.1.3 Septic System Management

Overall, septic systems have little impact on Strawbridge Lake, but there are a number of things that homeowners can do to minimize these effects of septic systems on water quality. Examples of septic system Do's and Don't's are as follows:

DO NOT:

1. Add excessive amounts of harsh chemicals to the system. Normal household chemicals in normal amounts will not hurt the system.

2. Physically damage the system by driving over the units with heavy vehicles, digging up the system for other utility lines, etc.

3. Connect a garbage grinder to the system.

4. Pour cooking oil, fat, motor oil, etc. down the drain.

5. Put disposable diapers, sanitary napkins, tampons or other material containing non-biodegradable substances into the system.

6. Use excessive amounts of water in the home.

7. Bathe and wash clothes at the same time, or do repeated loads of washing one after the other.

8. Plant trees over or near the absorption area. Roots will enter and clog the pipes.

DO:

1. Protect the system from surface drainage. Divert downspouts and surface water away from the system.

2. Check scum and sludge levels in a SEPTIC TANK at least once each year and pump if necessary.

3. Check for proper operation of AEROBIC TANKS weekly following manufacturers instructions. It is extremely important to make sure that all components are functioning properly and that air is being continually supplied to the unit. Do not shut off aerobic tanks for vacations or other extended absences from home.

4. Protect the system and surrounding area from damage. This is especially important for elevated sand mound systems. Keep grass cut to allow sun heat to evaporate moisture.

5. Keep a record of the location and dimensions of the system. If purchasing, obtain the location and other pertinent information from the previous owner.

6. Install water saving devices.

7. Operate washing machine/dishwasher with full loads only.

5.1.4 Shoreline Stabilization

It is extremely difficult to quantitatively describe the impact of shoreline erosion on water quality. Sediments entering a lake through its tributaries are carried by currents and can be measured by collecting total suspended solid data. In contrast, shoreline erosion often causes portions of the bank to collapse into the lake. Eroded banks make for unsightly and dangerous conditions for lake users. In fact, shoreline stabilization costs may be justified on the basis of reducing liability.

A combination of structural controls such as gabions and rip-rap and non-structural controls should be used on the shore of both streams and the lake. The gabions should be used in the most heavily used area and be topped with a silt barrier and three dimensional geo-web held in place with a landscaping timber. The gabion top can then be back-filled to hide the rock, allowing grass to grow right up to the landscape timber on top of the gabion.

5.1.5 Storm Sewer Modification

<u>Diversion of Sewers</u>

It is possible to divert storm drainage out of a watershed. However, this would not be practical for Strawbridge Lake, because it would require almost a complete replacement of the existing system. Furthermore, the amount of pollution entering Strawbridge Lake from storm water is small relative to the tributaries

Solid Separators

Another method of controlling urban runoff is to install solid separators within the storm sewer system. Based on the analysis of the sediments entering and accumulating in Strawbridge Lake, solid separators would only remove about 10 percent of the sediments in stormwater. The solid separators are designed to remove relatively coarse particles while approximately 90 percent of the sediments entering Strawbridge Lake are fine sediments which would not be removed in a solid separator.

5.2 In-Lake Management Methods

In-lake restoration strategies are geared towards reducing the internal loading of phosphorus from lake sediments, improving water quality, increasing the depth of the lake, and controlling nuisance aquatic vegetation. The number of feasible alternatives for Strawbridge Lake are limited due to its shallowness, fast flushing rate, and high pollutant loadings from the watershed. An evaluation matrix based on the previously outlined criteria is presented in the following table and these options are discussed in the paragraphs that follow.

5.2.1 Dredging

The physical removal of lake sediments can be used to achieve one or more objectives. The most obvious advantage of dredging is the removal of accumulated sediments and deepening of the lake. Also, dredging Strawbridge Lake would remove virtually all plants from the lake bottom. The entire macrophyte would be eliminated, including the seeds and roots, thereby preventing a quick recurrence of nuisance growths. Also, if the lake can be made deep enough. Costs for dredging are high, but the benefits are long-term, as long as something is done to minimize the amount of sediment entering the lake.

Some of the problems associated with dredging are the re-suspension of sediments and nutrients, the disturbance of the benthic (lake bottom) community, and the disturbance of both fishery nesting and refuge areas. During the dredging operation, sediments and nutrients are often re-suspended, which may result in algal blooms, increased turbidity, and decreased dissolved oxygen concentrations. In removing in-lake sediments, many of the residing aquatic organisms will be physically removed or smothered by the settling sediments in areas adjacent to the actual operation. However, the continued improvement of dredging equipment and dredging methods have helped to minimize these adverse impacts.

There are several sites under consideration as sediment disposal areas. The most promising site is located on North Church Street approximately 2 1/2 miles from the lake. The area that would be used is between the Township's leaf composting site and a wetland. Another potential site is Memmorial Field, which is very close to the upper basin of Strawbridge Lake. However, this site is only about four acres and also is adjacent to an area which may be considered a wetland. In addition, the Pennsauken Landfill may also be able to be used, but it may be difficult to obtain the required permits. The ultimate decision on which site, or combination of sites, will be used is dependent on the amount of sdiment removed.

Lake sediments can be removed by mechanical or hydraulic methods. Mechanical dredging can be performed in-lake or after draining the lake. In-lake dredging is generally performed using a clam shell bucket operated from a crane located on shore or mounted to a barge. If a drawdown is utilized, lake sediments are excavated using bulldozers (or other excavation equipment) after the lake is drawn down and the sediment are sufficiently de-watered. Once the sediment is removed, this material must be loaded into trucks and hauled to the disposal site. If sediments cannot be sufficiently dewatered on site, a water-tight truck will be needed. This adds to the volume that must be transported thereby increasing trucking costs. In hydraulic dredging, a dredging barge is unloaded from a trailer into the lake. The barge is equipped with a cutterhead which dislodges the sediments which are pumped as a slurry from the barge to the disposal site via a pipeline. Because the sediments are transported as a slurry, a larger disposal/de-watering area is needed for this method.

The location of the dredge spoils disposal site is of primary concern when determining the feasibilty of hydraulic dredging. Since the immediate vicinity of Strawbridge Lake is quite developed, it will be difficult to find a site close to the lake that is big enough to allow adequate dewatering. Also, pumping costs for hydraulic dredging become prohibitive if the site is over one mile from the lake. The disruption of traffic patterns and inconveniences to property owners must also be considered when the pipeline route is designed. Overall, hydraulic dredging does not appear to be a viable alternative for Strawbridge Lake because there are currently no disposal sites close to the lake.

There are several reasons why it may not be feasible to drain Strawbridge Lake and excavate the sediments. Since the spillway structures do not allow the water to completely drawn down, water would have to be removed with the aid of siphons and/or pumps. The average water inflow rates are 26.3 and 9.3 cfs for the lower and the combined upper and middle basins, respectively. This means that even if each basin were completely drained, it would only take 1.2, 0.6, and 0.9 days under average flow conditions to completely refill the upper, middle and lower basins, respectively. In order to stop the lake from refilling a pumping rate in excess of 250,000 gallons per hour would be required. In addition, there are a large number of storm culverts which would wet the sediments along the shoreline during each rain event. Therefore, it may be impossible to de-water the sediments to the point that would allow the operation of heavy machinery.

The most feasible method of removing sediment from Strawbridge Lake is to use a bucket dredge or similar mechanical method. This method has several disadvantages. First, it is relatively slow and may leave uneven bottom contours. In addition, turbidity will likely be substantially elevated during dredge operation, but this can be decreased through the use of booms and containment curtains.

All three dredging alternatives will be further evaluated during the design stage of the Phase II program when a disposal site has been selected.

Lake Sedimentation

The three impoundments that make up the Strawbridge Lake system were constructed in the 1930's as Works Progress Administration (WPA) projects. Each basin has been dredged at least once since impoundment. The Upper Basin was dredged in 1959, the Middle Basin was dredged in 1962 and the Lower Basin was dredged in 1968 (U.S. COE, 1970).

Calculated sedimentation rates will vary based on the assumptions used and the time-frame considered. Although not conclusive, Moser (1985) estimates that sedimentation rates in the three basins may have changed with changes in land use in the watersheds. She concluded that accumulation rates for the three basins would be different due to differences in sediment sources, sediment composition and cross-sectional contour. She also indicated that changes in land use in the Strawbridge Lake watershed may have resulted in increased sedimentation rates. Estimates of sedimentation rates for the three basins based on annual load ranged from 1.2 cm/yr to 1.4 cm/yr. Estimates based on depth to pre-impoundment contact were slightly lower with average values between 0.83 cm/yr and 1.1 cm/yr. Estimates based on concentrations of Cesium in cores ranged from 0.71 to 1.7 cm/yr for dates after 1963. Strawbridge Lake Restoration Association volunteers compared their own 1990 bathymetric data (Sheckels and McChesney, 1990) to a 1980 bathymetric map (NJDEP, 1980) and obtained an approximate sedimentation rate for the three impoundments of 1.5 to 4.9 cm per year. Rates based on data collected in the current study ranged from 2.4 to 5.0 cm per year.

Based on these sedimentation rates it is possible to determine how long it would take Strawbridge Lake to return to its present depth following dredging if no watershed management techniques are employed. It has taken these basins between 24 and 33 years, since the date they were last dredged, to reach their present depths. However, sedimentation rates have likely increased in recent years due to changes in landuse. A sedimentation rate ranging from 2.4 to 5.0 cm per year was used to estimate the effective life of a dredging program in Strawbridge Lake. It was assumed that all of the unconsolidated sediments were removed from each basin. The current mean depth of Strawbridge Lake is 0.74 meter and the potential mean depth if all the unconsolidated sediments were removed is approximately 1.5 meter. Therefore, under these assumptions it would take the lake approximately 15.5 to 35 years to return to its current depth if it were completely dredged. This period can be substantially extended through the implementation of adequate watershed controls.

Permit Application Procedure

Prior to dredging several permits must be obtained. Since Strawbridge Lake is located within a floodplain, a Stream Encroachment Permit must be obtained from the U. S. Army Corps of Engineers (COE) and the NJDEPE for the dredge spoils de-watering site. Strawbridge Lake is located outside the Pinelands Protection area, therefore permits from the Pinelands Protection

Commission are not required. However, portions of Strawbridge Lake may be considered State regulated wetlands. The State of New Jersey requires the acquisition of a Freshwater Wetlands Permit for any wetland disturbance. (Freshwater Wetlands Protection Act NJAC 7:7A). Also, a Soil Erosion and Sedimentation Control Certification (and possibly a Freshwater Wetland Permit) will be required for for the sediment de-watering site.

If lake drawdown is utilized additional permits will be required. Stream Encroachment Permits for the lake and disposal site will be needed. Also, prior to lowering the lake, a Temporary Lake Lowering Permit and Dam Lowering Permit must be acquired.

The COE/NJDEPE will review the dredging permit application and sediment chemical data from this study to determine if dredging and de-watering will impact surface waters of the State. For the parameters tested, only lead exceeds the allowable concentration for application within residential areas. Lead concentrations are low enough for disposing sediments in non-residental areas.

Cost Considerations and Maximizing benefits

A variety of factors can affect the cost of a dredging project. As mentioned previously, it is probable that mechanical methods will be used to remove sediments from Strawbridge Lake because the spoils disposal site will probably be a relatively long distance from the lake. The main factors affecting the costs of mechanical dredging are: the amount of sediment removed, and sediment transport and disposal.

There are an estimated 37,000 cubic yards (28,000 cubic meters) of sediment in the Upper Basin, 20,000 cubic yards (15,000 cubic meters) of sediment in the Middle Basin and 72,000 cubic yards (55,000 cubic meters) of sediment in the Lower Basin. Since it is likely that the lake will be dredged in phases, it is important to prioritize efforts.

The largest amounts of park lands are found around the Upper and Lower Basins, and of these two basins, the upper one has a greater concentration of recreation facilities and has been more heavily impacted by siltation. Therefore, dredging efforts should concentrate on the Upper basin.

Disposal costs depend on sediment transport distances, topography, and other site constraints. Hauling costs vary with location and with the size of truck used. The proposed disposal site is approximately 2.5 miles from the lake, and a typical one mile round trip cost for hauling sediment is $2.50 per cubic yard. Disposal costs may be reduced if the sediments meet landfill performance standards for daily cover material. Application of the sediments onto farmland is another disposal alternative. However, two of the three sediment samples equalled or exceeded land application regulatory levels for arsenic (10 mg/kg) and selenium concentrations in the TCLP leachate were above drinking water standards (Section 3.5). Additionally, Strawbridge Lake sediments would be classified as "low grade" topsoil due to relatively low nutrient concentrations. To be of value as a fertile topsoil, the applied top dressing should be at a minimum one percent total phosphorus and one percent total Kjeldal nitrogen. The Strawbridge

Lake sediments are less than 0.15 percent total phosphorus and 0.3 percent total Kjeldal nitrogen.

5.2.2 Water Level Controls

Manipulation of water level is another method of deepening lakes. Obviously, a lake can be made deeper by raising its surface level. Another method is to lower the lake's water level in the hopes that sediments will consolidate upon exposure to air. However, these methods are not practical for Strawbridge Lake. Raising the water elevation would decrease the lake's recreational value by flooding the surrounding park land and would require extensive permitting. The effectiveness of water level drawdown in consolidating sediments has not been adequately documented by the scientific community. It is unlikely this method would substantially deepen Strawbridge lake. Furthermore, water level manipulation would require costly modifications to existing dam and spillway structures.

5.2.3 Mechanical Harvesting

While aquatic weeds colonize the majority of Strawbridge Lakes sediments, many of these plants are not visible from the shoreline. However, if reductions in sediment loadings are achieved and turbidity is reduced, the growth of macrophytes may increase. If aquatic weeds reach nuisance levels, SLRA and the Township should identify lake areas where macrophyte removal is desirable. Once these lake areas are identified, the lake-side property owners should receive cost estimates from local weed harvesting contractors. After all cost estimates have been received, the Township officials will be able to decide whether weed harvesting is a cost-effective tool for managing nuisance aquatic weeds.

Basically, weed harvesters consist of cutting implements mounted on to a barge which is powered by paddle wheels. The size and type of harvesting operation determines the type of machinery that should be used and the cost-effectiveness of purchasing equipment versus contracting a harvester. In general, those harvesters that cut the macrophytes and immediately remove them by means of a conveyor are most effective.

Aquatic weed harvesting is used for two lake restoration purposes: (1) to physically remove nuisance vegetation, and (2) to remove nutrients and organic matter from the lake ecosystem. Weed harvesting is a direct way to accomplish the first goal with minimal negative impacts. While harvesting will actually remove nutrients from Strawbridge Lake, the amounts would be insignificant relative to the watershed sources. Harvesting does not interfere with the use of a lake and does not introduce foreign substances (algicide or herbicides) to the ecosystem.

One problem with harvesting is that plants often regrow rapidly from stumps left behind by the harvester. Most lakes usually require two to three cuttings per year in order to maintain the weeds at a non-nuisance level. The frequency of cutting, however, may be reduced after several years of harvesting, or by lowering the harvesters cutter blades into the sediment.

The advantages of weed harvesting versus chemical application were evaluated for a small lake in Ohio (Conyers and Cooke, 1982). It was concluded that harvesting is much more effective than the recommended doses of Cutrine-Plus and Diquat in controlling the biomass, and harvesting would be less costly over a two-year period than chemical treatment for the same period.

There are several ways to establish a weed harvesting program: 1) purchase and operate your own harvester, 2) share a harvester with other townships and lake associations or establish a county-wide harvesting program, or 3) contract the harvesting to an outside service. Purchasing and running a harvester is initially the most expensive way to establish a harvesting program. Over the long-term, the initial expense will be offset by the cost of contracting out, but annual operational and maintenance costs will continue. The cost to an individual lake association or township can be reduced by sharing ownership among several lakes or by establishing a county-wide macrophyte harvesting program.

The cost for equipment depends on the size of the harvester and ranges between $50,000 and $120,000 for the mechanical weed harvester, shore conveyor and trailer. Weed harvesters can cut approximately one acre of weeds in 4 to 8 hours and typically cost about $200 per acre to operate not including the disposal of cut vegetation (New York DEC, 1990). The actual time and operational cost will be highly dependent on the harvester unit selected and the density of the macrophytes. The harvester should be able to cut a swath ranging from six to ten feet in width and to a depth up to eight feet. The use of mechanical harvesters is generally limited to lake depths greater than 2.0 feet due to poor maneuverability. It should be noted the above cost does not include weed disposal.

Instead of a lake association or a county purchasing its own weed harvesting equipment, a lake association may choose to contract out its weed harvesting duties. Nuisance aquatic weeds may be removed by two types of mechanical weed harvesting units. Mechanical weed harvester units are generally equipped with a cutter blade (as described above) or a hydraulic rake (commonly referred to as "hydrorake"). Typically, contractor rates for weed harvesting are quite variable and depend on the geographic location of the lake and local market prices. Weed harvesting fees are typically $250 to $350 per acre for barges equipped with cutter blades and $1,750 per acre for barges with hydraulic rakes. Though more expensive, hydroraking may be more cost-effective than weed harvesting with cutter blade units. For hydroraking, nuisance weed growth may not occur for 3-5 years after the initial raking because the root structure are partially removed. However, the disturbance to the benthic (sediment) ecosystem is greater and environmental impacts may be greater. For barges with cutter blades, aquatic weeds may have to be mowed several times during the growing season.

After harvesting, the weeds are usually unloaded from the harvester to trucks via shore conveyor units. Prior to the commencement of any weed harvesting activities, several weed disposal sites should be identified. Aquatic weeds compost well, thereby producing good mulching material. In many instances, the agricultural community will generally accept harvested weeds. In any of the above approaches to weed harvesting, it is important to find a close disposal site, thereby reducing hauling costs for weed disposal.

Currently harvesting is not recommended for Strawbridge Lake, but this technique should be reevaluated after dredging and watershed management has been implemented. One factor which limits the use of harvesters here is the lake's shallowness and the absence of boat ramps. If harvesting is considered further in the future, only the smaller models would be applicable.

5.2.4 Chemical Controls

Chemical treatment has been used extensively in lakes to control the growth of aquatic vegetation. Excessive macrophyte and algae growth can generally be controlled with herbicides and algicide if the proper chemical or combinations of chemicals are selected and properly applied. Over a short period of time chemicals are effective in killing vegetation and restoring the recreational use of a lake, thus their widespread use. Over a long period of time, chemical controls are unsuccessful because they treat only the symptoms of eutrophication, not the causes.

Excessive growth of algae could also be reduced through control of nutrient loading and siltation. The best method is to limit the nutrients entering the lake by controlling them at their source with watershed management practices such as land use controls, septic system maintenance, and erosion control. Macrophytes can also be controlled by stocking grass carp or harvesting.

Algicide

Copper sulfate and copper compounds are the most commonly used general algicide. The solubility of copper sulfate and subsequently its effectiveness is influenced by pH, alkalinity, and temperature. Copper sulfate is most effective in soft, mildly acidic waters. If added in excessive amounts, copper sulfate can be toxic to fish and other forms of aquatic life. It can also accumulate in the lake sediments. One of the problems with the use of copper sulfate is its specificity for only certain algae. It is successful in causing a change in the dominant species of algae in a body of water. There are times when the algae replacing the original problem species cause problems of their own, and these latter algae are not controlled by usual treatments of copper sulfate.

Herbicides

Chemical treatment provides only temporary relief from chronic aquatic weed problems. In many instances, application is required at least twice per year. Therefore, the costs for chemical treatment are relatively high. An experimental study on East Twin Lake in Ohio concluded that weed harvesting was far more cost-effective than chemical treatment (Conyers and Cooke, 1982).

Although the method of chemical control has been extensively used, there has been relatively little documentation regarding environmental impacts. Although refuted by chemical manufacturers, there are still questions regarding the toxicity of certain chemicals to fish and other food chain organisms. Copper sulfate has been shown to be toxic to fish under certain circumstances. Unlike compounds containing heavy metals, most of the organic chemicals do not appear to accumulate in lake systems.

Drawbacks to the use of herbicides include:

1. Vegetation is not removed from lake.
2. Plants die, decompose and release nutrients in the lake.
3. Dissolved oxygen concentrations are depleted by microbial decomposition. This may induce the release of nutrients from the sediments.
4. Algal blooms often occur as a result of increased nutrient levels.
5. Herbicides can be toxic to non-target species.
6. Some plant species may be tolerant to the herbicides.
7. Some herbicides are suspected to be mutagenic and carcinogenic.
8. The waiting period (10 days or more in most cases) following application of many herbicides interferes with recreational lake uses.
9. Unsightly conditions are often created.

If control of a periodic algal bloom or a specific stand of macrophytes is desired, the prudent use of chemical algicide and herbicides may be the most cost-effective treatment method. This methodology should only be considered if the target zone is small enough that other methods, such as grass carp or harvesting, would not be practical. Also, it is very important to gain public support prior to treating this lake with these chemicals. It is likely that many people would view these treatments as adding to Strawbridge Lake's pollution problem.

5.2.5 Biological Controls

Biomanipulation or food web manipulation (Shapiro, 1978) has been suggested as one method of controlling algal blooms in lakes. Theoretically, balancing phytoplankton, zooplankton, and fish populations will eliminate nuisance algal blooms. Biomanipulation usually involves reducing planktivorus fish (zooplankton-eating) and increasing piscivorous fish (fish-eating) populations.

By restructuring the aquatic food web, the number of larger zooplankton ("water fleas") species would increase, thereby reducing the algal populations through grazing.

In general, biomanipulation is not well understood because only a limited number of case studies have sufficiently documented its successes. In general, lakes are very complex ecosystems with numerous biological, chemical and physical interactions. By varying one or several biological components within a lake's food web, the effects may be dramatic at a given time, but how this change affects the lake in the future is poorly understood.

In addition to these biological controls, new microbiological agents, such as viral pathogens, are currently being developed through the use of biotechnology. While these technologies have a hopeful future, adequately tested products do not currently exist.

In contrast to the introduction of predatory fish or modifying of the food web, the effectiveness of using grass carp (*Ctenopharyngodon idella*) to control aquatic plants has been well documented in lake management studies. The introduction of grass carp is a cost effective method of controlling aquatic weeds. These fish live a long time, but plant consumption is the greatest during the first part of their life. Grass carp prefer tender plant species, and would wipe out desirable species as well as the less desirable species, such as bushy pondweed (*Najas*) and milfoil (*Myriophyllum*). Their ability to control waterlilies (*Nympheae* and *Nuphar*), however, is doubtful.

While triploid grass carp cannot reproduce, they are still considered an exotic species and can cause considerable damage if they get into areas where aquatic plants are desired. For this reason, grass carp stocking is prohibited in many states and highly regulated where allowed.

There are a number of negative effects associated with the introduction of grass carp. Grass carp may destroy desirable macrophyte species. Grazing by grass carp may reduce macrophyte biomass, but does not remove the nutrients from the lake. This may lead to increased eutrophication of a lake, with increased algal blooms. However, in a lake such as Strawbridge Lake, the importance of these internal processes are usually small relative to the pollutant loadings from its large watershed.

It is of primary importance that these fish are not over stocked, because the removal of too much vegetation can seriously damage the lake ecosystem. For example, the loss of too many plants can result in accelerated shoreline erosion and/or damage to the sport fishery. Furthermore once these fish are introduced to a lake they are difficult to remove, because they are not affected by electro-shocking equipment.

Stocking in the spring has the greatest effectiveness, because the damage inflicted on the plants will slow plant growth. Generally, it is best to stock in series, rather than all at once. Therefore, target macrophyte biomass control is generally not achieved in the first year.

The best stocking criterion is found in Wile et al. (1987), and while this guideline was developed for Illinois, it is adequate to make estimates for New Jersey waters. These stocking rates are based on water temperature, initial fish size, plant species, lake size, and percent areal macrophyte colonization and canopy coverage. Calculated stocking rate for the upper and middle basins is 33 fish per acre.

In New Jersey, stocking is permitted for lakes less than 10 acres in size where it can be reasonably assumed that the fish will not escape. Also, a minimum of 40 percent of the lake must be covered by nuisance vegetation which is preferred by these fish. Grass carp can not be stocked in areas identified as endangered species sites. Also, there are restrictions for state designated "Natural Areas", Exceptional Resource Wetlands and adjacent areas. Based on these criteria, only the middle and upper basins of Strawbridge Lake can be considered for stocking. The final decision would be based on an inspection by the NJDEPE Division of Fish, Game and Wildlife.

The New Jersey approved stocking rate ranges from 5 to 15 fish (8-11 inches in size) per acre. The goal of this stocking rate is to reduce vegetation to 20 to 40 percent coverage within two years. Additional fish cannot be stocked within two years of the initial treatment, unless significant mortality is documented. Since the maximum stocking rate for New Jersey is substantially lower than the calculated stocking rate, it is assumed the lake will have to be retreated after the two years has elapsed.

The use of triploid grass carp to control macrophytes is recommended to control macrophytes in Strawbridge Lake. Based on the current plant community, maximum stocking rates would be required, because the majority of the weeds present are unpalatable species. Furthermore, it is very likely that this treatment would have to be repeated after the two year waiting period in order to gain adequate weed control. It is important to emphasize that this treatment is not designed for quick results. Instead, its goal is to gain a cost effective long-term control of macrophyte biomass and to reduce the potential for excessive weed growth following the implementation of watershed management.

The cost of stocking grass carp is dependent on the size and the number of fish needed and the distance they must be shipped. Based on the maximum New Jersey stocking rate of 15 fish/acre the upper and middle basins of Strawbridge Lake will require 133 and 70 fish, respectively. Fish which are 8-10 inches long are a good choice for stocking, because they are easy to ship yet old enough to resist mortality. The cost for fish of this size ranges from 4 to 7 dollars each. The majority of grass carp fisheries are located in the southern states, and the quoted shipping costs are variable. The lowest shipping cost quote obtained was 3 dollars per box at eight fish per box plus a nominal fee for driving them to the airport. Assuming that the basins must be stocked at the maximum rate two times each, the overall costs are estimated to $3,500.

5.2.6 Physical Barriers

Physical sediment covering is another method which has been used to control macrophytes and sediment nutrient release. Researchers have experimented with various cover materials including sand, clay, and synthetic sheeting. The use of clay or sand are not considered to be applicable to Strawbridge Lake, because these methods involve decreasing the depth of the lake. Also, synthetic sheeting would not be a good choice for Strawbridge because it would likely become dislodged during heavy storm events.

5.2.7 Nutrient Inactivation

Since phosphorus-rich sediments will release phosphorus in the water column under anoxic (zero oxygen) conditions, water quality problems can continue in a lake long after watershed controls are implemented. By applying aluminum salts (commonly reffered to as alum) within the hypolimnion, a chemical barrier is established which can provide continuous control of phosphorus. Nutrient inactivation usually consists of adding aluminum salts (aluminum sulfate and/or sodium aluminate) to produce an aluminum hydroxide floc which forms a chemical bond with phosphorus. Under the appropriate lake conditions, this method has been known to reduce internal phosphorus loadings for periods of 5 to 15 years or more. Hypolimnetic alum treatments are most effective in deep lakes with a surface area greater than 50 acres in size and a low flushing rate, and where watershed inputs of phosphorus have been minimized.

Sediment Phosphorus release does not appear to be significant in Strawbridge Lake because no significant thermal stratification or oxygen depletion was observed. Therefore, alum treatment is not a viable alternative.

5.2.8 Dilution/Flushing

Dilution and flushing can improve water quality in eutrophic lakes by diluting the amount of phosphorus in the lake while increasing the flushing of algae from the lake. This technique works best in small eutrophic lakes that have low flushing rates (i.e. large lake surface area to watershed area) and is most cost effective when a large quantity of low-nutrient water is available. In most cases, the water supply for dilution and flushing is obtained by diversion of water from a nearby river, although the use of wells may also be used.

Again, this technique is not applicable to Strawbridge Lake. The lake already has a large volume of nutrient -laden water flowing through it.

5.2.9 Aeration and Artificial Circulation

The goal of aeration is to increase oxygen concentration within the water column. It is most commonly used to improve habitat for cold water fisheries and reduce dissolved iron and manganese concentrations in drinking water supplies. In addition, aeration has been used successfully to control anaerobic sediment phosphorus release. It has also been hypothesized that aeration can reduce sediment volume and accumulation rates by facilitating the decomposition of organic matter. However, these claims have not been adequately demonstrated.

The goal of artificial circulation is to reduce algal biomass by mixing algae throughout the water column. The premise is that rapid water mixing subjects the algae to damaging changes in hydrostatic pressure and unfavorable light conditions. The effectiveness of this technique in controlling algal biomass has been highly variable, and it is not uncommon to see substantial increases in biomass following treatment.

Aeration and artificial circulation can be accomplished in a number of ways depending on lake morphology and the goals of the project. In lakes deep enough to thermally stratify the hypolimnion alone can be aerated through oxygen injection or an air lift system. In shallow polymictic or weakly stratified lakes, bubblers can be used for both aeration and destratification.

System sizing and placement are of critical importance in order to obtain the project's objectives and avoid negative impacts.
Increased turbidity, nutrient concentrations, algal biomass, continued dissolved oxygen problems can result from sediment resuspension, if a system is not properly designed. Other potential side effects include increased water temperatures and nitrogen toxicity.

Strawbridge lake would not benefit from aeration, because low dissolved oxygen is not a problem in this lake. This lake has a very short water residence time, which means it is continually supplied with oxygenated water from its tributaries.

6.0 Lake and Watershed Management Program

Based on the results of the Phase I Study, a lake and watershed management program was developed. This program includes watershed management, in-lake management, water quality monitoring, and environmental education.

6.1 Watershed Management

Managing the watershed area that drains into Strawbridge Lake is important so that stormwater runoff can be controlled. Stormwater runoff delivers sediments and nutrients to Strawbridge Lake, resulting in conditions that adversely affect its recreational uses. The proposed watershed management program includes:

1. Establishment of a Watershed Management Committee to evaluate and coordinate watershed management activities in the Strawbridge Watershed.

2. Establishment of a "Watershed Watch" program to ensure that erosion and stormwater management controls are installed properly during construction activities and ensure that long-term stormwater controls are properly operated and maintained.

3. Implementation of Best Management Practices (BMPs) on agricultural lands within the watershed. All farms should have an approved Conservation Plan.

4. Implementation of urban Best Management Practices throughout the watershed on areas that have severe erosion or stormwater runoff problems.

5. Installation of erosion protection measures on eroding areas of streams and on the shoreline of Strawbridge Lake.

6. Evaluation of the creation of biofilters and the enhancement of existing wetlands in the Strawbridge Lake watershed to reduce the silt and nutrients entering Strawbridge Lake.

6.1.1 Watershed Management Committee

Moorestown Township should establish a Watershed Management Committee to coordinate all watershed management activities in the Strawbridge Lake Watershed. The overall goal of this committee is to develop a working relationship between the municipalities, the County, the Soil and Water Conservation District, citizen organizations, and others involved with the management of the Strawbridge Lake watershed. Specific objectives to be accomplished include:

1. Evaluation of existing subdivision and erosion control ordinances and their enforcement to determine whether changes are needed.

2. Assist in the coordination of all lake and watershed management activities.

3. Establish a "Watershed Watch" Program to ensure that erosion controls are properly installed during construction activities and to ensure that long-term stormwater controls are properly operated and maintained.

4. Communicate watershed problems or lack of compliance with local erosion control and stormwater management ordinances to the proper authority in charge of these activities.

5. Assist in obtaining funds for the implementation of lake and watershed management practices.

The Watershed Management Committee should consist of nine members appointed by the Moorestown Township Council and be officials or citizens representative of the three watershed communities.

6.1.2 "Watershed Watch" Program

A "Watershed Watch" program should be established to ensure that erosion and stormwater management controls are installed properly during construction activities and ensure that long-term stormwater controls are properly operated and maintained. Soil erosion and sediment control plans are reviewed by the Burlington County Soil Conservation District under the requirements of Chapter 251 of Public Law 1975 "Soil Erosion and Sediment Control Act". Chapter 251 requires that a detailed erosion and sediment control plan be developed and reviewed by the County Soil Conservation District. The problem of erosion and runoff, therefore, is not that an adequate erosion control plan has not been developed, the problem is usually that the plan is not properly implemented.

Based on their limited resources, personnel of the County Soil Conservation District perform field inspections of construction sites to ensure that the approved erosion control plan is being implemented. However, the conservation district staff cannot visit every site on a regular basis. Even if they could, construction sites can be in compliance one day and out of compliance the next day, depending on specific construction activities being performed.

A "Watershed Watch" Program would allow informed citizens to supplement the work of conservation district staff by observing erosion control measures at construction sites. If they see obvious signs of erosion and runoff problems, the citizens would contact the County Soil Conservation District which would then initiate a formal on-site inspection.

Due to legal and liability issues, citizens would not physically go on private property to formally inspect a construction site. Rather, they would observe obvious site conditions from a public access area such as a road or sidewalk. During rain events, they could also observe the condition of drainage channels and streams to see if excessive siltation appears to be occurring.

6.1.3 Agricultural Controls

Erosion and runoff from agricultural activities, especially cropland and livestock areas, generate large amounts of sediments and nutrients which flow into Strawbridge Lake. Agriculture accounts for approximately 37 percent of the land in the watershed.

Every farmer in the watershed should be encouraged to have and implement an up-to-date conservation plan. If state or federal funds are available, agricultural controls should be installed via a cost-share program whereby the farmer pays a portion of the costs and the state or federal agency pays a portion. The EPA Clean Lakes Program, for instance, provides a 50 percent cost-share for agricultural programs, depending, of course, on the availability of grant funds. The Soil Conservation Service (SCS) also provides funds for implementing agricultural controls.

6.1.4 Urban Controls

Urban runoff contributes a significant amount of sediments and nutrients to Strawbridge Lake. Particulate matter accumulates on impervious urban areas such as roadways, streets, parking lots, and roof tops. When it rains, these pollutants are washed into streams and ultimately to Strawbridge Lake. Impervious areas also produce a significantly larger volume of runoff than pervious areas; this increased stormwater runoff also has a much greater velocity of flow than runoff from pervious areas. Therefore, the increased volume and velocity of urban runoff causes severe erosion in drainage ditches and streams, resulting in an increased sediment and nutrient loading to Strawbridge Lake.

Based on the availability of local, state or federal funds, urban runoff problem areas should be identified and corrected. Often, street and roadway problems can be corrected using a portion of the annual maintenance funds of a municipality or county.

6.1.5 Stream and Shoreline Erosion Control

As discussed above, urbanization increases the impervious area resulting in increased stormwater flow and velocity. This increased stormwater flow and velocity usually exceeds the capacity of drainage channels and streams, resulting in increased streambank erosion.

Areas of severe streambank erosion should be identified, and, based on the availability of funds, erosion control measures should be implemented. Stream and shoreline erosion control measures include both structural controls, such as riprap, and non-structural controls, such as vegetative cover.

6.1.6 Biofilters

Biofilters area a combination of sedimentation basins and wetlands designed to remove sediments and nutrients from runoff by sedimentation and biological uptake or filtration. Stream and lake areas in the watershed should be evaluated to determine whether (1) biofilter should be installed and/or (2) existing wetlands should be enhanced or converted to biofilters.

6.2 In-Lake Management and Restoration

The goals of in-lake management and restoration techniques are to reverse the effects of past pollution and improve the lake's recreational potential. For Strawbridge Lake this involves: deepening the lake, aquatic weed control, shoreline stabilization, and potentially lake-side wetland enhancement.

6.2.1 Deepening the Lake

Dredging should be used to remove the accumulated unconsolidated sediments within Strawbridge Lake. Unconsolidated sediments are the loose sediments that were produced by sediments entering the lake from upstream erosion and runoff. The loss of volume and depth is the most serious problem in Strawbridge Lake, and dredging is the key to restoring lost recreation opportunities. The volume of sediments within each basin and the lake as a whole are presented in the following table.

Volumes of Unconsolidated Sediment in Strawbridge Lake (Cubic Yards)	
Upper Basin	37,000
Middle Basin	20,000
Lower Basin	72,000
Entire Basin	129,000

Since dredging is expensive and there are large amounts of sediment to be removed, dredging may have to be accomplished in phases. Dredging should begin with the upper basin and end with the lower basin. The amount of sediment to be removed during a particular phase will effect the design of all other aspects of the dredging project.

There are two general methods of dredging: hydraulic dredging and mechanical dredging. Hydraulic dredging consists of hydraulically pumping the sediments to a disposal area. Mechanical dredging usually consists of physically removing the sediments with a clamshell or similar device. Another method of mechanical dredging is to drawdown the lake and physically excavate the sediments with a bulldozer.

The preliminary evaluation of dredging methods indicates that mechanical dredging with a clamshell is the most feasible method. However, all three dredging methods will be further evaluated prior to the final selection and design of the dredging program. The final selection of the dredging method will be influenced by the sediment disposal site, which has not been selected yet.

6.2.2 Shoreline Stabilization and Wetlands Enhancement

Shoreline stabilization should be performed in Strawbridge Lake depending on the availability of local, state, and federal funds. The goal of shoreline stabilization is to enhance the aesthetic appeal of Strawbridge Lake Park, increase the area available for recreational activities, reduce the erosion occurring along the shorelines, and give added safety to park users.

Approximately 8,000 linear feet of lake shoreline would benefit from shoreline stabilization. Both structural controls, such as gabions and rip-rap, and non-structural controls such as vegetation should be used. Shoreline stabilization should be done after or during dredging operations. Within the constraints imposed by dredging operations, first priority should be the upper lake basin where most of the recreational facilities are located, second priority should be the lower lake basin which is heavily used for passive recreation; and the third priority should be the middle basin.

Another option that should be considered, especially for the lower basin, is enhancing wetlands along the lake's shoreline. This would improve wildlife habitat, beautify the lake and reduce the sediments and nutrients entering the lake.

6.2.3 Macrophyte Control

The control of macrophytes (nuisance aquatic weeds) is necessary to optimize recreational activities in Strawbridge Lake. This will be of increased importance after the implementation of watershed management practices. If these steps are not taken, substantial increases in macrophyte growth might occur following improvements in water transparency.

Grass carp should be purchased and stocked in the upper and middle basins of Strawbridge Lake. Since dredging operations may temporarily cause siltation in the lake which could be stressful to carp, the grass carp should be added to the basins after dredging activities are completed and the lake conditions are normal.

The effectiveness of the grass carp should be evaluated each year, and they should be re-stocked as necessary in accordance with state regulations.

The lower basin of Strawbridge Lake is too large to be stocked with grass carp. While macrophytes are not currently a serious problem in this basin, growth may increase if water clarity improves. If weed problems occur, weed harvesting and herbicide applications should be considered.

6.3 Water Quality Monitoring

A limited water quality monitoring program should be performed during and after implementation of the management plan to evaluate the effectiveness of the plan. As a minimum, water samples should be collected and analyzed from one station in each basin of Strawbridge Lake, during and for at least one year after implementation of the management plan. This is especially important during and after any lake dredging to ensure that dredging does not adversely affect downstream water quality. Water quality monitoring is required if EPA or NJDEPE Clean Lakes Program funds are used.

If the plan is implemented in phases, water quality monitoring should be performed for each phase.

6.4 Public Education Program

The Township's Public Education Program should be continued. Presentation of the video entitled "Strawbridge Lake - A Tarnished Treasure" has been a key factor in educating residents about the problems contributing to the deterioration of the lake and, also, in developing interest in the restoration project. Although this video has already been presented to most civic organizations, businesses and schools in the township, it might well be repeated as it is updated to remind the community of the on-going progress of the restoration project.

The annual public meetings on Lawn Care for Environmental Sensitivity have provided an avenue to educate residents about non-point source pollution with particular emphasis on those yards and properties that drain into the lake.

As part of the educational program, for the past three years volunteers have prepared posters and provided information about the lake's problems at annual "sidewalk days" in both Moorestown and Maple Shade Townships and, also, at all public events in Moorestown (e.g. Candlelight Night and the Horse Show).

Consideration should be given to expanding the existing public education program to include fact sheets on various topics including lake and watershed management, erosion control for construction activities, septic system maintenance, do's and don'ts for citizens, and the value of wetlands in lake management. Other forms of public education could include development of a slide show for school and civic presentations, development of materials for school science programs, and development of seminars on erosion control and stormwater management.

7.0 Project Costs

7.1 Cost Estimates

Costs for many elements of the recommended management plan cannot be estimated due to the site specific nature of the controls. Therefore, costs are not provided for the watershed management practices.

Costs for in-lake management practices such as dredging and stocking with grass carp can be estimated. The costs for dredging, however, depends on the method of dredging used, the disposal site, and the phasing of dredging operations. Cost estimates provided below are in 1993 dollars. The dredging costs assume that mechanical dredging will be performed and the disposal site will be located within 2½ miles of the lake.

Dredging Cost Estimates

Basin	Amount Dredged (cubic yards)	Dredging Cost
Upper	37,000	$861,000
Middle	20,000	465,000
Lower	72,000	1,674,000
Total	129,000	$3,000,000

These costs include design, permitting and dredging costs.

Grass Carp Cost Estimate

Stocking of Strawbridge Lake with Grass Carp is estimated to cost $3,500.

Other Costs

In addition to the above costs, any project funded by the Environmental Protection Agency (EPA) or NJDEPE will require that a water quality monitoring program be performed during and for one year after implementation of the plan. If the plan is implemented in phases, a water quality monitoring program is required for each phase. Along with the required water quality monitoring program, EPA funded projects require semi-annual progress reports and a final report documenting the Phase II program.

Cost estimates for the required water quality monitoring and documentation for a phased approach, such as dredging the Upper Basin, would probably cost approximately $30,000 to $40,000.

7.2 Funding Sources

Potential funding sources for implementation of the recommended management plan include the EPA Clean Lakes Program, the EPA 319 Nonpoint Source Program, NJDEPE funds, special appropriations, Soil Conservation Service funds, and local funds.

8.0 Environmental Evaluation

Since socio-economic and environmental impacts are part of the cost-effectiveness analysis for the restoration of Strawbridge Lake, many of these impacts were addressed during the evaluation of restoration alternatives. However, the impacts and their mitigative measures are formally documented below using the environmental evaluation checklist in the Clean Lakes Program Guidance Manual (U.S. EPA, 1980).

1. **Will the project displace people?**

   No.

2. **Will the project deface existing residences or residential areas?**

   There will be some inconvenience (i.e. increases in noise) to area residents during the dredging operation. However, inconveniences can be minimized through proper planning.

3. **Will the project be likely to lead to changes in established land use pattern or an increase in development pressure?**

   This is highly unlikely, because this area is already under high developmental pressures. However, improving agricultural lands through the installation of BMP's may actually enhance the desirability of the land for continued agricultural usage.

4. **Will the project adversely affect prime agricultural land or activities?**

   No. The recommended Best Management Practices (BMP's) will reduce sediment and nutrient losses from cropland and pastureland and should benefit agricultural activities.

5. **Will the project adversely affect park land, public land or scenic land?**

   No. Restoration activities will greatly enhance the recreational and aesthetic uses of the lake and adjacent park land. However, park use will be restricted during dredge operations.

6. **Will the project adversely affect lands or structures of historic, architectural,** archeological or cultural value?

   The project as planned involves no modifications to or activities which will impact existing structures. No lands which have not already been altered by agricultural or other development activities will be affected.

7. **Will the project lead to a significant long-range increase in energy demands?**

The selected restoration alternatives will not cause any significant increases in energy demand over the long-term.

8. **Will the project adversely affect short-term or long-term ambient air quality?**

Air quality may be affected over the short-term due to construction activities associated with agricultural BMP installation. All construction equipment should have proper emission controls and proper dust control practices should be used.

9. **Will the project adversely affect short-term or long-term noise levels?**

Noise levels may be temporarily affected by dredging and construction activities. All construction vehicles and equipment should use noise control devices.

10. **If the project involves the use of in-lake chemical treatment, will it cause any short-term or long-term effects?**

In-lake chemical treatments are recommended under the current conditions. However, if herbicides are needed in the future, there may be some side-effects.

11. **Will the project be located in a floodplain?**

Yes, but no adverse effects are expected.

12. **Will structures be constructed in the floodplain?**

Yes, structural shoreline will involve construction in the flood plane.

Prior to any construction activities associated with the above structures, all the necessary state and/or federal permits will be submitted.

13. **If the project involves physically modifying the lake shore, its bed, or its watershed, will the project cause any short or long-term adverse effects?**

In-lake dredging activities might cause temporary increases in lake turbidity. Other construction activities could result in the transportation of nutrients, sediments or other pollutants to downstream waters. All earthmoving activities will be conducted in a way to minimize the erosion potential and minimize in-lake turbidity.

14. Will the project have a significant adverse effect on fish and wildlife, wetlands or other wildlife habitat?

No adverse effects are expected. The planting of buffer strips, stream-bank stabilization, and re-vegetation of exposed eroding areas will have secondary benefits and will expand habitat areas for birds and mammals. During dredging, the loss of habitat for fish and benthic organisms is inevitable, but the negative impacts should be short-term.

15. Have all feasible alternative to the project been considered in terms of environmental impacts, resource commitment, public interest and cost?

All feasible alternatives for restoring Strawbridge Lake have been thoroughly analyzed. The recommended plan has minimal negative environmental impacts, and implementation of BMP's will improve management of land resources and water quality. Because of the complexity of the problems encountered in the lake and its watershed, the recommended approach using both in-lake and watershed management practices appears to be the most cost-effective method to improve fishing, aesthetics, and other lakeside uses.

16. Are there other measures not previously discussed which are necessary to mitigate adverse impacts resulting from the project?

There are no practical mitigation measures known at the present time which have not been discussed.

9.0 Public Participation

Strawbridge Lake Public Meeting

January 5, 1993
Minutes

Mr. John T. Terry, Township Manager, opened the meeting at 7:30 p.m., in the Moorestown Township Library Conference Room. Mr. Terry explained the purpose of the meeting, to provide the citizens of Burlington and Camden Counties an opportunity to comment on the proposed Lake Restoration and Management Plan for Strawbridge Lake. He also stated the professional service contract, to perform the Phase I Study, was awarded to the firm of F. X. Browne, an environmental consulting firm. Finally, he turned over the meeting to Dr. Browne, the firms founder and president who personally provided the overall management of the study.

Dr. Browne began the presentation by distributing a prepared fact sheet based on the findings of the Phase I Study. Dr. Browne gave specifics about the location of the lake, and its importance to the community. He then reported the morphometric and hydrologic characteristics of the lake, and the land use in the lake's drainage basin.

Next Dr. Browne revealed the problem that exists at Strawbridge Lake. His findings indicate the problem consists of nonpoint source pollution and shore line erosion. The buildup of sediment has reduced the average water depth to approximately 2.4 feet. In addition these sediments carry plant nutrients which causes an over abundance of algae and aquatic weeds.

Dr. Browne briefed the public about how the problems were addressed. The study was conducted under the EPA 314 Clean Lakes Program. Based on the study, Dr. Browne evaluated that Strawbridge Lake's most significant problem is sedimentation. This has caused the lake to lose about one half of its volume, this problem has generated many other ecological issues.

Dr. Browne proposed a management plan to restore and protect the lake. The plant consists of two elements: watershed management and in-lake restoration. Managing the watershed area that drains into Strawbridge Lake is important so that stormwater runoff can be controlled. Stormwater runoff delivers sediments and nutrients to the lake. In-lake restoration is to mechanically dredge the lake to remove excessive sediments and deepen the lake. As a result of dredging some unwanted weeds will be removed and the deeper water will improve the lake's fishery. Lastly, Dr. Browne explained that the aquatic weeds can be controlled by selective harvesting or by using grass carp.

Dr. Browne then opened the floor for questions.

1. *What is the analysis of the sediment, does it have any uses?*

   Dr. Browne stated that sediment can be used as landfill. Some of the nutrients contained in the sediment are not conductive as fertilizer or top soil.

2. *What are the levels of lead, what did the TCLP analysis find?*

   Dr. Browne clarified that none of the samples failed the TCLP analysis.

3. *If you fill the lake with carp to eat the polluted algae, wouldn't that just put the nitrogen and phosphorus back into the lake through the fish?*

   It's true that the carp will excrete some nitrogen and phosphorus back into the water but most of the nitrogen and phosphorus will become part of the growing carp. The main purpose of the carp is to remove nuisance weeds, not to remove nutrients from the lake.

4. *If the lake is clean, it would no longer be light limited causing an even larger algae problem. What are the plans to circumvent this problem?*

   Most of the phosphorus entering the lake are attached to the incoming sediments. Therefore, watershed management practices that reduce the pollution to the lake and increase the light penetration would also reduce the phosphorus entering the lake. It is believed that this reduced phosphorus would also reduce the algal population.

5. *What about the dynamic separator? Wouldn't it solve the sediment problem?*

   If dynamic separators were installed in all of the storm sewers entering the lake, only 12% of the watershed would be treated. Of that 12%, only 10% of the sediment particles would be removed since the sieve analyses indicate that 90% of the particles in the stormwater would not be removed by the separators. Therefore, dynamic separators are not a feasible alternative for Strawbridge Lake. Proper watershed management practices are a better alternative.

6. *What about a detention basin?*

   Because of the high watershed to lake ratio, a detention basin would have to be larger than the lake itself to properly settle incoming stormwater. A small detention basin would fill up with sediment almost immediately and would be ineffective. Therefore, a detention basin is not a feasible alternative for Strawbridge Lake.

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7. *If the ratio is 245 acres to 1, shouldn't the first priority be to stop the sediment from washing into the lake, before you remove the existing sediment?*

   Dr. Browne explained that the final management plan calls for watershed management practices and the in-lake restoration to be done simultaneously. This would solve the problem and produce preventive measures at the same time.

8. *If you remove the toxic sediment and landfill it, wouldn't it eventually leach into the water supply?*

   The EPA TCLP leaching tests show that the pollutants present in the sediment would not leach into the water supply.

9. *Is it realistic to think these three townships will work together, politically?*

   Mr. Terry and Dr. Browne agree that is possible. The consulting firm of F. X. Browne and Moorestown Township leaders met with Mt. Laurel Township leaders; the results were encouraging. Mt. Laurel leaders were very receptive and are willing to support a watershed management plan. A meeting is being scheduled with Evesham for the near future.

10. *Who would pay and bear the majority of the responsibility, Moorestown, especially the annual maintenance cost?*

    The Strawbridge Lake Restoration Project has already received $36,000 from the US EPA. The lake is contained within the boundaries of the Township of Moorestown; therefore, they will be responsible for the majority of the maintenance costs. There are many different grants available to lessen this burden. If Mt. Laurel and Evesham Townships take preventative steps to control the watershed runoff, future maintenance costs should be minimal.

11. *Where would the sediment be landfilled?*

    Mr. Terry reported two of the sites under consideration are the Township landfill and the Pennsauken landfill. Dr. Browne explained that the site must be close due to the fact that transport of the lake sediments over long distances is very costly.

12. *Are there other toxic items present besides nitrogen and phosphorus?*

    The sediment analyses will be in the final report. The only parameter of concern is lead which is present in too high concentration for residential disposal of the sediment. The sediment, however, can be disposed of on non-residential lands.

13. *How deep was the core taken to get the readings?*

    Dr. Browne reports the core sample was 3 ft., about 2.5 ft. will be dredged.

14. *What about stream diversion as a solution?*

    Stream diversion is not a possible solution because some of the surrounding area is a flood plain. Stream diversion would also be very expensive.

15. *What is the rate of flow of the streams from Rt. 38 and Church Street?*

    The rate of flow will appear in the final report.

16. *How much acreage is necessary for disposal of the dredged material?*

    The necessary acreage depends on the amount of dredging that is to be done and on the type of dredging operation.

17. *What is the recommended next step for the Township and Council to take?*

    Dr. Browne feels the next step that should be taken is to have council first review the management plan and report, adopt the Phase I report, discuss all the options, and make the decision on what route they feel is best. This would expedite the process, and Phase II could begin.

18. *Is it advantageous for the Township to begin clean up, to shown the EPA and other organizations the project is progressing?*

    Dr. Browne believes that grants will be easier to obtain if the Township can show progress. So, yes the project should begin as soon as possible.

19. *What would happen if we don't do anything?*

    Dr. Browne feels if ignored the problems will just worsen. The sediment will just keep pouring into the lake causing the water depth to lesson and the algae and aquatic weed level to increase. The problem can not be ignored; the situation has to be faced, if not now then in the future when the restoration will be more difficult, and much more costly.

20. *Can the dredged sediment be put on the shore or landscape surrounding the lake?*

    Dr. Browne believes if the sediment is put on the surrounding shore it might erode back into the lake. The sediment is not good top soil, it will not encourage plant growth.

21. *Have you looked at any park areas for a location to place the dredged sediment?*

    Some of the parks are under consideration, but when combined there is not enough acreage. Again, the problem that the sediment does not make good top soil is a factor.

22. *What about the site next to memorial field (mini-pond)?*

    Dr. Browne explains that site is still under research, it might be classified as a wet land so the sediment could not be placed there.

23. *What is going to be done to bridge the financial gap?*

    Dr. Browne reiterated that there are many grants available. Applications will need to be filled out, but they will hopefully fill most of the financial gap.

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APPENDIX A

GLOSSARY

Lake Ecology Primer

The ecological conditions of any lake is the summation of physical, chemical, and biological processes which occur in it. Temperature and dissolved oxygen measurements are usually reliable means of evaluating the ecological conditions of a lake. Life processes in the upper well lighted waters result in the uptake of nutrients and in the production of oxygen and organic material. At the bottom, the absence of light results in an environment which is colder than the surface and often devoid of dissolved oxygen. Photosynthetic production by green plants is the predominant life process at the surface while bacterial decomposition is the predominant process at the bottom. The supply of dissolved oxygen at the bottom may be depleted by bacterial decomposition and by various chemical processes associated with nutrient cycling.

Dissolved oxygen is necessary to support most forms of aquatic life. A minimum dissolved oxygen concentration of 5.0 milligrams per liter is usually required to support most fish. Warm water fish, such as bass and perch, often survive at lower oxygen levels. Oxygen levels in lakes are directly related to physical, chemical and biological activities occurring in the lake water. Measurement of dissolved oxygen is therefore an excellent indicator of the overall water quality of a lake.

Although lakes are usually in a balanced condition, two types of natural long-term changes are occurring: (1) The lake is gradually filling in with soil from upstream and surrounding land areas; and (2) the additional materials carried to the lake area usually stimulate increased plant production. The lake fills with both sediment and with the remains of plants and animals. The number of dead plants and animals increases as the production of organisms increases. These processes usually cause lakes to become shallower. The lake gradually tends to fill completely. As this process, called succession or aging, continues, the types of animals and plants also begin to change. Game fish such as bass, pike, and pan fish may be replaces by rough species such as carp, suckers, and bullheads. Rough fish are better adapted to live in a lake which is relatively old on the time scale of succession. Eventually the lake or pond becomes a bog or swamp. In turn the swamp tends to continue to fill in and, if conditions are right, a forest takes over.

Depending on the natural environmental conditions, the process of natural succession may take hundreds or even thousands of years. The actions of man, however, can considerably accelerate this aging process. It can be said, therefore, that lakes have both a chronological and ecological age. The chronological age is simply the number of years a lake has existed. The ecological age, on the other had, is a measure of the physical, chemical, and biological conditions of a lake. Relative to ecological age, most lakes are classified as being either oligotrophic, mesotrophic or eutrophic. An oligotrophic lake is an ecologically "young" lake that usually has low nutrient levels and low plant and animal productivity. A mesotrophic lake can be considered to be a "middle-aged" lake that contains average amounts of nutrients and has an average plant and animal productivity. A eutrophic lake is one that has a high nutrient content and a high plant and animal productivity. During the spring, summer, and fall, a eutrophic lake usually has an algal bloom or an excessive growth of aquatic plants.

GLOSSARY OF LAKE AND WATERSHED MANAGEMENT TERMS

Aeration: A process in which water is treated with air or other gases, usually oxygen. In lake restoration, aeration is used to prevent anaerobic condition or to provide artificial destratification.

Algal bloom: A high concentration of a specific algal species in a water body, usually caused by nutrient enrichment.

Algicide: A chemical highly toxic to algae.

Alkalinity: A quantitative measure of water's capacity to neutralize acids. Alkalinity results from the presence of bicarbonates, carbonates, hydroxides, salts, and occasionally of borates, silicates, and phosphates. Numerically, it is expressed as the concentration of calcium carbonate that has an equivalent capacity to neutralize strong acids.

Allochthonous: Describes organic matter produced outside of a specific stream or lake system.

Alluvial: Pertaining to sediments gradually deposited by moving water.

Artificial destratification: The process of inducing water currents in a lake to produce partial or total vertical circulation.

Artificial recharge: The addition of water to the groundwater reservoir by activities of man, such as irrigation or induced infiltration.

Assimilation: The absorption and conversion of nutritive elements into protoplasm.

Autochthon: Any organic matter indigenous to a specific stream or lake.

Autotrophic: The ability to synthesize organic matter from inorganic substances.

Background loading of concentration: The concentration of a chemical constituent arising from natural sources.

Base flow: Stream discharge due to groundwater flow.

Benthic oxygen demand: Oxygen demand exerted from the bottom of a stream or lake, usually by biochemical oxidation of organic material in the sediments.

Benthos: Organisms living on or in the bottom of a body of water.

Best management practices: Practices, either structural or non-structural, which are used to control nonpoint source pollution.

Bioassay: The use of living organisms to determine the biological effect of some substance, factor, or condition.

Biochemical oxidation: The process by which bacteria and other microorganisms break down organic material and remove organic matter from solution.

Biochemical oxygen demand (BOD), biological oxygen demand: The amount of oxygen used by aerobic organisms to decompose organic material. Provides an indirect measure of the concentration of biologically degradable material present in water or wastewater.

Biological control: A method of controlling pest organisms by introduced or naturally occurring predatory organisms, sterilization, inhibiting hormones, or other nonmechanical or nonchemical means.

Biological magnification, biomagnification: An increase in concentration of a substance along succeeding steps in a food chain.

Biomass: The total mass of living organisms in a particular volume or area.

Biota: All living matter in a particular region.

Blue-green algae: The phylum Cyanophyta, characterized by the presence of blue pigment in addition to green chlorophyll.

Catch basin: A collection chamber usually built at the curb line of a street, designed to admit surface water to a sewer or subdrain and to retain matter that would block the sewer.

Catchment: Surface drainage area.

Chemical control: A method of controlling pest organisms through exposure to specific toxic chemicals.

Chlorophyll: Green pigment in plants and algae necessary for photosynthesis.

Circulation period: The interval of time in which the thermal stratification of a lake is destroyed, resulting in the mixing of the entire water body.

Coagulation: The aggregation of colloidal particles, often induced by chemicals such as lime or alum.

Coliform bacteria: Nonpathogenic organisms considered a good indicator of pathogenic bacterial pollution.

Colorimetry: The technique used to infer the concentration of a dissolved substance in solution by comparison of its color intensity with that of a solution of known concentration.

Combined sewer: A sewer receiving both stormwater runoff and sewage.

Compensation point: The depth of water at which oxygen production by photosynthesis and respiration by plants and animals are at equilibrium due to light intensity.

Cover crop: A close-growing crop grown primarily for the purpose of protecting and improving soil between periods of permanent vegetation.

Crustacea: Aquatic animals with a rigid outer covering, jointed appendages, and gills.

Culture: A growth of microorganisms in an artificial medium.

Denitrification: Reduction of nitrates to nitrites or to elemental nitrogen by bacterial action.

Depression storage: Water retained in surface depressions when precipitation intensity is greater than infiltration capacity.

Design storm: A rainfall pattern of specified amount, intensity, duration, and frequency that is used as a basis for design.

Detention: Managing stormwater runoff or sewer flows through temporary holding and controlled release.

Detritus: Finely divided material of organic or inorganic origin.

Diatoms: Organisms belonging to the group Bacillariophyceae, characterized by the presence of silica in its cell walls.

Dilution: A lake restorative measure aimed at reducing nutrient levels within a water body by the replacement of nutrient-rich waters with nutrient-poor waters.

Discharge: A volume of fluid passing a point per unit time, commonly expressed as cubic meters per second.

Dissolved oxygen (DO): The quantity of oxygen present in water in a dissolved state, usually expressed as milligrams per liter of water, or as a percent of saturation at a specific temperature.

Dissolved solids (DS): The total amount of dissolved material, organic and inorganic, contained in water or wastes.

Diversion: A channel or berm constructed across or at the bottom of a slope for the purpose of intercepting surface runoff.

Drainage basin, watershed, drainage area: A geographical area where surface runoff from streams and other natural watercourses is carried by a single drainage system to a common outlet.

Dry weather flow: The combination of sanitary sewage and industrial and commercial wastes normally found in the sanitary sewers during the dry weather season of the year; or, flow in streams during dry seasons.

Dystrophic lakes: Brown-water lakes with a low lime content and a high humus content, often severely lacking nutrients.

Enrichment: The addition to or accumulation of plant nutrients in water.

Epilimnion: The upper, circulating layer of a thermally stratified lake.

Erosion: The process by which the soils of the earth's crust are worn away and carried from one place to another by weathering, corrosion, solution, and transportation.

Eutrophication: A natural enrichment process of a lake, which may be accelerated by man's activities. Usually manifested by one or more of the following characteristics: (a) excessive biomass accumulations of primary producers; (b) rapid organic and/or inorganic sedimentation and shallowing; or (c) seasonal and/or diurnal dissolved oxygen deficiencies.

Fecal streptococcus: A group of bacteria normally present in large numbers in the intestinal tracts of humans and other warm-blooded animals.

First flush: The first, and generally most polluted, portion of runoff generated by rainfall.

Flocculation: The process by which suspended particles collide and combine into larger particles or floccules and settle out of solution.

Gabion: A rectangular or cylindrical wire mesh cage (a chicken wire basket) filled with rock and used to protect against erosion.

Gaging station: A selected section of a stream channel equipped with a gage, recorder, and/or other facilities for determining stream discharge.

Grassed waterway: A natural or constructed waterway covered with erosion-resistant grasses, used to conduct surface water from an area at a reduced flow rate.

Green algae: Algae characterized by the presence of photosynthetic pigments similar in color to those of the higher green plants.

Heavy metals: Metals of high specific gravity, including cadmium, chromium, cobalt, copper, lead, mercury. They are toxic to many organisms even in low concentrations.

Hydrograph: A continuous graph showing the properties of stream flow with respect to time.

Hydrologic cycle: The movement of water from the oceans to the atmosphere and back to the sea. Many subcycles exist including precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transpiration.

Hypolimnion: The lower, non-circulating layer of a thermally stratified lake.

Intermittent stream: A stream or portion of a stream that flows only when replenished by frequent precipitation.

Irrigation return flow: Irrigation water which is not consumed in evaporation or plant growth, and which returns to a surface stream or groundwater reservoir.

Leaching: Removal of the more soluble materials from the soil by percolating waters.

Limiting nutrient: The substance that is limiting to biological growth due to its short supply with respect to other substances necessary for the growth of an organism.

Littoral: The region along the shore of a body of water.

Macrophytes: Large vascular, aquatic plants which are either rooted or floating.

Mesotrophic lake: A trophic condition between an oligotrophic and an eutrophic water body.

Metalimnion: The middle layer of a thermally stratified lake in which temperature rapidly decreases with depth.

Most probable number (MPN): A statistical indication of the number of bacteria present in a given volume (usually 100 ml).

Nannoplankton: Those organisms suspended in open water which because of their small size, cannot be collected by nets (usually smaller than approximately 25 microns).

Nitrification: The biochemical oxidation process by which ammonia is changed first to nitrates and then to nitrites by bacterial action.

Nitrogen, available: Includes ammonium, nitrate ions, ammonia, and certain simple amines readily available for plant growth.

Nitrogen cycle: The sequence of biochemical changes in which atmospheric nitrogen is "fixed," then used by a living organism, liberated upon the death and decomposition of the organism, and reduced to its original state.

Nitrogen fixation: The biological process of removing elemental nitrogen from the atmosphere and incorporating it into organic compounds.

Nitrogen, organic: Nitrogen components of biological origin such as amino acids, proteins, and peptides.

Nonpoint source: Nonpoint source pollutants are not traceable to a discrete origin, but generally result from land runoff, precipitation, drainage, or seepage.

Nutrient, available: That portion of an element or compound that can be readily absorbed and assimilated by growing plants.

Nutrient budget: An analysis of the nutrients entering a lake, discharging from the lake, and accumulating in the lake (e.g., input minus output = accumulation).

Nutrient inactivation: The process of rendering nutrients inactive by one of three methods: (1) Changing the form of a nutrient to make it unavailable to plants, (2) removing the nutrient from the photic zone, or (3) preventing the release or recycling of potentially available nutrients within a lake.

Oligotrophic lake: A lake with a small supply of nutrients, and consequently a low level of primary production. Oligotrophic lakes are often characterized by a high level of species diversification.

Orthophosphate: See phosphorus, available.

Outfall: The point where wastewater or drainage discharges from a sewer to a receiving body of water.

Overturn, turnovers: The complete mixing of a previously thermally stratified lake. This occurs in the spring and fall when water temperatures in the lake are uniform.

Oxygen deficit: The difference between observed oxygen concentrations and the amount that would be present at 100 percent saturation at a specific temperature.

Peak discharge: The maximum instantaneous flow from a given storm condition at a specific location.

Percolation test: A test used to determine the rate of percolation or seepage of water through natural soils. The percolation rate is expressed as time in minutes for a 1-inch fall of water in a test hold and is used to determine the acceptability of a site for treatment of domestic wastes by a septic system.

Perennial stream: A stream that maintains water in its channel throughout the year.

Periphyton: Microorganisms that are attached to or growing on submerged surfaces in a waterway.

Phosphorus, available: Phosphorus which is readily available for plant growth. Usually in the form of soluble orthophosphates.

Phosphorus, total (TP): All of the phosphorus present in a sample regardless of form. Usually measured by the persulfate digestion procedure.

Photic zone: The upper layer in a lake where sufficient light is available for photosynthesis.

Photosynthesis: The process occurring in green plants in which light energy is used to convert inorganic compounds to carbohydrates. In this process, carbon dioxide is consumed and oxygen is released.

Phytoplankton: Plant microorganisms, such as algae, living unattached in the water.

Plankton: Unattached aquatic microorganisms which drift passively through water.

Point source: A discreet pollutant discharge such as a pipe, ditch, channel, or concentrated animal feeding operation.

Population equivalent: An expression of the amount of a given waste load in terms of the size of human population that would contribute the same amount of biochemical oxygen demand (BOD) per day. A common base is 0.17 pounds (7.72 grams) of 5-day BOD per capita per day.

Primary production: The production of organic matter from light energy and inorganic materials, by autotrophic organisms.

Protozoa: Unicellular animals, including the ciliates and nonchlorophyllous flagellates.

Rainfall intensity: The rate at which rain falls, usually expressed in centimeters per hour.

Rational method: A means of computing peak storm drainage runoff (Q) by use of the formula Q = CIA, where C is a coefficient describing the physical drainage area, I is the average rainfall intensity, and A is the size of the drainage area.

Raw water: A water supply which is available for use but which has not yet been treated or purified.

Recurrence interval: The anticipated period in years that will elapse, based on average probability of storms in the design region, before a storm of a given intensity and/or total volume will recur; thus, a 10-year storm can be expected to occur on the average once every 10 years. Sewers are generally designed for a specific design storm frequency.

Riprap: Broken rock, cobbles, or boulders placed on earth surfaces, such as the face of a dam or the bank of a stream, for protection against the action of water (waves).

Saprophytic: Pertaining to those organisms that live on dead or decaying organic matter.

Scouring: The clearing and digging action of flowing water, especially the downward erosion caused by stream water in sweeping away mud and silt, usually during a flood.

Secchi depth: A measure of optical water clarity as determined by lowering a weighted Secchi disk into a water body to the point where it is no longer visible.

Sediment basin: A structure designed to slow the velocity of runoff water and facilitate the settling and retention of sediment and debris.

Sediment delivery ratio: The fraction of soil eroded from upland sources that reaches a continuous stream channel or storage reservoir.

Sediment discharge: The quantity of sediment, expressed as a dry weight or volume, transported through a stream cross-section in a given time. Sediment discharge consists of both suspended load and bedload.

Septic: A putrefactive condition produced by anaerobic decomposition of organic wastes, usually accompanied by production of malodorous gases.

Standing crop: The biomass present in a body of water at a particular time.

Sub-basin: A physical division of a larger basin, associated with one reach of the storm drainage system.

Substrate: The substance or base upon which an organism grows.

Suspended solids: Refers to the particulate matter in a sample, including the material that settles readily as well as the material that remains dispersed.

Swale: An elongated depression in the land surface that is at least seasonally wet, is usually heavily vegetated, and is normally without flowing water. Swales conduct stormwater into primary drainage channels and provide some groundwater recharge.

Terrace: An embankment or combination of an embankment and channel built across a slope to control erosion by diverting or storing surface runoff instead of permitting it to flow uninterrupted down the slope.

Thermal stratification: The layering of water bodies due to temperature-induced density differences.

Thermocline: See metalimnion.

Tile drainage: Land drainage by means of a series of tile lines laid at a specified depth and grade.

Total solids: The solids in water, sewage, or other liquids, including the dissolved, filterable, and nonfilterable solids. The residue left when a sample is evaporated and dried at a specified temperature.

Trace elements: Those elements which are needed in low concentrations for the growth of an organism.

Trophic condition: A relative description of a lake's biological productivity. The range of trophic conditions is characterized by the terms oligotrophic for the least biologically productive, to eutrophic for the most biologically productive.

Turbidity: A measure of the cloudiness of a liquid. Turbidity provides an indirect measure of the suspended solids concentration in water.

Urban runoff: Surface runoff from an urban drainage area.

Volatile solids: The quantity of solids in water, sewage, or other liquid, which is lost upon ignition at 600° C.

Waste load allocation: The assignment of target pollutant loads to point sources so as to achieve water quality standards in a stream segment in the most effective manner.

Water quality: A term used to describe the chemical, physical, and biological characteristics of water, usually with respect to its suitability for a particular purpose.

Water quality standards: State-enforced standards describing the required physical and chemical properties of water according to its designated uses.

Watershed: See drainage basin.

Weir: Device for measuring or regulating the flow of water.

Zooplankton: Protozoa and other animal microorganisms living unattached in water.

APPENDIX B

WATER QUALITY DATA

Water Quality Data: Basins

Location	DATE Year	Month	Day	PH units	ALK (CaCO3-mg/L)	COND (S)	NO3/NO2 (N-mg/L)
UPPER BASIN	92	3	18	6.7	22.0	372	
UPPER BASIN	92	4	1	6.8	20.0	331	0.69
UPPER BASIN	92	5	4	7.2	34	357	0.4
UPPER BASIN	92	5	19	7.1	32	377	0.355
UPPER BASIN	92	6	2	6.7	24	249.5	0.27
UPPER BASIN	92	6	16	7.3	25	341.5	0.245
UPPER BASIN	92	7	1	9.05	33	337	0.07
UPPER BASIN	92	7	15	8.8	24	223.5	0.09
UPPER BASIN	92	8	3	6.6	19	223	0.26
UPPER BASIN	92	8	24	7.6	26	294	0.08
MIDDLE BASIN	92	3	18	7.0	16.0	342	
MIDDLE BASIN	92	4	1	6.9	18.0	334	0.68
MIDDLE BASIN	92	5	4	7.3	30	352	0.37
MIDDLE BASIN	92	5	19	6.9	32	334	0.36
MIDDLE BASIN	92	6	2	6.8	24	198.7	0.28
MIDDLE BASIN	92	6	16	7.2	30	311.7	0.16
MIDDLE BASIN	92	7	1	7.2	30	313	0.25
MIDDLE BASIN	92	7	15	7.1	26	259	0.15
MIDDLE BASIN	92	8	3	6.6	16	213	0.33
MIDDLE BASIN	92	8	24	7.3	26	266	0.13
LOWER BASIN	92	3	18	7.0	26.0	290	
LOWER BASIN	92	4	1	6.7	20.0	309	0.54
LOWER BASIN	92	5	4	6.9	28	320	0.22
LOWER BASIN	92	5	19	6.7	28	294	0.26
LOWER BASIN	92	6	2	6.8	24	220	0.32
LOWER BASIN	92	6	16	6.8	26	299	0.15
LOWER BASIN	92	7	1	7	32	294	0.17
LOWER BASIN	92	7	15	6.9	20	261	0.27
LOWER BASIN	92	8	3	6.7	22	218	0.36
LOWER BASIN	92	8	24	7.5	28	259	0.17

Water Quality Data: Basins

Location	DATE Year	Month	Day	NH4 (N-mg/L)	TKN (N-mg/L)	TP (P-mg/L)	OP (P-mg/L)
UPPER BASIN	92	3	18				
UPPER BASIN	92	4	1	0.14	0.22	0.046	0.0005
UPPER BASIN	92	5	4	0.05	0.58	0.06	0.002
UPPER BASIN	92	5	19	0.15	0.43	0.053	0.0025
UPPER BASIN	92	6	2	0.2	0.58	0.0735	0.004
UPPER BASIN	92	6	16	0.05	0.44	0.067	0.0025
UPPER BASIN	92	7	1	0.05	0.58	0.057	0.001
UPPER BASIN	92	7	15	0.05	0.34	0.021	0.002
UPPER BASIN	92	8	3	0.05	0.43	0.069	0.004
UPPER BASIN	92	8	24	0.05	0.26	0.023	0.004
MIDDLE BASIN	92	3	18				
MIDDLE BASIN	92	4	1	0.05	0.28	0.029	0.0005
MIDDLE BASIN	92	5	4	0.05	0.54	0.069	0.003
MIDDLE BASIN	92	5	19	0.31	0.5	0.057	0.003
MIDDLE BASIN	92	6	2	0.19	0.58	0.064	0.003
MIDDLE BASIN	92	6	16	0.12	0.78	0.076	0.003
MIDDLE BASIN	92	7	1	0.15	0.61	0.064	0.001
MIDDLE BASIN	92	7	15	0.05	0.34	0.03	0.003
MIDDLE BASIN	92	8	3	0.05	0.44	0.068	0.004
MIDDLE BASIN	92	8	24	0.05	0.43	0.034	0.002
LOWER BASIN	92	3	18				
LOWER BASIN	92	4	1	0.05	0.21	0.102	0.002
LOWER BASIN	92	5	4	0.12	0.95	0.228	0.006
LOWER BASIN	92	5	19	0.28	0.6	0.235	0.005
LOWER BASIN	92	6	2	0.19	0.58	0.182	0.008
LOWER BASIN	92	6	16	0.13	0.78	0.202	0.011
LOWER BASIN	92	7	1	0.13	1.08	0.152	0.007
LOWER BASIN	92	7	15	0.05	0.64	0.154	0.01
LOWER BASIN	92	8	3	0.11	0.5	0.144	0.006
LOWER BASIN	92	8	24	0.05	1.51	0.29	0.01

Water Quality Data: Basins

Location	DATE Year	Month	Day	TSS (mg/L)	SECCHI (m)	CHLa (ug/L)	PHEO (ug/L)
UPPER BASIN	92	3	18	2.8	1.2		
UPPER BASIN	92	4	1	7.2	0.9	1.95	0.51
UPPER BASIN	92	5	4	1	0.8	18.24	2.9
UPPER BASIN	92	5	19	14.2	0.55	2.3	0.28
UPPER BASIN	92	6	2	16.4	0.5	2.13	2.77
UPPER BASIN	92	6	16	8.6	0.7	13.2	3.62
UPPER BASIN	92	7	1	4.8	1	2.4	1.1
UPPER BASIN	92	7	15	2.2	0.9	3.34	0.68
UPPER BASIN	92	8	3	7.7	0.8	7.73	0.97
UPPER BASIN	92	8	24	2.44	0.9	4.43	1.1
MIDDLE BASIN	92	3	18	3.2	1.0		
MIDDLE BASIN	92	4	1	7.7	1.0	1.34	0.12
MIDDLE BASIN	92	5	4	10	0.8	22.54	3.51
MIDDLE BASIN	92	5	19	9.2	0.5	3.39	1.36
MIDDLE BASIN	92	6	2	5.9	0.6	3.72	2.06
MIDDLE BASIN	92	6	16	11.2	0.7	23.6	7.17
MIDDLE BASIN	92	7	1	8.8	1	13.55	4.31
MIDDLE BASIN	92	7	15	3.6	1.1	7.64	1.69
MIDDLE BASIN	92	8	3	8.2	1	12.35	1.37
MIDDLE BASIN	92	8	24	3.6	1.2	6.57	1.48
LOWER BASIN	92	3	18	8.6	0.7		
LOWER BASIN	92	4	1	17.3	0.5	1.92	0.23
LOWER BASIN	92	5	4	23	0.3	34.79	4.78
LOWER BASIN	92	5	19	28.8	0.3	9.6	3.49
LOWER BASIN	92	6	2	20.4	0.4	14.74	4.74
LOWER BASIN	92	6	16	25.4	0.4	39.89	10.91
LOWER BASIN	92	7	1	16.9	0.4	14.9	12.5
LOWER BASIN	92	7	15	19.4	0.4	24.48	4.67
LOWER BASIN	92	8	3	19	0.5	11.4	1.04
LOWER BASIN	92	8	24	36	0.35	40.47	5.34

Water Quality Data: Tributaries

Location	DATE			PH	ALK	COND
	Year	Month	Day	units	(CaCO3-mg/L)	(S)
CHURCH STREET	92	3	18	6.5	20.0	374
CHURCH STREET	92	4	1	6.6	12.0	359
CHURCH STREET	92	5	4	6.6	30	364
CHURCH STREET	92	5	19	7.1	48	508
CHURCH STREET	92	6	2	6.4	20	337
CHURCH STREET	92	6	16	6.7	32	360
CHURCH STREET	92	7	1	7.1	40	360
CHURCH STREET	92	7	15	7.1	30	333
CHURCH STREET	92	8	3	6.4	18	262
CHURCH STREET	92	8	24	6.8	30	340
PENNSAUKEN	92	3	18	6.5	20.0	308
PENNSAUKEN	92	4	1	6.6	20.0	356
PENNSAUKEN	92	5	4	6.5	24	319
PENNSAUKEN	92	5	19	6.7	46	323
PENNSAUKEN	92	6	2	6.6	28	248
PENNSAUKEN	92	6	16	6.6	28	317
PENNSAUKEN	92	7	1	6.9	28	305
PENNSAUKEN	92	7	15	6.9	28	282
PENNSAUKEN	92	8	3	6.7	28	241
PENNSAUKEN	92	8	24	6.8	30	0.289
LAKE OUTLET	92	3	18	7.1	28.0	306
LAKE OUTLET	92	4	1	6.8	20.0	301
LAKE OUTLET	92	5	4	6.9	28	311
LAKE OUTLET	92	5	19	6.9	28	274
LAKE OUTLET	92	6	2	6.8	26	221
LAKE OUTLET	92	6	16	7	24	287
LAKE OUTLET	92	7	1	7.1	30	280
LAKE OUTLET	92	7	15	7	24	243
LAKE OUTLET	92	8	3	6.8	22	200
LAKE OUTLET	92	8	24	7.2	28	236

Water Quality Data: Tributaries

Location	DATE Year	Month	Day	OP (P-mg/L)	TSS (mg/L)
CHURCH STREET	92	3	18		2.8
CHURCH STREET	92	4	1	0.0005	5.2
CHURCH STREET	92	5	4	0.001	7.2
CHURCH STREET	92	5	19	0.002	13.5
CHURCH STREET	92	6	2	0.0005	11.7
CHURCH STREET	92	6	16	0.0005	15.9
CHURCH STREET	92	7	1	0.002	20
CHURCH STREET	92	7	15	0.004	19.6
CHURCH STREET	92	8	3	0.009	8.6
CHURCH STREET	92	8	24	0.001	7.6
PENNSAUKEN	92	3	18		3.2
PENNSAUKEN	92	4	1	0.001	12.1
PENNSAUKEN	92	5	4	0.001	14.7
PENNSAUKEN	92	5	19	0.007	15.5
PENNSAUKEN	92	6	2	0.0005	12.4
PENNSAUKEN	92	6	16	0.004	14
PENNSAUKEN	92	7	1	0.007	10.6
PENNSAUKEN	92	7	15	0.007	11.5
PENNSAUKEN	92	8	3	0.007	11.2
PENNSAUKEN	92	8	24	0.011	12.7
LAKE OUTLET	92	3	18		11.2
LAKE OUTLET	92	4	1	0.002	24.1
LAKE OUTLET	92	5	4	0.007	30
LAKE OUTLET	92	5	19	0.010	25.5
LAKE OUTLET	92	6	2	0.008	28.3
LAKE OUTLET	92	6	16	0.008	26.5
LAKE OUTLET	92	7	1	0.005	18.8
LAKE OUTLET	92	7	15	0.007	18.4
LAKE OUTLET	92	8	3	0.021	20.9
LAKE OUTLET	92	8	24	0.003	25

Water Quality Data: Tributaries

Location	DATE Year	Month	Day	NO3/NO2 (N-mg/L)	NH4 (N-mg/L)	TKN (N-mg/L)	TP (P-mg/L)
CHURCH STREET	92	3	18				
CHURCH STREET	92	4	1	0.64	0.05	0.27	0.018
CHURCH STREET	92	5	4	0.54	0.05	0.56	0.048
CHURCH STREET	92	5	19	0.3	0.12	0.3	0.051
CHURCH STREET	92	6	2	0.37	0.21	0.35	0.045
CHURCH STREET	92	6	16	0.46	0.44	0.63	0.065
CHURCH STREET	92	7	1	0.6	0.31	0.61	0.068
CHURCH STREET	92	7	15	0.48	0.21	0.55	0.076
CHURCH STREET	92	8	3	0.36	0.1	0.35	0.058
CHURCH STREET	92	8	24	0.6	0.1	0.3	0.035
PENNSAUKEN	92	3	18				
PENNSAUKEN	92	4	1	0.21	0.05	0.18	0.059
PENNSAUKEN	92	5	4	0.2	0.14	0.52	0.102
PENNSAUKEN	92	5	19	0.26	0.14	0.4	0.103
PENNSAUKEN	92	6	2	0.32	0.17	0.74	0.148
PENNSAUKEN	92	6	16	0.26	0.23	0.65	0.098
PENNSAUKEN	92	7	1	0.2	0.16	0.59	0.099
PENNSAUKEN	92	7	15	0.3	0.17	0.48	0.1
PENNSAUKEN	92	8	3	0.28	0.11	0.59	0.127
PENNSAUKEN	92	8	24	0.36	0.1	0.51	0.102
LAKE OUTLET	92	3	18				
LAKE OUTLET	92	4	1	0.54	0.05	0.22	0.130
LAKE OUTLET	92	5	4	0.23	0.05	0.75	0.236
LAKE OUTLET	92	5	19	0.29	0.23	0.5	0.193
LAKE OUTLET	92	6	2	0.3	0.17	0.65	0.224
LAKE OUTLET	92	6	16	0.11	0.05	0.98	0.272
LAKE OUTLET	92	7	1	0.06	0.17	0.89	0.205
LAKE OUTLET	92	7	15	0.22	0.05	0.83	0.152
LAKE OUTLET	92	8	3	0.35	0.1	0.55	0.188
LAKE OUTLET	92	8	24	0.06	0.005	1.3	0.215

Storm Sampling: Culverts

Culvert #	Culvert Size	DATE Year	Month	Day	COND. (S)	TP (P-mg/L)	TSS (mg/L)
1	30"	92	5	8	164.0	0.254	88.0
1	30"	92	6	5	115.7	0.296	127
1	30"	92	7	23	91.9	0.52	238.6
2	24"	92	5	8	275.0	0.080	13.9
2	24"	92	6	5	128.3	0.191	32
2	24"	92	7	23	190	0.188	15
3	24"	92	5	8	107.0	0.472	20.0
3	24"	92	6	5	49.7	0.236	45
3	24"	92	7	23	66.6	0.261	2.1
4	24"	92	5	8	39.3	0.418	30.0
4	24"	92	6	5	40.1	0.134	27
4	24"	92	7	23	158	0.29	52.3
5	18"	92	5	8	83.3	0.295	36.0
5	18"	92	6	5	97.5	0.224	21
5	18"	92	7	23	235	0.076	7.7
6	36"	92	5	8	66.5	0.475	35.0
6	36"	92	6	5	51.5	0.297	10
6	36"	92	7	23	186	0.353	8
7	18"	92	5	8	175.0	0.118	21.0
7	18"	92	7	23	203	0.202	22.9
8	30"	92	5	8	123.0	0.194	43.0
8	30"	92	6	5	460	0.914	58
8	30"	92	7	23	183	0.244	4
9	24"	92	5	8	187.0	0.168	35.3
9	24"	92	6	5	190.2	0.223	40
9	24"	92	7	23	247	0.066	15.4
10	36"	92	5	8	109.0	0.148	30.9
10	36"	92	6	5	68.2	0.343	16
10	36"	92	7	23	53.8	0.117	15.4
11	30"	92	5	8	208.0	0.065	30.7
11	30"	92	6	5	83.1	0.498	158
11	30"	92	7	23	98.3	0.14	13.3
12	24"	92	5	8	115.0	0.352	26.0
12	24"	92	6	5	60.1	0.387	17
12	24"	92	7	23	39.7	0.231	4.9
13	18"	92	5	8	89.0	0.056	23.0
13	18"	92	7	23	27.9	0.08	4.4
14	18"	92	6	6	147.7	0.159	2
15	18"	92	6	6	340	0.047	2
16	24"	92	6	6	143.8	0.2	15

Storm Sampling: Tributaries and Rain

	DATE Year	Month	Day	Alkalinity (CaCO3-mg/L)	COND (S)	NO3/NO2 (N-mg/L)	NH4 (N-mg/L	TKN (N-mg/L)	TP (P-mg/L)	OP (P-mg/L	Coliform (#/100ml)	Strep. (#/100ml)
RAIN	92	6	5	4		0.04		0.12	0.0005			
CHURCH	92	5	8	22.0	275.0	0.58	0.17	0.83	0.121	0.016		
CHURCH	92	6	5	18	118.1	0.24	0.05	0.51	0.196	0.032	7280	14980
CHURCH	92	7	23	18	112	1.96	0.05	0.57	0.198	0.019	19300	85900
PENNS.	92	5	8	26.0	202.0	0.38	0.16	0.75	0.127	0.003		
PENNS.	92	6	5	18	105.6	0.2	0.05	0.44	0.462	0.038	6980	11480
PENNS.	92	7	23	16	101	1.58	1.58	0.53	0.303	0.032	22900	56000
OUTLET	92	5	8	30.0	303.0	0.09	0.05	0.61	0.149	0.006		
OUTLET	92	6	5	22	128.8	0.13	0.05	0.39	0.169	0.032	3840	7480
OUTLET	92	7	23	26	122	1.14	0.05	0.58	0.137	0.022	15400	35300

Storm Sampling: Tributaries and Rain

	DATE Year	Month	Day	TSS (mg/L)	PH units
RAIN	92	6	5	0.5	6
CHURCH	92	5	8	30.8	6.6
CHURCH	92	6	5	34	6.7
CHURCH	92	7	23	68.8	6.7
PENNS.	92	5	8	29.0	5.7
PENNS.	92	6	5	62	7
PENNS.	92	7	23	38	6.5
OUTLET	92	5	8	26.0	6.8
OUTLET	92	6	5	28	6.9
OUTLET	92	7	23	19.1	6.6

APPENDIX C

PRECIPITATION DATA

Precipitation Data (in inches)

DATE year	month	day	Evesham Gage	Outlet Gage	
92	3	7	0.4		
92	3	11	0.72		
92	3	18			
92	3	19	1.02	1	First Reading
92	3	20	0.04		
92	3	22	0.02		
92	3	23	0.25	0.17	
92	3	26	0.13		
92	3	27	0.66		
92	3	28	0.03	0.54	
92	3	30	0.19	0.2	
92	4	2	0.05		
92	4	12	0.02		
92	4	16	0.16		
92	4	17	0.11	0.25	
92	4	18	0.14	0.17	
92	4	19	0.06	0.06	
92	4	22	0.1		
92	4	23	0.47	0.5	
92	4	26	0.03	0.1	
92	4	27	0.05		
92	5	2	0.02		
92	5	3	0.03		
92	5	5	0.02		
92	5	8	0.84		
92	5	9	0.54	1.54	
92	5	10	0.22		
92	5	11		0.2	
92	5	16	0.42	0.4	
92	5	25	0.15		
92	5	26	0.08		
92	5	27	0.07		
92	5	30	0.02		
92	5	31	1.2		
92	6	1	0		
92	6	2	0		
92	6	3	0		
92	6	4	0		
92	6	5	1.66	2.75	
92	6	6	1.63		
92	6	14		1.7	
92	6	19	1.3		
92	6	20	0.04		
92	6	24	0.1	0.2	
92	6	25	0.15		
92	6	26	0.02 last reading		
92	7	1			
92	7	4		1.25	
92	7	10		0.95	
92	7	23		0.3	
92	7	23		1.8	
92	7	31		2.5	
92	8	11		0.9	
92	8	12		0.4	

Precipitation Data (in inches)

DATE			Evesham	Outlet
year	month	day	Gage	Gage
92	8	17		0.4
92	8	18		0.65
92	8	19		0.45
92	8	20		0.1
92	8	25		0.3
92	8	27		0.5
92	8	28		0.5
92	8	29		0.5

APPENDIX D

PHYTOPLANKTON

UPPER STRAWBRIDGE LAKE 040192

TAXON	CELLS/ML
BACILLARIOPHYTA	
Achnanthes	12
Cocconeis	6
Gyrosigma	6
Nitzschia	6
Stauroneis	6
Synedra	30
CHLOROPHYTA	
Scenedesmus	24
CRYPTOPHYTA	
Cryptomonas	6
CYANOPHYTA	
Chroococcus	12
EUGLENOPHYTA	
Euglena	6
Trachelomonas	24
TOTAL	138
BACILLARIOPHYTA	66
CHLOROPHYTA	24
CRYPTOPHYTA	6
CYANOPHYTA	12
EUGLENOPHYTA	30

TAXON	UG/L
BACILLARIOPHYTA	
Achnanthes	4.8
Cocconeis	6
Gyrosigma	19.2
Nitzschia	4.8
Stauroneis	240
Synedra	24
CHLOROPHYTA	
Scenedesmus	2.4
CRYPTOPHYTA	
Cryptomonas	6
CYANOPHYTA	
Chroococcus	4.8
EUGLENOPHYTA	
Euglena	150
Trachelomonas	127.2
TOTAL	589.2
BACILLARIOPHYTA	298.8

CHLOROPHYTA	2.4
CRYPTOPHYTA	6
CYANOPHYTA	4.8
EUGLENOPHYTA	277.2

UPPER STRAWBRIDGE 050491

TAXON	CELLS/ML
BACILLARIOPHYTA	
Cocconeis	30
Fragilaria	30
Melosira	30
Nitzschia	30
Synedra	60
CHLOROPHYTA	
Ankistrodesmus	120
Scenedesmus	60
CHRYSOPHYTA	
Dinobryon	2100
Mallomonas	60
Synura	180
CRYPTOPHYTA	
Cryptomonas	660
CYANOPHYTA	
Chroococcus	1200
EUGLENOPHYTA	
Euglena	30

TOTAL	4590
BACILLARIOPHYTA	180
CHLOROPHYTA	180
CHRYSOPHYTA	2340
CRYPTOPHYTA	660
CYANOPHYTA	1200
EUGLENOPHYTA	30

TAXON	UG/L
BACILLARIOPHYTA	
Cocconeis	12
Fragilaria	9
Melosira	9
Nitzschia	24
Synedra	48
CHLOROPHYTA	
Ankistrodesmus	12
Scenedesmus	6
CHRYSOPHYTA	
Dinobryon	6300
Mallomonas	30
Synura	144
CRYPTOPHYTA	
Cryptomonas	1164
CYANOPHYTA	

Chroococcus	12
EUGLENOPHYTA	
Euglena	750
TOTAL	8520
BACILLARIOPHYTA	102
CHLOROPHYTA	18
CHRYSOPHYTA	6474
CRYPTOPHYTA	1164
CYANOPHYTA	12
EUGLENOPHYTA	750

UPPER STRAWBRIDGE 051992

TAXON	CELLS/ML
BACILLARIOPHYTA	
Synedra	30
CHLOROPHYTA	
Ankistrodesmus	120
CRYPTOPHYTA	
Cryptomonas	180
EUGLENOPHYTA	
Trachelomonas	30
TOTAL	360
BACILLARIOPHYTA	30
CHLOROPHYTA	120
CRYPTOPHYTA	180
EUGLENOPHYTA	30

TAXON	UG/L
BACILLARIOPHYTA	
Synedra	24
CHLOROPHYTA	
Ankistrodesmus	12
CRYPTOPHYTA	
Cryptomonas	342
EUGLENOPHYTA	
Trachelomonas	30
TOTAL	408
BACILLARIOPHYTA	24
CHLOROPHYTA	12
CRYPTOPHYTA	342
EUGLENOPHYTA	30

UPPER STRAWBRIDGE 060292

TAXON	CELLS/ML
BACILLARIOPHYTA	
Achnanthes	20
Cocconeis	20
Cyclotella	20
Gomphonema	20
Nitzschia	80
Synedra	80
CHLOROPHYTA	
Ankistrodesmus	20
CRYPTOPHYTA	
Cryptomonas	180
EUGLENOPHYTA	
Euglena	20
TOTAL	460
BACILLARIOPHYTA	240
CHLOROPHYTA	20
CRYPTOPHYTA	180
EUGLENOPHYTA	20

TAXON	UG/L
BACILLARIOPHYTA	
Achnanthes	2
Cocconeis	8
Cyclotella	8
Gomphonema	20
Nitzschia	64
Synedra	64
CHLOROPHYTA	
Ankistrodesmus	24
CRYPTOPHYTA	
Cryptomonas	358
EUGLENOPHYTA	
Euglena	10
TOTAL	558
BACILLARIOPHYTA	166
CHLOROPHYTA	24
CRYPTOPHYTA	358
EUGLENOPHYTA	10

UPPER STRAWBRIDGE 061892

TAXON	CELLS/ML
BACILLARIOPHYTA	
Navicula	60
Synedra	90
CHLOROPHYTA	
Ankistrodesmus	150
Scenedesmus	660
CHRYSOPHYTA	
Dinobryon	120
CRYPTOPHYTA	
Cryptomonas	270
EUGLENOPHYTA	
Euglena	90
Trachelomonas	120
PYRRHOPHYTA	
Glenodinium	60
TOTAL	1620
BACILLARIOPHYTA	150
CHLOROPHYTA	810
CHRYSOPHYTA	120
CRYPTOPHYTA	270
EUGLENOPHYTA	210
PYRRHOPHYTA	60

TAXON	UG/L
BACILLARIOPHYTA	
Navicula	60
Synedra	72
CHLOROPHYTA	
Ankistrodesmus	63
Scenedesmus	66
CHRYSOPHYTA	
Dinobryon	360
CRYPTOPHYTA	
Cryptomonas	78
EUGLENOPHYTA	
Euglena	45
Trachelomonas	120
PYRRHOPHYTA	
Glenodinium	180
TOTAL	1044

BACILLARIOPHYTA	132
CHLOROPHYTA	129
CHRYSOPHYTA	360
CRYPTOPHYTA	78
EUGLENOPHYTA	165
PYRRHOPHYTA	180

UPPER STRAWBRIDGE 070192

TAXON	CELLS/ML
BACILLARIOPHYTA	
Synedra	15
CHLOROPHYTA	
Scenedesmus	60
CRYPTOPHYTA	
Cryptomonas	75
CYANOPHYTA	
Oscillatoria	450
EUGLENOPHYTA	
Trachelomonas	45
PYRRHOPHYTA	
Glenodinium	30
TOTAL	675
BACILLARIOPHYTA	15
CHLOROPHYTA	60
CRYPTOPHYTA	75
CYANOPHYTA	450
EUGLENOPHYTA	45
PYRRHOPHYTA	30

TAXON	UG/L
BACILLARIOPHYTA	
Synedra	12
CHLOROPHYTA	
Scenedesmus	6
CRYPTOPHYTA	
Cryptomonas	15
CYANOPHYTA	
Oscillatoria	4.5
EUGLENOPHYTA	
Trachelomonas	45
PYRRHOPHYTA	
Glenodinium	90
TOTAL	172.5
BACILLARIOPHYTA	12
CHLOROPHYTA	6

CRYPTOPHYTA	15
CYANOPHYTA	4.5
EUGLENOPHYTA	45
PYRRHOPHYTA	90

UPPER STRAWBRIDGE 071592

TAXON	CELLS/ML
BACILLARIOPHYTA	
Nitzschia	15
CHLOROPHYTA	
Ankistrodesmus	15
Chlamydomonas	15
Coelastrum	300
Scenedesmus	60
Sorastrum	120
Tetraedron	15
CRYPTOPHYTA	
Cryptomonas	15
CYANOPHYTA	
Chroococcus	240
Oscillatoria	300
EUGLENOPHYTA	
Trachelomonas	75
TOTAL	1170
BACILLARIOPHYTA	15
CHLOROPHYTA	525
CRYPTOPHYTA	15
CYANOPHYTA	540
EUGLENOPHYTA	75

TAXON	UG/L
BACILLARIOPHYTA	
Nitzschia	12
CHLOROPHYTA	
Ankistrodesmys	7.5
Chlamydomonas	6
Coelastrum	108
Scenedesmus	6
Sorastrum	24
Tetraedron	37.5
CRYPTOPHYTA	
Cryptomonas	15
CYANOPHYTA	
Chroococcus	2.4
Oscillatoria	3
EUGLENOPHYTA	
Trachelomonas	75
TOTAL	296.4
BACILLARIOPHYTA	12
CHLOROPHYTA	189

CRYPTOPHYTA	15
CYANOPHYTA	5.4
EUGLENOPHYTA	75

UPPER STRAWBRIDGE 080392

TAXON	CELLS/ML
BACILLARIOPHYTA	
Nitzschia	15
CHLOROPHYTA	
Ankistrodesmus	165
Chlamydomonas	45
Closterium	15
Coelastrum	180
Scenedesmus	60
CRYPTOPHYTA	
Cryptomonas	420
CYANOPHYTA	
Merismopedia	240
Oscillatoria	300
EUGLENOPHYTA	
Trachelomonas	60
TOTAL	1500
BACILLARIOPHYTA	15
CHLOROPHYTA	465
CRYPTOPHYTA	420
CYANOPHYTA	540
EUGLENOPHYTA	60

TAXON	UG/L
BACILLARIOPHYTA	
Nitzschia	12
CHLOROPHYTA	
Ankistrodesmus	82.5
Chlamydomonas	4.5
Closterium	60
Coelastrum	36
Scenedesmus	6
CRYPTOPHYTA	
Cryptomonas	372
CYANOPHYTA	
Merismopedia	7.2
Oscillatoria	6
EUGLENOPHYTA	
Trachelomonas	60
TOTAL	646.2
BACILLARIOPHYTA	12
CHLOROPHYTA	189
CRYPTOPHYTA	372

CYANOPHYTA	13.2
EUGLENOPHYTA	60

UPPER STRAWBRIDGE 082492

TAXON	CELLS/ML
BACILLARIOPHYTA	
Cocconeis	60
Cyclotella	15
Eunotia	15
Fragilaria	1275
Gomphonema	15
Navicula	15
CHLOROPHYTA	
Ankistrodesmus	75
Dictyosphaerium	180
CHRYSOPHYTA	
Mallomonas	15
CRYPTOPHYTA	
Cryptomonas	90
CYANOPHYTA	
Oscillatoria	450
EUGLENOPHYTA	
Euglena	75
Trachelomonas	60
PYRRHOPHYTA	
Peridinium	15

TOTAL	2355
BACILLARIOPHYTA	1395
CHLOROPHYTA	255
CHRYSOPHYTA	15
CRYPTOPHYTA	90
CYANOPHYTA	450
EUGLENOPHYTA	135
PYRRHOPHYTA	15

TAXON	UG/L
BACILLARIOPHYTA	
Cocconeis	42
Cyclotella	37.5
Eunotia	15
Fragilaria	382.5
Gomphonema	15
Navicula	15
CHLOROPHYTA	
Ankistrodesmus	37.5
Dictyosphaerium	18
CHRYSOPHYTA	
Mallomonas	7.5
CRYPTOPHYTA	

Cryptomonas	18
CYANOPHYTA	
Oscillatoria	9
EUGLENOPHYTA	
Euglena	37.5
Trachelomonas	60
PYRRHOPHYTA	
Peridinium	45
TOTAL	739.5
BACILLARIOPHYTA	507
CHLOROPHYTA	55.5
CHRYSOPHYTA	7.5
CRYPTOPHYTA	18
CYANOPHYTA	9
EUGLENOPHYTA	97.5
PYRRHOPHYTA	45

MIDDLE STRAWBRIDGE LAKE 040192

TAXON	CELLS/ML
BACILLARIOPHYTA	
Achnanthes	12
Cocconeis	6
Melosira	12
Nitzschia	6
Stauroneis	6
Synedra	6
CRYPTOPHYTA	
Cryptomonas	18
CYANOPHYTA	
Oscillatoria	72
EUGLENOPHYTA	
Trachelomonas	6
TOTAL	144
BACILLARIOPHYTA	48
CRYPTOPHYTA	18
CYANOPHYTA	72
EUGLENOPHYTA	6

TAXON	UG/L
BACILLARIOPHYTA	
Achnanthes	1.2
Cocconeis	2.4
Melosira	3.6
Nitzschia	4.8
Stauroneis	11.4
Synedra	4.8
CRYPTOPHYTA	
Cryptomonas	18
CYANOPHYTA	
Oscillatoria	.7
EUGLENOPHYTA	
Trachelomonas	6
TOTAL	52.9
BACILLARIOPHYTA	28.2
CRYPTOPHYTA	18
CYANOPHYTA	.7
EUGLENOPHYTA	6

MIDDLE STRAWBRIDGE 050492

TAXON	CELLS/ML
BACILLARIOPHYTA	
Achnanthes	30
Synedra	60
CHLOROPHYTA	
Ankistrodesmus	240
Scenedesmus	60
CHRYSOPHYTA	
Dinobryon	6300
Synura	480
CRYPTOPHYTA	
Cryptomonas	1200
CYANOPHYTA	
Chroococcus	600
EUGLENOPHYTA	
Trachelomonas	30
TOTAL	9000
BACILLARIOPHYTA	90
CHLOROPHYTA	300
CHRYSOPHYTA	6780
CRYPTOPHYTA	1200
CYANOPHYTA	600
EUGLENOPHYTA	30

TAXON	UG/L
BACILLARIOPHYTA	
Achnanthes	3
Synedra	48
CHLOROPHYTA	
Ankistrodesmus	72
Scenedesmus	6
CHRYSOPHYTA	
Dinobryon	18900
Synura	384
CRYPTOPHYTA	
Cryptomonas	1770
CYANOPHYTA	
Chroococcus	6
EUGLENOPHYTA	
Trachelomonas	30
TOTAL	21219

BACILLARIOPHYTA	51
CHLOROPHYTA	78
CHRYSOPHYTA	19284
CRYPTOPHYTA	1770
CYANOPHYTA	6
EUGLENOPHYTA	30

MIDDLE STRAWBRIDGE 051992

TAXON	CELLS/ML
BACILLARIOPHYTA	
Cocconeis	20
Gomphonema	20
Melosira	20
CHLOROPHYTA	
Ankistrodesmus	60
Pediastrum	80
CHRYSOPHYTA	
Dinobryon	20
CRYPTOPHYTA	
Cryptomonas	60
EUGLENOPHYTA	
Trachelomonas	20
PYRRHOPHYTA	
Peridinium	20
TOTAL	320
BACILLARIOPHYTA	60
CHLOROPHYTA	140
CHRYSOPHYTA	20
CRYPTOPHYTA	60
EUGLENOPHYTA	20
PYRRHOPHYTA	20

TAXON	UG/L
BACILLARIOPHYTA	
Cocconeis	8
Gomphonema	20
Melosira	6
CHLOROPHYTA	
Ankistrodesmus	6
Pediastrum	16
CHRYSOPHYTA	
Dinobryon	60
CRYPTOPHYTA	
Cryptomonas	98
EUGLENOPHYTA	
Trachelomonas	20
PYRRHOPHYTA	
Peridinium	60
TOTAL	294

BACILLARIOPHYTA	34
CHLOROPHYTA	22
CHRYSOPHYTA	60
CRYPTOPHYTA	98
EUGLENOPHYTA	20
PYRRHOPHYTA	60

MIDDLE STRAWBRIDGE 060292

TAXON	CELLS/ML
BACILLARIOPHYTA	
Achnanthes	15
Fragilaria	15
Nitzschia	60
Synedra	60
CHLOROPHYTA	
Crucigenia	240
CRYPTOPHYTA	
Cryptomonas	330
EUGLENOPHYTA	
Euglena	30
Trachelomonas	15
TOTAL	765
BACILLARIOPHYTA	150
CHLOROPHYTA	240
CRYPTOPHYTA	330
EUGLENOPHYTA	45

TAXON	UG/L
BACILLARIOPHYTA	
Achnanthes	1.5
Fragilaria	4.5
Nitzschia	48
Synedra	48
CHLOROPHYTA	
Crucigenia	24
CRYPTOPHYTA	
Cryptomonas	162
EUGLENOPHYTA	
Euglena	15
Trachelomonas	15
TOTAL	318
BACILLARIOPHYTA	102
CHLOROPHYTA	24
CRYPTOPHYTA	162
EUGLENOPHYTA	30

MIDDLE STRAWBRIDGE 061892

TAXON	CELLS/ML
BACILLARIOPHYTA	
Cymbella	15
Navicula	15
Nitzschia	15
Synedra	60
CHLOROPHYTA	
Ankistrodesmus	90
Closteriopsis	15
Eudorina	840
Staurastrum	30
CHRYSOPHYTA	
Dinobryon	3600
Mallomonas	30
Synura	60
CRYPTOPHYTA	
Cryptomonas	240
EUGLENOPHYTA	
Euglena	45
Trachelomonas	165
TOTAL	5220
BACILLARIOPHYTA	105
CHLOROPHYTA	975
CHRYSOPHYTA	3690
CRYPTOPHYTA	240
EUGLENOPHYTA	210

TAXON	UG/L
BACILLARIOPHYTA	
Cymbella	22.5
Navicula	15
Nitzschia	12
Synedra	48
CHLOROPHYTA	
Ankistrodesmus	45
Closteriopsis	7.5
Eudorina	336
Staurastrum	24
CHRYSOPHYTA	
Dinobryon	10800
Mallomonas	547.5
Synura	48
CRYPTOPHYTA	
Cryptomonas	240
EUGLENOPHYTA	
Euglena	22.5
Trachelomonas	375

TOTAL	12543
BACILLARIOPHYTA	97.5
CHLOROPHYTA	412.5
CHRYSOPHYTA	11395.5
CRYPTOPHYTA	240
EUGLENOPHYTA	397.5

MIDDLE STRAWBRIDGE 070192

TAXON	CELLS/ML
BACILLARIOPHYTA	
Achnanthes	15
Fragilaria	210
Nitzschia	15
CHLOROPHYTA	
Ankistrodesmus	45
Chlamydomonas	15
Closterium	90
Scenedesmus	30
Staurastrum	15
Tetraedron	30
CHRYSOPHYTA	
Dinobryon	1350
CRYPTOPHYTA	
Cryptomonas	30
EUGLENOPHYTA	
Euglena	30
Trachelomonas	60
PYRRHOPHYTA	
Peridinium	120

TOTAL	2055
BACILLARIOPHYTA	240
CHLOROPHYTA	225
CHRYSOPHYTA	1350
CRYPTOPHYTA	30
EUGLENOPHYTA	90
PYRRHOPHYTA	120

TAXON	UG/L
BACILLARIOPHYTA	
Achnanthes	6
Fragilaria	63
Nitzschia	12
CHLOROPHYTA	
Ankistrodesmus	22.5
Chlamydomonas	6
Closterium	360
Scenedesmus	3
Staurastrum	12
Tetraedron	18
CHRYSOPHYTA	
Dinobryon	4050
CRYPTOPHYTA	
Cryptomonas	30
EUGLENOPHYTA	

Euglena	15
Trachelomonas	60
PYRRHOPHYTA	
Peridinium	2880
TOTAL	7537.5
BACILLARIOPHYTA	81
CHLOROPHYTA	421.5
CHRYSOPHYTA	4050
CRYPTOPHYTA	30
EUGLENOPHYTA	75
PYRRHOPHYTA	2880

MIDDLE STRAWBRIDGE 071592

TAXON	CELLS/ML
BACILLARIOPHYTA	
Achnanthes	15
Cocconeis	15
Eunotia	15
Nitzschia	15
CHLOROPHYTA	
Closterium	30
CRYPTOPHYTA	
Cryptomonas	165
CYANOPHYTA	
Anabaena	1125
EUGLENOPHYTA	
Euglena	15
Trachelomonas	135
PYRRHOPHYTA	
Peridinium	15
TOTAL	1545
BACILLARIOPHYTA	60
CHLOROPHYTA	30
CRYPTOPHYTA	165
CYANOPHYTA	1125
EUGLENOPHYTA	150
PYRRHOPHYTA	15

TAXON	UG/L
BACILLARIOPHYTA	
Achnanthes	1.5
Cocconeis	6
Eunotia	15
Nitzschia	12
CHLOROPHYTA	
Closterium	120
CRYPTOPHYTA	
Cryptomonas	33
CYANOPHYTA	
Anabaena	450
EUGLENOPHYTA	
Euglena	7.5
Trachelomonas	264
PYRRHOPHYTA	
Peridinium	45

TOTAL	954
BACILLARIOPHYTA	34.5
CHLOROPHYTA	120
CRYPTOPHYTA	33
CYANOPHYTA	450
EUGLENOPHYTA	271.5
PYRRHOPHYTA	45

MIDDLE STRAWBRIDGE 080392

TAXON	CELLS/ML
CHLOROPHYTA	
Ankistrodesmus	120
Chlamydomonas	120
Closterium	30
Coelastrum	120
Dictyosphaerium	60
Scenedesmus	60
Staurastrum	30
CRYPTOPHYTA	
Cryptomonas	645
EUGLENOPHYTA	
Euglena	15
Trachelomonas	180
PYRRHOPHYTA	
Peridinium	15
TOTAL	1395
CHLOROPHYTA	540
CRYPTOPHYTA	645
EUGLENOPHYTA	195
PYRRHOPHYTA	15

TAXON	UG/L
CHLOROPHYTA	
Ankistrodesmus	60
Chlamydomonas	12
Closterium	120
Coelastrum	24
Dictyosphaerium	6
Scenedesmus	6
Staurastrum	24
CRYPTOPHYTA	
Cryptomonas	645
EUGLENOPHYTA	
Euglena	7.5
Trachelomonas	180
PYRRHOPHYTA	
Peridinium	675
TOTAL	1759.5
CHLOROPHYTA	252
CRYPTOPHYTA	645
EUGLENOPHYTA	187.5
PYRRHOPHYTA	675

MIDDLE STRAWBRIDGE 082491

TAXON	CELLS/ML
BACILLARIOPHYTA	
Cocconeis	15
Eunotia	30
Fragilaria	60
Navicula	15
Nitzschia	15
Synedra	15
CHLOROPHYTA	
Ankistrodesmus	90
Chlamydomonas	60
Oocystis	60
Scenedesmus	60
CRYPTOPHYTA	
Cryptomonas	270
EUGLENOPHYTA	
Euglena	15
Trachelomonas	180
TOTAL	885
BACILLARIOPHYTA	150
CHLOROPHYTA	270
CRYPTOPHYTA	270
EUGLENOPHYTA	195

TAXON	UG/L
BACILLARIOPHYTA	
Cocconeis	6
Eunotia	30
Fragilaria	18
Navicula	15
Nitzschia	12
Synedra	12
CHLOROPHYTA	
Ankistrodesmus	45
Chlamydomonas	24
Oocystis	24
Scenedesmus	6
CRYPTOPHYTA	
Cryptomonas	270
EUGLENOPHYTA	
Euglena	7.5
Trachelomonas	180
TOTAL	649.5
BACILLARIOPHYTA	93
CHLOROPHYTA	99
CRYPTOPHYTA	270
EUGLENOPHYTA	187.5

LOWER STRAWBRIDGE 050492

TAXON	CELLS/ML
BACILLARIOPHYTA	
Achnanthes	30
Navicula	30
Nitzschia	30
Synedra	60
CHLOROPHYTA	
Actinastrum	480
Ankistrodesmus	150
Scenedesmus	120
CHRYSOPHYTA	
Dinobryon	1650
Synura	120
CRYPTOPHYTA	
Cryptomonas	1410
CYANOPHYTA	
Oscillatoria	2400
EUGLENOPHYTA	
Euglena	90
Trachelomonas	90
TOTAL	6660
BACILLARIOPHYTA	150
CHLOROPHYTA	750
CHRYSOPHYTA	1770
CRYPTOPHYTA	1410
CYANOPHYTA	2400
EUGLENOPHYTA	180

TAXON	UG/L
BACILLARIOPHYTA	
Achnanthes	3
Navicula	30
Nitzschia	24
Synedra	48
CHLOROPHYTA	
Actinastrum	48
Ankistrodesmus	15
Scenedesmus	12
CHRYSOPHYTA	
Dinobryon	4950
Synura	96
CRYPTOPHYTA	
Cryptomonas	2577
CYANOPHYTA	
Oscillatoria	24

EUGLENOPHYTA

Euglena	45
Trachelomonas	90

TOTAL	7962
BACILLARIOPHYTA	105
CHLOROPHYTA	75
CHRYSOPHYTA	5046
CRYPTOPHYTA	2577
CYANOPHYTA	24
EUGLENOPHYTA	135

LOWER STRAWBRIDGE 051992

TAXON	CELLS/ML
BACILLARIOPHYTA	
Achnanthes	30
Fragilaria	180
Melosira	30
Navicula	60
Nitzschia	60
CHLOROPHYTA	
Ankistrodesmus	270
Scenedesmus	30
CHRYSOPHYTA	
Dinobryon	360
Synura	30
CRYPTOPHYTA	
Cryptomonas	330
EUGLENOPHYTA	
Euglena	120
Trachelomonas	60
TOTAL	1560
BACILLARIOPHYTA	360
CHLOROPHYTA	300
CHRYSOPHYTA	390
CRYPTOPHYTA	330
EUGLENOPHYTA	180

TAXON	UG/L
BACILLARIOPHYTA	
Achnanthes	3
Fragilaria	54
Melosira	9
Navicula	60
Nitzschia	48
CHLOROPHYTA	
Ankistrodesmus	27
Scenedesmus	3
CHRYSOPHYTA	
Dinobryon	1080
Synura	24
CRYPTOPHYTA	
Cryptomonas	453
EUGLENOPHYTA	
Euglena	60
Trachelomonas	60
TOTAL	1881
BACILLARIOPHYTA	174

CHLOROPHYTA	30
CHRYSOPHYTA	1104
CRYPTOPHYTA	453
EUGLENOPHYTA	120

LOWER STRAWBRIDGE 060292

TAXON	CELLS/ML
BACILLARIOPHYTA	
Cocconeis	15
Nitzschia	30
CHLOROPHYTA	
Ankistrodesmus	180
Scenedesmus	120
CHRYSOPHYTA	
Dinobryon	60
CRYPTOPHYTA	
Cryptomonas	720
CYANOPHYTA	
Anabaena	3900
Aphanizomenon	5400
EUGLENOPHYTA	
Euglena	30
Trachelomonas	30
PYRRHOPHYTA	
Peridinium	15

TOTAL	10500
BACILLARIOPHYTA	45
CHLOROPHYTA	300
CHRYSOPHYTA	60
CRYPTOPHYTA	720
CYANOPHYTA	9300
EUGLENOPHYTA	60
PYRRHOPHYTA	15

TAXON	UG/L
BACILLARIOPHYTA	
Cocconeis	6
Nitzschia	24
CHLOROPHYTA	
Ankistrodesmus	90
Scenedesmus	12
CHRYSOPHYTA	
Dinobryon	180
CRYPTOPHYTA	
Cryptomonas	720
CYANOPHYTA	
Anabaena	1560
Aphanizomenon	270

EUGLENOPHYTA

Euglena	15
Trachelomonas	30

PYRRHOPHYTA

Peridinium	45

TOTAL	2952
BACILLARIOPHYTA	30
CHLOROPHYTA	102
CHRYSOPHYTA	180
CRYPTOPHYTA	720
CYANOPHYTA	1830
EUGLENOPHYTA	45
PYRRHOPHYTA	45

LOWER STRAWBRIDGE 061892

TAXON	CELLS/ML
BACILLARIOPHYTA	
Achnanthes	15
Gomohonema	15
Melosira	30
Navicula	60
Nitzschia	30
CHLOROPHYTA	
Actinastrum	360
Ankistrodesmus	270
Closteriopsis	30
Elakatothrix	30
Micractinium	240
Scenedesmus	240
CHRYSOPHYTA	
Dinobryon	2100
CRYPTOPHYTA	
Cryptomonas	210
CYANOPHYTA	
Oscillatoria	1500
EUGLENOPHYTA	
Euglena	30
Trachelomonas	105
TOTAL	5265
BACILLARIOPHYTA	150
CHLOROPHYTA	1170
CHRYSOPHYTA	2100
CRYPTOPHYTA	210
CYANOPHYTA	1500
EUGLENOPHYTA	135

TAXON	UG/L
BACILLARIOPHYTA	
Achnanthes	1.5
Gomphonema	15
Melosira	9
Navicula	120
Nitzschia	24
CHLOROPHYTA	
Actinastrum	36
Ankistrodesmus	135
Closteriopsis	30
Elakatothrix	3
Micractinium	720
Scenedesmus	24
CHRYSOPHYTA	
Dinobryon	6300
CRYPTOPHYTA	

Cryptomonas	210
CYANOPHYTA	
Oscillatoria	15
EUGLENOPHYTA	
Euglena	15
Trachelomonas	105
TOTAL	7762.5
BACILLARIOPHYTA	169.5
CHLOROPHYTA	948
CHRYSOPHYTA	6300
CRYPTOPHYTA	210
CYANOPHYTA	15
EUGLENOPHYTA	120

LOWER STRAWBRIDGE 070192

TAXON	CELLS/ML
BACILLARIOPHYTA	
Nitzschia	45
Synedra	30
CHLOROPHYTA	
Ankistrodesmus	180
Closterium	30
Crucigenia	240
Micractinium	600
Scenedesmus	360
CHRYSOPHYTA	
Dinobryon	2100
CRYPTOPHYTA	
Cryptomonas	60
CYANOPHYTA	
Anabaena	420
Oscillatoria	600
EUGLENOPHYTA	
Euglena	45
Trachelomonas	105
PYRRHOPHYTA	
Ceratium	15

TOTAL	4830
BACILLARIOPHYTA	75
CHLOROPHYTA	1410
CHRYSOPHYTA	2100
CRYPTOPHYTA	60
CYANOPHYTA	1020
EUGLENOPHYTA	150
PYRRHOPHYTA	15

TAXON	UG/L
BACILLARIOPHYTA	
Nitzschia	36
Synedra	24
CHLOROPHYTA	
Ankistrodesmus	90
Closterium	120
Crucigenia	24
Micractinium	1800
Scenedesmus	36
CHRYSOPHYTA	
Dinobryon	6300
CRYPTOPHYTA	

Cryptomonas	60
CYANOPHYTA	
Anabaena	168
Oscillatoria	12
EUGLENOPHYTA	
Euglena	22.5
Trachelomonas	379.5
PYRRHOPHYTA	
Ceratium	600
TOTAL	9672
BACILLARIOPHYTA	60
CHLOROPHYTA	2070
CHRYSOPHYTA	6300
CRYPTOPHYTA	60
CYANOPHYTA	180
EUGLENOPHYTA	402
PYRRHOPHYTA	600

LOWER STRAWBRIDGE 071592

TAXON	CELLS/ML
BACILLARIOPHYTA	
Cocconeis	15
Melosira	90
Nitzschia	30
CHLOROPHYTA	
Actinastrum	90
Ankistrodesmus	120
Chlamydomonas	60
Dictyosphaerium	60
Micractinium	180
Scenedesmus	360
Treubaria	15
CRYPTOPHYTA	
Cryptomonas	195
CYANOPHYTA	
Chroococcus	360
Oscillatoria	1290
EUGLENOPHYTA	
Euglena	90
Trachelomonas	105
TOTAL	3060
BACILLARIOPHYTA	135
CHLOROPHYTA	885
CRYPTOPHYTA	195
CYANOPHYTA	1650
EUGLENOPHYTA	195

TAXON	UG/L
BACILLARIOPHYTA	
Cocconeis	6
Melosira	27
Nitzschia	24
CHLOROPHYTA	
Actinastrum	18
Ankistrodesmus	28.5
Chlamydomonas	24
Dictyosphaerium	6
Micractinium	540
Scenedesmus	120
Treubaria	3
CRYPTOPHYTA	
Cryptomonas	111
CYANOPHYTA	
Chroococcus	3.6
Oscillatoria	25.8
EUGLENOPHYTA	
Euglena	1882.5

Trachelomonas	105
TOTAL	2924.4
BACILLARIOPHYTA	57
CHLOROPHYTA	739.5
CRYPTOPHYTA	111
CYANOPHYTA	29.4
EUGLENOPHYTA	1987.5

LOWER STRAWBRIDGE 080392

TAXON	CELLS/ML
BACILLARIOPHYTA	
Achnanthes	15
Eunotia	15
Fragilaria	60
Gomphonema	15
Gyrosigma	15
Melosira	30
Nitzschia	15
CHLOROPHYTA	
Ankistrodesmus	255
Chlamydomonas	60
Closterium	45
Coelastrum	180
Cosmarium	15
Oocystis	180
Pediastrum	180
Scenedesmus	120
CHRYSOPHYTA	
Mallomonas	15
CRYPTOPHYTA	
Cryptomonas	285
CYANOPHYTA	
Anabaena	750
Aphanizomenon	1800
Coelosphaerium	4500
Oscillatoria	3000
EUGLENOPHYTA	
Trachelomonas	75
PYRRHOPHYTA	
Peridinium	15

TOTAL	11640
BACILLARIOPHYTA	165
CHLOROPHYTA	1035
CHRYSOPHYTA	15
CRYPTOPHYTA	285
CYANOPHYTA	10050
EUGLENOPHYTA	75
PYRRHOPHYTA	15

TAXON	UG/L
BACILLARIOPHYTA	
Achnanthes	6
Eunotia	15
Fragilaria	18
Gomphonema	15
Gyrosigma	48
Melosira	9
Nitzschia	12

CHLOROPHYTA	
Ankistrodesmus	127.5
Chlamydomonas	6
Closterium	180
Coelastrum	36
Cosmarium	12
Oocystis	72
Pediastrum	36
Scenedesmus	12
CHRYSOPHYTA	
Mallomonas	60
CRYPTOPHYTA	
Cryptomonas	285
CYANOPHYTA	
Anabaena	2325
Aphanizomenon	90
Coelosphaerium	135
Oscillatoria	36
EUGLENOPHYTA	
Trachelomonas	75
PYRRHOPHYTA	
Peridinium	675
TOTAL	4285.5
BACILLARIOPHYTA	123
CHLOROPHYTA	481.5
CHRYSOPHYTA	60
CRYPTOPHYTA	285
CYANOPHYTA	2586
EUGLENOPHYTA	75
PYRRHOPHYTA	675

LOWER STRAWBRIDGE 082492

TAXON	CELLS/ML
BACILLARIOPHYTA	
Cymbella	15
Eunotia	15
Melosira	45
Navicula	15
Nitzschia	15
CHLOROPHYTA	
Ankistrodesmus	120
Coelastrum	180
Eudorina	120
Scenedesmus	120
CHRYSOPHYTA	
Other golden algae	12000
CRYPTOPHYTA	
Cryptomonas	120
CYANOPHYTA	
Anabaena	450
Oscillatoria	1800
EUGLENOPHYTA	
Euglena	30
Trachelomonas	240
PYRRHOPHYTA	
Peridinium	15

TOTAL	15300
BACILLARIOPHYTA	105
CHLOROPHYTA	540
CHRYSOPHYTA	12000
CRYPTOPHYTA	120
CYANOPHYTA	2250
EUGLENOPHYTA	270
PYRRHOPHYTA	15

TAXON	UG/L
BACILLARIOPHYTA	
Cymbella	22.5
Eunotia	60
Melosira	13.5
Navicula	15
Nitzschia	12
CHLOROPHYTA	
Ankistrodesmus	60
Coelastrum	36
Eudorina	156
Scenedesmus	12
CHRYSOPHYTA	

Other golden algae	6000
CRYPTOPHYTA	
Cryptomonas	24
CYANOPHYTA	
Anabaena	1395
Oscillatoria	36
EUGLENOPHYTA	
Euglena	15
Trachelomonas	240
PYRRHOPHYTA	
Peridinium	45
TOTAL	8142
BACILLARIOPHYTA	123
CHLOROPHYTA	264
CHRYSOPHYTA	6000
CRYPTOPHYTA	24
CYANOPHYTA	1431
EUGLENOPHYTA	255
PYRRHOPHYTA	45

LOWER STRAWBRIDGE LAKE 040192

TAXON	CELLS/ML
BACILLARIOPHYTA	
Navicula	18
Nitzschia	27
CHLOROPHYTA	
Ankistrodesmus	54
CHRYSOPHYTA	
Chromulina	9
Dinobryon	54
Mallomonas	18
Synura	9
CRYPTOPHYTA	
Cryptomonas	45
CYANOPHYTA	
Oscillatoria	90
EUGLENOPHYTA	
Euglena	9
TOTAL	333
BACILLARIOPHYTA	45
CHLOROPHYTA	54
CHRYSOPHYTA	90
CRYPTOPHYTA	45
CYANOPHYTA	90
EUGLENOPHYTA	9

TAXON	UG/L
BACILLARIOPHYTA	
Navicula	54
Nitzschia	21.6
CHLOROPHYTA	
Ankistrodesmus	5.4
CHRYSOPHYTA	
Chromulina	1.8
Dinobryon	162
Mallomonas	9
Synura	7.2
CRYPTOPHYTA	
Cryptomonas	45
CYANOPHYTA	
Oscillatoria	.9
EUGLENOPHYTA	
Euglena	4.5
TOTAL	311.4

BACILLARIOPHYTA	75.6
CHLOROPHYTA	5.4
CHRYSOPHYTA	180
CRYPTOPHYTA	45
CYANOPHYTA	.9
EUGLENOPHYTA	4.5

APPENDIX E

TEMPERATURE/DISSOLVED OXYGEN

1992 Temperature Profile Data
Middle Basin

March 19

Depth(m)	Temp.(°C)
0.0	6.0
0.5	6.0
1.0	6.0
1.1	6.0

April 1

Depth(m)	Temp.(°C)
0.0	10.1
0.5	10.1
1.0	9.9
1.2	9.9

May 4

Depth(m)	Temp.(°C)
0.0	19.5
0.5	19.5
1.0	19.0
1.2	19.0

May 19

Depth(m)	Temp.(°C)
0.0	19.5
0.5	19.2
1.0	19.0
1.2	18.2

June 2

Depth(m)	Temp.(°C)
0.0	17.5
0.5	17.2
1.0	16.5

July 1

Depth(m)	Temp.(°C)
0.0	26.5
0.5	26.0
0.7	25.5

July 15

Depth(m)	Temp.(°C)
0.0	28.2
0.5	28.2
1.0	27.9
1.3	27.0

August 3

Depth(m)	Temp.(°C)
0.0	26.9
0.5	24.0
1.0	23.8

August 26

Depth(m)	Temp.(°C)
0.0	24.2
0.5	23.2
1.0	22.8

1992 Temperature Profile Data
Lower Basin

March 19

Depth(m)	Temp.(°C)
0.0	6.2
0.5	6.2
0.9	6.1

April 1

Depth(m)	Temp.(°C)
0.0	10.8
0.5	10.5
1.0	10.0

May 4

Depth(m)	Temp.(°C)
0.0	18.5
0.5	18.2
1.0	18.2

May 19

Depth(m)	Temp.(°C)
0.0	17.4
0.5	17.2
1.0	17.2

June 2

Depth(m)	Temp.(°C)
0.0	18.8
0.5	17.5
1.0	17.0

July 1

Depth(m)	Temp.(°C)
0.0	26.5
0.5	26.0
0.7	25.5

July 15

Depth(m)	Temp.(°C)
0.0	28.0
0.5	27.2
1.0	27.0

August 3

Depth(m)	Temp.(°C)
0.0	25.0
0.5	22.8
1.0	22.4

August 26

Depth(m)	Temp.(°C)
0.0	25.0
0.5	22.2
1.0	21.5

1992 Dissolved Oxygen Profile Data
Upper Basin

March 19

Depth(m)	D.O. (mg/L)
0.0	11.9
0.5	12.0
1.0	12.1
1.2	11.9

April 1

Depth(m)	D.O. (mg/L)
0.0	9.7
0.5	9.6
1.0	9.6
1.1	9.6

May 4

Depth(m)	D.O. (mg/L)
0.0	11.3
0.5	11.5
1.0	11.4
1.2	11.3

May 19

Depth(m)	D.O. (mg/L)
0.0	9.2
0.5	9.8
1.0	11.2
1.2	11.5

June 2

Depth(m)	D.O. (mg/L)
0.0	7.4
0.5	7.2
1.0	7.5
1.2	5.2

July 1

Depth(m)	D.O. (mg/L)
0.0	10.9
0.5	11.8
1.0	10.7

July 15

Depth(m)	D.O. (mg/L)
0.0	11.8
0.5	8.0
1.0	0.9

August 3

Depth(m)	D.O. (mg/L)
0.0	6.7
0.5	5.7
1.0	5.4

August 26

Depth(m)	D.O. (mg/L)
0.0	12.9
0.5	12.5
1.0	3.5

1992 Dissolved Oxygen Profile Data
Middle Basin

March 19

Depth(m)	D.O. (mg/L)
0.0	13.3
0.5	13.4
1.0	13.8
1.1	14.4

April 1

Depth(m)	D.O. (mg/L)
0.0	11.4
0.5	11.3
1.0	11.2
1.2	12.0

May 4

Depth(m)	D.O. (mg/L)
0.0	10.5
0.5	11.0
1.0	11.2
1.2	8.0

May 19

Depth(m)	D.O. (mg/L)
0.0	7.5
0.5	7.3
1.0	7.3
1.2	7.2

June 2

Depth(m)	D.O. (mg/L)
0.0	6.6
0.5	7.8
1.0	5.6

July 1

Depth(m)	D.O. (mg/L)
0.0	10.7
0.5	10.2
0.7	9.2

July 15

Depth(m)	D.O. (mg/L)
0.0	8.6
0.5	8.6
1.0	4.7
1.3	2.5

August 3

Depth(m)	D.O. (mg/L)
0.0	6.4
0.5	4.7
1.0	4.1

August 26

Depth(m)	D.O. (mg/L)
0.0	8.8
0.5	7.1
1.0	5.4

1992 Dissolved Oxygen Profile Data
Lower Basin

March 19

Depth(m)	D.O. (mg/L)
0.0	11.8
0.5	11.8
0.9	11.9

April 1

Depth(m)	D.O. (mg/L)
0.0	10.2
0.5	10.1
1.0	9.6

May 4

Depth(m)	D.O. (mg/L)
0.0	9.7
0.5	9.4
1.0	9.2

May 19

Depth(m)	D.O. (mg/L)
0.0	6.6
0.5	6.5
1.0	5.1

June 2

Depth(m)	D.O. (mg/L)
0.0	7.4
0.5	9.8
1.0	5.8

July 1

Depth(m)	D.O. (mg/L)
0.0	5.4
0.5	4.9
0.7	4.6

July 15

Depth(m)	D.O. (mg/L)
0.0	8.2
0.5	3.3
1.0	3.0

August 3

Depth(m)	D.O. (mg/L)
0.0	6.7
0.5	5.6
1.0	1.8

August 26

Depth(m)	D.O. (mg/L)
0.0	11.5
0.5	10.0
1.0	7.2