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

Chautauqua County, New York

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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

Findley Lake (WI/PWL ID 0202-0004) is situated in the Town of Mina, within Chautauqua County, New York. Over the past couple of decades, the lake has experienced degraded water quality that has reduced the lake's recreational and aesthetic value. Recreational conditions in the lake have most often been described as "slightly impaired" for most recreational uses, and the lake was also most often described as having "definite algal greenness." Aquatic plants regularly grow to the lake surface (though not in 2005), and continue to impact recreation. Recreational assessments generally degrade during the summer, coincident with seasonal changes in water quality and weed densities- both weeds and algae strongly influence recreation Lake productivity has been more variable in recent years (lower in 2003 and 2004 and higher in 2005), although recreational assessments did not substantially improve. This may be due to the continuing presence of nuisance weeds, although the dominant plants may have changed from exotic plants (Eurasian water milfoil) to native plants (leafy pondweed) (NYS DEC, 2006).

A variety of sources of phosphorus are contributing to the poor water quality in Findley 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.

Findley Lake is presently among the lakes listed on the 1999 Allegheny River drainage basin PWL, with *aesthetics, fishing and fish survival* listed as *impaired* due to excessive nutrients, algae and weeds, and reduced water clarity (NYS DEC, 2006). The results from state sampling efforts confirm eutrophic conditions in Findley 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. In 2004, Findley Lake was added to the New York State Department of Environmental Conservation (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

Findley Lake was created by Alexander Findley in 1812 when damming the outlet of two ponds. The two ponds originally formed from melting glacial ice about 16,000 or 17,000 years ago (Shermet and Wilson, 2007). The dam is now controlled by the Findley Lake Property Owners, Inc. (Boria and Wilson, 2002). Lake level is regulated using a mechanical gate in the spillway at the lake outlet. Summer lake levels are maintained at about 1,420 feet above mean sea level (Boria and Wilson, 2002).

Findley Lake was sampled in 1937 as part of the Conservation Department (predecessor to NYS DEC) Biological Survey of the Allegheny River basin. This survey showed oxygen deficits starting at a depth between 15 and 20 feet from the lake surface. The field notes for the 1937 survey included the following (NYS DEC, 2006):

> "*This, the westernmost lake in New York State, is a very irregularly shaped body of water with numerous shallow bays and several islands. The level is maintained by a dam at the north end. A large part of the south end is a shallow area with flat bottom covered with a thick growth of hornwort, waterweed, and Robbins pondweed. These plants cover almost the entire bottom and apparently have been the most successful invaders of what was once a wooded area, as evidenced by the numerous large submerged stumps. In this same weed bed are found many plants of the broad-leaved pondweed (P.amplifolius), of najad and bladderwort, as well as the ubiquitous waterlilies and water shield. Along the marshy shore, at the south end of the lake, are extensive marshes of cattail and large floating masses of water smartweed. Other large weed beds were found at the north end of the lake and along the east side.*
>
> *Findley Lake has very poor bottom chemical conditions in the face of which it will be difficult if not impossible to improve production by stocking alone. To form the present lake, an 8-foot dam was built across the outlet of two small ponds. The total area of the two ponds was slightly more than half the area of the new lake. As a result about one-half of Findley Lake is less than 10 feet deep. Within recent years this shallow area has become quite completely choked with vegetation. During the summer this vegetation becomes so dense that only the tops are alive. In the lower levels where sufficient light fails to penetrate, the vegetation is dead or dying. While green plants normally aerate the water, here so little of the plant actually is green that stagnant conditions prevail on the bottom. It is not unusual for algal and rooted aquatic plant growths to become sufficiently unpleasant although these growths seldom become sufficiently abundant to affect fish life adversely. The conditions*

> *in Findley Lake, however, leads one to conclude that vegetation may become so abundant as to be detrimental to fishing and fish production.*
>
> *Bottom samples of water taken among the vegetation at a depth of 8 feet had only 0.4 parts per million of oxygen. In contrast to this in deeper water where vegetation is lacking and where surface winds can mix the water more completely, at a depth of 14 feet there were 3.96 parts per million of oxygen at one station. At this same station below the plane of the 14-foot contour or in that areas not greatly affected by surface winds, the oxygen dropped from 0.84 parts per million at 15 feet to 0.0 parts per million on the bottom at 31 feet. From this it can be seen that among the vegetation the oxygen is less at 8 feet than at almost twice the depth where the oxygen is lacking. The bottom chemical conditions were inadequate for fish needs. A probably contributing factor is the nature of the bottom. Most of the area flooded when the dam was built was low, muck land that in earlier times had probably been covered by natural ponds.*
>
> *To remedy the condition here will not be easy. Weed elimination by chemical methods is out of the question for the present since so far as is known, chemicals sufficiently strong to eliminate rooted vegetation on a large scale would kill all fish life. Algal blooms in water supply reservoirs are controlled by chemical means but here it probably could not be done without some harmful effect to fish life. Mechanical methods are the only safe means of removing rooted aquatic plants, laborious as the task may be. Wood saws or rakes may be used for the purpose but it should be pointed out that the weeds should be completely removed after they are cut for two reasons: (1) if left in the water to decompose and use up oxygen, the main purpose of their destruction would be defeated and (2) since many aquatic plants reproduce asexually, more cutting is not sufficient to stop their growth or to prevent them from spreading into other suitable areas. The process would have to be repeated as often as necessary"*

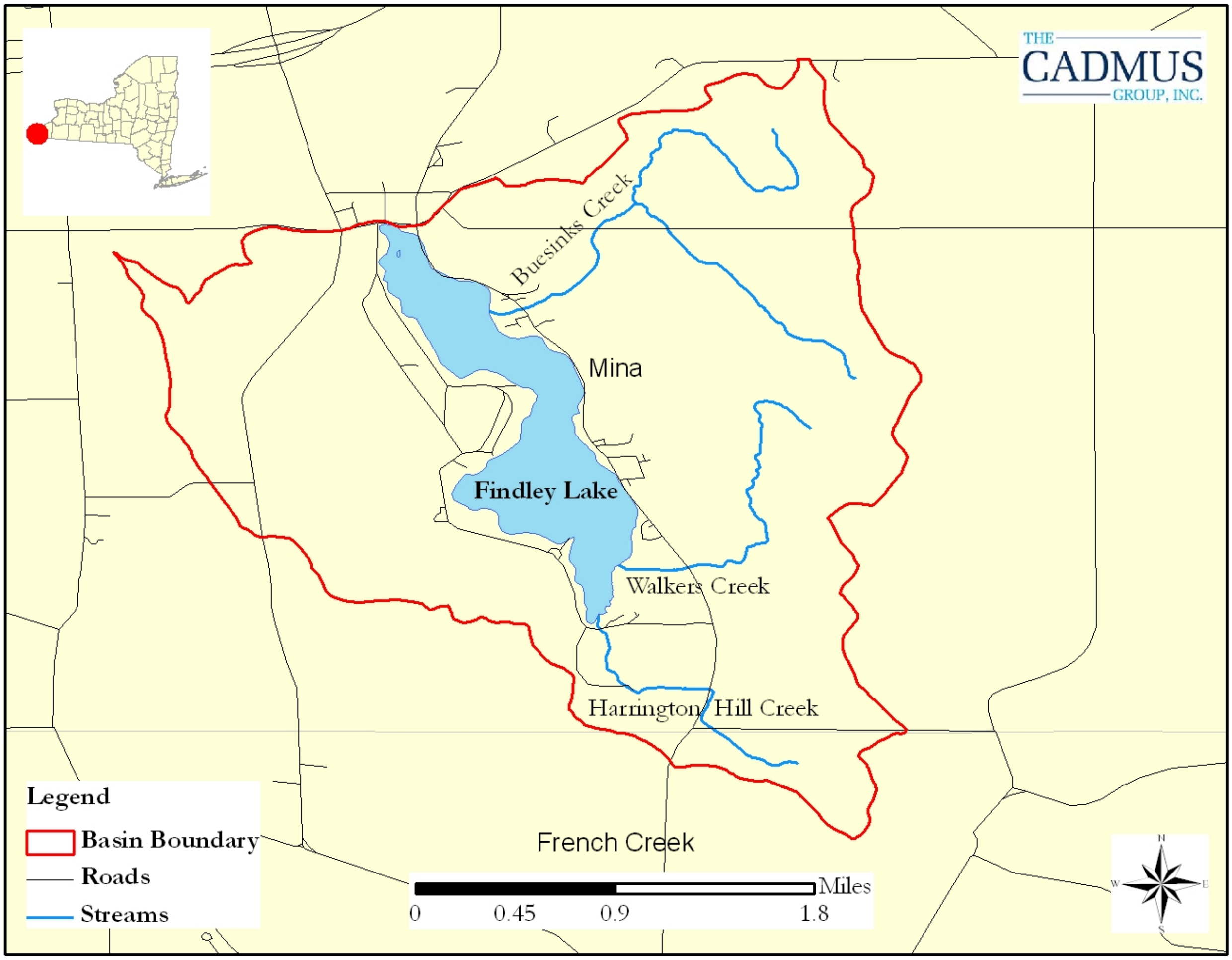
Findley Lake was sampled by NYS DEC as part of the state ambient lake monitoring program (referred to as the Lake Classification and Inventory (LCI) Survey) in 1976 and 1985. Findley Lake has been sampled as part of the NYS DEC Citizen Statewide Lake Assessment Program (CSLAP) since 1986. Water quality monitoring in Findley Lake historically indicated that the lake possesses relatively high nutrient (particularly phosphorus) readings, resulting in "slightly" to "substantially" impaired recreational conditions (NYS DEC, 2006).

2.2. Watershed Characterization

Findley Lake has a direct drainage basin area of 3,000 acres excluding the surface area of the lake (Figure 1). The topography of the basin exhibits irregularly-shaped rolling hills and valleys. Elevations in the lake's basin range from approximately 1,742 feet above mean sea level (AMSL) to as low as 1,420 feet AMSL at the surface of Findley Lake. The lake lies atop the Allegheny Plateau located south of and above the Lake Erie Plain (Boria and Wilson, 2002). The basin's uplands are composed of many small drumlins with intervening shallow swales or sometimes deep ravines. These features were sculpted about 18,000 to 16,000 years ago by the great Laurentide glacier, along with the central valley now occupied by Findley Lake. As the glacier melted away it left deposits of mostly sand and gravel under and marginal to Findley Lake. Ravines were cut during the past 16,000 years and continue to be carved today. Streams in these ravines cut, rearrange, and deposit rock and soil. For example, Buesink's Creek has a large gravel fan deposit that extends under the lake. The land uses and septic systems are on and in the surface of this glacial and post-glacial terrain (Shermet and Wilson, 2007).

There are 5 main tributaries that together drain 62% of Findley Lake's basin (Shermet and Wilson, 2007). The largest volume of water to the lake is from Buesink's Creek located on the northeast shore. Water exits the lake at the north into the West Branch of the French Creek, which gradually winds west then south, flowing into French Creek at Wattsburg, Pennsylvania (Boria and Wilson, 2002).

Figure 1. Findley Lake Direct Drainage Basin



Existing land use and land cover in the Findley 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). Ground-truthed land use data were provided by Chautauqua County to further improve on land use class adjustments performed within the basin. These data were particularly useful when development was obscured by forest canopy. 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 Findley Lake's drainage basin are listed in Table 1 and presented in Figures 3 and 4.

Figure 2. Aerial Image of Findley Lake

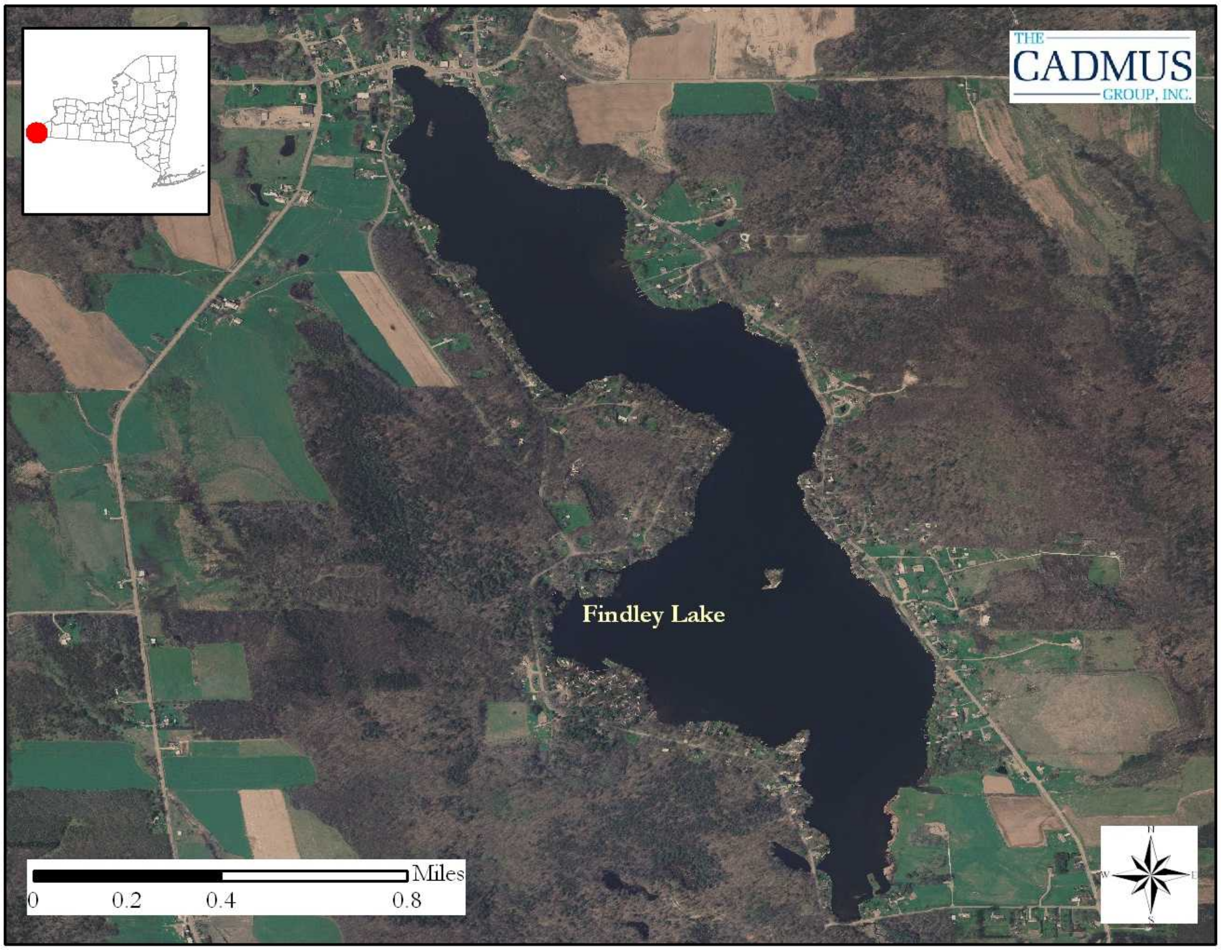


Table 1. Land Use Acres and Percent in Findley Lake Drainage Basin

Land Use Category	Acres	% of Drainage Basin
Open Water	2	0.1%
Agriculture	1,023	34%
Hay & Pasture	631	21%
Cropland	393	13%
Developed Land	242	8%
Low Intensity	233	8%
High Intensity	9	0.3%
Forest	1,719	57%
Wetlands	14	0.5%
TOTAL	**3,000**	**100%**

Figure 3. Percent Land Use in Findley Lake Drainage Basin

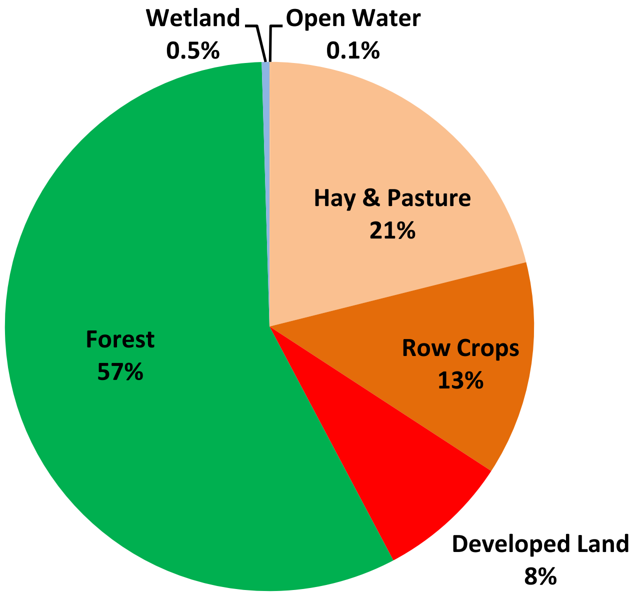
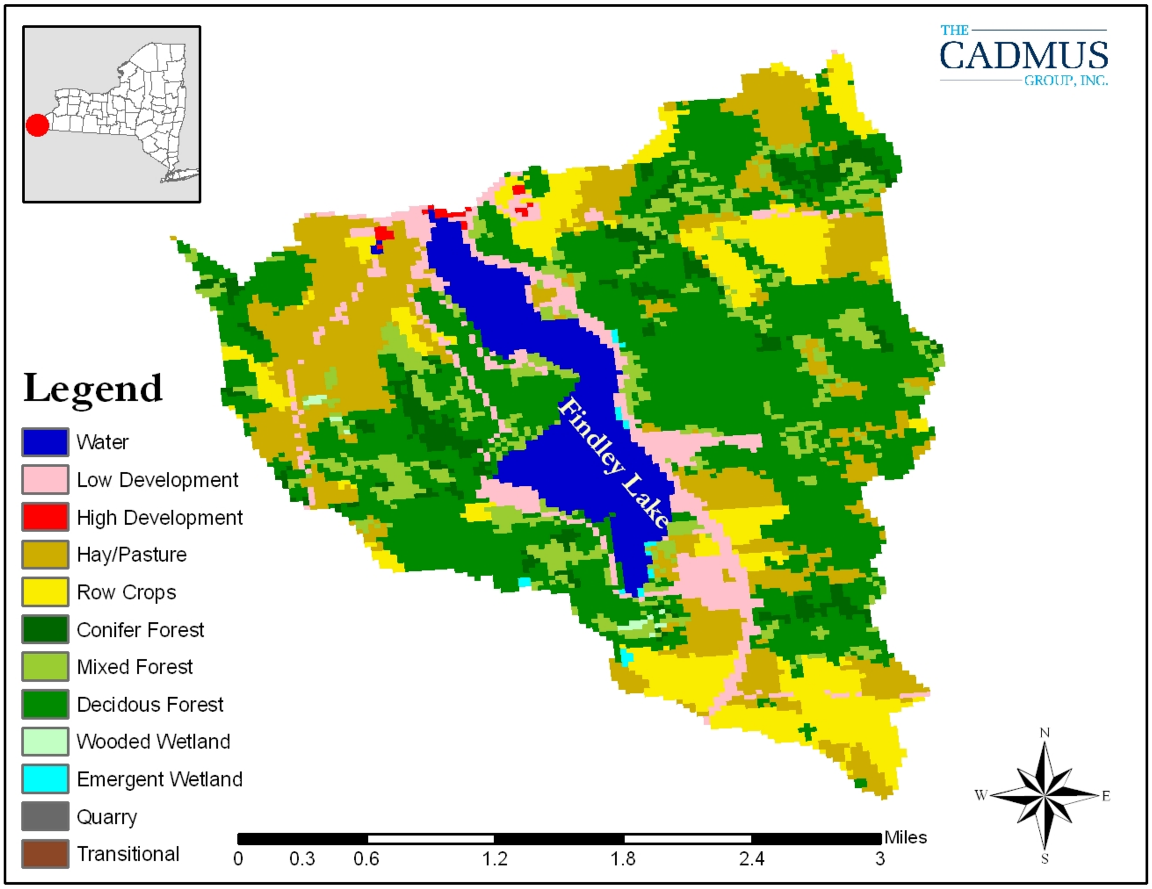


Figure 4. Land Use in Findley Lake Drainage Basin



2.3. Lake Morphometry

Findley Lake is a 296 acre waterbody at an elevation of about 1,420 feet AMSL. Figure 5 shows a bathymetric map for Findley Lake based on data provided by Chautauqua County (Boria and Wilson, 2002). Table 2 summarizes key morphometric characteristics for Findley Lake.

Figure 5. Bathymetric Map of Findley Lake

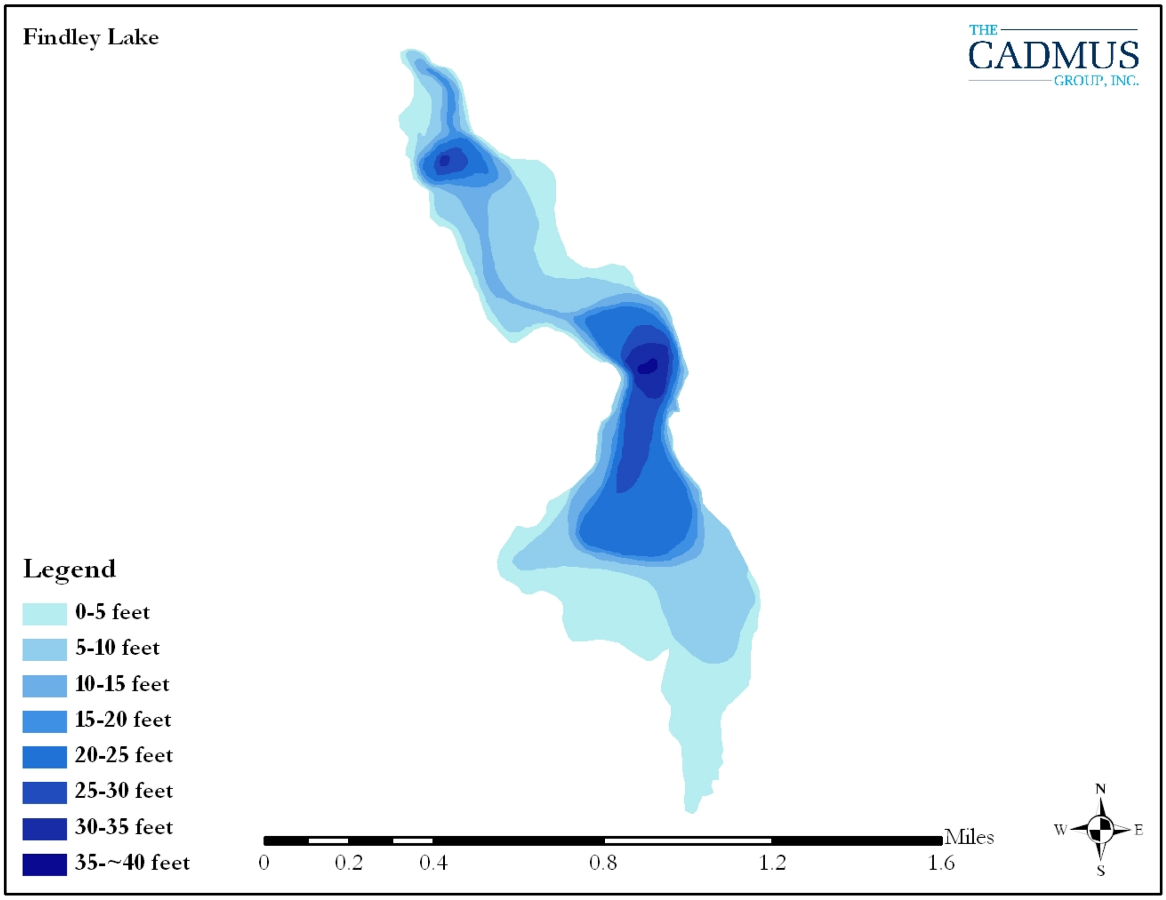


Table 2. Findley Lake Characteristics

Surface Area (acres)	296
Elevation (ft AMSL)	1,420
Maximum Depth (ft)	40
Mean Depth (ft)	11
Length (ft)	6,573
Width at widest point (ft)	2,670
Shoreline perimeter (ft)	30,177
Direct Drainage Area (acres)	3,000
Watershed: Lake Ratio	10:1
Mass Residence Time (years)	0.3
Hydraulic Residence Time (years)	0.7

2.4. Water Quality

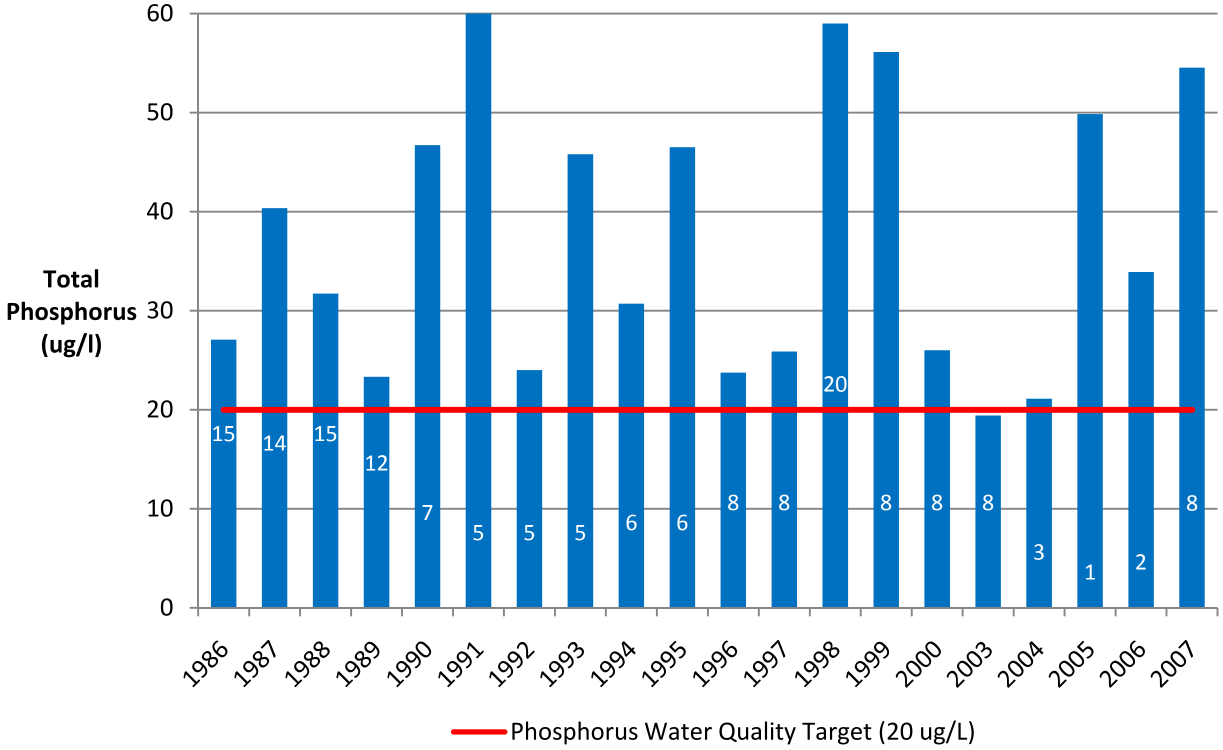
CSLAP is a cooperative volunteer monitoring effort between NYS DEC and the New York Federation of Lake Associations (FOLA). The goal of the program is to establish a volunteer lake monitoring program that provides data for a variety of purposes, including establishment of a long-term database for lakes 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 Findley Lake during the summers of 1986-2007. In addition to the CSLAP data, Findley Lake water quality data collected by Chautauqua County during the summer of 1998 were also obtained (Boria and Wilson, 2002). The results from these sampling efforts show eutrophic conditions in Findley 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. Figure 6 shows the summer mean epilimnetic phosphorus concentrations for phosphorus data collected during all sampling seasons and years in which Findley Lake was sampled as part of CSLAP; the number annotations on the bars indicate the number of data points included in each summer mean.

In 2003 and 2004, nutrient levels at the bottom of Findley Lake were comparable to those at the lake surface, although historically highly elevated readings suggested the bottom waters are poorly oxygenated and contribute to increases in surface water nutrient levels throughout the summer. This deepwater oxygen deficit was recorded in the lake at least back to the 1930s (NYS DEC, 2007). In 2007, however, phosphorus levels in the bottom waters averaged 0.20 mg/L, about four times higher than the levels in the epilimnion. The bottom waters of Findley Lake are showing nutrient levels substantially higher than those at the lake surface. When the water over the bottom sediments is devoid of dissolved oxygen (a condition known as anoxic; without oxygen) phosphorus is no longer chemically bound to the sediments and is free to rise out of the sediments into the over laying water. This, in turn, can result in algae blooms.

Figure 6. Summer Mean Epilimnetic Total Phosphorus Levels in Findley 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 Findley Lake is *B*, which means that the best usages of the lake are primary and secondary contact recreation and fishing. The lake must also be suitable for fish propagation and survival. 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 Findley 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 Findley 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.

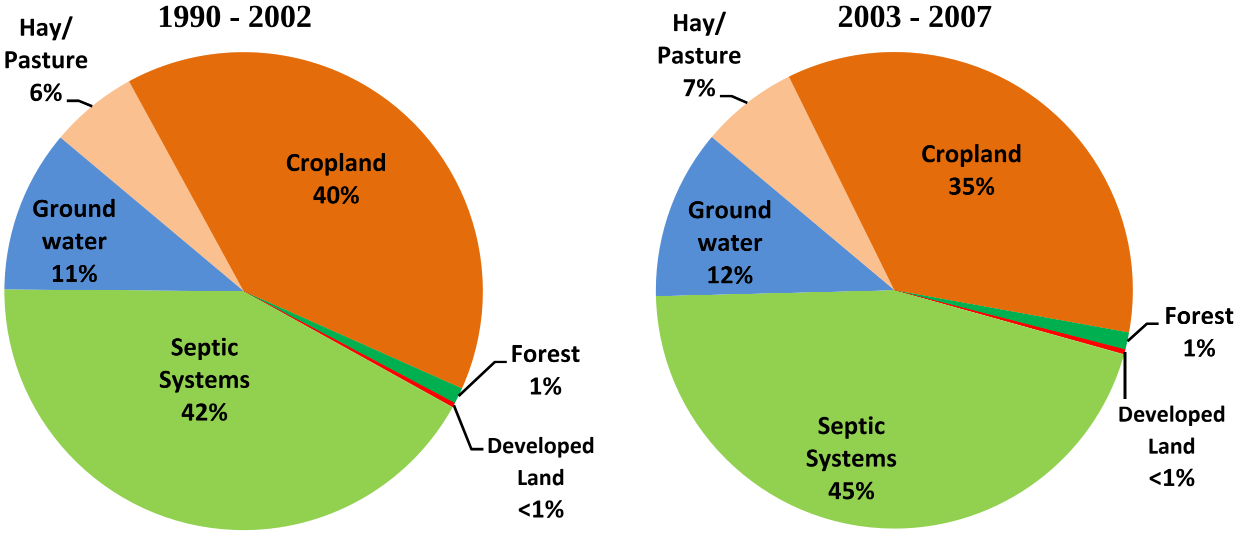
4.2. Sources of Phosphorus Loading

AVGWLF was used to estimate long-term mean annual phosphorus (external) loading to Findley Lake for two different time periods – 1990-2002 and 2003-2007. The estimated mean annual external loads of 1,009 lbs/yr (1990-2002) and 939 lbs/yr (2003-2007) of total phosphorus to Findley Lake were estimated to originate from the sources listed in Table 3 and shown in Figure 7. The 1990-2002 run was performed using the National Land Cover Database (NLCD) 2001 as is. For the 2003-2007 run, minor corrections were made to the NLCD 2001 based on analysis of orthoimagery (in particular, the reduction of cropland in the basin); further, the 2003-2007 model run also takes into account the adoption of nutrient management best management practices (BMPs) on 80% of the cropland in the basin. The TMDL for Findley Lake was developed using the 2003-2007 model run; therefore, the detailed source loading results (discussed in the following sections) are only provided for the 2003-2007 run. Appendix A provides the detailed simulation results from AVGWLF.

Table 3. Estimated Sources of Phosphorus Loading to Findley Lake

Source	Mean Annual Total Phosphorus Load (lbs/yr)	
	1990 – 2002	2003 – 2007
Hay/Pasture	60	62
Cropland	400	330
Forest	11	11
Developed Land	3	3
Stream Bank	0.4	0.4
Septic Systems	424	425
Groundwater	111	108
TOTAL	**1,009**	**939**

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

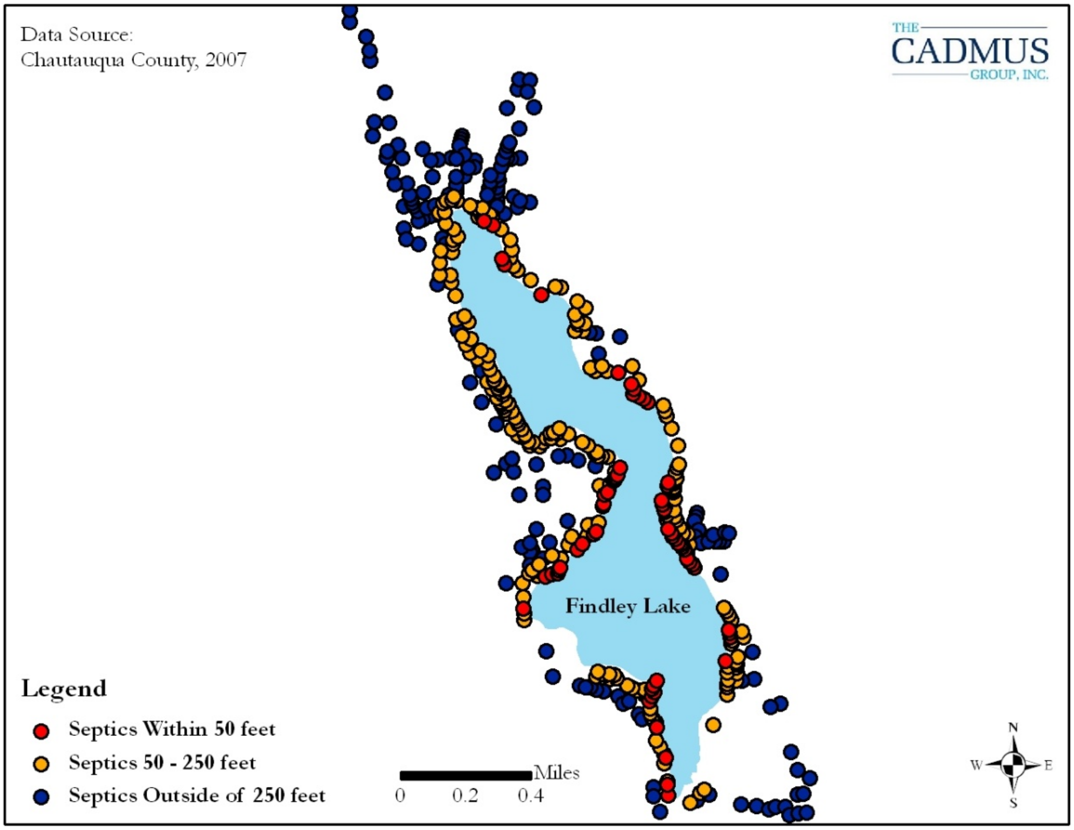


4.2.1. *Residential On-Site Septic Systems*

Residential on-site septic systems contribute an estimated 425 lbs/yr of phosphorus to Findley Lake, which is about 45% 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.

GIS analysis of septic parcel data from Chautauqua County for the basin shows approximately 61 houses within 50 feet of the shoreline and 213 houses between 50 and 250 feet of the shoreline; all of the houses are assumed to have septic systems (Figure 8). 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. Further, in order to account for summer populations at a campground and camp near the lake, an additional 225 individuals were added to the septic loading numbers for the summer period.

Figure 8. Findley Lake Septic Parcel Distribution



Nearly all of the septic systems around Findley Lake are within a sand and gravel aquifer, which permits the rapid movement of groundwater (Boria and Wilson, 2002). Within 50 feet of the shorelines, 100% of septic systems were categorized as short-circuiting. Between 50 and 250 feet of the shoreline, 50% of septic systems were categorized as short-circuiting, 10% were categorized as ponding systems, and 40% were categorized as normal systems. 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. Approximately 30% of the homes around the lake are assumed to be year-round residences, while 70% are seasonally occupied (i.e., June through August only). 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. The estimated population in the Findley Lake drainage basin served by normal and malfunctioning systems is summarized in Table 4.

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

	Normally Functioning	Ponding	Short Circuiting	Total
September – May	67	17	131	215
June – August (Summer)	312	78	550	940

4.2.2. *Agricultural Runoff*

Agricultural land encompasses 1,023 acres (34%) of the lake drainage basin and includes hay and pasture land (21%) and row crops (13%). Overland runoff from agricultural land is estimated to contribute about 392 lbs/yr of phosphorus loading to Findley Lake, which is 42% of the total phosphorus loading to the lake. 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 242 acres (8%) of the lake drainage basins. Stormwater runoff from developed land contributes about 3 lbs/yr of phosphorus to Findley Lake, which is less than 1% 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 1,719 acres (57%) of the lake drainage basin. Runoff from forested land is estimated to contribute about 11 lbs/yr of phosphorus loading to Findley Lake, which is about 1% 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 108 lbs/yr (11%) of the total phosphorus load to Findley Lake. With respect to groundwater, there is typically a small "background" concentration owing to various natural sources. In the Findley Lake drainage basin, the model-estimated groundwater phosphorus concentration is 0.01 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 60% of the groundwater load (65 lbs/yr) can be attributed to natural sources, including forested land and soils.

The remaining amount of the groundwater phosphorus load transported to the lake through groundwater (about 43 lbs/yr) likely originates from developed land sources (i.e., leached in dissolved form from the surface). 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	65	60%
Developed Land	43	40%
TOTAL	**108**	**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. Atmospheric phosphorus loads (75 mg/m^2/yr) were specified using data collected by USGS from a collection site at Mendon Ponds County Park, in New York (Sherwood, 2005).

Internal loading was not considered in the development of this TMDL due to lack of data to confirm internal loading. However, NYS DEC acknowledges the need for additional monitoring to determine if phosphorus migrates from the hypolimnion to the epiliminion, and if phosphorus release from sediment plays a significant role in phosphorus loading in Findley Lake. It will be important to make this determination in the near future as there is the possibility that, after external sources are reduced, internal loading may become increasingly more important in the total phosphorus loading in the lake, leading to a delay in water quality improvements.

5.0 DETERMINATION OF LOAD CAPACITY

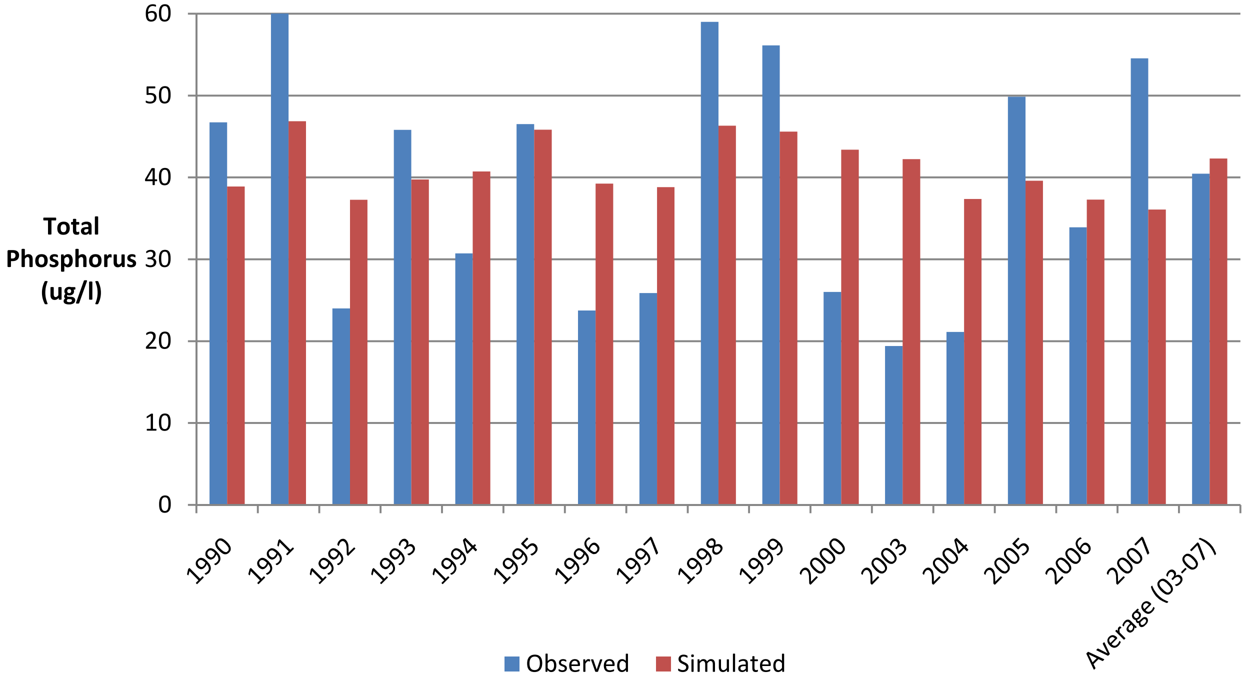
5.1. Lake Modeling Using the BATHTUB Model

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 Findley Lake. AVGWLF was used to derive a mean annual phosphorus loading 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 9). The TMDL for Findley Lake was developed using the long-term mean annual phosphorus loading to the lake for the period 2003-2007. 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 Findley Lake (Figure 9).

Figure 9. Observed vs. Simulated Summer Mean Epilimnetic Total Phosphorus Concentrations (μg/L) in Findley 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 Findley 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 Findley Lake is a mean annual load of 242 lbs/yr. The daily TMDL of 0.7 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 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 wastewater treatment plant discharges of treated wastewater effluent in the Findley Lake drainage 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 218 lbs/yr. Nonpoint sources that contribute total phosphorus to Findley 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 10 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.

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 Findley 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 24 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.

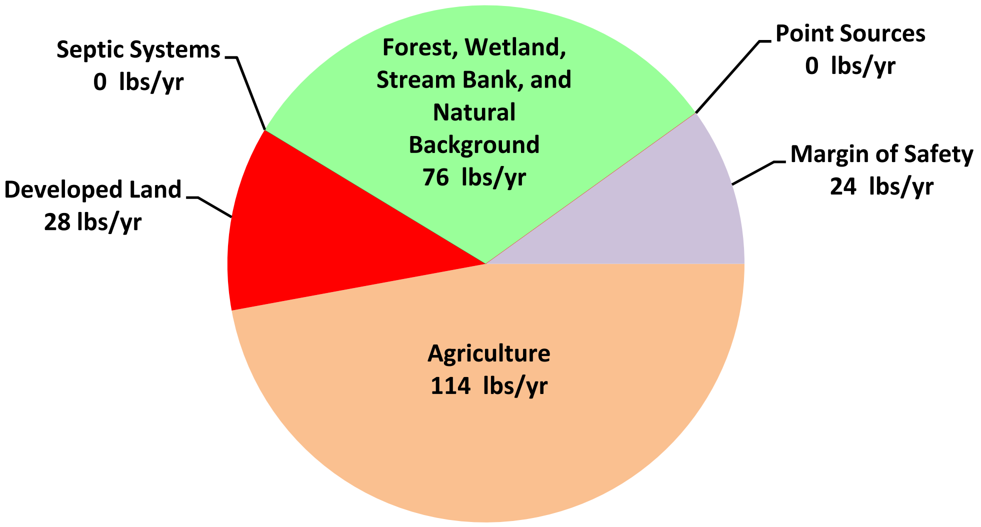
Table 6. Total Annual Phosphorus Load Allocations for Findley Lake[1]

Source	Total Phosphorus Load (lbs/yr)			% Reduction
	Current	Allocated	Reduction	
Agriculture	392	114	278	71%
Developed Land*	46	28	18	40%
Septic Systems	425	0	425	100%
Forest, Wetland, Stream Bank, and Natural Background	76	76	0	0%
LOAD ALLOCATION	**939**	**218**	**721**	**77%**
Point Sources	0	0	0	0%
WASTELOAD ALLOCATION	**0**	**0**	**0**	**0%**
LA + WLA	**939**	**218**	**721**	**77%**
Margin of Safety	---	24	--	---
TOTAL	**939**	**242**	**721**	**77%**

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

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

Figure 10. Total Phosphorus Load Allocations for Findley Lake (lbs/yr)



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 2002, The State of Findley Lake report and the 2002, The Management of Findley Lake and its Watershed report. Coordination with state agencies, federal agencies, local governments, and stakeholders such as Findley Lake Property Owners Inc. (FLPO), Findley 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 recommendations summarized in The State of Findley Lake report and the Management of Findley Lake and its Watershed report, 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 significant reductions from agricultural and developed lands. Meeting the necessary load reductions using this approach is the most technically achievable alternative. However, all of the reductions would be voluntary, so funding and public acceptance of this approach is essential to meeting the goals of the TMDL.

7.1.1. *Recommended Phosphorus Management Strategies for Septic Systems*

Due to the fact that septic systems are a major source of loading in the Findley Lake Watershed, restoration depends on elimination of that source. A systematic approach, such as the formation of a sanitary sewer district and discharge of treated wastewater outside of the watershed, is essential to achieving the load reductions specified above.

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 Non-point 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.

Chautauqua County Soil and Water Conservation District should continue to implement the AEM program on all 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 on any cropland where this is not already being done. This action was also recommended in The Management of Findley Lake and its Watershed report. Additional practices could be fully implemented in Tier 4 to reduce phosphorus loads, such as conservation tillage, stream fencing, rotational grazing and cover crops.

Although additional management practices could further reduce phosphorus loads from cropland, management practices alone could not achieve the load allocation for agriculture. Conversion of a significant portion of the cropland to hayland or conservation easements would be needed. Targeting these conversions to highly erodible land and riparian buffers would yield the best reductions. 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 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 Findley 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 Management of Findley Lake and its watershed 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.
- Construction site and post construction stormwater runoff control ordinance and inspection and enforcement programs.
- Pollution prevention practices for road and ditch maintenance.
- Management practices for the handling, storage and use of roadway deicing products

7.1.4. *Additional Protection Measures*

Measures to further protect water quality and limit the growth of phosphorus load that would otherwise offset load reduction efforts, as outlined in The Management of Findley Lake and its Watershed reports 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 tributaries and promote smart growth. 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. Findley Lake will be sampled at its deepest location (approximately 12 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 DEC GIS system is updated (land use, BMPs, etc.), these updates will be applied to the input data for the BATHTUB and AVGWLF models. The information will be incorporated into the New York State 305(b) report as needed.

8.0 PUBLIC PARTICIPATION

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 USEPA approval.

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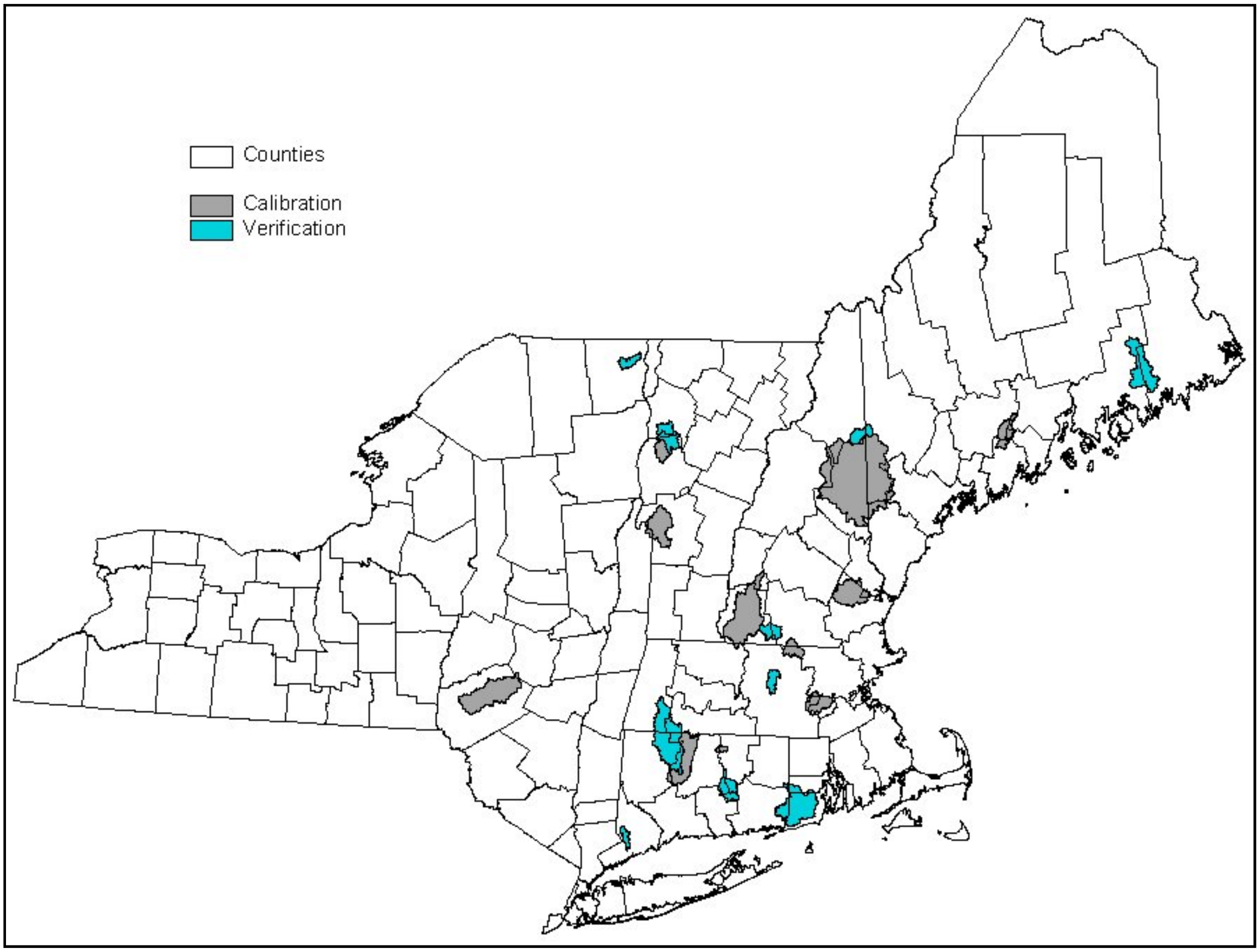
APPENDIX A. AVGWLF MODELING ANALYSIS

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 11). 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 11. 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 12.

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 12. Location of Physiographic Provinces in New York and New England

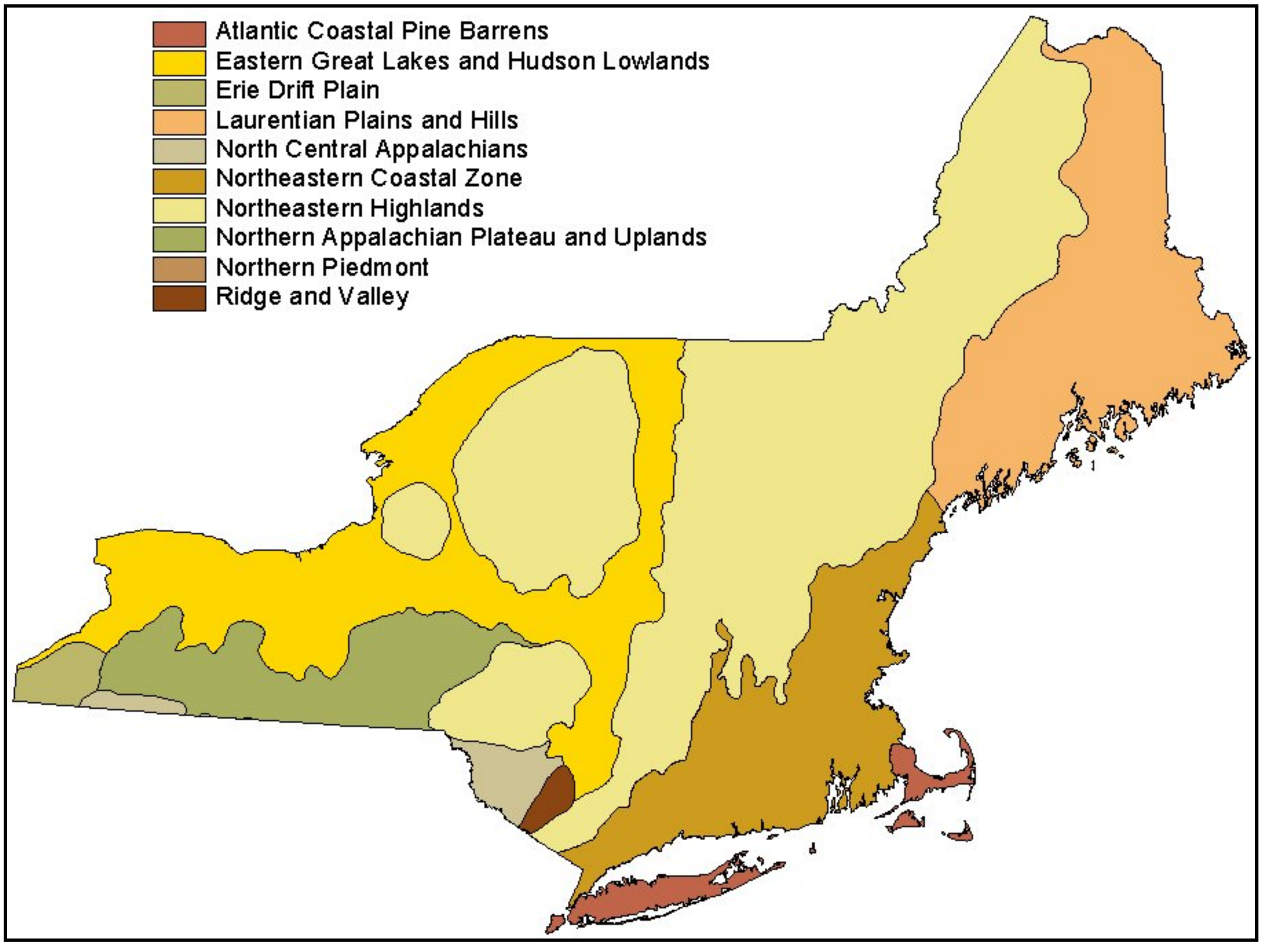


Table 7. AVGWLF Calibration Sites for use in the New York TMDL Assessments

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 Cobleskill, NY and Maryland, 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.

Confined Animal Feeding Operations (CAFOs)

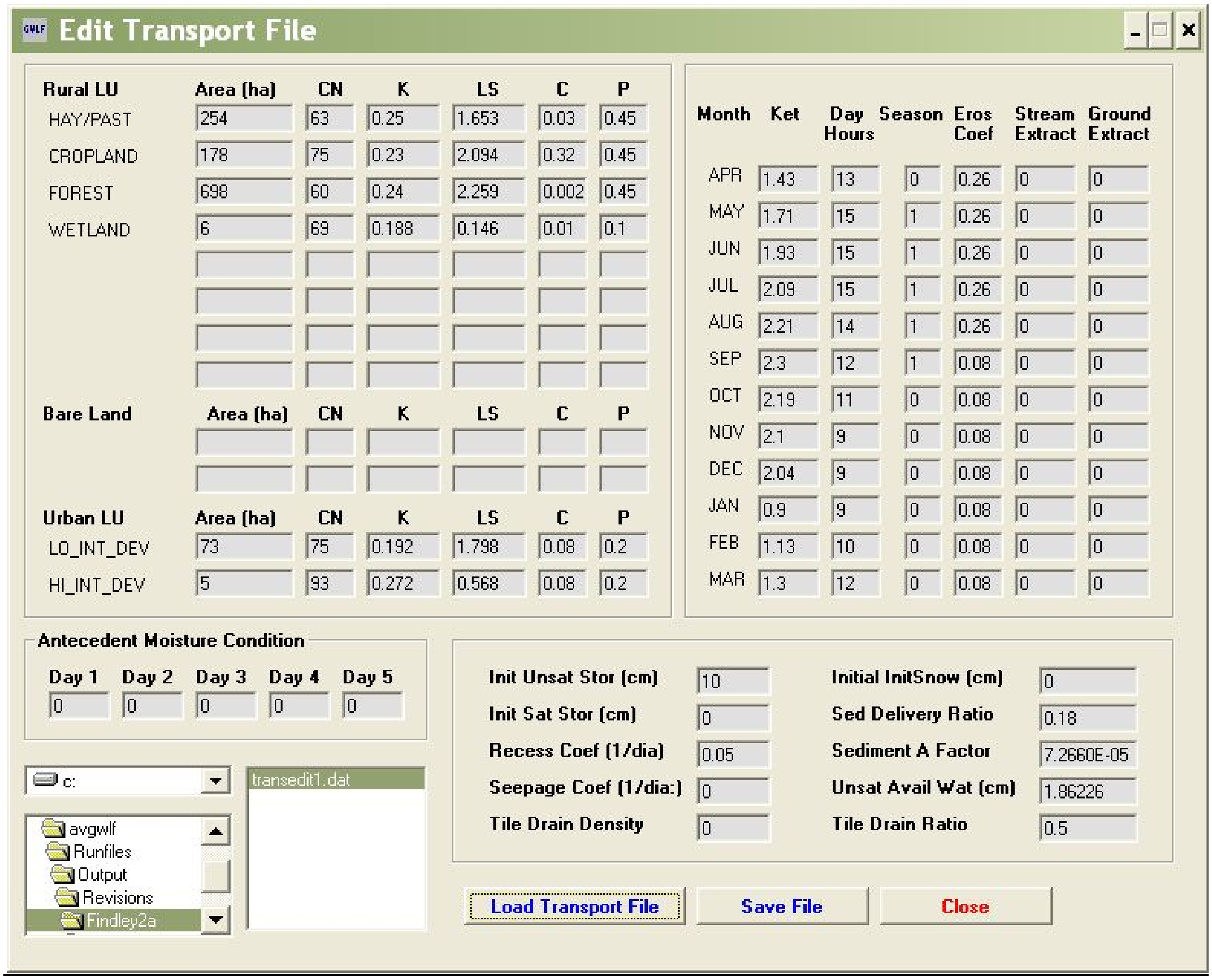
A state-wide Confined Animal Feeding Operation (CAFO) shapefile was provided by NYS DEC. CAFOs are categorized as either large or medium. The CAFO point can represent either the centroid of the farm or the entrance of the farm, therefore the CAFO point is more of a general gauge as to where further information 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 (2003-2007)

Input Transport File



Edit Transport File

Rural LU	Area (ha)	CN	K	LS	C	P
HAY/PAST	254	63	0.25	1.653	0.03	0.45
CROPLAND	178	75	0.23	2.094	0.32	0.45
FOREST	698	60	0.24	2.259	0.002	0.45
WETLAND	6	69	0.188	0.146	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	73	75	0.192	1.798	0.08	0.2
HI_INT_DEV	5	93	0.272	0.568	0.08	0.2

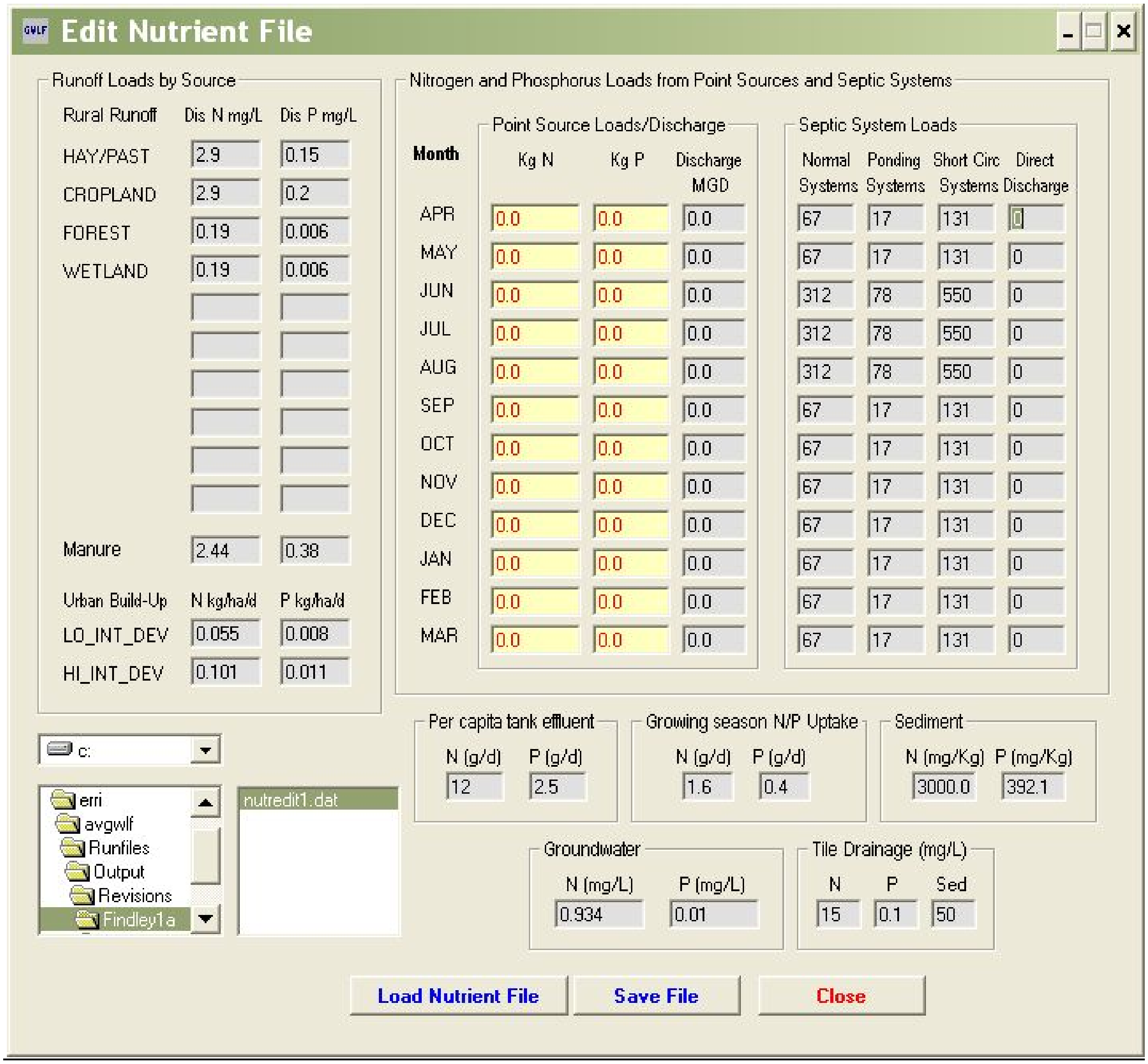
Month	Ket	Day Hours	Season	Eros Coef	Stream Extract	Ground Extract
APR	1.43	13	0	0.26	0	0
MAY	1.71	15	1	0.26	0	0
JUN	1.93	15	1	0.26	0	0
JUL	2.09	15	1	0.26	0	0
AUG	2.21	14	1	0.26	0	0
SEP	2.3	12	1	0.08	0	0
OCT	2.19	11	0	0.08	0	0
NOV	2.1	9	0	0.08	0	0
DEC	2.04	9	0	0.08	0	0
JAN	0.9	9	0	0.08	0	0
FEB	1.13	10	0	0.08	0	0
MAR	1.3	12	0	0.08	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	0.18
Recess Coef (1/dia)	0.05	Sediment A Factor	7.2660E-05
Seepage Coef (1/dia:)	0	Unsat Avail Wat (cm)	1.86226
Tile Drain Density	0	Tile Drain Ratio	0.5

Input Nutrient File



Runoff Loads by Source

Rural Runoff	Dis N mg/L	Dis P mg/L
HAY/PAST	2.9	0.15
CROPLAND	2.9	0.2
FOREST	0.19	0.006
WETLAND	0.19	0.006
Manure	2.44	0.38
Urban Build-Up	**N kg/ha/d**	**P kg/ha/d**
LO_INT_DEV	0.055	0.008
HI_INT_DEV	0.101	0.011

Nitrogen and Phosphorus Loads from Point Sources and Septic Systems

	Point Source Loads/Discharge			Septic System Loads			
Month	Kg N	Kg P	Discharge MGD	Normal Systems	Ponding Systems	Short Circ Systems	Direct Discharge
APR	0.0	0.0	0.0	67	17	131	0
MAY	0.0	0.0	0.0	67	17	131	0
JUN	0.0	0.0	0.0	312	78	550	0
JUL	0.0	0.0	0.0	312	78	550	0
AUG	0.0	0.0	0.0	312	78	550	0
SEP	0.0	0.0	0.0	67	17	131	0
OCT	0.0	0.0	0.0	67	17	131	0
NOV	0.0	0.0	0.0	67	17	131	0
DEC	0.0	0.0	0.0	67	17	131	0
JAN	0.0	0.0	0.0	67	17	131	0
FEB	0.0	0.0	0.0	67	17	131	0
MAR	0.0	0.0	0.0	67	17	131	0

Per capita tank effluent

N (g/d)	P (g/d)
12	2.5

Growing season N/P Uptake

N (g/d)	P (g/d)
1.6	0.4

Sediment

N (mg/Kg)	P (mg/Kg)
3000.0	392.1

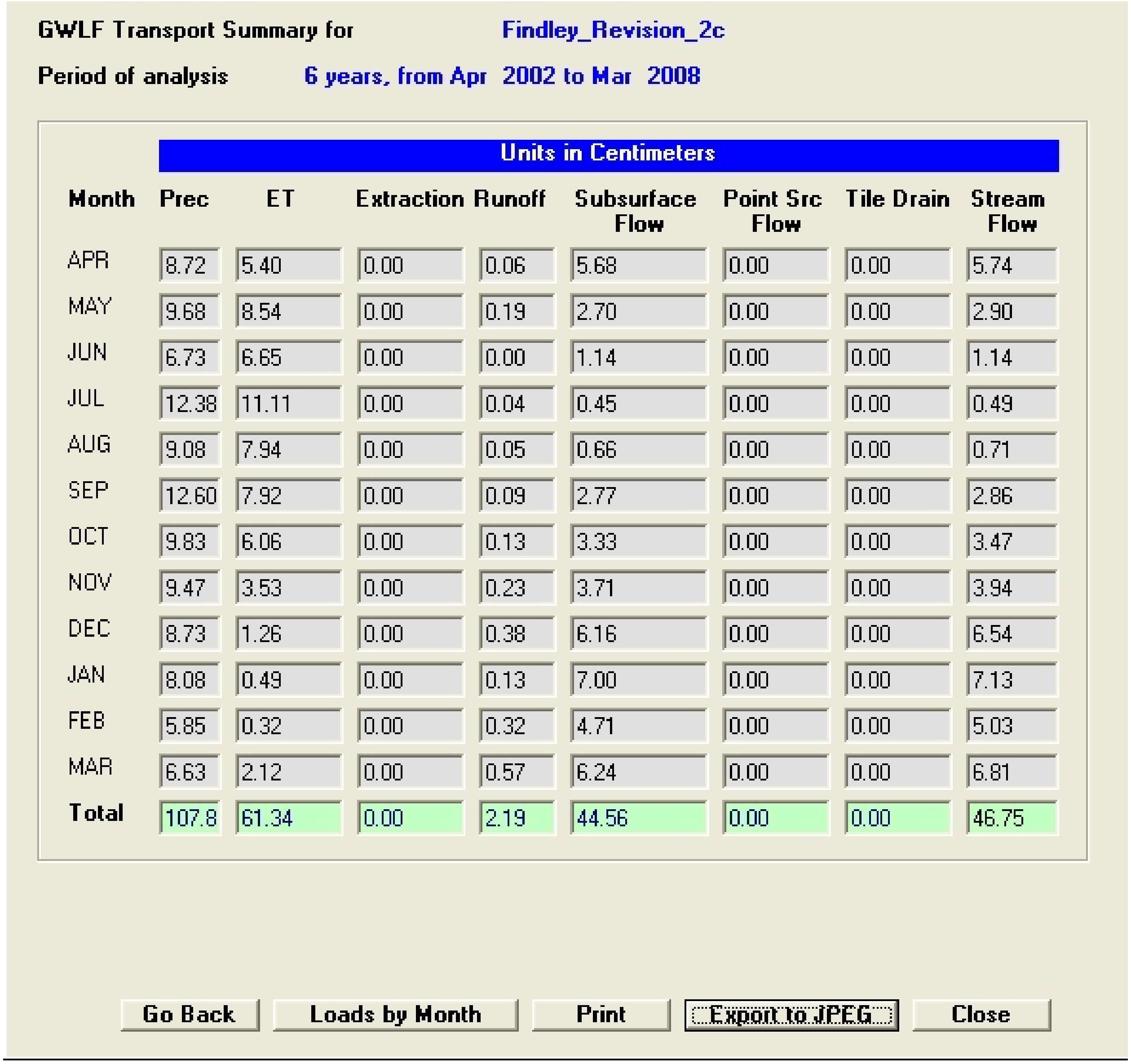
Groundwater

N (mg/L)	P (mg/L)
0.934	0.01

Tile Drainage (mg/L)

N	P	Sed
15	0.1	50

Simulated Hydrology Transport Summary



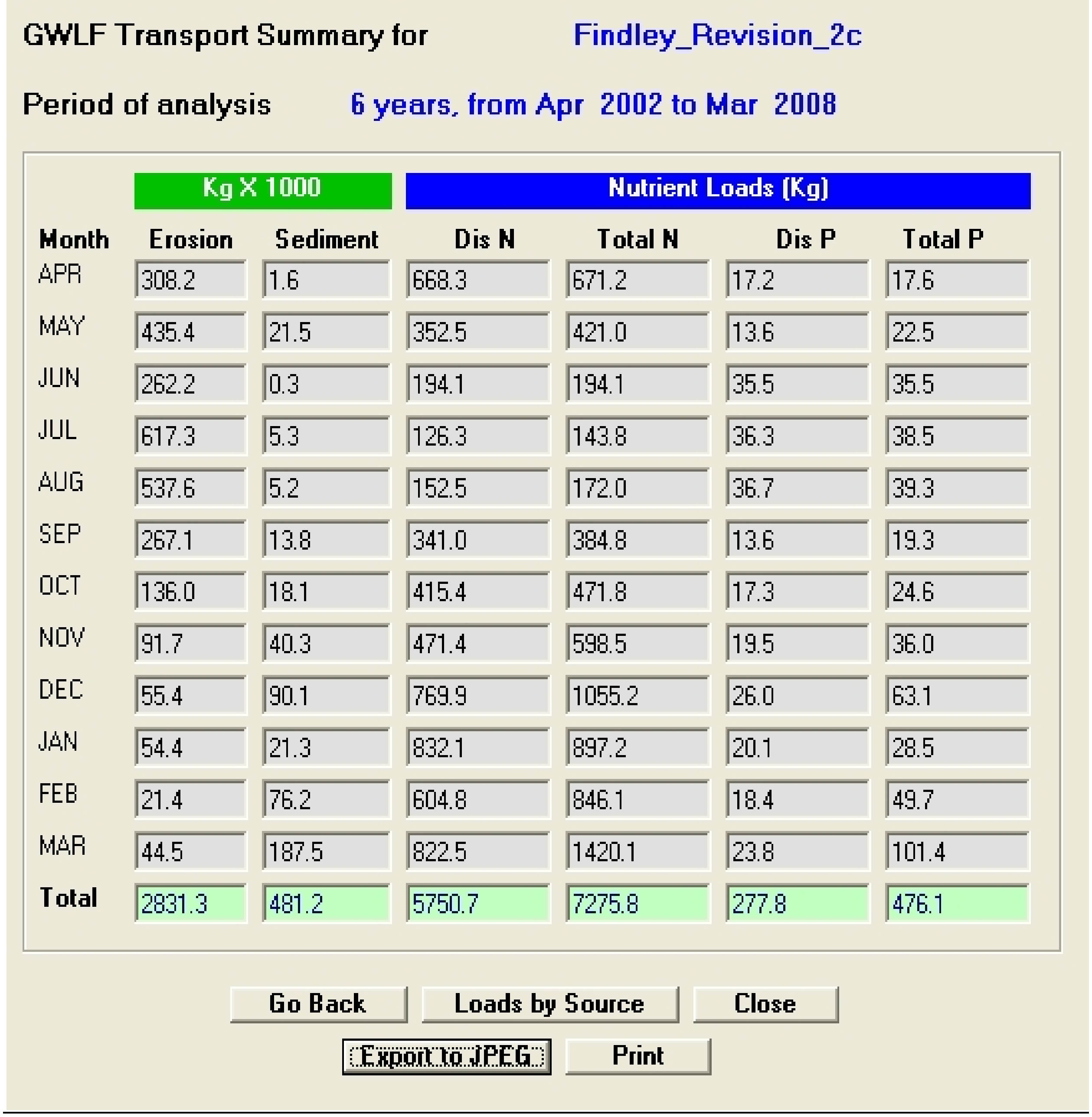
GWLF Transport Summary for Findley_Revision_2c

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	8.72	5.40	0.00	0.06	5.68	0.00	0.00	5.74
MAY	9.68	8.54	0.00	0.19	2.70	0.00	0.00	2.90
JUN	6.73	6.65	0.00	0.00	1.14	0.00	0.00	1.14
JUL	12.38	11.11	0.00	0.04	0.45	0.00	0.00	0.49
AUG	9.08	7.94	0.00	0.05	0.66	0.00	0.00	0.71
SEP	12.60	7.92	0.00	0.09	2.77	0.00	0.00	2.86
OCT	9.83	6.06	0.00	0.13	3.33	0.00	0.00	3.47
NOV	9.47	3.53	0.00	0.23	3.71	0.00	0.00	3.94
DEC	8.73	1.26	0.00	0.38	6.16	0.00	0.00	6.54
JAN	8.08	0.49	0.00	0.13	7.00	0.00	0.00	7.13
FEB	5.85	0.32	0.00	0.32	4.71	0.00	0.00	5.03
MAR	6.63	2.12	0.00	0.57	6.24	0.00	0.00	6.81
Total	107.8	61.34	0.00	2.19	44.56	0.00	0.00	46.75

Simulated Nutrient Transport Summary

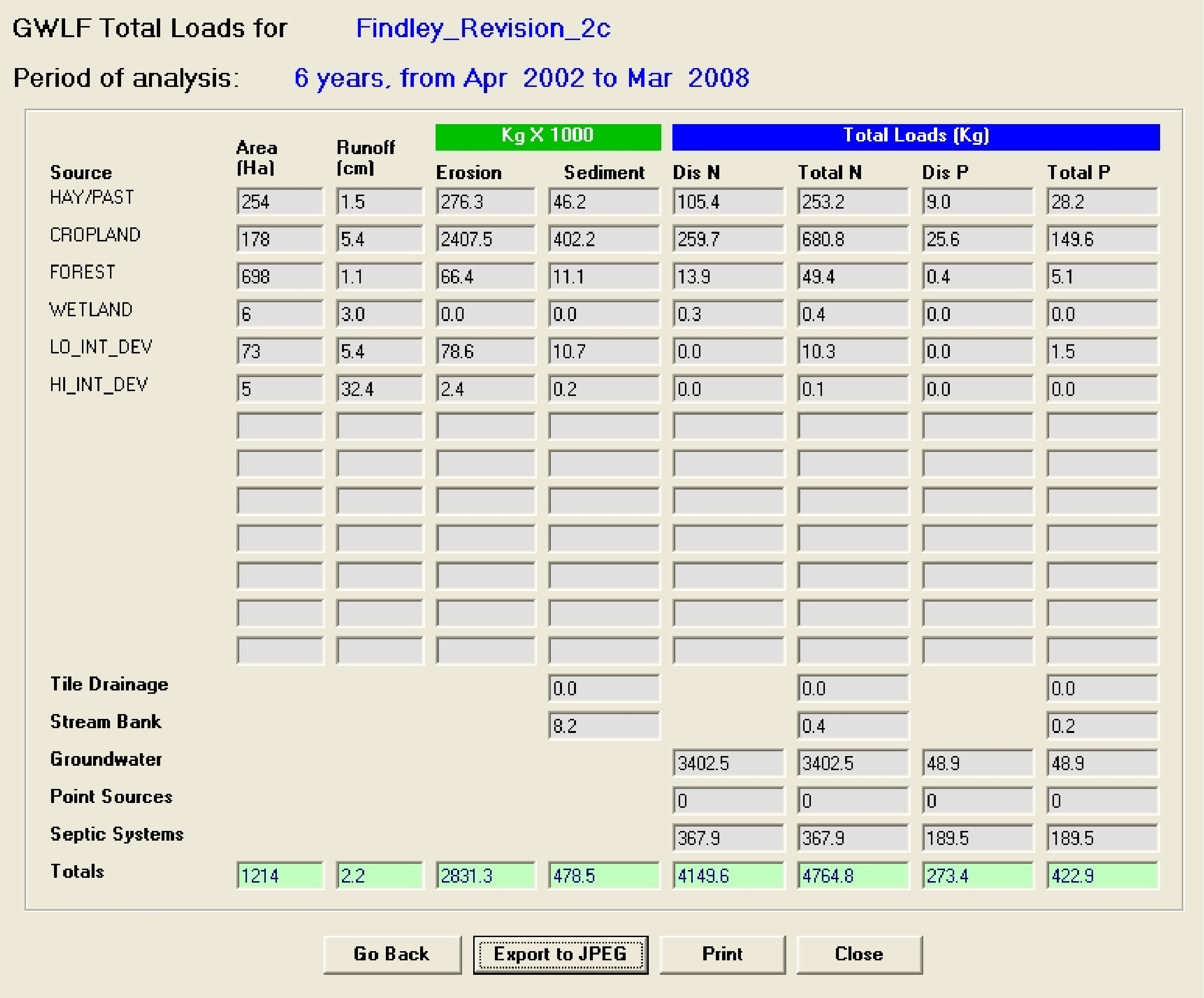


GWLF Transport Summary for Findley_Revision_2c

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	308.2	1.6	668.3	671.2	17.2	17.6
MAY	435.4	21.5	352.5	421.0	13.6	22.5
JUN	262.2	0.3	194.1	194.1	35.5	35.5
JUL	617.3	5.3	126.3	143.8	36.3	38.5
AUG	537.6	5.2	152.5	172.0	36.7	39.3
SEP	267.1	13.8	341.0	384.8	13.6	19.3
OCT	136.0	18.1	415.4	471.8	17.3	24.6
NOV	91.7	40.3	471.4	598.5	19.5	36.0
DEC	55.4	90.1	769.9	1055.2	26.0	63.1
JAN	54.4	21.3	832.1	897.2	20.1	28.5
FEB	21.4	76.2	604.8	846.1	18.4	49.7
MAR	44.5	187.5	822.5	1420.1	23.8	101.4
Total	2831.3	481.2	5750.7	7275.8	277.8	476.1

Simulated Total Loads by Source



GWLF Total Loads for Findley_Revision_2c

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

			Kg X 1000		Total Loads (Kg)			
Source	**Area (Ha)**	**Runoff (cm)**	**Erosion**	**Sediment**	**Dis N**	**Total N**	**Dis P**	**Total P**
HAY/PAST	254	1.5	276.3	46.2	105.4	253.2	9.0	28.2
CROPLAND	178	5.4	2407.5	402.2	259.7	680.8	25.6	149.6
FOREST	698	1.1	66.4	11.1	13.9	49.4	0.4	5.1
WETLAND	6	3.0	0.0	0.0	0.3	0.4	0.0	0.0
LO_INT_DEV	73	5.4	78.6	10.7	0.0	10.3	0.0	1.5
HI_INT_DEV	5	32.4	2.4	0.2	0.0	0.1	0.0	0.0
Tile Drainage				0.0		0.0		0.0
Stream Bank				8.2		0.4		0.2
Groundwater					3402.5	3402.5	48.9	48.9
Point Sources					0	0	0	0
Septic Systems					367.9	367.9	189.5	189.5
Totals	1214	2.2	2831.3	478.5	4149.6	4764.8	273.4	422.9

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 Findley Lake and its surrounding drainage area, as well as output from AVGWLF, a BATHTUB model was set up for Findley Lake. Mean annual phosphorus loading to the lake was simulated using AVGWLF for the period 1990-2007. The TMDL for Findley Lake was developed using the long-term mean annual phosphorus loading to the lake for the period 2003-2007. 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 Findley Lake. 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 Findley 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 Cobleskill, NY and Maryland, NY National Weather Services Stations for the 2003-2007 period. Evapotranspiration was derived from AVGWLF using daily weather data (2003-2007) 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 USGS from a collection site at Mendon Ponds County Park, in

New York (Sherwood, 2005). Atmospheric deposition is not a major source of phosphorus loading to Findley 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 Findley Lake were represented using an average of the observed summer mean phosphorus concentrations for years 2003-2007. 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)	1	NA
Precipitation (meters)	1.078	0.2*
Evaporation (meters)	0.613	0.3*
Atmospheric Load (mg/m^2-yr)- Total P	75.48	0.5*
Atmospheric Load (mg/m^2-yr)- Ortho P	43.52	0.5*

* Default model choice

Table 11. BATHTUB Model Input: Lake Variables

Morphometry	Mean	CV
Surface Area (km^2)	1.2	NA
Mean Depth (m)	3.3	NA
Length (km)	1.998	NA
Estimated Mixed Depth (m)	3.3	0.12
Observed Water Quality	**Mean**	**CV**
Total Phosphorus (ppb)	35.76	0.5

* Default model choice

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

Monitored Inputs	Mean	CV
Total Watershed Area (km^2)	12.14	NA
Flow Rate (hm^3/yr)	5.68	0.1
Total P (ppb)	75.05	0.2
Organic P (ppb)	48.71	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 Findley Lake are as follows:

Year	Observed	Simulated	T1	T2	T3
1990	47	39	0.37	0.69	0.34
1991	60	45	0.61	1.13	0.56
1992	24	36	-0.82	-1.53	-0.76
1993	46	37	0.45	0.83	0.41
1994	31	40	-0.53	-0.99	-0.49
1995	47	38	0.38	0.71	0.36
1996	24	38	-0.95	-1.76	-0.88
1997	26	39	-0.81	-1.51	-0.75
1998	59	45	0.55	1.03	0.51
1999	56	46	0.38	0.70	0.35
2000	26	43	-0.99	-1.85	-0.91
2003	19	40	-1.46	-2.71	-1.34
2004	21	37	-1.14	-2.12	-1.06
2005	50	40	0.46	0.86	0.43
2006	34	37	-0.19	-0.35	-0.18
2007	55	36	0.83	1.54	0.77
Average (03-07)	36	38	-0.14	-0.26	-0.13

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 Findley 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/yr)			% Reduction
	Current	Allocated	Reduction	
Agriculture*	1.1	0.3	0.8	71%
Developed Land*	0.1	0.1	0.1	40%
Septic Systems	1.2	0.0	1.2	100%
Forest, Wetland, Stream Bank, and Natural Background	0.2	0.2	0.0	0%
LOAD ALLOCATION	**2.6**	**0.6**	**2.0**	**77%**
Point Sources	0.0	0.0	0.0	0%
WASTELOAD ALLOCATION	**0.0**	**0.0**	**0.0**	**0%**
LA + WLA	**2.6**	**0.6**	**2.0**	**77%**
Margin of Safety	---	0.1	---	0%
TOTAL	**2.6**	**0.7**	**2.0**	**77%**

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