Amendment to the Northeast Water Quality Management Plan

Total Maximum Daily Loads for Phosphorus To Address 3 Eutrophic Lakes in the Northeast Water Region

LINCOLN PARK LAKES, HUDSON COUNTY
OVERPECK LAKE, BERGEN COUNTY
VERONA PARK LAKE, ESSEX COUNTY

Watershed Management Area 4
(Lower Passaic & Saddle River Watersheds)
Watershed Management Area 5
(Hackensack River, Hudson River, and Pascack Brook Watersheds)

Proposed:	January 21, 2003
Established:	March 28, 2003
Approved (by EPA Region 2):	September 17, 2003
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1.0 Executive Summary

The State of New Jersey's *2002 Integrated List of Waterbodies* identified several lakes in the Northeast 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	Lincoln Park Lakes	Jersey City, Hudson County	5	13.7
2	Overpeck Lake	Teaneck, Bergen County	5	225
3	Verona Park Lake	Verona, Essex County	4	12.7

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 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 development of a Lake Restoration Plan for each lake. These plans will consider what in-lake measures need to be taken to supplement the nutrient reduction measures 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).

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

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 Northeast Water Region (WMAs 3, 4, 5, and 6) as being eutrophic, as evidenced by elevated total phosphorus (TP), elevated chlorophyll-*a,* and/or macrophyte density that impairs recreational use (a qualitative assessment). Total phosphorus was used as the pollutant of concern, since this "independent" causal pollutant causes "dependent " responses in chlorophyll-*a* concentrations and/or macrophyte density. This report establishes two 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 to be "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 three 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 Northeast Water Region as being eutrophic for a total of 1,090 acres. These TMDLs will address 251 acres or approximately 23.0 percent of the total impaired 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, eutrophication is an environmentally important issue.

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

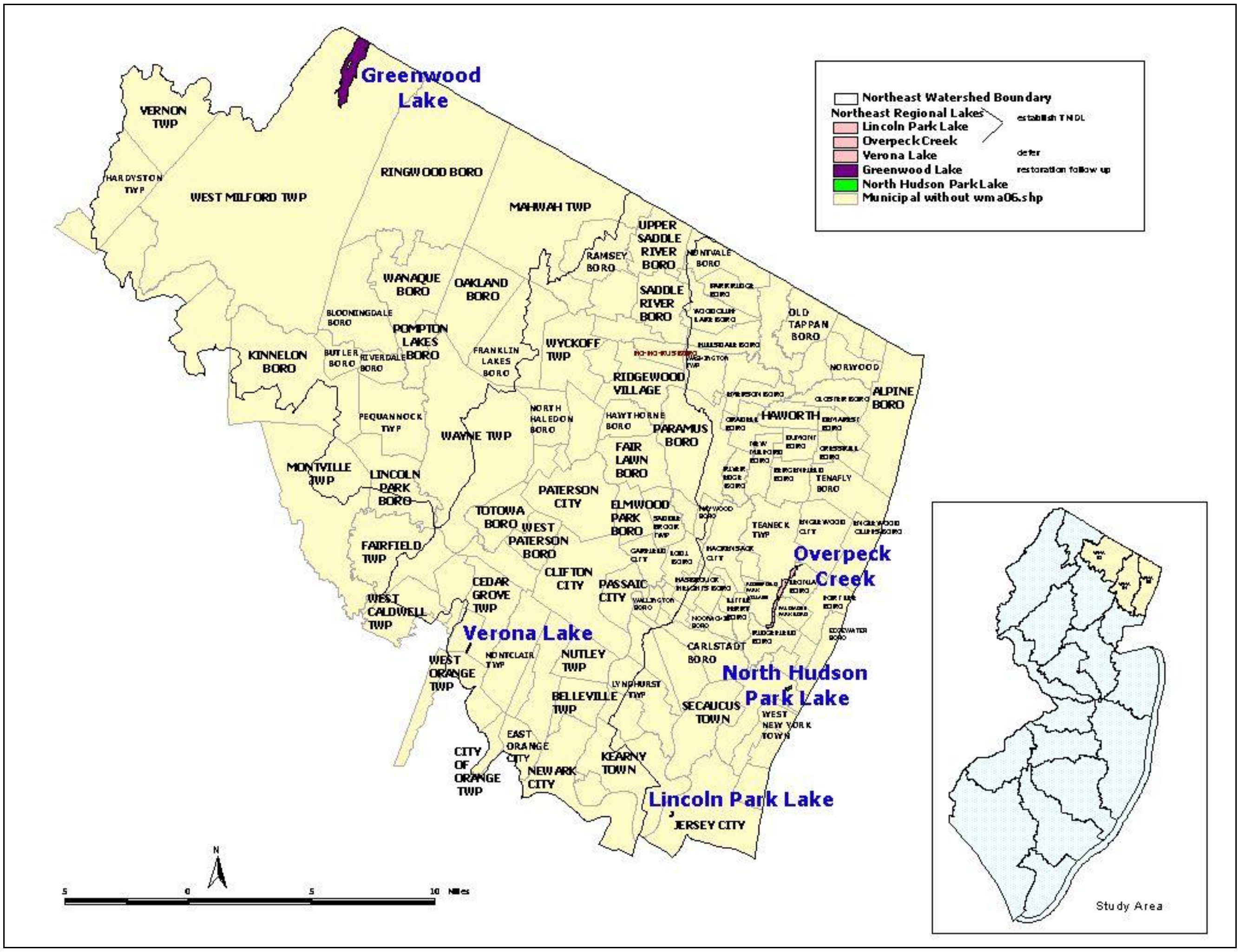
No.	WMA	Lake[a]	Lake Acres	Lakeshed Acres	Management Response
1	05	Lincoln Park Lakes	13.7	328	establish TMDL
2	05	Overpeck Lake	225	10,700	establish TMDL
3	04	Verona Park Lake	12.7	1,720	establish TMDL
4	03	Greenwood Lake	826[b]	14,800[c]	defer
5	05	North Hudson Park Lake	16.9	230	restoration follow-up

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

b While Greenwood Lake is about 1,920 acres, only 826 acres are in New Jersey.

c Watershed acreage taken from Phase 1 study of Greenwood Lake (Cirello *et al*, 1983).

Figure 1 **Eutrophic lakes in the Northeast Water Region on Sublist 5 of 2002 Integrated List**



These TMDLs will address a total of 239 acres of lakes with a corresponding total of 11,000 acres of land.

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.
- 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).

Watershed Management Area 4

Watershed Management Area 4 (WMA 4) includes the lower Passaic River (from the Pompton River confluence downstream to the Newark Bay) and its tributaries, including the Saddle River. The WMA 4 drainage area is approximately 180 square miles and lies within portions of Passaic, Essex, Hudson, Morris and Bergen Counties.

Two watersheds comprise WMA 4: the Lower Passaic River Watershed and Saddle River River Watershed. The **Lower Passaic River Watershed** originates from the confluence of the Pompton River downstream to the Newark Bay. This 33-mile section meanders through Bergen, Hudson, Passaic, and Essex Counties and includes a number of falls, culminating with the Great Falls at Paterson. This watershed has a drainage area of approximately 129 square miles. The major tributaries to this section of the Passaic River are the Saddle River, Preakness Brook, Second River, and Third River. The Saddle River is one of the larger tributaries to the Lower Passaic River. The **Saddle River Watershed** has a drainage area of approximately 51 square miles. Land in this watershed is extensively developed and contains many older cities and industrial centers including Newark, Paterson, Clifton, and East Orange.

Watershed Management Area 5

Watershed Management Area 5 (WMA 5) has a drainage area of approximately 165 square miles, which includes parts of Hudson and Bergen Counties. WMA 5 is comprised of three watersheds: Hackensack River Watershed, Hudson River Watershed and Pascack Brook Watershed. The Hackensack River originates in New York State and flows south to the Newark Bay. New Jersey's portion of the river is 31 miles long. The Hackensack River Watershed is approximately 85 square miles. Major tributaries include the Pascack Brook, Berry's Creek, Overpeck Creek, and Wolf Creek. The **Pascack Brook Watershed** has a drainage area of approximately 51 square miles.

The Hudson River is 315 miles long and begins in New York State at Lake Tear of the Clouds on the southwest side of Mount Marcy, New York's highest peak. The **Hudson River Watershed** is approximately 29 square miles. The Hudson River forms the boundary between New Jersey and New York States.

Although WMA 5 is the most populated of all the WMAs, approximately 50% of the land is still undeveloped, with more than 30% residential development. The remaining developed land is commercial/industrial use. Much of the lower **Hackensack River Watershed** is tidal marsh known as the Hackensack Meadowlands. The Meadowlands are home to more than 700 plant and animal species including several rare and threatened species

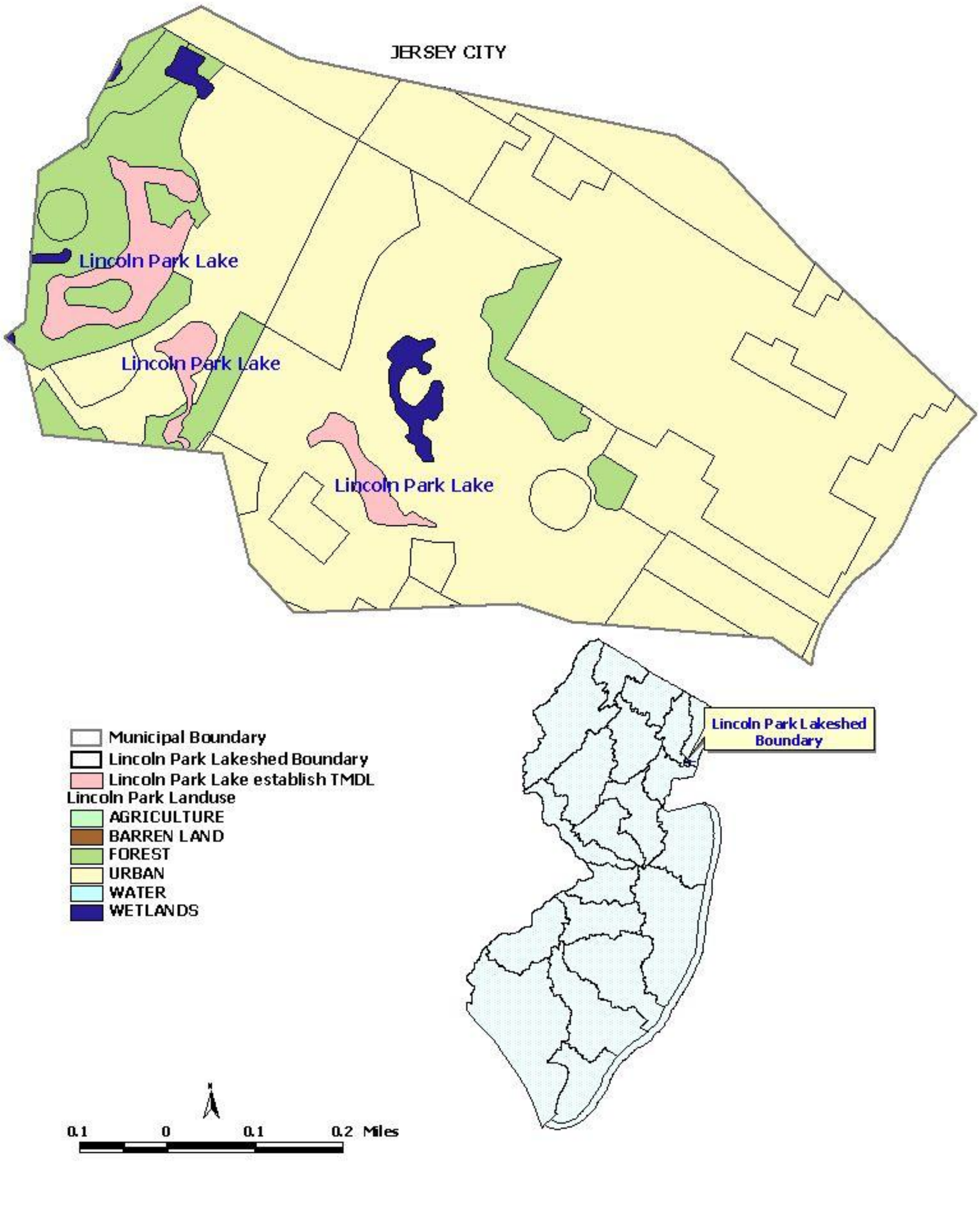
4.1 Lincoln Park Lakes

Lincoln Park Lakes are located in Jersey City, Hudson County, and drain a lakeshed of 326 acres within Jersey City. The lakeshed is 23.9 times the area of the lakes, making it very large[2]. The lakes consist of three small bodies of water within Lincoln Park, a recreational park adjacent to and partially within a marsh along the Hackensack River. Lincoln Park Lakes have no tributaries; most of the lakes' inflow is comprised of storm runoff and, to a lesser extent, springs around the upper lake. Mean depth (0.91m) and total inflow (379,000 m^3/yr) were obtained from the Lakes Classification Study for Lincoln Park Lakes (NJDEP, 1983a).

An Army Corps of Engineer bank and shoreline stabilization project began on Lincoln Park Lake in April of 2002. The project will replace an existing headwall, regrade much of the area adjacent to the lake and utilize bioengineering techniques around the circumference of the lake. A nature trail will be created along with compacted stone walkways and a forested upland restoration area between Route 1 and the shoreline. There will also be some turf areas created, which poses a potential problem of greater access for geese to the lake.

[2] A lakeshed seven times the area of its lake is considered small, whereas a lakeshed ten times the area of its lake is considered large (Holdren *et al*, 2001).

Figure 2 Lakeshed of Lincoln Park Lakes

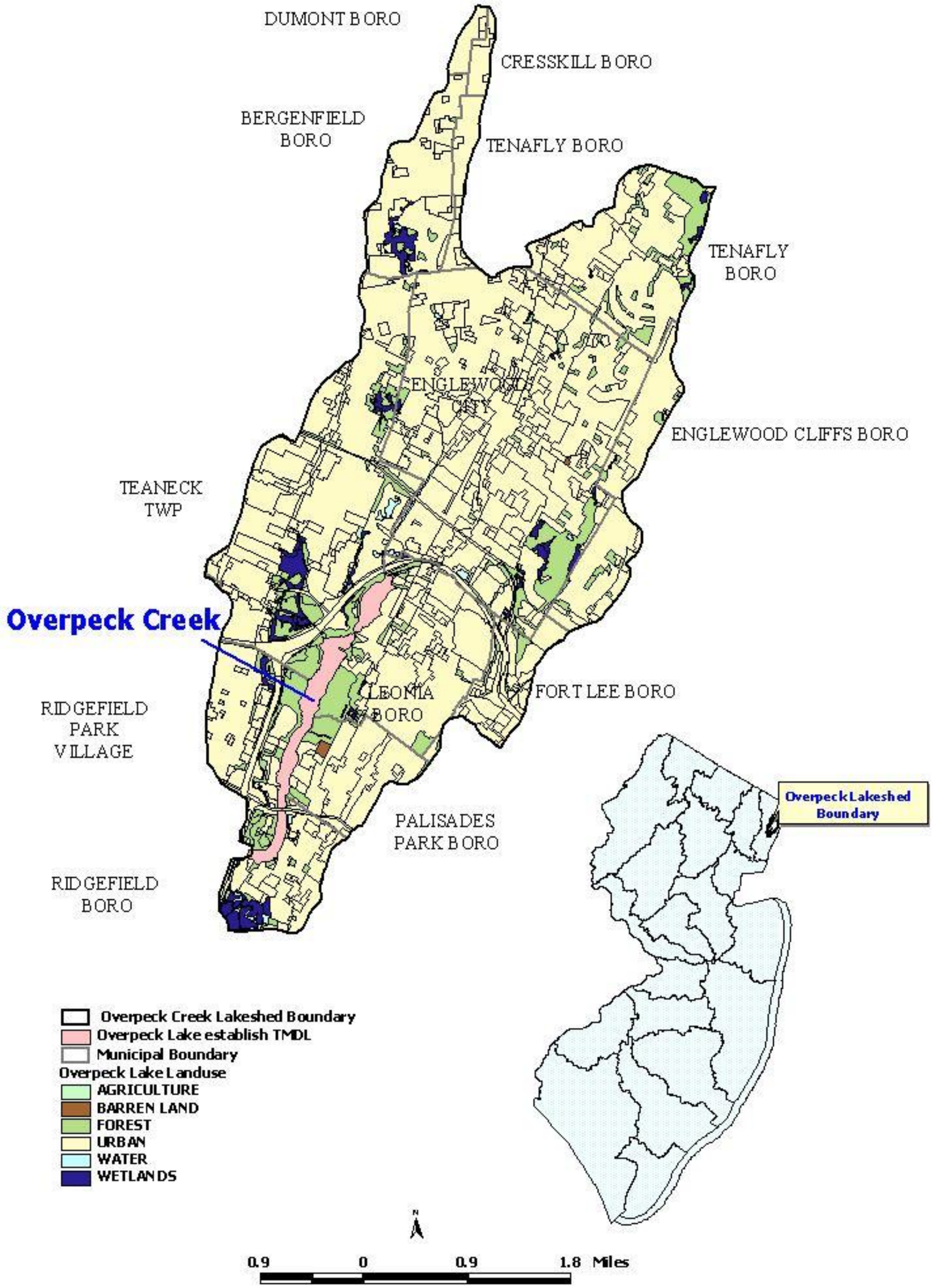


4.2 Overpeck Lake

Overpeck Lake is located in Teaneck Township, Leonia Borough, Palisades Park Borough, Ridgefield Park Village, and Ridgefield Borough in Bergen County. The lakeshed extends 10,657 acres into portions of 10 municipalities, and is 47.4 times the area of the lakes, making it very large. The lake, which includes 2 elongated basins, was formed by the impoundment of Overpeck Creek by the construction of tidal flood gates near the confluence with the Hackensack River in 1952. Most of the inflow to the lake comes from Overpeck Creek and Teaneck Creek. Mean depth (2.74m) and total inflow (14,800,000 m^3/yr) were obtained the Lakes Classification Study for Overpeck Lake (NJDEP, 1983c).

The original Creek had supported a freshwater and brackish wetland complex. The Overpeck Valley was utilized as a landfill area beginning in early 1960's and continuing until 1970. The wetland area on both sides of the creek and the lake became a landfill. Some land has been allowed to progress to a secondary succession on top of the uncapped landfill. Bergen County Park Commission has current plans to cap the old landfill and seal the bank berms, and create a park.

Figure 3 **Lakeshed of Overpeck Lake**

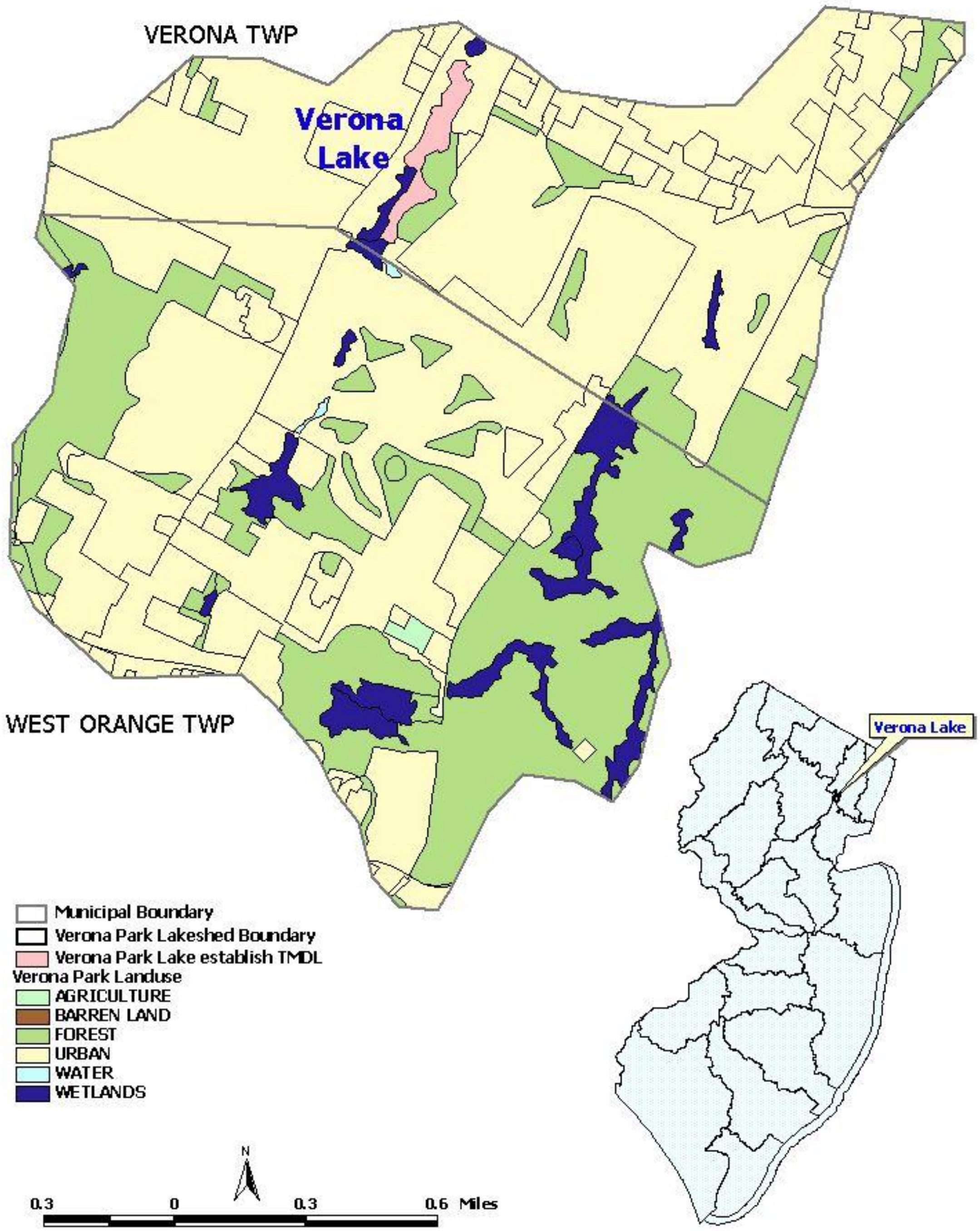


4.3 Verona Park Lake

Verona Park Lake is a 13-acre lake located in Verona, Essex County. The lake, which drains into the Peckman River, is classified as FW2-NT. Verona Park Lake was created in the early 1800s as a mill pond and consists of a north basin and a south basin. The watershed of Verona Park Lake is highly developed. Over the past few decades, silt and nutrient-laden stormwater runoff from surrounding commercial and residential land has resulted in excessive sediment and nutrient loading to the Lake. This accumulation of material has reduced the average water depth from 3.7 feet to 1.8 feet over a period of fifteen years.

Evaluation of water quality improvements in the Verona Park Lake, resulting from restoration/stabilization projects, both completed and on-going, is a necessary step prior to establishment of a TMDL. The projects were identified by a Phase-One Diagnostic and Feasibility Study (Essex County 1986). In 1990 Essex County installed gabions to stabilize 2,000 linear feet of shoreline to reduce nutrient load from sediment deposited due to erosion of shoreline. In January 2002 dredging to remove unconsolidated sediments was undertaken. The current project is a bio-engineering project, which along with aesthetic value will help to stabilize 920 feet of shoreline on the western side of the southern basin, thereby reducing nutrient influx. Planting of native vegetation will also help to restrict access of Canada geese to the lake. This project is a collaborative effort of Verona Park Constituency (an advocacy group), Essex County Department of Public Works and Essex County Department of Parks, Recreation and Community Affairs. The project was endorsed as a priority project by the Watershed Management Area 4 Public Advisory Committee, and funded by Federal 319(h) funds through the NJDEP grant selection process. Inspection of the site, to determine the success of the bio-engineering techniques for stabilization will be conducted for 5 years at the end of each growing season. The criteria for determining successful stabilization will be greater than 90% of the bank having a permanent and well-established cover of native vegetation at the end of the 5 year period. The management strategy for Canada geese control will be monitored and considered effective if there is a reduction in the population of Canada geese by at least 50%, as determined by the population counts pre and post installation of the native vegetation. The establishment of a TMDL and the resultant implementation strategy will be determined utilizing the more current information on water quality in Verona Park Lake provided as a follow-up to these projects.

Figure 4 **Lakeshed of Verona Park Lake**



4.4 Greenwood Lake

Located in WMA 3, Greenwood Lake spans both New Jersey and New York State. A bi-state Greenwood Lake Commission has been formed to address its environmental issues. New

Jersey adopted the bill to create the Greenwood Lake Commission (S1788(1R); P.L. 1999 c.402) in January of 2000. The companion bill (A00294 S416-A) was adopted by New York State in January of 2001. The 13 voting members include representatives from: Passaic County, NJ; the Township of West Milford, NJ; the Commissioner of the NJDEP or designee; Orange County, NY; the Village of Greenwood Lake, NY; the Town of Warwick, NY; the Commissioner of the NYDEC or a designee thereof; The Greenwood Lake Watershed Management District, a citizen advisory committee that has been active for more than 20 years; the North Jersey Water Supply Commission; the Orange County Water Authority; and from each state, an appointed representative, from the public sector with related expertise.

The Greenwood Lake Commission, composed of eminently qualified persons in the field of environmental issues and concerns, is a designated body for Greenwood Lake environmental concerns and is in the process of addressing such issues through varied means. For example, a project already undertaken was a dredging project, funded by New Jersey legislature for $2.5 million dollars (S-1073). The funding included: dredging in West Milford, New Jersey and the completion of any activities necessary to prepare to dredge those parts of Greenwood Lake within New Jersey; a preparation of an updated analysis of pollutant loadings to Greenwood Lake from the New Jersey portion of the watershed, to be called the "Updated Greenwood Lake Restoration and Management Plan", with any remaining funds to be utilized to further other recommended dredging activities as prioritized in the "Updated Greenwood Lake Restoration and Management Plan". The Department will defer to this bi-state Commission for the implementation of appropriate measures for addressing the trophic status of Greenwood Lake, rather than establishing a TMDL at this time.

There is also a federal pass through 319(h) NPS grant funded project on Belcher Creek, West Milford to provide NPS pollution remediation through the use of recessed catch basins along roadsides impacting the Belcher's Creek Corridor, and to provide educational information to the township residents regarding the impact of NPS pollution on water quality. Belcher's Creek flows into Pinecliff Lake and hence into Greenwood Lake. This project was identified by the Phase 1 Diagnostic – Feasibility Study of Greenwood Lake, New Jersey and New York (Princeton Aqua Science 1983). In addition, that study inferred based on the data that the majority of the nutrient load to Greenwood Lake was from stormwater runoff (Princeton Aqua Science 1983). A follow-up to both components of the project would be required to document the water quality improvements and the decrease of nutrient load, especially phosphorus, to Belcher's Creek and ultimately Greenwood Lake prior to establishing a TMDL.

4.5 North Hudson Park Lake

North Hudson Park Lake is a 16.9 acre man-made urban lake located in North Bergen, Hudson County. Historically, the lake has been used for boating, fishing, and passive recreation. In the early 1980s, the lake underwent restoration efforts funded in part by EPA through the Section 314 Clean Lakes Program, the Department's Green Acres Program, and Hudson County. Restoration efforts included mechanical dredging of 85,000 cubic yards of sediment, rehabilitation off the stormwater outlet structure, rehabilitation of the adjacent storm drains and repair of the lake shoreline walls.

As a result of erosion and failing storm drains, the lake depth had decreased to less than one meter. Dredging was accomplished by draining the lake and regrading the site. The total length of the shoreline is approximately 3800 linear feet. Restoration provided for the construction of a grass swale area around the majority of the lake shoreline which redirected stormwater runoff to the reconstructed storm drains. Approximately 2000 linear feet of perimeter wall was rebuilt. 18 storm drains were rehabilitated including the installation of grit and oil chambers thus reducing the overland transport of material into the Lake. After restoration, the bathymetry of the lake was restored to a more uniform contour, with the shoreline area generally between two to three feet deep and central portion of the lake between five to six feet deep.

After the project's completion, water quality analysis was conducted for phosphorus and Chlorophyll a. There was 53% reduction in total phosphorus values in-lake and algal density as measured by Chlorophyll-a demonstrated an approximate 3000 percent reduction in algal populations. The Department will follow up on the restoration with monitoring through the Lakes Monitoring Network (section 9.0).

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. No municipal point sources exist anywhere within the lakesheds of either Lincoln Park Lakes or Overpeck Lake. There is one CSO that discharges occasionally into a tributary of Overpeck Creek within the lakeshed of Overpeck Lake. CSOs are generally thought to be more important sources for fecal contamination than for phosphorus. One CSO within a large highly developed lakeshed will contribute a negligible load of phosphorus compared to the very high loads from runoff sources (see section 6.2). Therefore, point source contributions other than stormwater were assumed to be zero for the purposes of TMDL calculations for both Lincoln Park Lakes and Overpeck Lake.

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 3.

Table 3 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 loading rates for the lakes are shown in Table 4.

Table 4 Nonpoint and Stormwater Sources of Phosphorus Loads*

	Lincoln Park Lakes		Overpeck Lake		Verona Park Lake	
Nonpoint Source	acres	Kg TP/yr	acres	Kg TP/yr	acres	Kg TP/yr
medium / high density residential	87.8	56.9	4,860	3,150	646	419
low density / rural residential	0.0	0.0	1,460	414	36.5	10.3
commercial	24.5	19.8	888	719	143	116
industrial	10.4	7.2	565	389	2.8	1.9
mixed urban / other urban	153	62.0	1,290	523	318	129
agricultural	0.0	0.0	2.5	1.5	3.1	1.9

[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.

Nonpoint Source	Lincoln Park Lakes		Overpeck Lake		Verona Park Lake	
	acres	Kg TP/yr	acres	Kg TP/yr	acres	Kg TP/yr
forest, wetland, water	38.5	1.6	1,350	54.6	530	21.5
barren land	0.0	0.0	10.7	2.2	0.00	0.00
Direct air deposition on lake surface	13.7	0.4	225	6.4	12.8	0.4
TOTAL	326	148	10,700	5,260	1,690	699

* all figures rounded to not more than three significant digits

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 5.

Table 5 Empirical models considered by the Department

reference	steady-state TP concentration in lake (mg/l)	Secondary term	Application
Rast, Jones and Lee, 1983	$1.81\times NPL^{0.81}$	$NPL=\left(\frac{P_a\times DT/D_m}{1+\sqrt{DT}}\right)$	expanded database of mostly large lakes
Vollenweider and Kerekes, 1982	$1.22\times NPL^{0.87}$	$NPL=\left(\frac{P_a\times DT/D_m}{1+\sqrt{DT}}\right)$	mostly large natural lakes
Reckhow, 1980	$\frac{P_a}{13.2}$	none	Upper bound for closed lake
Reckhow, 1979a	$\frac{P_a}{(1.6+1.2\times Q_a)}$	$Q_a=\frac{Q_i}{A_l}$	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

reference	steady-state TP concentration in lake (mg/l)	Secondary term	Application
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
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)
Q_a = 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 5):

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: $0.07 < P_a < 31.4$ $g/m^2/yr$

[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.

For comparison, Table 6 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.

Table 6 Hydrologic and loading characteristics of lakes

Lake	Current Avg Influent [TP] (mg/l)	Target Avg Influent [TP] (mg/l)	Current Areal TP load ($g/m^2/yr$)	Target Areal TP load ($g/m^2/yr$)	Areal Water Load (m/year)
Lincoln Park Lakes	0.390	0.058	2.66	0.40	6.8
Overpeck Lake	0.355	0.038	5.78	0.62	16.3
Verona Park Lake	0.151	0.026	13.57	2.37	89.7

7.1 Current Condition

Using these estimated physical parameters and external loads, the predicted steady-state phosphorus concentration of each lake was calculated using the Reckhow (1979a) formulation and listed in Table 7. The current phosphorus load distribution for each lake is shown in Figures 5 to 7 below.

Figure 5 Current distribution of phosphorus load for Lincoln Park Lakes

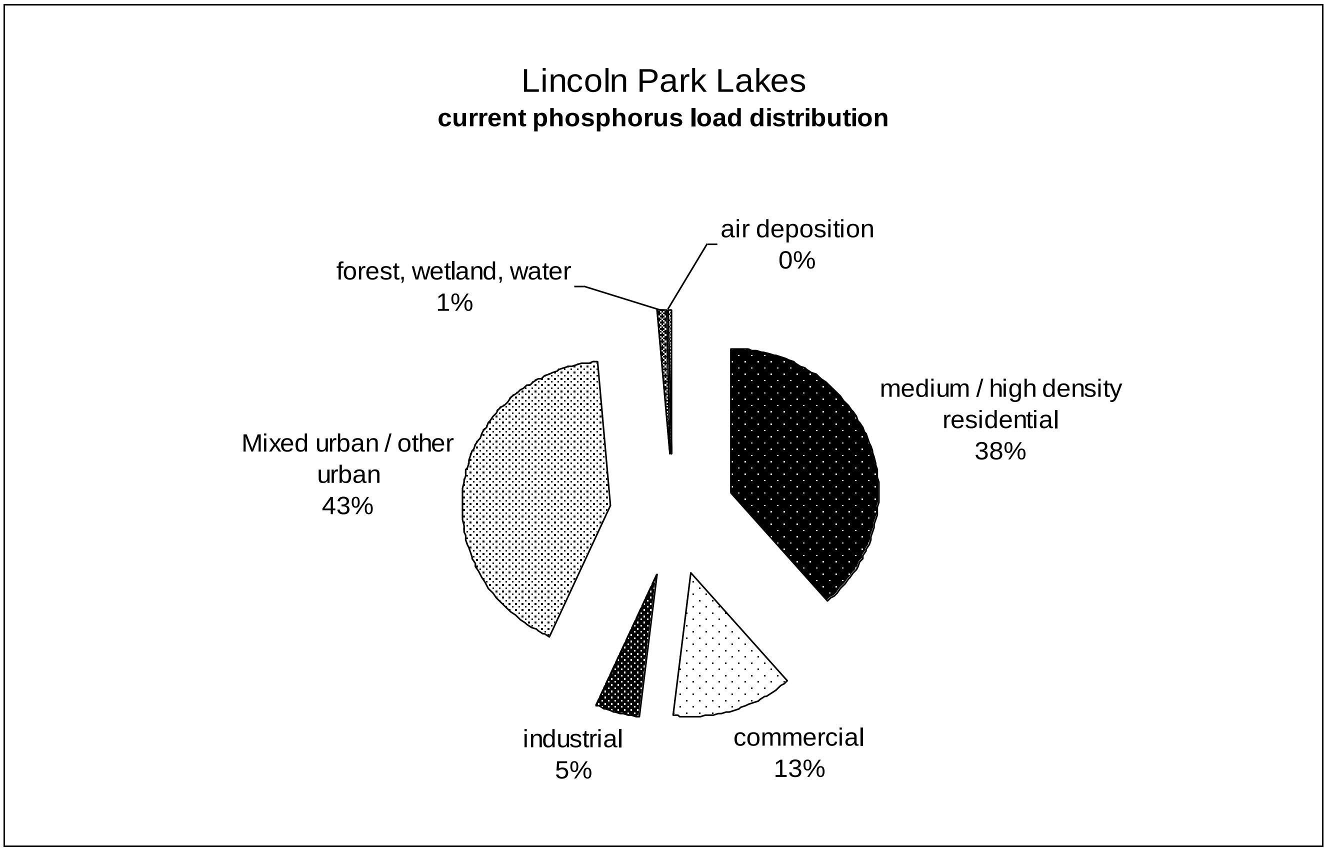


Figure 6 Current distribution of phosphorus load for Overpeck Lake

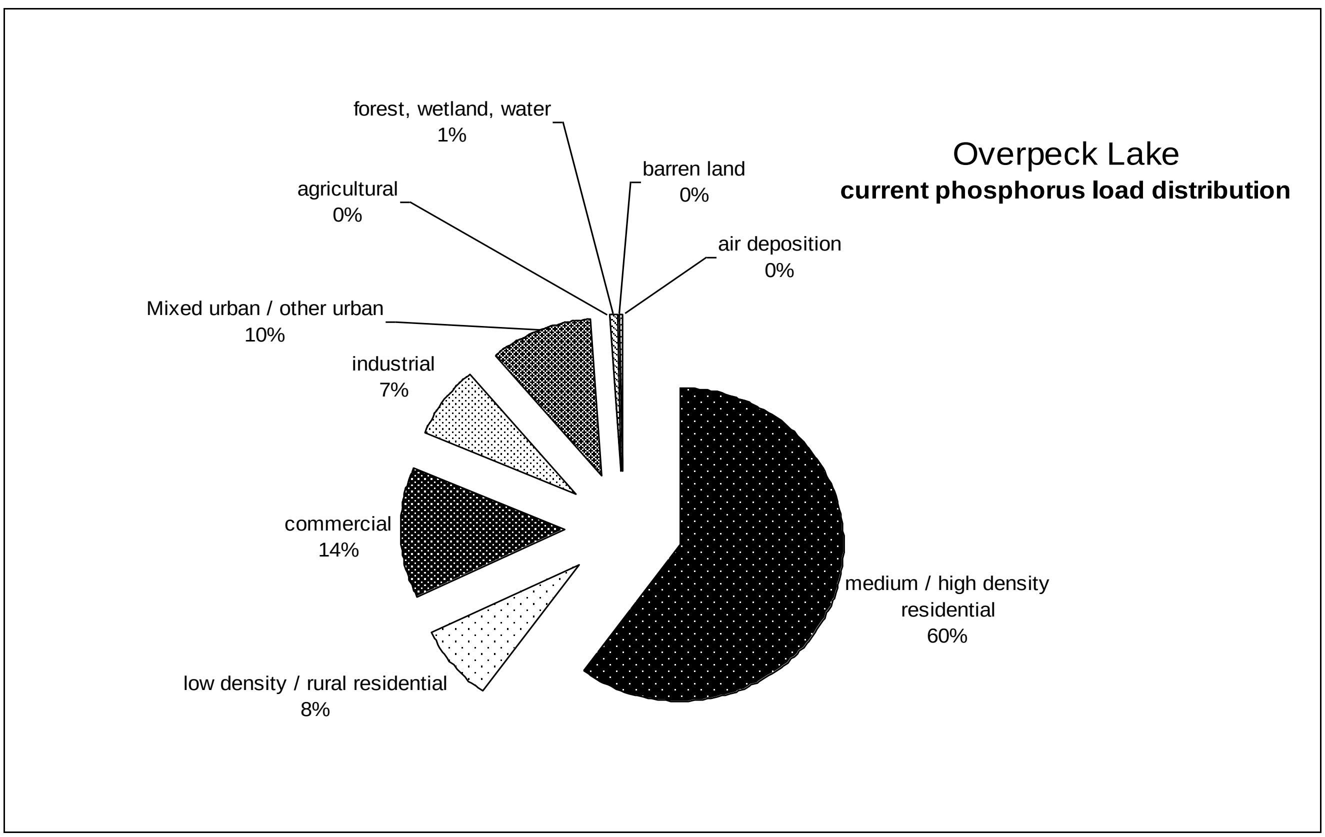
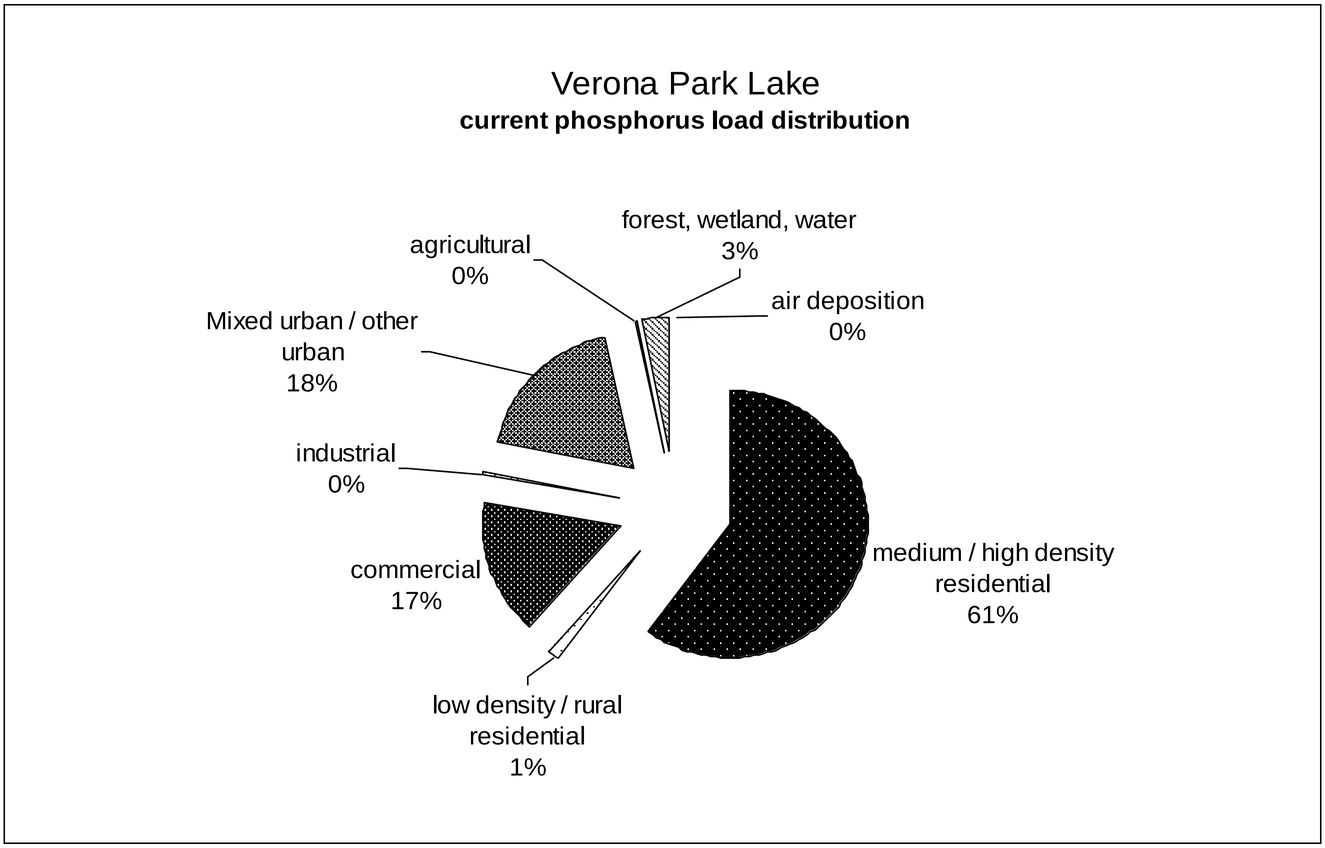


Figure 7 Current distribution of phosphorus load for Verona Park Lake



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. 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 7. The reference condition was developed for comparison purposes only and not used for any TMDL calculations.

7.3 Seasonal Variation/Critical Conditions

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):

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

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 7. 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%:

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

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. Overall reductions necessary to attain the target steady state concentration of 0.03 mg/l total phosphorus in each lake were calculated by comparing the current condition to the target condition (Table 7).

Table 7 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
Lincoln Park Lakes	0.14	0.012	0.03	0.02	85%
Overpeck Lake	0.19	0.015	0.03	0.02	89%
Verona Park Lake	0.11	0.011	0.03	0.02	82%

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 7 yields the same results. The acceptable loading capacity for each lake is provided in Table 9.

8.2 Reserve Capacity

Reserve capacity is an optional means of reserving a portion of the loading capacity to allow for future growth. The primary means by which future growth could increase phosphorus load is through the development of forest land within the lakesheds. Since developable land within the watersheds of these lakes is limited, especially in areas in close proximity to the lakes, reserve capacities are not included. Therefore, the loading capacities and accompanying WLAs and LAs must be attained in consideration of any new sources that may accompany future development. 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 (Table 9):

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

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 8. 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 8, 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 Table 8 are not themselves "Additional Measures" under proposed N.J.A.C. 7:14A-25.6 or 25.8.

Table 8 **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

In order to attain the TMDLs, the overall load reductions shown in Table 7, or those determined through additional monitoring, must be achieved. Since loading rates have been defined for at least eight source categories, countless combinations of source reductions could be used to achieve the overall reduction target. The selected scenarios focus on land use sources that can be affected by BMP implementation or NPDES regulation, requiring equal percent reductions from each in order to achieve the necessary overall load reduction (Table 9). 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 in order to better reflect actual implementation projects. The resulting TMDLs, rounded to two significant digits, are shown in Table 9 and illustrated in Figures 8 to 10.

Table 9 TMDL calculations for each lake (annual loads and percent reductions[a])

lake	Lincoln Park Lakes		% reduction	Overpeck Lake		% reduction	Verona Park Lake		% reduction
	kg TP/yr	% of LC		kg TP/yr	% of LC		kg TP/yr	% of LC	
loading capacity (LC)	33	100%	n/a	850	100%	n/a	190	100%	n/a
Point Sources other than Stormwater	n/a			n/a			n/a		
Nonpoint and Stormwater Sources									
medium / high density residential	7.7	24%	86%	300	36%	90%	62	33%	85%
low density / rural residential	0.0	0.0%	n/a	40	4.7%	90%	1.5	0.82%	85%
commercial	2.7	8.2%	86%	69	8.1%	90%	17	9.2%	85%
industrial	1.0	3.0%	86%	37	4.4%	90%	0.28	0.15%	85%
Mixed urban / other urban	8.5	26%	86%	50	5.9%	90%	19	10%	85%
agricultural	0.0	0.0%	n/a	1.5	0.2%	0%	1.9	1.0%	0%
forest, wetland, water	1.6	4.7%	0%	55	6.4%	0%	22	12%	0%
barren land	0.0	0.0%	n/a	2.2	0.3%	0%	0.0	0.0%	n/a
air deposition onto lake surface	0.39	1.2%	0%	6.4	0.7%	0%	0.36	0.19%	0%
Other Allocations									
explicit Margin of Safety	11	34%	n/a	290	34%	n/a	63	34%	n/a
Reserve Capacity	n/a			n/a			n/a		

a Percent reductions shown for individual sources are necessary to achieve overall reductions in Table 7.

Figure 8 **Phosphorus allocations for Lincoln Park Lakes TMDL**

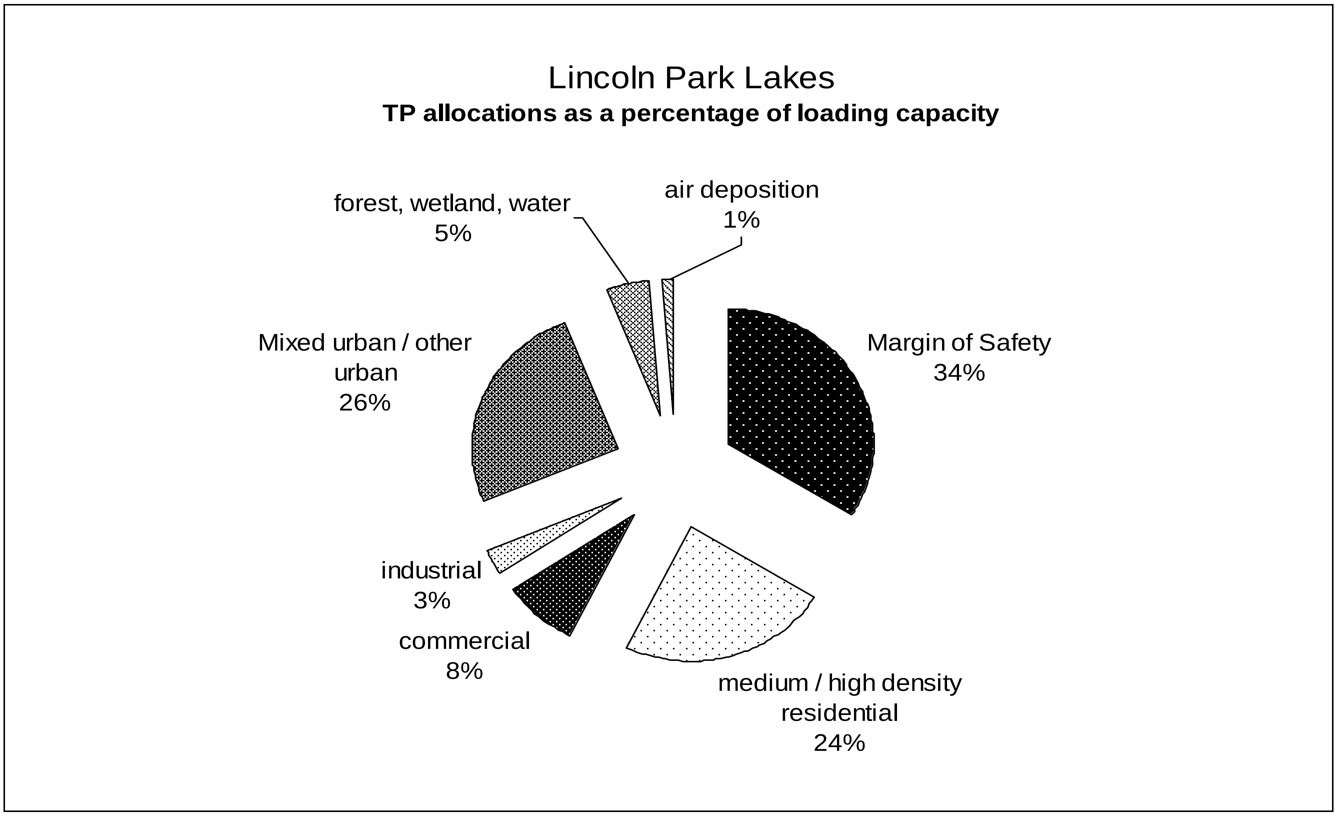


Figure 9 **Phosphorus allocations for Overpeck Lake TMDL**

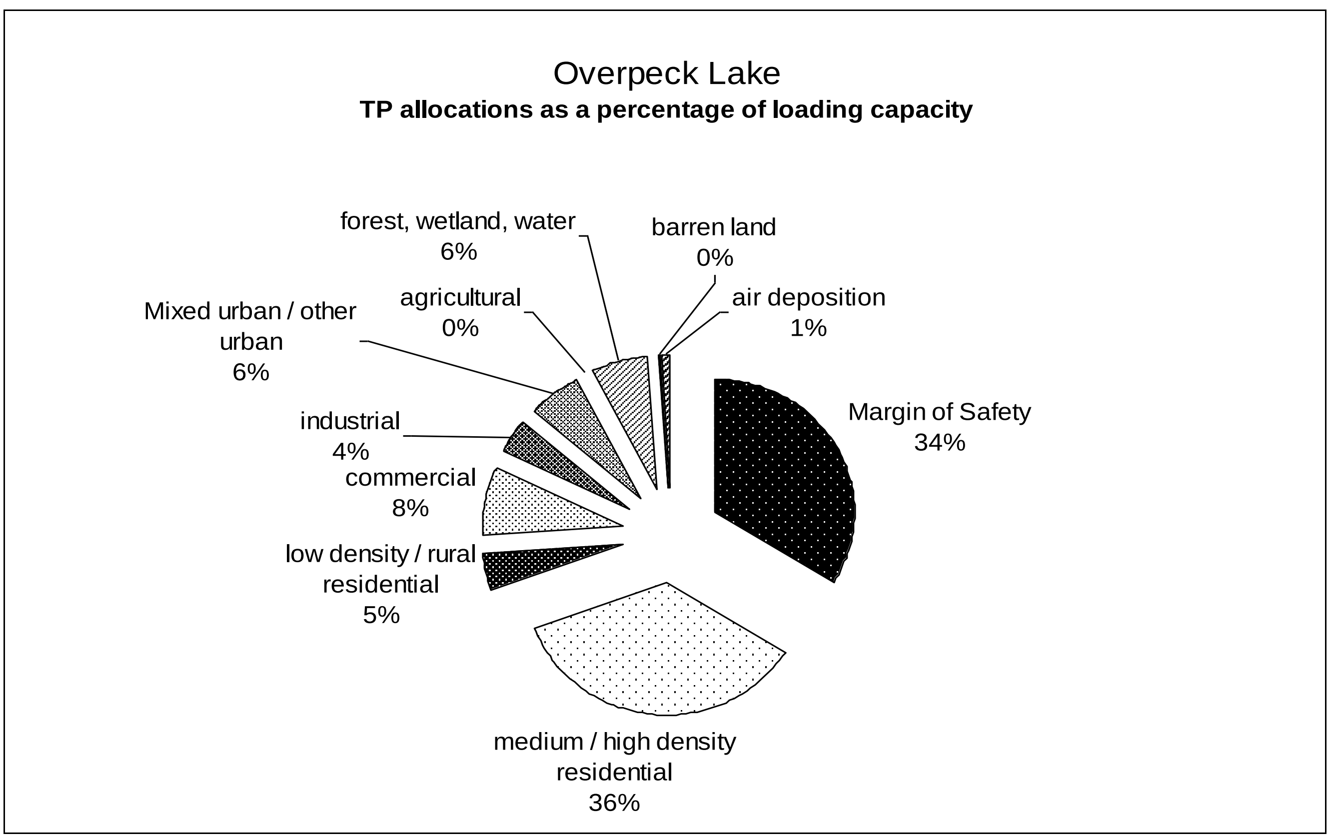
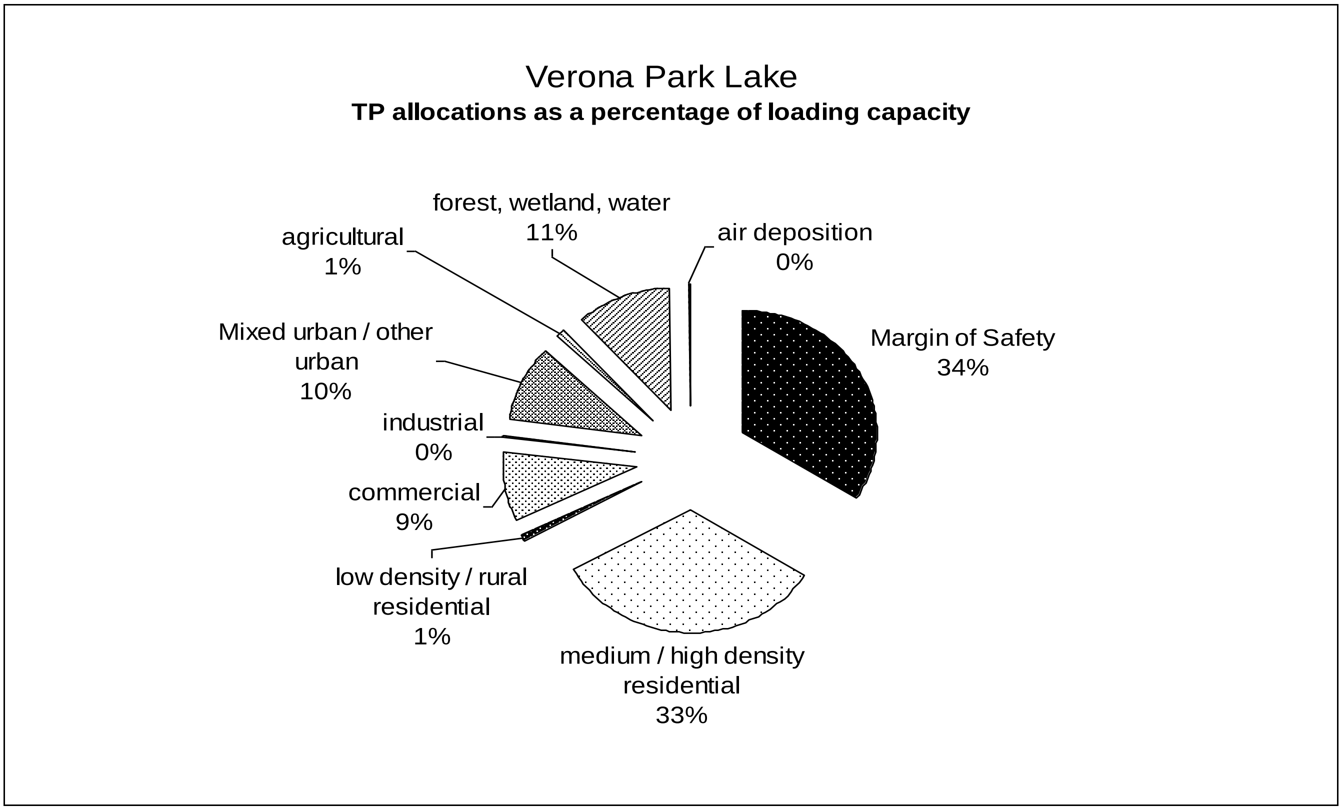


Figure 10 **Phosphorus allocations for Verona Park Lake TMDL**



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 measure 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 three of these lakes are shallow lakes, as defined by having a mean depth less than 3 meters, meaning 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 regions, one of which is the Northeast Region. The Eutrophic Lakes TMDL for the Northeast Water Region was developed with assistance from stakeholders in WMAs 4 and 5 as part of the Department's ongoing watershed management efforts. The Whippany River Watershed Project was a pilot effort initiated in October 1993 to aid the Department in developing a comprehensive watershed management process that could be replicable. From these auspicious beginnings the Department "geared up" for a statewide process in 1998 based on the premise of dividing the state into 20 watershed management areas. The watershed management process was initiated in limited watersheds across the state where strong grass roots efforts and federal efforts were already underway. These watersheds included the Musconetcong in WMA 1, Barnegat Bay in WMA 13, part of the Raritan in WMAs 8, 9, and 10 and WMA 6 which is comprised of the Whippany, Rockaway, Mid and Upper Passaic River watersheds.

In the Fall of 2000 the Department awarded two years worth of grant funding to 16 lead entities to serve as an arm of the Department and facilitate the watershed process for all 20 watershed management areas throughout the state. Deliverables from this process varied; from the formation of viable public advisory committees to the development of extensive watershed characterizations and assessments to the creation of water resource based open space mapping criteria to comprehensive education and outreach efforts. In the Fall of 2002 the Department for the most part once again assumed responsibility of leading the process to redirect efforts to focus on key initiatives such as smart growth and C1 designation. Through the creation of the 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 New Jersey Department of Environmental Protection, 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.

The Department recognizes that lake restoration requires a watershed approach. Lake Management 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, outreach 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 9.

Table 10 Implementation Schedule

Lake	Lake Characterization	Lake Restoration Plan
Lincoln Park Lakes	Summer 2005	Spring 2006
Overpeck Lake	Summer 2004	Spring 2005
Verona Park Lake	Summer 2005	Spring 2006

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 10. 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 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 the TMDL. Accordingly the Department shall propose each TMDL as an amendment to the appropriate areawide water quality management plan. As stated previously, part of the public participation process for the development and implementation of the TMDLs in the Northeast Water Region, The New Jersey Department of Environmental Protection's (Department) Division of Watershed Management – Northeast Bureau worked collaboratively with a series of stakeholder groups throughout New Jersey as part of the Department's ongoing watershed management efforts.

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.

The Northeast Bureau discussed with the WMA 3, WMA 4, WMA 5 and WMA 6 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 Northeast Water Region.

- Integrated Listing Methodology Presentations were made by the Northeast Bureau within the DWM to the Northeast TACs throughout the month June; requesting that they review the Integrated List and submit comments to the Department by the September deadline. Presentations were made to: WMA 5 TAC on June 18, 2002; WMA 6 TAC on June 20, 2002; WMA 3 TAC on June 21, 2002; and WMA 4 TAC on June 27, 2002.
- Expedited Fecal Coliform and Lake TMDL Presentations were given at the September TAC meetings. The finalized Sublist 5 list was also disseminated. The TACs were briefed about the executed Memorandum of Agreement between the Department and EPA Region 2 with the imminent timeline.
- At the October TAC meetings held in WMA 5 on October 15, 2002 and in WMA 4 on October 24, 2002 draft copies of the Northeast Fecal and Eutrophic Lake TMDL reports were distributed for informational purposes only. The WMA 4 and WMA 5 TACs were asked to review the euthophic lakes TMDL document and to think about additional sources of information pertaining to lake restoration and to provide that information to the Department. TAC members were advised that the formal comment period would be during the New Jersey Register Notice, but that the Department was interested in their input on policy issues affecting the development of the TMDL.
- At the December TAC meetings, the final draft Northeast Fecal and Eutrophic Lake TMDL reports were distributed for informal comments prior to the NJR Notice.

Additional public participation and input was received through the NJ EcoComplex. The Department contracted with Rutgers NJ EcoComplex (NJEC) in July 2001. 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 Northeast Bureau 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 Northeast Water Quality Management Plan. 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 January 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.

Appendix A: References

Annadotter, H., G. Cronberg, R. Aagren, B. Lundstedt, P.-A. Nilsson and S. Ströbeck, 1999. Multiple techniques for lake restoration. Hydrobiologia 395/396:77-85.

Birch, S. and J. McCaskie, 1999. Shallow urban lakes: a challenge for lake management. Hydrobiologia 395/396:365-377.

Center for Watershed Protection, 2001. *Watershed Protection Techniques: Urban Lake Management*. T.R. Schueler, Ed.in Chief. Ellicott City, MD. www.cwp.org.

Cirello, J., J.D. Koppen, S.J. Souza, R. Conner, D. Dorfman, M.A. Foote. 1983. Phase 1: Diagnostic-Feasibility Study of Greenwood Lake, New Jersey and New York. Princeton Aqua Science.

Cooke, G.D., P. Lombardo and C. Brant, 2001. Shallow and deep lakes: determining successful maangement options. Lakeline, Spring 2001, 42-46.

CH2MHILL (2000) PLOAD Version 3.0 An Arc View GIS Tool to calculate Nonpoint Sources of Pollution in Watershed and Stomwater projects, CH2MHILL, Herndon, VA

Cooke, G.D., E.B. Welch, S.A. Peterson, P.R. Newroth. 1993. Restoration and Management of Lakes and Reservoirs. Lewis Publishers.

Dillon, P.J. and F.H. Rigler, 1974. A test of a simple nutrient budget model predicting the phosphorus concentration in lake water. J. Fish. Res. Board Can. 31:1771-1778.

Donabaum, K., M. Schagerl and M.T. Dokulil, 1999. Integrated management to restore macrophyte domination. Hydrobiologia 395/396:87-97.

Eisenreich, S.J. and J. Reinfelder. 2001. The New Jersey Air Deposition Network: Interim Report. Department Environmental Sciences, Rutgers University.

Holdren, C., W. Jones, and J. Taggart, 2001. Managing Lakes and Reservoirs. North American Lake Management Society and Terrene Institute, in cooperation with U.S. Environmental Protection Agency. Madison, WI.

Hosper, S.H., 1998. Stable states, buffer and switches: an ecosystem approach to the restoration and management of shallow lakes in The Netherlands. Water Science Technology 37(3):151-164.

Madgwick, F.J., 1999. Strategies for conservation management of lakes. Hydrobiologia 395/396:309-323.

Melzer, A., 1999. Aquatic macrophytes as tools for lake management. Hydrobiologia 395/396:181-190.

Moss, B., J. Madgwick, G. Phillips, 1996. A Guide to the restoration of nutrient-enriched shallow lakes. Norfolk Broads Authority, 18 Colegate, Norwich, Norfolk NR133 1BQ, Great Britain.

Moss, B., M. Beklioglu, L. Carvalho, S. Kilinc, S. McGowan and D. Stephen. Vertically-challenged limnology; contrasts between deep and shallow lakes. Hydrobiologia 342/343:257-267.

National Research Council, Assessing the TMDL Approach to water quality management. National Academy Press, Washington, D.C. 2001

New Jersey Department of Environmental Protection. 2000. Report on the Establishment of TMDL for Phosphorus in Strawbridge Lake. Amendment to Tri-County WQMP.

New Jersey Department of Environmental Protection. 1998. Identification and Setting of Priorities for Section 303(d) Water Quality Limited Waters in New Jersey, Office of Environmental Planning.

New Jersey Department of Environmental Protection. 1983a. New Jersey Lakes Management Program Lakes Classification Study: Lincoln Park Lakes. Bureau of Monitoring and Data Management in association with Princeton Aqua Science.

New Jersey Department of Environmental Protection. 1983b. New Jersey Lakes Management Program Lakes Classification Study: North Hudson Park Lake. Bureau of Monitoring and Data Management in association with Princeton Aqua Science.

New Jersey Department of Environmental Protection. 1983c. New Jersey Lakes Management Program Lakes Classification Study: Overpeck Lake. Bureau of Monitoring and Data Management in association with Princeton Aqua Science.

New Jersey Department of Environmental Protection. 1983d. New Jersey Lakes Management Program Lakes Classification Study: Verona Park Lake. Bureau of Monitoring and Data Management in association with Princeton Aqua Science.

Ostrofsky, M.L., 1978. Modification of phosphorus retention models for use with lakes with low areal water loading. J. Fish. Res. Bd. Can. 35(12):1532-1536.

Perrow, M.R., A.J.D. Jowitt, J.H. Stansfield, G.L. Phillips, 1999. The practical importance of the interaction between fish, zooplankton and macrophytes in shallow lake restoration. Hydrobiologia 395/396:199-210.

Phillips, G., A. Bramwell, J. Pitt, J. Stansfield and M. Perrow, 1999. Practical application of 25 years' research into the management of shallow lakes. Hydrobiologia 395/395:61-76.

Rast, W., A. Jones and G.F. Lee, 1983. Predictive capability of U.S. OECD phosphorus loading-eutrophication response models. Journal WPCF 55(7):990-1002.

Reckhow, K.H., 1979a. Uncertainty analysis applied to Vollenweider's phosphorus loading criterion. J. Water Pollution Control Federation 51(8):2123-2128.

Reckhow, K.H., 1979b. Quantitative Techniques for the Assessment of Lake Quality. EPA-440/5-79-015.

Reckhow, K.H., 1977. Phosphorus Models for Lake Management. Ph.D. dissertation, Harvard University.

Reckhow, K.H., M.N. Beaulac and J.T. Simpson, 1980. Modeling phosphorus loading and lake response under uncertainty: a manual and compilation of export coefficients. EPA 440/5-80-011.

Rodiek, R.K., 1979. Some watershed analysis tools for lake management. In Lake Restoration, EPA 400/5-79-001.

Scheffer, M., 1990. Multiplicity of stable states in freshwater systems. Hydrobiologia 200/201:475-486.

Sutfin, C.H. May, 2002. Memo: EPA Review of 2002 Section 303(d) Lists and Guidelines for Reviewing TMDLs under Existing Regulations issued in 1992. Office of Wetlands, Oceans and Watersheds, U.S.E.P.A.

U.S.E.P.A., 1999. Protocol for Developing Nutrient TMDLs. Watershed Branch, Assessment and Watershed Protection Division, Washington, DC.

Vollenweider, R.A., and J. Kerekes, 1982. Eutrophication of Waters: Monitoring, Assessment and Control. Organization for Economic Cooperation and Development (OECD), Paris. 156 p.

Wayland, R.H. III. November 22, 2002. Memo: Establishing Total Maximum Daily Load (TMDL) Wasteload Aloocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs. Office of Wetlands, Oceans and Watersheds, U.S.E.P.A.

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.

Export Coefficient Database Reference List

Allison, F.E., E.M. Roller, and J.E. Adams, 1959. Soil Fertility Studies in Lysimeters Containing Lakeland Sand. Tech. Bull. 1199, U.S. Dept. of Agriculture, Washington, D.C. p. 1-62.

Apicella, G., 2001. Urban Runoff, Wetlands and Waterfowl Effects on Water Quality in Alley Creek and Little Neck Bay. TMDL Science Issues Conference, WEF Specialty Conference.

Athayde, D. N, P. E. Shelly, E. D. Driscoll, D. Gaboury and G.B. Boyd, 1983. Results of the Nationwide Urban Runoff Program: Final Report. USEPA Water Planning Division. Washington, DC.

Avco Economic Systems Corporation, 1970. Storm Water Pollution from Urban Land Activity. Rep.11034 FKL 07/70, Federal Water Qual. Adm., U.S. Dept. of Interior, Washington, D.C. p. 325.

Bannerman, R., K. Baun, M. Bohm, P. E. Hughes, and D. A. Graczyk, 1984. Evaluation of Urban Nonpoint Source Pollution Management in Milwaukee, County, Eisconsin, Report No. PB84-114164, U.S. Environmental Protection Agency, Region V, Chicago, IL.

Bengtson, R.L. and C.E. Carter, 1989. Simulating Soil Erosion in the Lower Mississippi Valley with the CREAMS Model. From: Application of Water Quality Models for Agricultural and Forested Watersheds, edited by D.B. Beasley and D.L Thomas. Southern Cooperative Series Bulletin No. 338.

Broadbent, F.E., and H.D. Chapman, 1950. A Lysimeter Investigation of Gains, Losses and Balance of Salts and Plant Nutrients in an Irrigated Soil. Soil Sci. Soc. Amer. Proc. 14:261-269.

Carter, Gail P., 1998. Estimation of Nonpoint Source Phosphorus and Nitrogen Loads in Five Watersheds in New Jersey's Atlantic Coastal Drainage Basin. Surveying and Land Information Systems, Vol. 58, no 3. pp167-177.

CH2M Hill, 2000. Technical Memorandum 1, Urban Stormwater Pollution Assessment, prepared for North Carolina Department of Environment and Natural Resources, Division of Water Quality.

Claytor, R.A. and T.R. Schueler, 1996. "Design of Stormwater Filtering Systems," The Center for Watershed Protection, Prepared for Chesapeake Research Consortium, Inc.

Corsi, S.R., D.J. Graczyk, D.W. Owens, R.T. Bannerman, 1997. Unit-Area Loads of Suspended Sediment, Suspended Solids, and Total Phosphorus From Small Watersheds of Wisconsin. USGS FS-195-97.

Delaware Valley Regional Planning Commission, 1977. Average Pollutant Concentrations Associated with Urban Agriculture and Forest Land Use. Working Paper 5.01-1, Extent of NPS Problems.

Eck, P., 1957. Fertility Erosion Selectiveness on Three Wisconsin Soils. Ph. D. Thesis, Univ. of Wisconsin, Madison, WI.

F.X. Brown, Inc., 1993. Diagnostic-Feasibility Study of Strawbridge Lake. FXB Project Number NJ1246-01.

Frink, C.R., 1991. Estimating Nutrient Exports to Estuaries. Journal of Environmental Quality. 20:717-724.

Horner, R., B. W. Mar, L. E. Reinelt, J. S. Richey, and J. M. Lee, 1986. Design of monitoring programs for determination of ecological change resulting from nonpoint source water pollution in Washington State. University of Washington, Department of Civil Engineering, Seattle, Washington.

Horner, R.R., 1992. Water Quality Criteria/Pollutant Loading Estimation/Treatment Effectiveness Estimation. In R.W. Beck and Associates. Covington Master Drainage Plan. King County Surface Water Management Division., Seattle, WA.

Horner, Richard R., Joseph J. Skupien, Eric H. Livingston, and H. Earl Shaver, 1994. Fundamentals of Urban Runoff Management: Technical and Institutional Issues. Prepared by the Terrene Institute, Washington, DC, in cooperation with the U.S. Environmental Protection Agency. EPA/840/B-92/002.

Johnston, W.R., F. Ittihadieh, R.M. Daum, and A.F. Pillsbury, 1965. Nitrogen and Phosphorus in Tile Drainage Effluent. Soil Sci. Soc. Amer. Proc. 29:287-289.

Knoblauch, H.C., L. Kolodny, and G.D. Brill, 1942. Erosion Losses of Major Plant Nutrients and Organic Matter from Collington Sandy Loam. Soil Sci. 53:369-378.

Loehr, R.C., 1974. Characteristics and comparative magnitude of non-point sources. Journal of WPCF 46(11):1849-1872.

Lopes, T.J., S.G. Dionne, 1998. A Review of Semivolatile and Volatile Organic Compounds in Highway Runoff and Urban Stormwater. U.S. Geological Survey, U.S. Department of Interior.

Marsalek, J., 1978. Pollution Due to Urban Runoff: Unit Loads and Abatement Measure, Pollution from Land Use Activities Reference Group. International Joint Commission, Windsor, Ontario.

McFarland, Anne M.S and L. M. Hauck, 2001. Determining Nutrient Export Coefficients and Source Loading Uncertainty Using In-stream Monitoring Data. Journal of the American Water Resources Association, pp. 223, 37. No. 1, February.

Menzel, R. G., E. D. Rhoades, A. E. Olness, and S. J. Smith, 1978. Variability of Annual Nutrient and Sediment Discharges in Runoff from Oklahoma Cropland and Rangeland. Journal of Environmental Quality, 7:401-406.

Mills, W.B., D.B. Porcella, M.J. Ungs, S.A. Gherini, K.V. Summers, L. Mok, G.L. Rupp, G.L. Bowie, 1985. Water Quality Assessment – A Screening Procedure for Toxic and Conventional Pollutants in Surface and Ground Water – Part I and II. EPA-600/6-85-002A&B.

Minshall, N.E., M.S. Nichols, and S.A. Witzel, 1969. Plant Nutrients in Base Flow of Streams in Southwestern Wisconsin. Water Resources. 5(3):706-713.

Mundy, C., M. Bergman, 1998. Technical Memorandum No. 29, The Pollution Load Screening Model: A tool for the 1995 District Water Management Plan and the 1996 Local Government Water Resource Atlases, Department of Water Resources, St. Johns River Water Management District.

NCDWQ, 1998. Neuse River Basinwide Water Quality Plan, Chapter 5, Section A.

Nelson, M.E., 1989. Predicting Nitrogen Concentrations in Ground Water An Analytical Model. IEP, Inc.

Northeast Florida Water Management District, 1994. St. Marks and Wakulla Rivers Resource Assessment and Greenway Protection Plan. Appendix 4.

Northern Virginia Planning District Commision, 1979. Guidebook for Screening Urban Nonpoint Pollution Management Strategies. Prepared for the Metropolitan Washington Council of Governments.

Novotny, V., H. Olem, 1994. Water Quality: Prevention, Identification, and Management of Diffuse Pollution. Van Nostrand Reinhold, NY

Omernik, J. M., 1976. The influence of land use on stream nutrient levels, US EPA January. EPA-60/3-76-014

Omni Environmental Corporation, 1991. Literature Search on Stormwater Pollutant Loading Rates. Literature cited from DVRPC 1977; Wanielista et al. 1977; Whipple and Hunter 1977; NVPDC 1980; USEPA 1983; Mills et al. 1985; Nelson 1989; Walker et al. 1989.

Omni Environmental Corporation, 1999. Whippany River Watershed Program Stormwater Model Calibration and Verification Report.

Overcash, M. R., F. J. Humenik, and J. R. Miner, 1983. Livestock Waste Management, Vol. II, CRC Press, Inc., Boca Raton, Florida.

Pacific Northwest Environmental Research Laboratory, 1974. Relationships Between Drainage Area Characteristics and Non-Point Source Nutrients in Streams. Prepared for the National Environmental Research Center, August 1974.

Panuska, J.C. and R.A. Lillie, 1995. Phosphorus Loadings from Wisconsin Watersheds: Recommended Phosphorus Export Coefficients for Agricultural and Forested Watersheds. Research Management Findings, Bureau of Research, Wisconsin Department of Natural Resources, Number 38.

Pitt, R.E., 1991. Nonpoint Source Water Pollution Management. Dep. Civil Eng., Univ. Alabama, Birmingham, AL.

Polls, Irwin and Richard Lanyon, 1980. Pollutant Concentrations from Homogeneous Land Uses. Journal of the Environmental Engineering Division.

Prey, J., D. Hart, A. Holy, J. Steuer, J. Thomas, 1996. A Stormwater Demonstration Project in Support of the Lake Superior Binational Program: Summary. Wisconsin Dept. of Natural Resources. (http://www.dnr.state.wi.us/org/water/wm/nps/tpubs/summary/lakesup.htm)

Rast, W. and G.F. Lee, 1978. Summary Analysis of the North American (U.S. Portion) OECD Eutrophication Project: Nutrient Loading -- Lake Response Relationships and Trophic State Indices., EPA-600/3-78-008.

Reckhow, K.H., M.N. Beaulac and J.T. Simpson, 1980. Modeling of Phosphorus Loading and Lake Response Under Uncertainty: A Manual and Compilation of Export Coefficients. Report No. EPA 440/5-80-011. U.S. EPA, Washington, D.C.

Ryding, S. and W. Rast, 1989. The Control of Eutrophication of Lakes and Reservoirs. Man and the Biosphere Series, United Nations Educational Scientific and Cultural Organization, Paris, France.

Schueler, T.R., 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Prepared for the Metropolitan Washington Council of Governments.

Sonzogni, W.C. and G.F. Lee, 1974. Nutrient Sources for Lake Mendota - 1972. Trans. Wisc. Acad. Sci. Arts Lett. 62:133-164.

Uchrin, C.G. and T.J. Maldanato, 1991. Evaluation of Hydrocarbons in Urban Runoff and in Detention Basins. Water Writes. Water Research Institute, Division of Coastal and Environmental Studies, Rutgers University.

United States Geological Survey, U.S. Department of the Interior, 1998. Comparison of NPDES Program Findings for Selected Cities in the United States, USGS Fact Sheet, January

USEPA, 1987. Guide to Nonpoint Source Pollution Control. U.S. EPA, Criteria and Standards Division, Washington D.C.

USEPA, 1993. Urban Runoff Pollution Prevention and Control Planning (handbook). EPA/625/R-93/004.

USEPA, 2000. Watershed Analysis and Management (WAM) Guide for Tribes. (http://www.epa.gov/owow/watershed/wacademy/wam/)

Uttormark, P.D., J.D. Chapin, and K.M. Green, 1974. Estimating nutrient loadings of lakes from non-point sources. U.S. Environmental Protection Agency, Washington, D.C. 112 p. (WRIL 160609). EPA-660/3-74-020.

Walker, J.F., 1989. Spreadsheet Watershed Modeling for Nonpoint Source Pollution Management in a Wisconsin Basin, Water Resources Bulletin, Vol. 25, no. 1, pp. 139-147.

Wanielista, M.P., Y.A. Yousef, and W.M. McLellon, 1977. Nonpoint Source Effects on Water Quality, Journal Water Pollution Control Federation, Part 3, pp. 441-451.

Washington State Department of Ecology, 2000. Stormwater Management Manual for Western Washington: Volume I Minimum Technical Requirements. Publication No. 99-11.

Weidner, R.B., A.G. Christianson, S.R. Weibel, and G.G. Robeck, 1969. Rural Runoff as a Factor in Stream Pollution. J. Water Pollution. Con. Fed. 36(7):914-924.

Whipple, W. and J.V. Hunter, 1977. Nonpoint Sources and Planning for Water Pollution Control. Journal Water Pollution Control Federation. pp. 15-23.

Whipple, W., et al., 1978. Effect of Storm Frequency on Pollution from Urban Runoff, J. Water Pollution Control Federation. 50:974-980.

Winter, J.G. and H.C. Duthie, 2000. Export Coefficient Modeling to assess phosporus loading in an urban watershed. Journal of American Water Resources Association. Vol. 36 No. 5.

Zanoni, A.E., 1970. Eutrophic Evaluation of a Small Multi-Land Use Watershed. Tech. Completion Rep. OWRR A-014-Wis., Water Resources Center, Univ. of Wisconsin, Madison, WI.

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

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

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

where:
- V = lake volume (10^3 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:

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

where:

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

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

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

Substituting for ρ as a function of h:

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

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

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

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

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

Substituting the equation for P_U:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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