Total Maximum Daily Load (TMDL) for Phosphorus in Cossayuna Lake

Washington County, New York

September 2008

Prepared for:

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1.0 INTRODUCTION

1.1. Background

In April of 1991, the United States Environmental Protection Agency (EPA) Office of Water's Assessment and Protection Division published "Guidance for Water Quality-based Decisions: The Total Maximum Daily Load (TMDL) Process." In July 1992, EPA published the final "Water Quality Planning and Management Regulation" (40 CFR Part 130). Together, these documents describe the roles and responsibilities of EPA and the states in meeting the requirements of Section 303(d) of the Federal Clean Water Act (CWA) as amended by the Water Quality Act of 1987, Public Law 100-4. Section 303(d) of the CWA requires each state to identify those waters within its boundaries not meeting water quality standards for any given pollutant applicable to the water's designated uses.

Further, Section 303(d) requires EPA and states to develop TMDLs for all pollutants violating or causing violation of applicable water quality standards for each impaired waterbody. A TMDL determines the maximum amount of pollutant that a waterbody is capable of assimilating while continuing to meet the existing water quality standards. Such loads are established for all the point and nonpoint sources of pollution that cause the impairment at levels necessary to meet the applicable standards with consideration given to seasonal variations and margin of safety. TMDLs provide the framework that allows states to establish and implement pollution control and management plans with the ultimate goal indicated in Section 101(a)(2) of the CWA: "water quality which provides for the protection and propagation of fish, shellfish, and wildlife, and recreation in and on the water, wherever attainable" (USEPA, 1991).

1.2. Problem Statement

Cossayuna Lake (WI/PWL ID 1103-0002) is situated in the Town of Argyle, within Washington County, northeast of the Capital District region of New York State. Over the past couple of decades, the lake has experienced degraded water quality that has reduced the lake's recreational and aesthetic value. Cossayuna Lake is presently among the lakes listed on the 1996 Upper Hudson River Drainage Basin Priority Waterbody Listings (PWL), with *bathing, fish survival, aesthetics,* and *boating* listed as *impaired* due to excessive algae and weeds (NYS DEC, 2007).

The recreational suitability of Cossayuna Lake has been mostly unfavorable since first evaluated by the New York State Department of Environmental Conservation (NYS DEC) in 1992. Recreational conditions are most often described as "slightly" to "substantially" impaired for most uses, and the lake has been described mostly as "not quite crystal clear" to having "definite algal greenness." Recreational assessments are typical of other lakes with similar water quality and plant densities (aquatic plants regularly grow to the lake surface, often densely, more so when clarity is high), and these assessments have been less favorable in recent years, despite the rise in water transparency. The recreational assessments degrade slightly during the summer, consistent with seasonal increases in lake productivity, although aquatic plant populations are generally stable during the summer (NYS DEC, 2007).

A variety of sources of phosphorus are contributing to the poor water quality in Cossayuna Lake. The water quality of the lake is influenced by runoff events from the drainage basin, as well as loading from nearby residential septic tanks. In response to precipitation, nutrients, such as phosphorus – naturally found in New York soils – drain into the lake from the surrounding drainage basin by way of streams, overland flow, and subsurface flow. Nutrients are then deposited and stored in the lake bottom sediments. Phosphorus is often the limiting nutrient in temperate lakes and ponds and can be thought of as a fertilizer; a primary food for plants, including algae. When lakes receive excess phosphorus, it "fertilizes" the lake by feeding the algae. Too much phosphorus can result in algae blooms, which can damage the ecology/aesthetics of a lake, as well as the economic well-being of the surrounding drainage basin community.

The results from state sampling efforts confirm eutrophic conditions in Cossayuna Lake, with the concentration of phosphorus in the lake violating the state guidance value for phosphorus (20 μg/L or 0.020 mg/L, applied as the mean summer, epilimnetic total phosphorus concentration), which increases the potential for nuisance summertime algae blooms. In 2004, Cossayuna Lake was added to the NYS DEC CWA Section 303(d) list of impaired waterbodies that do not meet water quality standards due to phosphorus impairments, but not designated as a "high priority for TMDL development" (NYS DEC, 2004). Based on this listing, a TMDL for phosphorus is being developed for the lake to address the impairment.

2.0 WATERSHED AND LAKE CHARACTERIZATION

2.1. History of the Lake and Watershed

Cossayuna Lake has been sampled by NYS DEC as part of several major state monitoring programs, including the NYS DEC Division of Water's Lake Classification and Inventory (LCI) survey in 1982 and 1987 and through a similar NYS DEC Division of Water program in 1976. The lake was first sampled as part of the Citizens Statewide Lake Assessment Program (CSLAP) in 1992. Early lake data suggest that conductivity was slightly lower and pH slightly higher; however, water clarity and phosphorus readings from earlier studies are within the same range as recent data (NYS DEC, 2007).

Cossayuna Lake was also sampled as part of the Conservation Department (predecessor to NYS DEC) Biological Survey of the Upper Hudson River basin in 1932. This monitoring program focused primarily on the relationship between water quality and fisheries management, although some of the water quality indicators evaluated through CSLAP were also monitored in 1932. Cossayuna Lake was described as follows (NYS DEC, 2007):

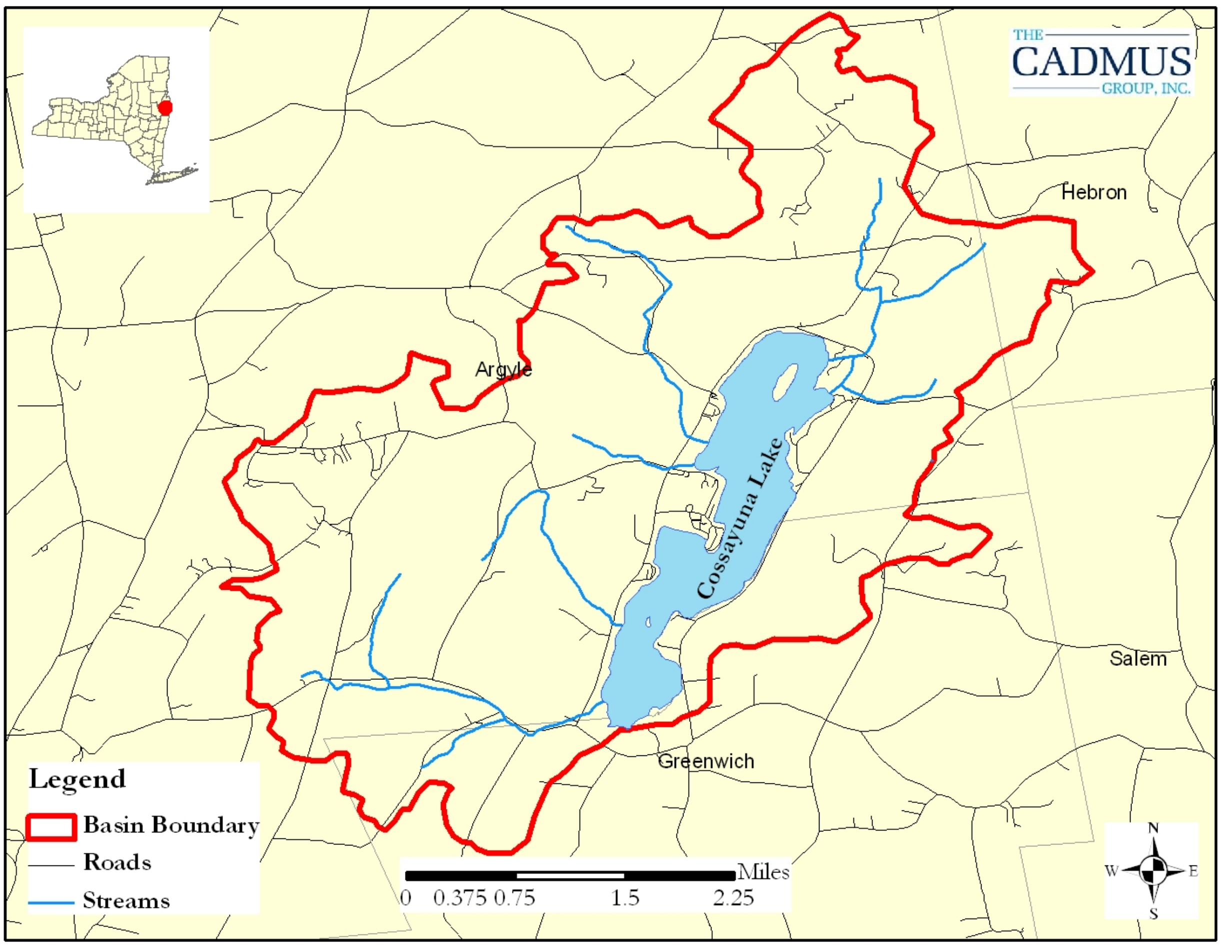
> *"There is considerable agitation among sportsmen and cottage owners to raise the water level by the construction of a three-foot dam at the foot of the lake. It is hoped by this method to increase the area of water which would be too deep to support the rank growth of vegetation which makes fishing difficult. It is safe to predict that an increase of three feet in the depth of Cossayuna would not materially affect the extent of the weed areas... It would improve the appearance of the lake by preventing the lower end from becoming practically dry in late summer"*

These data show that water transparency was much higher in 1932, although the same seasonal drop seen in present clarity measurements in Cossayuna Lake was also found in this earlier study. Although not measured through CSLAP, data collected in other monitoring programs have indicated that Cossayuna Lake exhibits deepwater oxygen depletion during the summer; this was not apparent in the 1932 study of the lake.

2.2. Watershed Characterization

Cossayuna Lake is part of the Upper Hudson River drainage basin with a southward flow draining into Whittaker Creek, Carter Creek, and the Battenkill River. The Battenkill River flows east into the Hudson River between the towns of Greenwich and Easton (Town of Argyle, 2001). Cossayuna Lake has a direct drainage basin area of 6,841 acres excluding the surface area of the lake (Figure 1). Elevations in the lake's basin range from approximately 1,165 feet above mean sea level (AMSL) to as low as 485 feet AMSL at the surface of Cossayuna Lake. Cossayuna Lake's watershed is distributed among the following townships: Argyle, 85%; Greenwich, 10%, Salem, 4%; Hebron, 1% (Town of Argyle, 2001).

Figure 1. Cossayuna Lake Direct Drainage Basin



Existing land use and land cover in the Cossayuna Lake drainage basin was determined from digital aerial photography and geographic information system (GIS) datasets. Digital land use/land cover data were obtained from the 2001 National Land Cover Dataset (Homer, 2004). The NLCD is a consistent representation of land cover for the conterminous United States generated from classified 30-meter resolution Landsat thematic mapper satellite imagery data. High-resolution color orthophotos were used to manually update and refine land use categories for portions of the drainage basin to reflect current conditions in the drainage basin (Figure 2). Appendix A provides additional detail about the refinement of land use for the drainage basin. Land use categories (including individual category acres and percent of total) in Cossayuna Lake's drainage basin are listed in Table 1 and presented in Figures 3 and 4.

Figure 2. Aerial Image of Cossayuna Lake

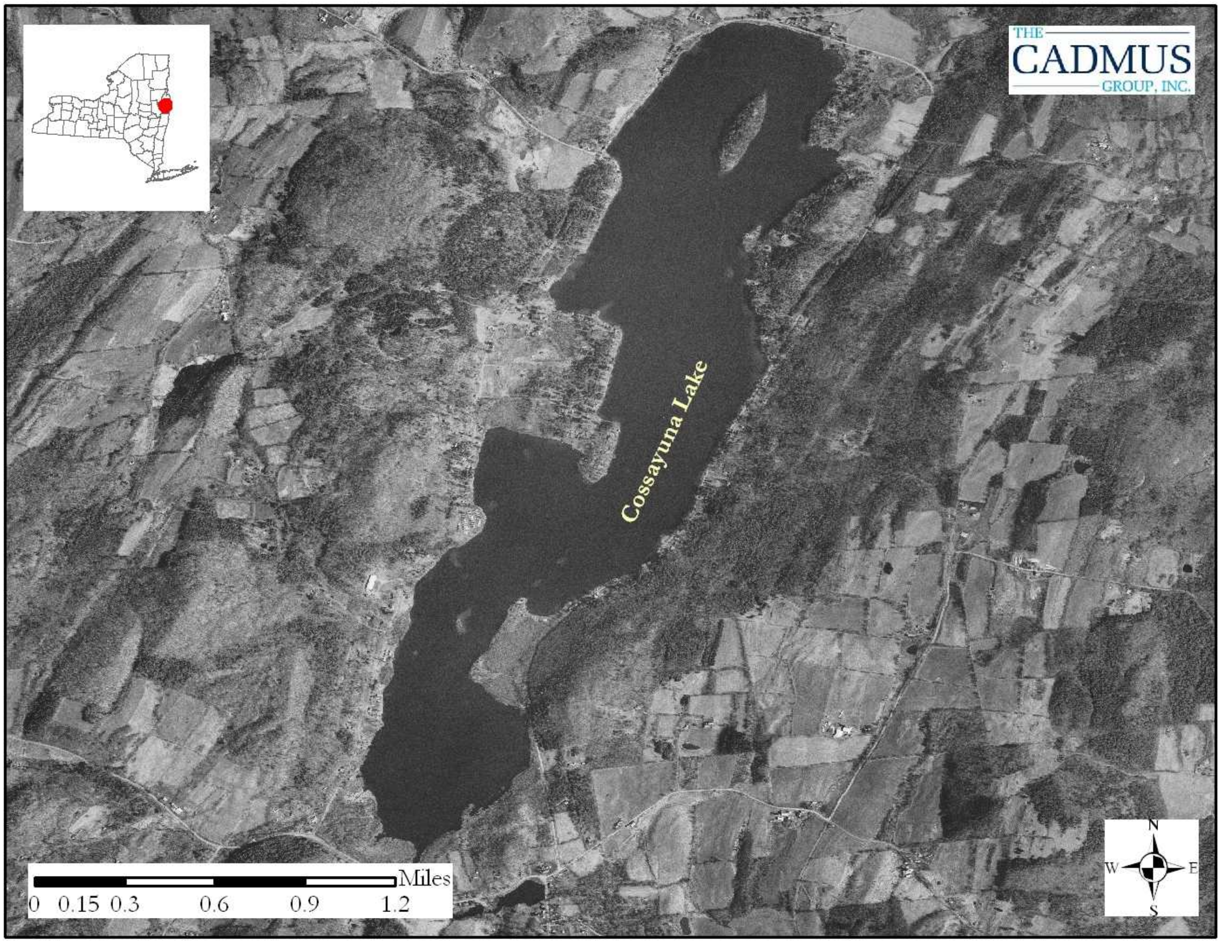


Table 1. Land Use Acres and Percent in Cossayuna Lake Drainage Basin

Land Use Category	Acres	% of Drainage Basin
Open Water	61	1%
Agriculture	1,593	23%
Hay & Pasture	1,409	20%
Cropland	184	3%
Developed Land	411	6%
Low Intensity	406	6%
High Intensity	5	0.1%
Forest	4,506	66%
Wetlands	270	4%
TOTAL	**6,841**	**100%**

Figure 3. Percent Land Use in Cossayuna Lake Drainage Basin

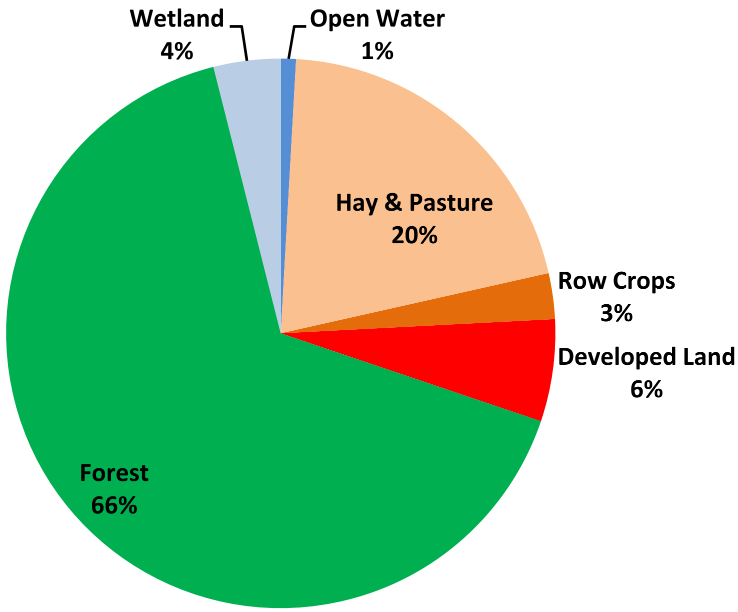
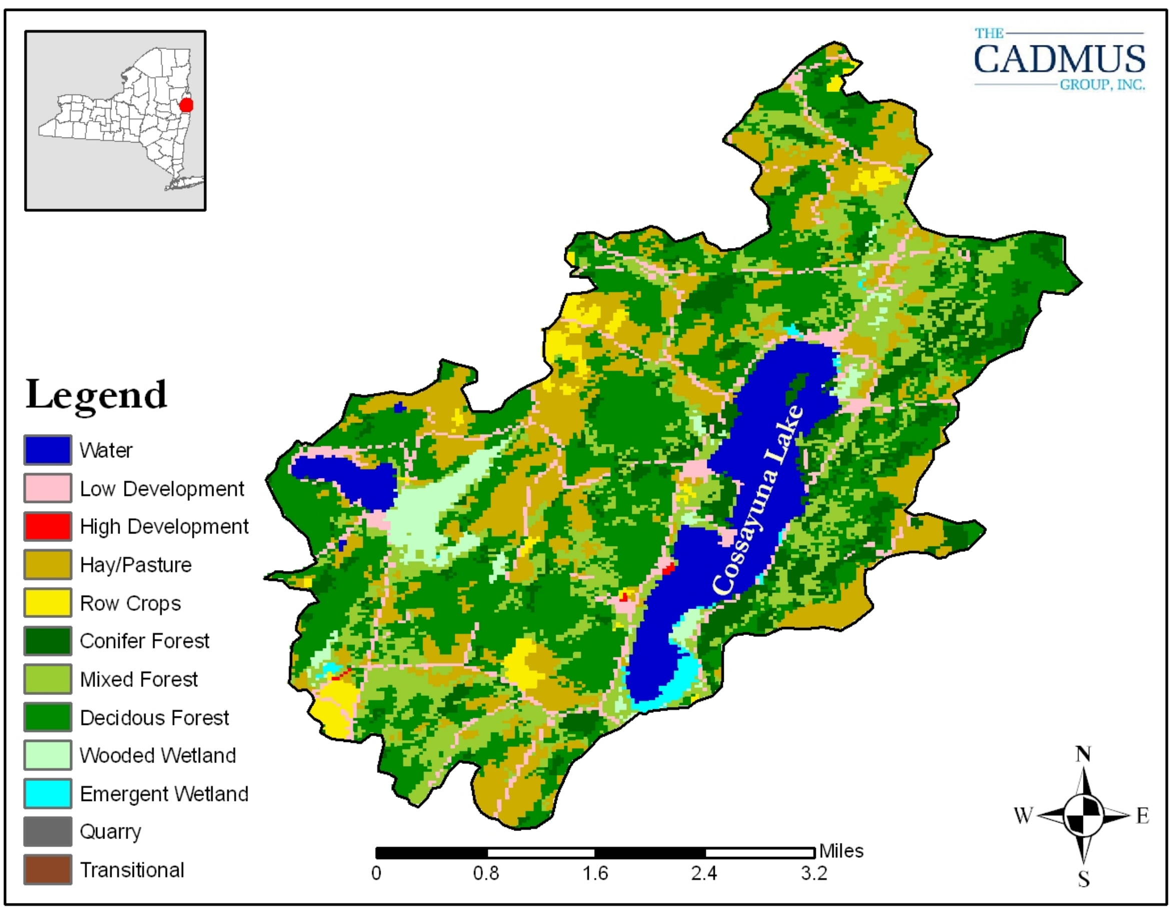


Figure 4. Land Use in Cossayuna Lake Drainage Basin



2.3. Lake Morphometry

Cossayuna Lake is a 649 acre waterbody at an elevation of about 485 feet AMSL. Figure 5 shows a bathymetric map for Cossayuna Lake based on a lake contour map developed by NYS DEC. Table 2 summarizes key morphometric characteristics for Cossayuna Lake.

Figure 5. Bathymetric Map of Cossayuna Lake

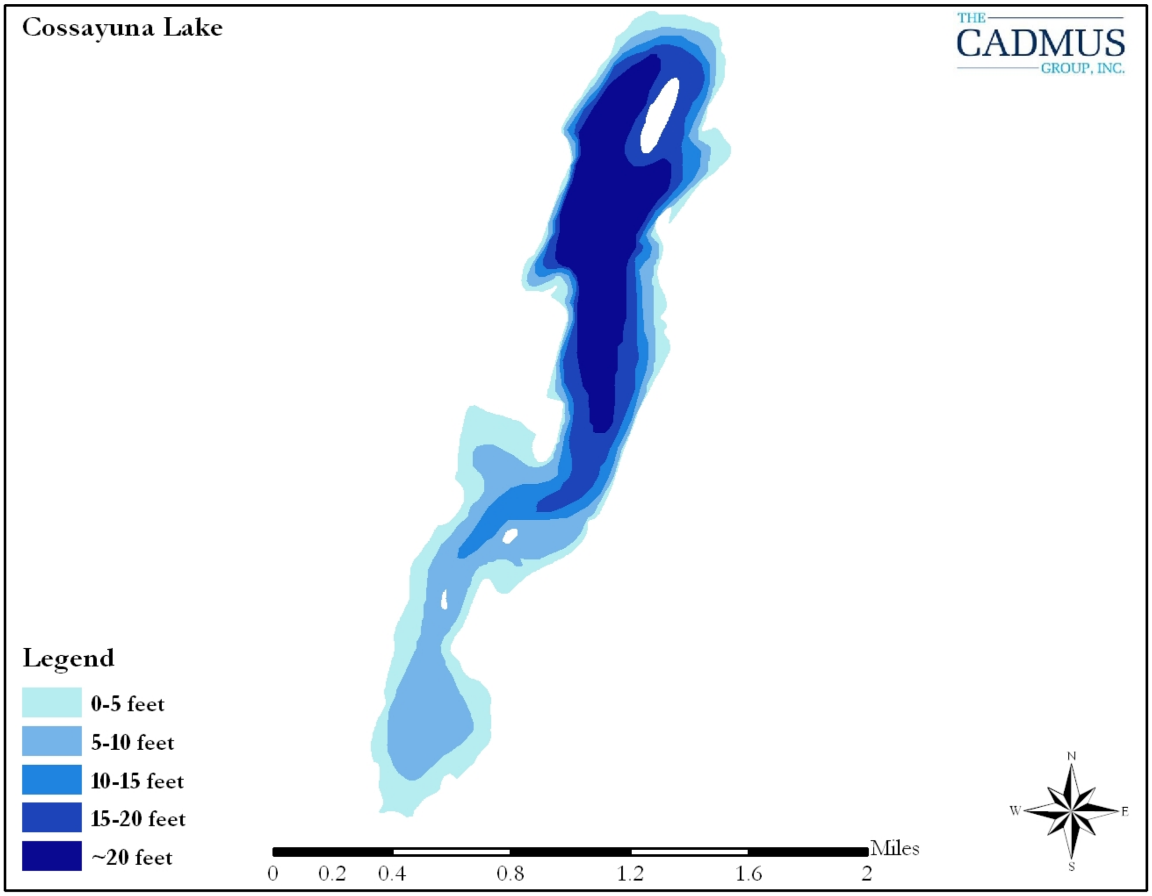


Table 2. Cossayuna Lake Characteristics

Surface Area (acres)	649
Elevation (ft AMSL)	485
Maximum Depth (ft)	20
Mean Depth (ft)	11
Length (ft)	10,014
Width at widest point (ft)	2,932
Shoreline perimeter (ft)	45,280
Direct Drainage Area (acres)	6,841
Watershed: Lake Ratio	11:1
Mass Residence Time (years)	0.2
Hydraulic Residence Time (years)	0.47

2.4. Water Quality

CSLAP is a cooperative volunteer monitoring effort between NYS DEC and the New York Federation of Lake Associations (FOLA). The goal of the program is to establish a volunteer lake monitoring program that provides data for a variety of purposes, including establishment of a long-term database for lakes in New York State, identification of water quality problems on individual lakes, geographic and ecological groupings of lakes, and education for data collectors and users. The data collected in CSLAP are fully integrated into the state database for lakes, have been used to assist in local lake management and evaluation of trophic status, spread of invasive species, and other problems seen in the state's lakes.

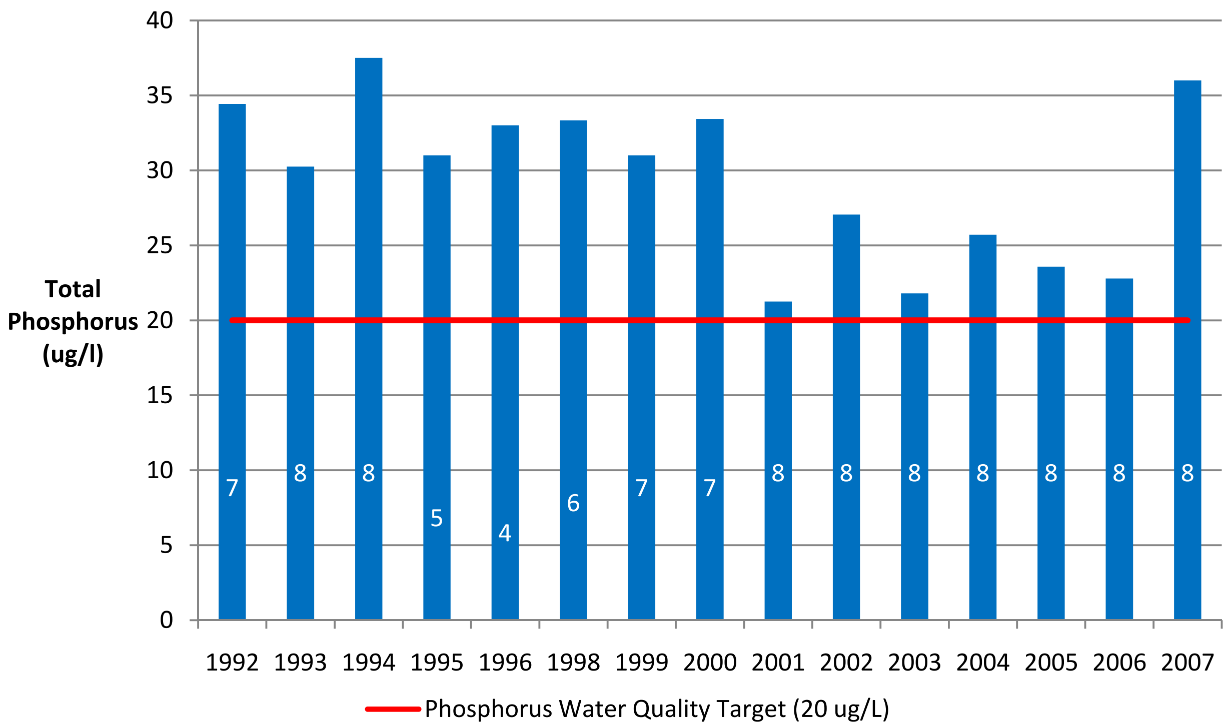
Volunteers undergo on-site initial training and follow-up quality assurance and quality control sessions are conducted by NYS DEC and trained NYS FOLA staff. After training, equipment, supplies, and preserved bottles are provided to the volunteers by NYS DEC for bi-weekly sampling for a 15 week period between May and October. Water samples are analyzed for standard lake water quality indicators, with a focus on evaluating eutrophication status-total phosphorus, nitrogen (nitrate, ammonia, and total), chlorophyll *a,* pH, conductivity, color, and calcium. Field measurements include water depth, water temperature, and Secchi disk transparency. Volunteers also evaluate use impairments through the use of field observation forms, utilizing a methodology developed in Minnesota and Vermont. Aquatic vegetation samples, deepwater samples, and occasional tributary samples are also collected by sampling volunteers at some lakes. Data are sent from the laboratory to NYS DEC and annual interpretive summary reports are developed and provided to the participating lake associations and other interested parties.

As part of CSLAP, a limited number of water quality samples were collected in Cossayuna Lake during the summers of 1992-2007. The results from these sampling efforts show eutrophic conditions in Cossayuna Lake, with the concentration of phosphorus in the lake exceeding the state guidance value for phosphorus (20 μg/L or 0.020 mg/L, applied as the mean summer, epilimnetic total phosphorus concentration), which increases the potential for nuisance summertime algae blooms. Figure 6 shows the summer mean epilimnetic phosphorus concentrations for phosphorus data collected during all sampling seasons and years in which Cossayuna Lake was sampled as part of CSLAP; the number annotations on the bars indicate the number of data points included in each summer mean.

The CSLAP dataset indicates that Cossayuna Lake is a *eutrophic*, or highly productive, lake, although the lake has become less productive in recent years. The productivity of Cossayuna Lake increases steadily (clarity drops as nutrient and algae levels rise) during the summer, resulting in recreational assessments that degrade slightly over the course of a typical sampling season (aquatic plant densities and coverage appear to be relatively stable over this period). This appears to be related to deepwater nutrient levels that are highly elevated relative to those measured at the lake surface. Deepwater phosphorus levels are higher than those measured at the lake surface; this suggests that nutrient release from bottom sediments is probably significant, and that deepwater oxygen levels probably become depleted during the summer. This was not apparent, however, in the 1930s assessment of the lake (NYS DEC, 2007).

Surface phosphorus readings decreased from the mid 1990s through 2006, resulting in a drop in algae levels and increase in water clarity readings. Phosphorus levels were higher in 2007, more closely resembling conditions from the mid 1990s, although algae levels and water clarity readings were similar to those from 2005 and most recent years. While these data continue to suggest that water quality conditions have improved, the annual variability in phosphorus readings and continued eutrophic conditions indicate a continuing susceptibility to algal blooms and recreational use impairments (NYS DEC, 2007).

Figure 6. Summer Mean Epilimnetic Total Phosphorus Levels in Cossayuna Lake



3.0 NUMERIC WATER QUALITY TARGET

The TMDL target is a numeric endpoint specified to represent the level of acceptable water quality that is to be achieved by implementing the TMDL. The water quality classification for Cossayuna Lake is *A*, which means that the most appropriate usages are a source of water supply for drinking, culinary, or food processing purposes; primary and secondary contract recreation; and fishing. New York State has a narrative standard for nutrients -- none in amounts that will result in growths of algae, weeds and slimes that will impair the waters for their best usages (6 NYSCRR Part 703.2). As part of its Technical and Operational Guidance Series (TOGS 1.1.1 and accompanying fact sheet, NYS, 1993), NYS DEC has suggested that for waters classified as ponded (i.e., lakes, reservoirs and ponds, excluding Lakes Erie, Ontario, and Champlain), the epilimnetic summer mean total phosphorus level shall not exceed 20 µg/L (or 0.02 mg/L), based on biweekly sampling, conducted from June 1 to September 30. This guidance value of 20 µg/L is the TMDL target for Cossayuna Lake.

4.0 SOURCE ASSESSMENT

4.1. Analysis of Phosphorus Contributions

The ArcView Generalized Watershed Loading Function (AVGWLF) watershed model was used in combination with the BATHTUB lake response model to develop the Cossayuna Lake TMDL. This approach consists of using AVGWLF to determine mean annual phosphorus loading to the lake, and BATHTUB to define the extent to which this load must be reduced to meet the water quality target. This approach required no additional data collection thereby expediting the modeling efforts.

The GWLF model was developed by Haith and Shoemaker (1987). GWLF simulates runoff and stream flow by a water-balance method based on measurements of daily precipitation and average temperature. The complexity of GWLF falls between that of a detailed, process-based simulation model and a simple export coefficient model that does not represent temporal variability. The GWLF model was determined to be appropriate for this TMDL analysis because it simulates the important processes of concern, but does not have onerous data requirements for calibration. AVGWLF was developed to facilitate the use of the GWLF model via an ArcView interface (Evans, 2002). Appendix A discusses the setup, calibration, and use of the AVGWLF model for lake TMDL assessments in New York.

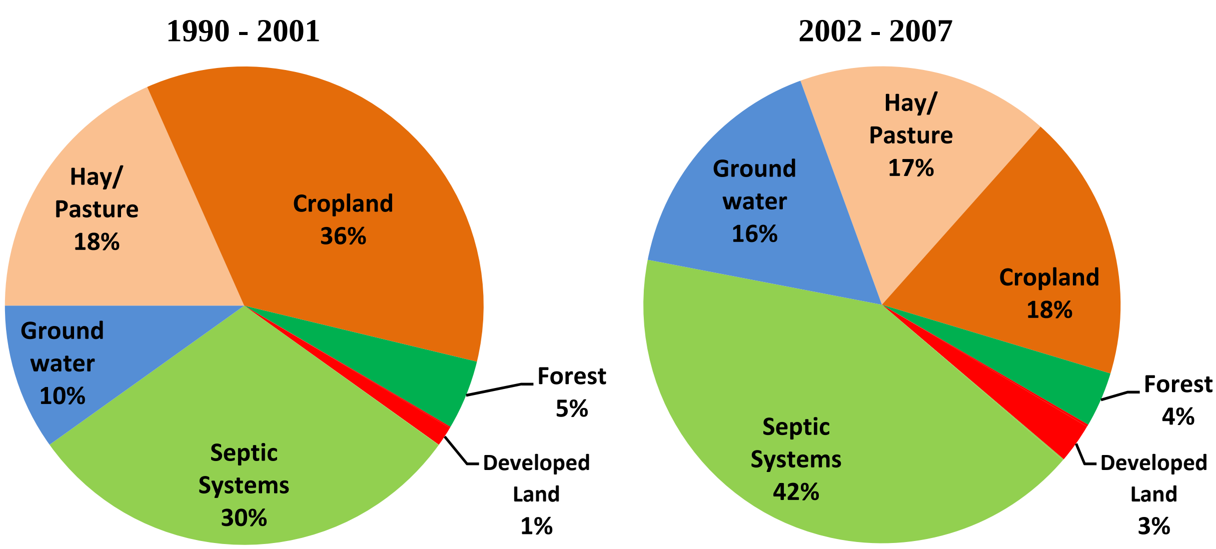
4.2. Sources of Phosphorus Loading

AVGWLF was used to estimate long-term mean annual phosphorus (external) loading to Cossayuna Lake for two different time periods – 1990-2001 and 2002-2007. The estimated mean annual external loads of 3,515 lbs/yr (1990-2001) and 2,544 lbs/yr (2002-2007) of total phosphorus to Cossayuna Lake were estimated to originate from the sources listed in Table 3 and shown in Figure 7. The 1990-2001 run was performed using the National Land Cover Database (NLCD) 2001 as is. For the 2002-2007 run, minor corrections were made to the NLCD 2001 based on analysis of orthoimagery; further, model parameters were adjusted to account for the retirement of cropland in the basin. The TMDL for Cossayuna Lake was developed using the 2002-2007 model run; therefore, the detailed source loading results (discussed in the following sections) are only provided for the 2002-2007 run. Appendix A provides the detailed simulation results from AVGWLF.

Table 3. Estimated Sources of Phosphorus Loading to Cossayuna Lake

Source	Mean Annual Total Phosphorus Load (lbs/yr)	
	1990 – 2001	2002 – 2007
Hay/Pasture	645	436
Cropland	1,244	460
Forest	165	95
Wetlands	3	4
Developed Land	47	68
Stream Bank	1	2
Septic Systems	1,062	1,062
Groundwater	347	418
TOTAL	**3,515**	**2,544**

Figure 7. Estimated Sources of Annual Total Phosphorus Loading to Cossayuna Lake



4.2.1. *Residential On-Site Septic Systems*

Residential on-site septic systems contribute an estimated 1,062 lbs/yr of phosphorus to Cossayuna Lake, which is about 42% of the total loading to the lake. Residential septic systems contribute dissolved phosphorus to nearby waterbodies due to system malfunctions. Septic systems treat human waste using a collection system that discharges liquid waste into the soil through a series of distribution lines that comprise the drain field. In properly functioning (normal) systems, phosphates are adsorbed and retained by the soil as the effluent percolates through the soil to the shallow saturated zone. Therefore, normal systems contribute very little phosphorus loads to nearby waterbodies. A septic system (ponding) malfunction occurs when there is a discharge of waste to the soil surface (where it is available for runoff); as a result, malfunctioning septic systems can contribute high phosphorus loads to nearby waterbodies. Short-circuited systems (those systems in close proximity to surface waters where there is limited opportunity for phosphorus adsorption to take place) also contribute significant phosphorus loads; septic systems within 250 feet of the lake are subject to potential short-circuiting, with those closer to the lake more likely to contribute greater loads. Additional details about the process for estimating the population served by normal and malfunctioning systems within the lake drainage basin is provided in Appendix A.

GIS analysis of orthoimagery for the basin shows approximately 307 houses within 50 feet of the shoreline and 102 houses between 50 and 250 feet of the shoreline; all of the houses are assumed to have septic systems. Within 50 feet of the shorelines, 100% of septic systems were categorized as short-circuiting systems. Between 50 and 250 feet of the shoreline, 25% of septic systems were categorized as short-circuiting, 10% were categorized as ponding systems, and 65% were categorized as normal systems. To convert the estimated number of septic systems to population served, an average household size of 2.61 people per dwelling was used based on the circa 2000 U.S. Census Bureau estimate for number of persons per household in New York State. To account for seasonal variations in population, NYS DEC obtained data from the county on the approximate percentage of seasonal homes surrounding the lake. Approximately 55% of the homes around the lake are assumed to be year-round residences, while 45% are seasonally occupied (i.e., June through August only). The estimated population in the Cossayuna Lake drainage basin served by normal and malfunctioning systems is summarized in Table 4.

Table 4. Population Served by Septic Systems in the Cossayuna Lake Drainage Basin

	Normally Functioning	Ponding	Short Circuiting	Total
September – May	95	15	477	587
June – August (Summer)	173	27	867	1,067

4.2.2. *Agricultural Runoff*

Agricultural land encompasses 1,593 acres (23%) of the lake drainage basin and includes hay and pasture land (20%) and row crops (3%). Overland runoff from agricultural land is estimated to contribute 896 lbs/yr of phosphorus loading to Cossayuna Lake during the period 2002-2007, which is 35% of the total phosphorus loading to the lake. This is substantially less than the 1,889 lbs/yr of phosphorus loading (54% of total load) to Cossayuna Lake in the time period prior to the retirement of cropland in the basin (1990-2001).

In addition to the contribution of phosphorus to the lake from overland agriculture runoff, additional phosphorus originating from agricultural lands is leached in dissolved form from the surface and transported to the lake through subsurface movement via groundwater. The process for estimating subsurface delivery of phosphorus originating from agricultural land is discussed in the Groundwater Seepage section (below). Phosphorus loading from agricultural land originates primarily from soil erosion and the application of manure and fertilizers. Implementation plans for agricultural sources will require voluntary controls applied on an incremental basis.

4.2.3. *Urban and Residential Development Runoff*

Developed land comprises 411 acres (6%) of the lake drainage basins. Stormwater runoff from developed land contributes 68 lbs/yr of phosphorus to Cossayuna Lake during the period 2002-

2007, which is about 3% of the total phosphorus loading to the lake. This load does not account for contributions from malfunctioning septic systems.

In addition to the contribution of phosphorus to the lake from overland urban runoff, additional phosphorus originating from developed lands is leached in dissolved form from the surface and transported to the lake through subsurface movement via groundwater. The process for estimating subsurface delivery of phosphorus originating from developed land is discussed in the Groundwater Seepage section (below).

Phosphorus runoff from developed areas originates primarily from human activities, such as fertilizer applications to lawns. Shoreline development, in particular, can have a large phosphorus loading impact to nearby waterbodies in comparison to its relatively small percentage of the total land area in the drainage basin.

4.2.4. *Forest Land Runoff*

Forested land comprises 4,506 acres (66%) of the lake drainage basin. Runoff from forested land is estimated to contribute 95 lbs/yr of phosphorus loading to Cossayuna Lake during the period 2002-2007, which is about 4% of the total phosphorus loading to the lake. Phosphorus contribution from forested land is considered a component of background loading.

4.2.5. *Groundwater Seepage*

In addition to nonpoint sources of phosphorus delivered to the lake by surface runoff, a portion of the phosphorus loading from nonpoint sources seeps into the ground and is transported to the lake via groundwater. Groundwater is estimated to transport 418 lbs/yr (16%) of the total phosphorus load to Cossayuna Lake during the period 2002-2007. With respect to groundwater, there is typically a small "background" concentration owing to various natural sources. In the Cossayuna Lake drainage basin, the model-estimated groundwater phosphorus concentration is 0.013 mg/L. The GWLF manual provides estimated background groundwater phosphorus concentrations for ≥90% forested land in the eastern United States, which is 0.006 mg/L. Consequently, about 46% of the groundwater load (193 lbs/yr) can be attributed to natural sources, including forested land and soils.

The remaining amount of the groundwater phosphorus load (about 225 lbs/yr) likely originates from agricultural or developed land sources (i.e., leached in dissolved form from the surface). It is estimated that 50% (112.5 lbs/yr) of the remaining 225 lbs/yr of phosphorus transported to the lake through groundwater originates from developed land and 50% (112.5 lbs/yr) from agricultural land. Table 5 summarizes this information.

Table 5. Sources of Phosphorus Transported in the Subsurface via Groundwater

	Total Phosphorus (lbs/yr)	% of Total Groundwater Load
Natural Sources	193	46%
Agricultural Land	112.5	27%
Developed Land	112.5	27%
TOTAL	**418**	**100%**

4.2.6. *Other Sources*

Atmospheric deposition, wildlife, waterfowl, and domestic pets are also potential sources of phosphorus loading to the lake. All of these small sources of phosphorus are incorporated into the land use loadings as identified in the TMDL analysis (and therefore accounted for). Further, the deposition of phosphorus from the atmosphere over the surface of the lake is accounted for in the lake model, though it is small in comparison to the external loading to the lake.

5.0 DETERMINATION OF LOAD CAPACITY

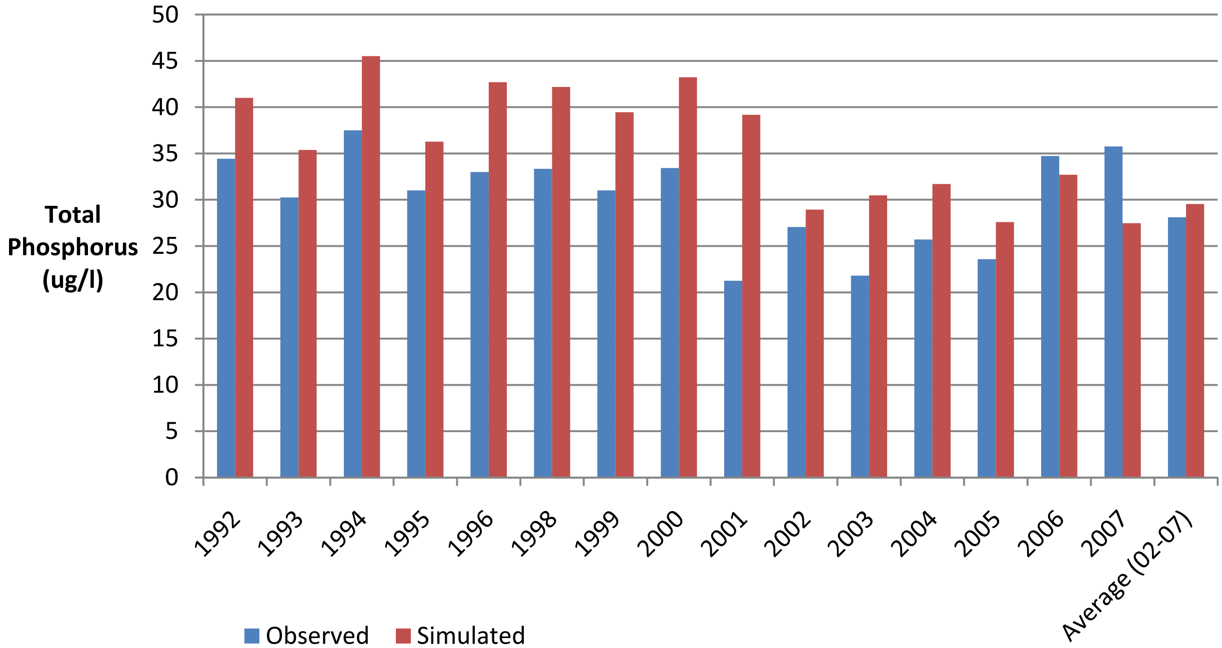
5.1. Lake Modeling Using the BATHTUB Model

BATHTUB was used to define the relationship between phosphorus loading to the lake and the resulting concentrations of total phosphorus in the lake. The U.S. Army Corps of Engineers' BATHTUB model predicts eutrophication-related water quality conditions (e.g., phosphorus, nitrogen, chlorophyll *a*, and transparency) using empirical relationships previously developed and tested for reservoir applications (Walker, 1987). BATHTUB performs steady-state water and nutrient balance calculations in a spatially segmented hydraulic network. Appendix B discusses the setup, calibration, and use of the BATHTUB model.

5.2. Linking Total Phosphorus Loading to the Numeric Water Quality Target

In order to estimate the loading capacity of the lake, simulated phosphorus loads from AVGWLF were used to drive the BATHTUB model to simulate water quality in Cossayuna Lake. AVGWLF was used to derive mean annual phosphorus loadings to the lake for the period 1990-2007; the individual year results were run through BATHTUB and compared against the observed summer mean phosphorus concentration for years with observed in-lake data (Figure 8). The TMDL for Cossayuna Lake was developed using the long-term mean annual phosphorus loading to the lake for the period 2002-2007. Using this load as input, BATHTUB was used to simulate water quality in the lake. The combined use of AVGWLF and BATHTUB provides a good fit to the observed data for Cossayuna Lake (Figure 8).

Figure 8. Observed vs. Simulated Summer Mean Epilimnetic Total Phosphorus Concentrations (μg/L) in Cossayuna Lake



The BATHTUB model was used as a "diagnostic" tool to derive the total phosphorus load reduction required to achieve the phosphorus target of 20 μg/L. The loading capacity of Cossayuna Lake was determined by running BATHTUB iteratively, reducing the concentration of the drainage basin phosphorus load until model results demonstrated attainment of the water quality target. The maximum concentration that results in compliance with the TMDL target for phosphorus is used as the basis for determining the lake's loading capacity. This concentration is converted into a loading rate using simulated flow from AVGWLF.

The maximum annual phosphorus load (i.e., the annual TMDL) that will maintain compliance with the phosphorus water quality goal of 20 μg/L in Cossayuna Lake is a mean annual load of 1,425 lbs/yr. The daily TMDL of 3.9 lbs/day was calculated by dividing the annual load by the number of days in a year. Lakes and reservoirs store phosphorus in the water column and sediment, therefore water quality responses are generally related to the total nutrient loading occurring over a year or season. For this reason, phosphorus TMDLs for lakes and reservoirs are generally calculated on an annual or seasonal basis. The use of annual loads, versus daily loads, is an accepted method for expressing nutrient loads in lakes and reservoirs. This is supported by EPA guidance such as *The Lake Restoration Guidance Manual* (USEPA, 1990) and *Technical Guidance Manual for Performing Waste Load Allocations, Book IV, lakes and Impoundments, Chapter 2 Eutrophication* (USEPA, 1986). While a daily load has been calculated, it is recommended that the annual loading target be used to guide implementation efforts since the annual load of total phosphorus as a TMDL target is more easily aligned with the design of best management practices (BMPs) used to implement nonpoint source and stormwater controls for lakes than daily loads. Ultimate compliance with water quality standards for the TMDL will be determined by measuring the lake's water quality to determine when the phosphorus guidance value is attained.

6.0 POLLUTANT LOAD ALLOCATIONS

The objective of a TMDL is to provide a basis for allocating acceptable loads among all of the known pollutant sources so that appropriate control measures can be implemented and water quality standards achieved. Individual wasteload allocations (WLAs) are assigned to discharges regulated by State Pollutant Discharge Elimination System (SPDES) permits (commonly called point sources) and unregulated loads (commonly called nonpoint sources) are contained in load allocations (LAs). A TMDL is expressed as the sum of all individual WLAs for point source loads, LAs for nonpoint source loads, and an appropriate margin of safety (MOS), which takes into account uncertainty (Equation 1).

Equation 1. Calculation of the TMDL

$$TMDL = \sum WLA + \sum LA + MOS$$

6.1. Wasteload Allocation (WLA)

There are no permitted wastewater treatment plant dischargers in the Cossayuna Lake basin. There are also no Municipal Separate Storm Sewer Systems (MS4s) in the basin. Therefore, the WLA is set at 0 (zero), and all of the loading capacity is allocated as a gross allotment to the load allocation.

6.2. Load Allocation (LA)

The LA is set at 1,282 lbs/yr. Nonpoint sources that contribute total phosphorus to Cossayuna Lake on an annual basis include loads from developed land, agricultural land, and malfunctioning septic systems. Table 6 lists the current loading for each source and the load allocation needed to meet the TMDL; Figure 9 provides a graphical representation of this information. Phosphorus originating from natural sources (including forested land, wetlands, and stream banks) is assumed to be a minor source of loading that is unlikely to be reduced further and therefore the load allocation is set at current loading.

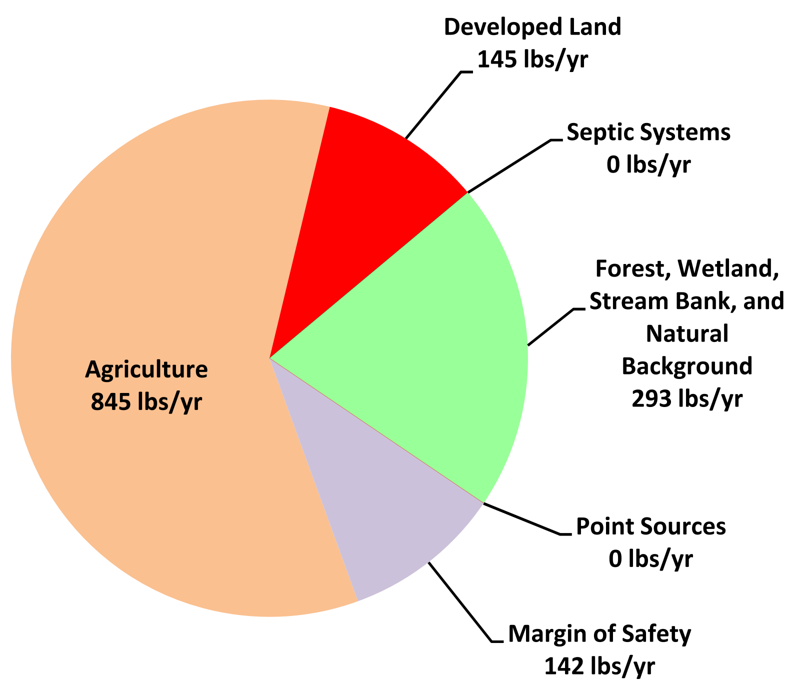
Table 6. Total Annual Phosphorus Load Allocations for Cossayuna Lake[1]

Source	Total Phosphorus Load (lbs/yr)			% Reduction
	Current	Allocated	Reduction	
Agriculture*	1,008	845	163	16%
Developed Land*	181	145	36	20%
Septic Systems	1,062	0	1,062	100%
Forest, Wetland, Stream Bank, and Natural Background	293	293	0	0%
LOAD ALLOCATION	**2,544**	**1,283**	**1,261**	**50%**
Point Sources	0	0	0	0%
WASTELOAD ALLOCATION	**0**	**0**	**0**	**0%**
LA + WLA	**2,544**	**1,283**	**1,261**	**50%**
Margin of Safety	---	142	---	---
TOTAL	**2,544**	**1,425**	---	---

1 - Note: The values reported in Table 6 are the annually integrated values. The daily equivalent values are provided in Appendix C of the TMDL support document.

* Includes phosphorus transported through surface runoff and subsurface (groundwater)

Figure 9. Total Phosphorus Load Allocations for Cossayuna Lake (lbs/yr)



6.3. Margin of Safety (MOS)

The margin of safety (MOS) can be implicit (incorporated into the TMDL analysis through conservative assumptions) or explicit (expressed in the TMDL as a portion of the loadings) or a combination of both. For the Cossayuna Lake TMDL, the MOS is explicitly accounted for during the allocation of loadings. An implicit MOS could have been provided by making conservative assumptions at various steps in the TMDL development process (e.g., by selecting conservative model input parameters or a conservative TMDL target). However, making conservative assumptions in the modeling analysis can lead to errors in projecting the benefits of BMPs and in projecting lake responses. Therefore, the recommended method is to formulate the mass balance using the best scientific estimates of the model input values and keep the margin of safety in the "MOS" term. The TMDL contains an explicit margin of safety corresponding to 10% of the loading capacity, or 142 lbs/yr. The MOS can be reviewed in the future as new data become available.

6.4. Critical Conditions

TMDLs must take into account critical environmental conditions to ensure that the water quality is protected during times when it is most vulnerable. Critical conditions were taken into account in the development of this TMDL. In terms of loading, spring runoff periods are considered critical because wet weather events transport significant quantities of nonpoint source loads to lakes. However, the water quality ramifications of these nutrient loads are most severe during middle or late summer. Therefore, BATHTUB model simulations were compared against observed data for the summer period only. Furthermore, AVGWLF takes into account loadings from all periods throughout the year, including spring loads.

6.5. Seasonal Variations

Seasonal variation in nutrient load and response is captured within the models used for this TMDL. In BATHTUB, seasonality is incorporated in terms of seasonal averages for summer. Seasonal variation is also represented in the TMDL by taking 17 years of daily precipitation data when calculating runoff through AVGWLF, as well as by estimating septic system loading inputs based on residency (i.e., seasonal or year-round). This takes into account the seasonal effects the lake will undergo during a given year.

7.0 IMPLEMENTATION

One of the critical factors in the successful development and implementation of TMDLs is the identification of potential management alternatives, such as BMPs and screening and selection of final alternatives in collaboration with the involved stakeholders. The ongoing watershed protection efforts (e.g., watershed characterization, restoration, and volunteer monitoring) have already been outlined in the 1999 Cossayuna Lake Watershed Management Plan. Coordination with state agencies, federal agencies, local governments, and stakeholders such as Cossayuna Lake Improvement Association (CLIA), Cossayuna Lake Watershed Management Team, the general public, environmental interest groups, and representatives from the nonpoint pollution sources will ensure that the proposed management alternatives are technically and financially feasible. NYS DEC, in coordination with these local interests, will address the sources of impairment, using primarily non-regulatory tools in this watershed, matching management strategies with sources, and aligning available resources to effect implementation.

NYS DEC recognizes that TMDL designated load reductions alone may not be sufficient to restore eutrophic lakes. The TMDL establishes the required nutrient reduction targets and provides some 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, as discussed in Section 7.2, and consideration of the Cossayuna Lake Watershed Management Plan, which discusses in-lake measures, such as water level control, that may need to be taken to supplement the nutrient reduction measures required by the TMDL.

7.1. Reasonable Assurance for Implementation

This TMDL was written based upon the elimination of phosphorus loading from septic systems in conjunction with slight reductions from agricultural and developed lands. Meeting the necessary load reductions using this approach is the most technically achievable alternative, however it may not be financially viable. Although other allocation alternatives exist, such as clustered treatment and on-site upgrades, they may not completely eliminate this source of phosphorus, so greater reductions from other sources would be needed, and reasonable assurance of meeting the TMDL would be lower.

7.1.1. *Recommended Phosphorus Management Strategies for Septic Systems*

Due to the fact that septic systems are the primary source of loading in the Cossayuna Lake Watershed, restoration depends on significant reductions from that source. A cooperative systematic approach involving the Towns of Argyle and Greenwich, such as the formation of a management district, will be essential to achieving the load reductions specified above. A study should be undertaken to evaluate alternatives, such as sewering with centralized treatment and discharge out of the watershed or clustered treatment and on-site upgrades. New York State has begun to offer funding for the abatement of inadequate onsite wastewater systems through the development and implementation of a septic system management program by a responsible management entity.

In the interim, a surveying and testing program should be implemented to document the location of septic systems and verify failing systems requiring replacement in accordance with the State Sanitary Code. State funding is also available for a voluntary septic system inspection and maintenance program or a septic system local law requiring inspection and repair. Property owners should be educated on proper maintenance of their septic systems and encouraged to make preventative repairs.

To further assist municipalities, NYS DEC is involved in the development of a statewide training program for onsite wastewater treatment system professionals. A largely volunteer industry group called the Onsite Wastewater Treatment Training Network (OTN) has been formed. NYS DEC has provided financial and staff support to the OTN during the last five years.

7.1.2. *Recommended Phosphorus Management Strategies for Agricultural Runoff*

The New York State Agricultural Environmental Management (AEM) Program was codified into law in 2000. Its goal is to support farmers in their efforts to protect water quality and conserve natural resources, while enhancing farm viability. AEM provides a forum to showcase the soil and water conservation stewardship farmers provide. It also provides information to farmers about Concentrated Animal Feeding Operation (CAFO) regulatory requirements, which helps to assure compliance. Details of the AEM program can be found at the New York State Soil and Water Conservation Committee (SWCC) website, http://www.nys-soilandwater.org/aem/index.html.

Using a voluntary approach to meet local, state, and national water quality objectives, AEM has become the primary program for agricultural conservation in New York. It also has become the umbrella program for integrating/coordinating all local, state, and federal agricultural programs. For instance, farm eligibility for cost sharing under the SWCC Agricultural Nonpoint Source Abatement and Control Grants Program is contingent upon AEM participation.

AEM core concepts include a voluntary and incentive-based approach, attending to specific farm needs and reducing farmer liability by providing approved protocols to follow. AEM provides a locally led, coordinated and confidential planning and assessment method that addresses watershed needs. The assessment process increases farmer awareness of the impact farm activities have on the environment and by design, it encourages farmer participation, which is an important overall goal of this implementation plan.

The AEM Program relies on a five-tiered process:

Tier 1 – Survey current activities, future plans and potential environmental concerns.

Tier 2 – Document current land stewardship; identify and prioritize areas of concern.

Tier 3 – Develop a conservation plan, by certified planners, addressing areas of concern tailored to farm economic and environmental goals.

Tier 4 – Implement the plan using available financial, educational and technical assistance.

Tier 5 – Conduct evaluations to ensure the protection of the environment and farm viability.

Washington County Soil and Water Conservation District should continue to implement the AEM program on farms in the watershed, focusing on identification of management practices that reduce phosphorus loads. These practices would be eligible for state or federal funding and because they address a water quality impairment associated with this TMDL, should score well.

Tier 1 could be used to identify farmers that for economic or personal reasons may be changing or scaling back operations, or contemplating selling land. These farms would be candidates for conservation easements, or conversion of cropland to hay, as would farms identified in Tier 2 with highly-erodible soils and/or needing stream management. Tier 3 should include a Comprehensive Nutrient Management Plan with phosphorus indexing. This action was also recommended in the Cossayuna Lake Watershed Management Plan. Additional practices could be fully implemented in Tier 4 to reduce phosphorus loads, such as conservation tillage, stream fencing, rotational grazing and cover crops. Also, riparian buffers reduce losses from upland fields and stabilize stream banks in addition to the reductions from taking the land in buffers out of production.

7.1.3. *Recommended Phosphorus Management Strategies for Urban Stormwater Runoff*

In March 2002, NYS DEC issued SPDES general permits GP-02-01 for construction activities, and GP-02-02 for stormwater discharges from municipal separate stormwater sewer system (MS4s) in response to the Federal Phase II Stormwater rules. These permits were re-issued, effective May 1, 2008, as GP-0-08-001 and GP-0-08-002, respectively. GP-0-08-002 applies to urbanized areas of New York State, so it does not cover the Cossayuna Lake Watershed.

Stormwater management in rural areas can be addressed through the Nonpoint Source Management Program. There are several measures, which, if implemented in the watershed, could directly or indirectly reduce phosphorus loads in stormwater discharges to the lake or watershed. Many of the following measures are also recommended in the Cossayuna Lake Watershed Management Plan:

- Public education regarding:
  - Lawn care, specifically reducing fertilizer use or using phosphorus-free products, now commercially available;
  - Cleaning up pet waste; and
  - Discouraging waterfowl congregation by restoring natural shoreline vegetation.
- Management practices to address any significant existing erosion sites. In particular there are two unpaved roads with steep grades located in the watershed with significant roadside ditch erosion that would benefit from stabilization measures.
- Construction site and post construction stormwater runoff control ordinance and inspection and enforcement programs.
- Pollution prevention practices for road and ditch maintenance.

7.1.4. *Additional Protection Measures*

Measures to further protect water quality and limit growth of phosphorus load that would otherwise offset load reduction efforts should be considered. The basic protections afforded by local zoning ordinances could be enhanced to limit non-compatible development, preserve natural vegetation along shorelines and promote smart growth. The Cossayuna Lake Watershed Management Plan recommended the implementation of a shoreline protection "belt" with guidelines for shoreline development and land use management tools that promote protection of water quality. The State of the Lake Report identifies eight regulated and eleven unregulated wetlands in the watershed. Identification of wildlife habitats, sensitive environmental areas, and key open spaces within the watershed could lead to their preservation or protection by way of conservation easements or other voluntary controls.

7.2. Follow-up Monitoring

A targeted post-assessment monitoring effort will determine the effectiveness of the implementation plan associated with the TMDL. Cossayuna Lake will be sampled at its deepest location (approximately 5-6 meters), during the warmer part of the year (May through September) on 8 sampling dates. Grab samples will be collected at 1.5 meter and in the hypolimnion. The samples will be analyzed for the phosphorus series (total phosphorus, total soluble phosphorus, and soluble reactive phosphorus), the nitrogen series (nitrate, ammonia, and total nitrogen), and chloride. The epilimnetic samples will be analyzed for chlorophyll *a* and the Secchi disk depth will be measured. A simple macrophyte survey will also be conducted one time during mid-summer.

In recent years, this monitoring has been done through CSLAP. If CSLAP is discontinued at this lake, the sampling will be repeated at a regular interval. The initial plan will be to set the interval at 5 years, but could vary based on the speed and extent of implementation. In addition, as the information on the NYS DEC GIS system is updated (land use, BMPs, etc.), these updates will be applied to the input data for the AVGWLF and BATHTUB models. The information will be incorporated into the New York State 305(b) report as needed.

8.0 PUBLIC PARTICIPATION

NYS DEC met with local representatives from the Washington County Water Quality Coordinating Committee and others from the Cossayuna Lake Watershed Management Team on November 5, 2007 to discuss TMDL fundamentals and development. A second meeting was held on February 11, 2008 to refine data and to receive local input on the draft TMDL. Notice of availability of the draft TMDL was made to local government representatives and interested parties. This draft TMDL was public noticed in the Environmental Notice Bulletin on July 23, 2008. A 30-day public review period was established for soliciting written comments from stakeholders prior to the finalization and submission of the TMDL for EPA approval. NYS DEC did not receive comments.

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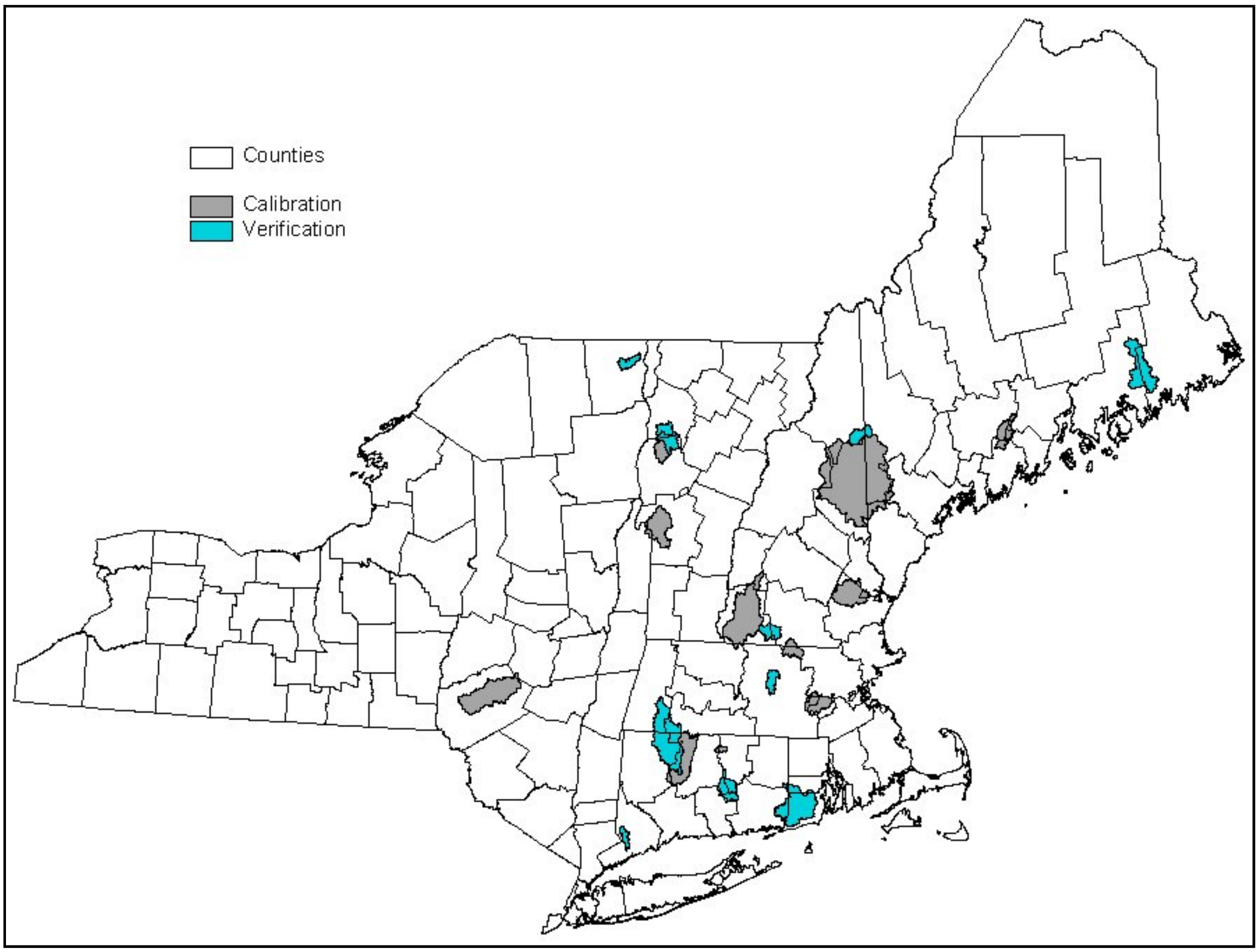
APPENDIX A. AVGWLF MODELING ANALYSIS

Northeast AVGWLF Model

The AVGWLF model was calibrated and validated for the northeast (Evans et al., 2007). AVGWLF requires that calibration watersheds have long-term flow and water quality data. For the northeast model, watershed simulations were performed for twenty-two (22) watersheds throughout New York and New England for the period 1997-2004 (Figure 10). Flow data were obtained directly from the water resource database maintained by the U.S. Geological Survey (USGS). Water quality data were obtained from the New York and New England State agencies. These data sets included in-stream concentrations of nitrogen, phosphorus, and sediment based on periodic sampling.

Figure 10. Location of Calibration and Verification Watersheds for the Northeast AVGWLF Model



Initial model calibration was performed on half of the 22 watersheds for the period 1997-2004. During this step, adjustments were iteratively made in various model parameters until a "best fit" was achieved between simulated and observed stream flow, and sediment and nutrient loads. Based on the calibration results, revisions were made in various AVGWLF routines to alter the manner in which model input parameters were estimated. To check the reliability of these revised routines, follow-up verification runs were made on the remaining eleven watersheds for the same time period. Finally, statistical evaluations of the accuracy of flow and load predictions were made.

To derive historical nutrient loads, standard mass balance techniques were used. First, the in-stream nutrient concentration data and corresponding flow rate data were used to develop load (mass) versus flow relationships for each watershed for the period in which historical water quality data were obtained. Using the daily stream flow data obtained from USGS, daily nutrient loads for the 1997-2004 time period were subsequently computed for each watershed using the appropriate load versus flow relationship (i.e., "rating curves"). Loads computed in this fashion were used as the "observed" loads against which model-simulated loads were compared.

During this process, adjustments were made to various model input parameters for the purpose of obtaining a "best fit" between the observed and simulated data. With respect to stream flow, adjustments were made that increased or decreased the amount of the calculated evapotranspiration and/or "lag time" (i.e., groundwater recession rate) for sub-surface flow. With respect to nutrient loads, changes were made to the estimates for sub-surface nitrogen and phosphorus concentrations. In regard to both sediment and nutrients, adjustments were made to the estimate for the "C" factor for cropland in the USLE equation, as well as to the sediment "a" factor used to calculate sediment loss due to stream bank erosion. Finally, revisions were also made to the default retention coefficients used by AVGWLF for estimating sediment and nutrient retention in lakes and wetlands.

Based upon an evaluation of the changes made to the input files for each of the calibration watersheds, revisions were made to routines within AVGWLF to modify the way in which selected model parameters were automatically estimated. The AVGWLF software application was originally developed for use in Pennsylvania, and based on the calibration results, it appeared that certain routines were calculating values for some model parameters that were either too high or too low. Consequently, it was necessary to make modifications to various algorithms in AVGWLF to better reflect conditions in the Northeast. A summary of the algorithm changes made to AVGWLF is provided below.

- **ET**: A revision was made to increase the amount of evapotranspiration calculated automatically by AVGWLF by a factor of 1.54 (in the "Pennsylvania" version of AVGWLF, the adjustment factor used is 1.16). This has the effect of decreasing simulated stream flow.

- **GWR:** The default value for the groundwater recession rate was changed from 0.1 (as used in Pennsylvania) to 0.03. This has the effect of "flattening" the hydrograph within a given area.

- **GWN:** The algorithm used to estimate "groundwater" (sub-surface) nitrogen concentration was changed to calculate a lower value than provided by the "Pennsylvania" version.

- **Sediment "a" Factor:** The current algorithm was changed to reduce estimated stream bank-derived sediment by a factor of 90%. The streambank routine in AVGWLF was originally developed using Pennsylvania data and was consistently producing sediment estimates that were too high based on the in-stream sample data for the calibration sites in the Northeast. While the exact reason for this is not known, it's likely that the glaciated terrain in the Northeast is less erodible than the highly erodible soils in Pennsylvania. Also, it is likely that the relative abundance of lakes, ponds and wetlands in the Northeast have an effect on flow velocities and sediment transport.

- **Lake/Wetland Retention Coefficients:** The default retention coefficients for sediment, nitrogen and phosphorus are set to 0.90, 0.12 and 0.25, respectively, and changed at the user's discretion.

To assess the correlation between observed and predicted values, two different statistical measures were utilized: 1) the Pearson product-moment correlation (R^2) coefficient and 2) the Nash-Sutcliffe coefficient. The R^2 value is a measure of the degree of linear association between two variables, and represents the amount of variability that is explained by another variable (in this case, the model-simulated values). Depending on the strength of the linear relationship, the R^2 can vary from 0 to 1, with 1 indicating a perfect fit between observed and predicted values. Like the R^2 measure, the Nash-Sutcliffe coefficient is an indicator of "goodness of fit," and has been recommended by the American Society of Civil Engineers for use in hydrological studies (ASCE, 1993). With this coefficient, values equal to 1 indicate a perfect fit between observed and predicted data, and values equal to 0 indicate that the model is predicting no better than using the average of the observed data. Therefore, any positive value above 0 suggests that the model has some utility, with higher values indicating better model performance. In practice, this coefficient tends to be lower than R^2 for the same data being evaluated.

Adjustments were made to the various input parameters for the purpose of obtaining a "best fit" between the observed and simulated data. One of the challenges in calibrating a model is to optimize the results across all model outputs (in the case of AVGWLF, stream flows, as well as sediment, nitrogen, and phosphorus loads). As with any watershed model like GWLF, it is possible to focus on a single output measure (e.g., sediment or nitrogen) in order to improve the fit between observed and simulated loads. Isolating on one model output, however, can sometimes lead to less acceptable results for other measures. Consequently, it is sometimes difficult to achieve very high correlations (e.g., R^2 above 0.90) across all model outputs. Given this limitation, it was felt that very good results were obtained for the calibration sites. In model calibration, initial emphasis is usually placed on getting the hydrology correct. Therefore, adjustments to flow-related model parameters are usually finalized prior to making adjustments to parameters specific to sediment and nutrient production. This typically results in better statistical fits between stream flows than the other model outputs.

For the monthly comparisons, mean R^2 values of 0.80, 0.48, 0.74, and 0.60 were obtained for the calibration watersheds for flow, sediment, nitrogen and phosphorus, respectively. When considering the inherent difficulty in achieving optimal results across all measures as discussed above (along with the potential sources of error), these results are quite good. The sediment load predictions were less satisfactory than those for the other outputs, and this is not entirely unexpected given that this constituent is usually more difficult to simulate than nitrogen or phosphorus. An improvement in sediment prediction could have been achieved by isolating on this particular output during the calibration process; but this would have resulted in poorer performance in estimating the nutrient loads for some of the watersheds. Phosphorus predictions were less accurate than those for nitrogen. This is not unusual given that a significant portion of the phosphorus load for a watershed is highly related to sediment transport processes. Nitrogen, on the other hand, is often linearly correlated to flow, which typically results in accurate predictions of nitrogen loads if stream flows are being accurately simulated.

As expected, the monthly Nash-Sutcliffe coefficients were somewhat lower due to the nature of this particular statistic. As described earlier, this statistic is used to iteratively compare simulated values against the mean of the observed values, and values above zero indicate that the model predictions are better than just using the mean of the observed data. In other words, any value above zero would indicate that the model has some utility beyond using the mean of historical data in estimating the flows or loads for any particular time period. As with R^2 values, higher Nash-Sutcliffe values reflect higher degrees of correlation than lower ones.

Improvements in model accuracy for the calibration sites were typically obtained when comparisons were made on a seasonal basis. This was expected since short-term variations in model output can oftentimes be reduced by accumulating the results over longer time periods. In particular, month-to-month discrepancies due to precipitation events that occur at the end of a month are often resolved by aggregating output in this manner (the same is usually true when going from daily output to weekly or monthly output). Similarly, further improvements were noted when comparisons were made on a mean annual basis. What these particular results imply is that AVGWLF, when calibrated, can provide very good estimates of mean annual sediment and nutrient loads.

Following the completion of the northeast AVGWLF model, there were a number of ideas on ways to improve model accuracy. One of the ideas relates to the basic assumption upon which the work undertaken in that project was based. This assumption is that a "regionalized" model can be developed that works equally well (without the need for resource-intensive calibration) across all watersheds within a large region in terms of producing reasonable estimates of sediment and nutrient loads for different time periods. Similar regional model calibrations were previously accomplished in earlier efforts undertaken in Pennsylvania (Evans et al., 2002) and later in southern Ontario (Watts et al., 2005). In both cases this task was fairly daunting given the size of the areas involved. In the northeast effort, this task was even more challenging given the fact that the geographic area covered by the northeast is about three times the size of Pennsylvania, and arguably is more diverse in terms of its physiographic and ecological composition.

As discussed, AVGWLF performed very well when calibrated for numerous watersheds throughout the region. The regionalized version of AVGWLF, however, performed less well for the verification watersheds for which additional adjustments were not made subsequent to the initial model runs. This decline in model performance may be a result of the regionally-adapted model algorithms not being rigorous enough to simulate spatially-varying landscape processes across such a vast geographic region at a consistently high degree of accuracy. It is likely that un-calibrated model performance can be enhanced by adapting the algorithms to reflect processes in smaller geographic regions such as those depicted in the physiographic province map in Figure 11.

Fine-tuning & Re-Calibrating the Northeast AVGWLF for New York State

For the TMDL development work undertaken in New York, the original northeast AVGWLF model was further refined by The Cadmus Group, Inc. and Dr. Barry Evans to reflect the physiographic regions that exist in New York. Using data from some of the original northeast model calibration and verification sites, as well as data for additional calibration sites in New York, three new versions of AVGWLF were created for use in developing TMDLs in New York State. Information on the fourteen (14) sites is summarized in Table 7. Two models were developed based on the following two physiographic regions: Eastern Great Lakes/Hudson Lowlands area and the Northeastern Highlands area. The model was calibrated for each of these regions to better reflect local conditions, as well as ecological and hydrologic processes. In addition to developing the above mentioned physiographic-based model calibrations, a third model calibration was also developed. This model calibration represents a composite of the two physiographic regions and is suitable for use in other areas of upstate New York.

Figure 11. Location of Physiographic Provinces in New York and New England

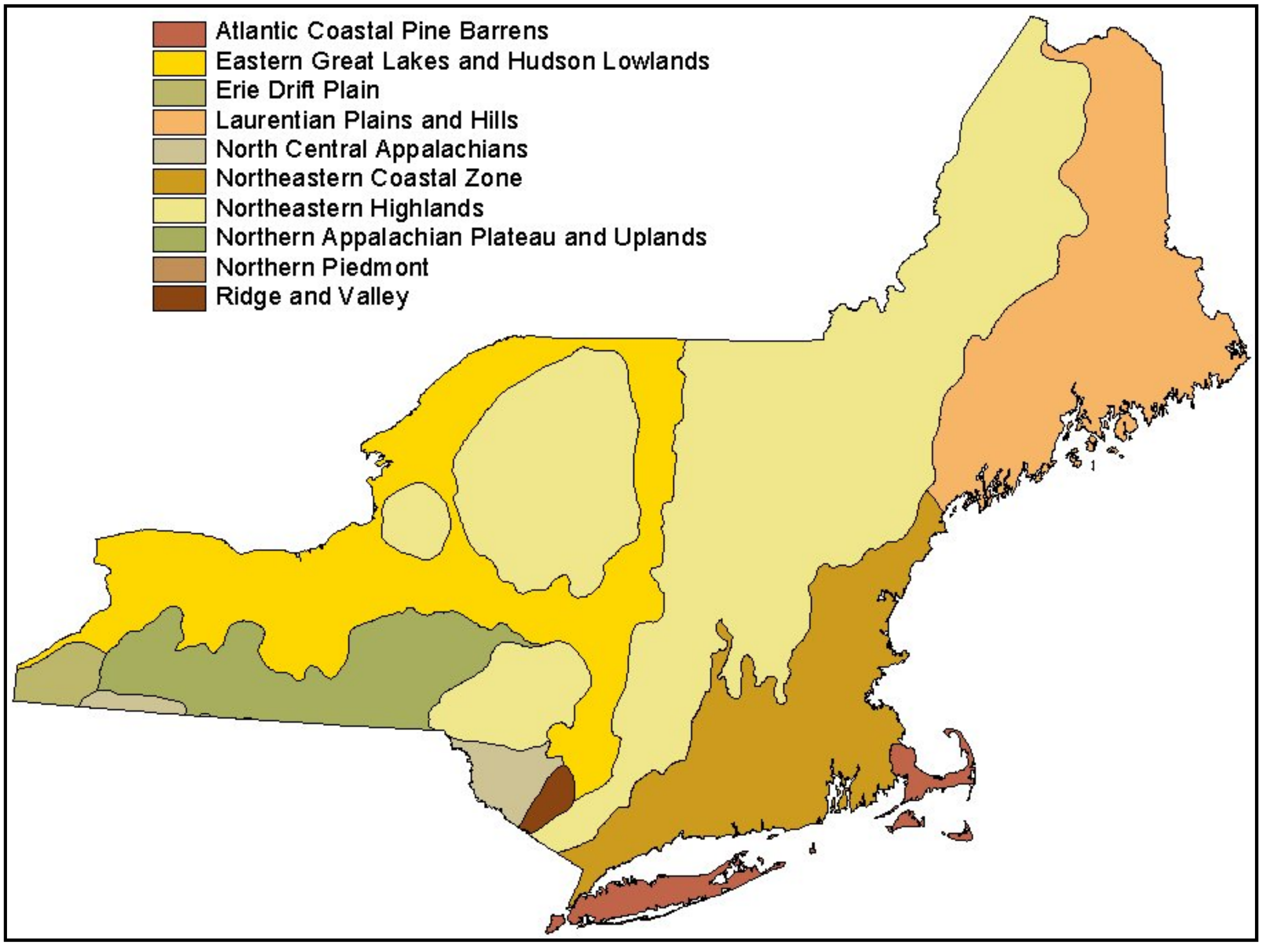


Table 7. AVGWLF Calibration Sites for use in the New York TMDL Assessments

Site	Location	Physiographic Region
Owasco Lake	NY	Eastern Great Lakes/Hudson Lowlands
West Branch	NY	Northeastern Highlands
Little Chazy River	NY	Eastern Great Lakes/Hudson Lowlands
Little Otter Creek	VT	Eastern Great Lakes/Hudson Lowlands
Poultney River	VT/NY	Eastern Great Lakes/Hudson Lowlands & Northeastern Highlands
Farmington River	CT	Northeastern Highlands
Saco River	ME/NH	Northeastern Highlands
Squannacook River	MA	Northeastern Highlands
Ashuelot River	NH	Northeastern Highlands
Laplatte River	VT	Eastern Great Lakes/Hudson Lowlands
Wild River	ME	Northeastern Highlands
Salmon River	CT	Northeastern Coastal Zone
Norwalk River	CT	Northeastern Coastal Zone
Lewis Creek	VT	Eastern Great Lakes/Hudson Lowlands

Set-up of the "New York State" AVGWLF Model

Using data for the time period 1990-2007, the calibrated AVGWLF model was used to estimate mean annual phosphorus loading to the lake. Table 8 provides the sources of data used for the AVGWLF modeling analysis. The various data preparation steps taken prior to running the final calibrated AVGWLF Model for New York are discussed below the table.

Table 8. Information Sources for AVGWLF Model Parameterization

WEATHER.DAT file	
Data	**Source or Value**
	Historical weather data from Glen Falls, NY and Whitehall, NY National Weather Services Stations
TRANSPORT.DAT file	
Data	**Source or Value**
Basin size	GIS/derived from basin boundaries
Land use/cover distribution	GIS/derived from land use/cover map
Curve numbers by source area	GIS/derived from land cover and soil maps
USLE (KLSCP) factors by source area	GIS/derived from soil, DEM, & land cover
ET cover coefficients	GIS/derived from land cover
Erosivity coefficients	GIS/derived from physiographic map
Daylight hrs. by month	Computed automatically for state
Growing season months	Input by user
Initial saturated storage	Default value of 10 cm
Initial unsaturated storage	Default value of 0 cm
Recession coefficient	Default value of 0.1
Seepage coefficient	Default value of 0
Initial snow amount (cm water)	Default value of 0
Sediment delivery ratio	GIS/based on basin size
Soil water (available water capacity)	GIS/derived from soil map
NUTRIENT.DAT file	
Data	**Source or Value**
Dissolved N in runoff by land cover type	Default values/adjusted using GWLF Manual
Dissolved P in runoff by land cover type	Default values/adjusted using GWLF Manual
N/P concentrations in manure runoff	Default values/adjusted using AEU density
N/P buildup in urban areas	Default values (from GWLF Manual)
N and P point source loads	Derived from SPDES point coverage
Background N/P concentrations in GW	Derived from new background N map
Background P concentrations in soil	Derived from soil P loading map/adjusted using GWLF Manual
Background N concentrations in soil	Based on map in GWLF Manual
Months of manure spreading	Input by user
Population on septic systems	Derived from census tract maps for 2000 and house counts
Per capita septic system loads (N/P)	Default values/adjusted using AEU density

Land Use

The 2001 NLCD land use coverage was obtained, recoded, and formatted specifically for use in AVGWLF. The New York State High Resolution Digital Orthoimagery (for the time period 2000 – 2004) was used to perform updates and corrections to the 2001 NLCD land use coverage to more accurately reflect current conditions. Each basin was reviewed independently for the potential need for land use corrections; however individual raster errors associated with inherent imperfections in the satellite imagery have a far greater impact on overall basin land use percentages when evaluating smaller scale basins. As a result, for large basins, NLCD 2001 is generally considered adequate, while in smaller basins, errors were more closely assessed and corrected. The following were the most common types of corrections applied generally to smaller basins:

1) Areas of low intensity development that were coded in the 2001 NLCD as other land use types were the most commonly corrected land use data in this analysis. Discretion was used when applying corrections, as some overlap of land use pixels on the lake boundary are inevitable due to the inherent variability in the aerial position of the sensor creating the image. If significant new development was apparent (i.e., on the orthoimagery), but was not coded as such in the 2001 NLCD, than these areas were re-coded to low intensity development.

2) Areas of water that were coded as land (and vise-versa) were also corrected. Discretion was used for reservoirs where water level fluctuation could account for errors between orthoimagery and land use.

3) Forested areas that were coded as row crops/pasture areas (and vise-versa) were also corrected. For this correction, 100% error in the pixel must exist (e.g., the supposed forest must be completely pastured to make a change); otherwise, making changes would be too subjective. Conversions between forest types (e.g., conifer to deciduous) are too subjective and therefore not attempted; conversions between row crops and pasture are also too subjective due to the practice of crop rotation. Correction of row crops to hay and pasture based on orthoimagery were therefore not undertaken in this analysis.

Phosphorus retention in wetlands and open waters in the basin can be accounted for in AVGWLF. AVGWLF recommends the following coefficients for wetlands and pond retention in the northeast: nitrogen (0.12), phosphorus (0.25), and sediment (0.90). Wetland retention coefficients for large, naturally occurring wetlands vary greatly in the available literature. Depending on the type, size and quantity of wetland observed, the overall impact of the wetland retention routine on the original watershed loading estimates, and local information regarding the impact of wetlands on watershed loads, wetland retention coefficients defaults were adjusted accordingly. The percentage of the drainage basin area that drains through a wetland area was calculated and used in conjunction with nutrient retention coefficients in AVGWLF. To determine the percent wetland area, the total basin land use area was derived using ArcView. Of this total basin area, the area that drains through emergent and woody wetlands were delineated to yield an estimate of total watershed area draining through wetland areas. If a basin displays large areas of surface water (ponds) aside from the water body being modeled, then this open water area is calculated by subtracting the water body area from the total surface water area.

On-site Wastewater Treatment Systems ("septic tanks")

GWLF simulates nutrient loads from septic systems as a function of the percentage of the unsewered population served by normally functioning vs. three types of malfunctioning systems: ponded, short-circuited, and direct discharge (Haith et al., 1992).

- **Normal Systems** are septic systems whose construction and operation conforms to recommended procedures, such as those suggested by the EPA design manual for on-site wastewater disposal systems. Effluent from normal systems infiltrates into the soil and enters the shallow saturated zone. Phosphates in the effluent are adsorbed and retained by the soil and hence normal systems provide no phosphorus loads to nearby waters.
- **Short-Circuited Systems** are located close enough to surface water (~15 meters) so that negligible adsorption of phosphorus takes place. The only nutrient removal mechanism is plant uptake. Therefore, these systems are always contributing to nearby waters.
- **Ponded Systems** exhibit hydraulic malfunctioning of the tank's absorption field and resulting surfacing of the effluent. Unless the surfaced effluent freezes, ponding systems deliver their nutrient loads to surface waters in the same month that they are generated through overland flow. If the temperature is below freezing, the surfacing is assumed to freeze in a thin layer at the ground surface. The accumulated frozen effluent melts when the snowpack disappears and the temperature is above freezing.
- **Direct Discharge Systems** illegally discharge septic tank effluent directly into surface waters.

GWLF requires an estimation of population served by septic systems to generate septic system phosphorus loadings. In reviewing the orthoimagery for the lake, it became apparent that septic system estimates from the 1990 census were not reflective of actual population in close proximity to the shore. Shoreline dwellings immediately surrounding the lake account for a substantial portion of the nutrient loading to the lake. Therefore, the estimated number of septic systems in the drainage basin was refined using a combination of 1990 and 2000 census data and GIS analysis of orthoimagery to account for the proximity of septic systems immediately surrounding the lake. If available, local information about the number of houses within 250 feet of the lakes was obtained and applied. Great attention was given to estimating septic systems within 250 feet of the lake (those most likely to have an impact on the lake). To convert the estimated number of septic systems to population served, an average household size of 2.61 people per dwelling was used based on the circa 2000 USCB census estimate for number of persons per household in New York State.

GWLF also requires an estimate of the number of normal and malfunctioning septic systems. This information was not readily available for the lake. Therefore, several assumptions were made to categorize the systems according to their performance. These assumptions are based on data from local and national studies (Day, 2001; USEPA, 2002) in combination with best professional judgment. To account for seasonal variations in population, data from the 2000 census were used to estimate the percentage of seasonal homes for the town(s) surrounding the lake. The failure rate for septic systems closer to the lake (i.e., within 250 feet) were adjusted to account for increased loads due to greater occupancy during the summer months. If available, local information about seasonal occupancy was obtained and applied. For the purposes of this analysis, seasonal homes are considered those occupied only during the month of June, July, and August.

Groundwater Phosphorus

Phosphorus concentrations in groundwater discharge are derived by AVGWLF. Watersheds with a high percentage of forested land will have low groundwater phosphorus concentrations while watersheds with a high percentage of agricultural land will have high concentrations. The GWLF manual provides estimated groundwater phosphorus concentrations according to land use for the eastern United States. Completely forested watersheds have values of 0.006 mg/L. Primarily agricultural watersheds have values of 0.104 mg/L. Intermediate values are also reported. The AVGWLF-generated groundwater phosphorus concentration was evaluated to ensure groundwater phosphorus values reasonably reflect the actual land use composition of the drainage basin and modifications were made if deemed unnecessary.

Point Sources

If permitted point sources exist in the drainage basin, their location was identified and verified by NYS DEC and an estimated monthly total phosphorus load and flow was determined using either actual reported data (e.g., from discharge monitoring reports) or estimated based on expected discharge/flow for the facility type.

Concentrated Animal Feeding Operations (CAFOs)

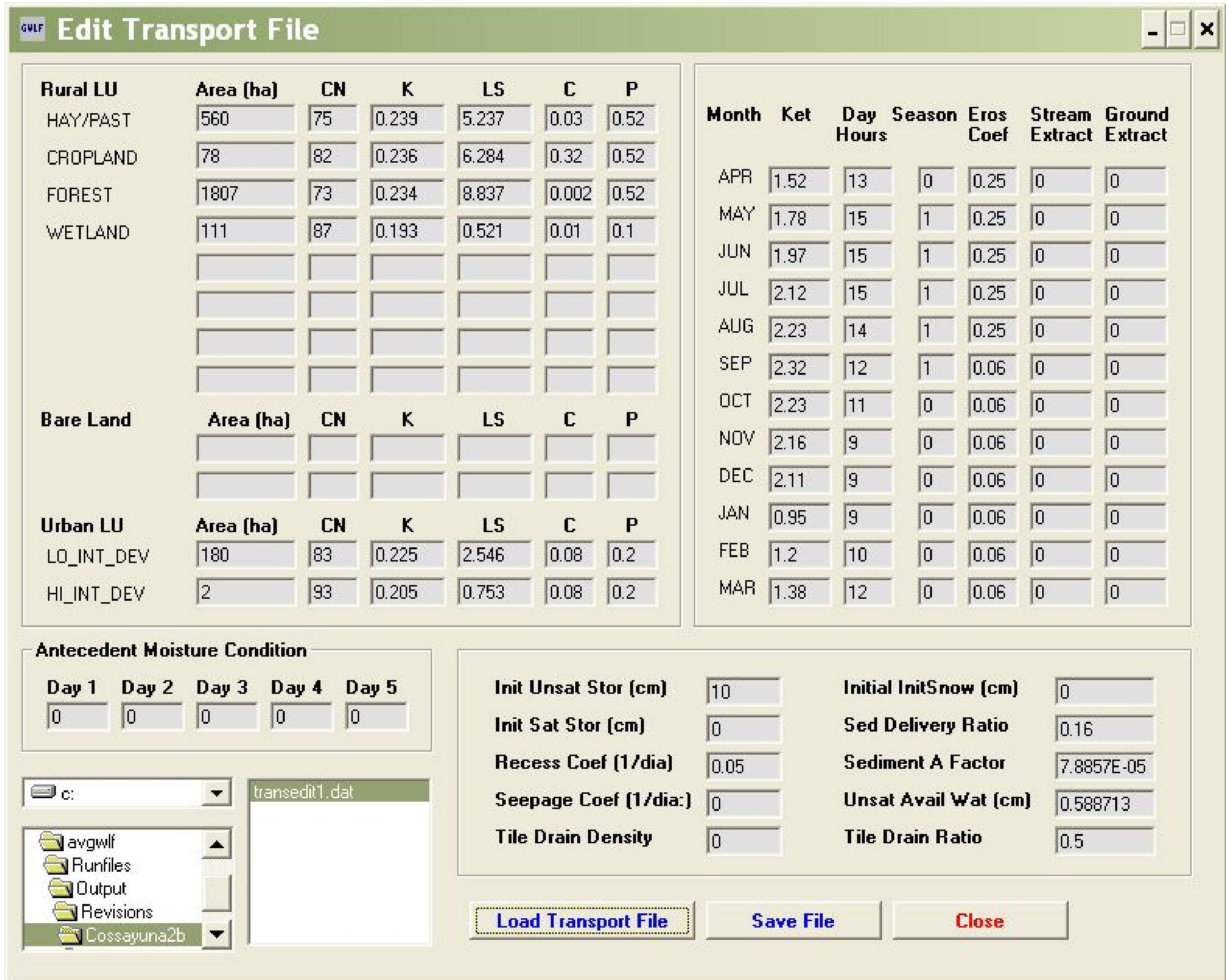
A state-wide Concentrated Animal Feeding Operation (CAFO) shapefile was provided by NYS DEC. CAFOs are categorized as either large or medium. The CAFO point can represent either the centroid of the farm or the entrance of the farm, therefore the CAFO point is more of a general gauge as to where further information should be obtained regarding permitted information for the CAFO. If a CAFO point is located in or around a basin, orthos and permit data were evaluated to determine the part of the farm with the highest potential contribution of nutrient load. In ArcView, the CAFO shapefile was positioned over the basin and clipped with a 2.5 mile buffer to preserve those CAFOS that may have associated cropland in the basin. If a CAFO point is found to be located within the boundaries of the drainage basin, every effort was made to obtain permit information regarding nutrient management or other best management practices (BMPs) that may be in place within the property boundary of a given CAFO. These data can be used to update the nutrient file in AVGWLF and ultimately account for agricultural BMPs that may currently be in place in the drainage basin.

Municipal Separate Storm Sewer Systems (MS4s)

Stormwater runoff within Phase II permitted Municipal Separate Storm Sewer Systems (MS4s) is considered a point source of pollutants. Stormwater runoff outside of the MS4 is non-permitted stormwater runoff and, therefore, considered nonpoint sources of pollutants. Permitted stormwater runoff is accounted for in the wasteload allocation of a TMDL, while non-permitted runoff is accounted for in the load allocation of a TMDL. NYS DEC determined there are no MS4s in this basin.

AVGWLF Model Simulation Results (2002-2007)

Input Transport File



Edit Transport File

Rural LU	Area (ha)	CN	K	LS	C	P
HAY/PAST	560	75	0.239	5.237	0.03	0.52
CROPLAND	78	82	0.236	6.284	0.32	0.52
FOREST	1807	73	0.234	8.837	0.002	0.52
WETLAND	111	87	0.193	0.521	0.01	0.1

Bare Land	Area (ha)	CN	K	LS	C	P

Urban LU	Area (ha)	CN	K	LS	C	P
LO_INT_DEV	180	83	0.225	2.546	0.08	0.2
HI_INT_DEV	2	93	0.205	0.753	0.08	0.2

Month	Ket	Day Hours	Season	Eros Coef	Stream Extract	Ground Extract
APR	1.52	13	0	0.25	0	0
MAY	1.78	15	1	0.25	0	0
JUN	1.97	15	1	0.25	0	0
JUL	2.12	15	1	0.25	0	0
AUG	2.23	14	1	0.25	0	0
SEP	2.32	12	1	0.06	0	0
OCT	2.23	11	0	0.06	0	0
NOV	2.16	9	0	0.06	0	0
DEC	2.11	9	0	0.06	0	0
JAN	0.95	9	0	0.06	0	0
FEB	1.2	10	0	0.06	0	0
MAR	1.38	12	0	0.06	0	0

Antecedent Moisture Condition

Day 1	Day 2	Day 3	Day 4	Day 5
0	0	0	0	0

Init Unsat Stor (cm)	10	Initial InitSnow (cm)	0
Init Sat Stor (cm)	0	Sed Delivery Ratio	0.16
Recess Coef (1/dia)	0.05	Sediment A Factor	7.8857E-05
Seepage Coef (1/dia:)	0	Unsat Avail Wat (cm)	0.588713
Tile Drain Density	0	Tile Drain Ratio	0.5

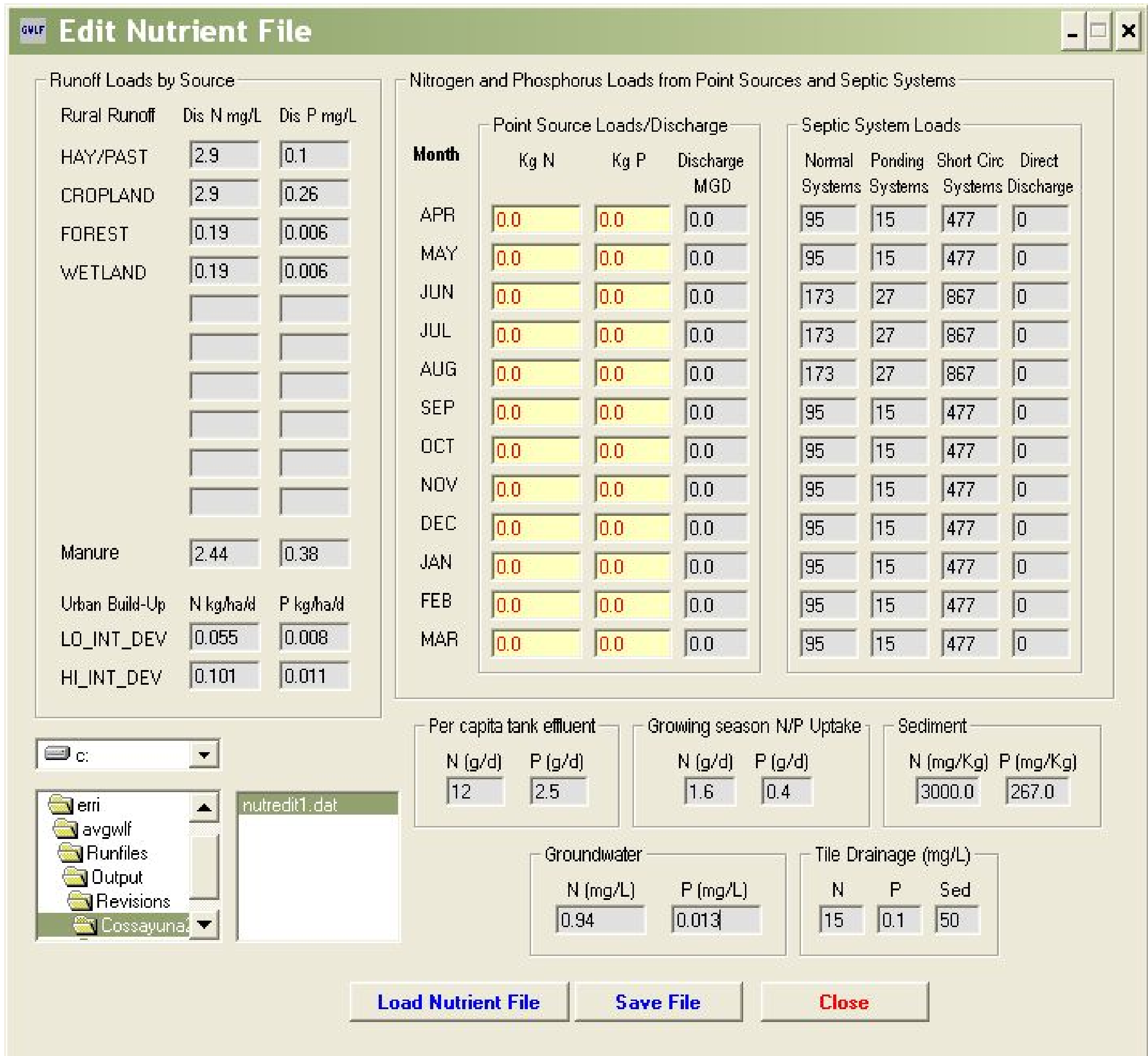
c:

avgwlf
Runfiles
Output
Revisions
Cossayuna2b

transedit1.dat

Load Transport File | Save File | Close

Input Nutrient File



Simulated Hydrology Transport Summary

GWLF Transport Summary for cossayuna_revision2b

Period of analysis 6 years, from Apr 2002 to Mar 2008

Units in Centimeters

Month	Prec	ET	Extraction	Runoff	Subsurface Flow	Point Src Flow	Tile Drain	Stream Flow
APR	10.58	3.72	0.00	0.91	6.54	0.00	0.00	7.45
MAY	10.52	7.02	0.00	0.25	5.04	0.00	0.00	5.29
JUN	11.63	7.26	0.00	0.31	4.06	0.00	0.00	4.37
JUL	11.92	8.26	0.00	0.15	3.73	0.00	0.00	3.88
AUG	9.87	7.87	0.00	0.11	2.64	0.00	0.00	2.75
SEP	10.03	5.37	0.00	0.43	2.80	0.00	0.00	3.23
OCT	11.78	4.58	0.00	1.02	4.90	0.00	0.00	5.92
NOV	10.60	2.46	0.00	0.50	6.34	0.00	0.00	6.83
DEC	10.18	0.90	0.00	1.73	6.56	0.00	0.00	8.28
JAN	7.10	0.27	0.00	1.51	6.11	0.00	0.00	7.62
FEB	5.77	0.25	0.00	0.66	3.57	0.00	0.00	4.23
MAR	7.48	1.79	0.00	2.47	5.54	0.00	0.00	8.00
Total	117.4	49.74	0.00	10.04	57.82	0.00	0.00	67.86

Go Back | Loads by Month | Print | Export to JPEG | Close

Simulated Nutrient Transport Summary

GWLF Transport Summary for cossayuna_revision2b

Period of analysis 6 years, from Apr 2002 to Mar 2008

	Kg X 1000		Nutrient Loads (Kg)			
Month	**Erosion**	**Sediment**	**Dis N**	**Total N**	**Dis P**	**Total P**
APR	1310.0	15.7	1864.5	1972.9	62.7	74.8
MAY	1148.9	8.4	1346.8	1402.0	47.5	53.8
JUN	1733.5	15.6	1161.6	1277.1	66.7	79.6
JUL	1596.0	4.1	1048.0	1090.1	65.7	71.0
AUG	1032.1	7.4	774.6	816.4	61.8	66.2
SEP	356.4	39.5	821.2	999.0	47.1	62.9
OCT	414.6	72.2	1458.9	1785.6	75.0	104.1
NOV	257.5	36.9	1709.9	1868.1	65.7	79.7
DEC	123.3	204.5	1998.2	2894.8	97.7	175.3
JAN	67.3	176.7	1890.1	2662.5	67.3	134.1
FEB	11.9	34.7	1077.7	1223.4	48.7	61.3
MAR	67.4	250.4	1957.4	3052.5	74.1	168.5
Total	8118.9	866.1	17108.7	21044.2	779.9	1131.2

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Export to JPEG | Print

Simulated Total Loads by Source

GWLF Total Loads for cossayuna_revision2b

Period of analysis: 6 years, from Apr 2002 to Mar 2008

Source	Area (Ha)	Runoff (cm)	Kg X 1000		Total Loads (Kg)			
			Erosion	Sediment	Dis N	Total N	Dis P	Total P
HAY/PAST	560	9.6	2484.2	258.0	1395.5	2532.1	100.0	197.8
CROPLAND	78	16.5	4373.3	454.1	335.4	2336.3	36.2	208.5
FOREST	1807	8.2	882.9	91.7	267.5	671.5	8.2	43.0
WETLAND	111	24.8	2.5	0.3	49.9	51.0	1.5	1.6
LO_INT_DEV	180	17.9	374.9	23.9	0.0	219.0	0.0	30.8
HI_INT_DEV	2	43.0	1.1	0.0	0.0	0.0	0.0	0.0
Tile Drainage				0.0		0.0		0.0
Stream Bank				23.0		1.7		0.7
Groundwater					14185.5	14185.5	189.8	189.8
Point Sources					0	0	0	0
Septic Systems					875.0	875.0	444.2	444.2
Totals	2738	10.0	8118.9	850.9	17108.7	20872.1	779.9	1116.4

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APPENDIX B. BATHTUB MODELING ANALYSIS

Model Overview

BATHTUB is a steady-state (Windows-based) water quality model developed by the U. S. Army Corps of Engineers (USACOE) Waterways Experimental Station. BATHTUB performs steady-state water and nutrient balance calculations for spatially segmented hydraulic networks in order to simulate eutrophication-related water quality conditions in lakes and reservoirs. BATHTUB's nutrient balance procedure assumes that the net accumulation of nutrients in a lake is the difference between nutrient loadings into the lake (from various sources) and the nutrients carried out through outflow and the losses of nutrients through whatever decay process occurs inside the lake. The net accumulation (of phosphorus) in the lake is calculated using the following equation:

Net accumulation = Inflow – Outflow – Decay

The pollutant dynamics in the lake are assumed to be at a steady state, therefore, the net accumulation of phosphorus in the lake equals zero. BATHTUB accounts for advective and diffusive transport, as well as nutrient sedimentation. BATHTUB predicts eutrophication-related water quality conditions (total phosphorus, total nitrogen, chlorophyll-a, transparency, and hypolimnetic oxygen depletion) using empirical relationships derived from assessments of reservoir data. Applications of BATHTUB are limited to steady-state evaluations of relations between nutrient loading, transparency and hydrology, and eutrophication responses. Short-term responses and effects related to structural modifications or responses to variables other than nutrients cannot be explicitly evaluated.

Input data requirements for BATHTUB include: physical characteristics of the watershed lake morphology (e.g., surface area, mean depth, length, mixed layer depth), flow and nutrient loading from various pollutant sources, precipitation (from nearby weather station) and phosphorus concentrations in precipitation (measured or estimated), and measured lake water quality data (e.g., total phosphorus concentrations).

The empirical models implemented in BATHTUB are mathematical generalizations about lake behavior. When applied to data from a particular lake, actual observed lake water quality data may differ from BATHTUB predictions by a factor of two or more. Such differences reflect data limitations (measurement or estimation errors in the average inflow and outflow concentrations) or the unique features of a particular lake (no two lakes are the same). BATHTUB's "calibration factor" provides model users with a method to calibrate the magnitude of predicted lake response. The model calibrated to current conditions (against measured data from the lakes) can be applied to predict changes in lake conditions likely to result from specific management scenarios, under the condition that the calibration factor remains constant for all prediction scenarios.

Model Set-up

Using descriptive information about Cossayuna Lake and its surrounding drainage area, as well as output from AVGWLF, a BATHTUB model was set up for Cossayuna Lake. Mean annual phosphorus loading to the lake was simulated using AVGWLF for the period 1990-2007. The TMDL for Cossayuna Lake was developed using the long-term mean annual phosphorus loading to the lake for the period 2002-2007. Using this load as input, BATHTUB was used to simulate water quality in the lake. After initial model development, NYS DEC sampling data were used to assess the model's predictive capabilities and, if necessary, "fine tune" various input parameters and sub-model selections within BATHTUB during a calibration process. Once calibrated, BATHTUB was used to derive the total phosphorus load reduction needed in order to achieve the TMDL target.

Sources of input data for BATHTUB include:

- Physical characteristics of the watershed and lake morphology (e.g., surface area, mean depth, length, mixed layer depth) - Obtained from CSLAP and bathymetric maps provided by NYS DEC or created by the Cadmus Group, Inc.
- Flow and nutrient loading from various pollutant sources - Obtained from AVGWLF output.
- Precipitation – Obtained from nearby National Weather Services Stations.
- Phosphorus concentrations in precipitation (measured or estimated), and measured lake water quality data (e.g., total phosphorus concentrations) – Obtained from NYS DEC or USGS.

Tables 9 – 12 summarize the primary model inputs for Cossayuna Lake, including the coefficient of variation (CV), which reflects uncertainly in the input value. Default model choices are utilized unless otherwise noted. Spatial variations (i.e., longitudinal dispersion) in phosphorus concentrations are not a factor in the development of the TMDL for Cossayuna Lake. Therefore, division of the lake into multiple segments was not necessary for this modeling effort. Modeling the entire lake with one segment provides predictions of area-weighted mean concentrations, which are adequate to support management decisions. Water inflow and nutrient loads from the lake's drainage basin were treated as though they originated from one "tributary" (i.e., source) in BATHTUB and derived from AVGWLF.

BATHTUB is a steady state model, whose predictions represent concentrations averaged over a period of time. A key decision in the application of BATHTUB is the selection of the length of time over which water and mass balance calculations are modeled (the "averaging period"). The length of the appropriate averaging period for BATHTUB application depends upon what is called the nutrient residence time, which is the average length of time that phosphorus spends in the water column before settling or flushing out of the lake. Guidance for BATHTUB recommends that the averaging period used for the analysis be at least twice as large as nutrient residence time for the lake. The appropriate averaging period for water and mass balance calculations would be 1 year for lakes with relatively long nutrient residence times or seasonal (6 months) for lakes with relatively short nutrient residence times (e.g., on the order of 1 to 3 months). The turnover ratio can be used as a guide for selecting the appropriate averaging period. A seasonal averaging period (April/May through September) is usually appropriate if it results in a turnover ratio exceeding 2.0. An annual averaging period may be used otherwise. Other considerations (such as comparisons of observed and predicted nutrient levels) can also be used as a basis for selecting an appropriate averaging period, particularly if the turnover ratio is near 2.0.

Precipitation inputs were taken from the observed long term mean daily total precipitation values from the Glen Falls, NY and Whitehall, NY National Weather Services Stations for the 2002-2007 period. Evapotranspiration was derived from AVGWLF using daily weather data (2002-2007) and a cover factor dependent upon land use/cover type. The values selected for precipitation and change in lake storage have very little influence on model predictions. Atmospheric phosphorus loads were specified using data collected by NYS DEC from the Cedar Lane Atmospheric Deposition Station located in Lake George Village, in Warren County. Atmospheric deposition is not a major source of phosphorus loading to Cossayuna Lake and has little impact on simulations.

Lake surface area, mean depth, and length were derived using GIS analysis of bathymetric data. Depth of the mixed layer was estimated using a multivariate regression equation developed by Walker (1996). Existing water quality conditions in Cossayuna Lake were represented using an average of the observed summer mean phosphorus concentrations for years 2002-2007. These data were collected through NYS DEC's CSLAP. The concentration of phosphorus loading to the lake was calculated using the average annual flow and phosphorus loads simulated by AVGWLF. To obtain flow in units of volume per time, the depth of flow was multiplied by the drainage area and divided by one year. To obtain phosphorus concentrations, the nutrient mass was divided by the volume of flow.

Internal loading rates reflect nutrient recycling from bottom sediments. Internal loading rates are normally set to zero in BATHTUB since the pre-calibrated nutrient retention models already account for nutrient recycling that would normally occur (Walker, 1999). Walker warns that nonzero values should be specified with caution and only if independent estimates or measurements are available. In some studies, internal loading rates have been estimated from measured phosphorus accumulation in the hypolimnion during the stratified period. Results from this procedure should not be used for estimation of internal loading in BATHTUB unless there is evidence the accumulated phosphorus is transported to the mixed layer during the growing season. Specification of a fixed internal loading rate may be unrealistic for evaluating response to changes in external load. Because they reflect recycling of phosphorus that originally entered the reservoir from the watershed, internal loading rates would be expected to vary with external load. In situations where monitoring data indicate relatively high internal recycling rates to the mixed layer during the growing season, a preferred approach would generally be to calibrate the phosphorus sedimentation rate (i.e., specify calibration factors < 1). However, there still remains some risk that apparent internal loads actually reflect under-estimation of external loads.

Table 9. BATHTUB Model Input Variables: Model Selections

Water Quality Indicator	Option	Description
Total Phosphorus	01	2nd Order Available Phosphorus*
Phosphorus Calibration	01	Decay Rate*
Error Analysis	01	Model and Data*
Availability Factors	00	Ignore*
Mass Balance Tables	01	Use Estimated Concentrations*

* Default model choice

Table 10. BATHTUB Model Input: Global Variables

Model Input	Mean	CV
Averaging Period (years)	0.5	NA
Precipitation (meters)	1.17	0.2*
Evaporation (meters)	0.50	0.3*
Atmospheric Load (mg/m^2-yr)- Total P	4.83	0.5*
Atmospheric Load (mg/m^2-yr)- Ortho P	2.91	0.5*

* Default model choice

Table 11. BATHTUB Model Input: Lake Variables

Morphometry	Mean	CV
Surface Area (km^2)	2.63	NA
Mean Depth (m)	3.4	NA
Length (km)	3.04	NA
Estimated Mixed Depth (m)	3.4	0.12
Observed Water Quality	**Mean**	**CV**
Total Phosphorus (ppb)	28.105	0.5

* Default model choice

Table 12. BATHTUB Model Input: Watershed "Tributary" Loading

Monitored Inputs	Mean	CV
Total Watershed Area (km^2)	27.38	NA
Flow Rate (hm^3/yr)	18.58	0.1
Total P (ppb)	62.12	0.2
Organic P (ppb)	44.00	0.2

Model Calibration

BATHTUB model calibration consists of:

1. Applying the model with all inputs specified as above
2. Comparing model results to observed phosphorus data
3. Adjusting model coefficients to provide the best comparison between model predictions and observed phosphorus data (only if absolutely required and with extreme caution).

Several t-statistics calculated by BATHTUB provide statistical comparison of observed and predicted concentrations and can be used to guide calibration of BATHTUB. Two statistics supplied by the model, T2 and T3, aid in testing model applicability. T2 is based on error typical of model development data set. T3 is based on observed and predicted error, taking into consideration model inputs and inherent model error. These statistics indicate whether the means differ significantly at the 95% confidence level. If their absolute values exceed 2, the model may not be appropriately calibrated. The T1 statistic can be used to determine whether additional calibration is desirable. The t-statistics for the BATHUB simulations for Cossayuna Lake are as follows:

Year	Observed	Simulated	T1	T2	T3
1992	34	41	-0.35	-0.65	-0.32
1993	30	35	-0.31	-0.58	-0.29
1994	38	46	-0.39	-0.72	-0.36
1995	31	36	-0.31	-0.58	-0.29
1996	33	43	-0.52	-0.96	-0.48
1998	33	42	-0.47	-0.88	-0.44
1999	31	39	-0.48	-0.90	-0.45
2000	33	43	-0.51	-0.96	-0.48
2001	21	39	-1.22	-2.27	-1.13
2002	27	29	-0.13	-0.25	-0.12
2003	22	30	-0.67	-1.25	-0.62
2004	26	32	-0.42	-0.78	-0.39
2005	24	28	-0.31	-0.58	-0.29
2006	35	33	0.12	0.22	0.11
2007	36	27	0.53	0.98	0.49
Average (02-07)	28	30	-0.10	-0.19	-0.09

In cases where predicted and observed values differ significantly, calibration coefficients can be adjusted to account for the site-specific application of the model. Calibration to account for model error is often appropriate. However, Walker (1996) recommends a conservative approach to calibration since differences can result from factors such as measurement error and random data input errors. Error statistics calculated by BATHTUB indicate that the match between simulated and observed mean annual water quality conditions in Cossayuna Lake is quite good. Therefore, BATHTUB is sufficiently calibrated for use in estimating load reductions required to achieve the phosphorus TMDL target in the lake.

APPENDIX C. TOTAL EQUIVALENT DAILY PHOSPHORUS LOAD ALLOCATIONS

Source	Total Phosphorus Load (lbs/day)			% Reduction
	Current	Allocated	Reduction	
Agriculture*	2.8	2.3	0.5	18%
Developed Land*	0.5	0.4	0.1	20%
Septic Systems	2.9	0.0	2.9	100%
Forest, Wetland, Stream Bank, and Natural Background	0.8	0.8	0.0	0%
LOAD ALLOCATION	**7.0**	**3.5**	**3.5**	**50%**
Point Sources	0.0	0.0	0.0	0%
WASTELOAD ALLOCATION	**0.0**	**0.0**	**0.0**	**0%**
LA + WLA	**7.0**	**3.5**	**3.5**	**50%**
Margin of Safety	---	0.4	---	---
TOTAL	**7.0**	**3.9**	---	---

* Includes phosphorus transported through surface runoff and subsurface (groundwater)