Total Maximum Daily Load
For Turbidity
Lower Gar Lake
Dickinson County, Iowa

December 2002
(Revised April 2003)

Iowa Department of Natural Resources
Water Resources Section

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Executive Summary

Waterbody Name	Lower Gar Lake
IDNR Waterbody ID	IA 06-LSR-02805-L
Hydrologic Unit Code	HUC10 230003010
Location	Sec. 32, T99N, R36W
Latitude:	42 Deg. 22 Min. N
Longitude	93 Deg. 4 Min. W
Use Designation Class	A (primary contact recreation) B (LW) (aquatic life) HQ
Watershed Area:	11,300 acres
Lake Area	242 acres
Tributaries	Lake Minnewashta Bull Ditch Spring Run Creek
Receiving Water Body	Milford Creek to the Little Sioux River
Major River Basin	Little Sioux River
Pollutant:	Phosphorous in watershed runoff, sediment re-suspension and internal nutrient recycling
Impaired Use	Aquatic life support
1998 303d Priority	High

The Federal Clean Water Act requires the development of a total maximum daily load (TMDL) for the pollutant(s) that causes a water body to be placed on the State of Iowa impaired waters list [303(d) list]. Lower Gar Lake is on the 1998 impaired waters list due to turbidity that creates a condition only partially supporting its aquatic life designated use. The 1998 assessment report echoes the 1994 and 1996 reports in its evaluation of the lake; the primary cause of the poor water quality is shallowness and the resultant re-suspension of nutrients and sediments. Lower Gar Lake is at the end of a system of important natural lakes of glacial origin and is a high priority for water quality improvement.

This document consists of a single TMDL for turbidity designed to provide Lower Gar Lake water quality that fully supports its designated uses. Sediment and adsorbed phosphorous delivered from the watershed and re-suspended from the lake bottom are targeted to address the turbidity 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 hit the target 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 includes a description of planned monitoring. The Lower Gar Lake TMDL will have two phases. Phase 1 will consist of setting a specific and quantifiable target for turbidity expressed as Carlson's trophic state index (TSI). Phase 2 will consist of implementing the monitoring plan, evaluating collected data, and readjusting target values if needed.

Monitoring is essential to all TMDLs in order to:

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

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

The Lower Gar Lake TMDL for turbidity has been prepared in compliance with the current (November 2002) 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:** Lower Gar Lake, S32, T99N, R36W, 2 miles NE of the City of Milford, Dickinson County.

2. **Identification of the pollutant and applicable water quality standards:** The pollutant causing the water quality impairment is algal turbidity caused by excess phosphorous and non-algal turbidity caused by re-suspension of bottom sediments. Designated uses for Lower Gar Lake are Primary Contact Recreation (Class A) and Aquatic Life (Class B(LW)). The excess nutrient input has impaired aesthetic and aquatic life water quality narrative criteria and hindered designated use.

3. **Quantification of the pollutant load that may be present in the waterbody and still allow attainment and maintenance of water quality standards:** The Phase 1 target of this TMDL is a Carlson's Trophic State Index (TSI) of 70 for total phosphorous and a TSI of 65 for secchi depth. This equates to a water column TP concentration of about 0.100 mg/l and a secchi transparency of 0.7 meters. The Phase

One total phosphorous load to the lake must not cause the lake to exceed TSI values of 70.

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 estimated annual total phosphorus load to Lower Gar Lake is 16,000 pounds per year. The Lower Gar Lake capacity for total phosphorous is 8,000 pounds per year based on lake response modeling. To achieve and maintain lake water quality goals and protect for beneficial uses, an average loading reduction of 8,000 pounds per year is required.

5. **Identification of pollution source category(s):** Nonpoint and internal sources of pollutants have been identified as the cause of impairment to Lower Gar Lake.

6. **Wasteload allocations for pollutants from point sources:** No significant point sources have been identified in the Lower Gar Lake watershed; therefore the wasteload allocation will be set at zero.

7. **Load allocations for pollutants from nonpoint sources:** A total phosphorous load allocation for the nonpoint source categories was developed to achieve compliance with the Lower Gar Lake load capacity. The nonpoint source categories are inflow from Lake Minnewashta, runoff from the 11,000 acres that drain directly to Lower Gar, and re-suspended sediment and recycled phosphorous.

8. **A margin of safety**: The implicit margin of safety for this TMDL is the result of a conservative assumption. A significant part of water column total phosphorous is not available for algal growth as shown by the TSI values for TP and chlorophyll. It has been conservatively assumed that all TP will be expressed as algae. The TSI value for total phosphorous is 76 and for chlorophyll is 68. Every 10 TSI unit increase represents a doubling of algal biomass. A large fraction of the turbidity impairment is the result of algal productivity and therefore the MOS is more than 100% of the estimated chlorophyll. Additionally, there are dual targets for this TMDL that assure restoration of aquatic life uses regardless of the accuracy of the modeled total phosphorous load that is the first target. The second target is the measurement of the aquatic life condition through bio-assessment and fisheries studies. These assessments will demonstrate whether or not the lake continues to be impaired after Phase 1 implementation. If the biological assessment of Lower Gar Lake indicates continued impairment the Phase 2 total phosphorous target will be adjusted as needed.

9. **Consideration of seasonal variation:** This TMDL was developed based on annual phosphorous loading.

10. **Allowance for reasonably foreseeable increases in pollutant loads:** An allowance for increased phosphorous loading was not included in this TMDL. Changes in Lower Gar Lake watershed landuse are unlikely except for some residential development. This use is as likely to reduce TP load as increase it. Intensification of activities that add to lake turbulence may increase suspended particulate turbidity and nutrient recycling.

11. **Implementation plan:** Although not required by the current regulations, water quality improvement implementation plans are being developed and used by Iowa Great Lakes watershed groups such as the Clean Water Alliance, the Dickinson County SWCD, and the Cooperative Lakes Area Monitoring Project. Evaluation of lake water quality and watershed land use is an ongoing local effort.

1. Introduction

The Federal Clean Water Act requires the development of a total maximum daily load (TMDL) for the pollutant(s) causing a water body to be placed on the State of Iowa impaired waters list. Lower Gar Lake is on the 1998 impaired waters list for turbidity resulting from elevated nutrient concentrations and the re-suspension of sediment. High nutrient concentrations, specifically total phosphorous, are the start of a causal chain leading to nuisance algal blooms that reduce transparency in the water column. This situation has created a water quality condition only partially supporting aquatic life use.

The 1998 assessment report reiterates the 1994 and 1996 reports in its evaluation of the lake. It states that the primary cause of the lake's poor water quality is shallowness and the resultant re-suspension of nutrients and sediments due to wind, boat traffic, and large numbers of rough bottom fish as well as nutrients delivered from the watershed.

The TMDL for Lower Gar Lake will determine total phosphorous that the lake can receive without impairment, i.e., comply with the Iowa Water Quality Standards.

This turbidity TMDL for Lower Gar Lake will:

- Identify the adverse impact that nutrient induced turbidity is having on aquatic life use and link this to water quality criteria compliance.
- Identify an acceptable phosphorous load capacity that ensures attainment of the lake's aquatic life use.
- Estimate how much the existing phosphorous load exceeds the load capacity.
- Identify phosphorous sources and allocate a load to each source.
- Provide a brief implementation plan to guide the IDNR, other agencies, and stakeholders in efforts to reduce loads to acceptable levels.

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 determine if prescribed load reductions are successful and whether or not the target values are sufficient to attain designated uses. Monitoring activities may include routine sampling and analysis, biological assessment, fisheries studies, and watershed and/or waterbody modeling.

The Lower Gar Lake TMDL will have two phases. Phase 1 will consist of setting a specific and quantifiable target for turbidity expressed as Carlson's trophic state index (TSI). Phase 2 will consist of implementing the monitoring plan, evaluating collected data, and readjusting target values if needed.

2. Lower Gar Lake, Description and History

Lower Gar Lake, at the end of a system of important natural lakes of glacial origin called the Iowa Great Lakes, is a high priority for water quality improvement. The Iowa Great Lakes include Spirit Lake, East and West Okoboji Lakes, Upper Gar Lake, Lake Minnewasta, and Lower Gar Lake.

2.1 The Lake

Lower Gar Lake is the last lake in the Iowa Great Lakes system, and is a natural lake that was first impounded in the nineteenth century. It is located in Dickinson County 2 miles northeast of Milford, Iowa. Lower Gar Lake has a surface area of 242 acres, a mean depth of 3.6 feet, a maximum depth of 6 feet, and a storage volume of 871 acre-feet.

Most of the western shoreline of Lower Gar Lake is privately owned, and current development on the east and northeast sides includes housing and a golf course. The lake has a directly draining watershed of 11,000 acres, drained by Bull Ditch and Spring Run Creek. Lower Gar's sheltered location encourages boating and water skiing when wind conditions limit such activities on the larger lakes in the system. Facilities for boating, swimming, fishing, camping, picnicking, and hiking are provided. Iowa Great Lakes tourism is vital to the local economy and permanent resident use is high for this particular lake.

Physical Features

Waterbody Name:	Lower Gar Lake
Hydrologic Unit Code:	HUC10 230003010
IDNR Waterbody ID	IA 06-LSR-02805-L
Location:	Sec. 32, T99N, R36W
Latitude:	42 Deg. 22 Min. N
Longitude:	93 Deg. 4 Min. W
Water Quality Standards Designated Uses	1. Primary Contact Recreation 2. Aquatic Life Support 3. High Quality Water
Tributaries	Lake Minnewashta Bull Ditch Spring Run Creek
Receiving Waterbody	Milford Creek to the Little Sioux River
Lake Surface Area	242 acres
Maximum Depth	6 feet
Mean Depth	3.6 feet
Volume	871 acre-feet
Length of Shoreline	3.9 miles
Watershed Area (direct draining)	11,300 acres
Watershed/Lake Area Ratio	47:1

Morphometry and Hydrology
Upper Gar Lake, Lake Minnewashta, and Lower Gar Lake are usually referred to as the “Gar Chain” lakes. Upper Gar Lake and Lake Minnewashta do not have surface drainage watersheds separate from Lake East Okoboji and can be considered an extension of the larger lake. Lower Gar Lake does have a separate watershed as well as being connected to Lake Minnewashta. Water from Lake East Okoboji, Lake West Okoboji, and Spirit Lake drain through the Gar chain of lakes. Lower Gar Lake is shallow and does not stratify and internal temperature does not differ much from surface temperature.

2.2 The Watershed

The Iowa Great Lakes Watershed is an area of about 140 square miles. Three-fourths of the watershed is in Dickinson County, Iowa and one-fourth is in Jackson County, Minnesota. The watershed that drains directly to Lower Gar Lake has an area of 11,300 acres and is located in the low plains ecoregion. The watershed to lake area ratio is 47 to 1, high for an Iowa natural lake of glacial origin.

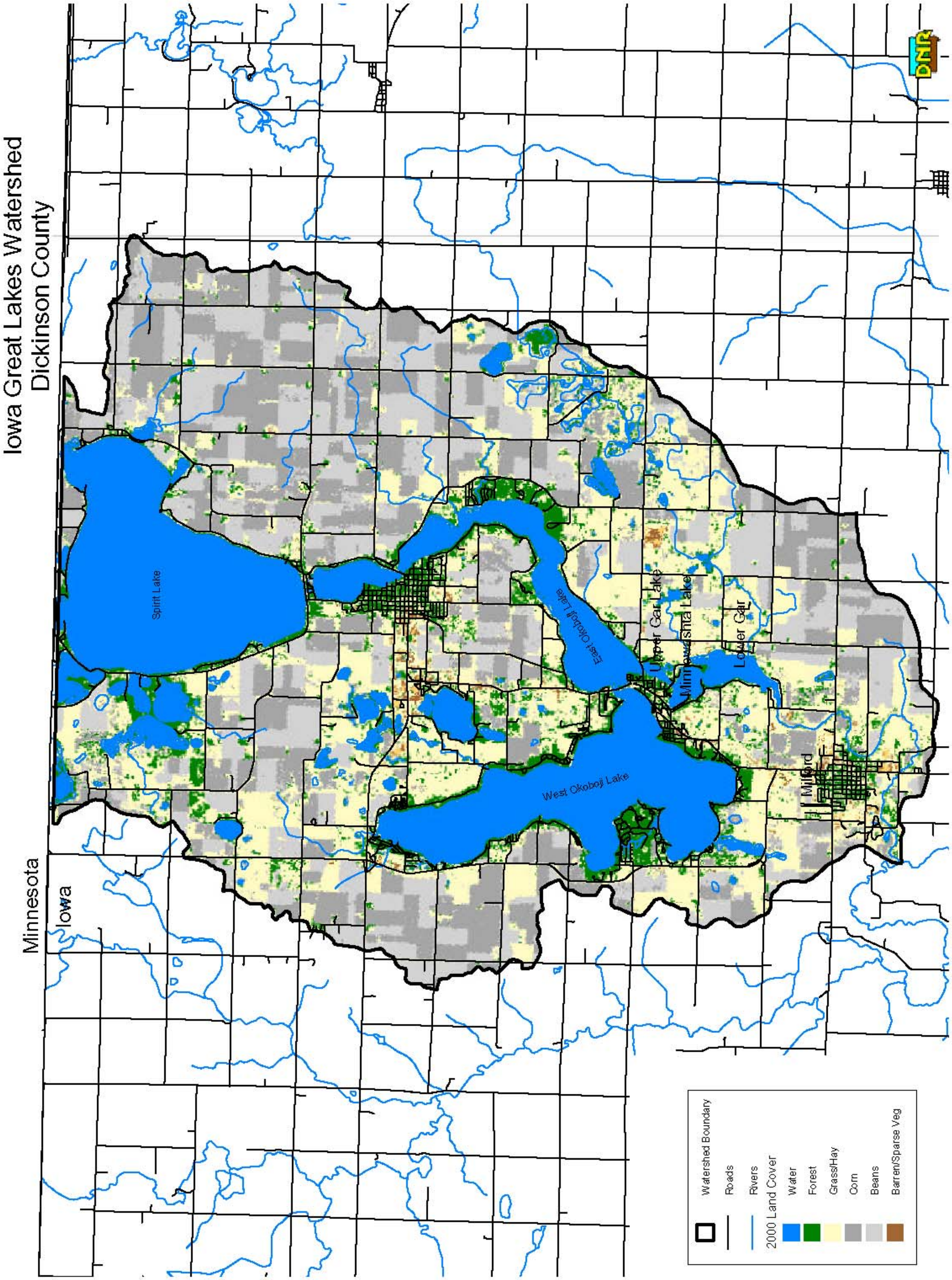
Climate
The climate in the area is classified as humid-continental. Annual temperatures can range from 110 F to –40 F and change as much as 50 F degrees in one day. Precipitation varies from severe storms to infrequent drought. Drought conditions are usually moderate. Annual precipitation is 28 inches, two-thirds of which falls between May and September

Land Use

Table 1. **2002 Landuse for Upper Gar/ Lower Gar/ Minnewashta Watershed**

Landuse	Area in Acres	Percent of Total Area
Cropland	8,433	67
CRP	1,889	15
Natural Areas	1,062	8
Wetlands	872	7
Urban	199	2
Other (roads, etc)	174	1
Total	12,629	100

Iowa Great Lakes and their watershed



2.3 History and Background

The Iowa Great Lakes and surrounding topography were formed during the last period of glaciation. The drainage originates in Jackson County, Minnesota and flows south through a series of lakes, eventually entering the Little Sioux River 1.5 miles south of the City of Milford. Loon Lake is the southernmost lake in Minnesota and it discharges over a stop-log spillway control structure into Spirit Lake. A spillway located in the south end of the lake controls Spirit Lake levels. Flow out of Spirit Lake goes into East Okoboji Lake. Lake levels for East Okoboji Lake, West Okoboji Lake, Upper Gar Lake, Minnewashta Lake, and Lower Gar Lake are controlled by either a spillway structure or road crossing, depending on lake levels, at the south end of Lower Gar Lake. The lakes are all connected by narrow passages.

Spirit Lake has a drainage area of 76 square miles that drains into East Okoboji Lake. Including the Spirit Lake drainage, the Okoboji chain of lakes drains 125 square miles. Spirit Lake has a surface area of 5,500 acres and is the largest natural lake in Iowa. The Okoboji chain has a surface area of 6,200 acres and maximum depths of from 134 feet in West Okoboji to 5 feet in Upper Gar. At spillway crest elevation the volume of the Okoboji chain and Spirit Lake is 260,000 acre-feet.

The lakes' natural outlets have been modified to better regulate water levels. The Spirit Lake outlet was moved 800 feet east when a railroad was constructed across the lake's natural outlet in the 1880's and has been modified since. The outlet at Lower Gar Lake has had several dams or spillways constructed since the 1890's. Modifications to the outflow spillway structure sizes and crest elevations were set by the Iowa General Assembly and future modifications would require the passage of legislation allowing them.

For the Okoboji chain, the record high lake level was set in the floods of 1993 when the water elevation was 4.66 feet above the Lower Gar Lake spillway crest. This was 2.4 feet higher than the previous record set in 1984.

Records show that a dam was built at the Lower Gar Lake outlet in 1896 and was destroyed during a flood in 1903. Another dam was built the following year and was removed in 1908. Another new dam was built in 1910. The existing spillway was constructed 230 feet downstream from Lower Gar Road in 1971. The weir crest is 165 feet wide.

3. TMDL for Turbidity

3.1 Problem Identification

Lower Gar Lake was put on the 1998 impaired waters list for turbidity. Recent and historical measurements of in-lake conditions indicate that accelerated eutrophication caused by excessive nutrient loading and sediment re-suspension is the cause of the Lower Gar Lake water quality impairment. The connection between highly eutrophic and hyper-eutrophic conditions and water quality impairments is well documented and recognized by the scientific community. These conditions promote heavy algal blooms throughout the summer, the prevalence of blue-green algae, severely limited clarity, floating algal scum, and the predominance of rough fish. Excess nutrient loading is often expressed as turbidity for assessment purposes.

The most common nutrient problem in Iowa lakes is excess phosphorous. Limiting phosphorous limits algal growth slowing eutrophication and consequent water quality impairments. The hyper-eutrophic condition of Lower Gar Lake makes total phosphorous the target pollutant for determining the total maximum pollutant load to the lake.

Impaired Beneficial Uses and Applicable Water Quality Standards
The Iowa Water Quality Standards (IAC, 1996) list the designated uses for Lower Gar Lake as:

Class “A”. Primary Contact Recreation. Waters in which recreational or other uses may result in prolonged and direct contact with the water with the risk of ingesting water such as swimming, water skiing, and canoeing.

Class “B (LW)”. Aquatic Life. Water in which a significant and viable aquatic community is maintained year round. Class B waters are to be protected for wildlife, fish, aquatic and semi-aquatic life, and secondary contact uses.

Class “HQ”. High Quality Water. Waters with exceptionally better quality than the minimum expected and with exceptional recreational and ecological importance. Special protection is warranted to maintain the unusual, unique, or outstanding physical, chemical, or biological characteristics which these waters possess.

Iowa does not have numeric standards for turbidity. Lower Gar Lake’s “partially supported” assessment for aquatic life uses was made by IDNR Fisheries staff based on information collected in 1992 and 1993. This 1994 evaluation was carried over to the 1996 and 1998 305(b) assessments. The partially supporting assessment caused the lake to be placed on the 1998 impaired waters list. The hyper-eutrophic lake condition is the direct cause of the turbidity impairment.

Severe algal blooms and loss of clarity have caused a condition incompatible with an aquatic community “normally associated with lake-like conditions”.

Data Sources:
Three sources of recent lake data were evaluated for this TMDL. These sources are independent, with collection and analyses being done by different institutions; the Iowa State University Limnology Laboratory, Iowa Lakeside Laboratory, and the University Hygienic Lab for the IDNR. Original data from each can be found in Appendix B.

The Iowa State University Lake Study began in 2000 and is scheduled to run through 2004. This study by the university Limnology Laboratory approximates a sampling scheme used by Roger Bachman in earlier Iowa lake studies. Samples are collected three times during the early, middle and late summer. Among the variables measured are secchi disk depth, phosphorous series, nitrogen series, TSS, and VSS. Data from 2000, 2001 and 2002 have been used to evaluate the lake’s trophic state and existing conditions for lake response modeling.

The second data source is the Bovbjerg Water Chemistry Laboratory of the Iowa Lakeside Lab. Lower Gar Lake data has been collected and analyzed since 1999 by Steve Fisher of the lab and others for the Cooperative Lakes Area Monitoring Project. Gary Phillips of Iowa Lakes Community College designed this project that focuses on phosphorous, nitrogen, chlorophyll a, and water clarity. From 1999 to 2002, six or seven samples have been taken at the same location each summer. This data has been used to evaluate the lake’s trophic state and existing conditions for lake response modeling.

The third data source is monitoring done in 2002 by the University Hygienic Laboratory (UHL) as an assessment survey for this TMDL. This monitoring included monthly and one event sampling at 6 lake tributaries and in the deepest part of the lake. This data has been used to evaluate the lake’s trophic state and existing conditions for lake response modeling

Interpreting Lower Gar Lake Water Quality Data
Iowa does not have numeric water quality criteria for nutrients or the associated reduction in transparency caused by turbidity. Carlson’s Trophic State Index (TSI) can provide a framework for water quality data evaluation and interpretation. The equations that generate the total phosphorous (TP), chlorophyll a (chlor a), and secchi depth (SD) index values are found below:

<u>Carlson’s TSI Equations:</u>

TSI (SD) = 60 – 14.41 (ln SD)
TSI CHL) = 9.81 (ln CHL) + 30.6
TSI (TP) = 14.42 (ln TP) + 4.15

The calculated TSI’s for these three variables locate the lake in a continuum of trophic state from oligotrophic to hyper-eutrophic. TSI values can also indicate if a lake is phosphorous or light limited for algal growth. If the calculated TSI values for TP, chlor a, and SD are about the same, then the lake is phosphorous limited.

Water Quality Conditions
The water quality condition of Lower Gar Lake has been evaluated by applying the TSI equations to the data collected by the three sources previously described.

Average values of the ISU Lake Study data are:

	2000 data	2001 data	2002 data	average
Total phosphorous,ug/l	204	91	189	161
Chlorophyll a, ug/l	70	22	38	43
Secchi depth, m	0.4	1.0	0.4	0.6

Average TSI values of all three studies

Study	TP, ug/l	Chlor a, ug/l	Secchi depth, m
ISU 2000 Iowa Lakes Study	161	43	0.6
Lakeside Lab data	159	50	0.5
IDNR TMDL/UHL data	120	38	0.5
Average for 3 studies	**147**	**44**	**0.53**
TSI values	**76**	**68**	**69**

These values indicate that algal growth tends toward light rather than phosphorous limitation. This is the result of non-algal turbidity.

Potential Pollution Sources

<u>Point Sources</u>: No significant phosphorous point sources exist in the Lower Gar Lake watershed. Wastewater from a large part of the Iowa Great Lakes watershed is transported to the WWTP in the City of Milford, just downstream from Lower Gar Lake. Gull Point State Park is a day visit park only.

<u>Nonpoint Sources</u>: There are three potential nonpoint phosphorus sources in the Lower Gar Lake watershed. They include the inflow from Lake Minnewashta, runoff from the watershed area that drains directly to the lake, and recycling of re-suspended material from the lake bottom.

Natural Background Conditions:
Natural background contributions of phosphorus were not separated from the total nonpoint source load.

3.2 TMDL Endpoint

There are two water quality targets for this TMDL. The first target, based on TSI values, is for a Phase 1 total phosphorous TSI (TP) target of 70 that is equivalent to a TP concentration of 100 ug/l and a TSI (secchi) of 65 that is the equivalent to a secchi depth of 0.71 meters.

The second target is the attainment of aquatic life uses as measured by fishery and biological assessments.

The Phase 2 fisheries aquatic life target will be attained when Lower Gar Lake fully supports aquatic life use as measured by an IDNR Fisheries Bureau assessment. This assessment will follow the *Statewide Biological Sampling Plan Protocol* (Larscheid, 2001). This protocol is being used to develop benchmarks for lake fisheries in Iowa. Results from the Lower Gar Lake assessment will be compared with these benchmarks that include age, growth, size structure, body condition, relative abundance, and species composition.

The Phase 2 biological aquatic life target will be attained when aquatic life uses are fully supported as measured by a bio-assessment directed by the IDNR bio-assessment group. Protocols for these assessments will include phytoplankton and zooplankton surveys that will be linked to an index and lake classification framework being developed by IDNR staff and Iowa State University. Since these protocols are under development, the assessment targets will be determined later as the indexing and classification work is completed.

Criteria for Assessing Water Quality Standards Attainment
Numeric Water Quality Standards Criteria:
There is not a numeric water quality criteria for algal nor non-algal turbidity.

Quantification of Water Quality Standards Criteria:
As previously illustrated, the cause of the turbidity impairment is algal and non-algal particles in the water column resulting from excess phosphorous and sediment, respectively. The transparency objective is defined by the secchi depth TSI of 65 and is related through the trophic state index to phosphorous and chlorophyll concentrations. The lake response modeling process tested decreasing annual phosphorus loads to Lower Gar Lake until the transparency objective as measured by secchi depth was achieved.

Selection of Environmental Conditions
The “critical condition” for which this nutrient TMDL applies is the entire year. An annual loading period was utilized in modeling Lower Gar Lake’s assimilative capacity and for estimating loading reductions necessary to meet in-lake water quality targets. This approach also takes into consideration that nutrients being lost from the water column and trapped in the bottom sediments have the potential to re-enter the water column at a later time. Non-point source controls will target those times when high loading occurs.

Waterbody Pollutant Loading Capacity
The load capacity for this nutrient TMDL is the annual amount of phosphorus Lower Gar Lake can receive and meet its designated use. Based on lake response modeling, the Phase 1 total phosphorus loading capacity for the lake is 8,000 pounds per year. The model predicts that water quality targets for total phosphorus and transparency (turbidity) will be achieved at this loading rate

3.3 Pollution Source Assessment

There are three Lower Gar Lake phosphorous sources. The first is the discharge from Lake Minnewashta. The second is from the watershed areas that drain directly into the lake. The third source is re-suspension of sediment and entrained phosphorous. The loads from these sources will be evaluated as follows:

- The estimated load from Lake Minnewashta will be the average Lake Minnewashta phosphorous concentration times the annual Lake Minnewashta discharge.
- The load from direct drainage will be estimated using watershed modeling.
- The load from recycling of re-suspended phosphorous will be what is left after the other two sources have been subtracted from the estimated total load.

Existing Phosphorus Load
The annual total phosphorus load to Lower Gar Lake is estimated to be 16,000 pounds per year. Of this, 6,100 pounds per year is delivered directly to Lower Gar Lake from the upstream lake system and watershed through Minnewashta Lake, 3,100 pounds per year from the watershed that drains directly to Lower Gar Lake, and 6,800 pounds per year from re-suspension and recycling of previously settled phosphorous.

Departure from Phosphorous Load Capacity
The Phase 1 targeted load capacity for Lower Gar Lake is 8,000 pounds of total phosphorous per year based on lake response modeling. To achieve and maintain Phase 1 water quality goals and protect for designated uses, a loading reduction of 50% is required.

Identification of Pollutant Sources
Since there are no significant point source discharges in the Lower Gar Lake watershed all pollutant sources are nonpoint.

Nonpoint Sources of Phosphorus
<u>Lake Minnewashta and the Upstream Lake System</u>. The TP load (6,100 pounds per year) from this source was estimated using the average TP concentration (132 ug/l) in Lake Minnewashta and the estimated annual flow (17,000 acre-feet) into Lower Gar Lake.
<u>Watershed</u>. The total phosphorus load from the watershed draining directly to the lake was estimated to be 3,100 pounds per year using a runoff volume of 3,700 acre-feet. This run-off volume equates to 4 inches per year in a watershed

that has many wetlands, potholes, lakes, and ponds to absorb and slow runoff. A significant portion of the watershed is managed by IDNR for wildlife.
Re-suspension and Recycling. The total phosphorous load from recycling of previously settled bottom material is estimated to be 6,800 pounds per year. This was determined by subtracting the contributions from the other two sources from the total load of 16,000 pounds.

Linkage of Sources to Endpoint
The average annual phosphorus load of 16,000 pounds per year to Lower Gar Lake originates entirely from nonpoint sources. To meet the TMDL endpoint, the annual nonpoint source phosphorus contribution to Lower Gar Lake needs to be reduced by 8,000 pounds.

3.4 Pollutant Allocation

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

Load Allocations
The Load Allocation (LA) for this TMDL is 8,000 pounds per year of total phosphorus and is distributed among the identified nonpoint source categories as follows.
3,000 pounds per year allocated to Lake Minnewashta and the upstream lake system.
2,600 pounds per year allocated to the 11,000 acre watershed that drains directly to Lower Gar Lake.
2,400 pounds per year allocated to re-suspension and recycling of previously settled phosphorous.

Margin of Safety
The implicit margin of safety for this TMDL is the result of a conservative assumption. A significant part of water column total phosphorous is not available for algal growth as shown by the TSI values for TP and chlorophyll. It has been conservatively assumed that all TP will be expressed as algae. The TSI value for total phosphorous is 76 and for chlorophyll is 68. Every 10 TSI unit increase represents a doubling of algal biomass. A large fraction of the turbidity impairment is the result of algal productivity and therefore the MOS is more than 100% of the estimated chlorophyll.

The dual TMDL targets will assure restoration of aquatic life uses even with the uncertainty inherent in the calculated total phosphorous target. The second target, measurement of aquatic life condition through fishery and biological assessments and comparing results to index and classification schemes, will show whether or not the impairment remains after Phase 1 implementation. The MOS for these assessments will be to use only the upper half of the index or classification range for this type of lake. If these assessments of Lower Gar Lake indicate continued impairment the Phase 2 total phosphorous target will be adjusted as needed.

3.5 Phosphorus TMDL Summary

WLA (0 pounds/year) + LA (8,000 pounds/year) / MOS (Implicit) = LC (8,000 pounds/year).

4.0 Implementation Plan

This TMDL implementation plan provides guidance for agencies and stakeholders working to improve Lower Gar Lake water quality. The emphasis is on reduction activities that target non-point source categories of phosphorous. These include:

Discharge from Lake Minnewashta and the directly draining watershed:
Over half of the Lower Gar Lake phosphorous load arrives with the flow from Lake Minnewashta or the direct run-off from the 11,000 acre watershed . An inventory of watershed phosphorous applications and a nutrient budget should be developed for the entire Iowa Great Lakes system. Increased residential and commercial development will make urban stormwater runoff an increasingly significant pollutant source.

Since much of the phosphorous from the watershed is associated with sediment, controls that reduce erosion in the Iowa Great Lakes' watershed will help to reduce water column TP in Lower Gar Lake. Erosion management practices include:
Gully and stream bed and bank erosion controls: Bed and bank erosion is often a significant sediment source when many upland erosion controls have been initiated. Problem locations should be identified and restoration activities should be targeted at these areas. 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 control: Erosion control activities include the maintenance of previously installed structures. Periodically evaluate watershed erosion control activities focusing on identified large sediment contributors. Emphasize row crop fields close to the lake or stream that have 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.

Turbulent sediment re-suspension and phosphorous recycling.
A large fraction of the TP load in Lower Gar Lake results from recycling of previously settled phosphorous. This phosphorous is entrained with sediment that is disturbed by wind action, motorboats, and large numbers of bottom feeding and dwelling fish. Suggested controls are:

- Reduce the numbers of bottom feeding fish.
- Reduce turbulence from motorboats.
- Minimize wind impacts with tree lines.
- Increase lake depth.
- Construct baffles to reduce turbulence.

Phosphorous Reduction Goal.
In addition to correction of the water quality impairment in Lower Gar Lake, the phosphorous reductions identified in this TMDL are necessary to protect the public and private investment in the Iowa Great Lakes. If future evaluations of the lake condition indicate that the phosphorous delivery goal is inadequate to prevent impairment, the TMDL will be revised and new phosphorous allocations will be made.

5. Monitoring and Evaluation Plan

Monitoring is an essential part of a phased TMDL and is central to:

- Assessing future beneficial use status;
- Determining if water quality is improving, degrading or status quo;
- Evaluating the effectiveness of implemented best management practices.

Lower Gar Lake monitoring will assess the lake's trophic state and compare it to the TP, chlorophyll, and secchi TSI objectives outlined in the TMDL. The monitoring and evaluation plan for Lower Gar Lake will consist of the following:

- The most important information for evaluation is the measurement of total phosphorous, chlorophyll a, and secchi depth for the calculation of tropic state. This is being done for the 2000 ISU Iowa Lake Study until 2005.
- Make a biological assessment to determine the current state of aquatic life uses.
- Perform additional watershed modeling to improve knowledge of the origin of watershed phosphorous and to assess the effectiveness of implemented management practices.
- Carry out continuous flow measurement of Minnewashta Lake discharge.

6.0 Public Participation

6.0 Public Participation

Public meetings regarding the procedure and timetable for developing the Lower Gar Lake TMDL were held on January 14, 2002, in Des Moines, Iowa; and on February 4, 2001 at the Maritime Museum in Arnolds Park, Iowa.

The initial public notice period was from December 6, 2002 to December 14, 2002 but was extended to December 31, 2002. During the public notice period the draft TMDL was available on the IDNR Internet site and copies of the draft TMDL were distributed to stakeholders and local interests. Due to high public interest in Iowa Great Lakes water quality and the Lower Gar Lake TMDL, an additional public meeting was held on January 21, 2003.

Appropriate comments received during the public notice period and during the January 21 public meeting were incorporated into the TMDL, specifically as items in evaluation and monitoring activities to be performed in 2003. Among these activities are measurement of TP load from the directly draining watershed and estimates of re-suspension TP load caused by wind, motorboats, and fish.

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Appendix A: Model inputs

Short Spreadsheet version of Eutromod Lake Response component-
Calibration of phosphorous load to in-lake data

Lower Gar Lake Response Model	Input data in green cells		Phosphorus (mg/l)	Chlorophyll a	Secchi Depth	Secchi Depth (inches)
Surface Acres (acres)	242	Monitored In-lake Value	0.1470	44	0.51	20
Lake Volume (ac-ft)	871	Predicted	0.1454	17.30	0.189	7.4
Inflow (ac-ft/year)	20,000	% Similar	0.99	0.39	0.37	
Inflow (cfs)						
Annual Precipitation	28		TSI - phosphorus	TSI - chlorophyll *a*	TSI - secchi	
Watershed P Loading (lbs)	16,000	Monitored In-lake Value	76.1	67.7	69.7	
Detention Time (years)	0.04	Predicted	76.2	58.6	84.0	
Lake Volume (10^6 m^3)	1.074	% Similar	1.00	0.87	0.83	
Volumetric Water Load (10^6 m^3/yr)	24.672					
Mean Depth (ft)	3.60		Watershed load to meet in-lake p concentration (lbs)	Watershed load to meet in-lake Chlorophyll *a* (lbs)	Watershed load to meet in-lake secchi (lbs)	
Mean Depth (m)	1.097					
Watershed P Loading (kg)	7258		Load Summary			
Precip P Load (kg)	34.8		Minimum	0		
Septic P Load (kg)	0		Mean	#DIV/0!		
WWTF P Load (kg)	0		Median	#NUM!		
Total P Loading (kg)	7292		Maximum	0		
Total P Loading (lbs)	16077					
Expected Total P-in	0.30					

Calibration of phosphorous load to in-lake data

Lower Gar Lake	Input data in green cells		Phosphorus (mg/l)	Chlorophyll a	Secchi Depth	Secchi Depth (inches)
Reduction %	50	Predicted	0.0946	13.89	0.25	9.8
Lake Volume (ac-ft)	871	Water Quality Goals	0.1000	30.00	0.71	28
Surface Acres (acres)	242	% Similar	0.95	0.46	0.35	
Detention Time (years)	0.04					
Watershed P Loading (lbs)	16000		TSI - phosphorus	TSI - chlorophyll *a*	TSI - secchi	
Reduced Watershed Load (lbs)	8000	Predicted	69.8	56.4	80.0	
Volumetric Water Load (10^6 m^3/yr)	24.672	Water Quality Goals	70.6	64.0	64.9	
Lake Volume (10^6 m^3)	1.074	% Similar	0.99	0.88	0.81	
Mean Depth (ft)	3.60					
Mean Depth (m)	1.097		Phosphorus load Reduction to meet p concentration water quality goal (lbs)	Phosphorus load reduction to meet Chlorophyll *a* water quality goal (lbs)	Phosphorus load reduction to meet secchi measurement goal (lbs)	
Watershed P Loading (kg)	7258					
Precip P Load (kg)	34.8		Reduction Summary			
Septic P Load (kg)	0		Minimum	0		
WWTF P Load (kg)	0		Mean	#DIV/0!		
Total Reduced P Loading (kg)	3646		Median	#NUM!		
Total Reduced P Loading (lbs)	8038		Maximum	0		
Expected Total P-in	0.148					

RESERVOIR EUTROPHICATION MODELING WORKSHEET

TITLE -> Lower Gar

Based on CNET.WK1 VERSION 1.0

VARIABLE	UNITS	Current	LC
WATERSHED CHARACTERISTICS...			
Drainage Area	km2	51.12	51.12
Precipitation	m/yr	0.86	0.86
Evaporation	m/yr	1	1
Unit Runoff	m/yr	0.09	0.09
Stream Total P Conc.	ppb	300	175
Stream Ortho P Conc.	ppb	90	52.5
Atmospheric Total P Load	kg/km2-yr	46	46
Atmospheric Ortho P Load	kg/km2-yr	23	23
POINT SOURCE CHARACTERISTICS...			
Flow	hm3/yr	0	0.0
Total P Conc	ppb	2000	2000.0
Ortho P Conc	ppb	1600	1600
RESERVOIR CHARACTERISTICS...			
Surface Area	km2	0.979	0.979
Max Depth	m	1.82	1.82
Mean Depth	m	1.22	1.22
Non-Algal Turbidity	1/m	0.79	0.5
Mean Depth of Mixed Layer	m	1.13	1.13
Mean Depth of Hypolimnion	m	0.37	0.37
Observed Phosphorus	ppb	147	100.0
Observed Chl-a	ppb	44	20.0
Observed Secchi	meters	0.53	1
MODEL PARAMETERS...			
BATHTUB Total P Model Number	(1-8)	4	4
BATHTUB Total P Model Name		CANFIELD	
BATHTUB Chl-a Model Number	(2,4,5)	2	2

VARIABLE	UNITS	Current	LC
AVAILABLE P BALANCE...			
Precipitation Load	kg/yr	45	45
NonPoint Load	kg/yr	1380	805
Point Load	kg/yr	0	0
Total Load	kg/yr	1425	850
Sedimentation	kg/yr	938	499
Outflow	kg/yr	488	352
PREDICTION SUMMARY...			
P Retention Coefficient	-	0.658	0.586
Mean Phosphorus	ppb	109.2	78.8
Mean Chlorophyll-a	ppb	47.4	37.4
Algal Nuisance Frequency	%	98.9	94.7
Mean Secchi Depth	meters	0.35	0.42
Hypol. Oxygen Depletion A	mg/m2-d	1651.7	1468.2
Hypol. Oxygen Depletion V	mg/m3-d	4464.1	3968.2
Organic Nitrogen	ppb	1296.4	1048.0
Non Ortho Phosphorus	ppb	98.9	74.4
Chl-a x Secchi	mg/m2	16.8	15.8
Principal Component 1	-	3.52	3.32
Principal Component 2	-	0.91	0.90
	Observed	Pred	Target
Carlson TSI P	76.2	71.9	67.2
Carlson TSI Chl-a	67.7	68.5	66.2
Carlson TSI Secchi	69.2	75.0	72.4
OBSERVED / PREDICTED RATIOS...			
Phosphorus		1.35	1.27
Chlorophyll-a		0.93	0.53

VARIABLE	UNITS	Current	LC
RESPONSE CALCULATIONS...			
Reservoir Volume	hm3	1.19438	1.19438
Residence Time	yrs	0.2676	0.2676
Overflow Rate	m/yr	4.6	4.6
Total P Availability Factor		1	1
Ortho P Availability Factor		0	0
Inflow Ortho P/Total P		0.306	0.311
Inflow P Conc	ppb	319.3	190.5
P Reaction Rate - Mods 1 & 8		3.7	2.2
P Reaction Rate - Model 2		4.0	2.3
P Reaction Rate - Model 3		8.5	5.1
1-Rp Model 1 - Avail P		0.402	0.483
1-Rp Model 2 - Decay Rate		0.391	0.474
1-Rp Model 3 - 2nd Order Fixed		0.289	0.356
1-Rp Model 4 - Canfield & Bachman		0.342	0.414
1-Rp Model 5 - Vollenweider 1976		0.659	0.659
1-Rp Model 6 - First Order Decay		0.789	0.789
1-Rp Model 7 - First Order Setting		0.820	0.820
1-Rp Model 8 - 2nd Order Tp Only		0.402	0.483
1-Rp - Used		0.342	0.414
Reservoir P Conc	ppb	109.2	78.8
Gp		0.232	0.232
Bp	ppb	127.1	81.2
Chla vs. P, Turb, Flushing	2	47.4	37.4
Chla vs. P Linear	4	30.6	22.1
Chla vs. P 1.46	5	76.6	47.5
Chla Used	ppb	47.4	37.4

BATHTUB Chl-a Model			
Name		P L Q	
Beta = 1/S vs. C Slope	m2/mg	0.042882	0.05
P Decay Calibration (normally =1)		1	1
Chlorophyll-a Calib (normally = 1)		1	1
Chla Temporal Coef. of Var.		0.35	0.35
Chla Nuisance Criterion	ppb	20	20
WATER BALANCE...			
Precipitation Flow	hm3/yr	0.84	0.84
NonPoint Flow	hm3/yr	4.60	4.60
Point Flow	hm3/yr	0.00	0.00
Total Inflow	hm3/yr	5.44	5.44
Evaporation	hm3/yr	0.98	0.98
Outflow	hm3/yr	4.46	4.46

Secchi	1.50	2.37
OBSERVED / PREDICTED T-STATISTICS...		
Phosphorus	1.09	0.88
Chlorophyll-a	-0.27	-2.31
Secchi	1.48	3.18

ml - Nuisance Freq Calc.	3.8	3.6
z	-2.288	-1.615
v	0.029	0.108
w	0.568	0.650
x	0.011	0.053

ORTHO P LOADS...				TOTAL P LOADS...	OrP Fraction		
Precipitation	kg/yr	23	23		0.5	45	45
NonPoint	kg/yr	414	242		0.3	1380	805
Point	kg/yr	0	0		0.8	0	0
Total	kg/yr	437	264			1425	850
Total	#/year	960	581			3136	1870

EUTROMOD is a water quality model that has two components. The first is the lake response model used in this TMDL. The second is a watershed nutrient loading model that has not been used here. The spreadsheet version used here was developed by the Nebraska Department of Environmental Quality. The NDEQ documentation for this version follows.

Instructions for Using the Lake Response Model
Simulation models facilitate the water quality planning process. One model is a spreadsheet-based program called EUTROMOD developed by Kenneth Reckhow of Duke University in 1992. The EUTROMOD model predicts watershed (nutrient) loading and in-lake conditions (water transparency, chlorophyll *a,* and total phosphorus concentration) based on land use, waterbody physical characteristics and other factors.

The accuracy of a model depends on the quality of data and information inputs. Model outputs are expressed as “average annual conditions”. Although simple compared to some other water quality models like AGNPS and SWAT, the watershed loading part of EUTROMOD requires information on land use, soil erodibility, cropping factors, sediment-attached nutrient concentrations, trapping efficiencies, etc. The data and information must represent “average” conditions that can be difficult to define.

Several variables can contribute to or influence the water quality response to nutrient inputs and, while models can predict waterbody conditions, it is difficult to dispute water quality data and information collected directly from the waterbody in question. The Nebraska Department of Environmental Quality has been monitoring lakes and reservoirs for several years and has developed a process whereby average annual conditions are described. What is lacking for several waterbodies is a measurement or an estimation of the annual nutrient “load” delivered to the lake.

The lake response model part of EUTROMOD requires minimal input to predict lake trophic conditions and average annual nutrient load. The Lake Response Model spreadsheet was developed using minimum inputs and calculations needed for the lake response part of the EUTROMOD water quality model.

In-Lake Calibration Worksheet
The following information is needed to complete the in-lake calibration worksheet. The cells that require inputs have been shaded green as shown in the calibration spreadsheet above.

Input	**Units**
Lake Surface Area	Acres
Lake Volume	Acre-Feet
Tributary/Watershed Inflow	Acre-feet/year or cubic feet/second
Annual Precipitation	Inches/Year
Observed In-lake Total Phosphorus	mg/l
Observed Chlorophyll *a*	mg/m^3
Observed In-lake transparency (secchi depth)	inches

Once the data has been entered, the phosphorus load (lbs/year) cell, shaded orange can be manipulated until the predicted conditions match the selected observed conditions. Input the value determined to best match the parameter (total p, chlorophyll a or secchi depth) into the appropriate cell.

Typically, the phosphorus load arrived at and used in waterbody planning (i.e. watershed management plans, TMDLs) will be based upon a calibration of the in-lake total phosphorus concentration. Regardless of which load is used, the in-lake response worksheet must be completed and remain completed before moving on, as the cells are linked.

On all worksheets, trophic state indices as defined by Carlson (1977, 1996) will be calculated for both the manually input and predicted water quality conditions.

Total Phosphorus and Watershed Load Reduction Worksheets

Water quality planning may include managing waterbody to meet water quality targets, goals or criteria (goals) for in-lake phosphorus, chlorophyll *a* or water transparency. Meeting these goals may require a reduction in the phosphorus load. To determine the load necessary to meet these goals, two worksheets have been developed. The Total Phosphorus Load Reduction Worksheet considers a reduction in the total load. That is, all source (watershed, precipitation, septic tanks and wastewater treatment facilities) loads are reduced equally. To complete this spreadsheet, the water quality goals for in-lake phosphorus, chlorophyll *a* or water transparency should be entered into the green cells. The orange reduction cell can then be varied until the predicted value(s) is/are equivalent to the water quality goals. The reduction should be a percentage reduction and input as a whole number (50, 80, etc.) not a decimal.

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Appendix B. Data and Data Evaluation

Lower Gar Lake
Lakeside Labs Data
Total Phosphorous values for 1999, 2000, 2001
TSI for total phosphorous

	TP		TP		TP
06/17/1999		05/16/2000		06/08/2001	0.077
06/18/1999		05/20/2000	0.138	06/09/2001	
06/30/1999		05/25/2000		06/10/2001	
07/01/1999		05/30/2000		06/14/2001	
07/02/1999		06/02/2000	0.187	06/21/2001	
07/06/1999		06/07/2000		06/22/2001	0.114
07/07/1999		06/16/2000	0.167	06/23/2001	
07/14/1999	0.245	06/17/2000		06/27/2001	
07/15/1999		06/22/2000		07/03/2001	0.105
07/18/1999		06/24/2000		07/11/2001	
07/28/1999	0.123	06/27/2000		07/16/2001	
08/02/1999		06/30/2000	0.112	07/19/2001	0.185
08/06/1999		07/05/2000		07/23/2001	
08/11/1999	0.148	07/06/2000		07/25/2001	
08/12/1999		07/08/2000		07/26/2001	
08/16/1999		07/09/2000		07/30/2001	
08/20/1999		07/14/2000	0.171	08/03/2001	0.171
08/24/1999		07/19/2000		08/08/2001	
08/25/1999	0.167	07/20/2000		08/10/2001	
08/31/1999		07/22/2000		08/11/2001	
09/08/1999	0.222	07/28/2000	0.183	08/20/2001	

09/09/1999		08/01/2000		08/22/2001	0.185
09/20/1999		08/02/2000		09/01/2001	0.226
09/22/1999	0.238	08/05/2000		09/03/2001	
09/23/1999		08/07/2000		09/05/2001	
10/06/1999	0.225	08/11/2000	0.160	09/10/2001	
10/07/1999		08/17/2000		09/17/2001	
10/15/1999		08/19/2000		09/21/2001	0.153
10/20/1999	0.112	08/20/2000		09/26/2001	
		08/25/2000	0.197		
		08/31/2000			
		09/02/2000			
		09/04/2000			
		09/09/2000	0.503		
		09/13/2000			
		09/14/2000			
		09/16/2000			
		09/18/2000			
		09/26/2000	0.133		
		09/27/2000			
		09/30/2000			
summer average	0.171		0.168		0.139
TP TSI	78		78		75

Lower Gar Lake
Lakeside Labs Data
Secchi depth values for 1999, 2000, 2001
TSI for secchi depth

	Secchi		Secchi		Secchi
06/17/1999		05/16/2000		06/08/2001	1.8
06/18/1999		05/20/2000	0.4	06/09/2001	
06/30/1999		05/25/2000		06/10/2001	
07/01/1999		05/30/2000		06/14/2001	
07/02/1999		06/02/2000	0.3	06/21/2001	
07/06/1999		06/07/2000		06/22/2001	0.6
07/07/1999		06/16/2000	0.4	06/23/2001	
07/14/1999	0.2	06/17/2000		06/27/2001	
07/15/1999		06/22/2000		07/03/2001	0.8
07/18/1999		06/24/2000		07/11/2001	
07/28/1999	0.5	06/27/2000		07/16/2001	
08/02/1999		06/30/2000	0.9	07/19/2001	0.2
08/06/1999		07/05/2000		07/23/2001	
08/11/1999	0.3	07/06/2000		07/25/2001	
08/12/1999		07/08/2000		07/26/2001	
08/16/1999		07/09/2000		07/30/2001	
08/20/1999		07/14/2000	0.5	08/03/2001	0.2
08/24/1999	0.4	07/19/2000		08/08/2001	
08/25/1999		07/20/2000		08/10/2001	
08/31/1999		07/22/2000		08/11/2001	
09/08/1999	0.2	07/28/2000	0.3	08/20/2001	
09/09/1999		08/01/2000		08/22/2001	0.2
09/20/1999		08/02/2000		09/01/200	0.2

				1	
09/22/1999	0.4	08/05/2000		09/03/2001	
09/23/1999		08/07/2000		09/05/2001	
10/06/1999	0.2	08/11/2000	0.4	09/10/2001	
10/07/1999		08/17/2000		09/17/2001	
10/15/1999		08/19/2000		09/21/2001	0.3
10/20/1999	0.6	08/20/2000		09/26/2001	
		08/25/2000	0.3		
		08/31/2000			
		09/02/2000			
		09/04/2000			
		09/09/2000	0.1		
		09/13/2000			
		09/14/2000			
		09/16/2000			
		09/18/2000			
		09/26/2000	0.9		
		09/27/2000			
		09/30/2000			
summer average	0.4		0.4		0.6
secchi TSI	75		72		67

Lower Gar Lake
Lakeside Labs Data
Chlorophyll a values for 1999, 2000, 2001
TSI for chlorophyll

	Chlor a		chlor a		chlor a
06/17/1999		05/16/2000		06/08/2001	12.07
06/18/1999		05/20/2000	9.02	06/09/2001	
06/30/1999		05/25/2000		06/10/2001	
07/01/1999		05/30/2000		06/14/2001	
07/02/1999		06/02/2000	54.93	06/21/2001	
07/06/1999		06/07/2000		06/22/2001	9.63
07/07/1999		06/16/2000	99.43	06/23/2001	
07/14/1999		06/17/2000		06/27/2001	
07/15/1999		06/22/2000		07/03/2001	37.29
07/18/1999		06/24/2000		07/11/2001	
07/28/1999	57.90	06/27/2000		07/16/2001	
08/02/1999		06/30/2000	59.08	07/19/2001	45.59
08/06/1999		07/05/2000		07/23/2001	
08/11/1999	48.85	07/06/2000		07/25/2001	

08/12/1999		07/08/2000		07/26/2001	
08/16/1999		07/09/2000		07/30/2001	
08/20/1999		07/14/2000	71.84	08/03/2001	73.03
08/24/1999		07/19/2000		08/08/2001	
08/25/1999		07/20/2000		08/10/2001	
08/31/1999		07/22/2000		08/11/2001	
09/08/1999	136.97	07/28/2000	18.32	08/20/2001	
09/09/1999		08/01/2000		08/22/2001	105.97
09/20/1999		08/02/2000		09/01/2001	127.67
09/22/1999	114.60	08/05/2000		09/03/2001	
09/23/1999		08/07/2000		09/05/2001	
10/06/1999	102.19	08/11/2000	16.79	09/10/2001	
10/07/1999		08/17/2000		09/17/2001	
10/15/1999		08/19/2000		09/21/2001	38.23
10/20/1999	13.70	08/20/2000		09/26/2001	
		08/25/2000	21.13		
		08/31/2000			
		09/02/2000			
		09/04/2000			
		09/09/2000	87.43		
		09/13/2000			
		09/14/2000			
		09/16/2000			
		09/18/2000			
		09/26/2000	8.98		
		09/27/2000			
		09/30/2000			
summer					
average	53.4		48.8		47.3
chlor a TSI	70		69		68