Amendment to the
Atlantic County Water Quality Management Plan
Cape May County Water Quality Management Plan
Middlesex County Water Quality Management Plan
Monmouth County Water Quality Management Plan
Ocean County Water Quality Management Plan
Tri-County Water Quality Management Plan

Total Maximum Daily Loads for Phosphorus To Address Nine Eutrophic Lakes in the Atlantic Coastal Water Region

DEAL LAKE, MONMOUTH COUNTY
DENNISVILLE LAKE, CAPE MAY COUNTY
FRANKLIN LAKE, MONMOUTH COUNTY
HAMMONTON LAKE, ATLANTIC COUNTY
HOOK'S CREEK LAKE, MIDDLESEX COUNTY
LAKE ABSEGAMI, BURLINGTON COUNTY
LILY LAKE, CAPE MAY COUNTY
LAKE POHATCONG, OCEAN COUNTY
NEW BROOKLYN LAKE, CAMDEN COUNTY

Watershed Management Area 12
(Monmouth Watersheds)
Watershed Management Area 13
(Barnegat Bay Watersheds)
Watershed Management Area 14
(Mullica Watersheds)
Watershed Management Area 15
(Great Egg Harbor Watersheds)
Watershed Management Area 16
(Cape May Watersheds)

Proposed: April 21, 2003
Established: June 27, 2003
Approved (by EPA Region 2):
Adopted:

New Jersey Department of Environmental Protection
Division of Watershed Management
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Contents

1.0 Executive Summary 7
2.0 Introduction 8
3.0 Background 8
3.1 305(b) Report and 303(d) List 8
3.2 Total Maximum Daily Loads (TMDLs) 10
3.3 Integrated List of Waterbodies 10
4.0 Pollutant of Concern and Area of Interest 10
4.1 Lake Como, Spring Lake, and Wreck Pond 13
4.2 Deal Lake 13
4.3 Franklin Lake 15
4.4 Hook's Creek Lake 16
4.5 Pohatcong Lake 18
4.6 Shenandoah Lake 19
4.7 Lake Absegami 20
4.8 Hammonton Lake 21
4.9 New Brooklyn Lake 23
4.10 Dennisville Lake 24
4.11 Lily Lake 25
5.0 Applicable Surface Water Quality Standards 26
6.0 Source Assessment 27
6.1 Assessment of Point Sources other than Stormwater 28
6.2 Assessment of Nonpoint Sources and Stormwater 28
7.0 Water Quality Analysis 32
7.1 Current Condition 34
7.2 Reference Condition 39
7.3 Seasonal Variation / Critical Conditions 39
7.4 Margin of Safety 39
7.5 Target Condition 41
8.0 TMDL Calculations 41
8.1 Loading Capacity 41
8.2 Reserve Capacity 41
8.3 Allocations 42
9.0 Follow-up Monitoring 52
10.0 Implementation 52
10.1 Lake Characterization 54
10.2 Reasonable Assurance 55
11.0 Public Participation 55
Appendix A: References 58
Appendix B: Database of Phosphorus Export Coefficients 62
Appendix C: Summary of Reckhow (1979a) model derivation 67
Appendix D: Derivation of Margin of Safety from Reckhow *et al* (1980) 68

Figures

Figure 1 Eutrophic lakes in the Atlantic Coastal Water Region on Sublist 5 of 2002 Integrated List ... 12
Figure 2 Lakeshed of Deal Lake ... 15
Figure 3 Lakeshed of Franklin Lake ... 16
Figure 4 Lakeshed of Hook's Creek Lake ... 18
Figure 5 Lakeshed of Pohatcong Lake ... 19
Figure 6 Lakeshed of Lake Absegami ... 21
Figure 7 Lakeshed of Hammonton Lake ... 22
Figure 8 Lakeshed of New Brooklyn Lake ... 23
Figure 9 Lakeshed of Dennisville Lake ... 25
Figure 10 Lakeshed of Lily Lake ... 26
Figure 11 Current distribution of phosphorus load for Deal Lake ... 34
Figure 12 Current distribution of phosphorus load for Franklin Lake ... 35
Figure 13 Current distribution of phosphorus load for Hooks Creek Lake ... 35
Figure 14 Current distribution of phosphorus load for Pohatcong Lake ... 36
Figure 15 Current distribution of phosphorus load for Absegami Lake ... 36
Figure 16 Current distribution of phosphorus load for Hammonton Lake ... 37
Figure 17 Current distribution of phosphorus load for New Brooklyn Lake ... 37
Figure 18 Current distribution of phosphorus load for Dennisville Lake ... 38
Figure 19 Current distribution of phosphorus load for Lily Lake ... 38
Figure 20 Phosphorus allocations for Deal Lake TMDL ... 48
Figure 21 Phosphorus allocations for Franklin LakeTMDL ... 48
Figure 22 Phosphorus allocations for Hooks Creek Lake TMDL ... 49
Figure 23 Phosphorus allocations for Pohatcong Lake TMDL ... 49
Figure 24 Phosphorus allocations for Absegami LakeTMDL ... 50
Figure 25 Phosphorus allocations for Hammonton LakeTMDL ... 50
Figure 26 Phosphorus allocations for New Brooklyn LakeTMDL ... 51
Figure 27 Phosphorus allocations for Dennisville LakeTMDL ... 51
Figure 28 Phosphorus allocations for Lily LakeTMDL ... 52

Tables

Table 1 Eutrophic Lakes for which Phosphorus TMDLs are being established ... 7
Table 2 Abridged Sublist 5 of the 2002 Integrated List of Waterbodies, eutrophic lakes ... 11
Table 3 Point Source Phosphorus Loads other than Stormwater ... 28
Table 4 Phosphorus export coefficients (Unit Areal Loads) ... 29
Table 5 Nonpoint and Stormwater Sources of Phosphorus Loads ... 30
Table 6 Nonpoint and Stormwater Sources of Phosphorus Loads (cont'd) ... 31
Table 7 Empirical models considered by the Department ... 32
Table 8 Hydrologic and loading characteristics of lakes ... 34
Table 9 Current condition, reference condition, target condition and overall percent reduction for each lake ... 41
Table 10 Distribution of WLAs and LAs among source categories ... 43
Table 11 TMDL calculations for each lake (annual loads and percent reductions[a]) ... 45

Table 12 TMDL calculations for each lake (annual loads and percent reductions[a], cont'd). 46
Table 13 TMDL calculations for each lake (annual loads and percent reductions[a], cont'd). 47
Table 14 Implementation Schedule..... 54

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1.0 Executive Summary

The State of New Jersey's *2002 Integrated List of Waterbodies* identified several lakes in the Atlantic Coastal Water Region as being eutrophic. This report establishes total maximum daily loads (TMDLs) for total phosphorus (TP) that address eutrophication of the lakes listed in Table 1.

Table 1 Eutrophic Lakes for which Phosphorus TMDLs are being established

TMDL Number	Lake Name	Municipality	WMA	Acres
1	Deal Lake	Asbury Park City; Loch Arbour Village; Allenhurst, Deal & Interlaken Boros; Ocean Township; Monmouth County	12	155.4
2	Franklin Lake	West Long Branch Borough; Monmouth County	12	14.6
3	Hook's Creek Lake	Old Bridge Township, Middlesex County	12	10.6
4	Pohatcong Lake	Little Egg Harbor Township, Tuckerton Borough; Ocean County	13	35.4
5	Absegami Lake	Bass River Township, Burlington County	14	52.6
6	Hammonton Lake	Hammonton Township, Atlantic County	14	61.4
7	New Brooklyn Lake	Winslow Township, Camden County	15	10.8
8	Dennisville Lake	Dennis Township, Cape May County	16	47.9
9	Lily Lake	Cape May Point Borough, Cape May County	16	15.8

These TMDLs serve as the foundation on which restoration plans will be developed to restore eutrophic lakes and thereby attain applicable surface water quality standards. A TMDL is developed as a mechanism for identifying all the contributors to surface water quality impacts and setting goals for load reductions for pollutants of concern as necessary to meet Surface Water Quality Standards (SWQS). The pollutant of concern for these TMDLs is phosphorus, since phosphorus is generally the nutrient responsible for overfertilization of inland lakes leading to cultural eutrophication. The Department's Geographic Information System (GIS) was used extensively to describe the lakes and lakesheds (drainage basins of the lakes).

In order to prevent excessive primary productivity[1] 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 due to overfertilization. Phosphorus sources were characterized on an annual scale (kg TP/yr) for both point and nonpoint sources. Runoff from land surfaces comprises a substantial source of phosphorus into lakes. An empirical model was used to relate annual phosphorus load and steady-state in-lake concentration of total phosphorus. To achieve the TMDLs, overall load reductions were calculated for at least eight and, depending on the amount of information available, up to 14 source categories. In order to track effectiveness of remediation measures (including TMDLs) and to develop baseline and trend information on lakes, the Department will augment its ambient monitoring program to include lakes on a rotating schedule. The implementation plan also calls for the collection of additional monitoring data and the

[1] Primary productivity refers to the growth rate of primary producers, namely algae and aquatic plants, which form the base of the food web.

development of a Lake Restoration Plan for each lake for which TMDLs are being established. These plans will consider what specific measures are necessary to achieve the nutrient reductions required by the TMDL, as well as what in-lake measures need to be taken to supplement the nutrient reductions required by the TMDL. Each TMDL shall be proposed and adopted by the Department as an amendment to the appropriate areawide water quality management plan(s) in accordance with N.J.A.C. 7:15-3.4(g).

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

2.0 Introduction

Sublist 5 (also known as List 5 or, traditionally, the 303(d) List) of the State of New Jersey's *2002 Integrated List of Waterbodies* identified several lakes in the Atlantic Coastal Water Region (WMAs 12, 13, 14, 15, and 16) as being eutrophic, as evidenced by elevated total phosphorus (TP), elevated chlorophyll-*a*, and/or macrophyte density that impairs recreational use (a qualitative assessment). This report establishes nine total maximum daily loads (TMDLs) that address total phosphorus loads to the identified lakes. These TMDLs serve as the foundation on which management approaches or restoration plans will be developed to restore eutrophic lakes and thereby attain applicable surface water quality standards. Several of the lakes are listed on Sublist 5 for impairments caused by other pollutants. These TMDLs address only the impairment of lakes due to eutrophication. Separate TMDL evaluations will be developed to address the other pollutants of concern. The waterbodies will remain on Sublist 5 until such time as TMDL evaluations for all pollutants have been completed and approved by the United States Environmental Protection Agency (USEPA).

A TMDL is considered "proposed" when NJDEP publishes the TMDL Report as a proposed Water Quality Management Plan Amendment in the New Jersey Register (NJR) for public review and comment. A TMDL is considered to be "established" when NJDEP finalizes the TMDL Report after considering comments received during the public comment period for the proposed plan amendment and formally submits it to EPA Region 2 for thirty (30)-day review and approval. The TMDL is considered "approved" when the NJDEP-established TMDL is approved by EPA Region 2. The TMDL is considered to be "adopted" when the EPA-approved TMDL is adopted by NJDEP as a water quality management plan amendment and the adoption notice is published in the NJR.

3.0 Background

3.1 305(b) Report and 303(d) List

In accordance with Section 305(b) of the Federal Clean Water Act (CWA) (33 U.S.C. 1315(B)), the State of New Jersey is required to biennially prepare and submit to the United States

Environmental Protection Agency (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.

In accordance with Section 303(d) of the CWA, the State is also required to biennially prepare and submit to USEPA a report that identifies waters that do not meet or are not expected to meet surface water quality standards (SWQS) after implementation of technology-based effluent limitations or other required controls. This report is commonly referred to as the 303(d) List. The listed waterbodies are considered water quality-limited and require total maximum daily load (TMDLs) evaluations. For waterbodies identified on the 303(d) List, there are three possible scenarios that may result in a waterbody being removed from the 303(d) List:

> **Scenario 1:** A TMDL is established for the pollutant of concern;
> **Scenario 2:** A determination is made that the waterbody is meeting water quality standards (no TMDL is required); or
> **Scenario 3:** A determination is made that a TMDL is not the appropriate mechanism for achieving water quality standards and that other control actions will result in meeting standards.

Where a TMDL is required (Scenario 1), it will: 1) specify the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards**;** and 2) allocate pollutant loadings among point and nonpoint pollutant sources.

Recent EPA guidance (Suftin, 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, which includes nine TMDLs, addresses the following items in the May 20, 2002 guideline document:

1. Identification of waterbody(ies), 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.
12. Submittal letter.

3.2 Total Maximum Daily Loads (TMDLs)

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. A TMDL is developed as a mechanism for identifying all the contributors to surface water quality impacts and setting goals for load reductions for pollutants of concern as necessary to meet SWQS.

Once one of the three possible delisting scenarios, noted above, is completed, states have the option to remove the waterbody and specific pollutant of concern from the 303(d) List or maintain the waterbody on the 303(d) list until SWQS are achieved. The State of New Jersey will be removing lakes from the 303(d) List for eutrophication once their TMDLS are approved by USEPA.

3.3 Integrated List of Waterbodies

In November 2001, USEPA issued guidance that encouraged states to integrate the 305(b) Report and the 303(d) List into one report. This integrated report assigns waterbodies to one of five categories. In general, Categories 1 through 4 include a range of designated use impairments with a discussion of enforceable management strategies, whereas Sublist 5 constitutes the traditional 303(d) List for waters impaired or threatened by a pollutant for which one or more TMDL evaluations are needed. Where more than one pollutant is associated with the impairment for a given waterbody, that waterbody will remain on Sublist 5 until one of the three possible delisting scenarios is completed. In the case of an Integrated List, however, the waterbody is not delisted but moved to one of the other categories.

Following USEPA's guidance, the Department chose to develop an Integrated Report for New Jersey. New Jersey's *2002 Integrated List of Waterbodies* is based upon these five categories and identifies water quality limited surface waters in accordance with N.J.A.C. 7:15-6 and Section 303(d) of the CWA. These TMDLs address eutrophic lakes, as listed on Sublist 5 of the State of New Jersey's *2002 Integrated List of Waterbodies.*

4.0 Pollutant of Concern and Area of Interest

Lakes were designated as eutrophic on Sublist 5 of the *2002 Integrated List of Waterbodies* as a result of evaluations performed through the State's Clean Lakes Program. Indicators used to determine trophic status included elevated total phosphorus (TP), elevated chlorophyll-*a,* and/or macrophyte density. The pollutant of concern for these TMDLs 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. Furthermore, of the major nutrients, phosphorus is the most effectively controlled through engineering technology and land use management (Holdren *et al*, 2001). 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. Phosphorus is generally the nutrient responsible for overfertilization of inland lakes leading to eutrophication.

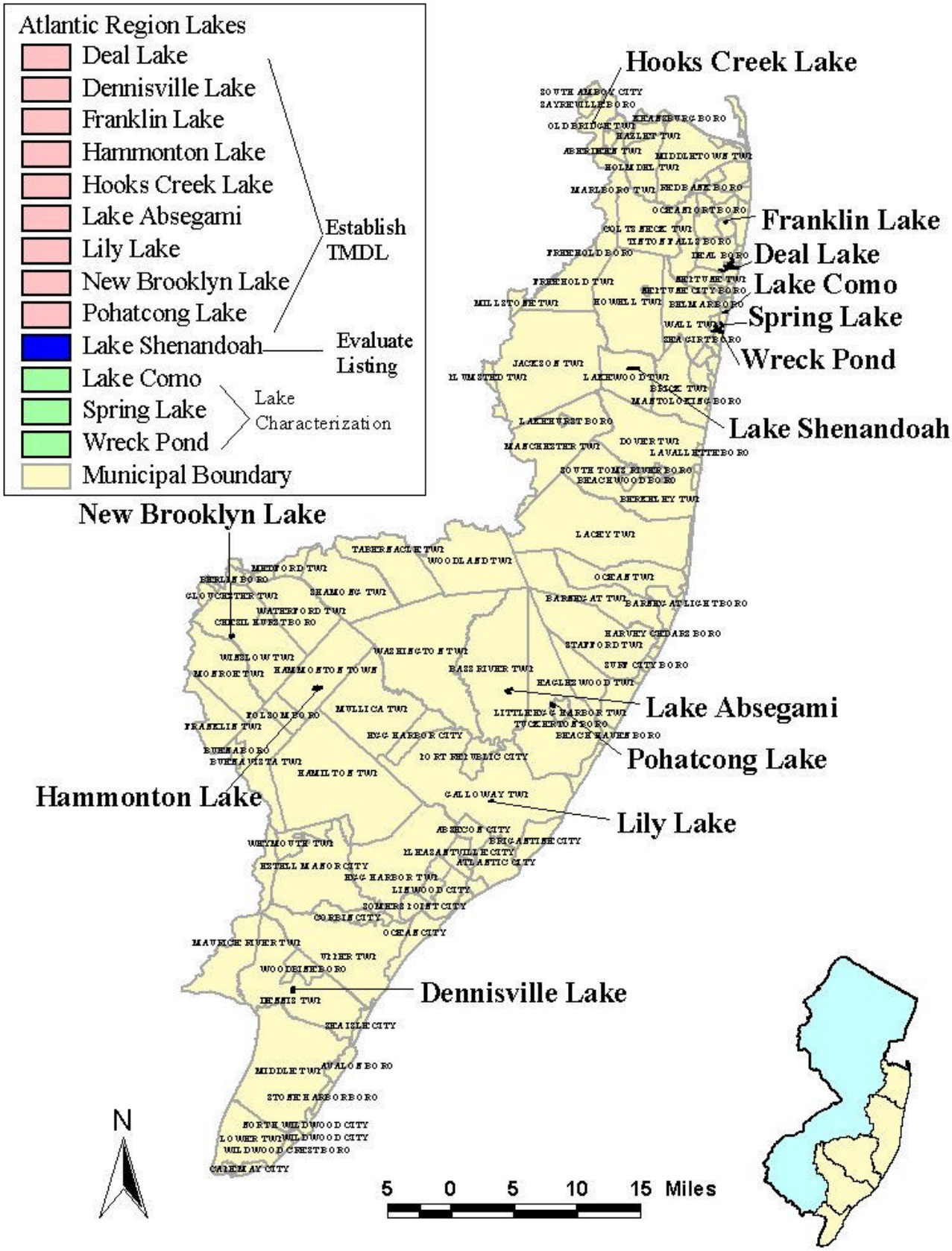
As reported in the *2002 Integrated List of Waterbodies*, the Department identified the following lakes in Atlantic Coastal Water Region as being eutrophic for a total of 631 acres. These nine TMDLs will address 442 acres or 70% of the total impaired lake acres in this region (Table 2). Eutrophic lake impairments are ranked as Low Priority in the *2002 Integrated List of Waterbodies* because they are not directly related to human health issues; however, lake eutrophication is important from an environmental perspective.

Table 2 Abridged Sublist 5 of the 2002 Integrated List of Waterbodies, eutrophic lakes

WMA	Lake[a]	Lake Acres	Lakeshed Acres	Management Response
12	Como Lake	35.5	813	lake characterization
12	Deal Lake	155.4	3990	establish TMDL
12	Franklin Lake	14.6	539	establish TMDL
12	Hooks Creek Lake	10.6	47	establish TMDL
12	Spring Lake	13.7	288	lake characterization
12	Wreck Pond	87.7	8310	lake characterization
13	Pohatcong Lake	35.4	7910	establish TMDL
13	Shenandoah Lake	51.9	17470	evaluate basis for listing
14	Absegami Lake	52.6	2350	establish TMDL
14	Hammonton Lake	61.4	1750	establish TMDL
15	New Brooklyn Lake	48.3	14700	establish TMDL
16	Dennisville Lake	47.9	2540	establish TMDL
15	Lily Lake	15.8	154	establish TMDL

a All of the waterbodies covered under these TMDLs have a FW2 classification.

Figure 1 Eutrophic lakes in the Atlantic Coastal Water Region on Sublist 5 of 2002 Integrated List



These TMDLs will address a total of 442 acres of lakes with a corresponding total of 34,000 acres of land within the affected lakesheds.

The Department's Geographic Information System (GIS) was used extensively to describe the lakes and lakesheds (watersheds of the lakes), 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 Statewide Lakes (Shapefile) with Name Attributes (from 95/97 Land Use/Land Cover) in New Jersey, published 7/13/2001 by NJDEP - Bureau of Freshwater and Biological Monitoring, http://www.state.nj.us/dep/gis/digidownload/zips/statewide/njlakes.zip.
- Lakesheds were delineated based on 14-digit hydrologic unit code coverage (HUC-14) and elevation contours.
  - NJDEP 14 Digit Hydrologic Unit Code delineations (DEPHUC14), published 4/5/2000 by New Jersey Geological Survey, http://www.state.nj.us/dep/gis/digidownload/zips/statewide/dephuc14.zip.
  - Statewide Elevation Contours (10 Foot Intervals), unpublished, auto-generated from: 7.5 minute Digital Elevation Models, published 7/1/1979 by U.S. Geological Survey.
  - NJDEP Statewide Elevation Contours (20 Foot Intervals), published 1987 by Bureau of Geographic Information and Analysis (BGIA), http://www.state.nj.us/dep/gis/digidownload/zips/statewide/stcon.zip.
  - NJDEP 10-meter Digital Elevation Grids, published 06/01/2002 by Bureau of Geographic Information and Analysis (BGIA), delineated by watershed management area.
- NJPDES Surface Water Discharges in New Jersey, (1:12,000), published 02/02/2002 by Division of Water Quality (DWQ), Bureau of Point Source Permitting - Region 1 (PSP-R1).

4.1 Lake Como, Spring Lake, and Wreck Pond

Lake Como, Spring Lake, and Wreck Pond are relatively small waterbodies (35.5 acres, 13.7 acres, and 87.7 acres, respectively) in the same vicinity as Deal Lake and Franklin Lake along the coastline of Monmouth County. The watersheds of these lakes are highly urbanized and large relative to the size of the lakes (22.9, 21.0, 94.8 times the size of the lakes, respectively). The large urbanized watersheds of these lakes supports the anecdotal evidence from local sampling programs that indicates these three waterbodies are impaired due to eutrophication. Hydrologic budgets have not been developed for these lakes, making it impossible to develop TMDLs at this time. Nevertheless, the Department has included these three lakes in the implementation plan in order to require both characterization and restoration plans for each lake.

4.2 Deal Lake

Deal Lake is a large, dendritic water body (155 acres) in Monmouth County with a shape reminiscent of a four-legged octopus. Four major tributaries attenuate into two larger ones,

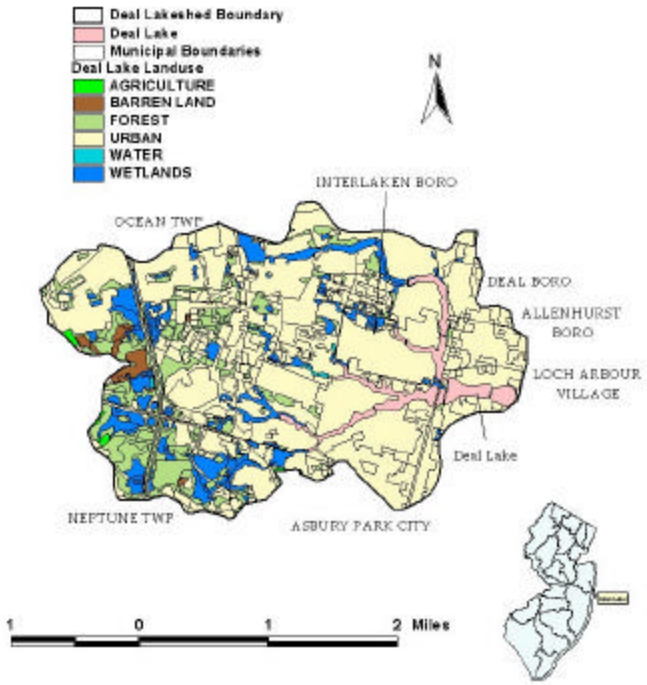
which then attenuate into one long neck and "head," which comprise the main basin. The lake originated through flooding of the gradually sloping coastal lowlands, and is separated from the Atlantic Ocean by a flume structure that permits lake outflow but prevents tidal inflow. The lakeshed is 26 times the area of the lake, making it very large[2]. Average depth was measured at 5.3 feet, with a range of up to 9 feet in the in the main basin. Total volume is estimated at 1,020,000 m^3, with total annual inflow estimated at 10,000,000 m^3/yr. Hydraulic retention time of the lake is approximately 37 days. The 3,990-acre lakeshed incorporates portions of Asbury Park City, Interlaken Boro, Allenhurst Boro, Loch Arbour Village, Deal Boro, Ocean Township, and Neptune Township. Mean depth and total annual inflow were obtained from the Deal lake Management/Restoration Plan (Princeton Aqua Science, 1983a).

As of 1986, least 135 storm drains empty directly into Deal Lake (Monmouth County Department of Health, 1986). Samples taken in 1986 and tested for fecal coliform and nitrates revealed that 5 of these drains contained sewage. One source was traced back to a house built in the 1950's with its lateral sewer line mistakenly connected into the storm drain. Other possibilities include pet waste washed in during rain events as well as infiltration from sewer main overload. In March of 1986, 39 of the 135 storm drains were flowing constantly. Very small wetlands areas scattered through-out the watershed have, for the most part, been left untouched, as well as some few remaining patches of forest; but in a great majority the land has been developed as either medium-to-high density residential with landscaping or commercial. Municipal and educational facilities are interspersed throughout the lakeshed. The educational complexes include multiple athletic fields. Two landfills exist within the lakeshed, as do one 9-hole and major portions of two 18-hole golf courses.

There are some springs located at the headwaters of some tributaries, but they are not believed to be the major source of water. Runoff volume is considerable, mostly from the extensive labyrinth of storm sewers, with some overland flow directly to the lake. Lake use no longer includes swimming, but as with any coastal community the potential is there. Boating and fishing are the primary activities that take place currently.

[2] A lakeshed seven times the area of its lake is considered small, whereas a lakeshed ten times the area of its lade is considered large (Holdren *et al*, 2002).

Figure 2 Lakeshed of Deal Lake



4.3 Franklin Lake

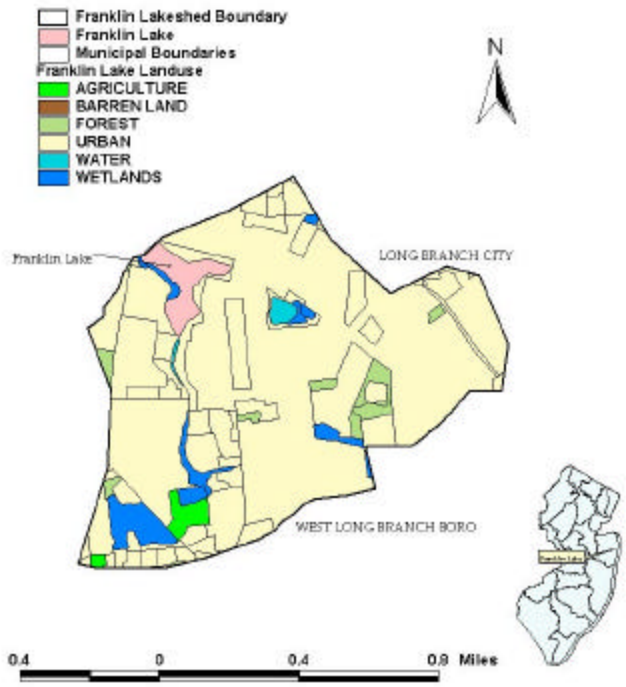
Franklin Lake is a pudgy "Y-shaped" waterbody located in the Borough of West Long Branch, Monmouth County, approximately two miles from the Atlantic Ocean. Franklin Lake is very shallow lake with a mean depth of 1.4 feet, reaching maximums of 2.9 feet. The lake's surface area is 14.6 acres and the lakeshed area is 538.7 acres, making the watershed-to-lake-surface-area ratio very large (36.8 to 1). Total lake volume is estimated to be 25,300 m^3. Mean discharge is approximately 1,070,000 m^3/y, making the mean hydraulic residence time about 9 days. Mean depth and annual discharge were obtained from the Franklin Lake Diagnostic-Feasibility Study (F.X. Browne Associates, Inc., 1989).

Franklin Lake is a public lake within a subwatershed that is extensively developed with medium-to-high density residences, multiple large commercial malls and retail outlets, a racetrack, an 18-hole golf course, and numerous educational facilities with requisite athletic fields. In the early 1980's complaints began appearing in local newspapers regarding foul odors emanating from the lake during the summer months. In 1983 the Monmouth County Regional Health Commission investigated and determined the lake was eutrophic; the foul odor was due to the release of hydrogen sulfide from anaerobic lake sediments. Historical

data indicates that in the early 1900's the average depth of Franklin Lake was 6-7 feet, indicating the possible extent of erosion and sedimentation.

The Franklin Lake lakeshed itself is approximately two-thirds medium residential with large lawns and landscaped areas, with much of the remainder comprised of two educational facilities, a large cemetery, and a small corporate area. The regional high school sprawls along the lake's entire western flank, and the adjacent athletic fields continue another equal distance beyond. Next to the high school on the other side is the Glenwood Cemetery, another large expanse of fertilized turf. Geese regularly congregate along the banks where there are open turf areas. There are no boat ramp facilities at the lake but it is stocked with trout for recreational fishing.

Figure 3 Lakeshed of Franklin Lake



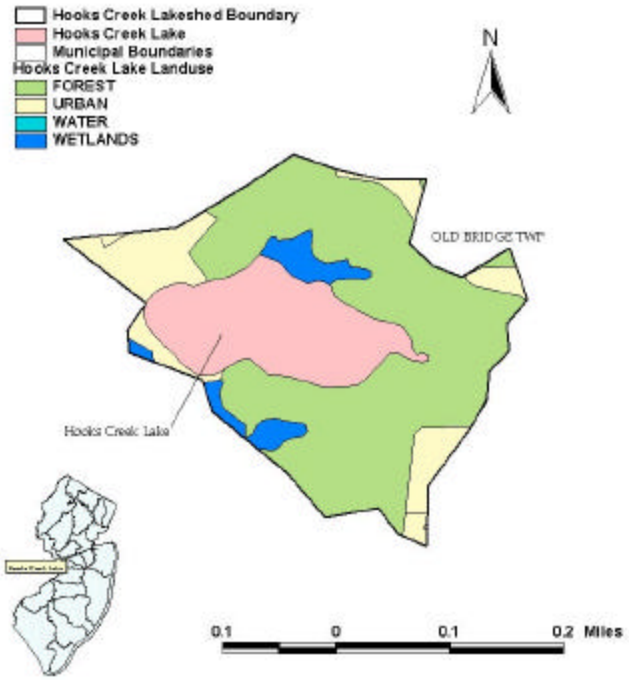
4.4 Hook's Creek Lake

Hook's Creek Lake is within Cheesequake State Park in Middlesex County. The park is adjacent to the Hook's Creek tidal marsh area, but the lake was isolated from tidal influence in 1984 via the placement of an embankment dam across the channel. Periodically however, during particularly high tides, the lake may become inundated with brackish water. The park

is also in the transitional zone where New Jersey's northern and southern regions converge, each with its own distinct geologic and terrestrial characteristics, making the park home to a wide variety of vegetation and landscapes. The lakeshed itself is in Old Bridge Township, and is 75% deciduous forest. The 15% of urban landuse is restricted to recreational activities such as camping areas, hiking trails, picnic areas, etc., but impervious cover does exist in the form of covered areas and outbuildings. The lake is stocked every spring with brook and rainbow trout, and often in fall again with channel catfish. A resident fishery also includes largemouth bass, perch, and sunfish. Small boats, limited to either self-propelled or with electric motors, can be launched fall through spring, but not during the traditional summer months between Labor Day and Memorial Day. The roughly oblong-shaped lake also has a designated swimming area, adjacent to which is a concession facility and bathhouse.

The surface area of the lake is 10.6 acres within a 46.6 acre watershed, resulting in a small lake surface to watershed area ratio (4.4 to 1). Total volume is approximately 72,800 m3. Assuming there has been no tidal flow into the lake, the mean hydraulic retention time is 0.71 yr, or 259 days. Mean discharge was estimated to be 102,500 m^3/yr. Mean depth is 5.5 feet with maximum depths of 7.3 feet. Mean depth and annual discharge were obtained from the Phase I Diagnostic/Feasibility Study of Hook's Creek Lake (Princeton Hydro, LLC, 2002). While phosphorus loads as well as phosphorus concentrations in Hook's Creek Lake are acceptable, a TMDL is hereby proposed in order to prevent phosphorus loads from increasing. In addition, the TMDL will require a Restoration Plan to build on the Phase 1 Study (Princeton Hydro, LLC, 2002) and specify in-lake measures that need to be taken to restore a clear-water condition that considers the shallow-lake the ecology of the lake.

Figure 4 Lakeshed of Hook's Creek Lake



4.5 Pohatcong Lake

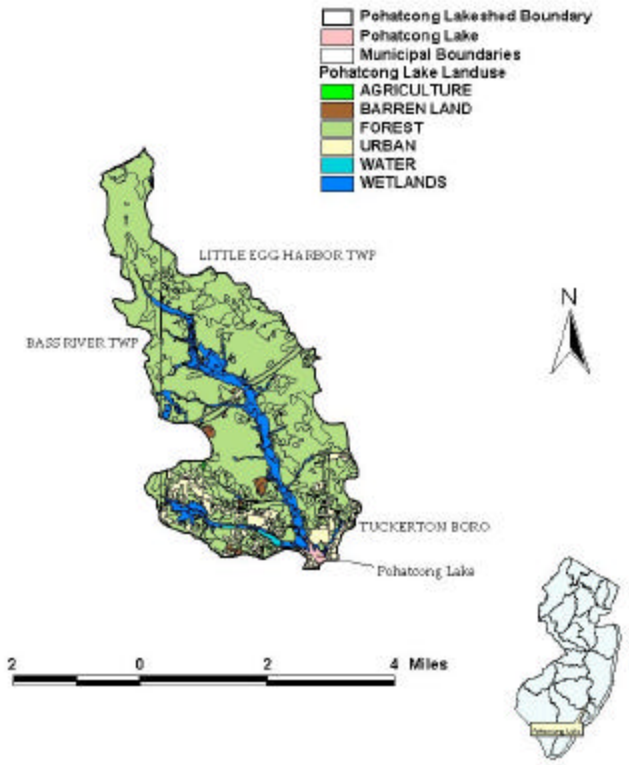
Pohatcong Lake is a shallow lake located mostly in Tuckerton Borough, but with a small appendage extending into Little Egg Harbor Township, both in Ocean County. The lake is irregularly shaped, somewhat like rectangle with two arms stretched upwards, which then attenuate into its two tributaries. The northern tributary, Mill Branch, drains about 76% of the watershed and is almost exclusively forested, extending into Bass River State Forest. The southern tributary, Gifford's Mill Branch, drains 19% of the watershed, with a large complex of educational facilities and athletic fields along its northern banks. The remaining 5% of the watershed drains directly into the lake, and is largely developed with residential and urban development. The lake's entire watershed is located within the Pinelands Region, and the lake is approximately 1.5 miles from Little Egg Harbor and the Atlantic Ocean.

Pohatcong Lake's surface area is 35.4 acres with a 7,910-acre lakeshed, making a drainage basin to lake surface area ratio of 223:1. The large drainage area and shallow lake conditions result in a rapid hydraulic retention time of about 2 days. Mean depth was measured at 3.4 feet with a maximum depth of 8.5 feet. Total lake volume is about 148,000 m3. There is just one outfall with an annual discharge of approximately 23,900,000 m3/yr. Mean depth and

annual discharge were obtained from the Diagnostic-Feasibility Study of Pohatcong Lake (F.X. Browne Associates, Inc., 1990).

Lake uses once included a public swimming beach at the Stanley H. "Tip" Seaman Park along the southern shore, which has subsequently been discontinued. Swimming is now limited to resident populations of gulls, ducks, and geese. Local information included that there is an ambient fish population, but no definitive data was found. One source spoke of the Township's desire to restore a second outfall for the lake, which was lost due to the construction of Route 9, and to install anadromous fish runs.

Figure 5 Lakeshed of Pohatcong Lake



4.6 Shenandoah Lake

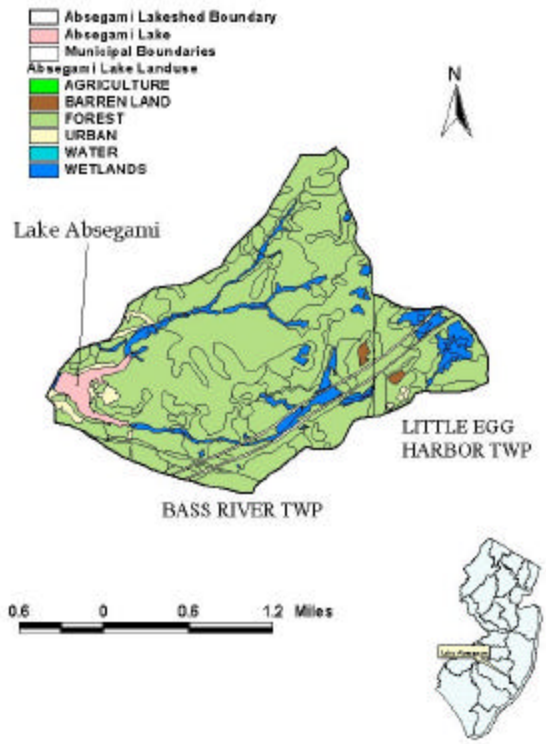
Shenandoah Lake is a 52-acre lake formed by a downstream impoundment of the South Branch of the Metedeconk River in Lakewood Township, Ocean County. Since the lake drains a very large lakeshed encompassing 17,474 acres, 5,327 acres of which have urban land uses, the lake may very well suffer from excessive nutrient loads. However, the Department does not have enough water quality information on Shenandoah Lake to make any assessment of its impairment status. The only water quality information the Department has

is a single water quality sample from 1992 taken as part of the Lake Water Quality Assessment Report. Additionally, the Department is not aware of any measurements of the lake's physical and hydrologic characteristics, such as annual flow, which are necessary to perform a TMDL analysis. Generally, as indicated in the Integrated Water Quality Monitoring and Assessment Methods Document published along with the *2002 Integrated List*, lakes whose only information consists of limited sampling through the Lake Water Quality Assessment program were placed on Sub-List 3, indicating their impairment status is not known. Shenandoah Lake was improperly placed on Sub-List 5 (Impaired Waters) based on the incorrect assumption that a Phase II diagnostic study had been funded for the lake.

4.7 Lake Absegami

Lake Absegami is a 52.6-acre lake located in Bass River State Forest, Bass River Township, Burlington County. The 2,352-acre lakeshed, which extends into Little Egg Harbor Township and consists mostly of forest and wetlands, is 44.7 times the area of the lake, making it very large. The mean depth of the lake is about 1 meters, while the maximum depth is about 2.3 meters. The volume of the lake, 211,000 m^3, gets flushed every 21 days by the mean annual flow of 3,700,000 m^3/yr. Lake Absegami, formed by impoundments of two branches of Tommy's Branch just before its confluence with the East Branch of Bass River, is the center for most of the recreational activities in the State Forest. Mean depth and annual discharge were obtained from the Phase I Diagnostic/Feasibility Study of Lake Absegami (Princeton Hydro, LLC, 2002).

Figure 6 Lakeshed of Lake Absegami



4.8 Hammonton Lake

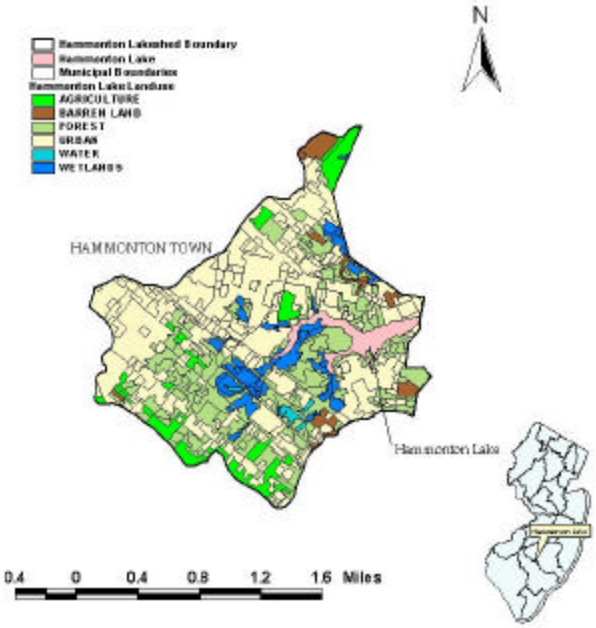
Hammonton Lake is a sprawling waterbody in Hammonton Township, Atlantic County, situated within the Pinelands region of Southern New Jersey. It is an elongated waterbody shaped roughly like a lower-case letter "h" written backwards. It is approximately 6,200 feet long and ranges between 300–500 feet wide. Mean depth has been calculated at 5 feet with maximum depths reaching 10 feet. Total surface area is 61 acres within a lakeshed area of 1,747 acres, making the ratio of watershed area to lake surface area 29:1. Total lake volume is approximately 379,000 m^3, with an average flow of 3,390,000 m^3/yr. Mean hydraulic retention time is about 41 days. Mean depth and annual discharge were obtained from the Hammonton Lake Diagnostic/Feasibility Study (Purcell Associates, 1981).

Originally a mill pond, the lake is an impoundment that goes back to the mid-1800's. The present 13-foot high dam located at its eastern end was built in 1919. A 7-foot wide spillway discharges into a culvert that flows underneath U.S. Route 30 (White Horse Pike). The lake is spring-fed and supplemented by small streams, storm drainage, direct precipitation, and overland flow, and subsequently forms the headwaters of Hammonton Creek. Traditional uses include swimming, non-power boating, fishing—anglers once came from miles away, and also aesthetics. Mesotrophic conditions with random shifts to eutrophic conditions,

however, have caused detrimental changes in the lake's water quality in recent decades, which have negatively impacted these lake uses.

Approximately half of the lakeshed is covered by residential development, which presses in upon the lake on multiple shores. The south-southwestern outskirts of the watershed include undeveloped parcels and agriculture lands, though these areas are on the decline due to development pressures. The spring-fed bathing area on the western shore was closed all year in 1999, predicating daily testing for fecal coliform starting in 2000. Due to the relatively slow movement of water that impedes recovery, the public beach is automatically closed after every rain event. The Township has adopted a geese ordinance and installed a ground water well to infuse additional volume into the lake to hasten recovery, and desires to restore the lake and protect its recreational value. While extensive restoration activities have been performed, most notably the Hammonton Lake Restoration Project completed in 1995, a TMDL is still warranted at this time. The lake restoration plan required by the TMDL will determine the extent to which past restoration efforts have been successful in restoring uses.

Figure 7 Lakeshed of Hammonton Lake

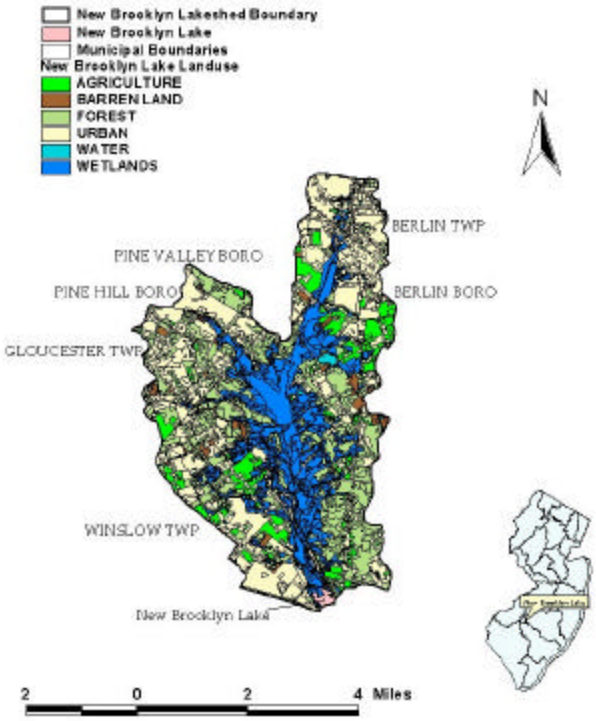


4.9 New Brooklyn Lake

New Brooklyn Lake is an impoundment of the Great Egg Harbor River located in Winslow Township, Camden County. The surface area of the lake is 48 acres with a drainage area of 14,700 acres, making the lake surface to drainage area ratio extremely large (300:1). Total volume is estimated to be 150,000 m^3, with a total inflow of 21,600,000 m^3/yr. Irregularities in dam construction made measuring outflow unreliable, so outflow is assumed to equal inflow. Mean depth was calculated to 5.8 feet. The lake's mean hydraulic retention time is calculated to be 2.5 days. The physical parameters noted above were obtained from the New Jersey Management Program Lakes Classification Study—New Brooklyn Lake, Winslow, Camden County (Princeton Aqua Science, 1983).

A substantial portion of the watershed is forest, with a large swath of it being forested wetlands, but an equal or greater amount has been developed into high-density residential interspersed with lower density housing and commercial undertakings. Agriculture and unforested open lands make up the remaining parcels. New Brooklyn Lake was once used extensively for recreation: swimming, boating, and fishing. Currently, however, excessive plant and algal growth has precluded most recreation.

Figure 8 Lakeshed of New Brooklyn Lake



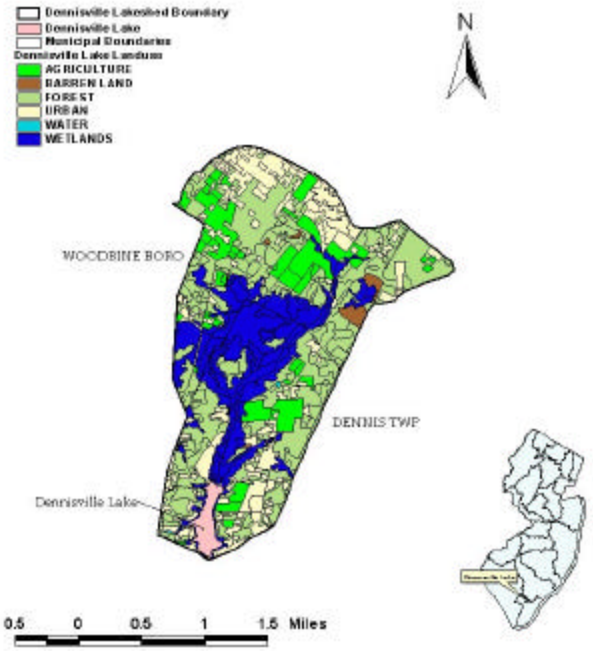
4.10 Dennisville Lake

Dennisville Lake—also known locally as Johnson's Mill Pond—is located just to the north of the small town of Dennisville in Dennis Township, Cape May County. Dennisville Lake is an impoundment lake that resulted when this unnamed tributary of Dennis Creek was damned in 1928. The outfall of the lake empties into a large wetland and cedar swamp area known as the Dennis Creek Wildlife Management Area. The lakeshed area is 2,500 acres while the lake's surface area is 48 acres, resulting in a lakeshed:lake area ratio of 53:1. Mean depth of the lake is 3.5 feet, with a maximum depth of 6 feet. Total volume is approximately 200,000 m^3 with an average hydraulic retention time of 16 days. Mean discharge at the outlet is calculated at 0.15 m^3/sec or 4,730,000 m^3 annually. Mean depth and total outflow were obtained from the Diagnostic/Feasibility Report for Dennisville Lake (F.X. Browne Associates, Inc., 1991).

The 3.7 square mile lakeshed is located in the Pinelands Protection Area. A 1987 New Jersey Department of Environmental Protection study indicated that effluent from the Woodbine State Colony Wastewater Treatment Plant discharging directly into Dennis Brook was causing excess productivity. The discharges were stopped in 1987 and effluent is now trucked off site. Water quality has since shown some improvement, but periodic and high phosphorous concentrations still occur, perhaps in part due to residual effects caused by the high levels of sedimentation.

Land use for the lakeshed is in large part evergreen forest and forested wetlands, approximately 65% when combined. Residential and commercial land use comprise about 15%. The remainder is cropland and pasture with ~2% accounting for lake and water surface. The residential portions are located mostly in the perimeter areas of the lake itself. The town of Woodbine and surrounding croplands and pasture occupy the northernmost part of the lakeshed, with a wide expanse of wetlands between it and the lake; both tributaries that converge north of the lake appear to be well-buffered with wetland and forest areas, although a solid waste landfill is located in the headwater region of the eastern tributary.. A Dennis Township Board of Education facility operates a Discharge to Groundwater (DGW) just off the bank of the northeastern quadrant of the lake. Monthly average flows generally fall within 2,000–4,000 gallons per day (gpd) during the school year, however, during the spring these averages may be considerably higher with daily maximums per month reaching as high as 19,200 gpd in May of 2002 and 20,270 gpd in April of 2001.

Figure 9 Lakeshed of Dennisville Lake

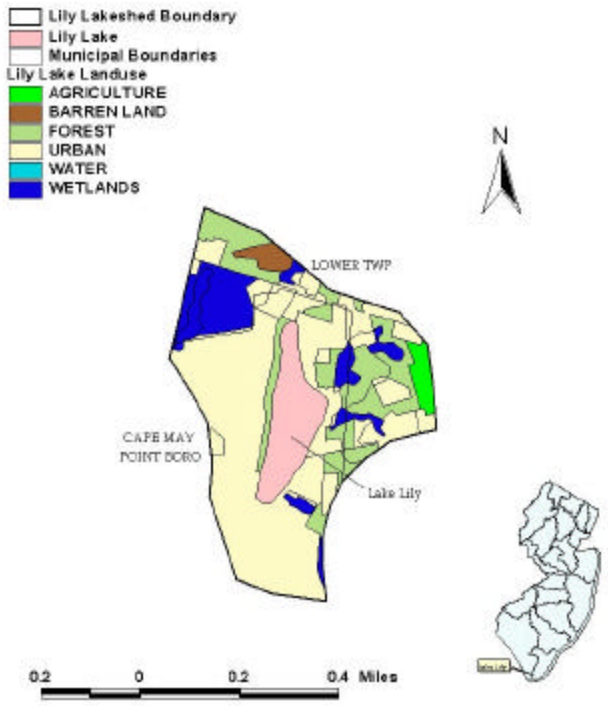


4.11 Lily Lake

Lily Lake is a small, shallow lake shaped like an elongated wedge, located in Cape May Point, Cape May County. Cape May Point occupies the southernmost tip of New Jersey, between the Delaware Bay and the Atlantic Ocean. Variable salinity has been recorded; saltwater intrusion is suspected. There are no tributaries to this lake; its hydrologic load is contributed mostly by groundwater infiltration through springs. Though much of the land bordering the lake is highly urbanized, contribution from surface runoff—as well as direct precipitation—is thought to be minimal. Lily Lake does, however, display symptoms of a eutrophic waterbody, with dense stands of aquatic weeds covering most of its surface during the summer. Due to these conditions, little or no recreational uses exist. Cape May Point is a critical juncture in the migratory paths of multiple species of birds, serving as a rest stop before or after crossing the expanse of the Delaware Bay. Lily Lake is an integral part of this bird sanctuary area, with a large area of forested wetlands to the north and a similarly large area of preserved salt marshes to the west. It is possible that this extensive population of temporary and year-round birds has a marked influence on the lake's nutrient load; however, this contribution has never been quantified.

Lily Lake's surface area is 15.8 acres within a 154-acre lakeshed, making the lake surface to drainage area ratio about 10:1. Mean depth is 2.9 feet, resulting in a lake volume of 56,500 m^3. Given the estimated outflow of 1,520,000 m^3/yr., mean hydraulic retention time is calculated to be about 14 days. Mean depth and annual discharge were obtained from the New Jersey Lakes Management Program Lakes Classification Study—Lily Lake, Cape may Point, Cape May County (Princeton Aqua Science, 1983). In order to quantify a groundwater load for this lake, the Department assumed that 75% of the inflow was from groundwater infiltration.

Figure 10 **Lakeshed of Lily Lake**



5.0 Applicable Surface Water Quality Standards

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.

Presently, no site-specific criteria apply to any of these lakes.

Also at N.J.A.C. 7:9B-1.5(g)2, the following is discussed:

> Except as due to natural conditions, nutrients shall not be allowed in concentrations that cause objectionable algal densities, nuisance aquatic vegetation, or otherwise render the waters unsuitable for the designated uses.

These TMDLs are designed to meet both numeric and narrative criteria of the SWQS.

All of the waterbodies covered under these TMDLs 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.

6.0 Source Assessment

Phosphorus sources 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.

6.1 Assessment of Point Sources other than Stormwater

Point sources of phosphorus other than stormwater were identified using the Department's GIS as all Major Municipal (MMJ), Minor Municipal (MMI), and Combined Sewer Overflow (CSO) discharges within each lakeshed. Other types of discharges, such as Industrial, were not included because their contribution, if any, is negligible compared to municipal discharges and runoff from land surfaces. Only one municipal point source exists within all the lakesheds of the lakes for which TMDLs are proposed. Camden County Vocational Technical School discharges to Sharps Branch within the lakeshed of New Brooklyn Lake. The current annual TP load was estimated by multiplying the average TP concentration, estimated to be 4 mg TP/l, by the average flow of 0.0234 million gallons per day (MGD), and converting to units of kg TP/yr. Average flow was calculated from data submitted to the Department as required in the form of Discharge Monitoring Reports. Similarly, the currently permitted annual TP load was estimated by multiplying the monthly average TP concentration by the permitted flow of 0.058 MGD, and converting to units of kg/yr. The permit for this facility does not include a phosphorus discharge limit or monitoring requirement.

Table 3 Point Source Phosphorus Loads other than Stormwater

Lake	NJPDES #	Facility Name	receiving water	current P load (kg TP/yr)	permitted P load (kg TP/yr)
New Brooklyn Lake	0031615.001A	Candem County Vo Tech School	Sharps Branch via storm sewer	129	321

6.2 Assessment of Nonpoint Sources and Stormwater

Runoff from land surfaces comprises most of the nonpoint and stormwater sources of phosphorus into lakes. Watershed loads for total phosphorus were therefore estimated using the Unit Areal Load (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 GIS system using the 1995/1997 land use coverage. The Department reviewed phosphorus export coefficients from an extensive database (Appendix B) and selected the land use categories and values shown in Table 4.

Table 4 Phosphorus export coefficients (Unit Areal Loads)

land use / land cover	LU/LC codes[3]	UAL (kg TP/ha/yr)
medium / high density residential	1110, 1120, 1150	1.6
low density / rural residential	1130, 1140	0.7
Commercial	1200	2.0
Industrial	1300, 1500	1.7
mixed urban / other urban	other urban codes	1.0
Agricultural	2000	1.5
forest, wetland, water	4000, 6000, 5000	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

For all lakes in this TMDL document, 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). Land uses and calculated runoff loading rates for each of the lakes are shown in Tables 5-6. Also included in Tables 5-6 are estimates of loading rates from septic systems, waterfowl and from internal sources (sediment regeneration, macrophyte decomposition) where such estimates had already been developed previously for each of the lakes. Finally, groundwater loads were estimated for lakes known to have a substantial groundwater flow component. The annual groundwater flow was multiplied by a phosphorus concentration of 0.1 mg TP/l and then converted to kg TP/yr.

[3] LU/LC code is an attribute of the land use coverage that provides the Anderson classification code for the land use. The Anderson classification system is a hierarchical system based on four digits. The four digits represent one to four levels of classification, the first digit being the most general and the fourth digit being the most specific description.

Table 5 Nonpoint and Stormwater Sources of Phosphorus Loads

Nonpoint Source	Deal Lake		Franklin Lake		Hooks Creek		Pohatcong Lake		Absegami Lake	
	acres	kg/yr	acres	kg/yr	acres	kg/yr	acres	kg/yr	acres	kg/yr
land use loads										
medium / high density residential	1520	982	331.5	215	0.0	0.0	124	80.3	0.0	0.0
low density / rural residential	33	95.2	23.2	6.6	0.0	0.0	304	86.2	4.5	1.3
commercial	39	318	47.9	38.7	0.3	0.3	54.8	44.4	0.0	0.0
industrial	96.7	66.5	0.0	0.0	0.0	0.0	6.0	4.1	0.0	0.0
mixed urban / other urban	54	222	72.7	29.4	6.4	2.6	191	77.4	77.8	31.5
agricultural	12.2	7.4	9.5	5.7	0.0	0.0	9.2	5.6	0.1	0.1
forest, wetland, water	850	34.4	39.2	1.6	29.2	1.2	7120	288	2210	89.3
barren land	78.1	15.8	0.1	0.0	0.0	0.0	64.8	13.1	11.2	2.3
other loads										
septic systems	n/a		n/a		n/a		n/a	288	n/a	
waterfowl				77.0						
internal load		75.0				3.1				13.1
tributary load		n/a		n/a		n/a		n/a		n/a
natural loads										
air deposition	155	4.4	14.6	0.4	10.6	0.3	35.4	1.0	52.6	1.5
groundwater	n/a		n/a		n/a	0.5	n/a		n/a	23.0
TOTAL	**3990**	**1820**	**538**	**374**	**46.6**	**7.9**	**7910**	**888**	**2350**	**162**

Table 6 Nonpoint and Stormwater Sources of Phosphorus Loads (cont'd)

Nonpoint Source	Hammonton Lake		New Brooklyn Lake		Dennisville Lake		Lily Lake	
	acres	kg/yr	acres	kg/yr	acres	kg/yr	acres	kg/yr
land use loads								
medium / high density residential	346	224	2830	1830	61.0	39.5	65	42.1
low density / rural residential	285	80.7	966	274	236	67.0	15.5	4.4
commercial	69.2	56.0	504	408	61.6	49.9	0	0
industrial	64.2	44.2	164	113	1.3	0.9	0	0
mixed urban / other urban	164	66.4	1200	484	136	54.9	5.6	2.3
agricultural	122	74.2	1180	715	341	207	3.3	2
forest, wetland, water	579	23.4	7448	301	1619	65.5	46.1	1.9
barren land	56.4	11.4	366	74.0	36.6	7.4	2.6	0.5
other loads								
septic systems	n/a		n/a		n/a		n/a	
waterfowl								
internal load						44.0		
tributary load		n/a		n/a		n/a		n/a
natural loads								
air deposition	61.4	1.7	48.3	1.4	47.9	1.4	15.8	0.4
groundwater	n/a		n/a		n/a		n/a	11.4
TOTAL	**1750**	**582**	**14700**	**4330**	**2541**	**556**	**154**	**65**

7.0 Water Quality Analysis

Empirical models were used to relate annual phosphorus load and steady-state in-lake concentration of total phosphorus. 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 Department surveyed the commonly used models in Table 7.

Table 7 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
Walker, 1977	$\frac{P_a \times DT / D_m}{(1 + 0.824 \times DT^{0.454})}$	none	oxic lakes with $D_m / DT < 50$ m/yr
Jones and Bachmann, 1976	$\frac{0.84 \times P_a}{(D_m \times (0.65 + DT^{-1}))}$	none	may overestimate P in shallow lakes with high D_m / DT
Vollenweider, 1975	$\frac{P_a}{(D_m \times (DT^{-1} + S))}$	$S = 10 / D_m$	Overestimate P lakes with high D_m / DT
Dillon-Kirchner, 1975	$\frac{P_a}{\left(13.2 + D_m / DT\right)}$	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

reference	steady-state TP concentration in lake (mg/l)	Secondary term	Application
Larsen-Mercier, 1975	Dillon-Rigler, 1974	$R = \frac{1}{1+\sqrt{1/DT}}$	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)
Qa = areal water load (m / yr) [4]
Q_i = total inflow (m^3/yr)
A_l = area of lake (m^2)
S = settling rate (per year)

Reckhow (1979a) model was selected because it has the broadest range of hydrologic, morphological and loading characteristics in its database. Also, the model includes an uncertainty estimate that was used to calculate a Margin of Safety. 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, which exhibit the following ranges of characteristics (see Symbol definitions after Table 7):

phosphorus concentration: $0.004 < P < 0.135$ mg / l
average influent phosphorus concentration: $P_a*DT / D_m < 0.298$ mg / l
areal water load: $0.75 < Q_a < 187$ m / yr
areal phosphorus load: $0.07 < P_a < 31.4$ $g/m^2/yr$

For comparison, Table 8 below summarizes the characteristics for each lake based on their current and target conditions as described below. While the target concentration for each lake (section 7) is well within the range, the areal phosphorus load provides a better representation of a lake's intrinsic loading characteristics. Also, it is the model's prediction of target condition that is being used to calculate the TMDL; if current loads are higher than the range that can produce reliable model results, this has no affect on the model's reliability to predict target condition under reduced loads. It should also be noted that no attempt was made to recalibrate the Reckhow (1979a) model for lakes in New Jersey or in this Water Region, since sufficient lake data were not available to make comparisons with model predictions of steady-state in-lake concentration of total phosphorus. The model was already calibrated to the dataset on which it is based, and is generally applicable to north temperate lakes that exhibit the range of characteristics listed previously.

[4] Areal water load is defined as the annual water load entering a lake divided by the area of the lake. Since, under steady-state conditions, the water coming in to the lake is equal to the water leaving the lake, either total inflow or total outflow can be used to calculate areal water load. If different values were reported for total inflow and total outflow, the Department used the higher of the two to calculate areal water load.

Table 8 Hydrologic and loading characteristics of lakes

Lake	Current Avg Influent [TP] (mg/l)	Target Avg Influent [TP] (mg/l)	Current Areal TP load (g/m²/yr)	Target Areal TP load (g/m²/yr)	Areal Water Load (m/year)
Deal Lake	0.182	0.038	2.89	0.61	15.9
Franklin Lake	0.349	0.037	6.32	0.66	18.1
Hook's Creek Lake	0.077	0.077	0.18	0.18	2.4
Pohatcong Lake	0.037	0.025	6.20	4.21	167
Absegami Lake	0.044	0.037	0.76	0.64	17.4
Hammonton Lake	0.172	0.041	2.34	0.56	13.6
New Brooklyn Lake	0.201	0.028	22.17	3.10	111
Dennisville Lake	0.118	0.033	2.87	0.81	24.2
Lily Lake	0.043	0.034	1.02	0.80	15.1

7.1 Current Condition

Using these estimated physical parameters and current loads, the predicted steady-state phosphorus concentration of each lake was calculated using the Reckhow (1979a) formulation and listed in Table 9. The current phosphorus load distribution for each lake is shown in Figures 11 to 19 below.

Figure 11 Current distribution of phosphorus load for Deal Lake

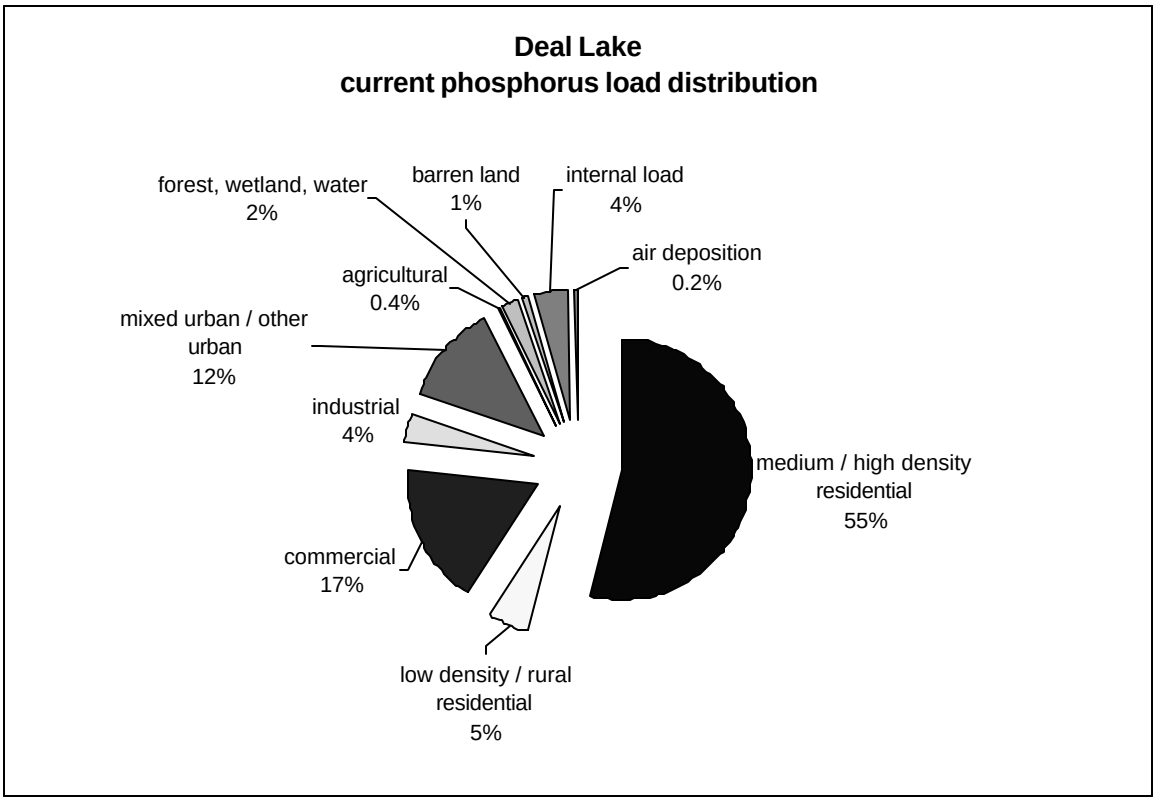


Figure 12 **Current distribution of phosphorus load for Franklin Lake**

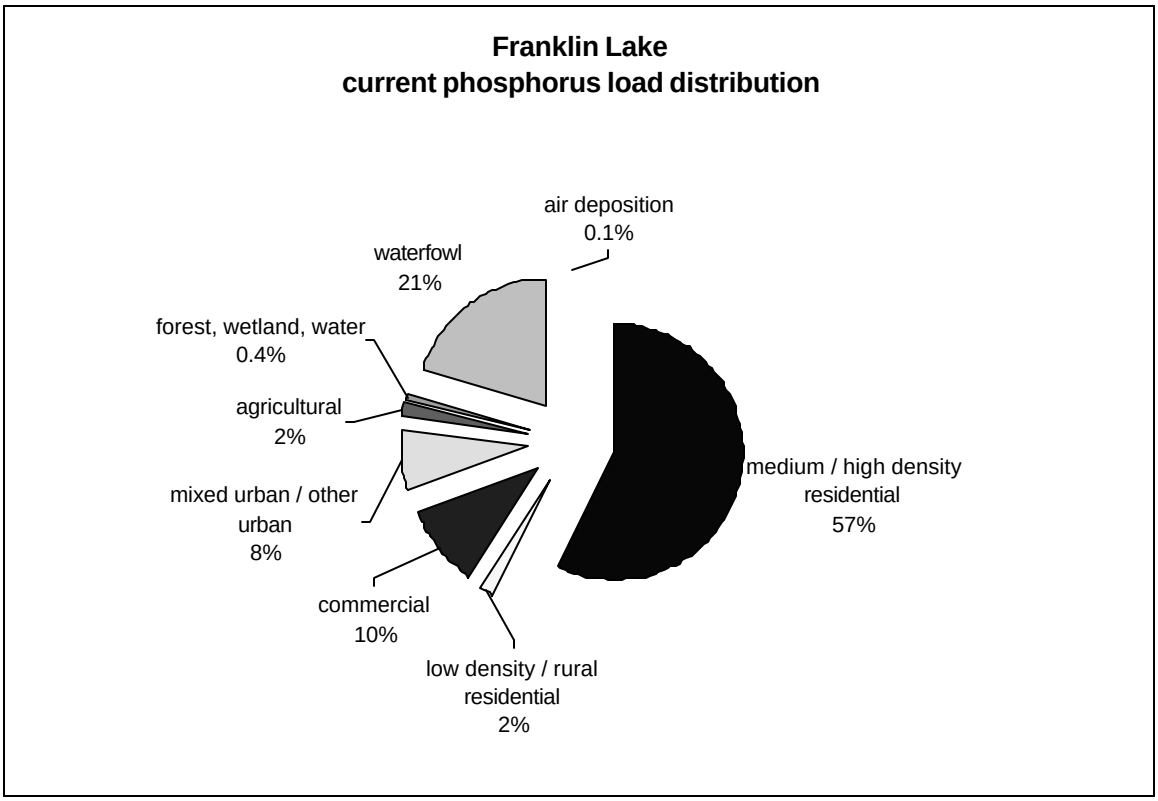


Figure 13 **Current distribution of phosphorus load for Hooks Creek Lake**

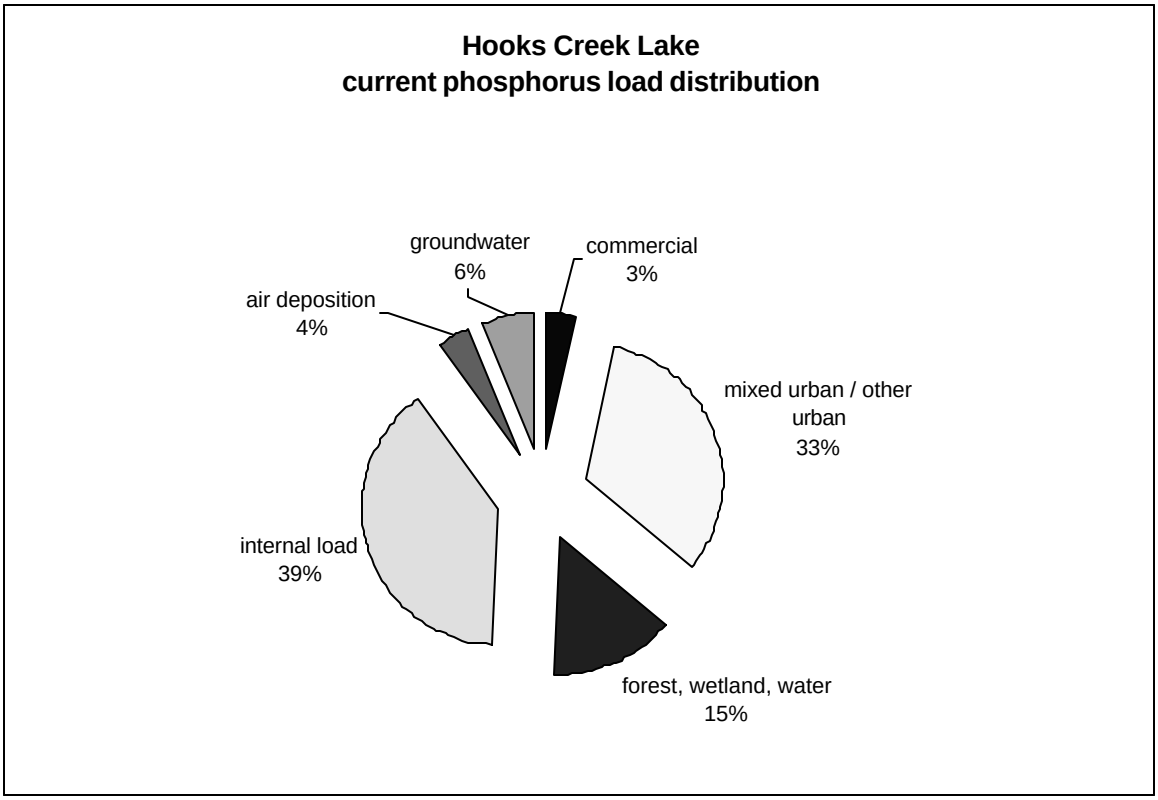


Figure 14 **Current distribution of phosphorus load for Pohatcong Lake**

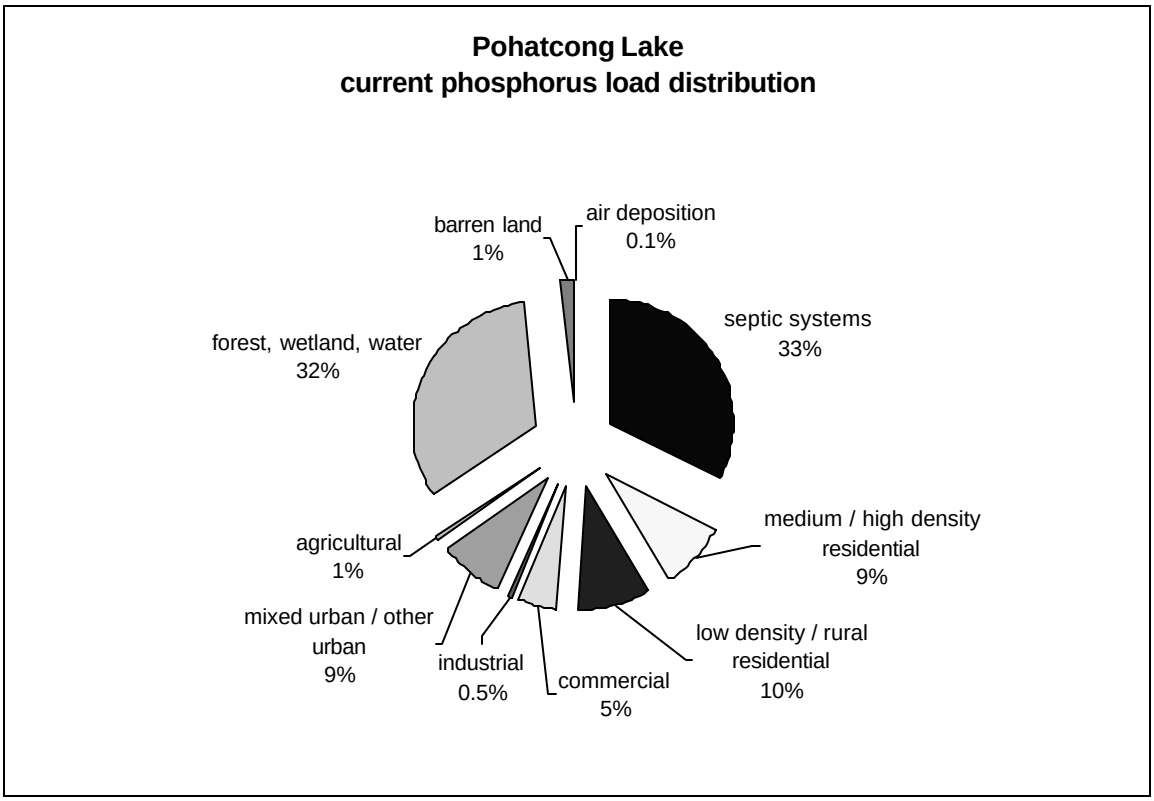


Figure 15 **Current distribution of phosphorus load for Absegami Lake**

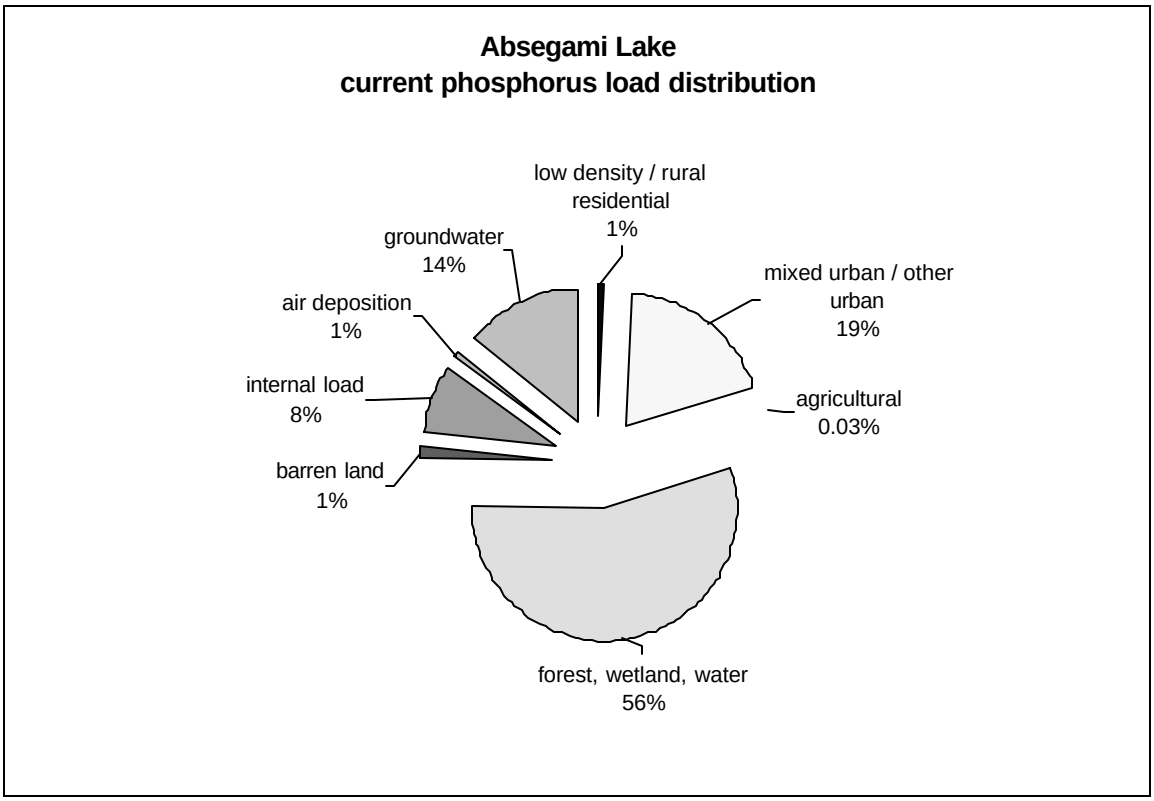


Figure 16 **Current distribution of phosphorus load for Hammonton Lake**

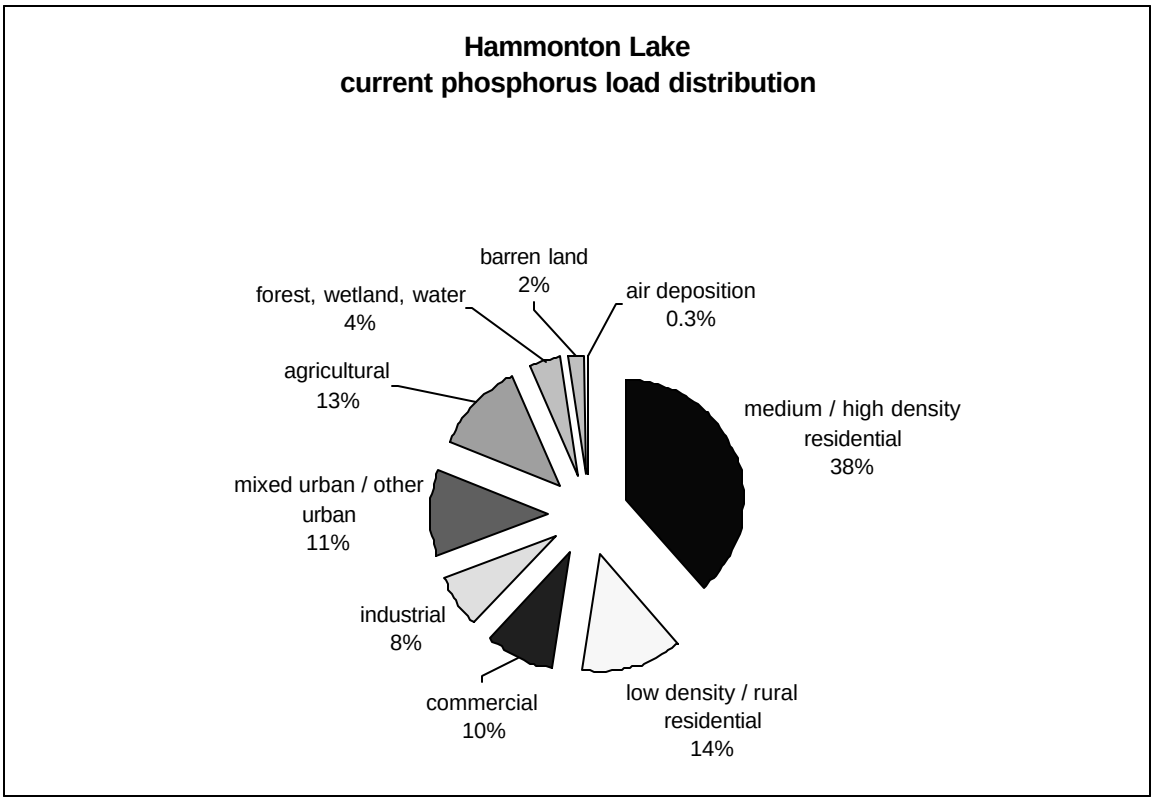


Figure 17 **Current distribution of phosphorus load for New Brooklyn Lake**

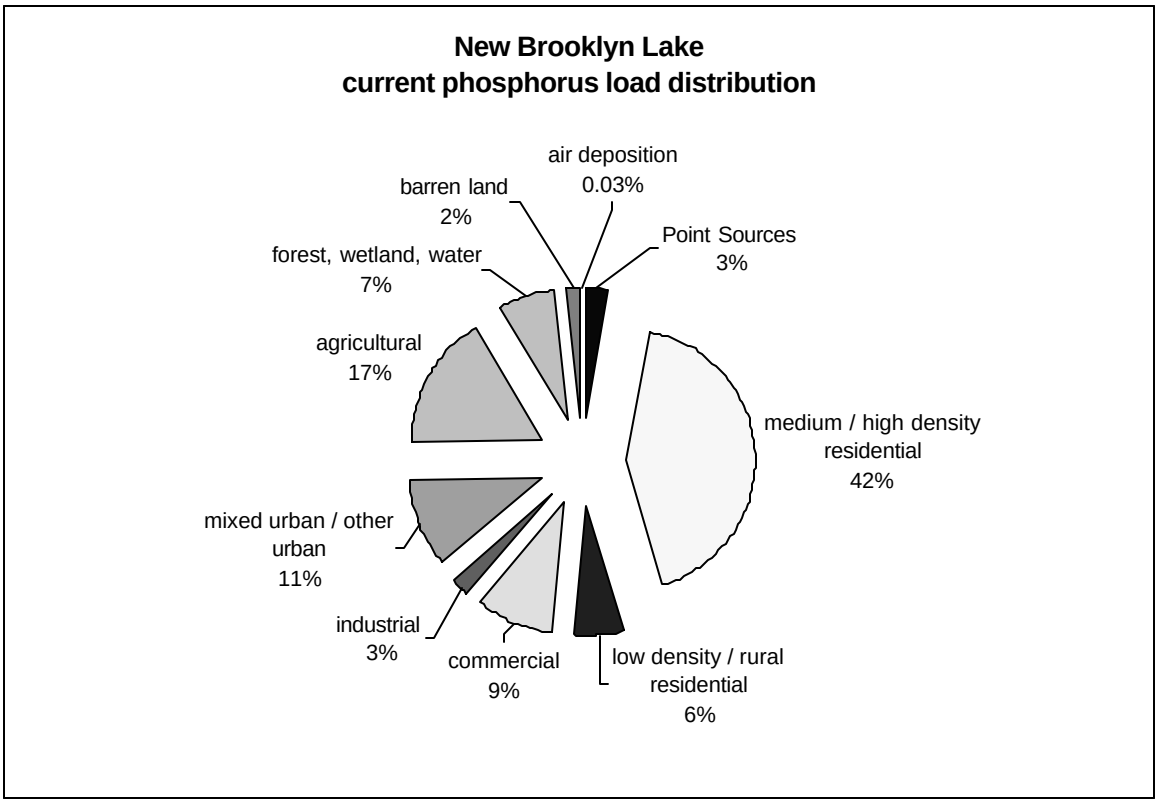


Figure 18 **Current distribution of phosphorus load for Dennisville Lake**

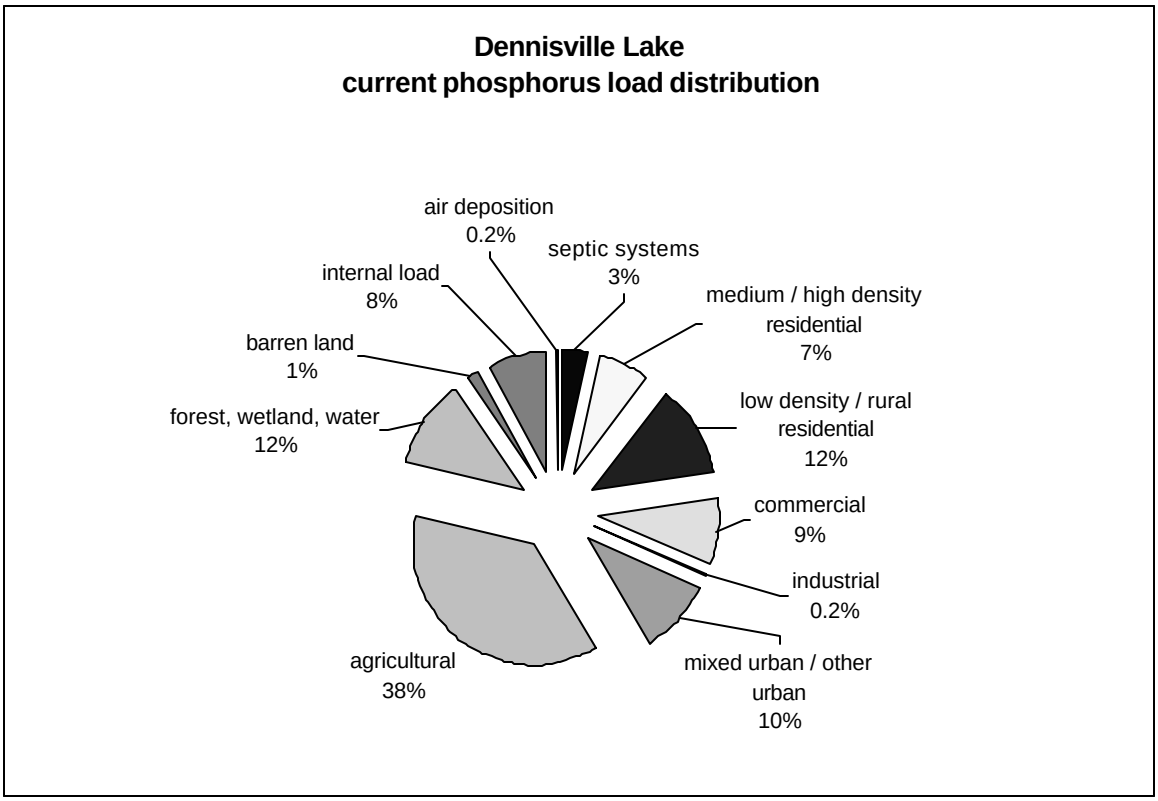
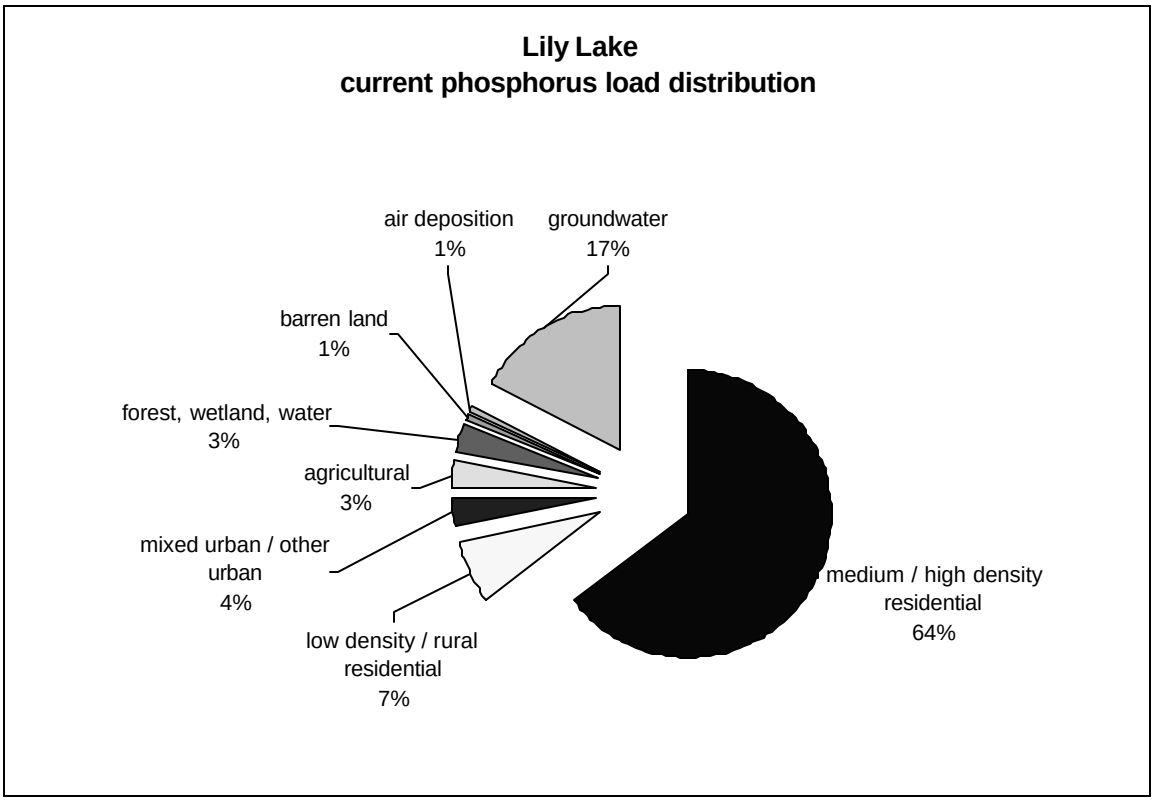


Figure 19 **Current distribution of phosphorus load for Lily Lake**



7.2 Reference Condition

A reference condition for each lake was estimated by calculating external loads as if the land use throughout the lakeshed were completely forest and wetlands. Estimates of air deposition and groundwater loads were included to calculate the reference condition. Using the same physical parameters and external loads from forest and wetlands, a reference steady-state phosphorus concentration was calculated for each lake using the Reckhow (1979a) formulation and listed in Table 9.

7.3 Seasonal Variation/Critical Conditions

These TMDLs will attain applicable surface water quality standards year round. The Reckhow model predicts steady-state phosphorus concentration. To account for data variability, the Department generally interprets threshold criteria as greater than 10% exceedance for the purpose of defining impaired waterbodies. Data from two lakes in New Jersey for which the Department had ready access to data (Strawbridge Lake, NJDEP 2000a; Sylvan Lake, NJDEP 2000b) exhibit peak (based on the 90th percentile) to mean ratios of 1.56 and 1.48, resulting in target phosphorus concentrations of 0.032 and 0.034 mg TP/l, respectively. Since the peak to mean ratios were close and the target concentration not very sensitive to differences in peak to mean ratios, the Department determined that a target phosphorus concentration of 0.03 mg TP/l is reasonably conservative. The seasonal variation was therefore assumed to be 67%, resulting in a target phosphorus concentration of 0.03 mg TP/l. 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.

7.4 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 these TMDL calculations, an implicit as well as explicit Margin of Safety (MOS) is provided.

These TMDLs contain an implicit margin of safety by using conservative critical conditions, over-estimated loads, and total phosphorus. Each conservative assumption is further explained below.

Critical conditions are accounted 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 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 adsorption onto land surfaces and in-stream kinetic

processes. Furthermore, the lakesheds are based on topography without accounting for the diversion of stormwater from lakes, which is common in urban areas. Neither are any reductions assumed due to the addition of lakeside vegetative buffer construction or other management practices aimed at minimizing phosphorus loads. Finally, 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 multiple conservative assumptions built in to the calculation, an additional explicit margin of safety 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):

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

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 margin of safety 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 margin of safety 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 9. Note that the explicit Margin of Safety is equal to 51% when expressed as a percentage over the predicted phosphorus concentration; when expressed as a percentage of total loading capacity, the Margin of Safety is equal to 34%:

$$\left(MoS_{lc} = \frac{MoS_p \times P}{P + \left(MoS_p \times P\right)} = \frac{MoS_p}{1 + MoS_p} = \frac{0.51}{1.51} = 0.34 \right),$$

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).

7.5 Target Condition

As discussed above, the current steady state concentration of phosphorus in each lake must be reduced to a steady state concentration of 0.03 mg/l to avoid exceeding the 0.05 mg/l phosphorus criterion. Using the Reckhow (1979a) formulation, the target conditions were calculated by reducing the loads as necessary to make the upper bound predictions (which incorporate the Margin of Safety) equal to the target phosphorus concentration of 0.03 mg TP/l. The target condition for each lake was adjusted as necessary (New Brooklyn Lake) to prevent it from being lower than the reference condition. The target condition for Hooks Creek Lake was set equal to the current condition, since the upper bound prediction assuming current loads is already less than the target phosphorus concentration of 0.03 mg TP/l. Overall reductions necessary to attain the target steady state concentration of total phosphorus in each lake were calculated by comparing the current condition to the target condition (Table 9).

Table 9 Current condition, reference condition, target condition and overall percent reduction for each lake

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
Deal Lake	0.094	0.009	0.030	0.020	79%
Franklin Lake	0.190	0.011	0.030	0.020	90%
Hook's Creek Lake	0.013	0.004	0.019	0.013	0%
Pohatcong Lake	0.029	0.011	0.030	0.020	32%
Absegami Lake	0.023	0.017	0.030	0.020	15%
Hammonton Lake	0.084	0.010	0.030	0.020	76%
New Brooklyn Lake	0.154	0.021	0.032	0.021	86%
Dennisville Lake	0.070	0.013	0.030	0.020	72%
Lily Lake	0.025	0.007	0.030	0.020	22%

8.0 TMDL Calculations

8.1 Loading Capacity

The Reckhow (1979a) model was used to solve for loading rate given the upper bound target concentration of 0.03 mg/l (which incorporates the Margin of Safety). Reducing the current loading rates by the percentages in Table 9 yields the same results. The acceptable loading capacity for each lake is provided in Tables 11-13.

8.2 Reserve Capacity

Reserve capacity is an optional means of reserving a portion of the loading capacity to allow for future growth. Reserve capacities are not included at this time. Therefore, the loading capacities and accompanying WLAs and LAs must be attained in consideration of any new sources that may accompany future development. The primary means by which future growth could increase phosphorus load is through the development of forest land within the lakesheds. The implementation plan includes the development of Lake Restoration Plans that

require the collection of more detailed information about each lakeshed. If the development of forest with the watershed of a particular lake is planned, the issue of reserve capacity to account for the additional runoff load of phosphorus may be revisited.

8.3 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 TMDLs for total phosphorus are therefore calculated as follows (Tables 11-13):

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

WLAs are hereby established for all NJPDES-regulated point sources within each source category, while LAs are established for stormwater sources that are not subject to NJPDES regulation and for all nonpoint sources. This distribution of loading capacity between WLAs and LAs is consistent with recent EPA guidance that clarifies existing regulatory requirements for establishing WLAs for stormwater discharges (Wayland, November 2002). Stormwater discharges are captured within the runoff sources quantified according to land use, as described previously. Distinguishing between regulated and unregulated stormwater is necessary in order to express WLAs and LAs numerically; however, "EPA recognizes that these allocations might be fairly rudimentary because of data limitations and variability within the system." (Wayland, November 2002, p.1) While the Department does not have the data to actually delineate lakesheds according to stormwater drainage areas subject to NJPDES regulation, the land use runoff categories previously defined can be used to estimate between them. Therefore allocations are established according to source categories as shown in Table 10. This demarcation between WLAs and LAs based on land use source categories is not perfect, but it represents the best estimate defined as narrowly as data allow. The Department acknowledges that there may be stormwater sources in the residential, commercial, industrial and mixed urban runoff source categories that are not NJPDES-regulated. Nothing in these TMDLs, including Table 10, shall be construed to require the Department to regulate a stormwater source under NJPDES that would not already be regulated as such, nor shall anything in these TMDLs be construed to prevent the Department from regulating a stormwater source under NJPDES. WLAs are hereby established for all NJPDES-regulated point sources, including stormwater, according to their source category. Quantifying WLAs and LAs according to source categories provides the best estimation defined as narrowly as data allow. However it is clearly noted that WLAs are hereby established for all NJPDES-regulated point sources within each source category, while

LAs are established for stormwater sources that are not subject to NJPDES regulation and for all nonpoint sources. The WLAs and LAs in Tables 11-13 are not themselves "Additional Measures" under proposed N.J.A.C. 7:14A-25.6 or 25.8.

Table 10 Distribution of WLAs and LAs among source categories

Source category	TMDL allocation
Point Sources other than Stormwater	WLA
Nonpoint and Stormwater Sources	
medium / high density residential	WLA
low density / rural residential	WLA
commercial	WLA
industrial	WLA
Mixed urban / other urban	WLA
agricultural	LA
forest, wetland, water	LA
barren land	LA
air deposition onto lake surface	LA
septic systems	LA
internal load	LA
tributary load	LA

In order to attain the TMDLs, load reductions must be achieved such that the total load does not exceed the loading capacity. Since loading rates have been defined for at least nine source categories, countless combinations of source reductions could be used to achieve the overall reduction target. The selected scenarios focus on land use and septic sources that can be affected by BMP implementation or NJPDES regulation, requiring equal percent reductions from each in order to achieve the necessary overall load reduction (Tables 11-13). The percent reductions themselves are not part of the TMDL, but are based on estimates of the current condition as described in section 7; they are provided for reference only. The Lake Restoration Plans developed for each lake as part of the TMDL implementation (section 10) may revisit the distribution of reductions among the various sources as determined through additional monitoring and in order to better reflect actual implementation projects.

The WLA of 80 kg TP / yr for Camden County Vo-Tech School was calculated by multiplying the proposed TP concentration limit of 1.0 mg TP / l by the currently permitted flow of 0.058 MGD, and converting to units of kg TP / yr. This WLA represents about a 75% decrease from currently permitted annual TP load of 321 kg / yr and a 38% decrease from the actual current annual TP load of 129 kg / yr (section 6.1). Because the lakeshed of New Brooklyn lake is 300 times the size of the lake, it was necessary to use the reference condition as the basis for the target condition. New Brooklyn lake requires substantial reductions of both point and nonpoint sources in the lakeshed in order to achieve the loading capacity. The WLA for this NJPDES permittee will therefore not be incorporated into a revised permit until a lake restoration plan has been developed for the lake. The lake restoration plan will need to address the feasibility of all source reductions and may have to evaluate the attainment of all uses for this lake.

The resulting TMDLs, rounded to two significant digits, are shown in Tables 11-13 and illustrated in Figures 20 to 28.

Table 11 TMDL calculations for each lake (annual loads and percent reductions[a])

lake	Deal Lake		%	Franklin Lake		%	Hook's Creek Lake		%
	kg TP/yr	% of lC	reduction	kg TP/yr	% of lC	reduction	kg TP/yr	% of lC	reduction
loading capacity (LC)	580	100%	n/a	59	100%	n/a	12	100%	n/a
Point Sources other than Stormwater									
minor municipal	n/a			n/a			n/a		
Nonpoint and Stormwater Sources									
medium / high density residential	180	32%	81%	21	36%	90%			
low density / rural residential	18	3.1%	81%	0.7	1.1%	90%			
commercial	59	10%	81%	3.9	6.5%	90%	0.3	2.2%	0%
industrial	12	2.1%	81%						
Mixed urban / other urban	41	7.1%	81%	2.9	5.0%	90%	2.6	22%	0%
agricultural	1.4	0.2%	81%	0.6	1.0%	90%			
forest, wetland, water	34	5.9%	0%	1.6	2.7%	0%	1.2	9.9%	0%
barren land	16	2.7%	0%	0.0	0.0%	0%			
septic systems									
waterfowl				7.7	13%	90%			
internal load	14	2.4%	81%				3.1	26%	0%
tributary load	n/a			n/a			n/a		
Natural Sources / Background									
air deposition onto lake surface	4.4	0.8%	0%	0.4	0.7%	0%	0.3	2.5%	0%
groundwater							0.5	4.2%	0%
Other Allocations									
explicit Margin of Safety	200	34%	n/a	20	34%	n/a	4.1	34%	n/a

a Percent reductions shown for individual sources are necessary to achieve overall reductions in Table 9.

Table 12 TMDL calculations for each lake (annual loads and percent reductions[a], cont'd)

lake	Pohatcong Lake		%	Absegami Lake		%	Hammonton Lake		%
	kg TP/yr	% of IC	reduction	kg TP/yr	% of IC	reduction	kg TP/yr	% of IC	reduction
loading capacity (LC)	910	100%	n/a	210	100%	n/a	210	100%	n/a
Point Sources other than Stormwater									
minor municipal	n/a			n/a			n/a		
Nonpoint and Stormwater Sources									
medium / high density residential	41	4.5%	49%				42	20%	81%
low density / rural residential	44	4.8%	49%	0.6	0.3%	54%	15	7.2%	81%
commercial	23	2.5%	49%				10	5.0%	81%
industrial	2.1	0.2%	49%				8.2	3.9%	81%
Mixed urban / other urban	40	4.4%	49%	15	7.0%	54%	12	5.9%	81%
agricultural	2.9	0.3%	49%	0.02	0.01%	54%	14	6.6%	81%
forest, wetland, water	290	32%	0%	89	43%	0%	23	11%	0%
barren land	13	1.4%	0%	2.3	1.1%	0%	11	5.5%	0%
septic systems	150	16%	49%						
waterfowl									
internal load				6.0	2.9%	54%			
tributary load	n/a			n/a			n/a		
Natural Sources / Background									
air deposition onto lake surface	1.0	0.1%	0%	1.5	0.7%	0%	1.7	0.8%	0%
groundwater				23	11%	0%			
Other Allocations									
explicit Margin of Safety	310	34%	n/a	70	34%	n/a	71	34%	n/a

a Percent reductions shown for individual sources are necessary to achieve overall reductions in Table 9.

Table 13 TMDL calculations for each lake (annual loads and percent reductions[a], cont'd)

lake	New Brooklyn Lake		%	Dennisville Lake		%	Lily Lake		%
	kg TP/yr	% of lC	reduction	kg TP/yr	% of lC	reduction	kg TP/yr	% of lC	reduction
loading capacity (LC)	900	100%	n/a	240	100%	n/a	77	100%	n/a
Point Sources other than Stormwater									
minor municipal	80	8.9%	75%[b]	n/a			n/a		
Nonpoint and Stormwater Sources									
medium / high density residential	67	7.5%	96%	6.8	2.9%	83%	30	40%	28%
low density / rural residential	10	1.1%	96%	12	4.9%	83%	3.2	4.10%	28%
commercial	15	1.7%	96%	8.6	3.6%	83%			
industrial	4.1	0.5%	96%	0.2	0.1%	83%			
Mixed urban / other urban	18	2.0%	96%	9.5	4.0%	83%	1.6	2.10%	28%
agricultural	26	2.9%	96%	36	15%	83%	1.4	1.90%	28%
forest, wetland, water	300	33%	0%	66	28%	0%	1.9	2.40%	0%
barren land	74	8.2%	0%	7.4	3.1%	0%	0.5	0.70%	0%
septic systems				3.1	1.3%	83%			
waterfowl									
internal load				7.6	3.2%	83%			
tributary load	n/a			n/a			n/a		
Natural Sources / Background									
air deposition onto lake surface	1.4	0.2%	0%	1.4	0.6%	0%	0.4	0.60%	0%
groundwater							11	15%	0%
Other Allocations									
explicit Margin of Safety	300	34%	n/a	80	34%	n/a	26	34%	n/a

a Percent reductions shown for individual sources are necessary to achieve overall reductions in Table 9.
b Percent reduction for point source is compared to currently permitted annual load, not actual current load.

Figure 20 **Phosphorus allocations for Deal Lake TMDL**

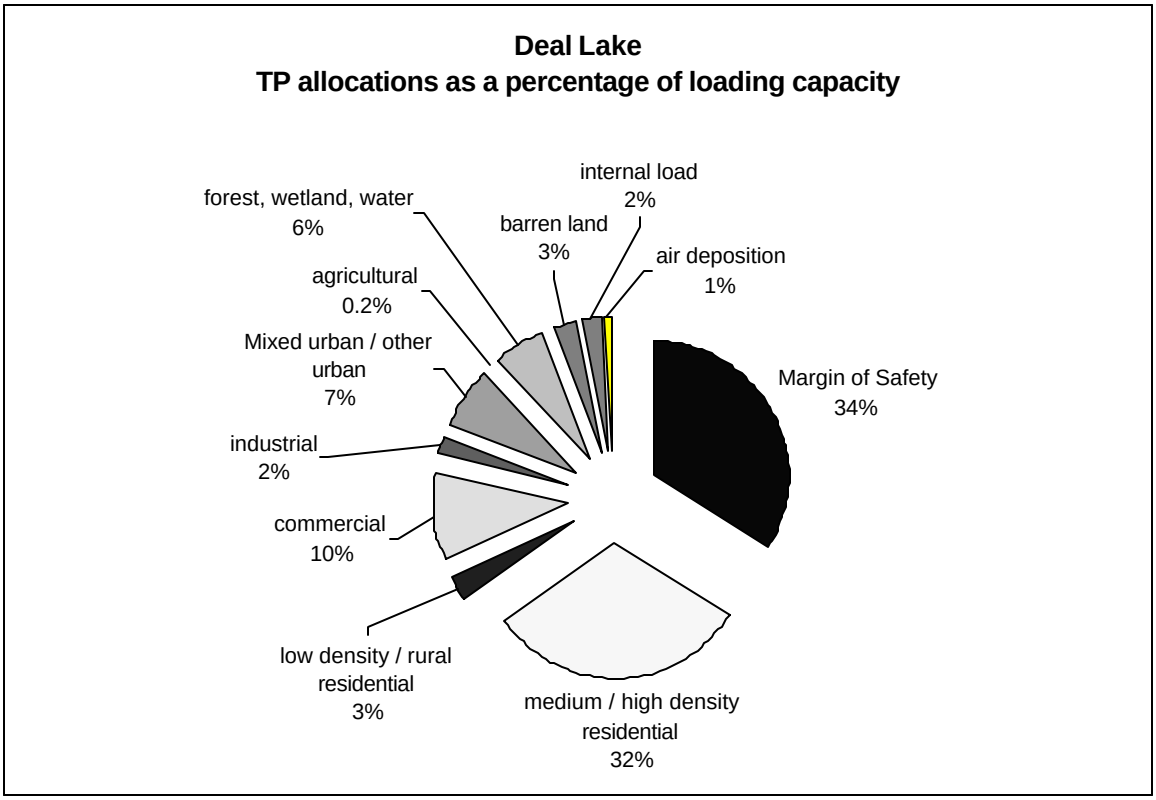


Figure 21 **Phosphorus allocations for Franklin LakeTMDL**

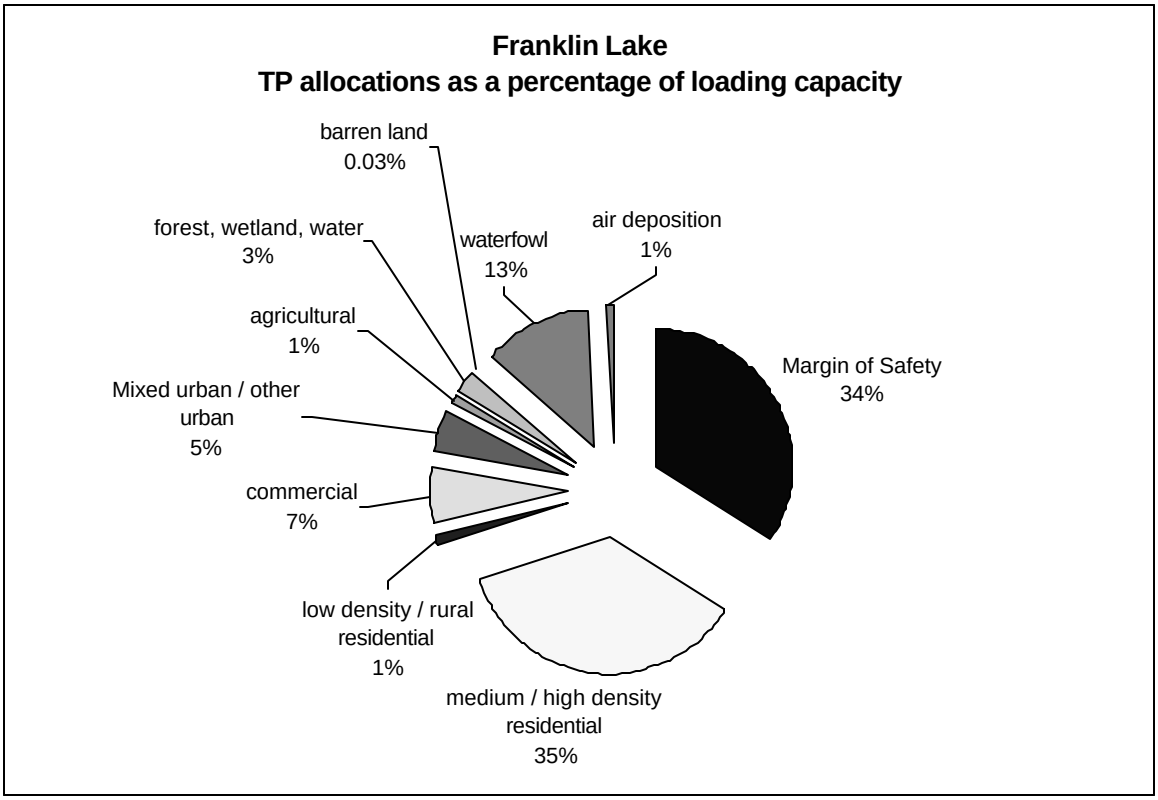


Figure 22 **Phosphorus allocations for Hooks Creek Lake TMDL**

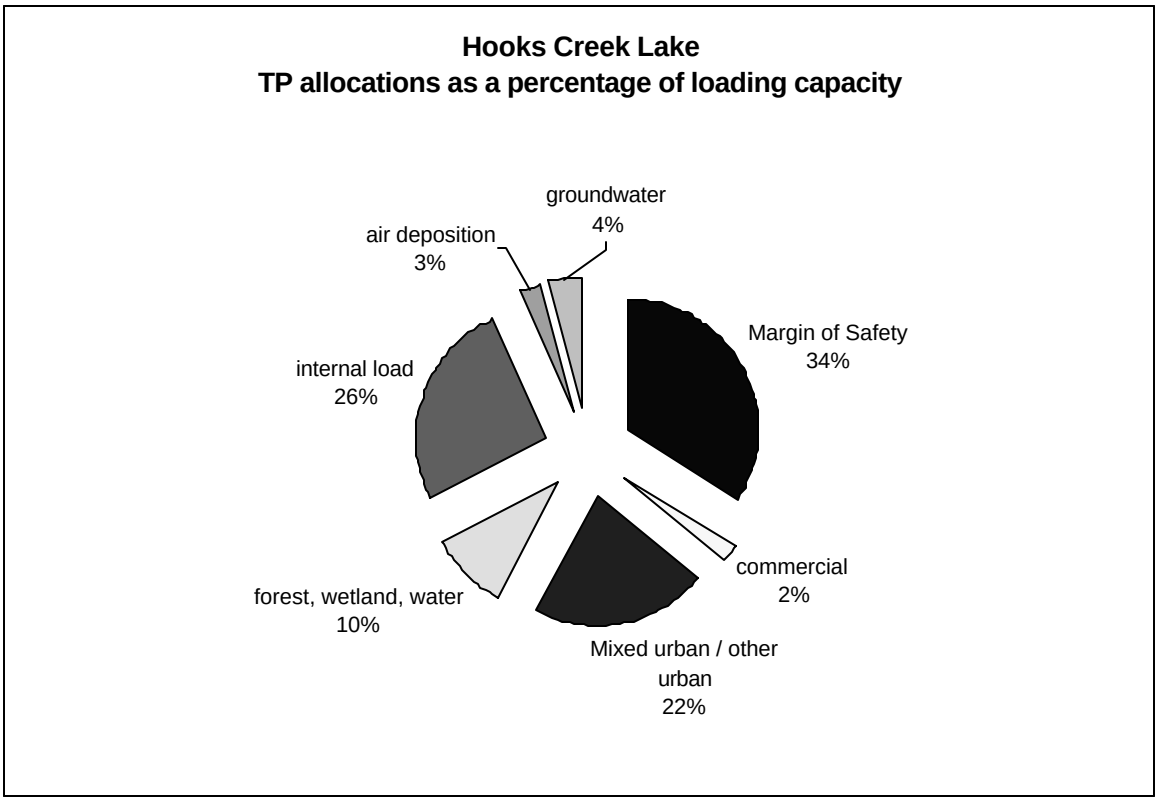


Figure 23 **Phosphorus allocations for Pohatcong Lake TMDL**

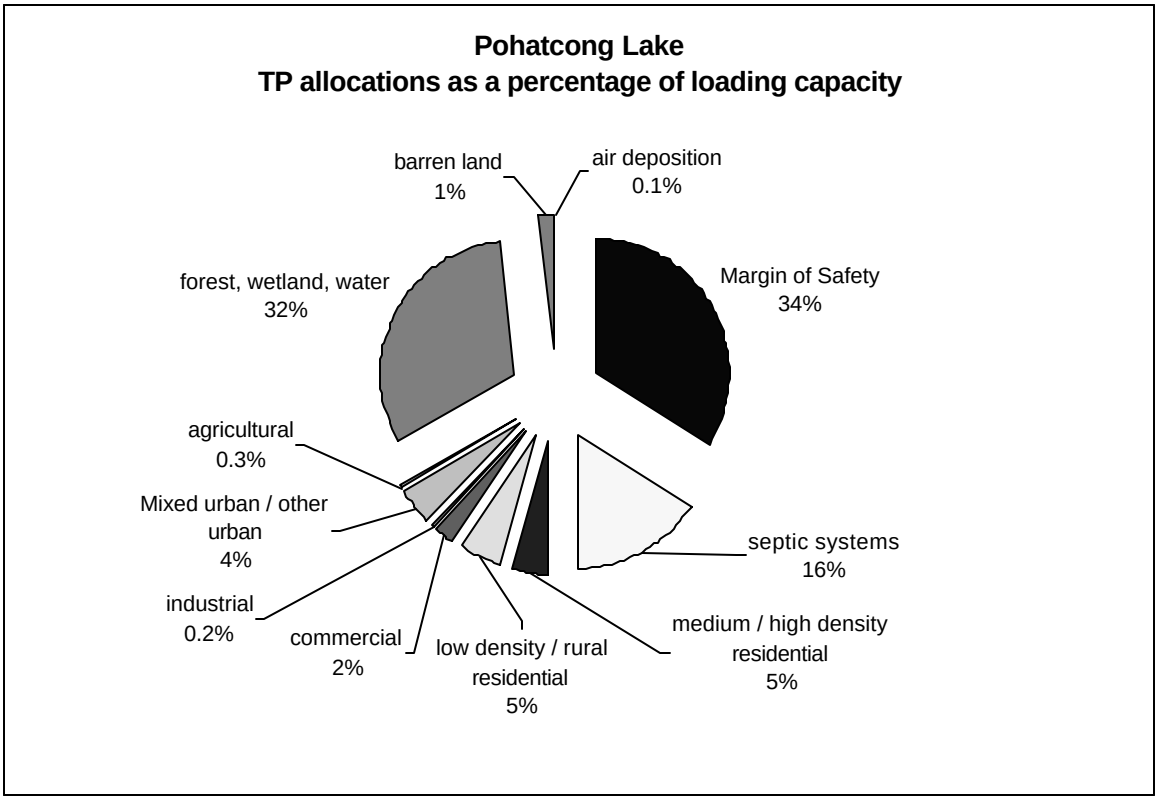


Figure 24 **Phosphorus allocations for Absegami LakeTMDL**

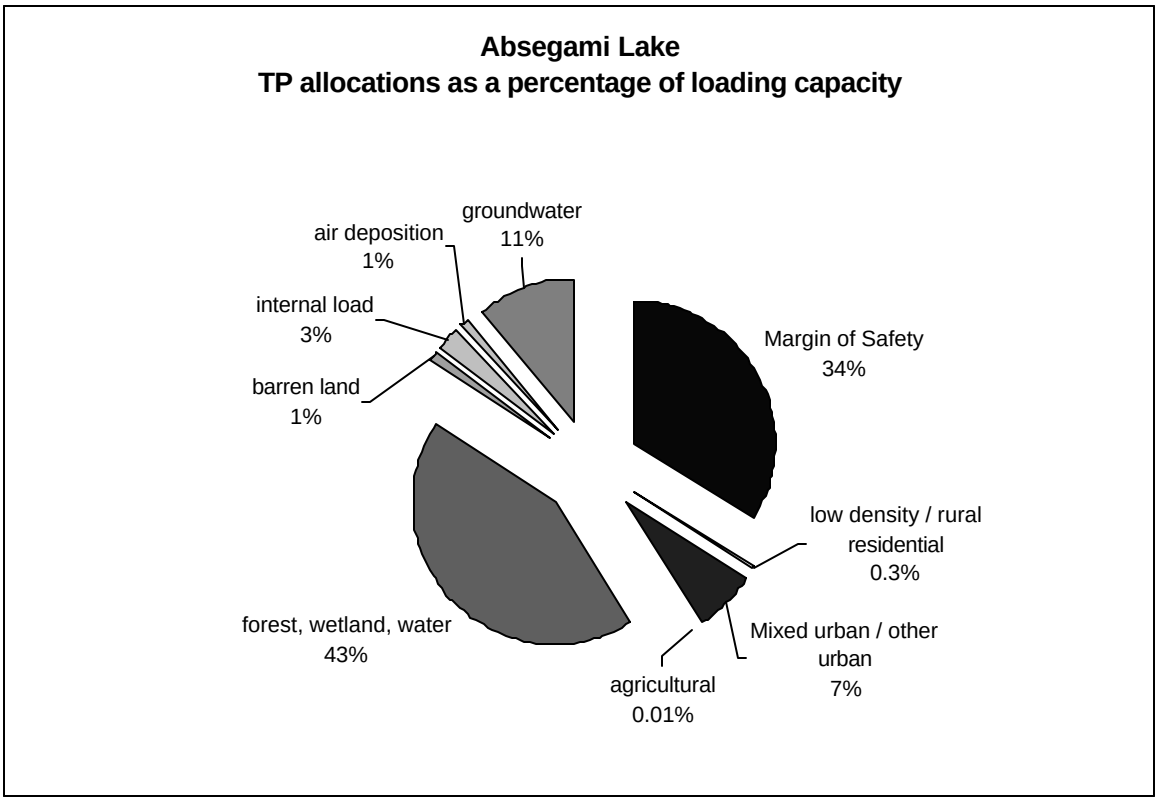


Figure 25 **Phosphorus allocations for Hammonton LakeTMDL**

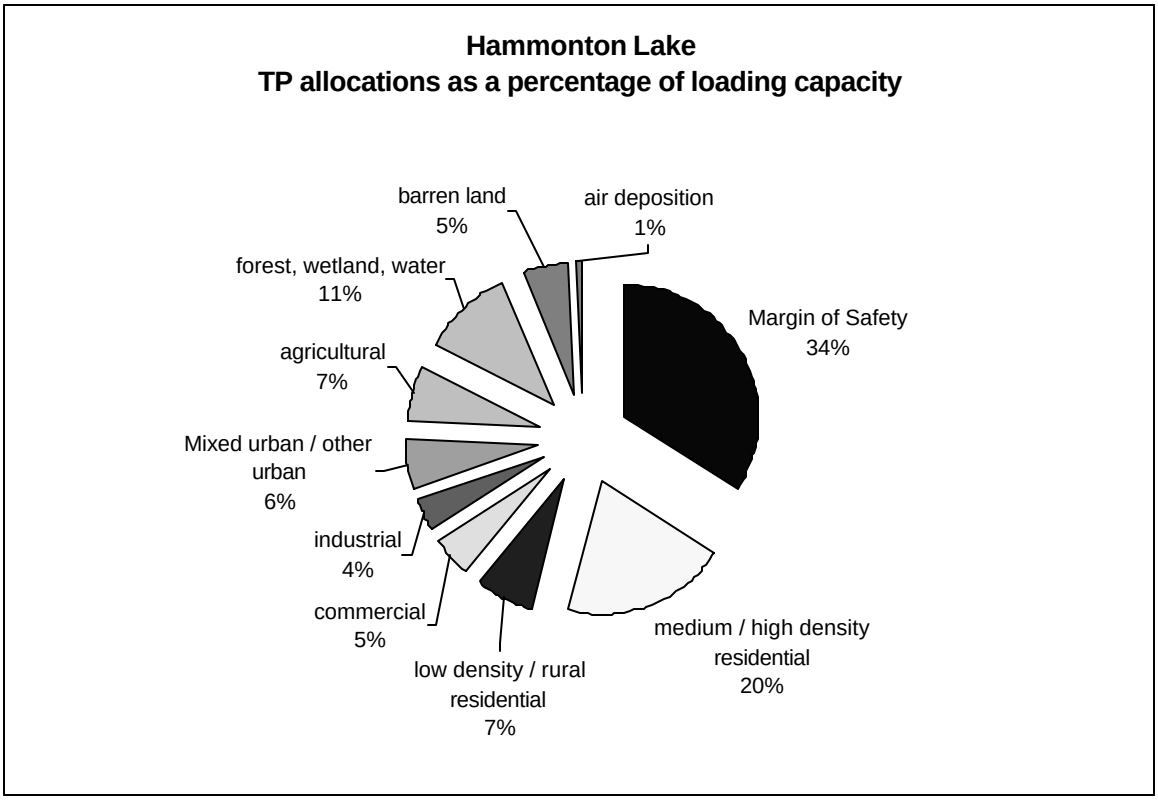


Figure 26 **Phosphorus allocations for New Brooklyn LakeTMDL**

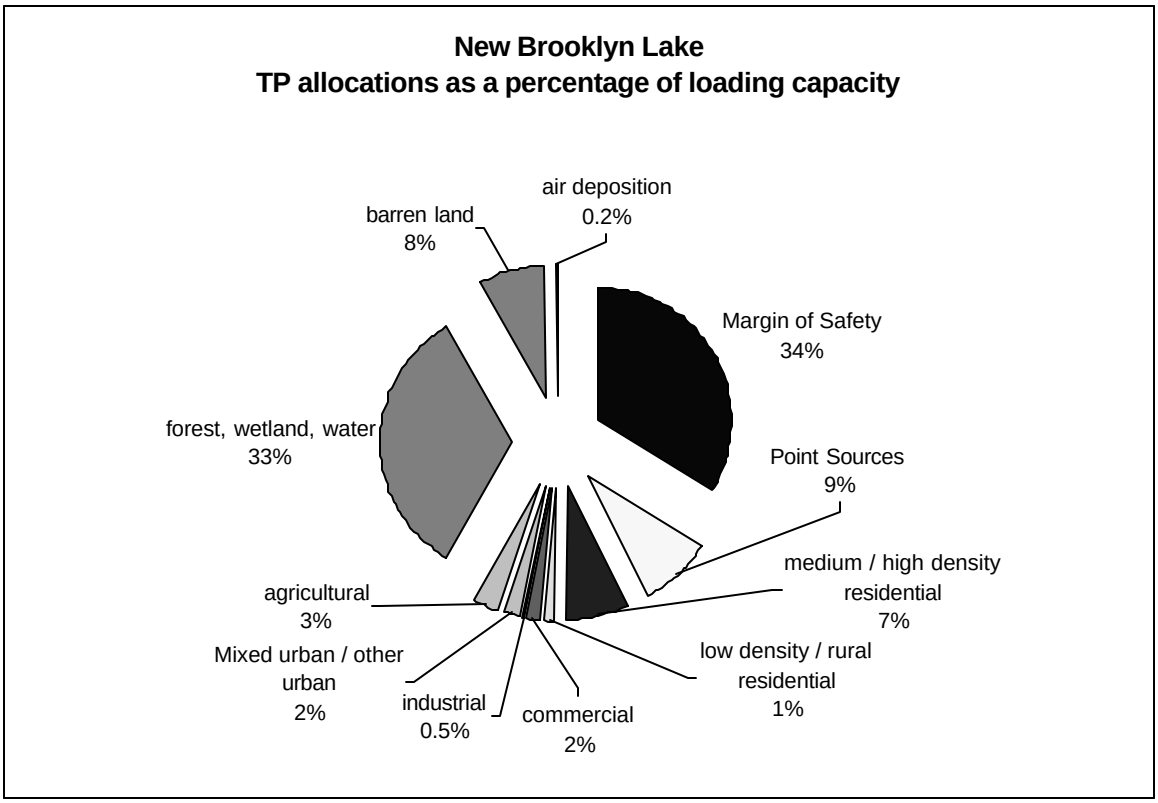


Figure 27 **Phosphorus allocations for Dennisville LakeTMDL**

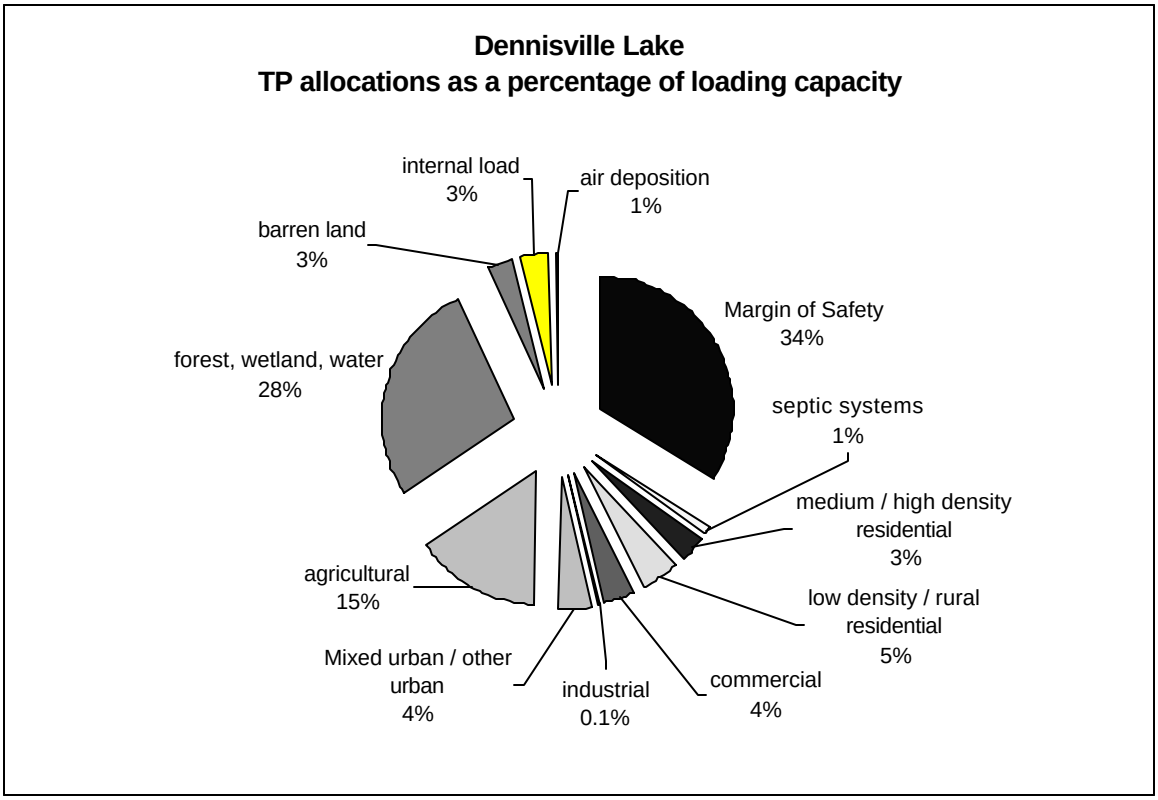
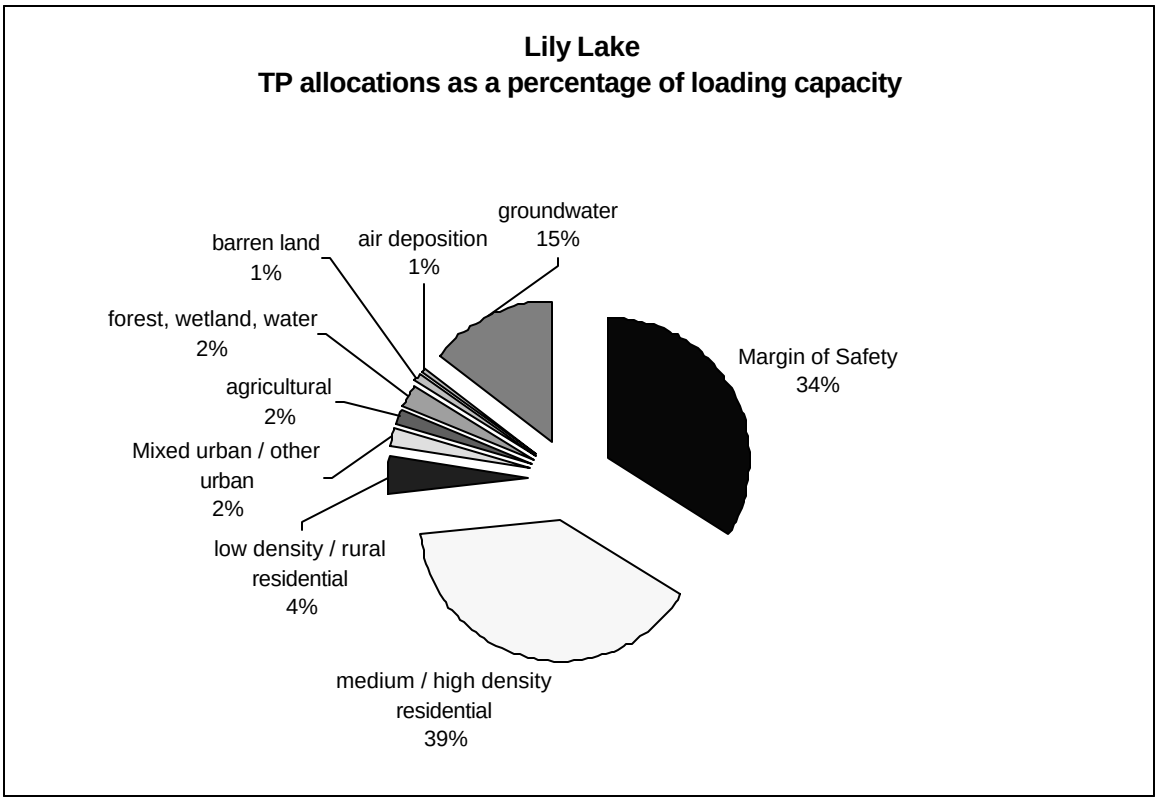


Figure 28 **Phosphorus allocations for Lily LakeTMDL**



9.0 Follow-up Monitoring

In order to track effectiveness of remediation measures (including TMDLs) and to develop baseline and trend information on lakes, the Department will augment its ambient monitoring program to include lakes on a rotating schedule. The details of a new Lakes Monitoring Network will be published by December 31, 2003. Lakes for which remediation measures have been performed will be given top priority on whatever rotating schedule is developed.

Follow-up monitoring will include evaluations (qualitative using a field index or quantitative) of algal blooms (presence, severity, extent) and aquatic vegetation (density, extent, diversity). Measurements such as secchi depths, nutrient concentrations, and chlorophyll-*a* will be included, in addition to dissolved oxygen, temperature and pH profiles. Basic hydrologic and morphometric information will be measured as necessary to obtain current data, including discharge and bathymetry. The details as to what data will be collected by the Lakes Monitoring Network will be included in the network description.

10.0 Implementation

The next steps toward implementation are preparation of lake characterizations and lake restoration plans, where they have not already been developed. In the development of these

plans, the loads by source will be revised, as necessary, to reflect refinements in source contributions. It will be on the basis of refined source estimates that specific strategies for reduction will be developed. These will consider issues such as cost and feasibility when specifying the reduction target for any source or source type. As appropriate, WLAs or other measures to be applied to traditional or stormwater point sources through NJPDES permits will be adopted by the Department as amendments to the applicable areawide Water Quality Management Plan.

The Department recognizes that TMDLs alone are not sufficient to restore eutrophic lakes. The TMDL establishes the required nutrient reduction targets and provides the regulatory framework to effect those reductions. However, the nutrient load only affects the eutrophication potential of a lake. The implementation plan therefore calls for the collection of additional monitoring data and the development of a Lake Restoration Plan for each lake. The plans will consider in-lake measures that need to be taken to supplement the nutrient reduction measures required by the TMDL. In addition, the plans will consider the ecology of the lake and adjust the eutrophication indicator target as necessary to protect the designated uses.

For instance, all of these lakes are shallow lakes, as defined by having a mean depth less than 3 meters. For a lake to be shallow means that most of the lake volume is within the photic zone and therefore more able to support aquatic plant growth (Holdren *et al*, 2001). Shallow lakes are generally characterized by either abundant submerged macrophytes and clear water or by abundant phytoplankton and turbid water. From an aquatic life and biodiversity perspective, it is desirable for shallow lakes to be dominated by aquatic plants rather than algae, especially phytoplankton. While lower nutrient concentrations favor the clear/plant state, either state can persist over a wide range of nutrient concentrations. Shallow lakes have ecological stabilizing mechanisms that tend to resist switches from clear/plant state to turbid/algae state, and vice-versa. The clear/plant state is more stable at lower nutrient concentrations and irreversible at very low nutrient concentrations; the turbid/algae state is more stable at higher nutrient concentrations. The Lake Restoration Plans for each lake will need to consider the ecological nuances of shallow and deep lakes.

The State of New Jersey has adopted a watershed approach to water quality management. That plan divides the state into five watershed management regions, one of which is the Atlantic Coastal Region. The Department recognizes that lake restoration requires a watershed approach. Lake Restoration Plans will be used as a basis to address overfertilization and sedimentation issues in watersheds that drain to these sensitive lakes. In addition, the Department will direct research funds to understand and demonstrate biomanipulation and other techniques that can be applied in New Jersey lakes to promote the establishment of healthy and diverse aquatic plant communities in shallow lakes. Finally, public education efforts will focus on the benefits of aquatic plants in shallow lakes and the balance of aquatic life uses with recreational uses of these lakes. With the combination of New Jersey's strong commitment to the collection and use of high quality data to support environmental decisions and regulatory programs, including TMDLs, the Department is

reasonably assured compliance with the total phosphorus criteria applicable to these eutrophic lakes.

10.1 Lake Characterization

Additional monitoring may be performed in order to develop the Lake Restoration Plans to implement these TMDLs. The level of characterization necessary to plan restoration will be specific to individual lakes depending on the remedial options being considered. During at least one or two summer trips, the following information may be collected as necessary.

- for shallow lakes, vegetation mapping using shore to center transects, measuring density and composition (emergents, rooted floaters, submergents, free-floating plants, submerged macro-algae)
- 1-5 mid-lake sampling stations as needed to characterize the lake
    - at least 2 samples per station per day; min 4 samples per trip
    - secchi depths
- chemistry (nutrients, chlorophyll-*a*, etc.)
    - surface, metalimnion, hypolimnion, and bottom if stratified
    - otherwise surface and bottom
- biology (integrated sample from mixed surface layer)
    - algal abundance and composition (greens, diatoms, blue-greens)
    - zooplankton abundance, composition and size ranges
- DO, temperature and pH profiles (hourly throughout day)

Where necessary, flow and water quality measurements of influent and effluent streams will be taken periodically from Spring to Fall, and fish abundance and composition will be assessed in early autumn.

The schedules for lake characterization and development of Lake Restoration Plans to implement these TMDLs are provided in Table 14.

Table 14 Implementation Schedule

Lake	Lake Characterization	Lake Restoration Plan
Como Lake	Summer 2008	Spring 2009
Deal Lake	Summer 2005	Spring 2006
Franklin Lake	Summer 2005	Spring 2006
Hooks Creek Lake[a]	Summer 2004	Spring 2005
Spring Lake	Summer 2008	Spring 2009
Wreck Pond	Summer 2008	Spring 2009
Pohatcong Lake	Summer 2006	Spring 2007
Absegami Lake[b]	Completed 2000 and 2001	Completed September 2002
Hammonton Lake	Summer 2006	Spring 2007
New Brooklyn Lake	Summer 2004	Spring 2005

Dennisville Lake	Summer 2007	Spring 2008
Lily Lake	Summer 2007	Spring 2008

a The Diagnostic / Feasibility study for Hooks Creek Lake (Princeton Hydro, 2002) provides much of the Lake Characterization information necessary to develop the Lake Restoration Plan. This schedule provides for additional biological monitoring and evaluation in order to restore a clear-water condition in the lake.

b The Diagnostic / Feasibility study for Absegami Lake (Princeton Hydro, 2002) fulfills the TMDL requirements for lake characterization and lake restoration planning.

10.2 Reasonable Assurance

Reasonable assurance for the implementation of these TMDLs has been considered for point and nonpoint sources for which phosphorus load reductions are necessary. These TMDLs obligate the Department to routinely monitor lake water quality as well as characterize and develop specific restoration plan for these particular lakes according to the schedule in Table 14. Moreover, stormwater sources for which WLAs have been established will be regulated as NJPDES point sources.

With the implementation of follow-up monitoring and development of Lake Restoration Plans through watershed management process, the Department is reasonably assured that New Jersey's Surface Water Quality Standards will be attained for these lakes. Activities directed in the watersheds to reduce nutrient loadings shall include a whole host of options, included but not limited to education projects that teach best management practices, approval of projects funded by CWA Section 319 Nonpoint Source (NPS) Grants, recommendations for municipal ordinances regarding feeding of wildlife, and pooper-scooper laws, and stormwater control measures.

11.0 Public Participation

The Department's watershed management process was designed to be a comprehensive stakeholder driven process that is representative of members from each major stakeholder group (agricultural, business and industry, academia, county and municipal officials, commerce and industry, purveyors and dischargers, and environmental groups). Through the creation of this watershed management planning process over the past several years, Public Advisory Committees (PACs) and Technical Advisory Committees (TACs) were created in all 20 WMAs. Whereas the PACs serve in an advisory capacity to the Department, and examined and commented on a myriad of issues in the watersheds, the TACs were focused on providing the scientific, ecological, and engineering integrity of the issues relevant to the mission of the PAC.

At the time the 2002 Integrated Water Quality Report was compiled, the Atlantic Coastal Watershed public participation process was being managed by the Department under contract with various entities: Monmouth County Board of Freeholders for WMA 12; the Barnegat Bay Estuary Program (BBEP) and Ocean County Board of Freeholders for WMA 13; the Pinelands Commission for WMA 14; Atlantic County Board of Freeholders for WMA 15; and Cape May County Board of Freeholders for WMA 16.

The Water Quality Management Planning Rules NJAC 7:15-7.2 encourages 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 each TMDL. Accordingly, the Department worked collaboratively with the stakeholder groups throughout New Jersey as part of the Department's ongoing watershed management efforts.

The Atlantic Coastal Bureau discussed with the WMA 12, WMA 13, WMA 14, WMA 15, and WMA 16 TAC members the Department's TMDL process through a series of presentations and discussions that lead up the development of the Expedited TMDLs for eutrophic lakes in the Atlantic Coastal Watershed Region. Subsequent requests for stakeholder input occurred via an electronic "Information-Share Request" sent out several times in January and February, which was then networked out to additional sources outside the TAC's and PAC's membership such as county health departments, watershed and water resource associations, regional colleges, and consulting firms. Committee members were advised that the formal comment period would be begin upon the April 21, 2003 publication in the New Jersey Register, but that the Department was interested in their input on policy issues affecting the development of the TMDL.

WMA 12

- The PAC executive committee was briefed about the executed MOA between the Department and EPA region 2 and copies of the MOA were distributed at the Executive Committee meeting held on 10/28/02
- Presentation was made to the PAC executive committee on 11/25/02; requested PAC review and comment on the list and maps of the lakes scheduled for expedited TMDLs.
- Expedited Eutrophic Lake TMDL presentation was given at a special meeting of interested members of the PAC on 11/26/02.

WMA 13

- A Power Point presentation on the new Integrated List methodology was given to the Barnegat Bay Estuary Program (BBEP) Science and Technical Advisory Committee (STAC) on 12/10/02 and to the BBEP-Advisory Committee (AC) on 2/4/02.
- An overview on the expedited TMDL process and a request for local input and information occurred at the BBEP-AC on 12/17/02.

WMA 14

- A meeting was held with the Technical Advisory Group (TAG), in the Fall of 2002, where multiple issues were discussed, including an overview of the expedited TMDL process and discussion of the new Integrated List methodology. A request was made for local input and participation and the Pinelands Commission subsequently queried their sciences office to research available technical information and disseminated the request for stakeholder input to their members.

WMA 15

- Stakeholder participation and input was coordinated through the Great Egg Harbor River Association. The Department held meetings with the river administrator to discuss the expedited TMDLs on 10/15/02, 11/7/02 and 12/10/02.

Public participation and input was also received through the NJ EcoComplex. The Department contracted with Rutgers NJ EcoComplex (NJEC) in September 2002. 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 by the Statewide Modeling Team at the SETAC Fall Workshop on September 13, 2002.

In accordance with N.J.A.C. 7:15–7.2(g), these TMDLs are hereby proposed by the Department as an amendment to the Water Quality Management Plans listed on the title page.

N.J.A.C. 7:15-3.4(g)5 states that when the Department proposes to amend the areawide plan on its own initiative, the Department shall give public notice by publication in a newspaper of general circulation in the planning area, shall send copies of the public notice to the applicable designated planning agency, if any, and may hold a public hearing or request written statements of consent as if the Department were an applicant. The public notice shall also be published in the New Jersey Register.

Notice of these TMDLs was published April 21, 2003 pursuant to the above noted Administrative Code, in order to provide the public an opportunity to review the TMDLs and submit comments. The Department has determined that due to the level of interest in these TMDLs, a public hearing will be held. Public notice of the hearing, provided at least 30 days before the hearing, was published in the New Jersey Register and in two newspapers of general circulation and will be mailed to the applicable designated planning agency, if any, and to each party, if any, who was requested to issue written statement of consents for the amendment.

All comments received during the public notice period and at any public hearings will become part of the record for these TMDLs. All comments will be considered in the establishment of these TMDLs and the ultimate adoption of these TMDLs. When the Department takes final agency action to establish these TMDLs, the final decision and supporting documentation will be sent to U.S.E.P.A. Region 2 for review and approval pursuant to 303(d) of the Clean Water Act (33 U.S.C. 1313(d)) and 40 CFR 130.7.

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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 judgement 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):

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

where:
- V = lake volume (10^3 m^3)
- 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 m^2)
- Q = annual outflow (10^3 m^3 / 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 / m^2 / 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: $P = \frac{P_a}{11.6 + 1.2 \cdot Q_a}$. **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:

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

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
$\boldsymbol{r}$ = 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 ($\boldsymbol{r}_u$) that the real phosphorus concentration is less than or equal to the upper bound phosphorus concentration is:

$$\boldsymbol{r}_u = \boldsymbol{r} + \frac{1-\boldsymbol{r}}{2} = \boldsymbol{r} + \frac{1}{2} - \frac{\boldsymbol{r}}{2} = \boldsymbol{r} \cdot \left(1 - \frac{1}{2}\right) + \frac{1}{2} = \frac{1}{2} \cdot \boldsymbol{r} + \frac{1}{2}$$

Substituting for $\boldsymbol{r}$ as a function of h:

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

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:

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

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 ($\boldsymbol{r}_u$) that the real phosphorus concentration is less than or equal to the upper bound phosphorus concentration:

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