Total Maximum Daily Load
For Algae and Turbidity
Mariposa Lake
Jasper County, Iowa

2004

Iowa Department of Natural Resources
TMDL & Water Quality Assessment Section

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1. Executive Summary

Table 1. Mariposa Lake Summary

Waterbody Name:	Mariposa Lake
County:	Jasper
Use Designation Class:	A1 (primary contact recreation) B(LW) (aquatic life)
Major River Basin:	Skunk River Basin
Pollutant:	Phosphorus
Pollutant Sources:	Nonpoint, internal recycle, atmospheric (background)
Impaired Use(s):	A1 (primary contact recreation)
2002 303d Priority:	Medium
Watershed Area:	580 acres
Lake Area:	18 acres
Lake Volume:	135 acre-ft
Detention Time:	0.3 years
TSI Target(s):	Total Phosphorus less than 70; Chlorophyll a less than 65; Secchi Depth less than 65
Total Phosphorus Load Capacity (TMDL):	330 pounds per year
Existing Total Phosphorus Load:	1,760 pounds per year
Load Reduction to Achieve TMDL:	1,430 pounds per year
Margin of Safety:	30 pounds per year
Wasteload Allocation:	0
Load Allocation:	300 pounds per year

The Federal Clean Water Act requires the Iowa Department of Natural Resources (IDNR) to develop a total maximum daily load (TMDL) for waters that have been identified on the state's 303(d) list as impaired by a pollutant. Mariposa Lake has been identified as impaired by algae and turbidity. The purpose of these TMDLs for Mariposa Lake is to calculate the maximum allowable nutrient loading for the lake associated with algae and turbidity levels that will meet water quality standards.

This document consists of TMDLs for algae and turbidity designed to provide Mariposa Lake water quality that fully supports its designated uses. Phosphorus, which is related through the Trophic State Index (TSI) to chlorophyll and Secchi depth, is targeted to address the algae and turbidity impairments.

Phasing TMDLs is an iterative approach to managing water quality that becomes necessary when the origin, nature and sources of water quality impairments are not well understood. In Phase 1, the waterbody load capacity, existing pollutant load in excess of this capacity, and the source load allocations are estimated based on the limited information available. A monitoring plan will be used to determine if prescribed load reductions result in attainment of water quality standards and whether or not the target values are sufficient to meet designated uses. Monitoring activities may include routine sampling and analysis, biological assessment, fisheries studies, and watershed and/or waterbody modeling.

Section 5.0 of this TMDL includes a description of planned monitoring. The TMDL will have two phases. Phase 1 will consist of setting specific and quantifiable targets for total phosphorus, algal biomass and Secchi depth expressed as Carlson's Trophic State

Index (TSI). Phase 2 will consist of implementing the monitoring plan, evaluating collected data, and readjusting target values if needed.
Monitoring is essential to all TMDLs in order to:

- Assess the future beneficial use status;
- Determine if the water quality is improving, degrading or remaining status quo;
- Evaluate the effectiveness of implemented best management practices.

The additional data collected will be used to determine if the implemented TMDL and watershed management plan have been or are effective in addressing the identified water quality impairments. The data and information can also be used to determine if the TMDLs have accurately identified the required components (i.e. loading/assimilative capacity, load allocations, in-lake response to pollutant loads, etc.) and if revisions are appropriate.

This TMDL has been prepared in compliance with the current regulations for TMDL development that were promulgated in 1992 as 40 CFR Part 130.7. These regulations and consequent TMDL development are summarized below:

1. **Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:** Mariposa Lake, S32, T81N, R18W, 6 miles northeast of Newton, Jasper County.

2. **Identification of the pollutant and applicable water quality standards:** The pollutants causing the water quality impairments are algae and turbidity associated with excessive nutrient (phosphorus) loading. Designated uses for Mariposa Lake are Primary Contact Recreation (Class A1) and Aquatic Life (Class B(LW)). Excess nutrient loading has impaired aesthetic and aquatic life water quality narrative criteria (567 IAC 61.3(2)) and hindered the designated uses.

3. **Quantification of the pollutant load that may be present in the waterbody and still allow attainment and maintenance of water quality standards:** The Phase 1 target of this TMDL is a Carlson's Trophic State Index (TSI) of less than 70 for total phosphorus, and TSI values of less than 65 for both chlorophyll a and Secchi depth. These values are equivalent to total phosphorus and chlorophyll concentrations of 96 and 33 ug/L, respectively, and a Secchi depth of 0.7 meters.

4. **Quantification of the amount or degree by which the current pollutant load in the waterbody, including the pollutant from upstream sources that is being accounted for as background loading, deviates from the pollutant load needed to attain and maintain water quality standards:** The existing mean values for Secchi depth, chlorophyll a and total phosphorus based on 2000 - 2003 sampling are 0.4 meters, 66 ug/L and 242 ug/L, respectively. An in-lake increase in Secchi transparency of 75% and in-lake reductions of 50% for chlorophyll a and 60% for total phosphorus are required to achieve and maintain lake water quality goals and protect for beneficial uses. The estimated existing annual total phosphorus load to Mariposa Lake is 1,760 pounds per year. The total phosphorus loading capacity for the lake is 330 pounds per year based on

lake response modeling. An average annual load reduction of 1,430 pounds per year is required.

5. **Identification of pollution source categories:** Nonpoint and atmospheric deposition (background) sources and internal recycling of phosphorus from the lake bottom sediments are identified as the cause of impairments to Mariposa Lake.

6. **Wasteload allocations for pollutants from point sources:** No significant point sources have been identified in the Mariposa Lake watershed. Therefore, the wasteload allocation will be set at zero.

7. **Load allocations for pollutants from nonpoint sources:** The total phosphorus load allocation for the nonpoint sources and internal recycle is 300 pounds per year including 10 pounds per year attributable to atmospheric deposition.

8. **A margin of safety:** An explicit numerical MOS of 30 pounds per year (10% of the calculated allowable phosphorus load) has been included to ensure that the load allocation will result in attainment of water quality targets.

9. **Consideration of seasonal variation:** This TMDL was developed based on the annual phosphorus loading that will result in attainment of TSI targets for the growing season (May through September).

10. **Allowance for reasonably foreseeable increases in pollutant loads:** An allowance for increased phosphorus loading was not included in this TMDL. Significant changes in the Mariposa Lake watershed landuse are unlikely. The shoreline of the lake and a substantial portion of the watershed are part of Mariposa County Park. Most of the remainder of the watershed landuse is dedicated to agricultural production. The addition or deletion of animal feeding operations within the small watershed could significantly increase or decrease nutrient loading. Future increases in the rough fish population or intensification of activities that add to lake turbulence could increase re-suspension of settled solids and internal phosphorus loading. Such events cannot be predicted and at this time conditions are not expected to change, therefore, an allowance for their potential occurrence was not included in the TMDL.

11. **Implementation plan:** Although not required by the current regulations, an implementation plan is outlined in the report.

2. Mariposa Lake, Description and History

2.1 The Lake

Mariposa Lake was constructed in 1952 and is located in central Iowa, 6 miles northeast of Newton. Approximately 17,000 visitors per year use Mariposa Lake Park for fishing, picnicking and hiking. In addition, two campgrounds provide areas for camping near the lake.

Table 2. Mariposa Lake Features

Waterbody Name:	Mariposa Lake (a.k.a. Ken Wolfe Lake)
Hydrologic Unit Code:	HUC10 0708010601
IDNR Waterbody ID:	IA 03-NSK-00350-L
Location:	Section 32 T81N R18W
Latitude:	41° 47' N
Longitude:	92° 58' W
Water Quality Standards Designated Uses:	1. Primary Contact Recreation (A1) 2. Aquatic Life Support (B(LW))
Tributaries:	Unnamed Creek (1), Unnamed Ponds (2)
Receiving Waterbody:	Unnamed Creek to Alloway Creek
Lake Surface Area:	18 acres
Maximum Depth:	16 feet
Mean Depth:	7.3 feet
Volume:	135 acre-feet
Length of Shoreline:	4,900 feet
Watershed Area:	580 acres
Watershed/Lake Area Ratio:	31:1
Estimated Detention Time:	0.3 years

Morphometry

Mariposa Lake has a mean depth of 7.3 feet and a maximum depth of 16 feet. The lake has a surface area of 18 acres and a storage volume of approximately 135 acre-feet. Temperature and dissolved oxygen sampling indicate that temperature and oxygen levels in Mariposa Lake decrease with increased depth through much of the growing season.

Hydrology

Mariposa Lake is fed by a small, unnamed creek. Mariposa Lake feeds into a tributary of Alloway Creek, a tributary of the North Skunk River. The estimated annual average detention time for Mariposa Lake is 0.3 years based on outflow. The methodology and calculations used to determine the detention time are shown in Appendix A.

2.2 The Watershed

The Mariposa Lake watershed has an area of approximately 580 acres and has a watershed to lake ratio of 31:1. The 2002 landuses and associated areas for the watershed were obtained from satellite imagery and are shown in Table 3.

Table 3. 2002 Landuse in Lake Mariposa watershed.

Landuse	Area in Acres	Percent of Total Area
Row Crop	320	55.2
Grassland	130	22.4
Forest	80	13.8
Alfalfa	20	3.4
Other	30	5.2
Total	580	100

A more recent watershed assessment was completed in May 2004 by the Jasper County Soil and Water Conservation District to determine current landuses and associated cropping practice (CP) factors for use in calculating soil loss and delivery. The 2004 assessment shows that the major landuse in the watershed is row crop, with 378 acres (66%) in either corn or soybeans. Mariposa County Park, which is owned and managed by the Jasper County Conservation Board, occupies 125 acres (22%) around the lake and has various ground cover types, including prairie, timber, and mowed lawn near the camping and picnicking areas. Other landuses in the 2004 watershed assessment include permanent grass, pasture, farmsteads and roads.

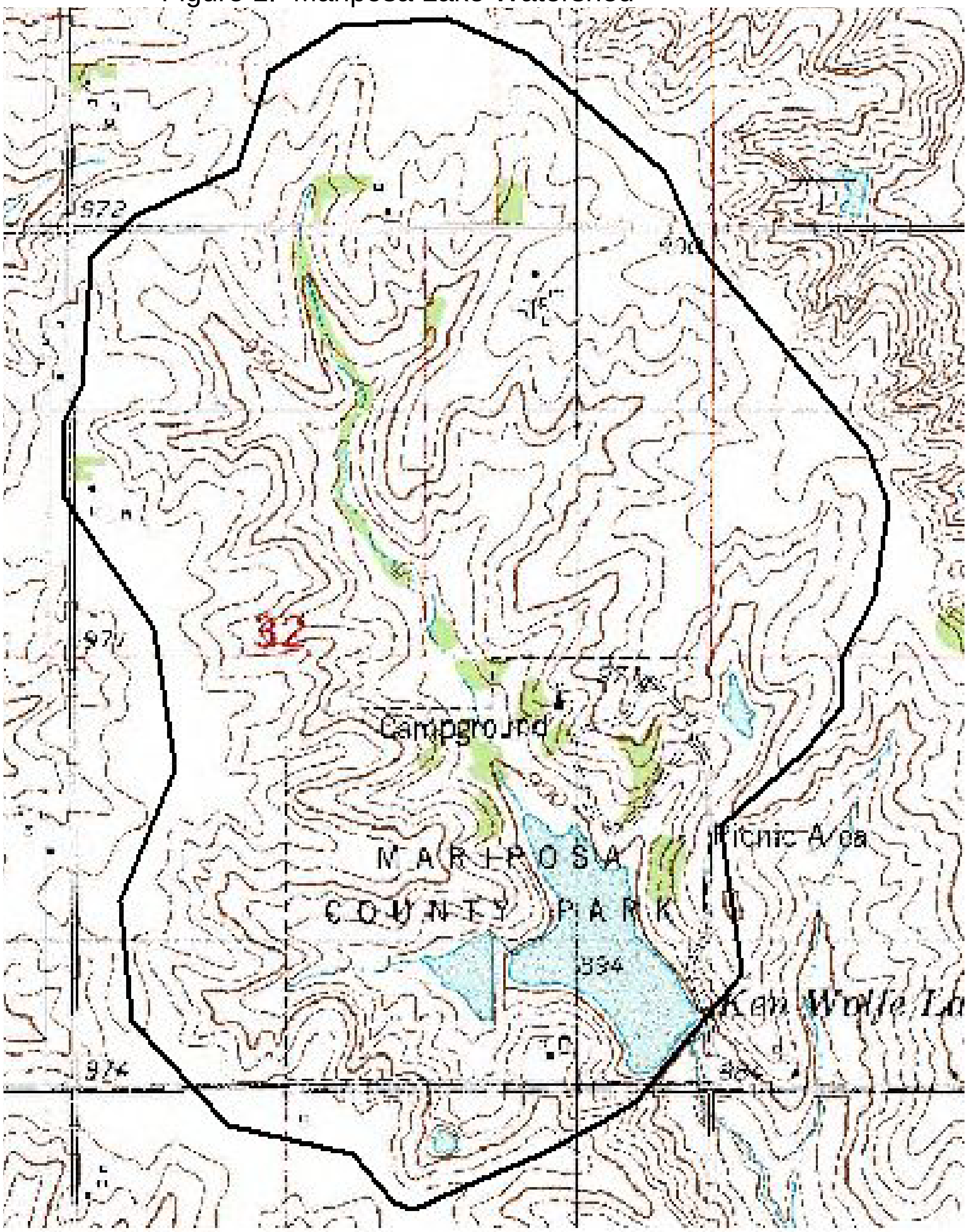
One open feedlot is present in the upper portion of the watershed. Based on typical animal space requirements for feeder cattle, the feedlot has a potential capacity of 265 beef animal units. Open feedlots are unroofed or partially roofed animal feeding operations in which no crop, vegetation, or forage growth or residue cover is maintained during the period that animals are confined in the operation. Runoff from open feedlots can deliver substantial quantities of nutrients to a waterbody dependent upon factors such as proximity to a water surface, number and type of livestock and manure controls.

There are two ponds in the Mariposa Lake watershed, one on the east drainage area of the lake constructed in 1974, and one on the west drainage area constructed in 1972.

The watershed is gently to steeply sloped (2-25%). The Fayette, Lindley, Tama, and Downs soils in the watershed are primarily forest-derived.

2002 and 2004 landuse maps are shown in Appendix D.

Figure 1. Mariposa Lake Watershed



3. TMDL for Algae and Turbidity

3.1 Problem Identification

Impaired Beneficial Uses and Applicable Water Quality Standards

The Iowa Water Quality Standards (8) list the designated uses for Mariposa Lake as Primary Contact Recreational Use (Class A1) and Aquatic Life (Class B(LW)). In 1998, Mariposa Lake was included on the impaired water list as recommended by the DNR Fisheries and Water Quality Bureaus due to elevated levels of nutrients and siltation. The siltation impairment was re-evaluated in 2002, but the lake remains on the 303(d) list due to algae and turbidity impairments. The Iowa Water Quality Standards (8) do not include numeric criteria for algae or turbidity but they do include narrative standards that are applicable to Mariposa Lake stating that "such waters shall be free from materials attributable to wastewater discharges or agricultural practices producing objectionable color, odor, or other aesthetically objectionable conditions" (8). Therefore, the impaired water quality assessment was made based on measured chlorophyll and transparency values indicating algae and turbidity conditions that are producing objectionable color, odor, or other aesthetically objectionable conditions

In 2002, the Class A designated use was assessed as "partially supported" after several years in which the use was categorized as "not assessed" due to lack of current information. The Class B use has been listed as "partially supported" since 1992. This assessment was based on the 2000-01 ISU lake survey, an ISU report on lake phytoplankton, and information from the DNR Fisheries Bureau. Data from these sources suggest impairments to the Class A (primary contact) uses through presence of aesthetically objectionable blooms of algae and presence of nuisance algal species (e.g., bluegreen algae). The hyper-eutrophic conditions at this lake, along with information from the IDNR Fisheries Bureau, cause the Class B(LW) aquatic life uses to be assessed as "partially supported".

Data Sources

Water quality surveys have been conducted on Mariposa Lake in 1979, 1990, and 2000-03 (1,2,3,4,5,20). Data from these surveys is available in Appendix B.

Iowa State University Lake Study data from 2000 to 2003 were evaluated for this TMDL. This study is scheduled to run through 2004 and approximates a sampling scheme used by Roger Bachman in earlier Iowa lake studies. Samples are collected three times during the early, middle and late summer. A number of water quality parameters are measured including Secchi disk depth, phosphorus series, nitrogen series, TSS, and VSS.

Interpreting Mariposa Lake Water Quality Data

Based on mean values from ISU sampling during 2000 - 2003, the ratio of total nitrogen to total phosphorus for this lake is 12:1. Data on inorganic suspended solids from the ISU sampling suggest that this lake may be subject to occasional episodes of high levels of non-algal turbidity. The median level of inorganic suspended solids in the 130 lakes sampled for the ISU lake survey in 2000 and 2001 was 5.27 mg/L. The median level of inorganic suspended solids at Mariposa Lake during the same time period was 10.8 mg/l, the 34th highest of the 130 lakes.

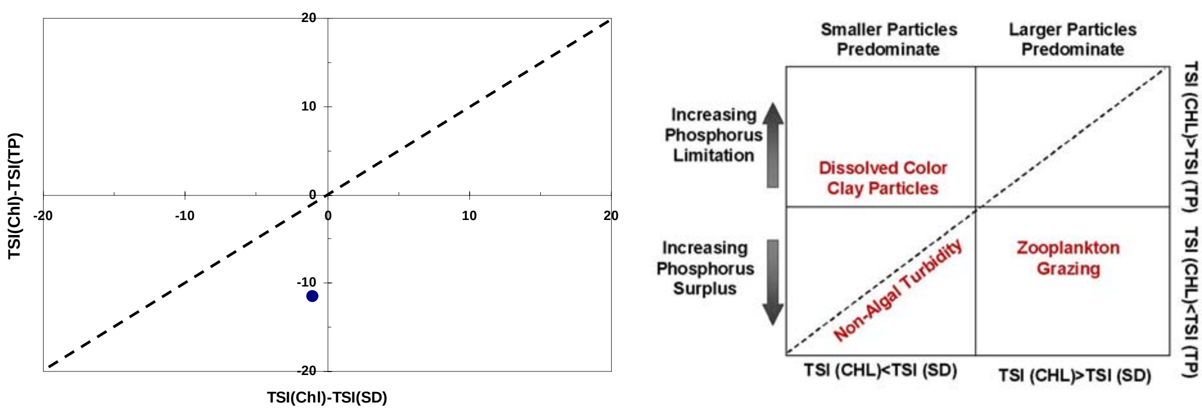
Comparisons of the TSI values for chlorophyll, Secchi depth and total phosphorus for all available in-lake sampling indicate possible limitation of algal growth attributable to light attenuation by elevated levels of inorganic suspended solids (see Figure 2 and Appendix C).

TSI values for 2000 - 2003 monitoring data are shown in Table 4. TSI values for all historical monitoring data and an explanation of Carlson's Trophic State Index are given in Appendix C.

Table 4. Mariposa Lake TSI Values (3,4,5,20)

Sample Date	TSI (SD)	TSI (CHL)	TSI (TP)
6/26/2000	73	82	79
7/24/2000	83	40	98
8/13/2000	77	43	95
5/29/2001	70	56	74
6/25/2001	65	75	62
7/30/2001	73	75	83
6/3/2002	73	70	73
7/8/2002	83	80	81
8/5/2002	77	72	80
6/2/2003	63	67	69
7/7/2003	70	--	73
8/4/2003	83	64	89

Figure 2. Mariposa Lake 2000 - 2003 Mean TSI Multivariate Comparison Plot (22)



Data from ISU phytoplankton sampling in 2000 and 2001 indicate that bluegreen algae (Cyanophyta) tend to dominate the summertime phytoplankton community of Mariposa Lake. The number of available samples (three per summer) is insufficient to fully characterize the frequency of algal blooms. However, the sampling does indicate a high level of bluegreen wet mass relative to other Iowa lakes. The 2000 average summer wet mass of bluegreen algae at this lake (190 mg/l) was the sixth highest of 131 lakes sampled. The 2001 average summer wet mass of bluegreen algae declined to 15 mg/L but still comprised approximately 50% and 99% of the total phytoplankton community in May and July samples, respectively. Sampling for cyanobacterial toxins has not been conducted at Mariposa Lake. 2000 and 2001 phytoplankton sampling results are given in Appendix B.

Potential Pollution Sources

Water quality in Mariposa Lake is influenced only by watershed nonpoint sources and internal recycling of pollutants from bottom sediments. There are no point source discharges in the watershed.

Natural Background Conditions

For the phosphorus load attributable to atmospheric deposition directly on the lake surface, the annual average concentration of phosphorus in precipitation was assumed to be 0.05 mg/L based on a review of available literature (11,17,18,19) and the default values used in the EUTROMOD and WILMS modeling programs. Contributions of phosphorus attributable to dry atmospheric deposition were not separated from the direct precipitation load. Potential phosphorus contributions from groundwater influx were not separated from the total nonpoint source load.

3.2 TMDL Target

The Phase 1 targets for this TMDL is a mean TSI value of less than 70 for total phosphorus, and mean TSI values of less than 65 for both chlorophyll and Secchi depth. These values are equivalent to total phosphorus and chlorophyll concentrations of 96 and 33 ug/L respectively, and a Secchi depth of 0.7 meters.

Table 5. Mariposa Lake Existing vs. Target TSI Values

Parameter	**2000-2003 Mean TSI**	**2000-2003 Mean Value**	**Target TSI**	**Target Value**	**Minimum In-Lake Increase or Reduction Required**
Chlorophyll	72	66 ug/L	<65	<33 ug/L	50% Reduction
Secchi Depth	73	0.4 meters	<65	>0.7 meters	75% Increase in transparency
Total Phosphorus	83	242 ug/L	<70	<96 ug/L	60% Reduction

A second target is the attainment of aquatic life uses as measured by fishery and biological assessments. The aquatic life target for this TMDL will be achieved when the fishery of Mariposa Lake is determined to be fully supporting the aquatic life uses. This determination will be accomplished through an assessment conducted by the IDNR Fisheries Bureau.

Criteria for Assessing Water Quality Standards Attainment

The State of Iowa does not have numeric water quality criteria for algae or turbidity. The cause of the algae and turbidity impairments is algal blooms caused by excessive nutrient loading to the lake. The nutrient-loading objective is defined by a mean total phosphorus TSI of less than 70, which is related through the Trophic State Index to chlorophyll a and Secchi depth. The TSI is not a standard, but is used as a guideline to relate phosphorus loading to the algal impairment for TMDL development purposes and to describe water quality that will meet Iowa’s narrative water quality standards.

Selection of Environmental Conditions

The critical condition for which the TMDL TSI target values apply is the growing season (May through September). It is during this period that nuisance algal blooms are prevalent. The existing and target total phosphorus loadings to the lake are expressed as annual averages. The model selected for estimating phosphorus loading to the lake utilizes growing season mean (GSM) in-lake total phosphorus concentrations to calculate an annual average total phosphorus loading.

Modeling Approach

A number of different empirical models that predict annual phosphorus load based on measured in-lake phosphorus concentrations were evaluated. In addition, watershed phosphorus delivery using both export coefficients and an annual loading function model as outlined in Reckhow's EUTROMOD User's Manual (10) was calculated. The results from both approaches were compared to select the best-fit empirical model.

Table 6. Model Results

Model	Predicted Existing Annual Total Phosphorus Load (lbs/yr) for in-lake GSM TP = ANN TP = 242 ug/L, SPO TP = 111 ug/L	Comments
Loading Function	1,910	Reckhow (10); 90% pond trap efficiency
EPA Export	1,060	EPA/5-80-011
WILMS Export	840	"most likely" export coefficients
Reckhow 1991 EUTROMOD Equation	16,900	GSM model
Canfield-Bachmann 1981 Natural Lake	690	GSM model
Canfield-Bachmann 1981 Artificial Lake	1,760	GSM model
Reckhow 1977 Anoxic Lake	320	GSM model
Reckhow 1979 Natural Lake	790	GSM model. P out of range
Reckhow 1977 Oxic Lake (z/Tw < 50 m/yr)	440	GSM model. P out of range
Nurnberg 1984 Oxic Lake	690 (internal load = 0)	Annual model. P out of range
Walker 1977 General Lake	190	SPO model.
Vollenweider 1982 Combined OECD	830	Annual model.
Vollenweider 1982 Shallow Lake	880	Annual model.

Of the empirical models evaluated, the Vollenweider and Canfield-Bachmann Artificial Lake models resulted in values closest to the Loading Function and export estimates while remaining within the parameter ranges used to derive them. Although the Vollenweider Shallow Lake Model gives a result within the range of watershed delivery estimates, this is an annual model that should ideally be used in combination with annual average in-lake phosphorus estimates. The available in-lake phosphorus monitoring data for Mariposa Lake corresponds with the growing season. In addition, the Loading Function Model utilized the current (2004) landuse assessment and should provide a more accurate estimate of phosphorus delivery than either of the export models. The Canfield-Bachmann model predicted value is closest to the Loading Function Model estimate. Therefore, the Canfield-Bachmann Artificial Lake relationship was selected as best-fit empirical model.

The equation for the Canfield-Bachmann Artificial Lake Model is:

$$P = \frac{L}{z\left[0.114\left(L/z\right)^{0.589} + p\right]}$$

where

$P =$ predicted in-lake total phosphorus concentration (ug/L)
$L =$ areal total phosphorus load (mg/m^2)
$z =$ lake mean depth (meters)
$p =$ lake flushing rate (yr^{-1})

The calculations for the existing total phosphorus load to Mariposa Lake are as follows:

$$P = 242(\mu g / L) = \frac{10{,}690(mg/m^2)}{2.2(m)\left[0.114\left(\frac{10{,}690(mg/m^2)}{2.2(m)}\right)^{0.589} + 3.05(yr^{-1})\right]}$$

The calculations for the total phosphorus load capacity are:

$$P = 96(\mu g / L) = \frac{1{,}990(mg/m^2)}{2.2(m)\left[0.114\left(\frac{1{,}990(mg/m^2)}{2.2(m)}\right)^{0.589} + 3.05(yr^{-1})\right]}$$

The annual total phosphorus load is obtained by multiplying the areal load (L) by the lake area in square meters and converting the resulting value from milligrams to pounds.

Waterbody Pollutant Loading Capacity

The chlorophyll a and Secchi depth objectives are related through the Trophic State Index to total phosphorus. The load capacity for this TMDL is the annual amount of phosphorus Mariposa Lake can receive and meet its designated uses. Based on the selected lake response model and a target TSI (TP) value of less than 70, the Phase 1 total phosphorus loading capacity for the lake is 330 pounds per year.

3.3 Pollution Source Assessment

There are two quantified phosphorus sources for Mariposa Lake in this TMDL. The first is the phosphorus load from the watershed areas that drain directly into the lake and the phosphorus recycled from lake sediments. The second source is atmospheric deposition. Note that load contributions from groundwater influx have not been separated from the total nonpoint source loads.

Existing Load

The annual total phosphorus load to Mariposa Lake is estimated to be 1,760 pounds per year based on the selected lake response model. This estimate includes 1,750 pounds per year from a combination of nonpoint sources in the watershed and the internal phosphorus load recycled from the lake bottom sediment as well as an estimated load of 10 pounds per year from atmospheric deposition.

Departure from Load Capacity

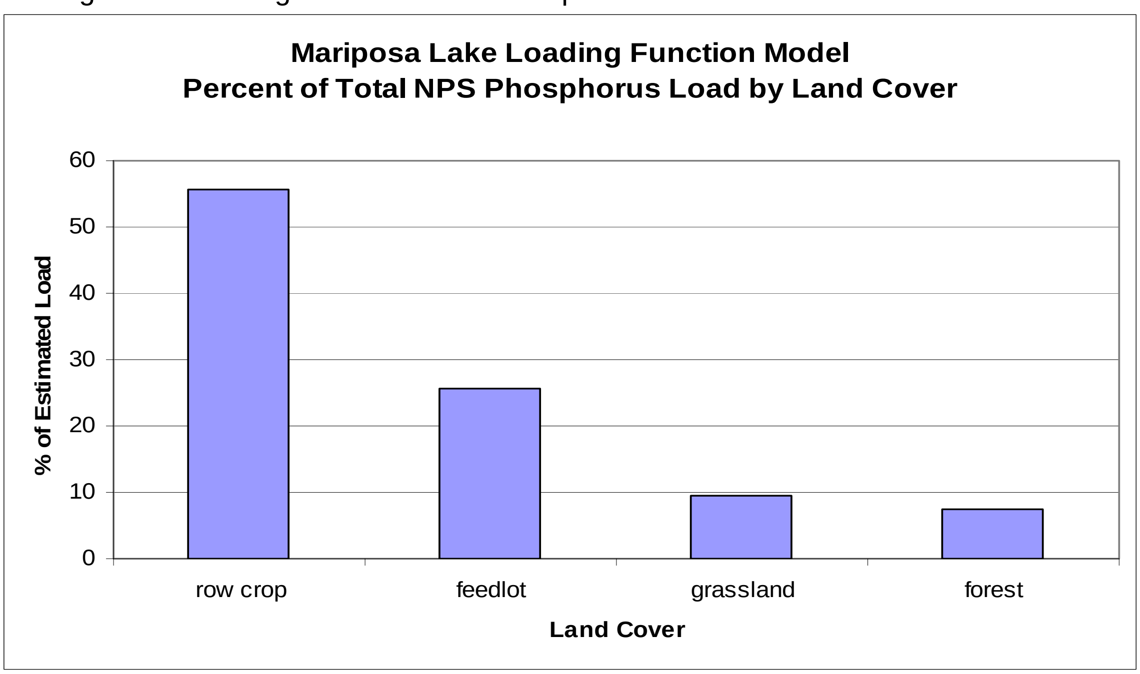
The Phase 1 targeted load capacity for Mariposa Lake is 330 pounds per year or 0.6 pounds per year per acre of watershed area. The estimated existing load is 1,760 pounds per year or 3.0 pounds per year per acre of watershed area if all loads were attributed to the watershed without any internal recycling of phosphorus.

Identification of Pollutant Sources

There are no significant point source discharges in the Mariposa Lake watershed. From the Loading Function Model, the most nonpoint source phosphorus delivered to the lake is from row crop landuse as shown in Figure 3. The Loading Function Model also indicates a significant portion of the total phosphorus load from the single feedlot located in the watershed. The loading from the feedlot was estimated based on an export coefficient of 200 lbs/acre/year (21). Actual loading from the feedlot may vary substantially from this estimate depending on the number of animals, extent of use and other factors. It should be noted that while the Loading Function Model provides estimates of the primary potential pollutant sources, it was used only for comparison purposes to select an empirical lake response model in the development of existing and target total phosphorus loads identified in this TMDL. Existing and target loads were calculated from measured and target in-lake total phosphorus concentrations using the selected lake response model as shown in *Section 3.2, Modeling Approach*.

Other sources of phosphorus capable of being delivered to the water body exist. These sources include septic systems and toilet pits from campsites and individual residences. Manure and waste from wildlife, pets, etc. also contribute to the phosphorus loading. Unfortunately, the potential phosphorus being contributed from these sources is difficult to quantify. These potential sources have been considered, but are deemed smaller contributors or have less impact than the sources previously identified. However, these sources will be evaluated and quantified as required in Phase II of this TMDL.

Figure 3. Loading Function Model Nonpoint Source Contributions



Linkage of Sources to Target

Excluding background sources, the average annual phosphorus load to Mariposa Lake originates entirely from nonpoint sources and internal recycling. To meet the TMDL endpoint, the annual nonpoint source and internal recycling contribution to Mariposa Lake needs to be reduced by 1,430 pounds per year.

3.4 Pollutant Allocation

Wasteload Allocation

Since there are no significant phosphorus point source contributors in the Mariposa Lake watershed, the Waste Load Allocation (WLA) is zero pounds per year.

Load Allocation

The Load Allocation (LA) for this TMDL is 300 pounds per year of total phosphorus distributed as follows:

- 290 pounds per year allocated to the Mariposa Lake watershed and internal recycling of phosphorus from the lake bottom sediments.
- 10 pounds per year allocated to atmospheric deposition.

Margin of Safety (MOS)

An explicit numerical MOS of 30 pounds per year (10% of the calculated allowable phosphorus load) has been included to ensure that the load allocation will result in attainment of water quality targets.

4. Implementation Plan

The following implementation plan is not a required component of a Total Maximum Daily Load but can provide department staff, partners, and watershed stakeholders with a strategy for improving Mariposa Lake water quality.

If the entire phosphorus load were attributed to watershed sources, the estimated loading from watershed sources would need to be reduced from 3-pounds/year/acre to 0.6 pounds/year/acre to meet the TMDL. However, this does not account for the internal recycled load, which could be significant.

Among the mechanisms of resuspension are bottom feeding rough fish such as carp, wind-driven waves and currents, and boat propellers. Methods are needed to evaluate the magnitude of the phosphorus load from internal recycling, preferably by direct measurement of resuspension and recycling from lake bottom sediment. The department is investigating methods of measuring sediment phosphorus flux by evaluating lake sediment cores. This work is being done at Iowa State University and is supported by an EPA grant.

Because of the uncertainty as to how much of the phosphorus load originates in the watershed and how much is recycled from lake bottom sediment, an adaptive management approach is recommended. In this approach management practices to reduce both watershed loads and recycled loads are incrementally applied and the results monitored to determine if water quality goals have been achieved. Also, the reductions in watershed loads will require land management changes that take time to implement. For these reasons, the following timetable is suggested for watershed improvements:

- Reduce watershed and recycle loading from 1,800 pounds per year to 1,200 pounds per year by 2010.
- Reduce watershed and recycle loading from 1,200 pounds per year to 600 pounds per year by 2015.
- Reduce watershed and recycle loading from 600 pounds per year to 300 pounds per year by 2020.

Best management practices to reduce nutrient delivery, particularly phosphorus, should be emphasized in the Mariposa Lake watershed. These practices include the following:

- Nutrient management on production agriculture ground to achieve the optimum soil test range. This soil test range is the most profitable for producers to sustain in the long term.
- The open feedlot in the watershed needs to be assessed for water quality impacts on the lake and the level of pollutant control required needs to be determined.
- Incorporate or subsurface apply phosphorus (manure and commercial fertilizer) while controlling soil erosion. Incorporation will physically separate the phosphorus from surface runoff.
- Continue encouraging the adoption of reduced tillage systems, specifically no till and strip tillage.
- Initiate a fall-seeded cover crop incentive program. Target low residue producing crops (e.g. soybeans) or low residue crops after harvest (e.g. corn silage fields). This practice increases residue cover on the soil surface and improves water infiltration.
- Through incentives, add landscape diversity to reduce runoff volume and/or velocity through the strategic location of contour grass buffer strips, filter strips, and grass waterways, etc.
- Install terraces, ponds, or other erosion and water control structures at appropriate locations within the watershed to control erosion and reduce delivery of sediment and phosphorus to the lake.

In addition to the external nutrient loading from watershed sources to Mariposa Lake, it is believed there may be a significant internal loading component due to rough fish and wind and wave action on the lake. This internal component can be controlled through fish management to control rough fish (i.e., carp), rip rap along the shoreline to reduce shoreline erosion, and dredging to remove nutrients from the lake system and deepen the lake so that it more completely stratifies.

As part of any improvement to Mariposa Lake, the ponds located on the east and west tributaries should be assessed to determine current operating efficiency. It is important to determine if they are still removing sediment and nutrients before discharging to the lake or if they have become a source of sediment and nutrients.

In addition to the east and west ponds, the possibility of adding a wetland on the north end of the lake on the main tributary should be investigated. A wetland at this location will help remove sediment and nutrients before they are transported to the lake. It could also provide educational benefits since it would be located near an existing hiking trail.

5. Monitoring

Further monitoring is needed at Mariposa Lake to follow-up on the implementation of the TMDL. This monitoring will, at a minimum, meet the minimum data requirements established by Iowa's 305(b) guidelines for a complete water quality assessment (3 lake samples per year over 3 years, 10 lake samples over 2 years, etc.). This data will be collected by 2010. Mariposa Lake has been included in the five-year lake study conducted by Iowa State University under contract with the IDNR. Although this lake monitoring program concluded in 2004, it may be extended under a new lake monitoring strategy. The TMDL program is committed to monitoring waters where TMDLs have been completed, and in the absence of a statewide lake monitoring program, follow-up monitoring will be conducted through the TMDL program.

As noted in *Section 4, Implementation*, the phosphorus load due to internal recycling needs to be measured and evaluated. The department is working with Iowa State University to develop a method for quantifying phosphorus sediment flux that will clarify its impact on lakes such as Mariposa. When a protocol for measuring phosphorus flux becomes available, coring will be done for this lake and the recycling load component estimated.

6. Public Participation

Presentations were given to the Jasper County Soil and Water Conservation District on April 20, 2004 and to the Jasper County Conservation Board on June 10, 2004. A second public meeting was held in Newton on October 26, 2004 to present the draft TMDL to the public. This meeting was attended by representatives of The Jasper County Conservation Board, the Jasper Soil and Water Conservation District, Iowa Farm Bureau, and the DNR Fisheries Bureau. Comments received were reviewed and given consideration and, where appropriate, incorporated into the TMDL.

7. References

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8. Appendix A - Lake Hydrology

General Methodology

Purpose

There are approximately 127 public lakes in Iowa. The contributing watersheds for these lakes range in area from 0.028 mi^2 to 195 mi^2 with mean and median values of 10 mi^2 and 3.5 mi^2, respectively. Few, if any, of these lakes have gauging data available to determine flow statistics for the tributaries that feed into them. A select few have some type of stage information that may be useful in determining historical discharge from the lake itself.

With the large number of lakes on the State's 303(d) list and the requirement for rapid development of TMDLs for these lakes, it was realized that a method to quickly estimate flow statistics for required lake response model inputs would be desirable. In an attempt to achieve this goal, flow data and watershed characteristics for a number of USGS gauging stations with small contributing watershed areas were compiled and evaluated via both simple and multiple linear regressions. The primary focus of this evaluation was estimation of the average annual flow statistic for input to empirical lake response models. However, regression equations for monthly average and calendar year flow statistics were also developed that may be of additional use.

It should be noted that attempts were made to develop regression equations for low-flow streamflow statistics (1Q10, 7Q10, 30Q10, 30Q5 and harmonic mean) but the relationships derived were for the most part considered too weak (R^2 adj.< 70%) to be of practical use. One exception to this is the 30Q5 statistic, which gave an R^2 adj. of 85%. In addition, regression equations were developed for monthly flow prediction models for two months (January and May). Once again, the relationships did not exhibit a high level of correlation and due to the large amount of data required to develop these models, development of equations for additional months was not attempted.

Data

Flow data and watershed characteristics from 26 USGS gauging stations were used to derive the regression equations. The ranges of basin characteristics used to develop the regression equations are shown in Table A-1.

Drainage areas were taken directly from USGS gauge information available at http://water.usgs.gov/waterwatch/ . Precipitation values were obtained through the Iowa Environmental Mesonet IEM Climodat Interface at http://mesonet.agron.iastate.edu/climodat/index.phtml . Where weather and gauging stations were not located in the same town, precipitation information was obtained from the weather station located in the town with the shortest straight-line distance from the gauging station.

Average basin slope and land cover percentages were determined using Arc View and statewide coverages clipped within HUC-12 sub-watersheds. It should be noted that the smallest basin coverages used in determining land cover percentages and average basin slopes were single HUC-12 units (i.e. no attempt was made to subdivide HUC-12 basins into smaller units where the drainage area was less than the area of the HUC-12 basin). Therefore, the regression models assume that for very small watersheds the land cover percentages of the HUC-12 basin are representative of the watershed located within the basin.

The Hydrologic Region for each station was determined from Figure 1 of USGS Water-Resources Investigation Report 87-4132, Method for Estimating the Magnitude and Frequency of Floods at Ungaged Sites on Unregulated Rural Streams in Iowa. None of the stations included in the analyses were located in Regions 1 or 5. This is reflected in the regression equations developed that utilize the hydrologic region as a variable.

Table A-1. Ranges of Basin Characteristics Used to Develop the Regression Equations

Basin Characteristic	Name in equations	Minimum	Mean	Maximum
Drainage Area (mi^2)	DA	2.94	80.7	204
Mean Annual Precip (inches)	$\bar{P}_A$	26.0	34.0	36.2
Average Basin Slope (%)	S	1.53	4.89	10.9
Landcover - % Water	W	0.020	0.336	2.80
Landcover - % Forest	F	2.45	10.3	29.9
Landcover - % Grass/Hay	G	9.91	31.3	58.7
Landcover - % Corn	C	6.71	31.9	52.3
Landcover - % Beans	B	6.01	23.1	37.0
Landcover - % Urban/Artificial	U	0	2.29	7.26
Landcover - % Barren/Sparse	B'	0	0.322	2.67
Hydrologic Region	H	Regions 1 - 5 used for delineation but data for USGS stations in Regions 2, 3 & 4 only.		

Methods

Simple regression models were developed for annual average and monthly average statistics with drainage area as the sole explanatory variable. Multiple linear regression models considering all explanatory variables were developed utilizing stepwise regression in Minitab. All data with the exception of the Hydrologic Region were log transformed. Explanatory variables with regression coefficients that were not statistically different from zero (p-value greater than 0.05) were not utilized.

Equation Variables

Table A-2. Regression Equation Variables

Annual Average Flow (cfs)	$\overline{Q}_{A}$
Monthly Average Flow (cfs)	$\overline{Q}_{MONTH}$
Annual Flow – calendar year (cfs)	Q_{YEAR}
Drainage Area (mi^2)	DA
Mean Annual Precip (inches)	$\overline{P}_{A}$
Mean Monthly Precip (inches)	$\overline{P}_{MONTH}$
Antecedent Mean Monthly Precip (inches)	$\overline{A}_{MONTH}$
Annual Precip – calendar year (inches)	P_{YEAR}
Antecedent Precip – calendar year (inches)	A_{YEAR}
Average Basin Slope (%)	S
Landcover - % Water	W
Landcover - % Forest	F
Landcover - % Grass/Hay	G
Landcover - % Corn	C
Landcover - % Beans	B
Landcover - % Urban/Artificial	U
Landcover - % Barren/Sparse	B'
Hydrologic Region	H

Equations

Table A-3. Drainage Area Only Equations

Equation	R^2 adjusted (%)	PRESS (log transform)
$\overline{Q}_{A} = 0.832DA^{0.955}$	96.1	0.207290
$\overline{Q}_{JAN} = 0.312DA^{0.950}$	85.0	0.968253
$\overline{Q}_{FEB} = 1.32DA^{0.838}$	90.7	0.419138
$\overline{Q}_{MAR} = 0.907DA^{1.03}$	96.6	0.220384
$\overline{Q}_{APR} = 0.983DA^{1.02}$	93.1	0.463554
$\overline{Q}_{MAY} = 1.97DA^{0.906}$	89.0	0.603766
$\overline{Q}_{JUN} = 2.01DA^{0.878}$	88.9	0.572863
$\overline{Q}_{JUL} = 0.822DA^{0.977}$	87.2	0.803808
$\overline{Q}_{AUG} = 0.537DA^{0.914}$	74.0	1.69929
$\overline{Q}_{SEP} = 0.123DA^{1.21}$	78.7	2.64993
$\overline{Q}_{OCT} = 0.284DA^{1.04}$	90.2	0.713257
$\overline{Q}_{NOV} = 0.340DA^{0.999}$	89.8	0.697353
$\overline{Q}_{DEC} = 0.271DA^{1.00}$	86.3	1.02455

Table A-4. Multiple Regression Equations

Equation	R^2 adjusted (%)	PRESS (log transform)
$\overline{Q}_A = 1.17 \times 10^{-3} DA^{0.998} \overline{P}_A^{1.54} S^{-0.261} (1+F)^{0.249} C^{0.230}$	98.7	0.177268 (n=26)
$\overline{Q}_{JAN} = 0.213 DA^{0.997} \overline{A}_{JAN}^{0.949}$	89.0	0.729610 (n=26;same for all $\overline{Q}_{MONTH}$)
$\overline{Q}_{FEB} = 2.98 DA^{0.955} \overline{A}_{FEB}^{0.648} G^{-0.594} (1+F)^{0.324}$	97.0	0.07089
$\overline{Q}_{MAR} = 6.19 DA^{1.10} B^{-0.386} G^{-0.296}$	97.8	0.07276
$\overline{Q}_{APR} = 1.24 DA^{1.09} \overline{A}_{APR}^{1.64} S^{-0.311} B^{-0.443}$	97.1	0.257064
$\overline{Q}_{MAY} = 10^{(-3.03+0.114H)} DA^{0.846} \overline{P}_A^{2.05}$ Hydrologic Regions 2, 3 & 4 Only	92.1	0.958859
$\overline{Q}_{MAY} = 1.86 \times 10^{-3} DA^{0.903} \overline{P}_A^{1.98}$	90.5	1.07231
$\overline{Q}_{JUN} = 10^{(-1.47+0.0729H)} DA^{0.891} C^{0.404} \overline{P}_{JUN}^{1.84} (1+F)^{0.326} G^{-0.387}$ Hydrologic Regions 2, 3 & 4 Only	97.0	0.193715
$\overline{Q}_{JUN} = 8.13 \times 10^{-3} DA^{0.828} C^{0.478} \overline{P}_{JUN}^{2.70}$	95.9	0.256941
$\overline{Q}_{JUL} = 1.78 \times 10^{-3} DA^{0.923} \overline{A}_{JUL}^{4.19}$	91.7	0.542940
$\overline{Q}_{AUG} = 4.17 \times 10^{7} DA^{0.981} (1+B')^{-1.64} (1+U)^{0.692} \overline{P}_A^{-7.2} \overline{A}_{AUG}^{4.59}$	90.4	1.11413
$\overline{Q}_{SEP} = 1.63 DA^{1.39} B^{-1.08}$	86.9	1.53072
$\overline{Q}_{OCT} = 5.98 DA^{1.14} B^{-0.755} S^{-0.688} (1+B')^{-0.481}$	95.7	0.375296
$\overline{Q}_{NOV} = 5.79 DA^{1.17} B^{-0.701} G^{-0.463} (1+U)^{0.267} (1+B')^{-0.397}$	95.1	0.492686
$\overline{Q}_{DEC} = 0.785 DA^{1.18} B^{-0.654} (1+U)^{0.331} (1+B')^{-0.490}$	92.4	0.590576
$Q_{YEAR} = 3.164 \times 10^{-4} DA^{0.942} P_{YEAR}^{2.39} A_{YEAR}^{1.02} S^{-0.206} \overline{P}_A^{1.27} C^{0.121} (1+U)^{0.0966}$	83.9	32.6357 (n=716)

General Application

In general, the regression equations developed using multiple watershed characteristics will be better predictors than those using drainage area as the sole explanatory variable. The single exception to this appears to be for the May Average Flow worksheet where the PRESS statistic values indicate that use of drainage area alone results in the least error in the prediction of future observations.

Although 2002 land cover grids for the state are now available with 19 different classifications, the older 2000 land cover grids with 9 different classifications were used in developing the regression equations. The 2000 land cover grids should be used in development of flow estimates using the equations.

The equations were developed from stream gauge data for watersheds with relatively minor open water surface percentages relative to other types of land cover (see Table A-1). For application to lake watersheds, particularly those with small watershed/lake area ratios, the basin slope and land cover percentages taken from HUC-12 basins may need to be adjusted so that the hydraulic budget components of surface inflow and direct precipitation on the lake itself can be treated separately. One method of accomplishing this is by subtraction of lake water surface acreage from the total land cover and slope (lakes will have 0% slope) acreages and recalculation of the % coverages. The watershed (drainage) area used in the equations should not include the area of the lake surface.

Application to Mariposa Lake - Calculations

Table A-5. Mariposa Lake Hydrology Calculations

Lake	Mariposa Lake	
Type	Artificial	
Inlet(s)	Unnamed Creek	
Outlet(s)	Unnamed Creek	
Volume	135	(acre-ft)
Lake Area	18	(acres)
Mean Depth	7.30	(ft)
Drainage Area	575	(acres)
Mean Annual Precip	32.89	(inches)
Average Basin Slope	6.01	(%)
%Water	0.344695519	
%Forest	12.38988893	
%Grass/Hay	15.56352495	
%Corn	23.69346471	
%Beans	46.11085965	
%Urban/Artificial	1.471049058	
%Barren/Sparse	0.271578288	
Hydrologic Region	3	
Mean Annual Class A Pan Evap	48	(inches)
Mean Annual Lake Evap	35.52	(inches)
Est. Annual Average Inflow	416.06	(acre-ft)
Direct Lake Precip	50.65	(acre-ft/yr)
Est. Annual Average Det. Time (inflow + precip)	0.2890	(yr)
Est. Annual Average Det. Time (outflow)	0.3274	(yr)

9. Appendix B - Sampling Data

Table B-1. Data collected in 1979 by Iowa State University (Bachmann, 1980)

Parameter	6/27/1979	7/31/1979	8/30/1979
Secchi Depth (m)	0.8	0.9	0.6
Chlorophyll (ug/L)	47.5	63.1	89.1
NO_3+NO_2-N (mg/L)			0.05
Total Phosphorus (ug/l as P)	135	178	184
Alkalinity (mg/L)	126	129	121

Data above is averaged over the upper 6 feet.

Table B-2. Data collected in 1990 by Iowa State University (Bachmann, 1994)

Parameter	5/30/1990	7/02/1990	7/30/1990
Secchi Depth (m)	0.3	0.7	0.8
Chlorophyll (ug/L)	21.4	19.4	30.7
Total Nitrogen (mg/L as N)	6	5.9	3.9
Total Phosphorus (ug/l as P)	406.9	146.4	164.7
Total Suspended Solids (mg/L)	61.1	21.1	35.7
Inorganic Suspended Solids (mg/L)	49.4	8.5	24.8

Data above is for surface depth.

Table B-3. Data collected in 2000 by Iowa State University (Downing and Ramstack, 2001)

Parameter	6/26/2000	7/24/2000	8/14/2000
Secchi Depth (m)	0.4	0.2	0.3
Chlorophyll (ug/L)	186	2	4
NH_3+NH_4^+ -N (ug/L)	761	3064	2822
NH_3 –N (un-ionized) (ug/L)	31	178	34
NO_3+NO_2-N (mg/L)	0.26	3.52	0.07
Total Nitrogen (mg/L as N)	2.5	2.74	2.74
Total Phosphorus (ug/l as P)	188	668	540
Silica (mg/L as SiO_2)	46	34	31
pH	7.9	8.1	7.3
Alkalinity (mg/L)	132	149	157
Total Suspended Solids (mg/L)	34.5	41.8	12.8
Inorganic Suspended Solids (mg/L)	12.0	18.2	6.1
Volatile Suspended Solids (mg/L)	22.5	23.6	6.7

Table B-4. Data collected in 2001 by Iowa State University (Downing and Ramstack, 2002)

Parameter	5/29/2001	6/25/2001	7/30/2001
Secchi Depth (m)	0.5	0.7	0.4
Chlorophyll (ug/L)	13	93	89
NH_3+NH_4^+ -N (ug/L)	617	424	785
NH_3 –N (un-ionized) (ug/L)	41	119	16
NO_3+NO_2-N (mg/L)	2.19	4.40	0.35
Total Nitrogen (mg/L as N)	3.20	6.69	1.8
Total Phosphorus (ug/l as P)	123	57	239
Silica (mg/L as SiO_2)	11	8	14
pH	8.4	8.9	8.4
Alkalinity (mg/L)	111	127	103
Total Suspended Solids (mg/L)	14.5	20.7	16.1
Inorganic Suspended Solids (mg/L)	10.3	11.3	6.4
Volatile Suspended Solids (mg/L)	4.1	9.3	9.7

Table B-5. Data collected in 2002 by Iowa State University (Downing et al., 2003)

Parameter	**6/03/2002**	**7/08/2002**	**8/05/2002**
Secchi Depth (m)	0.4	0.2	0.3
Chlorophyll (ug/L)	57	147	71
$NH_3+NH_4^+$ -N (ug/L)	341	216	321
NH_3 –N (un-ionized) (ug/L)	34	196	219
NO_3+NO_2-N (mg/L)	0.95	0.31	0.08
Total Nitrogen (mg/L as N)	2.17	0.81	1.10
Total Phosphorus (ug/l as P)	118	211	192
Silica (mg/L as SiO_2)	3	5	6
pH	8.3	10.1	9.5
Alkalinity (mg/L)	129	80	81
Total Suspended Solids (mg/L)	32.7	66.7	44.5
Inorganic Suspended Solids (mg/L)	14.7	15.3	25.5
Volatile Suspended Solids (mg/L)	18.0	51.4	19.1

Table B-6. Data collected in 2003 by Iowa State University (Downing et al., 2004)

Parameter	**6/2/2003**	**7/7/2003**	**8/4/2003**
Secchi Depth (m)	0.8	0.5	0.2
Chlorophyll (ug/L)	39.5	-	29.8
$NH_3+NH_4^+$ -N (ug/L)	473	499	458
NH_3 –N (un-ionized) (ug/L)	90	91	230
NO_3+NO_2-N (mg/L)	4.28	1.22	0.13
Total Nitrogen (mg/L as N)	6.51	2.55	2.59
Total Phosphorus (ug/l as P)	91	117	366
Silica (mg/L as SiO_2)	1.26	3.37	7.55
pH	8.8	8.5	9.2
Alkalinity (mg/L)	88	87	64
Total Suspended Solids (mg/L)	25	25	62
Inorganic Suspended Solids (mg/L)	17	12	19
Volatile Suspended Solids (mg/L)	8	13	43

Table B-7. 2000 Phytoplankton Data (Downing and Ramstack, 2001)

	6/26/2000	**7/24/2000**	**8/14/2000**
Division	**Wet Mass (mg/L)**	**Wet Mass (mg/L)**	**Wet Mass (mg/L)**
Cyanophyta	3.5E+02	2.0E+02	2.1E+01
Cryptophyta	0.0E+00	3.1E-02	3.1E+00
Chlorophyta	3.0E+00	1.7E-02	0.0E+00
Dinophyta	0.0E+00	0.0E+00	0.0E+00
Chrysophyta	0.0E+00	3.9E-02	7.5E-02
Euglenophyta	1.4E-01	3.5E-01	9.1E-01
TOTAL	**3.5E+02**	**2.0E+02**	**2.5E+01**

Table B-8. 2001 Phytoplankton Data (Downing and Ramstack, 2002)

	5/29/2001	6/25/2001	7/30/2001
Division	**Wet Mass (mg/L)**	**Wet Mass (mg/L)**	**Wet Mass (mg/L)**
Chlorophyta	5.12E+00	2.35E+00	1.72E-01
Chrysophyta	1.91E+01	3.90E-01	0.00E+00
Cryptophyta	0.00E+00	0.00E+00	1.13E-01
Cyanobacteria	2.05E+01	0.00E+00	2.47E+01
Dinophyta	1.48E+00	0.00E+00	0.00E+00
Euglenophyta	0.00E+00	0.00E+00	0.00E+00
Total	4.61E+01	2.74E+00	2.50E+01

Additional lake sampling results and information can be viewed at:
http://limnology.eeob.iastate.edu/

10. Appendix C - Trophic State Index

Carlson's Trophic State Index

Carlson's Trophic State Index is a numeric indicator of the continuum of the biomass of suspended algae in lakes and thus reflects a lake's nutrient condition and water transparency. The level of plant biomass is estimated by calculating the TSI value for chlorophyll-a. TSI values for total phosphorus and Secchi depth serve as surrogate measures of the TSI value for chlorophyll.

The TSI equations for total phosphorus, chlorophyll and Secchi depth are:

$$TSI\ (TP) = 14.42\ \ln(TP) + 4.15$$

$$TSI\ (CHL) = 9.81\ \ln(CHL) + 30.6$$

$$TSI\ (SD) = 60 - 14.41\ \ln(SD)$$

TP = in-lake total phosphorus concentration, ug/L

CHL = in-lake chlorophyll-a concentration, ug/L

SD = lake Secchi depth, meters

The three index variables are related by linear regression models and *should* produce the same index value for a given combination of variable values. Therefore, any of the three variables can theoretically be used to classify a waterbody.

Table C-1. Changes in temperate lake attributes according to trophic state (modified from U.S. EPA 2000, Carlson and Simpson 1995, and Oglesby et al. 1987).

TSI Value	Attributes	Primary Contact Recreation	Aquatic Life (Fisheries)
50-60	eutrophy: anoxic hypolimnia; macrophyte problems possible	[none]	warm water fisheries only; percid fishery; bass may be dominant
60-70	blue green algae dominate; algal scums and macrophyte problems occur	weeds, algal scums, and low transparency discourage swimming and boating	Centrarchid fishery
70-80	hyper-eutrophy (light limited). Dense algae and macrophytes	weeds, algal scums, and low transparency discourage swimming and boating	Cyprinid fishery (e.g., common carp and other rough fish)
>80	algal scums; few macrophytes	algal scums, and low transparency discourage swimming and boating	rough fish dominate; summer fish kills possible

Table C-2. Summary of ranges of TSI values and measurements for chlorophyll-a and Secchi depth used to define Section 305(b) use support categories for the 2004 reporting cycle.

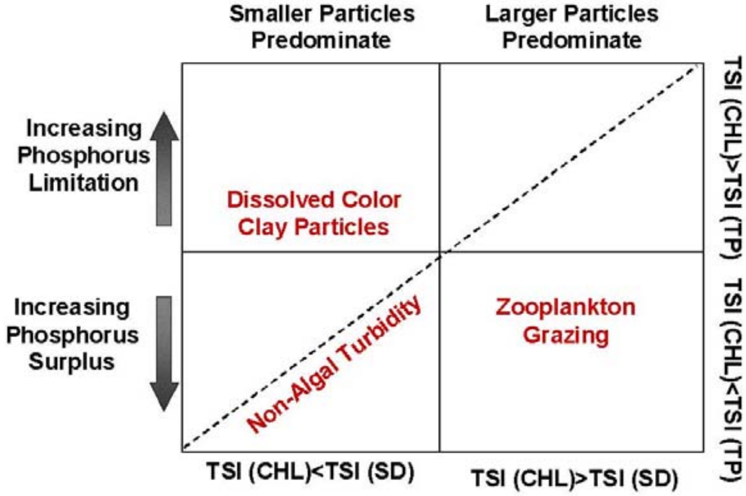
Level of Support	TSI value	Chlorophyll-a (ug/l)	Secchi Depth (m)
fully supported	<=55	*<=12*	*>1.4*
fully supported / threatened	55 → 65	*12 → 33*	*1.4 → 0.7*
partially supported (evaluated: in need of further investigation)	65 → 70	*33 → 55*	*0.7 → 0.5*
partially supported (monitored: candidates for Section 303(d) listing)	65-70	*33 → 55*	*0.7→ 0. 5*
not supported (monitored or evaluated: candidates for Section 303(d) listing)	>70	*>55*	*<0.5*

Table C-3. Descriptions of TSI ranges for Secchi depth, phosphorus, and chlorophyll-a for Iowa lakes.

TSI value	Secchi description	Secchi depth (m)	Phosphorus & Chlorophyll-a description	Phosphorus levels (ug/l)	Chlorophyll-a levels (ug/l)
> 75	extremely poor	< 0.35	extremely high	> 136	> 92
70-75	very poor	0.5 – 0.35	very high	96 - 136	55 – 92
65-70	poor	0.71 – 0.5	high	68 – 96	33 – 55
60-65	moderately poor	1.0 – 0.71	moderately high	48 – 68	20 – 33
55-60	relatively good	1.41 – 1.0	relatively low	34 – 48	12 – 20
50-55	very good	2.0 – 1.41	low	24 – 34	7 – 12
< 50	exceptional	> 2.0	extremely low	< 24	< 7

The relationship between TSI variables can be used to identify potential causal relationships. For example, TSI values for chlorophyll that are consistently well below those for total phosphorus suggest that something other than phosphorus limits algal growth. The TSI values can be plotted to show potential relationships as shown in Figure C-1.

Figure C-1. Multivariate TSI Comparison Chart (Carlson)



Mariposa Lake TSI Values

Table C-4. 1979 Mariposa Lake TSI Values (Bachmann)

Sample Date	TSI (SD)	TSI (CHL)	TSI (TP)
6/27/1979	65	69	75
7/31/1979	62	71	79
8/30/1979	67	75	79

Table C-5. 1990 Mariposa Lake TSI Values (Bachmann)

Sample Date	TSI (SD)	TSI (CHL)	TSI (TP)
5/30/1990	77	61	91
7/2/1990	65	60	76
7/30/1990	63	64	78

Table C-6. 2000 - 2003 Mariposa Lake TSI Values (Downing et al.)

Sample Date	TSI (SD)	TSI (CHL)	TSI (TP)
6/26/2000	73	82	79
7/24/2000	83	40	98
8/13/2000	77	43	95
5/29/2001	70	56	74
6/25/2001	65	75	62
7/30/2001	73	75	83
6/3/2002	73	70	73
7/8/2002	83	80	81
8/5/2002	77	72	80
6/2/2003	63	67	69
7/7/2003	70	--	73
8/4/2003	83	64	89

11. Appendix D - Land Use Maps

Figure D-1. Mariposa Lake Watershed 2002 Landuse

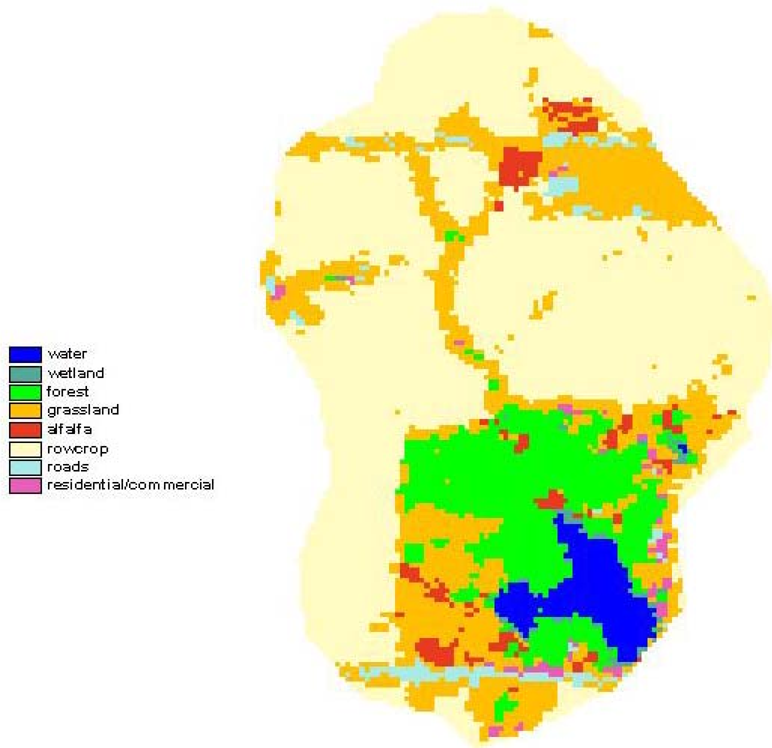


Figure D-2. Mariposa Lake Watershed 2004 Site Assessment