Amendment to the
Tri-County Water Quality Management Plan

Total Maximum Daily Loads for Total Phosphorus
To Address Four Streams Segments and Two Lakes in
Cooper River Watershed, Camden County
Lower Delaware Water Region

Watershed Management Area 18
COOPER RIVER AT LINDENWOLD
COOPER RIVER AT LAWNSIDE
COOPER RIVER AT HADDONFIELD
NORTH BRANCH COOPER RIVER AT KRESSON
COOPER RIVER LAKE
EVANS POND and WALLWORTH LAKE

Proposed:	**April 19, 2004**
Established:	**August 25, 2004**
Approved (by EPA Region 2):	**September 30, 2004**
Adopted:	

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1.0 Executive Summary

In accordance with Section 305(b) of the Federal Clean Water Act (CWA), the State of New Jersey developed *2002 Integrated List of Waterbodies* (35 N.J.R. 470(a), January 21, 2003. Three (3) stream segments in the Cooper River Watershed were listed as being phosphorous impaired, as indicated by elevated total phosphorus (TP). The *Proposed* 2004 *Integrated List of Waterbodies* (36 N.J.R. 1238(b) March 1, 2004) identified one (1) additional impaired segment for phosphorus in this watershed. The proposed amendment to the Tri-County Water Quality Management Plan will establish four total maximum daily loads (TMDLs) for TP that address phosphorus impairment of the stream segments as listed in Table 1. In addition, two TMDLs for TP will be established that address phosphorus impairment of the three lakes in the Cooper River watershed as listed in Table 2. A TMDL for Kirkwood Lake was previously established and will be integrated with these six TMDLs.

Table 1 Phosphorus-impaired stream segments of the Cooper River for which phosphorus TMDLs are being established.

TMDL Number	WMA	Station Name/Waterbody	Site ID	County(s)	River Miles
1	18	Cooper River at Lindenwold	01467120	Camden	1.6
2	18	Cooper River at Lawnside	01467140	Camden	13.6
3	18	Cooper River at Haddonfield	01467150	Camden	1.0
4	18	Cooper River N Br at Kresson	01467155	Camden, Burlington	9.0
Total River Miles					25.2

Table 2 Phosphorus-impaired lakes in the Cooper River Watershed for which phosphorus TMDLs are being established.

TMDL Number	WMA	Lake Name	Municipality (ies); Camden County	Acres
5	18	Cooper River Lake	Camden City, Pennsauken Township, Collingswood Borough, Haddonfield Borough, Cherry Hill Township	192.1
6	18	Evans Pond and Wallworth Lake*	Haddonfield Borough, Cherry Hill Township	17.9
	18	Kirkwood Lake **	Voorhees Township, Lindenwold Borough	24.9

* Added to the report based on monitoring data from stations upstream an downstream
** Moved to Sublist 4a in the draft 2004 Integrated List of Waterbodies

These six TMDLs identify sources of phosphorus and establish load reductions required in order to attain applicable surface water quality standards (SWQSs).

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 streams and lakes.

The lakes were selected as the critical locations for all six TMDLs. It was determined that this approach would also ensure attainment of the SWQS for the impaired stream segments. 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 six source categories. In order to track effectiveness of remediation measures (including TMDLs) and to develop baseline and trend information on lakes and streams, 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 for which a TMDLis being established. These plans will consider what specific measures are necessary to achieve the nutrient reductions required by the TMDL as well as what in-lake measures need to be taken to supplement the nutrient reductions required by the TMDL.

Each TMDL shall be proposed and adopted by the Department as an amendment to the Tri-County Water Quality Management Plan in accordance with N.J.A.C. 7:15-3.4(g).

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

2.0 Introduction

Sublist 5 (also known as the 303(d) List) of the State of New Jersey's *Proposed 2004 Integrated List of Waterbodies* identified several waterbodies in the Cooper River watershed, Lower Delaware Water Region, as being impaired by phosphorus, as evidenced by the presence of total phosphorus at concentrations in excess of the standards. This report establishes six TMDLs, which address phosphorus loads to the identified waterbodies. This TMDL document includes management approaches or restoration plans to reduce loadings of total phosphorus from various sources in order to attain applicable surface water quality standards for total phosphorus. The segments addressed in this document are listed on Sublist 5 for impairment caused by other pollutants; these TMDLs address only total phosphorus impairments. Separate TMDL evaluations will be developed to address the other pollutants of concern. The waterbodies will remain on Sublist 5 with respect to other impairments until such time as TMDL evaluations for all pollutants have been completed and approved by EPA. With respect to the total phosphorus impairments, the waterbodies will be moved to Sublist 4 following approval of the TMDLs by USEPA.

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

A TMDL is considered "proposed" when The Department 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 the Department 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 a thirty (30)-day review period. The TMDL is considered "approved" when the TMDL is approved by EPA Region 2. The TMDL is considered to be "adopted" when the approved TMDL is adopted by the Department as a water quality management plan amendment.

3.0 Background

A TMDL represents the assimilative or carrying capacity of a waterbody, taking into consideration point and nonpoint sources of pollutants of concern, natural background and surface water withdrawals. A TMDL quantifies the amount of a pollutant a waterbody 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 to identify all the contributors to surface water quality impacts and set load reductions for pollutants of concern as necessary to meet SWQS.

The Federal Clean Water Act under Section 303(d) requires states to identify "Impaired Waters" where specific designated uses are not fully supported. For these waters, the state is required to establish total maximum daily loads (TMDLs) in accordance with a priority ranking. To carry out this mandate, the Department prepares a list of impaired waters. Section 305(b) of the Act also requires states to periodically assess and report on the overall quality of their waters. Historically, the Department has summarized the water quality of the state in a biennial report entitled New Jersey's Water Quality Inventory Report (also known as the 305b Report). EPA issued guidance that encouraged states to integrate the two reports into a single report. Beginning with the *2002 Integrated List of Waterbodies*, the Department opted to use the single report approach.

In July 2003, EPA again issued guidance for the 2004 reports that encouraged states to integrate the 305(b) Report and the 303(d) List into one report. The Department has updated the *2002 Integrated Water Quality Monitoring and Assessment Methods Document*. This document includes a description of the quality assurance requirements as well as the rationale for the placement of waterbodies in Sublists 1 through 5. The *2004 Integrated List of Waterbodies* will be submitted to the EPA for approval as part of the *2004 Integrated Water Quality Monitoring and Assessment Report*.

EPA guidance dated July 21, 2003 describes the statutory and regulatory requirements for approvable TMDLs, as well as additional information generally needed for EPA 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 six TMDLs, addresses the following components:

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 (EPA does not require and does not approve TMDL implementation plans).
11. Public Participation.

4.0 Pollutant of Concern and Area of Interest

The pollutant of concern for these TMDLs is 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 can be 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 systems. Consequently, phosphorus is frequently a prime determinant of algal activity in a stream or lake. Eutrophication has been described as the acceleration of the natural aging process of surface waters. It is characterized by excessive loading of silt, organic matter, and nutrients, causing high biological production and decreased basin volume (Cooke et al, 1993). Symptoms of eutrophication (primary impacts) include oxygen super-saturation during the day, oxygen depletion during the 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.

As a result of monitoring conducted by the Department, TP concentrations were found to exceed New Jersey's SWQS, published at N.J.A.C. 7-9B et seq., for the stream segments and lakes in the Cooper River Watershed as identified in Table 2. The State of New Jersey's 2002 *Integrated List of Waterbodies* (35 N.J.R. 470 (a), January 21, 2003), identifed three stream segments in the Cooper River Watershed as being phosphorus impaired. These impairments were carried over to the Proposed 2004 *Integrated List of Waterbodies* (36 N.J.R. 1238(b), March 1, 2004), which also identifed one additional impaired segment for phosphorus. These TMDLs address four phosphorus impaired stream segments from Sublist 5 and one phosphorus impaired lake from Sublist 3 (Cooper River Lake). In addition, based on monitoring data from stations upstream and downstream, the Department has determined that the Evans Pond and Wallworth Lake system are impaired and will prepare a TMDL for these waterbodies as well. These two artificial lakes were formed in 1913 by building two consecutive dams on the Cooper River (see Appendix G). A TMDL was proposed for Kirkwood Lake (35 N.J.R. 1727(a), April 21, 2003) and subsequently approved by EPA Region 2 on September 30, 2003 (written communication); the Department has integrated this lake TMDL with the current proposed TMDLs for continuity in addressing the phosphorus impairments in the Cooper River watershed.

Table 3 Phosphorus-impaired sites in the Cooper River Watershed for which phosphorus TMDLs are being established.

TMDL No	Station Name/Waterbody	Site ID	Lake Area	River Miles	Management Response
1	Cooper River at Lindenwold	1467120	--	1.6	establish TMDL
2	Cooper River at Lawnside	1467140	--	13.6	establish TMDL
3	Cooper River at Haddonfield	1467150	--	1.0	establish TMDL
4	Cooper River N Br at Kresson	1467155	--	9.0	establish TMDL
5	Evans Pond and Wallworth Lake	--	17.89	--	establish TMDL
6	Cooper River Lake	--	192.1	--	establish TMDL
	Kirkwood Lake	--	24.91	--	TMDL established in 2003, in 2004 proposed to move to Sublist 4

These six TMDLs will address 25.2 river miles and 235 acres of lake surface area with a corresponding total of 22,500 acres of land within the affected watershed. Together with the established TMDLs for Kirkwood Lake, these TMDLs will cover the entire non-tidal part of the Cooper River watershed. The implementation plans also will be developed to address phosphorus reduction for the whole non-tidal Cooper River watershed. Segments that appear on the 2002 Integrated List were identified as Medium Priority (1, 2 and 3); segments that appear on the 2004 Integrated List were identified as High Priority (1, 3 and 4). The lakes for which TMDLs have been developed (5 and 6) were on Sublist 3 or not listed and were not ranked.

Data Sources

The Department's Geographic Information System (GIS) was used extensively to describe the Cooper River Watershed characteristics. In concert with the USEPA's November 2001 listing guidance, the Department is using Reach File 3 (RF3) from the 2002 Integrated Report to represent rivers, stream, lakes and lakesheds (watersheds of the lakes). The following is general information regarding the data used to describe the watershed management area:

- 1995/97 Land use/Land cover Update, published 12/01/2000 by NJDEP Bureau of Geographic Information and Analysis, delineated by watershed management area.
- Lakes 2003, Lakes Coverage, NJDEP - Bureau of Freshwater and Biological Monitoring, upublished coverage, created March 2003.
- 2004 Assessed Rivers coverage, NJDEP, Watershed Assessment Group, unpublished coverage.

- 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).
- County Boundaries: Published 11/01/1998 by the NJDEP, Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA), "NJDEP County Boundaries for the State of New Jersey." Online at: http://www.state.nj.us/dep/gis/digidownload/zips/statewide/stco.zip
- Detailed stream coverage (RF3) by County: Published 11/01/1998 by the NJDEP, Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA). "Hydrography of Camden County, New Jersey (1:24000)." Online at: http://www.state.nj.us/dep/gis/digidownload/zips/strm/
- NJDEP Existing Water Quality Stations in New Jersey, published 5/12/2003, NJDEP, Division of Land Use Management (LUM), Water Monitoring & Standards, Bureau of Freshwater Biological Monitoring (BFBM)
- http://www.state.nj.us/dep/gis/digidownload/zips/statewide/ewqpoi.zip
- NJDEP Ambient Stream Quality Monitoring Sites, published 5/30/2001, NJDEP , Bureau of Freshwater Biological Monitoring (BFBM), http://www.state.nj.us/dep/gis/digidownload/zips/statewide/swpts01.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.
- NJDEP Hillshade Grid for New Jersey (100 meter), published 05/01/2002, Department of Environmental Protection (NJDEP), Office of Information Resources Management (OIRM), Bureau of Geographic Information and Analysis (BGIA), online at: http://www.state.nj.us/dep/gis/digidownload/zips/statewide/nj100mhill.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.

4.1 Description of the Cooper River Watershed and Impaired Waterbodies

The Cooper River watershed is a part of the Water Management Area 18 (WMA 18) in the Lower Delaware Water Region. The Cooper River watershed encompasses approximately 37 square miles within the WMA 18. The non-tidal mainstem Cooper River extends 16 miles from the Cooper River Parkway Dam, which marks the head of tide, located at Kaighn Avenue in Camden, to Gibbsboro. The river flow direction is generally from southeast to northwest as it empties to the Delaware River at Camden City. The significant tributaries include: North Branch Cooper River, Millard Creek, Woodcrest Creek, and Tindale Run. Land use is primarily urban and suburban as the Cooper River watershed drains the densest populated part of southwestern New Jersey in Camden County. The main urban centers include Camden, Pennsauken, Collingswood, Cherry Hill, Haddonfield, and Haddon Township, which are situated mainly along the Cooper River's main stem and areas adjacent to North Branch Cooper River. Major impoundments include, going upstream from the Cooper River Parkway Dam, Cooper River Lake, Hopkins Pond (on the Cooper River's west tributary), Wallworth Lake, Evans Pond, Kirkwood Lake, Bridgewood Lake, Woodland Lake, Linden Lake, and Edgewood Lake. Figure 1 is provided as a Cooper River watershed overview map. All of the streams in the Cooper River watershed have been classified as FW2 Non-trout.

Figure 1 Spatial extent of the impaired segments in the Cooper River Watershed, WMA 18, for which TMDLs are being developed

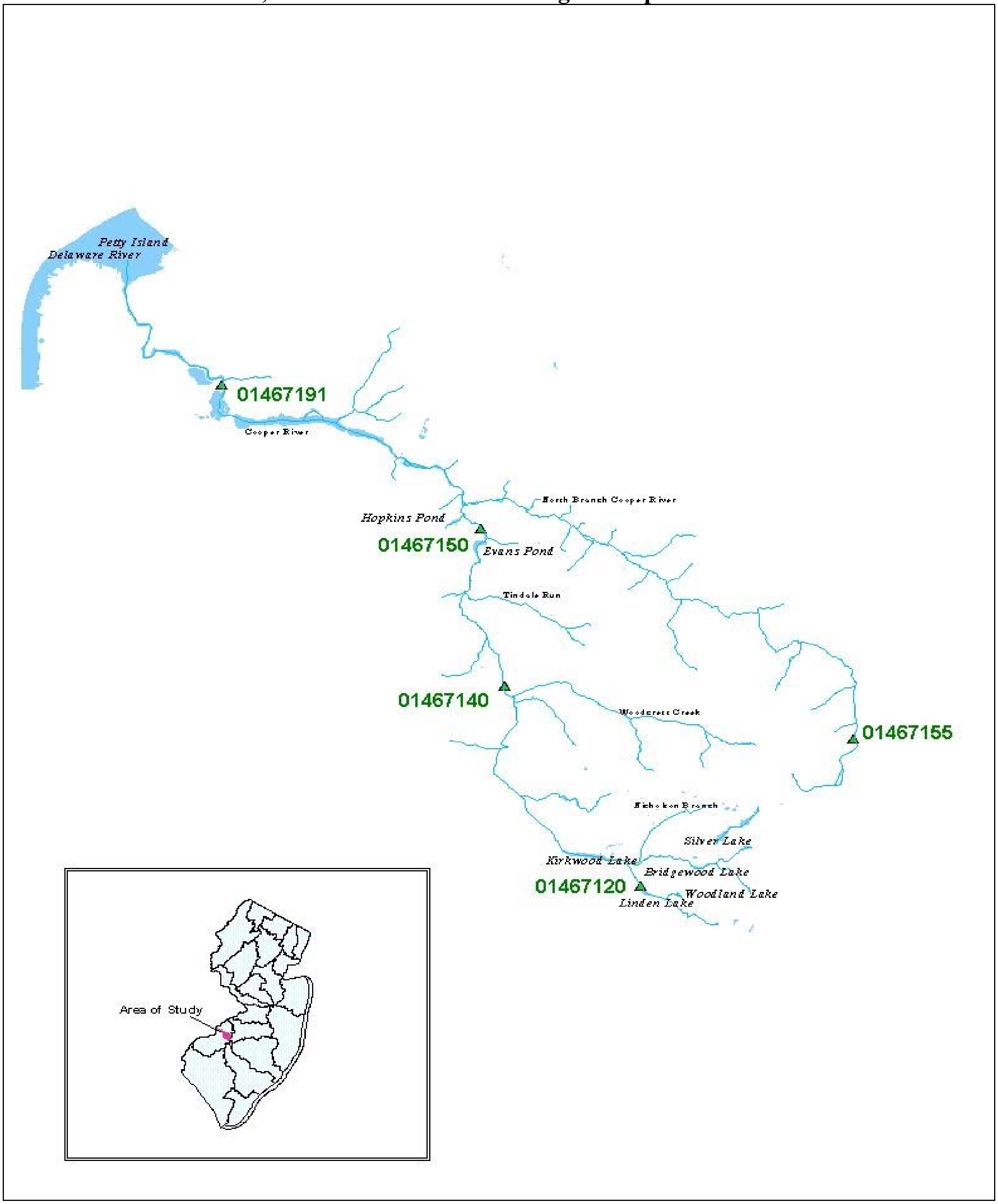


Figure 2 Map of Four Segments in the Cooper River Watershed

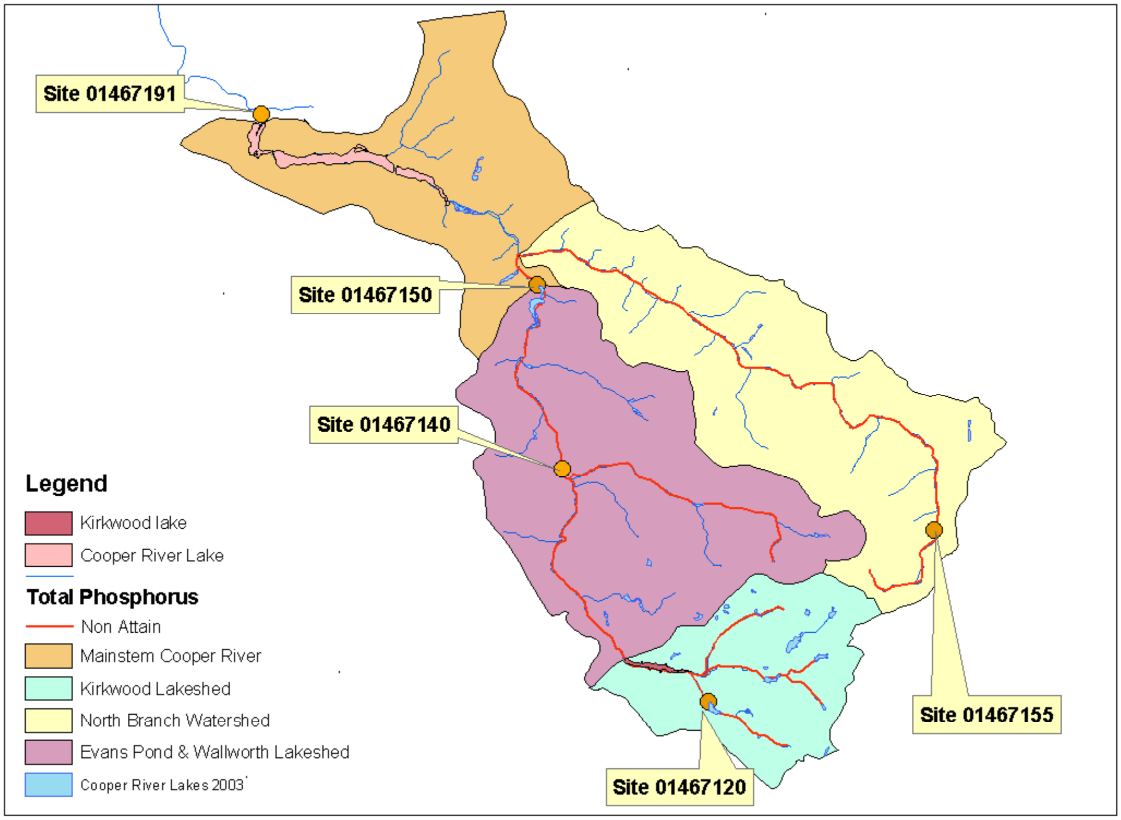


Table 4 Description of the spatial extent of each phosphorus impairment in the Cooper River Watershed, WMA 18

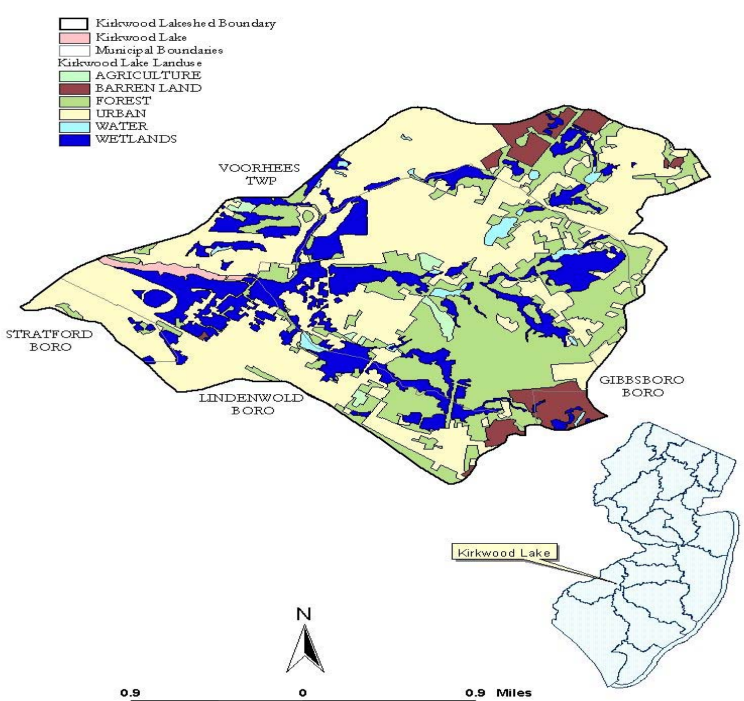
Site Name	USGS Station ID #	River Miles / Lake Area	Description of the impaired segments
Cooper River at Lindenwold	**01467120**	1.6	Cooper River watershed upstream of the Lindenwold monitoring station and downstream portion to the confluence with the Northern parts of the South Branch Cooper River. This stream stretch was covered by 2003 TMDL for Kirkwood Lake.
Cooper River at Lawnside	**01467140**	13.6	South Branch Cooper River segments from Evans Pond to the headwaters excluding most southern segment with Station 01467120 (see above).
Cooper River at Haddonfield	**01467150**	1.0	South Branch Cooper River segment from confluence with the North Branch Cooper River including Evans Pond and Wallworth Lake.
North Branch Cooper River at Kresson	**01467155**	9.0	North Branch Cooper River watershed upstream of the confluence with the Cooper River main stem at Cherry Hill
Cooper River Lake	**01467191**		Cooper River watershed upstream of the Cooper River Parkway Dam located at Kaighn Avenue in Camden. The Station #01467191 is located on the tidal side of the dam and is under tidal influence. This segment covers entire watershed, with the exception of Kirkwood Lake watershed.

Site Name	USGS Station ID #	River Miles / Lake Area	Description of the impaired segments
Wallworth Lake and Evans Pond	**01467150**		Cooper River watershed upstream from the Wallworth Lake dam. This lakeshed includes Evans Pond and excludes Kirkwood Lake watershed. Monitoring station #01467150 is located on the Wallworth Lake
Kirkwood Lake	**01467120**		Cooper River watershed upstream from the outlet of the lake. This lakeshed includes Kirkwood Lake, Linden Lake, Bridgewood Lake, Silver Lake, and Woodland Lake watersheds. It includes segment with the monitoring station #01467120.

4.1.1 Kirkwood Lake

Kirkwood Lake is a small, narrow lake approximately 0.75 miles in length and is located on the boundary of Voorhees and Lindenwold, Camden County. Historically, the lake has been used for fishing, boating and swimming purposes. More recently, these uses have lessened with the associated decrease in water quality. It has a total surface area of 25 acres, a volume of 215,000 m^3, a mean depth of 2.1 m, and a hydraulic detention time of around 8 days (depth and discharge taken from NJDEP 1983). The 3250-acre lakeshed is about 130 times the size of the lake and has a high percentage of urban land use. The primary tributaries to Kirkwood Lake include the Cooper River, Millard Creek, and Nicholson Branch. The USGS station #01467120 phosphorus impaired segment is located in the Kirkwood Lake watershed. A TMDL, already approved by EPA in 2003 for Kirkwood Lake, will address the phosphorus impaired segment at Norcross Road at Lindenwold.

Figure 3 Lakeshed of Kirkwood Lake with Land Use Coverage



4.1.2 Evans Pond and Wallworth Lake

Evans Pond and Wallworth Lake are artificial lakes formed in 1913 by two dams across the Cooper River. Both lakes are located on the boundary of Cherry Hill Township and Haddonfield Borough and bounded by Kings Highway and Brace Road. Evans Pond dam forms a 14-acre lake. The Wallworth Lake dam is located about 0.5 mile downstream from the Evans Pond dam and forms a 3.3-acre lake. A 55.65 acre park known as Wallworth Park surrounds these lakes.

The USGS station #01467150 is located on the northeast side of the Wallworth Lake, close to the dam. Continuous flow data have been collected from 1964 up to the present. Over the years sediment has substantially filled both lakes, decreasing their water capacities. Accumulated bottom sediments may be rich in phosphorus which, under high flow condition, is released to the water column.

4.1.3 Cooper River Lake

The Cooper River Lake was formed in 1940, when the Cooper River Parkway dam was built at Kaighn Avenue in Camden City. The dam prevents tidal flow upstream into Cooper River Lake at high tide, even though the elevation of the Cooper River Lake is lower than the high tide levels. Cooper River Lake is a narrow lake, about two miles long with the surface area approximately 192 acres. It drains a watershed of 37 square miles. The maximum depth is 2.1 m and the average depth is 1.2 m. It is expected that a considerable layer of bottom sediments has accumulated in the lake, decreasing its capacity. Cooper River Park (347 acres) runs along the lake through Pennsauken, Collingswood and Haddon Township. The lake is used for rowing events. A fish ladder has been constructed at the Cooper River dam and in May 1998 the river was stocked with fish.

Figure 4 Evans Pond/Wallworth Lake Watershed

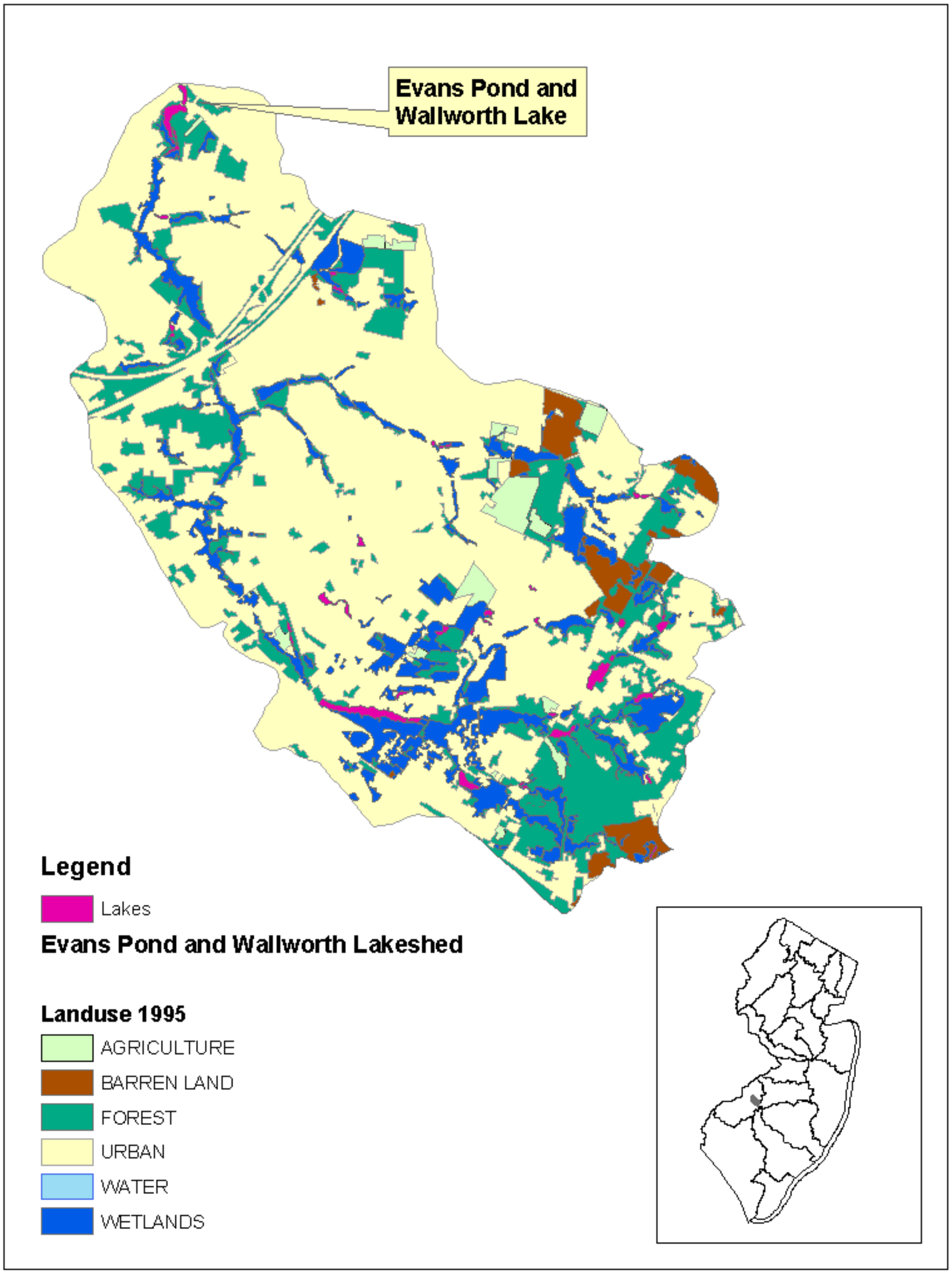
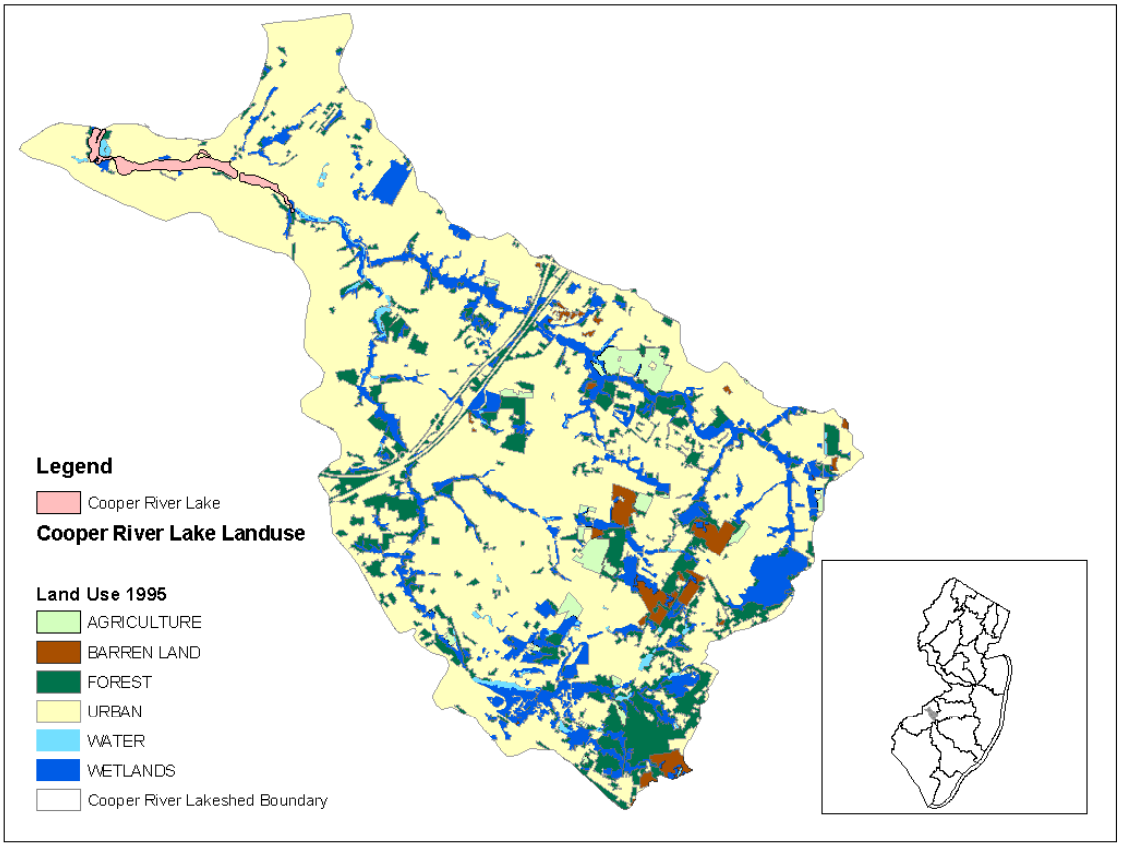


Figure 5 Lakeshed of Cooper River Lake with Land Use Coverage



5.0 Pollutant of Concern and Applicable Surface Water Quality Standards

The pollutant of concern is phosphorus. The standards for phosphorus, as stated in N.J.A.C. 7:9B-1.14(c) of the New Jersey Surface Water Quality Standards (SWQS) for Fresh Water 2 (FW2) waters are:

Phosphorus, Total (mg/l):

i. Lakes: Phosphorus as total P shall not exceed 0.05 in any lake, pond, reservoir, or in a tributary at the point where it enters such bodies of water, except where site-specific criteria are developed pursuant to N.J.A.C. 7:9B-1.5(g)3.

ii. Streams: Except as necessary to satisfy the more stringent criteria in paragraph i. above or where site-specific criteria are developed pursuant to N.J.A.C. 7:9B1.5(g)3, phosphorus as total P shall not exceed 0.1 in any stream, unless it can be demonstrated that total P is not a limiting nutrient and will not otherwise render the waters unsuitable for the designated uses.

Also as stated in N.J.A.C. 7:9B-1.5(g)2:

Nutrient policies are as follows:

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.

The impaired 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 (NJAC 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

In order to evaluate and characterize total phosphorus loadings in the waterbodies of interest in these TMDLs, and thus propose proper management responses, source assessments are warranted. Source assessments include identifying the types of sources and their relative contributions to total phosphorus loadings, in both time and space variables. 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

By 1996, all municipal and industrial discharges to the Cooper River watershed were eliminated. A total of thirty-nine individual sewage treatment plants, previously discharging inadequately treated effluent into the Cooper River and its tributaries, were connected to the upgraded and expanded Camden County Municipal Utility Authority (CCMUA) facility located in Camden City, which discharges to the Delaware River. As a result of these changes, overall surface water quality has improved in the Cooper River watershed; however, the monitoring data still indicate phosphorus impairment in the Cooper River watershed.

6.2 Assessment of Nonpoint and Stormwater Point Sources

Nonpoint and stormwater point sources include storm-driven loads such as runoff from various land uses that transport phosphorus from sources such as geese, farms, and domestic pets to the receiving water. The phosphorus deposited in the lakes and streams sediments could be an additional source of phosphorus released to the water column under certain conditions. Domestic pet waste, geese waste, as well as loading from storm water detention basins and sediments will be addressed by the Phase II MS4 program. Nonpoint sources also include steady-inputs from “illicit” sources such as failing sewage conveyance systems, sanitary sewer overflows (SSOs), and failing or inappropriately located septic systems. When “illicit” sources are identified, either through the Phase II MS4 requirements or trackdown studies conducted by the Department, appropriate enforcement measures will be taken to eliminate them.

Runoff from land surfaces comprises most of the nonpoint and stormwater point sources of phosphorus into lakes. Watershed loads were 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 EPA'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 5.

Table 5 Phosphorus export coefficients (Unit Areal Loads)

land use / land cover	LU/LC codes[2]	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/ha/yr was used to estimate air deposition of phosphorus directly onto the lake surface. This value was developed from statewide mean concentrations of total phosphorus from the New Jersey Air Deposition Network (Eisenreich and Reinfelder, 2001). Land uses and calculated runoff loading rates for each of the watersheds are shown in Table 6.

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

Table 6 Nonpoint and Stormwater Sources of Phosphorous Loads

Nonpoint Source	Cooper River Main Stem		Evans Pond & Wallworth Lake Lakeshed		Kirkwood Lake Lakeshed		North Branch Cooper River Lakeshed		Cooper River Lake Watershed	
	acres	kg/yr	acres	kg/yr	acres	kg/yr	acres	kg/yr	acres	kg/yr
land use loads										
medium / high density residential	2219	1437	3998	2589	742	481	2854	1848	9072	5874
low density / rural residential	68.9	19.5	662	188	212	60.1	789	223	1520	431
commercial	651	527	1002	811	260	211	460	372	2152	1742
industrial	226	155.6	214	147	38.6	26.6	87.1	59.9	527	363
mixed urban / other urban	1063	430	1361	551	342	139	733	297	3158	1278
agricultural	0	0	256	155	39.3	23.9	231	140	487	296
forest, wetland, water	454	18.4	3068	124	1410	57.0	1773	71.7	5313	215
barren land	2.23	0.45	360	72.7	184	37.3	160	32.3	521	105
other loads										
septic systems	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
waterfowl	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
internal load	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
tributary load	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
natural loads										
air deposition	192	5.44	17.89	0.5	24.9	0.7			192	5.44
groundwater	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TOTAL	**4916**	**2594**	**10939**	**4638**	**3250**	**1040**	**7087**	**3045**	**22749**	**10309**

7.0 Water Quality Analysis

As described in EPA guidance, a TMDL identifies the loading capacity of a waterbody for a particular pollutant. EPA regulations define loading capacity as the greatest amount of loading that a waterbody can receive without violating water quality standards (40 C.F.R. 130.2). The loadings are required to be expressed as either mass-per-time, toxicity, or other appropriate measures (40 C.F.R. 130.2(i)). 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.

7.1 Historical Surface Water Quality Data Overview

The United States Geological Survey (USGS) has collected monitoring data on the Cooper River since 1908. Although the monitored stations and monitoring schedule have changed over the years, the historical data is useful to understand trends in water quality over time. Table 7 shows all of the historical and current monitoring stations in the Cooper River watershed.

Table 7 Historical Monitoring in the Cooper River Watershed

USGS Station #	Data for period	Station Location
01467120	105 samples: 1975-1991 (USGS) 1998 (NJDEP-metal recon.), 2002 (NJDEP-TMDL)	Cooper River at Norcross Road at Lindenwold, NJ
01467130	51 samplings: 1964-1982 (USGS)	Cooper River at Kirkwood, NJ
01467140	93 samples: 1975- 1991 (USGS), 1998 (NJDEP-metal recon.), 2001 (NJDEP-diurnal Oxygen), 2002 (NJDEP-TMDL)	Cooper River at Lawnside, NJ
01467150	311 samples: 1925-8/7/02 (USGS) 2001 (NJDEP) diurnal Oxygen	Cooper River at Haddonfield, NJ
01467155	27 samples: 1997-9/4/2002 (USGS), 1998(NJDEP-metal recon.), 2001 (NJDEP-diurnal Oxygen), 2002 (NJDEP-TMDL)	North Branch Cooper River at Kresson, NJ
01467180	3 samples: 1964, 1967, 1977 (USGS)	North Branch Cooper River at Ellisburg, NJ
01467181	34 samplings: 1975- 1978 (USGS), 2002 (NJDEP-TMDL)	North Branch Cooper River at Erlton, NJ
01467190	56 samplings: 1969-1983 (USGS)	Cooper River at Camden, NJ
01467191	2000-2002 (NJDEP-EWQ sampling)	Cooper River at Camden (Kaighn Ave – tidal influenced)
01467193	3 samples: 1980 (USGS)	Cooper River at Camden (below Federal Street-tidal influenced)

The water samples collected in the very early monitoring period were tested mainly to assess the fecal coliform count and biological oxygen demand (BOD5). Other parameters were added as water quality assessment matured.

Based on the pre-1998 Ambient Stream Quality Monitoring data, the Cooper River exceeded the SWQS for phosphorus at three stations. The Department determined in its *Surface Water Quality Inventory Report of 1998*, that the surface water quality standard for total phosphorus was not met at Lindenwold (#01467120), Lawnside (#01467140) and Haddonfield (#01467150). The Kresson station on the North Branch Cooper River (#01467155), included in the USGS monitoring program in 1997, exceeded TP concentration criterion and, in 2002, was added to the Sublist 5 of the *Integrated List of Waterbodies.*

In 2000, the Department collected additional surface water quality data to enhance the established ambient network. Under this program, station #01467191, located in Camden at Kaighn Avenue, was monitored eight times from December 2000 to September 2002.

Currently, the Cooper River watershed is monitored at Haddonfield (#01467150) and Kresson (#01467155).

7.1.1 Lindenwold (Station #01467120)

The Lindenwold station (#01467120) is located at the head of the Cooper River, at the outlet of Linden Lake and upstream of Kirkwood Lake. The watershed discharging to this location covers about one square mile. The water samples were collected for chemical analysis from November 1975 to May 1991 on a 6 to 7 times per year schedule. In August 1998, the Department monitored this station for three consecutive days with the focus on metal contamination. Flow data were not collected during the sampling events. In 2002, the Department collected six samples from June 18th to October 1st to obtain data for TMDL development.

A total of seventy eight TP results were obtained from 1975 through October 2002. From the TP concentration data set, seven samples (9 percent) exceeded the 0.1 mg/L TP criterion for streams, but 30 percent of samples exceeded the 0.05 mg/L TP criterion for lakes and lake inflow. TP concentration ranged between 0.01 mg/L and 0.21 mg/l with an average of 0.053 mg/L.

Figure 6 Changes in Phosphorus Concentration with Flow

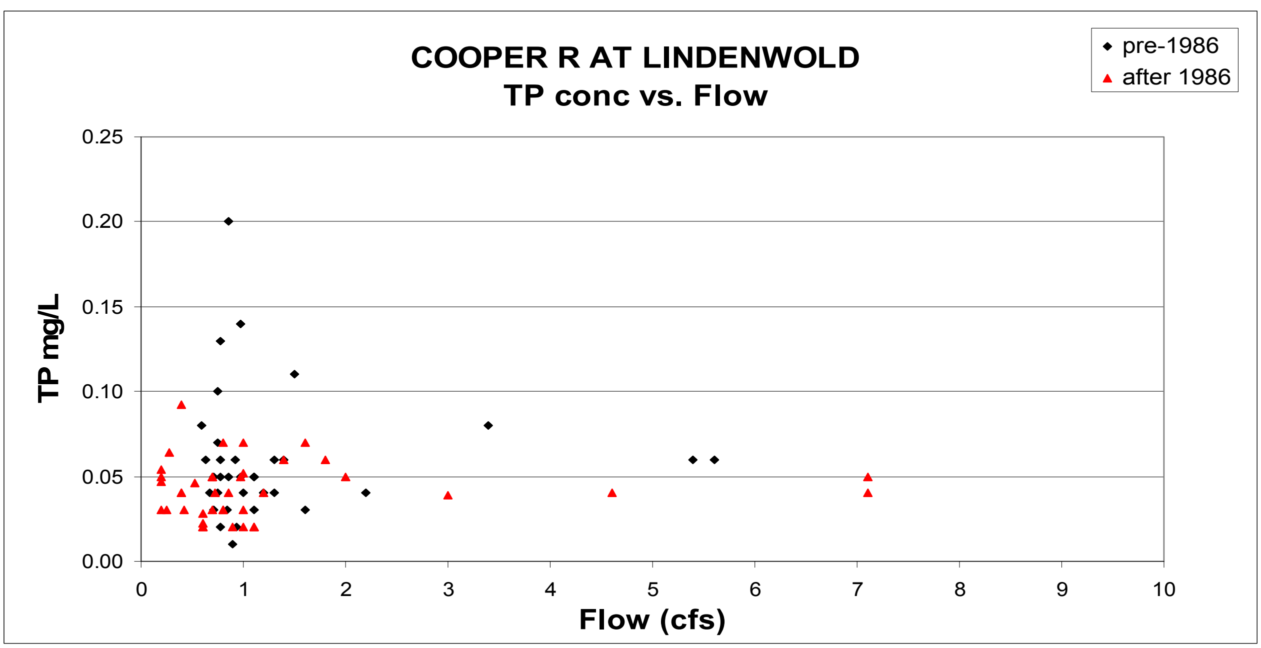
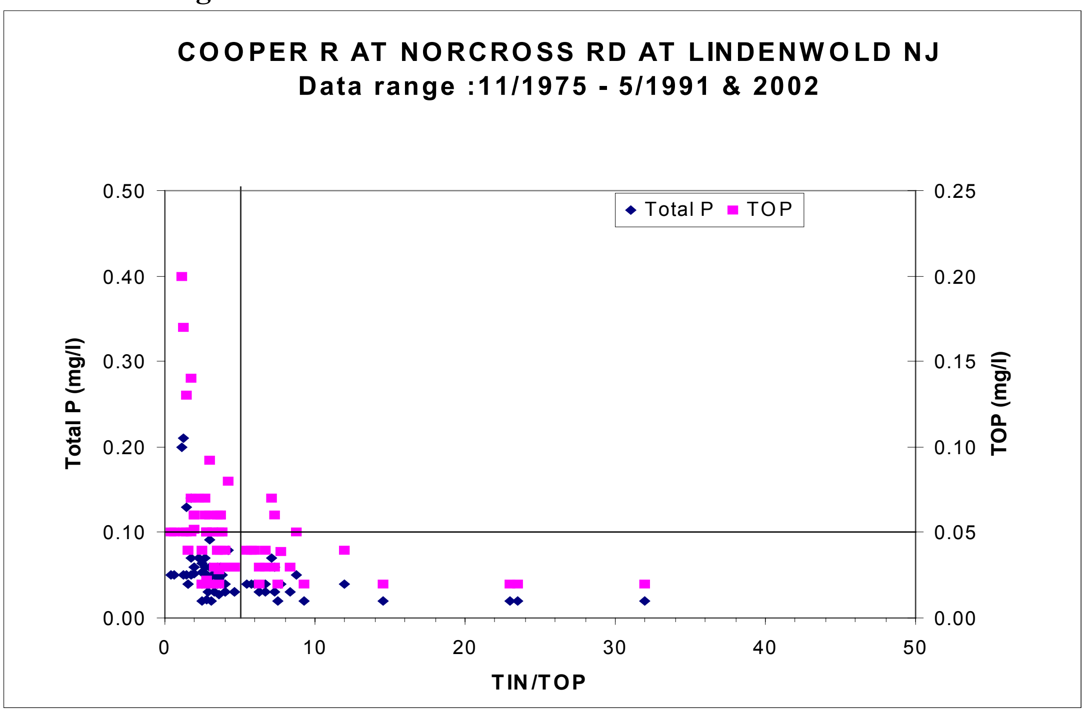


Figure 6 illustrates changes in TP concentration compared to flow rate. The monitoring results are presented in two different time periods: before 1986 and from 1986 to 2002. This distinction was made because point source discharges began to be eliminated and phosphorus concentrations tended to decline. The flow rate ranged from 0.1 to 12.0 cubic feet per second (cfs) with 1.4 cfs average flow. Under low flow conditions the changes in the phosphorus concentration were more differentiated.

The Department's Division of Water Quality's March 2003 guidance document entitled, *"Technical Manual for Phosphorus Evaluations (N.J.A.C. 7:9B-1.14(c)) for NJPDES Discharge to Surface Water Permits"*, recommends considering ratios of nitrogen and phosphorus as an indicator of a nutrient rich environment suitable for algal overgrowth. When the ratio of total inorganic nitrogen (TIN) to total orthophosphate (TOP) is smaller than or equal to 5, then phosphorus is not limiting the system. Figure 7 depicts the relationship of the two key nutrients at the Lindenwold station. At the Lindenwold station, when total phosphorus TP > 0.1 mg/L when a total organic phosphorus TOP < 0.05 mg/L, the ratio TIN/TOP did not exceed 5. This suggests that phosphorus is not the limiting nutrient. For a more detailed explanation, please refer to Appendix C.

Figure 7 Limiting Nutrients



TIN = dissolved nitrite, nitrate and ammonia. TIN calculated as: a sum of dissolved ammonia (P00608) & dissolved nitrite and nitrate (P00631) or a sum of total ammonia (P00610) and total nitrite & nitrate (P00630)

TOP = dissolved reactive phosphorus: orthophosphorus (P00671) if available, or dissolved phosphorus (P00666) if available, or total phosphorus (P00665)

7.1.2 Lawnside (Station #01467140)

The Lawnside monitoring station is located on the Cooper River, downstream from Kirkwood Lake and downstream from the location where the Woodcrest Creek merges with the Cooper River. The watershed draining to this station is about 13 square miles with 63% characterized as an urban/suburban land use, 18% forest, 10% wetland, 3% agriculture, and the remaining 6% is covered by barren land and water. This station was continuously monitored by USGS from 1975 to 1991 on a 6 to 7 times per year schedule. In August 1998, the Department monitored this station for three consecutive days with the focus on metal contamination. Flow data were not collected during this sampling event. In 2001, the Department performed a three-day sampling event designed to determine algal growth. The results were inconclusive. The next sampling event occurred during the summer of 2002; the Department performed six sampling rounds designed to augment nutrient data for the TMDLs.

The phosphorus results (see Figure 8) ranged from 6.7 mg/L in 1976 to 0.03 mg/L in 1991 and include the highest concentrations recorded in the Cooper River watershed. The average TP concentration for the period 1975-1991 was 1.42 mg/L. This station was discontinued as an ambient station in 1991. The post-1991 data is limited in value. For example, the 2002 monitoring data were taken during a very low flow period (drought emergency) and phosphorus results may not be characteristic. The phosphorus concentration for June-October 2002 varied from a minimum value of 0.20 mg/L to the maximum value of 2.29 mg/L with an average from six samplings equal to 0.83 mg/L.

Figure 8 Changes in Phosphorus Concentration with Flow Rate

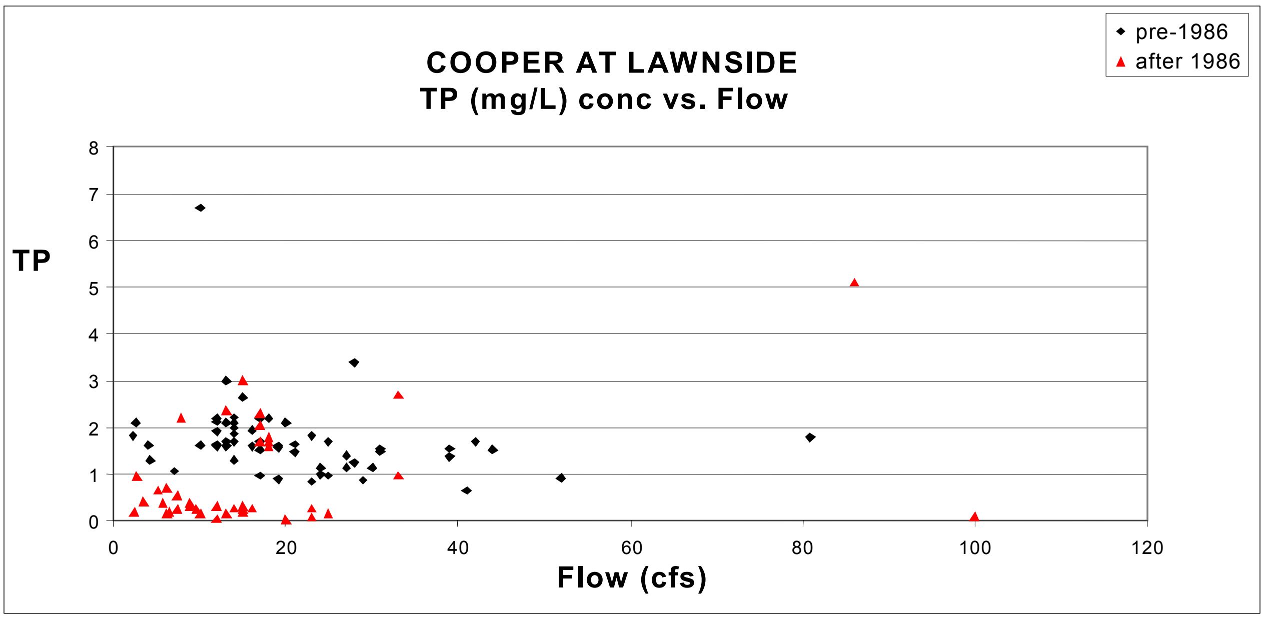
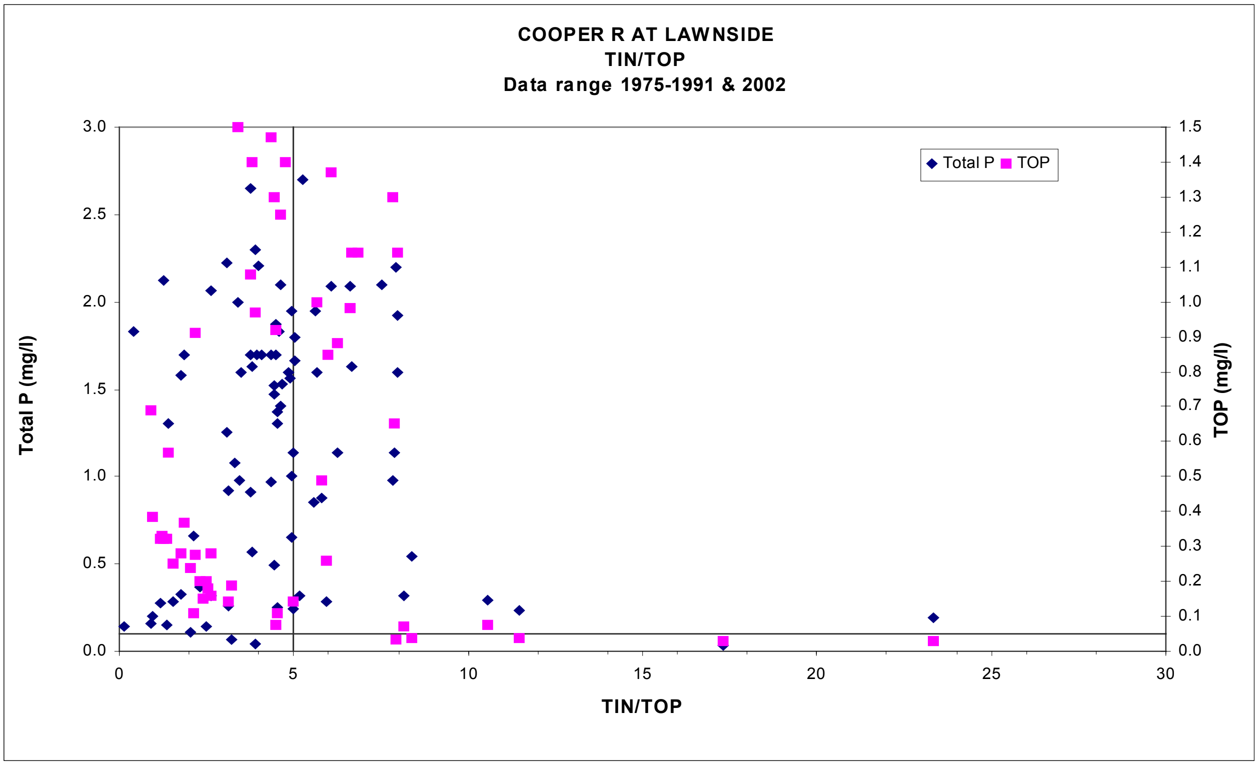


Figure 8 illustrates changes in the TP concentration relative to flow changes. The TP results are presented in two time periods: before 1986 and after 1986, when most of point-source discharges were connected to CCMUA. The TP concentration significantly decreased from an average TP concentration of 1.676 mg/L to an average TP concentration of 0.861 mg/L. While data is inconclusive, the pre-1986 data show concentrations relatively steady with flow and the post 1986 data suggest nonpoint sources are more significant.

Figure 9 Limiting Nutrients



TIN = dissolved nitrite, nitrate and ammonia. TIN calculated as: a sum of dissolved ammonia (P00608) & dissolved nitrite and nitrate (P00631) or a sum of total ammonia (P00610) and total nitrite & nitrate (P00630)
TOP = dissolved reactive phosphorus: orthophosphorus (P00671) if available, or dissolved phosphorus (P00666) if available, or total phosphorus (P00665)

Figure 9 shows the relationship of the two key nutrients at the Lawnside station. The majority (69%) of the TIN/TOP nutrient ratios are below or equal to 5. This suggests that phosphorus is not the limiting nutrient most of the time.

7.1.3 Haddonfield (Station 01467150)

The Haddonfield monitoring station is located close to the Wallworth Lake dam. The drainage area covers about 18 square miles. The land use in the watershed is 68% urban. (The other uses include: forest 17%, wetland 9%, barren land 3%, agriculture 2%, and water about 1%. The station was monitored by USGS from 1972 to 1978. The monitoring schedule was resumed in August 1991 and is continued to the present time.

Figure 10 demonstrates changes in phosphorus concentration over the monitoring period. The total phosphorus concentration varies from 0.036 mg/L to 1.43 mg/L with the average value for TP of 0.25 mg/L. The flow rate is steady most of the time as a result of controlled flows on Evans Pond and Wallworth Lake. Because the Haddonfield station is at the outlet of the Wallworth Lake, the data may be more representative of water quality in the lake than ambient stream conditions. When the runoff water flashes the lakes during a flooding condition, the phosphorus concentration slightly increases.

Figure 10 Changes in Phosphorus Concentration with Flow Rate

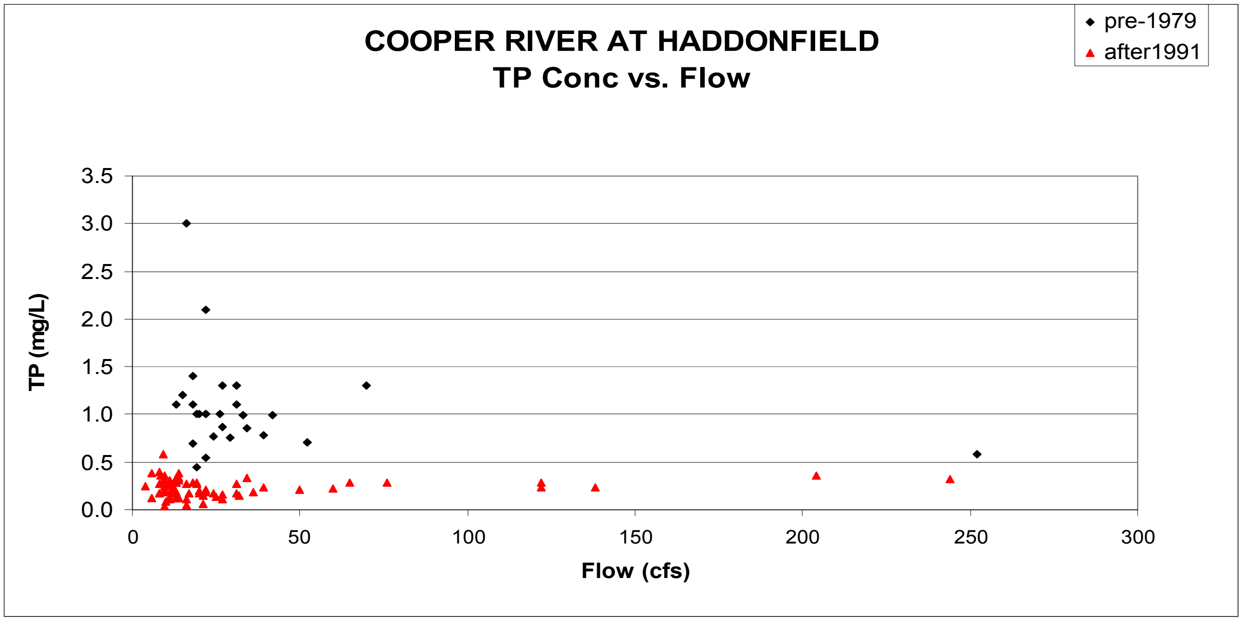
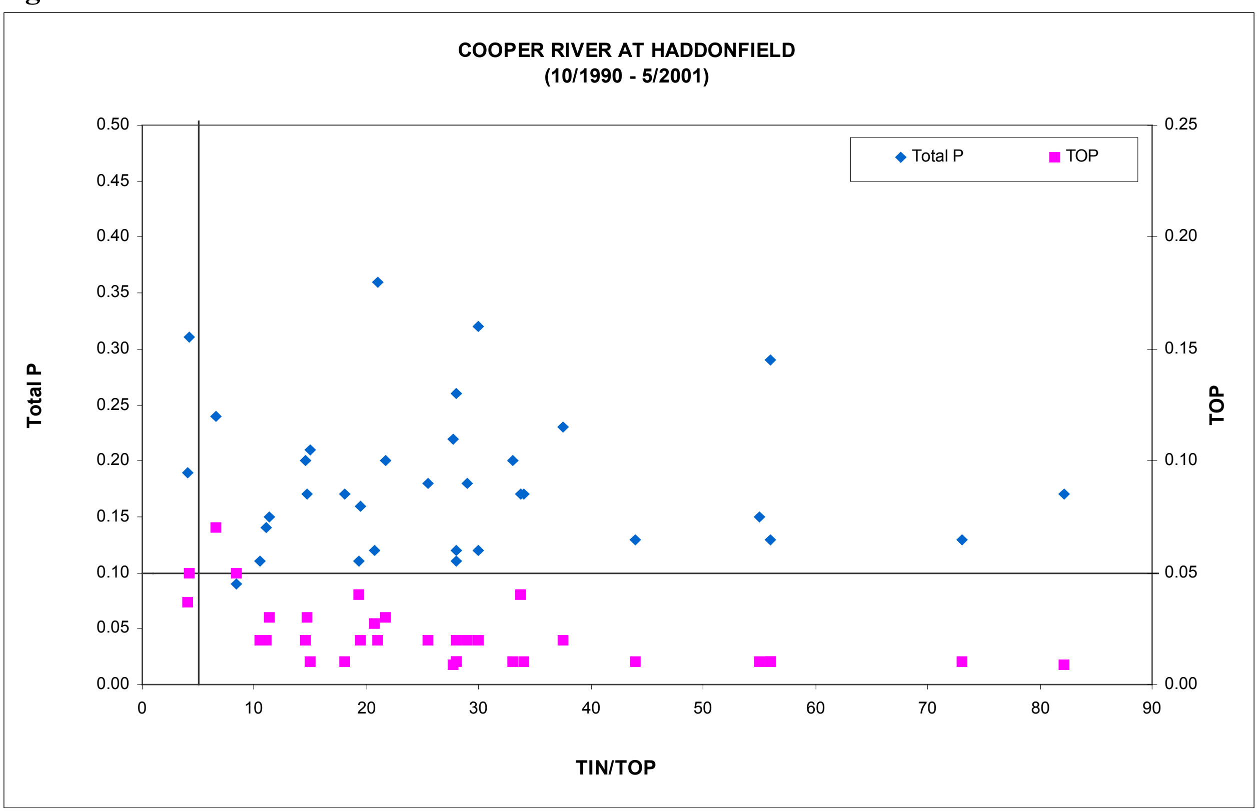


Figure 11 Nutrients Limitations



TIN = dissolved nitrite, nitrate and ammonia. TIN calculated as: a sum of dissolved ammonia (P00608) & dissolved nitrite and nitrate (P00631) or a sum of total ammonia (P00610) and total nitrite & nitrate (P00630)
TOP = dissolved reactive phosphorus: orthophosphorus (P00671) if available, or dissolved phosphorus (P00666) if available, or total phosphorus (P00665)

Analyzing Figure 11, the phosphorus concentration exceeds the lake criterion of 0.05 mg/L in 99% of samples (1991-2002 data set) and, for the same data set, 95.5% of TP results exceeded the 0.1 mg/L stream criterion. Most of the data (93 percent) suggest that phosphorus is a limiting nutrient (TP>0.1 mg/l, TOP≤0.05 mg/L, and TIN/TOP>5). However, because the station characterizes the lake more than the stream, this may not be relevant ot applicability of the in-stream criterion.

7.1.4 Kresson, Station 01467155

This station was added to the USGS monitoring program in 1997. The station is located at the head of the North Branch Cooper River. The watershed area discharging to this station is about one square mile with the 48% of watershed covered by urban/suburban areas, 34% wetland, 18% forest, and about 0.5% is covered by barren land.

The total phosphorus concentrations are presented at Figure 12. In two samples of 11 (18%), the total phosphorus concentration exceeded 0.1mg/L value. The flow rate was not recorded at the Kresson station. Based on this data, the stream segment was listed as an impaired body of water. Figure 12 illustrates changes in the phosphorus concentration over the sampling period.

Figure 12 Changes in Phosphorus Concentration

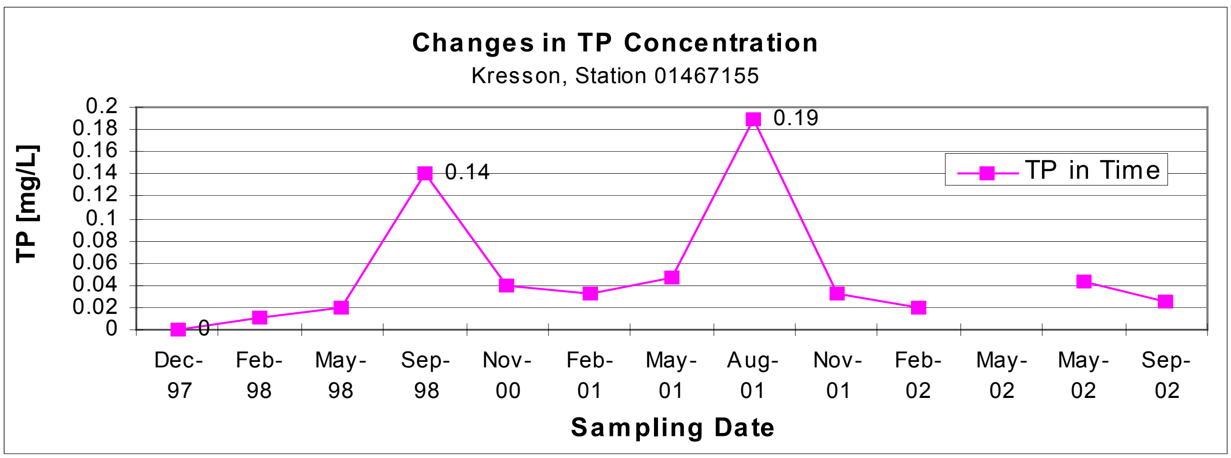
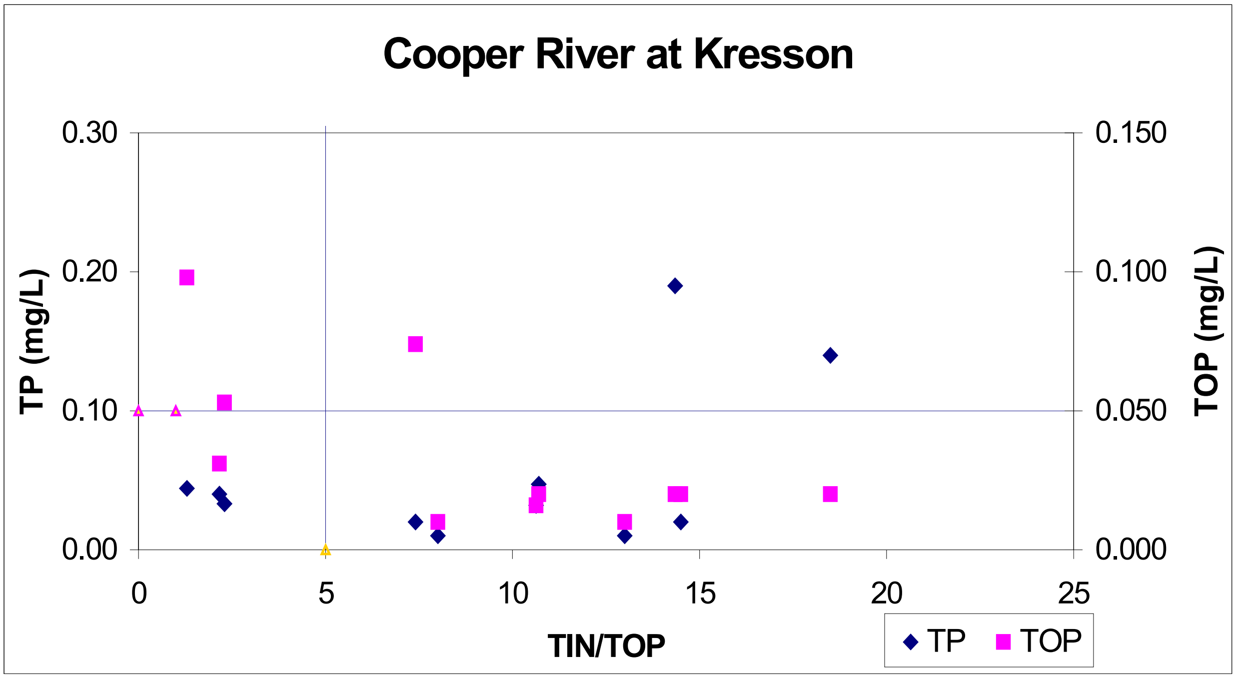


Figure 13 Nutrient Limitations



TIN = dissolved nitrite, nitrate and ammonia. TIN calculated as: a sum of dissolved ammonia (P00608) & dissolved nitrite and nitrate (P00631) or a sum of total ammonia (P00610) and total nitrite & nitrate (P00630)
TOP = dissolved reactive phosphorus: orthophosphorus (P00671) if available, or dissolved phosphorus (P00666) if available, or total phosphorus (P00665)

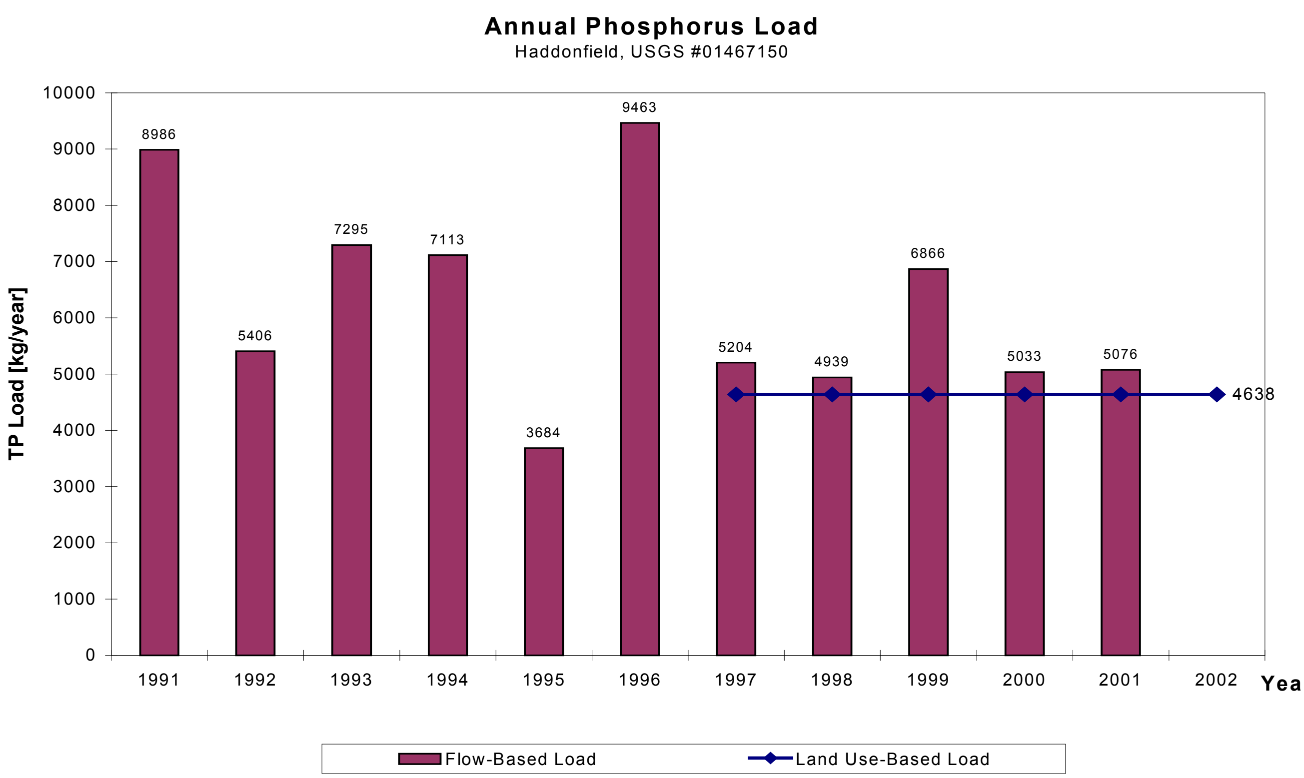
Total phosphorus concentration of TP > 0.1 mg/L was violated two times of eleven sampling events during the monitoring period (18% of samples). The graph suggests that phosphorus is the limiting nutrient for both results where TP>0.1mg/L, TOP≤0.05 mg/L, and TIN/TOP>5. These exceedances occurred after very high rainfall events.

7.2 Analysis of Phosphorus Loadings

Based on the history of effluent discharges from point sources, the water quality in the Cooper River deteriorated. In 1970’s and 1980’s the contamination of the Cooper River became an issue affecting biological life and human health. To improve water quality, all point sources of surface water contamination were eliminated by diverting point source effluents to the water treatment plant at CCMUA. As demonstrated in Figures 6, 8, 10, and 12, water quality in the Cooper River has improved, but the TP concentration is still above SWQS criteria for phosphorus in stream (0.1 mg/L) and/or for phosphorus in streams emptying into lakes (0.05 mg/L), thus warranting TMDLs.

The monitoring data from USGS Station #01467150 in Haddonfield were used to calculate phosphorus load to the Evans Pond and Wallworth Lake. For the monitoring period 1991-2001, based on the annual average flow and average annual phosphorus concentration, the phosphorus load was calculated. Figure 14 presents annual phosphorus loadings to the Evans Pond and Wallworth Lake. After eliminating point sources of phosphorus in 1996, the phosphorus load from 1997 to 2001 is stable. The highest load was calculated for the year 1999, what is most likely an effect of an intensive washout from excessive rainfall (Hurricane Floyd). Sources of phosphorus could include phosphorus from sediments as well as nonpoint sources from the entire watershed.

Figure 14 Phosphorus Load Calculations for the Haddonfield Monitoring Station



On Figure 14 is also shown the phosphorus loading calculated for the same watershed but based on the unified land use as presented in Table 5 (section 6). The loads based on an annual average flow and annual average TP are 6 to 11 percent higher except the 1999 load, an exception attributed to Hurricane Floyd.

Based on this fit and because the Haddonfield station is the only station in the Cooper River watershed monitored continuously from 1991 to the present time, the Department made a decision to use land use to calculate annual phosphorus loading for all impaired segments.

The geographic configuration of the watershed includes multiple run-of-the-river lakes, including Cooper River Lake and the downstream terminus of the drainage area. The numeric criterion for TP in lakes is more stringent than the criterion for streams, 0.05 mg/l compared to 0.01 mg/l. Therefore, the lakes were selected as the critical locations and the load reductions needed to achieve the in-lake criterion will also address the stream TP impairments in the watershed. While this approach is intuitively valid, the relationship was tested and verified as detailed in Appendix H.

7.3 Model Selection

Empirical lake 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 8.

Table 8 Empirical models considered by the Department

reference	steady-state TP concentration in lake (mg/l)	Secondary term	Application
Rast, Jones and Lee, 1983	$1.81 \times NPL^{0.81}$	$NPL = \left(\frac{P_a \times DT / D_m}{1 + \sqrt{DT}} \right)$	Expanded database of mostly large lakes
Vollenweider and Kerekes, 1982	$1.22 \times NPL^{0.87}$	$NPL = \left(\frac{P_a \times DT / D_m}{1 + \sqrt{DT}} \right)$	mostly large natural lakes
Reckhow, 1980	$\frac{P_a}{13.2}$	none	Upper bound for closed lake
Reckhow, 1979a	$\frac{P_a}{(11.6 + 1.2 \times Q_a)}$	$Q_a = \frac{Q_i}{A_l}$	**General north temperate lakes, wide range of loading concentration, areal loading, and water load**
Walker, 1977	$\frac{P_a \times DT / D_m}{(1 + 0.824 \times DT^{0.454})}$	none	oxic lakes with $D_m / DT < 50$ m/yr
Jones and Bachmann, 1976	$\frac{0.84 \times P_a}{(D_m \times (0.65 + DT^{-1}))}$	none	may overestimate P in shallow lakes with high D_m / DT

reference	steady-state TP concentration in lake (mg/l)	Secondary term	Application
Vollenweider, 1975	$\frac{P_a}{\left(D_m \times \left(DT^{-1} + S\right)\right)}$	$S = {10}/{D_m}$	Overestimate P lakes with high ${D_m}/{DT}$
Dillon-Kirchner, 1975	$\frac{P_a}{\left(13.2 + {D_m}/{DT}\right)}$	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)
Qa = areal water load (m/yr) [3]
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 D. 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 8):

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

[3] 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.

areal phosphorus load: $0.07 < P_a < 31.4$ g/m²/yr

For comparison, Table 9 below summarizes the characteristics for each lake based on their current and target conditions as described below. The above ranges of characteristics apply to most of the lakes covered under these TMDLs; however, the areal water load for Evans Pond and Wallworth Lake is outside the calibration range (340.4 m/year). Nevertheless, the model still remains the best choice since it has the broadest range of lake characteristics in its database. 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 data set on which it is based, and is generally applicable to north temperate lakes that exhibit the range of characteristics listed previously.

Table 9 Hydrologic and loading characteristics of lakes

Lake	Current Avg Influent [TP] (mg/l)	Target Avg Influent [TP] (mg/l)	Current Areal TP load (g/m²/yr)	Target Areal TP load (g/m²/yr)	Areal Water Load (m/year)
Kirkwood Lake	0.109	0.026	10.27	2.47	94.0
Evans Pond and Wallworth Lake	0.188	0.037	64.06	6.10	340
Cooper River Lake	0.201	0.041	13.25	1.19	66.0

7.4 Current Condition

Using these estimated physical parameters and current loads, the predicted steady-state phosphorus concentration of each lake was calculated using the Reckhow (1979a) formulation as listed in Table 7. The current phosphorus load distribution for each lake is shown in Figures 15 to 17 below.

Figure 15 Current distribution of phosphorus load for Kirkwood Lake

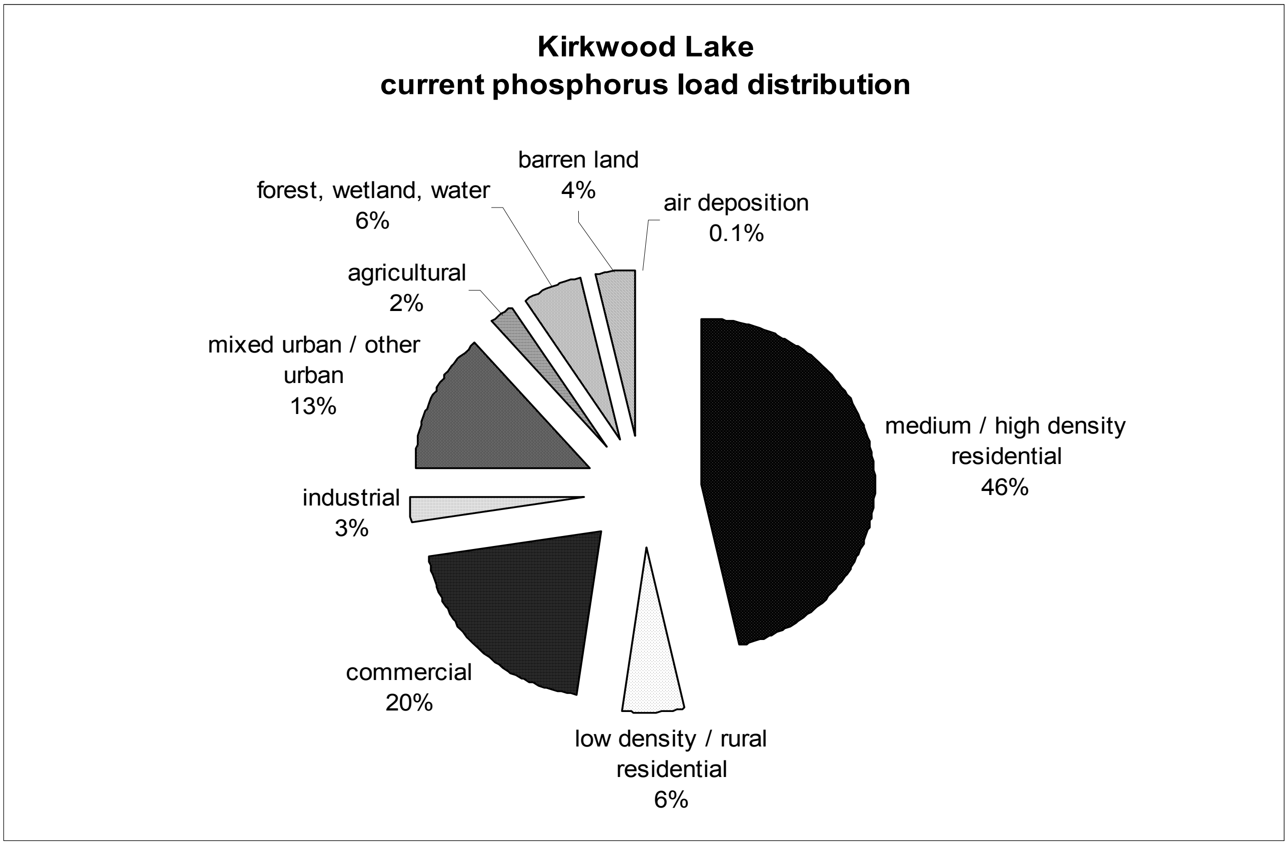


Figure 16 Current distribution of phosphorus for Evans Pond and Wallworth Lake

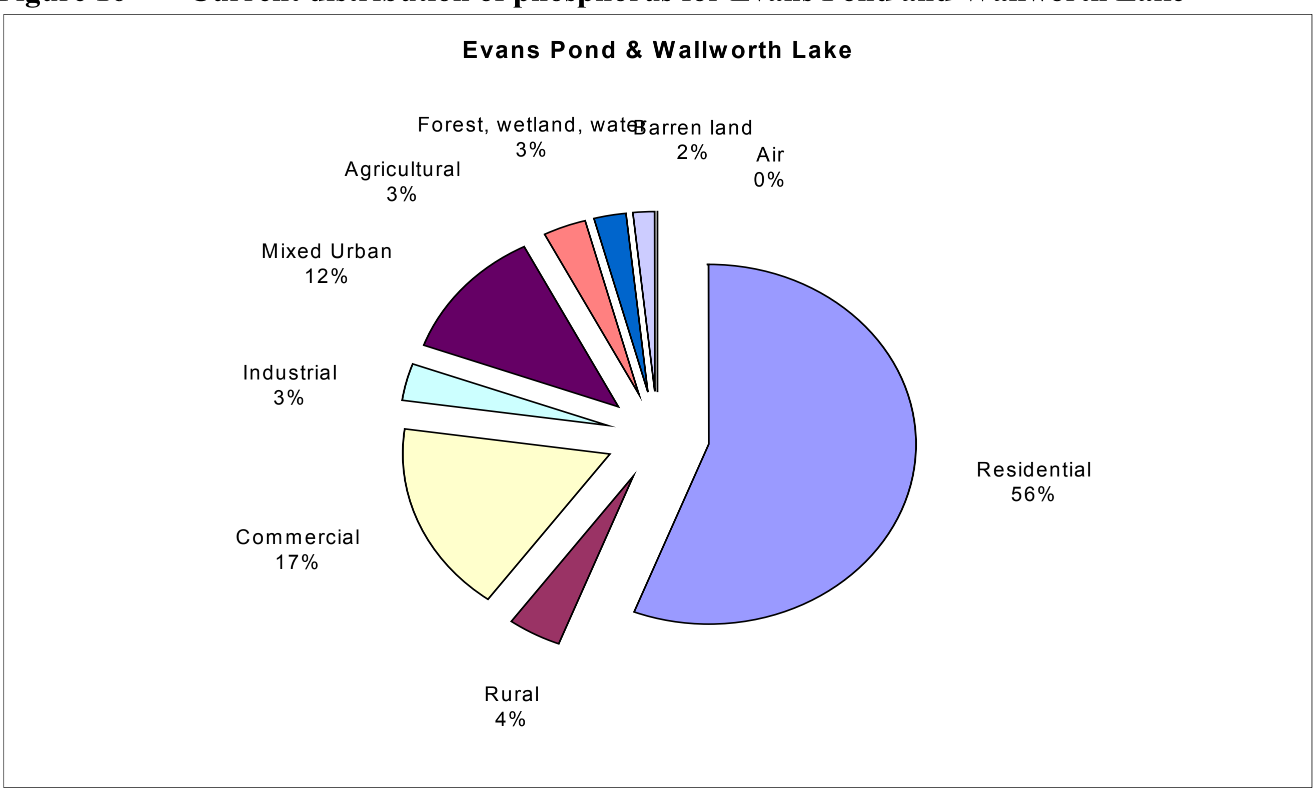
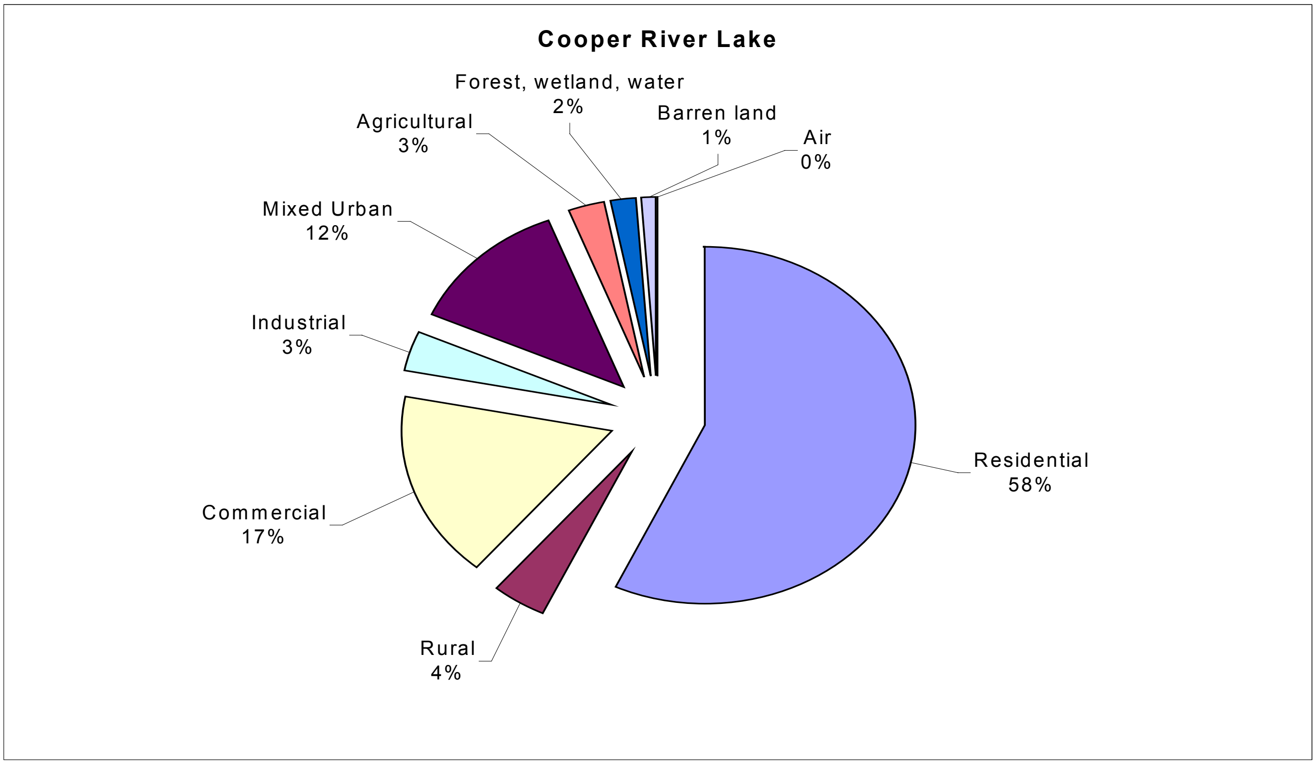


Figure 17 **Current distribution of phosphorus for Cooper River Lake**



7.5 Reference Condition

A reference condition for each lake was estimated by calculating external loads as if the land use throughout the lakeshed were completely forest and wetlands. Estimates of air deposition loads were included to calculate the reference condition. Using the same physical parameters and external loads from forest and wetlands, a reference steady-state phosphorus concentration was calculated for each lake using the Reckhow (1979a) formulation and listed in Table 10.

7.6 Seasonal Variation/Critical Conditions

These TMDLs will attain applicable surface water quality standards year round. The Reckhow model predicts steady-state phosphorus concentration. To account for data variability, the Department generally interprets threshold criteria as greater than 10% exceedance for the purpose of defining impaired waterbodies. Data from two lakes in New Jersey for which the Department had ready access to data (Strawbridge Lake, NJDEP 2000a; Sylvan Lake, NJDEP 2000b) exhibit peak (based on the 90th percentile) to mean ratios of 1.56 and 1.48, resulting in target phosphorus concentrations of 0.032 and 0.034 mg TP/l, respectively. Since the peak to mean ratios were close and the target concentration not very sensitive to differences in peak to mean ratios, the Department determined that a target phosphorus concentration of 0.03 mg TP/l is reasonably conservative. The seasonal variation was therefore assumed to be 67%, resulting in a target phosphorus concentration of 0.03 mg TP/l. Since it is the annual pollutant load rather than the load at any particular time that determines overall lake water quality (Section 6), the target phosphorus concentration of 0.03 mg TP/l accounts for critical conditions.

7.7 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 is 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 E):

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

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

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

Setting the probability to 90% yields a 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 10. Note that the explicit Margin of Safety is equal to 51% when expressed as a percentage over the predicted phosphorus concentration; when expressed as a percentage of total loading capacity, the Margin of Safety is equal to 34%:

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

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

7.8 Target Condition

As discussed above, when considering the seasonal variation, the steady state concentration of phosphorus in the lake must be equal to or less than 0.03 mg/L to avoid exceeding the 0.05mg/L phosphorus criterion. Using Reckhow (1979a), any predicted concentration has a margin of safety of 51% when expressed as a percentage over predicted phosphorus concentration. To assure the compliance of 0.03 mg/L, the predicted concentration can not be higher than 0.02 mg/L (0.02 + 0.02 * 51% = 0.03 mg/L) considering the effect of MOS. Therefore, 0.02 mg/L is chosen as the target concentration to attain the standard while 0.03 mg/L is defined as the upper bound target condition. Portion of the load corresponding to 0.03 mg/L will be addressed as MOS. In this case, the percentage of MOS is 34% (0.51/1.51 = 34%). The overall reduction necessary to attain the standard level in each lake was calculated by comparing the current concentration (calculated using the Reckhow model) to 0.02 mg/L, the target concentration (Table 10). Because most of these lakes drain very large watersheds, the reference condition is very close to the target concentration; thus the overall load reductions necessary to achieve the target conditions are quite substantial.

Table 10 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
Kirkwood Lake	0.083	0.011	0.030	0.020	76%
Evans Pond and Wallworth Lake	0.152	0.0145	0.030	0.020	87%
Cooper River Lake	0.146	0.0131	0.030	0.020	86%

8.0 TMDL Calculations

8.1 Loading Capacity

Given the upper bound target concentration of 0.03 mg/l (which incorporates the margin of Safety), the Reckhow (1979a) model was used to solve the loading capacity for Evans Pond and Wallworth Lake watershed and Copper River Lake watershed, which is 912 kg/yr and 2110 kg/yr, respectively. As shown in Figure 2, the entire Cooper River Lake watershed was geographically divided into four segments, Kirkwood Lake watershed, Evans Pond and Wallworth Lake watershed excluding Kirkwood Lake watershed, northern branch of Cooper River Lake Watershed, and the watershed of main stem Cooper River. The loading capacity of Kirkwood Lake, 380 kg/yr, was determined previously in the approved Kirkwood Lake TMDL. Therefore, the loading capacity for the rest of the Kirkwood Ponds and Wallworth Lake watershed is allowed to be 532 kg/yr. Subtracting the loading capacity for Evans Pond and Wallworth Lake watershed (including Kirkwood Lake watershed) from the entire Cooper River Lake watershed, the remaining 1198 kg/yr is determined to be the loading capacity for northern branch and main stem watershed. As explained in the Allocation section, 1198 kg/yr is further divided into 693 kg/yr for the northern branch and 505 for the main stem watershed based on the land use coverage. The acceptable loading capacity for each segment and for the entire Cooper River Lake watershed is provided in Tables 11-15.

8.2 Reserve Capacity

Reserve capacity is an optional means of reserving a portion of the loading capacity to allow for future growth. Because the watershed is almost entirely developed, management strategies designed to reduce phosphorus loads from existing development will be equally effective with respect to future development. Therefore, the loading capacities and accompanying WLAs and LAs must be attained in consideration of any new sources that may accompany future development.

8.3 Allocations

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

The TMDLs for total phosphorus are therefore calculated as follows (Tables 10-15):

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

WLAs are hereby established for all NJPDES-regulated point sources within each source category, while LAs are established for stormwater sources that are not subject to NJPDES regulation and for all nonpoint sources. This distribution of loading capacity between WLAs and LAs is consistent with recent EPA guidance that clarifies existing regulatory requirements for establishing WLAs for stormwater discharges (Wayland, November 2002). Stormwater discharges are captured within the runoff sources quantified according to land use, as described previously. Distinguishing between regulated and unregulated stormwater is necessary in order to express WLAs and LAs numerically; however, "EPA recognizes that these allocations might be fairly rudimentary because of data limitations and variability within the system" (Wayland, November 2002, p.1). While the Department does not have the data to actually delineate lakesheds according to stormwater drainage areas subject to NJPDES regulation, the land use runoff categories previously defined can be used to estimate between them. Therefore allocations are established according to source categories as shown in Table 11. 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. A list of NJPDES permitted stormwater dischargers may be found in Appendix F. The permits for these facilities were evaluated and it was determined that they are general permits and do not require phosphorus monitoring. 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 11, shall be construed to require the Department to regulate a stormwater source under NJPDES that would not already be regulated as such, nor shall anything in these TMDLs be construed to prevent the Department from regulating a stormwater source under NJPDES. WLAs are hereby established for all NJPDES-regulated point sources, including stormwater, according to their source category. Quantifying WLAs and LAs according to source categories provides the best estimation defined as narrowly as data allow. However, it is clearly noted that WLAs are hereby established for all NJPDES-regulated point sources within each source category, while LAs are established for stormwater sources that are not subject to NJPDES regulation and for all nonpoint sources. The WLAs and LAs in Tables 12-16 are not themselves "Additional Measures" under proposed N.J.A.C. 7:14A-25.6 or 25.8.

Table 11 Distribution of WLAs and LAs among source categories

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

In order to attain the TMDLs, the overall load reductions shown in Table 10, 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. Among the total allowable loading capacity, 34% of it is reserved for the Margin of Safety given by the uncertainty in the Reckhow model. In addition, the current loading is assumed to be unchangeable for air deposition and certain types of land use, such as forest/wetland/water and barren land. Therefore, the reduction from other loading sources need be sufficient to achieve the necessary overall load reductions. Equal percent reduction is applied to all the loading sources that can be affected by BMP implementation. The reduction rate for Kirkwood Lake watershed is obtained from the previously approved TMDL for Kirkwood Lake. The reduction rate is calculated to be 92.9% for the Evans Pond and Wallworth Lake watershed excluding Kirkwood Lake watershed and 88% for non-Evans Pond and Wallworth Lake portion of the Cooper River Lake watershed. The current loading from each type of land use is used to calculate the allocation based on the reduction rate. For the Northern Branch Cooper River and the Main Stem Cooper River segments, the sum of the allocation is divided by 66% to compute the individual loading capacity.

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 Tables 12-16 and illustrated in Figures 18 to 22. The reductions for Kirkwood Lake are taken from the previously established TMDL and are not intended to be considered new or amended for that impaired waterbody.

Table 12 TMDL calculations for Kirkwood Lake (annual loads and percent reductions[a]

lake	Kirkwood Lake		% reduction
	kg TP/yr	% of LC	
loading capacity (LC)	380	100%	n/a
Point Sources other than Stormwater			
minor municipal	n/a		
Nonpoint and Stormwater Sources			
medium / high density residential	79	21%	84%
low density / rural residential	9.8	2.6%	84%
commercial	34	9.2%	84%
industrial	4.4	1.2%	84%
Mixed urban / other urban	23	6.0%	84%
agricultural	3.9	1.0%	84%
forest, wetland, water	57	15%	0%
barren land	37	9.9%	0%
septic systems	n/a		
waterfowl	n/a		
internal load	n/a		
tributary load	n/a		
Natural Sources / Background			
air deposition onto lake surface	0.7	0.2%	0%
groundwater	n/a		
Other Allocations			
explicit Margin of Safety	130	34%	n/a

Percent reductions shown for individual sources are necessary to achieve overall reductions in Table 10.

Figure 18 Phosphorus allocations for Kirkwood Lake

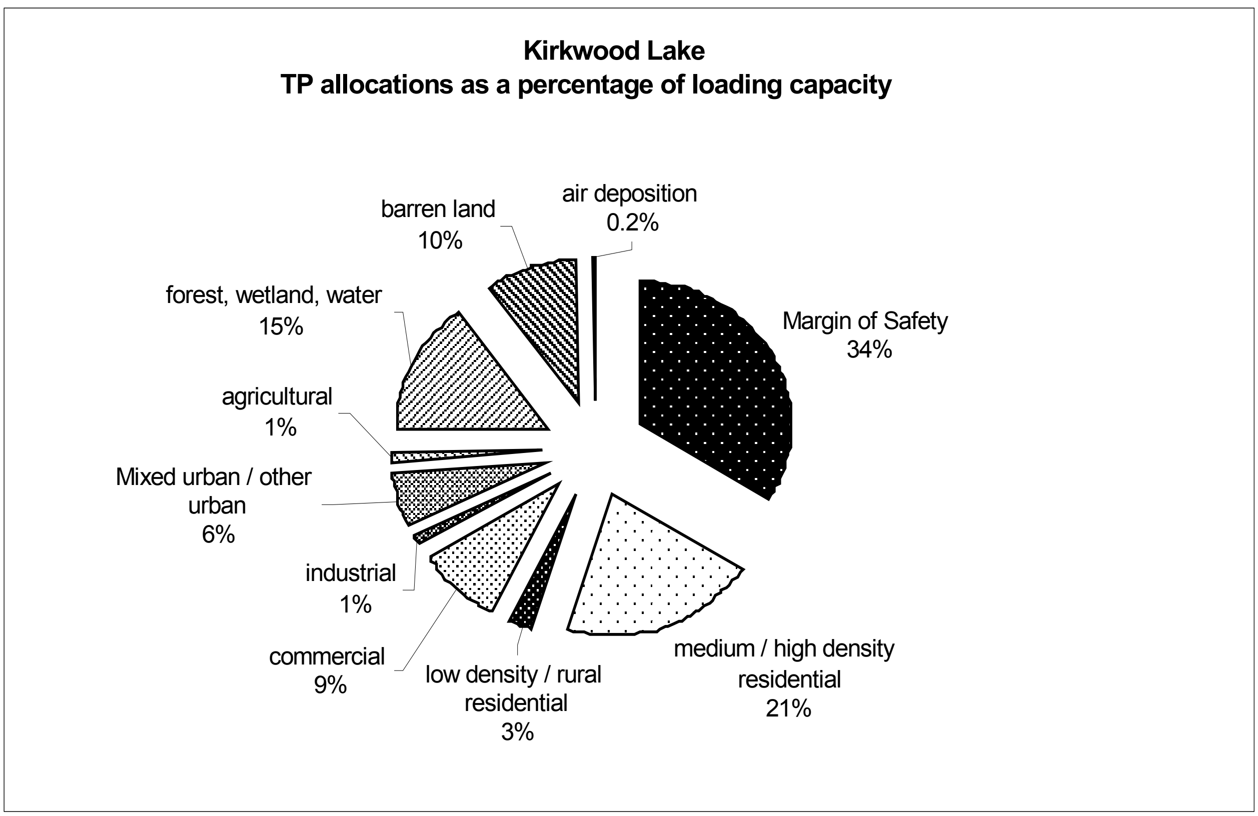


Table 13 TMDL calculations for Evans Pond & Wallworth Lake (w/o Kirkwood Lake) (annual loads and percent reductions*)

lake	Evans Pond & Wallworth Lake		% reduction
	kg TP/yr	% of LC	
loading capacity (LC)	532	100%	n/a
Point Sources other than Stormwater			
minor municipal	n/a		
Nonpoint and Stormwater Sources			
medium / high density residential	150	28.2%	92.9%
low density / rural residential	9	1.7%	92.9%
commercial	43	8%	92.9%
industrial	8.6	1.6%	92.9%
Mixed urban / other urban	29	5.5%	92.9%
agricultural	9.3	1.8%	92.9%
forest, wetland, water	66	12%	0%
barren land	35	7%	0%
septic systems	n/a		
waterfowl	n/a		
internal load	n/a		
tributary load	n/a		
Natural Sources / Background			
air deposition onto lake surface	1	0.1%	0%
groundwater	n/a		
Other Allocations			
explicit Margin of Safety	181	34%	n/a

***Percent reductions shown for individual sources are necessary to achieve overall reductions in Table 10.**

Figure 19 Phosphorus allocations for Evans Pond and Wallworth Lake (without Kirkwood Lake)

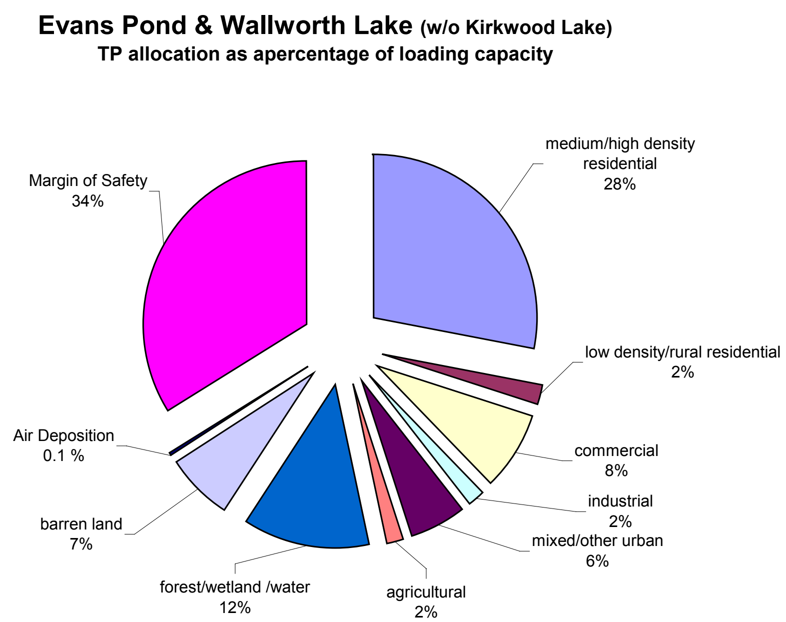


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Table 14 TMDL calculations for North Branch Cooper River (annual loads and percent reductions*)

lake	North Branch Cooper River		% reduction
	kg TP/yr	% of LC	
loading capacity (LC)	693	100%	n/a
Point Sources other than Stormwater			
minor municipal	n/a		
Nonpoint and Stormwater Sources			
medium / high density residential	222	32%	88%
low density / rural residential	27	4%	88%
commercial	45	6%	88%
industrial	7	1%	88%
Mixed urban / other urban	36	5%	88%
agricultural	17	2%	88%
forest, wetland, water	72	10%	0%
barren land	32	5%	0%
septic systems	n/a		
waterfowl	n/a		
internal load	n/a		
tributary load	n/a		
Natural Sources / Background			
air deposition onto lake surface	-	-	0%
groundwater	n/a		
Other Allocations			
explicit Margin of Safety	236	34%	n/a

*Percent reductions shown for individual sources are necessary to achieve overall reductions in Table 10.

Figure 20 Phosphorus allocations for North Branch Cooper River

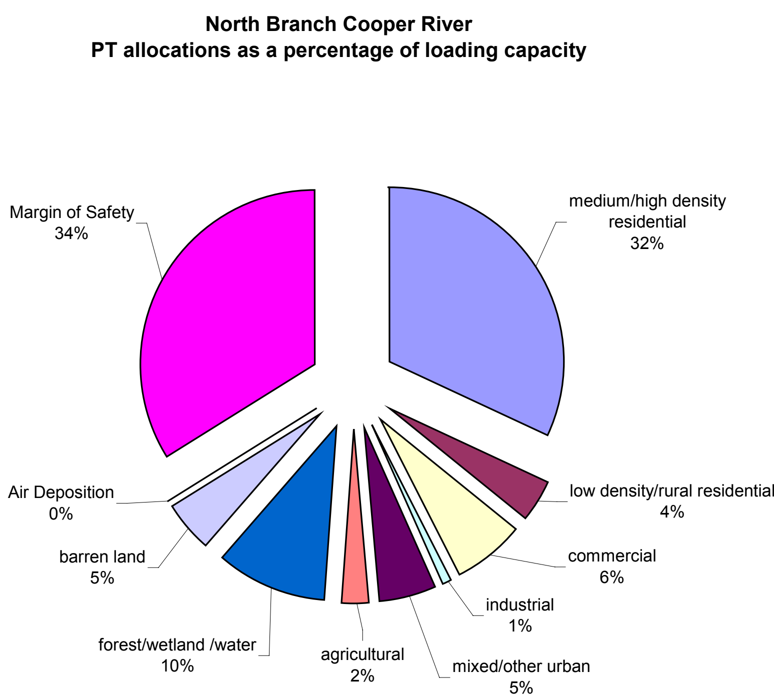

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Table 15 TMDL calculations for Main Stem (annual loads and percent reductions*)

lake	Cooper River Main Stem		% reduction
	kg TP/yr	% of LC	
loading capacity (LC)	505	100%	n/a
Point Sources other than Stormwater			
minor municipal	n/a		
Nonpoint and Stormwater Sources			
medium / high density residential	173	34%	88%
low density / rural residential	2	0.5%	88%
commercial	63	13%	88%
industrial	19	4%	88%
Mixed urban / other urban	52	10%	88%
agricultural	-	-	0%
forest, wetland, water	18	4%	0%
barren land	0.5	0.1%	0%
septic systems	n/a		
waterfowl	n/a		
internal load	n/a		
tributary load	n/a		
Natural Sources / Background			
air deposition onto lake surface	5.4	1%	0%
groundwater	n/a		
Other Allocations			
explicit Margin of Safety	172	34%	n/a

***Percent reductions shown for individual sources are necessary to achieve overall reductions in Table 10.**

Figure 21 Phosphorus allocations for Cooper River Main Stem

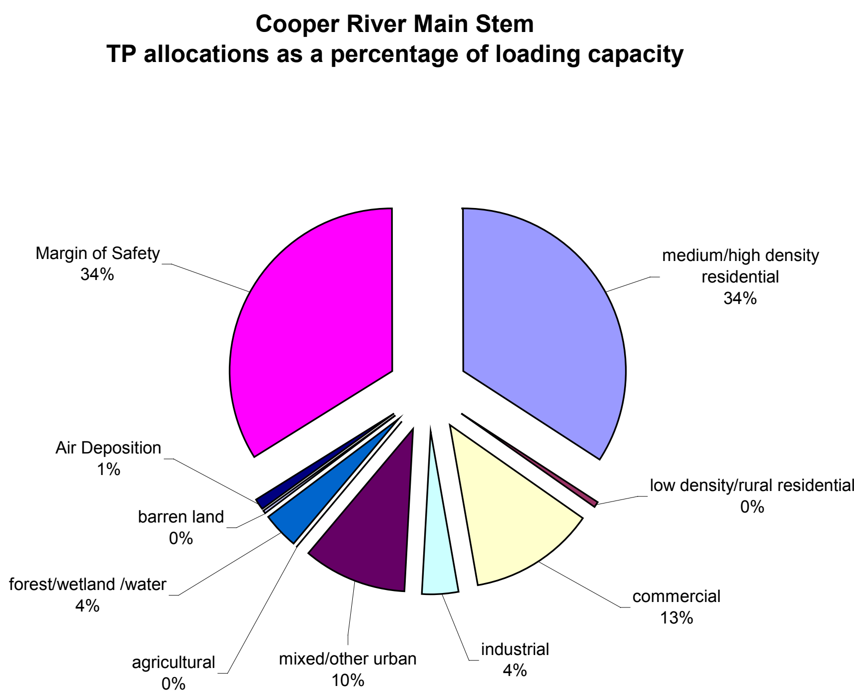

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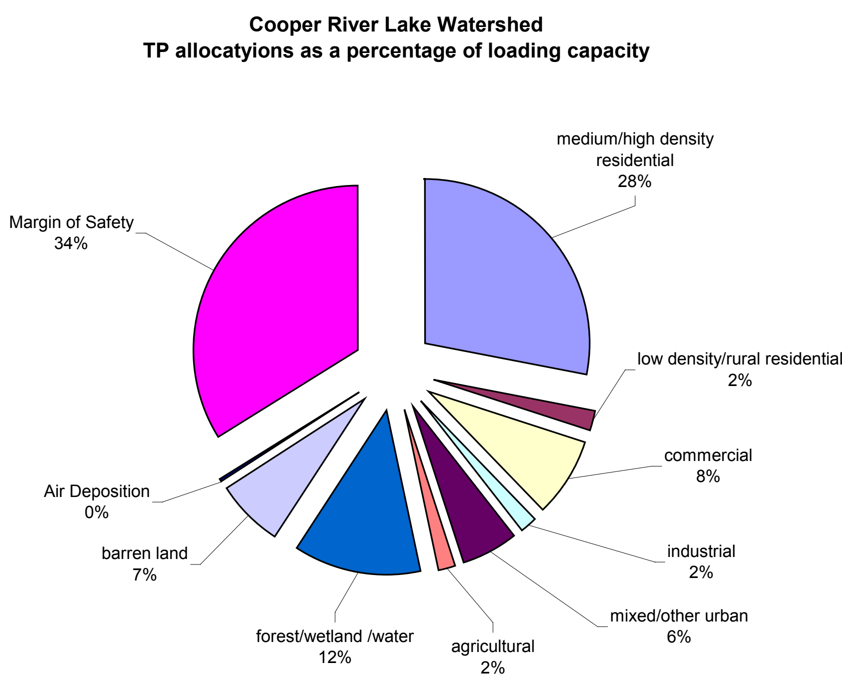
Table 16 TMDL calculations for the entire Cooper River Lake Watershed (annual loads and percent reductions*)

lake	Cooper River kg TP/yr	Cooper River % of LC	% reduction
loading capacity (LC)	2110	100%	n/a
Point Sources other than Stormwater			
minor municipal	n/a		
Nonpoint and Stormwater Sources			
medium / high density residential	624	30%	89.4%
low density / rural residential	48	2.3%	88.8%
commercial	185	9%	89.4%
industrial	39	1.8%	89.3%
Mixed urban / other urban	140	6.6%	89.1%
agricultural	30	1.4%	89.8%
forest, wetland, water	213	10%	0%
barren land	105	5%	0%
septic systems	n/a		
waterfowl	n/a		
internal load	n/a		
tributary load	n/a		
Natural Sources / Background			
air deposition onto lake surface	7	0.3%	0%
groundwater	n/a		
Other Allocations			
explicit Margin of Safety	718	34%	n/a

***Percent reductions shown for individual sources are necessary to achieve overall reductions in Table 10.**

Figure 22 Phosphorus allocations for Cooper River Lake



9.0 Follow-up Monitoring

In the Cooper River watershed almost all monitored stations exceeded SWQSs for phosphorus concentration. Moreover, the exceedances decreased after eliminating all point-source dischargers in 1996, but still test results show elevated phosphorus concentration. The elevated phosphorus concentration at the Cooper River watershed could be caused by:

- releases of phosphorus accumulated in the bottom sediments during the period of time in which there were point sources dischargers and which are still released to the water column,
- phosphorus released by biological activity from decomposition of the organic matter,
- phosphorus in runoff from the entire watershed.

In evaluating the remaining impairments in the Cooper River watershed, particularly dissolved oxygen, a targeted sampling study will be performed of the sediments to determine the significance of the sediments in phosphorus concentrations and in exerting an oxygen demand.

The Water Resources Division of the U.S. Geological Survey and the Department have cooperatively operated the Ambient Stream Monitoring Network (ASMN) in New Jersey since the 1970s. The ASMN currently includes approximately 115 stations that are routinely monitored on a quarterly basis. The data from this network has been used to assess the quality of freshwater streams and percent load reductions. The Department is also initiating an ambient lake monitoring network. The ambient networks, as well as the targeted studies, will be the means to determine the effectiveness of TMDL implementation.

10.0 Implementation

The next steps toward implementation are preparation of lake characterization and lake restoration plans, where they have not already been developed. In the development of these plans, the loads by source will be revised, as necessary, to reflect refinements in source contributions. It will be on the basis of refined source estimates that specific strategies for reduction will be developed. These will consider issues such as cost and feasibility when specifying the reduction target for any source or source type. As appropriate, WLAs or other measures to be applied to traditional or stormwater point sources through NJPDES permits will be adopted by the Department as amendments to the applicable areawide Water Quality Management Plan.

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

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

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

10.1 Watershed Characterization and Restoration Plans

In order to develop the Lake Restoration Plans to implement these TMDLs, additional monitoring may be performed. 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 17.

Table 17 Implementation Schedule

Lake	Lake Characterization	Lake Restoration Plan
Kirkwood Lake	Summer 2006	Spring 2007
Evans Pond & Wallworth Lake	Summer 2006	Spring 2007
North Branch Cooper River	Summer 2006	Spring 2007
Cooper River Main Stem	Summer 2006	Spring 2007

Management measures are "economically achievable measures for the control of the addition of pollutants from existing and new categories and classes of nonpoint and stormwater sources of pollution, which reflect the greatest degree of pollutant reduction achievable through the application of the best available nonpoint and stormwater source pollution control practices, technologies, processes, siting criteria, operating methods, or other alternatives" (USEPA, 1993).

Development of effective management measures depends on accurate source assessment. Phosphorus is contributed to the environment from a number of sources including fertilizer application on agricultural lands, fertilizer application on lawns, discharge from treatment plants and the natural process of decomposition. Phosphorus from these sources can reach waterbodies directly, through overland runoff, or through sewage or stormwater conveyance facilities. Each potential source will respond to one or more management strategies designed to eliminate or reduce that source of phosphorus. Each management strategy has one or more entities that can take lead responsibility to effect the strategy. Various funding sources are available to assist in accomplishing the management strategies. The Department will address the sources of impairment through systematic source trackdown, matching strategies with sources, selecting responsible entities and aligning available resources to effect implementation.

On February 2, 2004 the Department promulgated two sets of stormwater rules. The first set, N.J.A.C. 7: 8 update the state's Stormwater Management Rules for the first time since their original adoption in 1983. The rules establish new statewide minimum standards for stormwater management. These standards will also become requirements of several state-issued permits such as freshwater wetlands and stream encroachment permits. The second set of adopted stormwater rules are the Phase II New Jersey Pollutant Discharge Elimination System Stormwater Regulation Program Rules N.J.A.C. 7:14A, which require municipalities, large public complexes such as hospitals, and highway systems to develop stormwater management programs consistent with Tier A or B or other requirements through the New Jersey Pollutant Discharge Elimination System (NJPDES) permit program.

A 300-foot buffer to protect Category One (C1) waterbodies will be required. C1 protection is the highest form of water quality protection in the state, preventing any measurable deterioration in the existing water quality. The rules also apply the buffer to tributaries of C1 waterbodies within the immediate watershed of C1 waterbodies. In total, the buffers will impact 6,093 stream miles – including the 3,307 miles of currently designated C1 rivers and streams and an additional 2,786 miles of non-C1 tributaries to C1 streams.

The Stormwater Management Rules include performance standards for ground water recharge to protect the integrity of the state's aquifers. They establish a standard of maintaining 100 percent of the average annual ground water recharge for new development projects, a major initiative toward mitigating future droughts and flooding.

In addition to recharge standards, the regulations also stress water quality controls, such as best management practices to reduce runoff of total suspended solids (TSS) by 80 percent and other pollutants including nutrients to the maximum extent feasible. The rules require low impact designs for stormwater management systems that maintain natural vegetation and drainage and reduce clear-cutting and the unnecessary loss of trees and minimize impervious surface.

The stormwater discharged to the impaired segments through "small municipal separate storm sewer systems" (small MS4s) will be regulated under the Department's Phase II NJPDES stormwater rules for the Municipal Stormwater Regulation Program. Under these rules and associated general permits, many municipalities (and various county, State, and other agencies) in the Cooper River Watershed will be required to implement various control measures that should substantially reduce phosphorus loadings, including adoption and enforcement of low phosphorus fertilizer and pet waste disposal ordinances, prohibiting the feeding of unconfined wildlife on public property, cleaning catch basins, performing good housekeeping at maintenance yards, and providing related public education and employee training.

Sewage conveyance facilities are potential sources phosphorus in that equipment failure or operational problems may result in the release of untreated sewage. These sources, once identifed, can be eliminated through appropriate corrective measures that can be affected through the Department's enforcement authority. Inadequate on-site sewage disposal can also be a source of phosphorus. The Department has committed a portion of its FY 03 CWA Section 319(h) pass through grant funds to assist municipalities in meeting Phase II requirements. Inn addition, The New Jersey Environmental Infrastructure Financing Program, which includes New Jersey's State Revolving fund, provides low interest loans to assist in correction of water quality problems related to stormwater and wastewater management.

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

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

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

- **The Conservation Reserve Enhancement Program (CREP)** The New Jersey Departments of Environmental Protection and Agriculture, in partnership with the Farm Service Agency and Natural Resources Conservation Service, has recently submitted a proposal to the USDA to offer financial incentives for agricultural landowners to voluntarily implement conservation practices on agricultural lands through CREP. NJ CREP will be part of the USDA's Conservation Reserve Program (CRP). The enrollment of farmland into CREP in New Jersey is expected to improve stream health through the installation of water quality conservation practices on New Jersey farmland.

Short Term Management Strategies

Short-term management measures include projects recently completed; underway or planned that will address sources of phosphorus load. Pertinent projects in the Cooper River Watershed are as follows:

Riparian Buffer Fencing Project for Cooper River Lake
In SFY 01, the Delaware Riverkeeper Network received a $8,450.00 Section 319(h) NPS grant to continue efforts of previous riparian buffer restoration work started by the Riverkeeper in 1994. To address the severe sedimentation from excessive urban stormwater runoff (from both upstream and in-lake sources) the Riverkeeper had previously restored 2 miles of riverbank using bio-engineering methods of erosion control, including coconut fiber logs and blankets in addition to planting shrubs grasses and trees. As a result, a 35-50 buffer of vegetation was created along much of the 1-mile project site. Because the buffer was in jeopardy of mowing to the waters edge, which would have greatly reduced the effectives of the BMP, this project supplemented sections of existing riparian buffer with larger plant stock and installed split rail fencing along selected sections to delineate the restoration site. No mow signs were also placed strategically to advise maintenance personnel not to mow the buffer area. This project resulted in the reduction of shoreline erosion and NPS from degrading Cooper River Lake and the Cooper River Watershed.

Biofilter Wetland Cooper River Lake
Camden County received a $159,450 section 319(h) NPS grant in SFY 01 to construct a biofilter wetland on the north side of Cooper River Lake in Collingswood. The creation of biofilter

wetlands improves water quality by extending the detention time within the wetland. This enables sediments with adsorbed pollutants to settle out, and allows the plants and micro-organisms within the wetland to take up the nutrients and biodegrade various pollutants, in addition to enabling certain chemical transformations.

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. The Department has initiated an ambient lake monitoring network and proposes to characterize and develop specific restoration plans for these particular lakes according to the schedule in Table 17. 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 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 require the Department to initiate a public process prior to the development of each TMDL and to allow public input to the development of the TMDL. Further, the Department shall propose each TMDL as an amendment to the appropriate areawide water quality management plan in accordance with procedures at N.J.A.C. 7:15-3.4(g). As part of the public participation process for the development and implementation of the TMDLs for phosphorus to address eutrophic lakes in the Lower Delaware Water Region, the Department worked collaboratively with stakeholders in WMA 18. Stakeholder meetings were held in December 2002 to explain the Kirkwood Lake phosphorus TMDL and more recently on March 31, 2004 to explain the TMDL document. The purpose of the informal meetings was for stakeholders to identify areas of concern based on their local knowledge. The stakeholders were encouraged to provide any additional source information through the formal comment period after advertisement of the TMDL proposal in the New Jersey Register.

Additional input was received through the Rutgers New Jersey EcoComplex (NJEC). The Department contracted with NJEC in August 2001. The NJEC consists of a review panel of New Jersey University professors whose role is to provide comments on the Department's technical approaches for development of TMDLs and management strategies. The Rechow method for lake TMDLs was presented previously to the NJEC, while the Technical Approach for the Cooper River Watershed was presented to the NJEC on December 12, 2003.

Amendment Process

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 Tri-County WQMP.

Notice proposing these TMDLs was published April 19, 2004 in the New Jersey Register and in newspapers of general circulation in the affected area in order to provide the public an opportunity to review the TMDLs and submit comments. In addition, a public hearing was held on May 25, 2004. Notice of the proposal and the hearing was provided to applicable designated planning agencies and to affected municipalities.

Appendix A :References

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Appendix B: Database of Phosphorus Export Coefficients

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

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

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Appendix C: Phosphorus Criterion Applicability Determination

This discussion is taken from the New Jersey Department of Environmental Protection's 2003 report, *Technical Manual for Phosphorus Evaluation for NJPDES Discharge to Surface Water Permits,* Division of Water Quality, N.J.A.C. 7:9b-1.14(c).

Is Phosphorus Limiting?

The limiting nutrient can be evaluated using available nutrient concentrations by using the following thresholds to exclude phosphorus as the limiting nutrient (The acronyms TIN and DRP refer to biologically-available forms of nitrogen and phosphorus, respectively: TIN = dissolved nitrite, nitrate and ammonia; DRP = dissolved reactive phosphorus):

IF	[DRP] $\geq$ 0.05 mg/l
OR	TIN/DRP $\leq$ 5
THEN	phosphorus can be excluded as the limiting nutrient

Figures 2 and 3 show examples of how to plot pairs of TP and DRP data along a TIN/DRP axis to visually evaluate the phosphorus limitation thresholds at a particular location. By making the TP range twice the DRP range, the thresholds of 0.1 mg/l TP and 0.05 mg/l DRP coincide, simplifying the interpretation. Episodes when TP > 0.1 mg/l AND DRP $\leq$ 0.05 mg/l and TIN/DRP $\geq$ 5 can be identified by seeing TP in the upper right quadrant while DRP is in the lower right quadrant. If phosphorus cannot be excluded as the limiting nutrient for more than 10% of the samples that exceed the 0.1 mg/l threshold (a minimum of 2 samples), then the 0.1 mg/l criterion is applicable.

Figure 1: Example of site where 0.1 mg/l criterion is applicable and exceeded

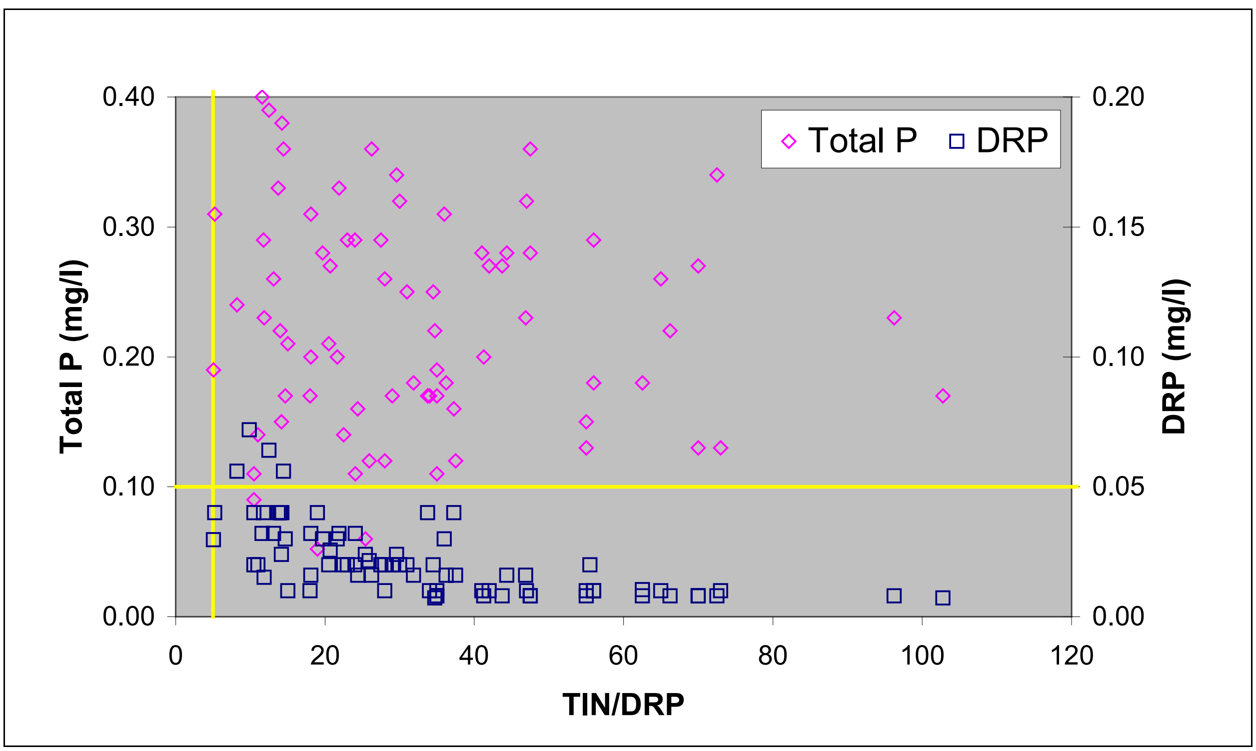
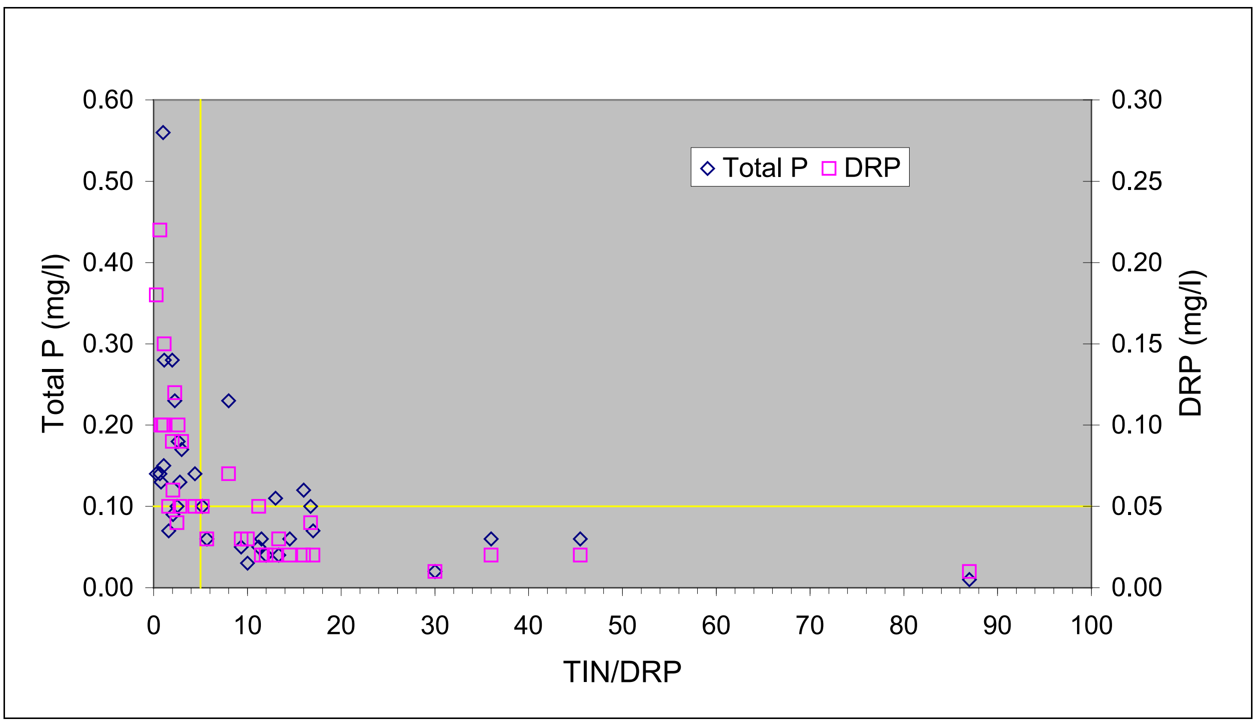


Figure 2: Example of site where phosphorus is not limiting algal growth when 0.1 mg/l threshold is exceeded



Please note that the use of the acronym DRP has been replaced with the acronym TOP for Figures 7, 9, 11, and 13. TOP stands for total organic phosphorus.

Appendix D: 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):

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

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

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

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

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

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

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

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

where:
- P_a = areal phosphorus loading rate (g/m²/yr)
- z = mean depth (m)
- T = hydraulic detention time (yr)

Q_a = Q/A = areal water load (m/yr).

Using least squares regression on a database of 47 north temperate lakes, Reckhow fit the effective settling velocity using a function of areal water load:

$$P = \frac{P_a}{11.6 + 1.2 \cdot Q_a}$$ **Equation 4**

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

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

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

where:

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

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

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

Substituting for ρ as a function of h:

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

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

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

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

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

Substituting the equation for P_U:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Appendix F: Stormwater Dischargers into Cooper River Watershed

NJPDES Permit Number	PI Number	Facility Name	Municipality	Effective Start Date	Expiration Date	Discharge Category Code	Discharge Category Description
NJG0144533	196552	WILLIAM R HALL CO	Lindenwold Boro	7/30/03	5/31/07	5G2	Basic Industrial Stormwater GP - NJ0088315 (5G2)
NJG0119768	48595	UNITED PARCEL SERVICE	Lawnside Boro	6/1/02	5/31/07	5G2	Basic Industrial Stormwater GP - NJ0088315 (5G2)
NJG0120553	48656	CATELLI BROTHERS INC	Collingswood Boro	6/1/02	5/31/07	5G2	Basic Industrial Stormwater GP - NJ0088315 (5G2)
NJG0120537	48654	NATIONAL KEYSTONE PRODUCTS CO	Cherry Hill Twp	6/1/02	5/31/07	5G2	Basic Industrial Stormwater GP - NJ0088315 (5G2)
NJG0003999	46605	VICTORY REFRIGERATION LLC	Cherry Hill Twp	6/1/02	5/31/07	5G2	Basic Industrial Stormwater GP - NJ0088315 (5G2)
NJG0117196	48386	INCOLN GRAPHICS INC	Cherry Hill Twp	6/1/02	5/31/07	5G2	Basic Industrial Stormwater GP - NJ0088315 (5G2)
NJG0104612	47526	RCA-BUZBY LANDFILL	Voorhees Twp	6/1/02	5/31/07	5G2	Basic Industrial Stormwater GP - NJ0088315 (5G2)
NJG0121011	48702	L & L REDI-MIX INC/PLANT 2	Voorhees Twp	10/1/03	9/30/08	CPM	Concrete Products Management (GP)
NJG0121096	48707	L & L REDI-MIX INC/GIBBSBORO B	Voorhees Twp	10/1/03	9/30/08	CPM	Concrete Products Management (GP)
NJG0146471	215808	LINK BURNS MFG CO INC	Voorhees Twp	1/28/04	5/31/07	5G2	Basic Industrial Stormwater GP - NJ0088315 (5G2)

Appendix G: Cooper River Watershed's Photo-documentation

Cooper River Parkway Dam at Kaighn Avenue in Camden City: the tide gates prevent flow upstream during a high tide.

Cooper River Parkway Dam at Kaighn Avenue (from the lake side)

View on the Cooper River Lake from the Cooper River Parkway Dam

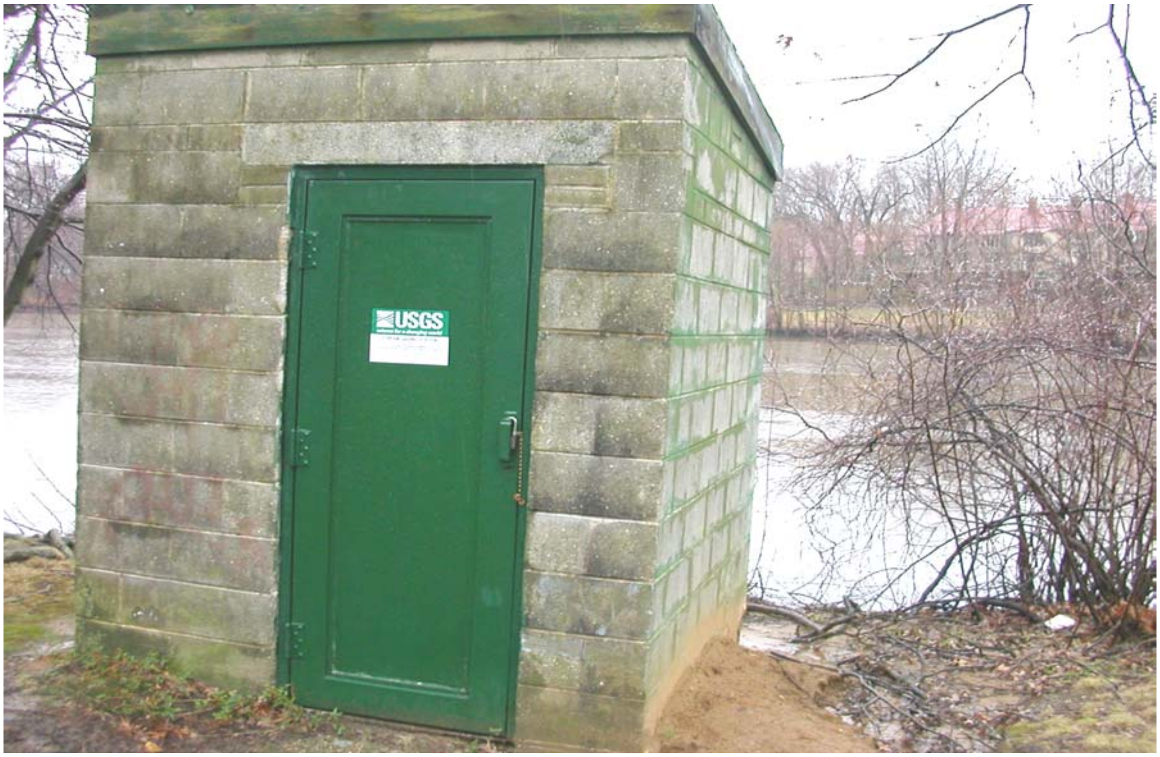
Cooper River Lake between Kaighn Avenue and Rt 130

Cooper River Lake at Route 130 bridge, Collingswood. View on the Cooper River Lake from the east side toward west

Cooper River Lake between Rt 130 and Wallworth Dam

Wallworth Lake Dam, View from the bridge - Wallworth Park in Haddonfied

Wallworth Lake: Fishway from Wallworth Lake to Evans Pond, at the bottom of the picture, stormwater discharge. North side of the lake



USGS Station #01467150 at north side of the Wallworth Lake

Wallworth Lake, USGS station 01467150

Spill through the Evans Pond Dam to Wallworth Lake

As above

Appendix H: Validation of Lakes as Endpoints for Stream Segment Impairments

The stream segments were assessed to determine whether or not the 0.1 mg/l TP stream standard should apply. Because applicability of the standard could not be ruled out, an approach was developed to verify that achieving the lake criterion would also serve to attain SWQS in the stream segments.

Summary of Impairment Measures for Stream Segments: Evaluation of 1998 and 2002 sampling results

1. LINDENWOLD
Station 01467120, outlet of Linden Lake

Nutrient Parameters	Impairment Triggers
Diurnal Dissolved Oxygen **NOT TESTED: no conclusion**	1. Daytime average is 3 mg/L or more higher than nighttime average 2. Minimum DO threshold is violated in greater than 10% of the samples taken during the night 3. DO daily average violates the applicable 24-hour average criteria Phosphorus is rendering the water unsuitable for aquatic life use if both 1 and 2 **or** 1 and 3 occur in any single 3-day sampling event
AND Periphyton Concentration (Chl a) **NOT TESTED: no conclusion**	>150 mg/m² Seasonal Mean > 200 mg/m² Individual Sample
AND Phytoplankton Concentration (Chl a) **Results** **from 3.7 µg/L to 47.9 µg/L (six results)** **2002: seasonal mean 21.5 µg/L: not impaired**	>24 µg/L Seasonal Mean > 32 µg/L 2 week mean

Phosphorus limiting IF [DRP] $\geq$ 0.05 mg/L	**NO** **DRP** = 0.02 mg/L for the 2002's season
OR **TIN/DRP** $\leq$ **5**	**78% of TIN/DRP** $\leq$ **5;** **22% of TIN/DRP** $\geq$ **5**
PHOSPHORUS CAN NOT BE EXCLUDED AS THE LIMITING NUTRIENT	

2. LAWNSIDE
Station 01467140

Nutrient Parameters	Impairment Triggers
Diurnal Dissolved Oxygen <u>**Results:**</u> **1. 0.7 mg/L** **2. 100% samples do not violate DO threshold** **3. DO daily average does not violate 5.0 mg/L standard for FW-2NT** **Phosphorus <u>is not rendering</u> the water unsuitable for aquatic life use**	1. Daytime average is 3 mg/L or more higher than nighttime average 2. Minimum DO threshold is violated in greater than 10% of the samples taken during the night 3. DO daily average violates the applicable 24-hour average criteria Phosphorus is rendering the water unsuitable for aquatic life use if both 1 and 2 <u>**or**</u> 1 and 3 occur in any single 3-day sampling event
AND Periphyton Concentration (Chl a) **NOT TESTED: no conclusion**	>150 mg/m^2 Seasonal Mean > 200 mg/m^2 Individual Sample
AND Phytoplankton Concentration (Chl a) <u>**Results**</u> **from 1.5 μg/L to 11.2 μg/L (six results)** **Seasonal mean 2002: 5.98 μg/L: not impaired**	>24 μg/L Seasonal Mean > 32 μg/L 2 week mean

Phosphorus limiting IF [DRP] ≥ 0.05 mg/L	**NO** **DRP ≥ 0.05 mg/L in 56% samples**
OR **TIN/DRP ≤ 5**	**TIN/DRP ≤ 5 in 33% (3 of 9)**
PHOSPHORUS CAN NOT BE EXCLUDED AS THE LIMITING NUTRIENT	

3. KRESSON
Station 01467155

Nutrient Parameters	**Impairment Triggers**
Diurnal Dissolved Oxygen <u>**Results:**</u> **1. 2.45 mg/L** **2. 100% samples do not violate DO threshold** 3. **DO daily average does not violate 5.0 mg/L standard for FW-2NT** **Phosphorus <u>is not rendering</u> the water unsuitable for aquatic life use**	1. Daytime average is 3 mg/L or more higher than nighttime average 2. Minimum DO threshold is violated in greater than 10% of the samples taken during the night 3. DO daily average violates the applicable 24-hour average criteria Phosphorus is rendering the water unsuitable for aquatic life use if both 1 and 2 <u>**or**</u> 1 and 3 occur in any single 3-day sampling event
AND Periphyton Concentration (Chl a) **NOT TESTED: no conclusion**	>150 mg/m^2 Seasonal Mean > 200 mg/m^2 Individual Sample
AND Phytoplankton Concentration (Chl a) **Results: from 0.0 to 1.9 μg/L** **Seasonal mean 2002: 0.68 μg/L: not impaired**	>24 μg/L Seasonal Mean > 32 μg/L 2 week mean

Phosphorus limiting IF [DRP] ≥ 0.05 mg/L	**YES** **DRP ≥ 0.05 mg/L in 100% samples**
OR **TIN/DRP ≤ 5**	**TIN/DRP ≤ 5 in 12.5% (1 of 8)**
PHOSPHORUS CAN NOT BE EXCLUDED AS THE LIMITING NUTRIENT	

Data assessment for TMDL development

The following analysis was completed to ensure that using the lakes as the critical locations for TP and concluding that load reductions calculated to attain the lake SWQS of 0.05 mg/l will result in attainment of the stream standard of 0.1 mg/l is valid. Where sufficient concentration and flow data were available, a method that determines the percent reduction based on the linear regression of daily total phosphorus loading (pound per day, lb/day) versus flow (cubic feet per second, cfs) was used. The method was adapted from "TMDL Development Using Load Duration Curves" as presented at an ASIWPCA TMDL "Brown Bag" by Tom Stiles (Kansas Department of Health and Environment), Andrew Sullivan (Texas Natural Resource Conservation Commission), Charles Martin (Virginia Department of Environmental Quality), and Bruce Cleland (America's Clean Water Foundation), May 16, 2002.

To get the percent reduction, the technique in “TMDL Development Using Load Duration Curves” (Stiles et al., 2002) was modified to 1) use instantaneous flow measurements in place of a flow-duration (cumulative frequency of average daily flows), 2) use a load versus flow in place of a load versus flow probability relationship, and 3) provide more certainty in the location of the y-intercept. In many cases, long-term continuous flow monitoring data are not available along streams requiring TMDLs. When continuous flow data are not available, flows must be estimated using either continuous flow records from a flow measurement station in a nearby watershed, or by using a constant flow per unit drainage area. Both of these flow estimating techniques introduce variability that is inherent to the use of data from other locations or from approximations of watershed characteristics. Therefore, the modifications to the regression technique permit the use of fewer flow data while providing a site-specific analysis of loading exceedances over a range of measured flows.

Percent loading reduction is the difference between the upper 95 percent confidence limit of the slope of the regression for the loadings exceeding the target loading line and the slope of the target loading. The resultant percent reduction is the same whether the y-axis is expressed as pounds per day, pounds per year, or as metric units of kilograms per day or per year.

The referenced approach requires enough historical flow and concentration data to define a representative flow duration curve and associated loading duration curve. The concept of this approach is to determine the average of the loading exceedances derived from the measured data loadings that exist between the probability curve of the associated regulatory loading target and a selected upper confidence limit of a regression through the exceedances. The regulatory loading target and measured pollutant loadings are plotted against flow duration.

For the Haddonfield (Station 01467150), the actual phosphorus loadings are compared to the 0.1 mg/L total phosphorus target (presented as daily loadings) (Figure 1) . Exceedances are analyzed and load reductions are calculated. Also the upper 95 percent confidence limit for the regression of the exceedances are calculated and plotted. Finally, the percent reduction in total phosphorus loads (difference between the upper 95 percent confidence limit of the exceedance regression and the target load regression) are calculated to maintain compliance with the both standards (0.05 mg/L and 0.1 mg/L TP SWQSs.)

The same method was used for the Lawnside segment (Station 01467140). The data set consisted of 38 TP concentration data with the corresponding flows. These data were collected from 1986 through 1991, 1998, and 2002. For the statistical analysis, a set of 34 pairs of TP concentration-flow data were used. Figure 2 presents actual phosphorus loadings (points), linear exceedence regression line, and an upper 95% confidence line and shows how they relate to the target load at 0.1 mg/L TP for Lawnside. Exceedances are analyzed and load reductions calculated as well as the upper 95 percent confidence limit for the regression of the exceedances. The percent reduction in total phosphorus loads (difference between the upper 95 percent confidence limit of the exceedance regression and the target load) is calculated to maintain compliance with a 0.1 mg/L TP standard for the stream.

For remaining stream segments, Lindenwold (01467120) and Kresson (01467155), this method could not be applied because of the lack of flow data. Instead, a linear relationship, between load reduction and in-stream concentration was assumed to exist. The load reduction needed to attain the SWQS for streams was calculated, based on the highest recorded data point. Data for these stations is presented in Figures 3 and 4. Table 1 summarizes the load reductions required using the TMDL methodology and the two alternate methods for assessing attainment of SWQS in stream segments.

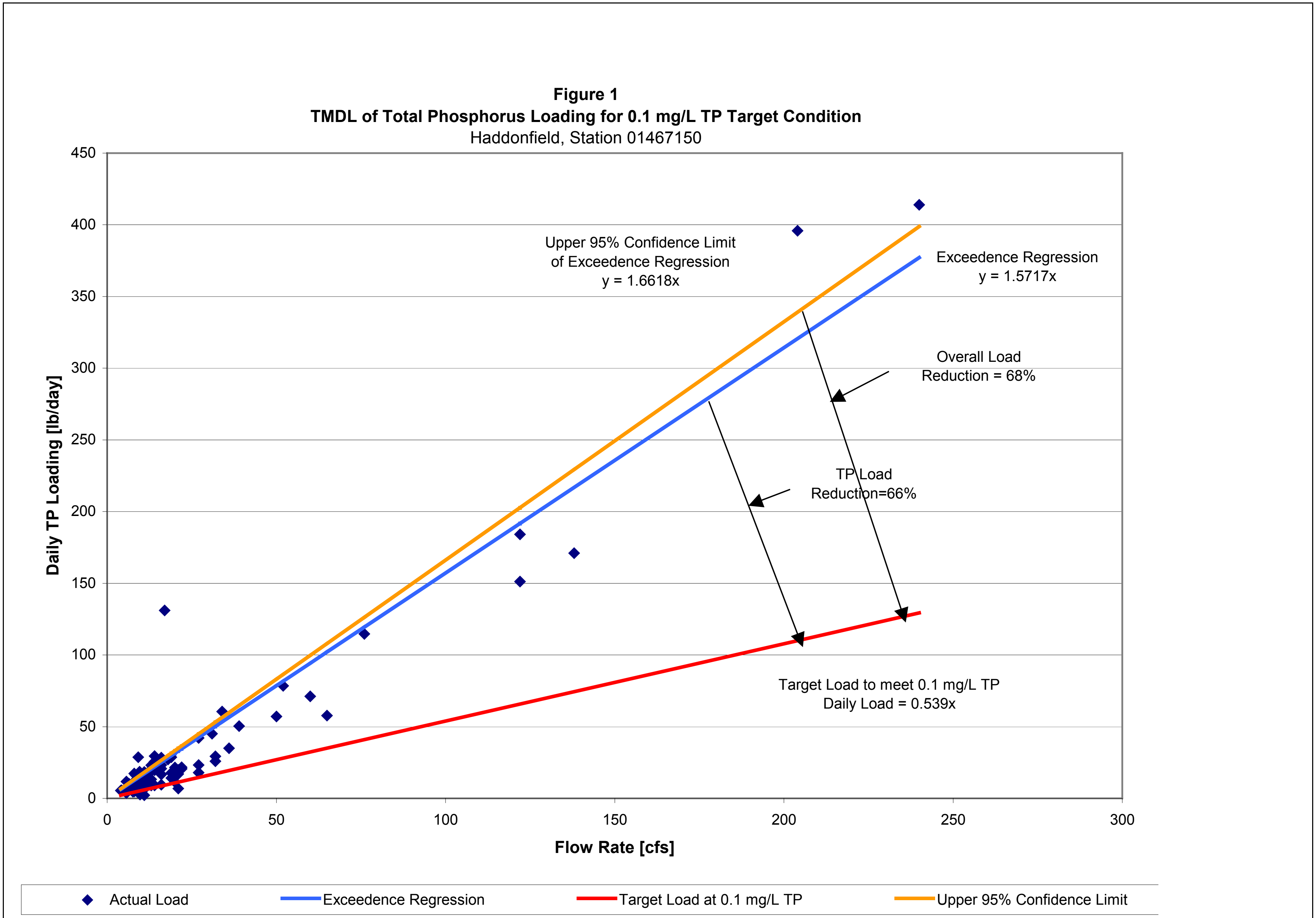


Figure 1
TMDL of Total Phosphorus Loading for 0.1 mg/L TP Target Condition
Haddonfield, Station 01467150
Daily TP Loading [lb/day]
Flow Rate [cfs]
0
50
100
150
200
250
300
350
400
450
0
50
100
150
200
250
300
Upper 95% Confidence Limit
of Exceedence Regression
y = 1.6618x
Exceedence Regression
y = 1.5717x
Overall Load
Reduction = 68%
TP Load
Reduction=66%
Target Load to meet 0.1 mg/L TP
Daily Load = 0.539x
Actual Load
Exceedence Regression
Target Load at 0.1 mg/L TP
Upper 95% Confidence Limit

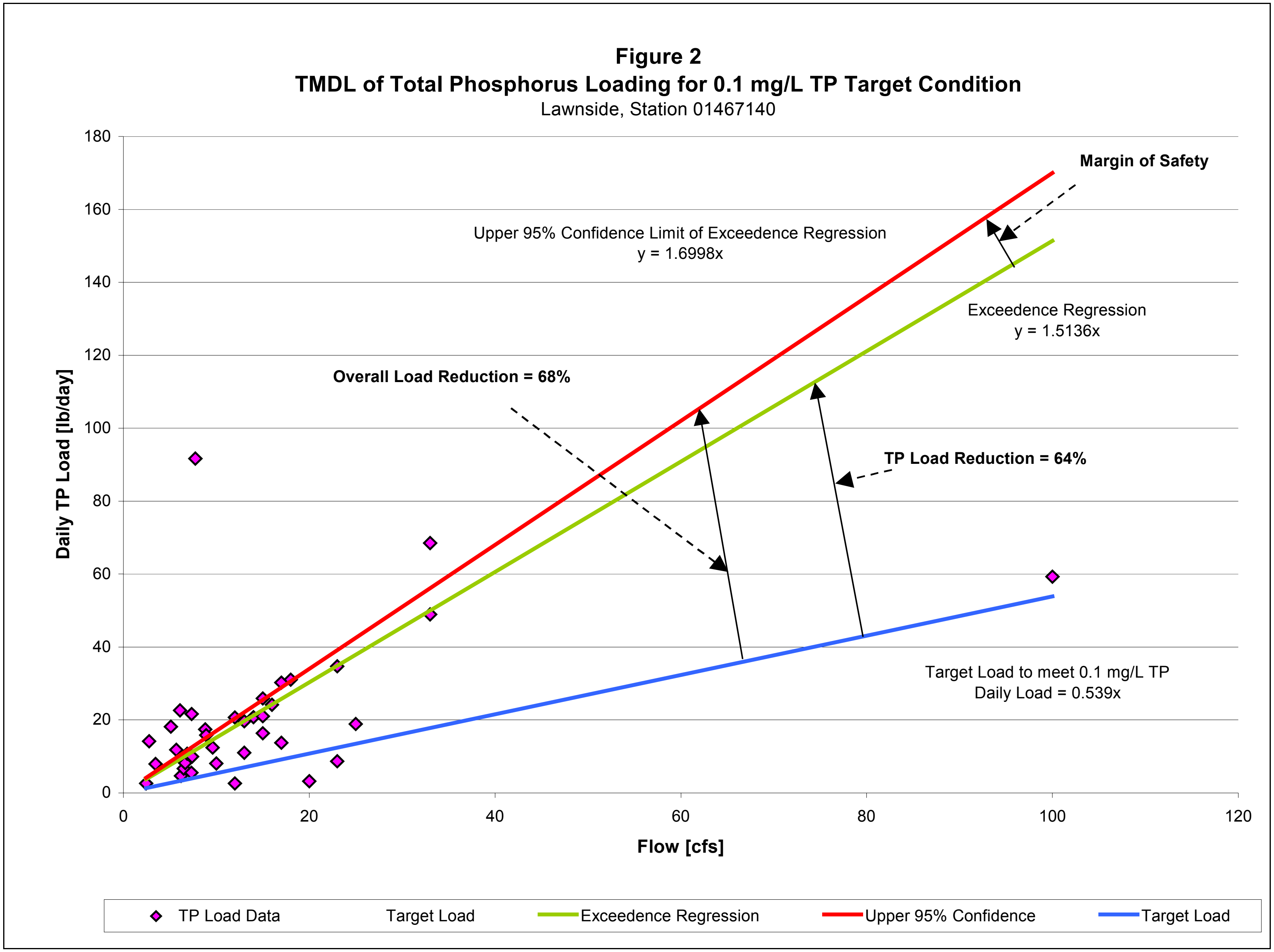


Figure 2
TMDL of Total Phosphorus Loading for 0.1 mg/L TP Target Condition
Lawnside, Station 01467140
Margin of Safety
Upper 95% Confidence Limit of Exceedence Regression
y = 1.6998x
Exceedence Regression
y = 1.5136x
Overall Load Reduction = 68%
TP Load Reduction = 64%
Target Load to meet 0.1 mg/L TP
Daily Load = 0.539x
Daily TP Load [lb/day]
Flow [cfs]
0
20
40
60
80
100
120
140
160
180
0
20
40
60
80
100
120
TP Load Data
Target Load
Exceedence Regression
Upper 95% Confidence
Target Load

Haddonfield 01467150

SUMMARY OUTPUT (Load exceedences for TP>0.1mg/L)

Regression Statistics	
Multiple R	0.957857671
R Square	0.917491318
Adjusted R Square	0.905145639
Standard Error	19.56525199
Observations	82

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	344792.83	344792.83	900.7148738	2.68495E-45
Residual	81	31006.72593	382.7990855		
Total	82	375799.5559			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	1.571744434	0.045236558	34.74500535	1.99167E-50	1.481737802	1.661751066

Note: 1. The highest monitoring result was rejected (outlier)
2. Only four TP concentrations were below SWQS of 0.1 mg/L

To achieve water quality standard at the Haddonfield station at the TP concentration of 0.1 mg/L (SWQS for streams), the required reductions are as follows:

Target Load (lb/day) for the given TP SWQS of 0.1 mg/L = 0.0.539 x flow (cfs)

Required TP Load Reduction based on the regression line: (from Figure 1)

Required TP Load Reduction = $(1-\frac{0.539}{1.5717}) = 0.6571x100\% = 66\%$

TP Load reduction required, based on the Upper 95% Confidence Limit of the regression line:

Load Reduction = $1-\frac{0.539}{1.6618}=0.6757x100\%=68\%$

The loading capacity is determined by 68% reduction on the existing loading, of which 5% will be a margin of safety (MOS):

MOS = $\frac{0.6757-0.6571}{1-0.6571}\,x100\%=5\%$

Lawnside, station 01467140

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.833613479
R Square	0.694911433
Adjusted R Square	0.662653369
Standard Error	7.363080178
Observations	32

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3828.108843	3828.108843	70.60983848	2.22978E-09
Residual	31	1680.663441	54.21494971		
Total	32	5508.772284			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A
X Variable 1	1.513610114	0.090307071	16.76070434	4.28999E-17	1.329427526	1.697792702

Note:

1. One highest monitoring result was rejected, did not fit to data population (outlier);
2. Three TP concentration results were below 0.1 mg/L (SWQS of 0.1 mg/L for the stream)

To achieve SWQS for streams, total phosphorus concentration of 0.1 mg/L TP, the required reductions are as follows:

Target Load (lb/day) for the given TP concentration of 0.1 mg/L = 0.539 x flow (cfs)

Required TP Load Reduction based on the regression line: (from Figure 2)

$$\text{Required TP Load Reduction} = (1 - \frac{0.539}{1.5136})x100\% = 64\%$$

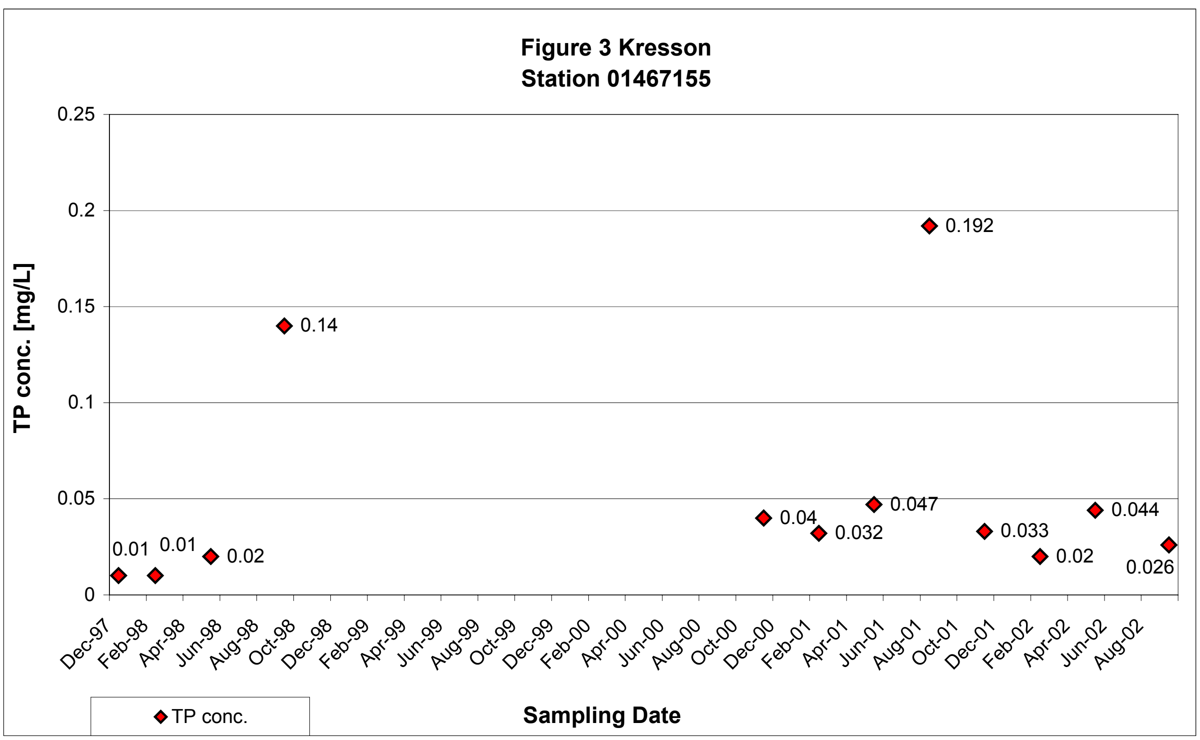
TP Load reduction required, based on the Upper 95% Confidence Limit of the regression line:

$$\text{Load Reduction} = (1 - \frac{0.539}{1.6978})x100\% = 68\%$$

The loading capacity is determined by 64% reduction on the existing loading, of which 24% will be margin of safety (MOS):

$$\text{MOS} = \frac{68\% - 64\%}{100\% - 64\%} = 11\%$$

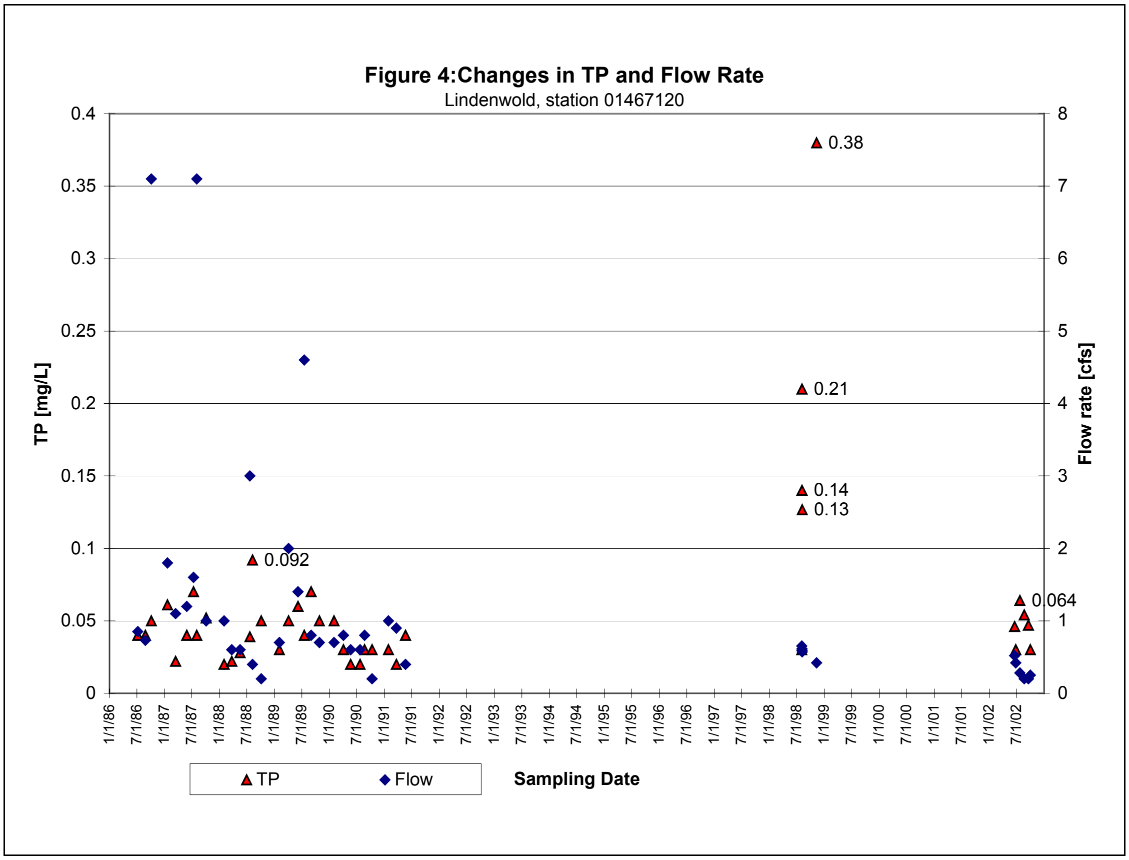
Kresson, station 01467155



The reduction required to achieve a SWQS of 0.1 mg/L for the highest TP concentration result (0.192 mg/L) is 47%. The total phosphorus reduction required for the Cooper River North Branch, as calculated from the Reckhow model for the Cooper

River Lakeshed, is 86%. It is concluded that, if the required reduction of 86% is reached for the Cooper River Lakeshed, it will satisfy the 47% reduction required to reduce the highest ever recorded TP concentration, and the SWQS of 0.1 mg/L TP will be attained in stream.

Lindenwold, station 01467120



The reduction required to achieve a SWQS of 0.1 mg/L, compared to the highest TP concentration of 0.38 mg/L TP, is 74%. The required reduction of 76% for the Kirkwood Lake watershed, as calculated from the Reckhow empirical model (April 2003 TMDLs), will also satisfy a 74% percent reduction required for the highest ever recorded TP concentration to meet a SWQS of 0.1 mg/L TP.

Table1: Comparison of Reductions Required

Lake Endpoints and Alternate Method for Stream Segments

TMDL	**Watershed** **Impaired Site**	**Target TP Conc.** **(mg/L)**	**Reduction Required in Proposed TMDL**	**Reduction Required from alternative method**
	Kirkwood Lake	0.05	76%	--
1	Lindenwold 01467120	0.1	--	74%
2	**Evans Pond & Wallworth Lake**	0.05	87%	--
3	Haddonfield - 01467150	0.1	--	68%
4	Lawnside - 01467140	0.1	--	68%
5	**Cooper River Lake**	0.05	86%	--
6	Kresson - 01467155	0.1	--	47%