Amendment to the Sussex County Water Quality Management Plan

Total Maximum Daily Load To Address Phosphorus and Fish Community Impairments in Swartswood Lake in the Northwest Water Region

Watershed Management Area 1

Proposed:	May 16, 2005
Established:	August 31, 2005
Approved:	September 28, 2005
Adopted:	

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Table of Contents

Figures

Tables

1.0 Executive Summary

The State of New Jersey's *2004 Integrated List of Waterbodies* identified Swartswood Lake in Sussex County as being impaired for phosphorus, fish community and mercury in fish tissue. The Department believes that addressing the excessive levels of phosphorus, along with additional management measures, will also address the fish community impairment. This report establishes the total maximum daily load (TMDL) for total phosphorus (TP) to address total phosphorus and fish community impairments in Swartswood Lake. The mercury in fish tissue impairment will require a more regionalized approach. A TMDL is developed to identify all the contributors to surface water quality impacts and establish load reductions for pollutants of concern as necessary to meet Surface Water Quality Standards (SWQS). The pollutant of concern for this TMDL is phosphorus; phosphorus is the nutrient responsible for overfertilization of inland lakes leading to cultural eutrophication and, in this case, an impaired fish community.

In order to prevent excessive primary productivity and consequent impairment of recreational, water supply and aquatic life designated uses, the SWQS define both numerical and narrative criteria that address eutrophication in lakes. All possible phosphorus sources were characterized on an annual scale (kg TP/yr). Runoff from land surfaces, septic systems, and internal loading from the lake sediment comprise the significant sources of phosphorus into the lake. An empirical model was used to relate annual phosphorus load and steady-state in-lake concentration of total phosphorus. To achieve the TMDL, overall load reductions were calculated for different source categories. An implementation plan has been developed for this TMDL, which includes measures to achieve the necessary reductions in load. A bathymetric survey, additional in-lake monitoring and sediment monitoring are also called for to better quantify phosphorus contributions and tailor actions to achieve the needed reduction.

This TMDL Report is consistent with EPA's May 20, 2002 guidance document entitled: "Guidelines for Reviewing TMDLs under Existing Regulations issued in 1992," (Sutfin, 2002) which describes the statutory and regulatory requirements for approvable TMDLs.

2.0 Introduction

In accordance with Section 303(d) of the Federal Clean Water Act (CWA) (33 U.S.C. 1315(B)), the State of New Jersey is required biennially to prepare and submit to the USEPA a report that identifies waters that do not meet or are not expected to meet SWQS after implementation of technology-based effluent limitations or other required controls. This report is commonly referred to as the 303(d) List. In accordance with Section 305(b) of the CWA, the State of New Jersey is also required biennially to prepare and submit to the USEPA a report addressing the overall water quality of the State's waters. This report is commonly referred to as the 305(b) Report or the Water Quality Inventory Report. The *Integrated List of Waterbodies* combines these two assessments and assigns waterbodies to one of five sublists. Sublists 1 through 4 include waterbodies that are generally unimpaired (Sublist 1 and 2), have limited assessment or data availability (Sublist 3), are impaired due to pollution rather than pollutants or have had a TMDL or other enforceable management measure approved by EPA (Sublist 4). Sublist 5 constitutes the traditional 303(d) list for waters impaired or threatened by one or more pollutants, for which a TMDL may be required.

Sublist 5 of the State of New Jersey's *2004 Integrated List of Waterbodies* identified Swartswood Lake as being impaired for phosphorus, as evidenced by elevated total phosphorus (TP), elevated chlorophyll-*a,* and/or macrophyte density that impairs recreational use (a qualitative assessment). Total phosphorus is the pollutant of concern, since this "independent" causal pollutant results in "dependent" responses in chlorophyll-*a* concentrations and/or macrophyte density. Swartswood Lake is also listed as impaired with respect to the fish community, as the result of decline in the ability of the lake to support a cold water fishery, primarily trout, and other stresses on the fish community due to eutrophication caused by excessive phosphorus. The Department believes that reducing the levels of phosphorus is prerequisite to addressing the problems observed in the fish community. Achieving the phosphorus TMDL, along with other management measures discussed under implementation, will address the fish community impairment.

A TMDL represents the assimilative or carrying capacity of a waterbody, taking into consideration point and nonpoint source of pollutants of concern, natural background and surface water withdrawals. A TMDL quantifies the amount of a pollutant a water body can assimilate without violating a state's water quality standards and allocates that load capacity to known point sources in the form of wasteload allocations (WLAs), nonpoint sources in the form of load allocations (LAs), and a margin of safety (MOS). A TMDL is developed to identify all the contributors to surface water quality impacts and set load reductions for pollutants of concern needed to meet SWQS.

Recent EPA guidance (Sutfin, 2002) describes the statutory and regulatory requirements for approvable TMDLs, as well as additional information generally needed for USEPA to determine if a submitted TMDL fulfills the legal requirements for approval under Section 303(d) and EPA regulations. The Department believes that this TMDL report addresses the following items in the May 20, 2002 guideline document:

1. Identification of waterbody, pollutant of concern, pollutant sources and priority ranking.
2. Description of applicable water quality standards and numeric water quality target(s).
3. Loading capacity – linking water quality and pollutant sources.
4. Load allocations.
5. Wasteload allocations.
6. Margin of safety.
7. Seasonal variation.
8. Reasonable assurances.
9. Monitoring plan to track TMDL effectiveness.
10. Implementation (USEPA is not required to and does not approve TMDL implementation plans).
11. Public Participation.

This report establishes a TMDL for phosphorus to address phosphorus and fish community impairments in Swartswood Lake, and sets forth the management approaches needed to attain applicable surface water quality standards and designated uses. The Department will be removing Swartswood Lake from Sublist 5 of the 303(d) List for phosphorus, and fish community impairments, once this TMDL is approved by USEPA. The mercury in fish tissue impairment will be addressed in the future, as it will require a more regional response.

3.0 Pollutant of Concern and Area of Interest

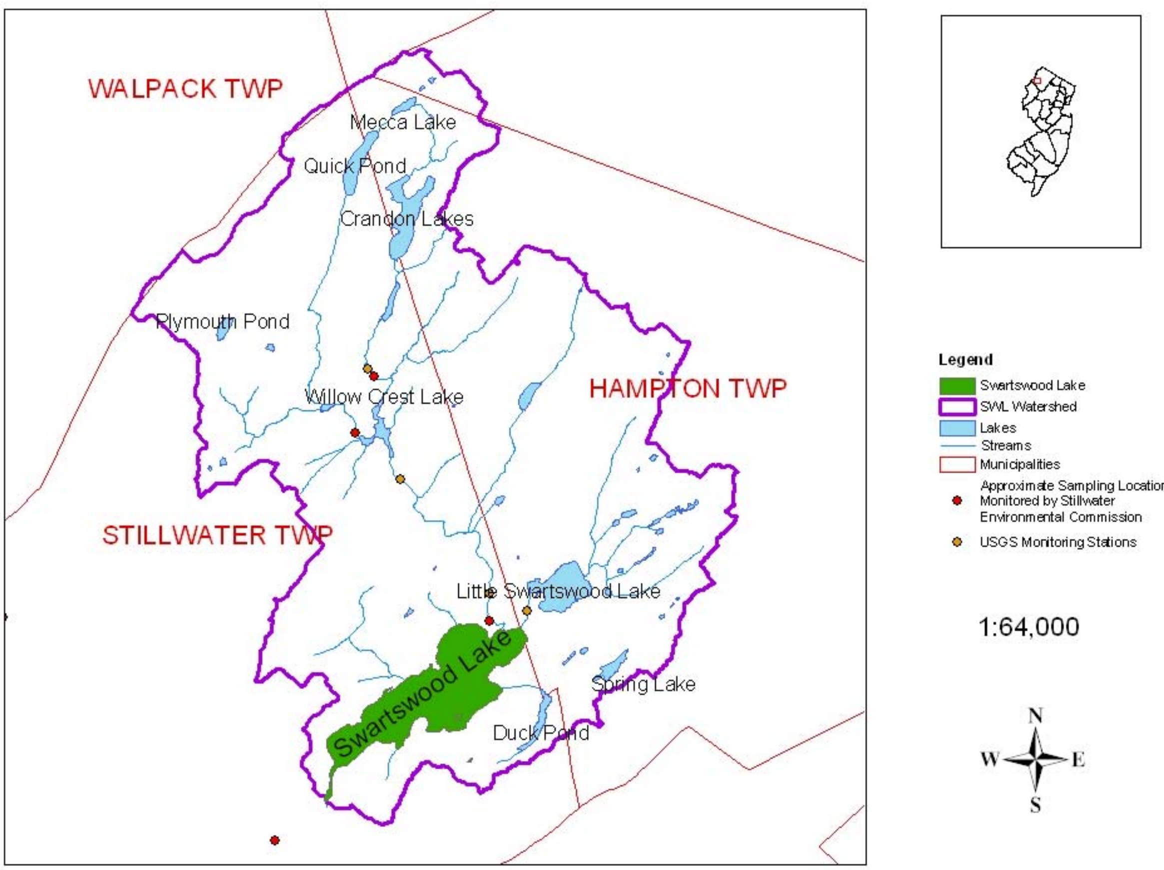
As shown in Figure 1, Swartswood Lake is a public lake primarily located in Stillwater Township, with a small portion in Hampton Township, Sussex County, New Jersey. Swartswood Lake is part of the Swartswood State Park and is heavily utilized for a variety of recreational pursuits including fishing, swimming and boating. The lake's average depth is 6.7 meters, its surface area is 505 acres and its volume is 1.35 x 10^7 m^3 (Table 1). The annual hydrologic budget of the lake was computed to be 2.08 x10^7 m^3/yr as the result of a previous study conducted by Coastal Environmental Services in 1990. Swartswood Lake's watershed encompasses a total area of approximately 10,713 acres, excluding the lake's surface area. Several small lakes are located within the watershed, including Little Swartswood Lake, Quick Pond, Crandon Lake, and Willow Crest Lake (See Figure 1). Neldon Brook (also called Spring Brook) and its tributaries are the major streams in the watershed.

Table 1 Characteristics of Swartswood Lake

Lake Area (acre)	Lakeshed Area (acre)	Outflow[a] (m^3/yr)	Volume[a] (m^3)	Average Depth[a] (m)	Maximum Depth[a] (m)
505	11,218	2.08E+07	1.35E+07	6.7	12.8

a: taken from Diagnostic and Feasibility Study for Swartswood Lake (Coastal Environmental Services, 1990)

Figure 1 Location of Swartswood Lake and Watershed



Swartswood Lake was designated as impaired for phosphorus and fish community, as well as mercury in fish tissue, on Sublist 5 of the *2004 Integrated List of Waterbodies* as a result of evaluations performed through the State's Clean Lakes Program and fishery surveys. Indicators used to determine trophic status included elevated total phosphorus (TP), elevated chlorophyll-*a,* and/or macrophyte density. The pollutant of concern for this TMDL is total phosphorus. The mechanism by which phosphorus can cause use impairment is via excessive primary productivity. Phosphorus is an essential nutrient for plants and algae, but is considered a pollutant because it can stimulate excessive growth (primary production). Phosphorus is most often the major nutrient in shortest supply relative to the nutritional requirements of primary producers in freshwater lakes; consequently, phosphorus is frequently a prime determinant of the total biomass in a lake. Eutrophication has been described as the acceleration of the natural aging process of surface waters. It is characterized by excessive loading of silt, organic matter, and nutrients, causing high biological production and decreased basin volume (Cooke et al, 1993). Symptoms of eutrophication (primary impacts) include oxygen super-saturation during the day, oxygen depletion during night, and high sedimentation (filling in) rate. Algae and aquatic plants are the catalysts for these processes. Secondary biological impacts can include loss of biodiversity and structural changes to communities, such as in the impaired fish community, discussed further below.

In order to prevent excessive primary productivity and consequent impairment of recreational, water supply and aquatic life designated uses, the Surface Water Quality Standards (SWQS, N.J.A.C. 7:9B) define both numerical and narrative criteria that address eutrophication in lakes due to overfertilization. The total phosphorous (TP) criterion for freshwater lakes at N.J.A.C. 7:9B – 1.14(c)5 reads as follows:

> For freshwater 2 classified lakes, Phosphorus as total phosphorus shall not exceed 0.05 mg/l 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 to satisfy N.J.A.C. 7:9B-1.5(g)3.

N.J.A.C. 7:9B-1.5(g)3 states:

> The Department may establish site-specific water quality criteria for nutrients in lakes, ponds, reservoirs or stream, in addition to or in place of the criteria in N.J.A.C. 7:9B-1.14, when necessary to protect existing or designated uses. Such criteria shall become part of the SWQS.

All of the waterbodies covered under this TMDL have a FW2 classification. The designated uses, both existing and potential, that have been established by the Department for waters of the State classified as such are as stated below:

In all FW2 waters, the designated uses are (N.J.A.C. 7:9B-1.12):
1. Maintenance, migration and propagation of the natural and established aquatic biota;
2. Primary and secondary contact recreation;
3. Industrial and agricultural water supply;
4. Public potable water supply after conventional filtration treatment (a series of processes including filtration, flocculation, coagulation and sedimentation, resulting in substantial particulate removal but no consistent removal of chemical constituents) and disinfection; and
5. Any other reasonable uses.

Presently, no site-specific criteria apply to this lake. Therefore the existing SWQS criterion of 0.05 mg/l will apply for Swartswood Lake, and will be the measure to determine the effectiveness of this

TMDL. This TMDL will address the phosphorus and fish community impairments and will cover 505 acres of the lake area and a total of 11,218 acres of land within the watershed. Total phosphorus and fish community impairments are ranked as Medium and Low Priority respectively in the *2004 Integrated List of Waterbodies*.

Fish Community Impairment

The water quality characteristics of Swartswood Lake play a key role in determining the presence, abundance, and distribution of fish species. In 1950, when the first fishery survey was conducted on Swartswood Lake by the New Jersey Division of Fish and Wildlife (NJDFW), it was reported that the lake afforded reasonably good fishing and supported a typical warmwater fishery (largemouth bass, chain pickerel, yellow perch, sunfish, and bullheads) as well as smallmouth bass and alewives. There was no indication of any problems related to the fishery or water quality (NJDFW, 1950). Suitable summer trout habitat was documented and annual stocking of trout commenced. During the 60's and 70's the lake had a notable reputation for producing sizable holdover trout.

However, effects of eutrophication in the form of excessive aquatic macrophyte growth and algal blooms began to impact the lake's recreational activities and aesthetics. The lake's water quality became an increasing concern and prompted the county to commission a diagnostics and feasibility study that was completed in 1990 (CES, 1990). In 1992 NJDFW conducted another fishery survey of Swartswood Lake. A respectable warmwater fishery was documented. In particular the bass population was considered balanced and in good condition. However, a decline in the holdover trout fishery was noted and attributed to declining water quality that reduced summer trout habitat (NJDFW, 2002).

A more recent survey was locally commissioned to assess the lake's game and forage fish community structure in 2002. The study was conducted in June and fish were sampled over a three-day period (Princeton Hydro, 2002). Findings of this report indicated a "stunting" of the largemouth bass population and the loss of trout as carry-over fish. In October 2002, NJDFW collected additional information regarding the bass population in Swartswood Lake and concluded that the largemouth bass population was in a better condition than the smallmouth bass population. The small mouth bass decline was attributed to increases in the density of aquatic macrophytes, which represented a loss of preferred habitat for small mouth bass (NJDFW, 2003). Optimal vegetative cover promotes bass survival and growth and may have affects on forage abundance (Bettoli et al. 1992, 1993). But extremely abundant macrophytes growing due to eutrophication can negatively affect bass growth due to reduced foraging efficiency (Bettoli et al. 1992). Excessive densities of aquatic plants have been documented throughout the littoral zone of Swartswood Lake.

Holdover trout decline is attributed to another effect of excessive primary productivity, fluctuations in dissolved oxygen and pH. Suitable summer trout habitat is considered to be $\leq$21 °C and $\geq$4 mg/L dissolved oxygen, and pH not to exceed 8. Mid-summer, when strong thermal stratification develops in the lake, is the most difficult time for fish. Water near the surface of the lake - the epilimnion - is too warm for them, while the water near the bottom - the hypolimnion - has too little oxygen. Eutrophication exacerbates this condition by producing algae and aquatic plants in large quantities. Respiration and decomposition of plant material can reduce oxygen to stressful levels. Photosynthesis and respiration produce swings in pH, as well, sometimes outside of the optimal zone.

The effect of the deteriorated littoral zone habitat and decline in the ability to support holdover trout resulted in the impaired assessment with respect to fish community. Although other management measures, such as selective macrophyte harvesting, may also be needed, the first step to restoring the fish community is to control eutrophication effects by controlling phosphorus levels.

Geographic Information System (GIS) Coverage

The Department's Geographic Information System (GIS) was used extensively to describe the lake and the watershed of the lake, specifically the following data coverages:

- 1995/97 Land use/Land cover Update, published 12/01/2000 by NJDEP Bureau of Geographic Information and Analysis, delineated by watershed management area.
- NJDEP Countywide Lakes and Streams (Shapefile) with Name Attributes for Sussex County to describe the lakes and streams located within the watershed. http://www.nj.gov/dep/gis/lakesshp.html and http://www.nj.gov/dep/gis/strmshp.html
- Lakeshed and subbasins were delineated jn NJBASIN using its automatic delineation function based on NJDEP 10-meter Digital Elevation Grid for WMA 1. (http://www.nj.gov/dep/gis/wmalattice.html) The manual QC check was conducted on the boundaries automatically generated by NJBASIN and necessary modifications were made to appropriately delineate the lakeshed and subbasins.
- NJDEP's 2000 Census Block Shapefile http://www.nj.gov/dep/gis/stateshp.html#CENBLK
- NJDEP's 2002 Orthophotography Image for Sussex County. http://njgin.nj.gov/OIT_IW/index.jsp

4.0 Source Assessment

As the result of 1990 Diagnostic and Feasibility Study for Swartswood Lake, the potential sources of phosphorus in the lake were evaluated and the annual influx of phosphorus from different sources was quantified. According to the study, the annual TP load is sizable (1904 kg/yr), with approximately equal amounts originating from external and internal sources. There are no wastewater treatment facilities within the watershed. The annual TP septic load was estimated to be 369 kg/yr and the load resulting from internal regeneration was 832 kg/yr. The remainder of the load was attributed to stormwater runoff. The Diagnostic Study on Swartswood Lake was conducted over 15 years ago, so previous estimations of phosphorus loadings from various sources have been updated in this TMDL using the most recent data available.

Phosphorus loads were characterized on an annual scale (kg TP/yr). Long-term pollutant loads are typically more critical to overall lake water quality than the load at any particular short-term time period (e.g. day). Storage and recycling mechanisms in the lake, such as luxury uptake and sediments dynamics, allow phosphorus to be used as needed regardless of the rate of delivery to the system. Also, empirical lake models use annual loads rather than daily or monthly loads to estimate in-lake concentrations.

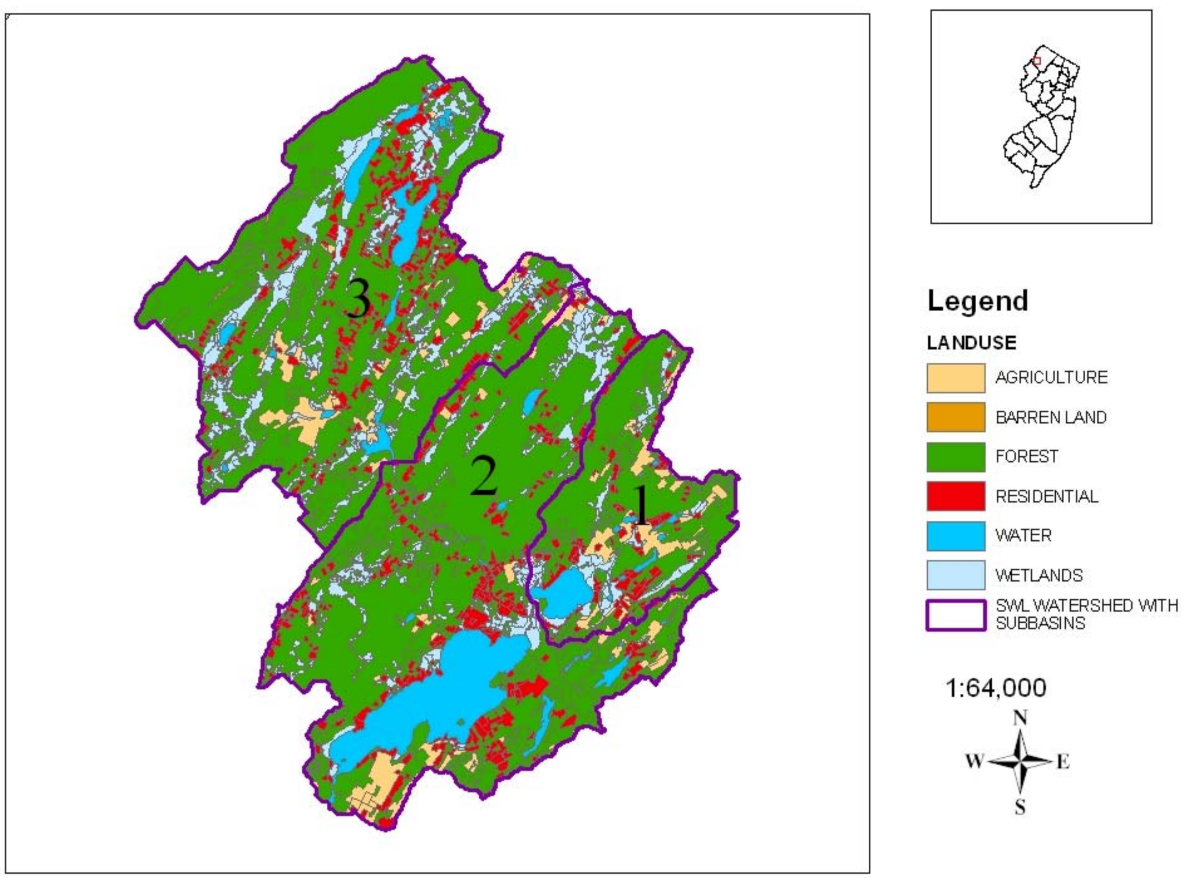
Point Source Loading

There are no NJPDES-regulated discharges present in the watershed. There are also no stormwater point sources subject to regulation under the Clean Water Act.

Land Use Loads:

Runoff from land surfaces is a nonpoint source of phosphorus into the lake. The surface runoff load is estimated using the UAL methodology, which applies pollutant export coefficients obtained from literature sources to the land use patterns within the watershed, as described in USEPA's Clean Lakes Program guidance manual (Reckhow, 1979b). Land use was determined using the Department's 1995/1997 land use GIS coverage. As part of TMDL development, the Department reviewed phosphorus export coefficients from an extensive database (Appendix B). The selected values for the land use categories existing in Swartswood Lake watershed are summarized in Table 2.

Figure 2 Land Use Type in Swartswood Lake Watershed



A UAL of 0.07 kg TP/ha/yr was used to estimate air deposition of phosphorus directly onto the lake surface. This value was developed from statewide mean concentrations of total phosphorus from the New Jersey Air Deposition Network (Eisenreich and Reinfelder, 2001).

There are several small lakes located in the lakeshed. As suggested in the Diagnostic and Feasibility Study, each lake has a retention effect on the phosphorus entering into it. Considering the size of Swartswood Lake, the size of the drainage area associated with the lake, and the effect of retention on

TP loading to Swartswood Lake, the entire watershed is further divided into three subbasins (shown in Figure 2). Subbasin 1 represents the areas where runoff drains first into Little Swartswood Lake before entering into Swartswood Lake. It is assumed that 100% of the TP runoff loading from Subbasin 2 will enter into Swartswood Lake. To the west side of Swartswood Lake is the area where runoff drains directly into Swartswood Lake. To the east side of Swartswood Lake are Duck Pond, Spring Lake and other ponds that are landlocked and drain into Swartswood Lake by way of ground water. It is assumed that the retention effect from these small water bodies and loss of TP in ground water are negligible. The drainage area of Willow Crest Lake constitutes Subbasin 3. The retention factor of Willow Crest Lake needs be considered when quantifying the contribution of TP load from this portion to Swartswood Lake. To avoid unnecessary complexity, the retention effects of other lakes in Subbasin 3 were not considered given the relatively small drainage area associated with each lake. The retention factors developed in the Diagnostic and Feasibility Study are used in the computation, which are 0.66 and 0.5 for Little Swartswood Lake and Willow Crest Lake, respectively. Tables 3 and 4 summarize the land use distribution and the loading distribution for the three individual subbasins and overall for the entire Swartswood lakeshed. These calculations show that the loadings from surface runoff are mainly contributed from forest and agriculture land uses. There is also a large resident goose population, which would contribute load both directly and through runoff.

Table 2 Phosphorus Export Coefficients (Unit Areal Loads)

Land use/Land Cover	LU/LC Codes	UAL (kg TP/ha/yr)
medium / high density residential	1120	1.6
low density / rural residential	1130, 1140	0.7
Commercial	1200	2.0
Mixed urban/other urban	1400, 1700, 1800	1.0
Agricultural	2000	1.5
Forest, wetland, water	1750, 2140, 2150, 4000, 6000, 5000, 7430	0.1
Barren land	7000	0.5

Units: 1 hectare (ha) = 2.47 acres
1 kilogram (kg) = 2.2 pounds (lbs)
1 kg/ha/yr = 0.89 lbs/acre/yr

Septic Systems:

There are no wastewater treatment facilities within the drainage area of the lake. The houses surrounding Swartswood Lake are all connected to individual septic systems. The TP load contributed to the lake as a result of onsite septic system use was quantified using the same methodology documented in the Phase 1 Study (PAS, 1983). The number of houses within 200 meters of the lake's shoreline was initially determined by the Department using 2000 census data in conjunction with the most recent aerial photos available. To refine this approach, the Swartswood Lake Watershed Association provided the Department with a direct count of the total number of households and the number of seasonal units. Based on these sources, there are 78 year-round households and 31 seasonal units identified within 200 meters of Swartswood Lake's shoreline. There are 22 year-round households and 8 seasonal units located within 200 meters of Little Swartswood Lake's shoreline. Census data indicated that the average size of these dwellings is about 2.8 persons/dwelling for those around Swartswood Lake and 3 persons/dwelling for those around Little Swartswood Lake. A loading coefficient, 1.07kg TP/capita/yr, which was used in the Phase 1 Study, is utilized to compute the annual load from the year-round units. Half of this value, 0.54 kg TP/capita/yr, is used to calculate the loading from the seasonal units assuming that these units are occupied for 6 months of the year. As a result, the septic system loading directly to Swartswood Lake is 276 kg TP/yr and 83 kg TP/yr to Little Swartswood Lake. Considering the retention effect of Little Swartswood Lake, about 28 kg/yr of TP enters into Swartswood Lake as a result of septic systems around Little Swartswood Lake. Therefore, the total loading contributed by septic systems is estimated to be 304 kg TP/ year. Septic system load from the houses around the upstream tributaries and lakes was not computed because this loading source would have little effect on the lake loading given the long distance to the lake.

Internal Loading:

In the Diagnostic and Feasibility Study, internal loading was quantified to be 832 kg/yr, which accounted for almost half of the total annual load. There is no new data to update the current internal loading. Therefore, in this TMDL, it is assumed that the internal loading is 832 kg/yr. The current phosphorus load distribution for Swartswood Lake is shown in Figure 3 below.

Figure 3 Current distribution of phosphorus load for Swartswood Lake

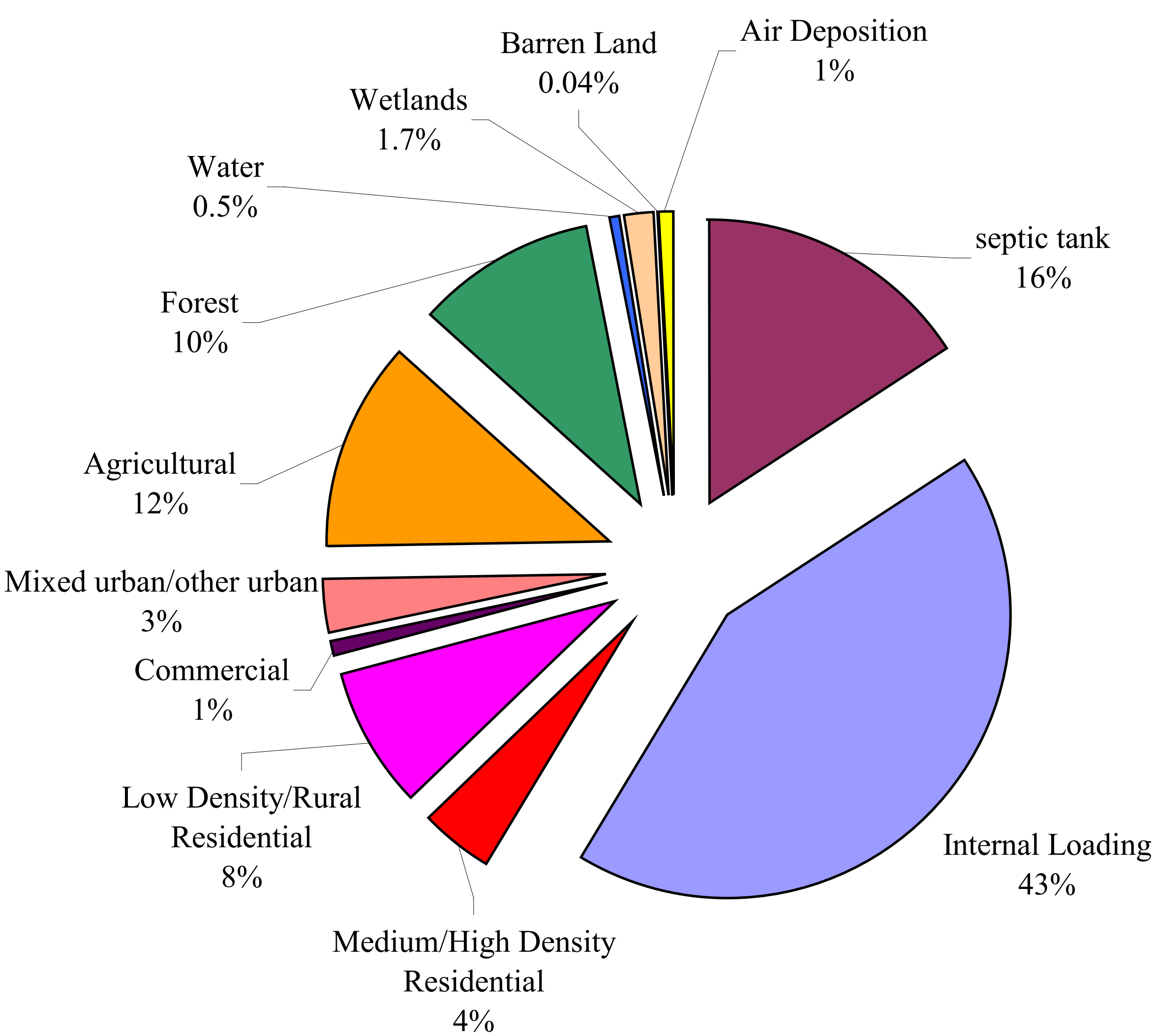


Table 3 Land Use Distribution in Swartswood Lakeshed

Land Use/Land Cover	Subbasin 1[1]		Subbasin 2[1]		Subbasin 3[1]		Entire Watershed	
	Area (acre)	Percentage	Area (acre)	Percentage	Area (acre)	Percentage	Area (acre)	Percentage
Forest	974	61.3%	3,143	64.2%	3,086	65.2%	7,204	64.2%
Agricultural	169	10.7%	221	4.5%	199	4.2%	590	5.3%
Water	109	6.9%	596	12.2%	206	4.4%	911	8.1%
Wetlands	165	10.4%	389	8.0%	744	15.7%	1,298	11.6%
Medium/High Density Residential	18	1.1%	47	1.0%	139	2.9%	204	1.8%
Low Density/Rural Residential	133	8.4%	362	7.4%	315	6.7%	810	7.2%
Commercial		-	14	0.3%	2	0.03%	15	0.1%
Mixed urban/other urban	19	1.2%	126	2.6%	34	0.7%	179	1.6%
Barren Land		-		-	7	0.2%	7	0.1%
Total	**1,589**	**100%**	**4,897**	**100%**	**4,732**	**100%**	**11,218**	**100%**

Table 4 Runoff Loading Distribution in Swartswood Lakeshed

Land Use/Land Cover	Subbasin 1[1]		Subbasin 2[1]		Subbasin 3[1]		Entire Watershed	
	Load (kg/yr)	Percentage	Load (kg/yr)	Percentage	Load (kg/yr)	Percentage	Load[2] (kg/yr)	Percentage
Forest	39	19%	127	26%	125	26%	203	25%
Agricultural	103	49%	134	27%	121	25%	230	29%
Water	4	2%	4	1%	8	2%	9	1%
Wetlands	7	3%	16	3%	30	6%	33	4%
Medium/High Density Residential	12	6%	30	6%	90	19%	79	10%
Low Density/Rural Residential	38	18%	102	21%	89	19%	160	20%
Commercial			11	2%	1	0.3%	12	1%
Mixed urban/other urban	8	4%	51	10%	14	3%	60	8%
Barren Land					1.5	0.3%	1.5	0.3%
Air Deposition			14	3%			14	2%
Total	**211**	**100%**	**490**	**100%**	**480**	**100%**	**802**	**100%**

1. Subbasin 1 refers to the Lakeshed of Little Swartswood Lake. Subbasin 3 is the watershed corresponding to Willow Crest Lake. Subbasin 2 is the portion of the lakeshed which drains directly to Swartswood Lake.
2. Load to Swartswood Lake = (1-0.66) *Loading contributed by Subbasin 1 + loading contributed by Subbasin 2 + (1-0.5) * loading contributed by Subbasin 3.

5.0 Water Quality Analysis

In-lake water quality monitoring was conducted over the course of several growing seasons (see Appendix E). In 1994, Coastal Environmental Service collected monthly samples at different depths in the lake from April to September, a total of 12 samples. It was found that the deep layer TP concentration was higher than the concentration at the surface, with the surface concentration ranging from below the detection limit of 0.02 mg/L to 0.05 mg/L, and the deep concentration ranging from below 0.02 mg/L to 0.16 mg/L. For the deep layer concentration, the occurrence of the highest concentration in August indicated the impact of the internal loading on the in-lake concentration. As the consultant to Swartswood Lake and Watershed Association, Malcolm Pirnie collected in-lake samples in the past three years from different depths and at different locations, including a total of 18 samples from two sampling events in 2002 and one each in 2003 and 2004. Similar to the 1994 sampling result, it is observed that the surface TP concentration was lower than the concentration in the deep layer. Based on these 18 samples, there was no evident difference among the surface concentrations collected from the different stations in the lake.

6.0 Technical Approach

Due to the limitation of the available data, the Department chose an empirical model as the most appropriate means to relate annual phosphorus load and steady-state in-lake concentration of total phosphorus. The Department surveyed the commonly used models in Table 5. These empirical models consist of equations derived from simplified mass balances that have been fitted to large datasets of actual lake measurements. The resulting regressions can be applied to lakes that fit within the range of hydrology, morphology and loading of the lakes in the model database. The Reckhow (1979a) model was selected because the hydrologic, morphological and loading characteristics of Swartswood Lake fit well within the assumptions of the model and because it appeared to give the best predictive results for phosphorus concentration. These characteristics are summarized in Table 6.

Table 5 Empirical models considered by the Department

reference	steady-state TP concentration in lake (mg/l)	Secondary term	Application
Rast, Jones and Lee, 1983	$1.81 \times NPL^{0.81}$	$NPL = \left(\frac{P_a \times DT / D_m}{1 + \sqrt{DT}} \right)$	expanded database of mostly large lakes
Vollenweider and Kerekes, 1982	$1.22 \times NPL^{0.87}$	$NPL = \left(\frac{P_a \times DT / D_m}{1 + \sqrt{DT}} \right)$	mostly large natural lakes
Reckhow, 1980	$\frac{P_a}{13.2}$	none	Upper bound for closed lake
Reckhow, 1979a	$\frac{P_a}{(11.6 + 1.2 \times Q_a)}$	$Q_a = \frac{Q_i}{A_l}$	General north temperate lakes, wide range of loading concentration, areal loading, and water load

reference	steady-state TP concentration in lake (mg/l)	Secondary term	Application
Walker, 1977	$\dfrac{P_a \times DT/D_m}{\left(1 + 0.824 \times DT^{0.454}\right)}$	none	oxic lakes with $D_m/DT < 50$ m/yr
Jones and Bachmann, 1976	$\dfrac{0.84 \times P_a}{\left(D_m \times \left(0.65 + DT^{-1}\right)\right)}$	none	may overestimate P in shallow lakes with high D_m/DT
Vollenweider, 1975	$\dfrac{P_a}{\left(D_m \times \left(DT^{-1} + S\right)\right)}$	$S = 10/D_m$	Overestimate P lakes with high D_m/DT
Dillon-Kirchner, 1975	$\dfrac{P_a}{\left(13.2 + D_m/DT\right)}$	none	low loading concentration range
Dillon-Rigler, 1974	$P_a \times DT/D_m \times (1 - R)$	R = phosphorus retention coefficient	general form
Ostrofksy, 1978	Dillon-Rigler, 1974	$R = 0.201 \times e^{(-0.0425 \times Q_a)} + 0.5743 \times e^{-0.00949 * Q_a}$	lakes that flush infrequently
Kirchner-Dillon, 1975	Dillon-Rigler, 1974	$R = 0.426 \times e^{\left(-0.271 \times D_m/DT\right)} + 0.5743 \times e^{-0.00949 * D_m/DT}$	general application
Larsen-Mercier, 1975	Dillon-Rigler, 1974	$R = \dfrac{1}{1 + \sqrt{1/DT}}$	Unparameterized form

where:
NPL = normalized phosphorus loading
P_a = areal phosphorus loading ($g/m^2/yr$)
DT = detention time (yr)
D_m = mean depth (m)
Q_a = areal water load (m/yr)
Q_i = total inflow (m^3/yr)
A_l = area of lake (m^2)
S = settling rate (per year)

The Reckhow (1979a) model is described in USEPA Clean Lakes guidance documents: Quantitative Techniques for the Assessment of Lake Quality (Reckhow, 1979b) and Modeling Phosphorus Loading and Lake Response Under Uncertainty (Reckhow *et al*, 1980). The derivation of the model is summarized in Appendix C. The model relates TP load to steady state TP concentration, and is generally applicable to north temperate lakes.

Table 6 Hydrologic and Loading Characteristics of Swartswood Lake

Parameters	Ranges of Characteristics Reckhow Model can fit		Swartswood Lake	
	Min	Max	Current condition	Target Condition[3]
TP Conc. (mg/L)	0.004	0.135	0.040[1]	0.03
Avg. Influent TP Conc. (mg/L)[2]		0.298	0.11	0.07
Q_a, Areal Water Load (m/yr)	0.75	187	10.2	N/A
P_a, Areal TP Load ($g/m^2/yr$)	0.07	31.4	1.07	0.71

Note:
1. Predicted in-lake annual average concentration using Reckhow model (see section below).
2. Calculated using Pa*DT/Dm.
3. As explained below, the target concentration is 0.03 mg/L when considering the seasonal variability. The other parameters under target condition were all calculated based on the target concentration.

Current Condition

Using these physical parameters and estimated external loads, the predicted steady-state phosphorus concentration of the lake was calculated using the Reckhow (1979a) formulation to be 0.040 mg/L (listed in Table 7). The average TP concentration of all the samples collected in 1994 was 0.039 mg/L. And all the samples collected between 2002 and 2004 determined a mean TP concentration of 0.052 mg/L. Using all the available data, the mean in-lake TP was calculated to be 0.047 mg/L. These average concentrations compare well to the concentration predicted by the Reckhow model.

Reference Condition

A reference condition for Swartswood Lake was estimated by calculating external loads as if the land use throughout the lakeshed were completely forest and wetlands and the loads from septic tank systems and internal recycling were assumed to be zero. Estimates of air deposition loads were included to calculate the reference condition. Using the same physical parameters and external loads from forest, wetlands and air deposition, a reference steady-state phosphorus concentration was calculated for Swartswood Lake using the Reckhow (1979a) formulation and listed in Table 7. The reference condition was developed to estimate what the TP concentration would be under pristine conditions and assure that the target concentration based on the SWQS are achievable. For Swartswood Lake, the target steady state concentration is 0.03 mg/l while the steady state concentration under the reference condition is only 0.005 mg/l. Therefore, the target concentration is achievable and is used for the TMDL calculations.

Seasonal Variation/Critical Conditions

The peak (based on the 90th percentile) to mean ratio was examined for both the 1994 samples and the samples collected between 2002 and 2004. The 1994 samples indicated a peak to mean ratio of 1.42. The same ratio for the 2002-2004 data is 1.62. These two site-specific peak-to-mean ratios would result in target phosphorus concentrations of 0.035 mg/L and 0.031 mg/L, respectively. In previous lake TP TMDLs established by the Department, a critical condition of 0.03 mg/L was chosen based on the peak-to-mean ratios of 1.56 and 1.48 observed from Strawbridge Lake and Sylvan Lake, respectively ((Strawbridge Lake, NJDEP 2000a; Sylvan Lake, NJDEP 2000b). It was assumed that this condition is representative of lakes, in general, in New Jersey. These peak-to-mean ratios result in target phosphorus concentrations of 0.032 and 0.0324 mg TP/l, which were rounded to 0.03 mg TP/l. This compares well with the value of 0.035 mg/l and 0.031 mg/L for Swartswood Lake. Therefore, the Department determined that a target phosphorus concentration of 0.03 mg TP/l is appropriate for use in this TMDL. Since it is the annual pollutant load rather than the load at any particular time that determines overall lake water quality (section 6), the target phosphorus concentration of 0.03 mg TP/l accounts for critical conditions.

Margin of Safety

A Margin of Safety (MOS) is provided to account for "lack of knowledge concerning the relationship between effluent limitations and water quality." (40 CFR 130.7(c)). A MOS 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 USEPA guidance (Sutfin, 2002), can be either explicit or implicit (i.e., addressed through conservative assumptions used in establishing the TMDL). For this TMDL calculation, an implicit and an explicit MOS are provided.

This TMDL contains an implicit margin of safety by using conservative critical conditions and total phosphorus as the basis for reductions. Critical conditions are accounted for by comparing peak concentrations to mean concentrations and adjusting the target concentration accordingly (0.03 mg TP/l instead of 0.05 mg TP/l). In addition, the 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 between dissolved orthophosphorus, which is available for algal growth, and unavailable forms of phosphorus (e.g. particulate). While many forms of phosphorus are converted into orthophosphorus in the lake, many are captured in the sediment, for instance, and never made available for algal uptake.

In addition to the conservative assumptions built in to the calculation, an additional explicit MOS was included to account for the uncertainty in the model itself. As described in Reckhow *et al* (1980), the Reckhow (1979a) model has an associated standard error of 0.128, calculated on log-transformed predictions of phosphorus concentrations. Transforming the terms in the model error analysis from Reckhow *et al* (1980) yields the following (Appendix D):

$$MoS_p = \sqrt{1 / ((1-\rho) * 4.5)} \times \left(10^{0.128} - 1\right),$$

where: MoS_p = margin of safety as a percentage over the predicted phosphorus concentration;

ρ = the probability that the real phosphorus concentration is less than or equal to the predicted phosphorus concentration plus the margin of safety as a concentration.

Setting the probability to 90% yields a MOS of 51% when expressed as a percentage over predicted phosphorus concentration or estimated external load. The external load for each lake was therefore multiplied by 1.51 to calculate an "upper bound" estimate of steady-state phosphorus concentration. An additional explicit MOS was included in the analyses by setting the upper bound calculations equal to the target phosphorus concentration of 0.3 mg TP/l, as described in the next section and shown in Table 7. Note that the explicit MOS is equal to 51% when expressed as a percentage over the predicted phosphorus concentration; when expressed as a percentage of total loading capacity, the MOS is equal to 33.3%:

$$\left(MoS_{lc} = \frac{MoS_p \times P}{P + \left(MoS_p \times P\right)} = \frac{MoS_p}{1 + MoS_p} = \frac{0.51}{1.51} = 0.333 \right),$$

where: MoS_p = margin of safety expressed as a percentage over the predicted phosphorus concentration or external load;
MoS_{lc} = margin of safety as a percentage of total loading capacity;
P = predicted phosphorus concentration (or external load).

Target Condition

As discussed above, when considering the seasonal variation, the steady state concentration of phosphorus in the lake must be equal to or less than 0.03 mg/L to avoid exceeding the 0.05 mg/L phosphorus criterion. Using Reckhow (1979a), any predicted concentration has a MOS of 51% when expressed as a percentage over the predicted phosphorus concentration. To assure compliance with the 0.03 mg/L target, the predicted concentration can not be higher than 0.02 mg/L (0.02 + 0.02*51% = 0.03 mg/L) considering the effect of the MOS. Therefore, 0.02 mg/L is chosen as the target concentration to attain the standard while 0.03 mg/L is defined as the upper bound target condition. The load corresponding to a 0.03 mg/L in-lake concentration is defined as the allowable loading capacity of the lake. The overall reduction to attain the standard level in Swartswood Lake was calculated by comparing the current concentration (calculated using Reckhow Model) to 0.02 mg/L, the target concentration (Table 7).

Table 7 Current condition, reference condition, target condition and overall percent reduction for Swartswood Lake

Current condition [TP] (mg/L)	Reference Condition [TP] (mg/L)	Upper Bound Target Condition [TP] (mg/L)	Target Condition [TP] (mg/L)	Overall TP load Reduction (%)
0.040	0.005	0.03	0.02	50%

7.0 TMDL Calculations

Loading Capacity

The Reckhow (1979a) model was used to solve for loading rate given the upper bound target concentration of 0.03 mg/l. This loading rate is used as the loading capacity for the lake and 33.3% of it accounts for the MOS as determined by the uncertainty associated with Reckhow Model. The acceptable loading capacity for Swartswood Lake is provided in Table 8.

Reserve Capacity

Reserve capacity is an optional means of reserving a portion of the loading capacity to allow for future growth. The primary means by which future growth could increase phosphorus load is through the development of forest land within the lakeshed. Phosphorus contributions from future development are expected to be controlled through implementation of the Stormwater Management Rules, which establish quality standards for TSS and nutrients. The follow up monitoring and implementation plan will require the collection of more detailed information about the lakeshed, which may result in revisions to the loading capacity and/or allocations. The loading capacities and accompanying load allocations must be attained in consideration of any new sources that may accompany future development.

Allocations

USEPA regulations at 40 CFR § 130.2(i), state that "pollutant loadings may 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 due to the storage and recycling mechanisms in the lake. Also, most available empirical lake models, such as the Reckhow model used in this analysis, use annual loads rather than daily loads to estimate in-lake concentrations.

The TMDL for total phosphorus is as follows, and values are given in Table 8:

TMDL = loading capacity
= Sum of the wasteload allocations (WLAs) + load allocations (LAs) + margin of safety + reserve capacity.

In order to attain the TMDL, the overall load reduction shown in Table 7 must be achieved. Since loading rates have been defined for multiple source categories, countless combinations of source reductions could be used to achieve the overall reduction target. The selected scenario requires equal percent reduction from internal loading, septic tank loading and land use sources that can be affected by BMP implementation. The resulting TMDL, LAs and MOS are shown in Table 8 and illustrated in Figure 4. Because there are no point sources, the WLA is 0. Based on follow up monitoring, it may be necessary to revisit the distribution of reductions among the various sources, for example, by focusing on the most cost efficient and/or economically achievable measures.

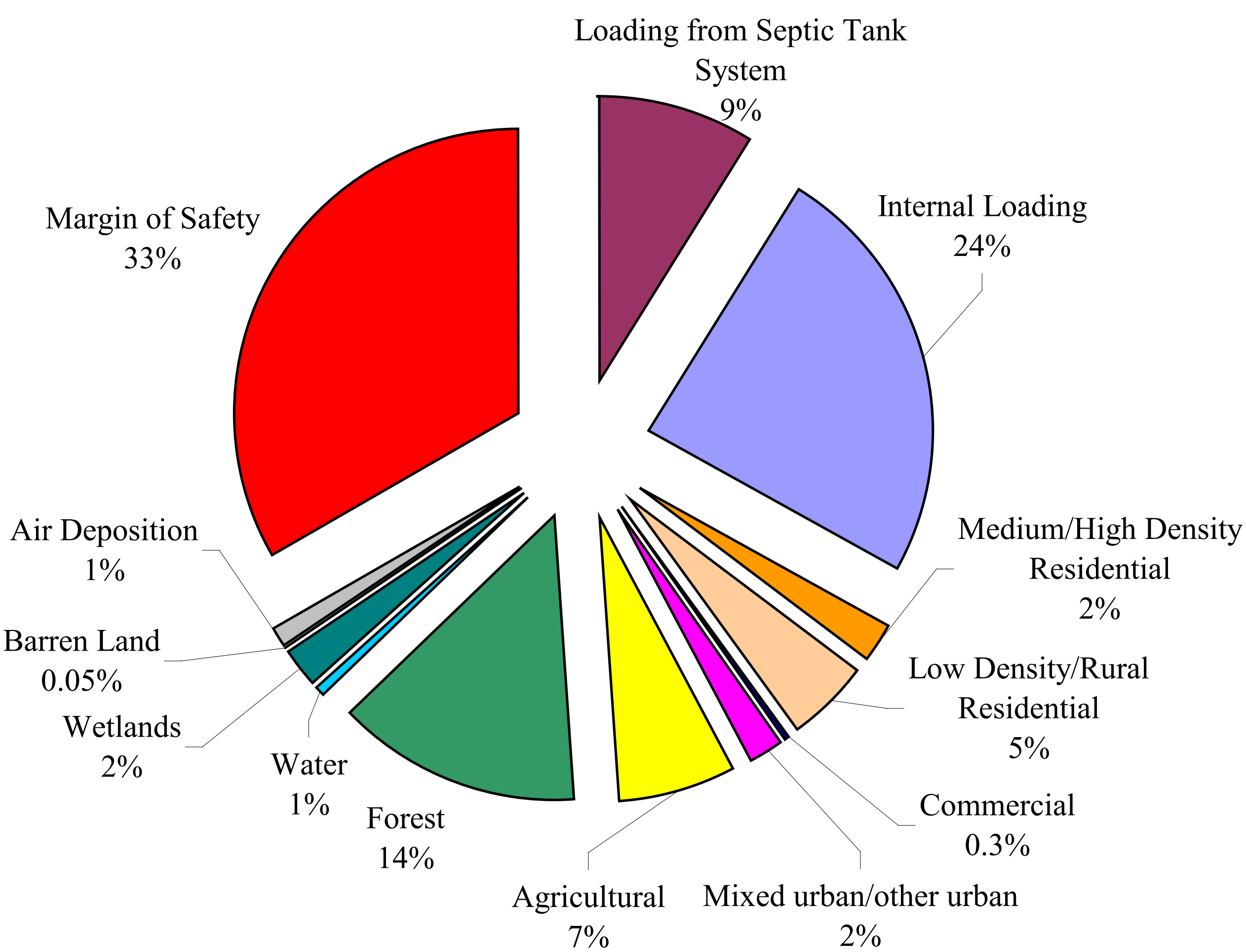
Table 8 TMDL calculations for Swartswood Lake (annual loads and percent reductions)

	Loading Capacity (LC) or Total Maximum Daily Load			**Existing Load**
	Kg TP/yr	% of LC	Reduction % of Existing Load	Kg TP/yr
Total	**1,461**	100%	50%	1,938
Margin of Safety	**487**	33%		
LAs by source*				
Loading from Septic Tank System	**129.3**	9%	57%	304
Internal Loading	**353.6**	24%	57%	832
Land Use Surface Runoff Medium/High Density Residential	**33.7**	2.3%	57%	79

Low Density/Rural Residential	**68.0**	4.7%	57%	160
Commercial	**5.0**	0.3%	57%	12
Mixed urban/other urban	**25.7**	1.8%	57%	60
Agricultural	**97.7**	6.7%	57%	230
Forest	**203.0**	14%	0%	203
Water	**9.4**	0.6%	0%	9.4
Wetlands	**33.1**	2.3%	0%	33.1
Barren Land	**0.7**	0.05%	0%	0.7
Air Deposition	**14.3**	1.0%	0%	14.3

***There are no point sources, neither traditional nor stormwater point sources, in the lakeshed; WLA=0**

Figure 4 Phosphorus allocations for Swartswood Lake TMDL



8.0 Follow-up Monitoring

Follow up monitoring for Swartswood Lake should include a bathymetric survey and sediment sampling. This will assist in refining implementation options. The survey findings will be instrumental in guiding selection of specific areas for dissolved oxygen monitoring and, potentially, in the selection of lake locations for installing additional aeration systems. The lake is largely groundwater fed, and groundwater elevation and water quality sampling may add to the knowledge base and guide management decisions. While most of the data collected by USGS and Stillwater Township Environmental Commission from tributaries at baseflow or near baseflow conditions were generally below 0.05 mg./L (Appendix F), these data could underestimate phosphorus reaching the lake. Therefore, storm event sampling is also recommended. Funding of this work will be pursued using 319(h) or State funds.

In addition, the Department plans to sample 1 or 2 lakes with established TMDLs per year. Sampling will be performed 3 times (Spring, Summer and Fall) and parameters to be analyzed include NO_2 + NO_3 Nitrogen, NO_3 Nitrogen, Total Kjeldahl Nitrogen, Ammonia, Total Phosphorus, Alkalinity and Hardness. Samples would be taken at up to 3 in-lake station as well as at the lake outlet. Typical field measurements (DO, conductivity, pH and temp) will also be taken for each station. With the establishment of this TMDL, Swartswood Lake will be included on the list of lakes that will be considered for inclusion in this additional monitoring effort.

9.0 Implementation

Phosphorus load reductions needed to attain the selected endpoint will be accomplished through regulatory and non-regulatory tools, matching management strategies with sources, determining responsible entities and aligning available resources to assist with implementation activities.

Point sources by definition include domestic wastewater treatment plants, industrial wastewater treatment plants, industrial stormwater sources and municipal stormwater facilities (MS4s) regulated under the Phase II stormwater permitting program that are subject to regulation under NPDES. There are no point sources in the lakeshed.

For the purposes of a TMDL document, nonpoint sources include stormwater that is not subject to regulation under the NPDES program, including NJPDES regulated Tier B communities, effluent from septic tanks, contributions from internal loading, and direct inputs from domestic animals and wildlife that have access to water bodies. To achieve the necessary phosphorus reductions for Swartswood Lake and its lakeshed, the three identified source categories of stormwater runoff, internal loading and septic contribution must all be targeted.

Management strategies for various source categories are summarized in the table below. These potential implementation measures should be viewed as possible options for the achievement of the necessary reductions. However, this is a preliminary list, and other options that may be identified as the result of follow up monitoring and other studies will be considered as well.

All options identified in this document will need to be further investigated and individually evaluated to determine the feasibility of any such option for its applicability to the conditions in the Swartswood lakeshed. Consideration must be given to the installation and maintenance requirements, the need for state or local approvals, and the overall potential of each option to lead to appreciable reductions in in-lake phosphorus levels.

Table 9 Management Strategies

Source Category	Responses	Potential Responsible Entity	Possible Funding options
Stormwater Runoff	Initially: Low phosphorus fertilizer ordinances, Goose management programs. Possible future additional measures: pet waste and wildlife feeding ordinances, catch basin clean out, street sweeping, stormwater basin retrofits.	NJDEP Division of Parks and Forestry (through Swartswood State Park), municipalities, residents, watershed stewards.	319(h) Grant Funding, State sources, non-governmental grant programs.
	Agricultural land: Develop and implement conservation plans or resource management plans for agricultural lands, including identification and management of any known subsurface drainage pipes originating from farm fields within the lakeshed.	Property owner, NRCS staff	EQIP, CRP, CREP
Septic Contribution	1) septic management programs (including scheduled pumpouts and maintenance), innovative septic design such as leachate filters, sanitary surveys (such as dye tests, visual inspection for overflows, smoke tests, investigation of illegal connections) and correction of	1) Sussex County Planning Department, Sussex County Board of Health, Municipalities, residents, watershed stewards 2) NJDEP, conservation groups.	New Jersey Environmental Infrastructure Financing Program; private funding sources.

	problems found. 2) Other options include the voluntary sale of residential properties for conversion into open space		
Internal Loading	Expansion of existing aeration system, removal of biomass (hydroraking), localized dredging in swimming area	NJDEP Division of Parks and Forestry (through Swartswood State Park), Municipalities, watershed stewards.	State funding through Div. of Parks and Forestry capital improvements

Stormwater Regulation

On February 2, 2004 the Department promulgated two sets of stormwater rules: The Phase II New Jersey Pollutant Discharge Elimination System (NJPDES) Stormwater Rules, N.J.A.C. 7:14A and the Stormwater Management Rules, N.J.A.C. 7:8

The Phase II NJPDES Stormwater rules require municipalities, counties, highway systems, and large public complexes to develop stormwater management programs consistent with the NJPDES permit requirements. The stormwater discharged through "municipal separate storm sewer systems" (MS4s) will be regulated under the Department's Phase II NJPDES stormwater rules. Under these rules and associated general permits, the municipalities (and various county, State, and other agencies) in the Swartswood lakeshed will be required to implement various control measures. For the municipalities, which are classified as Tier B municipalities, these control measures are public education and control of stormwater from new development and redevelopment.

Each impaired watershed was assessed for the applicability of a mandatory low phosphorous fertilizer ordinance to aid in the reduction of phosphorus loading from nonpoint sources. If the watershed contained a high percentage of agricultural land uses, it was determined that the greatest nonpoint source reductions would be achieved through the implementation of agricultural BMPs, and therefore the low phosphorus fertilizer ordinance for urban land uses was not required as an additional measure. However, in those subwatersheds which contained a small percentage of agricultural land uses, and a high percentage of urban land uses, it was determined that the low phosphorus fertilizer ordinance was necessary in order to effectively reduce the phosphorus load originating from the urban land uses.

In the Swartswood Lake watershed, it was determined that the low phosphorus fertilizer ordinance was required based on the guidelines provided above. Therefore, all municipalities with contributory drainage area into the impaired lakeshed (Stillwater Township and Hampton Township) will be required to adopt an ordinance as an additional measure that prohibits the outdoor application of fertilizer other than low phosphorus fertilizer, consistent with a model ordinance provided by the Department. Fertilizer does not include animal or vegetable manure or compost. This model ordinance has been posted on www.njstormwater.org. The additional measure is as follows:

Fertilizer Ordinance

Minimum Standard: Stillwater and Hampton Townships shall adopt and enforce an ordinance consistent with the Department's model ordinance, prohibiting the use of fertilizer containing phosphorus, except as needed for establishing new vegetation after disturbance in accordance with the requirements established under the Soil Erosion and Sediment Control Act, N.J.S.A. 4:24-39 et seq. and implementing rules.

Measurable Goal: Stillwater and Hampton Townships shall certify annually that they have met the Fertilizer Ordinance minimum standard.

Implementation: Within 6 months from adoption of the TMDL, Stillwater and Hampton Townships shall have fully implemented the Fertilizer Ordinance minimum standard.

Follow up monitoring may determine that additional measures are required, which would then be incorporated into Phase II permits. For the municipalities, additional measures that may be considered could include adoption and enforcement of a pet waste disposal ordinance, prohibiting the feeding of unconfined wildlife, cleaning catch basins, performing good housekeeping at maintenance yards, goose management programs, and providing related employee training. Additional measures that may be considered may also include, where feasible, retrofit of stormwater management facilities to include water quality controls, conversion to bioretention facilities, or reconfiguring to allow non-erosive, distributed flow to be discharged through vegetated stream buffers.

The Stormwater Management Rules have been updated for the first time since their original adoption in 1983. These rules establish statewide minimum standards for stormwater management in new development, and the ability to analyze and establish region-specific performance standards targeted to the impairments and other stormwater runoff related issues within a particular drainage basin through regional stormwater management plans. The Stormwater Management rules are currently implemented through the Residential Site Improvement Standards (RSIS) and the Department's Land Use Regulation Program (LURP) in the review of permits such as freshwater wetlands, stream encroachment, CAFRA, and Waterfront Development.

The Stormwater Management Rules focus on the prevention and minimization of stormwater runoff and pollutants in the management of stormwater. The rules require every project to evaluate methods to prevent pollutants from becoming available to stormwater runoff and to design the project to minimize runoff impacts from new development through better site design, also known as low impact development. Some of the issues that are required to be assessed for the site are the maintenance of existing vegetation, minimizing and disconnecting impervious surfaces, and pollution prevention techniques. In addition, performance standards are established to address existing groundwater that contributes to baseflow and aquifers, to prevent increases to flooding and erosion, and to provide water quality treatment through stormwater management measures for TSS and nutrients.

Furthermore, the New Jersey Stormwater Management rules establish a 300-foot special water resource protection area (SWRPA) around Category One (C1) waterbodies and their intermittent and perennial tributaries, within the HUC 14 subwatershed. In the SWRPA, new development is typically limited to existing disturbed areas to maintain the integrity of the C1 waterbody. C1 waters receive the highest form of water quality protection in the state, which prohibits any measurable deterioration in the existing water quality. Within the Swartswood lakeshed, Swartswood Lake itself is classified as FW2-TM and the Little Swartswood Lake is classified as FW2-NT, and both are listed as C1 for antidegradation.

Agricultural measures

Several programs are available to assist farmers in the development and implementation of conservation management plans and resource management plans. The Natural Resource Conservation Service is the primary source of assistance for landowners in the development of resource management pertaining to soil conservation, water quality improvement, wildlife habitat enhancement, and irrigation water management. The USDA Farm Services Agency performs most of the funding assistance. All agricultural technical assistance is coordinated through the locally led Soil Conservation Districts. The funding programs include:

The Environmental Quality Incentive Program (EQIP) is designed to provide technical, financial, and educational assistance to farmers/producers for conservation practices that address natural resource concerns, such as water quality. Practices under this program include integrated crop management, grazing land management, well sealing, erosion control systems, agri-chemical handling facilities, vegetative filter strips/riparian buffers, animal waste management facilities and irrigation systems.

The Conservation Reserve Program (CRP) is designed to provide technical and financial assistance to farmers/producers to address the agricultural impacts on water quality and to maintain and improve wildlife habitat. CRP practices include the establishment of filter strips, riparian buffers and permanent wildlife habitats. This program provides the basis for the Conservation Reserve Enhancement Program (CREP).

Conservation Reserve Enhancement Program (CREP) The New Jersey Departments of Environmental Protection and Agriculture, in partnership with the Farm Service Agency and Natural Resources Conservation Service, signed a $100 million CREP agreement earlier this year. This program matches $23 million of State money with $77 million from the Commodity Credit Corp. within USDA. Through CREP, financial incentives are offered for agricultural landowners to voluntarily implement conservation practices on agricultural lands. NJ CREP will be part of the USDA's Conservation Reserve Program (CRP). There will be a ten-year enrollment period, with CREP leases ranging between 10-15 years. The State intends to augment this program to make these leases permanent easements. The enrollment of farmland into CREP in New Jersey is expected to improve stream health through the installation of water quality conservation practices on New Jersey farmland.

Short-Term Management Measures:

Short-term management strategies include existing projects dubbed "Action Now" that are on the ground projects funded by the Department to address NPS impairments to an impaired waterbody. Funding sources include Clean Water Act 319(h) NPS funds and other state sources.

The following project is currently ongoing in the TMDL study area. This project was funded through a 319(h) grant and is expected to have an immediate and positive effect on water quality:

> The Swartswood Lake and Watershed Association has been involved in stormwater projects funded by the Clean Water Act Section 319(h) grants to improve water quality, such as the installation of a five-unit hypolimnetic aeration system in an effort to protect the trout fishery. This project includes weed harvesting, aeration, and nonpoint source controls, aimed at correcting the large growths of aquatic weeds, algae, and dissolved oxygen that is not optimal

for holdover trout in deeper waters of the lake. In addition, various stormwater BMPs have been installed in the area surrounding the lake, including the construction of two stormwater detention basins in the State Park and the upgrade of a swale and several stormwater catch basins in the impaired watershed.

It is recommended that an evaluation of the aerator system be conducted to estimate how well the system is functioning, and to determine the extent to which additional aerators are warranted or would be beneficial in reaching the intended goals.

In addition, a Regional Stormwater Management Plan is being developed for the Swartswood lakeshed through another 319(h) grant. The results of this plan, along with the results of the Hampton and Stillwater Townships Municipal Stormwater Management Plans, can serve as a foundation for the future implementation strategies.

After implementing the TMDL, if necessary, additional fish restoration and management measures may be needed to restore the impaired fish community. Such measures may include but are not limited to the following:

- fish habitat restoration, enhancement, and subsequent protection;
- aquatic vegetation control including herbicide application and/or mechanical removal for the purposes of fishery management;
- fish stocking and other direct fish community manipulation measures; and
- managing fishing pressure and harvesting.

Specific management measures will be taken through time as deemed appropriate to establish and maintain the fish community desired for the lake.

Priority Stream Segment Restoration Plans

In addition to the generic and specific, current and future implementation measures identified above, the Department, through its watershed management program, is undertaking the development of watershed restoration plans for priory stream segment. These restoration plans will identify specific measures ands the means to accomplish them, beyond those identified in this TMDL report, that will assist in the attainment of the required load reductions. Due to the number of TMDLs recently generated, the Department must prioritize which stream segments will be the focus of initial consideration. The Department's nutrient policy identifies that, "Except as due to natural conditions, nutrients shall not be allowed in concentrations that cause objectionable algal densities, nuisance aquatic vegetation, abnormal diurnal fluctuations in dissolved oxygen or pH, changes to the composition of aquatic ecosystems, or otherwise render the water unsuitable for the designated uses (N.J.A.C. 7:9B-1.5(g)3) ."

With respect to nutrient TMDLs, the initial priority will be given to those streams where the impairments exist in the impaired stream or downstream lakes, beyond simple exceedance of the water quality criterion. Other priority considerations include:

- Headwater area;
- Proximity to drinking water supply;
- Proximity to recreation area;

- Possibility of adverse human health conditions;
- Proximity to a lake intake;
- Existence of eutrophication;
- Phosphorus is identified as the limiting nutrient;
- Existence of use impairments;
- Ability to create a measurable change;
- Probability of human source;
- Stream Classifications;
- High success level.

Reasonable Assurance

Commitment to carry out the activities described in the implementation plan to reduce phosphorus loads provides reasonable assurance that the SWQS will be attained for phosphorus in the Swartswood Lake. Reasonable Assurance for the implementation of these TMDLs has been considered for point and nonpoint sources for which phosphorus load reductions are necessary. Moreover, stormwater sources for which WLAs have been established will be regulated as NJPDES point sources. Follow-up monitoring will identify if the strategies implemented are completely, or only partially successful. It will then be determined if other management measures can be implemented to fully attain the SWQS or if it will be necessary to consider other approaches, such as use attainability.

10.0 Public Participation

The Water Quality Management Planning Rules NJAC 7:15-7.2 requires the Department to initiate a public process prior to the development of each TMDL and to allow public input to the Department on policy issues affecting the development of the TMDL. An informal presentation of the findings and results of this TMDL was provided to the stakeholders on March 5, 2005 at the Stillwater Township Municipal Building.

Additional public participation and input was received through the New Jersey EcoComplex. The role of NJEC is to provide comments on the Department's management strategies, including those related to the development of TMDL values. NJEC consists of a review panel of New Jersey University professors who provide a review of the technical approaches developed by the Department. The New Jersey Statewide Protocol for Developing Eutrophic Lakes TMDLs was presented to NJEC on September 27, 2002 and was subsequently reviewed. Feedback received from NJEC was incorporated into the TMDLs to address lake eutrophication. New Jersey's Statewide Protocol for Developing Lake and Fecal TMDLs was also presented at the SETAC Fall Workshop on September 13, 2002.

Amendment Process

In accordance with N.J.A.C. 7:15–7.2(g), this TMDL was proposed by the Department as an amendment to the Sussex County Water Quality Management Plan. Notice of this TMDL was published May 16, 2005 in the New Jersey Register and the Star Ledger in order to provide the public an opportunity to review the TMDL and submit comments. Additional public participation was provided at the Public Hearing for the Swartswood Lake TMDL that was held June 20, 2005 at 7 PM at the Hampton Township Municipal Building. The public comment period ended on July 5, 2005. However, the Department received a written request to extend the pubic comment period. The request was granted, and the comment period was extended until August 29, 2005. Notification of the extension was published in the New Jersey Register on August 15, 2005. Following approval of this TMDL by the EPA, the TMDL will be adopted as an amendment to the Sussex County WQMP.

Department initiated changes include the following:

1. A section of Fish Community Impairment was added in "3.0 Pollutant of Concern and Area of Interest" to provide additional information on the nature of the fish community impairment and how addressing the TP impairment will address the fish community impairment.
2. Further discussion was added to clarify that no point sources subject to regulation under the CWA are present in the watershed.

Four comment letters and one email were received on the proposed TMDLs. 4 people testified the public hearing.

1. Shari McSweeney (written comments)
   Municipal Clerk, Stillwater Township
   PO Box 1
   Middleville, New Jersey 07855

2. Nathaniel Sajdak - Wallkill River Watershed Coordinator (testimony)
   Sussex County Municipal Utilities Authority
   Watershed Planning Division
   34 South Route 94
   Lafayette, NJ 07848

3. Randall Sprague (testimony)
   Swartswood Lake Watershed Association

4. Ed Szabo, Trustee (testimony and written comments)
   Paradise Fishing Club

5. Michael Vreeland (testimony)
   Vreeland Associates

6. Mrs. Barb Sachau (email)
   15 Elm St.
   Florham Park, NJ 07932

7. Hope Nemickas (written comments)
   Project Environmental Scientist
   Malcolm Pirnie
   17-17 Route 208 North
   Fair Lawn, NJ 07410
   On behalf of Swartswood Lakes and Watershed Association, Inc. (SLWA)

A summary of comments to the proposal, and the Department's Responses to those comments follow. The number(s) in brackets at the end of each comment corresponds to the commenter(s) listed above.

<u>Comment 1</u>

The commenters request that the Department extend the public comment period to allow adequate time for the affected municipalities to review and comment on the low phosphorus fertilizer model ordinance. (1, 5)

Response 1
The Department understands the need for additional time for review of the model ordinance. Recognizing that the Department did not provide the model ordinance to the municipalities at the start of the comment period, the extension of the comment period was deemed to be necessary and was subsequently granted. The public comment period was originally scheduled to end on July 5, 2005, and was extended to August 29, 2005. In addition, the Department looks forward to working with the municipalities to address any remaining concerns regarding the draft model ordinance, and to make adjustments to the ordinance as needed to achieve its intended outcome of reducing the nonpoint source contribution of phosphorus from developed land uses in the watershed.

Comment 2
The commenters expressed their appreciation to the Department for incorporating the local stakeholders in a review of the draft TMDL document and for addressing the comments received during that review process. (2, 3, 7)

Response 2
The Department is greatly encouraged by the level of local support in the Swartswood Lake watershed and values the comments and insight that were provided by the local stakeholders.

Comment 3
The commenter expressed the need for the Department to continue to support the work of local watershed groups and to continue the funding of watershed based project in the future. (2, 7)

Response 3
The Department recognizes the importance of the watershed stakeholder process and will continue to encourage the work that is being done at the local level to improve water quality statewide. Funding opportunities continue to exist through the Department's 319(h) grant funding program for the creation of watershed restoration plans and for implementation of actions identified in previously completed watershed restoration plans. The Department would like to commend Swartswood Lake and Watershed Association for its continued involvement in the assessment and protection of the Swartswood Lake and its watershed.

Comment 4
The commenter expressed appreciation to the Department for the establishment of this TMDL. The commenter also stated that the local stakeholders have been involved in efforts to improve the lake since 1990, and have received over a million dollars in grants for lake related work. (4)

Response 4
The Department is grateful for the support of this TMDL. With the continued efforts of the Swartswood Lake and Watershed Association, Paradise Fishing Club, Swartswood State Park and other involved stakeholder groups, it is anticipated that the implementation plan in this TMDL document can be accomplished resulting in improvements to the lake and its watershed.

Comment 5

The commenter suggested that all algae blooms be recorded by location, date, time, weather, temperature etc, and confirmed with photos and video tape as a permanent record, including the observers name, address, telephone number, E-mail. (4)

Response 5
The Department believes that keeping a detailed record of algal blooms will be beneficial to discerning trends and evaluating effectiveness of implementation measures. The Department's volunteer monitoring program is available to assist stakeholders to implement this action.

Comment 6
The commenter suggested establishing a methodology and record keeping process to get members of the Swartswood Lake and Watershed Association, Inc., Paradise Fishing Club, Emmons Lane Association, and Sailing Club etc. to voluntarily submit septic pump out data to a centralized file. This may encourage a formal septic management program for eventual adoption by municipal government. (4)

Response 6
The Department concurs with the need to have a septic management program instituted in the Swartswood Lake drainage area, as septic systems are a significant portion of the phosphorus load. The Department intends to make planning pass through grants available for this purpose and anticipates employing the wastewater management planning process to effect septic management in needy areas.

Comment 7
The commenter offered to furnish annual holdover trout data to the Department. (4)

Response 7
The Department appreciates the offer and contacted the commenter in this regard. The fish data and other information relevant to the fish community provided by the commenter were utilized to further characterize the fish community situation in the Lake.

Comment 8
The commenter requested that the Low Phosphorus Fertilizer Model Ordinance under consideration be limited to the Swartswood Lake Watershed Area and not be an ordinance of general application throughout the Township due to the lack of enforceability. (1)

Response 8
The Department is willing to work with the townships affected by the low phosphorus ordinance requirement to evaluate the possibility of limiting the scope of the ordinance to the sections of the towns that fall within the watershed of Swartswood Lake. The Department will coordinate with the Townships to investigate whether this can be done. Factors that will be evaluated include 1) what percentage of the overall area of the township falls outside of the lake watershed, 2) what land uses exist in those areas outside the lake watershed, and 3) which waterbodies those land areas drain to and 4) the impairment status of the receiving waterbodies.

Comment 9
The commenter thinks that all phosphorus sales of any kind should be banned in the entire state of New Jersey. It is clear that all of New Jersey's lakes are being negatively impacted by the overuse of

phosphorus. All agricultural business use of phosphorus should be banned in addition to a ban on homeowner use. (6)

Response 9

While overuse or improper use of fertilizer containing phosphorus contributes to phosphorus impairment in many waterways, a statewide ban of phosphorus sales is not warranted. The Department believes that the best approach to dealing with use of phosphorus as a fertilizer is as described in the TMDL. Agricultural land uses should employ conservation or water resource management plans designed by the local Soil Conservation District/NRCS to ensure use of the proper amounts of fertilizer in the proper way so that crop growth is optimized and water quality is protected. Non-agricultural use is proposed to be regulated by the adoption of a low phosphorus ordinance in the affected drainage area.

Comment 10

The commenter emphasized that additional monitoring will be necessary and suggested that the following monitoring be conducted: (1) monitoring of nutrient in Neldon's Brook during greater than baseflow conditions; (2) independent evaluation of the effectiveness of the aeration system; (3) continued monitoring of in-lake conditions. One or two seasons of more frequent sampling should be conducted to start; (4) more complete flow (in-flow and out-flow) monitoring; and (5) further investigation of septic loading. As algal blooms are highly stochastic events, continued monitoring of in-lake conditions is critical to build a long-term database with which to attempt to discern trends. (7)

Response 10

The Department concurs with the commenter that additional monitoring will be beneficial to better understand the issues in the lake. Some of the suggested monitoring will be conducted as part of the currently on-going 319 projects and, as needed, in development of a more specific watershed restoration plan under the priority stream segment initiative. In addition, the Department anticipates future funding opportunities for the development of Lake Characterization reports, and would encourage the Swartswood Lake stakeholders to apply for such funding when it becomes available.

Comment 11

The commenter noted that several Best Management Practices (BMPs) for stormwater management have already been implemented in the watershed with 319(h) grant funding, including construction of two stormwater detention basins in the State Park and upgrade of several stormwater catch basins and one swale that discharge directly to the lake or Neldon's Brook. (7)

Response 11

The Department appreciates this additional information on recent projects that will help to address the phosphorus impairment. This information has been added to the text to further describe the work accomplished through these 319(h) grants.

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Appendix B: Database of Phosphorus Export Coefficients

In December 2001, the Department concluded a contract with the USEPA, Region 2, and a contracting entity, TetraTech, Inc., the purpose of which was to identify export coefficients applicable to New Jersey. As part of that contract, a database of literature values was assembled that includes approximately four-thousand values accompanied by site-specific characteristics such as location, soil type, mean annual rainfall, and site percent-impervious. In conjunction with the database, the contractor reported on recommendations for selecting values for use in New Jersey. Analysis of mean annual rainfall data revealed noticeable trends, and, of the categories analyzed, was shown to have the most influence on the reported export coefficients. Incorporating this and other contractor recommendations, the Department took steps to identify appropriate export values for these TMDLs by first filtering the database to include only those studies whose reported mean annual rainfall was between 40 and 51 inches per year. From the remaining studies, total phosphorus values were selected based on best professional judgment for eight land uses categories.

The sources incorporated in the database include a variety of governmental and non-governmental documents. All values used to develop the database and the total phosphorus values in this document are included in the below reference list.

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Appendix C: Summary of Reckhow (1979a) model derivation

The following general expression for phosphorus mass balance in lake assumes the removal of phosphorus from a lake occurs through two pathways, the outlet (M_o) and the sediments (ϕ):

$$V \cdot \frac{dP}{dt} = M_i - M_o - \phi \qquad \textbf{Equation 1}$$

where:
- V = lake volume (10^3 m³)
- P = lake phosphorus concentration (mg/l)
- M_i = annual mass influx of phosphorus (kg/yr)
- M_o = annual mass efflux of phosphorus (kg/yr)
- ϕ = annual net flux of phosphorus to the sediments (kg/yr).

The sediment removal term is a multidimensional variable (dependent on a number of variables) that has been expressed as a phosphorus retention coefficient, a sedimentation coefficient, or an effective settling velocity. All three have been shown to yield similar results; Reckhow's formulation assumes a constant effective settling velocity, which treats sedimentation as an areal sink.

Assuming the lake is completely mixed such that the outflow concentration is the same as the lake concentration, the phosphorus mass balance can be expressed as:

$$V \cdot \frac{dP}{dt} = M_i - v_s \cdot P \cdot A - P \cdot Q \qquad \textbf{Equation 2}$$

where:
- v_s = effective settling velocity (m/yr)
- A = area of lake (10^3 m²)
- Q = annual outflow (10^3 m³/yr).

The steady-state solution of Equation 2 can be expressed as:

$$P = \frac{P_a}{v_s + z/T} = \frac{P_a}{v_s + Q_a} \qquad \textbf{Equation 3}$$

where:
- P_a = areal phosphorus loading rate (g/m²/yr)
- z = mean depth (m)
- T = hydraulic detention time (yr)
- Q_a = Q/A = areal water load (m/yr).

Using least squares regression on a database of 47 north temperate lakes, Reckhow fit the effective settling velocity using a function of areal water load: $P = \dfrac{P_a}{11.6 + 1.2 \cdot Q_a}$. **Equation 4**

Appendix D: Derivation of Margin of Safety from Reckhow *et al* (1980)

As described in Reckhow *et al* (1980), the Reckhow (1979a) model has an associated standard error of 0.128, calculated on log-transformed predictions of phosphorus concentrations. The model error analysis from Reckhow *et al* (1980) defined the following confidence limits:

$$P_L = P - h \cdot \left(10^{(\log P - 0.128)} - P\right)$$
$$P_U = P + h \cdot \left(10^{(\log P + 0.128)} - P\right)$$
$$\rho \geq 1 - \frac{1}{2.25 \cdot h^2}$$

where:
- P_L = lower bound phosphorus concentration (mg/l);
- P_U = upper bound phosphorus concentration (mg/l);
- P = predicted phosphorus concentration (mg/l);
- h = prediction error multiple
- ρ = the probability that the real phosphorus concentration lies within the lower and upper bound phosphorus concentrations, inclusively.

Assuming an even-tailed probability distribution, the probability (ρ_u) that the real phosphorus concentration is less than or equal to the upper bound phosphorus concentration is:

$$\rho_u = \rho + \frac{1-\rho}{2} = \rho + \frac{1}{2} - \frac{\rho}{2} = \rho \cdot \left(1 - \frac{1}{2}\right) + \frac{1}{2} = \frac{1}{2} \cdot \rho + \frac{1}{2}$$

Substituting for ρ as a function of h:

$$\rho_u = \frac{1}{2} \cdot \left(1 - \frac{1}{2.25 \cdot h^2}\right) + \frac{1}{2} = \frac{1}{2} - \frac{1}{4.5 \cdot h^2} + \frac{1}{2} = 1 - \frac{1}{4.5 \cdot h^2}$$

Solving for h as a function of the probability that the real phosphorus concentration is less than or equal to the upper bound phosphorus concentration:

$$\frac{1}{4.5 \cdot h^2} = 1 - \rho_u$$
$$h^2 = \frac{1}{4.5(1-\rho_u)}$$
$$h = \sqrt{\frac{1}{4.5(1-\rho_u)}}$$

Expressing Margin of Safety (MoS_p) as a percentage over the predicted phosphorus concentration yields:

$$MoS_p = \frac{P_U}{P} - 1 = \frac{P_U - P}{P}$$

Substituting the equation for $P_{U:}$

$$MoS_p = \frac{P + h \cdot \left(10^{(\log P + 0.128)} - P\right) - P}{P} = \frac{h \cdot \left(10^{(\log P + 0.128)} - P\right)}{P}$$

$$P \cdot MoS_p = h \cdot \left(10^{(\log P + 0.128)} - P\right)$$

$$\frac{P \cdot MoS_p}{h} = 10^{(\log P + 0.128)} - P$$

$$\frac{P \cdot MoS_p}{h} + P = 10^{(\log P + 0.128)}$$

Taking the log of both sides and solving for margin of safety:

$$\log\left(\frac{P \cdot MoS_p}{h} + P\right) = \log P + 0.128$$

$$\log\left(\frac{P \cdot MoS_p}{h} + P\right) - \log P = 0.128$$

$$\log\left(P\left(\frac{MoS_p}{h} + 1\right)\right) - \log P = 0.128$$

$$\log P + \log\left(\frac{MoS_p}{h} + 1\right) - \log P = 0.128$$

$$\log\left(\frac{MoS_p}{h} + 1\right) = 0.128$$

$$\frac{MoS_p}{h} + 1 = 10^{0.128}$$

$$\frac{MoS_p}{h} = 10^{0.128} - 1$$

$$MoS_p = h\left(10^{0.128} - 1\right)$$

Finally, substituting for *h* yields Margin of Safety (MoS_p) as a percentage over the predicted phosphorus concentration, expressed as a function of the probability (ρ_u) that the real phosphorus concentration is less than or equal to the upper bound phosphorus concentration:

$$MoS_p = \sqrt{1 / \left((1 - \rho_u) * 4.5\right)} \times \left(10^{0.128} - 1\right)$$

Appendix E: In-Lake Water Column Monitoring Data Referenced in the TMDL Analysis

1. Data in **Swartswood Lake Water Quality Monitoring Annual Report 1994**, prepared for Sussex County Board of Freeholders, prepared by Coastal Environmental Services, Inc, January 1995Data collected during

	Surface		Deep	
Sampling Date	TP, mg/L	Qualifier	TP, mg/L	Qualifier
4/27/1994	0.02		0.02	U
5/25/1994	0.02	U	0.038	
6/24/1994	0.02	U	0.036	
7/28/1994	0.02	U	0.056	
8/30/1994	0.03		0.16	
9/30/1994	0.037		0.048	

2. In-lake Water Column Samples Collected by Malcolm Pirnie

Sample ID	SL-1S		SL-1D		SL-2S		SL-2D	
Sampling Date	06/24/02		06/24/02		06/24/02		06/24/02	
Location	Swartswood Central		Swartswood Central		Swartswood North		Swartswood North	
Depth	1m		10 m		1m		10 m	
Ammonia - mg/l	0.1	U	0.1	U	0.1	U	0.1	U
Nitrate - mg/l	0.1	U	0.1	U	0.1	U	0.1	U
TotalPhosphorus - mg/l	0.03	U	0.03	U	0.03	U	0.034	
TSS - mg/L	10.0	U	10.0	U	10.0	U	10.0	U
Turbidity - NTU	2.3		2.4		2.0		2.4	

Sample ID	SL-1S		SL-1D		SL-2S		SL-2D	
Sampling Date	8/8/02		8/8/02		8/8/02		8/8/02	
Location	Swartswood Central		Swartswood Central		Swartswood North		Swartswood North	
Depth	1m		10 m		1m		10 m	
Ammonia - mg/l	0.1	U	0.44	U	0.1	U	0.39	U
TotalPhosphorus - mg/l	0.03	U	0.18	U	0.03	U	0.15	
Alkalinity - mg/L	71.3		80		70.2		83.2	
Turbidity - NTU	1.5		3.5		1.6		2.7	

Sample ID	SW-1		SW-12		SW-2		SW-3		SW-4	
Sampling Date	8/28/03		8/28/03		8/28/03		8/28/03		8/28/03	
Location	Swartswood Central		Swartswood Central		Swartswood Central		Swartswood South		Swartswood South	
Depth	9m		9m		1m		9m		1m	
Ammonia - mg/l	0.12		0.19		0.1	U	0.15		0.1	U
TotalPhosphorus - mg/l	0.042		0.06		0.036		0.052		0.02	
Alkalinity - mg/L	120		64.0		58.0		66.0		90.0	
Turbidity - NTU	1.0		0.7		2.1		0.7		2.0	

Sample ID	SW-3S		SW-10		SW-4D		SW-5S		SW-6D	
Sampling Date	07/07/04		07/11/04		07/11/04		07/11/04		07/11/04	
Location	Swartswood Central		Duplicate of SW-3S		Swartswood Central		Swartswood South		Swartswood South	
Depth	1 m		1 m		3 m		1 m		7.5 m	
Alkalinity - mg/l	72.0		72.0		72.0		71.0		70.0	
Ammonia - mg/l	0.1	U	0.1	U	0.1	U	0.1	U	0.1	U
TotalPhosphorus - mg/l	0.05		0.042		0.044		0.047		0.11	
Turbidity - NTU	1.5		1.4		1.75		1.25		1.1	

Appendix F: Tributary Water Column Monitoring Data Referenced in the TMDL Analysis

Table 1 Tributary Stations Sampled by USGS in 2004

Station Number	Latitude	Longtitude	Description
1443462	41.112	74.847	Neldon's Brook Hampton Rd.
1443464	41.099	74.842	Neldon's Brook Old Tannery Rd.
1443466	41.085	74.827	Neldon's Brook Swartswood, Rd
1443468	41.083	74.821	Indian Creek Swartswood Rd.

Note: Location of stations can be found in Figure 1.

Figure 1 Total Phosphorus Concentration at the Tributary Stations Sampled by USGS in 2004

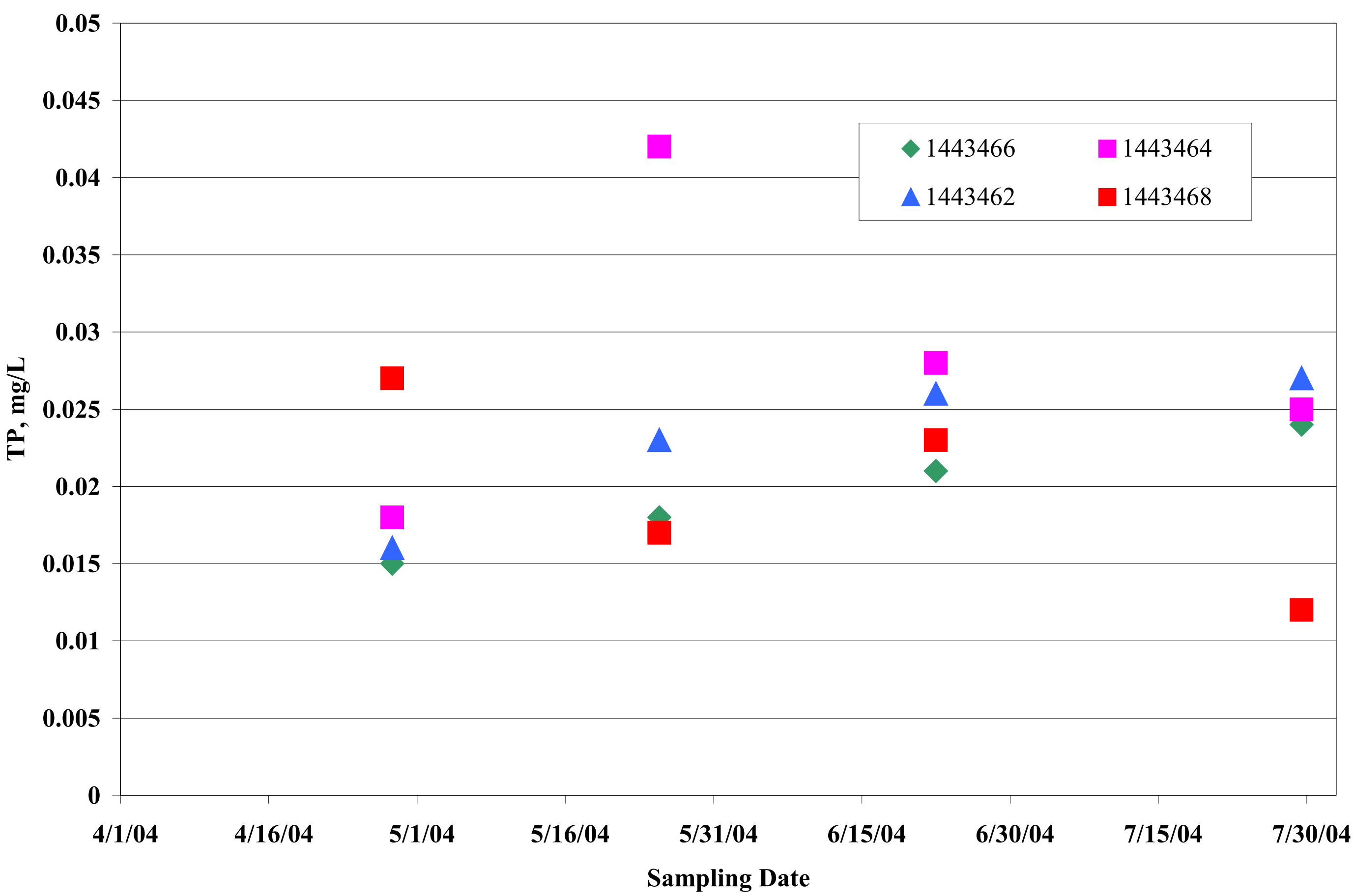

Table 2 Stream Surface Water Sampling Stations Within Stillwater Township Monitored by The Stillwater Township Environmental Commission (STEC)
(from the spring of 1984 to present)

Station	Description 1	Description 2
Site 1	old Schoolhouse Rd. at Hardwick border	Off old Schoolhouse Rd. along dirt road on Blair Academy property, below confluence of North and South branch of Blair Creek
Site 2	Fairview Lk. Rd. bridge past Owassa Rd.	Off Fariview Lake Road downstream from bridge about 50 feet
Site 3	Pondbrook Road at Middleville Rd.	Off Pond Brook Rd downstream from Middleville Rd about 100 feet
Site 4	Mt. Benevolence Road before Hampton Rd	Off Mt. Benevolence Rd. upstream about 50 feet from the bridge by Stonybrook (formerly Crandon Lodge) before intersection of Mt. Benevolence Rd and Hampton Rd.
Site 5	Hampton Rd. Bridge	Off Hampton Rd about 50 feet downstream from bridge
Site 6	Swartswood Rd Bridge	Off Swartswood Rd about 50 feet donwstream from bridge by "Tosties"
Site 7	Main St Bridge	Off Main Street about 50 feet downstream from bridge by Grist Mill

Note: Site 4, 5 and 6 are located within Swartswood Lake Watershed, as shown on Figure 1.

Figure 2 Total Phosphorus Concentration Observed at Site 4

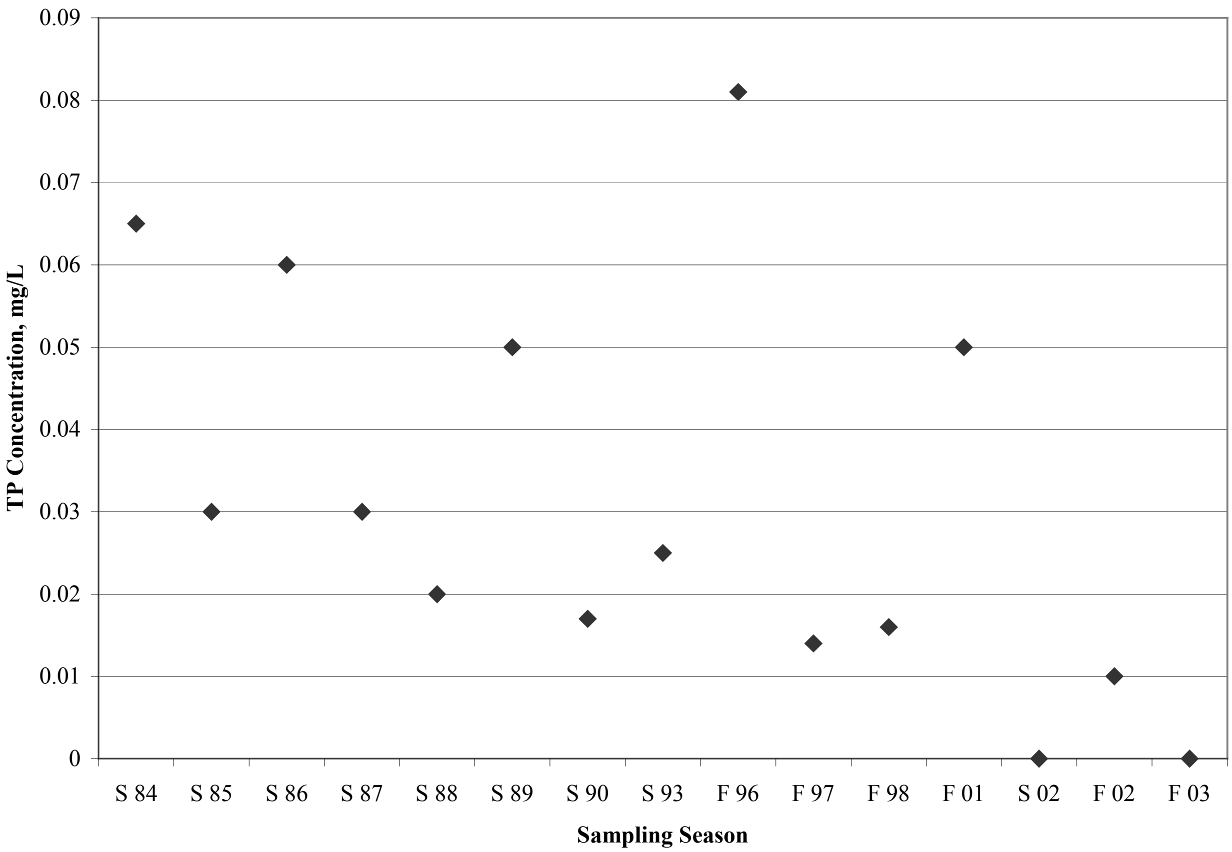

Figure 3 Total Phosphorus Concentration Observed at Site 5

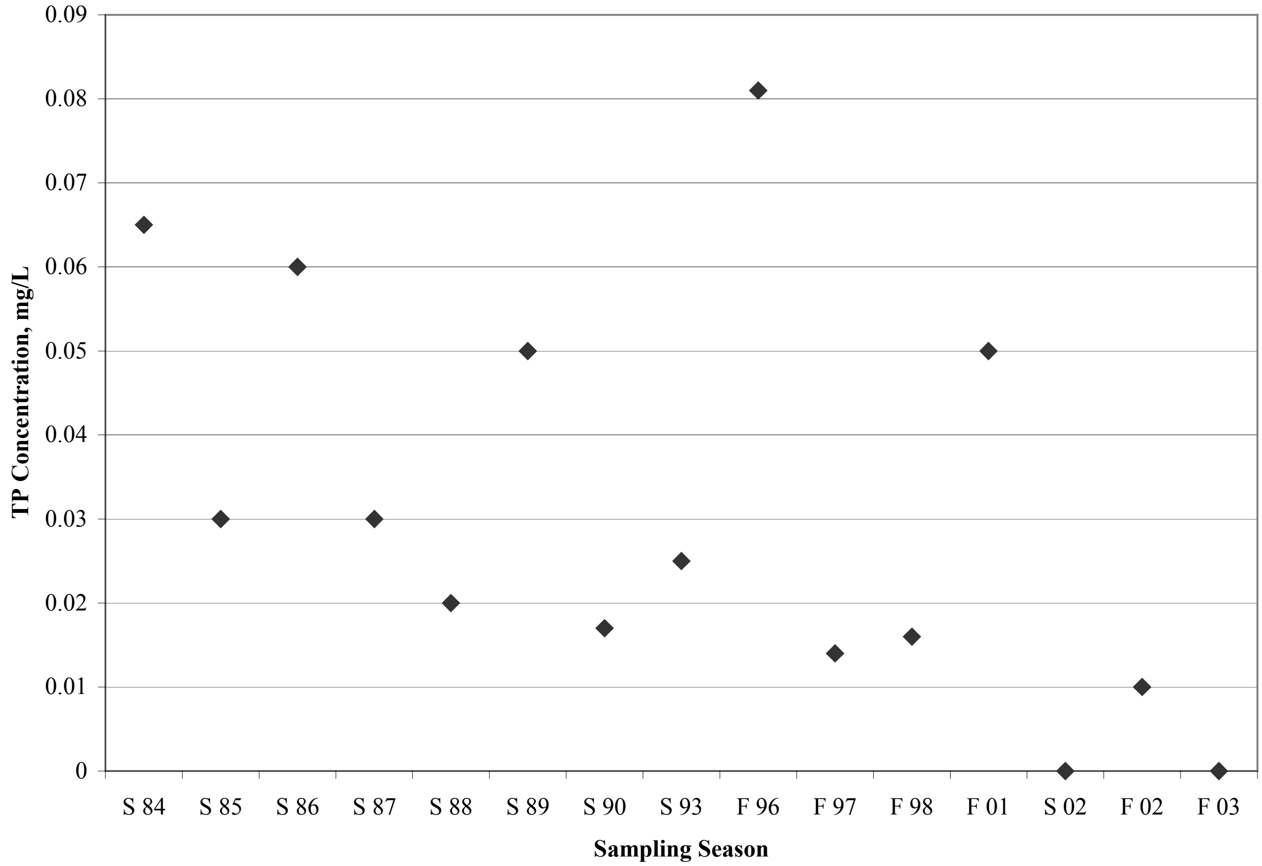

Figure 4 Total Phosphorus Concentration Observed at Site 6