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

Schoharie County, New York

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Prepared for:

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1.0 INTRODUCTION

1.1. Background

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

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

1.2. Problem Statement

Summit Lake (WI/PWL ID 1202-0014) is situated in the Town of Summit, within Schoharie County, New York. Over the past couple of decades, the lake has experienced degraded water quality that has reduced the lake's recreational and aesthetic value. Recreational suitability has become less favorable in Summit Lake due to an increase in weed densities and a perceived drop in water clarity in the lake. Recreational assessments have shifted from "excellent" to "slightly" and "substantially" impaired for most uses over the last several years. The lake is regularly described as "having definite algal greenness", although actual transparency measurements have not decreased. Rooted aquatic plants, absent from the lake surface as recently as 1994, had begun forming dense coverage of the lake surface by 2001. The productivity of Summit Lake increases over the summer months, consistent with observations from other shallow lakes. Summit Lake was listed on the Mohawk River Basin PWL in 1996, with *aesthetics, boating, bathing, and fishing* listed as *stressed* due to excessive weed growth. (NYS DEC, 2002)

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

The results from state sampling efforts confirm eutrophic conditions in Summit Lake, with the concentration of phosphorus in the lake exceeding the state guidance value for phosphorus (20 μg/L or 0.020 mg/L, applied as the mean summer, epilimnetic total phosphorus concentration), which increases the potential for nuisance summertime algae blooms. In 2004, Summit Lake was added to the New York State Department of Environmental Conservation (NYS DEC) CWA Section 303(d) list of impaired waterbodies that do not meet water quality standards due to phosphorus impairments (NYS DEC, 2008). Based on this listing, a TMDL for phosphorus is being developed for the lake to address the impairment.

2.0 WATERSHED AND LAKE CHARACTERIZATION

2.1. Watershed Characterization

Summit Lake has a direct drainage basin area of 219 acres excluding the surface area of the lake (Figure 1). Elevations in the lake's basin range from approximately 2,438 feet above mean sea level (AMSL) to as low as 2,060 feet AMSL at the surface of Summit Lake.

Existing land use and land cover in the Summit Lake drainage basin was determined from digital aerial photography and geographic information system (GIS) datasets. Digital land use/land cover data were obtained from the 2001 National Land Cover Dataset (NLCD, Homer, 2004). The NLCD is a consistent representation of land cover for the conterminous United States generated from classified 30-meter resolution Landsat thematic mapper satellite imagery data. High-resolution color orthophotos were used to manually update and refine land use categories for portions of the drainage basin to reflect current conditions in the drainage basin (Figure 2). Appendix A provides additional detail about the refinement of land use for the drainage basin. Low density residential acreage has been increased from that used to prepare the draft TMDL to include the full extent of shoreline development. Land use classified as agriculture in the draft TMDL has been change to forest and low density residential development based on comments received during the public comment period and a site investigation. Land use categories (including individual category acres and percent of total) in Summit Lake's drainage basin are listed in Table 1 and presented in Figures 3 and 4.

Figure 1. Summit Lake Direct Drainage Basin

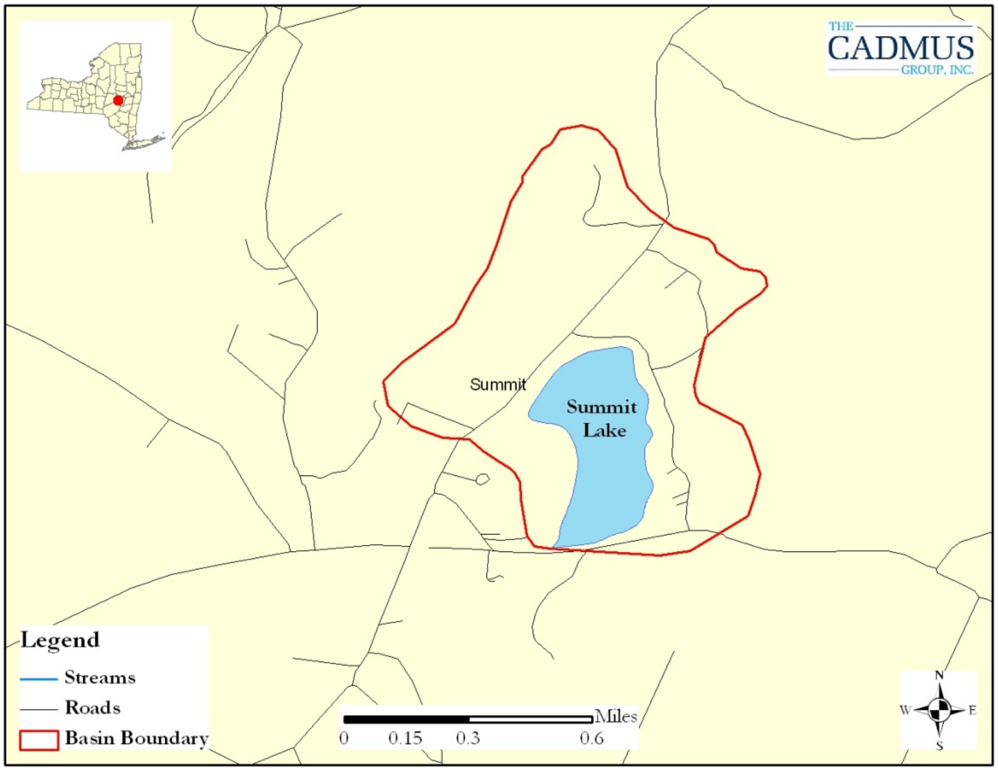


Figure 2. Aerial Image of Summit Lake

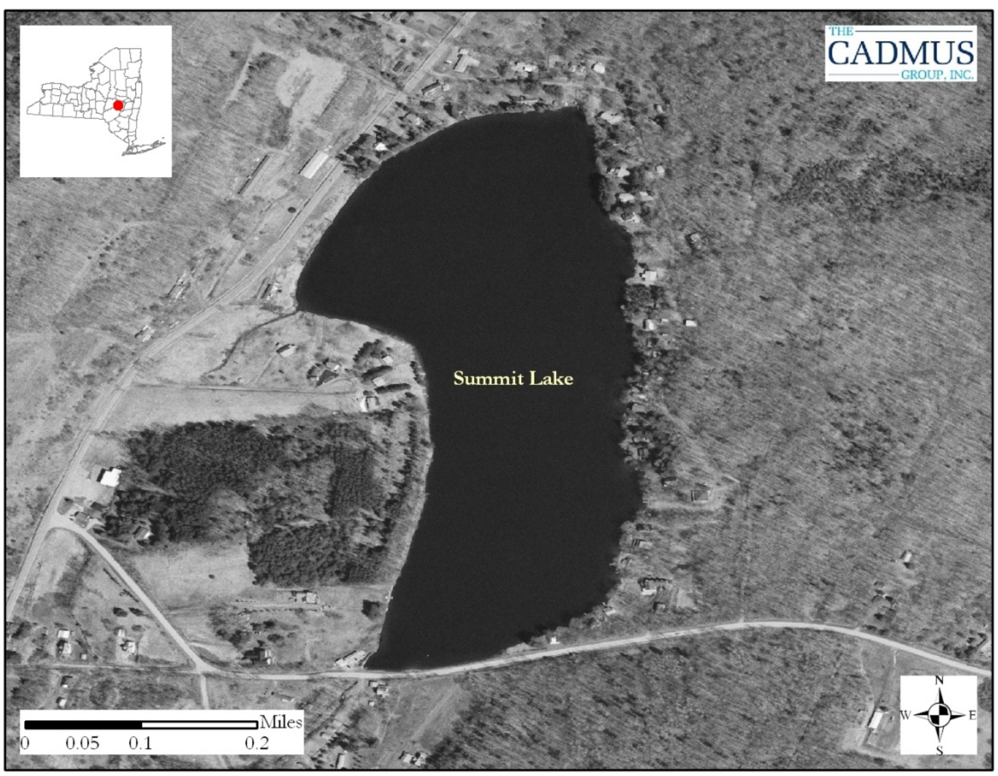


Table 1. Land Use Acres and Percent in Summit Lake Drainage Basin

Land Use Category	Acres	% of Drainage Basin
Open Water	0.2	0.1%
Developed Land	38.7	17.7%
Low Intensity	38.7	17.7%
High Intensity	0.0	0%
Forest	179.0	81.7%
Wetlands	1.2	0.5%
TOTAL	**219.1**	**100%**

Figure 3. Percent Land Use in Summit Lake Drainage Basin

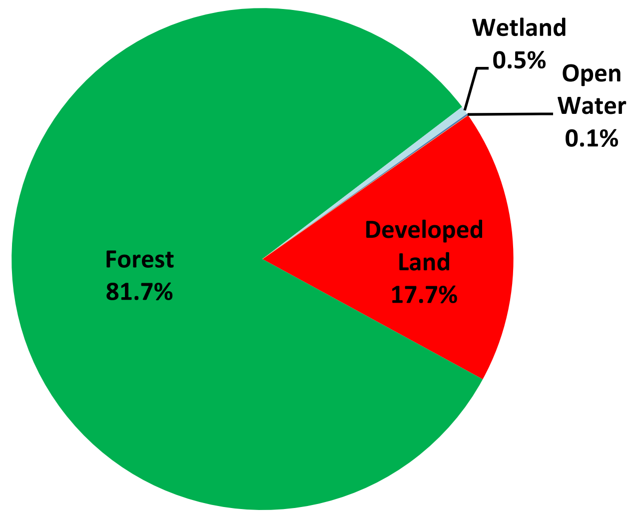
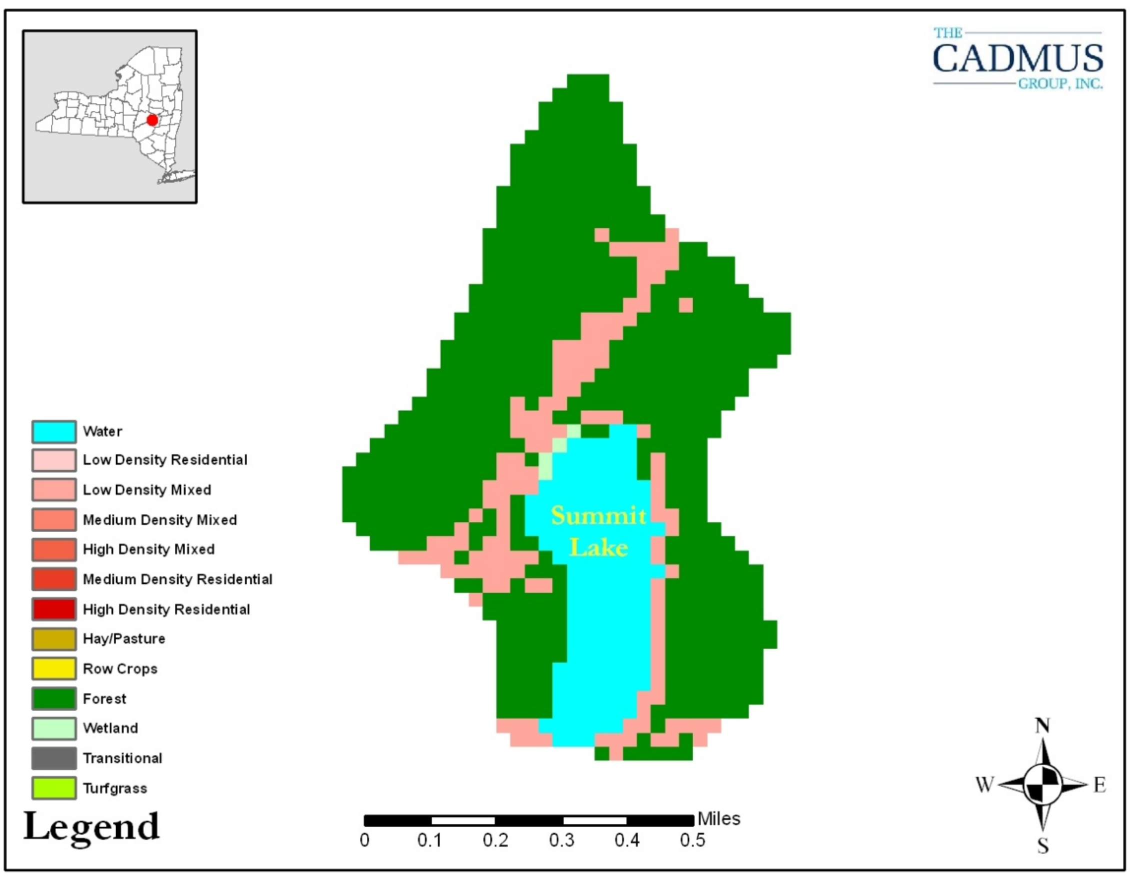


Figure 4. Land Use in Summit Lake Drainage Basin



2.2. Lake Morphometry

Summit Lake is a 43 acre waterbody at an elevation of about 2,060 feet AMSL. Figure 5 shows a bathymetric map for Summit Lake based on data collected during the summer of 2007. Table 2 summarizes key morphometric characteristics for Summit Lake.

Figure 5. Bathymetric Map of Summit Lake

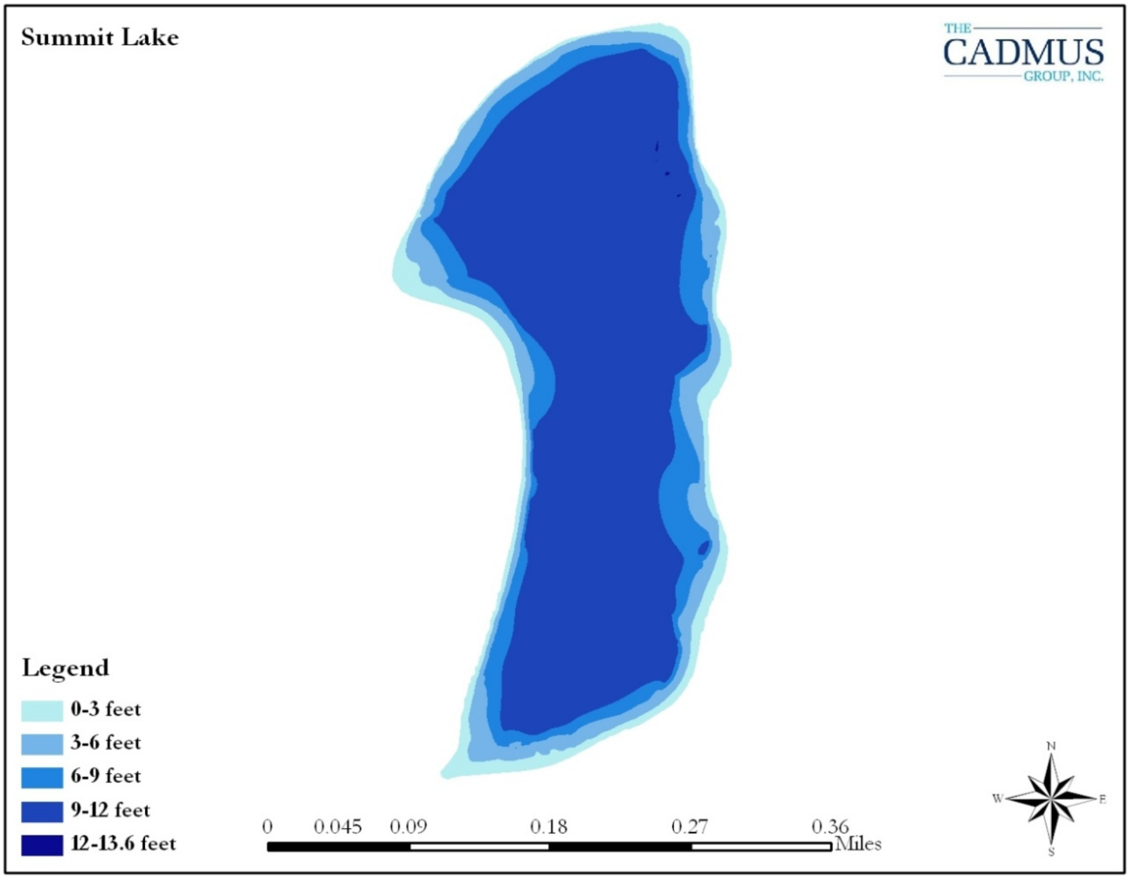


Table 2. Summit Lake Characteristics

Surface Area (acres)	43
Elevation (ft AMSL)	2,060
Maximum Depth (ft)	14
Mean Depth (ft)	10
Length (ft)	2,562
Width at widest point (ft)	1,159
Shoreline perimeter (ft)	6,661
Direct Drainage Area (acres)	219
Watershed: Lake Ratio	5:1
Mass Residence Time (years)	0.7
Hydraulic Residence Time (years)	1.2

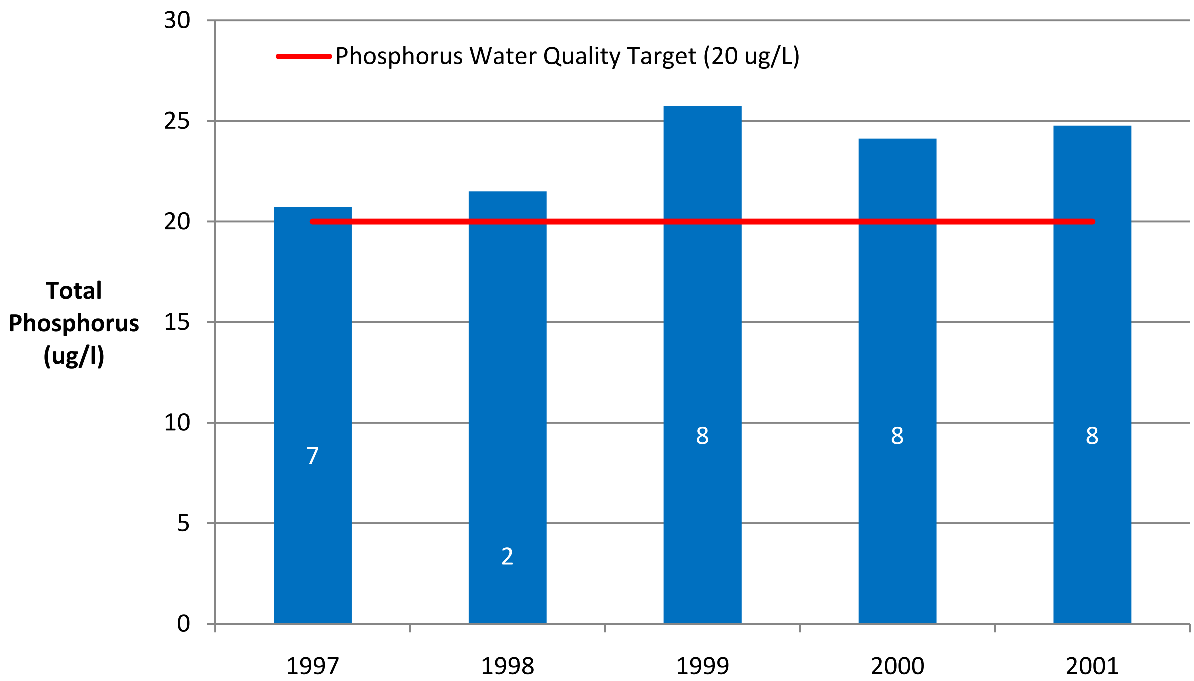
2.3. Water Quality

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

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

As part of CSLAP, a limited number of water quality samples were collected in Summit Lake during the summers of 1997-2001. The results from these sampling efforts show eutrophic conditions in Summit Lake, with the concentration of phosphorus in the lake exceeding the state guidance value for phosphorus (20 μg/L or 0.020 mg/L, applied as the mean summer, epilimnetic total phosphorus concentration), which increases the potential for nuisance summertime algae blooms. Figure 6 shows the summer mean epilimnetic phosphorus concentrations for phosphorus data collected during all sampling seasons and years in which Summit Lake was sampled as part of CSLAP; the number annotations on the bars indicate the number of data points included in each summer mean.

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



3.0 NUMERIC WATER QUALITY TARGET

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

4.0 SOURCE ASSESSMENT

4.1. Analysis of Phosphorus Contributions

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

MapShed incorporates an enhanced version of the Generalized Watershed Loading Function (GWLF) model developed by Haith and Shoemaker (1987) and the RUNQUAL model also developed by Haith (1993). GWLF and RUNQUAL simulate runoff and stream flow by a water-balance method based on measurements of daily precipitation and average temperature. The complexity of the two models falls between that of detailed, process-based simulation models and simple export coefficient models that do not represent temporal variability. The enhanced GWLF model within MapShed was determined to be appropriate for this TMDL analysis because it simulates the important processes of concern, but do not have onerous data requirements for calibration. MapShed was developed to facilitate the use of the GWLF and RUNQUAL models via a MapWindow interface (Evans, 2009). Appendix A discusses the setup, calibration, and use of the MapShed model for lake TMDL assessments in New York.

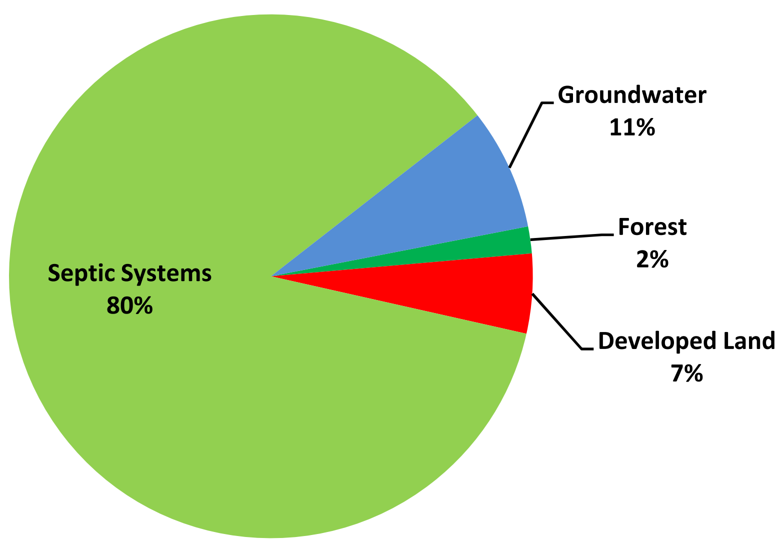
4.2. Sources of Phosphorus Loading

MapShed was used to estimate long-term (1990-2004) mean annual phosphorus (external) loading to Summit Lake. The estimated mean annual external load of 39 lbs/yr of total phosphorus that enters Summit Lake 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 Summit Lake

Source	Total Phosphorus (lbs/yr)
Forest	0.9
Developed Land	2.8
Septic Systems	31.3
Groundwater	4.2
TOTAL	**39.2**

Figure 7. Estimated Sources of Total Phosphorus Loading to Summit Lake



4.2.1. ***Residential On-Site Septic Systems***

Residential on-site septic systems contribute an estimated 31 lbs/yr of phosphorus to Summit Lake, which is about 80% of the total loading to the lake. Residential septic systems contribute dissolved phosphorus to nearby waterbodies due to system malfunctions. Septic systems treat human waste using a collection system that discharges liquid waste into the soil through a series of distribution lines that comprise the drain field. In properly functioning (normal) systems, phosphates are adsorbed and retained by the soil as the effluent percolates through the soil to the shallow saturated zone. Therefore, normal systems contribute very little phosphorus loads to nearby waterbodies. A ponding septic system malfunction occurs when there is a discharge of waste to the soil surface (where it is available for runoff); as a result, malfunctioning septic systems can contribute high phosphorus loads to nearby waterbodies. Short-circuited systems (those systems in close proximity to surface waters where there is limited opportunity for phosphorus adsorption to take place) also contribute significant phosphorus loads; septic systems within 250 feet of the lake are subject to potential short-circuiting, with those closer to the lake more likely to contribute greater loads. Additional details about the process for estimating the population served by normal and malfunctioning systems within the lake drainage basin is provided in Appendix A.

GIS analysis of orthoimagery for the basin shows approximately 23 houses within 50 feet of the shoreline and 27 houses between 50 and 250 feet of the shoreline; all of the houses are assumed to have septic systems. Within 50 feet of the shorelines, 65% of septic systems were categorized as short-circuiting and 35% were categorized as normal systems. Between 50 and 250 feet of the shoreline, 10% of septic systems were categorized as short-circuiting, 10% were categorized as ponding systems, and 80% were categorized as normal systems. To convert the estimated number of septic systems to population served, an average household size of 2.61 people per dwelling was used based on the circa 2000 USCB census estimate for number of persons per household in New York State. To account for seasonal variations in population, information provided by NYS DEC and comments provided during the public comment period from local residents were used to estimate the percentage of seasonal homes surrounding the lake. Approximately 10% of the homes around the lake are assumed to be year-round residences, while 90% are seasonally occupied (i.e., June through August only). The estimated population in the Summit Lake drainage basin served by normal and malfunctioning systems is summarized in Table 4.

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

	Normally Functioning	Ponding	Short Circuiting	Total
September – May	8	1	5	14
June – August (Summer)	77	7	46	130

4.2.2. *Urban and Residential Development Runoff*

Developed land comprises about 39 acres (18%) of the lake drainage basins. Stormwater runoff from developed land contributes less than 3 lb/yr of phosphorus to Summit Lake, which is 7% of the total phosphorus loading to the lake. This load does not account for contributions from malfunctioning septic systems. Phosphorus runoff from developed areas originates primarily from human activities, such as fertilizer applications to lawns. Shoreline development, in particular, can have a large phosphorus loading impact to nearby waterbodies in comparison to its relatively small percentage of the total land area in the drainage basin.

4.2.3. *Forest Land Runoff*

Forested land comprises 179 acres (82%) of the lake drainage basin. Runoff from forested land is estimated to contribute less than 1 lbs/yr of phosphorus loading to Summit Lake, which is 2% of the total phosphorus loading to the lake. Phosphorus contribution from forested land is considered a component of background loading. Additional phosphorus originating from forest land is leached in dissolve form from the surface and transported to the lake though subsurface movement via groundwater. The process for estimating subsurface delivery of phosphorus originating from forest land is discussed in the Groundwater Seepage section (below).

4.2.4. *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 approximately 4 lbs/yr (11%) of the total phosphorus load to Summit Lake. With respect to groundwater, there is typically a small "background" concentration owing to various natural sources. In the Summit Lake drainage basin, the model-estimated groundwater phosphorus concentration is 0.006 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, 100% of the groundwater load (4 lbs/yr) can be attributed to natural sources, including forested land and soils.

4.2.5. *Other Sources*

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

5.0 DETERMINATION OF LOAD CAPACITY

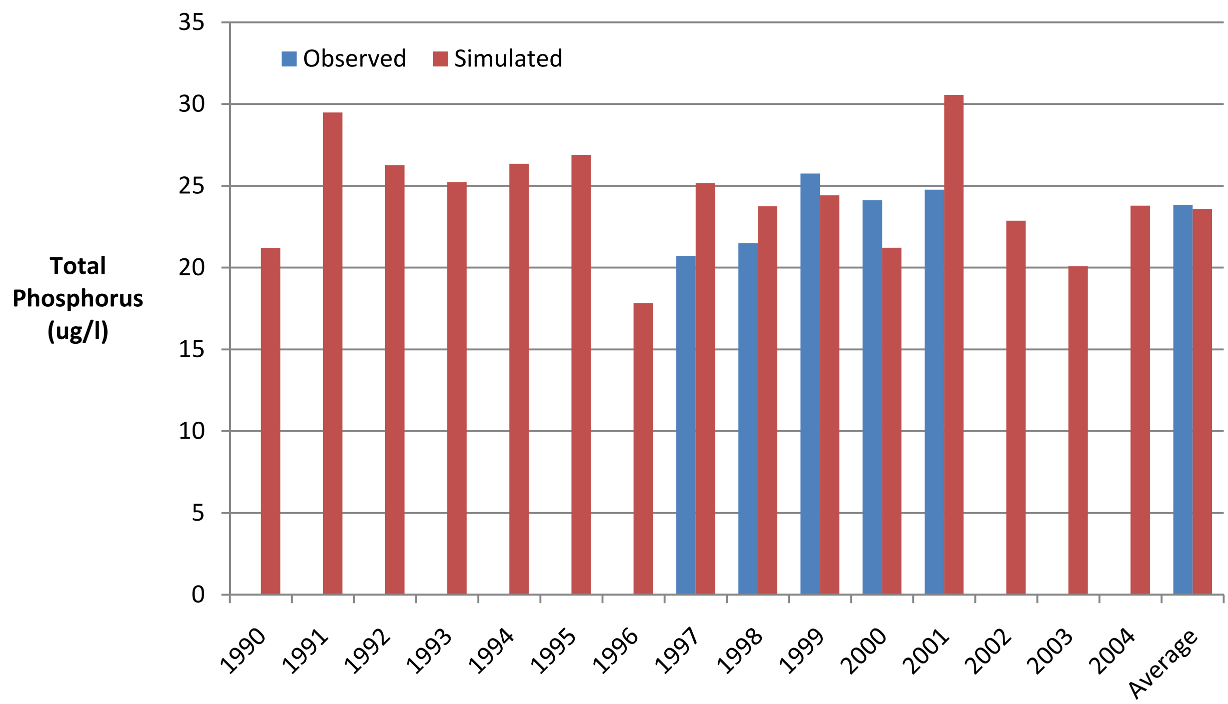
5.1. Lake Modeling Using the BATHTUB Model

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

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

In order to estimate the loading capacity of the lake, simulated phosphorus loads from MapShed were used to drive the BATHTUB model to simulate water quality in Summit Lake. MapShed was used to derive a mean annual phosphorus loading to the lake for the period 1990-2004. 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 average of the lake's observed summer mean phosphorus concentrations for the years 1997-2001. Year-specific loading was also simulated with MapShed, run through BATHTUB, and compared against the observed summer mean phosphorus concentration for years with observed in-lake data. The combined use of MapShed and BATHTUB provides a good fit to the observed data for Summit Lake (Figure 8).

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



The BATHTUB model was used as a "diagnostic" tool to derive the total phosphorus load reduction required to achieve the phosphorus target of 20 µg/L. The loading capacity of Summit Lake was determined by running BATHTUB iteratively, reducing the concentration of the drainage basin phosphorus load until model results demonstrated attainment of the water quality target. The maximum concentration that results in compliance with the TMDL target for phosphorus is used as the basis for determining the lake's loading capacity. This concentration is converted into a loading rate using simulated flow from 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 Summit Lake is a mean annual load of 30.72 lbs/yr. The daily TMDL of 0.0841 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).

Equation 1. Calculation of the TMDL

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

6.1. Wasteload Allocation (WLA)

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

6.2. Load Allocation (LA)

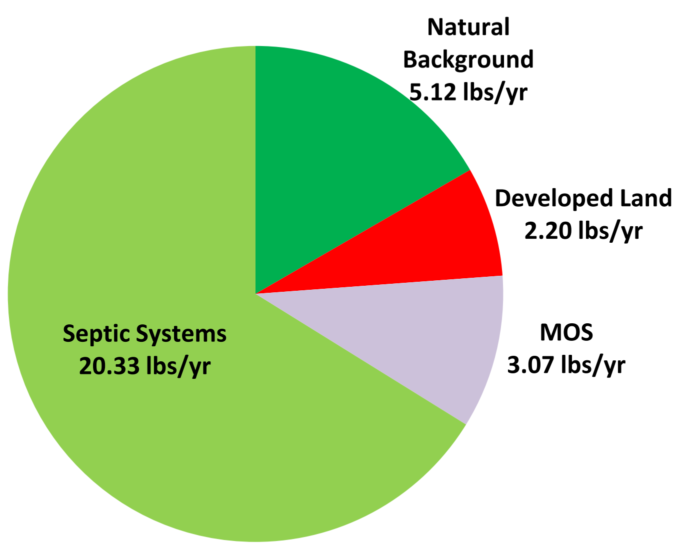
The LA is set at 28 lbs/yr. Nonpoint sources that contribute total phosphorus to Summit Lake on an annual basis include loads from developed land, agricultural land, and malfunctioning septic systems. Table 5 lists the current loading for each source and the load allocation needed to meet the TMDL; Figure 9 provides a graphical representation of this information. Phosphorus originating from natural sources (including forested land, wetlands, and stream banks) is assumed to be a minor source of loading that is unlikely to be reduced further and therefore the load allocation is set at current loading.

Table 5. Total Annual Phosphorus Load Allocations for Summit Lake*

Source	Total Phosphorus Load (lbs/yr)			% Reduction
	Current	Allocated	Reduction	
Developed Land	2.75	2.20	0.55	20%
Septic Systems	31.29	20.33	10.96	35%
Forest, Wetland, Stream Bank, and Natural Background Groundwater**	5.12	5.12	0	0%
LOAD ALLOCATION	**39.16**	**27.65**	**11.51**	**29%**
Point Sources	0	0	0	0%
WASTELOAD ALLOCATION	**0**	**0**	**0**	**0%**
LA + WLA	**39.16**	**27.65**	**11.51**	**29%**
Margin of Safety	---	3.072	---	---
TOTAL	**39.16**	**30.72**	**---**	**---**

* The values reported in Table 5 are annually integrated. Daily equivalent values are provided in Appendix C.
** Includes phosphorus transported through surface runoff and subsurface (groundwater)

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



6.3. Margin of Safety (MOS)

The margin of safety (MOS) can be implicit (incorporated into the TMDL analysis through conservative assumptions) or explicit (expressed in the TMDL as a portion of the loadings) or a combination of both. For the Summit Lake TMDL, the MOS is explicitly accounted for during the allocation of loadings. An implicit MOS could have been provided by making conservative assumptions at various steps in the TMDL development process (e.g., by selecting conservative model input parameters or a conservative TMDL target). However, making conservative assumptions in the modeling analysis can lead to errors in projecting the benefits of BMPs and in projecting lake responses. Therefore, the recommended method is to formulate the mass balance using the best scientific estimates of the model input values and keep the margin of safety in the "MOS" term. The TMDL contains an explicit margin of safety corresponding to 10% of the loading capacity, or 3.08 lbs/yr. The MOS can be reviewed in the future as new data become available.

6.4. Critical Conditions

TMDLs must take into account critical environmental conditions to ensure that the water quality is protected during times when it is most vulnerable. Critical conditions were taken into account in the development of this TMDL. In terms of loading, spring runoff periods are considered critical because wet weather events transport significant quantities of nonpoint source loads to lakes. However, the water quality ramifications of these nutrient loads are most severe during middle or late summer. Therefore, BATHTUB model simulations were compared against observed data for the summer period only. Furthermore, 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 14 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.

7.0 IMPLEMENTATION

One of the critical factors in the successful development and implementation of TMDLs is the identification of potential management alternatives, such as best management practices (BMPs) and screening and selection of final alternatives in collaboration with the involved stakeholders. Coordination with federal agencies, state agencies, local governments, and stakeholders such as the general public, environmental interest groups, and representatives from the nonpoint pollution sources will ensure that the proposed management alternatives are technically and financially feasible. NYS DEC, in coordination with these local interests, will address the sources of impairment using non-regulatory tools by matching management strategies with funding and available resources to effect implementation.

NYS DEC recognizes that TMDL designated load reductions alone may not be sufficient to restore eutrophic lakes. The TMDL establishes the required nutrient reduction targets and provides some regulatory framework to effect those reductions. However, the nutrient load only affects the eutrophication potential of a lake. The implementation plan therefore calls for the collection of additional monitoring data as discussed in Section 7.2. Monitoring is crucial to ensure that corrective measures implemented to achieve the TMDL pollutant allocations are effective and to compile data to inform future adjustments to TMDL implementation activities.

7.1. Reasonable Assurance for Implementation

7.1.1. *Recommended Phosphorus Management Strategies for Septic Systems*

Septic system management measures will be an important component of the implementation plan. Because septic loads are the most significant source of phosphorus, long-term management measures to address septic problems are necessary components. Failing or improperly functioning septic system can be a source of phosphorus, and the extent of the load is significantly determined by geologic and soil constraints, and proximity to the lake or other surface waters. A septic management plan, possibly including alternative treatment measures, will be necessary. The Town of Summit could adopt an ordinance, which requires proof of proper functioning systems and periodic pump-out as an on-going requirement. Alternative treatment may still be needed due to the environmental and site constraints in the area, so the Town may need to consider the formation of a management district for areas of concentrated development along the Lake shore or with severe site constraints. Training of on-site professionals and education of homeowners should be promoted through the State's Onsite training Network.

An in-depth investigation of septic issues could be an initial step. Issues to be covered include refining detailed information on the estimates of the number of septic systems which potentially impact the lake, the percentage of failing or improperly functioning systems, the ability of standard systems to function given specific geologic and soil restrictions, the area required for a properly functioning leach field given the environmental constraints, other options and a cost analysis.

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

NYS DEC issued SPDES general permits GP-0-08-001 for construction activities, and GP-0-08-002 for stormwater discharges from municipal separate stormwater sewer system (MS4s) in response to the federal Phase II Stormwater rules. GP-0-08-002 applies to urbanized areas of New York State, so it does not cover the Summit Lake watershed.

Stormwater management in rural areas can be addressed through the Nonpoint Source Management Program. There are several measures, which, if implemented in the watershed, could directly or indirectly reduce phosphorus loads in stormwater discharges to the lake or watershed. These measures include but are not limited to:

- Public education regarding:
  - Lawn care, specifically reducing fertilizer use or using phosphorus-free products, now commercially available,
  - Cleaning up pet waste, and

- Discouraging waterfowl congregation by restoring natural shoreline vegetation.

- Management practices to address any significant existing erosion sites.
- Construction site and post construction stormwater runoff control ordinance and inspection and enforcement programs.
- Pollution prevention practices for road and ditch maintenance.

7.1.3. *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.

7.2. Follow-up Monitoring

A targeted post-assessment monitoring effort will be initiated to determine the effectiveness of the implementation plan associated with the TMDL. Summit Lake will be sampled in 2010 at its deepest location during the warmer part of the year (May through September) on 8 sampling dates. Grab samples will be collected at a depth of 1.5 meters and in the hypolimnion. The samples will be analyzed for the phosphorus series (total phosphorus, total soluble phosphorus, and soluble reactive phosphorus), the nitrogen series (nitrate, ammonia and total nitrogen), and chloride. The epilimnetic samples will be analyzed for chlorophyll a and the Secchi disk depth will be measured. A simple macrophyte survey will also be conducted one time during midsummer.

Depending on the speed and extent of implementation, the sampling will be repeated at a regular interval. The initial plan will be to set the interval at 5 years. In addition, as the information on the DEC GIS system is updated (land use, BMPs, etc.), these updates will be applied to the input data for the models BATHTUB and AVGWLF. The information will be incorporated into the NY 305(b) report as needed.

8.0 PUBLIC PARTICIPATION

Notice of availability of the Draft TMDL was made to local government representatives and interested parties. This Draft TMDL was public noticed in the Environmental Notice Bulletin on July 15, 2009. A 30-day public review period was established for soliciting written comments from stakeholders prior to the finalization and submission of the TMDL for EPA approval. NYS DEC met with stakeholders on August 26th to refine data and receive local input on the draft TMDL. Written comments were received and the following is NYS DEC's response to comments:

1. **Comment:** The Lake View Inn ceased operations and, being the sole commercial business on the lake, we do not know if their closure has resulted in a reduction in the amount of phosphorus entering the lake.

Response: The former Lake View Inn is not located in the Summit Lake Watershed and therefore did not contribute a phosphorus load to the lake.

2. **<u>Comment</u>:** The land use map shows agricultural areas when there is no active farming in the watershed.

   Response: The land use map has been revised based on aerial photo interpretations and a site investigation. All of the agricultural areas have been changed to either forested land or developed land uses. Developed land acreage has also increased to reflect the homes along the lake shore that were not captured in the previous draft of the TMDL.

3. **<u>Comment</u>:** The report's assumptions on residency are inaccurate. Approximately 5-6 homes are year round residencies and the rest are seasonal.

   Response: The residency assumptions have been changed to reflect this comment. The revised TMDL assumes that 10 % of the homes in the watershed are year-round residencies and the remaining 90 % are seasonal residencies. Additionally, the failure rate assumptions were increased from the previous draft of the TMDL in order to make the model predictions fit the water quality data.

4. **<u>Comment</u>:** The study indicates that ongoing testing would be conducted on the lake, the most recent occurring in May 2009 thru October 2009. Since the results of such testing would reflect a more current reading into the health of the lake than the studies 1997-2001 data, wouldn't it be reasonable to delay sending the Summit Lake Report until those results are available?

   Response: The dates for follow-up monitoring listed in the draft TMDL have been changed to 2010. U.S. EPA recommends the preparation of a monitoring plan to track the effectiveness of TMDL implementation. As such, the data collected as part of this monitoring plan is not intended to aid in TMDL development.

5. **<u>Comment</u>:** The bottom of Summit Lake is full of muck. This muck may be several feet thick in areas. Undoubtedly, there was a problem with phosphorus loading in the lake in prior years which resulted in this over vegetation in the lake. However, if the problem (septic systems) had already been resolved, could the level of phosphorus still be high due to this muck now degrading?

   Response: There has been no information provided indicating that remediation of malfunctioning on-site systems has occurred in the watershed. Because concentrations of phosphorus in the lake are elevated throughout the growing season, external sources (on-site systems) appear to be the dominant source of phosphorus. Resuspension of sediments can however contribute to the phosphorus loading in shallow lakes. Quantifying the loading due to resuspension is difficult and beyond the scope of the model used in this TMDL.

6. **<u>Comment</u>:** The report does not quantify the effect that runoff from NYS Route 10 has on the lake. The runoff flows year-round and enters the lake via a culvert on the northern shore. This load needs to be quantified as it has a detrimental effect on the lake.

Response: The watershed model accounts for this phosphorus load as part of the loading from developed land. As noted in Response 2, the land use classified as developed land has increased. Subsequently, the load attributed to developed land has also increased. Some of the phosphorus load reductions needed to meet the water quality goal are assigned to the developed land category. The culvert and drainage ditch alongside NYS Route 10 were looked at during the site investigation. The bottom of the ditch is located in bedrock. No significant erosion was found nor was any aquatic growth (algae, biomass) present on the bedrock indicating that the runoff is not likely to have high concentrations of phosphorus.

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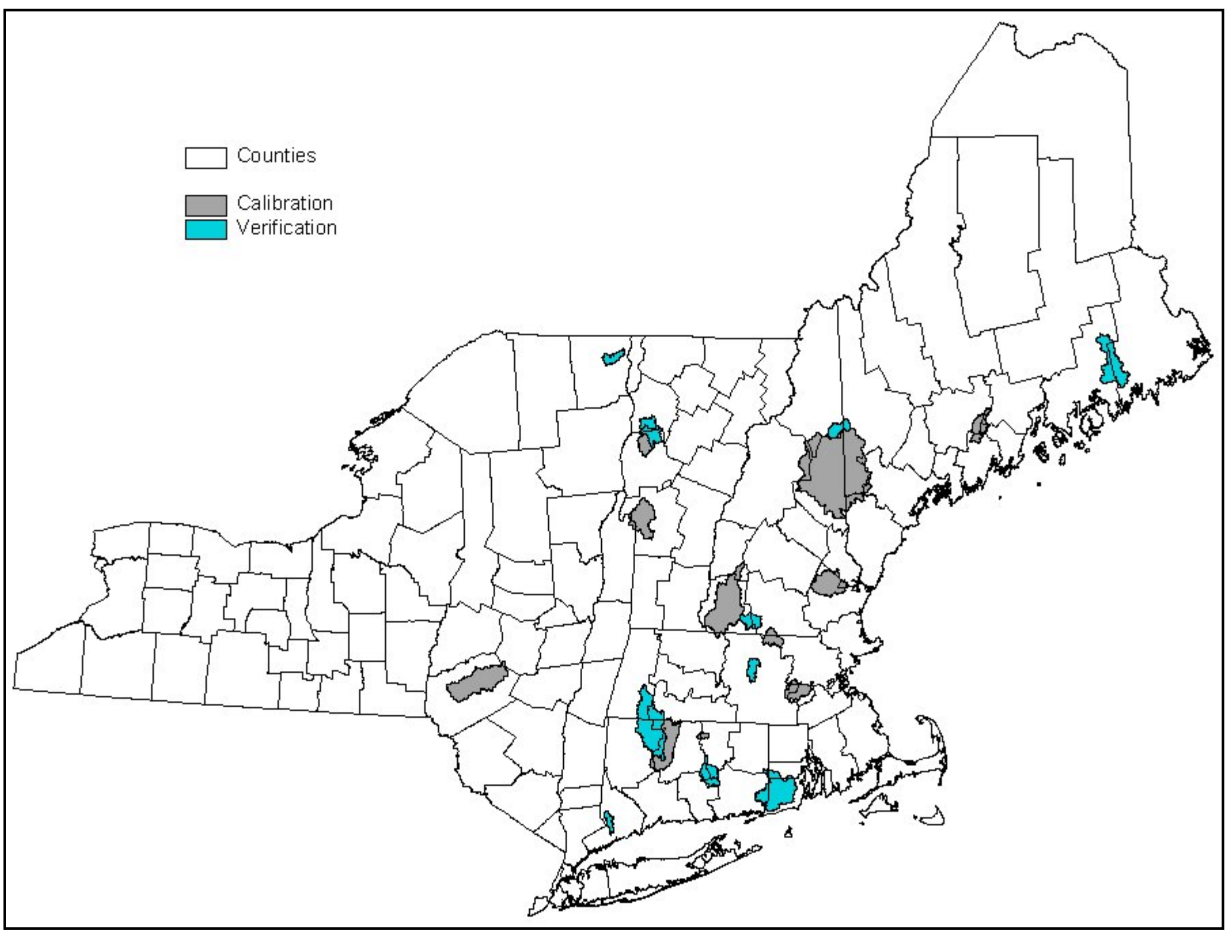
APPENDIX A. MAPSHED MODELING ANALYSIS

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

Figure 10. Location of Calibration and Verification Watersheds for the 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 11.

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

For the TMDL development work undertaken in New York, the original northeast AVGWLF model was further refined by The Cadmus Group, Inc. and Dr. Barry Evans to reflect the physiographic regions that exist in New York. Using data from some of the original northeast model calibration and verification sites, as well as data for additional calibration sites in New York, three new versions of AVGWLF were created for use in developing TMDLs in New York State. Information on the fourteen (14) sites is summarized in Table 6. 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

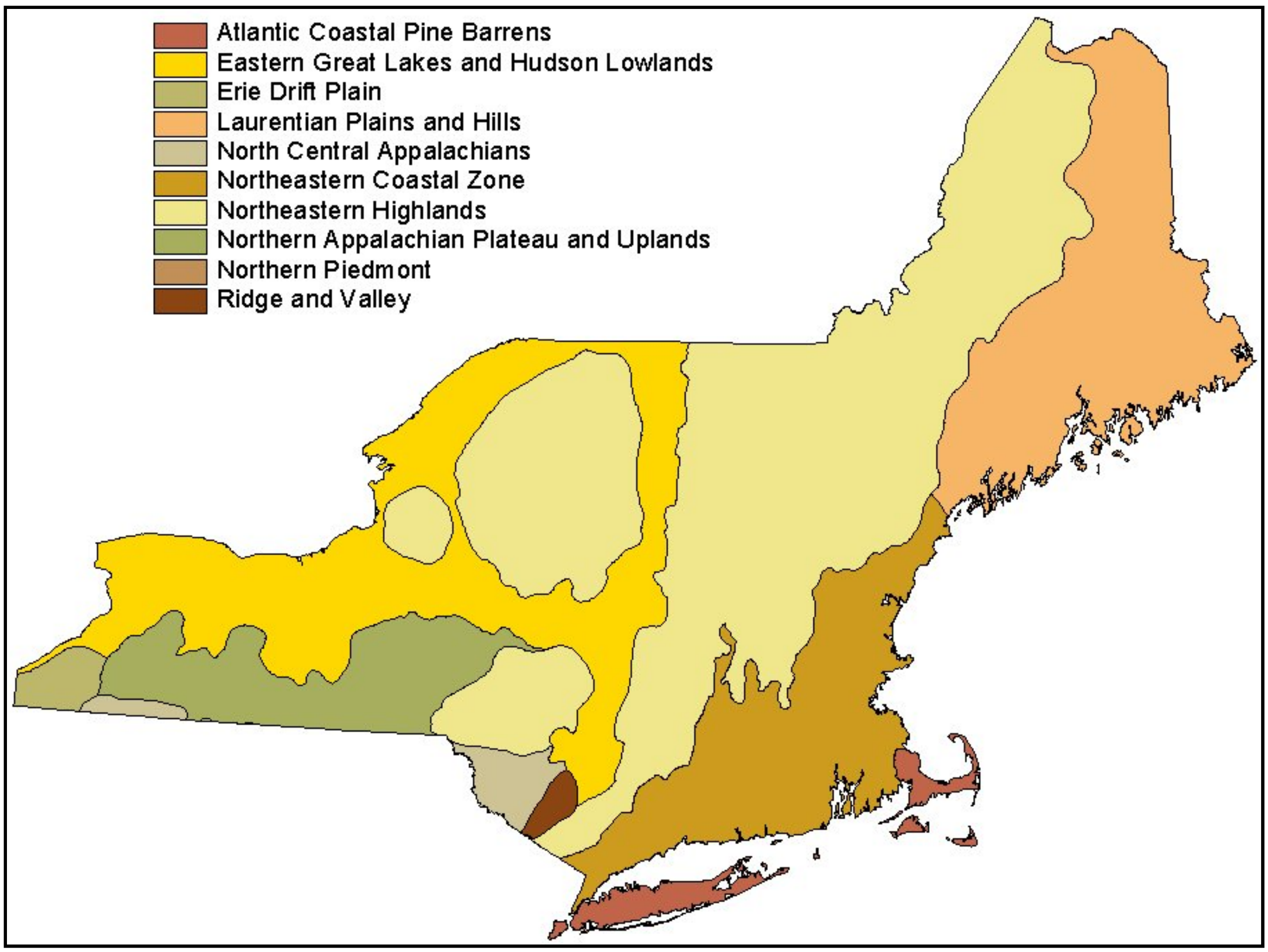


Table 6. AVGWLF Calibration Sites for use in the New York TMDL Assessments

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

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 State" MapShed Model

Using data for the time period 1990-2004, the calibrated MapShed model was used to estimate mean annual phosphorus loading to the lake. Table 7 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 7. Information Sources for MapShed Model Parameterization

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

Land Use

The 2001 NLCD land use coverage was obtained, recoded, and formatted specifically for use in 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 drainage basin 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.

On-site Wastewater Treatment Systems (“septic tanks”)

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 drainage basin was refined using a combination of 1990 and 2000 census data and GIS analysis of orthoimagery to account for the proximity of septic systems immediately surrounding the lake. If available, local information about the number of houses within 250 feet of the lakes was obtained and applied. Great attention was given to estimating septic systems within 250 feet of the lake (those most likely to have an impact on the lake). To convert the estimated number of septic systems to population served, an average household size of 2.61 people per dwelling was used based on the circa 2000 USCB census estimate for number of persons per household in New York State.

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 drainage basin and modifications were made if deemed unnecessary.

Point Sources

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

Concentrated Animal Feeding Operations (CAFOs)

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

Municipal Separate Storm Sewer Systems (MS4s)

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

MapShed Model Simulation Results

Input Transport File

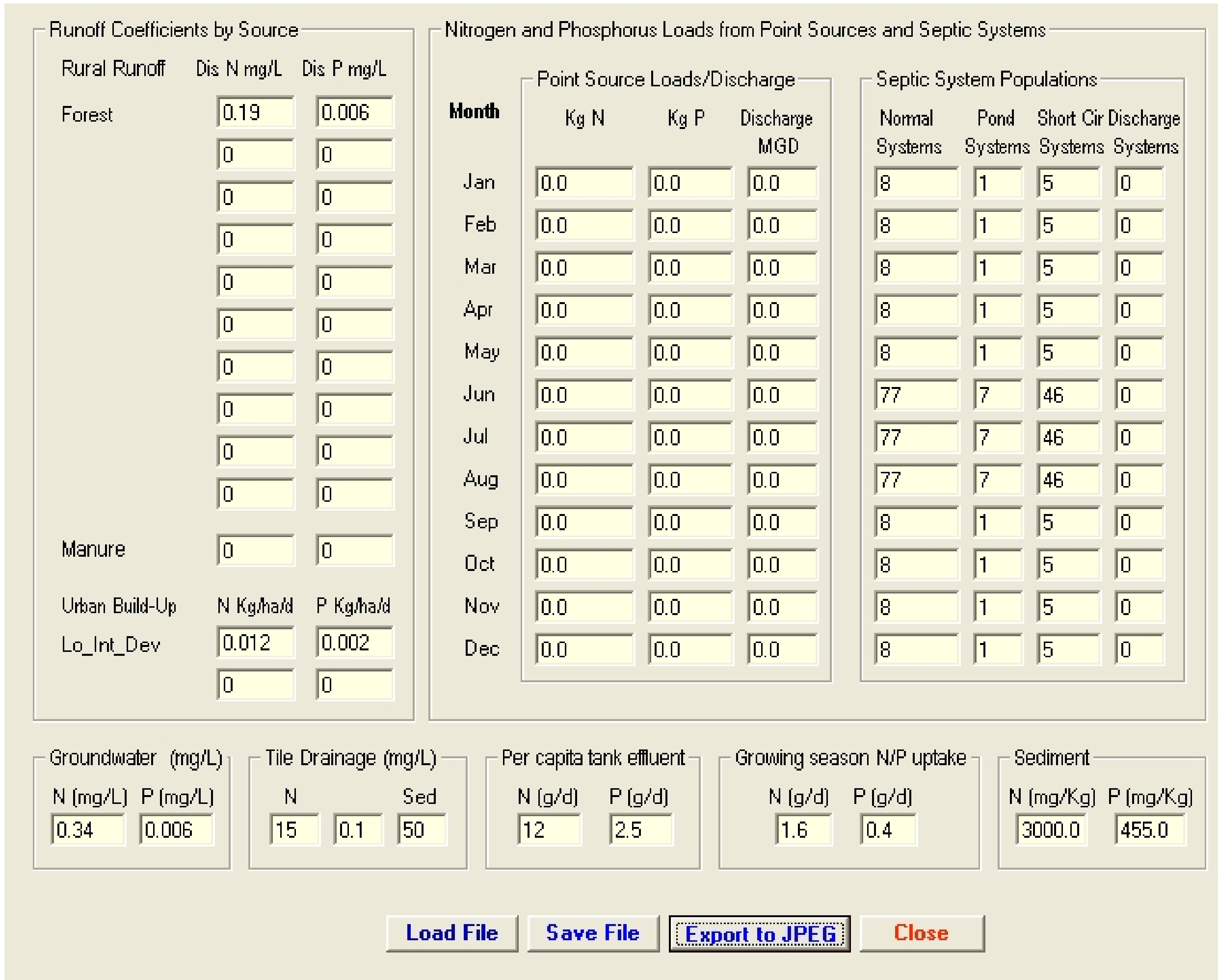
Rural LU	Area (ha)	CN	K	LS	C	P
Forest	71	73	0.24	0.587	0.002	0.45
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
Bare Land	**Area (ha)**	**CN**	**K**	**LS**	**C**	**P**
	0	0	0	0	0	0
	0	0	0	0	0	0
Urban LU	**Area (ha)**	**CN**	**K**	**LS**	**C**	**P**
Lo_Int_Dev	15	83	0.24	0.392	0.08	0.2
	0	0	0	0	0	0

Month	Ket	Day Hours	Season	Eros Coef	Stream Extract	Ground Extract
Jan	0.85	8.9	0	0.12	0	0
Feb	1.02	10.1	0	0.12	0	0
Mar	1.14	11.7	0	0.12	0	0
Apr	1.23	13.4	0	0.3	0	0
May	1.41	14.8	1	0.3	0	0
Jun	1.54	15.4	1	0.3	0	0
Jul	1.63	15.1	1	0.3	0	0
Aug	1.7	13.9	1	0.3	0	0
Sep	1.74	12.3	1	0.12	0	0
Oct	1.65	10.6	0	0.12	0	0
Nov	1.59	9.2	0	0.12	0	0
Dec	1.54	8.6	0	0.12	0	0

Init Unsat Stor (cm)	10	Initial Snow (cm)	0	Recess Coefficient	0.06
Init Sat Stor (cm)	0	Sed Delivery Ratio	0.1965	Seepage Coefficient	0
Unsat Avail Wat (cm)	2.14991	Tile Drain Ratio	0.5	Sediment A Factor	1.3011E-04
		Tile Drain Density	0		

Load File | Save File | Export to JPEG | Close

Input Nutrient File



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:

$$\text{Net accumulation} = \text{Inflow} - \text{Outflow} - \text{Decay}$$

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 Summit Lake and its surrounding drainage area, as well as output from MapShed, a BATHTUB model was set up for Summit Lake. 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 8 – 11 summarize the primary model inputs for Summit Lake, including the coefficient of variation (CV), which reflects uncertainty in the input value. Default model choices are utilized unless otherwise noted. Spatial variations (i.e., longitudinal dispersion) in phosphorus concentrations are not a factor in the development of the TMDL for Summit Lake. Therefore, division of the lake into multiple segments was not necessary for this modeling effort. Modeling the entire lake with one segment provides predictions of area-weighted mean concentrations, which are adequate to support management decisions. Water inflow and nutrient loads from the lake's drainage basin were treated as though they originated from one "tributary" (i.e., source) in BATHTUB and derived from 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 Cobleskill, NY and Lansing Manor, NY National Weather Service Stations for the 1990-2004 period. Evapotranspiration was derived from MapShed using daily weather data (1990-2004) 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 Summit Lake and has little impact on simulations.

Lake surface area, mean depth, and length were derived using GIS analysis of bathymetric data. Depth of the mixed layer was estimated using a multivariate regression equation developed by Walker (1999). Existing water quality conditions in Summit Lake were represented using an average of the observed summer mean phosphorus concentrations for years 1997-2001 (excluding 1998). These data were collected through NYS DEC's CSLAP. The concentration of phosphorus loading to the lake was calculated using the average annual flow and phosphorus loads simulated by 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 nonzero values should be specified with caution and only if independent estimates or measurements are available. In some studies, internal loading rates have been estimated from measured phosphorus accumulation in the hypolimnion during the stratified period. Results from this procedure should not be used for estimation of internal loading in BATHTUB unless there is evidence the accumulated phosphorus is transported to the mixed layer during the growing season. Specification of a fixed internal loading rate may be unrealistic for evaluating response to changes in external load. Because they reflect recycling of phosphorus that originally entered the reservoir from the watershed, internal loading rates would be expected to vary with external load. In situations where monitoring data indicate relatively high internal recycling rates to the mixed layer during the growing season, a preferred approach would generally be to calibrate the phosphorus sedimentation rate (i.e., specify calibration factors < 1). However, there still remains some risk that apparent internal loads actually reflect under-estimation of external loads.

Table 8. BATHTUB Model Input Variables: Model Selections

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

* Default model choice

Table 9. BATHTUB Model Input: Global Variables

Model Input	Mean	CV
Averaging Period (years)	1	NA
Precipitation (meters)	0.969	0.2*
Evaporation (meters)	0.535	0.3*
Atmospheric Load (mg/m^2-yr)- Total P	4.875	0.5*
Atmospheric Load (mg/m^2-yr)- Ortho P	2.605	0.5*

* Default model choice

Table 10. BATHTUB Model Input: Lake Variables

Morphometry	Mean	CV
Surface Area (km^2)	0.175	NA
Mean Depth (m)	2.985	NA
Length (km)	0.781	NA
Estimated Mixed Depth (m)	3	0.12
Observed Water Quality	**Mean**	**CV**
Total Phosphorus (ppb)	23.839	0.5

* Default model choice

Table 11. BATHTUB Model Input: Watershed "Tributary" Loading

Monitored Inputs	Mean	CV
Total Watershed Area (km^2)	0.86	NA
Flow Rate (hm^3/yr)	0.375	0.1
Total P (ppb)	47.455	0.2
Organic P (ppb)	43.485	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 Summit Lake are as follows:

Year	Observed	Simulated	T1	T2	T3
1997	21	25	-0.39	-0.73	-0.36
1999	22	24	-0.20	-0.37	-0.19
2000	26	24	0.11	0.20	0.10
2001	24	21	0.26	0.48	0.24
Average	24	24	0.02	0.04	0.02

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 Summit Lake is quite good. Therefore, BATHTUB is sufficiently calibrated for use in estimating load reductions required to achieve the phosphorus TMDL target in the lake.

APPENDIX C. TOTAL EQUIVALENT DAILY PHOSPHORUS LOAD ALLOCATIONS

Source	Total Phosphorus Load (lbs/d)			% Reduction
	Current	Allocated	Reduction	
Developed Land	0.0075	0.0060	0.0015	20%
Septic Systems	0.0857	0.0557	0.0300	35%
Forest, Wetland, Stream Bank, and Natural Background Groundwater*	0.0140	0.0140	0	0%
LOAD ALLOCATION	**0.1072**	**0.0757**	**0.0315**	**29%**
Point Sources	0	0	0	0%
WASTELOAD ALLOCATION	**0**	**0**	**0**	**0%**
LA + WLA	**0.1072**	**0.0757**	**0.0315**	**29%**
Margin of Safety	---	0.00841	---	---
TOTAL	**0.1072**	**0.0841**	**---**	**---**

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