New Jersey Department of Environmental Protection
Report on the Establishment of
Total Maximum Daily Load (TMDL)
For Phosphorus in Strawbridge Lake,
Moorestown Township, Burlington County, NJ
Amendment to the Tri-County Water Quality Management Plan

Proposed: July 3, 2000
Established: September 9, 2000
Approved: December 8, 2000
Adopted: June 22, 2003

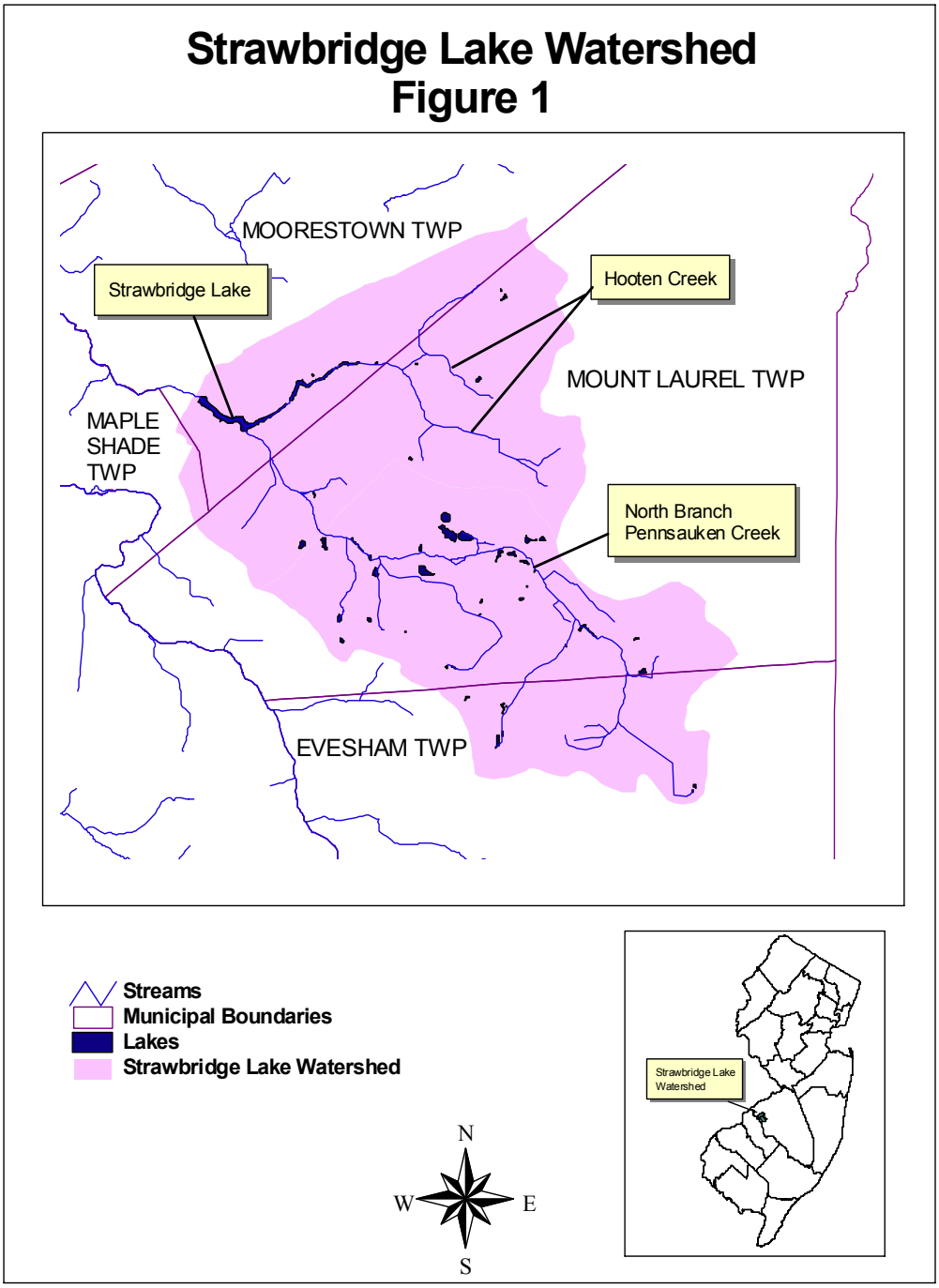
Introduction

A Total Maximum Daily Load (TMDL) represents the assimilative or loading capacity of the receiving water taking into consideration point and nonpoint sources of pollution, natural background, as well as surface water withdrawals. A TMDL is developed as a mechanism for identifying all the contributions to surface water quality impacts and setting goals for load reduction for specific pollutants as necessary to meet surface water quality standards. TMDLs are required, under section 303(d) of the federal Clean Water Act, to be developed for waterbodies that do not meet water quality standards after the implementation of technology-based effluent limitations. TMDLs may also be established to help maintain or improve water quality in waters that are not impaired. Regulations concerning TMDLs are contained in EPA's Water Quality Planning and Management Regulation (40 CFR § 130.7(c)).

Where TMDLs are required to address documented surface water quality impairments, allocations are made to the varying sources contributing to the water quality problem in order to reduce the total pollutant load received by the waterbody. Load reduction goals established through TMDLs are achieved through the issuance of wasteload allocations for point sources and load allocations for nonpoint source discharges. Since nonpoint source pollution, by definition, does not come from discrete, identifiable sources, load allocations would consist of the identification of categories of nonpoint sources that contribute to the parameters of concern. The load allocation would also include specific load reduction measures for the categories of sources, to be implemented through best management practices (BMPs) including local ordinances for stormwater management and nonpoint source pollution control, headwater protection practices, or other mechanisms or addressing the priority issues of concern. There are no point sources of pollution to the Strawbridge Lake, therefore only load allocations have been developed.

In May 1999, the New Jersey Department of Environmental Protection (NJDEP) and USEPA Region II entered into a Memorandum of Agreement (MOA) that included an 8-year schedule. Using this schedule, they agreed to produce TMDLs for all water quality limited segments on the 1998 Section 303(d) list of Water Quality Limited Waterbodies in New Jersey, or provide information necessary to remove waterbodies from the list.

Originally, a basic TMDL for Strawbridge Lake was to be established by the Department by December 31, 2000 under this MOA. However, in order to accommodate EPA's request to accelerate this TMDL schedule, the current deadline for the establishment of the Strawbridge Lake TMDL has been revised to August 15, 2000.
Since the watershed of Strawbridge Lake takes up the majority of the watershed of the North Branch of the Pennsauken Creek, this TMDL will be also be incorporated within the TMDL for the whole Pennsauken Creek, which is due to EPA by June 30, 2002.



Background

Strawbridge Lake is located in Moorestown Township in Burlington County, New Jersey (see Figure 1), although its 12.6 square mile watershed extends into portions of Mount Laurel and Evesham Townships in addition to Moorestown. The majority of the water-

shed of Hooten Creek and North Branch Pennsauken is contained in Mt. Laurel Township, while the headwaters of the North Branch are in Evesham Township. This long, tri-basin lake is a result of the impoundment of the confluence of Hooten Creek and the North Branch of the Pennsauken Creek that started in the late 1920's and was completed between 1931 to 1937. The lake receives surface runoff through Hooten Creek to the Upper and Middle Basins and the Lower Basin receives runoff from the headwaters of the North Branch of Pennsauken Creek. The discharge from the lake retains the name of the North Branch Pennsauken Creek that flows into the Delaware River approximately ten miles below the dam of the Lower Basin.

Strawbridge Lake is a 32.9-acre (13.3 hectares) lake with an average pre-dredged depth of 2.4 feet (0.74 meters) and a maximum depth of 8.0 feet (2.4 meters). Each basin has been dredged at least once since impoundment: the Upper Basin was dredged in 1959, the Middle Basin in 1962 and the Lower Basin in 1968 (USACOE, 1970). The most recent dredging of the lake basins started in the late 1990's: the Upper Basin was dredged in 1997, the Middle in 1999, and the first half of the Lower Basin began in the spring of 2000.

The watershed area that drains into the Strawbridge Lake is a complex mix of land uses including agriculture, mature residential subdivisions, new residential subdivisions, office parks, major transportation routes (I-295, NJ Turnpike, Rte. 38), shopping malls and large industrial complexes. The lake and its park around the perimeter are heavily used for passive recreational activities such as picnicking and bird watching. The lake is used for fishing, although the lake is no longer stocked. There are no swimming beaches on the lake, and before dredging, no canoes or shallow boats could be used.

The sub-watersheds that are delineated in this report are: Lake Basins, the land that drains directly into the three Lake basins; Hooten Creek; and the North Branch of the Pennsauken Creek.

Section 303(d) Listing and Applicable Surface Water Quality Standards

Applicable Surface Water Quality Standards (SWQS)

Strawbridge Lake is classified as FW-2 non-trout (N.J.A.C. 7:9B). Designated uses are primary contact recreation (i.e., swimming); secondary contact recreation (i.e., wading, boating); fishing (recreational and consumption) and the provision of a natural, scenic area. Criteria that are relevant to the 303(d) Listings for the Strawbridge Lake follow:

<u>Phosphorus</u>
Lakes: Phosphorus as total P shall not exceed 0.05 in any lake, pond or reservoir, or in a tributary at the point where it enters such bodies of water, except where site-specific criteria are developed. Note: Presently, no site-specific criteria apply to the Strawbridge Lake.

<u>Sedimentation</u>

There is no quantitative State criterion for sedimentation. The applicable suspended solids criterion is 40mg/l; however, Strawbridge Lake is not listed as impaired for suspended solids. There is, however, a narrative criterion for floating, colloidal, color and settleable solids (N.J.A.C. 7:9B-1.14(c)3I) that reads:

> None noticeable in the water or deposited along the shore or on the aquatic substrate in quantities detrimental to the natural biota. None which would render the waters unsuitable for the designated uses.

Chlordane in Fish Tissue:

There are no SWQS for chlordane in surface waters in New Jersey. However, the United States Food and Drug Administration has established a Maximum Permissible Level (MPL) for chlordane in foodstuffs (e.g., edible fillets of food fish) at 0.3 parts per million (ppm).

Heavy Macrophyte Growth

There is no State criterion for heavy macrophyte growth.

1998 Impaired Waterbodies List (303(d) List)

Strawbridge Lake has been included on 1996 and 1998 Impaired Waterbodies Lists due to water quality issues associated with eutrophication, specifically sedimentation, heavy macrophyte growth, and elevated phosphorus and chlordane contamination in fish tissue. These listings apply to all three basins of Strawbridge Lake.

Data sources for the inclusion of Strawbridge Lake on Impaired Waterbodies Lists for eutrophication issues are F.X. Browne, Associates (1993), and the Department's Clean Lakes Program. The Clean Lakes Program reviewed these data and reported this information to the 303(d) Program. The chlordane contamination in finfish tissue listing is based upon information supplied through NJDEP (1990) and Moser and others (1984).

Sedimentation: F.X. Browne (1993) has identified sedimentation as the primary problem in Strawbridge Lake. Sedimentation has reduced the mean lake depth from 4.9 to 2.4 feet thereby reducing the lake's aesthetic appeal. Sediment has also limited the lake's recreational value by impairing the fishery, contributing to eutrophication and preventing the use of small boats. F.X. Browne stated that sediment occupied over 50 percent of the lake's estimated total volume of 52 million gallons. The average sediment thickness as measured in 1992 was 2.5 feet.

Although there are no violations of the State's SWQS for suspended solids, in-lake levels were considered very high, progressively increasing from the Upper to the Lower Basin. In concert, Secchi disk transparency was poor, with the Lower Basin exhibiting

the lowest transparency. The implementation plan developed for the phosphorus TMDL is expected to address the sedimentation issue as well.

Phosphorus: In-lake data for total phosphorus collected from Strawbridge Lake during the summer of 1992 and discussed in F.X. Browne (1993) show levels to be marginal in the Upper and Middle Basins when compared to the applicable SWQS criterion; and unacceptable in the Lower Basin. Average total phosphorus levels in the summer were 0.052, 0.055 and 0.188 mg/l at the lake surfaces of the Upper, Middle and Lower Basins respectively. Year-around data taken from June, 1992 through April, 1993 at the outlet of the Lower Basin (Omni, 2000, Appendix A) show mean phosphorus concentrations in the summer and winter of 0.202 and 0.127 mg/l, respectively, the year-around mean being 0.165 mg/l. Based on the ratio between year-around mean and summer mean, the year-around means in the Upper, Middle and Lower Basins can be estimated based on the summer 1992 data to be 0.043, 0.045 and 0.154 mg/l, respectively.

Chlordane: Chlordane became a contaminant of concern for the North Branch of Pennsauken Creek and Strawbridge Lake in April of 1978. Due to concern about the levels of pesticides found in fish tissue, a ban of fishing, swimming and boating was announced in a News Release (NJDEP, 1978) after consultation with both State and County Health Departments. Fish sampling showed very high levels of the pesticide chlordane in the edible portions of the fish caught in these waters (i.e., 100 samples of over 13 different fish species). The US Food and Drug Administration have established a maximum permissible level (MPL) of 0.3 parts per million (ppm) for chlordane in food products. Thirty percent of the fish samples had levels in excess of 1.0 ppm and several exceeded 3.5 ppm.

Although the exact nature and source of the contamination remained unclear, NJDEP funded studies of sediment transport in these drainage areas. Moser (1985) indicated that possible improper use of chlordane as a termaticide (i.e., aerial spraying for termites instead of subterranean insertion near foundations) could have resulted in significant runoff and transport to the waters from the residential housing surrounding Strawbridge Lake. Subsequent fish sampling in 1981-1982, Belton et. al. (1983) indicated that the levels of chlordane had decreased since 1978 but were still in excess of the FDA maximum permissible level. Strawbridge Lake was again sampled in 1986 and still showed concentrations in edible tissue of fish in excess of 2 ppm (NJDEP, 1990).

In 1988, levels in all samples collected in Strawbridge Lake had dropped below the FDA permissible level of 0.3 ppm (NJDEP,1993). However, due to State-wide budget cutbacks in the mid-1990s, the Toxics in Biota Monitoring Program budget was severely reduced, and only three fish were collected from Strawbridge Lake at that time. This made it somewhat problematic as to whether the ban at Strawbridge Lake should be lifted.

Subsequently, funding levels for the Toxics in Biota Monitoring Program were restored in 1998 and samples collected in 1999 included 12 fish from Strawbridge Lake, which are currently being analyzed. Once assessed, DEP will evaluate 1) if the downward trend in chlordane contamination since the 1970s has continued, 2) whether regulatory

amendments are indicated concerning the fishing, swimming and boating bans; and 3) the impairment status of the water quality in Strawbridge Lake (i.e., 303(d) Listed Impaired Waters under Clean Water Act).

Intended Future 303(d) Actions

Constituent of Concern:	Intended Actions:
Elevated Phosphorus	Establish TMDL
Sedimentation	Address through Phosphorous TMDL such that the impairment will be resolved by the next listing cycle (2002)
Chlordane (in Fish Tissue)	If continued sampling confirms <0.3 ppm (MPL), Pursue 1) removal of the fish consumption advisories and 2) delisting;
Heavy macrophyte growth	Dredging; and if necessary, weed harvesting

Strawbridge Lake Monitoring Plan

1. Trophic Status: Strawbridge Lake should be monitored to determine post-dredging trophic status using an approved Quality Assurance Project Plan, which includes analysis of field QA samples. The Clean Lakes Program must approve monitoring design and methods. Sampling should be conducted at the Hooten Creek and Pennsauken Creek lake inlets, within each of the 3 lake basins and at the lake outlet. Since the Upper and Middle basins have been dredged and the material removed from the site, the monitoring could start there. After the Lower Basin is completed, monitoring should take place 1 year after all dredge materials are removed from the site. The monitoring should consider seasonality and include sampling during critical spring and summer seasons. Water column parameters of interest include:

Total Phosphorus (TP)	Chlorophyll a (Chl a)
Ortho- phosphate (PO4)	Phytoplankton
Total Kjeldahl Nitrogen (TKN)	Dissolved Oxygen Profiles (DO)
Nitrate + nitrite (NO3+NO2)	Dissolved Oxygen – Percent Saturation
Ammonia nitrogen (NH4-N)	Alkalinity
Total Suspended Sediments (TSS)	Ph
Temperature (T)	Fecal Coliform (FC)

In addition, bottom sediments should be collected for nutrients (TP, TN) to evaluate nutrient cycling.

Results will be used to evaluate trophic status and compliance with SWQS. If com-pliance with SWQS is demonstrated, delisting will be proposed. If SWQS are exceeded, delisting will not be pursued, and as appropriate, additional management measures will be implemented.

2. Chlordane in Fish Tissue: NJDEP collected 12 fish from Strawbridge Lake to evaluate current concentrations of chlordane. Results will be used in conjunction with previous studies to evaluate current fish consumption advisories and make any appropriate amendments to those advisories. Delisting will be pursued if fish consumption advisories are lifted.

Summary of Intended Actions

Phosphorus: The Department intends to establish a TMDL for this constituent of concern; see below.

Sedimentation: The Department intends to address the sedimentation issue by the following actions: 1) by the establishment of the TMDL for phosphorus which includes implementation measures which will address sedimentation. These include dredging the three basins of unconsolidated sediments; 2) continuing to implement BMPs throughout the watershed to decrease the amount of unconsolidated sediments entering the lake basins; and 3) monitoring the effects of implementation on the sedimentation rate. If the sedimentation rate is determined to be acceptable, then delisting will be pursued for this constituent of concern. Otherwise, additional solutions will be pursued, such as construction of a forebay to capture sediments and facilitate maintenance dredging in a confined area.

Chlordane in Fish Tissue: In 1988, fish tissue samples indicated that the levels of chlordane had dropped below the FDA permissible level of 0.3 ppm (NJDEP, 1993). Continued sampling of fish tissue from this lake has occurred but sufficient samples have not been collected to make a final determination. Twelve additional samples of fish tissue were taken in 1999. Very preliminary results from these data indicate that levels may be below the 0.3 ppm MPL, however, the full data set has not been fully assessed. In addition, the Department intends to take another set of fish tissue samples during the monitoring phase of this TMDL. If results from both of the data sets confirm the 1988 data, that the tissue from the fish have dropped below the FDA permissible level of 0.3 ppm, then the Department will pursue lifting the fish consumption advisories and delisting from the 303(d) list. Lifting of advisories would allow consumption of fish from these lake basins again, and thus restore the fishing and fish consumption designated uses.

Heavy Macrophyte Growth: As mentioned above and in the rest of this document, the Upper and Middle Basins of Strawbridge Lake have been dredged of their unconsolidated sediments. At the writing of this document, dredging has begun on the first half of the Lower Basin. Where completed, the dredging has deepened the lake basins noticeably and eliminated the growth that was present because of the shallowness of the basins, thus restoring one measure of aesthetic value to the lake. As the lake basins return to equilibrium, it is possible that macrophyte growth may return. As outlined in the Implementation Plan, it is possible that the Township may need to consider a program of weed harvesting if macrophyte growth becomes a problem. The Department

will monitor the lake and work with the Township and the PAC on future implementation initiatives that may be needed.

TMDL for Phosphorus in Strawbridge Lake, Burlington County, NJ

Water Quality Modeling

The Diagnostic-Feasibility Study of Strawbridge Lake (F.X. Browne, 1993) was approved by EPA through the Clean Lakes Program and forms the technical basis for the TMDL calculations. Hereafter in this document it will be referred to as the Clean Lakes Report. The analysis has been modified to correct errors in data presentation and manipulation and to take into account more recent land use information and New Jersey's adopted standard of 0.05 mg/l for total phosphorus. NJDEP's 1995 land use data show 80% less cropland/pasture and 27% more urban land uses compared to the information on which the analysis in the Clean Lakes Report was based.

The empirical model developed by Dillon and Rigler (1975) was used in the Clean Lakes Report because after a survey of commonly used models, Dillon and Rigler gave the best predictive results for phosphorus concentration in the Lower Basin. Using land uses in 1990 as estimated in the Clean Lakes Report, the model calculates the total phosphorus concentration to be 0.154 mg/l in the Lower Basin. As discussed above, the year-around total phosphorus mean in the Lower Basin, based on data taken from 1992 to 1993, was estimated to be 0.154 mg/l in one study [1] and 0.165 mg/l in another (Omni, 2000, Appendix A). In addition, Strawbridge Lake's hydrologic and morphological characteristics fit the assumptions within the model. The Dillon and Rigler model is described in EPA's Clean Lakes Manual, Quantitative Techniques for the Assessment of Lake Quality. The model relates allochthonous TP load to steady state TP concentration.

Watershed loads for total phosphorus were estimated using the Unit Areal Loadings methodology which uses the land use patterns within the watershed and pollutant export coefficients obtained from literature sources, as described in EPA's Clean Lakes Program guidance manual (Reckhow,1979). Land use was determined using the NJDEP's GIS system using 1995-1996 data. The export coefficients used from the Clean Lakes Report are: 2.04 kg/ha/yr for cropland/pasture; 0.71 kg/ha/yr for residential; 0.75 kg/ha/yr for lakes and ponds; 0.77 kg/ha/yr for industrial/commercial; 0.06 kg/ha/yr for mixed forest; and 0.07 kg/ha/yr for forested wetland.

As shown in Figure 2, the Strawbridge Lake watershed was divided into 3 sub-watersheds: Hooten Creek, North Branch of the Pennsauken Creek, and the watershed of the lake basins themselves. Existing land uses and calculated allochthonous loading rates for the three sub-watersheds are shown in Table 1. Loading rate estimates for septic tanks and waterfowl, which are not included in the runoff export coefficients, were dev-

[1] The Clean Lakes Program report used the summer mean of 0.188 mg/l to compare with model results. When adjusted for seasonal differences, the year-around average is actually 0.154 mg/l.

eloped in the Clean Lakes Report and included in Table 1. The North Branch of the Pennsauken Creek contributes 57% of the load to the Lower Basin of Strawbridge Lake, the Hooten Creek delivers 25% and the sub-watershed of the Lake delivers 18%.

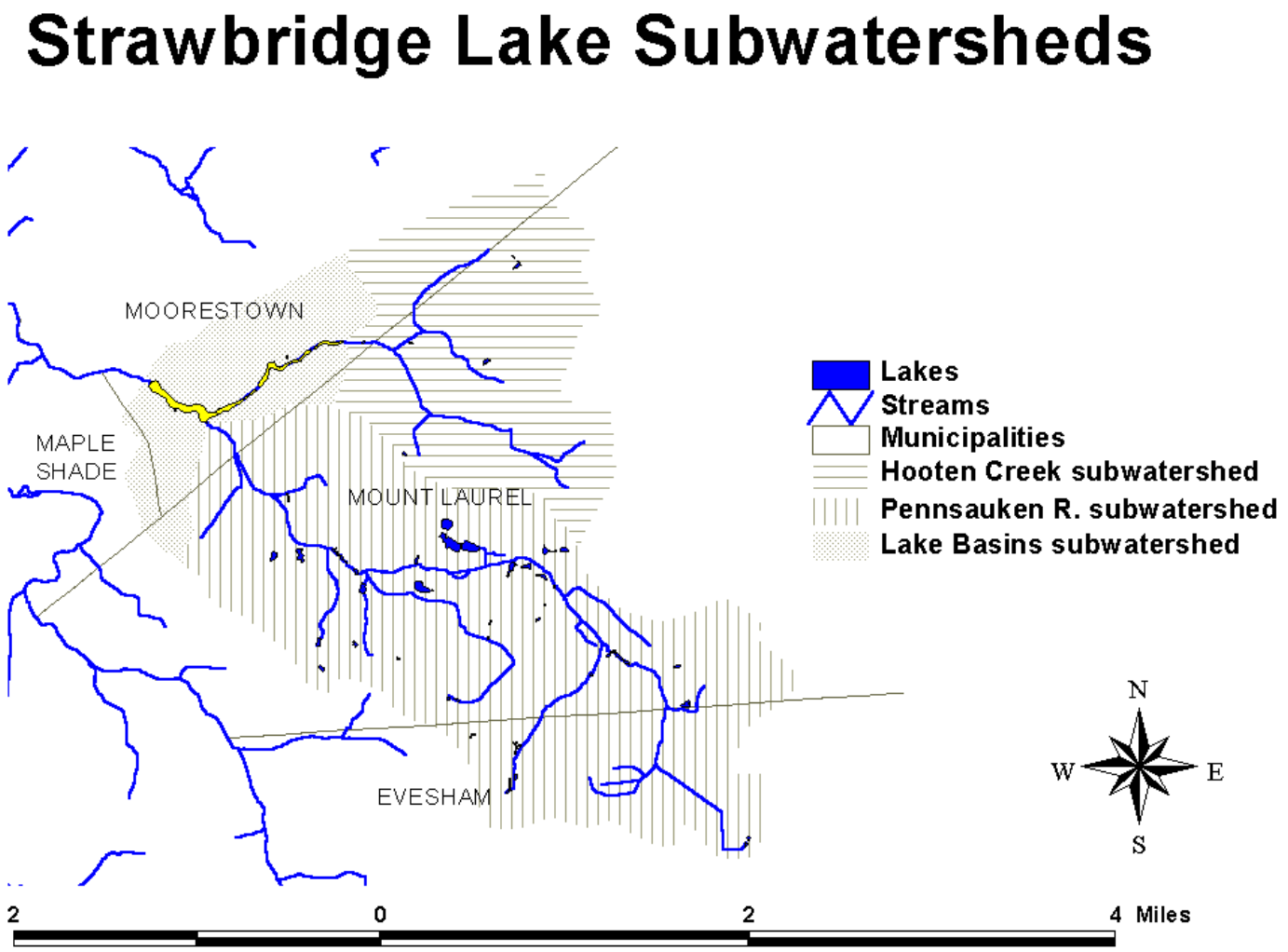
Table 1

LU/LC	kgTP/ ha/yr	Existing Land Use (hectares) Hooten Creek	Pennsauken Creek	Lake Basins	Current Loading Rate (kgTP/yr) Hooten Creek	Pennsauken Creek	Lake Basins
Commercial / Industrial	0.77	159	536	182	122	413	140
Cropland / Pasture	2.04	125	113	2	256	230	5
Forest / Barren Land	0.06	166	173	22	10	10	1
Residential	0.71	190	743	211	135	527	150
Surface Water	0.75	5	26	13	3	19	10
Wetland	0.07	252	400	8	18	28	1
Septic Tank							13
Waterfowl							70
TOTAL		896	1,990	439	544	1,228	390
Percentage		27%	60%	13%	25%	57%	18%

The current allochthonous load is estimated to be 2,162 kg/yr total phosphorus (Table 1). Therefore, the predicted unit areal phosphorus loading for the Lower Basin is calculated to be 24.8 g/m^2 /yr. The Lower basin receives flow (and load) from the entire watershed through the Upper and Middle Basins and the North Branch Pennsauken while the Upper/Middle Basins only receive discharge from Hooten Creek. Data taken in 1992 indicate that summer mean total phosphorous concentrations in the Upper and Middle Basins were 0.052 and 0.055 mg/l, respectively. While the model used for the Lower Basin over-predicts phosphorous concentrations in the Middle and Upper Basins[2] both the field data and the model confirm that the Lower Basin is the most sensitive component and therefore the one around which the TMDL calculations are based.

[2] Model calculations in the Clean Lakes Report do not reflect this over-prediction in the Middle and Upper basins because they are based on an incorrect flushing rate. The correct flushing rate is 220 times per year, not 720 as published in the Clean Lakes Report.

Figure 2


Strawbridge Lake Subwatersheds
MOORESTOWN
MAPLE SHADE
MOUNT LAUREL
EVESHAM
Lakes
Streams
Municipalities
Hooten Creek subwatershed
Pennsauken R. subwatershed
Lake Basins subwatershed
N
W
E
S
2
0
2
4 Miles

The current condition is calculated as follows using the Dillon-Rigler (1975) formulation.

$$P = LT(1-R)/z$$
$$= 0.088 \text{ mgTP/l}$$

Where:

P = annual average total phosphorous concentration, mg/l
L = unit areal phosphorous loading, $g/m^2/yr = 24.8$
T = detention time, yrs = $2.57e^{-3}$
R = phosphorus retention coefficient
= f(average depth, detention time) = 0.0447
z = average depth, m = 0.69

Dredging does not affect the phosphorus concentration using this formulation, since both detention time and average depth are increased by the same factor. The dredging will increase the mean depth from 0.69 meters to 1.32 meters and the detention time will also nearly double from $2.57e^{-3}$ years to $4.91e^{-3}$ years. The predicted steady-state phosphorus concentration using these estimated physical parameters and current allochthonous loads is 0.088mg/l.

Seasonal Variation/Critical Conditions

The target value for the phosphorus TMDL is adjusted to account for seasonal variation as follows: The Dillon-Rigler model predicts steady state phosphorus concentration. To account for seasonal variation, a peak to mean ratio was developed using data from the outlet of Strawbridge Lake. Two samples were taken twice a day on 20 occasions from June 1992 to April 1993 (Omni, 2000, Appendix B). Three values were not used because they were outliers and not consistent with the other sample taken on the same day. The 90^{th} percentile rank was used as the peak to account for data variability and to be consistent with the process used by the Department to define impaired water bodies. The seasonal variation was thereby determined to be 56%, resulting in a target phosphorus concentration of 0.032 mg/l.

Target Condition

The current steady state concentration of 0.088 mg/l of phosphorus must be reduced to a steady state of 0.032 mg/l to avoid exceeding the 0.05 mg/l phosphorus standard. To attain the target steady state concentration of 0.032mg/l total phosphorus, an overall reduction of 63.6% is necessary. The percent reduction was calculated by comparing the current condition of 0.088 mgTP/l to the target condition of 0.032 mgTP/l.

Loading Capacity

The Dillon-Rigler model was used to solve for loading rate given the target concentration of 0.032 mg/l. Reducing the current loading rate of 2,162 kgTP/yr by 63.6% yields the same result. The acceptable allochthonous loading capacity is 787 kgTP/yr.

Reserve Capacity

While developable land within the Strawbridge Lake watershed is limited, future growth is expected to convert some of the remaining farmland into commercial and residential land uses. Both of these land uses will result in less runoff loading of phosphorus than farmland. The implementation plan will emphasize, among others, forest preservation measures intended to preserve this important resource. Therefore, the reserve capacity is zero.

Margin of Safety

A margin of safety is required in order to account for uncertainty in the loading estimates, physical parameters and the model itself. The margin of safety, as described in EPA guidance, can be either explicit or implicit, (i.e., addressed through conservative assumptions used in establishing the TMDL). This TMDL contains an implicit margin of safety by using critical conditions, over-estimated loads, total phosphorus and dredging the lake. Each conservative assumption is further explained below.

Critical conditions are accounted for by comparing peak concentrations to mean concentrations and adjusting the target concentration accordingly (0.32 mg/TP/l instead of 0.05 mg/TP/l). In addition to the conservative approach used for critical conditions, the land use export methodology does not account for the distance between the land use and the lake, which will result in phosphorus reduction due to in-stream decay. Neither are any reductions assumed due to the addition of extensive lakeside vegetative buffer construction, biofilter wetlands or sedimentation chambers. Use of total phosphorus, as both the endpoint for the standard and in the loading estimates is a conservative assumption. Use of total phosphorous does not distinguish readily available phosphorus (e.g. dissolved ortho-phosphorus) which is available for algal growth from unavailable phosphorus (e.g. particulate).

Phosphorus load from sediment was never estimated in the Clean Lakes Report but is substantial based on the depth and high organic content of unconsolidated sediments. The sediments are as deep as the water column and rich in organic content. The removal of the unconsolidated sediment by dredging will convert the sediments from a substantial net source to a net sink of phosphorus due to settling.

Therefore, due to the multiple conservative assumptions built in to the calculation, an additional explicit margin of safety was not necessary.

Load Allocations

EPA regulations, 40 CFR § 130.2(i), state that “TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure.” For lake nutrient TMDLs it is appropriate to express the TMDL on a yearly basis. Long-term average pollutant loadings are typically more critical to overall lake water quality. Also, most available empirical lake models, such as the Dillon-Rigler model used in this analysis, use annual loads rather than daily loads to estimate in-lake concentrations.

The TMDL for total phosphorus is therefore calculated as follows (see Figure 3):

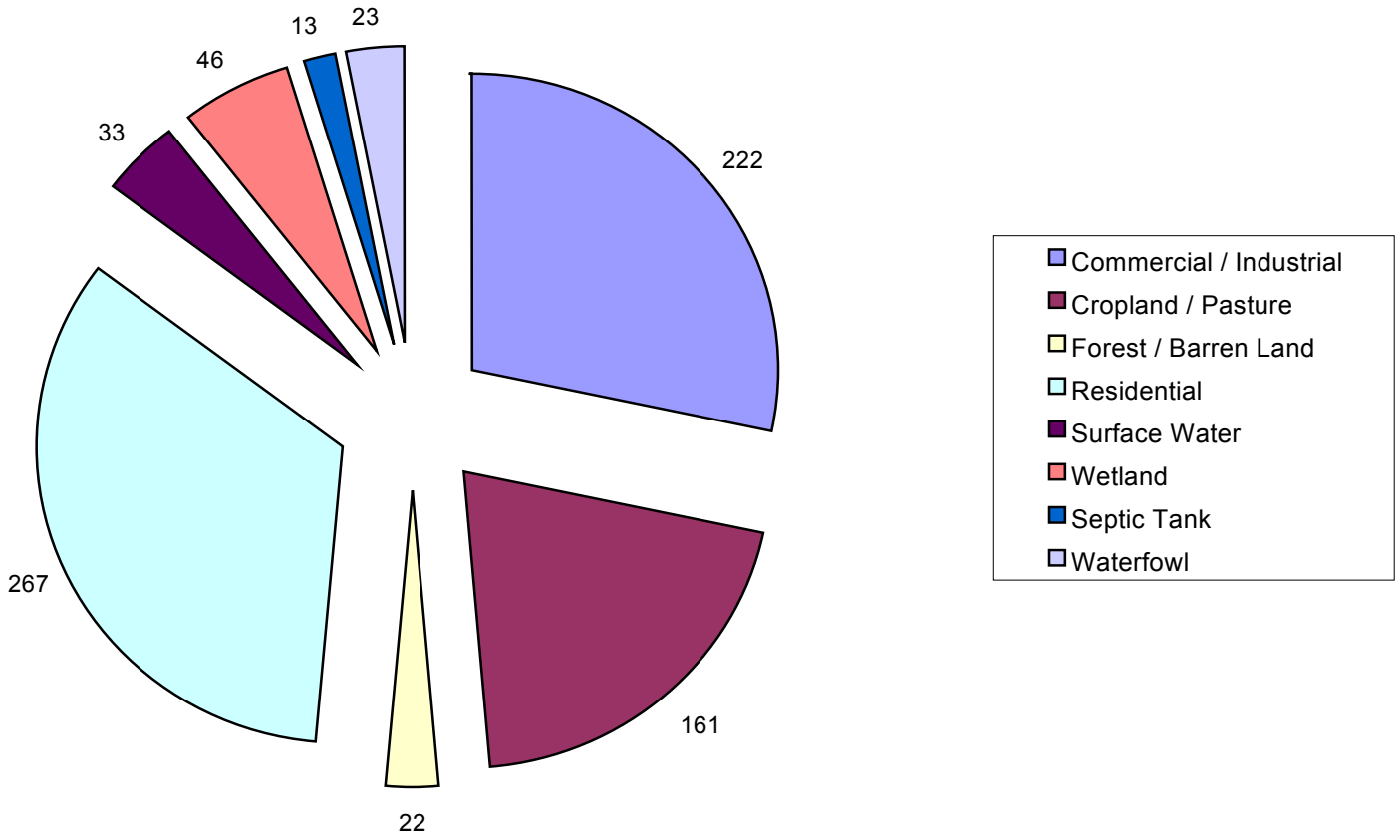
TMDL = loading capacity
= Sum of the load allocations + margin of safety + reserve capacity

where:

Loading capacity	=	787 kg/yr
Sum of load allocations	=	787 kg/yr
	=	222 kg/yr commercial/industrial
	+	161 kg/yr cropland / pasture
	+	22 kg/yr forest / barren land
	+	267 kg/yr residential
	+	33 kg/yr surface water
	+	46 kg/yr wetland
	+	13 kg/yr septic tank
	+	23 kg/yr waterfowl
Margin of safety	=	0
Reserve capacity	=	0

In order to attain the TMDL, an overall load reduction of 63.6% must be achieved. Since loading rates have been defined for the three sub-watersheds and eight source categories, countless combinations of source reduction could be used to achieve the overall reduction target. To be successful, a reduction strategy must include substantial reductions in all three sub-watersheds. The selected scenario is to apply the reductions equally in all three sub-watersheds, and to focus on sources that can be affected by BMP implementation. Therefore, in order to attain the TMDL, the following sources must each be reduced by 67%: commercial/industrial, cropland/pasture, residential and waterfowl.

Figure 3


Phosphorus TMDL Strawbridge Lake (kgTP/yr)
222
161
22
267
33
46
13
23
Commercial / Industrial
Cropland / Pasture
Forest / Barren Land
Residential
Surface Water
Wetland
Septic Tank
Waterfowl

Implementation Plan for Strawbridge Lake

An implementation plan is not required at this time as part of the TMDL. However, for completeness, options for addressing the phosphorus exceedances and high levels of sedimentation are listed below. A schedule will be developed, working with the townships and county government and with the watershed community through the Watershed Management process as well as other aspects of a public process. Recently, a contract to assist in the preparation of a watershed management plan has been signed, and is within Watershed Management Area #18 which is a priority area for this year in the Unified Watershed Assessment Program directing approximately $412,000 toward "Action Now" implementation projects.

Pre-TMDL Implementation

Within the Diagnostic-Feasibility Study for Strawbridge Lake, a program was proposed to lower the phosphorus and other pollutants to acceptable levels (F.X. Browne, 1993). There were six components of the program:

1. Establishment of a Watershed Management Committee to evaluate and coordinate watershed management activities in the Strawbridge Lake Watershed.
2. Establishment of a "Watershed Watch" program to ensure that erosion and stormwater management controls are installed properly during construction activities and ensure those long-term stormwater controls are properly operated and maintained.
3. Implementation of Best Management Practices (BMPs) on agricultural lands within the watershed, with the goal that 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.

Since the publication of the Diagnostic-Feasibility Study, the following actions have been accomplished, almost all under the direction of Moorestown Township in Moorestown:

- Moorestown Township has developed a working relationship with many cooperative entities in their quest to rehabilitate this Lake. Cooperating entities include Strawbridge Lake Watershed Committee, Strawbridge Lake Restoration Association, Delaware Riverkeeper Network, Americorps, Moorestown Environmental Advisory Committee, Save the Environment of Moorestown (STEM), and their consultant, Omni Environmental Corp., Princeton, NJ. They have been instrumental not only in developing projects but also funding them as listed below. These entities provide a diligent, willing

group to obtain feedback and discussion as well as physical labor engaged in volunteer aspects of these projects.

- Dredging:
  a) the Upper Basin was dredged of 37,000 cu. yds. of sediment;
  b) the Middle Basin was dredged of 20,000 cu. yds. (1999); and
  c) dredging began on the Lower Basin in Spring, 2000 estimated to be one-half of the total proposed: 70,000 cu.yds.

- Shoreline stabilization: 4,020 linear feet of lake shore was stabilized and retro-fitted with bio-engineering techniques to create a minimum of 10-20 feet vegetative buffer with tall grasses and shrubs to discourage Canada Geese, in particular. Because of the impending dredging, only 460 feet of rehabilitation was done on the Lower Basin, the remaining 3560 feet were constructed along the shorelines of the Upper and Middle Basins. An additional 2,400 feet of shoreline stabilization has started on a section of Strawbridge Lake Park along the Route 38 side between Pleasant Valley Ave, and the Route 38 bridge over the Pennsauken Creek (upper half of Lower Basin on south side).

- Public access sites: 240 feet of specially located public access sites interspersed

along the vegetative buffers as mentioned above. On the Lower Basin, 100 feet of public access sites were located; the rest were located along the Upper and Middle Basins. The public groups listed above provided important information in the location and design of these public access areas.

- Retrofitted stormwater outfalls/biofilter (pocket) wetlands: Four stormwater outfalls were retrofitted with two biofilter wetlands along the Lower Basin on the Haines Drive side of the lake (north side of lake in lake sub-drainage). Three stormwater discharges were retrofitted with sedimentation chambers and biofilter wetlands along the Upper Basin on the Route 38 side (south side of the lake in lake sub-drainage).

- Retrofit of commercial stormwater outfalls: Stormceptors (or their equal) were installed in the portion of the Moorestown Mall slated in the Mall's future expansion and reconstruction project. Stormwater from the Mall is piped directly into Pennsauken Creek, immediately upstream of the Lower Basin (inlake sub-drainage).

- Moorestown Township has passed (1999) a Stream Corridor ordinance for new development which stipulates the restoration and preservation of the vegetation in the 100-year flood plain and the development of a minimum 25 foot vegetative buffer.

Costs on the above restorative projects are: Current dredging of the 35,000 cu. yds. from the Lower Basin is $1.5 million and is being funded through a Bond by Moorestown Township. The Township estimates that an additional $1.5 million will be needed to dredge the remaining half of the unconsolidated sediments in the Lower Basin. Funding is being actively sought to pay for this second half of the dredging.

The rest of the above components have cost $2 million to date. Of the total expenditures of $3.5 million, Moorestown has provided 74% of the total; New Jersey (through various Departments and programs: 319(h) pass through from EPA, Wetlands Mitigation Council and Special appropriations), 16.3%; EPA, 6.7%; and private contributions, 3%.

Post-TMDL Implementation Plan

As a result of the calculations and loading estimates of the TMDL, the following additional components of the Implementation Plan are proposed:

1. Post-Dredging Water Monitoring of the Lake Basins: NJDEP will assume the water monitoring responsibility including phosphorous, starting first in the Upper and Middle Basins, using the recommendations as outlined above in the "Intended Future 303d Actions" part of the report (see pg. 6). Monitoring will be conducted in the Lower Basin when feasible, depending on the dredging schedule.

2. Retrofitting and rehabilitative BMPs: Each sub-basin has been assigned a load allocation corresponding to a 67% reduction. Modeling indicates that the Lower Basin receives the highest loadings from the North Branch of the Pennsauken Creek watershed (Table 1). Therefore, new rehabilitative and other retrofitting projects will need to be concentrated in the Pennsauken Creek. It is recommended that all stormwater basins originally constructed for flood control be systematically retrofitted to nonpoint source control basins throughout the watershed. The Department will work with the municipalities affecting the Lake, Moorestown, Maple Shade, Mt. Laurel and Evesham Townships, to enlist their support and cooperation with each of the components of this implementation plan, particularly in areas of acquiring financing, grants and permits (if any).

3. Farm conservation plans: According to the F.X. Browne program cited above, it was recommended that farm conservation plans be developed in order to reduce phosphorus loadings. The extent of application of this strategy must be assessed and remaining farms targeted for development of conservation management plans. Funding for implementing such plans is available through a federal program called EQIP (Environmental Quality Incentives Program) and the State's Conservation Cost Share Program.

4. Forest preservation/mitigation: As discussed above in the modeling section, any conversion of remaining forested areas of the watershed would negatively impact on the already very high loadings of phosphorous in this watershed. Efforts underway to acquire open space should be targeted at remaining forested tracts. Furthermore, the feasibility of actual large scale, forest mitigation (reforestation) should be investigated on suitable lands throughout the watershed, particularly in the North Branch of the Pennsauken Creek watershed. The Environmental Infrastructure Financing Program and the Garden State Trust, along with local open space programs, are sources of funds for this effort.

5. Land use in the Townships of Mt. Laurel, Evesham, Maple Shade and Moorestown: As part of the watershed management process, land use projection analyses will be prepared for the sub-watersheds to provide the basis to calculate NPS pollutant loading that can be expected with future land use. This will inform municipal officials regarding possible land use changes that should be considered along with the need to adopt site development ordinances that require use of BMPs. Use of BMPs integrated into new site development can reduce NPS pollutant loadings from phosphorus by 20 to 80% (NJDEP, 2000a).

One role of the recently formed Watershed Management Partnership in this Watershed Management Area #18 will be to educate the residents of the watershed on the necessity of specific ordinances and their enforcement. For example, forest preservation, stream corridor protection and advanced stormwater best management practices will be recommended, including detailed regular maintenance requirements. "No feed ordinances" for all waterfowl and wildlife and pet waste disposal ordinances will also be recommended, in addition to proper fertilization techniques for homes, corporate parks and golf courses. The latest drafts of the Department's *Best Management Practices for Control of Nonpoint Source Pollution from Stormwater* (NJDEP, 2000a) as well as the *Draft Guidance Manual: Best Management Practices for Golf Course Construction and Operation in New Jersey* (NJDEP, 2000b) are available to be used by all in the Watershed Management Area.

6. Four additional studies will be sponsored by the Department over the next two years, at a cost of approximately $100,000 in order to gather additional data and information necessary to attain the required reductions in loadings throughout the Lake's watershed, and further inform the model used to compute the TMDL for Pennsauken Creek:

a) Characterization of existing phosphorous and bacteria loadings from various land uses throughout the watershed, as well as long-term sedimentation rates in the lakes. A water quality sampling and sediment sampling program will be developed that will conform to the required QA/QC protocols. Samples will be collected during at least three storm events, and supplemental lake sampling will augment the Department's sampling. Sediment sampling will be conducted to determine the effect of sediment recycling on the in-lake pollutant concentration, and flow will also be measured during each sampling event in order to tie to loading.

b) A stormwater inventory and land use mapping for the watershed will be undertaken. Although stormwater is at the root of the pollution of this lake, very little data are available on the actual source of stormwater runoff, and further refinement of the land use data currently in the GIS will be obtained. This watershed is undergoing tremendous development and updated land use data will be critical to selection of NPS load reduction strategies.

c) A restoration master plan will be developed for this watershed. Using the US Department of Agriculture's Stream Visual Assessment Protocol, trained vol

unteers will assess the feeder streams and tributaries of this watershed, identify potential restoration sites, the root cause of the problem for each site and recommend several best management practices that can be used to remedy the problem and restore each site.

d) An assessment of the effectiveness of the BMPs currently constructed in this watershed: biofilter wetlands, sedimentation chambers, detention basins and vegetative buffers. Since all of these BMPs have been constructed in this watershed, many around the Lake, these data will be tremendously important in determining the effectiveness of the non-point source reduction actions already undertaken and those planned.

7. Depending on the results of water quality monitoring and sedimentation rate estimation, additional techniques may be necessary, especially on the Lower Basin:

a) If the additional depth of the lake due to dredging increases the amount of macrophytic growth in the basins, Moorestown may consider properly timed weed harvesting of this growth in order to decrease phosphorous loading to the lake.
b) Once the Lower Basin is totally dredged, aeration could be considered, if the basin is deep enough. This technique has been a very effective in Upper Sylvan Lake where the oxygenated water acts to oxidize any metals in the water, which then binds to phosphorous, thus tying up excess phosphorous.
c) The monitoring plan will include the collection of data necessary to estimate long-term sedimentation rates in the lake. Additional management actions may be necessary if the rates are determined to be unacceptable. For instance, it may be necessary to add structures near the basin inlets designed to settle out the bulk of the solids in a defined area that can be dredged more frequently and easily.

The Department has reasonable assurance that implementation of these measures will achieve the necessary load reductions, particularly in the Upper and Middle Basins of Strawbridge Lake, which were only slightly above the SWQS in 1992. For the Lower Basin, all of these steps may be required to achieve SWQS. The ongoing and proposed monitoring programs will measure progress toward goals and inform the TMDL process which has begun for the Pennsauken Creek watershed.

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