Total Maximum Daily Load
For Algae and Turbidity
Lake Cornelia,
Wright County, Iowa

2006

Iowa Department of Natural Resources
Watershed Improvement Section

Prepared by Parsons Corporation

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TMDL INFORMATION SHEET

Total Maximum Daily Load for Lake Cornelia

Waterbody: Lake Cornelia
Water Quality Impairment: Algae and Turbidity

County:	Wright County, Iowa
Nearby Cities:	Clarion
Lake Area:	243 acres
Watershed Area:	987 acres
Designated Use that is Impaired:	A1 (primary contact recreation); B (LW) (aquatic life)
303(d) Listing:	Algae Growth / Chlorophyll-a and Turbidity
Trophic State Index Targets:	Total Phosphorus < 64 (97% of current level) Chlorophyll < 65 Secchi Depth < 65

Summary of TMDL Results for Total Phosphorous

TMDL (lb/yr)	**442**
WLA (lb/yr)	**0**
LA (lb/yr)	**608**
MOS (lb/yr)	**49**
Existing Load (lb/yr)	**614**
% of Reduction	**28.1%**

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1.1 Watershed Description

Lake Cornelia is a 243-acre natural lake, located three and half miles north and two miles east of Clarion in Wright County. Lake Cornelia offers swimming, boating, skiing, fishing, and facilities for camping.

Lake Cornelia has been identified as impaired by algae blooms in response to high nutrient loading. Table 1 lists the key features of Lake Cornelia. Figure 1 shows the location of Lake Cornelia and its watershed. Figure 2 illustrates the land use of the Lake Cornelia watershed.

Table 1: Lake Cornelia Features

Waterbody Name:	Lake Cornelia
Hydrologic Unit Code:	07100005
IDNR Waterbody ID:	IA 04-UDM-02290-L
Location:	Section 16 T92N R24W
Latitude:	42° 47' N
Longitude:	93° 41' W
Water Quality Standards Designated Uses:	1. Aquatic Life Support 2. Primary Contact Recreation
Tributaries:	Unnamed creek
Receiving Waterbody:	Lake Cornelia
Lake Surface Area:	243 acres
Maximum Depth:	18 feet
Mean Depth:	8 feet
Volume:	1857 acre-feet
Length of Shoreline:	12,632 feet
Watershed Area:	987 acres
Watershed/Lake Area Ratio:	2.1:1
Estimated Detention Time:	1.9 years

Morphometry

Lake Cornelia has a mean depth of 8 feet and a maximum depth of 18 feet. The lake surface area is 243 acres and the storage volume is 1857 acre-feet.

Hydrology

Lake Cornelia is fed by an unnamed tributary. Average rainfall in the area is 31 inches. The annual average detention time for Lake Cornelia is 1.9 year based on inflow and direct precipitation. The methodology and calculations used to determine the detention times are shown in Appendix A.

2.2 Land Use

Lake Cornelia has a watershed area of 987 acres and has a watershed to lake ratio of 2.1 to 1. Land uses for Lake Cornelia watershed are listed in Table 2 and shown in Figure 2.

Table 2: Land Use in Lake Cornelia Watershed

Land Use	Area (acre)	Percent
cropland	457	46.3
water	262	26.6
permanent grass	125	12.6
park	47	4.7
road	45	4.6
farmstead	38	3.9
pasture	13	1.3
Total	987	100

There are no point sources or confined animal feeding operations (CAFO) within the Lake Cornelia watershed.

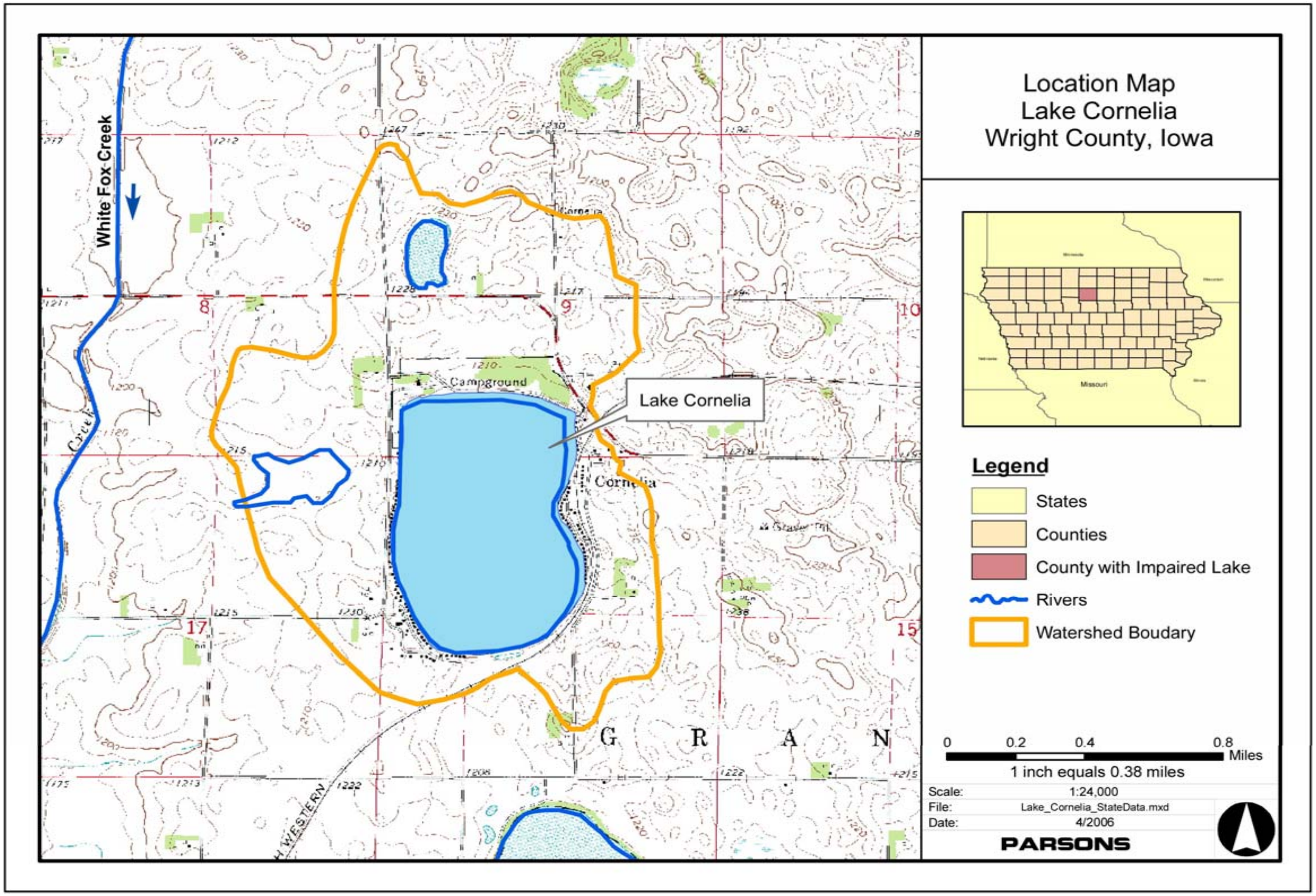


Figure 1: Location Map for Lake Cornelia

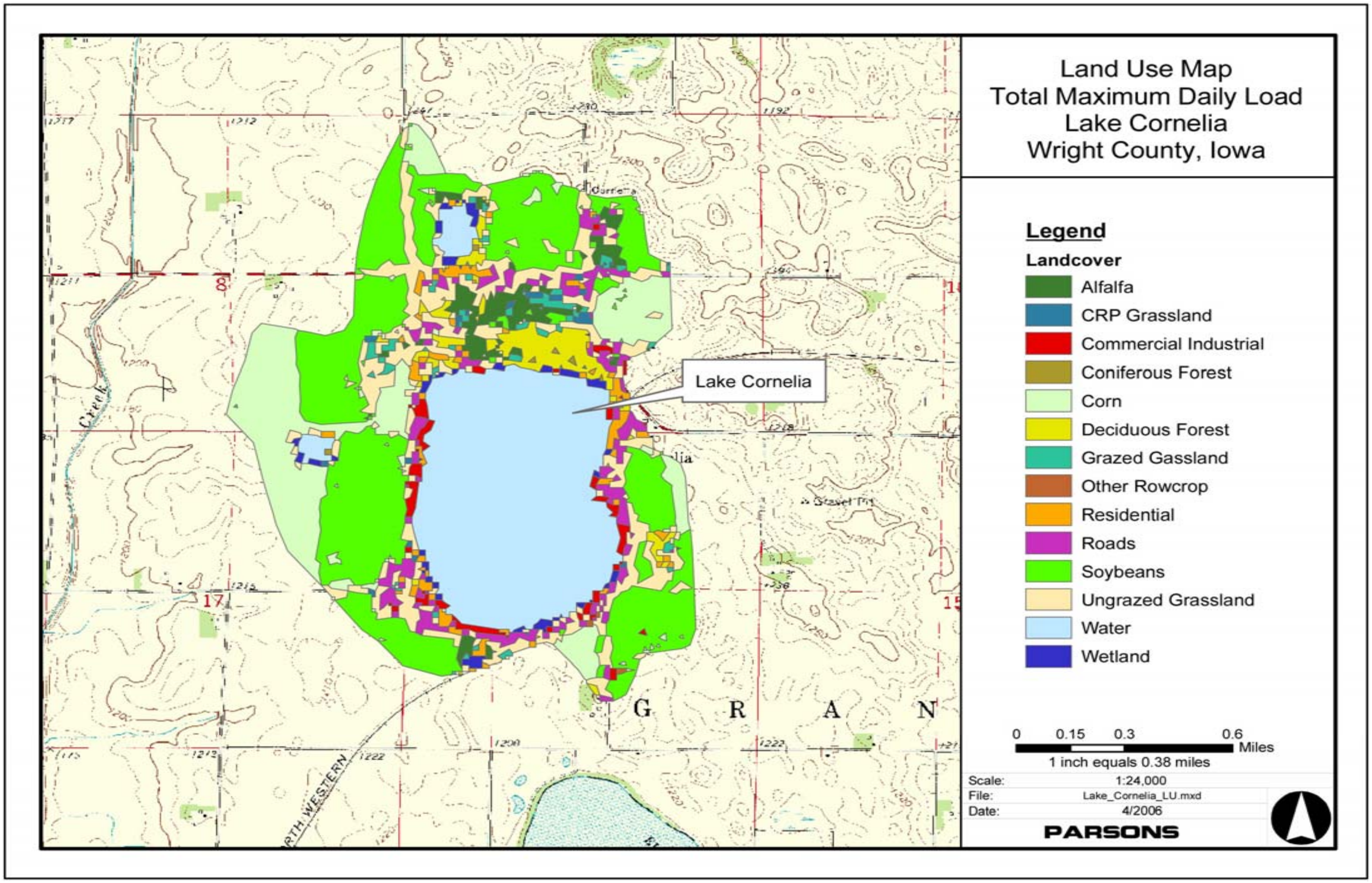


Figure 2: Land Use Map for Lake Cornelia

1.2 Problem Identification and Current Conditions

Section 303(d) of the Clean Water Act and the USEPA Water Quality Planning and Management Regulation (40 CFR Part 130) requires states to develop Total Maximum Daily Loads (TMDLs) for waterbodies not meeting applicable water quality standards or designated uses under technology-based controls. TMDLs identify the maximum amount of a pollutant that a waterbody can assimilate and still meet water quality standards.

The Iowa Water Quality Standards (IAC 567-61) list the designated uses for Lake Cornelia as Primary Contact Recreational Use (Class A) and Aquatic Life (Class B(LW)).

Lake Cornelia was included on the impaired waters list due to algae and turbidity impairments. The Class A (primary contact recreation) uses are assessed (monitored) as "fully supporting / threatened" due to slightly elevated turbidity related to levels of algae and inorganic suspended solids at Lake Cornelia. The Class B(LW) aquatic life uses are assessed (evaluated) as "fully supporting / threatened" due to algae and non-algal turbidity.

Data Sources

The primary data used to assess Lake Cornelia water quality and develop this TMDL are from an Iowa State University Lake Study from 2000 - 2005. Samples were collected three times during the summer growing season. The samples were analyzed for variables including chlorophyll, secchi depth, the important forms of phosphorus and nitrogen, and suspended solids. Appendix B provides a data summary.

Lake Cornelia Water Quality Assessment

Carlson’s trophic state index (TSI) has been used to relate total phosphorous (TP), algae (as measured by chlorophyll), and transparency (as measured by secchi depth) to set water quality targets. TSI values for the monitoring data are shown in Table 3. Using the median values from this survey from 2000 through 2005, Carlson's TSI values for TP, chlorophyll-a, and secchi depth are 66, 45, and 67, respectively. A detailed explanation of the TSI can be found in Appendix C.

Table 3: Lake Cornelia TSI Values Based on Iowa Lake Survey Data

Sample Data				TSI Values		
DATE: Jul. 2000 – Aug. 2005	**Secchi Depth (m)**	**Chlorophyll (µg/L)**	**Total Phosphorus (µg/L)**	**Secchi Depth**	**Chlorophyll**	**Total Phosphorus**
average	0.69	14.5	78	65	57	67
median	**0.61**	**4.3**	**72**	**67**	**45**	**66**
TARGETS	**> 0.70**	**< 33**	**< 96**	**< 65**	**< 65**	**< 70**

These index values suggest (1) marginally low levels of phosphorus in the water column, (2) moderately low (and less than expected) levels of chlorophyll-a, and (3) marginally low transparency and slightly elevated turbidity.

The TSI value for TP is higher than TSI for chlorophyll. This implies there are limitations to algae growth besides phosphorus (e.g. non-algal particulates). Comparison of TSI values for chlorophyll, secchi depth and TP for Lake Cornelia indicate some limitation of algal growth attributable to light attention by elevated suspended solids.

Plots that compare the three TSI variables are shown in Figures 3 and 4.

Figure 3: Lake Cornelia Median TSI Multivariate Comparison Plot
(Plotted Point: -22.2, -20.9)

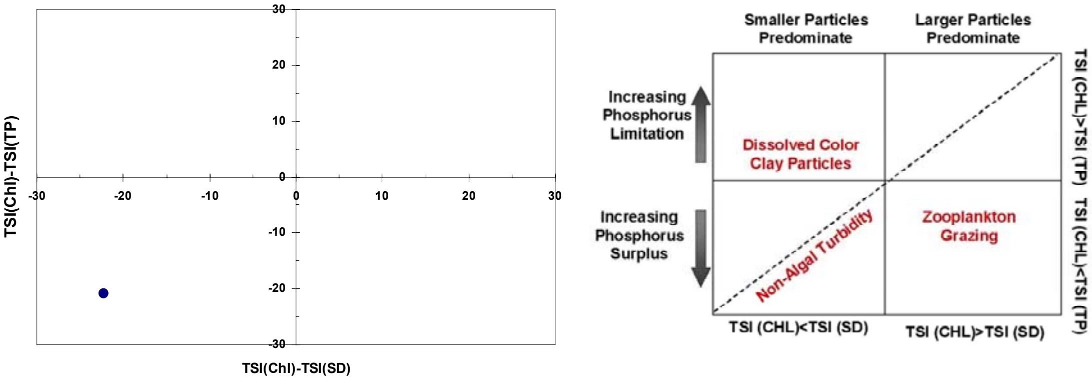
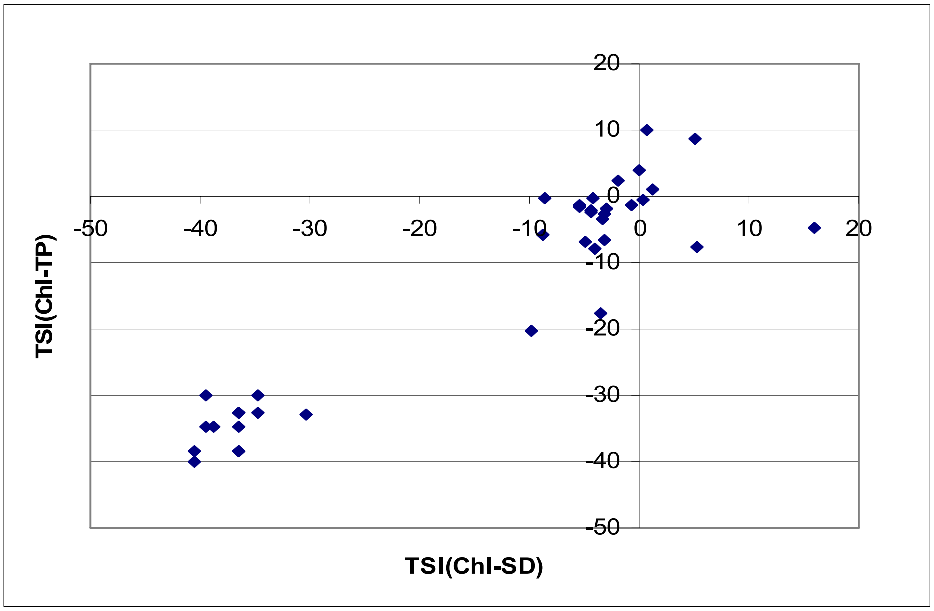


Figure 4: Lake Cornelia TSI Comparison Plot



In Figure 4, the cluster of data points below (-30, -30) for both TSI (Chl-SD) and TSI (Chl-TP) suggest that non-algal turbidity is a very strong component of the low transparency problem much of the time. At other times (i.e. data cluster around the axis) the problem of visibility is likely related to chlorophyll.

Based on median values from ISU sampling from 2000 through 2005, the ratio of total nitrogen to total phosphorus for Lake Cornelia is 24. The levels of inorganic suspended solids at this lake are somewhat elevated and suggest the potential for contributing to in-lake turbidity. The median level of inorganic suspended solids in the 131 lakes sampled for the ISU lake survey from 2000 through 2005 was 5 mg/l; the median level at Lake Cornelia from 2000 through 2005 was 6.9 mg/l. Thus, the somewhat elevated TSI value for secchi depth suggest a threat to full support of the Class A (primary contact) and Class B(LW) uses through presence of turbidity and blooms of algae that could potentially lead to aesthetically objectionable conditions.

The levels of nuisance algal species (i.e., bluegreen algae) at Lake Cornelia are relatively low and do not appear to either threaten or impair the designated uses of this lake. However, data from statewide lake survey suggest that when algae blooms are present, bluegreen algae (Cyanophyta) tend to dominate the summertime phytoplankton community of this lake, especially in mid to late summer when greater than 90% of wet mass is comprised of bluegreen algae. The average summer mass of bluegreen algae in 2000 at this lake (6.1 mg/l) is low relative to most other Iowa lakes (47th lowest of the 131 lakes sampled) and does not suggest a significant water quality impact.

Although the lake still has marginally excessive nutrients which stimulate summer algae blooms and the desirable growth of submergent vegetation has not increased substantially, Lake Cornelia has consistently shown improvement over the past fifteen years. Much of the improvement in water quality can be attributed to completion of a sanitary sewer system around this lake in the mid-1980s. Secchi disc readings during early summer over the past five years have varied from 1.5 feet to 3 feet. Nuisance blue-green algae blooms have not been a problem in recent years.

1.3 TMDL Endpoint

The ultimate goal of this TMDL is to reduce the excessive algae and turbidity in Lake Cornelia. A TMDL target has been established to link water chemistry, particularly nutrients, to the characteristic of an ecosystem (e.g. lake) that may be affected by exposure, or in this case cause observed algae bloom and lake transparency problems. Water quality targets are quantifiable measures that are protective of water use attainment similar to water quality standards.

Iowa does not have numeric water quality criteria for algae or turbidity. The cause of Lake Cornelia algae and turbidity impairments is algal blooms caused by excessive nutrient loading to the lake and inorganic suspended solids due to re-suspension of sediment. The TSI is used as a guideline to relate phosphorus loading to the algal and turbidity impairment for TMDL development. It describes and explains nutrient conditions that will allow a waterbody to meet Iowa's narrative water quality standards.

Typically, a total phosphorus TSI of less than 70, which is related through the trophic state index to chlorophyll a and secchi depth, defines the nutrient-loading target. Thus the Phase I targets for lake TMDLs in Iowa are normally median TSI values of less than 70 for TP, and a median TSI value of less than 65 for both chlorophyll and secchi depth. These values are equivalent to TP and chlorophyll concentrations of 96 and 33 µg/L, respectively, and a secchi depth of 0.7 meters.

Because secchi depth is in non-compliance for Lake Cornelia (i.e. TSI value of 67 based on median water quality data is greater than target TSI of 65), the objective of this TMDL is to improve the secchi depth by (67-65)/67 = 3%. Assuming a 1:1 response between TSI (SD) and TSI (TP), the target TSI for total phosphorus is set at 97% of its current TSI level, which corresponds (65.9*0.97) = 63.9 (rounded as 64 in Table 4). TSI of 64 for TP corresponds to in-lake TP target concentration of 63 µg/L. Table 4 describes TMDL existing and target values for TSI and concentrations in Lake Cornelia.

Table 4: Lake Cornelia Existing vs. Target Values

Parameter	2000-2005 Median TSI	Target TSI	2000-2005 Median Value	Target Value	Water quality improvements needed, as defined by TSI
Total Phosphorus	66	<64	72 µg/l	<63 µg/L	3% Reduction
Chlorophyll a	45	<65	4.3 µg/l	<33 µg/L	0% Reduction
Secchi Depth	67	<65	0.61 m	>0.7 meters	3% Increase

Inorganic suspended solids (i.e. non-algal turbidity) contribute to turbidity in Lake Cornelia. Although current levels are not causing an impairment to Lake Cornelia, inorganic suspended solids levels are threatening the designated uses of the lake. Because the ambient water quality improvement through BMP implementations to reduce phosphorus load would also translate to a commensurate reduction in sediment, non-algal turbidity would thereby improve and secchi depth would expect to be in full compliance. However, future monitoring will be needed to determine if phosphorus loading reduction will result in full compliance of the TSI target for secchi depth.

2. Calculation of Total Maximum Daily Load

The following equation was used to calculate the TMDL.

TMDL = WLA + LA + MOS (Eq. 1)

where:

TMDL: Total Maximum Daily Load
WLA: Waste Load Allocation (for point sources)
LA: Load Allocation (for non-point sources)
MOS: Margin of Safety

2.1 TMDL Calculation

TMDL is defined as the maximum pollutant load that a waterbody can assimilate and still attain water quality standards. The TMDL for Lake Cornelia calculates the maximum allowable phosphorus loading that will meet narrative standards for nuisance algal blooms and turbidity, thus provide water quality fully supporting the lake's designated uses. The relationship of total phosphorus to chlorophyll a (algae indicator) and secchi depth (turbidity indicator) is made by using Carlson's Trophic State Index.

The Lake Phosphorus Worksheet developed by Iowa Department of Natural Resources was used as the modeling tool for this TMDL analysis.

2.1.1 Modeling Procedures and Results

The procedures used to estimate TP loads to Lake Cornelia consist of:

1. Estimating the delivered loads from point and non-point sources in the watershed using three different methods. These include the Loading Function Model component of EUTROMOD, EPA export coefficients, and WILMS export coefficients.
2. Estimating the annual TP load to Lake Cornelia using measured in-lake phosphorous concentrations, estimated hydraulic detention time, and mean depth as inputs for eleven different empirical models.
3. Comparing the estimated TP loads based on watershed sources and the empirical models to select the best-fit empirical model for existing loads.
4. Estimating the allowable TP loads at the target concentration (TP=63 µg/L) for the lake, using the selected empirical model.

Table 5 lists the watershed and lake response models used to evaluate the existing and targeted Lake Cornelia water quality conditions.

Watershed Load Estimates

The three watershed load estimates in Table 5 are different because the procedures and assumptions about loads from different land uses and the way that these are accounted for are different.

The loading function procedure is based on the Annual Loading Function Model within the EUTROMOD Watershed and Lake Model by Reckhow (1990) to evaluate nutrient load delivered to lakes. It incorporates approximations of both soluble phosphorous in the runoff to Lake Cornelia and the sediment attached phosphorus derived from erosion modeling and an estimated delivery ratio that considers watershed size and ecoregion. Export coefficients in EPA and WILMS methods are unit area annual averages for phosphorous loads associated with a particular land use.

The estimated annual average TP load by the Loading Function Method, EPA Export Coefficient Method and WILMS Export Coefficient Model is 1,407 lbs/year, 503 lbs/year and 395 lbs/year, respectively.

In-Lake Response Load Estimates

In-lake monitoring data is used in conjunction with empirical mass balance models to estimate total phosphorus loads delivered to the lake that would cause the observed concentrations. These loads include the watershed nonpoint and point source loads, phosphorus recycled by re-suspension of sediment, and phosphorous from direct rainfall and dry deposition.

The relatively low phosphorus (72 µg/L) and inorganic suspended solids (6.9 mg/L) at Lake Cornelia indicate an insignificant internal loading component.

Table 5: Model Results for Lake Cornelia

Watershed Load Estimates	**Predicted Existing Annual TP Load (lbs/yr)[1]**	**Comments**
Loading Function Method	1,536	Reckhow (Eutromod)
EPA Export Coefficient Method	530	EPA 440-5-80-011
WILMS Export Coefficient Model	395	"most likely" export coefficients[3]
In-lake response load estimates		
1. Canfield-Bachmann 1981 Natural Lake	614	Growing Season Mean (GSM) model
2. Canfield-Bachmann 1981 Artificial Lake	1,049	GSM model
3. Reckhow Natural Lake	1,895	GSM model
4. Reckhow Anoxic Lake	144	GSM model
5. Reckhow Oxic Lake (Z/Tw < 50 m/year)	625	GSM model
6. Vollenweider 1982 Combined OECD	349	Annual Model[2]
7. Vollenweider 1982 Shallow Lake and Reservoir	408	Annual Model[2]
8. Walker Reservoir	644	Annual Model[2]
9. Simple First Order (Walker)	1,308	Annual Model[2]
10. First Order Settling	656	Annual Model[2]
11. Nurnberg 1984 Oxic Lake - Lake response external load when internal load = zero	374 (Internal Load =0)	Annual Model[2]

(1) For in-lake GSM concentration TP = ANN TP = 72 µg/l (which is lower than target TP 96 µg/l). This is the average of the ISU Lake Study TP values, from 2000 to 2005.

(2) Note that P annual = P growing season for polymictic lakes.

(3) There are three values estimates for the WILMS export coefficients, low, most likely, and high.

After verifying whether all model parameters are within acceptable ranges, the applicable in-lake response models in Table 5 with parameters in the acceptable range are:

- Canfield-Bachmann 1981 Natural Lake, 614 lbs/year
- Vollenweider 1982 Shallow Lake and Reservoir, 408 lbs/year

Canfield-Bachmann Natural Lake model is preferred because the results are closer to the estimates by the Loading Function Method and EPA Export Coefficient Method. In addition, it is a growing season mean (GSM) model, which is suitable to address the requirement of "critical condition" in the TMDL development.

The equation for the Canfield-Bachmann Natural Lake model is:

$$P = \frac{L}{z[0.162(L/z)^{0.458} + p]}$$

where,

P = predicted in-lake total phosphorus concentration (µg/L)

L = areal total phosphorus load (mg/m^2 of lake area per year)

z = lake mean depth (meters)

p = lake flushing rate (yr^{-1})

The Canfield-Bachmann Natural Lake Model predicts a current phosphorous loading of 614 lbs/yr. Further confirmation with IDNR's field specialist reveals this modeled number is relatively high for adjacent areas of Lake Cornelia watershed, which is more conservative in the TMDL analysis and thus can be viewed as an implicit margin of safety.

The chlorophyll a and secchi depth objectives are related through the Trophic State Index to total phosphorus. The loading capacity for this TMDL is the annual amount of total phosphorus that Lake Cornelia can receive but still meet its designated uses.

Based on selected lake response model and a target TSI (TP) value of less than 64 (corresponding to an in-lake average TP concentration of 63 µg/L), the TMDL for total phosphorus is 491 lbs/year. This TMDL has established annual loads rather than daily loads because the lake response is a result of the loading for an extended time period prior to any given measurement. There is little, if any benefit, in modeling the lake on a daily basis nor to establish targets on a daily basis. While localized turbidity and, to some degree, algae may be tracked as responding to short-term rainfall, targets set on a yearly basis or on a daily basis would not change the implementation practices necessary for this non-point source only TMDL.

2.1.2 Estimate of Existing Loads:

There are two quantified phosphorus sources for Lake Cornelia 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 (internal load). The second source is atmospheric deposition.

Existing Load

The existing annual total phosphorus load to Lake Cornelia is estimated to be 614 lbs/year, based on the selected lake response model. Given relatively low TP and inorganic suspended solids (ISS) values and lack of site-specific data for lake sediment, the internal load for Lake Cornelia is assumed as insignificant.

Departure from Loading Capacity

The loading capacity of total phosphorus for Lake Cornelia is 491 lbs/year. The existing watershed load is estimated as 614 lbs/year. Therefore, a load reduction of 123 lbs/year is needed in order to achieve water quality goals and protect the designated uses.

Identification of Pollutant Sources

There are no significant point source discharges in the Lake Cornelia watershed. Most phosphorous is delivered to the lake from nonpoint sources. Figure 5 shows the TP loads for the external watershed sources estimated by the Loading Function Model. As can be seen, most nonpoint source phosphorus delivered to the lake is from cropland.

Linkage of Pollution Sources to TMDL Target

The pollutant sources of TP from the watershed have been linked to the water quality impairment through the use of the Loading Function model and EPA export coefficient model, along with the selected in-lake response model.

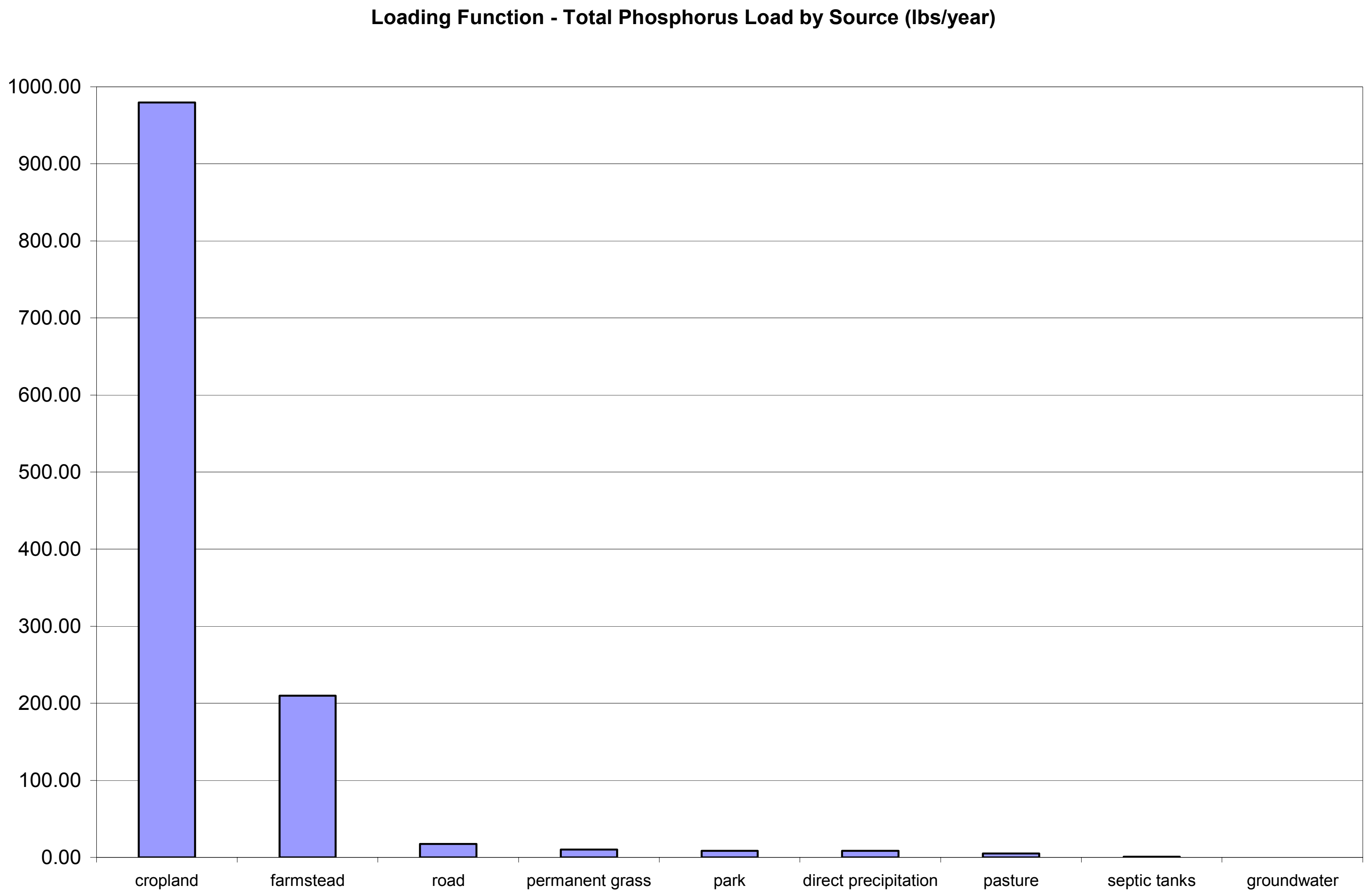


Figure 5: Loading Function Model - Total Phosphorus Load by Source (lbs/year)

2.2 Consideration of Critical Condition and Seasonal Variations

(1) Critical Condition

The Clean Water Act [40 CFR 130.7(c)(1)] and USEPA'S TMDL regulations require that in developing TMDLs, one must "*take into account the critical conditions for stream flow, loading, and water quality parameters*". The "critical condition" is generally defined as the condition when the physical, chemical, and biological characteristics of the receiving water environment interact with the effluent to produce the greatest potential adverse impact on aquatic biota and existing or characteristic water uses. The intent of this requirement is to ensure that the water quality of the receiving water body is protected during times when it is most vulnerable.

The critical condition for this TMDL study is during the growing season (May through September) when nuisance algal blooms and low transparency in the lake are most likely to occur. During this critical flow period, impacts from wet weather sources are limited since storm runoff is minimal under dry weather conditions.

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 annual average total phosphorus loading.

(2) Considerations of Seasonal Variations

The TMDL target was derived using May through September data when nuisance algal blooms and low transparency in Lake Cornelia were most likely to occur. By using data from this most problematic period instead of the entire year, the target is meant to prevent nuisance algal bloom and low transparency occurrences year-round. If a phosphorus limit were instituted for the growing season only, it would ignore the effects of nutrient re-suspension in the water column within Lake Cornelia.

2.3 Margin of Safety

The Margin of Safety (MOS) is included to account for uncertainties associated with TMDL development. Based on data availability for this TMDL study and guidance from EPA and IDNR, an explicit margin of safety 10% of loading capacity is reserved for MOS. In addition, as discussed earlier, the modeled number using Lake Phosphorus Worksheet for Lake Cornelia application is more conservative and can be viewed as an implicit MOS.

2.4 Waste Load Allocation:

The Waste Load Allocation (WLA) is the maximum allowable amount of the pollutant that can be assigned to point sources. There are no point sources or CAFOs in the Lake Cornelia watershed. Therefore, the WLA for this TMDL is set as zero pounds per year.

2.5 Load Allocation:

Load Allocation (LA) can be calculated from (Eq. 1) by subtracting WLA and MOS from TMDL.

TMDL = WLA + LA + MOS

LA = TMDL – MOS – WLA (Eq. 2)
= 491– 10%*491 – 0 = 442 lbs/yr

LA for this TMDL is further divided into watershed non-point sources and atmospheric deposition. Assuming atmospheric deposition consists of 10% of total LA, the watershed nonpoint source load is:

442 lbs/yr – 10%*442 lbs/yr = 398 lbs/yr

2.6 Percentage of Reduction:

Estimating required percentage of reduction is given as follows:

Determination of Required Load Reduction
% TP Reduction = (Existing Load – LA) / Existing Loading (Eq. 3)
= (614 – 442) / 614 = 28.1%

A TP load reduction of 28.1% is needed in order to achieve water quality goals and protect the designated uses.

Table 6: Summary of TMDL Results for Lake Cornelia

TMDL (lb/yr)	**491**
WLA (lb/yr)	**0**
LA (lb/yr)	**442**
MOS (lb/yr)	**49**
Existing Load (lb/yr)	**614**
% of Reduction	**28.1%**

3. Reasonable Assurance

Reasonable assurance of TMDL established for Lake Cornelia will require a comprehensive approach that addresses:

- non-point source pollution (since there are no point sources in the watershed),
- existing and potential future sources,
- regulatory and voluntary approaches.

There is reasonable assurance that the goals of the TMDL for Lake Cornelia can be met with proper watershed planning, implementation of BMPs, and strong financial mechanisms. As can be seen in the development of the TMDL, there are two major components to the phosphorous inputs for Lake Cornelia, the external watershed load and the internal recycled load. 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 to phosphorous reduction 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.

Reaching the reduction goals established by this TMDL will only occur through changes in current land use practices, including the incorporation of best management practices (BMPs). BMPs that would be helpful in lowering the amount of nutrients and sediments reaching Lake Cornelia include riparian buffer strips, strip cropping, contour plowing, and conservation crop rotation, among many others. The Natural Resources Conservation Service maintains a National Handbook of Conservation Practices (NHCP), which provides information on a variety of BMPs (USDA, 2005). The NHCP is available online at (http://www.nrcs.usda.gov/technical/standards/nhcp.html). Many of the practices described in the handbook could be used on agricultural lands in the Lake Cornelia watershed to help limit impairments due to algae growth and turbidity.

Determining the most appropriate BMPs, where they should be installed, and actually putting them into practice, will require the development and implementation of a comprehensive watershed restoration plan. Development of any watershed restoration plan will involve the gathering of site-specific information regarding current land uses and existing conservation practices. Successful implementation of the activities necessary to address current use impairment in Lake Cornelia watershed will require local citizen’s active interest in the watershed and cooperation of other relevant entities. By developing a nutrient TMDL for Lake Cornelia, the stage has been set for local citizens to design and implement restoration plans to correct current use impairments.

4. Implementation Plan

An 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 Lake Cornelia water quality. This plan will continue to be developed in cooperation with local partners through the public participation process.

During the public meeting held at Lake Cornelia, local residents expressed concern towards increased amounts of aquatic vegetation in the lake. During the meeting, IDNR staff indicated that an increase in aquatic macrophytes could help improve water clarity and overall water quality in the lake, while also providing valuable habitat for the fishery in the lake. Residents were largely opposed to increased amounts of “weeds” as they were referred to. Lake Cornelia has experienced a significant decrease in the amount of aquatic vegetation in the lake over the past decade, particularly along the southeast portion of the lake, where bulrushes were once dominant. The decrease in aquatic vegetation has decreased as development around the lake has continued to increase. It may be possible to manage the vegetation so that the water quality benefits are realized while the impact to local users is minimized. For this to occur, local residents and users of the lake will need to be supportive of increased levels of aquatic plants and work with the local DNR fisheries biologist and the Wright County Conservation Board.

Comments were also received on the management of rough fish, particularly carp, in the lake. Lake Cornelia has had commercial harvesting of carp in the past, although not recently. IDNR fisheries staff continue to monitor and manage the fishery at the lake, and if rough fish populations become excessive, management controls, such as commercial harvesting, will need to be put in place.

Local residents and members of the Wright County Conservation Board expressed concern over the IDNR designated watershed boundary. It was stated that the road on the west side of the lake (Obrien Ave) actually intercepts much of the drainage from the west, and that the effective drainage to the west of Lake Cornelia extends only to the road. The IDNR will conduct a field visit of the watershed in the fall of 2006 to verify the watershed boundary of Lake Cornelia.

Needed restoration efforts in the watershed include several sites that may be suitable for wetland restoration or the use of wetlands to slow and treat tile drainage prior to entering the lake. Several areas in the watershed would benefit from the installation of filters or buffers.

Water quality in Lake Cornelia has shown significant improvement since the installation of a sanitary sewer system in the mid 1980’s. An assessment of the septic systems of the rural houses in the watershed that are not connected to the sanitary sewer should be completed to ensure that the systems meet codes and are functioning properly.

5. Monitoring

Further monitoring is needed at Lake Cornelia 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.). Lake monitoring is currently ongoing at Lake Cornelia, with a minimum of three samples collected per growing season.

6. Public Participation

A public meeting was held at the Lake Cornelia shelter on July 26, 2006 to discuss the Lake Cornelia TMDL and begin development of the implementation strategy. Public comments were received during the meeting and were incorporated into the implementation plan for local stakeholders to utilize in making improvements to Lake Cornelia and the watershed.

References

Alexander, R. B., Smith, R. A., and Schwarz, G. E. (2004). Estimates of Diffuse Phosphorus Sources in Surface Wastes of the United States using a spatially referenced watershed model, *Water Sciences and Technology*, 49(3): 1-10

Bachmann, R.W., M.R. Johnson, M.V. Moore, and T.A. Noonan (1980). Clean lakes classification study of Iowa's lakes for restoration. Iowa Cooperative Fisheries Research Unit and Department of Animal Ecology, Iowa State University, Ames, Iowa. 715 p.

Bachmann, R.W., T.A. Hoyman, L.K. Hatch, and B.P. Hutchins (1994). A classification of Iowa's lakes for restoration. Iowa State University, Ames, Iowa. 517 p.

Canfield, D. E. Jr., and R. W. Bachmann (1981). Prediction of total phosphorus concentrations, chlorophyll a, and secchi depths in natural and artificial lakes. Can. J. Fish. Aquat. Sci. 38: 414-423

Carlson, R. E. (1977). A trophic state index for lakes. Limnology and Oceanography 25:378-382.

Carlson, R.E. and J. Simpson (1996). A Coordinator's Guide to Volunteer Lake Monitoring Methods. North American Lake Management Society, 96p. http://dipin.kent.edu/tsi.htm

Iowa General Assembly (2004). Iowa Administrative Code, Chapter 567-61: Water Quality Standards, http://www.legis.state.ia.us/IAC.html

Iowa Department of Natural Resources (IDNR) (2004). Iowa Section 303(d) Impaired Waters Listings, http://wqm.igsb.uiowa.edu/WQA/303d.html

Iowa Department of Natural Resources (IDNR) (2005). Iowa State University Statewide Lake Study, http://limnology.eeob.iastate.edu/lakereport/

Iowa Department of Natural Resources (IDNR) (2006). Water Quality Improvement Plans – Publications and Report, http://www.iowadnr.com/water/watershed/pubs.html

Iowa State University (2005). Center for Agricultural Research and Rural Development (CARD) Resource and Environmental Policy Division. Iowa Lakes Valuation Project. Available at http://www.card.iastate.edu/lakes/

Reckhow, K. H. (1990). EUTROMOD Watershed and Lake Modeling Software Tech. Transfer. North American Lake Management Society.

Renard, K. G., G. R. Foster, G. A. Weesies, D. K. McCool, and D. C. Yoder (1997). Predicting soil erosion by water: A guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE). U.S. Department of Agriculture, Agriculture Handbook No. 703. 404 pp.

Toy, T. J. and Foster, G. R. (1998). Guidelines for the Use of the Revised Universal Soil Loss Equation (RUSLE) Version 1.06 on Mined Lands, Construction Sites, and Reclaimed Lands, Western Regional Coordinating Center, Office of Surface Mining, Denver, Colorado..

U.S. Army Corps of Engineers (2004). Review of Published Export Coefficient and Event Mean Concentration (EMC) Data, Report ERDC TN-WRAP-04-3

U. S. Department of Agriculture (USDA) (2000). Predicting Rainfall Erosion Losses, the Revised Universal Soil Loss Equation (RUSLE), Natural Resources Conservation Service - Field Office Technical Guide.

U. S. Department of Agriculture (USDA) (2005). National Handbook of Conservation Practices (NHCP), http://www.nrcs.usda.gov/technical/standards/nhcp.html

USEPA (1980). Modeling Phosphorus Loading and Lake Response under Uncertainty: A Manual and Compilation of Export Coefficients, EPA Report 440-5-80-011

USEPA (1998). Lake and Reservoir Bioassessment and Biocriteria, EPA Report 841-B-98-007

USEPA (1999). Protocol for Developing Nutrient TMDLs (First Edition), EPA Report 841-B-99-007

USEPA (1999a). Draft Guidance for Water Quality-based Decisions: The TMDL Process (Second Edition), EPA Report 841-D-99-001

Walker, W.W. (2004). BATHTUB - Version 6.1. Simplified Techniques for Eutrophication Assessment & Prediction. USACE Waterways Experiment Station, Vicksburg, MS.

Wisconsin Department of Natural Resources (2003). Wisconsin Lake Modeling Suite Program Documentation and User's Manual. 2003 PUBL-WR-363-94.

Appendices

Appendix A – Lake Cornelia Hydrologic Calculations

Appendix B – Sampling Data

Appendix C – Trophic State Index

Appendix A – Lake Cornelia Hydrologic Calculations

Lake	Cornelia	
Type	Impoundment	
Inlet(s)	Unnamed Creek	
Outlet(s)	Unnamed Creek	
Volume	1857	acre-feet
Surface Area	243	acres
Watershed Area	987	acres
Mean Annual Precipitation	30.57	inches
Average Basin Slope	1.00	%
% Forest (2000 Land Cover)	3.49	
% Corn (2000 Land Cover)	13.79	
% Rowcrop (2002 Land Cover)	29.00	
Basin Soils Average % Sand	30.00	
Soil Permeability	1.30	inches/hour
Mean Annual Class A Pan Evaporation	48.00	inches
Evaporation Coefficient	0.70	
Optional User Input Inflow Estimate		acre-feet/year
Optional User Input Runoff Component		acre-feet/year
Optional User Input Baseflow Component		acre-feet/year
Mean Depth	8.0	feet
Drainage Area	745	acres
Drainage Area	1.16	square miles
Drainage Area/Lake Area	3.07	
Mean Annual Lake Evaporation	33.60	inches
Mean Annual Lake Evaporation	680.40	acre-feet/year
Annual Average Inflow	0.58	cfs
Annual Average Inflow	418.75	acre-feet/year
Runoff Component	449.66	acre-feet/year
Baseflow Component	-30.91	acre-feet/year
Direct Precipitation on Lake Surface	619.04	acre-feet/year
Inflow + Direct Precipitation	1037.79	acre-feet/year
% Inflow	40.35	
% Direct Precipitation	59.65	
Outflow	357.39	acre-feet/year
HRT Based on Inflow + Direct Precipitation	1.87	year
HRT Based on Outflow	5.44	year

Appendix B – Sampling Data

Table B-1. Data collected in 1980 Bachmann Report

Lake Survey Year	1979
Secchi Disk Depth (m)	0.6
Chlorophyll a (µg/L)	32.4
TOT Phosphorus (µg/L)	61.4
Kjeldahl Nitrogen (mg/L)	1.5
Ammonia Nitrogen (mg/L)	0.1
Nitrate + Nitrite Nitrogen (mg/L)	0.1
Seston Dry Weight (mg/L)	20.3
Turbidity	8.2
TOT Hardness (mg/L) as $CaCO_3$	148.4
Calcium Hardness (mg/L) as $CaCO_3$	58.2
TOT Alkalinity (mg/L) as $CaCO_3$	141.8
Dissolved Oxygen (mg/L)	7.8
Specific Conductance (micohmes/cm) at 25° C	305
Sulfate (mg/L)	3.1
Chloride (mg/L)	16.1
Sodium (mg/L)	12
Potassium (mg/L)	7

Table B-2. Data collected in 1994 Bachmann Report

Lake Survey Year	1990
Secchi Disk Depth (m)	0.8
Chlorophyll a (µg/L)	130.8
TOT Phosphorus (µg/L)	80
TOT Nitrogen (mg/L)	2.2
Inorganic Suspended Solids (mg/L)	10.9
TOT Suspended Solids (mg/L)	27.9

Table B-3. Data collected in 2000 by Iowa State University

Parameter	**7/10/2000**	**7/31/2000**	**8/29/2000**
Lake Depth (m)	5.2	5.3	4
Thermocline Depth (m)	NIL	2.5	NIL
Secchi Disk Depth (m)	0.6	0.4	0.8
Temperature(^{o}C)	26.4	24.8	23.5
Dissolved Oxygen (mg/L)	8.4	7.8	9.1
Dissolved Oxygen Saturation (%)	104	94	107
Specific Conductivity (µS/cm)	543.3	373.2	342.3
Turbidity (NTU)	21.6	14.3	21.2
Chlorophyll a (µg/L)	29.5	3.5	10.3
Total Phosphorus as P (µg/L)	214	143	125
Total Nitrogen as N (mg/L)	1.67	1.58	1.39
Nitrate + Nitrite (NO_3 + NO_2) as N (mg/L)	0.17	0.11	0.28
TN:TP ratio	8	11	11
pH	6.8	8.1	7.8
Alkalinity as $CaCO_3$ (mg/L)	194	178	185
Inorganic Suspended Solids (mg/L)	9	10	6
Volatile Suspended Solids (mg/L)	15	10	4
Total Suspended Solids (mg/L)	24	20	10

Table B-4. Data collected in 2001 by Iowa State University

Parameter	**6/4/2001**	**7/9/2001**	**8/6/2001**
Lake Depth (m)	5.5	5	5.6
Thermocline Depth (m)	NIL	3.5	NIL
Secchi Disk Depth (m)	1.9	1.4	1.5
Temperature(^{o}C)	16.4	26.3	28.8
Dissolved Oxygen (mg/L)	10.5	10	8.1
Dissolved Oxygen Saturation (%)	108	123	105
Specific Conductivity (µS/cm)	324.5	498.7	395.2
Turbidity (NTU)	9.6	14.4	15.2
Chlorophyll a (µg/L)	5.2	20.9	55.7
Total Phosphorus as P (µg/L)	33	84	134
Total Nitrogen as N (mg/L)	1.72	1.55	1.24
Nitrate + Nitrite (NO_3 + NO_2) as N (mg/L)	0.56	0.11	0.24
TN:TP ratio	52	19	9
pH	8.2	8.7	7.8
Alkalinity as $CaCO_3$ (mg/L)	157	184	177
Inorganic Suspended Solids (mg/L)	4	3	4
Volatile Suspended Solids (mg/L)	5	6	10
Total Suspended Solids (mg/L)	9	9	14

Table B-5. Data collected in 2002 by Iowa State University

Parameter	**6/10/2002**	**7/15/2002**	**8/12/2002**
Lake Depth (m)	5.5	5.2	5.2
Thermocline Depth (m)	NIL	3.4	NIL
Secchi Disk Depth (m)	1	0.5	0.4
Temperature(^{o}C)	22.4	26.3	25
Dissolved Oxygen (mg/L)	-	9.5	7
Dissolved Oxygen Saturation (%)	-	118	84
Specific Conductivity (µS/cm)	385	812.1	378.8
Turbidity (NTU)	9.5	19.2	50.2
Chlorophyll a (µg/L)	12.9	23.2	44.4
Total Phosphorus as P (µg/L)	41	54	91
SRP as P (µg/L)	2	1	3
Total Nitrogen as N (mg/L)	1.28	1.12	1.43
Ammonia Nitrogen (NH_3 + NH_4^+) as N (µg/L)	285	225	291
Ammonia Nitrogen (NH_3) as N (un-ionized)(µg/L)	30	39	44
Nitrate + Nitrite (NO_3 + NO_2) as N (mg/L)	0.33	0.18	0.22
TN:TP ratio	31	21	16
pH	8.4	8.5	8.5
Alkalinity as $CaCO_3$ (mg/L)	190	178	172
Silica as Si (mg/L)	6.82	10.92	14.58
Dissolved Organic Carbon (mg/L)	-	-	13.85
Inorganic Suspended Solids (mg/L)	6	-	10
Volatile Suspended Solids (mg/L)	7	-	15
Total Suspended Solids (mg/L)	13	5	25

Table B-6. Data collected in 2003 by Iowa State University

Parameter	**6/9/2003**	**7/14/2003**	**8/11/2003**
Lake Depth (m)	5.4	5.3	5.1
Thermocline Depth (m)	NIL	4.4	4
Secchi Disk Depth (m)	0.7	0.8	0.6
Temperature(^{o}C)	18	24.5	25.6
Dissolved Oxygen (mg/L)	9.6	9.1	8.7
Dissolved Oxygen Saturation (%)	102	108	106
Specific Conductivity (µS/cm)	360.3	362	386.1
Turbidity (NTU)	21.1	23.2	23.8
Chlorophyll a (µg/L)	24.7	29	30.3
Total Phosphorus as P (µg/L)	66	65	81
SRP as P (µg/L)	1	3	1
Total Nitrogen as N (mg/L)	1.74	1.45	1.56
Ammonia Nitrogen (NH_3 + NH_4^+) as N (µg/L)	126	339	387
Ammonia Nitrogen (NH_3) as N (un-ionized)(µg/L)	12	57	56
Nitrate + Nitrite (NO_3 + NO_2) as N (mg/L)	0.47	0.17	0.15
TN:TP ratio	26	23	19
pH	8.5	8.6	8.5
Alkalinity as $CaCO_3$ (mg/L)	120	109	114
Silica as Si (mg/L)	7.84	10.75	9.5
Dissolved Organic Carbon (mg/L)	14	14	13.57
Inorganic Suspended Solids (mg/L)	15	12	12
Volatile Suspended Solids (mg/L)	12	9	28
Total Suspended Solids (mg/L)	26	21	40

Table B-7. Data collected in 2004 by Iowa State University

Parameter	**6/7/2004**	**7/12/2004**	**8/9/2004**
Lake Depth (m)	5.4	5.4	5.3
Thermocline Depth (m)	4.5	3	NIL
Secchi Disk Depth (m)	1	0.9	0.6
Temperature(^{o}C)	21.6	24.7	23.5
Dissolved Oxygen (mg/L)	10.9	9.6	10
Dissolved Oxygen Saturation (%)	123	115	117
Specific Conductivity (µS/cm)	372.3	392	381
Turbidity (NTU)	13.3	10.7	46
Chlorophyll a (µg/L)	39.4	17.2	39.6
Total Phosphorus as P (µg/L)	41	50	83
SRP as P (µg/L)	1	2	5
Total Nitrogen as N (mg/L)	1.42	1.15	2.02
Ammonia Nitrogen (NH_3 + NH_4^+) as N (µg/L)	39	135	36
Ammonia Nitrogen (NH_3) as N (un-ionized)(µg/L)	8	17	1
Nitrate + Nitrite (NO_3 + NO_2) as N (mg/L)	0.44	0.32	0.44
TN:TP ratio	34	23	24
pH	8.7	8.4	8.8
Alkalinity as $CaCO_3$ (mg/L)	142	174	175
Silica as Si (mg/L)	3.64	7.81	10.71
Dissolved Organic Carbon (mg/L)	10.23	9.04	8.75
Inorganic Suspended Solids (mg/L)	4	3	8
Volatile Suspended Solids (mg/L)	5	11	12
Total Suspended Solids (mg/L)	9	14	19
Microcystin (ng/L)	17.7	41.1	778.1

Table B-8. Data collected in 2005 by Iowa State University

Parameter	**6/13/2005**	**7/18/2005**	**8/8/2005**
Lake Depth (m)	5.5	6	5.4
Thermocline Depth (m)	NIL	5.1	NIL
Secchi Disk Depth (m)	0.4	0.5	0.5
Temperature(^{o}C)	24.1	27.4	25.7
Dissolved Oxygen (mg/L)	10.5	6.3	8.6
Dissolved Oxygen Saturation (%)	125	79	105
Specific Conductivity (µS/cm)	371.8	369.6	398.7
Turbidity (NTU)	17.4	14.4	19.8
Chlorophyll a (µg/L)	83.1	22.8	55.9
Total Phosphorus as P (µg/L)	63	78	74
SRP as P (µg/L)	-	-	-
Total Nitrogen as N (mg/L)	1.6	1.69	1.6
(Phenate)Ammonia Nitrogen (NH_3 + NH_4^+) as N (µg/L)	166.4	23.8	63.4
(Phenate)Ammonia Nitrogen (NH_3) as N (un-ionized)(µg/L)	30.7	2.7	9.3
Nitrate + Nitrite (NO_3 + NO_2) as N (mg/L)	0.18	0.16	0.19
TN:TP ratio	25	22	21
pH	8.6	8.3	8.5
Alkalinity as $CaCO_3$ (mg/L)	157	152	155
Silica as Si (mg/L)	7.62	11.57	12.31
Dissolved Organic Carbon (mg/L)	10.67	10.93	12.85
Inorganic Suspended Solids (mg/L)	13	14	9
Volatile Suspended Solids (mg/L)	23	25	14
Total Suspended Solids (mg/L)	35	39	24
Microcystin (ng/L)	46.1	37.5	47

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

Table B-9. TSI values calculated from the Iowa Lake Survey data through 2005 and the mean and median values for the Secchi depth, chlorophyll, and total phosphorus

	Sample Data				TSI Values		
DATE	SOURCE	Secchi Depth (m)	Chlorophyll (µg/l)	Total Phosphorus (µg/l)	Secchi Depth	Chlorophyll	Total Phosphorus
7/10/2000	IA St. Univ.	0.60	29.5	210	67	64	81
7/31/2000	IA St. Univ.	0.40	3.5	140	73	43	75
8/29/2000	IA St. Univ.	0.80	10.3	130	63	53	74
6/4/2001	IA St. Univ.	1.90	5.2	30	51	47	53
7/9/2001	IA St. Univ.	1.40	20.9	80	55	60	67
8/6/2001	IA St. Univ.	1.50	55.7	130	54	70	74
6/10/2002	IA St. Univ.	1.00	12.9	40	60	56	57
7/15/2002	IA St. Univ.	0.50	23.2	50	70	61	61
8/12/2002	IA St. Univ.	0.40	44.4	90	73	68	69
6/9/2003	IA St. Univ.	0.70	24.7	70	65	62	65
7/14/2003	IA St. Univ.	0.80	29.0	60	63	64	63
8/11/2003	IA St. Univ.	0.60	30.3	80	67	64	67
6/7/2004	IA St. Univ.	0.90	39.4	40	62	67	57
6/17/2004	IA-DNR	0.60	35.0	60	67	65	63
6/17/2004	IA-DNR	0.50	1.0	50	70	31	61
6/17/2004	IA-DNR	0.50	1.0	70	70	31	65
6/17/2004	IA-DNR		31.0			64	
6/17/2004	IA-DNR		5.0			46	
6/17/2004	IA-DNR		36.0			66	
6/17/2004	IA-DNR		1.0			31	
6/17/2004	IA-DNR		1.0			31	
6/17/2004	IA-DNR		31.0			64	
6/17/2004	IA-DNR		5.0			46	
6/17/2004	IA-DNR		31.0			64	
6/17/2004	IA-DNR		1.0			31	
6/17/2004	IA-DNR		1.0			31	
6/17/2004	IA-DNR		27.0			63	
6/17/2004	IA-DNR		5.0			46	
7/8/2004	IA-DNR	0.69	21.0	80	65	60	67
7/8/2004	IA-DNR	0.69	1.0	60	65	31	63
7/8/2004	IA-DNR	0.69	1.0	50	65	31	61
7/8/2004	IA-DNR		19.0			59	
7/8/2004	IA-DNR		2.0			37	
7/8/2004	IA-DNR		18.0			59	
7/8/2004	IA-DNR		1.0			31	
7/8/2004	IA-DNR		1.0			31	
7/8/2004	IA-DNR		16.0			58	
7/8/2004	IA-DNR		2.0			37	
7/8/2004	IA-DNR		19.0			59	
7/8/2004	IA-DNR		1.0			31	
7/8/2004	IA-DNR		1.0			31	
7/8/2004	IA-DNR		18.0			59	

	Sample Data				TSI Values		
DATE	**SOURCE**	**Secchi Depth (m)**	**Chlorophyll (µg/l)**	**Total Phosphorus (µg/l)**	**Secchi Depth**	**Chlorophyll**	**Total Phosphorus**
7/12/2004	IA St. Univ.	0.90	17.2	50	62	59	61
7/12/2004	IA-DNR		16.0	80		58	67
7/12/2004	IA-DNR		1.0			31	
7/12/2004	IA-DNR		1.0			31	
7/12/2004	IA-DNR		15.0			57	
7/12/2004	IA-DNR		1.0			31	
7/19/2004	IA-DNR	0.69	22.0	60	65	61	63
7/19/2004	IA-DNR	0.61	1.0	60	67	31	63
7/19/2004	IA-DNR	0.61	1.0	60	67	31	63
7/19/2004	IA-DNR		21.0			60	
7/19/2004	IA-DNR		1.0			31	
7/19/2004	IA-DNR		22.0			61	
7/19/2004	IA-DNR		1.0			31	
7/19/2004	IA-DNR		1.0			31	
7/19/2004	IA-DNR		21.0			60	
7/19/2004	IA-DNR		1.0			31	
7/19/2004	IA-DNR		19.0			59	
7/19/2004	IA-DNR		1.0			31	
7/19/2004	IA-DNR		1.0			31	
7/19/2004	IA-DNR		18.0			59	
7/19/2004	IA-DNR		1.0			31	
8/5/2004	IA-DNR	0.61	47.0	80	67	68	67
8/5/2004	IA-DNR	0.61	1.0	90	67	31	69
8/5/2004	IA-DNR	0.52	1.0	70	69	31	65
8/5/2004	IA-DNR		45.0			68	
8/5/2004	IA-DNR		1.0			31	
8/5/2004	IA-DNR		37.0			66	
8/5/2004	IA-DNR		1.0			31	
8/5/2004	IA-DNR		1.0			31	
8/5/2004	IA-DNR		36.0			66	
8/5/2004	IA-DNR		1.0			31	
8/5/2004	IA-DNR		38.0			66	
8/5/2004	IA-DNR		1.0			31	
8/5/2004	IA-DNR		1.0			31	
8/5/2004	IA-DNR		36.0			66	
8/5/2004	IA-DNR		1.0			31	
8/9/2004	IA St. Univ.	0.60	39.6	80	67	67	67
8/16/2004	IA-DNR	0.46	36.0	80	71	66	67
8/16/2004	IA-DNR	0.46	1.0	100	71	31	71
8/16/2004	IA-DNR	0.46	1.0	90	71	31	69
8/16/2004	IA-DNR		34.0			65	
8/16/2004	IA-DNR		1.0			31	
8/16/2004	IA-DNR		37.0			66	
8/16/2004	IA-DNR		1.0			31	
8/16/2004	IA-DNR		1.0			31	

	Sample Data				TSI Values		
DATE	**SOURCE**	**Secchi Depth (m)**	**Chlorophyll (µg/l)**	**Total Phosphorus (µg/l)**	**Secchi Depth**	**Chlorophyll**	**Total Phosphorus**
8/16/2004	IA-DNR		1.0			31	
8/16/2004	IA-DNR		37.0			66	
8/16/2004	IA-DNR		1.0			31	
8/16/2004	IA-DNR		1.0			31	
8/16/2004	IA-DNR		35.0			65	
8/16/2004	IA-DNR		1.0			31	
9/3/2004	IA-DNR	0.61	27.0	60	67	63	63
9/3/2004	IA-DNR	0.61	1.0	90	67	31	69
9/3/2004	IA-DNR	0.61	1.0	60	67	31	63
9/3/2004	IA-DNR		25.0			62	
9/3/2004	IA-DNR		2.0			37	
9/3/2004	IA-DNR		25.0			62	
9/3/2004	IA-DNR		1.0			31	
9/3/2004	IA-DNR		1.0			31	
9/3/2004	IA-DNR		24.0			62	
9/3/2004	IA-DNR		1.0			31	
9/3/2004	IA-DNR		23.0			61	
9/3/2004	IA-DNR		1.0			31	
9/3/2004	IA-DNR		1.0			31	
9/3/2004	IA-DNR		22.0			61	
9/3/2004	IA-DNR		1.0			31	
9/14/2004	IA-DNR	0.61	30.0	100	67	64	71
9/14/2004	IA-DNR	0.61	1.0	90	67	31	69
9/14/2004	IA-DNR	0.61	1.0	70	67	31	65
9/14/2004	IA-DNR		28.0			63	
9/14/2004	IA-DNR		2.0			37	
9/14/2004	IA-DNR		30.0			64	
9/14/2004	IA-DNR		1.0			31	
9/14/2004	IA-DNR		1.0			31	
9/14/2004	IA-DNR		28.0			63	
9/14/2004	IA-DNR		1.0			31	
9/14/2004	IA-DNR		26.0			63	
9/14/2004	IA-DNR		1.0			31	
9/14/2004	IA-DNR		1.0			31	
9/14/2004	IA-DNR		24.0			62	
9/14/2004	IA-DNR		1.0			31	
6/13/2005	IA St. Univ.	0.40	83.1	63	73	74	64
7/18/2005	IA St. Univ.	0.50	22.8	78	70	61	67
8/8/2005	IA St. Univ.	0.50	55.9	74	70	70	66
average		**0.69**	**14.5**	**78**	**65**	**57**	**67**
median		**0.61**	**4.3**	**72**	**67**	**45**	**66**
TARGETS		**> 0.7**	**< 33**	**< 96**	**< 65**	**< 65**	**< 70**

Table B-10. Summary table of measurements made on all Lake Cornelia sampling stations between July 2000 & August 2005. All dates, depths & stations are combined.

Parameter	**Units**	**Mean**	**Median**	**Standard Error**	**n**
Total Phosphorus	µg/L as P	78	72	5	40
Total Nitrogen	mg/L as N	1.67	1.70	0.04	40
Nitrate-Nitrogen	mg/L as N	0.26	0.24	0.03	18
Ammonia-Nitrogen	mg/L as N	0.0595	0.0500	0.0078	34
Chlorophyll *a*	µg/L	14.5	4.3	1.4	128
Secchi depth	m	0.69	0.61	0.05	39
Alkalinity	mg/L as $CaCO_3$	160	160	3	40
Dissolved Oxygen	mg/L	8.9	9.0	0.2	38
Specific Conductance	µmhos/cm	383	370	13	39
Total Suspended Solids	mg/L	21	20	1.4	40
Volatile Suspended Solids	mg/L	11.2	12	0.7	36
Inorganic Suspended Solids	mg/L	7.5	6.9	6.9	14
pH	neg. log H^+ conc.	8.43	8.30	0.04	39
Turbidity	NTU	19.5	19.1	1.4	39

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, µg/L
CHL = in-lake chlorophyll-a concentration, µg/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 USEPA (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	weeds, 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 (µg/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.

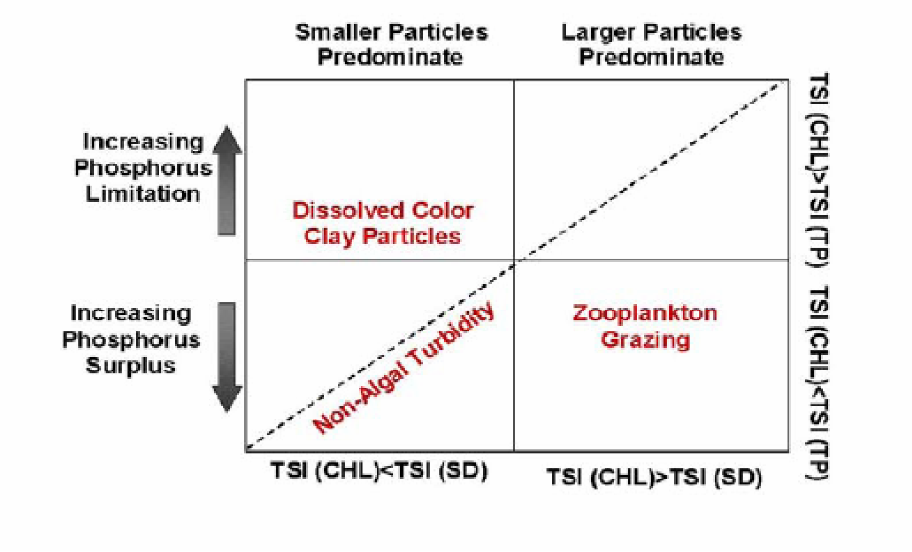


Figure C-1. Multivariate TSI Comparison Chart (Carlson)