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

Columbia County, New York

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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, 1991b).

1.2. Problem Statement

Kinderhook Lake (Water Index Number: H-204-2-7-P24, PWL ID: 1310-0002) is situated in the Towns of Kinderhook and Chatham, within Columbia 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. Kinderhook Lake was listed on the Lower Hudson River Basin PWL in 1998, with *fish consumption* and *recreation* listed as *impaired,* and *bathing* and *aesthetics* listed as *stressed* due to excessive weed growth, algae, and PCB contamination (NYS DEC, 2005).

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

The results from state sampling efforts confirm eutrophic conditions in Kinderhook Lake, with the concentration of phosphorus in the lake exceeding the state guidance value for phosphorus (20 $\mu g \cdot l^{-1}$

or 0.020 $mg \cdot l^{-1}$, applied as the mean summer, epilimnetic total phosphorus concentration), which increases the potential for nuisance summertime algae blooms. In 2002, Kinderhook 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, and has been designated as a "high priority for TMDL development" (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. History of the Lake and Watershed

Kinderhook Lake has had water quality issues associated with blue green algae (cyanobacteria) for over 80 years. Excessive growth of invasive aquatic plants ("weeds") became a serious problem in the 1960s and 1970s. Various management strategies, including copper sulfate treatment and mechanical weed cutting, were implemented with little success. However, beginning in 2001, the Kinderhook Lake Corporation has been treating the Lake and the Valatie Kill tributary with both copper compounds and alum, in an effort to control algal and non-algal particles. This effort, along with a winter drawdown of the lake, appears to be reducing the problems associated with nuisance aquatic plants. Monitoring is ongoing (Collins, 2006) and will be discussed in more detail in Section 3.

2.2. Watershed Characterization

Kinderhook Lake has a direct drainage basin area of 24,805 acres excluding the surface area of the lake (Figure 2-1). Elevations in the lake's basin range from approximately 1,345 feet above mean sea level (AMSL) to as low as 288 feet AMSL at the surface of Kinderhook Lake.

Existing land use and land cover in the Kinderhook 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 orthoimagery 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 2-2). Appendix A provides additional detail about the refinement of land use for the drainage basin. Land use categories (including individual category acres and percent of total) in Kinderhook Lake's drainage basin are listed in Table 2-1 and presented in Figures 2-3 and 2-4.

Figure 2-1. Kinderhook Lake Direct Drainage Basin (Yellow triangle- Valatie Kill sampling location, 2008-2010)

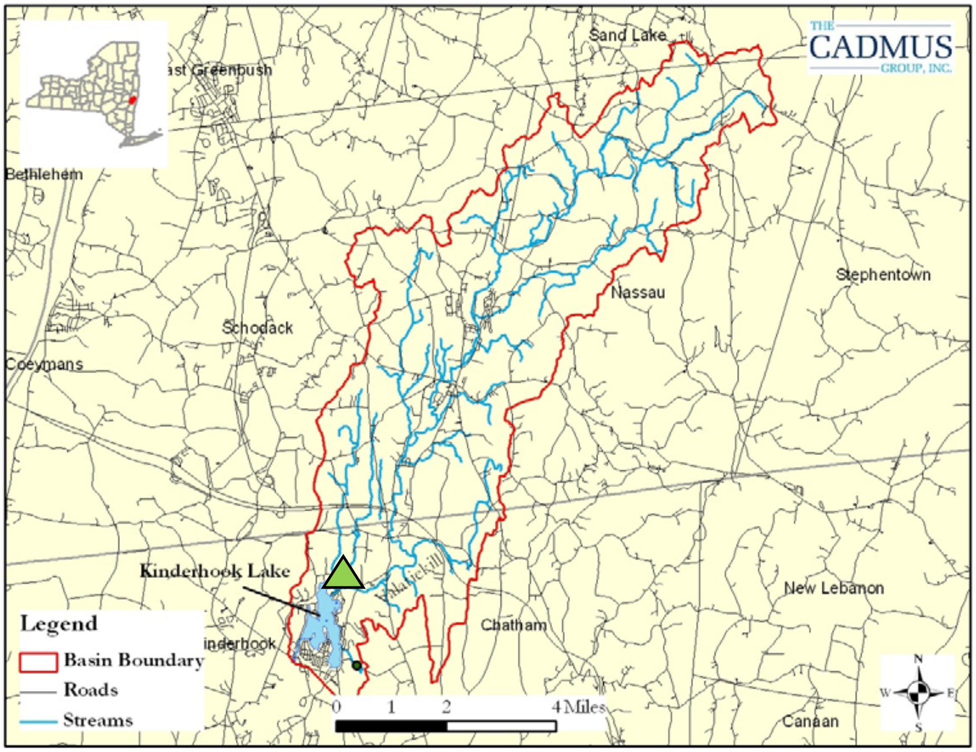


Figure 2-2. Aerial Image of Kinderhook Lake

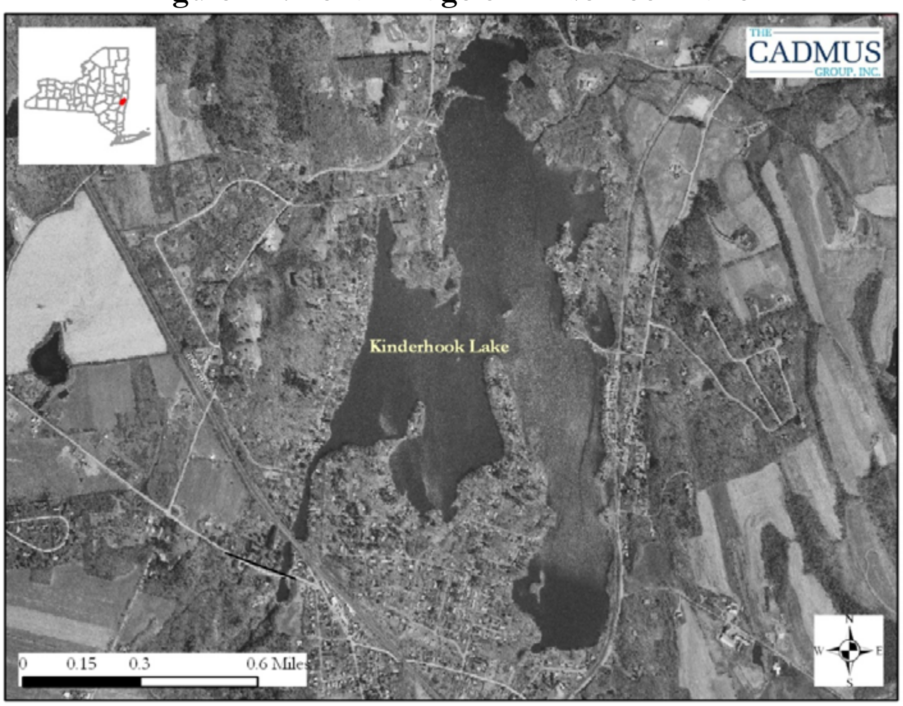


Table 2-1. Land Use Acres and Percent in Kinderhook Lake Drainage Basin

Land Use Category	Acres	% of Drainage Basin
Open Water	271	1%
Agriculture	5,689	23%
Hay & Pasture	5,216.2	21%
Cropland	472.5	2%
Developed Land	2,731	11%
Low Intensity	2,513	10%
High Intensity	218	1%
Forest	15,330	62%
Wetlands	784	3%
TOTAL	**24,805**	**100%**

Figure 2-3. Percent Land Use in Kinderhook Lake Drainage Basin

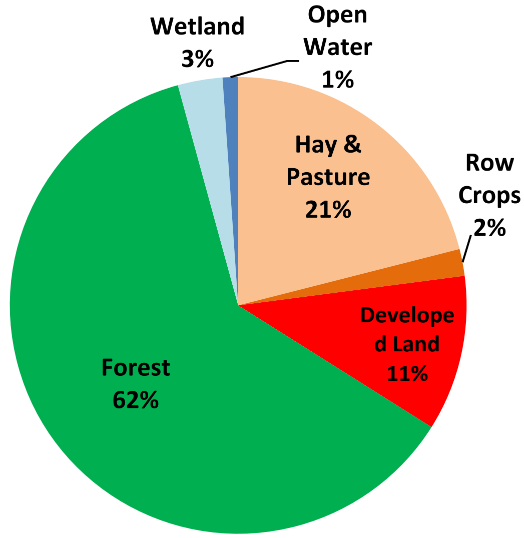
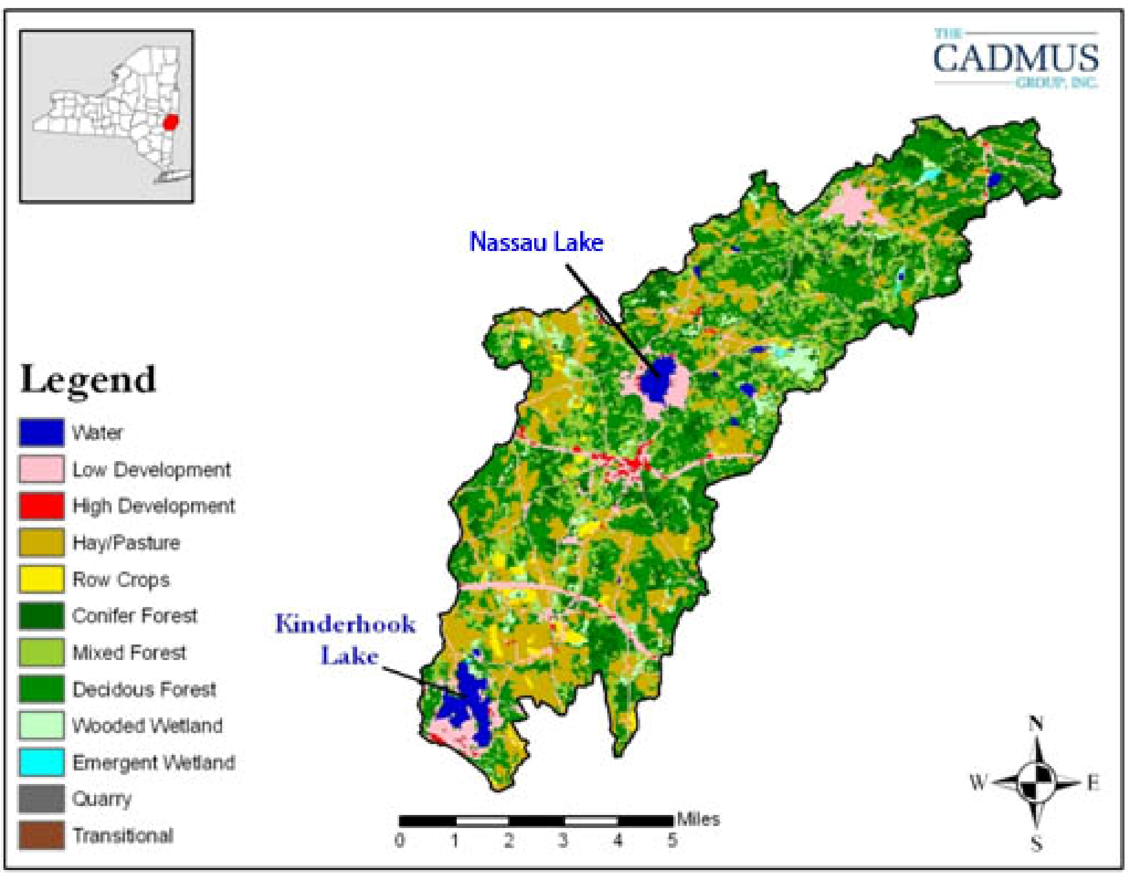


Figure 2-4. Land Use in Kinderhook Lake Drainage Basin



2.3. Lake Morphometry

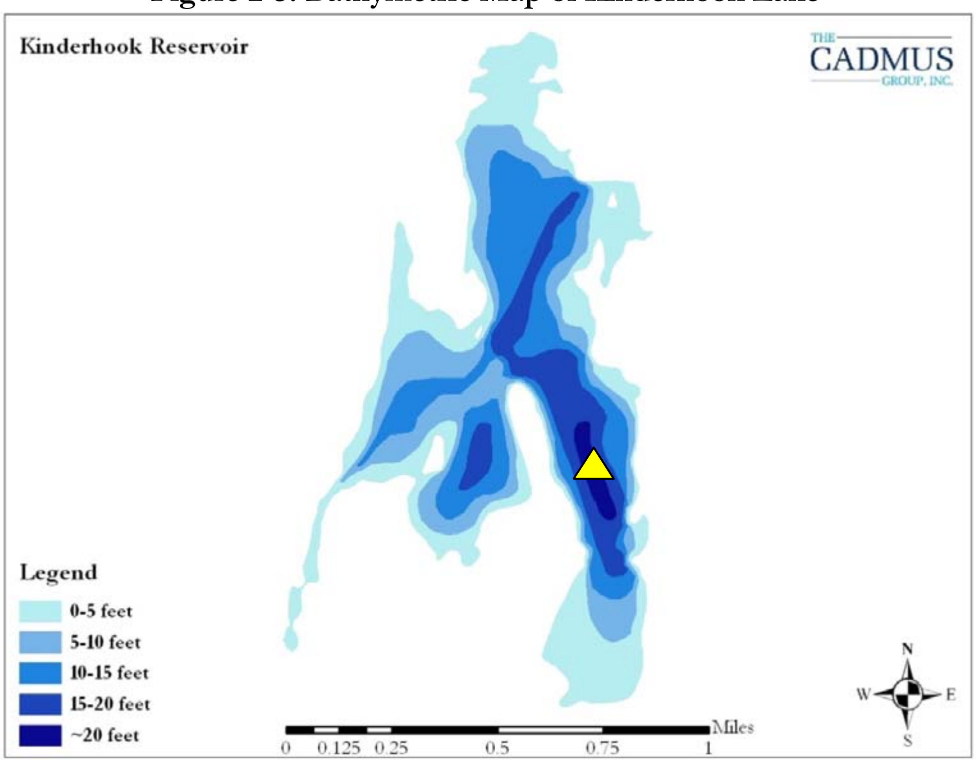
Kinderhook Lake is a 345 acre waterbody at an elevation of about 288 feet AMSL. Figure 2-5 shows a bathymetric map developed by The Cadmus Group, Inc. for Kinderhook Lake based on bathymetric maps provided by NYS DEC. Table 2-2 summarizes key morphometric characteristics for Kinderhook Lake. Kinderhook Lake has a very large watershed to lake surface area ratio and thus has a hydraulic retention time of 0.1 years. Thus, the water quality of the Lake is determined to a large extent by the condition of the Valatie Kill and activities in the watershed.

2.4. Water Quality

2.4.1. Historical Water Quality (1996-2001).

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.

Figure 2-5. Bathymetric Map of Kinderhook Lake



(Yellow triangle- Lake sampling location, 2009)

Table 2-2. Kinderhook Lake Characteristics

Surface Area (acres)	345
Elevation (ft AMSL)	288
Maximum Depth (ft)	30
Mean Depth (ft)	15
Length (ft)	8,329
Width at widest point (ft)	3,066
Shoreline perimeter (ft)	42,637
Direct Drainage Area (acres)	24,805
Watershed: Lake Ratio	72:1
Mass Residence Time (years)	0.05
Hydraulic Residence Time (years)	0.1

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.

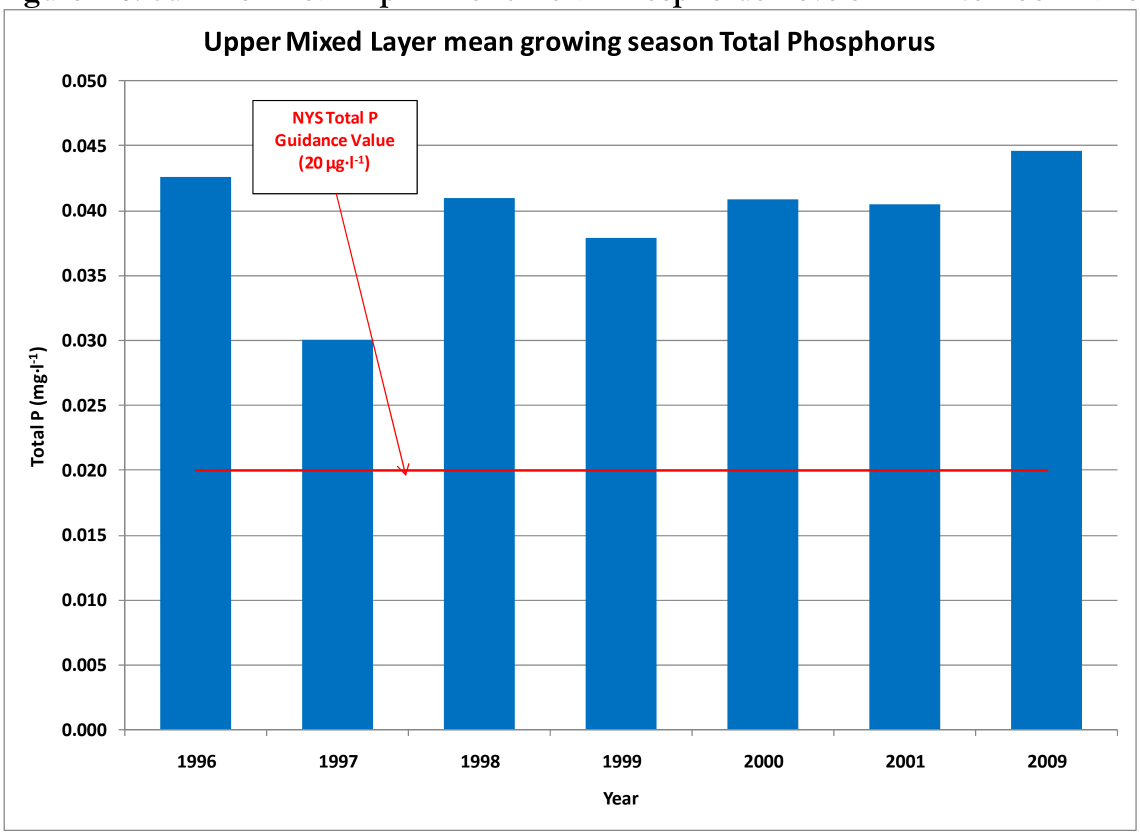
NYS DEC's Lake Classification and Inventory (LCI) program was initiated in 1982 and is conducted by NYS DEC staff. Each year, approximately 10-25 water bodies are sampled in a specific geographic region of the state. The waters selected for sampling are considered to be the most significant in that particular region, both in terms of water quality and level of public access. Samples are collected for pH, ANC, specific conductance, temperature, oxygen, chlorophyll *a*, nutrients and plankton at the surface and with depth at the deepest point of the lake, 4-7 times per year (with stratified lakes sampled more frequently than shallow lakes). Sampling generally begins during May and ends in October.

The LCI effort had been suspended after 1992, due to resource (mostly staff time) limitations, but was resumed again in 1996 on a smaller set of lakes. Since 1998, this program has been geographically linked with the Rotating Integrated Basin Sampling (RIBS) stream monitoring program conducted by the NYS DEC Bureau of Watershed Assessment. LCI sites are chosen within the RIBS monitoring basins (Susquehanna River basin in 1998, Long Island Sound/Atlantic Ocean and Lake Champlain basins in 1999, Genesee and Delaware River basins in 2000, and the Mohawk and Niagara Rivers basins in 2001, Upper Hudson River and Seneca/Oneida/Oswego Rivers basins in 2002, and the Lake Champlain, Lower Hudson River, and Atlantic Ocean/Long Island Sound basin in 2003) from among the waterbodies listed on the NYS Priority Waterbodies

List for which water quality data are incomplete or absent, or from the largest lakes in the respective basin in which no water quality data exists within the NYSDEC database. This cycle has been and will continue to be repeated at a five year interval.

As part of CSLAP and LCI, a limited number of water quality samples were collected in Kinderhook Lake during the summers of 1996-2001. The results from these sampling efforts show eutrophic conditions in Kinderhook Lake, with the concentration of phosphorus in the lake exceeding the state guidance value for phosphorus (20 $\mu g \cdot l^{-1}$ or 0.020 $mg \cdot l^{-1}$, applied as the mean summer, Upper Mixed Layer (UML) total phosphorus concentration), which increases the potential for nuisance summertime algae blooms. Figure 2-6 shows the summer mean epilimnetic phosphorus concentrations for phosphorus data collected during all sampling seasons and years in which Kinderhook Lake was sampled as part of CSLAP and LCI; the number annotations on the bars indicate the number of data points included in each summer mean.

Figure 2-6. Summer Mean Epilimnetic Total Phosphorus Levels in Kinderhook Lake



2.4.2. Recent Water Quality (2008-2010)

As per an agreement with USEPA Region 2, detailed sampling was conducted for four of the lakes, ponds and reservoirs in New York State which had both water-based recreation impairments and was scheduled for TMDL development. These waterbodies were Basic Creek Reservoir (Albany

County), Sleepy Hollow Lake (Greene County), Robinson Pond (Columbia County) and Kinderhook Lake.

2.4.2.1. Lake Sampling (2009)

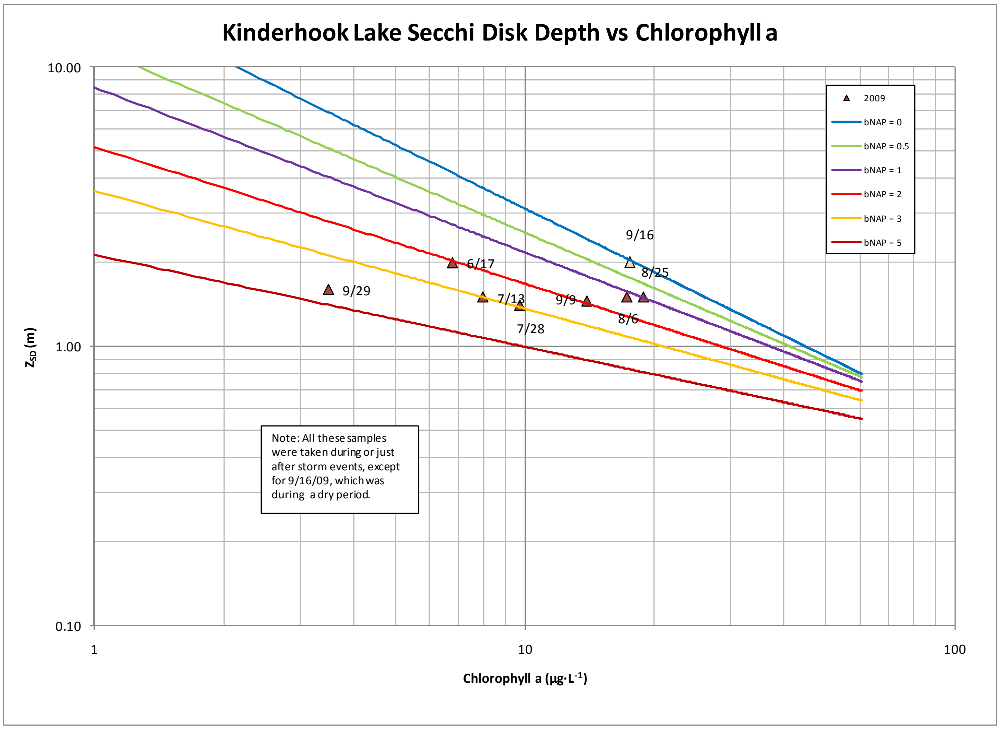
Kinderhook Lake was sampled 8 times during the growing season of 2009 at the location of maximum depth (see Figure 2-5). The raw data are listed in Appendix E. Samples were collected both from the UML and the Lower Water Layer (LWL). On 4 dates, multiple samples were collected from the LWL, to assess the chemical variability with depth.

Samples were analyzed using standard methods and operation procedures, as per the Quality Assurance Program Plan (Quinn, 2008). Samples were analyzed for the phosphorus and nitrogen series, chlorophyll a and chloride. Selected samples were analyzed for arsenic and iron. Secchi disk depth and depth profiles for dissolved oxygen and water temperature were also recorded.

2.4.2.1.1. Lake Optical Properties

An optical model (Effler et. al, 2008, Perkins et al, 2010) was applied to the Secchi disk depth and chlorophyll a data, in order to partition the impacts of algal and non-algal particles on optical properties. A version of the model was programmed in Microsoft Excel. Although the model also requires an independent measurement of both extinction coefficient and dissolved organic carbon (DOC), it was modified to exclude the former (relying solely on Secchi disk depth) and the latter was estimated at 4 $mg \cdot l^{-1}$, which is consistent with the true color (TC) values measured by the CSLAP program (1997-2001, 16.9±5.1 mg $Pt \cdot l^{-1}$) and LCI (1996, 20.2±3.2 mg $Pt \cdot l^{-1}$), based on DOC/TC regressions. The results of the model are shown in Figure 2-7.

Figure 2-7.

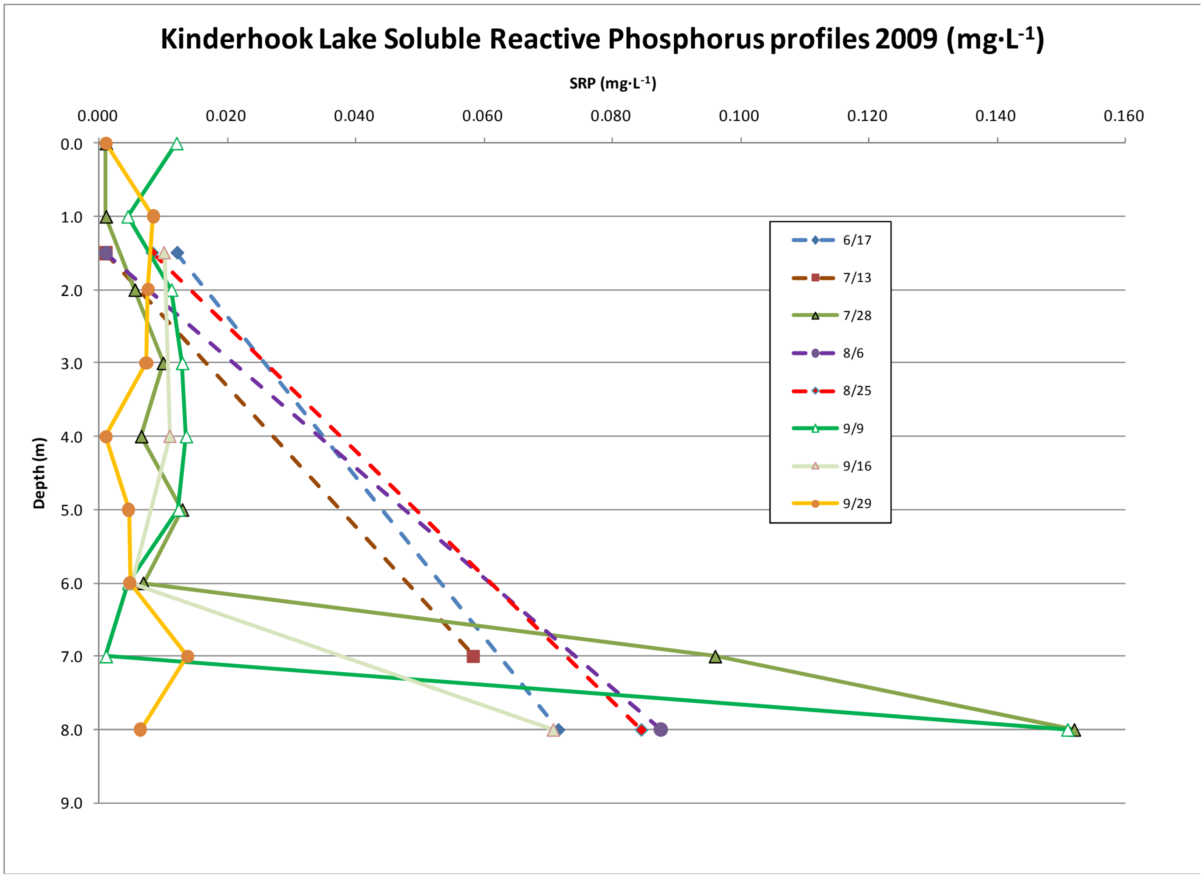


Except for the 9/16/09 sampling date, the remaining samples indicated a considerable non-algal component to the optical properties (b_{NAP} between 1 and 3). Also, except for the mid-September sample, which was collected during a dry weather period, the remaining Lake samples were collected during or just after high runoff event periods. This indicates that the transparency of Kinderhook Lake is not only influenced by the levels of phytoplankton, but also by suspended sediment entering from the watershed during periods of high runoff and possibly even resuspended bottom material. For the last decade, both alum and copper treatments also may have influenced the condition of the Lake.

2.4.2.1.2. Lake Phosphorus Depth Profiles

The LWL exhibits elevated levels of total phosphorus, soluble reactive phosphorus (SRP), ammonia nitrogen and iron. Figure 2-8 shows depth profile data for SRP. The SRP levels in the LWL are somewhat elevated when compared to the UML values and steadily increase until thermal stratification breaks down in late September, 2009. Kinderhook Lake's LWL has been treated for a number of years with alum (aluminum sulfate) to reduce algal and non-algal particles and this will be discussed further in Sections 3.0 and 4.27.

Figure 2-8.



2.4.2.1.3. Lake Mean Growing Season Conditions

The mean values for the UML of Kinderhook during 2009 are shown in Table 2-3.

Table 2-3.
Kinderhook Lake Upper Mixed Layer Growing Season Mean Water Quality (2009)

Parameter	Chl a (µg/L)	Cl (mg/L)	Total P (mg/L)	Sol React P (mg/L)	NH4-N (mg/l)	NOx-N (mg/L)	Total Kjeldahl N (mg/L)	Org N (mg/L)	Total N (mg/L)	Tot N: Tot P	Sol Inorg N:P	Z_{SD} (m)
UML mean	11.96	32.1	0.045	0.006	0.050	0.014	0.614	0.564	0.627	31:1	23:1	1.62

The mean growing season total phosphorus value of 45 $\mu g \cdot l^{-1}$ is somewhat higher than the range of the 1996-2001 historical data presented in Table 2-6, although this could be explained by the number of sampling dates in 2009 (7of 8 total) that occurred during or just after storm events.

2.4.2.2. The Water Quality of Kinderhook Creek

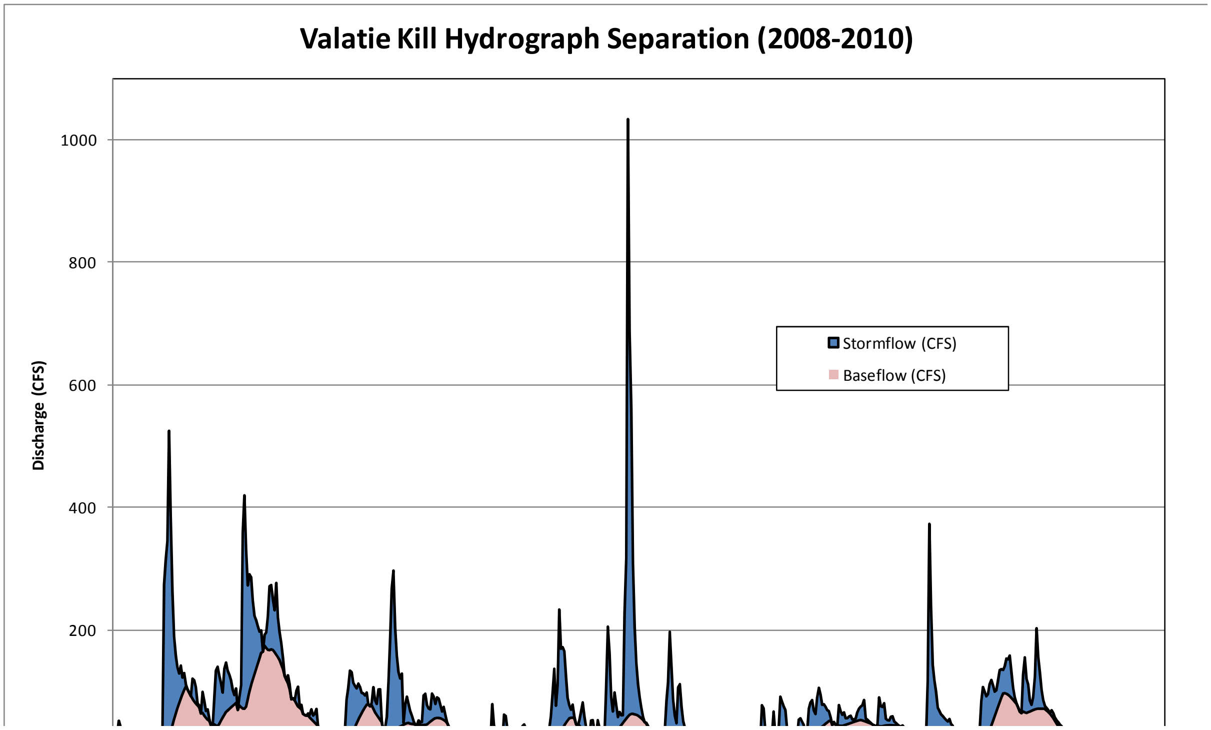
An automatic sampling station was established on the Valatie Kill, just upstream of the Lake (Figure 2-1) and was operational from September, 2008 to June 2010. Water level, turbidity, water temperature and specific conductance were measured at 15 minute intervals (Quinn, 2008). Stream discharge measurements were made to develop a rating curve for the site, as per standard methods (USGS, 1982). Thirty four storm events were sampled, each with approximately 10 individual samples collected. The samples were analyzed for the phosphorus and nitrogen series, chloride and total suspended sediment. The raw data is presented in Appendix F.

An Event Mean Concentration (EMC) was calculated for each parameter and each event. These results are also included in Appendix F. There were also over 50 baseflow samples collected and analyzed. A two compartment model was used to separate the discharge into storm flow and base flow for each event and each non-event period (Figure 2-9). Discharge weighted mean EMCs were calculated for six consecutive hydrologic seasons, resulting in seasonal and annual mass loadings for each parameter (Appendix F). These loadings were compared with predictions obtained from AVGWLF.

What can also be seen in examining Figure 2-9, is that the storm event in late July, 2009 had a peak discharge of over 1,000 CFS and an averaged discharge of 532 CFS, which would make it somewhere around the 100 year storm. With the Lake having a hydraulic retention time of approximately 0.1 years, it is not difficult to conclude that storms of this nature could completely replace all the water in the Lake with runoff from the watershed. For example, the volume of the Lake calculated from Table 2-2 is 2.25×10^8 ft^3 (6.38×10^6 m^3). In comparison, the measured volume of the late July, 2009 storm event was 2.64×10^8 ft^3 (7.48×10^6 m^3) or somewhat more than the entire volume of the Lake.

The total phosphorus and soluble reactive phosphorus loads for the 642 day period that was sampled at the Valatie Kill site were 6,691 Kg and 2,650 Kg, respectively. When corrected for unsampled direct drainage, those represent annual loads from the entire watershed of 3,808 $Kg \cdot yr^{-1}$ and 1,508 $Kg \cdot yr^{-1}$ (8,388 $lb \cdot yr^{-1}$ and 3,322 $lb \cdot yr^{-1}$). The total phosphorus loading is somewhat greater than the mean value projected by AVGWLF, which is 3,089 $Kg \cdot yr^{-1}$ (6,805 $lb \cdot yr^{-1}$). This is understandable, considering that the sampled water year was wetter than normal.

Figure 2-9.



In addition, annual runoff at the Valatie Kill station was projected for each water year from 1990 to 2009, by comparing the runoff at this site to eight nearby USGS gages, including one on the Valatie Kill @ Nassau, NY. By using the sampling period discharge-weighted EMC for total phosphorus of 62 $\mu g \cdot l^{-1}$, annual loads were estimated for each water year. The annual runoff and total phosphorus loads are shown in Table 2-4. The mean water year runoff for the period was 20.64±6.97 $in \cdot yr^{-}$ (52.43±17.71 $cm \cdot yr^{-1}$) and the mean water year total phosphorus load at the Valatie Kill site was 2,689±908 $Kg \cdot yr^{-1}$ (5,924±2001 $lb \cdot yr^{-1}$). This translates out to a mean water year load from the entire watershed of 3,190±1,078 $Kg \cdot yr^{-1}$ (7,028±2374 $lb \cdot yr^{-1}$), which is somewhat higher than the mean value projected by AVGWLF.

Table 2.4
Total Phosphorus Loadings to Kinderhook Lake, Projected from Observed Data from 2008-2010 (Water Years 1990-2009)

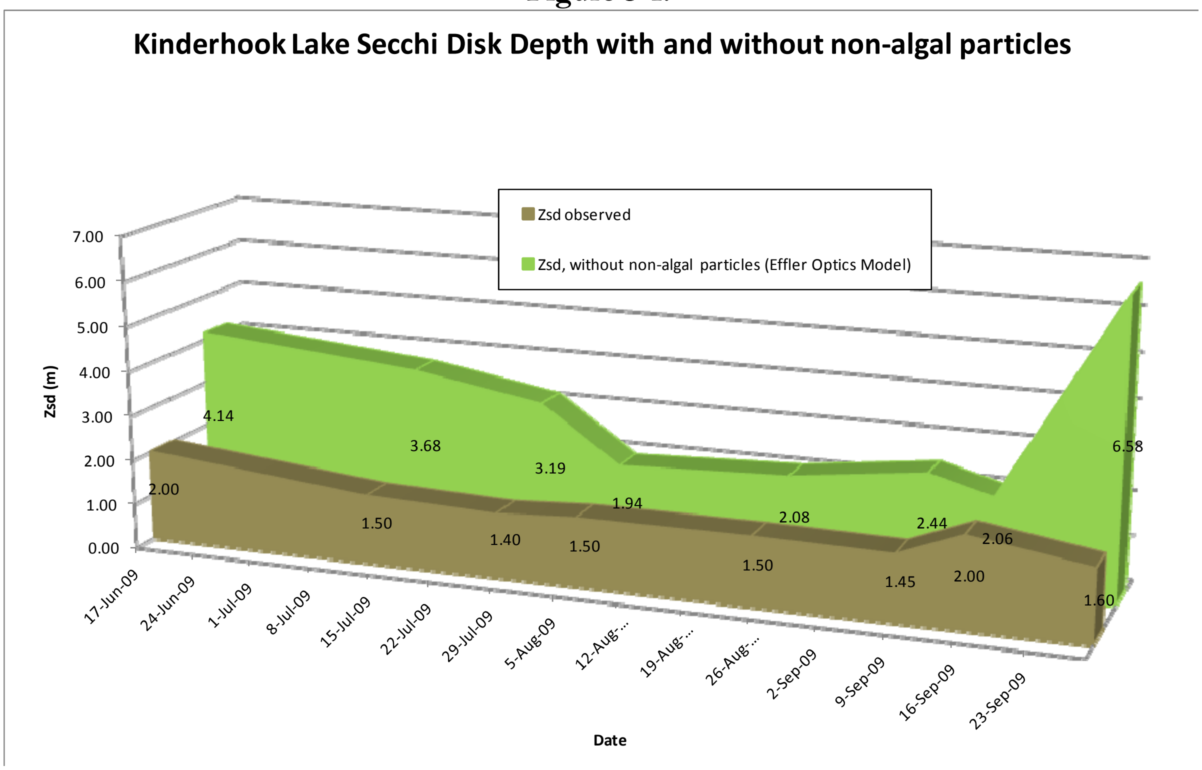
Parameter	Watershed Area	WY 1990	WY 1991	WY 1992	WY 1993	WY 1994	WY 1995	WY 1996	WY 1997	WY 1998	WY 1999
Runoff ($cm \cdot yr^{-1}$)	@ gage	58.33	35.28	48.19	57.98	31.57	71.63	65.43	36.63	35.84	53.77
Total P Load ($kg \cdot yr^{-1}$ @ 0.062 $mg \cdot l^{-1}$)	@ gage	2992	1810	2472	2974	1619	3674	3356	1879	1839	2758
Total P Load ($lb \cdot yr^{-1}$ @ 0.062 $mg \cdot l^{-1}$)	@ gage	6590	3986	5445	6550	3567	8093	7393	4138	4050	6075
Total P Load ($lb \cdot yr^{-1}$ @ 0.062 $mg \cdot l^{-1}$)	watershed	7819	4730	6460	7771	4232	9602	8771	4910	4805	7208

Parameter	Watershed Area	WY 2000	WY2001	WY 2002	WY 2003	WY 2004	WY 2005	WY 2006	WY 2007	WY 2008	WY 2009	Mean (1990-2009)
Runoff ($cm \cdot yr^{-1}$)	@ gage	38.66	19.19	56.17	54.92	46.70	79.61	55.70	67.99	92.90	42.13	52.43±17.71
Total P Load ($kg \cdot yr^{-1}$ @ 0.062 $mg \cdot l^{-1}$)	@ gage	1983	984	2881	2817	2395	4084	2857	3487	4765	2161	2689±908
Total P Load ($lb \cdot yr^{-1}$ @ 0.062 $mg \cdot l^{-1}$)	@ gage	4368	2168	6346	6205	5276	8995	6293	7681	10495	4759	5924±2001
Total P Load ($lb \cdot yr^{-1}$ @ 0.062 $mg \cdot l^{-1}$)	watershed	5182	2572	7529	7361	6260	10672	7467	9114	12452	5647	7028±2374

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 Kinderhook 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 $\mu g \cdot l^{-1}$ (or 0.02 $mg \cdot l^{-1}$), based on biweekly sampling, conducted from June 1 to September 30. This guidance value of 20 $\mu g \cdot l^{-1}$ is the TMDL target for Kinderhook Lake.

Figure 3-1.

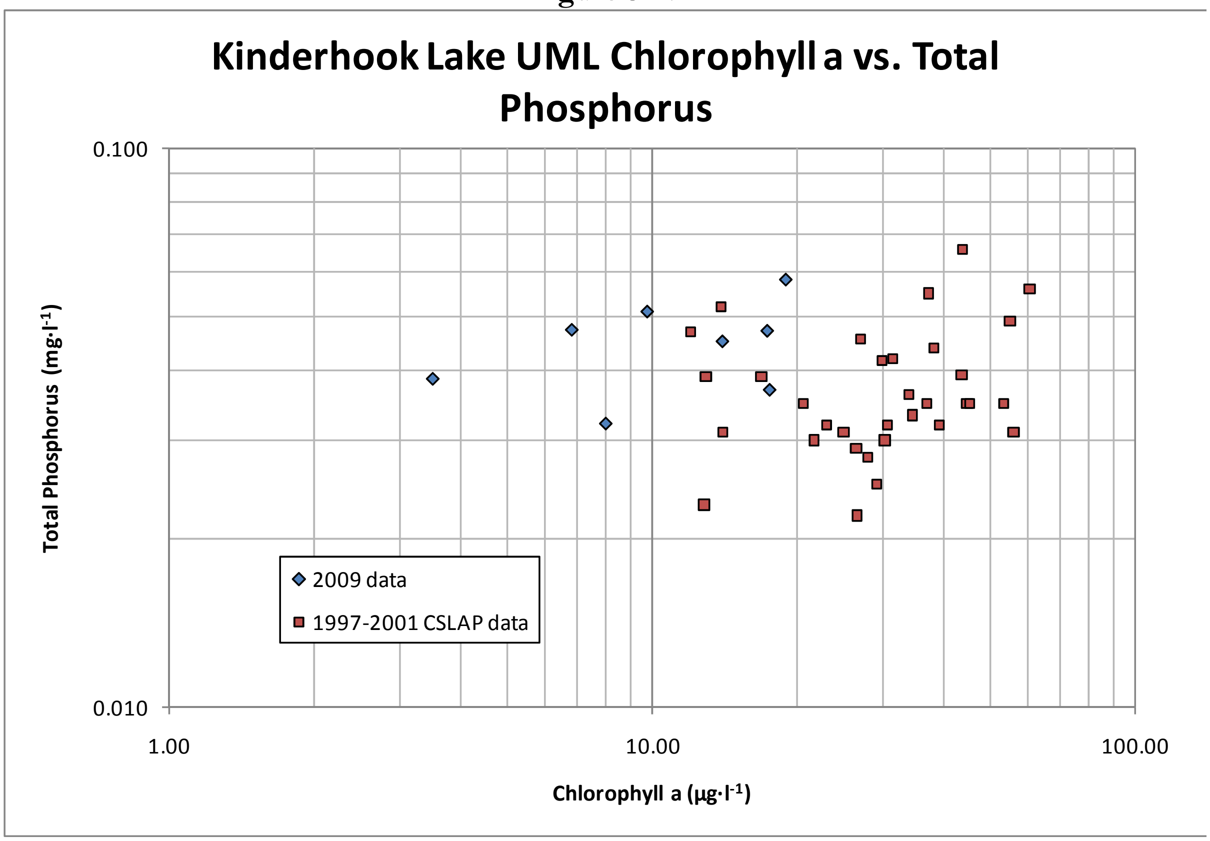


However, as can be seen from examination of Figure 2-7, the Secchi disk transparency of the Lake is only partially controlled by the levels of chlorophyll a. Non-algal particles from land runoff and possibly resuspension of shallow bottom sediments are also contributing to lack of water clarity in Kinderhook Lake. Figure 3-1 shows both the observed Secchi disk depth and the Secchi disk depth predicted by the Effler Optical Model, but without the inclusion of non-algal particles. Although these non-algal particles also contain some phosphorus, the underlying assumptions in the development of the Statewide phosphorus guidance value do not hold for Kinderhook Lake. In general, there is a good relationship between total phosphorus and chlorophyll a levels in NY State Lakes. The Fact Sheet states (p 2) that:

> ***"In addition to phosphorus, other water quality indices can be used to determine the trophic status of a waterbody. It is recommended that any sampling program to obtain the phosphorus data, include at a minimum, the measurement of water transparency, or Secchi depth. The sampling protocol should also include the collection of chlorophyll a. The use of Secchi and chlorophyll a data are generally the indicators that the public use to perceive water quality, i.e., clarity and "scum." When the Secchi and chlorophyll data are used in conjunction with phosphorus, a comprehensive summary of the water quality conditions at the surface of the lake is provided."***

In contrast, there is a weak relationship between chlorophyll a levels and total phosphorus in Kinderhook Lake (Figure 3-2). This also indicates that at least some of the phosphorus in the UML is non-algal in nature.

Figure 3-2.



Since there is also only a weak relationship between the transparency of Kinderhook Lake and chlorophyll a levels, additional studies are needed to disaggregate the algal and non-algal components of the Lake's optics. This will be discussed further in Section 7.2, Follow up Monitoring.

In addition, Kinderhook Lake has been treated by the Kinderhook Lake Corporation with both copper compounds and aluminum sulfate (alum) to control both algal and non-algal turbidity. The copper treatments extend back more than 50 years. The recent treatments (1998-2010) are summarized in Table 3-1 (Collins, 2010). These treatments have been permitted by NYSDEC.

Table 3-1.
Copper and Alum Treatments at Kinderhook Lake (1998-2010)

Year	Copper	Alum	Comments
1998	no	no	
1999	no	no	
2000	?	?	No information
2001	no	25,000 lb	
2002	no	24,000 lb – UML 20,000 lb - LWL	
2003	no	12,000 lb – UML 43,050 lb - LWL	
2004	1,000 lb	15,000 lb – UML 20,500 lb – LWL 8,000 lb - Inlet	$CuSO_4$
2005	1,000 lb	9,000 lb – UML 10,500 lb – LWL	$CuSO_4$
2006	1,000 lb	10,000 lb – UML 15,000 lb – LWL 1,700 lb - Inlet	$CuSO_4$
2007	180 gal?	1,500 lb – UML 20,500 lb – LWL	Copper possibly applied as Cutrine (chelated Cu)
2008	5,850 lb	no	$CuSO_4$
2009	6,000 lb?	5,000 lb –LWL 1,000 lb - Inlet	Alum applied in 1,000 lb amounts on June 4, 10 & 30, August 17 & 28. $CuSO_4$ treatment questionable.
2010	6,000 lb	4,000 lb - LWL	$CuSO_4$

4.0 SOURCE ASSESSMENT

4.1. Analysis of Phosphorus Contributions

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

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

4.2. Sources of Phosphorus Loading

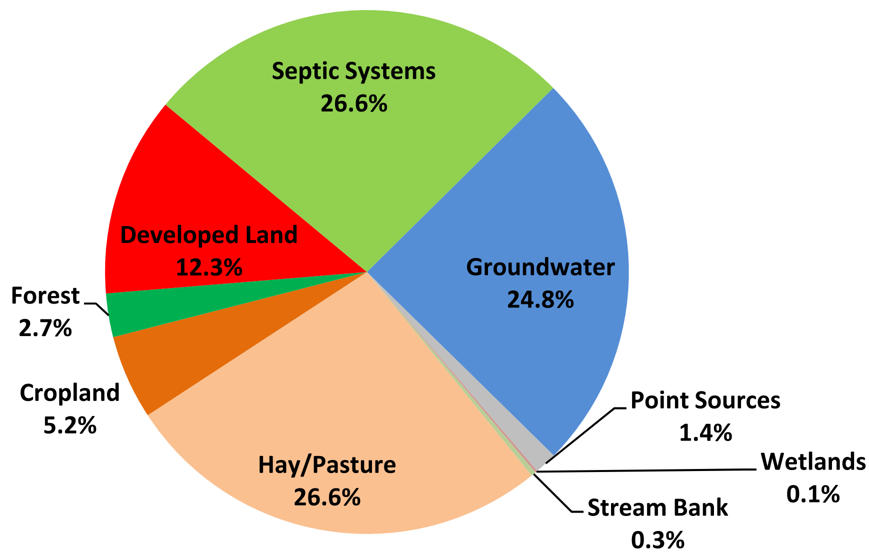
AVGWLF was used to estimate long-term (1990-2004) mean annual phosphorus (external) loading to Kinderhook Lake. The estimated mean annual external load of 6,805 $lb \cdot yr^{-1}$ of total phosphorus that enters Kinderhook Lake comes from the sources listed in Table 4-1 and shown in Figure 4-1. Appendix A provides the detailed simulation results from AVGWLF.

Table 4-1. Estimated Sources of Phosphorus Loading to Kinderhook Lake

Source	Total Phosphorus ($lb \cdot yr^{-1}$) +
Hay/Pasture	1,812
Cropland	354
Forest	183
Wetland	9
Developed Land	840
Stream Bank	20
Septic Systems	1,808
Groundwater	1,685
Point Sources	94
TOTAL	**6,805**

+ To convert to Kg·yr-1, multiply by 0.454.

Figure 4-1. Estimated Sources of Total Phosphorus Loading to Kinderhook Lake



4.2.1. Residential On-Site Septic Systems

Residential on-site septic systems contribute an estimated 1,808 $lb \cdot yr^{-1}$ of phosphorus to Kinderhook Lake, which is about 27% 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 50 houses within 50 feet of the shoreline, 169 houses between 50 and 250 feet of the shoreline, and 312 houses next to significant tributaries to the lake; all of the houses are assumed to have septic systems. Within 50 feet of the shorelines, 100% of septic systems were categorized as short-circuiting. For houses between 50 and 250 feet of the shoreline and on tributaries, 75% of septic systems were categorized as short-circuiting, 10% were categorized as ponding systems, and 15% 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, data from the 2000 census were used to estimate the percentage of seasonal homes for the town(s) surrounding the lake. Approximately 89% of the homes around the lake are assumed to be year-round residences, while 11% are seasonally occupied (i.e., June through August only). The estimated population in the Kinderhook Lake drainage basin served by normal and malfunctioning systems is summarized in Table 4-2.

Table 4-2. Population Served by Septic Systems in the Kinderhook Lake Drainage Basin

	Normally Functioning	Ponding	Short Circuiting	Total
September – May	167	111	952	1,230
June – August (Summer)	188	125	1071	1,384

4.2.2. Agricultural Runoff

Agricultural land encompasses 5,689 acres (23%) of the lake drainage basin and includes hay and pasture land (21%) and row crops (2%). Overland runoff from agricultural land is estimated to contribute 2,166 $lb \cdot yr^{-1}$ of phosphorus loading to Kinderhook Lake, which is 32% of the total phosphorus loading to the lake.

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

4.2.3. Urban and Residential Development Runoff

Developed land comprises 2,731 acres (11%) of the lake drainage basins. Stormwater runoff from developed land contributes 840 $lb \cdot yr^{-1}$ of phosphorus to Kinderhook Lake, which is 12% of the total phosphorus loading to the lake. This load does not account for contributions from malfunctioning septic systems.

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

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

4.2.4. Point Source Facilities

There are 3 permitted wastewater treatment plant dischargers in the Kinderhook Lake Basin (Table 4-3).

Table 4.3 Permitted Surface Wastewater Discharges – Kinderhook Lake Watershed

NPDES #	Name	Estimated Discharge (MGD)	Estimated Annual Load ($lb \cdot yr^{-1}$)
NY0222861	Cedar Acres Trailer Park	0.009	69.1
NY0029424	Chadwick Manor Apartments	0.0026	19.8
NY0212725	Smith's Cottages	0.00063	4.8

Estimated monthly total phosphorus concentration and flow was provided by NYSDEC for these facilities; these estimates are provided in Appendix D. AVGWLF uses this information to calculate phosphorus loading from the point sources. Estimated total phosphorus loading from the point sources (combined) is 94 $lb \cdot yr^{-1}$ (less than 1.5% of the total loading to Kinderhook Lake).

4.2.5. Forest Land Runoff

Forested land comprises 15,330 acres (62%) of the lake drainage basin. Runoff from forested land is estimated to contribute about 183 $lb \cdot yr^{-1}$ of phosphorus loading to Kinderhook Lake, which is about 3% 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).

4.2.6. 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 1,685 $lb \cdot yr^{-1}$ (25%) of the total phosphorus load to Kinderhook Lake. With respect to groundwater, there is typically a small "background" concentration owing to various natural sources. In the Kinderhook Lake drainage basin, the model-estimated groundwater phosphorus concentration is 0.019 $mg \cdot l^{-1}$. The GWLF manual provides estimated background groundwater phosphorus concentrations for ≥90% forested land in the eastern United States, which is 0.006 $mg \cdot l^{-1}$. Consequently, about 32% of the groundwater load (532 $lb \cdot yr^{-1}$) can be attributed to natural sources, including forested land and soils.

The remaining amount of the groundwater phosphorus load (about 1,153 $lb \cdot yr^{-1}$) likely originates from agricultural or developed land sources (i.e., leached in dissolved form from the surface). It is estimated that of the remaining phosphorus transported to the lake through groundwater 322 $lb \cdot yr^{-1}$ originates from developed land and 831 $lb \cdot yr^{-1}$ originates from agricultural land, proportional to their respective surface runoff loads. Table 4-4 summarizes this information.

Table 4-4. Sources of Phosphorus Transported in the Subsurface via Groundwater

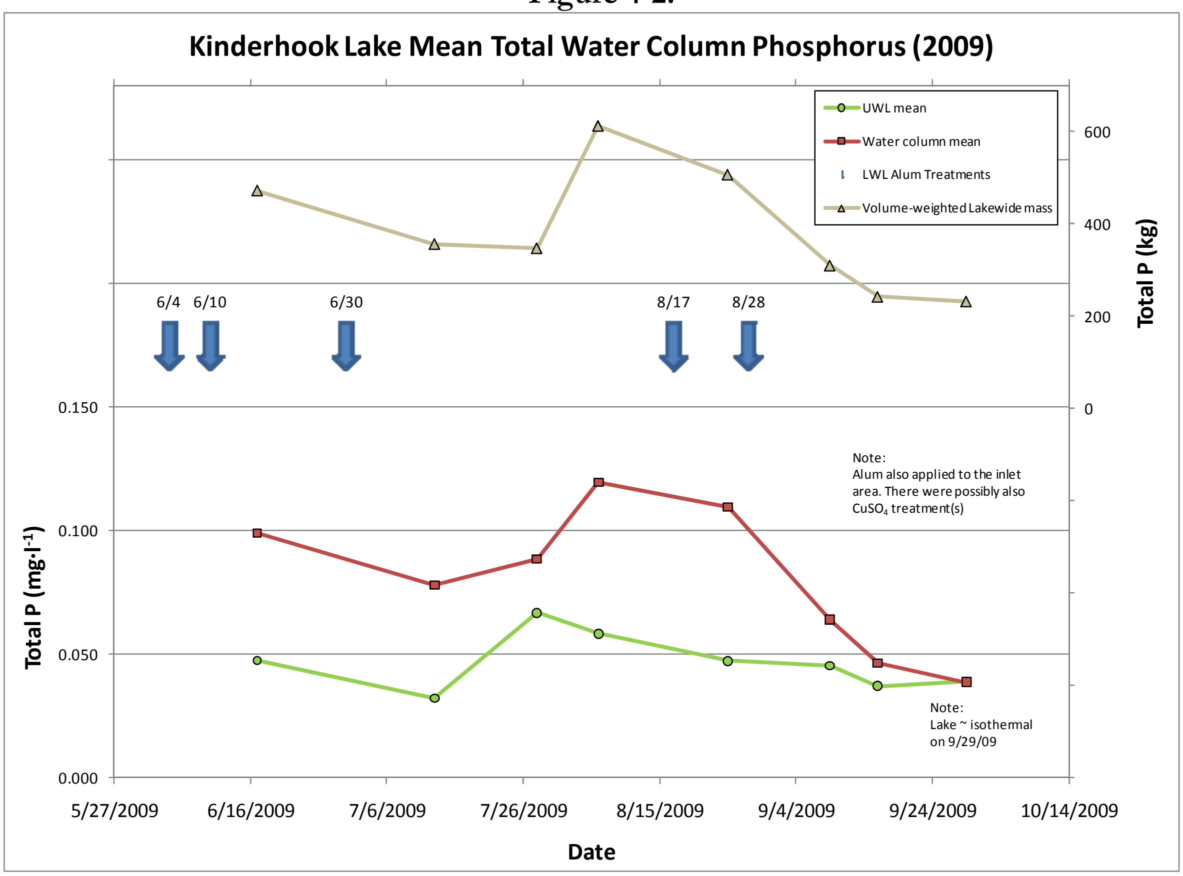
	Total Phosphorus ($lb \cdot yr^{-1}$)+	% of Total Groundwater Load
Natural Sources	532	32%
Agricultural Land	831	49%
Developed Land	322	19%
TOTAL	**1,685**	**100%**

+ To convert to kg·yr-1, multiply by 0.454.

4.2.7. Internal Load

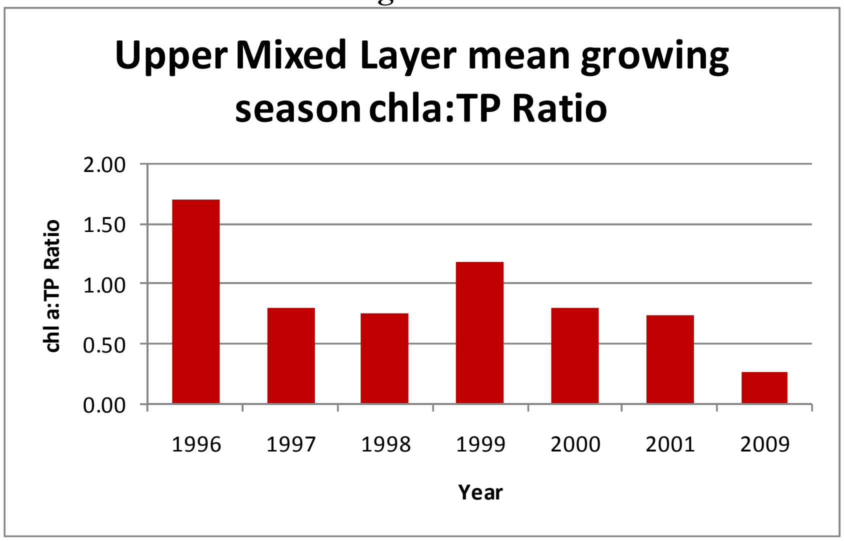
As can be seen from Table 3-1, Kinderhook Lake has been treated with alum to control turbidity. In addition, since alum can also bind up dissolved phosphorus, these two mechanisms may have reduced the internal loading of phosphorus to the lake, beginning in 2001. However, the data available are not sufficient to quantify the internal load of phosphorus and this component was not explicitly included in either the annual P budget or the lake modeling. The mean water column and LWL concentration and volume-weighted Lakewide mass of total P for 2009 is shown in Figure 4-2, along with the dates of the LWL alum treatments.

Figure 4-2.



Examination of the 1996-2001 and 2009 water quality data, indicates that even though there has been no significant reduction in the total phosphorus levels in the UML, but there has been a decline in the chlorophyll a levels (Figure 4-3). This change was probably related to the combined effects of copper and alum treatments.

Figure 4-3.



4.2.8. Other Sources

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

5.0 DETERMINATION OF LOAD CAPACITY

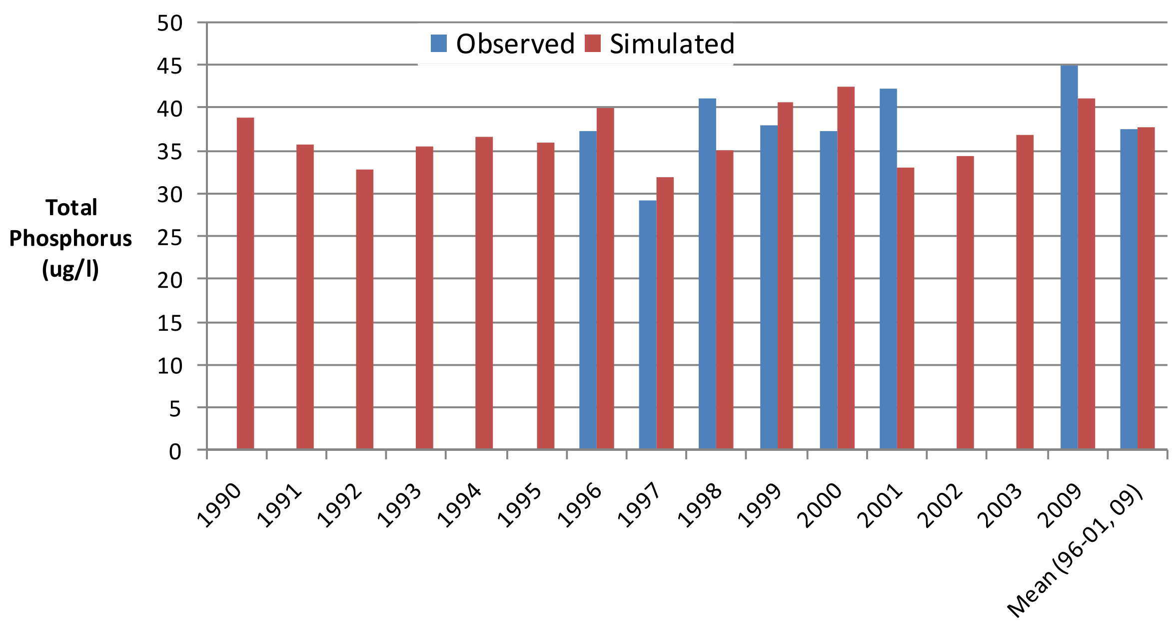
5.1. Lake Modeling Using the BATHTUB Model

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

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

In order to estimate the loading capacity of the lake, simulated phosphorus loads from AVGWLF were used to drive the BATHTUB model to simulate water quality in Kinderhook Lake. AVGWLF 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 1996-2001 and 2009. Year-specific loading was also simulated with AVGWLF, run through BATHTUB, and compared against the observed summer mean phosphorus concentration for years with observed in-lake data. The combined use of AVGWLF and BATHTUB provides a good fit to the observed data for Kinderhook Lake (Figure 5-1).

Figure 5-1. Observed vs. Simulated Summer Mean Epilimnetic Total Phosphorus Concentrations (μg/L) in Kinderhook 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 $\mu g \cdot l^{-1}$. The loading capacity of Kinderhook Lake was determined by running BATHTUB iteratively, reducing the concentration of the drainage basin phosphorus load until model results demonstrated attainment of the water quality target. The maximum concentration that results in compliance with the TMDL target for phosphorus is used as the basis for determining the lake's loading capacity. This concentration is converted into a loading rate using simulated flow from AVGWLF.

The maximum annual phosphorus load (i.e., the annual TMDL) that will maintain compliance with the phosphorus water quality goal of 20 $\mu g \cdot l^{-1}$ in Kinderhook Lake is a mean annual load of 3,128 lbs/yr. The daily TMDL of 8.6 $lb \cdot d^{-1}$ 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

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

Permitted facilities discharge less than an estimated two percent of the total watershed load.
The bulk of the reductions need to come from agricultural land and septic systems, which account for most of the estimated load in the watershed.

6.1. Wasteload Allocation (WLA)

The WLA for Kinderhook Lake is set at 189 $lb \cdot yr^{-1}$. There are three SPDES permitted wastewater treatment plant dischargers in the Kinderhook Lake watershed. Because these three facilities are relatively small sand filter systems, requiring phosphorus reductions is not practical. The two largest discharges are to Nassau Lake so reducing that load would have less benefit to Kinderhook Lake. Consequently, the WLA for these wastewater treatment plant dischargers will be set at existing estimated loads.

In addition to the wastewater treatment plant dischargers, there is a Municipal Separate Storm Sewer System (MS4) within the basin, the Town of Schodack, which is subject to the general permit issued by NYS DEC. The MS4 general permit extended the coverage from the automatically designated "urbanized area" located to the west of the Kinderhook Lake watershed, to the Town boundaries which extend into the watershed and are therefore subject to certain MS4 regulatory program requirements. About one quarter of the developed land in the watershed is located within the Town of Schodack MS4, so that proportion of the developed land stormwater load is attributed to the MS4. Because this area does not contain much high density development, only a 10 percent reduction would be required by this TMDL.

6.2. Load Allocation (LA)

The LA is set at 2,815 $lb \cdot yr^{-1}$. Nonpoint sources that contribute total phosphorus to Kinderhook Lake on an annual basis include loads from developed land, agricultural land, and malfunctioning septic systems. Table 6-1 lists the current loading for each source and the load allocation needed to meet the TMDL. 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. Reducing phosphorus in stormwater from low- density developed land can be most cost effectively accomplished by pollution prevention, such as controlling fertilizer use. Retrofitting existing stormwater systems is much less cost-effective, so the reductions projected from this source are relatively low. The most effective reduction would be to eliminate the load from septic systems, which would be undertaken predominantly by waterfront property owners that would benefit from the resulting water quality improvement. The remainder of the reductions needs to come from agricultural land, which is the largest sector of the estimated load in the watershed.

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 Kinderhook 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 312 $lbs \cdot yr^{-1}$. The MOS can be reviewed in the future as new data become available.

6.4. Critical Conditions

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

6.5. Seasonal Variations

Seasonal variation in nutrient load and response is captured within the models used for this TMDL. In BATHTUB, seasonality is incorporated in terms of seasonal averages for summer. Seasonal variation is also represented in the TMDL by taking 14 years of daily precipitation data when calculating runoff through AVGWLF, as well as by estimating septic system loading inputs based on residency (i.e., seasonal or year-round). This takes into account the seasonal effects the lake will undergo during a given year.

Table 6-1. Total Annual Phosphorus Load Allocations for Kinderhook Lake*

Source	Total Phosphorus Load ($lb\cdot yr^{-1}$)+			% Reduction
	Current	Allocated	Reduction	
Agriculture**	2,997	930	2,067	69%
Developed Land** (unregulated stormwater)	952	857	95	10%
Septic Systems	1,808	0	1,808	100%
Forest, Wetland, Stream Bank, and Natural Background**	745	745	0	0%
LOAD ALLOCATION	**6,502**	2,532	3,970	61%
Cedar Acres Trailer Park (NPDES ID: NY0222861)	69	69	0	0%
Chadwick Manor Apartments (NPDES ID: NY0029424)	20	20	0	0%
Smith's Cottages (NPDES ID: NY0212725)	5	5	0	0%
Developed Land (regulated MS4 stormwater)	210	189	21	10%
WASTELOAD ALLOCATION	**304**	**283**	**21**	7%
LA + WLA	**6,805**	**2,815**	3,991	59%
Margin of Safety	---	313	---	---
TOTAL	**6,805**	**3,128**	3,678	**---**

* The values reported in Table 6 are annually integrated. Daily equivalent values are provided in Appendix C.
** Includes phosphorus transported through surface runoff and subsurface (groundwater)
+ To convert to Kg·yr-1, multiply by 0.454.

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. Local stakeholders have already invested in major watershed phosphorus load reduction projects to improve the water quality of Kinderhook Lake. A large portion of the agricultural land is now managed. There has been evidence of the accumulation of phosphorus in the bottom waters of Kinderhook Lake that could have the potential to release phosphorus into the UML during the later part of the growing season. However, a continued program of treatment with alum and copper compounds has probably reduced this potential. As watershed load reduction efforts progress, the likelihood for significant internal LWL releases of phosphorus will diminish.

Coordination with state agencies, federal agencies, local governments, and specific stakeholders such as the Kinderhook Lake Corporation, the two County Environmental Management Councils, the general public, environmental interest groups, and representatives from the nonpoint pollution categories will consider on-going adaptive management alternatives that are technically and financially feasible. NYS DEC, in coordination with these local interests, will address any additionally identified sources of impairment, using non-regulatory tools in this watershed, matching management strategies with sources, and aligning available resources to effect implementation.

NYS DEC recognizes that TMDL designated load reductions alone, may not be sufficient to restore some eutrophic lakes. The TMDL establishes the required nutrient reduction targets. 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, to determine the effectiveness of nutrient reduction management practices, and adapt implementation according to the future response in lake water quality.

7.1. Reasonable Assurance for Implementation

This TMDL was written with elimination of the load from septic systems, and significant load reductions from agriculture, because those sectors are estimated to contribute the majority of controllable phosphorus load. There also needs to be some load reductions from developed land to meet the phosphorus target concentration in Kinderhook Lake. Meeting the necessary load reductions using this approach is the most technically achievable however it may not be financially viable, because it would require considerable change to farming operations. Providing reasonable assurance of meeting this TMDL will be done through adaptive implementation since most of the remaining load reductions are non-regulatory.

7.1.1. Recommended Phosphorus Management Strategies for Septic Systems

A surveying and testing program should be implemented to document the location of septic systems and verify failing systems requiring replacement in accordance with the State Sanitary Code. New York State has begun to offer funding for the abatement of inadequate onsite wastewater systems through the development and implementation of a septic system management program by a responsible management entity.

State funding is also available for a voluntary septic system inspection and maintenance program or a septic system local law requiring inspection and repair. Property owners should be educated on proper maintenance of their septic systems and encouraged to make preventative repairs.

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

In 2010 a new State law to improve water quality makes it illegal for stores in New York to stock fresh supplies of household dishwasher detergents that contain phosphorus. Stores had 60 days to sell old inventories. Sales for commercial use are to end July 1, 2013.

Ultimately some form of sewering would likely be needed in concentrated development areas with inadequate area or soil conditions, such as lakeshore properties. The septic system management program also could be used to identify other areas where most systems do not meet current design standards or experience operating problems and thereby prioritize areas for sewering.

This citation is from the Town of Kinderhook Comprehensive Plan (2000):

> *The Town should examine and implement alternatives to public water and sewage systems to serve the Niverville and Kinderhook Lake area. Decentralized or on-site systems should be evaluated since this system is especially suited to rural areas and is cost effective. Any approach to expanding or providing water or sewer should include communication and partnership, when needed, with both villages. Decentralized systems manage collection, treatment and/or reuse of waste water from individual homes or businesses, isolated communities, industries or other facilities.*

7.1.2. Recommended Phosphorus Management Strategies for Agricultural Runoff

Although much has been done in terms of agricultural management, these practices are not credited by the watershed model in estimating load. There are no large farms regulated by NYSDEC as Concentrated Animal Feeding Operations (CAFOs) in the Kinderhook Lake watershed.

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

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

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

The AEM Program relies on a five-tiered process:

- Tier 1 – Survey current activities, future plans and potential environmental concerns.
- Tier 2 – Document current land stewardship; identify and prioritize areas of concern.
- Tier 3 – Develop a conservation plan, by certified planners, addressing areas of concern tailored to farm economic and environmental goals.
- Tier 4 – Implement the plan using available financial, educational and technical assistance.
- Tier 5 – Conduct evaluations to ensure the protection of the environment and farm viability.

Columbia County Soil and Water District AEM survey conducted about eight year ago reported that there were one crop, two horse, one beef, and two dairy farms in the Kinderhook Lake watershed. These farms reported the following livestock: 60 horses, 311 beef cows and 573 dairy cows. According to the AEM survey, land that was actively dedicated to agriculture totaled 1,925 Acres

Rensselaer County Soil and Water District reports that farming activity has diminished recently in their part of the watershed such that there are no more dairy operations, but still some beef production.

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

Tier 1 could be used to identify farmers that for economic or personal reasons may be changing or scaling back operations, or contemplating selling land. These farms would be candidates for conservation easements, or less intensive farming such as conversion of row cropland to hay, as would farms identified in Tier 2 with highly-erodible soils and/or needing stream management. , However, any effort to reduce production could come into conflict with local plans and policies, such as the Town of Chatham farmland protection law etc. Tier 3 should include a Comprehensive Nutrient Management Plan with phosphorus indexing. Additional practices could be fully implemented in Tier 4 to reduce phosphorus loads, such as conservation tillage, stream fencing, rotational grazing and cover crops. Also, riparian buffers reduce losses from upland fields and stabilize stream banks in addition to the reductions from taking the land in buffers out of production.

Table 6-1 does not account for the load reduction practices that have already been implemented or resulted from less farming operations; therefore a portion of the reduction may have already been achieved. Despite this progress, loads from agriculture remain the dominant source of phosphorus loading to Kinderhook Lake. Without further load reductions, water quality improvements in Kinderhook Lake may be diminished.

7.1.3. Recommended Phosphorus Management for Stormwater Runoff

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NYSDEC issued SPDES general permits GP-0-10-001 for construction activities, and GP-0-10-002 for stormwater discharges from municipal separate stormwater sewer systems (MS4s) in response to the federal Phase II Stormwater rules. The MS4 permit originally only applied to urbanized areas of New York State, so it did not apply to the portion of the Town of Schodack in the Kinderhook Lake Watershed. On January 11, 2010, the Town of Schodack (NYR20A003, NOI Submitted: 3/5/2003) voluntarily requested that MS4 permit coverage be extended to the town boundaries in accordance with their local law, thereby extending the MS4 area into the Kinderhook Lake watershed. There is only minimal development in this section of the Town which is generally drained by road ditches. The additional designation of these areas only requires implementation of Minimum Control Measures (4) Construction Site Stormwater Runoff Control and (5) Post Construction Stormwater Management in Development and Redevelopment.

Part 3.B.3 Future TMDL Areas of GP-0-10-002 include the provision that:

> If a *TMDL* is approved in the future by EPA for any waterbody or watershed into which a *small MS4 discharges*, the *covered entity* must review the applicable *TMDL* to see if it includes requirements for control of *stormwater discharges*. If a *covered entity* is not meeting the *TMDL* wasteload allocations, it must, within 180 days of written notification from the *Department*, modify its *SWMP* to ensure that the reduction of the *POC* specified in the *TMDL* is achieved.

Upon EPA approval of this TMDL, the Department will work with the Town of Schodack to modify its Storm Water Management Program.

All new development throughout the watershed will be covered by enhanced phosphorus design requirements when GP-0-10-001 is reissued in 2015 for construction activities.

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:

- Public education regarding:
    - Lawn care, specifically reducing fertilizer use or using phosphorus-free products, now commercially available; New York State passed on July 15, 2010 the Household Detergent and Nutrient Runoff Law (Chapter 205 of the laws of 2010) that prohibits the sale and application of lawn fertilizers containing phosphorus starting in 2012.
    - Cleaning up pet waste; and

- Discouraging waterfowl congregation by restoring natural shoreline vegetation.

- Management practices to address any significant existing erosion sites.
- Construction site and post construction stormwater runoff control ordinance and inspection and enforcement programs.
- Pollution prevention practices for road and ditch maintenance.
- Management practices for the handling, storage and use of roadway deicing products.

7.1.4. Additional Protection Measures

Kinderhook Lake has been treated with copper sulfate and alum to control both algal and non-algal particles (Table 3-1). Although there is a continuing accumulation of phosphorus in the LWL during the summer stratification period, it is possible that the rate of accumulation might be even larger, were the chemical treatments to be discontinued (Section 4.27). Thus, this practice should continue as needed into the future

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. The Town of Kinderhook Comprehensive Plan provides examples of some of these management measures already in practice. 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 is necessary to determine the effectiveness of the implementation plan associated with the TMDL. The initial plan will be to encourage renewed participation in the Citizens State Lake Assessment Program (CSLAP). If the Lake again became a part of CSLAP, the Lake would be sampled at its deepest location (Figure 2-5), during the warmer part of the year (June through September) on 8 sampling dates. Grab samples would be collected at 1.5 meters and in the Lower Water Layer (LWL). The samples would 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 would be analyzed for chlorophyll a and the Secchi disk depth would be measured. A simple macrophyte survey would also be conducted one time during mid-summer.

More detailed monitoring is needed to determine the optical properties of the Lake. This monitoring is needed in order to determine the exact composition of the particles in the Lake and their sources. Such a study would determine the mix of algal and non-algal particles and how each type influences the Lake’s transparency. Once this information is known, this Implementation Plan will be adjusted to target the sources of particles (resuspended shallow bottom sediments, eroded soil particles from the watershed, streambank erosion and phytoplankton). This monitoring should be coordinated with any field work that is undertaken in the ongoing evaluation of the copper and alum treatments.

In addition, as 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 future NY 305(b) reports as needed.

7.3. Nassau Lake and the Valatie Kill

Nassau Lake (H-204- 2- 7-P34) is located upstream of Kinderhook Lake (Figure 2.4) and is also listed on the 2010 NYS 303(d) List as having a use impairment related to phosphorus. The causes of the impairment are onsite wastewater treatment systems and urban runoff. Any management actions described by this TMDL to reduce phosphorus load to Kinderhook Lake will also reduce the phosphorus load to Nassau Lake, although it is beyond the scope of this document to project the benefits to Nassau Lake. Using AVGWLF, the annual total phosphorus load to Nassau Lake was estimated at 1,172 $kg \cdot yr^{-1}$ (2,584 $lb \cdot yr^{-1}$).

Kinderhook Lake, Nassau Lake and two of the three segments of the Valatie Kill are also listed on the 2010 NYS 303(d) List as impaired by polychlorinated biphenyls (PCBs) from contaminated sediments and land disposal sites. The source of the PCBs is primarily the Dewey Loeffel Landfill which is an inactive hazardous waste site. The facility is located four miles northeast of the Village of Nassau, within a low-lying, 19.6-acre easement between two wooded hills. Formerly, the site was used as a dump for hazardous waste generated by several companies including General Electric (GE), Bendix Corporation and Schenectady Chemicals. The site had been previously remediated, but recent monitoring has shown that the remediation may not have been completely successful. In March 2010, the Dewey Loeffel Landfill was proposed by USEPA, for inclusion to the Superfund National Priorities List (NPL) of the country's most hazardous waste sites.

Some of the management actions taken to reduce phosphorus load to Kinderhook Lake will also reduce the total suspended sediment load to Kinderhook Lake, which in turn will reduce the PCB loads to Kinderhook Lake, Nassau Lake and the Valatie Kill. However, it is beyond the scope of this document to project the benefits of such load reductions to these waterbodies.

8.0 PUBLIC PARTICIPATION

An initial meeting was held on February 23, 2009, with the Columbia County Environmental Management Council to discuss the TMDL process. NYSDEC also consulted with the Rensselaer County Soil and Water Conservation District on the status of agricultural Best Management Practices (BMPs) and the assessment of loads from agriculture because of much of the phosphorus load is attributed to that sector.

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 August 3, 2011. A 30-day public review period was established for soliciting written comments from stakeholders prior to the finalization and submission of the TMDL for USEPA approval. A number of written comments were received. Both the comments and NYS DEC's responses to comments are included in Appendix G.

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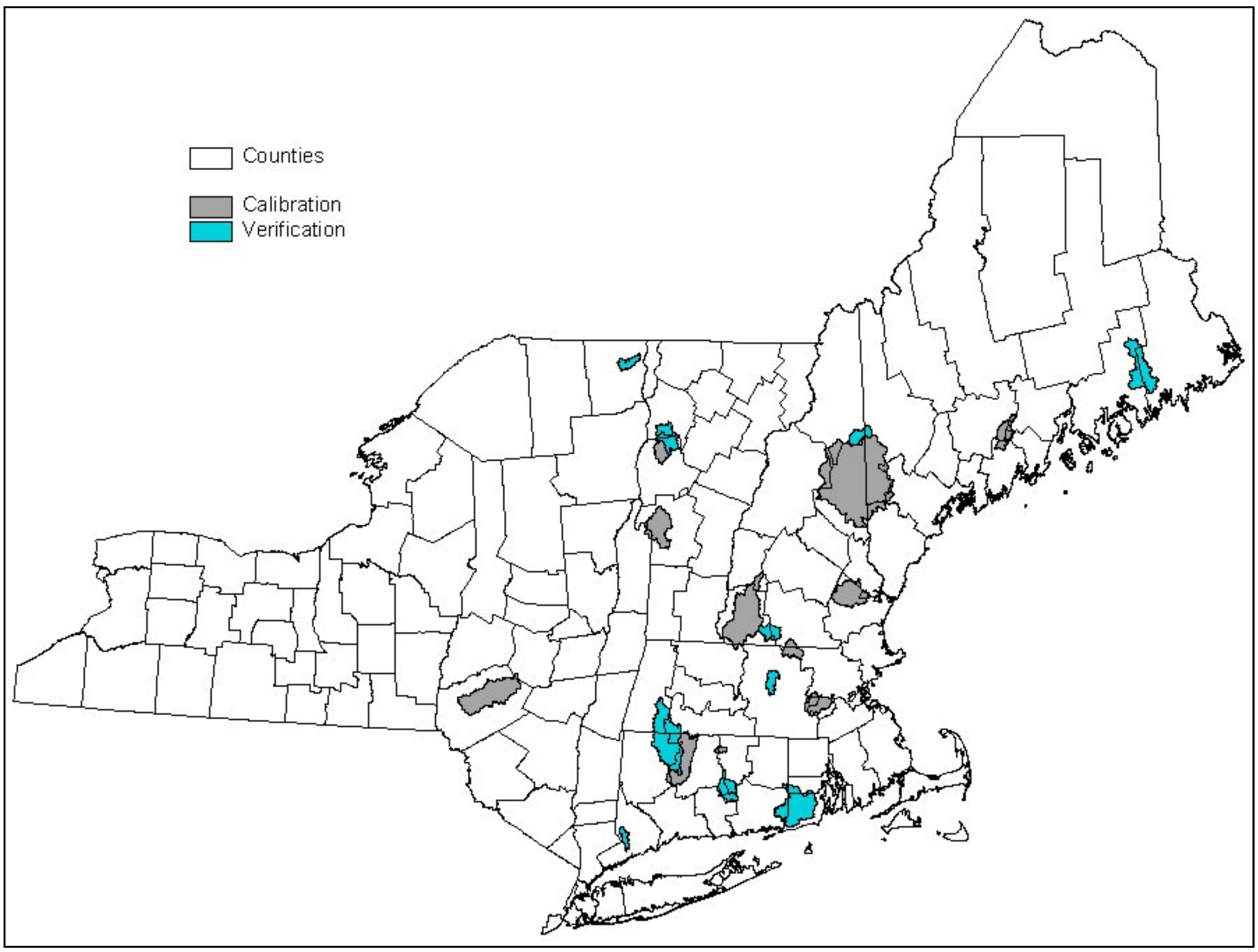
APPENDIX A. AVGWLF MODELING ANALYSIS

Northeast AVGWLF Model

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

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



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

As discussed, AVGWLF performed very well when calibrated for numerous watersheds throughout the region. The regionalized version of AVGWLF, however, performed less well for the verification watersheds for which additional adjustments were not made subsequent to the initial model runs. This decline in model performance may be a result of the regionally-adapted model algorithms not being rigorous enough to simulate spatially-varying landscape processes across such a vast geographic region at a consistently high degree of accuracy. It is likely that un-calibrated model performance can be enhanced by adapting the algorithms to reflect processes in smaller geographic regions such as those depicted in the physiographic province map in Figure A-1.

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 A-1. 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 A-1. Location of Physiographic Provinces in New York and New England

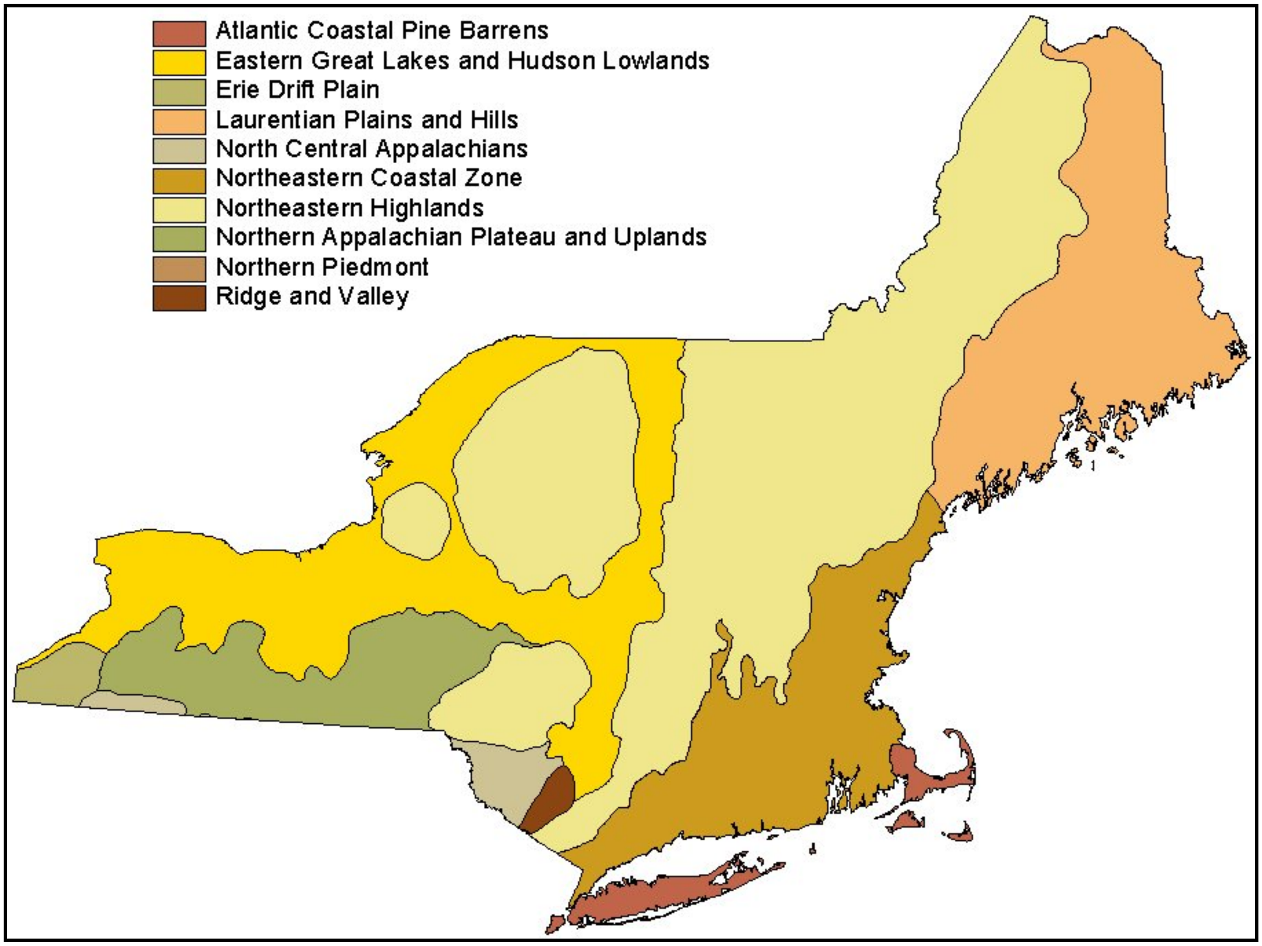


Table A-1. AVGWLF Calibration Sites for use in the New York TMDL Assessments

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

Lewis Creek	VT	Eastern Great Lakes/Hudson Lowlands

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

Using data for the time period 1990-2004, the calibrated AVGWLF model was used to estimate mean annual phosphorus loading to the lake. Table A-2 provides the sources of data used for the AVGWLF modeling analysis. The various data preparation steps taken prior to running the final calibrated AVGWLF Model for New York are discussed below the table.

Table A-2. Information Sources for AVGWLF Model Parameterization

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

	counts
Per capita septic system loads (N/P)	Default values/adjusted using AEU density

Land Use

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

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

2) Areas of water that were coded as land (and 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.

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

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

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

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

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

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

Groundwater Phosphorus

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

Point Sources

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

Concentrated Animal Feeding Operations (CAFOs)

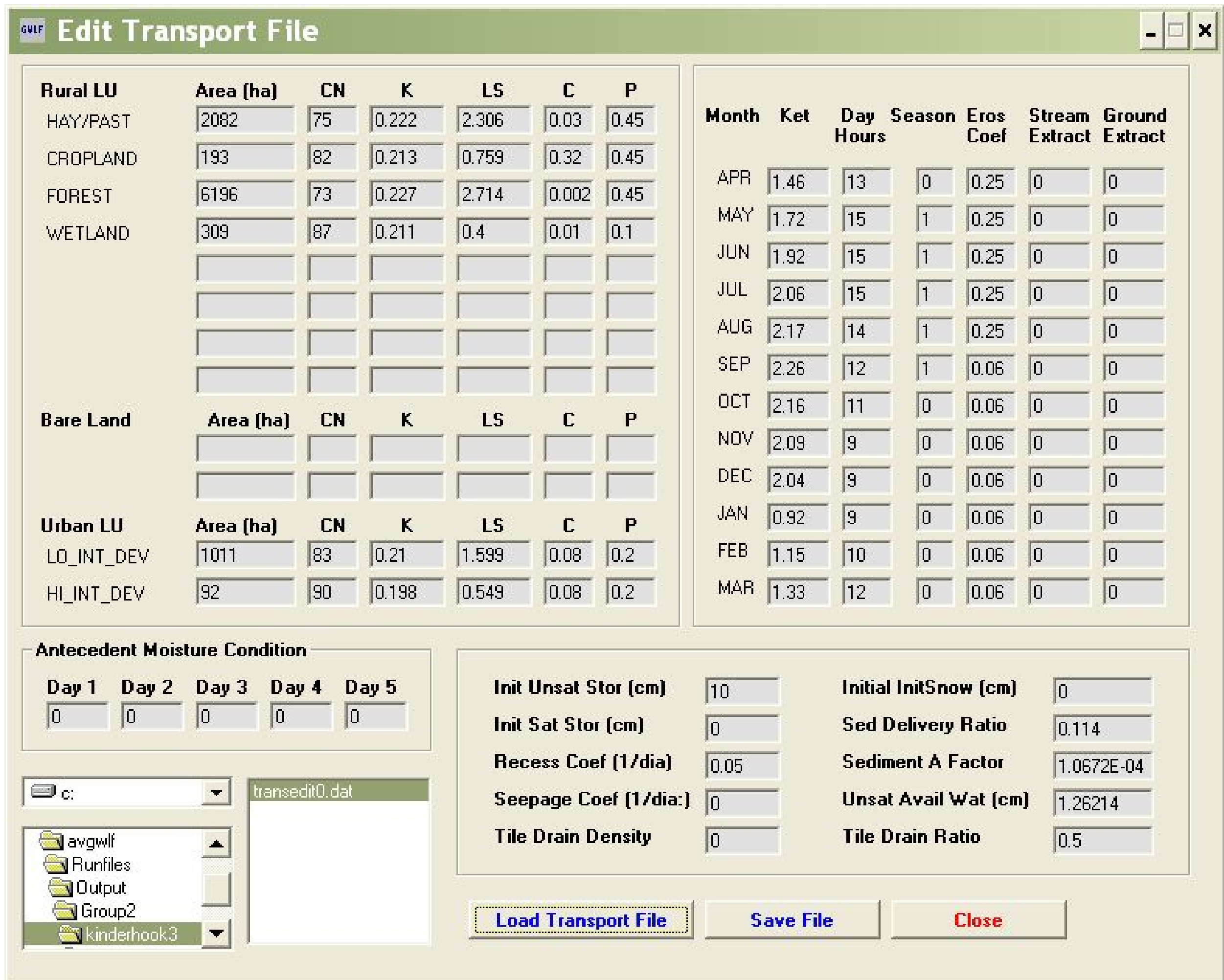
A state-wide Concentrated Animal Feeding Operation (CAFO) shapefile was provided by NYS DEC. CAFOs are categorized as either large or medium. The CAFO point can represent either the centroid of the farm or the entrance of the farm, therefore the CAFO point is more of a general gauge as to where further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

Municipal Separate Storm Sewer Systems (MS4s)

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

AVGWLF Model Simulation Results

Input Transport File



Edit Transport File

Rural LU	Area (ha)	CN	K	LS	C	P
HAY/PAST	2082	75	0.222	2.306	0.03	0.45
CROPLAND	193	82	0.213	0.759	0.32	0.45
FOREST	6196	73	0.227	2.714	0.002	0.45
WETLAND	309	87	0.211	0.4	0.01	0.1

Bare Land	Area (ha)	CN	K	LS	C	P

Urban LU	Area (ha)	CN	K	LS	C	P
LO_INT_DEV	1011	83	0.21	1.599	0.08	0.2
HI_INT_DEV	92	90	0.198	0.549	0.08	0.2

Month	Ket	Day Hours	Season	Eros Coef	Stream Extract	Ground Extract
APR	1.46	13	0	0.25	0	0
MAY	1.72	15	1	0.25	0	0
JUN	1.92	15	1	0.25	0	0
JUL	2.06	15	1	0.25	0	0
AUG	2.17	14	1	0.25	0	0
SEP	2.26	12	1	0.06	0	0
OCT	2.16	11	0	0.06	0	0
NOV	2.09	9	0	0.06	0	0
DEC	2.04	9	0	0.06	0	0
JAN	0.92	9	0	0.06	0	0
FEB	1.15	10	0	0.06	0	0
MAR	1.33	12	0	0.06	0	0

Antecedent Moisture Condition

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

Init Unsat Stor (cm)	10	Initial InitSnow (cm)	0
Init Sat Stor (cm)	0	Sed Delivery Ratio	0.114
Recess Coef (1/dia)	0.05	Sediment A Factor	1.0672E-04
Seepage Coef (1/dia:)	0	Unsat Avail Wat (cm)	1.26214
Tile Drain Density	0	Tile Drain Ratio	0.5

c:

avgwlf

Runfiles

Output

Group2

kinderhook3

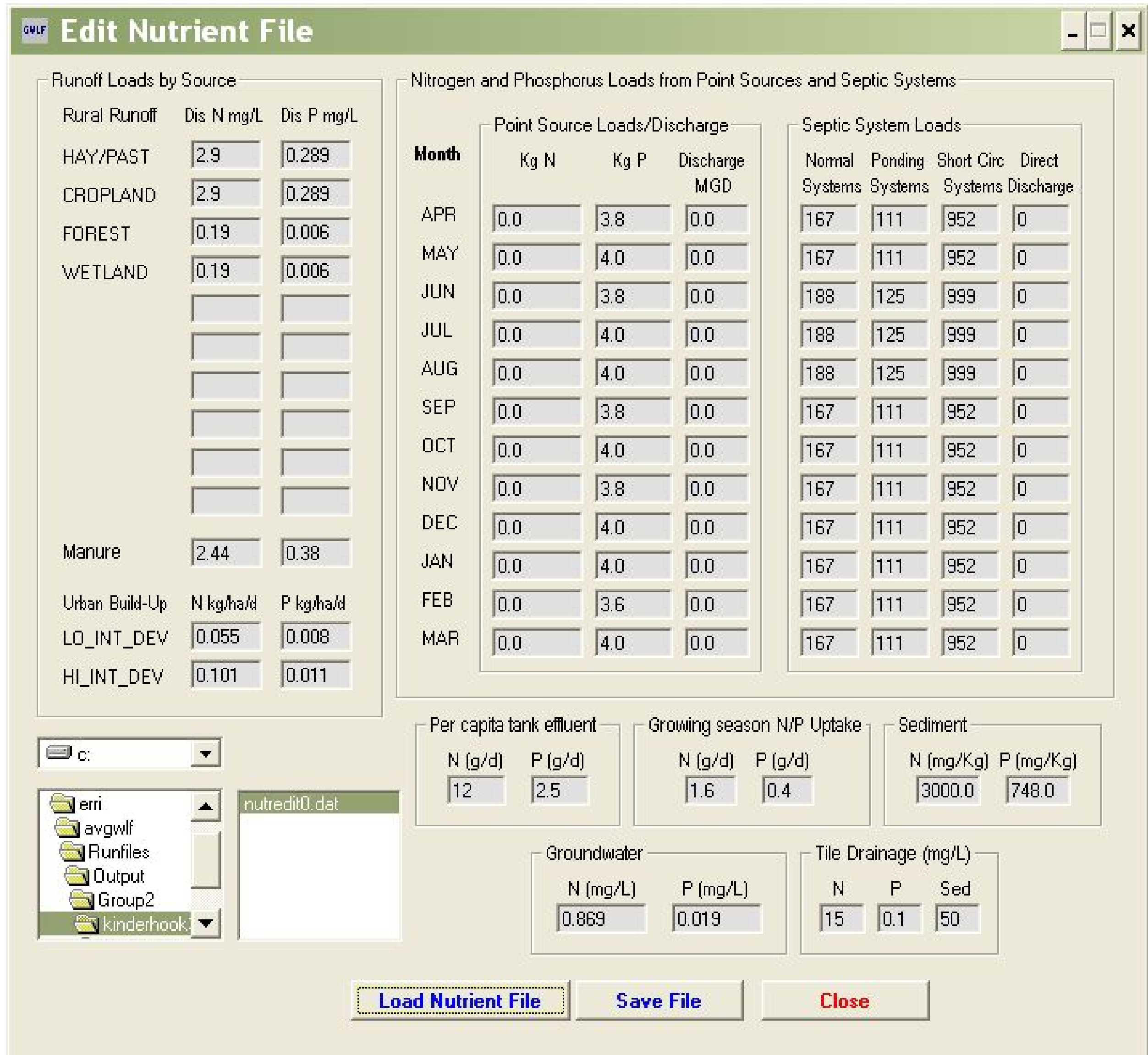
transedit0.dat

Load Transport File

Save File

Close

Input Nutrient File



Simulated Hydrology Transport Summary

GWLF Transport Summary for Kinderhook_040708a

Period of analysis 14 years, from Apr 1990 to Mar 2004

Units in Centimeters

Month	Prec	ET	Extraction	Runoff	Subsurface Flow	Point Src Flow	Tile Drain	Stream Flow
APR	9.31	5.27	0.00	0.71	5.82	0.00	0.00	6.53
MAY	10.60	7.65	0.00	0.12	4.05	0.00	0.00	4.17
JUN	10.13	8.12	0.00	0.43	2.43	0.00	0.00	2.85
JUL	8.78	7.59	0.00	0.27	1.56	0.00	0.00	1.83
AUG	10.69	7.85	0.00	0.65	1.79	0.00	0.00	2.44
SEP	11.21	7.05	0.00	0.72	1.99	0.00	0.00	2.71
OCT	9.96	5.59	0.00	0.86	3.39	0.00	0.00	4.25
NOV	8.94	2.38	0.00	0.90	3.97	0.00	0.00	4.88
DEC	9.06	1.19	0.00	1.72	4.95	0.00	0.00	6.68
JAN	7.56	0.28	0.00	1.09	4.40	0.00	0.00	5.49
FEB	5.32	0.55	0.00	1.10	4.10	0.00	0.00	5.20
MAR	9.14	2.40	0.00	1.68	6.42	0.00	0.00	8.10
Total	110.6	55.92	0.00	10.26	44.88	0.00	0.00	55.13

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

Simulated Nutrient Transport Summary

GWLF Transport Summary for Kinderhook_040708a

Period of analysis 14 years, from Apr 1990 to Mar 2004

	Kg X 1000		Nutrient Loads (Kg)			
Month	**Erosion**	**Sediment**	**Dis N**	**Total N**	**Dis P**	**Total P**
APR	761.5	9.9	5037.0	5439.9	211.3	275.0
MAY	905.7	6.1	3263.8	3443.8	134.8	162.2
JUN	970.0	6.7	2241.6	2654.3	127.7	192.9
JUL	885.1	6.3	1480.2	1940.5	105.6	179.4
AUG	1186.6	10.4	1904.6	2654.7	132.4	255.1
SEP	339.4	11.8	2036.7	2329.3	148.5	205.1
OCT	271.6	16.0	3207.6	3529.1	197.1	262.8
NOV	204.3	16.2	3679.3	3962.2	208.8	268.1
DEC	119.9	32.6	4924.8	5422.3	295.5	412.9
JAN	23.0	19.5	4224.2	4435.5	213.9	267.2
FEB	19.7	18.1	3984.8	4167.6	202.7	249.2
MAR	97.8	28.0	6162.3	6514.4	284.5	370.2
Total	5784.4	181.7	42146.8	46493.8	2262.8	3100.1

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Simulated Total Loads by Source

GWLF Total Loads for Kinderhook_040708a

Period of analysis: 14 years, from Apr 1990 to Mar 2004

Source	Area (Ha)	Runoff (cm)	Kg X 1000 Erosion	Kg X 1000 Sediment	Total Loads (Kg) Dis N	Total Loads (Kg) Total N	Total Loads (Kg) Dis P	Total Loads (Kg) Total P
HAY/PAST	2082	9.6	2979.4	55.4	4803.5	5708.8	591.4	821.8
CROPLAND	193	15.6	930.3	17.3	729.3	1011.9	88.8	160.8
FOREST	6196	8.3	711.5	13.2	872.2	1088.3	28.1	83.2
WETLAND	309	22.8	5.4	0.1	118.7	120.3	3.8	4.2
LO_INT_DEV	1011	16.8	1124.6	12.5	0.0	2551.5	0.0	378.9
HI_INT_DEV	92	29.2	33.2	0.3	0.0	17.8	0.0	2.0
Tile Drainage				0.0		0.0		0.0
Stream Bank				74.2		20.2		9.1
Groundwater					34239.4	34239.4	764.3	764.3
Point Sources					0	0	42.48	42.48
Septic Systems					1383.7	1383.7	743.9	743.9
Totals	9883	10.3	5784.4	172.9	42146.8	46142.0	2262.8	3010.6

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APPENDIX B. BATHTUB MODELING ANALYSIS

Model Overview

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

Net accumulation = Inflow – Outflow – Decay

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

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

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

Model Set-up

Using descriptive information about Kinderhook Lake and its surrounding drainage area, as well as output from AVGWLF, a BATHTUB model was set up for Kinderhook Lake. Mean annual phosphorus loading to the lake was simulated using AVGWLF 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 AVGWLF output.
- Precipitation – Obtained from nearby National Weather Services Stations.
- Phosphorus concentrations in precipitation (measured or estimated), and measured lake water quality data (e.g., total phosphorus concentrations) – Obtained from NYS DEC.

Tables B-1 – B-4 summarize the primary model inputs for Kinderhook 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 Kinderhook Lake. Therefore, division of the lake into multiple segments was not necessary for this modeling effort. Modeling the entire lake with one segment provides predictions of area-weighted mean concentrations, which are adequate to support management decisions. Water inflow and nutrient loads from the lake's drainage basin were treated as though they originated from one "tributary" (i.e., source) in BATHTUB and derived from AVGWLF.

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

Precipitation inputs were taken from the observed long term mean daily total precipitation values from the Grafton, NY and Hudson, NY National Weather Services Stations for the 1990-2004 period. Evapotranspiration was derived from AVGWLF 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 Cedar Lane Atmospheric Deposition Station located in Lake George Village, in Warren County. Atmospheric deposition is not a major source of phosphorus loading to Kinderhook 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 Kinderhook Lake were represented using an average of the observed summer mean phosphorus concentrations for years 1996-2001. These data were collected through NYS DEC's CSLAP and LCI. The concentration of phosphorus loading to the lake was calculated using the average annual flow and phosphorus loads simulated by AVGWLF. To obtain flow in units of volume per time, the depth of flow was multiplied by the drainage area and divided by one year. To obtain phosphorus concentrations, the nutrient mass was divided by the volume of flow.

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

Table B-1. 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 B-2. BATHTUB Model Input: Global Variables

Model Input	Mean	CV
Averaging Period (years)	0.5	NA
Precipitation (meters)	0.554	0.2*
Evaporation (meters)	0.280	0.3*
Atmospheric Load (mg/m^2-yr)- Total P	4.829	0.5*
Atmospheric Load (mg/m^2-yr)- Ortho P	2.907	0.5*

* Default model choice
** Precipitation and evaporation are reflective of the averaging period.

Table B-3. BATHTUB Model Input: Lake Variables

Morphometry	Mean	CV
Surface Area (km^2)	1.40	NA
Mean Depth (m)	4.500	NA
Length (km)	2.532	NA
Estimated Mixed Depth (m)	4.2	0.12
Observed Water Quality	**Mean**	**CV**
Total Phosphorus (ppb)	36.792	0.5

* Default model choice

Table B-4. BATHTUB Model Input: Watershed "Tributary" Loading

Monitored Inputs	Mean	CV
Total Watershed Area (km^2)	98.83	NA
Flow Rate (hm^3/yr)	54.485	0.1
Total P (ppb)	56.656	0.2
Organic P (ppb)	42.931	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 Kinderhook Lake are as follows:

Year	Observed	Simulated	T1	T2	T3
1996	37	40	-0.14	-0.26	-0.13
1997	29	32	-0.17	-0.32	-0.16
1999	38	35	0.31	0.58	0.29
2000	37	41	-0.14	-0.25	-0.13
2001	42	42	-0.25	-0.47	-0.24
Average	37	37	0.01	0.02	0.01

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 (1999) 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 Kinderhook 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 ANNUAL PHOSPHORUS LOAD ALLOCATIONS

Source	Total Phosphorus Load ($lb \cdot yr^{-1}$)+			% Reduction
	Current	Allocated	Reduction	
Agriculture	2,997	930	2,067	69%
Developed Land (unregulated stormwater)	952	857	95	10%
Septic Systems	1,808	0	1,808	100%
Forest, Wetland, Stream Bank, and Natural Background	745	745	0	0%
LOAD ALLOCATION	**6,502**	2,532	3,970	61%
Cedar Acres Trailer Park (NPDES ID: NY0222861)	69	69	0	0%
Chadwick Manor Apartments (NPDES ID: NY0029424)	20	20	0	0%
Smith's Cottages (NPDES ID: NY0212725)	5	5	0	0%
Developed Land (regulated MS4 stormwater)	210	189	21	10%
WASTELOAD ALLOCATION	**304**	**283**	**21**	7%
LA + WLA	**6,805**	**2,815**	3,991	59%
Margin of Safety	---	313	---	---
TOTAL	**6,805**	**3,128**	3,678	**---**

+ Note that loads do not exactly add up due to rounding to whole pounds.

APPENDIX D. ESTIMATED DISCHARGE DATA FOR POINT SOURCE FACILITIES

Cedar Acres Trailer Park (NPDES ID: NY0222861)

Month	Total Phosphorus (mg/l)	Estimated Discharge (MGD)
January	2.5	0.010
February	2.5	0.009
March	2.5	0.009
April	2.5	0.010
May	2.5	0.008
June	2.5	0.008
July	2.5	0.008
August	2.5	0.008
September	2.5	0.009
October	2.5	0.010
November	2.5	0.010
December	2.5	0.010

Chadwick Manor Apartments (NPDES ID: NY0029424)

Month	Total Phosphorus (mg/l)	Estimated Discharge (MGD)
January	2.5	0.0026
February	2.5	0.0026
March	2.5	0.0026
April	2.5	0.0026
May	2.5	0.0026
June	2.5	0.0026
July	2.5	0.0026
August	2.5	0.0026
September	2.5	0.0026
October	2.5	0.0026
November	2.5	0.0026
December	2.5	0.0026

Smith's Cottages (NPDES ID: NY0212725)

Month	Total Phosphorus (mg/l)	Estimated Discharge (MGD)
January	2.5	0.00063
February	2.5	0.00063
March	2.5	0.00063
April	2.5	0.00063
May	2.5	0.00063
June	2.5	0.00063
July	2.5	0.00063
August	2.5	0.00063
September	2.5	0.00063
October	2.5	0.00063
November	2.5	0.00063
December	2.5	0.00063

APPENDIX E. KINDERHOOK LAKE WATER QUALITY DATA

SAMPLE_ID	Date	Stratum	Depth (m)	Chl a (µg/L)	Cl (mg/L)	Total P (mg/L)	Sol React P (mg/L)	NH4-N (mg/l)	NOx-N (mg/L)	Total Kjeldahl N (mg/L)	Org N (mg/L)	Total N (mg/L)	Total Fe (mg/L)	Total As (mg/L)	Z_{SD} (m)	Sol Fe (mg/L)	Sol As (mg/L)
09-KL-01-001	6/17/09 13:00	KL-1.5m	1.5	6.80	40.9	0.047	0.012	0.005	0.017	0.480	0.475	0.497	#N/A	#N/A	2.00	#N/A	#N/A
09-KL-01-002	6/17/09 13:00	KL-8m	8.0	#N/A	41.9	0.121	0.072	0.539	0.001	0.900	0.361	0.901	#N/A	#N/A	#N/A	#N/A	#N/A
09-KL-01-003	7/13/09 11:15	KL-1.5m	1.5	8.00	37.8	0.032	0.001	0.005	0.001	0.550	0.545	0.551	#N/A	#N/A	1.50	#N/A	#N/A
09-KL-01-004	7/13/09 11:15	KL-7m	7.0	#N/A	41.2	0.098	0.058	0.574	0.004	1.000	0.426	1.004	#N/A	#N/A	#N/A	#N/A	#N/A
09-KL-30-001	7/28/09 13:00	KL-0m	0.0	8.50	35.6	0.036	0.001	0.049	0.001	0.460	0.411	0.461	#N/A	#N/A	1.40	#N/A	#N/A
09-KL-31-001	7/28/09 13:00	KL-1m	1.0	11.00	35.7	0.067	0.001	0.035	0.001	0.580	0.545	0.581	#N/A	#N/A	#N/A	#N/A	#N/A
09-KL-32-001	7/28/09 13:00	KL-2m	2.0	23.70	35.5	0.041	0.006	0.005	0.004	0.510	0.505	0.514	#N/A	#N/A	#N/A	#N/A	#N/A
09-KL-33-001	7/28/09 13:00	KL-3m	3.0	#N/A	35.5	0.038	0.010	0.030	0.071	0.300	0.270	0.371	#N/A	#N/A	#N/A	#N/A	#N/A
09-KL-34-001	7/28/09 13:00	KL-4m	4.0	#N/A	35.5	0.032	0.007	0.031	0.083	0.310	0.279	0.393	#N/A	#N/A	#N/A	#N/A	#N/A
09-KL-35-001	7/28/09 13:00	KL-5m	5.0	#N/A	36.5	0.050	0.013	0.042	0.052	0.380	0.338	0.432	#N/A	#N/A	#N/A	#N/A	#N/A
09-KL-36-001	7/28/09 13:00	KL-6m	6.0	#N/A	39.6	0.045	0.007	0.250	0.009	0.510	0.260	0.519	0.050	#N/A	#N/A	0.033	#N/A
09-KL-37-001	7/28/09 13:00	KL-7m	7.0	#N/A	39.9	0.142	0.096	0.987	0.001	1.250	0.263	1.251	0.510	#N/A	#N/A	0.009	#N/A
09-KL-38-001	7/28/09 13:00	KL-8m	8.0	#N/A	42.0	0.186	0.152	1.350	0.001	1.570	0.220	1.571	0.663	#N/A	#N/A	0.004	#N/A
09-KL-21-040	7/28/09 13:00	QA	8.0	#N/A	40.7	0.162	0.130	1.140	0.002	1.340	0.200	1.342	#N/A	#N/A	#N/A	#N/A	#N/A
09-KL-01-005	8/6/09 12:10	KL-1.5m	1.5	18.90	23.3	0.058	0.001	0.005	0.001	0.670	0.665	0.671	#N/A	#N/A	1.50	#N/A	#N/A
09-KL-01-006	8/6/09 12:10	KL-8m	8.0	#N/A	43.0	0.133	0.088	1.630	0.006	2.070	0.440	2.076	#N/A	#N/A	#N/A	#N/A	#N/A
09-KL-01-007	8/25/09 12:30	KL-1.5m	1.5	17.30	29.3	0.047	0.008	0.016	0.001	0.690	0.674	0.691	#N/A	#N/A	1.50	#N/A	#N/A
09-KL-01-008	8/25/09 12:30	KL-8m	8.0	#N/A	39.8	0.136	0.085	1.660	0.001	1.900	0.240	1.901	#N/A	#N/A	#N/A	#N/A	#N/A
09-KL-30-002	9/9/09 12:45	KL-0m	0.0	5.30	26.9	0.054	0.012	0.005	0.039	0.680	0.675	0.719	#N/A	#N/A	1.45	#N/A	#N/A
09-KL-31-002	9/9/09 12:45	KL-1m	1.0	19.10	30.0	0.043	0.004	0.028	0.003	0.580	0.552	0.583	#N/A	#N/A	#N/A	#N/A	#N/A
09-KL-32-002	9/9/09 12:45	KL-2m	2.0	17.50	30.2	0.038	0.011	0.021	0.002	0.620	0.599	0.622	#N/A	#N/A	#N/A	#N/A	#N/A
09-KL-33-002	9/9/09 12:45	KL-3m	3.0	#N/A	29.2	0.041	0.013	0.017	0.005	0.610	0.593	0.615	#N/A	#N/A	#N/A	#N/A	#N/A
09-KL-34-002	9/9/09 12:45	KL-4m	4.0	#N/A	26.3	0.031	0.014	0.099	0.088	0.630	0.531	0.718	#N/A	#N/A	#N/A	#N/A	#N/A
09-KL-35-002	9/9/09 12:45	KL-5m	5.0	#N/A	26.6	0.031	0.012	0.067	0.086	0.560	0.493	0.646	#N/A	#N/A	#N/A	#N/A	#N/A
09-KL-36-002	9/9/09 12:45	KL-6m	6.0	#N/A	29.2	0.028	0.005	0.599	0.005	1.000	0.401	1.005	0.050	0.005	#N/A	#N/A	#N/A
09-KL-37-002	9/9/09 12:45	KL-7m	7.0	#N/A	28.9	0.042	0.001	1.080	0.007	1.420	0.340	1.427	0.109	0.005	#N/A	#N/A	#N/A
09-KL-38-002	9/9/09 12:45	KL-8m	8.0	#N/A	36.7	0.166	0.151	2.340	0.001	2.470	0.130	2.471	0.806	0.005	#N/A	#N/A	#N/A
09-KL-01-009	9/16/09 11:45	KL-1.5m	1.5	17.50	28.9	0.037	0.010	0.027	0.007	0.630	0.603	0.637	#N/A	#N/A	2.00	#N/A	#N/A
09-KL-34-003	9/16/09 11:45	KL-4m	4.0	#N/A	30.1	0.019	0.011	0.184	0.074	0.560	0.376	0.634	0.050	0.005	#N/A	#N/A	#N/A
09-KL-36-003	9/16/09 11:45	KL-6m	6.0	#N/A	29.5	0.030	0.005	0.497	0.015	0.880	0.383	0.895	0.050	0.005	#N/A	#N/A	#N/A

SAMPLE_ID	Date	Stratum	Depth (m)	Chl a (µg/L)	Cl (mg/L)	Total P (mg/L)	Sol React P (mg/L)	NH4-N (mg/l)	NOx-N (mg/L)	Total Kjeldahl N (mg/L)	Org N (mg/L)	Total N (mg/L)	Total Fe (mg/L)	Total As (mg/L)	Z_{SD} (m)	Sol Fe (mg/L)	Sol As (mg/L)
09-KL-38-003	9/16/09 11:45	KL-8m	8.0	#N/A	30.8	0.091	0.071	1.520	0.005	1.920	0.400	1.925	0.542	0.005	#N/A	#N/A	#N/A
09-KL-30-004	9/29/09 11:30	KL-0m	0.0	3.50	31.9	0.034	0.001	0.171	0.082	0.670	0.499	0.752	0.148	0.002	1.60	0.016	0.002
09-KL-31-004	9/29/09 11:30	KL-1m	1.0	#N/A	32.1	0.036	0.008	0.183	0.068	0.650	0.467	0.718	0.174	0.002	#N/A	0.016	0.002
09-KL-32-004	9/29/09 11:30	KL-2m	2.0	#N/A	31.9	0.032	0.008	0.192	0.070	0.710	0.518	0.780	0.173	0.002	#N/A	0.016	0.002
09-KL-33-004	9/29/09 11:30	KL-3m	3.0	#N/A	31.9	0.048	0.007	0.205	0.073	0.640	0.435	0.713	0.168	0.002	#N/A	0.016	0.002
09-KL-34-004	9/29/09 11:30	KL-4m	4.0	#N/A	31.8	0.025	0.001	0.187	0.067	0.590	0.403	0.657	0.172	0.002	#N/A	0.039	0.002
09-KL-35-004	9/29/09 11:30	KL-5m	5.0	#N/A	31.9	0.033	0.005	0.189	0.065	0.610	0.421	0.675	0.172	0.002	#N/A	0.094	0.002
09-KL-36-004	9/29/09 11:30	KL-6m	6.0	#N/A	31.9	0.034	0.005	0.219	0.067	0.680	0.461	0.747	0.182	0.002	#N/A	0.016	0.002
09-KL-37-004	9/29/09 11:30	KL-7m	7.0	#N/A	33.3	0.068	0.014	0.502	0.060	1.110	0.608	1.170	0.364	0.002	#N/A	0.056	0.002
09-KL-38-004	9/29/09 11:30	KL-8m	8.0	#N/A	33.6	0.038	0.006	0.669	0.052	1.020	0.351	1.072	0.395	0.002	#N/A	0.090	0.002

APPENDIX F. VALATIE KILL WATER QUALITY AND MASS LOADING DATA

SAMPLE_ID	Date	Q (CFS)	TSS (mg/L)	Cl (mg/L)	Total P (mg/L)	Sol React P (mg/L)	NH4-N (mg/L)	NOx-N (mg/L)	TKN (mg/L)	Total N (mg/L)
08-KL-11-001	7/24/08 11:30	#N/A	29.4	28.4	0.104	0.033	0.095	0.100	0.639	0.739
08-KL-11-002	9/26/08 11:45	40.21	4.7	38.5	0.041	0.018	0.005	0.388	0.363	0.751
08-KL-11-003	9/26/08 17:40	51.58	8.6	39.5	0.029	0.004	0.005	0.049	0.536	0.585
08-KL-11-004	9/26/08 23:40	47.42	3.1	38.6	0.027	0.004	0.005	0.087	0.439	0.526
08-KL-11-005	9/27/08 5:40	37.75	4.2	38.0	0.026	0.006	0.005	0.020	0.395	0.415
08-KL-11-006	9/27/08 23:40	27.61	20.2	39.4	0.031	0.004	0.005	0.088	0.481	0.569
08-KL-11-007	9/28/08 17:40	23.67	2.3	40.5	0.027	0.004	0.005	0.242	0.419	0.661
08-KL-11-008	9/28/08 23:40	40.96	1.2	36.1	0.032	0.007	0.005	0.187	0.464	0.651
08-KL-11-009	9/29/08 5:40	38.69	7.8	40.5	0.028	0.005	0.005	0.203	0.456	0.659
08-KL-11-010	10/27/08 13:30	308.58	5.1	25.9	0.049	0.017	0.005	0.060	0.576	0.636
08-KL-11-011	10/28/08 2:30	252.82	#N/A	#N/A	#N/A	#N/A	#N/A	0.002	#N/A	#N/A
08-KL-11-012	10/28/08 9:30	290.53	#N/A	#N/A	#N/A	#N/A	#N/A	0.004	#N/A	#N/A
08-KL-11-013	10/28/08 16:30	393.94	#N/A	#N/A	#N/A	#N/A	#N/A	0.003	#N/A	#N/A
08-KL-11-014	10/28/08 23:30	522.51	#N/A	#N/A	#N/A	#N/A	#N/A	0.004	#N/A	#N/A
08-KL-11-015	10/29/08 6:30	519.03	#N/A	#N/A	#N/A	#N/A	#N/A	0.005	#N/A	#N/A
08-KL-11-016	10/29/08 13:30	539.46	#N/A	#N/A	#N/A	#N/A	#N/A	0.004	#N/A	#N/A
08-KL-11-017	10/29/08 20:30	497.07	#N/A	#N/A	#N/A	#N/A	#N/A	0.003	#N/A	#N/A
08-KL-11-018	10/30/08 10:30	389.65	#N/A	#N/A	#N/A	#N/A	#N/A	0.014	#N/A	#N/A
08-KL-11-019	10/31/08 21:30	231.54	#N/A	#N/A	#N/A	#N/A	#N/A	0.129	#N/A	#N/A
08-KL-11-020	11/3/08 5:30	139.82	#N/A	#N/A	#N/A	#N/A	#N/A	0.264	#N/A	#N/A
09-KL-21-021	11/24/08 20:35	42.74	50.9	33.9	0.096	0.030	0.005	0.828	0.720	1.548
09-KL-21-022	11/25/08 8:35	73.06	18.1	33.8	0.099	0.055	0.005	0.965	0.470	1.435
09-KL-21-023	11/25/08 14:35	104.03	14.6	32.0	0.095	0.063	0.005	0.872	0.390	1.262
09-KL-21-024	11/25/08 20:35	122.25	11.5	30.5	0.104	0.074	0.005	0.845	0.370	1.215
09-KL-21-025	11/26/08 2:35	137.22	12.7	29.3	0.058	0.031	0.005	0.530	0.360	0.890
09-KL-21-026	11/26/08 8:35	134.08	11.9	27.7	0.113	0.067	0.029	0.847	0.440	1.287
09-KL-21-027	11/27/08 2:35	140.45	11.0	27.2	0.093	0.070	0.027	0.720	0.360	1.080
09-KL-21-028	11/28/08 14:35	127.74	4.8	26.2	0.043	0.035	0.021	0.473	0.260	0.733
09-KL-21-029	11/30/08 14:35	91.73	17.0	28.5	0.172	0.119	0.019	1.360	0.610	1.970
09-KL-21-030	12/09/08 23:15	68.96	25.8	27.6	0.155	0.080	0.013	1.220	0.480	1.700
09-KL-21-031	12/11/08 5:15	103.67	28.8	30.9	0.160	0.061	0.040	0.860	0.440	1.300
09-KL-21-032	12/11/08 23:15	134.48	17.3	35.3	0.096	0.051	0.005	0.794	0.350	1.144
09-KL-21-033	12/12/08 5:15	269.70	55.6	49.3	0.169	0.057	0.005	0.580	0.470	1.050
09-KL-21-034	12/12/08 11:15	385.75	40.4	44.9	0.150	0.066	0.023	0.631	0.700	1.331
09-KL-21-035	12/12/08 17:15	468.72	38.6	31.9	0.179	0.083	0.042	0.832	0.640	1.472
09-KL-21-036	12/12/08 23:15	411.42	26.7	28.7	0.146	0.071	0.019	0.864	0.550	1.414
09-KL-21-037	12/13/08 23:15	392.75	13.3	29.7	0.142	0.085	0.054	1.080	0.660	1.740
09-KL-21-038	12/14/08 5:15	361.33	14.8	21.6	0.068	0.035	0.070	0.465	0.410	0.875
09-KL-21-039	12/15/08 11:15	265.23	18.0	23.4	0.088	0.052	0.017	0.651	0.370	1.021
09-KL-11-001	2/27/09 2:25	74.84	19.5	40.8	0.020	0.009	0.005	0.368	0.190	0.558
09-KL-11-002	2/27/09 14:25	78.99	8.6	42.3	0.015	0.011	0.005	0.261	0.230	0.491
09-KL-11-003	2/28/09 2:25	115.60	13.4	45.6	0.025	0.012	0.005	0.360	0.300	0.660
09-KL-11-004	2/28/09 14:25	99.35	12.0	47.9	0.020	0.006	0.005	0.276	0.260	0.536

SAMPLE_ID	Date	Q (CFS)	TSS (mg/L)	Cl (mg/L)	Total P (mg/L)	Sol React P (mg/L)	NH4-N (mg/L)	NOx-N (mg/L)	TKN (mg/L)	Total N (mg/L)
09-KL-11-005	3/1/09 2:25	87.45	12.9	47.6	0.020	0.007	0.005	0.328	0.240	0.568
09-KL-11-006	3/1/09 14:25	84.67	14.7	43.8	0.023	0.011	0.005	0.259	0.260	0.519
09-KL-11-007	3/6/09 8:10	25.88	13.3	40.6	0.023	0.012	0.010	0.521	0.120	0.641
09-KL-11-008	3/8/09 8:10	51.66	7.6	40.8	0.014	0.011	0.010	0.419	0.240	0.659
09-KL-11-009	3/9/09 8:10	110.73	27.2	64.9	0.033	0.009	0.010	0.267	0.290	0.557
09-KL-11-010	3/10/09 8:10	174.18	17.9	43.9	0.034	0.010	0.010	0.197	0.190	0.387
09-KL-11-011	3/10/09 20:10	212.24	12.1	37.9	0.029	0.010	0.010	0.131	0.230	0.361
09-KL-11-012	3/12/09 11:45	301.04	5.6	33.8	0.024	0.012	0.010	0.195	0.190	0.385
09-KL-11-013	3/12/09 18:15	264.85	29.1	34.7	0.028	0.006	0.010	0.215	0.360	0.575
09-KL-11-014	3/13/09 0:15	238.91	25.9	34.6	0.031	0.007	0.005	0.174	0.410	0.584
09-KL-11-015	3/13/09 6:15	216.75	5.9	34.5	0.009	0.007	0.010	0.153	0.210	0.363
09-KL-11-016	3/14/09 0:15	175.51	22.6	34.3	0.015	0.006	0.010	0.277	0.250	0.527
09-KL-11-017	3/16/09 0:15	121.49	10.3	33.5	0.015	0.005	0.010	0.243	0.400	0.643
09-KL-11-018	3/17/09 6:15	132.50	4.2	36.0	0.021	0.008	0.016	0.258	0.260	0.518
09-KL-11-019	3/18/09 12:15	33.68	3.4	33.1	0.012	0.012	0.005	0.364	0.260	0.624
09-KL-11-020	3/29/09 5:30	43.49	6.2	42.0	0.013	0.010	0.005	0.214	0.290	0.504
09-KL-11-021	3/29/09 17:30	47.36	22.0	42.2	0.025	0.010	0.010	0.268	0.320	0.588
09-KL-11-022	3/29/09 23:30	75.50	17.0	42.7	0.023	0.010	0.005	0.269	0.330	0.599
09-KL-11-023	3/30/09 5:30	81.94	13.0	46.4	0.015	0.012	0.005	0.233	0.290	0.523
09-KL-11-024	3/30/09 11:30	95.13	19.3	44.8	0.026	0.010	0.005	0.177	0.370	0.547
09-KL-11-025	3/30/09 17:30	99.90	15.6	44.5	0.024	0.010	0.005	0.199	0.350	0.549
09-KL-11-026	3/30/09 23:30	103.50	13.7	43.0	0.023	0.009	0.010	0.172	0.360	0.532
09-KL-11-027	3/31/09 5:30	101.30	7.7	42.5	0.022	0.007	0.005	0.196	0.340	0.536
09-KL-11-028	3/31/09 17:30	89.52	6.6	42.8	0.017	0.009	0.010	0.132	0.300	0.432
09-KL-11-029	4/1/09 11:30	75.36	9.0	41.5	0.024	0.008	0.005	0.230	0.340	0.570
09-KL-11-030	5/6/09 23:45	8.19	14.8	47.1	0.029	0.008	0.005	0.331	0.300	0.631
09-KL-11-031	5/7/09 5:45	24.98	11.7	43.1	0.032	0.008	0.005	0.298	0.300	0.598
09-KL-11-032	5/7/09 11:45	35.50	9.1	48.2	0.028	0.010	0.005	0.209	0.320	0.529
09-KL-11-033	5/7/09 18:00	37.66	47.1	48.3	0.047	0.009	0.005	0.156	0.560	0.716
09-KL-11-034	5/8/09 6:00	34.95	21.0	46.5	0.017	0.008	0.005	0.127	0.280	0.407
09-KL-11-035	5/9/09 0:00	23.99	14.8	44.9	0.021	0.009	0.005	0.097	0.380	0.477
09-KL-11-036	5/9/09 12:00	20.10	15.7	44.7	0.022	0.007	0.010	0.106	0.310	0.416
09-KL-11-037	5/9/09 18:00	22.63	14.9	44.3	0.021	0.009	0.005	0.133	0.320	0.453
09-KL-11-038	5/10/09 0:00	51.37	17.6	46.0	0.031	0.008	0.005	0.070	0.350	0.420
09-KL-11-039	5/10/09 6:00	98.99	30.2	42.0	0.039	0.008	0.005	0.083	0.460	0.543
09-KL-11-040	5/10/09 12:00	81.71	34.5	38.7	0.048	0.009	0.005	0.118	0.470	0.588
09-KL-11-041	5/11/09 0:00	58.83	27.5	40.0	0.030	0.010	0.005	0.072	0.380	0.452
09-KL-11-042	5/11/09 18:00	38.57	62.5	40.3	0.035	0.009	0.005	0.134	0.410	0.544
09-KL-11-043	5/12/09 12:00	28.53	12.5	43.4	0.028	0.009	0.005	0.157	0.350	0.507
09-KL-11-044	5/13/09 12:00	19.88	1.4	45.1	0.025	0.012	0.005	0.233	0.260	0.493
09-KL-11-045	5/16/09 18:15	12.10	17.6	44.6	0.017	0.006	0.005	0.214	0.290	0.504
09-KL-11-046	5/17/09 0:15	26.01	13.0	41.2	0.030	0.007	0.010	0.405	0.320	0.725
09-KL-11-047	5/17/09 6:15	53.56	32.5	50.2	0.036	0.007	0.010	0.174	0.400	0.574
09-KL-11-048	5/17/09 12:15	69.95	42.0	46.8	0.034	0.006	0.005	0.190	0.580	0.770
09-KL-11-049	5/17/09 18:15	72.29	11.1	43.2	0.035	0.009	0.010	0.184	0.360	0.544

SAMPLE_ID	Date	Q (CFS)	TSS (mg/L)	Cl (mg/L)	Total P (mg/L)	Sol React P (mg/L)	NH4-N (mg/L)	NOx-N (mg/L)	TKN (mg/L)	Total N (mg/L)
09-KL-11-050	5/18/09 0:15	71.06	31.1	41.3	0.028	0.007	0.005	0.098	0.410	0.508
09-KL-11-051	5/18/09 18:15	52.23	11.9	40.9	0.027	0.006	0.005	0.109	0.370	0.479
09-KL-11-052	5/19/09 12:15	37.05	6.0	41.3	0.019	0.024	0.011	0.189	0.320	0.509
09-KL-11-053	5/24/09 8:50	3.88	9.8	44.7	0.012	0.004	0.005	0.281	0.180	0.461
09-KL-11-054	5/26/09 20:50	0.50	6.1	46.9	0.018	0.007	0.005	0.518	0.230	0.748
09-KL-11-055	5/27/09 2:50	1.08	4.2	45.7	0.019	0.007	0.005	0.531	0.340	0.871
09-KL-11-056	5/27/09 8:50	9.91	4.9	47.2	0.019	0.006	0.005	0.413	0.260	0.673
09-KL-11-057	5/27/09 14:50	27.79	4.4	45.9	0.022	0.007	0.005	0.396	0.260	0.656
09-KL-11-058	5/28/09 13:15	41.96	5.1	42.2	0.039	0.023	0.048	0.297	0.270	0.567
09-KL-11-058a	5/29/09 7:30	45.56	10.9	39.8	0.025	0.014	0.036	0.235	0.320	0.555
09-KL-11-059	5/29/09 19:30	46.34	18.6	40.6	0.032	0.005	0.019	0.378	0.470	0.848
09-KL-11-060	5/30/09 7:30	42.37	17.5	40.3	0.029	0.008	0.024	0.346	0.380	0.726
09-KL-11-061	5/30/09 19:30	33.88	17.2	40.4	0.020	0.007	0.021	0.200	0.400	0.600
09-KL-11-062	6/1/09 1:30	17.89	5.3	41.6	0.014	0.010	0.035	0.351	0.310	0.661
09-KL-11-063	6/2/09 7:30	6.42	14.9	42.4	0.031	0.013	0.005	0.391	0.320	0.711
09-KL-11-064	6/3/09 13:30	2.29	1.3	44.6	0.028	0.018	0.045	0.389	0.290	0.679
09-KL-11-079	6/11/09 20:15	0.50	19.8	48.9	0.037	0.011	0.005	0.040	0.520	0.560
09-KL-11-080	6/12/09 2:15	7.70	35.1	45.4	0.044	0.010	0.005	0.285	0.460	0.745
09-KL-11-067	6/12/09 20:15	45.79	10.2	43.8	0.030	0.011	0.005	0.121	0.300	0.421
09-KL-11-068	6/13/09 20:15	43.78	23.0	39.3	0.043	0.009	0.005	0.241	0.390	0.631
09-KL-11-069	6/14/09 8:15	63.13	17.7	42.8	0.038	0.011	0.005	0.045	0.400	0.445
09-KL-11-070	6/15/09 2:15	67.06	12.8	39.2	0.040	0.016	0.005	0.125	0.380	0.505
09-KL-11-071	6/15/09 14:15	87.78	17.6	39.7	0.040	0.014	0.005	0.003	0.370	0.373
09-KL-11-072	6/15/09 20:15	162.98	63.0	34.0	0.091	0.010	0.005	0.034	0.700	0.734
09-KL-11-073	6/16/09 2:15	156.08	28.7	36.5	0.052	0.013	0.005	0.003	0.480	0.483
09-KL-11-074	6/16/09 8:15	150.37	18.6	36.9	0.061	0.026	0.005	0.139	0.480	0.619
09-KL-11-075	6/16/09 14:15	131.44	15.0	36.6	0.040	0.010	0.010	0.005	0.480	0.485
09-KL-11-076	6/17/09 2:15	93.44	10.0	38.7	0.036	0.011	0.005	0.025	0.430	0.455
09-KL-11-077	6/17/09 14:15	69.81	6.2	39.3	0.033	0.014	0.005	0.122	0.410	0.532
09-KL-11-078	6/18/09 13:45	117.45	17.6	44.0	0.069	0.038	0.031	0.180	0.520	0.700
09-KL-11-082	6/18/09 19:45	167.37	42.9	35.6	0.064	0.038	0.078	0.116	0.540	0.656
09-KL-11-083	6/19/09 1:45	211.94	14.9	32.4	0.040	0.019	0.044	0.058	0.470	0.528
09-KL-11-084	6/19/09 7:45	242.96	22.5	31.2	0.043	0.014	0.017	0.009	0.460	0.469
09-KL-11-086	6/20/09 1:45	200.83	4.6	31.7	0.019	0.011	0.010	0.096	0.330	0.426
09-KL-11-087	6/20/09 19:45	152.94	1.7	31.8	0.019	0.011	0.013	0.033	0.350	0.383
09-KL-11-088	6/21/09 13:45	174.56	1.4	32.1	0.016	0.015	0.016	0.056	0.290	0.346
09-KL-11-089	6/22/09 13:45	167.25	1.7	32.3	0.028	0.019	0.028	0.087	0.310	0.397
09-KL-11-090	6/23/09 13:45	116.67	1.4	32.4	0.020	0.017	0.025	0.126	0.320	0.446
09-KL-11-091	6/24/09 13:45	79.65	1.4	33.1	0.020	0.014	0.024	0.099	0.310	0.409
09-KL-11-092	7/7/09 20:20	31.56	22.9	40.1	0.080	0.011	0.005	0.003	0.890	0.893
09-KL-11-093	7/8/09 2:20	39.03	11.1	41.6	0.035	0.016	0.020	0.252	0.390	0.642
09-KL-11-094	7/8/09 8:20	47.01	6.8	40.1	0.027	0.019	0.027	0.209	0.310	0.519
09-KL-11-095	7/8/09 20:20	60.62	11.3	38.3	0.029	0.015	0.005	0.179	0.240	0.419
09-KL-11-096	7/9/09 8:20	54.81	16.3	37.3	0.032	0.020	0.026	0.072	0.360	0.432

SAMPLE_ID	Date	Q (CFS)	TSS (mg/L)	Cl (mg/L)	Total P (mg/L)	Sol React P (mg/L)	NH4-N (mg/L)	NOx-N (mg/L)	TKN (mg/L)	Total N (mg/L)
09-KL-11-097	7/10/09 2:20	41.23	11.6	37.8	0.019	0.013	0.026	0.090	0.300	0.390
09-KL-11-098	7/11/09 14:20	20.53	3.8	40.4	0.011	0.014	0.005	0.160	0.250	0.410
09-KL-11-099	7/11/09 20:20	25.68	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
09-KL-11-100	7/12/09 2:20	36.50	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
09-KL-11-101	7/12/09 8:20	55.60	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
09-KL-11-102	7/12/09 14:20	58.71	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
09-KL-11-103	7/12/09 20:20	54.25	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
09-KL-11-104	7/13/09 14:20	34.54	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
09-KL-11-105	7/17/09 14:30	103.65	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
09-KL-11-106	7/17/09 20:25	109.11	15.0	33.6	0.033	0.009	0.010	0.001	0.390	0.391
09-KL-11-107	7/18/09 2:25	146.25	29.1	33.5	0.080	0.024	0.010	0.455	0.570	1.025
09-KL-11-108	7/18/09 8:25	190.83	25.8	30.9	0.058	0.023	0.019	0.076	0.420	0.496
09-KL-11-109	7/18/09 14:25	236.87	27.6	29.7	0.063	0.030	0.005	0.161	0.440	0.601
09-KL-11-110	7/18/09 20:25	240.45	32.7	30.7	0.067	0.033	0.022	0.222	0.460	0.682
09-KL-11-111	7/19/09 2:25	211.81	11.1	31.3	0.053	0.029	0.005	0.126	0.360	0.486
09-KL-11-112	7/19/09 14:25	143.63	21.4	32.5	0.084	0.031	0.005	0.212	0.520	0.732
09-KL-11-113	7/20/09 8:25	93.26	15.1	33.6	0.045	0.023	0.010	0.226	0.350	0.576
09-KL-11-114	7/21/09 8:25	58.92	13.8	34.9	0.040	0.024	0.005	0.247	0.310	0.557
09-KL-11-115	7/21/09 14:25	62.81	15.9	34.4	0.027	0.011	0.005	0.256	0.210	0.466
09-KL-11-116	7/21/09 20:25	74.56	5.1	35.1	0.023	0.013	0.005	0.216	0.170	0.386
09-KL-11-117	7/22/09 14:25	101.06	44.9	32.9	0.042	0.017	0.005	0.243	0.220	0.463
09-KL-11-118	7/23/09 2:25	89.68	13.1	33.1	0.039	0.017	0.010	0.168	0.210	0.378
09-KL-11-119	7/23/09 14:25	73.12	4.8	33.2	0.023	0.008	0.010	0.092	0.290	0.382
09-KL-11-120	7/29/09 16:30	439.72	110.0	19.8	0.194	0.003	0.005	0.002	1.240	1.242
09-KL-11-121	7/29/09 22:30	806.44	65.3	15.4	0.119	0.009	0.023	0.119	0.900	1.019
09-KL-11-122	7/30/09 4:30	1061.18	87.0	13.9	0.122	0.001	0.005	0.001	0.840	0.841
09-KL-11-123	7/30/09 10:30	1105.33	70.7	17.3	0.105	0.003	0.005	0.036	0.790	0.826
09-KL-11-124	7/30/09 16:30	1057.30	77.0	17.4	0.085	0.003	0.013	0.013	0.610	0.623
09-KL-11-125	7/31/09 4:30	761.13	57.0	16.4	0.051	0.005	0.005	0.001	0.490	0.491
09-KL-11-126	7/31/09 22:30	674.45	16.1	16.9	0.044	0.010	0.005	0.113	0.490	0.603
09-KL-11-127	8/1/09 22:30	405.48	20.7	16.9	0.057	0.011	0.005	0.297	0.590	0.887
09-KL-11-128	8/3/09 4:30	228.65	13.3	21.9	0.054	0.019	0.016	0.436	0.540	0.976
09-KL-11-129	8/4/09 10:30	147.08	4.0	25.4	0.030	0.008	0.056	0.303	0.490	0.793
09-KL-11-130	8/21/09 18:30	58.49	139.0	35.9	0.437	0.013	0.022	0.014	2.620	2.634
09-KL-11-131	8/22/09 6:30	75.69	20.9	32.6	0.034	0.014	0.005	0.041	0.460	0.501
09-KL-11-132	8/22/09 18:30	90.11	24.3	26.7	0.063	0.010	0.005	0.001	0.580	0.581
09-KL-11-133	8/23/09 6:30	116.06	22.2	24.3	0.067	0.014	0.015	0.001	0.630	0.631
09-KL-11-134	8/24/09 0:30	126.10	17.9	24.9	0.062	0.011	0.017	0.001	0.510	0.511
09-KL-11-135	8/24/09 6:30	181.69	39.8	22.3	0.100	0.011	0.012	0.001	0.760	0.761
09-KL-11-136	8/24/09 12:30	232.13	31.1	21.3	0.084	0.010	0.023	0.001	0.610	0.611
09-KL-11-137	8/24/09 18:30	216.63	16.7	21.5	0.069	0.010	0.021	0.005	0.590	0.595
09-KL-11-138	8/25/09 0:30	183.24	10.9	22.3	0.064	0.011	0.030	0.033	0.560	0.593
09-KL-11-139	8/25/09 12:30	132.48	14.4	22.8	0.071	0.012	0.015	0.119	0.500	0.619
09-KL-11-140	8/27/09 0:45	68.93	11.1	22.2	0.044	0.020	0.005	0.082	0.540	0.622
09-KL-11-141	8/28/09 18:45	43.60	5.2	29.1	0.027	0.021	0.023	0.317	0.410	0.727

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09-KL-11-142	8/29/09 0:45	63.33	4.0	26.0	0.038	0.026	0.015	0.442	0.430	0.872
09-KL-11-143	8/29/09 6:45	93.15	6.4	28.7	0.043	0.030	0.005	0.484	0.470	0.954
09-KL-11-144	8/29/09 12:45	113.16	3.8	27.1	0.026	0.021	0.005	0.215	0.350	0.565
09-KL-11-145	8/30/09 0:45	129.36	11.1	25.2	0.033	0.022	0.029	0.167	0.440	0.607
09-KL-11-146	8/30/09 18:45	97.72	6.3	25.2	0.028	0.021	0.005	0.070	0.420	0.490
09-KL-11-147	8/31/09 12:45	70.93	8.7	21.3	0.036	0.015	0.047	0.063	0.500	0.563
09-KL-11-148	9/26/09 22:15	7.83	2.2	48.3	0.016	0.021	0.005	0.896	0.220	1.116
09-KL-11-149	9/27/09 16:15	11.93	7.4	43.6	0.039	0.031	0.005	0.745	0.330	1.075
09-KL-11-150	9/27/09 22:15	18.13	2.8	40.1	0.025	0.019	0.005	0.438	0.330	0.768
09-KL-11-151	9/28/09 4:15	19.86	1.2	39.3	0.027	0.032	0.005	0.431	0.320	0.751
09-KL-11-152	9/28/09 10:15	20.57	3.4	39.3	0.027	0.020	0.005	0.448	0.330	0.778
09-KL-11-154	10/17/09 16:00	8.73	1.1	39.3	0.010	0.010	0.005	0.611	0.340	0.951
09-KL-11-155	10/17/09 22:00	55.18	11.4	36.4	0.027	0.011	0.005	0.253	0.410	0.663
09-KL-11-156	10/18/09 4:00	78.03	15.3	33.4	0.050	0.013	0.005	0.112	0.460	0.572
09-KL-11-157	10/18/09 16:00	76.66	7.6	24.0	0.030	0.013	0.005	0.053	0.450	0.503
09-KL-11-158	10/19/09 22:00	68.15	4.2	22.8	0.028	0.007	0.005	0.042	0.440	0.482
09-KL-11-159	10/20/09 16:00	17.98	3.4	24.3	0.031	0.005	0.005	0.158	0.490	0.648
09-KL-11-160	10/22/09 10:00	6.50	1.3	30.2	0.016	0.008	0.010	0.671	0.440	1.111
09-KL-11-161	10/24/09 4:45	6.99	6.2	33.4	0.034	0.009	0.005	0.838	0.440	1.278
09-KL-11-162	10/24/09 10:45	8.72	4.4	34.0	0.039	0.018	0.005	0.893	0.410	1.303
09-KL-11-163	10/24/09 16:45	20.36	9.1	34.3	0.046	0.015	0.005	0.498	0.420	0.918
09-KL-11-164	10/24/09 22:45	88.04	45.1	24.7	0.143	0.026	0.005	0.096	0.790	0.886
09-KL-11-165	10/25/09 4:45	90.39	19.8	23.7	0.110	0.037	0.014	0.537	0.640	1.177
09-KL-11-166	10/25/09 16:45	49.25	9.0	26.4	0.066	0.023	0.005	0.301	0.480	0.781
09-KL-11-167	10/26/09 4:45	31.21	11.6	30.4	0.070	0.029	0.005	0.408	0.470	0.878
09-KL-11-168	10/26/09 10:45	27.32	5.6	32.4	0.047	0.018	0.005	0.310	0.410	0.720
09-KL-11-169	10/27/09 16:45	21.30	3.5	32.7	0.040	0.019	0.026	0.470	0.430	0.900
09-KL-11-170	10/28/09 4:45	22.52	5.3	32.2	0.040	0.019	0.019	0.427	0.420	0.847
09-KL-11-171	10/28/09 10:45	24.70	4.6	32.9	0.045	0.020	0.038	0.538	0.470	1.008
09-KL-11-172	10/28/09 16:45	49.58	8.9	32.1	0.053	0.022	0.017	0.341	0.430	0.771
09-KL-11-173	10/28/09 22:45	62.13	9.4	29.9	0.055	0.020	0.030	0.277	0.430	0.707
09-KL-11-174	10/29/09 4:45	89.72	17.6	29.1	0.077	0.023	0.041	0.392	0.610	1.002
09-KL-11-175	10/29/09 9:50	99.01	11.5	28.5	0.055	0.020	0.018	0.103	0.480	0.583
09-KL-11-175a	10/29/09 15:50	93.65	9.3	26.2	0.037	0.012	0.005	0.037	0.420	0.457
09-KL-11-176	10/30/09 9:50	82.94	4.4	24.8	0.032	0.017	0.005	0.117	0.370	0.487
09-KL-11-177	10/31/09 9:50	74.60	5.0	24.9	0.032	0.012	0.005	0.079	0.390	0.469
09-KL-11-178	11/1/09 21:50	63.55	3.9	25.8	0.035	0.016	0.005	0.138	0.390	0.528
09-KL-11-179	11/3/09 9:50	21.64	1.2	28.4	0.034	0.021	0.005	0.388	0.310	0.698
09-KL-11-180	11/9/09 11:00	54.58	4.7	29.7	0.018	0.012	0.005	0.186	0.380	0.566
09-KL-11-181	11/10/09 11:00	58.16	4.0	24.8	0.019	0.011	0.005	0.112	0.470	0.582
09-KL-11-182	11/11/09 11:00	50.37	3.2	24.5	0.025	0.011	0.005	0.167	0.460	0.627
09-KL-11-183	11/14/09 2:15	14.53	5.5	27.8	0.015	0.005	0.005	0.321	0.620	0.941
09-KL-11-184	11/14/09 8:15	21.00	4.0	26.0	0.014	0.005	0.005	0.312	0.480	0.792
09-KL-11-185	11/14/09 14:15	27.83	5.1	27.9	0.013	0.010	0.005	0.177	0.410	0.587
09-KL-11-186	11/14/09 20:15	56.09	9.7	26.2	0.024	0.006	0.005	0.129	0.440	0.569

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09-KL-11-187	11/15/09 2:15	79.10	14.5	26.2	0.023	0.012	0.005	0.122	0.450	0.572
09-KL-11-188	11/15/09 14:15	68.49	5.5	25.4	0.024	0.011	0.005	0.048	0.460	0.508
09-KL-11-189	11/16/09 2:15	70.20	4.7	23.9	0.023	0.006	0.005	0.071	0.710	0.781
09-KL-11-190	11/16/09 14:15	84.94	5.8	22.8	0.027	0.004	0.005	0.028	0.580	0.608
09-KL-11-191	11/17/09 2:15	83.95	7.3	22.7	0.027	0.006	0.020	0.049	0.480	0.529
09-KL-11-192	11/17/09 14:15	84.88	6.8	22.5	0.033	0.010	0.005	0.169	0.510	0.679
09-KL-11-193	11/19/09 8:15	62.04	3.7	23.9	0.025	0.004	0.010	0.169	0.460	0.629
09-KL-11-194	11/20/09 2:45	59.61	2.9	23.9	0.014	0.014	0.005	0.141	0.280	0.421
09-KL-11-195	11/20/09 8:45	89.10	12.6	24.0	0.023	0.012	0.005	0.127	0.310	0.437
09-KL-11-196	11/20/09 14:45	105.56	9.5	23.2	0.021	0.008	0.005	0.050	0.320	0.370
09-KL-11-197	11/21/09 8:45	107.10	6.9	21.5	0.026	0.012	0.005	0.093	0.340	0.433
09-KL-11-198	11/22/09 2:45	101.65	5.7	22.0	0.020	0.011	0.005	0.084	0.320	0.404
09-KL-11-199	11/23/09 8:45	76.19	2.8	22.7	0.018	0.010	0.005	0.134	0.300	0.434
09-KL-11-200	11/25/09 8:45	74.20	2.8	22.8	0.020	0.009	0.005	0.127	0.310	0.437
09-KL-11-201	12/2/09 4:45	41.10	2.9	27.1	0.013	0.014	0.005	0.315	0.290	0.605
09-KL-11-202	12/2/09 22:45	44.08	3.4	27.4	0.013	0.012	0.005	0.253	0.260	0.513
09-KL-11-203	12/3/09 4:45	52.07	4.9	25.8	0.016	0.012	0.005	0.233	0.260	0.493
09-KL-11-204	12/3/09 10:45	83.27	17.4	24.4	0.028	0.012	0.005	0.127	0.310	0.437
09-KL-11-205	12/3/09 16:45	95.52	10.9	23.8	0.022	0.013	0.005	0.112	0.330	0.442
09-KL-11-206	12/3/09 22:45	85.75	9.6	23.0	0.025	0.010	0.017	0.086	0.360	0.446
09-KL-11-207	12/4/09 22:45	58.65	3.8	24.2	0.018	0.013	0.011	0.213	0.350	0.563
09-KL-11-208	12/5/09 16:45	55.99	3.7	24.5	0.018	0.014	0.020	0.252	0.290	0.542
09-KL-11-209	12/5/09 22:45	77.89	5.2	23.9	0.020	0.013	0.013	0.227	0.290	0.517
09-KL-11-210	12/6/09 4:45	68.65	4.1	24.6	0.019	0.011	0.005	0.239	0.250	0.489
09-KL-11-211	12/6/09 16:45	61.95	5.4	26.8	0.022	0.008	0.005	0.274	0.270	0.544
09-KL-11-212	12/7/09 10:45	54.28	3.8	25.7	0.025	0.021	0.005	0.312	0.290	0.602
09-KL-11-213	12/26/09 5:00	42.58	5.0	26.6	0.011	0.009	0.016	0.374	0.240	0.614
09-KL-11-214	12/26/09 17:00	46.04	7.0	28.5	0.018	0.010	0.005	0.362	0.280	0.642
09-KL-11-215	12/26/09 23:00	49.48	6.9	27.5	0.017	0.009	0.005	0.332	0.250	0.582
09-KL-11-216	12/27/09 5:00	65.64	15.4	33.1	0.023	0.012	0.005	0.295	0.330	0.625
09-KL-11-217	12/27/09 11:00	99.18	34.0	39.8	0.043	0.012	0.005	0.248	0.470	0.718
09-KL-11-218	12/27/09 17:00	110.35	25.4	34.8	0.032	0.010	0.005	0.219	0.330	0.549
09-KL-11-219	12/27/09 23:00	94.14	17.9	31.3	0.028	0.011	0.005	0.258	0.330	0.588
09-KL-11-220	12/28/09 5:00	78.59	12.7	28.9	0.022	0.012	0.005	0.284	0.300	0.584
09-KL-11-221	12/28/09 11:00	72.10	10.2	27.3	0.021	0.011	0.005	0.318	0.240	0.558
10-KL-11-001	1/25/10 4:15	18.28	3.4	36.7	0.012	0.027	0.005	0.584	0.050	0.634
10-KL-11-002	1/25/10 10:15	41.04	28.7	33.7	0.059	0.009	0.016	0.451	0.300	0.751
10-KL-11-003	1/25/10 16:15	149.25	77.6	33.7	0.183	0.012	0.025	0.298	0.890	1.188
10-KL-11-004	1/25/10 22:15	320.55	91.8	28.0	0.149	0.005	0.005	0.261	0.710	0.971
10-KL-11-005	1/26/10 4:15	321.71	50.3	19.2	0.066	0.027	0.005	0.253	0.450	0.703
10-KL-11-006	1/26/10 10:15	376.93	48.4	20.1	0.078	0.009	0.005	0.237	0.370	0.607
10-KL-11-007	1/26/10 16:15	425.61	38.1	19.4	0.056	0.017	0.010	0.191	0.350	0.541
10-KL-11-008	1/26/10 22:15	365.76	26.4	18.7	0.035	0.006	0.010	0.201	0.280	0.481
10-KL-11-009	1/27/10 4:15	292.09	19.0	18.7	0.033	0.008	0.005	0.218	0.210	0.428
10-KL-11-010	1/27/10 10:15	236.22	16.7	19.5	0.032	0.007	0.010	0.237	0.190	0.427

SAMPLE_ID	Date	Q (CFS)	TSS (mg/L)	Cl (mg/L)	Total P (mg/L)	Sol React P (mg/L)	NH4-N (mg/L)	NOx-N (mg/L)	TKN (mg/L)	Total N (mg/L)
10-KL-11-011	1/27/10 20:00	185.93	18.4	20.3	0.033	0.006	0.005	0.232	0.260	0.492
10-KL-11-012	2/5/10 10:45	52.98	5.0	26.5	0.033	0.011	0.012	0.654	0.120	0.774
10-KL-11-013	2/23/10 0:15	13.60	16.2	41.2	0.043	0.018	0.005	0.863	0.270	1.133
10-KL-11-014	2/25/10 0:15	19.80	11.1	58.3	0.019	0.021	0.010	0.797	0.160	0.957
10-KL-11-015	2/25/10 12:15	26.10	10.6	70.6	0.016	0.010	0.005	0.688	0.170	0.858
10-KL-11-016	2/26/10 0:15	67.58	22.6	98.4	0.050	0.020	0.005	0.546	0.390	0.936
10-KL-11-017	2/26/10 12:15	87.30	24.5	75.5	0.048	0.016	0.010	0.540	0.300	0.840
10-KL-11-018	2/27/10 12:15	107.56	15.9	48.0	0.025	0.016	0.005	0.366	0.220	0.586
10-KL-11-019	2/28/10 12:15	95.83	11.5	49.4	0.020	0.013	0.005	0.358	0.210	0.568
10-KL-11-020	3/1/10 12:15	87.81	9.0	46.1	0.014	0.013	0.005	0.376	0.160	0.536
10-KL-11-021	3/2/10 12:15	86.85	7.6	46.1	0.020	0.009	0.010	0.340	0.190	0.530
10-KL-11-022	3/4/10 12:15	114.64	6.5	39.4	0.016	0.013	0.010	0.330	0.170	0.500
10-KL-11-023	3/6/10 12:15	96.50	6.7	38.3	0.019	0.019	0.005	0.314	0.180	0.494
10-KL-11-024	3/22/10 9:00	61.84	4.2	28.6	0.027	0.009	0.005	0.484	0.230	0.714
10-KL-11-025	3/22/10 15:00	62.41	14.4	28.9	0.058	0.011	0.010	0.026	0.540	0.566
10-KL-11-026	3/22/10 21:00	66.84	10.0	29.3	0.025	0.006	0.010	0.342	0.270	0.612
10-KL-11-027	3/23/10 3:00	97.53	30.2	36.7	0.053	0.012	0.005	0.411	0.410	0.821
10-KL-11-028	3/23/10 9:00	126.47	23.6	36.3	0.054	0.017	0.005	0.503	0.360	0.863
10-KL-11-029	3/23/10 21:00	143.72	15.7	28.0	0.037	0.012	0.005	0.272	0.350	0.622
10-KL-11-030	3/24/10 9:00	162.47	10.0	26.5	0.038	0.013	0.005	0.237	0.310	0.547
10-KL-11-031	3/24/10 21:00	140.44	6.9	26.8	0.021	0.006	0.020	0.252	0.330	0.582
10-KL-11-032	3/25/10 15:00	115.46	8.5	29.1	0.023	0.010	0.005	0.290	0.390	0.680
10-KL-11-033	3/26/10 9:00	110.90	5.0	30.2	0.020	0.008	0.010	0.192	0.350	0.542
10-KL-11-034	3/28/10 9:00	77.33	3.9	30.1	0.016	0.009	0.005	0.254	0.340	0.594
10-KL-11-035	3/29/10 18:15	96.97	4.0	32.2	0.009	0.007	0.010	0.066	0.210	0.276
10-KL-11-036	3/30/10 0:15	100.57	5.2	30.3	0.017	0.007	0.005	0.147	0.230	0.377
10-KL-11-037	3/30/10 12:15	114.78	8.0	30.9	0.036	0.022	0.005	0.455	0.250	0.705
10-KL-11-038	3/30/10 18:15	143.58	16.4	33.7	0.040	0.014	0.010	0.418	0.300	0.718
10-KL-11-039	3/31/10 0:15	180.01	17.4	29.8	0.041	0.014	0.005	0.282	0.350	0.632
10-KL-11-040	3/31/10 6:15	209.13	20.0	27.1	0.066	0.022	0.005	0.638	0.470	1.108
10-KL-11-041	3/31/10 12:15	213.36	12.1	26.6	0.033	0.011	0.005	0.340	0.360	0.700
10-KL-11-042	4/1/10 0:15	182.17	10.3	26.9	0.022	0.007	0.005	0.306	0.360	0.666
10-KL-11-043	4/1/10 12:15	153.09	6.1	27.4	0.026	0.007	0.005	0.178	0.230	0.408
10-KL-11-044	4/2/10 6:15	140.55	5.2	27.8	0.011	0.004	0.024	0.120	0.280	0.400
10-KL-11-045	4/2/10 18:15	120.00	5.2	29.0	0.014	0.018	0.016	0.045	0.240	0.285
10-KL-11-046	4/6/10 9:30	70.86	2.6	31.0	0.018	0.007	0.005	0.263	0.200	0.463
10-KL-11-047	5/8/10 0:30	11.13	12.2	40.7	0.033	0.003	0.010	0.244	0.280	0.524
10-KL-11-048	5/8/10 6:30	12.48	18.8	38.4	0.027	0.003	0.010	0.285	0.330	0.615
10-KL-11-049	5/8/10 12:30	21.35	17.5	39.8	0.044	0.003	0.005	0.189	0.380	0.569
10-KL-11-050	5/8/10 18:30	30.57	18.0	41.0	0.041	0.003	0.005	0.148	0.410	0.558
10-KL-11-051	5/9/10 0:30	34.92	18.5	39.5	0.037	0.003	0.005	0.147	0.260	0.407
10-KL-11-052	5/9/10 12:30	27.02	9.9	39.0	0.025	0.003	0.005	0.183	0.160	0.343
10-KL-11-053	5/10/10 12:30	19.58	4.7	37.3	0.015	0.003	0.005	0.166	0.160	0.326
10-KL-11-054	6/5/10 18:15	3.64	9.5	47.2	0.025	0.003	0.010	0.328	0.320	0.648
10-KL-11-055	6/6/10 6:15	4.58	15.7	46.7	0.036	0.003	0.005	0.404	0.380	0.784

SAMPLE_ID	Date	Q (CFS)	TSS (mg/L)	Cl (mg/L)	Total P (mg/L)	Sol React P (mg/L)	NH4-N (mg/L)	NOx-N (mg/L)	TKN (mg/L)	Total N (mg/L)
10-KL-11-056	6/6/10 12:15	6.47	10.8	43.0	0.031	0.003	0.010	0.340	0.360	0.700
10-KL-11-057	6/6/10 18:15	16.59	26.6	45.3	0.043	0.003	0.005	0.190	0.420	0.610
10-KL-11-058	6/7/10 0:15	15.83	27.2	47.0	0.051	0.009	0.005	0.276	0.400	0.676
10-KL-11-059	6/7/10 6:15	18.03	16.4	44.8	0.046	0.007	0.010	0.279	0.370	0.649
10-KL-11-060	6/7/10 12:15	18.58	16.2	45.1	0.052	0.003	0.005	0.229	0.520	0.749
10-KL-11-061	6/7/10 18:15	17.26	17.0	44.6	0.051	0.003	0.010	0.276	0.520	0.796
10-KL-11-062	6/8/10 6:15	14.67	15.2	41.8	0.056	0.005	0.005	0.351	0.450	0.801
10-KL-11-063	6/8/10 18:15	10.99	17.1	40.8	0.060	0.003	0.010	0.271	0.380	0.651
10-KL-11-064	6/9/10 12:15	10.42	10.4	39.7	0.064	0.003	0.005	0.319	0.390	0.709
10-KL-11-065	6/10/10 7:15	9.89	8.2	41.3	0.035	0.006	0.014	0.362	0.390	0.752
10-KL-11-066	6/11/10 7:15	13.08	10.5	39.7	0.038	0.008	0.005	0.392	0.410	0.802
10-KL-11-067	6/12/10 13:15	13.90	16.4	39.1	0.077	0.010	0.005	0.365	0.550	0.915
10-KL-11-068	6/12/10 19:15	14.61	21.9	39.4	0.060	0.006	0.005	0.204	0.510	0.714
10-KL-11-069	6/13/10 1:15	32.66	20.2	38.9	0.055	0.006	0.005	0.204	0.480	0.684
10-KL-11-070	6/13/10 7:15	41.73	23.1	39.3	0.069	0.009	0.005	0.338	0.510	0.848
10-KL-11-071	6/13/10 13:15	41.22	16.5	37.0	0.045	0.003	0.005	0.164	0.420	0.584
10-KL-11-072	6/13/10 19:15	42.19	14.6	34.3	0.049	0.003	0.005	0.131	0.450	0.581
10-KL-11-073	6/14/10 1:15	40.18	11.8	33.8	0.046	0.006	0.010	0.175	0.520	0.695
10-KL-11-074	6/14/10 13:15	33.84	8.4	33.5	0.040	0.006	0.005	0.186	0.460	0.646
10-KL-11-075	6/15/10 13:15	21.88	6.4	34.0	0.042	0.003	0.010	0.162	0.490	0.652
10-KL-11-076	6/17/10 9:15	12.88	3.1	37.0	0.051	0.019	0.005	0.390	0.330	0.720

Valatie Kill Event Mean Concentrations, Discharge, Baseflow and Stormflow (2008-2010)

Sampled Event	Start	End	Duration (min)	Full Qbar (CFS)	Approx Qsf (CFS)	Approx Qbf (CFS)	Samples Qbar (CFS)	EMC TSS (mg/L)	EMC Cl (mg/L)	EMC Total P (µg/L)	EMC Sol React P (µg/L)	EMC NH4-N (mg/L)	EMC NOx-N (mg/L)	EMC TKN (mg/L)	EMC Total N (mg/L)
1	9/26/08 11:45	9/29/08 5:40	3955	35.3	26.5	8.8	38.5	6.2	38.8	30.1	6.6	0.005	0.152	0.448	0.599
2	10/28/08 2:30	11/3/08 5:30	8820	304.6	265.2	39.4	377.6	#N/A	#N/A	#N/A	#N/A	#N/A	0.022	#N/A	#N/A
3	11/24/08 20:35	11/30/08 14:35	8280	115.2	68.8	46.4	108.1	13.8	29.3	94.0	61.1	0.015	0.794	0.410	1.204
4	12/09/08 23:15	12/15/08 11:15	7920	261.3	187.4	74.0	286.2	28.7	32.5	136.7	65.4	0.033	0.765	0.543	1.308
5	2/27/09 2:25	3/1/09 14:25	3600	91.5	20.6	70.9	90.1	13.4	44.9	20.8	9.0	0.005	0.310	0.251	0.561
6	3/6/09 8:10	3/18/09 12:15	17525	143.0	105.9	37.0	158.4	15.6	37.4	23.6	8.3	0.010	0.215	0.273	0.487
7	3/29/09 5:30	4/1/09 11:30	4680	81.2	37.1	44.1	81.3	12.9	43.4	21.4	9.4	0.006	0.203	0.333	0.536
8	5/6/09 23:45	5/13/09 12:00	9375	37.8	32.2	5.6	39.1	26.2	43.2	33.5	8.8	0.005	0.129	0.393	0.521
9	5/16/09 18:15	5/19/09 12:15	3960	52.6	42.0	10.6	49.3	23.0	43.9	30.1	8.7	0.007	0.174	0.406	0.581
10	5/24/09 8:50	6/3/09 13:30	14680	18.8	18.0	0.8	21.5	11.8	41.6	27.0	10.7	0.026	0.317	0.345	0.662
11	6/11/09 20:15	6/24/09 13:45	18330	114.3	93.9	20.4	117.9	17.0	35.1	40.9	16.9	0.019	0.072	0.427	0.499
12	7/7/09 20:20	7/11/09 14:20	5400	42.0	16.1	25.9	42.1	12.2	39.1	32.8	15.7	0.017	0.141	0.372	0.513
14	7/17/09 20:25	7/23/09 14:25	8280	118.9	95.3	23.6	130.9	22.0	32.1	54.6	23.6	0.010	0.188	0.388	0.576
15	7/29/09 16:30	8/4/09 10:30	8280	532.0	471.6	60.5	668.7	62.7	16.9	93.5	5.6	0.010	0.074	0.721	0.794
16	8/21/09 18:30	8/27/09 0:45	7575	120.4	98.2	22.2	134.7	26.6	23.8	85.1	11.6	0.017	0.022	0.669	0.691
17	8/28/09 18:45	8/31/09 12:45	3960	98.1	67.4	30.8	85.0	6.8	26.0	32.6	22.3	0.017	0.236	0.428	0.664
18	9/26/09 22:15	9/28/09 10:15	2160	14.3	6.8	7.5	15.7	3.2	41.0	27.1	24.5	0.005	0.531	0.316	0.848
19	10/17/09 16:00	10/22/09 10:00	6840	43.0	35.3	7.7	44.5	8.9	28.9	33.1	10.8	0.005	0.135	0.442	0.578
20	10/24/09 4:45	10/26/09 10:45	3240	46.1	39.5	6.6	40.3	21.7	26.9	95.4	26.8	0.008	0.362	0.596	0.958
21	10/27/09 16:45	11/3/09 9:50	9665	60.4	47.6	12.8	58.8	8.4	28.0	46.2	17.7	0.017	0.211	0.441	0.652
22	11/9/09 11:00	11/11/09 11:00	2880	53.6	33.3	20.3	54.4	4.1	26.5	20.1	10.8	0.005	0.167	0.452	0.619
23	11/14/09 2:15	11/19/09 8:15	7560	67.8	47.4	20.4	59.4	7.1	24.4	24.7	7.4	0.007	0.111	0.511	0.622
24	11/20/09 2:45	11/25/09 8:45	7560	88.1	49.4	38.8	87.6	6.6	22.8	20.9	10.5	0.005	0.103	0.314	0.417
25	12/2/09 4:45	12/4/09 22:45	3960	63.4	20.7	42.7	65.8	8.8	24.7	20.8	12.0	0.008	0.168	0.316	0.484
26	12/5/09 16:45	12/7/09 10:45	2520	63.8	20.3	43.5	63.8	4.5	25.0	20.6	13.0	0.010	0.258	0.277	0.535
27	12/26/09 5:00	12/28/09 11:00	3240	71.5	29.2	42.3	73.1	17.4	31.8	26.3	11.0	0.006	0.284	0.322	0.606
28	1/25/10 4:15	2/5/10 10:45	16230	125.6	94.4	31.2	232.2	41.5	21.6	68.3	11.2	0.008	0.244	0.384	0.628
29	2/23/10 0:15	3/6/10 12:15	16560	80.4	55.2	25.2	73.1	12.5	53.5	25.1	14.9	0.007	0.415	0.218	0.633
30	3/22/10 9:00	3/28/10 9:00	8640	110.5	45.6	65.0	105.9	12.4	29.9	33.7	10.6	0.008	0.297	0.351	0.647

Sampled Event	Start	End	Duration (min)	Full Qbar (CFS)	Approx Qsf (CFS)	Approx Qbf (CFS)	Samples Qbar (CFS)	EMC TSS (mg/L)	EMC Cl (mg/L)	EMC Total P (µg/L)	EMC Sol React P (µg/L)	EMC NH4-N (mg/L)	EMC NOx-N (mg/L)	EMC TKN (mg/L)	EMC Total N (mg/L)
31	3/29/10 18:15	4/6/10 9:30	10995	120.6	50.5	70.1	143.8	10.7	29.0	30.6	12.0	0.008	0.298	0.311	0.609
32	5/8/10 0:30	5/10/10 12:30	3600	24.5	12.9	11.6	22.4	14.6	39.5	32.7	2.5	0.006	0.179	0.283	0.462
33	6/5/10 18:15	6/9/10 12:15	5400	12.2	8.2	4.0	12.5	17.9	44.1	49.6	4.0	0.007	0.279	0.428	0.707
34	6/10/10 7:15	6/17/10 9:15	10200	21.7	15.1	6.6	26.5	14.5	36.6	50.8	6.0	0.006	0.225	0.468	0.694

Valatie Kill Mass Load Calculations (2008-2010)

Water

Period Start	Period End	Total Days	Total VKill Qbar (CFS)	Total VKill Qsf (CFS)	Total VKill Qbf (CFS)	Sampled Days	Sampled VKill Qbar (CFS)	Sampled VKill Qsf (CFS)	Sampled VKill Qbf (CFS)	Total VKill Qbar (m3)	Total VKill Qsf (m3)	Total VKill Qbf (m3)	Sampled VKill Qbar (m3)	Sampled VKill Qsf (m3)	Sampled VKill Qbf (m3)	% Sampled VKill Qbar (m3)	% Sampled VKill Qsf (m3)	% Sampled VKill Qbf (m3)
09/26/08	01/31/09	127	117.54	51.23	66.31	20.12	179.09	136.96	42.13	36521138	15918720	20602952	8816236	6742453	2073783	24%	42%	10%
02/01/09	06/30/09	149	60.38	31.99	28.38	50.10	77.03	49.97	27.06	22009565	11663201	10346972	9442017	6125345	3316672	43%	53%	32%
07/01/09	09/30/09	91	81.17	53.34	27.83	24.76	154.31	125.90	28.41	18070514	11874535	6196415	9347785	7626696	1721089	52%	64%	28%
10/01/09	02/05/10	127	52.93	23.26	29.67	44.23	68.34	41.71	26.63	16447207	7227443	9220176	7395332	4514011	2881322	45%	62%	31%
02/06/10	06/30/10	144	44.68	15.73	28.95	38.47	61.65	31.24	30.42	15741186	5541405	10200413	5802713	2940128	2862585	37%	53%	28%

Event EMCs

Period Start	Period End	EMC TSS (mg/L)	EMC Cl (mg/L)	EMC Total P (µg/L)	EMC Sol React P (µg/L)	EMC NH4-N (µg/L)	EMC NOx-N (mg/L)	EMC TKN (mg/L)	EMC Total N (mg/L)	EMC Org N (mg/L)	EMC Inorg N (mg/L)
09/26/08	01/31/09	22.6	32.1	115.6	59.1	25.5	0.4	0.498	0.921	0.472	0.449
02/01/09	06/30/09	21.0	38.2	67	30	18	0.431	0.399	0.829	0.381	0.448
07/01/09	09/30/09	40.7	23.5	73	12	13	0.105	0.597	0.702	0.584	0.118
10/01/09	02/05/10	15.3	25.5	39	13	8	0.203	0.393	0.597	0.385	0.211
02/06/10	06/30/10	12.3	36.2	32	11	7	0.310	0.314	0.624	0.306	0.318

Baseflow Means

Period Start	Period End	Baseflow TSS (mg/L)	Baseflow Cl (mg/L)	Baseflow Total P (µg/L)	Baseflow Sol React P (µg/L)	Baseflow NH4-N (µg/L)	Baseflow NOx-N (mg/L)	Baseflow TKN (mg/L)	Baseflow Total N (mg/L)	Baseflow Org N (mg/L)	Baseflow Inorg N (mg/L)
09/26/08	01/31/09	16.1	37.3	49	15	5	0.402	0.501	0.902	0.496	0.407
02/01/09	06/30/09	9.8	42.9	21	11	9	0.286	0.275	0.561	0.266	0.295
07/01/09	09/30/09	6.0	32.4	26	16	16	0.268	0.368	0.637	0.353	0.284
10/01/09	02/05/10	4.0	28.7	23	13	9	0.405	0.322	0.727	0.313	0.414
02/06/10	06/30/10	7.2	36.9	31	8	7	0.340	0.284	0.624	0.276	0.347

Direct Runoff

Period Start	Period End	Direct Runoff TSS (mg/L)	Direct Runoff Cl (mg/L)	Direct Runoff Total P (µg/L)	Direct Runoff Sol React P (µg/L)	Direct Runoff NH4-N (µg/L)	Direct Runoff NOx-N (mg/L)	Direct Runoff TKN (mg/L)	Direct Runoff Total N (mg/L)	Direct Runoff Org N (mg/L)	Direct Runoff Inorg N (mg/L)
09/26/08	01/31/09	24.6	30.5	136	73	32	0.430	0.497	0.927	0.465	0.462
02/01/09	06/30/09	27.1	35.6	92	41	22	0.509	0.466	0.975	0.444	0.531
07/01/09	09/30/09	48.6	21.5	84	11	12	0.068	0.649	0.717	0.637	0.080
10/01/09	02/05/10	22.6	23.4	49	12	7	0.074	0.439	0.513	0.432	0.081
02/06/10	06/30/10	17.3	35.5	34	14	8	0.282	0.343	0.625	0.336	0.289

Period Loads

Period Start	Period End	Period Load TSS (Kg)	Period Load Cl (Kg)	Period Load Total P (Kg)	Period Load Sol React P (Kg)	Period Load NH4-N (Kg)	Period Load NOx-N (Kg)	Period Load TKN (Kg)	Period Load Total N (Kg)	Period Load Org N (Kg)	Period Load Inorg N (Kg)
09/26/08	01/31/09	473562	1253480	3181	1464	610	15124	18224	33348	17614	15734
02/01/09	06/30/09	417786	859068	1293	590	354	8896	8277	17173	7923	9250
07/01/09	09/30/09	613486	456185	1157	230	242	2469	9987	12456	9745	2711
10/01/09	02/05/10	199943	433858	560	210	133	4274	6139	10413	6006	4407
02/06/10	06/30/10	169196	573429	500	157	116	5028	4795	9823	4679	5144

Period	Duration (days)	Load TSS (Kg)	Load Cl (Kg)	Load Total P (Kg)	Load Sol React P (Kg)	Load NH4-N (Kg)	Load NOx-N (Kg)	Load TKN (Kg)	Load Total N (Kg)	Load Org N (Kg)	Load Inorg N (Kg)	Runoff (m3)
Sampled	642	1873973	3576021	6691	2650	1455	35791	47423	83213	45968	37246	108789610
Annual	365.4	1066589	2035324	3808	1508	828	20371	26991	47362	26163	21199	61918572

Notes:

The Sampling period was divided up into 5 hydrologic seasons. The 15 minute continuous discharge record was then separated into stormflow (Q_{sf}) and baseflow (Q_{bf}) by period. The same was done for the discharge during sampled events. The sampled Event Mean Concentrations (EMCs) and mean concentrations during baseflow were also summarized by period. By subtracting the sampled baseflow load from the total sampled load and dividing by the direct runoff discharge, a sampled stormflow (or direct runoff) mean concentration was calculated for each period.

Then the load for each period was calculated by multiplying the direct runoff mean concentration to the total direct runoff discharge, multiplying the baseflow mean concentration by the total baseflow discharge and adding the two terms. Finally a load for the sampled period (642 days) and an estimated annual load (365.4 days) were calculated.

Valatie Kill Loads estimated from a composite of similar nearby USGS gaged watersheds (WY90-WY09)

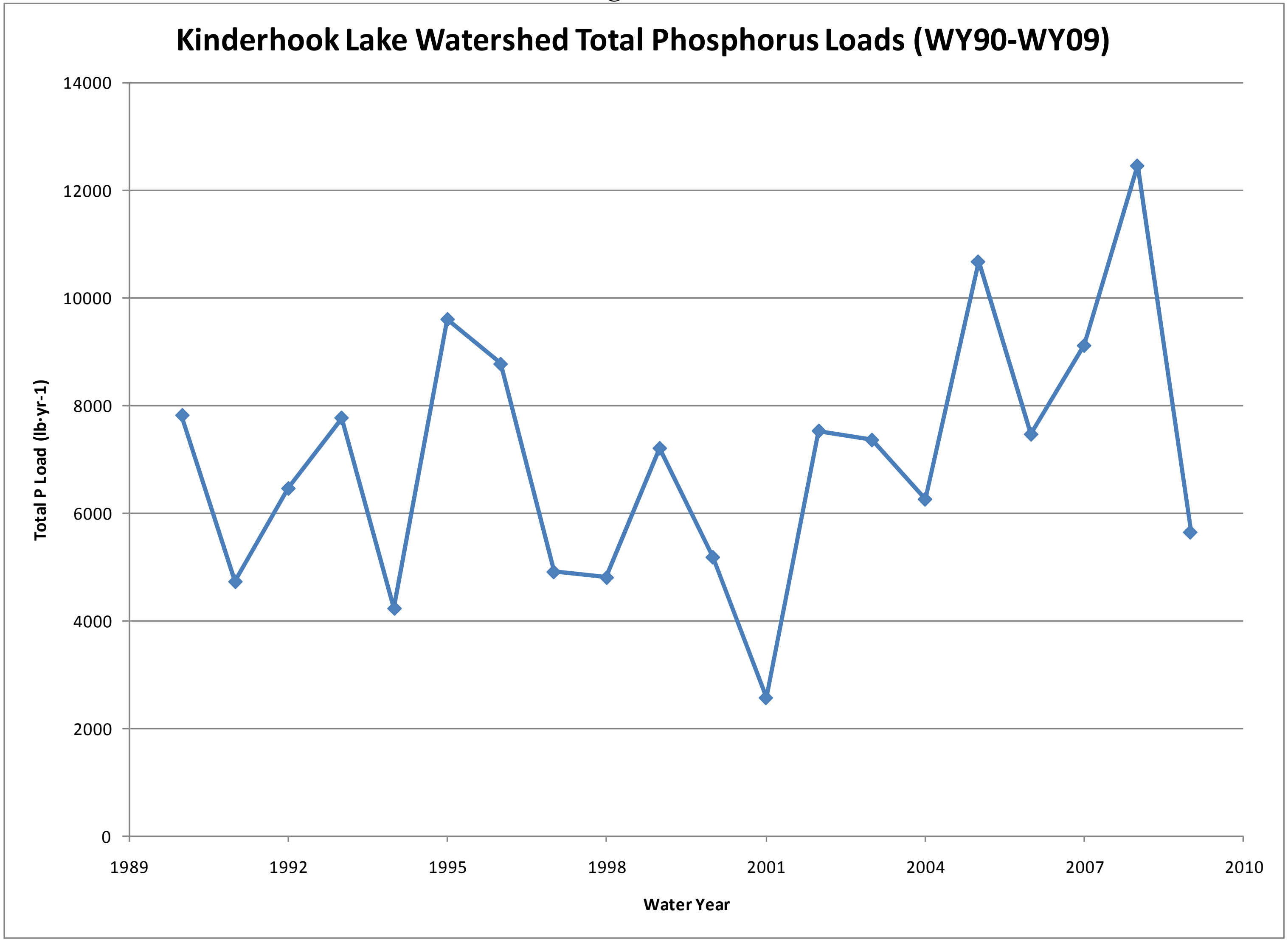
Site	Watershed Area (m2)	Qbar WY 90 (CFS/m2)	Qbar WY 91 (CFS/m2)	Qbar WY 92 (CFS/m2)	Qbar WY 93 (CFS/m2)	Qbar WY 94 (CFS/m2)	Qbar WY 95 (CFS/m2)	Qbar WY 96 (CFS/m2)	Qbar WY 97 (CFS/m2)	Qbar WY 98 (CFS/m2)	Qbar WY 99 (CFS/m2)	Qbar WY 00 (CFS/m2)	Qbar WY 01 (CFS/m2)	Qbar WY 02 (CFS/m2)	Qbar WY 03 (CFS/m2)	Qbar WY 04 (CFS/m2)	Qbar WY 05 (CFS/m2)
Valatie Kill @ Nassau Qbar (CFS)	2.455E+07	1.22	1.11	1.28	1.49	0.79	2.10	1.36	1.44	1.21	2.31	1.20	0.93	2.00	1.98	1.47	2.31
Salmon Creek @ Lime Rock, CT Qbar (CFS)	7.615E+07	1.64	1.40	1.71	2.09	1.22	2.49	2.29	1.41	1.34	1.98	1.44	0.80	2.05	2.01	1.68	2.72
Lisha Kill Nr Guilderland, NY Qbar (CFS)	7.615E+07	#N/A	#N/A	#N/A	0.59	0.26	0.79	0.59	#N/A	#N/A	#N/A	0.57	0.34	0.78	0.97	0.60	0.90
Glowegee Creek @ W. Milton, NY @ Nassau Qbar (CFS)	6.734E+07	1.50	1.16	1.74	1.69	0.95	1.95	1.76	1.66	0.86	1.69	1.45	1.19	1.56	1.88	1.48	1.92
Hoosic River nr. Williamstown, MA Qbar (CFS)	3.263E+08	2.09	1.79	2.11	2.20	1.56	2.88	2.32	2.03	1.65	2.71	2.13	1.72	2.42	2.82	2.21	2.99
Walloomsac River nr. N. Bennington, VT Qbar (CFS)	2.875E+08	1.89	1.71	1.89	2.05	1.29	2.64	1.91	1.96	1.82	2.48	1.77	1.71	2.07	2.53	1.92	2.64
Hoosic River @ Eagle Bridge Qbar (CFS)	1.321E+09	1.80	1.64	1.89	2.17	1.24	2.66	2.00	1.84	1.68	2.64	1.74	1.56	2.07	2.53	1.88	2.81
Battenkill below the Mill @ Battenville, NY Qbar (CFS)	1.026E+09	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	1.59	2.43	1.81	1.60	1.86	2.19	1.94	2.59
Valatie Kill Qbar (CFS)	8.273E+07	1.25	1.02	1.40	1.68	0.91	2.08	1.90	1.06	1.04	1.56	1.12	0.56	1.63	1.59	1.35	2.31
	USGS	1.69	1.47	1.77	1.75	1.04	2.21	1.75	1.72	1.45	2.32	1.51	1.23	1.85	2.11	1.65	2.36

Site	Watershed Area (m2)	Qbar WY 90 (CFS/m2)	Qbar WY 91 (CFS/m2)	Qbar WY 92 (CFS/m2)	Qbar WY 93 (CFS/m2)	Qbar WY 94 (CFS/m2)	Qbar WY 95 (CFS/m2)	Qbar WY 96 (CFS/m2)	Qbar WY 97 (CFS/m2)	Qbar WY 98 (CFS/m2)	Qbar WY 99 (CFS/m2)	Qbar WY 00 (CFS/m2)	Qbar WY 01 (CFS/m2)	Qbar WY 02 (CFS/m2)	Qbar WY 03 (CFS/m2)	Qbar WY 04 (CFS/m2)	Qbar WY 05 (CFS/m2)
Valatie Kill Runoff (cm/yr)	@ gage	58.33	35.28	48.19	57.98	31.57	71.63	65.43	36.63	35.84	53.77	38.66	19.19	56.17	54.92	46.70	79.61
Valatie Kill TP load (Kg/yr @ 0.062 mg/L)	@ gage	2992	1810	2472	2974	1619	3674	3356	1879	1839	2758	1983	984	2881	2817	2395	4084
Valatie Kill load (lb/yr @ 0.062 mg/L)	@ gage	6590	3986	5445	6550	3567	8093	7393	4138	4050	6075	4368	2168	6346	6205	5276	8995
Valatie Kill load (lb/yr @ 0.062 mg/L)	watershed	7819	4730	6460	7771	4232	9602	8771	4910	4805	7208	5182	2572	7529	7361	6260	10672

Site	Watershed Area (m2)	Qbar WY 06 (CFS/m2)	Qbar WY 07 (CFS/m2)	Qbar WY 08 (CFS/m2)	Qbar WY 09 (CFS/m2)
Valatie Kill @ Nassau Qbar (CFS)	2.455E+07	1.61	1.80	1.83	1.10
Salmon Creek @ Lime Rock, CT Qbar (CFS)	7.615E+07	1.97	2.36	2.49	1.68
Lisha Kill Nr Guilderland, NY Qbar (CFS)	7.615E+07	0.80	1.01	0.68	0.59
Glowegee Creek @ W. Milton, NY @ Nassau Qbar (CFS)	6.734E+07	1.92	1.92	1.54	1.19
Hoosic River nr. Williamstown, MA Qbar (CFS)	3.263E+08	2.49	2.89	2.80	2.43
Walloomsac River nr. N. Bennington, VT Qbar (CFS)	2.875E+08	2.40	2.54	2.59	2.09
Hoosic River @ Eagle Bridge Qbar (CFS)	1.321E+09	2.25	2.44	2.42	1.91
Battenkill below the Mill @ Battenville, NY Qbar (CFS)	1.026E+09	2.20	2.53	2.25	1.84
Valatie Kill Qbar (CFS)	8.273E+07	1.61	1.97	2.69	1.22
	USGS	1.96	2.19	2.02	#N/A

Site	Watershed Area (m2)	Qbar WY 06 (CFS/m2)	Qbar WY 07 (CFS/m2)	Qbar WY 08 (CFS/m2)	Qbar WY 09 (CFS/m2)	Mean (1990-2009)
Valatie Kill Runoff (cm/yr)	@ gage	55.70	67.99	92.90	42.13	52.43±17.71
Valatie Kill TP load (Kg/yr @ 0.062 mg/L)	@ gage	2857	3487	4765	2161	2689±908
Valatie Kill load (lb/yr @ 0.062 mg/L)	@ gage	6293	7681	10495	4759	5924±2001
Valatie Kill load (lb/yr @ 0.062 mg/L)	watershed	7467	9114	12452	5647	7028±2374

Figure F-1


Kinderhook Lake Watershed Total Phosphorus Loads (WY90-WY09)
Total P Load (lb·yr-1)
14000
12000
10000
8000
6000
4000
2000
0
1989
1992
1995
1998
2001
2004
2007
2010
Water Year

APPENDIX G. RESPONSIVENESS SUMMARY

An initial meeting was held on February 23, 2009, with the Columbia County Environmental Management Council to discuss the TMDL process. 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 August 3, 2011. 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. Written comments were received and the following is NYS DEC's response to comments:

1. **Comment: Public Participation provided public outreach to Columbia County but none to Rensselaer County until the draft TMDL was out there. Since the majority of the watershed is in Rensselaer County, why wasn't there any outreach to Rensselaer County?**

Response: NYSDEC consulted with the Rensselaer County Soil and Water Conservation District on the status of agricultural Best Management Practices (BMPs) and the assessment of loads from agriculture because of much of the phosphorus load is attributed to that sector. For this TMDL, the focus was on the receiving water, Kinderhook Lake, but when the NYSDEC begins work on the phosphorus TMDL for Nassau Lake, DEC will focus its public participation in Rensselaer County.

2. **Comment: The TMDL states that the activities to be followed for the reduction of Phosphorus will reduce the PCBs in the Kinderhook Lake, Nassau Lake & the Valatie Kill. Since the new PCBs come from groundwater contamination, how does this work?**

Response: The previous PCB remedial efforts conducted by General Electric (GE), were directed at the Dewey Loeffel Landfill. Since USEPA felt that those efforts were not working as efficiently as they should have, they have recommended additional land-based cleanup. To date, GE has not been required to do any remedial work within Nassau Lake, the Valatie Kill or Kinderhook Lake, like for example, dredging. However, the bottom sediments in Nassau Lake, the Valatie Kill and Kinderhook Lake continue to have higher than background levels of PCBs. Since certain urban and agricultural BMPs that are directed at reducing phosphorus loadings may also reduce suspended sediment transport from Nassau Lake, there may also be some reduction in PCB transport to Kinderhook Lake.

3. **Comment: Septic systems are a problem. In the case of Nassau Lake and the Village of Nassau, and public sewers should be encouraged.**

Response: Comment is acknowledged.

4. **Comment: Relative to septic system input, most houses and leach fields are so close to the lake that the only solutions would be holding tanks or a sewer system. The chances of either are slim.**

Response: Comment is acknowledged

5. **Comment: Will the Town of Nassau MS4 waiver be rescinded?**

Response: No, only a small percentage of the developed land in the watershed is in the Town of Nassau. Instead of expanded MS4 controls, this TMDL will focus on the construction permit requirements, so that all phosphorus loads from significant future development in the watershed would be controlled.

6. **Comment: There were several comments with details on the historic use of alum, its perceived effect and the opinion that it would be unlikely to be used in the future.**

Response: Attempting to quantify the actual reduction in internal loading of phosphorus for any lake is not precise. The 2009 Lake sampling by DEC, plus additional CSLAP work does show that the phosphorus levels in the lower waters are now, not particularly elevated. For purposes of the document, NYSDEC decide to assume that the internal P load is now insignificant when compared to the other sources of phosphorus.

APPENDIX H. TOTAL EQUIVALENT DAILY PHOSPHORUS LOAD ALLOCATIONS

Source	Total Phosphorus Load (lb·da^{-1})+			% Reduction
	Current	Allocated	Reduction	
Agriculture	8.21	2.55	5.66	69%
Developed Land (unregulated stormwater)	2.61	2.35	0.26	10%
Septic Systems	4.95	0.00	4.95	100%
Forest, Wetland, Stream Bank, and Natural Background	2.04	2.04	0.00	0%
LOAD ALLOCATION	17.81	6.94	10.88	61%
Cedar Acres Tr. Park (NPDES ID: NY0222861)	0.19	0.19	0.00	0%
Chadwick Manor Apts (NPDES ID: NY0029424)	0.05	0.05	0.00	0%
Smith's Cottages (NPDES ID: NY0212725)	0.01	0.01	0.00	0%
Developed Land (regulated MS4 stormwater)	0.58	0.52	0.06	10%
WASTELOAD ALLOCATION	0.83	0.78	0.06	7%
LA + WLA	18.64	7.71	10.93	59%
Margin of Safety		0.86		---
TOTAL	18.64	8.57	10.08	---

+ Note that loads do not exactly add up due to rounding to whole pounds.