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

Putnam County, New York

June 2016

Prepared for:

U.S. Environmental Protection Agency
Region 2
290 Broadway
New York, NY 10007

Prepared by:

NYSDEC
Bureau of Water Resource Management

TABLE OF CONTENTS

FIGURES

TABLES

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 can receive 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

Lake Carmel (WI/PWL ID 1302-0006) is located in the Town of Kent, in Putnam County, New York (Figure 1). Over the past few decades, the lake water quality has declined and has affected the lake's recreational and aesthetic value. Lake Carmel was listed on the Lower Hudson River Basin PWL in 2002 (NYS DEC, 2002).

Data collected by DEC and its monitoring programs indicated eutrophic (i.e. characterized by nutrient enrichment, such as phosphorus, leading to excessive plant growth) conditions in Lake Carmel. The concentration of phosphorus in the lake exceeded 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 (see Figure 6 for Summer Mean Epilimnetic Total Phosphorus Levels in Lake Carmel). In 2004, Lake Carmel was added to the New York State Department of Environmental Conservation (NYS DEC) CWA Section 303(d) list of impaired waterbodies as recreation is impaired due to algal/weed growth and nutrients, specifically phosphorus as the lake does not meet New York's water quality guidance value for phosphorus. Based on this listing, a TMDL for phosphorus is being developed for the lake to address the impairment.

According to information provided by watershed residents who attended a public meeting on July 29, 2014, the lake is used for the following: swimming, boating, fishing, and its aesthetic value. About half of the residents said they were able to use the lake the way they wanted while the other half indicated either "no", "yes and no", or "did not use the lake". Watershed residents expressed concerns about water clarity, sedimentation, stormwater runoff, and nutrient pollution to Lake Carmel.

In August 2014 and again in July 2015, the Putnam County Department of Health closed several beaches in the Lake Carmel Park District after visual tests showed an abundance of blue-green algae. As of the writing of this TMDL, the Town intends to apply copper sulfate to the lake as a temporary solution; officials are seeking longer-term alternatives to treat the water. While reporting on the beach closure, a news reporter noticed "a strong smell of sewage" at Lake Carmel's Beach 3.

A variety of sources of phosphorus are contributing to the reduced water quality in Lake Carmel. The water quality of the lake is influenced by runoff from the watershed and input from nearby residential septic systems. Runoff from the watershed is caused by precipitation. Nutrients, such as phosphorus (naturally found in New York soils) enter the lake from the surrounding watershed by way of streams, overland flow, and subsurface (groundwater) flow. The nutrients are deposited and stored in the lake bottom sediments and used by aquatic plants to grow.

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, excessive weed growth, and reduced water clarity which impacts the ecology, aesthetics, and recreational uses of a lake. This may also affect the economy of the community within the watershed.

2.0 WATERSHED AND LAKE CHARACTERIZATION

2.1. Watershed Characterization

Lake Carmel has a watershed of 8,150 acres (Figure 1). Watershed elevations range from 1,332 feet above mean sea level (AMSL) to 619 feet AMSL at the lake surface. Existing land use and land cover in the Lake Carmel watershed was determined from digital aerial photography and geographic information system (GIS) datasets, and field-verified by Department staff. Digital land use/land cover data were obtained from the 2006 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 watershed to reflect current conditions in the watershed (Figure 2). Appendix A provides additional detail about the refinement of land use for the watershed. Land use categories (including individual category acres and percent of total) in Lake Carmel's watershed are listed in Table 1 and presented in Figures 3 and 4.

Figure 1: Lake Carmel Watershed

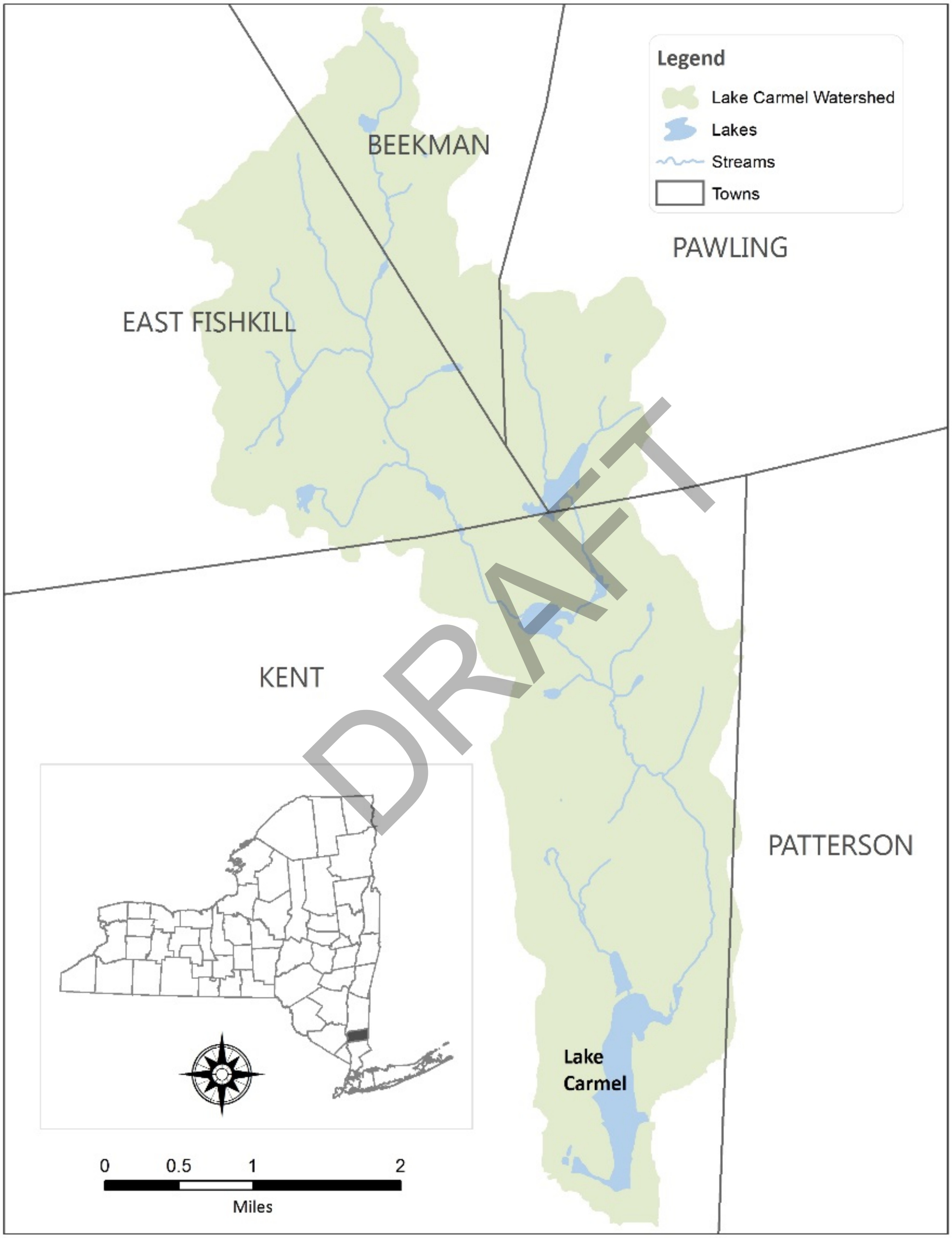


Figure 2: Aerial Image of Lake Carmel

Figure 3: Percent Land Use in the Lake Carmel Watershed

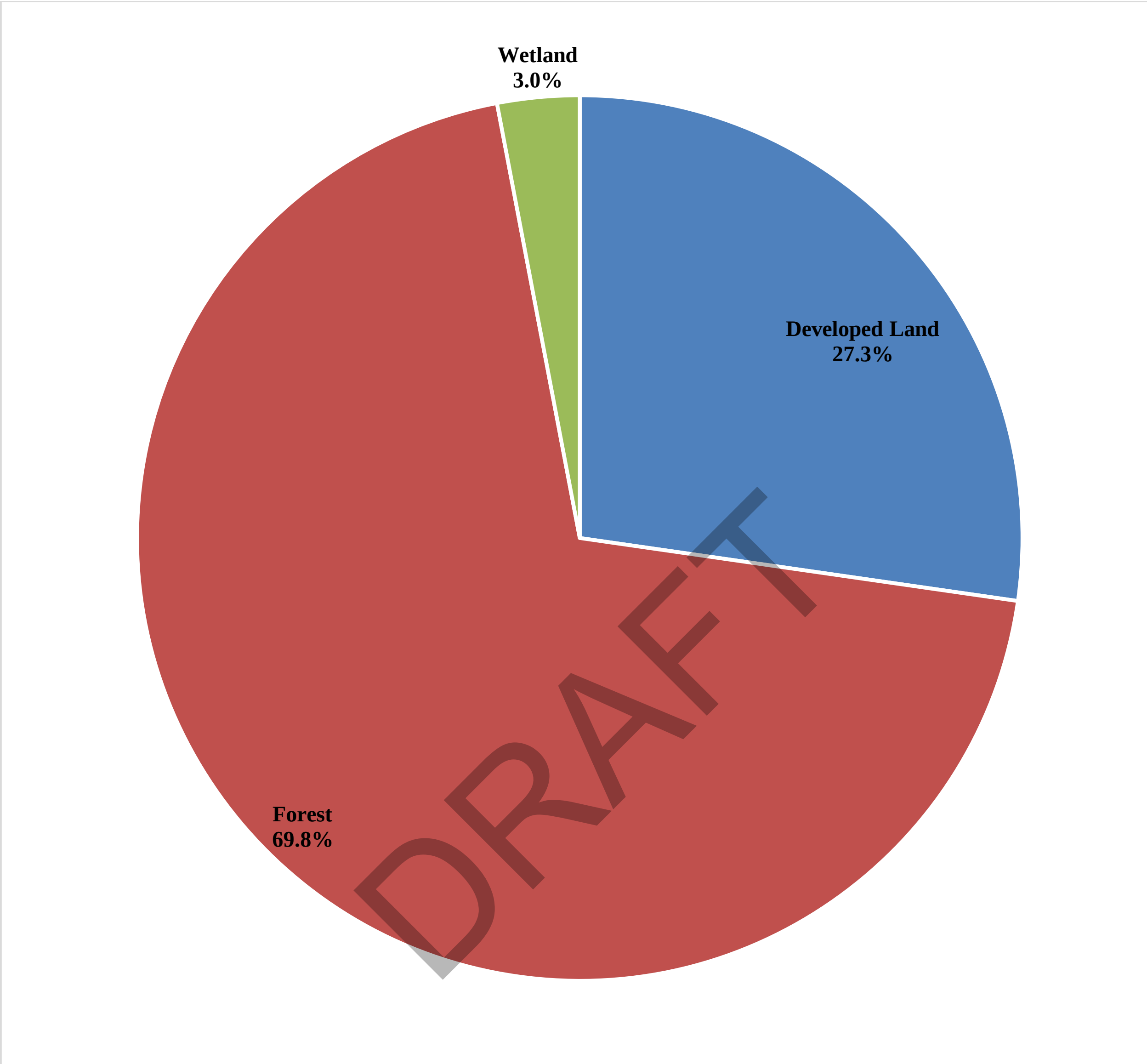
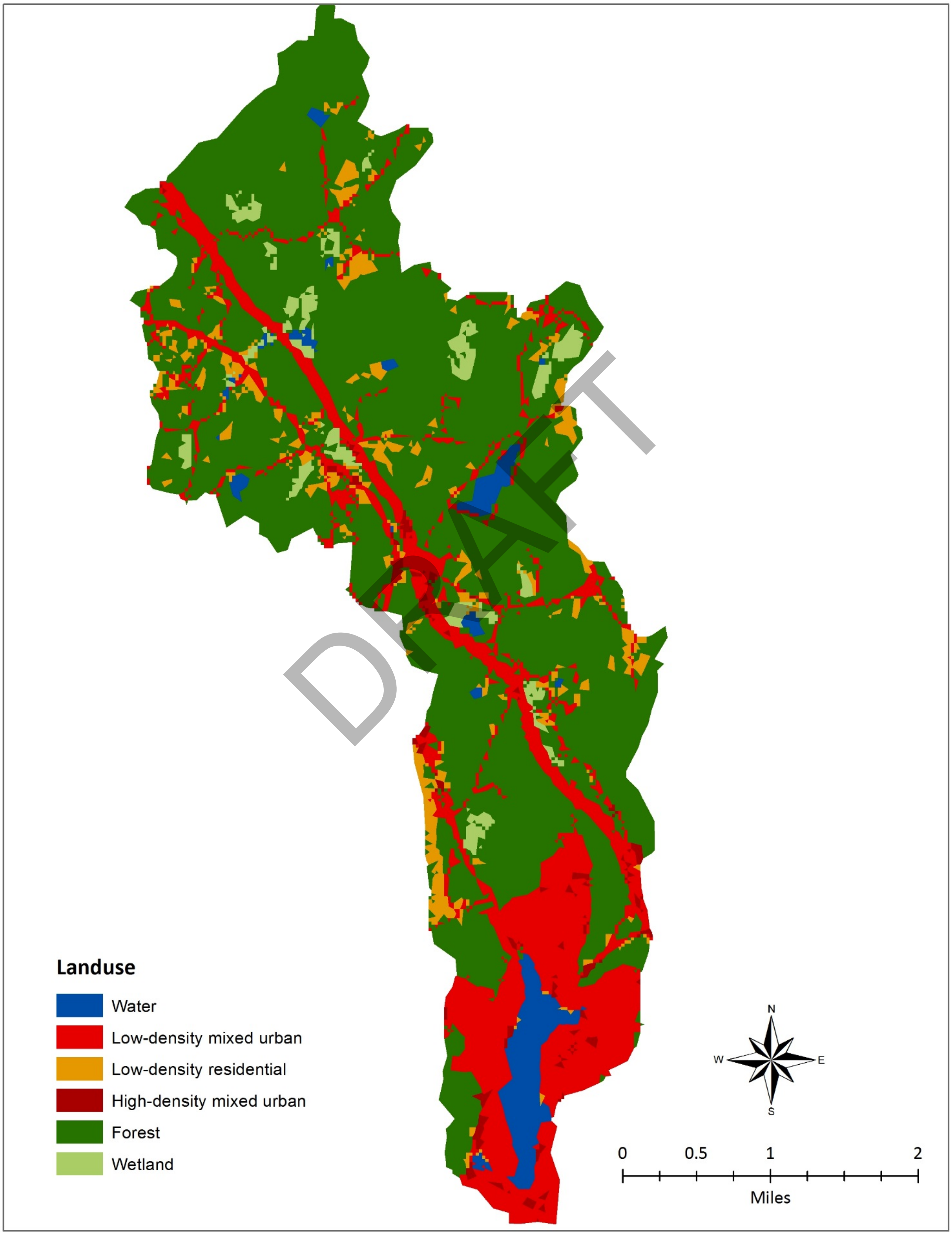


Table 1: Land Use in the Lake Carmel Watershed

Land Use Category	Acres	% of Watershed
Developed Land	2,135	27.3%
Low Intensity	2,026	25.9%
High Intensity	109	1.4%
Forest	5,461	69.8%
Wetlands	232	3.0%
Total	7,828	100%

Figure 4: Land Use in the Lake Carmel Watershed



2.2. Lake Morphometry

Lake Carmel is a 186 acre lake at an elevation of approximately 619 feet AMSL. Figure 5 shows a bathymetric map for Lake Carmel based on data collected during the summer of 2007. Table 2 summarizes key morphometric characteristics for Lake Carmel.

Figure 5: Bathymetric Map of Lake Carmel

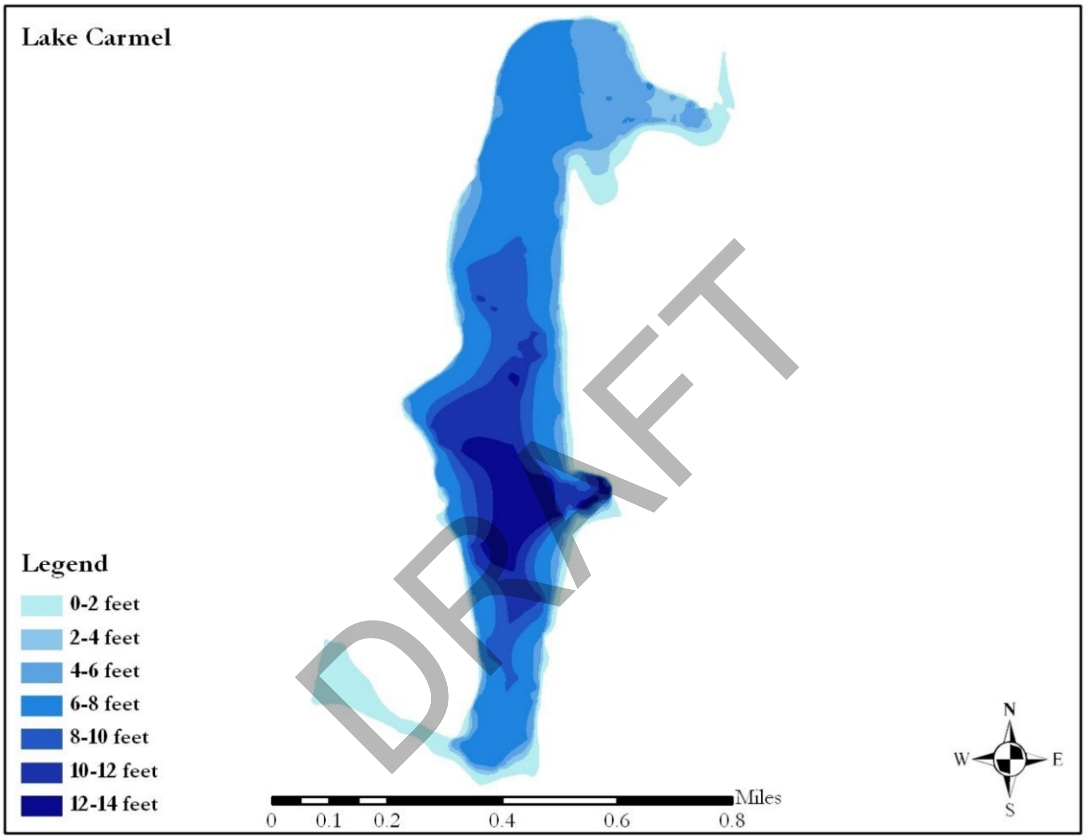


Table 2: Lake Carmel Characteristics

Surface Area (acres)	186
Elevation (ft AMSL)	619
Maximum Depth (ft)	14
Mean Depth (ft)	7
Length (ft)	7,093
Width at widest point (ft)	2,266
Shoreline perimeter (miles)	4.5
Direct Drainage Area (acres)	8,150
Watershed: Lake Ratio	44:1
Mass Residence Time (days)	26
Hydraulic Residence Time (days)	25

2.3. Water Quality

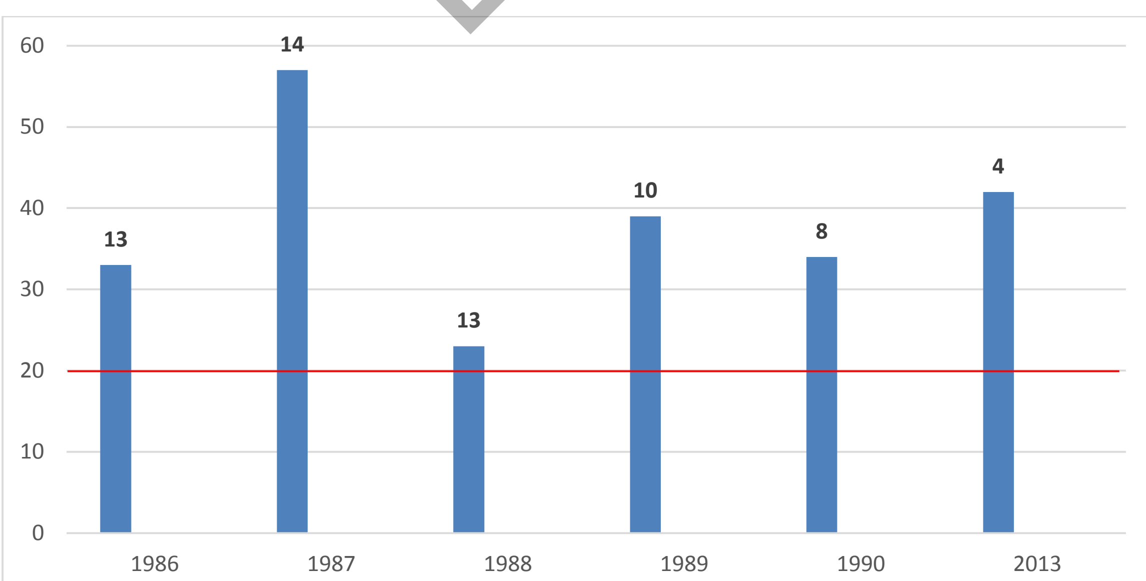
Water quality data was collected from Lake Carmel through the Citizen Statewide Lake Assessment Program (CSLAP) by trained volunteers during the summers of 1986-1990 and by DEC staff during the summer of 2013. Public perception of the lake indicates recreational suitability to be very unfavorable, and is described as "substantially" impacted. The lake is described as not supporting recreational uses ("recreation impossible"). Assessments have noted that aquatic plants grow very close to the surface and are very dense. (DEC/DOW, BWAM, CSLAP, 1996).

The concentration of phosphorus in the lake exceeded the state guidance value for phosphorus (20 µg/L or 0.020 mg/L, applied as the mean summer, epilimnetic (the layer of water above the thermocline) total phosphorus concentration, indicating eutrophic conditions in Lake Carmel. Figure 6 shows the summer mean epilimnetic phosphorus concentrations for phosphorus data collected during all sampling seasons.

NYS DEC's CSLAP is a cooperative volunteer monitoring effort between NYS DEC and the New York Federation of Lake Associations (FOLA). For more information about CSLAP, what water quality parameters are collected and how the data is used, visit DEC's CSLAP web page. http://www.dec.ny.gov/chemical/81576.html).

Information collected from Lake Carmel watershed residents at the informational session on July 29, 2014 supports that lake uses have been impaired by nutrients. Watershed residents identified weeds, algae and mucky bottom as impediments to lake use. However, some residents still use the lake for swimming, boating, fishing and its aesthetic value.

Figure 6: Summer Mean Epilimnetic Total Phosphorus Levels in Lake Carmel



Phosphorus Water Quality Target (20 ug /L). The numbers above the bars indicate the number of data points included in each summer's sampling

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 Lake Carmel is Class *B*, which means that the best usages of the lake are primary and secondary contact recreation (i.e., swimming and boating) and fishing. The lake must also be suitable for fish to reproduce and survive. New York State's narrative standard for nutrients is "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 advised that the epilimnetic summer average of total phosphorus levels in waters classified as ponded (i.e., lakes, reservoirs and ponds, excluding Lakes Erie, Ontario, and Champlain), should not exceed 20 µg/L based on biweekly sampling, conducted from June 1 to September 30. This guidance value of 20 µg/L is the TMDL target for Lake Carmel.

4.0 SOURCE ASSESSMENT

4.1. Models used to Analyze Phosphorus Contributions

The MapShed watershed model and the BATHTUB lake response model were used to develop the Lake Carmel TMDL. MapShed determines the mean annual phosphorus loading to the lake. BATHTUB defines how much this load must be reduced to meet the water quality target.

Within the MapShed program, the GWLF model developed by Haith and Shoemaker (1987) was used to simulate stormwater runoff and stream flow by a water-balance method based on measurements of daily precipitation and average air temperature from 1986 through 2013. The GWLF model is appropriate for this TMDL analysis because it simulates processes of concern, but does not have complex data requirements for calibration. Appendix A discusses the setup, calibration, and use of the MapShed model for lake TMDL assessments in New York.

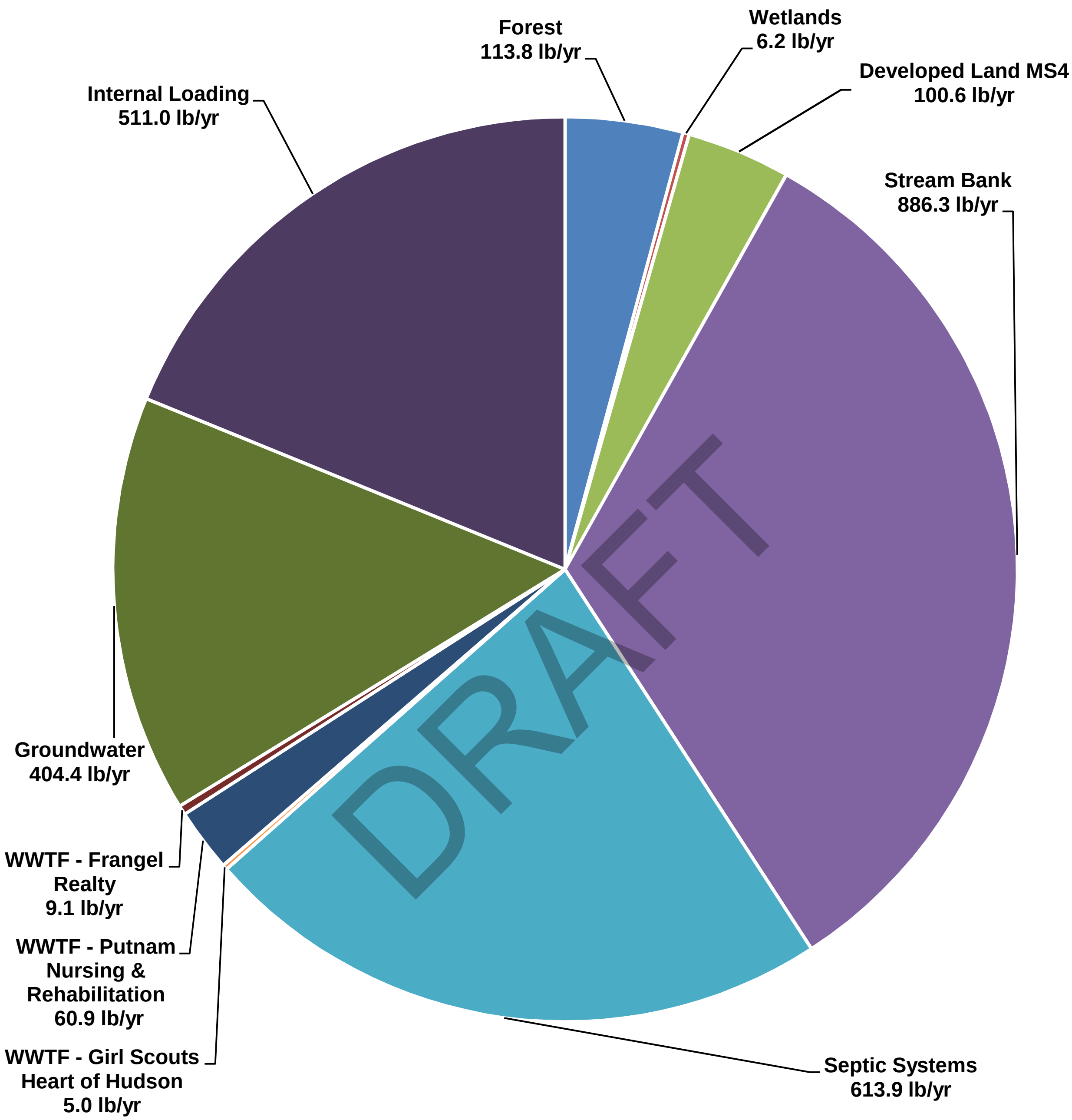
4.2. Sources of Phosphorus Loading

MAPSHED was used to estimate long-term (1986-2013) seasonal phosphorus (external) loading to Lake Carmel. The estimated mean growing season load of 2,711.2 lbs of total phosphorus that enters Lake Carmel comes from the sources listed in Table 3 and shown in Figure 7. Appendix A provides the detailed simulation results from MapShed.

Table 3: Estimated Sources of Phosphorus Loading to Lake Carmel

Source	Total Phosphorus (lb/yr)	Percent (%)
Stream Bank Erosion	886.3	32.6%
Wetland	6.2	0.2%
Forest	113.8	4.2%
Groundwater	404.4	14.9%
Septic Systems	613.9	22.6%
Internal Loading	511	18.8%
Putnam Nursing & Rehabilitation WWTF SPDES# NY0028924	60.9	2.2%
Girl Scouts Heart of Hudson WWTF SPDES #NY0102181	5.0	0.2%
Frangel Realty WWTF SPDES #	9.1	0.3%
MS4 Developed Land: T/Kent NYR20A346, T/Patterson NYR20A140, T/Pawling NYR20A472, T/Beekman NYR20A365, T/E. Fishkill, NYR20A183	100.6	3.7%
	2,711.2	**100%**

Figure 7: Estimated Sources of Total Phosphorus Loading to Lake Carmel



4.2.1. Residential On-Site Septic Systems

All houses in the Lake Carmel Watershed are served by private septic systems. Lake Carmel is intensely developed and many of the parcels are served by septic systems and individual wells on lots as small as 4,000 square feet. These houses were constructed originally as summer cottages, and like many lake side developments, have over the decades been converted to year-round residences. Additionally, many of the property owners have constructed additions, including increasing the number of bedrooms and bathrooms, and kitchen renovations including the addition of washing machines and dishwashers that discharge into their septic systems. Many of these septic systems manifest deficiencies during the wetter periods throughout the year. Residents report smelling effluent during the winter months while driving near the lake. Leaching of effluent upward from malfunctioning septic fields washes onto roads, nearby properties and streams by rainfall runoff, resulting in potential contamination of nearby shallow wells that are constructed near the lake front.

Residential on-site septic systems contribute an estimated 613.9 lb/yr of total phosphorus to Lake Carmel, which is 22.6% of the total loading to the lake. The introduction of phosphorus into lakes from septic systems is a major concern. While that source may not be the largest component of the total phosphorus load, the impacts can be substantial because it is in a soluble form, readily available to algae. The soluble phosphorous is immediately available to plants and algae, and would effectively fertilize a lake by orders of magnitude more than an equal amount entering from a fluvial source. Residential septic systems discharge dissolved phosphorus to nearby waterbodies when they malfunction. In properly functioning systems, phosphates are adsorbed and retained by the soil as the wastewater travels through the soil to the groundwater. A septic system may malfunction if there is not sufficient permeable soil for the wastewater to travel through. The wastewater may then discharge to the ground surface. These system malfunctions are characterized as “ponding”. A septic system in close proximity to surface waters may malfunction when the effluent is not sufficiently treated because the groundwater table is too shallow and/or there is insufficient separation distance from the septic system to the waterbody. The effluent from the septic system laterals may then discharge directly to groundwater, rather than being filtered through intermediary soil first. These system malfunctions are characterized as “short-circuiting”. Both of these types of septic system malfunctions can contribute high phosphorus loads to nearby waterbodies.

The Department used the proximity of septic systems to Lake Carmel to estimate septic system malfunction. This metric is consistent with other TMDLs developed for small lakes that have numerous lake front properties and reflects the conclusion that groundwater tables adjacent to waterbodies are typically too high to allow for the effective functioning of a septic system. Further support for this determination is contained in a recent near shore septic study by the Otsego Lake Watershed Council which determined a 50% malfunction rate for septic systems within 500 feet of Otsego Lake.

Using this metric, septic systems serving houses that are within 50 feet of Lake Carmel or a tributary of the lake were categorized as short-circuiting. For houses between 50 and 250 feet of Lake Carmel or a tributary of the lake, 25% of the septic systems were categorized as short-circuiting and 10% were categorized as ponding systems. Analysis of orthoimagery for the Lake Carmel watershed shows 38 houses within 50 feet of Lake Carmel or a tributary of the lake and 316 houses between 50 and 250 feet of Lake Carmel or a tributary of the lake; all of these houses are assumed to have septic systems. To convert the estimated number of septic systems to the population served, an average household size of 2.6 people per dwelling was used based on the 2010 United States Census Bureau estimate for number of persons per household in New York State. To account for seasonal variations in population, information obtained from the Town of Kent was used. Approximately 98% of the homes around the lake are reported to be year-round residences, while 2% are seasonally occupied (i.e., June through August only). The estimated population in the Lake Carmel watershed served by normal and malfunctioning systems is summarized in Table 4.

Table 4: Residences Served by Septic Systems

	Normally Functioning	Ponding	Short Circuiting	Total
September - May	3,368	31	117	3,446
June - August	3,468	31	117	3,516

4.2.2. Point Source Discharges

There are three permitted wastewater treatment facility (WWTF) dischargers in the Lake Carmel watershed. The combined design flow of the three WWTPs is 26,260 gallons per day. The phosphorus discharge limits of these three WWTFs are currently 1.0 mg/l each, per NYC Watershed Rules and Regulations Additionally, all five Towns that comprise the Lake Carmel watershed are designated MS4s, because they are located within the larger, impaired, NYC East of Hudson Watershed. .

4.2.3. Urban and Residential Development Runoff

Developed land comprises 2,135 acres (27%) of the Lake Carmel watershed. Stormwater runoff from developed land contributes 100.6 lb/yr of phosphorus to Lake Carmel, which is 3.7% 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.

Phosphorus runoff from developed areas originates primarily from human activities. 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 watershed.

4.2.4. Forest Land Runoff

Forested land comprises 5,461 acres (70%) of the lake watershed. Runoff from forested land is estimated to contribute 113.8 lbs/yr of phosphorus loading to Lake Carmel, which is 4.2% 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 404.4 lbs/yr (14.9%) of the total phosphorus load to Lake Carmel. With respect to groundwater, there is typically a small "background" concentration from various natural sources. In the Lake Carmel watershed, 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 (255 lbs/yr) can be attributed to natural sources, including forested land and soils.

The remaining amount of the groundwater phosphorus load likely originates from developed land sources (i.e., leached in dissolved form from the surface). It is estimated that the remaining 170 lbs/yr of phosphorus transported to the lake through groundwater originates from developed land. Table 5 summarizes this information.

Table 5: Total Phosphorus Transported via Groundwater

	Total Phosphorus (lbs/yr)	% of Total Groundwater Load
Natural Sources	242.6	60%
Developed Land	161.8	40%
TOTAL	**404.4**	**100%**

4.2.6. Internal Loading

Lake Carmel is known to exhibit excessive aquatic plant growth and measurements have shown periods of low dissolved oxygen in the bottom waters of the lake. An internal load of 0.6 mg/m^2 /day of phosphorus was estimated using the BATHTUB lake model. This loading rate produced good agreement between the measured and modeled in-lake total phosphorus concentrations during the BATHTUB model calibration. This corresponds to a growing season load of 511 lb of phosphorus, or about 18.8% of the total.

4.2.7. Streambank Erosion

Two streams feed Lake Carmel: the Middle Branch Croton River and Stump Pond Stream. The source of the Middle Branch is a small pond just west of the Kent Town Hall across State Route 52. From there the stream runs along Route 52 in a southerly direction for approximately one mile before emptying into Lake Carmel. The source of Stump Pond

Stream is Ludington Lake in the Town of Beekman. From there Stump Pond Stream runs southerly for approximately seven miles, through Lake Dutchess, Browns Pond and Stump Pond before emptying into Lake Carmel.

The rate of streambank erosion is estimated in the Mapshed model by first calculating an average watershed-specific lateral erosion rate. This lateral erosion rate is a function of watershed slope, soil type and land use, all of which are calculated by region-specific data layers utilized by Mapshed. After the lateral erosion rate has been computed, the total sediment load generated via streambank erosion is calculated by multiplying the lateral erosion rate by the total length of streams in the watershed, an average streambank height, and an average soil bulk density value. Modeling of the Lake Carmel watershed indicates streambank erosion is a primary source of sedimentation and total phosphorus loading in Lake Carmel. The streambank erosion component of the total phosphorus load to Lake Carmel is estimated to be 886.3 lb/yr or 32.6% of the total watershed phosphorus loading.

4.2.8. Other Sources

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

5.0 DETERMINATION OF LOAD CAPACITY

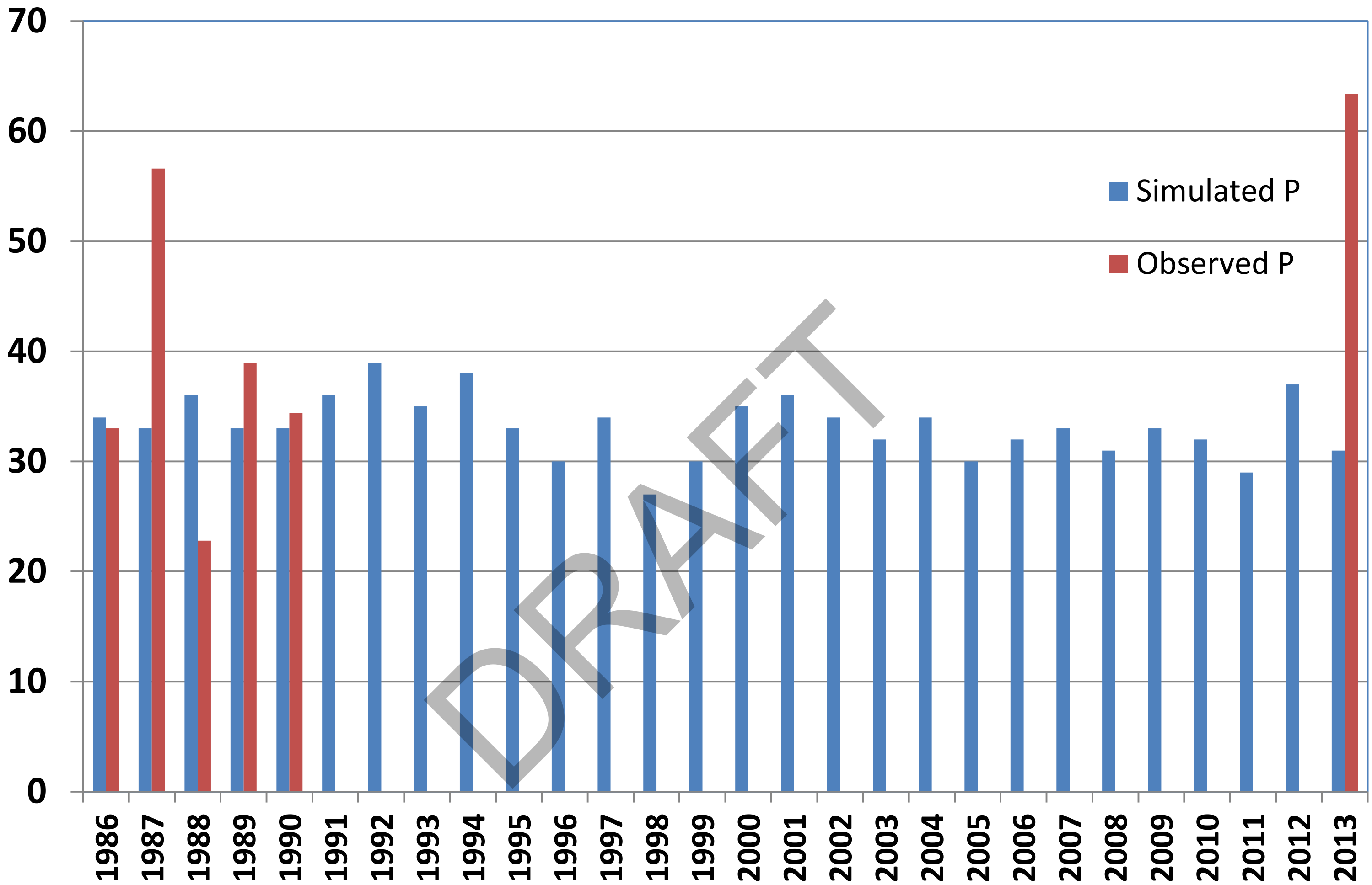
5.1. Lake Modeling Using the BATHTUB Model

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

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

In order to estimate the loading capacity of the lake, simulated phosphorus loads from MapShed were used to drive the BATHTUB model to predict water quality in Lake Carmel. MapShed was used to derive a mean annual phosphorus loading to the lake for the period 1990-2013. Using this load as input, BATHTUB was used to simulate water quality in the lake. The results of the BATHTUB simulation were compared against the lake's observed summer mean phosphorus concentration for 1986-1990 and 2013. In 1987 and 2013 the observed values were substantially higher than modeled values, however overall the modeled and observed values fit well. (See Table 13 in Appendix B, p. 53 for validation results showing 28 year simulated value within 97% of six years of monitoring data. The conclusion is that the combined use of MapShed and BATHTUB provides a decent fit to the observed data for Lake Carmel (Figure 8).

Figure 8: Observed vs. Modeled Average Phosphorus Concentrations (ug/l) in Lake Carmel



The BATHTUB model was used as a “diagnostic” tool to determine the total phosphorus load reduction required to achieve the phosphorus target of 20 µg/L. The loading capacity of Lake Carmel was determined by running BATHTUB iteratively, reducing the concentration of the watershed 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 MapShed.

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 Lake Carmel is a mean annual load of 1,230 lbs/yr. The daily TMDL 3.37 lbs/day was calculated by dividing the annual load by the number of days in a year. Lakes and reservoirs store phosphorus in the water column and sediment, therefore water quality responses are generally related to the total nutrient loading occurring over a year or season. For this reason, phosphorus TMDLs for lakes and reservoirs are generally calculated on an annual or seasonal basis. The use of annual loads, versus daily loads, is an accepted method for expressing nutrient loads in lakes and reservoirs. This is supported by EPA guidance such as *The Lake Restoration Guidance Manual* (USEPA 1990) and *Technical Guidance Manual for Performing Waste Load Allocations, Book IV, lakes and Impoundments, Chapter 2 Eutrophication* (USEPA 1986). While a daily load has been calculated, it is recommended that the annual loading target be used to guide implementation efforts since the annual load of total phosphorus as a TMDL target is more easily aligned with the design of best management practices (BMPs) used to implement nonpoint source and stormwater controls for lakes than daily loads. Ultimate compliance with water quality standards for the TMDL will be determined by measuring the lake's water quality to determine when the phosphorus guidance value is attained.

6.0 POLLUTANT LOAD ALLOCATIONS

The objective of a TMDL is to provide a basis for allocating acceptable loads among all of the known pollutant sources so that appropriate control measures can be implemented and water quality standards achieved. Individual waste load 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).

6.1. Wasteload Allocation (WLA)

<u>WWTF Dischargers:</u>

There are three permitted wastewater treatment facility (WWTF) dischargers in the Lake Carmel watershed. The combined design flow of the three WWTFs is 26,260 gallons per day.

Girl Scouts Heart of Hudson SPDES # NY0102181 is a seasonal facility operating between May 1 and October 31 and has a design flow of 3,260 GPD and discharge limit of 1.0 mg/l. The annual phosphorus load from this WWTF is 5.0 #/yr.

Putnam Nursing and Rehabilitation SPDES # NY0028924 has a design flow of 20,000 GPD and discharge limit of 1.0 mg/l. The annual phosphorus load from this WWTF is 60.9 #/yr.

Frangel Realty SPDES # NY0143863 has a design flow of 3,000 GPD and discharge limit of 1.0 mg/l. Effluent currently flowing to Frangel Realty WWTP has been diverted and is now being treated at Kent Manor WWTF in the Palmer Lake Watershed.

The current phosphorus discharge limits for the *Girl Scouts Heart of Hudson* and *Putnam*

Nursing and Rehabilitation WWTFs are 1.0 mg/l each, per NYC Watershed Rules and Regulations. The Department intends to modify the phosphorus discharge limits in the SPDES permits for Putnam Nursing and Rehabilitation WWTF to 0.2 mg/l, and for Girl Scouts Heart of Hudson WWTF to 0.4 mg/l.

<u>MS4s</u>

The Lake Carmel Watershed is located in five towns, Carmel, Patterson, East Fishkill, Pawling and Beekman, all of which are designated MS4s. As part of this designation, the Towns are subject to the MS4 Permit "Heightened Requirements" because they are located in the NYC East of Hudson (Middle Branch Reservoir) Watershed. As noted in Section 7, these MS4s are subject to reductions resulting from the Middle Branch TMDL. The TMDL assumes a 10% reduction in MS4 developed land phosphorus loading because of implementation of the MS4 Permit requirements, including the enhanced MS4 permit requirement that all septic systems in the MS4 be inspected and tanks pumped once every five years and, where necessary, repaired. Additional reductions in developed land can be anticipated due to implementation of the Nutrient Runoff Law, which restricts the use of lawn fertilizer and prohibits phosphorus in dishwashing detergents sold in NY State.

An enhanced surveying and testing program, above and beyond the requirements of the MS4 Permit requirements, could be implemented to document the location of septic systems and verify failing systems, requiring replacement in accordance with the NY State Sanitary Code. Property owners should be educated on proper maintenance of their septic systems and encouraged to make preventative repairs.

6.2. Load Allocation (LA)

Nonpoint sources that contribute total phosphorus to Lake Carmel include malfunctioning septic systems, stream bank erosion, groundwater, open land, forest and wetlands.

Table 6 lists the current loading for each source and the load allocation needed to meet the TMDL; Figure 9 provides a graphical representation of this information. Phosphorus originating from the natural sources mentioned above (including forested land and wetlands) 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.

The largest loads are from Internal Loading, Streambank Erosion and Septic Systems, and the TMDL can be met only with substantial reduction or elimination of these loads.

Septic systems contributing phosphorus to the lake should be sewered, which will reduce the loading completely if the WWTF discharges to the outlet of the lake or outside of the Lake Carmel watershed. The TMDL calls for the sewering of the near lake properties and the discharge of the wastewater treatment facility effluent to the outlet of the lake, in order to completely eliminate the septic load from the lake.

After reducing the waste load allocation to the maximum extent possible, and allowing for a margin of safety, the remaining Load Allocation is 1,002.4 lbs/yr. The Stream Bank Erosion allocation is 478 lb/yr. Internal loads were allocated in Lake Carmel under the assumption that the internal load will decrease proportionally to decreases in external loads, and are set at zero. The Septic load will be eliminated once the near lake properties are connected to a WWTF.

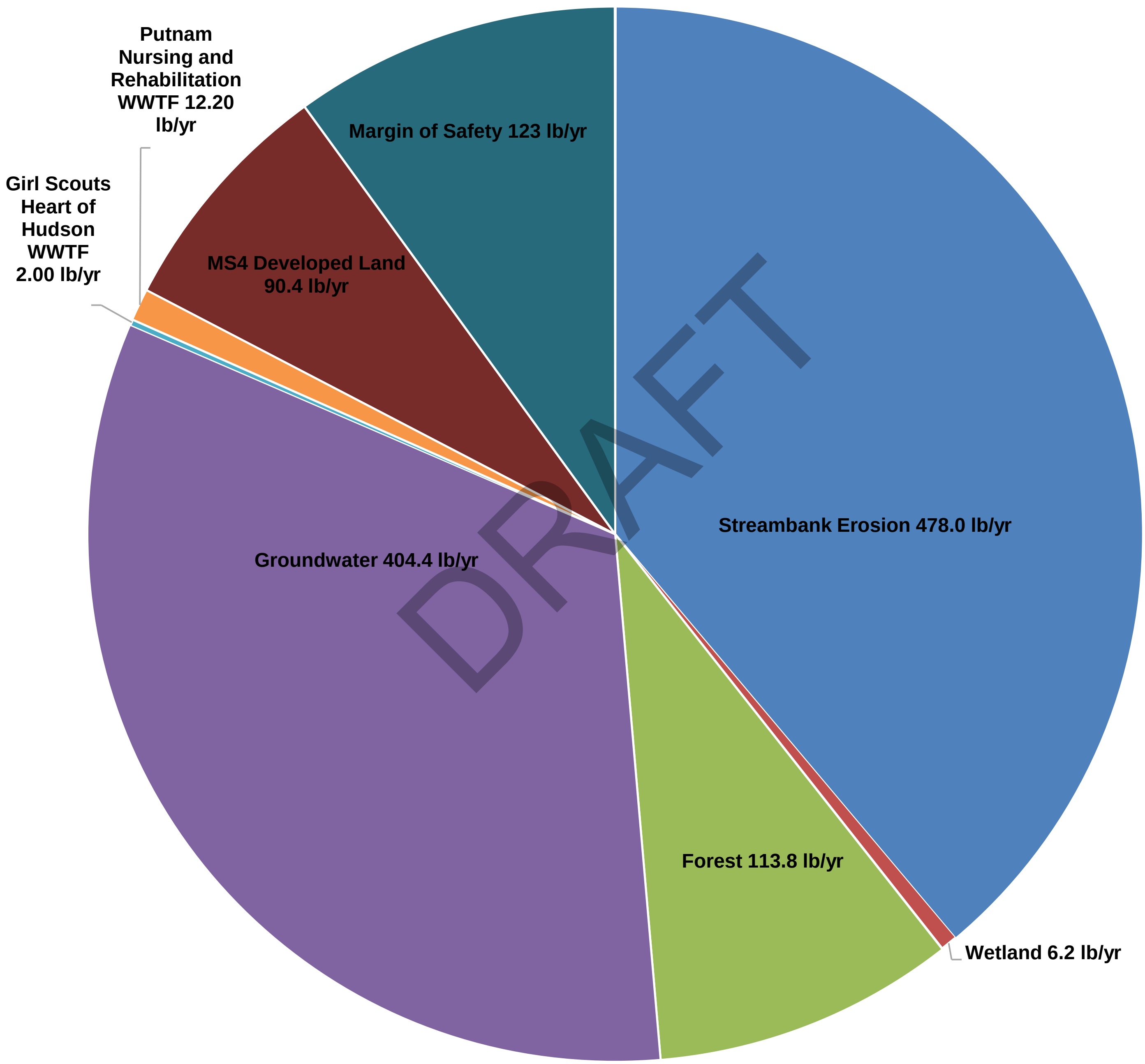
6.3. Margin of Safety (MOS)

The margin of safety (MOS) is explicitly accounted for during the allocation of loadings. That is, the individual model inputs contain no MOS, but 10% of the estimated total loading capacity, (123 lbs/yr) was allocated as a MOS to account for uncertainty.

Table 6: Total Annual Phosphorus Load Allocations for Lake Carmel Watershed

	Current	Allocated	Reduction	% Reduction
Stream Bank Erosion	886.3	478.0	408.3	46%
Wetland	6.2	6.2	0	0
Forest	113.8	113.8	0	0
Groundwater	404.4	404.4	0	0
Septic Systems	613.9	0	613.9	100%
Internal Loading	511	0	511	100%
LOAD ALLOCATION TOTAL	**2,535.6**	**1,002.4**	**1,533.2**	**40%**
WWTF: *Girl Scouts Heart of Hudson* SPDES # NY0102181	5.0	2.0	3.0	60%
WWTF: *Putnam Nursing and Rehabilitation* SPDES # NY0028924	60.9	12.2	48.7	80%
WWTF: *Frangel Realty* SPDES # NY143863	9.1	0	9.1	100%
MS4 Developed Land: T/Kent SPDES #NYR20A346 T/Patterson SPDES #NYR20A140 T/Pawling SPDES #NYR20A472 T/Beekman SPDES #NYR20A365 T/E. Fishkill SPDES #NYR20A183	100.6	90.4	10.2	10%
WASTELOAD ALLOCATION TOTAL	**175.6**	**104.6**	**75.9**	**42%**
LA + WLA	2,711.2	1,107	-	-
10% Margin of Safety	-	123	-	-
TOTAL	**2,711.2**	**1,230**	1,604.2	59%

Figure 9: Total Phosphorus Loading Allocations for Lake Carmel Watershed



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, MapShed 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 24 years of daily precipitation data when calculating runoff through MapShed, 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.

6.6. Other Considerations

Some phosphorus sources are more problematic than others. For example, as previously discussed, the phosphorus contained in the effluent from septic systems is in a soluble reactive form. This means that the phosphorus is immediately available to plants and algae, and will effectively fertilize a lake by orders of magnitude more than an equal amount of phosphorus that enters the lake in particulate form suspended in stormwater runoff or as streambank erosion.

This factor was considered in the reductions and allocations because the source of the most troublesome impairments (excessive weed growth and algae blooms). For this reason, to alleviate these impairments most effectively requires that phosphorus loading due to septic failure be addressed.

7.0 IMPLEMENTATION

Effective implementation of TMDL phosphorus load reduction requirements is the most important part of the TMDL process, and should involve the participation of all stakeholders. Watershed residents are the primary force behind improving the water quality in the lake. Additionally, there are some tasks that local government is required to take. For example, Towns are required to implement measures to reduce sediments and nutrients in urban runoff under their MS4 permit. But the majority of actions needed to restore the lake's water quality, habitat and aesthetics are optional. In most cases, residents are not required to implement specific management practices. The success of the TMDL implementation plan relies on the initiative of residents to bring people together as well as to seek out technical assistance and funding where required.

This document is the beginning of a process. It points residents in the direction of working together with agencies to improve the water quality of the lake. Polluted runoff, including the nutrient and sediment problems identified in this TMDL, comes from several sources. Everyone in the watershed contributes to the problem or the solution--how household and landscaping chemicals and automotive fluids are used and disposed of, how water is conserved or wasted, disposal of green waste, maintenance of residences and businesses, use of garbage disposals, etc. A successful program requires broad participation.

This implementation strategy emphasizes the importance of citizen involvement in setting short- and long-term goals, tracking progress, and adapting to future research and monitoring. Regardless of the main cause or causes, many of the solutions are the same. They can range from traditional conservation practices that reduce soil erosion on construction sites and other areas of exposed soil to innovative practices and programs that increase water storage on the land, to decrease the intensity of erosive effects of stormwater runoff, to more stringent point source control.

There are presently three (3) WWTFs in the Lake Carmel watershed. Effluent from one WWTF (Frangel Realty) has been redirected to be treated by Kent Manor WWTF, located in the adjacent Lake Carmel watershed; its flow is therefore not included in the wasteload allocation. DEC will revise the SPDES permits for the remaining two WWTFs in the Lake Carmel watershed which are both currently permitted to discharge phosphorus at a concentration of 1.0 mg/l, to more stringent limits.

Each Town in the Lake Carmel watershed is responsible for enforcing the terms of the SPDES Construction Permit and ensuring that *owners or operators* of all construction activities that involve soil disturbances between five thousand (5,000) square feet and one (1) acre of land must obtain coverage under the Construction Permit.

The Towns are also responsible for complying with the enhanced criteria specified in the MS4 General Permit, including the requirement to develop a local law requiring homeowners to inspect and pump septic systems at least once every five years. A substantial portion of the phosphorus load to Lake Carmel comes from deficient septic systems close to the lake. DEC recommends that septic effluent from houses closest to the lake be treated by a WWTF.

The Town of Kent, where Lake Carmel is located, has installed hydrodynamic separators (HDS) to filter stormwater before it enters the lake. The HDS units are located across Rt 52 from the bottom of Barrett Hill Road and at Putnam Road. The HDS units collect sediment that would otherwise enter the lake. The units periodically fill up and require maintenance. The Town of Kent Highway Department continues to maintain the units on an annual basis and as needed.

Additionally, a key component of the larger *Croton Watershed TMDL Implementation Plan, NYSDEC 2009*, is a non-point source load reduction requirement that was allocated to each MS4 in the Croton Watershed to be obtained through the construction of stormwater retrofits. The Town of Kent has, in conjunction with other Croton Watershed

Towns, constructed several stormwater retrofits to intercept stormwater runoff before it reaches Lake Carmel. These retrofits are designed to reduce sedimentation and phosphorus loading to the lake and should positively affect the lake's water quality.

The East of Hudson Watershed Corporation, a coalition of MS4s formed in 2011 to collectively respond to the Department's MS4 mandates and that include the Towns of Kent, Pawling and Patterson, has implemented stream bank stabilization practices for which DEC has awarded phosphorus reduction credit toward the Towns' MS4 stormwater retrofit phosphorus reduction requirement. These practices should be implemented along appropriate segments of the Middle Branch Croton River and Stump Pond Creek. The Department will allow phosphorus reduction credits to the EOHWC where stream stabilization practices are sited in the Lake Carmel watershed and are attributable to excessive stormwater runoff.

East Fishkill and Beekman are not members of the EOHWC and do not obtain credits for the collective actions of the group's members. These two municipalities have independent obligations under the *Croton Watershed TMDL Implementation Plan, NYSDEC 2009,* and should consider implementation of projects in the Lake Carmel basin that would benefit both Lake Carmel and the overall Croton watershed.

7.1. Reasonable Assurance for Implementation

The phosphorus load reduction required to meet the TMDL is calculated to be 1,609 lb/yr (59% reduction).

TMDL modeling indicates that lake sedimentation due to stream bank erosion, along with septic systems and stormwater runoff are principal sources of phosphorus loading in the Lake Carmel watershed. The elimination of septic system loading may be accomplished by providing sewer service for lake-front and near lake front properties. Stream bank erosion is a more complex problem because the causes of this erosion are not as easily determined. Typically, however, land with high a percentage of impervious surfaces that drains into the streams increases the rate and intensity of stormwater runoff, which can increase erosion of a stream channel. High impervious surface coupled with steep slopes and more intense storm events will further erode the stream corridors and lose habitat and soil over time.

The TMDL implementation strategy also includes implementation of stormwater control provisions in permits now in effect, as described below. The proposed load reductions also include an assumption that septic loading will decrease due to compliance with the New York State (NYS) *Household Detergent and Nutrient Runoff* Law.

7.1.1. Recommended Phosphorus Management Strategies for Septic Systems

This TMDL recommends eliminating phosphorus loading from deficient near-lake septic systems by sewering the near-lake developed parcels in the watershed and instituting a management system to assure proper design and operation of any remaining individual systems.

The Towns in the Lake Carmel watershed all have passed local laws in conformance with the enhanced MS4 General Permit provisions requiring that all septic systems be inspected and pumped out at least once every 5 years, and where necessary, remediated. The MS4 Permit provisions that requires an investigation and inspection references the EPA Publication “Illicit Discharge Detection and Elimination: A Guidance Manual for Program Development and Technical Assessment”, which outlines various procedures to conduct such an investigation and inspection to satisfy the requirement. The Department requires that the field investigation and inspection include both the septic tank and the disposal field.

New homes are required to have septic systems conforming to NYS Department of Health's 10NYCRR Appendix 75-A (75-A) which define the criteria for wastewater treatment standards for residential onsite wastewater treatment systems. Alternatively, residences may connect to municipal wastewater systems. As per 75-A, a 100 ft setback is required from waterbodies to leachfields. Homes with a cesspool are required to upgrade to a septic system conforming to 75-A whenever a bedroom is added to the house.

Homeowners may conduct dye tests for the purpose of identifying cesspool overflows and determining if wastewater is being discharged to the lake. If dye released in a toilet later appears in the lake water, then there is a discharge of wastewater to the lake. The Lake Carmel community in partnership with PCHD should conduct an assessment of septic systems and cesspools within 100 feet of the lake or a tributary stream in the Lake Carmel watershed to determine where deficient systems occur, educate homeowners on management practices for septic systems and cesspools and options for improving wastewater treatment, and order upgrades where needed. Properties adjacent to the lake are the highest priority for dye testing. The assessment should develop a database of wastewater systems in proximity to Lake Carmel and tributary streams.

Watershed load reductions are also attributed to the anticipated benefits of the recent passage of Chapter 205 of the NYS Laws of 2010, the *Household Detergent and Nutrient Runoff Law* (amending section 35-105 and adding a new Title 21 to Article 17 of the Environmental Conservation Law) which was signed into law on July 15, 2010. This law restricts the sale and application of fertilizers containing phosphorus for lawns and limits the phosphorus content of automatic dishwashing detergent. This legislation will reduce phosphorus in dishwashing detergents sold in NY State and this should reduce the phosphorus contribution from on-site wastewater systems, especially those in substandard condition.

7.1.2 Recommended Phosphorus Management Strategies for Wastewater Treatment Plants

The New York City Watershed Rules and Regulations (WR&Rs) require all wastewater treatment facilities (WWTFs) in the East of Hudson Watershed to remove phosphorus using best management practices (BMPs) as specified in SPDES permit limits.

There are three WWTFs in the Lake Carmel watershed. Flow from one WWTF (Frangel Realty) has been re-directed as part of a consolidation of flows into a newly constructed

WWTF that discharges outside the Lake Carmel watershed. Additional phosphorus reduction from the other two point sources (Girl Scouts Heart of Hudson and the Putnam Nursing and Rehab) will be obtained by modifying those SPDES permits to require phosphorus limits of 0.4 mg/l for Girl Scouts Heart of Hudson WWTF and 0.2 mg/l for Putnam Nursing and Rehab WWTF.

DEC will modify the SPDES permits for Girl Scouts Heart of Hudson (#0102181) and Putnam Nursing and Rehabilitation Center (#0028924). The two WWTFs are both currently permitted to discharge at 1.0 mg/l. The current calculated load for the three WWTFs is 79.9 lb/yr. With these SPDES permit modifications and the removal of the Frangel Realty WWTF the phosphorus reduction to Lake Carmel is calculated to be 60.8 lb/yr. The waste load allocation for Lake Carmel is therefore set at 14.2 lb/yr.

NYCDEP is obligated per their WR&Rs to pay for capital improvements and associated operation and maintenance at WWTFs within their drinking water watershed, including phosphorus removal to meet the limits provided in SPDES permits for such facilities. As per the Lake Carmel TMDL, the phosphorous limits for Putnam Nursing and Girl Scouts Heart of Hudson will be reduced to 0.2 mg/l and 0.4 mg/l respectively. Development of these limits was based on NYCDEP agreement to continue to provide funding to meet the revised permit limits.

7.1.3 Recommended Phosphorus Management Strategies for Stormwater Runoff

NYS DEC issued SPDES general permits GP-0-10-001 for construction activities, and GP-0-10-002 for stormwater discharges from MS4s.

The MS4 General Permit requires MS4s to institute minimum measures, including:

- Public education, more specifically:
    - o Sensible lawn care, specifically reducing fertilizer use or using phosphorus-free products, now readily available to consumers. The previously mention phosphorus legislation, restricts the sale and application of lawn fertilizers containing phosphorus.
    - o Cleaning up pet waste, and
    - o Discouraging waterfowl congregation near waterbodies, by restoring natural shoreline vegetation.

- Illicit discharge and detection requirements, such as mapping the sanitary sewersheds and septic pumpout, inspection, and where required, remediation every five years;

- Construction site and post construction stormwater runoff control:
    - o Ordinance, inspection and enforcement programs, and
    - o Assurance of no net increase of pollutants from the MS4 taking into account construction.

- Pollution prevention practices for road and ditch maintenance

- Management practices for the handling, storage and use of deicing products.

The MS4 permit also requires that MS4s in the NYC East of Hudson watershed must develop or modify their stormwater treatment plans to address additional phosphorus reduction requirements.

All of the Towns in the Lake Carmel watershed are part of the New York City East of Hudson (EOH) Watershed and are designated as MS4s (Kent, Paterson, Pawling, Beekman and East Fishkill). Each of these Towns has a phosphorus reduction requirement to be obtained by implementing stormwater retrofits to the MS4 conveyance systems. Retrofit work is ongoing throughout the East of Hudson watershed including several retrofits constructed in the Lake Carmel basin, which are expected to improve Lake Carmel water quality. Consideration should be given to siting a retrofit project in the Lake Carmel watershed for the purpose of compliance with the EOH retrofit program requirement and to benefit Lake Carmel water quality.

As stated in Section 7.1.1, phosphorus load reductions are attributable to implementation of the Household Detergent and Nutrient *Runoff Law* restricting the sale and application of fertilizers containing phosphorus for lawns. For example, the City of Ann Arbor enacted an ordinance in 2007 to limit phosphorus application to lawns, resulting in an estimated 22% reduction in phosphorus entering the Huron River.

7.1.4 Recommended Phosphorus Management Strategies for Streambank Erosion

Addressing the problem of streambank erosion requires an understanding of both stream dynamics and the management of streamside vegetation. Soil erosion and stream bank erosion can occur due to construction activities, road projects, drainage projects and urban runoff. Dramatic increases in stormwater runoff through the stream channel will cause accelerated streambank erosion (the process of a stream seeking to reestablish a stable size and pattern due to an external change). An increase in runoff within a stream channel will result in the stream channel adjusting to the additional flow, which will increase streambank erosion. Any land use changes in a watershed, such as clearing land or development, can increase stream bank erosion. The damage or removal of streamside vegetation reduces bank stability and can cause an increase in stream bank erosion. A degraded streambed results in higher and often unstable, eroding banks. Stream stability is an active process, and while streambank erosion is a natural part of this process, human development activities often accelerate erosion. Streambank erosion increases the amount of sediment transported by the stream, resulting in the loss of fertile stream bed causing a decline in the quality of riparian and stream habitat, in addition, depositing excess sediment and phosphorus to Lake Carmel, where much of the sediment eventually settles.

Many of the methods for dealing with streambank erosion, stabilization and restoration are expensive to install and maintain. Solutions such as rock riprap or gabions (wire baskets filled with rock) may solve the erosion problem, but may not improve stream habitat or its aesthetic value. Natural channel design principles look to nature for the blueprint to restore a stream to an appropriate dimension, pattern and profile. Soil bioengineering practices, native material revetments and in stream structures help to stabilize eroding banks. The following techniques may be used to move a stream toward a healthy, naturally stable and self-maintaining system.

Soil Bioengineering Practices

Bioengineering uses plant materials in a structural way to reinforce and stabilize eroding streambanks. This technique relies on the use of dormant cuttings of willows, shrub dogwoods and other plants that root easily. Bioengineering practices range from simple live stakes to complex structures such as fabricated lifts incorporating erosion control blankets, plants and compacted soil.

Native Material Revetments

These practices use native materials, wood and stone, to armor streambanks and deflect flow away from them. Low rock walls and log cribwalls can be used to armor the bank. Rootwads armor the bank and provide protection downstream by deflecting the flow away from the bank.

In-Stream Structures

Rock and logs can be used to construct a variety of structures that stabilize the streambed and banks. Cross vanes are rock structures that stabilize the streambed while aiding in streambank stabilization. Rock or log vanes redirect stream flow away from the toe of the streambank and help to stabilize the bank upstream and downstream from the structure. Where these practices are used, the protection should last long enough to allow appropriate vegetation to become established and provide for long term bank stability. The streamside vegetation improves habitat on the land and in the stream by providing shade, cover and food. Several of the streambank stabilization structures, such as root wads, are also excellent fish habitat improvement structures.

Riparian Buffers

A riparian buffer is any land near a stream where the vegetation acts as a buffer to the flow of often pollutant-laden stormwater. These areas usually contain native grasses, flowers, shrubs and trees that line the stream banks. A healthy riparian area is evidence of wise land use management.

Riparian areas help to prevent sediment, nutrient and other pollutants from reaching a stream. Riparian buffers are most effective at improving water quality when they include a native grass or herbaceous filter strip along with deep rooted trees and shrubs along the stream. Riparian vegetation is a major source of energy and nutrients for stream communities. They are especially important in small, headwater streams where up to 99% of the energy input may be from woody debris and leaf litter.

Riparian vegetation slows floodwaters, thereby helping to maintain stable streambanks and protect downstream property. By slowing down floodwaters and rainwater runoff, the riparian vegetation allows water to soak into the ground and recharge groundwater. Slowing floodwaters allows the riparian zone to function as a site of sediment deposition, trapping sediments that build stream banks and would otherwise degrade our streams and rivers.

Degraded riparian buffers reduce water quality values, reduce wildlife and fish populations, cause serious property damage (bank erosion) and loss of valuable agricultural lands. Removal of riparian vegetation results in increased water temperatures and decreased dissolved oxygen. The loss of shade exposes soils to drying out by wind and sunlight and reduces the water storage capacity of the riparian area. Loss of riparian vegetation causes streambank erosion. Eroding banks contribute to sedimentation and lead to a wide shallow stream with little habitat value. These factors result in significant reductions in aquatic stream life.

Rehabilitating riparian buffers is key to restoring natural stream functions and aquatic habitats. There are many economic benefits derived from increased riparian habitat, channel stabilization, improved water quality, improved wildlife and fish populations, improved aesthetics, and other associated values. Depending on the surrounding land use and area topography, riparian buffers should range from 25 to 100 feet wide on each side of the stream.

Runoff can be directed towards riparian buffers and other undisturbed natural areas delineated in site planning to infiltrate runoff, reduce runoff velocity and remove pollutants. Natural depressions can be used to temporarily detain and infiltrate water, particularly in areas with more permeable soils. Preserving steep slopes and building on flatter areas helps to prevent soil erosion and minimizes stormwater runoff; helps to stabilize hillsides and soils and reduces the need for cut-and-fill and grading.

7.1.5 Additional Protection Measures

Measures to further protect water quality and limit the growth of phosphorus load that would otherwise offset load reduction efforts should be considered. The basic protections afforded by local zoning ordinances could be enhanced to limit non-compatible development, preserve natural vegetation along shorelines and 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.

7.1.5.1. Aquatic Plant Control

Lake Carmel is presently used for swimming, boating, fishing and other uses such as wildlife viewing. Lake Carmel is relatively shallow and contains various weeds and algae which interfere with the present uses of the lake. Although aquatic plants are an important to lake ecosystems and to fish and wildlife, excessive weeds usually indicate a larger problem such as excessive sedimentation and nutrients as well as the potential introduction of invasive species, most of which cannot be eradicated.

Lake Carmel currently contains various aquatic plants, including the following:

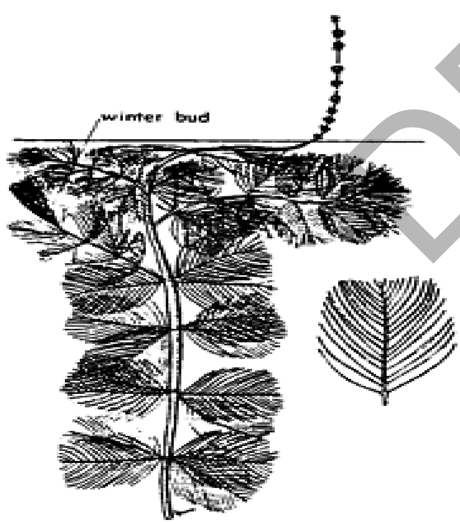
Invasive (exotic) plants

- Eurasian watermilfoil
- Brittle naiad

- Nuisance (native) plants
    - Coontail
    - Duckweed
- Beneficial (native) plants
    - Water lilies
    - Water net

Eurasian Watermilfoil (Myriophyllum spicatum)- Eurasian watermilfoil has slender stems up to 3 m long. The submerged leaves are usually between 15–35 mm long and are borne in pinnate (feather-like) whorls of four, with numerous thread-like leaflets roughly 4–13 mm long. Flowers are produced in the leaf axils (male above, female below) on a spike 5–15 cm long held vertically above the water surface, each flower inconspicuous, orange-red, 4–6 mm long. Eurasian water milfoil has 12- 21 pairs of leaflets.

In lakes or other aquatic areas where native aquatic plants are not well established, Eurasian watermilfoil can quickly spread. It has been known to crowd out native plants and create dense surface canopies or dense stands within the water that interfere with recreational activity. Eurasian watermilfoil can grow from broken off stems which increases the rate in which the plant can spread and grow



Brittle naiad (Najas minor)- is an annual aquatic plant which prefers calm waters, such as ponds, reservoirs and lakes and is capable of growing in depths up to 4 meters. Brittle Naiad grows in dense clusters and has highly branched stems. These stems fragment easily and this plant is capable of propagation from stem fragments or from small seeds which grow along its stem. The small flowers are located in clusters along the leaf axils. The leaves of the plant are opposite, unbranched, strap-shaped, and are around 4.5 centimeters in length. The leaves have serrations which are visible to the naked eye.

The presence of this plant is a problem because its dense growth covers wide areas, inhibiting the growth of native species of aquatic macrophytes. The thick, clustering growths of brittle naiad can make fishing access or the operation of a boat difficult in a pond or lake. Brittle naiad may spread to new areas by stem fragments carried on a boat's hull, deck, propeller or trailer, and it does particularly well in lakes with varying water levels or disturbed bottom characteristics, since the reproductive seeds are usually resistant to these disturbances. This plant is less likely than Eurasian watermilfoil to create recreational problems.

Coontail (Ceratophyllum dersum) - grows in still or very slow-moving water. The stems reach lengths of 1–3 m, with numerous side shoots making a single specimen appear as a large, bushy mass. The leaves produced in whorls of six to twelve, each leaf 8–40 mm long, simple, or forked into two to eight thread-like segments edged with spiny teeth; they are stiff and brittle. It is monoecious with separate male and female flowers produced on the same plant. The flowers are small, 2 mm long, with eight or more greenish-brown petals; they are produced in the leaf axils. Its dense growth can outcompete native underwater vegetation, particularly in turbid water, leading to loss of biodiversity. However, this is a native plant that would be considered more valuable than Eurasian watermilfoil or brittle naiad for a health aquatic plant community.

Duckweed (Lemnoideae) - Duckweeds, or water lens, are flowering aquatic plans which float on or just beneath the surface of still or slow-moving bodies of fresh water and wetlands. These plants are very simple, lacking an obvious stem or leaves. The greater part of each plant is a small organized "thallus" or "frond" structure only a few cells thick, often with air pockets that allow it to float on or just under the water surface. Duckweeds tend to be associated with fertile, even eutrophic conditions. Duckweed is an important high-protein food source for waterfowl. The tiny plants provide cover for fry of many aquatic species. The plants are used as shelter by pond water species such as bullfrogs and bluegills. Although at times growing at nuisance levels, this plant is another native species preferred to Eurasian watermilfoil or brittle naiad.

Many lakes with aquatic invasive species plants have a weed problem. While nutrients can contribute to a weed problem, removing the nutrients will not solve the weed problem. As such, most weed management strategies involve the removal of the aquatic invasive species plants- in the case of Lake Carmel, Eurasian watermilfoil and, to a lesser extent, brittle naiad.

Some plant management tools may create significant impacts and as such, the benefits may not outweigh risks. Consideration should be given to selecting actions with lesser side effects. The method or methods chosen should be dictated by the goals desired to be obtained.   Potential goals for weed management in Lake Carmel include surface reduction of weeds to: 1) improve boating; 2) clear edges for anglers; and 3) clear whole sections for swimming. Decisions need to be made as to whether to manage weeds in: 1) part of or the whole lake; 2) in the early summer or the entire summer; and the desired duration of control (e.g. short term, long term).

Other factors include how much money is available for weed management, and whether consultant services are necessary or if it can be done with citizen volunteers.
The first and best line of defense is PREVENTION:

- Visual inspection - assume all dangling plants are invasive
- Disinfection - Hot water, disinfectant
- Quarantining - Delay entering lake until any transported plants have been dried or inactivated
- Intercepting - Remove plants before they leave other infected lakes
- Regulating their sale and transport

Management actions are discussed in detail in *Diet for a Small Lake* which is available on NYSDEC website (http://www.dec.ny.gov/ chemical/82123.html). Chapter 6 discusses each aquatic plant management option in detail.

Options for weed control in Lake Carmel – Overview

If the goal is to manage relatively small areas (swimming area, boat channels), it is possible to implement the following techniques with citizen volunteers.

- Hand harvesting
- Benthic barriers

If the goal is to manage a large area (whole lake), a consultant would need to be retained and consideration could be given to the following techniques:

- Herbicides- EWM only- triclopyr; EWM and coontail- fluridone
- Grass carp

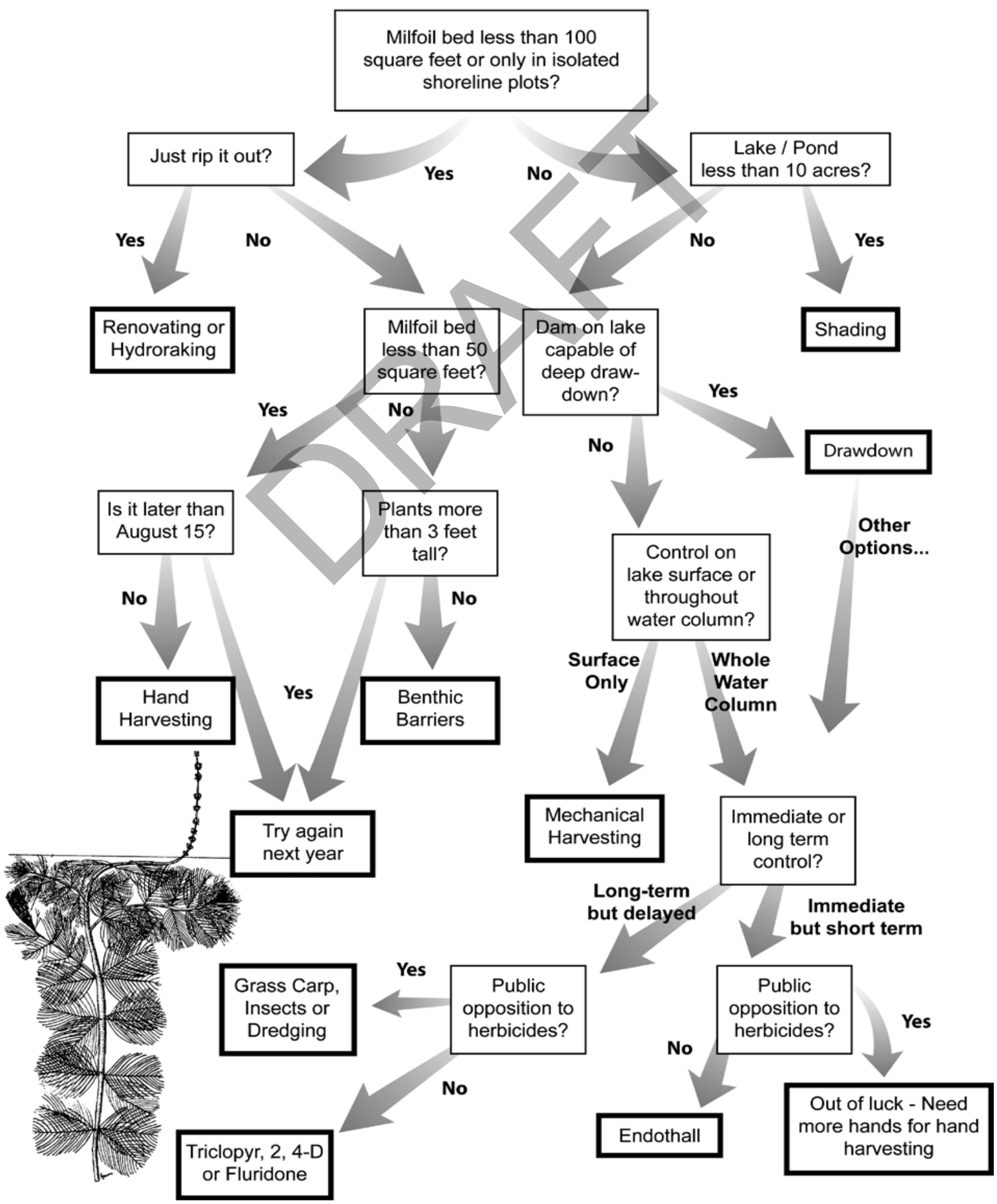
Listed below is a comprehensive table of potential weed control options for Lake Carmel including the recommended techniques noted above:

Control Options	**Is it possible?**	**How effective at controlling bad plants?**	**How will it damage good plants?**	**How much does it cost?**	**Permits needed?**	**Can we do it ourselves?**
Do Nothing	Yes	Not Applicable	Not applicable	Pay Later	None	Yes
Hand/diver Harvesting	Yes	Will control any plant in easy-to-pluck patches	May remove good plants by accident	Whole lake—approx $65k Swimming area(s)—approx. $10k	No (unless whole lake)	Yes
Benthic Barrier	Yes, but limited to swimming or boating channel	Will control plants under the barriers	Will also eliminate good plants under barrier	Whole—not used Swimming areas—approx. 10k	No (unless whole lake or barriers permanent)	Yes
Cutting	Yes	Not very effective with Eurasian Watermilfoil and coontail	Good plants may be cut by accident	Whole lake—not viable Swimming areas= labor only	No	Yes (but be careful)
Shading	Yes	Not very effective	If it works, will impact good plants too	Whole lake—approx $40k Swimming areas—not viable	Yes, if certain products are used	Yes, if landscaping product used No, if pesticides used
Herbivorous insects	Yes	Not effective with Eurasian Watermilfoil	Will not damage good plants	Whole lake—approx. $200k Swimming areas—not likely restricted to area	Yes, Article 11 (Possess?)	No, authorized applicator through permit
Drawdown	No	Somewhat effective, but some exotics will increase	May remove good plants by accident	Whole lake—no cost Swimming areas—not possible	Maybe, Article 15 (Protection of Waters Permit**)	Not possible as plant control tool
Mechanical harvesting	Probably not	Effective	Good plants will be removed too	Whole lake—approx. $150k to purchase Swimming areas—not likely	Probably not	No
Aquatic herbicides	Yes	Eurasian watermilfoil-very effective Coontail—fairly effective	Less effective on lilies, duckweed Depends on herbicide used	Whole lake—approx. $125k Swimming areas—not likely to stay in area	Yes	No, need licensed applicator
Grass Carp	Yes, if outlet can be screened	Fairly effective	Some good plants may be damaged	Whole lake—approx. $60k Swimming areas—fish will wander	Yes, Article 11	No, need licensed applicator
Dredging	Probably not	Fairly effective	Good plants will be removed too	Whole lake—prob. not feasible Swimming areas-$300k?	Yes	No

Other alternatives include utilizing Integrated Plant Management (IPM), (combining two or more management techniques). IPM can target any/all invasives and is often viewed as a more comprehensive approach as it can combine local and lakewide management techniques. Care should be taken to ensure that techniques are compatible so there are no side effects. The costs and need for permits will depend on the management techniques chosen.

Decision trees help guide initial decision-making process based on the key factors for each infestation. Key factors may include: Management objectives, permitting, side effects, longevity and cost. A decision tree for watermilfoil control follows:

Decision Tree for Eurasian Watermilfoil Control



7.1.5.2 Blue Green Algae Blooms

During summer 2014 and summer 2015 the Putnam County Department of Health closed several Lake Carmel beaches due to an abundance of blue-green algae. Blue green algae can release toxins that affect people through skin exposure and gastrointestinal or asthma-like symptoms, including nausea, vomiting, diarrhea, skin or throat irritation, allergic reactions or breathing difficulties. Swimming can also be affected by the ugly appearance and smell from algae that accumulated along the surface or shoreline. People and pets should avoid swimming in heavily discolored water or surface scums, and they should also not handle algae material--scums or algae covering weeds along the shoreline.

Lake residents can reduce the likelihood of algae blooms in Lake Carmel by reducing the amount of nutrients (phosphorus and nitrogen) that enter the lake. This can be accomplished by:

- sewering the lake properties,
- limiting lawn fertilization,
- maintaining shoreline buffers,
- maintaining and pumping out septic tanks,
- reducing streambank erosion and stormwater runoff, and
- maintaining water movement in the lake.

Algae Control Management actions are discussed in detail in *Diet for a Small Lake* which is available on NYSDEC website (http://www.dec.ny.gov/ chemical/82123.html) (Chapter 7 discusses each aquatic plant management option in detail).

Algae Control Options for Lake Carmel

Control Options	Is it possible?	Pros	Cons	How much does it cost?	Permits needed?	Can we do it ourselves?
Barley Straw	Yes	Cheap, Easy, DIY, No Evidence of Harm, Some Anecdotal Evidence It Works	Only Anecdotal Evidence, Removal of Spent Bales	Whole Lake = $5-6k Swimming areas = $500 (if placed near edge, outside	None or Not Allowed	Yes
Algeacides	Yes -Chemically Wipe Out Algae by Contact	Short Term Control, Immediate, Usually Effective	Non-Target Impacts, Controversial, Some Limits on Use, Can Push Toxins Into Water	Whole lake—approx $12-15k. Swimming areas—$3-$5k (usually done as whole lake)	ECL Article 15/Part 327, Article 17/SPDES General Permit, Article 24)	No – need licensed applicator
Biomanipulation	Yes – stock fish to eat algae (or to eat fish that eat zooplankton that eat algae)	Can be effective. One and Done, “Natural”, Improve Fishery	Unclear as to how effective Disrupt Fish/food web Community, Hard To Reverse, Highly Variable Success; Assume BB/Carp Dominate Lake	$100-200/ 100 fish; 100-1000 fish/acre	Article 11	No – need permit applicator

Lake Management Resources

Diet for a Small Lake
(http://www.dec.ny.gov/chemical/82123.html)

- Chapter 6 discusses each aquatic plant management option in detail
- Chapter 7 discusses each algae control option in detail

Harmful Blue-green Algae Blooms

- General information— http://www.dec.ny.gov/chemical/77118.html
- Bloom Notices— http://www.dec.ny.gov/chemical/83310.html
- Frequently Asked Questions— http://www.dec.ny.gov/chemical/91570.html

Invasive Species

- General information about invasive species—http://www.dec.ny.gov/animals/265.html
- Aquatic invasive species in NYS— http://www.dec.ny.gov/animals/50121.html
- How to prevent the spread of aquatic invasive species— http://www.dec.ny.gov/animals/48221.html

Citizens Statewide Lake Assessment Program (CSLAP)

- Need to be a member of the NY Federation of Lake Associations—http://www.nysfola.org/
- Apply to NYSFOLA for 2015
- General information about CSLAP— http://www.dec.ny.gov/chemical/81576.html

7.2 Follow-up Monitoring

A targeted post-assessment monitoring effort is necessary to determine the effectiveness of the implementation plan associated with the TMDL. Annual growing season monitoring of the pond and watersheds would inform the implementation process. Lake Carmel should be sampled in the summer growing season (June through September) on 8 sampling dates at its deepest location. Grab samples should be collected at a 1.5 meter depth. The samples should be analyzed for the phosphorus series (total phosphorus, total soluble phosphorus, and soluble reactive phosphorus). The Secchi disk depth should be recorded. A simple macrophyte survey should also be conducted once during midsummer.

7.3 Summary

Septic Systems:

Residential septic systems discharge effluent containing dissolved phosphorus to nearby waterbodies when they are malfunctioning. A septic system can malfunction if there is not sufficient permeable soil for the wastewater to travel through and the wastewater is forced upward to discharge to the ground surface. A septic system in close proximity to surface waters can malfunction because the groundwater table is high and there is insufficient treatment of effluent before it reaches the groundwater. Often where these septic systems are located close to waterbodies the laterals discharge directly to the groundwater without any treatment. This contributes significant phosphorus loads to the waterbody. As a result, malfunctioning septic systems can contribute high phosphorus loads to nearby waterbodies.

The most effective solution to eliminate the phosphorus loading from the deficient septic systems that surround Lake Carmel is to connect these properties to a Waste Water Treatment Facility that will operate according to the phosphorus limits contained in the NYC Watershed Rules and Regulations.

Streambank Erosion:

As watershed areas are developed for residential, commercial, industrial, and transportation land uses the amount of impervious surfaces increases. The increase in impervious surfaces changes the timing and volume of storm water that is delivered to nearby streams. In addition, changes in stream volume between storms, the height of groundwater tables, and the rate and volume of stream erosion are likely outcomes of increased watershed imperviousness.

The development of land to build houses, stores, parking lots and roads all create these impervious surfaces that effectively seal surfaces, repel water and prevent rainfall and snow melt from infiltrating into the soil. The result is increased volume and intensity of stormwater runoff that can often cause MS4 conveyances (which include unimproved roadside ditches) and other receiving waters and streams to erode. When the velocity of the runoff decreases sufficiently, this eroded soil ultimately settles out, usually where streams enter still water. Where the tributaries of Lake Carmel (Middle Branch Croton River and Stump Pond Stream) enter the lake, excessive amounts of sediments have accumulated. This was verified by DEC staff at the north end of Lake Carmel in December 2014 and expressed as a concern by the lake community residents at the public meeting on July 29th.

The rate of sedimentation and resultant phosphorus loading to the lake can be reduced by:

- Working with the East of Hudson Watershed Corporation (EOHWC) to stabilize the stream channels that empty into Lake Carmel; i.e. providing toe protection, native or non-invasive vegetative cover, drop structures, armoring stream banks with materials that combine structure with vegetation. This work will both improve the water quality of the lake as well as provide phosphorus reduction credit toward the EOHWC MS4 Permit requirement. Working with EOHWC to site stormwater retrofits that reduce stormwater runoff from developed land from adversely affecting the lake, through the construction of infiltration and filtration stormwater practices.
- Work with EOHWC to identify large areas of impervious cover which currently discharge directly to waterbodies during runoff events and attempt to install runoff reduction practices to reduce the rate of runoff and therefore reduce in-stream erosion. These practices would also potentially reduce the phosphorous being discharged to the Lake Carmel watershed.
- Establishing protected riparian buffer strips along the stream to filter pollutants and debris in runoff before it enters the stream channel via regulatory land use changes.
- Maintaining a regular practice of street sweeping to reduce sediment-laden stormwater from reaching the streams that feed Lake Carmel.

MS4:

The municipal separate stormwater systems (MS4s) in the Lake Carmel watershed all contribute phosphorus to Lake Carmel via the collection of stormwater from roadways and other impervious surfaces. This stormwater is discharged into tributaries and from there into the lake. Recent field work revealed extensive sedimentation at the north end of Lake Carmel, visible because the water level was low due to lack of recent rainfall. This sedimentation and the resultant phosphorus loading to the lake can be reduced by:

- Limiting the creation of pavement and other impervious surfaces through local land use regulatory changes.
- Creating conservation easement areas to limit further development.
- Limit clearing and grading of sites being developed to the minimum amount needed for development.
- Enforcing the terms of the SPDES Construction General Permit and the SPDES MS4 General Permit.
- Installing stormwater retrofit practices.

8.0 PUBLIC PARTICIPATION

The Department held an informational meeting on July 29th, 2014 in the Town of Kent, to engage the interested public in discussion, answer lake management questions and to hear the community's water quality and water use goals for Lake Carmel.

Notice of availability of the proposed TMDL was made to local government representatives and interested parties. The proposed TMDL was public noticed in the Environmental Notice Bulletin on June 1, 2016. A 30-day public review period was established for soliciting written comments from stakeholders prior to the finalization and submission of the TMDL for EPA approval. Comments will be accepted until close of business on July 1, 2016. Written comments received and the Department's responses will be published below:

<insert public comments and Department responses>

9.0 REFERENCES

ASCE Task Committee on Definition of Criteria for Evaluation of Watershed Models of the Watershed Management Committee, Irrigation and Drainage Division, 1993. Criteria for evaluation of watershed models. Journal of Irrigation and Drainage Engineering, Vol. 199, No. 3.

Day, L.D., 2001. Phosphorus Impacts from Onsite Septic Systems to Surface Waters in the Cannonsville Reservoir Basin, NY. Delaware County Soil and Water Conservation District, Walton, NY, June, 2001.

Evans, B.M., D.W. Lehning, K.J. Corradini, *Summary of Work Undertaken Related to Adaptation of MapShed for Use in New England and New York.* 2007.

Evans, B.M., D.W. Lehning, K.J. Corradini, G.W. Petersen, E. Nizeyimana, J.M. Hamlett, P.D. Robillard, and R.L. Day, 2002. A Comprehensive GIS-Based Modeling Approach for Predicting Nutrient Loads in Watersheds. Journal of Spatial Hydrology, Vol. 2, No. 2.

Haith, D.A. and L.L. Shoemaker, 1987. Generalized Watershed Loading Functions for Stream Flow Nutrients. Water Resources Bulletin, 23(3), pp. 471-478.

Homer, C. C. Huang, L. Yang, B. Wylie and M. Coan. 2004. *Development of a 2001 National Landcover Database for the United States. Photogrammetric Engineering and Remote Sensing*, Vol. 70, No. 7, July 2004, pp. 829.

National Atmospheric Deposition Program (NRSP-3). 2007. NADP Program Office, Illinois State Water Survey, 2204 Griffith Dr., Champaign, IL 61820.

New York State, 2004. New York State Water Quality Report 2004. NYS Department of Environmental Conservation, Division of Water, Bureau of Watershed Assessment and Management.

New York State, 1998. 6 NYS Codes Rules and Regulations, Part 703.2, Narrative Water Quality Standards.

New York State, 1993. New York State Fact Sheet, Ambient Water Quality Value for Protection of Recreational Uses, Substance: Phosphorus, Bureau of Technical Services and Research. NYS Department of Environmental Conservation.

Sherwood, D.A., 2005, Water resources of Monroe County, New York, water years 2000-02— atmospheric deposition, ground water, streamflow, trends in water quality, and chemical loads in streams: U.S. Geological Scientific Investigations Report 2005-5107, 55 p.

United States Army Corps of Engineers, Engineer Research and Development Center., 2004. Flux, Profile, and BATHTUB: Simplified Procedures for Eutrophication Assessment and Prediction. <http://el.erdc.usace.army.mil/elmodels/emiinfo.html>.

USEPA. 2002. *Onsite Wastewater Treatment Systems Manual.* EPA/625/R-00/008. February 2002

USEPA, 1999. Protocol for Developing Sediment TMDLs (First Edition). EPA 841-B-99-004. Office of Water (4503F), United States Environmental Protection Agency, Washington, DC.

USEPA. 1990. *The Lake and Reservoir Restoration Guidance Manual*. 2nd Ed. and *Monitoring Lake and Reservoir Restoration (Technical Supplement)*. Prepared by North American Lake Management Society. EPA 440/4-90-006 and EPA 440/4-90-007.

USEPA. 1986. Technical Guidance Manual for Performing Wasteload Allocations, Book IV: Lakes, Reservoirs and Impoundments, Chapter 2: Eutrophication. EPA 440/4-84-019, p. 3-8.

United States Census Bureau, Statistical Abstract of the United States: 2012, *Table 61. Households and Persons Per Household by Type of Household: 1990-2010*

Watts, S., B. Gharabaghi, R.P. Rudra, M. Palmer, T. Boston, B. Evans, and M. Walters, 2005. Evaluation of the GIS-Based Nutrient Management Model CANWET in Ontario. In: Proc. 58th Natl. Conf. Canadian Water Resources Assoc., June 2005, Banff, Canada.

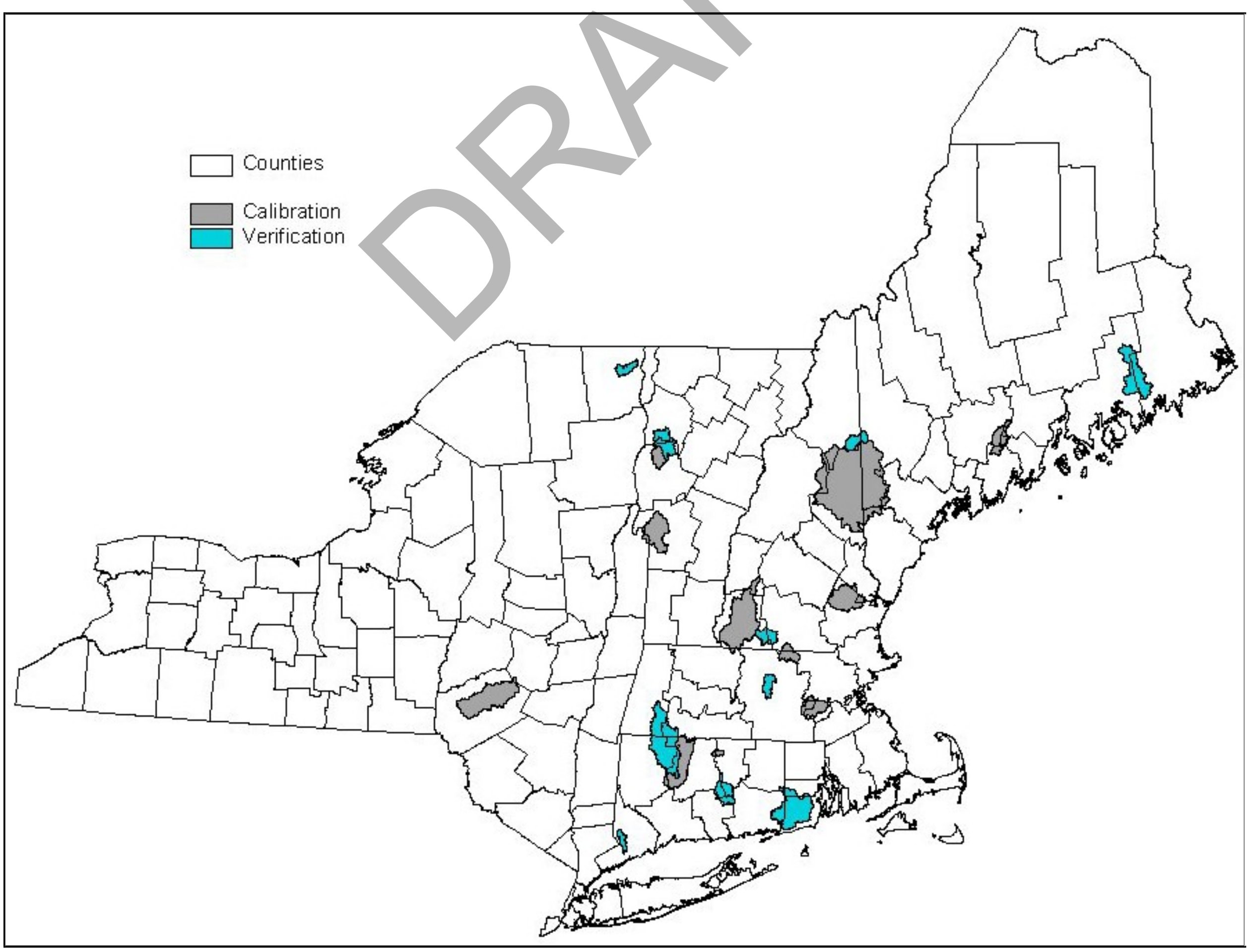
APPENDIX A. MAPSHED MODELING ANALYSIS

The MapShed model was developed in response to the need for a version of AVGWLF that would operate in a non-proprietary GIS package. AVGWLF had previously been calibrated for the Northeastern U.S. in general and New York specifically. Conversion of the calibrated AVGWLF to MapShed involved the transfer of updated model coefficients and a series of verification model runs. The calibration and conversion of the models is discussed in detail in this section.

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 22). Flow data were obtained directly from the water resource database maintained by the U.S. Geological Survey (USGS). Water quality data were obtained from the New York and New England State agencies. These data sets included in-stream concentrations of nitrogen, phosphorus, and sediment based on periodic sampling.

Figure 10: Location of Calibration & Verification Watersheds for the Original 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 23.

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 20. Two models were developed based on the following two physiographic regions: Eastern Great Lakes/Hudson Lowlands area and the Northeastern Highlands area. The model was calibrated for each of these regions to better reflect local conditions, as well as ecological and hydrologic processes. In addition to developing the above mentioned physiographic-based model calibrations, a third model calibration was also developed. This model calibration represents a composite of the two physiographic regions and is suitable for use in other areas of upstate New York.

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

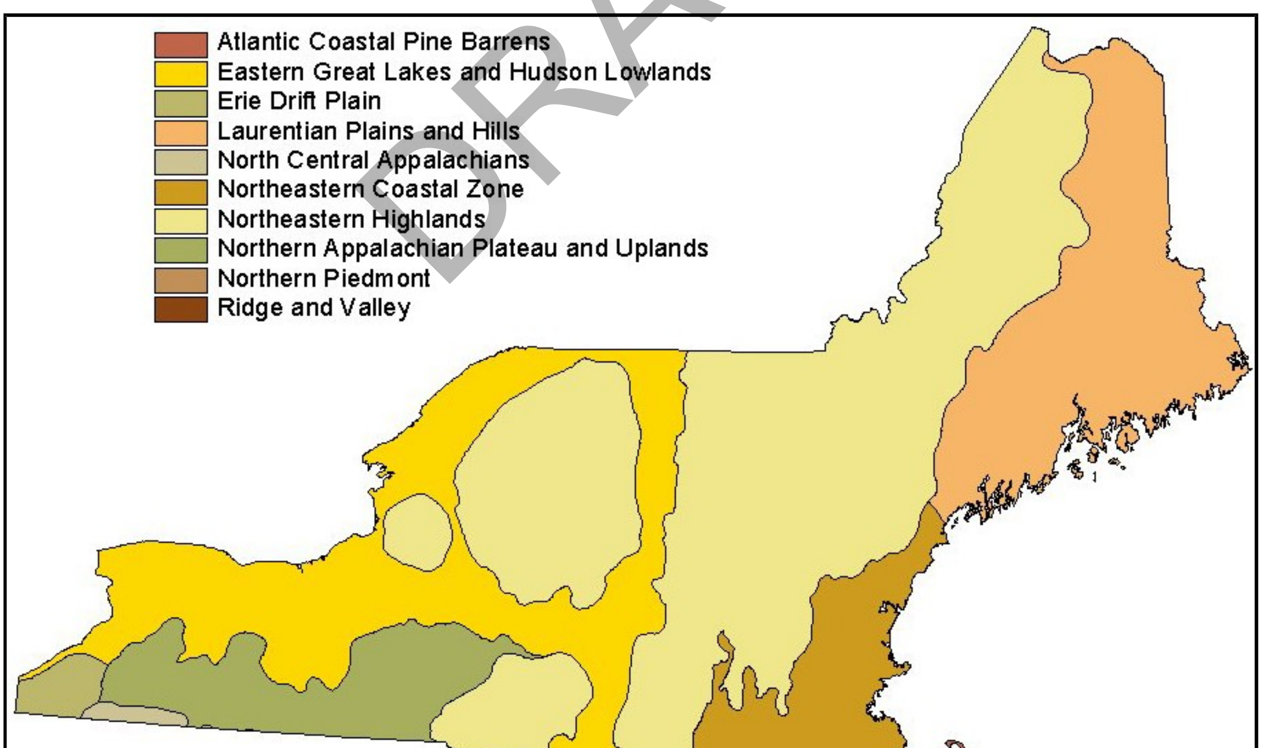


Table 7: AVGWLF Calibration Sites for use in the New York TMDL Assessments

Site	Location	Physiographic Region
Owasco Lake	NY	Eastern Great Lakes/Hudson Lowlands
West Branch	NY	Northeastern Highlands
Little Chazy River	NY	Eastern Great Lakes/Hudson Lowlands
Little Otter Creek	VT	Eastern Great Lakes/Hudson Lowlands
Poultney River	VT/NY	Eastern Great Lakes/Hudson Lowlands & Northeastern Highlands
Farmington River	CT	Northeastern Highlands
Saco River	ME/NH	Northeastern Highlands
Squannacook	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

Conversion of the AVGWLF Model to MapShed and Inclusion of RUNQUAL

The AVGWLF model requires that users obtain ESRI's ArcView 3.x with Spatial Analyst. The Cadmus Group, Inc. and Dr. Barry Evans converted the New York-calibrated AVGWLF model for use in a non-proprietary GIS package called MapWindow. The converted model is called MapShed and the software necessary to use it can be obtained free of charge and operated by any individual or organization who wishes to learn to use it. In addition to incorporating the enhanced GWLF model, MapShed contains a revised version of the RUNQUAL model, allowing for more accurate simulation of nutrient and sediment loading from urban areas.

RUNQUAL was originally developed by Douglas Haith (1993) to refine the urban runoff component of GWLF. Using six urban land use classes, RUNQUAL differentiates between three levels of imperviousness for residential and mixed commercial uses. Runoff is calculated for each of the six urban land uses using a simple water-balance method based on daily precipitation, temperature, and evapotranspiration. Pollutant loading from each land use is calculated with exponential accumulation and washoff relationships that were developed from empirical data. Pollutants, such as phosphorus, accumulate on surfaces at a certain rate (kg/ha/day) during dry periods. When it rains, the accumulated pollutants are washed off of the surface and have been measured to develop the relationship between accumulation and washoff. The pervious and impervious portions of each land use are modeled separately and runoff and contaminant loads are added to provide total daily loads. RUNQUAL is also capable of simulating the effects of various urban best management practices (BMPs) such as street sweeping, detention ponds, infiltration trenches, and vegetated buffer strips.

Set-up of the New York MapShed Model

Using data for the time period 1990-2007, the calibrated MapShed model was used to estimate mean annual phosphorus loading to the ponds. Table 21 provides the sources of data used for the MapShed modeling analysis. The various data preparation steps taken prior to running the final calibrated MapShed Model for New York are discussed below the table.

Table 8: Information Sources for MapShed Model Parameterization

WEATHER.DAT file	
Data	**Source or Value**
	Historical weather data from Rochester, NY and Albion, NY National Weather Service 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	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	Default values/adjusted using GWLF Manual
Dissolved P in runoff by land cover	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	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
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 MapShed. The New York State High Resolution Digital Orthoimagery (for the time period 2003 –2005) 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 vice-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 vice-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.

In addition to the corrections described above, low and high intensity development land uses were further refined for some lakes to differentiate between low, medium, and high density residential; and low, medium, and high density mixed urban areas. These distinctions were based primarily upon the impervious surface coverage and residential or mixed commercial land uses. The following types of refinements were the focus of the land use revision efforts:

1) Areas of residential development were identified. Discretion was used in the reclassification of small forested patches embedded within residential areas. Care was taken to maintain the "forest" classification for significant patches of forest within urban areas (e.g. parks, large forested lots within low-density residential areas). Individual trees (or small groups of trees) within residential areas were reclassified to match the surrounding urban classification, in accordance with the land use classifications described in the MapShed manual. Areas identified as lawn grasses surrounding residential structures were reclassified to match the surrounding urban classification, in accordance with the land use classifications in the

MapShed manual.

2) Areas of medium-density mixed development were identified. Discretion was used during the interpretation and reclassification of urban areas, based on the land use classification definitions in the MapShed manual. When appropriate, pixels were also reclassified as “low” or “high” density mixed development.

3) Golf courses were identified and classified appropriately.

Total phosphorus concentrations in runoff from the different urban land uses was acquired from the National Stormwater Quality Database (Pitt, *et al.*, 2008). These data were used to adjust the model’s default phosphorus accumulation rates. These adjustments were made using best professional judgment based on examination of specific watershed characteristics and conditions.

Phosphorus retention in wetlands and open waters in the basin can be accounted for in MapShed. MapShed 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 watershed area that drains through a wetland area was calculated and used in conjunction with nutrient retention coefficients in MapShed. 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.

<u>On-site Wastewater Treatment Systems (“septic tanks”)</u>

MapShed, following the method from 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.

MapShed 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 watershed 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.

MapShed 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 MapShed. 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

MapShed -generated groundwater phosphorus concentration was evaluated to ensure groundwater phosphorus values reasonably reflect the actual land use composition of the watershed and modifications were made if deemed unnecessary.

Point Sources

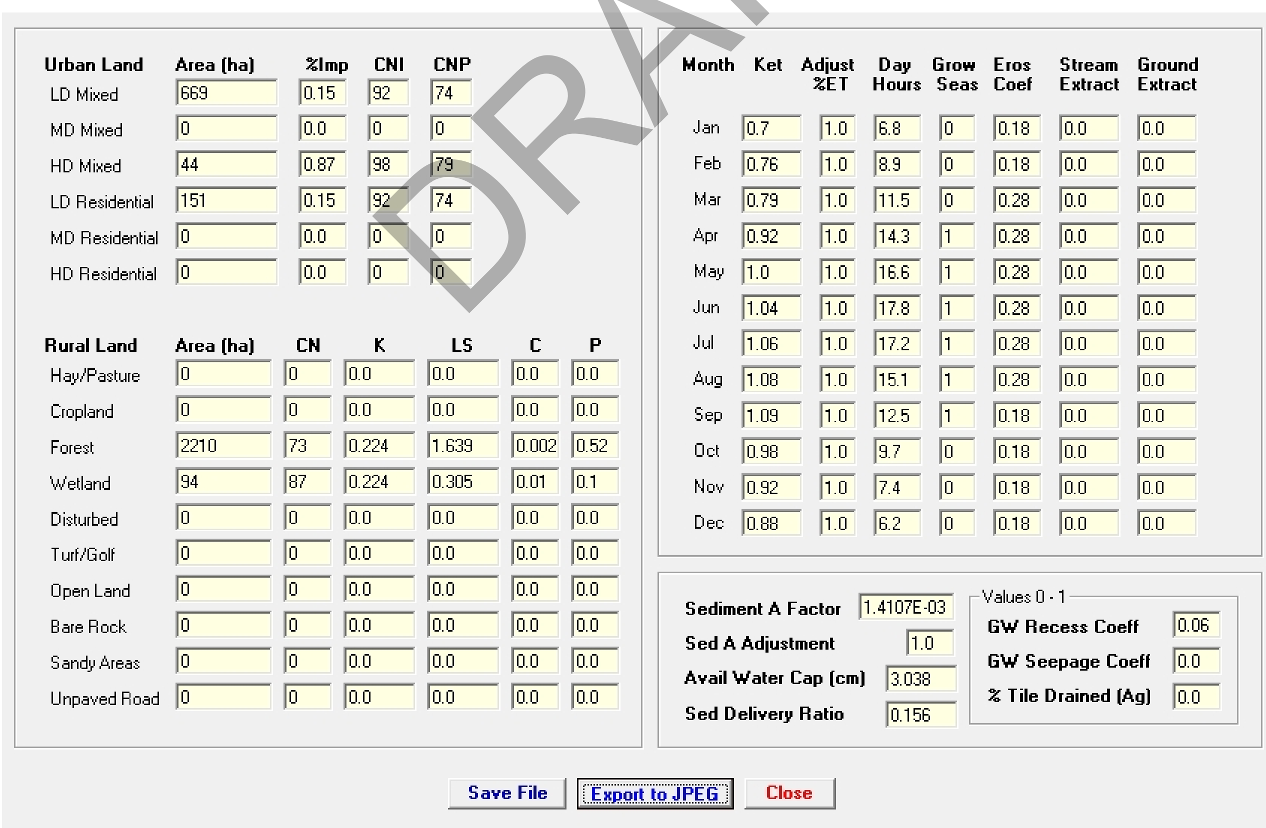
Permitted point sources in the watershed were identified and verified by NYS DEC and an estimated monthly total phosphorus load and flow was determined using SPDES permitted design flow.

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.

MapShed Model Simulation Files:

Transport Data Editor



Urban Land	Area (ha)	%Imp	CNI	CNP
LD Mixed	669	0.15	92	74
MD Mixed	0	0.0	0	0
HD Mixed	44	0.87	98	79
LD Residential	151	0.15	92	74
MD Residential	0	0.0	0	0
HD Residential	0	0.0	0	0

Rural Land	Area (ha)	CN	K	LS	C	P
Hay/Pasture	0	0	0.0	0.0	0.0	0.0
Cropland	0	0	0.0	0.0	0.0	0.0
Forest	2210	73	0.224	1.639	0.002	0.52
Wetland	94	87	0.224	0.305	0.01	0.1
Disturbed	0	0	0.0	0.0	0.0	0.0
Turf/Golf	0	0	0.0	0.0	0.0	0.0
Open Land	0	0	0.0	0.0	0.0	0.0
Bare Rock	0	0	0.0	0.0	0.0	0.0
Sandy Areas	0	0	0.0	0.0	0.0	0.0
Unpaved Road	0	0	0.0	0.0	0.0	0.0

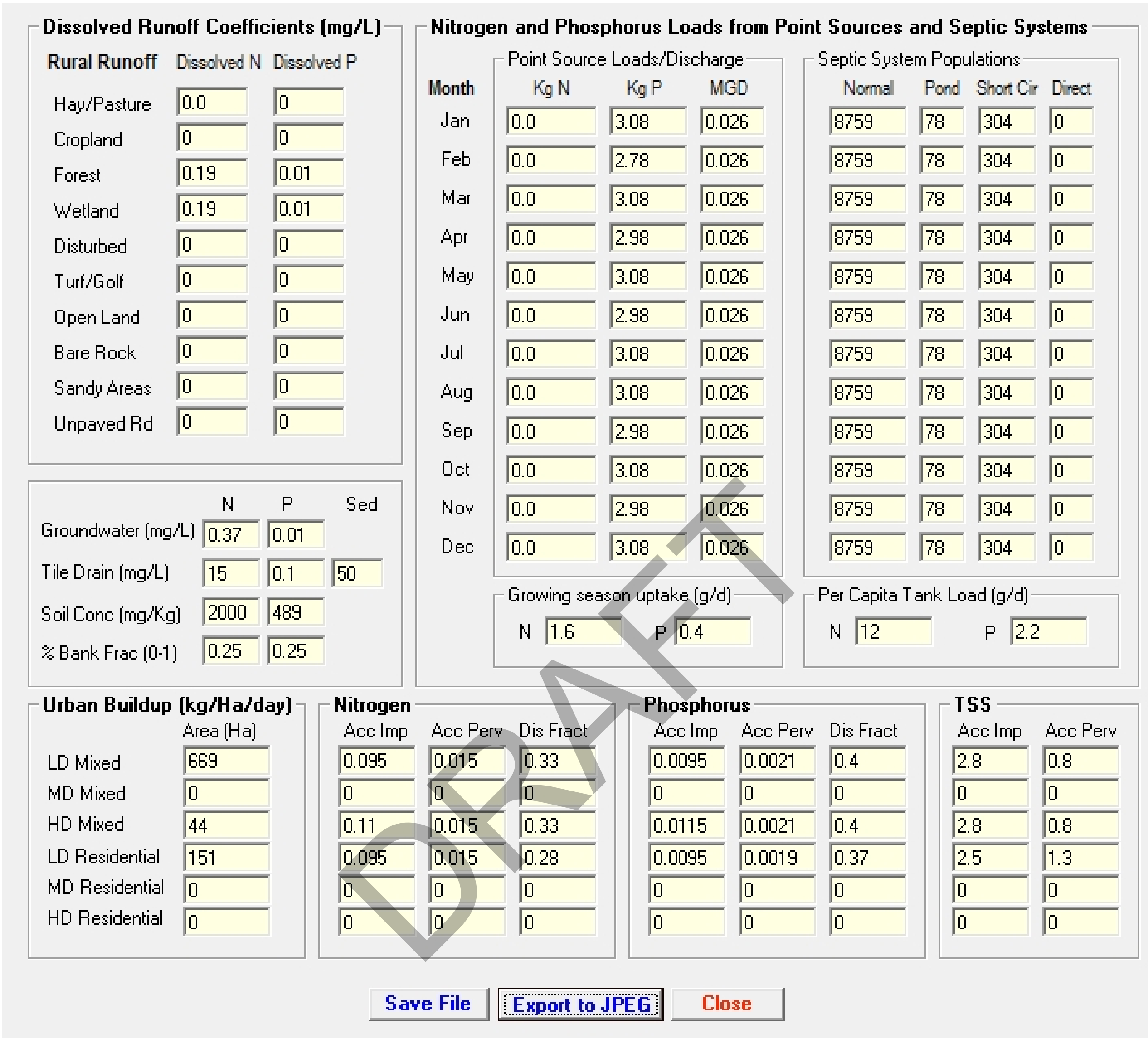
Month	Ket	Adjust %ET	Day Hours	Grow Seas	Eros Coef	Stream Extract	Ground Extract
Jan	0.7	1.0	6.8	0	0.18	0.0	0.0
Feb	0.76	1.0	8.9	0	0.18	0.0	0.0
Mar	0.79	1.0	11.5	0	0.28	0.0	0.0
Apr	0.92	1.0	14.3	1	0.28	0.0	0.0
May	1.0	1.0	16.6	1	0.28	0.0	0.0
Jun	1.04	1.0	17.8	1	0.28	0.0	0.0
Jul	1.06	1.0	17.2	1	0.28	0.0	0.0
Aug	1.08	1.0	15.1	1	0.28	0.0	0.0
Sep	1.09	1.0	12.5	1	0.18	0.0	0.0
Oct	0.98	1.0	9.7	0	0.18	0.0	0.0
Nov	0.92	1.0	7.4	0	0.18	0.0	0.0
Dec	0.88	1.0	6.2	0	0.18	0.0	0.0

Sediment A Factor	1.4107E-03
Sed A Adjustment	1.0
Avail Water Cap (cm)	3.038
Sed Delivery Ratio	0.156

Values 0 - 1

GW Recess Coeff	0.06
GW Seepage Coeff	0.0
% Tile Drained (Ag)	0.0

Nutrient Data Editor



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 Lake Carmel and its surrounding drainage area, as well as output from MapShed, a BATHTUB model was set up for Lake Carmel. Mean annual phosphorus loading to the lake was simulated using MapShed for the period 1990-2004. 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 MapShed 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.

Tables 9 – 12 summarize the primary model inputs for Lake Carmel. 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 Lake Carmel. 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 watershed were treated as though they originated from one "tributary" (i.e., source) in BATHTUB and derived from MapShed.

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 Stormville, NY and Yorktown, NY National Weather Service Stations for the 1990-2013 period. Evapotranspiration was derived from MapShed using daily weather data (1990-2013) and a cover factor dependent upon land use/cover type. The values selected for precipitation and change in lake storage have very little influence on model predictions. Atmospheric phosphorus loads were specified using data collected by NYS DEC from the Moss Lake Atmospheric Deposition Station located in Herkimer County, NY. Atmospheric deposition is not a major source of phosphorus loading to Lake Carmel 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 Lake Carmel were represented using the average observed summer mean phosphorus concentration for the years 1986-1990, and 2013. These data were collected through CSLAP (1986-1990) and NYSDEC (2013). The concentration of phosphorus loading to the lake was calculated using the average annual flow and phosphorus loads simulated by MapShed. 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 nonzerovalues 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	0	2nd Order Settling Velocity*
Phosphorus Calibration	01	Decay Rate*
Error Analysis	0	Model and Data*
Availability Factors	00	Ignore*
Mass Balance Tables	0	Use Estimated Concentrations*

* Default model choice

Table 10: BATHTUB Model Input: Global Variables

Model Input	Mean	CV
Averaging Period (years)	0.5	NA
Precipitation (meters)	0.65	0.2*
Evaporation (meters)	0.263	0.3*
Atmospheric Load (mg/m^2-yr)- Total P	4.87	0.5*
Atmospheric Load (mg/m^2-yr)- Ortho P	2.61	0.5*

* Default model choice

Table 11: BATHTUB Model Input: Lake Variables

Morphometry	Mean	CV
Surface Area (km^2)	0.75	NA
Mean Depth (m)	2.27	NA
Length (km)	2.16	NA
Estimated Mixed Depth (m)	2.27	0.12
Observed Water Quality	**Mean**	**CV**
Total Phosphorus (ppb)	39.3	0.5

* Default model choice

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

Monitored	Mean	CV
Total Watershed Area (km^2)	32.9	NA
Flow Rate (hm^3/yr)	23.33	0.1
Total P (ppb)	37.6	0.2
Organic P (ppb)	18.01	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 Lake Carmel are as follows:

Table 13: BATHTUB Model T-Statistics

Year	Observed	Simulated	T1	T2	T3
1986	33.0	34		-0.11	-0.33
1987	56.6	33		2.06	6.46
1988	22.8	36		-1.72	-5.06
1989	38.9	33		0.60	2.01
1990	34.4	33		0.14	0.48
2013	63.4	31		2.62	9.09
28 yr average	41.5	39		0.07	0.21

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 Lake Carmel is quite good for 1986 and 1990, fairly good for 1988 and 1989 and moderately accurate for 1987 and 2013.

In average, 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

	Current	Allocated	Reduction	% Reduction
Stream Bank Erosion	2.428	1.310	1.119	46%
Wetland	0.017	0.017	0	0
Forest	0.312	0.312	0	0
Groundwater	1.108	1.108	0	0
Septic Systems	1.682	0	1.682	100%
Internal Loading	1.400	0	1.400	100%
LOAD ALLOCATION TOTAL	**6.947**	**2.746**	**4.201**	**40%**
WWTF: *Girl Scouts Heart of Hudson* SPDES # NY0102181	0.014	0.005	0.009	60%
WWTF: *Putnam Nursing and Rehabilitation* SPDES # NY0028924	0.167	0.033	0.133	80%
WWTF: *Frangel Realty* SPDES # NY143863	0.025	0	0.025	100%
MS4 Developed Land: T/Kent NYR20A346, T/Patterson NYR20A140, T/Pawling NYR20A472, T/Beekman NYR20A365, T/E. Fishkill, NYR20A183	0.276	0.248	0.028	10%
WASTELOAD ALLOCATION TOTAL	**0.481**	**0.286**	**0.195**	**42%**
LA + WLA	7.428	3.033	-	-
10% Margin of Safety	-	0.337	-	-
TOTAL	**7.428**	**3.370**	4.396	59%