A Total Maximum Daily Load (TMDL) for the Little Lake Wissota embayment of Lake Wissota Chippewa County, Wisconsin

Aerial photo of Little Lake Wissota following summer runoff event (WDNR photo).

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INTRODUCTION

Little Lake Wissota is a 400-acre eutrophic embayment of Lake Wissota, an impoundment of the Chippewa River near Chippewa Falls, Wisconsin (Hydrologic Unit Code 07050005, Wisconsin Waterbody Identification Code 2152800). The embayment has a maximum depth of 43 feet and a drainage area of approximately 67 square miles. Paint Creek is the primary source of surface water inflow to Little Lake Wissota (Figure 1).

The Little Lake Wissota watershed is located in the North Central Hardwood Forest Ecoregion (Omernick and Gallant, 1988). This EPA Ecoregion is characterized by nearly level to rolling glacial till plains, significant agricultural land use and lakes with phosphorus concentrations greater than 50 ppb, indicative of eutrophic conditions. The lake was placed on the Wisconsin 303(d) impaired waters list in 1998 with a high priority ranking due to eutrophication and pH criteria exceedances. In addition, recreational uses are limited during the summer due to poor water quality from excess phosphorus (P) and sediment loading (Table 1). Land cover in the watershed is primarily agricultural and forest (Table 2). The goal of this TMDL is to reduce levels of phosphorus and sediment loading and decrease the extent and severity of summer algal blooms in Little Lake Wissota.

PROBLEM STATEMENT

Little Lake Wissota is highly eutrophic with excessive concentrations of phosphorus and chlorophyll (a measure of algal densities) in its surface waters during the months of May through September (USACE 2004, Brakke 1997). Sediment and phosphorus from nonpoint sources of pollution enter the lake primarily from the Paint Creek watershed. Phosphorus is dissolved in the water or bound to sediment particles, and once in the system, this phosphorus becomes available to plants and algae. The lake's relatively shallow depth, phosphorus-laden sediments and excessive water column phosphorus levels, contribute to significant algal blooms during the growing season (May - September). These eutrophic conditions impair recreational activities in the lake. In addition, algal blooms in Little Lake Wissota are accompanied by pH exceedances. The elevated lake pH levels are due to removal of carbon dioxide from water during photosynthesis (by macrophytes and algae). This reduction in carbon dioxide levels during daylight results in pH levels that frequently exceed the state criterion of 9.0. A reduction in sediment and phosphorus loads to the lake would result in a decrease in chlorophyll levels and reduction in maximum pH levels.

WATER QUALITY STANDARDS

Currently, Wisconsin does not have numeric water quality criteria for phosphorus or sediment. However, Little Lake Wissota is not currently meeting the narrative water quality criterion as defined in NR 102.04 (1); Wis. Admin. Code:

"To preserve and enhance the quality of waters, standards are established to govern water management decisions. Practices attributable to municipal, industrial, commercial, domestic, agricultural, land development or other activities shall be controlled so that all waters including the mixing zone and the effluent channel meet the following conditions at all times and under all

Figure 1. Little Lake Wissota Watershed

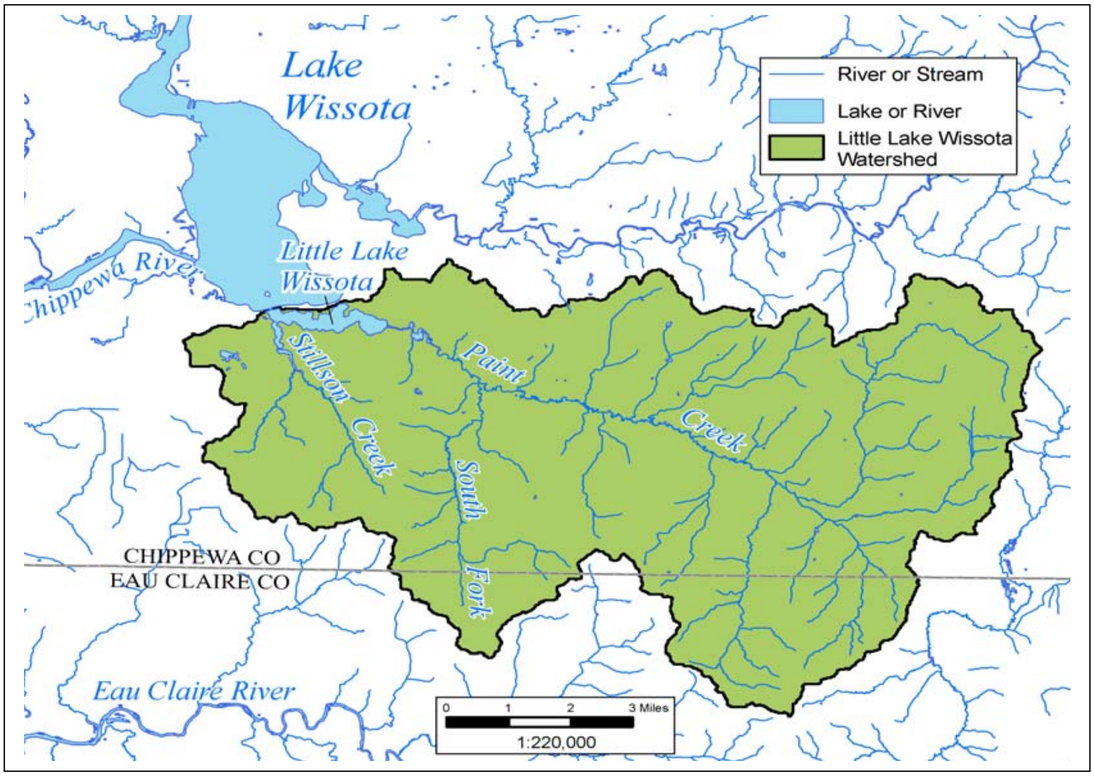

Table 1. Impaired waters listing information for Little Lake Wissota embayment of Lake Wissota.

Waterbody Name	WBIC	Impaired Waters ID	Pollutants	Impairments	Priority
Wissota Lake	2152800	538	Phosphorus, Sediment	Eutrophication, pH exceedances	High

Table 2. Summary of land cover within the Little Lake Wissota Watershed. (Source: modified from WISCLAND 1992).

Land Cover	Area [acres]	Area [%]
Forest-Mixed	17,335	40%
Cropland	16,222	38%
Pasture	4,427	10%
Wetlands-Mixed	3,085	7%
Residential-Medium Density	1,624	4%
Water	501	1%
Totals:	43,194	

flow conditions: (a) Substances that will cause objectionable deposits on the shore or in the bed of a body of water, shall not be present in such amounts as to interfere with public rights in waters of the state, (b) Floating or submerged debris, oil, scum or other material shall not be present in such amounts as to interfere with public rights in waters of the states, (c) Materials producing color, odor, taste or unsightliness shall not be present in such amounts as to interfere with public rights in waters of the state."

This criterion describes acceptable water quality conditions and guides the Wisconsin Department of Natural Resources (WDNR) in setting numeric target pollutant concentrations. The application of a narrative criterion for Little Lake Wissota requires the development of a site-specific lake phosphorus value for the purpose of this TMDL. *For purposes of this TMDL, sediment is considered an objectionable deposit.*

The designated use of Little Lake Wissota is described in S. NR 102.04(3) intro., and (b), Wis. Adm. Code as:

"FISH AND OTHER AQUATIC LIFE USES. The department shall classify all surface waters into one of the fish and other aquatic life subcategories described in this subsection. Only those use subcategories identified in pars. (a) to (c) shall be considered suitable for the protection and propagation of a balanced fish and other aquatic life community as provided in federal water pollution control act amendments of 1972, PL 92-500; 33 USC 1251 et.seq.

"(b) Warm water sport fish communities. This subcategory includes surface waters capable of supporting a community of warm water sport fish or serving as a spawning area for warm water sport fish."

The applicable water quality standard for this TMDL is listed in S. NR 102.04(4) intro, and (c), Wis. Adm. Code as follows:

"Standards for Fish and Aquatic Life. Except for natural conditions, all waters, classified for fish and aquatic life shall meet the following criteria:

"(c) pH. The pH shall be within the range of 6.0 to 9.0, with no change greater than 0.5 units outside the estimated natural seasonal maximum and minimum."

Little Lake Wissota was listed as impaired in 1998 due to documented violations of the water quality criterion for pH. These pH exceedances are related to excessive algal productivity, due to excessive phosphorus in Little Lake Wissota. Reductions in phosphorus concentrations will result in reductions in algal bloom intensity and frequency, and decreased pH levels.

The water quality target for phosphorus for Little Lake Wissota is based on a site-specific goal of 48 ppb total phosphorus (summer lake surface mean concentration). This target will reduce algal blooms and reduce pH exceedances to meet TMDL goals. Since there are no numeric water quality standards for sediment in Wisconsin, the TMDL for sediment is derived from load reductions needed to meet in lake phosphorus and chlorophyll goals.

MONITORING & MODELING BACKGROUND

To determine the extent of the water quality problems in Little Lake Wissota, monitoring was conducted by the WDNR and the U.S. Army Corps of Engineers (USACE) in 2001-2003. The study included continuous flow monitoring and bi-weekly and storm event water quality sampling near the mouth of Paint Creek. Sampling in Little Lake Wissota was conducted bi-weekly in mid-lake from May through September in 2001 and 2002. *In situ* profiles of temperature, dissolved oxygen, pH, and conductivity were collected at 1-m intervals at each station. Water samples were collected at the surface for chlorophyll analysis and at the surface and near bottom for analysis of total phosphorus and soluble reactive phosphorus. All lake water samples were collected by WDNR personnel and sent to the Wisconsin State Laboratory of Hygiene for analysis using standard laboratory protocols. Stream samples collected by USACE staff were analyzed at the Eau Galle Aquatic Ecology Laboratory in Spring Valley, Wisconsin (USACE 2004).

Paint Creek had a mean daily flow of 2.08 and 2.13 cubic meters per second during the summer (May-September) of 2001 and 2002, respectively. The summer hydraulic residence time of Little Lake Wissota was ~ 45 days during both years. The mean summer total phosphorus in Little Lake Wissota surface waters was 68 and 62 ppb in 2001 and 2002, respectively. Flow-weighted summer concentrations of total and soluble reactive phosphorus entering the lake from Paint Creek were 0.08 – 0.09 mg/L and 0.04 – 0.05 mg/L, respectively. The measured total phosphorus load from the Paint Creek watershed was estimated at 13,618 in 2001 and 11,332 pounds in 2002.

The annual sediment load to Little Lake Wissota was estimated at 1,323 and 1,041 tons in 2001 and 2002, respectively. Sediment deposited in Little Lake Wissota contribute phosphorus to the water column via recycling under anoxia or high pH conditions (both which exist in the lake during summer). Laboratory derived internal phosphorus loading rates were moderate under anoxic conditions (17 - 21 mg m^{-2} d^{-1}) suggesting some potential for phosphorus flux from bottom sediments (USACE 2004). A summary of the various loads for nonpoint sources in the watershed are shown in Table 3.

Table 3. Measured sediment and phosphorus loads and yields by land use in the Little Lake Wissota watershed.

Land Cover	Area (ha)	Area (%)	Total Phosphorus Yield (lbs/ha/yr)	Sediment Yield (tons/ha/yr)	Total Phosphorus Load (lbs/yr)	Sediment Yield (tons/yr)
Pasture	1,792	10%	0.401	0.011	719	20
Water	203	1%	NA	NA	NA	NA
Row Crop Ag	6,565	38%	1.051	0.303	6,903	1,990
Wetlands-Mixed	1,248	7%	0.478	0.016	597	21
Forest-Mixed	7,015	40%	0.073	0.004	505	31
Residential-Medium Density	657	4%	0.238	0.021	156	14
Totals:	17,480				8,880	2,076

Modeling

The Wisconsin Trophic State Index (TSI) (Lillie et al. 1993) was estimated for the lake using the USACE computer program BATHTUB (Walker 1996) and mean Secchi transparency values and surface concentrations of total phosphorus and chlorophyll measured over the period May through September of both years. The phosphorus TSI boundary between mesotrophic and eutrophic lakes is 50; this study found the lake eutrophic at a mean phosphorus TSI of 65 over the two summers.

The BATHTUB model was also used to predict total phosphorus, chlorophyll, and Secchi transparency in Little Lake Wissota under different loading scenarios. Model coefficients were calibrated against data collected during the summer of 2001 and these coefficients were then used to predict lake responses to phosphorus loading reductions for the summer of 2002.

Simulated decreases in external phosphorus loading from Paint Creek resulted in decreases in the average summer concentration of total phosphorus and chlorophyll in the surface waters and increases in Secchi depth transparency (Appendix 1-Figures 1a and 2a). For example, a 50% reduction in measured summer external phosphorus loading resulted in a predicted ~ 40% decrease in total phosphorus and a 50% decrease in chlorophyll concentrations in the lake. In contrast, simulated total phosphorus loading increases resulted in a substantial increase in total phosphorus and chlorophyll and decrease in Secchi transparency. A simulated increase in external phosphorus loading of 150% over current conditions resulted in a 31% increase in total phosphorus and a 48% increase in chlorophyll levels during the summer.

BATHTUB modeling was also used to examine changes in the bloom frequency of algal populations in the lake under conditions of simulated decrease or increase in external phosphorus loading during both summers. Under current external phosphorus loading conditions, model results suggest that algae blooms on the order of 30 mg/m^3 chlorophyll (i.e., visible to the eye and considered an aesthetic problem) occurred about 32% of the time during the summer in the lake (Appendix 1). Algae blooms of over 20 mg/m^3 chlorophyll occurred about 57% of the time.

The Soil and Water Assessment Tool (SWAT Arnold *et al*., 2005) model was used to predict flow, sediment, and phosphorus loads to Little Lake Wissota. The SWAT model is a distributed parameter, daily time step model that was developed by the USDA-ARS to assess non-point source pollution from watersheds and subwatersheds. SWAT simulates hydrologic and related processes to predict the impact of land use management on water, sediment, nutrient and pesticide export. Crop and management components within the model permit reasonable representation of the actual cropping, tillage and nutrient management practices typically used in this area of the state. Major processes simulated within the SWAT model include: surface and groundwater hydrology, weather, soil water percolation, crop growth, evapotranspiration, agricultural management, urban and rural management, sedimentation, nutrient cycling and fate, pesticide fate, and water and constituent routing.

SWAT model incorporated three basic rotations that were used to simulate cropping practices in the watershed. These rotations were selected by WDNR staff because they represent agricultural practices that are both reasonable and feasible for this part of the state. A dairy rotation consisted of one year of corn grain, one year of corn silage, followed by three years of alfalfa. The first year of the alfalfa rotation was simulated with oats as a nurse crop and harvested as oat hay. Two cash crop rotations were also simulated; a two year corn grain and soybean rotation and a three year rotation consisting of two years of corn grain and one year of soybeans (Appendix 2).

The model was calibrated for hydrology by balancing surface water, groundwater, and evapotranspiration for calendar year 2002. Once the simulated average annual water export was within ten percent of the monitored flows, simulations were run with daily output for comparison to monitored daily flows. Once the surface runoff to base flow contribution of streamflow was calibrated, the sediment contributions from the sub basins were calibrated to the 2002 data on a monthly basis. Simulated results were then compared to values estimated based on monitored data. The modeled 10-year average annual phosphorus nonpoint source load to Little Lake Wissota was estimated at approximately 8,832 pounds.

The scenarios in Table 4 below are modifications to the existing (baseline) SWAT model simulation to explore the impact of changes in phosphorus export resulting from various management and land use changes. The model scenarios are based on local knowledge of feasible and potentially effective agricultural best management alternatives. The summary shows the simulated management scenarios and their impact on long term average growing season (May-September) phosphorus export from the watershed. The SWAT analysis indicates that a combination of agricultural changes including conversion of cropland to no-till, managing soil phosphorus levels to plant needs and conversion of a portion of cropland to non-cropland uses (i.e. horse pasture, rural residential, CRP, etc.) could theoretically result in an approximate 49% reduction in the baseline phosphorus load.

Table 4. SWAT model simulated seasonal phosphorus loads under various management scenarios in the Little Lake Wissota watershed.

Management Scenario	Seasonal Phosphorus Load (pounds)	Percent of Baseline Phosphorus Load (%)
Baseline condition	4,374	100
All cash crop to corn (no soybeans)	4,323	99
All cash crop to no till	3,796	87
10% cropland conversion to horse farms, CRP, etc.	3,713	85
All agriculture soils to optimum Bray P-1*	3,131	72
No till + optimum Bray P-1	2,888	66
No till, optimum Bray P-1, 10% cropland conversion	2,227	51

* Bray P-1 is a soil chemistry testing method commonly used in Wisconsin to measure soil phosphorus availability to crops.

LINKAGE ANALYSIS

Establishing a link between watershed characteristics and resulting water quality is a crucial step in TMDL development. Sediment export in the Paint Creek watershed provides a phosphorus transport mechanism which impacts overall lake water quality in Little Lake Wissota. The primary concern of sediment loading to Little Lake Wissota is its capacity to transfer phosphorus from the watershed to the lake bottom. These phosphorus-laden sediments contribute to summer algal blooms, especially under anoxic conditions in the hypolimnion. The sediment TMDL is derived from load reductions needed to meet in-lake phosphorus and chlorophyll goals. As measures are taken to reduce soil phosphorus levels and cropland soil erosion in the watershed, sediment and phosphorus export to the lake will similarly decrease.

Phosphorus enters the stream and lake as dissolved phosphorus and sediment-bound typically during rainfall and runoff events. Phosphorus loading to the lake causes eutrophication, characterized by excessive algal growth and pH fluctuations. Algal blooms result in pH increases due to removal of carbon dioxide from minimally buffered water during photosynthesis (by macrophytes and algae). A reduction in carbon dioxide levels during daylight hours results in pH increases (at times above the water quality standard of 9.0). A reduction in phosphorus levels in the lake would result in a decrease in chlorophyll levels (a measure of productivity) and a reduction in maximum pH levels. Although, the water quality criterion for pH in Little Lake Wissota was not a primary consideration for setting targets for the TMDL, the loading reductions for phosphorus and sediment identified in this TMDL will reduce pH exceedances in the lake.

TMDL DEVELOPMENT

The goal of this TMDL is to reduce the amount of phosphorus and sediment loading and the corresponding frequency and severity of summer algal blooms in Little Lake Wissota. Since Wisconsin does not have numeric water quality criteria for phosphorus and sediment, site specific targets were chosen based on existing data and modeling results. In order to achieve a measurable improvement in lake water quality, a summer epilimnetic weighted-mean goal for phosphorus of 48 ppb has been established for the Little Lake Wissota TMDL. This goal reflects achievable phosphorus load reductions in the watershed based on feasible restoration scenarios using the SWAT model (Table 4), stakeholder input and best professional judgment of WDNR staff.

Applying the BATHTUB model, the phosphorus concentration goal of 48 ppb corresponds to a summer mean chlorophyll-a biological target concentration of 20 ppb and Secchi depth of 1.5 meters. The phosphorus goal also represents a 20% reduction in the length of time (approximately 30 days) the lake would experience summer chlorophyll concentrations greater than or equal to 20 ppb (a bloom condition). By meeting the TMDL goal concentration of 48 ppb in Little Lake Wissota, the narrative water quality criteria stated in NR 102.04 (1); Wis. Admin. Code will be met. Achieving the phosphorus goal will decrease the frequency and intensity of algal blooms that currently impair recreational uses and reduce pH exceedances to less than 5% of the critical period of May – September (Appendix 3).

After the lake phosphorus goal was identified for this TMDL, the SWAT model was used to determine the corresponding amount of sediment reduction needed to meet the goal. A seasonal and annual sediment loading reduction goal of 26% was identified for the TMDL based on this approach.

LOADING CAPACITY

The total loading capacity is the sum of the wasteload allocations for permitted point sources, load allocations for non-point sources, and a margin of safety, as generally expressed in the following equation:

TMDL Load Capacity = WLA + LA + MOS

WLA = Wasteload Allocation (Point sources)
LA = Load Allocation (Nonpoint sources)
MOS = Margin of Safety

The loading capacity provides a baseline for calculating the amount of pollutant reduction needed to bring a waterbody into compliance with water quality criteria and/or designated uses. The total phosphorus loading capacity of Little Lake Wissota is a function of an identified mean summer epilimnetic in-lake phosphorus concentration goal of 48 ppb. Nutrient loads above this capacity result in use impairments and frequent water quality criteria exceedances as discussed earlier in this report.

The BATHTUB model output was used to determine the level of phosphorus load reduction necessary to achieve a mean total phosphorus concentration of 48 ppb (which corresponds to 20 ppb chlorophyll-a) in Little Lake Wissota. The total loading capacity for Little Lake Wissota is 5,900 lbs/year of phosphorus and 757 tons/year of sediment. At these phosphorus and sediment loading levels, the occurrence of severe algae blooms and exceedances of the pH criteria will be significantly reduced. *Based on the relationship between in-lake goals and phosphorus loading from the watershed, a 34% reduction in the annual phosphorus load and 26% reduction in the sediment load from nonpoint sources are needed to achieve the in-lake water quality goals.*

WASTELOAD ALLOCATION

Permitted point sources in the watershed are storm sewer outfalls in the Town of Lafayette stormwater management area (Fig. 2). The Town of Lafayette was issued a WPDES permit to regulate discharges from its Municipal Separate Storm Sewer System (MS4) (WPDES Permit No. WI-S050121). Because of the highly permeable soils in the drainage area, 88 to 95% of stormwater runoff infiltrates before it reaches the lake and 95 to 99% of particulate phosphorus and suspended solids are removed (Chippewa County LCD, 2007).

The annual point source load to Little Lake Wissota from the storm water conveyance system is approximately 60 lbs of phosphorus and 10 tons of sediment based on a Source Loading and Management Model (SLAMM) analysis of the drainage area. The Town of Lafayette requires all new land divisions and development to have on-site stormwater treatment, and due to sandy soils and the high level of infiltration, it is anticipated there will be very little discharge from future developments. The annual point source MS4 wasteload allocation is set at 60 lbs of phosphorus and 10 tons of suspended solids.

Other permitted industrial facilities and construction sites in the watershed are covered under a WPDES general permit. Due to the transitory nature and uncertainty of facility locations and whether they are discharging the pollutant of concern, a group wasteload allocation was identified for these facilities. The general permit wasteload allocation is based on the assumption that discharges from traditional municipal and industrial point sources represent a measure of commercial and residential human activity in a catchment. Presumably, general permit activity also represents commercial and residential human activity in a catchment. Consequently, it was assumed that there is a relationship between phosphorus discharges from monitored point source loads and unmonitored general permit discharges.

The phosphorus wasteload allocation for general permits was estimated as 2% of the unit area load from individually permitted point sources in the Lower Chippewa River Basin (in which the Little Lake Wissota watershed is located). The annual phosphorus wasteload allocation for general permits is 13 pounds, with a reserve capacity of 19 pounds (3% of the unit area load) for future growth.

The sediment wasteload allocation for general permits is based on the ratio of phosphorus MS4 allocation to the general permit phosphorus allocation. The general permit wasteload allocation for sediment is 2.2 tons per year, with a reserve capacity of 3.2 tons per year (calculated based on an equal ratio of current permits to reserve capacity for phosphorus).

Figure 2. MS4 Stormwater Management Area for Town of Lafayette and Little Lake Wissota.

LOAD ALLOCATION

A watershed calibrated SWAT model was used to develop nonpoint source load allocations for Little Lake Wissota. The SWAT land use model was developed and calibrated using the 2001-2003 monitoring data. The baseline phosphorus and sediment loads to Little Lake Wissota are based on estimated long-term (10 year) SWAT simulations. The load reduction and in-lake water quality goals for the lake were based on model simulations and best professional judgment of WDNR staff (see Monitoring and Modeling Background section).

Phosphorus

Table 3 provides a summary of model estimated long term mean seasonal phosphorus loads from nonpoint sources. The SWAT model predicts that implementation of BMPs in the watershed will achieve a higher percentage phosphorus load reduction on an annual basis than during the May-September period. Consequently, a 30% phosphorus load reduction goal for the May-September period and a 34% reduction in the annual phosphorus load was established. These loading reduction goals are based on what modeling determined was achievable in the watershed and the necessary improvements in lake water quality. A basin-wide annual phosphorus load reduction of 34% results in a nonpoint source load allocation of 5,810 pounds and a daily load allocation of approximately 16 pounds (Table 5).

Sediment

As previously mentioned, the sediment loading capacity is primarily based upon the amount of sediment reduction needed to achieve the in-lake phosphorus goal. The annual phosphorus reduction goal of 34% translates to a sediment loading reduction goal of 26% and an annual sediment load allocation of 742.8 tons (Table 6).

Table 5. Summary of annual and daily total phosphorus load and wasteload allocations for the Little Lake Wissota watershed.

Category	Current Annual Phosphorus Load (pounds)	Annual Phosphorus Load Allocation (pounds)	TMDL for Phosphorus (pounds/day)
Nonpoint Sources*	8,832	5,810	15.92
Point Sources Town of Lafayette MS4** General Permit	 60 13	 60 13	 0.16 0.04
Reserve Capacity for General Permits		19	0.05
Totals:	8,905	5,902	16.17

*Based on 10-year average SWAT modeled phosphorus load from nonpoint sources.
**MS4 collection system currently captures 95-99% of stormwater phosphorus load.

MARGIN OF SAFETY

A margin of safety (MOS) is a required component of the TMDL to account for uncertainty of the relationship between pollutant loads and quality of the receiving waterbody. The statutory requirement that TMDLs incorporate a MOS is intended to account for uncertainty in the available data or in the actual effect controls will have on loading reductions and receiving water quality. The MOS may be either implicitly accounted for by choosing conservative assumptions about loading estimates or water quality response, or is explicitly accounted for during the allocation of loads.

Table 6. Summary of annual and daily sediment TMDL load and wasteload allocations for the Little Lake Wissota watershed.

Category	Current Annual Sediment Load (tons)	Annual Sediment Load Allocation (tons)	TMDL for Sediment (tons/day)
Nonpoint Sources*	1,008	742.8	2.04
Point Sources			
Town of Lafayette MS4**	10	10	0.03
General Permit	2.2	2.2	<0.01
Reserve Capacity for General Permits		3.2	<0.01
Totals:	1,020.2	758.2	2.08

* Based on 10-year average SWAT modeled sediment load.
** MS4 collection system currently captures 95-99% of stormwater sediment load.

An implicit margin of safety is provided by calibration parameters chosen for the BATHTUB chlorophyll-a sub model that tend to over predict in-lake chlorophyll levels for a given phosphorus level (see Figure 6 in Appendix 2). This provides an implicit margin of safety as we would expect that if in-lake phosphorus goals are met under the TMDL, chlorophyll levels should be lower than those predicted by the model and hence fewer exceedances of the pH criterion.

TMDL implementation will occur on an iterative basis so that course corrections, based on periodic monitoring and reevaluation, can adjust the strategy to meet the TMDL goal. After the first phase of nutrient reduction efforts, reevaluation will identify those activities that need to be strengthened or other activities that need to be implemented to reach the standards. This type of iterative approach is more cost effective than over-engineering to conservatively inflated margins of safety (Walker 2003).

SEASONAL VARIATION

As the term implies, TMDLs must be expressed as maximum daily loads. However, TMDLs may be expressed in other terms when appropriate. In this case, the TMDL is also expressed in terms of the allowable annual load of phosphorus and sediment. Although critical conditions occur during summer (May-September) when algal growth is more likely to interfere with water uses and result in pH exceedances, lakes are generally not sensitive to daily or short term loading. Historically, nuisance algal blooms in Little Lake Wissota have been limited to the summer and late summer season when optimal light and water temperatures exist to support blue green algae. While most blue green algal growth occurs during these times, there are reasons to apply the phosphorus TMDL to a longer time period. First, there is potential for spring and early summer deposition of phosphorus-laden sediments into the lake and in stream sediment pools of the tributaries. These sediment pools likely release phosphorus throughout the growing season. There is also a possibility that during a warm, dry spring or fall, significant algal growth may occur outside the May-September period.

Although algal bloom conditions and pH exceedances generally occur during the summer period, phosphorus control from nonpoint sources results from practices that affect phosphorus loading during the entire open water period. For example, cropping practices in spring and summer may affect soil runoff during the entire open water season. In addition, manure spread on fields during winter months may contribute significantly to phosphorus loads during early spring runoff. The technical basis for evaluating the effectiveness of nonpoint source controls using the SWAT model is based on annual phosphorus and sediment loss. Thus, developing a TMDL is more meaningful on an annual rather than a daily or seasonal basis.

REASONABLE ASSURANCE

The Clean Water Act requires that states provide a "reasonable assurance" that the TMDL will be implemented. Reasonable assurance for this TMDL will be provided through a variety of voluntary and/or regulatory means. The TMDL will be implemented through enforcement of current regulations, financial incentives and various local, state and federal pollution control programs, including:

<u>WPDES Permits –</u> The Department issued a specific WPDES permit to the Town of Lafayette to regulate discharges from their MS4 outfalls.

Other permitted industrial facilities and construction sites in the watershed are covered under the WPDES general permitting process. If these facilities are meeting current general permit requirements, they are considered in compliance with the wasteload allocation defined in this TMDL.

<u>Wisconsin Administrative Code NR151</u> identifies performance standards and prohibitions to control polluted nonpoint source runoff. The rule also sets urban performance standards to control construction site erosion and manage runoff from urban development.

The WDNR and Chippewa County Land Conservation Department (LCD) will implement agricultural and non-agricultural performance standards and manure management prohibitions to address sediment and nutrient loadings in the Little Lake Wissota watershed. Many landowners voluntarily install Best Management Practices (BMPs) to help improve water quality and comply with the performance standards. Cost sharing may be available for many of these BMPs. In some cases, farmers will not be required to comply with the agricultural performance standards and prohibitions unless they are offered at least 70% in cost sharing funds. If cost-share money is offered but not accepted, those in violation of the standards will be required to implement BMPs to comply with the rule.

<u>Targeted Runoff Management (TRM) Grants –</u> The Chippewa County LCD may apply for TRM grants through the WDNR. These grants are competitive financial awards to support small-scale, short term projects (up to 24 months) to reduce runoff pollution. Both urban and agricultural projects can be funded through TRM grants which require a local contribution to the project. The state cost share maximum is $150,000 per grant. Projects that correct violations of the performance standards and prohibitions and reduce runoff pollution to impaired waters are a high priority for this grant program.

Lake Protection Grants are available to assist lake users, lake communities and local governments to undertake projects that protect and restore lakes and their ecosystems. This program is administered under Wisconsin Administrative Code NR 191, and typically provides up to 75% state cost sharing assistance up to $200,000 per project. These projects may include watershed management projects, lake restoration, shoreland and wetland restoration, or any other projects that will protect or improve lakes.

The Environmental Quality Incentive Program (EQIP) is a federal cost-share program administered by the Natural Resources Conservation Service (NRCS) that provides farmers with technical and financial assistance. Farmers receive flat rate payments for installing and implementing runoff management practices. Projects include terraces, waterways, diversions, and contour strips to manage agricultural waste, promote stream buffers, and control erosion on agricultural lands.

USDA Farm Service Agency's (FSA) Conservation Reserve Program (CRP) is a voluntary program available to agricultural producers to help safeguard environmentally sensitive land. Producers enrolled in CRP plant long term, resource conserving covers to improve the quality of water, control soil erosion, and enhance wildlife habitat. In return, the FSA provides participants with rental payments and cost share assistance.

PUBLIC PARTICIPATION

A local stakeholder advisory group was formed in September 2007 to provide input in developing the Little Lake Wissota TMDL. The advisory group consisted of WDNR staff, Chippewa County LCD staff, town officials, lake association members and other private individuals. Local advisory meeting dates and minutes were sent to US EPA with the TMDL Submittal and are available upon request.

A press release and public notice for the first draft of the Little Lake Wissota TMDL was sent out on January 30, 2009 starting the formal public comment period from January 30 to March 2, 2009. A news release was sent to local newspapers and the draft TMDL was provided to the local advisory group for their review. The news release, public notice and draft TMDL were placed on the WDNR website at: http://dnr.wi.gov/org/water/wm/wqs/303d/Draft_TMDLs.html.

Comments were received by US EPA regarding inclusion of stormwater and WPDES general permits. Comments were also received by Midwest Environmental Advocates on March 2, 2009. Comments to responses were sent to US EPA with the TMDL Submittal and are available upon request.

Due to significant changes in the TMDL, a second press release and public notice was released in August, 2009. This indicated another 30-day comment period from August 19 until September 16, 2009. The new draft TMDL was sent to Midwest Environmental Advocates at this time. No public comments were received during this second comment period.

IMPLEMENTATION

This TMDL identifies water quality goals and wasteload allocations that will reduce the severity and extent of algae blooms in Little Lake Wissota. The next step following approval of the TMDL will be to develop an implementation plan that specifically describes how these goals will be achieved. The implementation planning process is expected to be completed following approval of the TMDL.

The implementation planning process will develop strategies to effectively utilize existing federal, state, and county programs to achieve nonpoint source load reduction goals outlined in the TMDL. Generally, funding sources are available to install BMPs, but most of these sources do not include funds to hire local staff.

The implementation plan will address various management issues including:

- Funding priorities to implement cost effective BMPs in the watershed
- Funding for local land conservation department staff
- Develop or identify existing organizations or agencies to lead implementation
- Develop targeted agricultural performance standards (if needed)
- Determine how and when to implement agricultural performance standards

Developing an implementation plan will require a collaborative effort that utilizes the funding and expertise of various agencies and private organizations. Participating partners will likely include the Chippewa County LCD, WDNR, lake shore property owners the TMDL advisory group and possibly other interested parties. An inter-agency cooperative agreement will be developed to define contributing roles and responsibilities of each respective partner. Details of the implementation plan will include project goals, actions, costs, timelines, reporting requirements, and evaluation criteria.

Stormwater Management

<u>Development within WPDES stormwater permit area</u>: The modeled point source load (from storm sewers) is 60 lbs of total phosphorus annually. All new land divisions and development are required to have on-site stormwater treatment.

As stated in the Town of Lafayette's current stormwater permit (WI-S050121), the town shall assess whether additional control measures are necessary to meet the TMDL wasteload allocation. Possible measures to achieve this goal could include; requiring all future land division proposals to have "zero" discharge (which will require infiltration of all stormwater) and requiring development not involving land division (single lots) to meet NR151 performance standards.

Another recommendation for the Town of Lafayette would be to incorporate a zero-discharge requirement for the 100-year 5.8 inch design storm, for development involving land division that falls within the WPDES permitted area. This would not be burdensome to developers, as current development is essentially meeting this on-site treatment requirement.

<u>Development outside the MS4 area</u>: Development that falls outside the WPDES permit area but within the Little Lake Wissota watershed will be treated as nonpoint sources, and be required to meet NR151 performance standards. All construction sites over one acre will be regulated by a WPDES general permit issued by the Department regardless of where they are in the watershed.

<u>Shoreland direct drainage development:</u> The implementation plan should address this area and recommend that the Town of Lafayette adopt a zero-phosphorus fertilizer ordinance, and promote rain gardens & infiltration.

MONITORING

Depending on availability of funding, water quality monitoring will be conducted by the WDNR in Little Lake Wissota and its watershed beginning an appropriate length of time following initiation of TMDL implementation. This monitoring would provide an interim evaluation of project effectiveness and goals. The monitoring approach would generally replicate monitoring conducted in 2001-2002 as outlined in USACE (2004).

Pollutant loads would be measured for two years at a station located on Paint Creek just above where it enters Little Lake Wissota. Stream flow would be measured continuously and water chemistry samples collected bi-weekly for two years. Lake water quality would be monitored following the protocol outlined in USACE (2004). Land use data should be updated as needed, which in conjunction with the monitoring data, could be used to develop an updated watershed SWAT loading model for Little Lake Wissota. The watershed model and an updated lake response model would be used to re-evaluate project goals and evaluate progress in implementing the TMDL.

Volunteer monitoring

An ongoing monitoring effort sponsored by the Wisconsin Self-Help Citizen Lake Monitoring program provides basic water quality data collected by local volunteers. Self-help volunteers have been collecting Secchi depth data in Little Lake Wissota somewhat inconsistently since about 2001. In order to more effectively measure implementation effectiveness, this monitoring should be more consistent and include summer monthly Secchi depth, total phosphorus and chlorophyll samples.

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Appendix 1. BATHTUB and SWAT model outputs for summer 2001 in Little Lake Wissota.

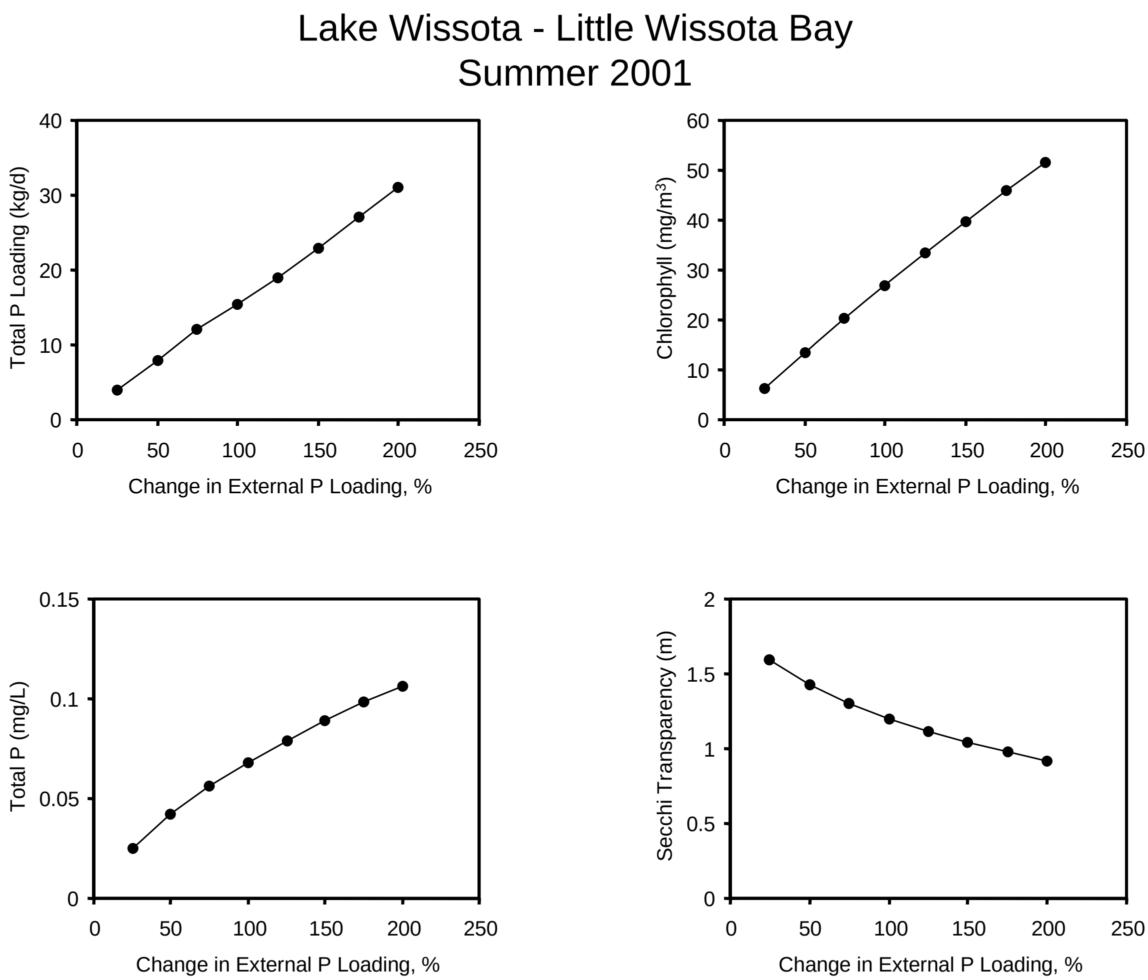

Figure 1a. Bathtub model output of predicted changes in summer mean total phosphorus (P), chlorophyll, and Secchi transparency as a function of increases (i.e., > 100%) or decreases (i.e., < 100%) in 2001 P loading conditions to Little Lake Wissota (USCOE 2004).

Appendix 1 (cont.). BATHTUB and SWAT model outputs for summer 2002 in Little Lake Wissota.

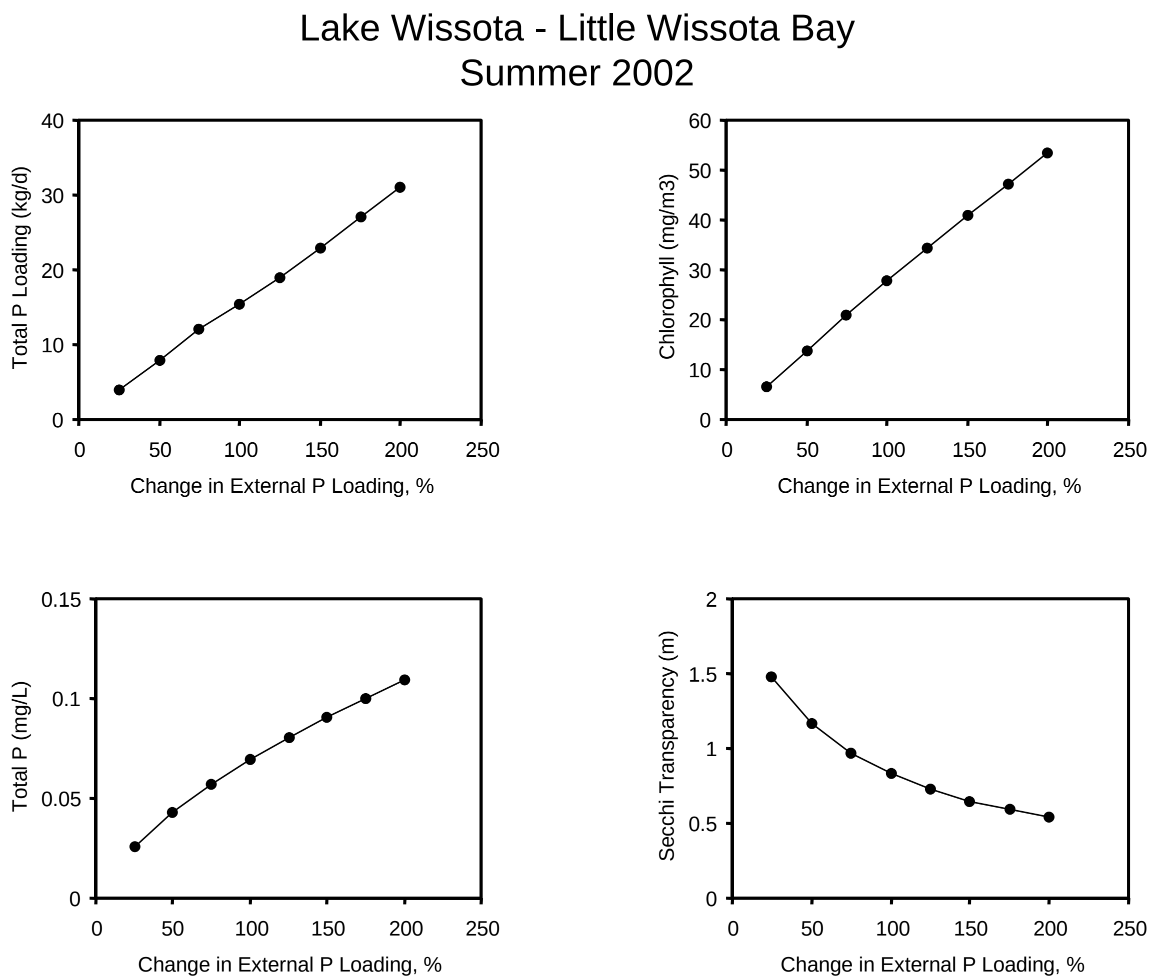

Figure 1b. Bathtub model output of predicted changes in summer mean total phosphorus (P), chlorophyll, and Secchi transparency as a function of increases (i.e., > 100%) or decreases (i.e., < 100%) in 2002 P loading conditions to Little Lake Wissota (USCOE 2004).

Appendix 1 (cont.). BATHTUB and SWAT model outputs for Little Lake Wissota TMDL.

Model	Variable	Baseline Conditions (1)	TMDL Conditions (2)	Percent of Baseline Conditions
BATHTUB	Total P (ug/L)	68.7	48.4	70%
BATHTUB	Chl-A (ug/L)	27.2	20.0	73%
BATHTUB	SECCHI (M)	1.2	1.5	127%
BATHTUB	FREQ(CHL-a>10) %	90.4	79.0	87%
BATHTUB	FREQ(CHL-a>20) %	57.3	37.7	66%
BATHTUB	FREQ(CHL-a>30) %	31.9	16.7	52%
BATHTUB	FREQ(CHL-a>40) %	17.5	7.6	44%
BATHTUB	FREQ(CHL-a>50) %	9.8	3.7	37%
BATHTUB	FREQ(CHL-a>60) %	5.6	1.9	33%
SWAT	Mean Summer Flow (cms)	1.635	1.635	100%
SWAT	P Load (kg/Summer)	1667.9	1167.6	70%
SWAT	Summer Mean P Conc (ug/L)	92	64.4	70%
SWAT	Mean Annual Flow (cms)	1.505	1.505	100%
SWAT	Annual P Load (kg/yr)	4011.8	2649.6	66%
SWAT	Annual TSS Load (MT/yr)	916	678	74%

(1) Baseline Conditions = 10 year mean estimated summer load to Little Lake Wissota (1994-2003)
(2) Projected TMDL Conditions = 70% of baseline conditions (30% seasonal P load reductions)

Appendix 2. Little Lake Wissota TMDL SWAT model setup (prepared by Pat Oldenburg, WDNR).

Project Setting

Little Lake Wissota is a major embayment of Lake Wissota in southern Chippewa County in West Central Wisconsin. The embayment is separated from the main body of the reservoir by a causeway with a relatively narrow opening and has water quality considerably different from the main body of the reservoir. The two main tributaries to Little Lake Wissota are Paint and Stillson Creeks, the total contributing watershed is 175 km2 (66 mi2). The embayment has a surface area of 162 ha (400 ac), a maximum depth of 40 feet and a mean depth of 5.1 m (16.7 ft) for a basin volume of 6,730 ac-ft.

The purpose of this study was to identify these "source areas" through the use of a model capable of geospatially simulating the environmental processes and land management activities taking place in the watershed over time. The ArcView interface version of the Soil and Water Assessment Tool (SWAT) developed by the United States Department of Agriculture – Agricultural Research Service (USDA-ARS) was the model selected to accomplish this objective. SWAT is a distributed parameter daily time step model that was developed to address non-point source pollution from watersheds and large river basins. SWAT simulates hydrologic and related processes to predict the impact of management on water, sediment, nutrient and pesticide export from rural basins. By simulating different management scenarios, the relative reduction of pollutant loading for each scenario was quantified.

SWAT Model Setup

The Soil and Water Assessment Tool (SWAT) was used to predict flow, sediment, and phosphorus loads for the Little Lake Wissota Embayment of Lake Wissota in West Central Wisconsin. The version of the model used for this study was AVSWAT Version 2000.

Watershed delineation was performed using the ArcView interface for SWAT (AVSWAT) and the 30-meter digital elevation model (DEM) for Wisconsin. The watershed was divided into 7 sub-watersheds or sub basins (Figure 1, Table 1) that were further divided into 85 hydrologic response units (HRUs). SWAT uses HRUs to group areas of hydrologically similar land use, management, and soil properties within the sub-watersheds. Automated routines within AVSWAT were used to generate stream and hydrologic characteristics, slope and slope lengths and flow path and channel characteristics for each sub-watershed.

Land cover within the watershed was determined from the 1992 WISCLAND land cover GIS layer, which is based on LANDSAT Thematic Mapper images. A custom look-up table was created to convert the WISLAND codes into SWAT land cover and urban codes. Because of the nature of interpretation and classification, dominant plant species were identified for such generic codes as "Grassland" and matched to those plants with similar physiology in the SWAT land cover database. Classifications for forested areas were grouped as mixed forest. See Table 2 for a summary of land use within the Little Lake Wissota watershed. Adjustments were made to land uses in sub basin 1 in an attempt to account for land use changes in the sub basin which occurred between 1992 and 2003.

Table 3 describes the current estimation of management practices (crop rotations, nutrient additions, and tillage practices) for cropped lands in the Little Lake Wissota watershed. Three basic rotations were used to simulate cropping practices in the watershed. A dairy rotation consisting of one year of corn grain, one year of corn silage, followed by three years of alfalfa. The first year of the alfalfa rotation was simulated with oats as a nurse crop and taken off as oat hay. There were two cash crop rotations simulated, a two year corn grain and soybean rotation and a three year rotation consisting of two years of corn grain and one year of soybeans. Table 4 depicts how these three basic scenarios were distributed among the sub basins.

In order to simulate the distributed nature of crops grown across the watershed, the basic scenarios were actually input into the model with various rotation starting years. For example, with the cropland under the corn-corn-soybean rotation, roughly one third of the area was modeled the first year corn, the second year corn, and the third year as soybean. Another third was modeled with the first year as corn, the second year as soybean, and the third year as corn. Finally, the remainder of the cropland was modeled with the first year as soybean, the second year as corn, and the third year as corn.

An important parameter in SWAT is the concentration of phosphorus in the soil, unfortunately detailed soil test information from the Little Lake Wissota was not available. For modeling purposes the county wide averages were used for agricultural soils and the Bray P-1 value was input into the model as the labile phosphorus. This resulted in a value of either 56 mg/kg or 43 mg/kg depending on soil type. For grassland and residential areas the labile phosphorus was set at 30 mg/kg. This value is higher than what normal background values would be. However, it is also likely that these areas have received past inputs of phosphorus either from past use as croplands, animal grazing areas or lawn fertilizers. For wetlands and forested areas the labile phosphorus was set at 12 mg/kg.

Model Calibration and Validation

A tributary flow monitoring station was located on Paint Creek at County K (i.e., upstream of Little Wissota Bay, Lake Wissota). Stage elevations were monitored at 15-minute intervals using stage height recorders equipped with pressure transducers. Mean daily stage elevations were converted to volumetric flow (cubic meters per second; cms) using stage-discharge relationships generated under different flow regimes. Flows at all monitoring stations were determined between April, 2001, and September, 2003.

Grab samples from all flow monitoring stations were collected from mid-stream at biweekly intervals using an integrating water column sampler. Samples were analyzed for total suspended solids (TSS), total nitrogen, total phosphorus, and soluble reactive phosphorus. Constituent loadings were estimated using the computer model Flux. For details on the constituent loading see the U.S. Corps of Engineers Report (James 2004).

The model was first calibrated for hydrology by balancing surface water, groundwater, and evapotranspiration for calendar year 2002. The hydrology was balanced first on a yearly basis by looking at average annual results and annual rainfall to runoff ratios. Surface and groundwater were calibrated by adjusting the alpha factor (percent of base flow contribution), the soil available water capacity, the soil evaporation compensation factor and other groundwater parameters. A base flow separation model run using the April 2001 through 2003 monitoring data indicated that approximately 36% of the stream flow came from base flow. The Priestley-Taylor evapotranspiration routine was selected because provided the best results.

The crop yields reported by the model were also checked against statistics published by the Wisconsin Agricultural Statistics Service. Crop growth has a very large impact on the water budget in the hydrologic system and the amount of biomass and residue remaining on fields is a large factor in sediment transport.

Once the simulated average annual water export was within ten percent of the estimated value, simulations were run with daily output for comparison to monitored daily flows. Most of the effort was focused on matching base flow and the occurrences of peak flows (Figure 2).
Once the surface runoff to base flow contribution of stream flow was being simulated correctly, the sediment contributions from the sub basins were calibrated to the 2002 data on a monthly basis. Simulated results were compared to values estimated based on monitored data (Figures 3 and 4). A summary of SWAT model calibration statistics is provided in Table 5.

SWAT Model Scenarios

Once the model was satisfactorily calibrated and validated, different scenarios were analyzed to determine the relative impact of changes in management practices on nutrient export. Scenarios were simulated using tools provided by the model interface as well as through manipulation of model outputs.

- Conversion of all cash crop rotations from corn/soybeans to continuous corn to reflect the increased demand for corn for ethanol production.
- Conversion of all cash crop rotations to no-till cropping systems. Observations from Chippewa County staff indicated that there appears to be a gradual transition from the current reduced tillage systems to no-till in the watershed.
- Conversion of 10% of cropland in the watershed to grassland. Over the past decade there has been a conversion of croplands to rural residential and recreational property. Rather than changing land uses in the model, export coefficients were developed for the various land uses over a 10 year simulation period. The average load from the base scenario was then adjusted accordingly.
- Bringing all cropland soils in the basin from their current average Bray P-1 values down to agronomic optimum. For this scenario phosphorus levels were reduced from current levels of 43 mg/kg down to 23 mg/kg for soils in subsoil fertility group D and reduced from 56 mg/kg down to 37 mg/kg was used for soils in subsoil fertility group E. No changes were made to phosphorus levels in the other land use categories.
- Conversion of all cash crop rotations to no-till cropping systems and bringing all cropland soils in the basin from their current average Bray P-1 values down to agronomic optimum.
- The above scenario plus the conversion of 10% of cropland in the watershed to grassland.

BATHTUB Model Setup, Calibration, and Validation

The computer model BATHTUB (Walker 1996) was used to predict trophic response of Little Lake Wissota. The lake was previously modeled as part of the Corps project, however that model did not account for the entire drainage area, rather only those portions of the watershed above the stream monitoring station were include in the loading estimate and subsequent BATHTUB model calibration. In order to account for this discrepancy and more closely link the BATHTUB response model with the SWAT model simulated loads from May – September 2002 and 2003 (rather than the monitored loads) and observed water quality data were used as inputs to the BATHTUB model. For details on the constituent loading see the Corps Report (James 2004).

The BATHTUB model was calibrated for using May – September 2002 data and validated using May – September 2003 data. Based on the 2002 data the Vollenweider phosphorus settling model was selected with a calibration coefficient of 0.879. This model takes into account phosphorus loading rate, mean depth and flushing rate. For chlorophyll-a the linear model was selected. Results of the BATHTUB modeling are shown in figure 5 and 6. For both years the predicted phosphorus concentrations match the observed values quite well. On the contrary the chlorophyll-a model did not fit well for both years. When fit to the 2002 data the model apparently over-predicted chlorophyll for 2003. However, there was a method change at the Wisconsin State Laboratory of Hygiene. In 2002 chlorophyll-a was determined using a trichromatic method and in 2003 it was determined using a flourometric method. Review of data collected on several other lakes in 2002 and 2003 revealed similar differences by did not reveal any clear bias between the two methods (K. Schreiber, pers. comm.). In looking at Secchi data it appears that the lake should have had similar concentrations of chlorophyll since the mean Secchi depths were only 0.1 m greater in 2003 when compared to 2002.

The calibrated BATHTUB model was then used to estimate a longer term average water quality in Little Lake Wissota by determining the lake response to the 10 year mean loading calculated by the calibrated SWAT model. This long term average was used as the basis for examining the impacts of changes in loading on lake water quality. Changes in lake water quality were examined by developing response curves for total phosphorus, Secchi depth, chlorophyll-a and algal bloom frequencies. These response curves were created manipulating inflow concentrations by various percentages from the long term average and holding flows constant. The results of this analysis are shown in Figures 7 through 10.

Discussion

Analyses of the modeling results indicate that there is considerable variation in loading from agricultural lands in the watershed, with 10 year mean estimates ranging from 0.84 kg/ha for agricultural lands in sub basin 5 to 0.23 kg/ha for agricultural lands in sub basin 1 (Figure 11). In looking at individual HRUs the variation was even greater, from 1.05 to 0.17 kg/ha (Table 6). Hence, certain sub basins and cropping practices could be targeted initially in the implementation planning where best management practice (BMP) implementation would provide the most “bang for the buck”.

The modeling results also point toward the fact that nutrient export can be significantly reduced through changes in nutrient management and improved tillage practices. Since the basin was primarily modeled using reduced tillage practices the impact of a transition to no-till while significant, was not tremendous in many instances. However, on HRUs with heavier soils and steeper slopes phosphorus export was reduced by over 20% by conversion to no-till, conversely on lighter (A) soils and flatter slopes the reductions were minimal (<5%). On the other hand, reduction soil test phosphorus resulted in a greater and more uniform reduction in phosphorus export (24-41% reduction). Therefore, it appears that phosphorus based nutrient management should be an important member of the suite of BMPs that could be implemented in the Little Lake Wissota watershed. Overall predicted impacts of the modeled scenarios are shown in Figure 12.

Based on the BATHTUB modeling and lake monitoring of Little Lake Wissota it appears that the lake should respond fairly quickly to reductions in watershed loading as internal loading appears minimal. While it may be unlikely that implementation of watershed BMPs will eliminate nuisance algal blooms, implementation should be able to significantly reduce the frequency and intensity of blooms.

Throughout the course of this project every attempt was made to accurately simulate natural processes. However, given the limitations inherent to modeling, such as the accuracy of data inputs and various assumptions made, consideration should be given to evaluating absolute and relative loads. As an analytical tool, the SWAT model performed as desired to evaluate the relative impact of the various scenarios and target "source areas" to help prioritize the implementation of management activities. Likewise the BATHTUB model performed as desired to evaluate the relative impact of reductions in long term phosphorus loading.

Figure 1. Map of the Little Lake Wissota watershed and sub basins

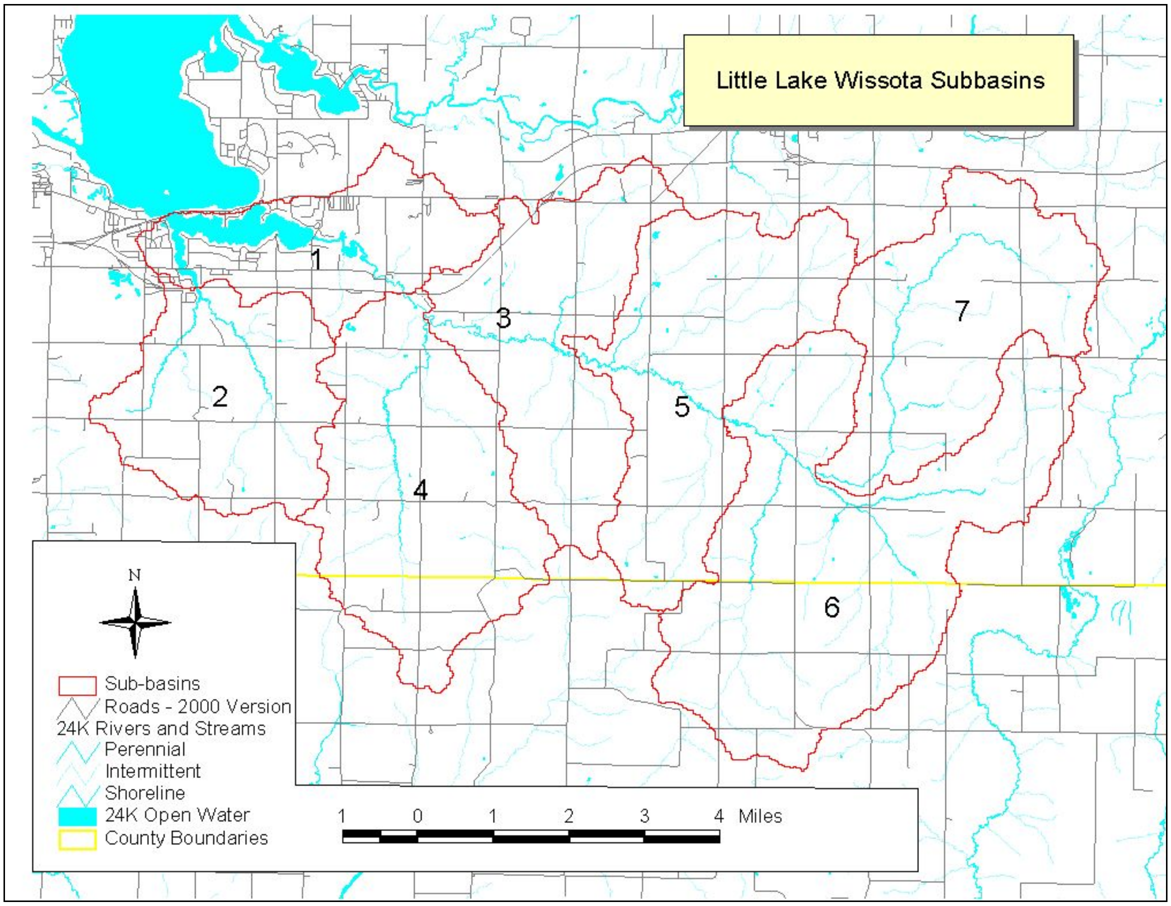

Table 1. Summary of land area in the Little Lake Wissota sub basins.

Sub basin no.	Area [acres]	Area [%]
1	3,685	9%
2	5,703	13%
3	4,576	11%
4	5,533	13%
5	6,401	15%
6	6,795	16%
7	10,502	24%
Σ	43,195	

Table 2. Summary of land use within the Little Lake Wissota watershed.

Land Cover	Area [acres]	Area [%]
Pasture	4,427	10%
Water	501	1%
Corn	7,138	17%
Wetlands-Mixed	3,085	7%
Alfalfa	9,084	21%
Forest-Mixed	17,335	40%
Residential-Medium Density	1,624	4%

Table 3. Agricultural crop rotations used in the SWAT model for the Little Lake Wissota watershed.

Rotation -- Dairy 1			
Year	**Crop**	**Tillage**	**Nutrient Additions**
1	Corn Grain	Spring Disk (2 passes), Fall Chisel	Spring 365 kg/ha 46-00-00; Spring 56 kg/ha 6-24-24; Fall Manure 4,000 kg/ha
2	Corn Silage	Spring Disk (2 passes), Fall Chisel	Spring 365 kg/ha 46-00-00; Spring 56 kg/ha 6-24-24; Fall Manure 4,000 kg/ha
3	Oats/Alfalfa	Spring Disk (2 passes)	Spring Manure 4,000 kg/ha; Fall Manure 4,000 kg/ha *
4	Alfalfa	None	Fall Manure 4,000 kg/ha
5	Alfalfa	Fall Moldboard	Fall Manure 4,000 kg/ha
Rotation -- Cash 1			
Year	**Crop**	**Tillage**	**Nutrients Additions**
1	Soybeans	Spring Disk, Fall Chisel	Spring 84 kg/ha 10-20-20
2	Corn Grain	Spring Disk, Fall Chisel	Spring 56 kg/ha 10-20-20; Spring 448 kg/ha 46-00-00
3	Corn Grain	Spring Disk, Fall Chisel	Spring 56 kg/ha 10-20-20; Spring 448 kg/ha 46-00-00
Rotation -- Cash 2			
Year	**Crop**	**Tillage**	**Nutrients Additions**
1	Soybeans	Spring Disk, Fall Chisel	Spring 84 kg/ha 10-20-20
2	Corn Grain	Spring Disk, Fall Chisel	Spring 56 kg/ha 10-20-20; Spring 448 kg/ha 46-00-00

Table 4. Summary of crop rotation distribution among sub basins in the Little Lake Wissota watershed.

Sub basin #	HRU#	HRU Designation	Area [acres]	Soil Class	Rotation
1	3	Corn-->CORN/WI048	475	A	Cash 2
2	12	Corn-->CORN/WI048	436	A	Cash 1
2	13	Corn-->CORN/WI049	309	D	Cash 1
2	16	Alfalfa-->ALFA/WI048	602	A	Cash 2
2	17	Alfalfa-->ALFA/WI049	815	D	Cash 2
3	25	Corn-->CORN/WI043	207	B	Dairy 1
3	26	Corn-->CORN/WI048	679	A	Cash 1
3	27	Corn-->CORN/WI056	136	B	Cash 1
3	30	Alfalfa-->ALFA/WI043	135	B	Dairy 1
3	31	Alfalfa-->ALFA/WI048	340	A	Cash 2
3	32	Alfalfa-->ALFA/WI056	187	B	Cash 1
4	41	Corn-->CORN/WI048	567	A	Cash 2
4	42	Corn-->CORN/WI049	227	D	Cash 1
4	43	Corn-->CORN/WI056	591	B	Dairy 1
4	46	Alfalfa-->ALFA/WI048	138	A	Cash 2
4	47	Alfalfa-->ALFA/WI049	352	D	Cash 2
4	48	Alfalfa-->ALFA/WI056	823	B	Cash 2
5	57	Corn-->CORN/WI043	809	B	Cash 1
5	58	Corn-->CORN/WI048	388	A	Dairy 1
5	61	Alfalfa-->ALFA/WI043	1379	B	Cash 2
5	62	Alfalfa-->ALFA/WI048	553	A	Cash 2
6	70	Corn-->CORN/WI043	894	B	Dairy 1
6	71	Corn-->CORN/WI050	520	B	Cash 1
6	74	Alfalfa-->ALFA/WI043	1191	B	Dairy 1
6	75	Alfalfa-->ALFA/WI050	1024	B	Dairy 1
7	81	Corn-->CORN/WI043	899	B	Dairy 1
7	84	Alfalfa-->ALFA/WI043	1460	B	Dairy 1

Figure 2. Comparison of observed and model predicted stream flows in Paint Creek at CTH K.

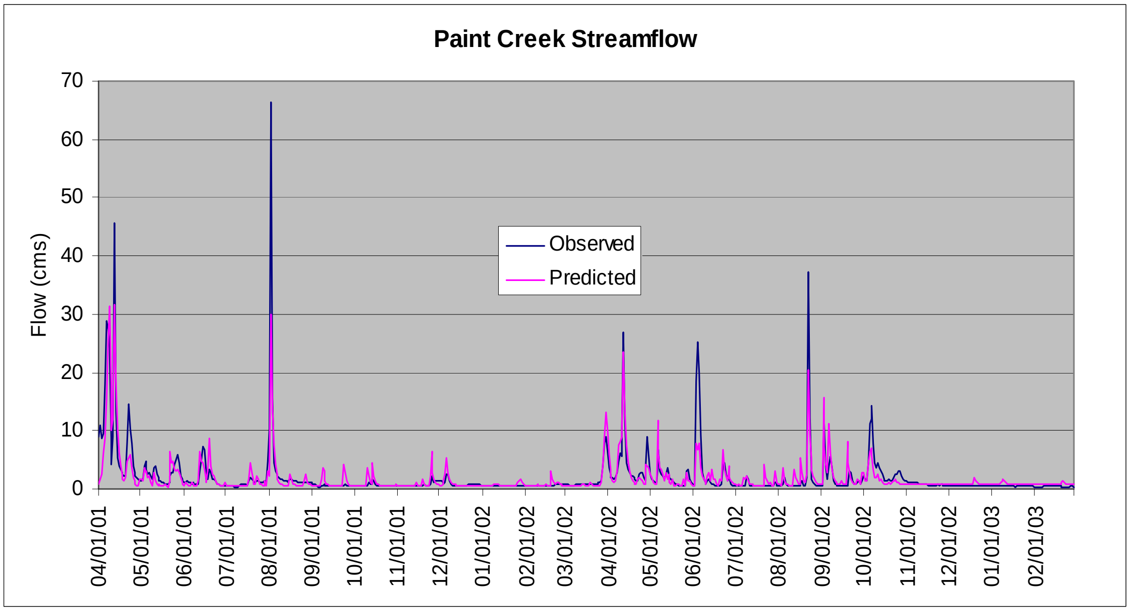

Figure 3. Comparison of observed and model predicted total phosphorus loads for Paint Creek at CTH K.

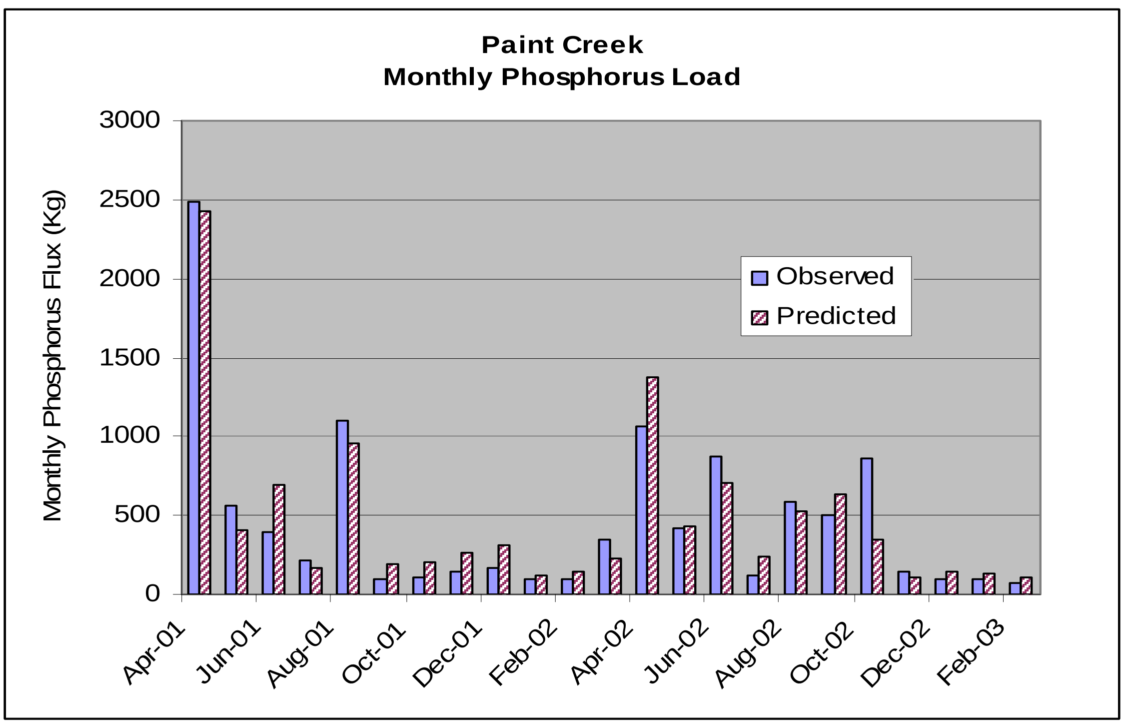

Figure 4. Comparison of observed and model predicted suspended sediment loads for Paint Creek at CTH K.

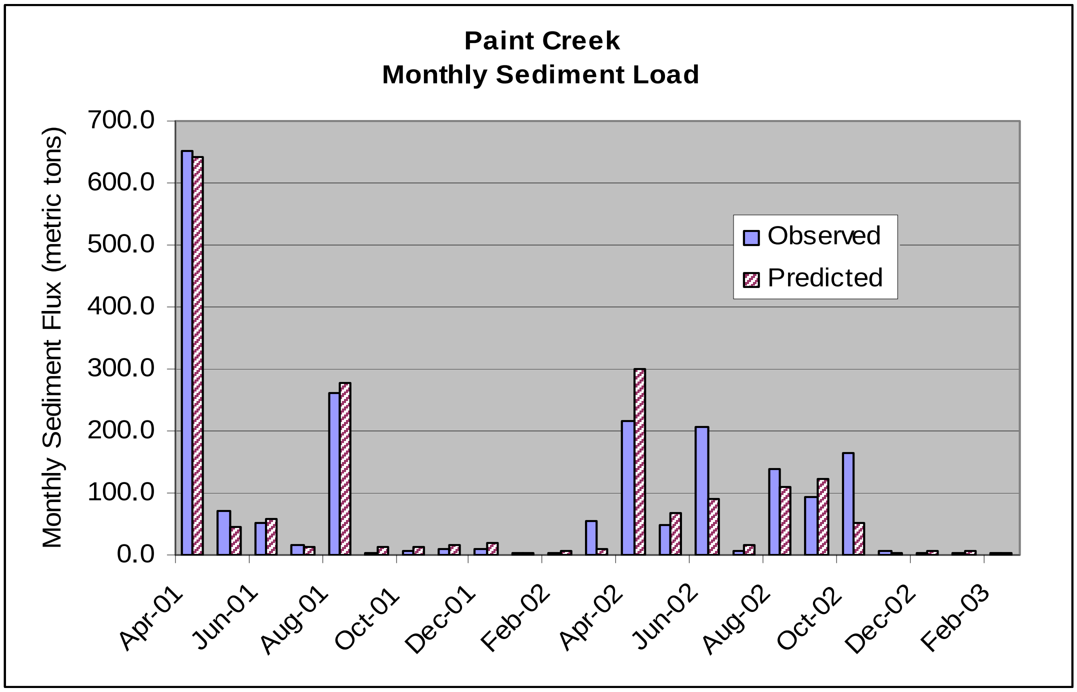

Table 5. Calibration statistics for the SWAT model used in the Little Lake Wissota TMDL.

	Daily Flow		
Measure	Calibration Time Period	Validation Time Period	Whole Period of Record
% Difference for Period of Record	-1%	-8%	-5%
Nash-Sutcliff Coefficient of Efficiency	0.68	0.72	0.71
R^2	0.69	0.75	0.73
	Monthly Flow		
Measure	Calibration Time Period	Validation Time Period	Whole Period of Record
% Difference for Period of Record	-1%	-8%	-5%
Nash-Sutcliff Coefficient of Efficiency	0.80	0.91	0.88
R^2	0.79	0.97	0.93
	Monthly Sediment		
Measure	Calibration Time Period	Validation Time Period	Whole Period of Record
% Difference for Period of Record	-17%	2%	-7%
Nash-Sutcliff Coefficient of Efficiency	0.80	0.91	0.88
R^2	0.79	0.97	0.93
	Monthly Phosphorus		
Measure	Calibration Time Period	Validation Time Period	Whole Period of Record
% Difference for Period of Record	-4%	8%	2%
Nash-Sutcliff Coefficient of Efficiency	0.80	0.91	0.88
R^2	0.79	0.97	0.93

Figure 5. Little Lake Wissota BATHTUB Model Results for Total Phosphorus.

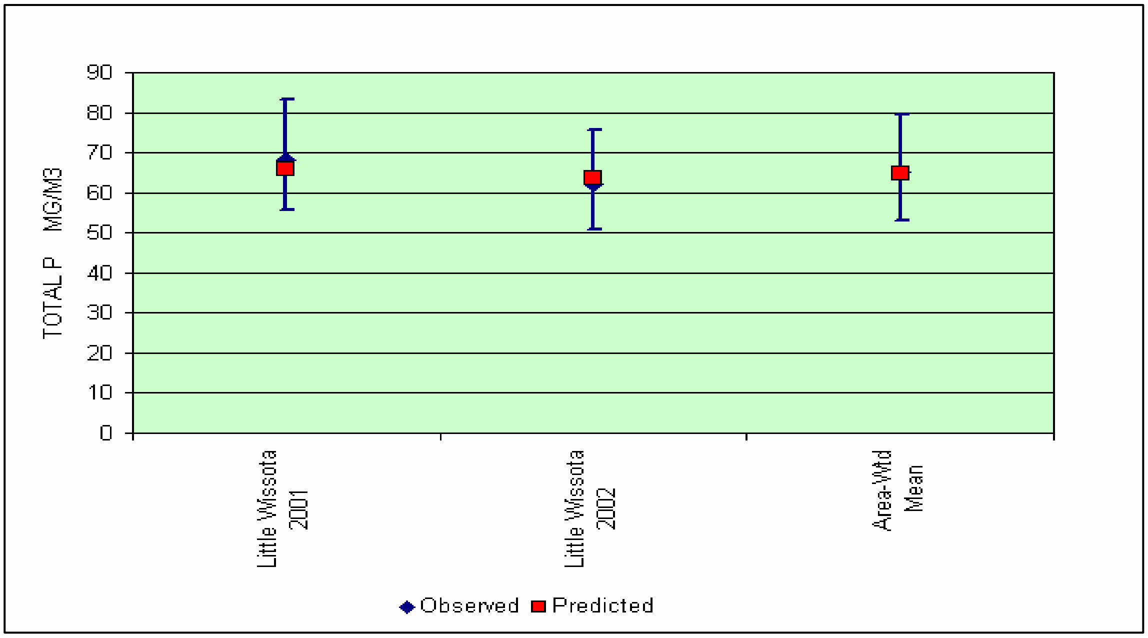

Figure 6. Little Lake Wissota BATHTUB Model Results for Chlorophyll-a.

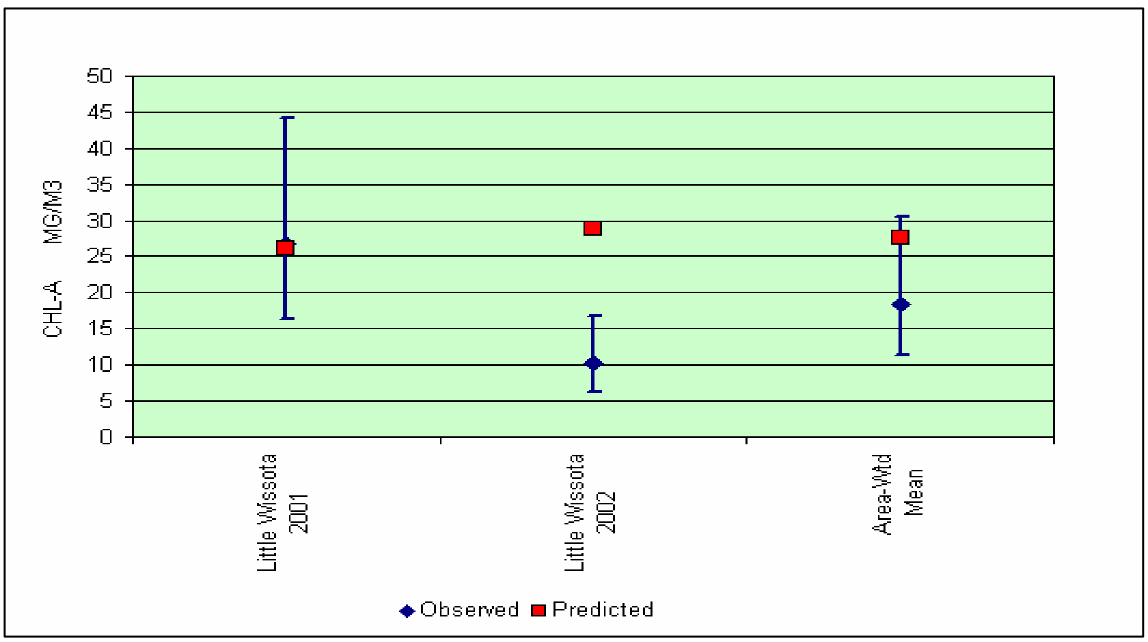

Figure 7. BATHTUB Predicted Total Phosphorus Response Curve for Little Lake Wissota.

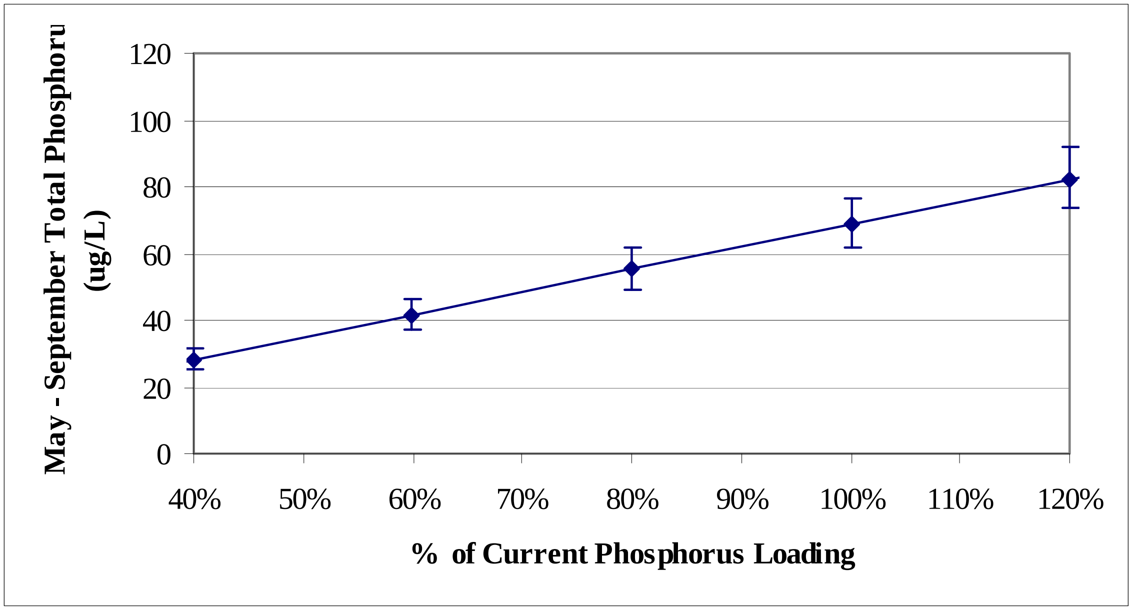

Figure 8. BATHTUB Predicted Secchi Depth Response Curve for Little Lake Wissota.

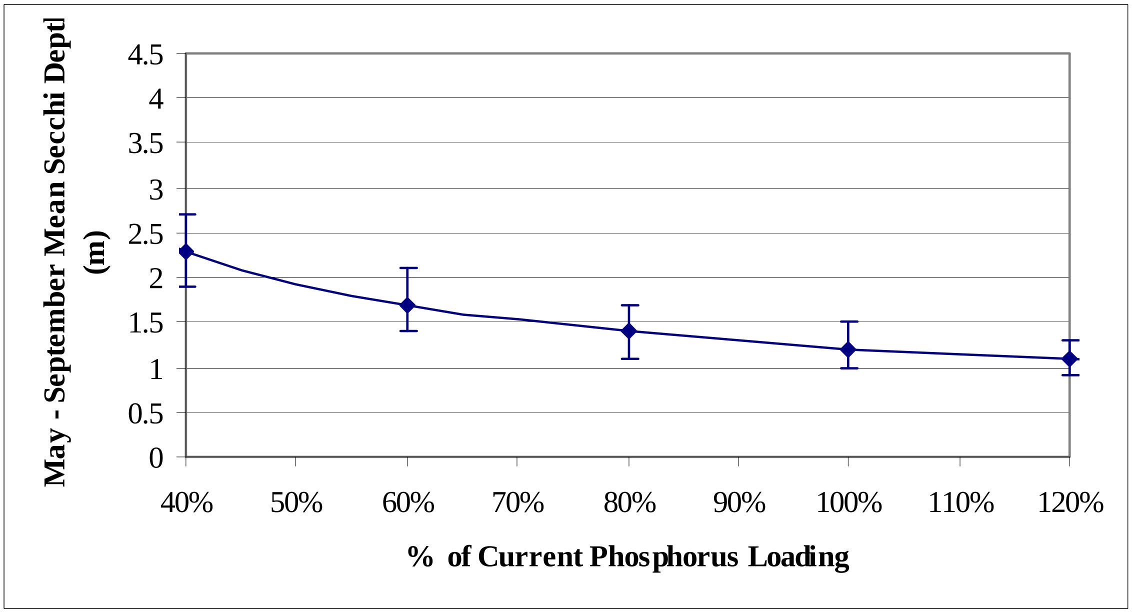

Figure 9. BATHTUB Predicted Chlorophyll-a Response Curve for Little Lake Wissota.

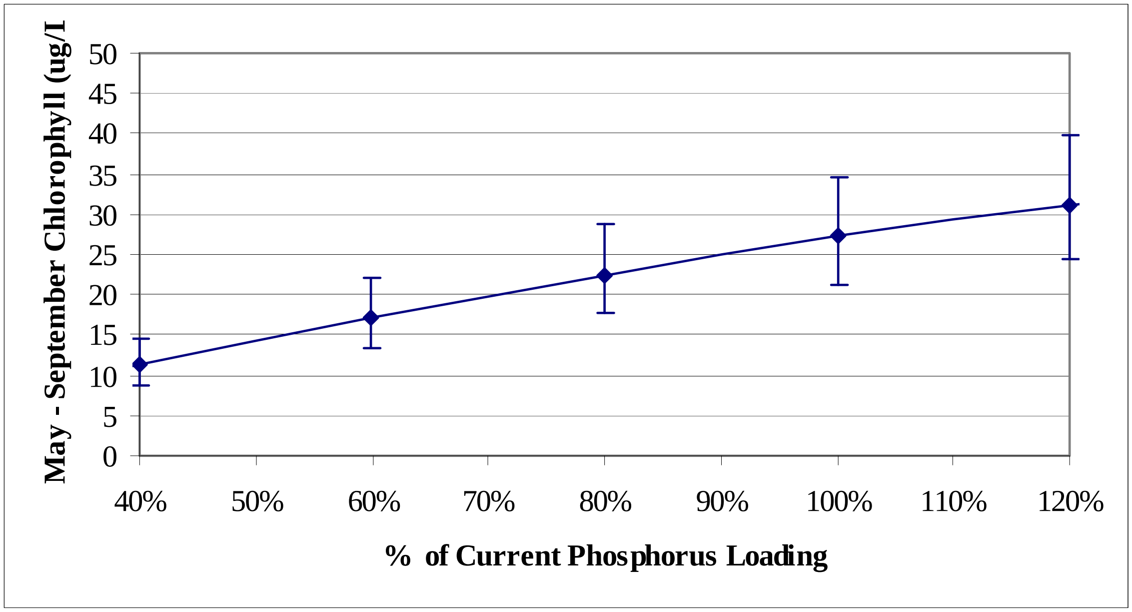

Figure 10. BATHTUB Predicted Algal Bloom Frequency Response Curve for Little Lake Wissota.

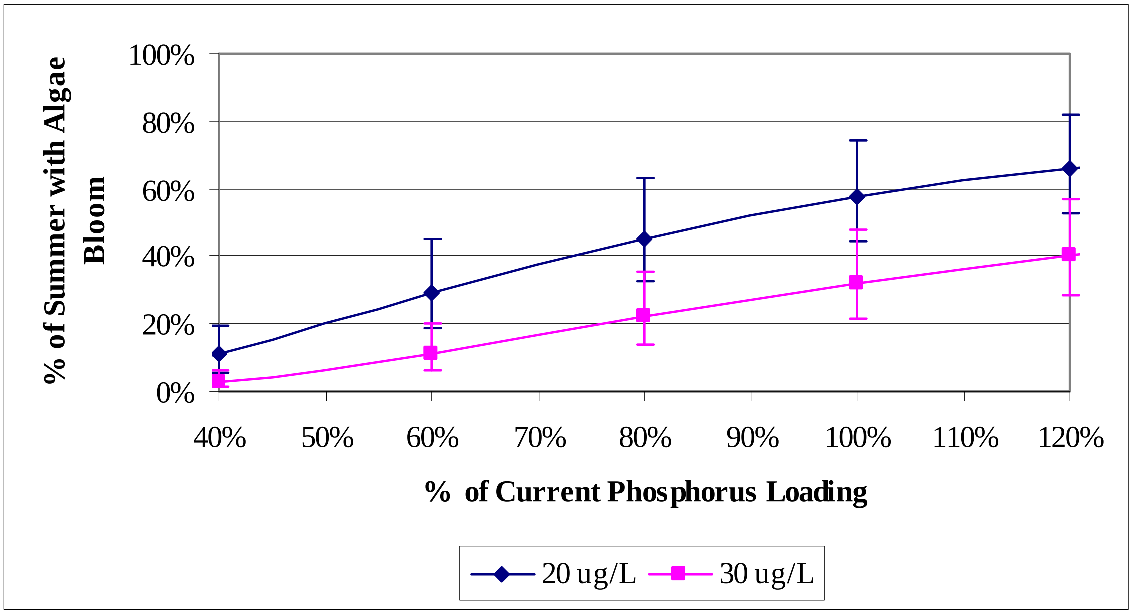

Table 6. Summary of SWAT Predicted 10 Year Mean Phosphorus Export from Agricultural HRUs in the Little Lake Wissota Watershed.

Subbasin	System	Soil Series	Hydrologic Soil Group	Area (km^2)	Phosphorus Export (kg/ha)
6	Cash	Seaton	B	2.106	1.05
2	Cash	Elkmound	D	4.552	0.86
5	Cash	Flambeau	B	8.855	0.79
4	Cash	Elkmound	D	2.340	0.56
6	Dairy	Seaton	B	4.144	0.51
7	Dairy	Flambeau	B	9.548	0.41
2	Cash	Menahga	A	4.199	0.39
6	Dairy	Flambeau	B	8.439	0.38
4	Cash	Ludington	B	3.332	0.34
5	Cash	Menahga	A	2.237	0.33
3	Cash	Ludington	B	1.304	0.27
4	Cash	Menahga	A	2.851	0.26
3	Dairy	Flambeau	B	1.385	0.25
3	Cash	Menahga	A	4.122	0.23
1	Cash	Menahga	A	1.921	0.23
5	Dairy	Menahga	A	1.572	0.21
4	Dairy	Ludington	B	2.393	0.17

Figure 11. SWAT Model Predicted Agricultural Land Phosphorus Yields in the Little Lake Wissota Watershed.

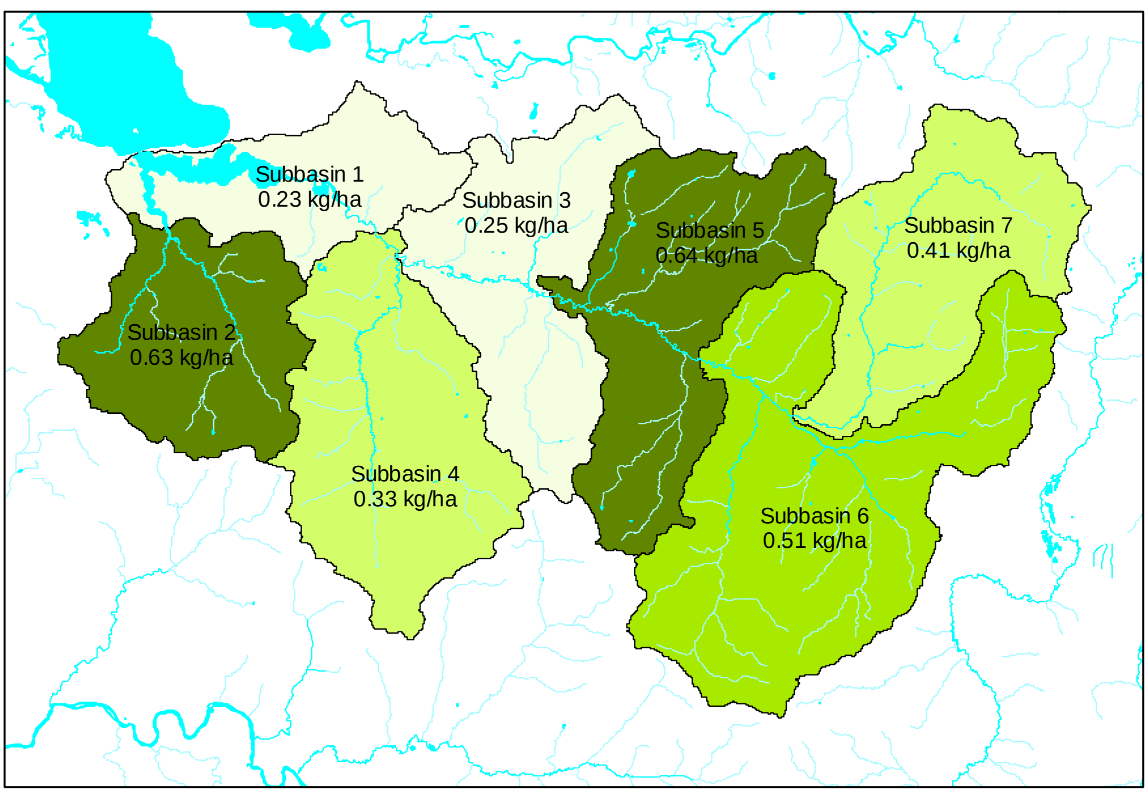

Figure 12. SWAT Model Predicted Reductions in Phosphorus Loading to Little Lake Wissota

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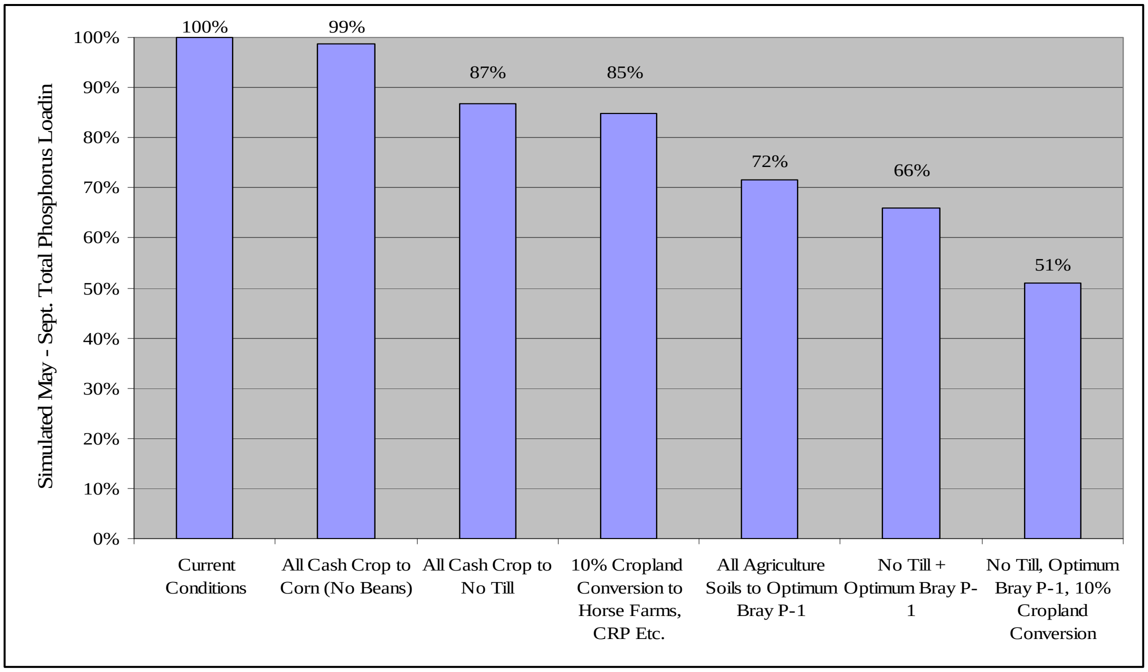


Appendix 3. Relationship between pH and Chlorophyll in Little Lake Wissota

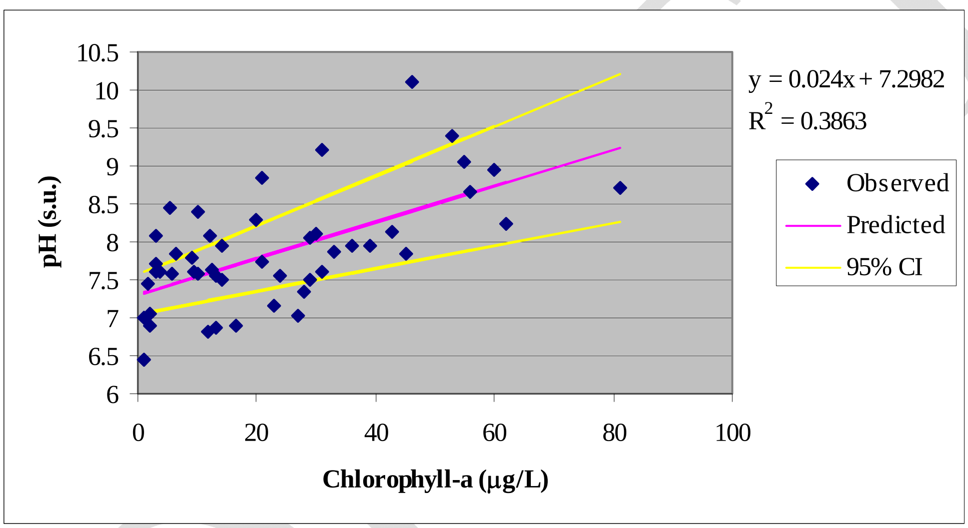
DATE: May 5, 2009

TO: Ken Schreiber -WCR

FROM: Pat Oldenburg - WCR

SUBJECT: Little Lake Wissota pH-Chlorophyll relationship.

In response to EPA comments on the Little Lake Wissota TMDL, I took a further look at the pH data from the Little Lake Wissota and Moon Bay embayments of Lake Wissota. I feel it is appropriate to pool this data as the alkalinities of the two embayments are similar and the alkalinity is a major factor in the pH - chlorophyll relationship.



As evident in the above graph, there is considerable scatter in the data, which is to be expected given all the variables involved in determining the amount of CO_2 in the water column. Some of these variables act on longer time scales such as algal community composition and surface temperature and other variables act at short time scales such as sunlight intensity and surface mixing.

In any event, there is a statistically significant relationship between measured chlorophyll and pH at the 1% level (linear regression). From this regression, the 95% confidence interval of the average pH value for a given chlorophyll value can be estimated. In this instance, the upper 95% confidence interval line intercepts a pH of 9.0 at 45 µg/L chlorophyll. In other words, at a chlorophyll-a concentration of 45 µg/L, there is only a 1 in 20 chance that the mean pH would be greater than 9.0. Note that the prediction interval, which would be the range of expected values for an *individual* pH value would be greater than the confidence interval of the mean. Because water quality conditions vary over a continuum, 100% compliance is theoretically unachievable in any natural system, therefore I propose that rather than looking at the prediction interval for pH

Summary statistics for pH – chlorophyll relationship in Little Lake Wissota:

Regression Statistics	
Multiple R	0.62079
R Square	0.385381
Adjusted R Square	0.372576
Standard Error	0.59006
Observations	50

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	10.47895	10.47895	30.09712	1.51E-06
Residual	48	16.71222	0.348171		
Total	49	27.19117			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 90.0%*	*Upper 90.0%*
Intercept	7.303559	0.128438	56.86453	1.06E-45	7.045317	7.5618	7.08814	7.518978
X Variable 1	0.023921	0.00436	5.486084	1.51E-06	0.015154	0.032688	0.016608	0.031235

we look at the results in terms of confidence interval. Current (2008) department guidance on 303(d) listing does not identify specific thresholds for frequency and duration of exceedances of the pH criterion (or any other criteria for that matter). Therefore I would propose that we consider using best professional judgment in considering what frequency of pH exceedances is acceptable.

If we look at the bloom predictions from the BATHTUB model we can estimate the potential for bloom frequencies and hence exceedances of the pH standard of 9.0. Under the TMDL condition (mean total P = 48 ug/l), we would expect that chlorophyll-a would exceed 45 μg/L about 5% of the time.

Chlorophyll-a (μg/L)	Frequency of Bloom Occurrence under TMDL Condition
>10	79.0%
>20	37.7%
>30	16.7%
>40	7.6%
>50	3.7%
>60	1.9%

In looking at the combination of where the upper 95% confidence interval of the regression line intercepts the pH criterion (45 μg/L) and knowing that we would expect that blooms would infrequently (~5%) exceed this value, we could predict that exceedances of the pH criterion should occur less than 5% of the time.

Alternatively, exceedance frequencies were computed for given ranges of chlorophyll-a based on monitoring in Little Lake Wissota and Moon Bay:

Chlorophyll-a (μg/L)	# of pH/chlorophyll sample pairs	# of pH values over 9.0	Percent Exceedances
Chl-a <10	15	0	0%
10 ≤ Chl-a < 20	11	0	0%
20 ≤ Chl-a < 30	8	0	0%
30 ≤ Chl-a < 40	6	1	17%
40 ≤ Chl-a	9	3	33%

If we then combine this pH exceedance frequency analysis with the bloom frequency analysis, assuming that simple multiplication of the frequency analysis is valid, we can estimate the potential exceedance frequency:

Chlorophyll-a (μg/L)	Frequency of Bloom Occurrence Under TMDL Condition	Percent pH Exceedances @ Chlorophyll Concentration	Estimated pH Exceedance Frequency
20 ≤ Chl-a < 30	83.3%	0%	0.0%
30 ≤ Chl-a < 40	9.1%	17%	1.5%
40 ≤ Chl-a	7.6%	33%	2.5%
		Σ	4.1%

In conclusion, under the TMDL conditions we would expect that pH exceedances should occur less than 5% of the time. The appropriate threshold needs to be addressed through assessment methodology or 303(d) listing/delisting guidance.

Raw data from Little Lake Wissota and Moon Bay (Chlorophyll -a either surface grab or 2 meter integrated sample; pH data taken at 1 m depth):

	Little Lake Wissota		Moon Bay	
Date	Chlorophyll -a (μg/L)	pH (s.u.)	Chlorophyll -a (μg/L)	pH (s.u.)
8-May-89	28	7.35	13	7.55
6-Jun-89	2	6.90	23	7.15
13-Jul-89	60	8.95	45	7.85
15-Aug-89	24	7.55	81	8.70
3-May-01	31	7.61	13	7.78
16-May-01	27	7.03	29	8.05
31-May-01	2.9	7.60	14	7.50
13-Jun-01	29	7.50	2.1	7.06
27-Jun-01	21	8.84	53	9.40
11-Jul-01	55	9.04	56	8.66
24-Jul-01	30	8.11	21	7.75
7-Aug-01	31	9.21	46	10.10
22-Aug-01	14	7.96	36	7.96
5-Sep-01	12	8.09	62	8.25
18-Sep-01	10	8.40	33	7.86
14-May-02	3	7.70	3	8.08
29-May-02	1.08	6.45	8.93	7.80
10-Jun-02	0.98	6.45	1.03	7.01
26-Jun-02	5.33	8.45	1.77	7.45
8-Jul-02	6.33	7.85	19.9	8.30
25-Jul-02	3.75	7.60	5.69	7.58
7-Aug-02	12.3	7.63	9.4	7.60
20-Aug-02	39.1	7.95	42.7	8.12
3-Sep-02	13	6.87	11.9	6.82
16-Sep-02	10	7.59	16.4	6.90