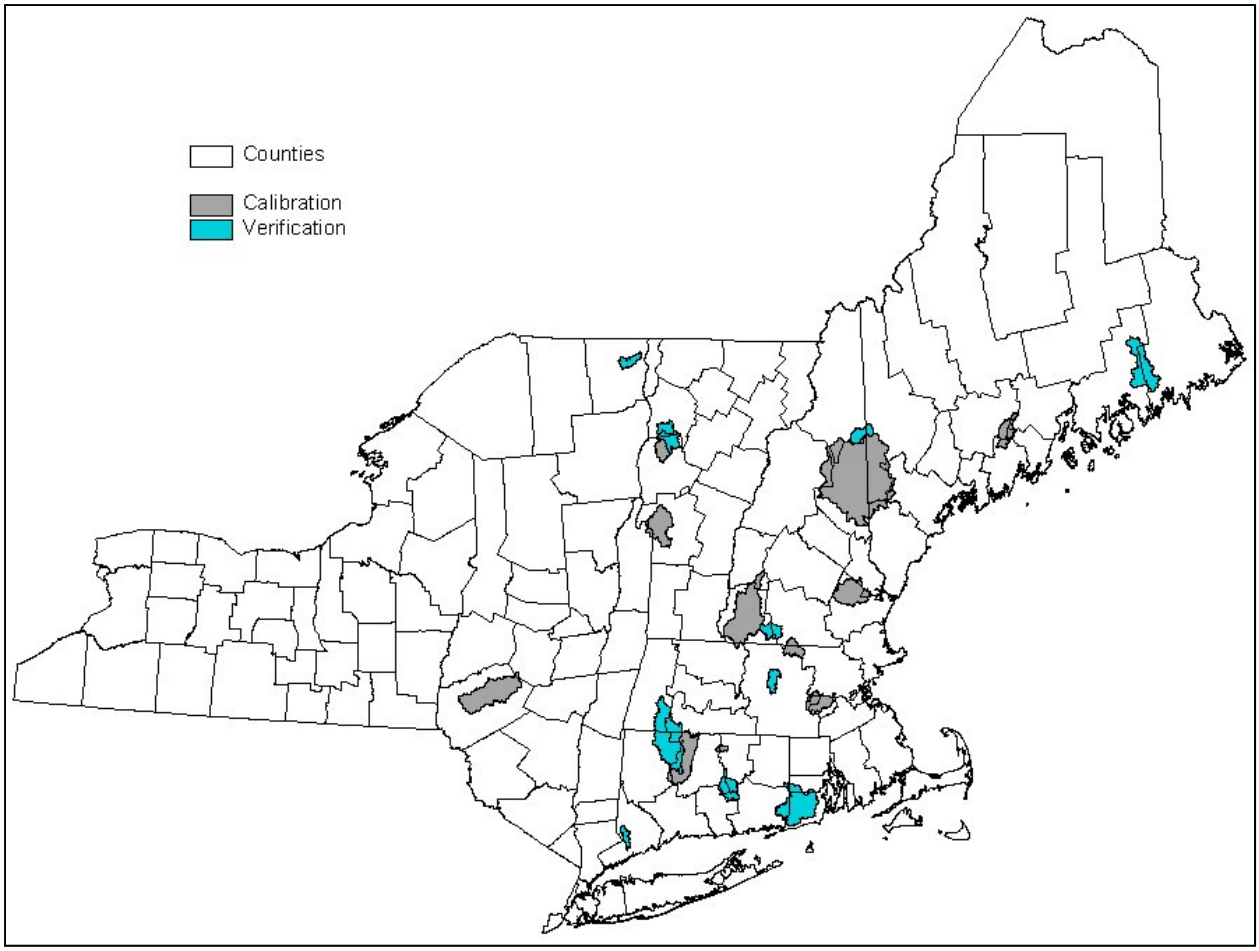
APPENDIX A. MAPSHED MODELING ANALYSIS

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 22. 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 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 23. Location of Physiographic Provinces in New York and New England

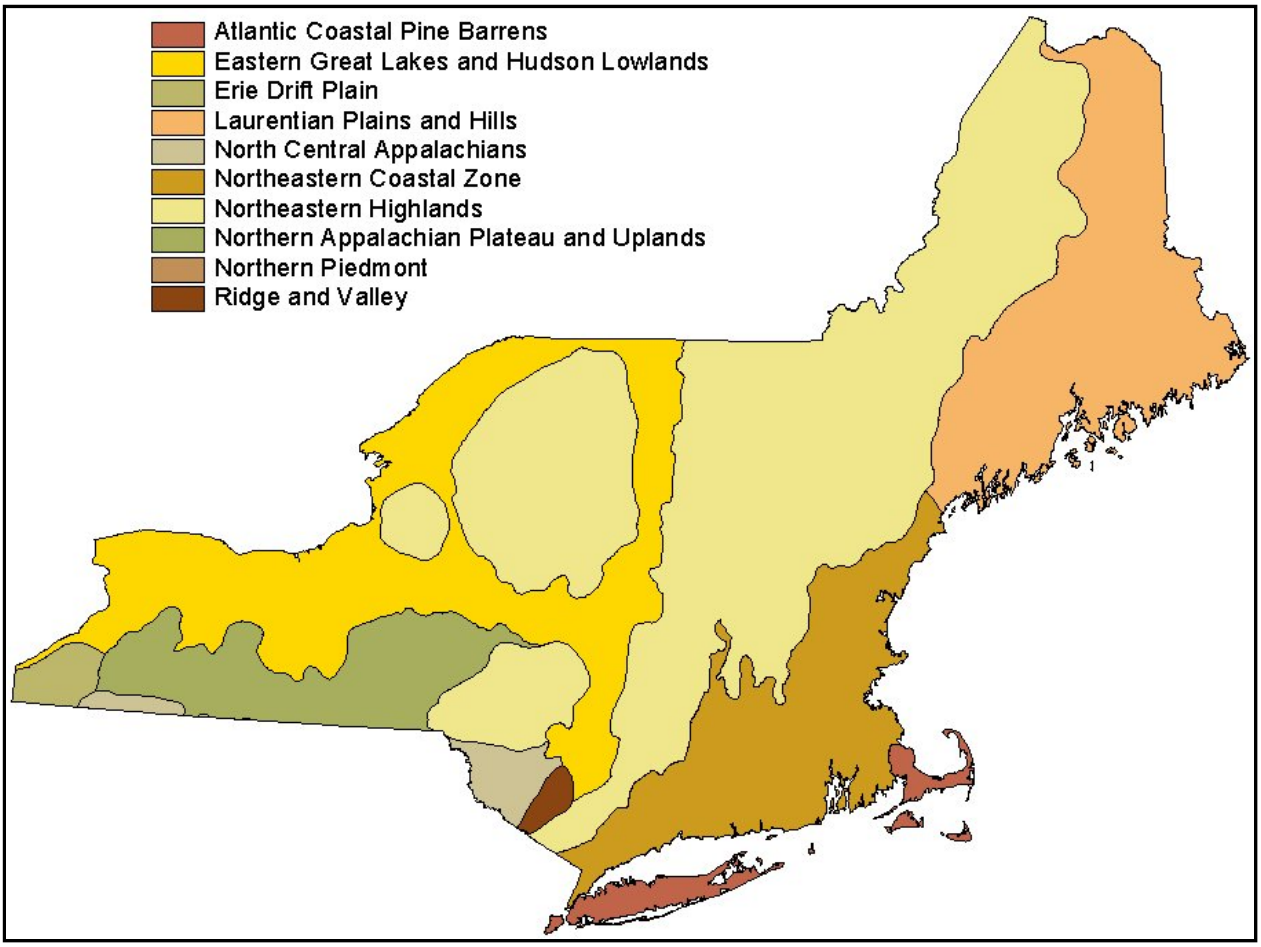


Table 20. AVGWLF Calibration Sites for use in the New York TMDL Assessments

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 1990-2007, 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 21. 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 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.

MapShed Model Simulation Files for Buck Pond

Input Transport File

Rural LU	Area (ha)	CN	K	LS	C	P
Hay/Past	440	63	0.326	0.178	0.029	0.449
Cropland	349	75	0.345	0.173	0.319	0.449
Forest	1288	60	0.294	0.156	0.001	0.449
Wetland	304	87	0.406	0.064	0.01	0.1
Quarry	9	85	0.357	0.155	0.08	0.1
Turf_Grass	45	58	0.24	0.149	0.08	0.2
	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	264	80	0.355	0.128	0.08	0.2
Hi_Int_Dev	49	93	0.322	0.164	0.08	0.2

Month	Ket	Day Hours	Season	Eros Coef	Stream Extract	Ground Extract
Jan	0.59	9.2	0	0.059	0	0
Feb	0.74	10.2	0	0.059	0	0
Mar	0.86	11.7	0	0.059	0	0
Apr	0.94	13.3	0	0.249	0	0
May	1.11	14.6	1	0.249	0	0
Jun	1.24	15.1	1	0.249	0	0
Jul	1.33	14.8	1	0.249	0	0
Aug	1.4	13.8	1	0.249	0	0
Sep	1.46	12.3	1	0.059	0	0
Oct	1.4	10.7	0	0.059	0	0
Nov	1.35	9.4	0	0.059	0	0
Dec	1.32	8.9	0	0.059	0	0

Init Unsat Stor (cm)	10	Initial Snow (cm)	0	Recess Coefficient	0.049921
Init Sat Stor (cm)	0	Sed Delivery Ratio	0.1457	Seepage Coefficient	0
Unsat Avail Wat (cm)	2.545036	Tile Drain Ratio	0.5	Sediment A Factor	6.9942E-05
		Tile Drain Density	0		

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Input Nutrient File

Runoff Coefficients by Source

Rural Runoff	Dis N mg/L	Dis P mg/L
Hay/Past	2.9	0.334
Cropland	2.9	0.334
Forest	0.19	0.006
Wetland	0.19	0.006
Quarry	0.012	0.002
Turf_Grass	2.5	1.969
	0	0
	0	0
	0	0
	0	0
Manure	2.44	0.38

Urban Build-Up	N Kg/ha/d	P Kg/ha/d
Lo_Int_Dev	0.012	0.002
Hi_Int_Dev	0.101	0.011

Nitrogen and Phosphorus Loads from Point Sources and Septic Systems

Month	Point Source Loads/Discharge: Kg N	Kg P	Discharge MGD	Septic System Populations: Normal Systems	Pond Systems	Short Cir Systems	Discharge Systems
Jan	0.0	0.0	0.0	226	56	282	0
Feb	0.0	0.0	0.0	226	56	282	0
Mar	0.0	0.0	0.0	226	56	282	0
Apr	0.0	0.0	0.0	226	56	282	0
May	0.0	0.0	0.0	226	56	282	0
Jun	0.0	0.0	0.0	380	58	146	0
Jul	0.0	0.0	0.0	380	58	146	0
Aug	0.0	0.0	0.0	380	58	146	0
Sep	0.0	0.0	0.0	226	56	282	0
Oct	0.0	0.0	0.0	226	56	282	0
Nov	0.0	0.0	0.0	226	56	282	0
Dec	0.0	0.0	0.0	226	56	282	0

Groundwater (mg/L) N (mg/L)	P (mg/L)	Tile Drainage (mg/L) N		Sed	Per capita tank effluent N (g/d)	P (g/d)	Growing season N/P uptake N (g/d)	P (g/d)	Sediment N (mg/Kg)	P (mg/Kg)
1.659	0.03	15	0.1	50	12	2.5	1.6	0.4	3000.0	908.0

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Input Runqual File

Landuse Categories

	Area (Ha)	% Imp	CNI	CNP
LD_Mixed	264	0.15	92	74
MD_Mixed	95	0.52	98	79
HD_Mixed	49	0.87	98	79
LD_Residential	148	0.15	92	74
MD_Residential	1171	0.52	92	74
Hd_Residential	0	0	0	0
Open_Land	2437	0.05	90	74

Nitrogen (Kg/Ha/day)

Acc Imp	Acc Perv	Dis Fract
0.045	0.012	0.33
0.073	0.012	0.33
0.101	0.012	0.33
0.045	0.012	0.28
0.09	0.022	0.28
0	0	0

EMC (mg/L) 1.5

Phosphorus (Kg/Ha/day)

Acc Imp	Acc Perv	Dis Fract
0.0045	0.0019	0.4
0.0067	0.0019	0.4
0.0112	0.0019	0.4
0.0045	0.0016	0.37
0.0045	0.0039	0.37
0	0	0

EMC (mg/L) 0.12

TSS

EMC (mg/L)
60
70
80
90
100
0
90

Subsurface Flow

GWN (mg/L) 1.5973

GWP (mg/L) 0.0647

Streambank Erosion

A Factor 1.9237E-03 Streams (Km) 78 Soil N (ppm) 50.0

Hardened Streams (Km) 0 Soil P (ppm) 100.0

Urban BMPs

Detention Basins

Detention basin volume (m^3) 1006680

Basin dead storage (m^3) 249670

Basin surface area (m^2) 124835

Basin days to drain 2

Basin cleaning month 5

Infiltration and Buffer Strips

Infiltration retention runoff (cm) 0

Fraction of area treated (0 - 1) 0.0

Vegetative buffer strip width (m) 0

Fraction of streams treated (0 - 1) 0.0

Combined Sewer Overflows

Avg. raw sewage N (mg/L) 35

Avg. raw sewage P (mg/L) 10

Critical rainfall (cm/day) 1

Day Hrs/Grow Seas.

Month	Day Hrs	Grow	Adjust. % ET
Jan	9.2	0	1
Feb	10.2	0	1
Mar	11.7	0	1
Apr	13.3	0	1
May	14.6	1	1
Jun	15.1	1	1
Jul	14.8	1	1
Aug	13.8	1	1
Sep	12.3	1	1
Oct	10.7	0	1
Nov	9.4	0	1
Dec	8.9	0	1

Point Sources

Kg N	Kg P	Discharge MGD
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	0.0
0	0	0.0

Street Sweeping

No per month
0
0
0
0
1
0
0
0
0
0
0
0

GW Seep and GW Recess Coef

GW Seep 0 GW Recess 4.9921

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MapShed Model Simulation Files for Long Pond

Input Transport File

Rural LU	Area (ha)	CN	K	LS	C	P
Hay/Past	1202	63	0.335	0.259	0.029	0.519
Cropland	1041	75	0.348	0.194	0.319	0.519
Forest	1779	73	0.303	0.205	0.001	0.519
Wetland	340	80	0.293	0.207	0.01	0.1
Quarry	9	85	0.24	0.262	0.08	0.1
Turf_Grass	43	71	0.289	0.151	0.08	0.2
	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	418	80	0.312	0.277	0.08	0.2
Hi_Int_Dev	17	90	0.311	0.04	0.08	0.2

Month	Ket	Day Hours	Season	Eros Coef	Stream Extract	Ground Extract
Jan	0.76	9.2	0	0.059	0	0
Feb	0.95	10.2	0	0.059	0	0
Mar	1.1	11.7	0	0.059	0	0
Apr	1.21	13.3	0	0.249	0	0
May	1.45	14.6	1	0.249	0	0
Jun	1.62	15.1	1	0.249	0	0
Jul	1.76	14.8	1	0.249	0	0
Aug	1.86	13.8	1	0.249	0	0
Sep	1.94	12.3	1	0.059	0	0
Oct	1.84	10.7	0	0.059	0	0
Nov	1.77	9.4	0	0.059	0	0
Dec	1.72	8.9	0	0.059	0	0

Init Unsat Stor (cm)	10	Initial Snow (cm)	0	Recess Coefficient	0.049868
Init Sat Stor (cm)	0	Sed Delivery Ratio	0.1329	Seepage Coefficient	0
Unsat Avail Wat (cm)	3.238102	Tile Drain Ratio	0.5	Sediment A Factor	7.8560E-05
		Tile Drain Density	0		

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Input Nutrient File

Runoff Coefficients by Source

Rural Runoff	Dis N mg/L	Dis P mg/L
Hay/Past	2.9	0.345
Cropland	2.9	0.345
Forest	0.19	0.006
Wetland	0.19	0.006
Quarry	0.012	0.002
Turf_Grass	2.5	2.049
	0	0
	0	0
	0	0
	0	0
Manure	2.44	0.38

Urban Build-Up	N Kg/ha/d	P Kg/ha/d
Lo_Int_Dev	0.012	0.002
Hi_Int_Dev	0.101	0.011

Nitrogen and Phosphorus Loads from Point Sources and Septic Systems

Month	Point Source Loads/Discharge: Kg N	Kg P	Discharge MGD	Septic System Populations: Normal Systems	Pond Systems	Short Cir Systems	Discharge Systems
Jan	0.0	130.4	1.017	528	132	660	0
Feb	0.0	100.9	0.955	528	132	660	0
Mar	0.0	105.5	1.226	528	132	660	0
Apr	0.0	100.3	1.215	528	132	660	0
May	0.0	132.6	5.214	528	132	660	0
Jun	0.0	134.2	4.312	547	137	684	0
Jul	0.0	150.0	4.352	547	137	684	0
Aug	0.0	149.6	4.231	547	137	684	0
Sep	0.0	127.9	4.332	528	132	660	0
Oct	0.0	122.6	4.04	528	132	660	0
Nov	0.0	107.4	2.94	528	132	660	0
Dec	0.0	124.5	0.998	528	132	660	0

Groundwater (mg/L) N (mg/L)	P (mg/L)	Tile Drainage (mg/L) N		Sed	Per capita tank effluent N (g/d)	P (g/d)	Growing season N/P uptake N (g/d)	P (g/d)	Sediment N (mg/Kg)	P (mg/Kg)
1.862	0.05	15	0.1	50	12	2.5	1.6	0.4	3000.0	945.0

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Input Runqual File

Landuse Categories

	Area (Ha)	% Imp	CNI	CNP
LD_Mixed	418	0.15	92	74
MD_Mixed	122	0.52	98	79
HD_Mixed	17	0.87	98	79
LD_Residential	483	0.15	92	74
MD_Residential	380	0.52	92	74
Hd_Residential	0	0	0	0
Open_Land	4414	0.05	90	74

Nitrogen (Kg/Ha/day)

Acc Imp	Acc Perv	Dis Fract
0.045	0.012	0.33
0.073	0.012	0.33
0.101	0.012	0.33
0.045	0.012	0.28
0.09	0.022	0.28
0	0	0

EMC (mg/L) 1.5

Phosphorus (Kg/Ha/day)

Acc Imp	Acc Perv	Dis Fract
0.009	0.0019	0.4
0.01	0.0019	0.4
0.0112	0.0019	0.4
0.0067	0.0016	0.37
0.0112	0.0039	0.37
0	0	0

EMC (mg/L) 0.12

TSS

EMC (mg/L)
60
70
80
90
100
0
90

Subsurface Flow

GWN (mg/L) 1.8618

GWP (mg/L) 0.07

Streambank Erosion

A Factor 1.8978E-04 Streams (Km) 86 Soil N (ppm) 50.0

Hardened Streams (Km) 0 Soil P (ppm) 100.0

Urban BMPs

Detention Basins

Detention basin volume (m^3) 254756

Basin dead storage (m^3) 63690

Basin surface area (m^2) 31845

Basin days to drain 2

Basin cleaning month 5

Infiltration and Buffer Strips

Infiltration retention runoff (cm) 0

Fraction of area treated (0 - 1) 0.0

Vegetative buffer strip width (m) 0

Fraction of streams treated (0 - 1) 0.0

Day Hrs/Grow Seas.

Month	Day Hrs	Grow	Adjust. % ET
Jan	9.2	0	1
Feb	10.2	0	1
Mar	11.7	0	1
Apr	13.3	0	1
May	14.6	1	1
Jun	15.1	1	1
Jul	14.8	1	1
Aug	13.8	1	1
Sep	12.3	1	1
Oct	10.7	0	1
Nov	9.4	0	1
Dec	8.9	0	1

Point Sources

Kg N	Kg P	Discharge MGD
0	104	0.93
0	79	0.97
0	95	1.19
0	75	1.18
0	135	5.25
0	116	4.35
0	123	4.34
0	118	4.22
0	107	4.29
0	99	4.02
0	78	2.89
0	94	0.93

Street Sweeping

No per month
0
0
0
0
1
0
0
0
0
0
0
0

Combined Sewer Overflows

Avg. raw sewage N (mg/L) 35

Avg. raw sewage P (mg/L) 10

Critical rainfall (cm/day) 1

GW Seep and GW Recess Coef

GW Seep 0 GW Recess 4.9868

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MapShed Model Simulation Files for Cranberry Pond

Input Transport File

Rural LU	Area (ha)	CN	K	LS	C	P
Hay/Past	16	75	0.49	0.041	0.029	0.519
Cropland	9	82	0.49	0.039	0.319	0.519
Forest	60	73	0.49	0.07	0.001	0.519
Wetland	90	87	0.49	0.001	0.01	0.1
	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	28	83	0.49	0.032	0.08	0.2
	0	0	0	0	0	0

Month	Ket	Day Hours	Season	Eros Coef	Stream Extract	Ground Extract
Jan	1.04	9.2	0	0.058	0	0
Feb	1.31	10.2	0	0.058	0	0
Mar	1.51	11.7	0	0.058	0	0
Apr	1.66	13.3	0	0.243	0	0
May	1.82	14.6	1	0.243	0	0
Jun	1.95	15.1	1	0.243	0	0
Jul	2.04	14.8	1	0.243	0	0
Aug	2.11	13.8	1	0.243	0	0
Sep	2.16	12.3	1	0.058	0	0
Oct	2.16	10.7	0	0.058	0	0
Nov	2.15	9.4	0	0.058	0	0
Dec	2.14	8.9	0	0.058	0	0

Init Unsat Stor (cm)	10	Initial Snow (cm)	0	Recess Coefficient	0.048675
Init Sat Stor (cm)	0	Sed Delivery Ratio	0.1931	Seepage Coefficient	0
Unsat Avail Wat (cm)	2.89	Tile Drain Ratio	0.5	Sediment A Factor	8.5125E-05
		Tile Drain Density	0		

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Input Nutrient File

Runoff Coefficients by Source

Rural Runoff	Dis N mg/L	Dis P mg/L
Hay/Past	2.9	0.278
Cropland	2.9	0.278
Forest	0.19	0.006
Wetland	0.19	0.006
	0	0
	0	0
	0	0
	0	0
	0	0
	0	0
Manure	2.44	0.38

Urban Build-Up	N Kg/ha/d	P Kg/ha/d
Lo_Int_Dev	0.012	0.002
	0	0

Nitrogen and Phosphorus Loads from Point Sources and Septic Systems

Month	Point Source Loads/Discharge: Kg N	Kg P	Discharge MGD	Septic System Populations: Normal Systems	Pond Systems	Short Cir Systems	Discharge Systems
Jan	0.0	0.0	0.0	6	2	8	0
Feb	0.0	0.0	0.0	6	2	8	0
Mar	0.0	0.0	0.0	6	2	8	0
Apr	0.0	0.0	0.0	6	2	8	0
May	0.0	0.0	0.0	6	2	8	0
Jun	0.0	0.0	0.0	6	2	8	0
Jul	0.0	0.0	0.0	6	2	8	0
Aug	0.0	0.0	0.0	6	2	8	0
Sep	0.0	0.0	0.0	6	2	8	0
Oct	0.0	0.0	0.0	6	2	8	0
Nov	0.0	0.0	0.0	6	2	8	0
Dec	0.0	0.0	0.0	6	2	8	0

Groundwater (mg/L) N (mg/L)	P (mg/L)	Tile Drainage (mg/L) N		Sed	Per capita tank effluent N (g/d)	P (g/d)	Growing season N/P uptake N (g/d)	P (g/d)	Sediment N (mg/Kg)	P (mg/Kg)
0.818	0.03	15	0.1	50	12	2.5	1.6	0.4	3000.0	708.0

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Input Runqual File

Landuse Categories

	Area (Ha)	% Imp	CNI	CNP
LD_Mixed	28	0.15	92	74
MD_Mixed	7	0.52	98	79
Hd_Mixed	0	0	0	0
LD_Residential	13	0.15	92	74
MD_Residential	42	0.52	92	74
Hd_Residential	0	0	0	0
Open_Land	175	0.05	90	74

Nitrogen (Kg/Ha/day)

Acc Imp	Acc Perv	Dis Fract
0.045	0.012	0.33
0.073	0.012	0.33
0	0	0
0.045	0.012	0.28
0.09	0.022	0.28
0	0	0

EMC (mg/L) 1.5

Phosphorus (Kg/Ha/day)

Acc Imp	Acc Perv	Dis Fract
0.009	0.0019	0.4
0.009	0.0019	0.4
0	0	0
0.009	0.0016	0.37
0.0112	0.0039	0.37
0	0	0

EMC (mg/L) 0.12

TSS

EMC (mg/L)
60
70
0
90
100
0
90

Subsurface Flow

GWN (mg/L) 0.8183

GWP (mg/L) 0.0493

Streambank Erosion

A Factor 2.0841E-04 Streams (Km) 7 Soil N (ppm) 50.0

Hardened Streams (Km) 0 Soil P (ppm) 100.0

Urban BMPs

Detention Basins

Detention basin volume (m^3) 0

Basin dead storage (m^3) 0

Basin surface area (m^2) 0

Basin days to drain 0

Basin cleaning month 0

Infiltration and Buffer Strips

Infiltration retention runoff (cm) 0

Fraction of area treated (0 - 1) 0.0

Vegetative buffer strip width (m) 0

Fraction of streams treated (0 - 1) 0.0

Day Hrs/Grow Seas.

Month	Day Hrs	Grow	Adjust. % ET
Jan	9.2	0	1
Feb	10.2	0	1
Mar	11.7	0	1
Apr	13.3	0	1
May	14.6	1	1
Jun	15.1	1	1
Jul	14.8	1	1
Aug	13.8	1	1
Sep	12.3	1	1
Oct	10.7	0	1
Nov	9.4	0	1
Dec	8.9	0	1

Point Sources

Kg N	Kg P	Discharge MGD
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	0.0
0	0	0.0

Street Sweeping

No per month
0
0
0
0
0
0
0
0
0
0
0
0

Combined Sewer Overflows

Avg. raw sewage N (mg/L) 35

Avg. raw sewage P (mg/L) 10

Critical rainfall (cm/day) 1

GW Seep and GW Recess Coef

GW Seep 0 GW Recess 4.8675

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APPENDIX B. BATHTUB MODELING ANALYSIS

Model Overview

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

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

The pollutant dynamics in the pond are assumed to be at a steady state, therefore, the net accumulation of phosphorus in the pond 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 pond 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 pond water quality data (e.g., total phosphorus concentrations).

The empirical models implemented in BATHTUB are mathematical generalizations about pond behavior. When applied to data from a particular pond, actual observed pond 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 pond (no two ponds are the same). BATHTUB's "calibration factor" provides model users with a method to calibrate the magnitude of predicted pond response. The model calibrated to current conditions (against measured data from the ponds) can be applied to predict changes in pond conditions likely to result from specific management scenarios, under the condition that the calibration factor remains constant for all prediction scenarios.

Model Set-up

A BATHTUB model was set up for Buck, Long and Cranberry Ponds using output from MapShed and descriptive information regarding the ponds and their surrounding drainage basins. Mean annual phosphorus loading to the ponds was simulated using MapShed for the period 1990-2007. 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 bathymetric maps provided by NYS DEC or other source, 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 Service's Stations.
- Phosphorus concentrations in precipitation (measured or estimated), and measured lake water quality data (e.g., total phosphorus concentrations) – Obtained from NYS DEC, USGS, and Makarewicz and Lampman (1994).

Tables 22-33 summarize the primary model inputs for Buck, Long, and Cranberry Ponds, 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 Buck, Long, and Cranberry Ponds. Therefore, division of the ponds into multiple segments was not necessary for this modeling effort. Modeling the entire pond with one segment provides predictions of area-weighted mean concentrations, which are adequate to support management decisions. Water inflow and nutrient loads from the ponds' drainage basins 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 pond. Guidance for BATHTUB recommends that the averaging period used for the analysis be at least twice as large as nutrient residence time for the pond. The appropriate averaging period for water and mass balance calculations would be 1 year for ponds with relatively long nutrient residence times or seasonal (6 months) for ponds 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 Rochester, NY and Albion, NY National Weather Service Stations for the 1990-2007 period. Evapotranspiration was derived from MapShed using daily weather data (1990-2007) and a cover factor dependent upon land use/cover type. The values selected for precipitation and change in pond storage have very little influence on model predictions. Atmospheric phosphorus loads were

specified using data collected by the New Jersey Atmospheric Deposition Network (Koelliker et. al, 2004).

Pond 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 Buck and Cranberry Ponds were represented using an average of the observed summer mean phosphorus concentrations for years 2000 (NYSDEC LCI) and 2009 (NYSDEC LCI and unpublished data provided via DEC personal communication with Dr. Joseph Makarewicz, 10/19/09), while existing water quality conditions in Long Pond were represented using an average of the observed summer mean phosphorus concentrations for years 2003-2007 (NYSDEC LCI) and 2009 (NYSDEC LCI and unpublished data provided via DEC personal communication with Dr. Joseph Makarewicz, 10/19/09). The concentration of phosphorus loading to the ponds was calculated using the average annual flow and phosphorus loads simulated by MapShed. For years with observed data, the concentration of internal loading was calculated using the concentration of external loading, the hydraulic residence time, and lake phosphorus concentrations. Otherwise, the concentration of internal loading was calculated assuming concentrations were proportional to the average of years with observed data. 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). However, for lakes that have been previously exposed to excessive loading, the normal nutrient recycling models may not be sufficient. In these lakes, phosphorus builds up in the sediments, which can then become a significant source of phosphorus loading, especially in shallow lakes such as Cranberry and Long Ponds. 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.

Buck Pond

Table 22. BATHTUB Model Input Variables: Model Selections

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

* Default model choice

Table 23. BATHTUB Model Input: Global Variables

Model Input	Mean	CV
Averaging Period (years)	0.5	NA
Precipitation (meters)	0.45	0.2*
Evaporation (meters)	0.25	0.3*
Atmospheric Load (mg/m^2-yr)- Total P	7.45	0.5*
Atmospheric Load (mg/m^2-yr)- Ortho P	4.30	0.5*

* Default model choice

Table 24. BATHTUB Model Input: Ponds Variables

Morphometry	Mean	CV
Surface Area (km^2)	0.69	NA
Mean Depth (m)	0.48	NA
Length (km)	1.66	NA
Estimated Mixed Depth (m)	0.5	0.12
Observed Water Quality	**Mean**	**CV**
Total Phosphorus (ppb)	45.53	0.5

* Default model choice

Table 25. BATHTUB Model Input: Watershed "Tributary" Loading

Monitored Inputs	Mean	CV
Total Watershed Area (km^2)	41.62	NA
Flow Rate (hm^3/yr)	17.04	0.1
Total P (ppb)	51.39	0.2
Organic P (ppb)	50.58	0.2

Long Pond

Table 26. BATHTUB Model Input Variables: Model Selections

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

* Default model choice

Table 27. BATHTUB Model Input: Global Variables

Model Input	Mean	CV
Averaging Period (years)	0.5	NA
Precipitation (meters)	0.45	0.2*
Evaporation (meters)	0.28	0.3*
Atmospheric Load (mg/m^2-yr)- Total P	7.45	0.5*
Atmospheric Load (mg/m^2-yr)- Ortho P	4.30	0.5*

* Default model choice

Table 28. BATHTUB Model Input: Ponds Variables

Morphometry	Mean	CV
Surface Area (km^2)	1.95	NA
Mean Depth (m)	2.13	NA
Length (km)	2.45	NA
Estimated Mixed Depth (m)	2.1	0.12
Observed Water Quality	**Mean**	**CV**
Total Phosphorus (ppb)	162.99	0.5
Internal Load	**Mean**	**CV**
Total Phosphorus (mg/m^2 - day)	13.02	0.1

* Default model choice

Table 29. BATHTUB Model Input: Watershed "Tributary" Loading

Monitored Inputs	Mean	CV
Total Watershed Area (km^2)	58.34	NA
Flow Rate (hm^3/yr)	24.05	0.1
Total P (ppb)	162.70	0.2
Organic P (ppb)	140.90	0.2

Cranberry Pond

Table 30. BATHTUB Model Input Variables: Model Selections

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

* Default model choice

Table 31. BATHTUB Model Input: Global Variables

Model Input	Mean	CV
Averaging Period (years)	1	NA
Precipitation (meters)	0.90	0.2*
Evaporation (meters)	0.58	0.3*
Atmospheric Load (mg/m^2-yr)- Total P	7.45	0.5*
Atmospheric Load (mg/m^2-yr)- Ortho P	4.30	0.5*

* Default model choice

Table 32. BATHTUB Model Input: Ponds Variables

Morphometry	Mean	CV
Surface Area (km^2)	0.91	NA
Mean Depth (m)	1.25	NA
Length (km)	1.59	NA
Estimated Mixed Depth (m)	1.3	0.12
Observed Water Quality	**Mean**	**CV**
Total Phosphorus (ppb)	60.56	0.5
Internal Load	**Mean**	**CV**
Total Phosphorus (mg/m^2 - day)	0.169	0.1

* Default model choice

Table 33. BATHTUB Model Input: Watershed "Tributary" Loading

Monitored Inputs	Mean	CV
Total Watershed Area (km^2)	2.65	NA
Flow Rate (hm^3/yr)	0.85	0.1
Total P (ppb)	79.13	0.2
Organic P (ppb)	51.66	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 Buck, Long, and Cranberry Ponds are as follows:

Buck Pond

Year	Observed	Simulated	T1	T2	T3
1993	155	43	2.56	4.76	2.40
1994	159	50	2.30	4.28	2.16
2000	46	53	-0.28	-0.52	-0.26
Average (00, 09)	46	46	-0.03	-0.06	-0.03

Long Pond

Year	Observed	Simulated	T1	T2	T3
1993	303	170	1.16	2.15	1.08
1994	293	181	0.96	1.79	0.90
2000	220	192	0.27	0.50	0.25
2003	147	170	-0.29	-0.54	-0.27
2004	171	178	-0.08	-0.15	-0.07
2005	155	165	-0.12	-0.23	-0.12
2006	179	165	0.16	0.31	0.15
2007	164	157	0.09	0.17	0.08
Average (03-07, 09)	163	163	0.00	0.00	0.00

Cranberry Pond

Year	Observed	Simulated	T1	T2	T3
1993	156	59	1.94	3.60	1.79
1994	152	66	1.67	3.11	1.54
2000	66	69	-0.08	-0.14	-0.07
Average (00, 09)	61	61	0.00	0.00	0.00

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 Buck, Long, and Cranberry Ponds is quite good. Therefore, BATHTUB is sufficiently calibrated for use in estimating load reductions required to achieve the phosphorus TMDL target in the ponds.

APPENDIX C. TOTAL EQUIVALENT DAILY PHOSPHORUS LOAD ALLOCATIONS

Buck Pond

Source	Total Phosphorus Load (lbs/d)			% Reduction
	Current	Allocated	Reduction	
Agriculture*	0.855	0.171	0.684	80%
Developed Land (non-regulated groundwater)	0.810	0.486	0.324	40%
Septic Systems	1.121	0.000	1.121	100%
Forest, Wetland, Stream Bank, and Natural Background*	0.296	0.296	0.000	0%
LOAD ALLOCATION	**3.082**	**0.953**	**2.129**	**69%**
Point Sources	0.000	0.000	0.000	---
Developed Land (regulated MS4 stormwater)	2.205	0.981	1.224	55%
WASTELOAD ALLOCATION	**2.205**	**0.981**	**1.224**	**55%**
LA + WLA	**5.287**	**1.934**	**3.353**	**63%**
Margin of Safety	---	0.2149	---	---
TOTAL	**5.287**	**2.149**	**---**	**---**

* Includes phosphorus transported through surface runoff and subsurface (groundwater)
** As noted in the text, this daily maximum will not be used as the basis for permit limits.

Long Pond

Source	Total Phosphorus Load (lbs/d)			% Reduction
	Current	Allocated	Reduction	
Agriculture*	4.686	0.483	4.203	90%
Developed Land (non-regulated groundwater)	2.043	0.469	1.574	77%
Septic Systems	4.106	0.000	4.106	100%
NYS Barge Canal	1.215	1.215	0.000	0%
Forest, Wetland, Stream Bank, and Natural Background*	0.595	0.595	0.000	0%
Internal Loading	55.821	0.000	55.821	100%
LOAD ALLOCATION	**68.466**	**2.762**	**65.704**	**96%**
Spencerport (V) WWTP	6.119	0.000	6.119	100%
Northwood School	0.601	0.100	0.501	83%
Kirby's Courtyard Inn	0.305	0.051	0.254	83%
September Place & Gates Trailer Park	0.398	0.066	0.332	83%
Hess Mobile Home Park	0.200	0.033	0.167	83%
Braemar Country Club	0.123	0.020	0.13	84%
Maier Autohaus	0.007	0.001	0.006	85%
Developed Land (regulated MS4 stormwater)	3.217	0.322	2.895	90%
WASTELOAD ALLOCATION	**10.970**	**0.593**	**10.377**	**95%**
LA + WLA	**79.436**	**3.355**	**76.081**	**96%**
Margin of Safety	---	0.3728	---	---
TOTAL	**79.436**	**3.728**	**---**	**---**

* Includes phosphorus transported through surface runoff and subsurface (groundwater)
** As noted in the text, this daily maximum will not be used as the basis for permit limits.

Cranberry Pond

Source	Total Phosphorus Load (lbs/d)			% Reduction
	Current	Allocated	Reduction	
Agriculture*	0.042	0.010	0.032	75%
Developed Land (non-regulated groundwater)	0.056	0.045	0.011	20%
Septic Systems	0.051	0.000	0.051	100%
Forest, Wetland, Stream Bank, and Natural Background*	0.022	0.022	0.000	0%
Internal Loading	0.338	0.000	0.338	100%
LOAD ALLOCATION	**0.509**	**0.077**	**0.432**	**85%**
Point Sources	0.000	0.000	0.000	---
Developed Land (regulated MS4 stormwater)	0.236	0.047	0.189	80%
WASTELOAD ALLOCATION	**0.236**	**0.047**	**0.189**	**80%**
LA + WLA	**0.745**	**0.124**	**0.621**	**83%**
Margin of Safety	---	0.0138	---	---
TOTAL	**0.745**	**0.138**	**---**	**---**

* Includes phosphorus transported through surface runoff and subsurface (groundwater)
** As noted in the text, this daily maximum will not be used as the basis for permit limits.

APPENDIX D. ESTIMATED DISCHARGE DATA FOR NYS BARGE CANAL AND WASTEWATER TREATMENT PLANTS

Long Pond

NYS Barge Canal

Month	Total Phosphorus (mg/l)	Estimated Discharge (MGD)
January	0	0
February	0	0
March	0	0
April	0	0
May	0.072	4.33
June	0.080	3.55
July	0.091	3.62
August	0.087	3.55
September	0.068	3.55
October	0.061	3.26
November	0.029	2.07
December	0	0

Spencer Port Wastewater Treatment Plant (NPDES ID: NY0020656)

Month	Total Phosphorus (mg/l)	Estimated Discharge (MGD)
January	0.962	0.951
February	0.84	0.890
March	0.606	1.161
April	0.598	1.149
May	0.76	0.819
June	1.008	0.697
July	1.13	0.666
August	1.252	0.615
September	0.962	0.716
October	0.9094	0.714
November	0.8554	0.807
December	0.928	0.932

Northwood School (NPDES ID: NY0090476)

Month	Total Phosphorus (mg/l)	Estimated Discharge (MGD)
January	3	0.024
February	3	0.024
March	3	0.024
April	3	0.024
May	3	0.024
June	3	0.024
July	3	0.024
August	3	0.024
September	3	0.024
October	3	0.024
November	3	0.024
December	3	0.024

Kirby's Courtyard Inn (NPDES ID: NY0160806)

Month	Total Phosphorus (mg/l)	Estimated Discharge (MGD)
January	3	0.0122
February	3	0.0122
March	3	0.0122
April	3	0.0122
May	3	0.0122
June	3	0.0122
July	3	0.0122
August	3	0.0122
September	3	0.0122
October	3	0.0122
November	3	0.0122
December	3	0.0122

September Place & Gates Trailer Park (NPDES ID: NY0087416)

Month	Total Phosphorus (mg/l)	Estimated Discharge (MGD)
January	3	0.0159
February	3	0.0159
March	3	0.0159
April	3	0.0159
May	3	0.0159
June	3	0.0159
July	3	0.0159
August	3	0.0159
September	3	0.0159
October	3	0.0159
November	3	0.0159
December	3	0.0159

Hess Mobile Home Park (NPDES ID: NY0069761)

Month	Total Phosphorus (mg/l)	Estimated Discharge (MGD)
January	3	0.008
February	3	0.008
March	3	0.008
April	3	0.008
May	3	0.008
June	3	0.008
July	3	0.008
August	3	0.008
September	3	0.008
October	3	0.008
November	3	0.008
December	3	0.008

Braemar Country Club (NPDES ID: NY0093777)

Month	Total Phosphorus (mg/l)	Estimated Discharge (MGD)
January	3	0.0049
February	3	0.0049
March	3	0.0049
April	3	0.0049
May	3	0.0049
June	3	0.0049
July	3	0.0049
August	3	0.0049
September	3	0.0049
October	3	0.0049
November	3	0.0049
December	3	0.0049

Maier Autohaus (NPDES ID: NY0246824)

Month	Total Phosphorus (mg/l)	Estimated Discharge (MGD)
January	3	0.0003
February	3	0.0003
March	3	0.0003
April	3	0.0003
May	3	0.0003
June	3	0.0003
July	3	0.0003
August	3	0.0003
September	3	0.0003
October	3	0.0003
November	3	0.0003
December	3	0.0003