Total Maximum Daily Loads
For Nutrients and Siltation
Lake Meyer
Winneshiek County, Iowa

2005

Iowa Department of Natural Resources
TMDL & Water Quality Assessment Section

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1. Executive Summary

Table 1. Lake Meyer Summary

Waterbody Name:	Lake Meyer
County:	Winneshiek
Use Designation Class:	A1 (primary contact recreation) B(LW) (aquatic life)
Major River Basin:	Turkey River Basin
Pollutants:	Phosphorus, Sediment
Pollutant Sources:	Nonpoint, internal recycle, atmospheric (background)
Impaired Use(s):	A1 (primary contact recreation) B(LW) (aquatic life)
2002 303d Priority:	Low
Watershed Area:	1,590 acres
Lake Area:	33 acres
Lake Volume:	409 acre-ft
Detention Time:	0.4 years
TSI (nutrient) Targets:	Total Phosphorus less than 65 (existing); Chlorophyll a less than 65; Secchi Depth less than 65
Total Phosphorus Load Capacity (TMDL):	1,870 pounds per year
Existing Total Phosphorus Load:	1,870 pounds per year
Total Phosphorus Load Reduction to Achieve TMDL:	N/A
Total Phosphorus Margin of Safety:	Implicit
Total Phosphorus Wasteload Allocation:	0
Total Phosphorus Load Allocation:	1,870 pounds per year
Sediment Load Capacity (TMDL):	1,570 tons per year
Existing Sediment Load:	1,570 tons per year
Sediment Load Reduction to Achieve TMDL:	N/A
Sediment Margin of Safety:	Implicit
Sediment Wasteload Allocation:	0
Sediment Load Allocation:	1,570 tons 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. Lake Meyer has been identified as impaired by nutrients and siltation. The purpose of these TMDLs for Lake Meyer is to calculate the maximum allowable nutrient and sediment loads that the lake can receive and still meet water quality standards.

This document consists of TMDLs for nutrients and siltation designed to provide Lake Meyer 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 nutrient impairment. Sediment delivery is targeted to address the siltation impairment.

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, Secchi depth and sediment delivery. The targets for total phosphorus, algal biomass, and Secchi depth will be related to the lake's trophic state through 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:** Lake Meyer, S33, T97N, R9W, 3 miles southwest of Calmar, Winneshiek County.

2. **Identification of the pollutant and applicable water quality standards:** The pollutants causing the water quality impairments are nutrients and siltation associated with excessive phosphorus and sediment loading. Designated uses for Lake Meyer are Primary Contact Recreation (Class A1) and Aquatic Life (Class B(LW)). Excess nutrient and sediment loading have 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 nutrient targets are Carlson's Trophic State Index (TSI) values of less than 65 (existing) for total phosphorus, chlorophyll a, and Secchi depth. TSI values of 65 are equivalent to total phosphorus and chlorophyll concentrations of

70 and 33 ug/L, respectively, and a Secchi depth of 0.7 meters. The Phase 1 sediment target is a sediment delivery rate that will result in the loss of less than a third of the original lake volume within an 80-year design life.

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 1.3 meters, 28 ug/L and 70 ug/L, respectively. Based on these values, all of the nutrient targets have been achieved. The estimated existing annual total phosphorus load to Lake Meyer is 1,870 pounds per year. Since the nutrient targets are currently being met, the total phosphorus loading capacity has been set at the existing load.

   The estimated existing sediment load is 1,570 tons per year. The sediment load associated with the targeted volume loss is 2,500 tons per year. The existing sediment load is currently below the desired endpoint, therefore, the load capacity has been set at the existing load.

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 sources of phosphorus loading to Lake Meyer. Nonpoint sources are identified as the sources of sediment loading to the lake.

6. **Wasteload allocations for pollutants from point sources:** No significant point sources have been identified in the Lake Meyer watershed. Therefore, the wasteload allocations 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 1,870 pounds per year including 10 pounds per year attributable to atmospheric deposition. The sediment load allocation for nonpoint sources is 1,570 tons per year.

8. **A margin of safety:** The nutrient targets for Lake Meyer have already been achieved. Therefore, an explicit Margin of Safety (MOS) for nutrients has not been included in the load calculations. An implicit MOS is present in that existing average TSI values for chlorophyll and Secchi depth are currently below their targets. An additional implicit MOS is present in that the lake response model used to estimate the allowable loading results in a value that is 32% less than the watershed loading predicted by the Loading Function Model, which uses the most recent landuse assessment information to estimate watershed phosphorus delivery.

For sediment delivery, an implicit margin of safety is present in that the load capacity has been set at the estimated existing load of 1,570 tons per year. This is well below the 2,500 tons per year associated with the targeted volume loss of less than a third of the original lake volume within an 80-year design life.

9. **Consideration of seasonal variation:** The nutrient TMDL was developed based on the annual phosphorus loading that will result in attainment of TSI targets for the growing season (May through September). An annual loading period was used to define Lake Meyer's sediment loading capacity. Sediment loads are actually the result of periodic intensive and/or high volume precipitation events. Non-point source controls are typically designed for average annual long-term conditions.

10. **Allowance for reasonably foreseeable increases in pollutant loads:** An allowance for increased phosphorus or sediment loading was not included in the TMDLs. Significant changes in the Meyer Lake watershed landuses are unlikely. The majority of the watershed landuse is dedicated to agricultural production. The watershed includes a portion of the City of Calmar and some residential development could occur. The addition or deletion of grazing or livestock operations within the watershed could increase or decrease nutrient and sediment 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 TMDLs.

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

2. Lake Meyer, Description and History

2.1 The Lake

Lake Meyer was constructed in 1968 and is located in northeast Iowa, 3 miles southwest of Calmar. Public use for Lake Meyer is estimated at 15,500 visitors per year. Users of the lake and of Lake Meyer County Park enjoy fishing, picnicking, camping and hiking. Although the lake is designated a primary contact recreation water, there are no beach or swimming facilities provided. Lake Meyer County Park is 160 acres with 60 acres of woodland, marsh, stream bank, and prairie bordering the nature center.

Table 2. Lake Meyer Features

Waterbody Name:	Lake Meyer
Hydrologic Unit Code:	HUC10 0706000402
IDNR Waterbody ID:	IA 01-TRK-02245-L
Location:	Section 33 T97N R9W
Latitude:	43° 10' N
Longitude:	91° 55' W
Water Quality Standards Designated Uses:	1. Primary Contact Recreation (A1) 2. Aquatic Life Support (B(LW))
Tributaries:	Unnamed Creeks (2)
Receiving Waterbody:	Unnamed Creek to Turkey River
Lake Surface Area:	33 acres
Maximum Depth:	24 feet
Mean Depth:	12 feet
Volume:	409 acre-feet
Length of Shoreline:	11,300 feet
Watershed Area:	1,590 acres
Watershed/Lake Area Ratio:	49:1
Estimated Detention Time:	0.4 years

Morphometry

Lake Meyer has a mean depth of 12 feet and a maximum depth of 24 feet. The lake has a surface area of 33 acres and a volume of approximately 409 acre-feet. Temperature and dissolved oxygen sampling indicate that the lake strongly stratifies and exhibits hypolimnetic anoxia during the growing season.

Hydrology

Two unnamed tributaries feed Lake Meyer. Lake Meyer discharges from a dam on the west end to an unnamed tributary of the Turkey River. The estimated annual average detention time for Lake Meyer is 0.4 years based on outflow. The methodology and calculations used to determine the detention time are shown in Appendix A.

2.2 The Watershed

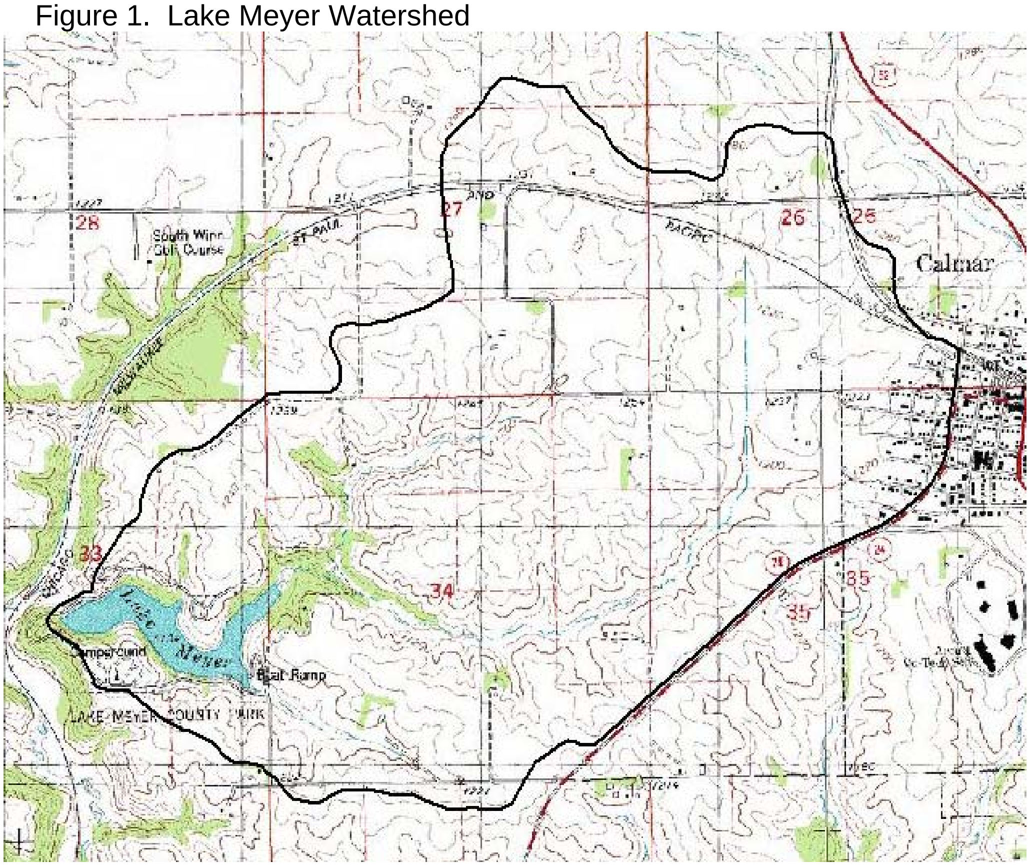
The Lake Meyer watershed has an area of approximately 1,590 acres and has a watershed to lake ratio of 49:1. The 2002 landuses and associated areas for the watershed were obtained from satellite imagery and are shown in Table 3. 2002 and 2003 landuse maps are shown in Appendix D. Figure 1 shows the topographic relief map of the Lake Meyer watershed.

Table 3. 2002 Landuse in Lake Meyer watershed.

Landuse	Area in Acres	Percent of Total Area
Row Crop	740	46.5
Grassland	410	25.8
Alfalfa	210	13.2
Forest	100	6.3
Other	130	8.2
Total	1,590	100

A more recent watershed assessment was completed in 2003 by the Winneshiek 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 2003 assessment shows that the major landuse in the watershed is row crop, with 1,030 acres (65%) in either corn or soybeans. Other major landuses in the 2003 watershed assessment include CRP (11%), timber (7%) and residential (4%).

Figure 1. Lake Meyer Watershed



Nearly 60% of the watershed is moderately sloping to very steep sloped (5-40%) forest or prairie-forest soils derived from loess. The soil types in this area are Fayette, Downs, Dubuque, and Nordness. The other 40% of the watershed soils are gently to strongly sloping (2-14%) prairie or forest derived soils of the following types: Winneshiek, Marlean, Rockton, Fayette, and Downs.

Prior to the construction of the dam for Lake Meyer in 1968, the Natural Resources Conservation Service conducted soil loss predictions and sediment delivery estimates to assist with the design. The upland sediment delivery ratio for the lake's watershed was calculated to be 34%. The estimated sediment delivery rate to the lake would be about 4,100 tons per year (3 acre-feet). At this rate, the lake would have a lifespan of 176 years. However, the lake would be severely limited for recreational purposes such as boating and fishing, in a much shorter time period, perhaps 80-85 years.

Soil conservation practices were in use in approximately 60% of the watershed in the early 1990s (Bachmann, 1994). In 1999, Winneshiek County SWCD received funds from the Iowa Public Owned Lakes Program to cost share additional conservation practices in the watershed. A terracing project and a grade stabilization project were completed under this funding program. The grade stabilization structure was constructed where drainage enters into the northeast part of the lake. This structure receives run-off from 350 acres and was designed to trap 98% of the sediment entering the structure's water retention area. This reduced the amount of sediment from entering Lake Meyer by 617 tons per year.

Current conservation farming practices in the watershed include terraces, waterways, conservation tillage, strip cropping, crop rotation, and buffer strips. Soil loss calculations using RUSLE indicated the average soil loss on cropped acres in the watershed is between three and four tons per acre per year. A GIS soil loss assessment estimated the sheet and rill soil loss in the watershed of approximately 1.9 tons per acre per year. The sediment delivery to the lake from the watershed was calculated to be 0.48 tons per acre per year (765 tons per year for the watershed). With the installation of a proposed grade stabilization structure the sediment delivery rate is estimated to be 0.28 tons per acre per year (438 tons per year for the watershed). These rates are far below the 4,100 tons per year that the structure was designed to hold.

Two open feedlots are present in the watershed. Based on typical animal space requirements for feeder cattle, the feedlots have a potential capacity of 60 beef animal units. One confinement animal feeding operation (CAFO) with an estimated 150 dairy animal units is also present within the watershed. Of the livestock producers in the watershed, one has indicated he will not be raising livestock in the future and is interested in enrolling the pasture in the Continuous Conservation Reserve Program.

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. CAFOs are animal feeding operations in which animals are confined to areas which are totally roofed. CAFOs typically utilize earthen or concrete structures to contain and store manure prior to land application. Nutrients from CAFOs are delivered via runoff from land applied manure or from leaking/failing storage structures.

The watershed includes approximately 90 acres of the City of Calmar. The storm water from this portion of the city is discharged through five outlets to a tributary of Lake Meyer.

3. TMDLs for Nutrients and Siltation

3.1 TMDL for Nutrients

3.1.1 Problem Identification

Impaired Beneficial Uses and Applicable Water Quality Standards

The Iowa Water Quality Standards (8) list the designated uses for Lake Meyer as Primary Contact Recreational Use (Class A1) and Aquatic Life (Class B(LW)). In 1998, Lake Meyer was included on the impaired water list as recommended by the DNR Fisheries Bureau. At that time, the Class A use was not assessed and the Class B use was assessed as "partially supported."

In 2002, the Class A and B designated uses were both assessed as "partially supported" for Lake Meyer. This assessment was based upon the 2000-01 ISU lake survey, an ISU report on lake phytoplankton, and information from the DNR Fisheries bureau. 2000 - 2003 sampling data show that average chlorophyll-a and Secchi depth TSI values are currently below the impairment threshold value of 65 (see Table C-2 in Appendix C).

The Iowa Water Quality Standards (8) do not include numeric criteria for nutrients but they do include narrative standards that are applicable to Lake Meyer 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).

Data Sources

Water quality surveys have been conducted on Lake Meyer in 1979, 1992, and 2000-03 (1,2,3,4,5,20). Additional water quality data was collected by the University of Iowa Hygenics Laboratory (UHL) from July through September of 2003. Data from the 1979, 1992, and 2000 - 2003 surveys is available in Appendix B. UHL sampling data from 2003 can be accessed at http://wqm.igsb.uiowa.edu/iastoret/.

Iowa State University Lake Study data from 2000 to 2003 and UHL monitoring data from 2003 were evaluated for this TMDL. The ISU study is scheduled to run through 2004 and approximates a sampling scheme used by Roger Bachman in earlier Iowa lake studies. Samples are collected at one location (maximum depth) 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. The UHL monitoring includes samples taken six times during the growing season at each of three lake locations (shallow, mean and maximum depth) with measured water quality parameters similar to the ISU Lake Study.

Interpreting Lake Meyer 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 34:1. Data on inorganic suspended solids from the ISU sampling indicate relatively low levels of non-algal turbidity. The median level of inorganic suspended solids in the 131 lakes sampled for the ISU lake survey from 2000 to 2002 was 4.8 mg/L. The median level of inorganic suspended solids at Lake Meyer during the same time period was 2.3 mg/l, the 24th lowest of the 131 lakes.

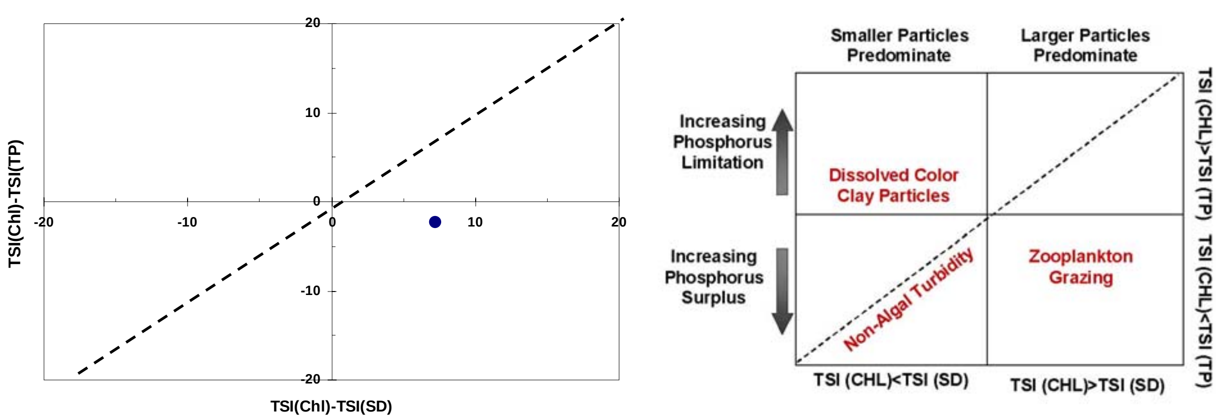
Comparisons of the TSI values for chlorophyll, Secchi depth and total phosphorus for 2000 - 2003 in-lake sampling indicate slight limitation of algal growth potentially attributable to zooplankton grazing (see Figure 2 and Appendix C).

TSI values for 2000 - 2003 ISU and UHL maximum depth 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. Lake Meyer TSI Values (3,4,5,20)

Sample Date	Source	TSI (SD)	TSI (CHL)	TSI (TP)
7/6/2000	ISU	60	63	67
8/1/2000	ISU	67	63	59
9/12/2000	ISU	67	48	59
6/6/2001	ISU	40	41	52
7/31/2001	ISU	--	--	67
8/7/2001	ISU	73	71	71
6/12/2002	ISU	42	37	52
7/17/2002	ISU	57	61	69
8/13/2002	ISU	70	57	66
6/11/2003	ISU	65	66	78
7/10/2003	UHL	67	74	63
7/15/2003	ISU	62	58	68
7/22/2003	UHL	67	71	61
8/5/2003	UHL	73	66	57
8/13/2003	ISU	67	64	65
8/19/2003	UHL	67	68	57
9/15/2003	UHL	67	68	71
9/30/2003	UHL	67	72	81

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



Data from ISU phytoplankton sampling in 2000 and 2001 indicate that bluegreen algae (Cyanophyta) comprise a relatively large portion of the summertime phytoplankton community. The number of available samples (three per summer) is insufficient to fully characterize the frequency of algal blooms. The 2000 average summer wet mass of bluegreen algae at this lake (11 mg/l) was the 57th highest of 131 lakes sampled with bluegreens consisting of approximately 76% of the phytoplankton community. The 2001 average summer wet mass of bluegreen algae declined to 8 mg/L with bluegreens comprising approximately 37% of the phytoplankton community. Sampling for cyanobacterial toxins was not been conducted at Lake Meyer for the 2000 - 2003 sampling period. 2000 and 2001 phytoplankton sampling results are given in Table B-7 of Appendix B.

Potential Pollution Sources

The potential nutrient sources for Lake Meyer are watershed nonpoint sources and internal recycling of pollutants from bottom sediments. There are no nutrient 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.

3.1.2 TMDL Target

The Phase 1 targets for this TMDL are mean TSI values of less than 65 (existing) for total phosphorus, chlorophyll and Secchi depth. These values are equivalent to total phosphorus and chlorophyll concentrations of 70 and 33 ug/L, respectively, and a Secchi depth of 0.7 meters. Mean chlorophyll and Secchi depth values for Lake Meyer for 2000 - 2003 sampling are currently below impairment threshold values. Therefore, the target for total phosphorus has been set at the existing concentration.

Table 5. Lake Meyer 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	63	28 ug/L	<65	<33 ug/L	N/A
Secchi Depth	56	1.3 meters	<65	>0.7 meters	N/A
Total Phosphorus	65	70 ug/L	<65 (existing)	<70 ug/L	N/A

Criteria for Assessing Water Quality Standards Attainment

The State of Iowa does not have numeric water quality criteria for nutrients. The nutrient-loading objective is defined by a mean total phosphorus TSI of less than 65 (existing), 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 chlorophyll and Secchi depth 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 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. Finally, the lake was segmented and Walker's BATHTUB (23) program was used with the Walker Reservoir Model to account for spatial variations in water quality with respect to sampling location. The results from all 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 = 70 ug/L, SPO TP = 76 ug/L	Comments
Loading Function	2,730	Reckhow (10); 90% pond trap efficiency
EPA Export	1,480	EPA/5-80-011
WILMS Export	1,200	"most likely" export coefficients
Reckhow 1991 EUTROMOD Equation	570	GSM model
Canfield-Bachmann 1981 Natural Lake	380	GSM model
Canfield-Bachmann 1981 Artificial Lake	540	GSM model
Reckhow 1977 Anoxic Lake	240	GSM model
Reckhow 1979 Natural Lake	480	GSM model. P out of range
Reckhow 1977 Oxic Lake (z/Tw < 50 m/yr)	340	GSM model. P out of range
Nurnberg 1984 Oxic Lake	430 (internal load = 0)	Annual model. P out of range
Walker 1977 General Lake	330	SPO model
Vollenweider 1982 Combined OECD	480	Annual model
Vollenweider 1982 Shallow Lake	560	Annual model
Walker Reservoir	640	GSM model
Walker Reservoir (BATHTUB)	1,870	GSM model. Segmented.

All of the empirical models evaluated gave results that were significantly below the watershed load estimates. Lake Meyer is elongated with a shoreline development ratio of approximately 2.5 and strongly stratifies. Also, the sampling location for the majority of available sampling data (maximum depth) is at the end of the lake opposite the main tributary channel. Therefore, it was concluded that the empirical models alone did not adequately account for spatial variations in water quality. The BATHTUB program, which uses empirical eutrophication models but also accounts for advective and diffusive transport in a segmented network, was used to address this issue.

For the BATHTUB program, the lake was divided into four segments (upper pool, upper/mid pool, mid-pool and near dam). The total influent load was then adjusted to match the predicted in-lake concentration with observed sampling data at the maximum depth location. Because only one year of shallow and mean depth sampling was available (versus four years of maximum depth sampling), the model was not calibrated to the observed area-weighted mean concentration. In addition, nutrient partitioning was not modeled due to lack of site-specific data for tributary ortho phosphorus concentrations. The selected model used in the BATHTUB program was the Walker Reservoir Model.

The equation for the Walker Reservoir Model is:

$$P = \frac{-1 + (1 + 4A_1 P_i T)^{0.5}}{2A_1 T}$$

where

$$A_1 = {0.17Q_s}/{(Q_s + 13.3)}$$

Q_s = surface overflow rate (meters/year)
P = predicted in-lake total phosphorus concentration (ug/L)
P_i = inflow total phosphorus concentration (ug/L)
T = hydraulic residence time (years)

The predicted load from the BATHTUB program using the Walker Reservoir Model is within the range of watershed load estimates. Input and output from the BATHTUB program is shown in Appendix E.

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 Lake Meyer can receive and meet its designated uses. Based on the selected lake response model and a target TSI (TP) value of less than 65 (existing), the Phase 1 total phosphorus loading capacity for the lake is 1,870 pounds per year.

3.1.3 Pollution Source Assessment

There are two quantified phosphorus sources for Lake Meyer 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 Lake Meyer is estimated to be 1,870 pounds per year based on the selected lake response model. This estimate includes 1,860 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.

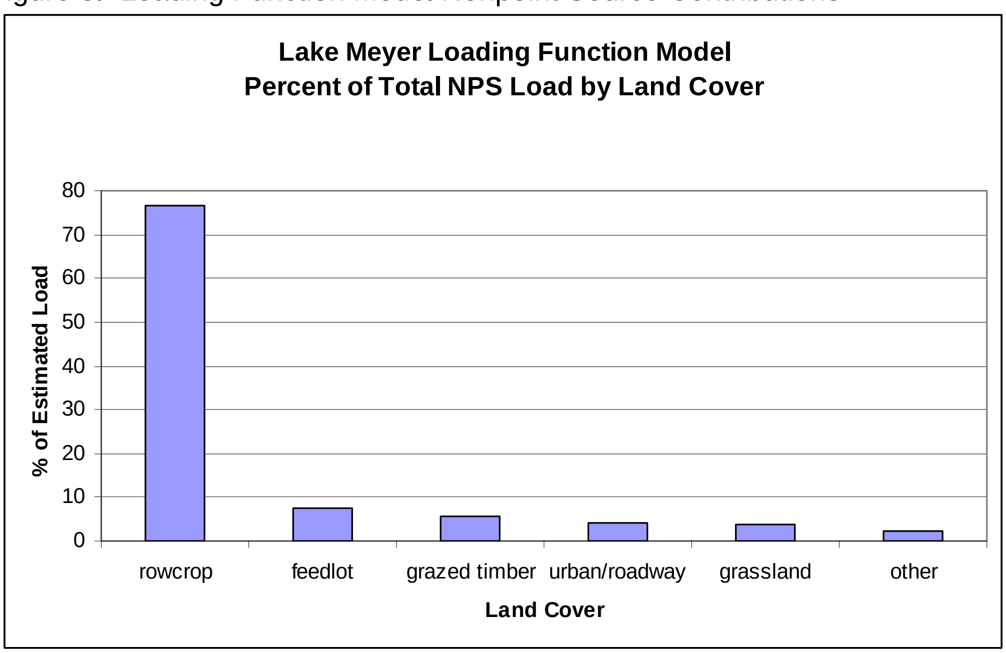
Departure from Load Capacity

Observed 2000 - 2003 average chlorophyll and Secchi depth values for Lake Meyer are currently below impairment threshold values. Therefore, the targeted load capacity for total phosphorus is set at the existing load. The Phase 1 targeted load capacity and estimated existing load for Lake Meyer is 1,870 pounds per year or 1.2 pounds per year per acre of watershed area.

Identification of Pollutant Sources

There are no significant point source discharges in the Lake Meyer watershed. From the Loading Function Model, most of the nonpoint source phosphorus delivered to the lake is from row crop landuse as shown in Figure 3. The Loading Function Model also indicates significant loads from open feedlots, grazed timber, urban/roadway and grassland landuses. The loading from feedlots was estimated based on an export coefficient of 200 lbs/acre/year (21). Actual loading from the feedlots 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 the target total phosphorus load identified in this TMDL. The target load was calculated from measured in-lake total phosphorus concentrations using the selected lake response model as described in *Section 3.1.2, Modeling Approach.*

Figure 3. Loading Function Model Nonpoint Source Contributions



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 2 of this TMDL.

Linkage of Sources to Target

Excluding background sources, the average annual phosphorus load to Lake Meyer originates entirely from nonpoint sources and internal recycling. To meet the TMDL, the annual nonpoint source and internal recycling total phosphorus contribution to Lake Meyer needs to be limited to less than 1,870 pounds per year.

3.1.4 Pollutant Allocation

Wasteload Allocation

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

Load Allocation

The Load Allocation (LA) for this TMDL is 1,870 pounds per year of total phosphorus distributed as follows:

- 1,860 pounds per year allocated to the Lake Meyer watershed and internal recycling of phosphorus from the lake bottom sediments.

- 10 pounds per year allocated to atmospheric deposition.

Margin of Safety

The nutrient targets for Lake Meyer have already been achieved. Therefore, an explicit Margin of Safety (MOS) for nutrients has not been included in the load calculations. An implicit MOS is present in that existing TSI values for chlorophyll and Secchi depth are currently below their targets. An additional implicit MOS is present in that the lake response model used to estimate the allowable loading results in a value that is 32% less than the watershed loading predicted by the Loading Function Model, which uses the most recent landuse assessment information to estimate watershed phosphorus delivery.

3.1.5 Nutrient TMDL Summary

The equation for the total maximum daily load shows the lake total phosphorus load capacity.

TMDL = Load Capacity (1,870 lbs/year) = WLA (zero lbs/year) + LA (1,870 lbs/year) + MOS (implicit)

3.2 TMDL for Siltation

3.2.1 Problem Identification

In 1998, Lake Meyer was placed on the impaired water list for siltation. This impairment remained on the 2002 list. Excessive sediment deposition impairs normal aquatic life in many ways:

- Reductions of volume and depth are critical in the shallow bay areas of lakes, where fish utilize the habitat for spawning and rearing of young. These bays are especially vulnerable to siltation, where sediment settles out as stream velocities decrease.
- Shallow lakes are more susceptible to summer algal blooms and winter fish kills due to the loss of volume of water under the winter ice that can provide dissolved oxygen.
- Shallow water favors rough fish such as bullheads and carp. As rough fish populations increase, they tend to overgraze available macrophytes and increase internal sediment and nutrient recycling by stirring bottom sediments

To understand the nature and extent of the siltation problem in Lake Meyer, it is important to know how much silt has accumulated and how much of the volume has been lost. IDNR and US Geological Survey have cooperated to develop a method to map the current and original lake bottoms and sediment volume using sonar equipment.

These estimates show that the lake has lost significant volume, depth and some surface area near the inlet. The Lake Meyer siltation problem is predictable because the watershed to lake area ratio of 49:1 is greater than IDNR's current guideline of 20:1 and the estimated sediment delivery ratio (SDR) is high at 34%. This high sediment delivery ratio is the result of a relatively small drainage area (which results in less distance for sediment to travel to reach surface water), the presence of steep slopes, and the presence of erosive soils.

Bathymetry for Lake Meyer was performed and a sediment volume estimate was made by the USGS. The USGS mapping and sediment estimating procedure are outlined in Appendix G. The result of this work was an estimate that 18% of the original lake volume was filled with sediment since 1968 when the dam forming the lake was constructed. The total siltation estimate tells how much sediment accumulated over 36 years but not when this occurred.

Data Sources

A bathymetric survey was conducted by the USGS under contract with the DNR in the summer of 2003. This data provides the current and historical lake bottom and an estimate of the amount of sediment accumulated in the lake. Data from this survey show that the current water volume in the lake is 17,800,000 ft^3 (409 ac-ft) and the sediment volume is 3,800,000 ft^3 (87 ac-ft). This represents an 18% loss in volume over the last 36 years.

The evaluation of soil loss from the watershed was performed using RUSLE erosion modeling within the IDNR geographic information system.

Interpreting Lake Meyer Water Quality Data

The bathymetric mapping completed in 2003 by USGS provides the most accurate data on the loss of volume at Lake Meyer. For the 2003 USGS bathymetry and siltation estimate, the lake bottom mapping was performed separately from the siltation estimate. The volume between the existing lake bottom and the sonar derived original bottom was calculated and this volume is the estimate for the siltation volume of 87 acre-feet. As stated in *Section 2.2*, the NRCS calculated soil loss predictions and sediment delivery estimates to assist with the design of the dam. Based on the estimated sediment delivery rates, Lake Meyer would completely fill with sediment in 176 years, but would become severely limited much sooner than that, perhaps in 80-85 years.

Although a specific design life was not calculated for Lake Meyer prior to its construction, this information suggests a useful life of 80 to 85 years. Therefore, the selected design life for Phase 1 of this TMDL is 80 years. Based on the watershed to lake ratio, landuses in the watershed, and the calculated sediment delivery rate for Lake Meyer, the loss of volume causing an impairment of recreational and aquatic life use is one third of the original volume of Lake Meyer. This results in a loss of 165 acre-feet over the lifespan of the lake, with an average sedimentation rate of 2.1 acre-feet per year.

During the design of Lake Meyers, NRCS provided estimates for the annual sediment mass that would be delivered to the lake, 4,100 tons/year, as well as a volume associated with this mass, 3 acre-feet/year. This conversion of mass to volume assumes a sediment specific weight of 63 lb/cf. A specific weight of 65 lb/cf has been used for the development of this TMDL because,

- 65 lb/cf is a frequently calculated specific weight for silt in Iowa Lakes when more data is available,
- consolidation over the life of the lake increases the specific weight, and
- it is not clear how the NRCS made their estimate.

Sediment cores were taken when the USGS did the Lake Meyer bathymetry and silt volume estimate and this data, not yet available, will provide the information needed for an accurate specific weight estimate in Phase 2. Table 7 summarizes Lake Meyer sediment accumulation between 1968 and 2003.

Table 7. Sedimentation estimates based on bathymetric mapping completed in 2003 by USGS.

Original Lake Volume (1968)	Existing Lake Volume	Cumulative Sedimentation	Average Sedimentation Rate
496 ac-ft	409 ac-ft	87ac-ft	2.4 ac-ft / yr

The volume loss, or inversely, the sediment gain, between 1968 and 2003 was 87 acre-feet (18% loss of volume). Although the specific sediment delivery rates and when the siltation occurred are unclear, the average annual sedimentation rate between 1968 and 2003 was 2.4 acre-feet per year.

Potential Pollution Sources

The potential sediment sources for Lake Meyer are cropland sheet and rill erosion, shoreline erosion, streambank erosion, and gully erosion. In addition, less significant sources present in the watershed include construction and development activities, grasslands, and forest. There are no point source discharges in the watershed.

Natural Background Conditions

Natural background contributions of sediment were not separated from the total non-point source load.

3.2.2 TMDL Target

The useful life of Lake Meyer is 80 years, at which time recreational and aquatic life uses will become impaired. To ensure that Lake Meyer meets its useful life, a sediment delivery target has been established. This target is based on the volume of sediment that can be delivered to the lake annually and not cause an impairment of the lake's designated uses. This results in a volume loss of 2.1 acre-feet per year, or a sediment delivery of 2,900 tons per year over the design life of the lake.

Criteria for Assessing Water Quality Standards Attainment

The State of Iowa does not have numeric water quality criteria for siltation. Siltation is a loss of lake volume, area, and depth that can be measured. For Lake Meyer, the volume loss from 1968 to 2003 is known to be 87 acre-feet. To meet the designated uses for Lake Meyer, the average sedimentation rate should not exceed 2.1 acre-feet of the 80-year life of the lake.

Selection of Environmental Conditions

The critical condition for which this sediment TMDL applies is the entire year. An annual loading period was used to define Lake Meyer's sediment loading capacity. Sediment loads are actually the result of periodic intensive and/or high volume precipitation events. Non-point source controls are typically designed for long-term average annual conditions.

Waterbody Pollutant Loading Capacity

The load capacity for this siltation TMDL is the amount of sediment deposited in Lake Meyer annually that does not exceed the rate based on the design life of the lake. The silt storage volume is a third of the original lake volume or 165 acre feet. The total storage volume spread over the 80-year design life of Lake Meyer results in an average annual sedimentation rate of 2.1 acre-feet per year. However, over the first 36 years, the lake lost 87 acre-feet, resulting in an average annual volume loss of 2.4 acre-feet and an average annual sediment load of 3,400 tons per year. Since Lake Meyer received sediment above the expected annual rate for the first 36 years, the sediment delivery for the next 44 years must be lowered to an annual average of 1.8 acre-feet, or a sediment delivery rate of 2,500 tons per year.

The trap efficiency of Lake Meyer was calculated using the Brune method (24) at 93%. For the purposes of this TMDL, the delivered watershed sediment load is set the same as the deposited sediment load.

3.2.3 Pollution Source Assessment

Lake Meyer sediment sources fall into two categories. The first is upland sheet and rill erosion estimated using watershed erosion models. These models are also used to estimate impacts of implemented erosion control practices. The second category is gully, shoreline, streambed, and stream bank erosion. These sources are considered minimal at this time due to the extensive watershed work that has taken place in the Lake Meyer watershed over the last ten years. One area of stream bank erosion does persist along the drainage below Calmar, but even this area is considered minor in its sediment contribution. Any erosion from this stretch of stream bank will be caught by the proposed pond that will be constructed along this drainage in 2005.

Three estimates of upland sediment delivery before and after erosion control practices are available. These are:

- 2003 IDNR estimates based on RUSLE equations and IDNR GIS coverages (see Appendix F)
- Lake Meyer Watershed estimates based on RUSLE modeling and assumptions about erosion control effectiveness
- Average annual sediment delivery based on the sediment volume in the lake

From 1968-2003, the average annual volume loss was 2.4 acre-feet per year (3,400 tons per yr). Table 8 shows current sediment delivery rates from sheet and rill erosion based on a sediment delivery ratio of 34%. The current sediment delivery to Lake Meyer is estimated at 770 tons per year.

Table 8. Sediment Delivery Estimates, IDNR RUSLE modeling, SDR = 34%

IDNR estimates, 2003 RUSLE modeling	Total estimated watershed erosion, tons/year	Unit basis, tons/acre/year
Current conditions, sheet and rill erosion, no delivery	3,160	2.0
Sediment delivery, current conditions w/existing structures	770	0.5
Sediment delivery, current conditions w/existing and proposed structures	440	0.3

Existing Load

The average annual sediment delivery to Lake Meyer from 1968-2003 was 3,400 tons per year. The current sediment delivery rate from sheet and rill erosion based on existing land use conditions and best management practices is 770 tons per year. Gully, shoreline, stream bank, and streambed erosion have not been quantified, but are considered minimal based on information provided by local NRCS and DSC staff regarding the best management practices already installed. An estimated annual sediment delivery rate of 800 tons per year is used for the current rate of gully, shoreline, stream bank, and streambed erosion. Therefore the current total sediment delivery rate to Lake Meyer is 1,570 tons per year.

Departure from Load Capacity

The current sediment delivery rate to Lake Meyer is 1,570 tons per year. This equates to a rate of 1.1 acre-feet per year, well below the needed rate of 1.8 acre-feet per year. Therefore the current loading capacity should either be maintained or reduced at 1,570 tons per year of sediment. This sediment target should ensure that water quality is not reduced beyond the current level.

Identification of Pollutant Sources

There are no significant point source sediment discharges in the Lake Meyer watershed. Non-point source identification and sediment quantification were established with data and modeling done for previous watershed projects and through the application of an IDNR developed model based on the RUSLE and GIS data input in 2002.

Two categories of non-point sources of sediment have been identified in the Lake Meyer watershed. These are upland sheet and rill erosion, gully, shoreline, streambed, and stream bank erosion.

Linkage of Sources to Target

The existing average annual sediment load of 1,570 tons per year to Lake Meyer originates entirely from non-point sources. This sediment load needs to be reduced or maintained. The target for this siltation TMDL is an average annual rate of sediment delivery that will not cause water quality impairments.

3.2.4 Pollutant Allocation

Wasteload Allocation

There are no significant sediment point source contributors in the Lake Meyer watershed. Therefore, the sediment Waste Load Allocation (WLA) is zero tons per year.

Load Allocation

The Load Allocation (LA) for this siltation TMDL is 1,570 tons per year of sediment and is distributed among the identified non-point sources. In the absence of detailed source information, the load has been divided between the two source categories as follows:

- Stream bed, stream bank, shoreline and gully erosion = 800 tons per year
- Upland sheet and rill erosion = 770 tons per year

Margin of Safety

The margin of safety for this TMDL is implicit. The load capacity has been set at the estimated existing load of 1,570 tons per year. This is well below the 2,500 tons per year associated with the targeted volume loss of less than a third of the original lake volume within an 80-year design life.

3.2.5 Siltation TMDL Summary

The equation for the total maximum daily load shows the lake sediment load capacity.

TMDL = Load Capacity (1,570 tons/year) = WLA (zero tons/year) + LA (1,570 tons/year) + MOS (implicit)

4. Implementation Plan

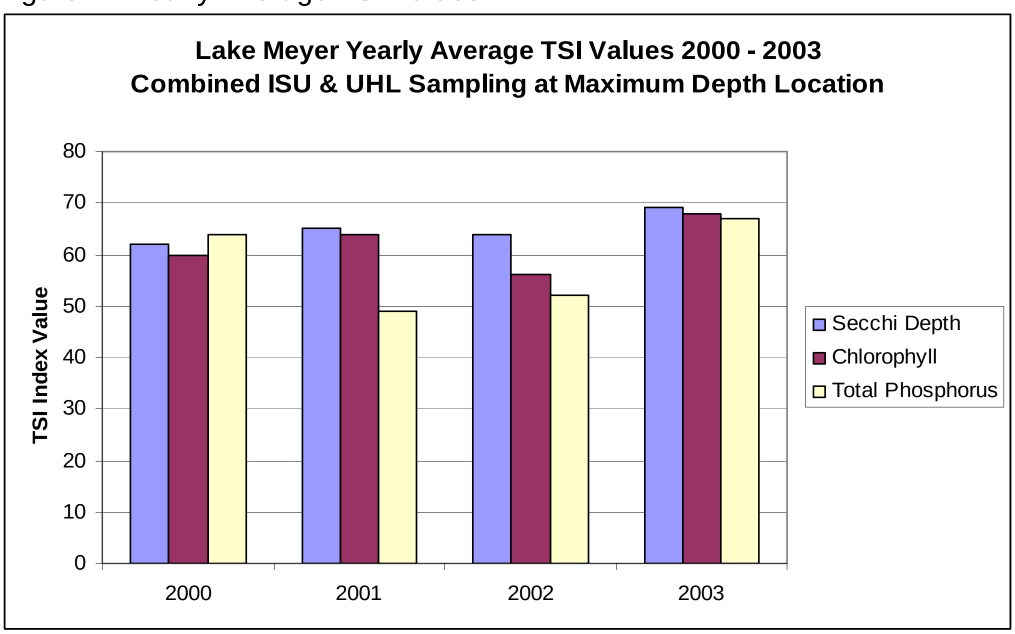
The following implementation plan is not a required component of a Total Maximum Daily Load but can provide department staff, partners, and watershed stakeholders with a strategy for improving Lake Meyer water quality.

4.1 Nutrients

Based on 2000 - 2003 monitoring data for chlorophyll and Secchi depth, the existing average annual nutrient loading to Lake Meyer is below that which would cause impairment due to algal turbidity. However, observed TSI values for these parameters do indicate an overall increasing trend during the monitoring period as shown in Figure 4. This trend emphasizes the need for continuation of existing and implementation of new management practices that will prevent degradation of water quality.

If the entire phosphorus load were attributed to watershed sources, the estimated loading from watershed sources would need to be maintained below 1.2 pounds per acre per year to meet the TMDL target. However, this does not account for the internal recycled load, which could be significant.

Figure 4. Yearly Average TSI Values



Among the potential mechanisms of internal loading are resuspension of bottom sediments from bottom feeding rough fish such as carp, wind-driven waves and currents, and boat propellers. Significant internal loading may also occur during turnover events when accumulated phosphorus-laden sediment is disturbed. 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.

Best management practices to reduce nutrient delivery, particularly phosphorus, should be emphasized in the Lake Meyer 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 feedlots 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 recommended best management practices on agricultural land, there are practices that can be implemented in the residential areas that contribute stormwater flows to the lake. These include use of low or no-phosphorous fertilizers on lawns and use of appropriate erosion controls on construction sites.

Internal loading 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.

The Winneshiek County Soil and Water Conservation District has proposed a grade stabilization project that will reduce the amount of sediment and nutrients entering the lake. The project is currently scheduled for the summer of 2005. This project will reduce delivery of sediment-attached phosphorus to the lake by an estimated 480 pounds per year.

4.2 Siltation

Although the Lake Meyer watershed is currently meeting the sediment delivery target, there are still management practices that can be implemented to improve the water quality of the lake.

Gully and streambed and bank erosion: The extent of gully, stream bank, and streambed erosion needs to be quantified. Local NRCS and DSC staff have identified a segment of the stream directly below Calmar as having some erosion. Local field staff have also noted that significant work has been done in the watershed to correct gully and stream bank erosion. Significant stream and gully sediment contributions should be identified and stream bank restoration work done. Any problem locations should have restoration activities targeted at eroding stream banks contributing significant sediment. Suggested controls are:

- Install check dams on smaller tributaries to reduce peak flows during runoff events.
- Install stream bank protection using vegetation and graded rock.
- Stabilize stream banks by shaping and removing overhangs.

Overland sheet and rill erosion: Erosion control activities, including the maintenance of installed structures, need to continue in the watershed. The watershed should be periodically evaluated and erosion control activities focused on identified sediment contributors. Emphasis should be on row crop fields close to the lake or stream and having steeper slopes without effective management practices in place. Suggested controls are:

- Management practices that will increase crop residue such as no-till farming,
- Construct terraces and grassed waterways.
- Install buffer strips along stream corridors.
- Construct grade stabilization structures to reduce head cutting and gully expansion.

In addition to the recommended best management practices on agricultural land, there are practices that can be implemented in the residential areas that contribute stormwater flows to the lake. These include education and enforcement of stormwater controls on development ground and maintaining clean streets, gutters, and storm sewers.

As mentioned in *Section 4.1*, the Winneshiek County Soil and Water Conservation District has proposed a grade stabilization project that will reduce the amount of sediment and nutrients entering the lake. The project is currently scheduled for the summer of 2005. This project will reduce delivery of sediment to the lake by an estimated 330 tons per year.

5. Monitoring

Further monitoring is needed at Lake Meyer 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. Lake Meyer 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.

Current measurements of gully, shoreline, streambed, and stream bank erosion need to be obtained. The IDNR will work with local NRCS and DSC staff to collect this data to verify and improve the implementation of this TMDL.

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. 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

A public meeting was held in Calmar regarding the proposed TMDL for Lake Meyer on May 3, 2004 with representatives of the City of Calmar, the Soil and Water Conservation District, the County Board of Supervisors, and the County Conservation Board. A second public meeting was held on January 6, 2005 to present and discuss the draft TMDL for Lake Meyer. This meeting was also attended by representatives of the Winneshiek CCB, City of Calmar, NRCS, and the IDNR Fisheries Bureau. Comments received were reviewed and given consideration and, where appropriate, incorporated into the TMDL.

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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)	$\overline{P}_A$	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)**
$\overline{Q}_A = 1.17\times10^{-3}DA^{0.998}\overline{P}_A^{\,1.54}S^{-0.261}(1+F)^{0.249}C^{0.230}$	98.7	0.177268 (n=26)
$\overline{Q}_{JAN} = 0.213DA^{0.997}\overline{A}_{JAN}^{\,0.949}$	89.0	0.729610 (n=26;same for all $\overline{Q}_{MONTH}$)
$\overline{Q}_{FEB} = 2.98DA^{0.955}\overline{A}_{FEB}^{\,0.648}G^{-0.594}(1+F)^{0.324}$	97.0	0.07089
$\overline{Q}_{MAR} = 6.19DA^{1.10}B^{-0.386}G^{-0.296}$	97.8	0.07276
$\overline{Q}_{APR} = 1.24DA^{1.09}\overline{A}_{APR}^{\,1.64}S^{-0.311}B^{-0.443}$	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
$\overline{Q}_{MAY} = 1.86\times10^{-3}DA^{0.903}\overline{P}_A^{\,1.98}$	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
$\overline{Q}_{JUN} = 8.13\times10^{-3}DA^{0.828}C^{0.478}\overline{P}_{JUN}^{\,2.70}$	95.9	0.256941
$\overline{Q}_{JUL} = 1.78\times10^{-3}DA^{0.923}\overline{A}_{JUL}^{\,4.19}$	91.7	0.542940
$\overline{Q}_{AUG} = 4.17\times10^{7}DA^{0.981}(1+B')^{-1.64}(1+U)^{0.692}\overline{P}_A^{\,-7.2}\overline{A}_{AUG}^{\,4.59}$	90.4	1.11413
$\overline{Q}_{SEP} = 1.63DA^{1.39}B^{-1.08}$	86.9	1.53072
$\overline{Q}_{OCT} = 5.98DA^{1.14}B^{-0.755}S^{-0.688}(1+B')^{-0.481}$	95.7	0.375296
$\overline{Q}_{NOV} = 5.79DA^{1.17}B^{-0.701}G^{-0.463}(1+U)^{0.267}(1+B')^{-0.397}$	95.1	0.492686
$\overline{Q}_{DEC} = 0.785DA^{1.18}B^{-0.654}(1+U)^{0.331}(1+B')^{-0.490}$	92.4	0.590576
$Q_{YEAR} = 3.164\times10^{-4}DA^{0.942}P_{YEAR}^{\,2.39}A_{YEAR}^{\,1.02}S^{-0.206}\overline{P}_A^{\,1.27}C^{0.121}(1+U)^{0.0966}$	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 Lake Meyer - Calculations

Table A-5. Lake Meyer Hydrology Calculations

Lake	Lake Meyer	
Type	Impoundment	
Inlet(s)	unnamed(2)	
Outlet(s)	unnamed to Turkey R.	
Volume	409	(acre-ft)
Lake Area	33	(acres)
Mean Depth	12.47	(ft)
Drainage Area	1591	(acres)
Mean Annual Precip	32.4	(inches)
Average Basin Slope	6.6	(%)
%Water	0	
%Forest	4.82	
%Grass/Hay	41.64	
%Corn	46.36	
%Beans	5.61	
%Urban/Artificial	1.57	
%Barren/Sparse	0	
Hydrologic Region	2	
Mean Annual Class A Pan Evap	45	(inches)
Mean Annual Lake Evap	33.3	(inches)
Est. Annual Average Inflow	1040.76	(acre-ft)
Direct Lake Precip	88.70	(acre-ft/yr)
Est. Annual Average Det. Time (inflow + precip)	0.3621	(yr)
Est. Annual Average Det. Time (outflow)	0.3939	(yr)

9. Appendix B - Sampling Data

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

Parameter	7/2/1979	7/31/1979	9/10/1979
Secchi Depth (m)	--	0.5	1.0
Chlorophyll (ug/L)	6.5	23.6	86.1
NO_3+NO_2-N (mg/L)	--	--	1.6
Total Phosphorus (ug/l as P)	89	82	108
Alkalinity (mg/L)	164	150	181

Data above is averaged over the upper 6 feet.

Table B-2. Data collected in 1992 by Iowa State University (Bachmann, 1994)

Parameter	6/22/1992	7/14/1992	8/20/1992
Secchi Depth (m)	1.4	1.4	0.4
Chlorophyll (ug/L)	56.9	27.8	168.5
Total Nitrogen (mg/L as N)	6.5	4.2	3.2
Total Phosphorus (ug/l as P)	54	54	89
Total Suspended Solids (mg/L)	--	6.2	21.8
Inorganic Suspended Solids (mg/L)	--	1.2	3.8

Data above is for surface depth.

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

Parameter	7/06/2000	8/01/2000	9/12/2000
Secchi Depth (m)	1.0	0.6	0.6
Chlorophyll (ug/L)	27	26	6
NH_3+NH_4^+ -N (ug/L)	529	702	1310
NH_3 –N (un-ionized) (ug/L)	1	30	
NO_3+NO_2-N (mg/L)	2.12	0.72	0.43
Total Nitrogen (mg/L as N)	3.33	2.36	2.19
Total Phosphorus (ug/l as P)	79	45	44
Silica (mg/L as SiO_2)	18	29	20
pH	6.4	7.9	7
Alkalinity (mg/L)	190	161	199
Total Suspended Solids (mg/L)	6.8	2.6	5.7
Inorganic Suspended Solids (mg/L)	4.1	0.0	3.5
Volatile Suspended Solids (mg/L)	2.7	2.6	2.2

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

Parameter	6/06/2001	7/31/2001	8/07/2001
Secchi Depth (m)	4.0	--	0.4
Chlorophyll (ug/L)	3	--	59
NH_3+NH_4^+ -N (ug/L)	447	288	596
NH_3 –N (un-ionized) (ug/L)	12	34	272
NO_3+NO_2-N (mg/L)	2.9	0.36	0.27
Total Nitrogen (mg/L as N)	4.02	1.37	1.48
Total Phosphorus (ug/l as P)	27	79	104
Silica (mg/L as SiO_2)	5	11	13
pH	8.0	9.1	9.0
Alkalinity (mg/L)	190	113	110
Total Suspended Solids (mg/L)	4.7	--	5.3
Inorganic Suspended Solids (mg/L)	1.1	--	--
Volatile Suspended Solids (mg/L)	3.6	--	--

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

Parameter	6/12/2002	7/17/2002	8/13/2002
Secchi Depth (m)	3.5	1.2	0.5
Chlorophyll (ug/L)	2	23	15
NH_3+NH_4^+ -N (ug/L)	173	138	333
NH_3 –N (un-ionized) (ug/L)	18	47	48
NO_3+NO_2-N (mg/L)	0.94	0.35	0.12
Total Nitrogen (mg/L as N)	1.30	1.13	1.31
Total Phosphorus (ug/l as P)	27	92	75
Silica (mg/L as SiO_2)	1	3	4
pH	8.4	8.9	8.5
Alkalinity (mg/L)	191	146	140
Total Suspended Solids (mg/L)	--	13.2	6.0
Inorganic Suspended Solids (mg/L)	--	6.6	0.0
Volatile Suspended Solids (mg/L)	--	6.6	6.0

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

Parameter	6/11/2003	7/15/2003	8/13/2003
Secchi Depth (m)	0.7	0.9	0.6
Chlorophyll (ug/L)	38	17	29
NH_3+NH_4^+ -N (ug/L)	506	109	84
NH_3 –N (un-ionized) (ug/L)	--	15	27
NO_3+NO_2-N (mg/L)	7.94	<0.07	0.15
Total Nitrogen (mg/L as N)	9.05	1.52	1.43
Total Phosphorus (ug/l as P)	173	81	69
Silica (mg/L as SiO_2)	5	3	5
pH	--	8.5	8.9
Alkalinity (mg/L)	--	106	108
Total Suspended Solids (mg/L)	15	12	16
Inorganic Suspended Solids (mg/L)	5	3	4
Volatile Suspended Solids (mg/L)	10	9	12

Table B-7. 2000 and 2001 Phytoplankton Data (Downing and Ramstack, 2001, 2002)

	2000	**2001**
Division	**Wet Mass (mg/L)**	**Wet Mass (mg/L)**
Bacillariophyta	0.482	0.418
Chlorophyta	0.005	0.181
Chrysophyta	0	11.009
Cryptophyta	1.623	1.11
Cyanobacteria	10.674	8.488
Dinophyta Wet	1.096	1.389
Euglenophyta	0.082	0.061
Total	13.963	22.655

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

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:

$$\text{TSI (TP)} = 14.42 \ln(\text{TP}) + 4.15$$

$$\text{TSI (CHL)} = 9.81 \ln(\text{CHL}) + 30.6$$

$$\text{TSI (SD)} = 60 - 14.41 \ln(\text{SD})$$

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.

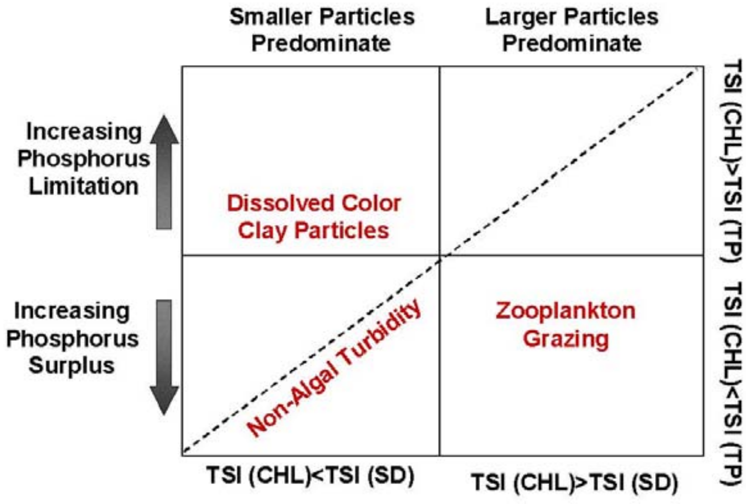
Level of Support	**TSI value**	**Chlorophyll-a (ug/l)**	**Secchi Depth (m)**
fully supported	<=55	*<=12*	*>1.4*
fully supported / threatened	55 ➔ 65	*12 ➔ 33*	*1.4 ➔ 0.7*
partially supported (evaluated: in need of further investigation)	65 ➔ 70	*33 ➔ 55*	*0.7 ➔ 0.5*
partially supported (monitored: candidates 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)



Lake Meyer TSI Values

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

Sample Date	TSI (SD)	TSI (CHL)	TSI (TP)
7/2/1979	--	49	69
7/31/1979	70	62	68
9/10/1979	60	74	72

Table C-5. 1992 Lake Meyer TSI Values (Bachmann)

Sample Date	TSI (SD)	TSI (CHL)	TSI (TP)
6/22/1992	55	70	62
7/14/1992	55	63	62
8/20/1992	73	81	69

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

Sample Date	TSI (SD)	TSI (CHL)	TSI (TP)
7/6/2000	60	63	67
8/1/2000	67	63	59
9/12/2000	67	48	59
6/6/2001	40	41	52
7/31/2001	--	--	67
8/7/2001	73	71	71
6/12/2002	42	37	52
7/17/2002	57	61	69
8/13/2002	70	57	66
6/11/2003	65	66	78
7/15/2003	62	58	68
8/13/2003	67	64	65

Table C-7. 2003 Lake Meyer TSI Values (UHL maximum depth)

Sample Date	TSI (SD)	TSI (CHL)	TSI (TP)
7/10/2003	67	74	63
7/22/2003	67	71	61
8/5/2003	73	66	57
8/19/2003	67	68	57
9/15/2003	67	68	71
9/30/2003	67	72	81

11. Appendix D - Land Use Maps

Figure D-1. Lake Meyer Watershed 2002 Landuse

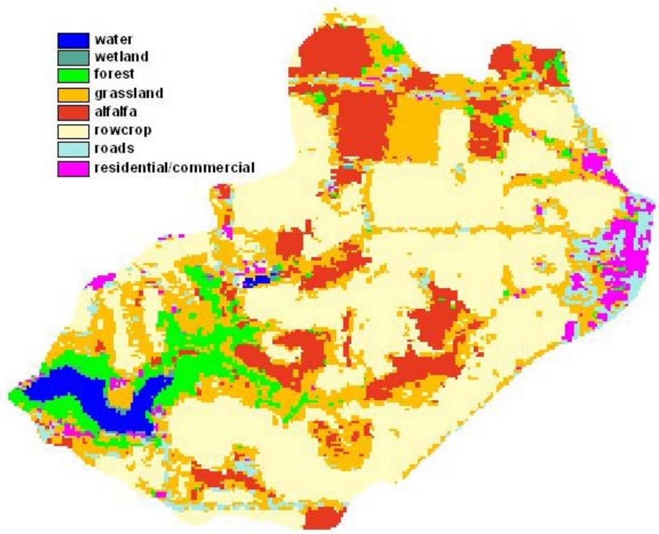
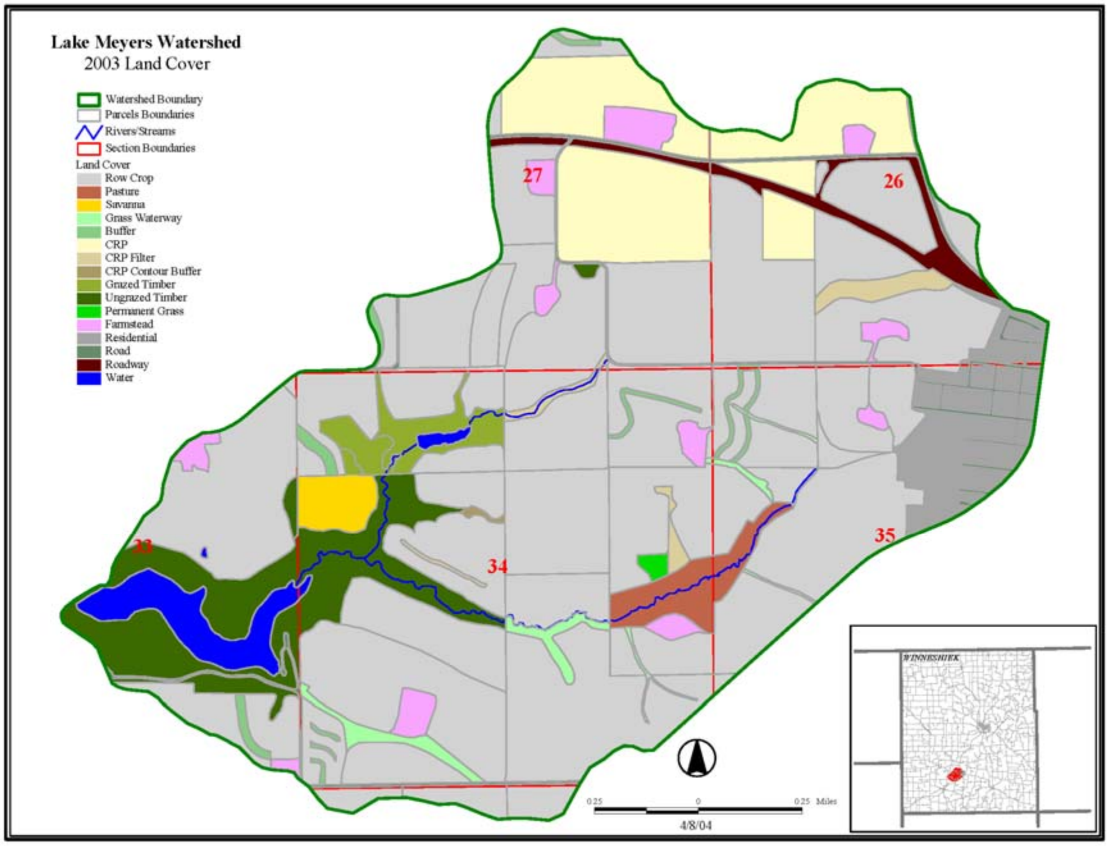


Figure D-2. Lake Meyer Watershed 2003 Site Assessment



12. Appendix E - Bathtub Program Input/Output

Lake Meyer
File: C:\bath\meyerfinal.btb
Description:

four segments in series; suggested default values for model options & model coefficients; phosphorus budgets based upon total P only; availability factors ignored

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.823	0.2
Evaporation (m)	0.846	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	41	0.50
Total N	0	0.00
Ortho P	20.5	0.50
Inorganic N	0	0.00

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	1	2ND ORDER, AVAIL P
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	2	P, LIGHT, T
Secchi Depth	1	VS. CHLA & TURBIDITY
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean
1	Upper Pool	2	1	0.02225	1.488	0.308	1.487	0.12	0	0	0.08	0.2	0	0	0
2	Upper Mid Pool	3	1	0.02225	3.012	0.308	3	0.12	0	0	0.08	5.57	0	0	0
3	Mid Pool	4	1	0.0445	3.78	0.392	3.7	0.12	0	0	0.08	3	0	0	0
4	Near Dam	0	1	0.0445	5.3	0.28	4.8	0.12	0	0	0.08	3.37	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	102	0.23	2100	0	82	0.16	0.57	0.04	1900	0	10	0	0	0
3	0	0	80	0.19	1900	0	71	0.12	0.62	0.05	1700	0	10	0	0	0
4	0	0	70.25	0.1	2700	0	28	0.27	1.3	0.29	1400	0	16.4	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
2	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
3	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
4	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic I
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean
1	stream a	1	1	6.44	1.288	0.1	0	0	654	0	0	0	223	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.025	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0

Lake Meyer
File: C:\bath\meyerfinal.btb

Segment & Tributary Network

--------Segment:	1	Upper Pool	
Outflow Segment:	2	Upper Mid Pool	
Tributary:	1	stream a	Type: Monitored Inflow
--------Segment:	2	Upper Mid Pool	
Outflow Segment:	3	Mid Pool	
--------Segment:	3	Mid Pool	
Outflow Segment:	4	Near Dam	
--------Segment:	4	Near Dam	
Outflow Segment:	0	Out of Reservoir	

Lake Meyer
File: C:\bath\meyerfinal.btb

Hydraulic & Dispersion Parameters

Seg	Name	Outflow Seg	Net Inflow hm^3/yr	Resid Time years	Overflow Rate m/yr	Velocity km/yr	Dispersion--------> Estimated km^2/yr	Numeric km^2/yr	Exchange hm^3/yr
1	Upper Pool	2	1.3	0.0257	57.9	12.0	4.5	1.8	0.9
2	Upper Mid Pool	3	1.3	0.0521	57.8	5.9	1.2	0.9	0.2
3	Mid Pool	4	1.3	0.1308	28.9	3.0	1.3	0.6	0.7
4	Near Dam	0	1.3	0.1836	28.9	1.5	0.9	0.2	0.0

Morphometry

Seg	Name	Area km^2	Zmean m	Zmix m	Length km	Volume hm^3	Width km	L/W -
1	Upper Pool	0.0	1.5	1.5	0.3	0.0	0.1	4.3
2	Upper Mid Pool	0.0	3.0	3.0	0.3	0.1	0.1	4.3
3	Mid Pool	0.0	3.8	3.7	0.4	0.2	0.1	3.5
4	Near Dam	0.0	5.3	4.8	0.3	0.2	0.2	1.8
Totals		0.1	3.8			0.5		

Lake Meyer
File: C:\bath\meyerfinal.btb

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	1	1	stream a	6.4	1.3	1.66E-02	0.10	0.20
PRECIPITATION				0.1	0.1	4.83E-04	0.20	0.82
TRIBUTARY INFLOW				6.4	1.3	1.66E-02	0.10	0.20
***TOTAL INFLOW				6.6	1.4	1.71E-02	0.09	0.21
ADVECTIVE OUTFLOW				6.6	1.3	1.82E-02	0.11	0.20
***TOTAL OUTFLOW				6.6	1.3	1.82E-02	0.11	0.20
***EVAPORATION					0.1	1.15E-03	0.30	

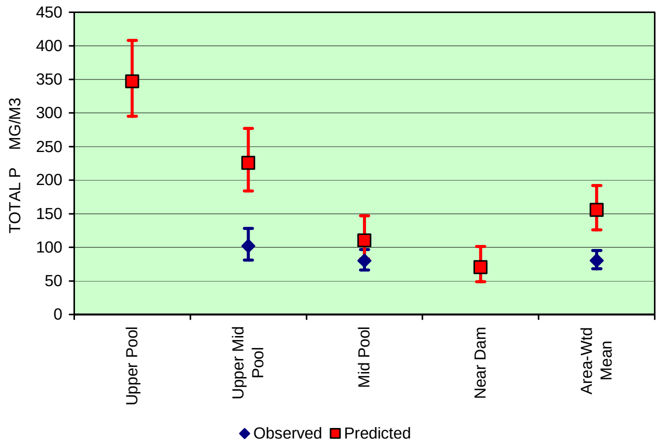
Overall Mass Balance Based Upon Component: **Predicted TOTAL P** — **Outflow & Reservoir Concentrations**

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	%Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	stream a	842.4	99.4%	7.10E+03	99.9%	0.10	654.0	130.8
PRECIPITATION				5.5	0.6%	7.49E+00	0.1%	0.50	49.8	41.0
TRIBUTARY INFLOW				842.4	99.4%	7.10E+03	99.9%	0.10	654.0	130.8
***TOTAL INFLOW				847.8	100.0%	7.10E+03	100.0%	0.10	606.5	129.0
ADVECTIVE OUTFLOW				90.3	10.6%	1.21E+03		0.39	70.3	13.7
***TOTAL OUTFLOW				90.3	10.6%	1.21E+03		0.39	70.3	13.7
***RETENTION				757.6	89.4%	6.33E+03		0.11		

Overflow Rate (m/yr)	9.6	Nutrient Resid. Time (yrs)	0.0926
Hydraulic Resid. Time (yrs)	0.3924	Turnover Ratio	10.8
Reservoir Conc (mg/m3)	156	Retention Coef.	0.894

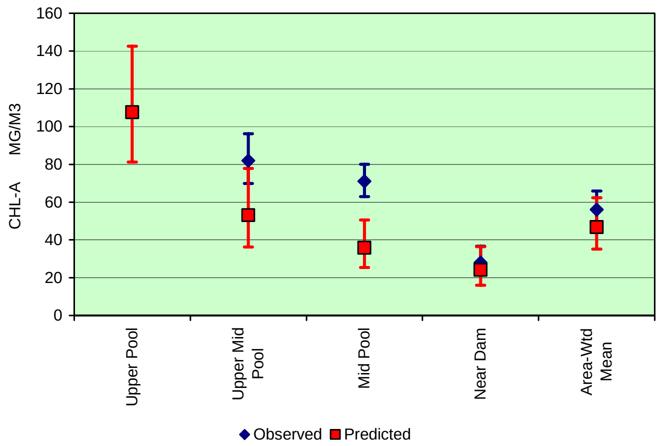
Lake Meyer
File: **C:\bath\meyerfinal.btb**
Variable: **TOTAL P MG/M3**

Segment	Predicted Mean	CV	Observed Mean	CV
Upper Pool	347.1	0.16		
Upper Mid Pool	225.7	0.21	102.0	0.23
Mid Pool	110.3	0.29	80.0	0.19
Near Dam	70.3	0.36	70.3	0.10
Area-Wtd Mean	155.7	0.21	80.5	0.17



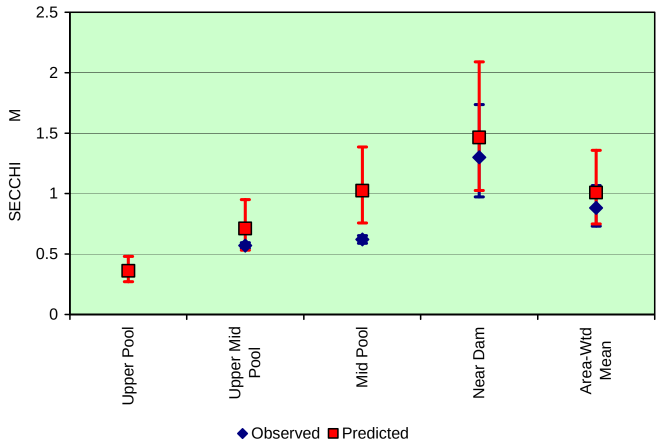
Lake Meyer
File: **C:\bath\meyerfinal.btb**
Variable: **CHL-A MG/M3**

Segment	Predicted Mean	CV	Observed Mean	CV
Upper Pool	107.6	0.28		
Upper Mid Pool	53.1	0.38	82.0	0.16
Mid Pool	35.9	0.34	71.0	0.12
Near Dam	24.1	0.41	28.0	0.27
Area-Wtd Mean	46.8	0.29	56.0	0.16



Lake Meyer
File: **C:\bath\meyerfinal.btb**
Variable: **SECCHI M**

Segment	**Predicted Mean**	**CV**	**Observed Mean**	**CV**
Upper Pool	0.4	0.29		
Upper Mid Pool	0.7	0.29	0.6	0.04
Mid Pool	1.0	0.30	0.6	0.05
Near Dam	1.5	0.36	1.3	0.29
Area-Wtd Mean	1.0	0.30	0.9	0.19



13. Appendix F - Erosion Model and Model inputs

The Revised Universal Soil Loss Equation (RUSLE) (25) is an erosion model designed to predict the longtime annual average soil loss (A) carried by runoff from specific field slopes in specified cropping and management systems. The equation used by RUSLE is:

A=(R)x(K)x(L)x(S)x(C)x(P)

- A= computed spatial average soil loss and temporal average soil loss per unit of area expressed in the selected units for K and for the period selected for R. Typically, A is expressed as tons/acre/year.
- R= rainfall-runoff erosivity factor. The rainfall erosion index plus a factor for any significant runoff from snowmelt.
- K= soil erodibility factor. The soil loss rate per erosion index unit for a specified soil as measured on a standard plot, which is defined as a 72.6-ft length of uniform 9% slope in continuous clean-till fallow.
- L= slope length factor. The ratio of soil loss from the field slope length to soil loss from a standard plot length under identical conditions.
- S= slope steepness factor. The ratio of soil loss from the field slope gradient to soil loss from a standard plot gradient under identical conditions.
- C= cover management factor. The ratio of soil loss from an area with specified cover and management to soil loss from an identical area in tilled continuous fallow.
- P= support practice factor. The ratio of soil loss with a support practice like contouring, strip-cropping, or terracing to soil loss with straight row farming up and down the slope.

Data from IDNR soil, landuse and other GIS coverages have been used as input to the RUSLE equation. The IDNR RUSLE erosion model uses a grid of 30 by 30 meter cells to estimate gross sheet and rill erosion. Sediment yield is the quantity of gross erosion that is delivered to a specific location such as a water body. Sediment yield was calculated using the NRCS Sediment Delivery Procedure (14).

Figure F-1. Lake Meyer RUSLE modeling results, sediment delivery without structures

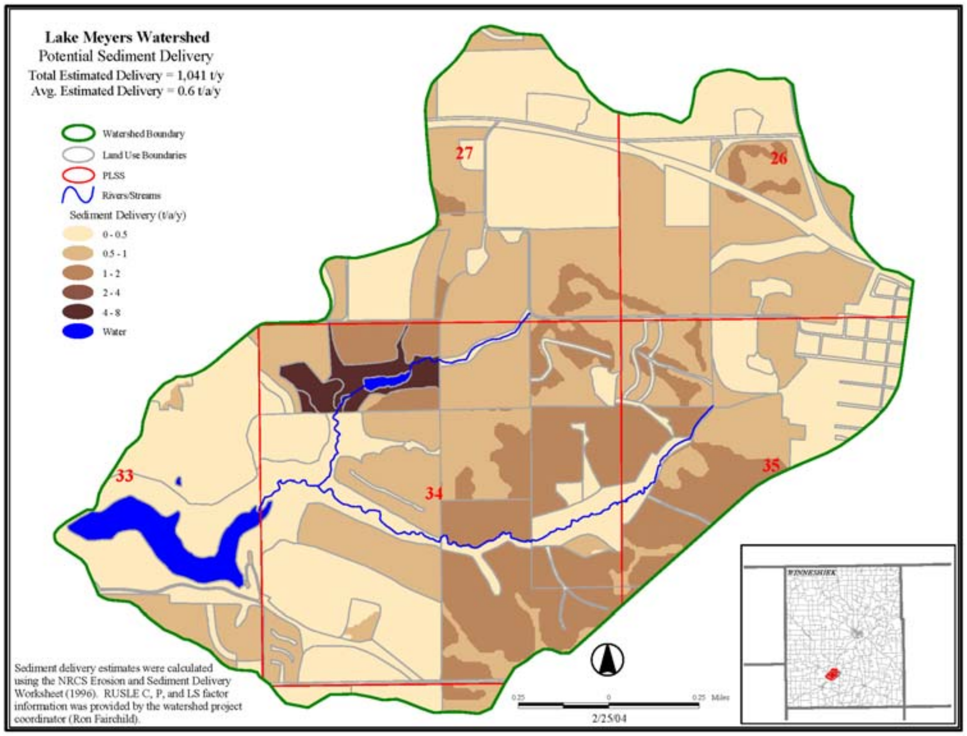


Figure F-2. Lake Meyer RUSLE modeling results with existing structures

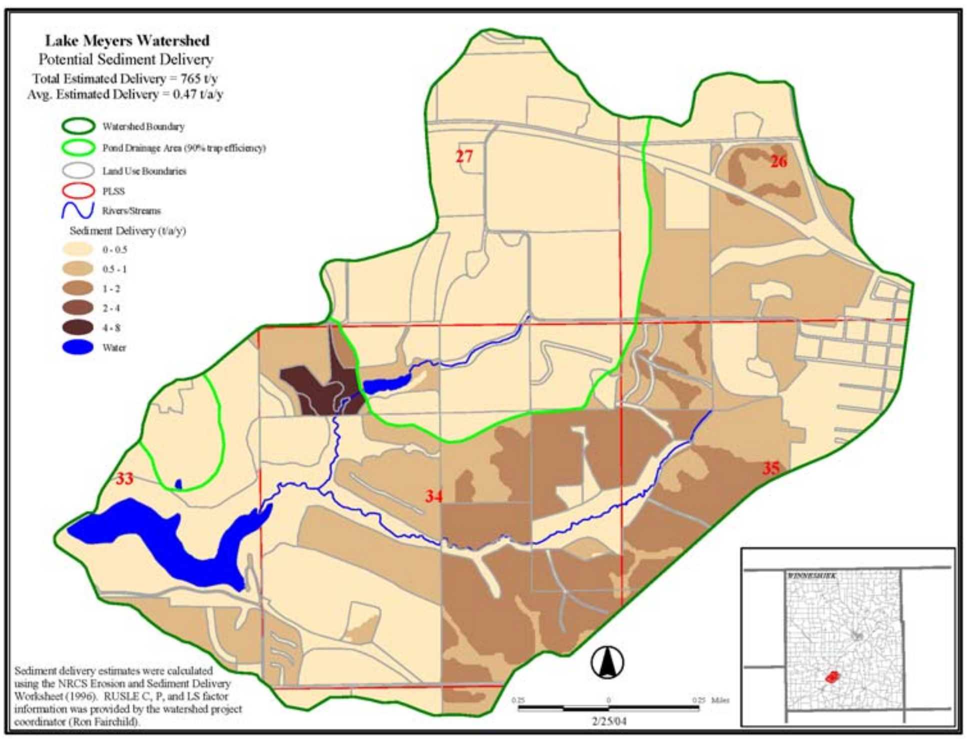
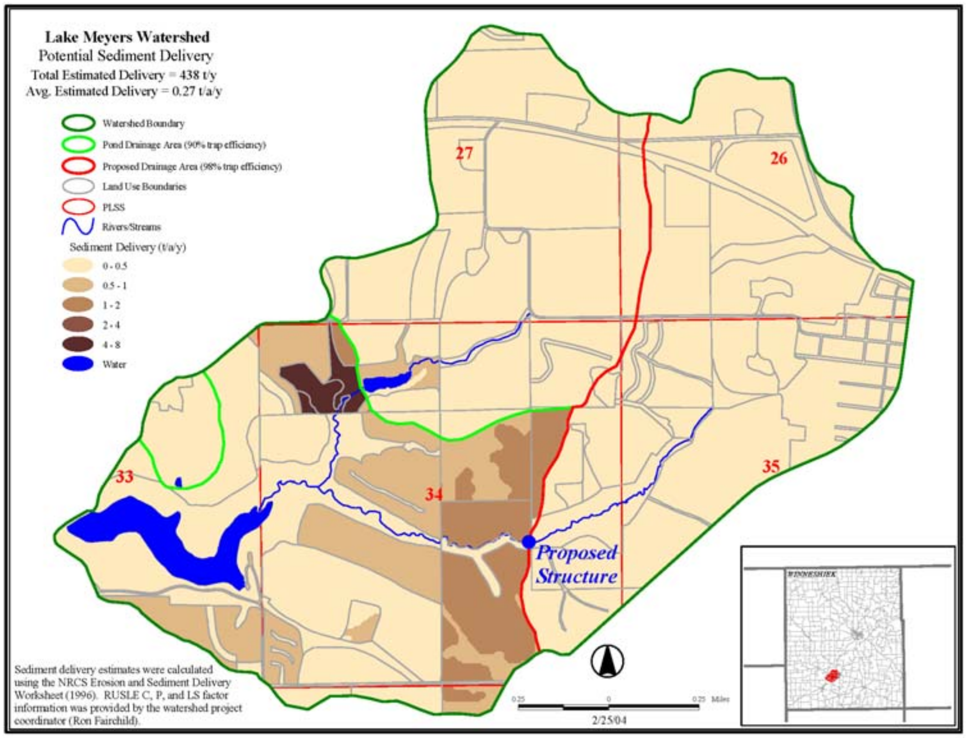


Figure F-3. Lake Meyer RUSLE modeling results, with existing and proposed structures



14. Appendix G - Lake Bed and Sediment Mapping

Summarized Excerpts from:
Lake Bed and Sediment Mapping Standard Operation Procedures
On Iowa Lakes, and Reservoirs
Version 1.0, February 23, 2004
By Jason C. McVay, S. Mike Linhart, Jon F. Nania
U.S. Department of the Interior, U.S. Geological Survey

Introduction
The Iowa District of the United States Geological Survey (USGS) began a lake bathymetric mapping program in June 2001 on Lake Delhi in east central Iowa resulting in a published bathymetric map and report. Since the work at Lake Delhi other opportunities for lake bathymetric and sediment mapping have arisen. This manual outlines office preparation, field data collection, and data editing for bathymetric and sedimentation mapping used by the Iowa district on Iowa lakes and reservoirs. A brief discussion of water quality sampling methods is included.

Bathymetric Mapping
Bathymetry mapping can provide useful information for water quality managers to address sedimentation issues on Iowa's Lakes and Reservoirs. In order to have a consistent method for comparing historic data to present day data it was determined that the water depths should be converted into National Geodetic Vertical Datum (NGVD) of 1929. The map production steps are office preparation, field data collection, and office post-processing of the data and construction of the maps.

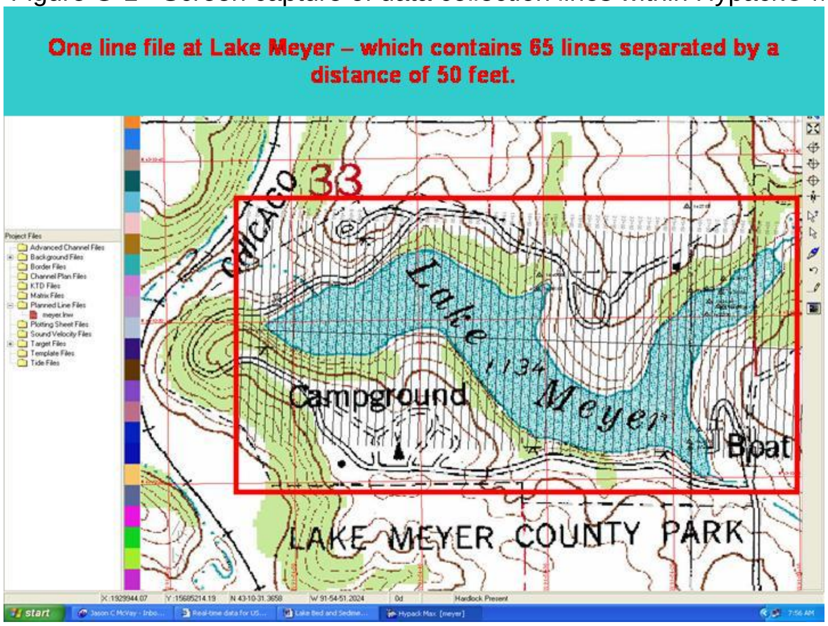
Computer Setup
Preparation includes computer setup and identifying the location of established benchmarks. Computer preparation work involves loading background maps (digital raster USGS topographic maps) in the file format. Background map files are used to help establish the lines that will be used for data collection. These map files are then converted to a local projection and datum to be used with the hydrographic data collection software. With the background maps in the correct projection and datum, the hydrographic mapping software can then be set up to collect the data in the correct projection and datum. The files are projected in UTM, Zone 15, north, and into NAD-83.

These background files are loaded into software where line files can be created. The line files are used to ensure that data are collected in an efficient and representative manner. Line files contain many individual lines that are placed a set distance apart from one another (figure 1).

The basis for determining the orientation and distance between the lines is affected by several factors. The first being the location of submerged original creek beds, where data must be collected perpendicular to the original creek beds, usually located in coves or inlets. Surveying along lines that are set parallel to the creek bed could miss the original profile of the creek. Fewer line files are needed if the lake is round in nature and devoid of any large coves. Conversely, if there are large coves in the lake, then several line files may need to be created.

The topography of a lake bed will also affect the number and location of lines needed. More closely spaced lines need to be located, in areas of the lake where there is greater variation in lake bed elevation, for example areas with submerged or exposed islands associated with steep drop offs. Other lakes may have relatively flat beds with little elevation change and would not require the lines to be as closely spaced. The location and spacing of these lines can vary greatly, even within the same lake.

Figure G-1 - Screen capture of data collection lines within Hypack® Max



The above factors are used as a guide to determine the number, orientation, and spacing between lines. There is not a set formula to determine the distance between lines. The bathymetry work in Iowa, by the USGS, over the past few years has shown an average of about 125 feet between lines. Efficiency and cost of data collection should also be taken into consideration when setting up the data collection lines.

Location of Benchmarks
The next step in office preparation is to locate established benchmarks as close as possible to the lake, so that elevation data can be referenced to the National Geodetic Vertical Datum (NGVD) of 1929. Efforts to locate established benchmarks include contacting local and state agencies that work directly with the individual bodies of water, locating benchmarks using USGS 1:24,000 quadrangle maps, and accessing the National Geodetic Survey datasheet web page. Benchmarks that are found are generally first or second order and believed to be stable and viable.

Bathymetry Data Collection

GPS Accuracy

The accuracy of the differential Global Positioning System (GPS) location is recorded at the beginning of data collection. Horizontal data are collected using differential GPS that has an accuracy of less than one meter. Each lake survey must be assessed to determine the most accurate and available differential GPS acquisition method to be used. There are several ways of measuring the accuracy of the differential GPS before and during data collection, including standard deviation, position dilution of precision (PDOP), and signal to noise ratio. Accuracy increases as the signal strength increases. A value of six or more indicates a strong enough signal for differential position. These indicators of GPS accuracy are constantly monitored and any problems are noted on the field sheet.

Lake Surface Elevation

The lake surface elevation is obtained by measuring down from a reference point with a known elevation to the water surface. Measurements of the lake surface elevation are made at the beginning and end of each day. This technique involves measuring down from the reference point with a steel tape or an engineers rule and read to the nearest one hundredth of a foot.

The NGVD of the reference point can be determined using one of three different methods depending on the situation encountered at the field site: (1) the reference point can be an existing benchmark on the lake itself or; (2) elevations can be surveyed in from a known benchmark to a newly established reference point on the lake or; (3) GPS static data collection is used to establish a reference point elevation.

Shallow Water Limitations
Present limitations of the data collection equipment restrict data collection to depths greater than 3.3 feet. This limitation is a function of how deep the transducer is set in the water column (draft), and other acoustical properties. The acoustic constraints are basic sound travel properties that include side lobe interference and blanking distance.

For areas that are too shallow to profile or that are congested with debris, depths are collected using the target point method. The boat is driven into the shallow water where a depth is obtained using a top-set rod or some other manual measuring device. At each depth location, a horizontal GPS value is determined which will be manually incorporated into sounding data during processing. Determining the number and the location of target points is based on the amount of contour change in, and the size of, the shallow water areas.

Shore points
Shore points are collected to define the shoreline of the lake or reservoir. These points are collected by touching the bow of the boat to the shoreline. A GPS antenna is mounted at the bow and a laptop with the data acquisition software is logging these locations. A transducer is not used for this aspect of lake mapping. The depths at these points are considered to have a value of zero and will later be converted to the water surface elevation of the lake. Shore points are collected wherever there is a change of direction in the shoreline.

Perimeter
The purpose of the perimeter drive is to merge the data collected on the main body of the lake to the shore points. Perimeter data collection involves both transducer and GPS data. The boat is driven around the entire lake along the shore line at depths greater than the 3.3 foot threshold.

Bathymetry data editing
Bathymetry data are edited using special software. This involves removing data spikes, converting the depth data into NGVD, entering target point depth values, and exporting the data into an XYZ format. Theses methods can be found in the software operations manual.

Sediment Thickness Mapping
Recent advancements in hydro-acoustic technology and equipment have given rise to several new applications being developed. These advancements have given the Iowa District an opportunity to use a simple, compact, and effective system for the determination of sediment thickness in lakes and reservoirs. Present procedures for determining the sediment thickness are discussed in the following pages.

Sediment Thickness Data Collection
There are several quality assurance (QA) methods used in the bathymetric and sediment mapping work. The sediment mapping QA methods are similar to the bathymetric methods and include GPS accuracy, transducer draft, and depth calibration. Bathymetric and seismic data are collected at the same time using the same line spacing. The sediment thickness data are collected using a different software package (SDI Depth).

During data collection, SDI Depth interprets the signals from each of the five different transducers within the transducer array and displays them digitally on the computer screen. Depths are monitored closely. If the lake depth falls outside of the initial range set in SDI Depth, then incorrect values may be observed. In a lake where there is large variation in depth, the range setting may need to be changed several times during data collection. Since the bathymetry software and SDI depth are using the same transducers, this range setting will affect both sets of data.

Target and Calibration Cores

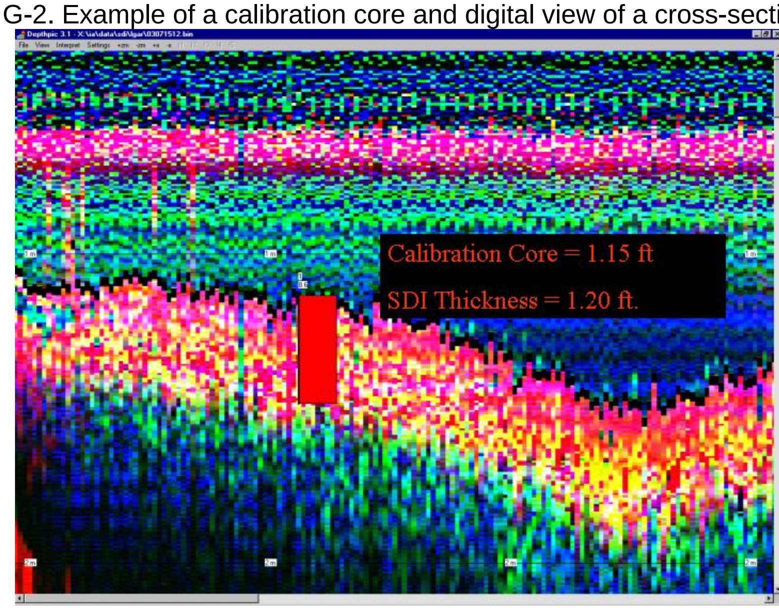
Sediment mapping has the same water depth limitations as the bathymetry. Collection of sediment cores is needed in lake areas where seismic data collection is not possible. Sediment cores are used to interpret sediment thickness during post-processing. Upon collection of the core samples, a visual determination of the original lake bottom is found and a physical measurement of the recent sedimentation is made. The original lake bottom may be determined by inspecting the core for a layer of grasses, twigs, color and/or hardness changes, and texture change set below a layer of sediment. The original lakebed is the same kind of material as the area surrounding the lake. Sediment thickness is recorded on the field form (along with the GPS locations) to be used during post processing. The equipment used for coring consists of a 6 to 12 ft., 2 5/8" diameter clear butyrate tube attached to a vibrating coring head.

Calibration cores are used to validate the digital data being collected by the seismic equipment. Calibration cores are collected in the same manor as the target cores. The selection of core locations is specific to each lake. Five cores is usually sufficient to validate digital data in a small lake without large coves or inlets. When anomalies are observed during seismic data collection the location is recorded for possible coring. At least five calibration cores are collected for each lake.

Sediment thickness data processing

The data editing process utilizes a software package that removes spikes and other false depth values. Digitization of the recent sediment deposition layer is also performed. A file containing the calibration core data is opened during editing and is viewed on the screen in the cross-section of the digital data (see below). After digitization, sediment thickness files are exported in XYZ format to be used in mapping software packages.

Figure G-2. Example of a calibration core and digital view of a cross-section.



GIS Work

Bathymetry and sediment thickness contour maps are produced using a GIS package. Calculations are also performed to produce lake and sediment thickness volumes. Files of processed data from software are converted into point coverages representing discrete point locations of bathymetry or sediment thickness and the appropriate projection and datum are applied (for Iowa: UTM, zone 15, datum NAD83). The point coverages are put into gridding or tin model applications within the GIS software to produce three-dimensional surfaces representing bathymetry or sediment thickness. The surfaces are then contoured and adjusted for any interpretive errors. Volumetric calculations are also performed within the grid or tin model applications. To ensure that consistent and viable surface modeling techniques are being used, quality assurance methods are currently being developed by the Iowa District. The various methods used to develop maps and calculate volumes are discussed within the individual software user manuals.

Water Quality

In addition to the bathymetry and sediment mapping, water-quality data are collected. Field parameters (specific conductance, pH, temperature, and dissolved oxygen) are collected at the same location as the core samples. If water depths are less than twelve feet, water column measurements are taken at one-foot intervals using a multi-parameter meter. When the water depth is twelve feet or greater ten equally spaced readings are made. The data are entered and stored in the USGS National Water Information System (NWIS) database.

Cores samples are analyzed for nutrients and particle size distribution. Two cores are collected at each location. One is sent to the cooperator (IDNR) and the other is processed by Iowa District USGS personnel. For samples processed by the Iowa District, the core barrels are split open. Two samples are taken from each, one from the upper portion of recent sedimentation and one just above the break between recent deposition and the original bed material. Sediment nutrient samples are sent to the NWQL for analysis. The bottom material size analysis is done at the Iowa District Sediment Laboratory. A whole water sample for suspended sediment is also collected and is analyzed for concentration by the Iowa District Sediment Laboratory

Summary

This procedure manual discusses the current techniques used by the Iowa District of the United States Geological Survey. Techniques and procedures for the collection and processing of bathymetric and sediment thickness data may change and develop over time as the need for improvements become apparent.