Environmental Protection Agency

Region 7

Total Maximum Daily Load

For Algae and Turbidity

Ventura Marsh (IA 02-WIN-00456-L_0)

Cerro Gordo/Hancock Counties, Iowa

for Karen A. Flournoy ____________________ 3-24-10

William A. Spratlin Date

Director

Water, Wetlands and Pesticide Division

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Acronyms and Abbreviations

µg/L	Micrograms per liter
CHL	Chlorophyll-*a*
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
COV	Coefficient of Variation
CWA	Clean Water Act
EPA	United States Environmental Protection Agency
ft	feet
g/L	Gram per liter
HH	Human Health
HUC	Hydrologic Unit Code
IA	Iowa
ID	Identification
IDNR	Iowa Department of Natural Resources
ISS	Inorganic Suspended Sediment
ISU	Iowa State University
Kg/day	Kilograms per day
$Kg/m^2/yr$	Kilograms per square meter per year
LA	Load Allocation
lb	pound
lb/day	Pounds per day
lb/year	Pounds per year
LC	Load Capacity
µg/L	Microgram per liter
m	meter
m/day	Meter per day
m^3/day	Cubic meters per day
m/month	Meter per month
mg/L	Milligrams per liter
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System
n/a	Not available
NA	Not applicable
NLCD	National Land Cover Database
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resource Conservation Service
TMDL	Total Maximum Daily Load

Acronyms and Abbreviations (continued)

TP	Total Phosphorus
Tons/day	Tons per day
Tons/year	Tons per year
TSS	Total Suspended Solids
WLA	Wasteload Allocation
WQS	Water Quality Standards

1 SUMMARY

Ventura Marsh, located in the headwaters of Clear Lake in Cerro Gordo and Hancock Counties, Iowa, has historically served as the prime spawning habitat for the fish population of Clear Lake. There is an outfall structure that includes a fish trap and rod barrier to keep carp out of the marsh. The fish trap has not been functional for the past 30 years, and as a result, carp have been able to move freely between the marsh and the lake. Poor water quality conditions in the marsh are attributed to the large population of bottom feeding carp that has colonized the marsh.

The Ventura Marsh Total Maximum Daily Load (TMDL) for aquatic life impairment will use both Inorganic Suspended Solids (ISS) and Total Phosphorus (TP) as surrogate water quality targets for turbidity and algae. This TMDL is being established in accordance with Section 303(d) of the Clean Water Act (CWA), which requires a TMDL for each water body on a state's Section 303(d) List of impaired waters, herein referred to as 303(d) List, and in accordance with requirements of Section 303 of the CWA, Water Quality Planning and Management Regulations (40 Code of Federal Regulations [CFR] Part 130), and United States Environmental Protection Agency (EPA) guidance. The EPA is establishing this TMDL to fulfill the requirements of the Consent Decree established as part of the *Sailors, Inc., Mississippi River Revival and Sierra Club v. EPA,* lawsuit (No. 98-134-MJM) of December 17, 2001. Ventura Marsh (IA 02-WIN-00456-L_0) is included in the Consent Decree because it was on the Iowa 1998 303(d) List due to an exotic species impairment of Iowa's Water Quality Standards (WQS). In addition, Ventura Marsh is currently on the 2006 303(d) List for impairments to aquatic life designated beneficial uses due to algae and turbidity.

This document includes a TMDL for Ventura Marsh for aquatic life uses based primarily on information from a study conducted by Iowa State University (ISU) in 1999 and 2000 as part of the Clear Lake Diagnostic and Feasibility Study (Downing et al., 2001). Results of the ISU study suggest that excessive turbidity related to algal biomass and to resuspension of bottom sediments, primarily by common carp (but also by black bullheads and possibly wind/wave action), impact water clarity, zooplankton composition, and macrophyte distribution of the wetland. The rational for listing Ventura Marsh on the 2006 303(d) List (Iowa Department of Natural Resources [IDNR], 2006a) was “aesthetically objectionable conditions, in part, due to common carp.” Ventura Marsh is located on the border of Cerro Gordo County and Hancock County, Iowa, west of the city of Clear Lake. Table 1 summarizes basic information on Ventura Marsh.

Table 1. Ventura Marsh (IA 02-WIN-00456-L_0) Summary

Water Body Name	Ventura Marsh
Water Body ID Number	IA 02-WIN-00456-L_0
Segment Description	Entire Wetland
County	Cerro Gordo and Hancock
Use Designation Classes	Aquatic Life [Class B (LW)], Human Health (HH)
Major River Basin	Winnebago (HUC 07080203)
Listed Pollutants	Algae and Turbidity
TMDL Pollutant	Inorganic Suspended Solids and Total Phosphorus
Pollutant Sources	Nonpoint Sources
Impaired Use	Aquatic Life [Class B (LW)]
2006 303(d) Priority	Low
Watershed Area	4,625 acres
Ventura Marsh Area	187 acres (listed as 225 acres on Iowa's ADB)
Load Allocation	ISS = 3.6 tons/day (617 tons/year) TP = 241 lb/day (41,276 lb/year)
Wasteload Allocation (WLA) for Point Sources	No Point Sources in Watershed; WLA = 0
Wasteload Allocation for MS4	No MS4 Permits in Watershed; WLA = 0

This TMDL establishes numeric water quality targets for ISS and TP for Ventura Marsh that, when achieved, will result in the water body attaining its designated beneficial uses. The ISS and TP loading capacities (LC) established for this impaired water body are used in this TMDL as water quality surrogates for aquatic life. The TMDL demonstrates the link between ISS, TP, and aquatic life uses and quantifies the pollutant loading Ventura Marsh can assimilate while meeting WQS. The TMDL also establishes the pollutant load allocation necessary to meet the WQS based on the relationship between pollutant sources and in-marsh conditions. The TMDL consists of a wasteload allocation (WLA), a load allocation (LA), and a margin of safety (MOS). The WLA is the portion of the total pollutant load apportioned to point sources, while the LA is the portion apportioned to nonpoint sources. The MOS is the portion of the TMDL intended to account for the uncertainty concerning the relationship between the allocated loads and resulting water quality.

The key elements supporting the development of the ISS and TP TMDL are summarized below:

1. **Name and geographic location of the impaired or threatened water body for which the TMDL is being established:** Ventura Marsh, S19, T96N, R22W (Cerro Gordo/Hancock County line), the entire wetland.
2. **Identification of the pollutant and applicable WQS:** Ventura Marsh (IA 02-WIN-00456-L_0) has been identified as impaired due to "aesthetically objectionable conditions, in part, due to common carp" based on data from the ISU Clear Lake Diagnostics and Feasibility Study (Downing et al., 2001). The current condition of

Ventura Marsh violates the EPA approved state of Iowa general use narrative criteria [567 IAC 61.3(2)c and e] that state:

- "waters shall be free from materials attributable to wastewater discharges or agricultural practices producing objectionable color, odor, or other aesthetically objectionable conditions," and
- "waters shall be free from substances, attributable to wastewater discharges or agricultural practices, in quantities which would produce undesirable or nuisance aquatic life."

Algae and turbidity are reported as the cause of the 303(d) Listing in the 2006 Iowa Integrated Report (IDNR, 2006a).

3. **Quantification of the pollutant load that may be present in the water body and still allow attainment and maintenance of the WQS:** The water quality target for this TMDL is 2.0 milligrams per liter (mg/L) for ISS and 68.0 micrograms per liter (µg/L) for TP. The loading targets are 617 tons/year (3.6 tons/day) for ISS and 41,276 pounds per year (lb/year) (241 lb/day) for TP. These values correlate with water quality conditions representative of expected macrophyte growth, algal densities, water clarity, nutrients and zooplankton supporting beneficial designated uses, as well as act as a translation of the narrative criteria written to protect against aesthetically objectionable conditions and nuisance aquatic life.
4. **Quantification of the amount by which the current pollutant load in the water body, including the pollutant from upstream sources that is being accounted for as background loading, deviates from the pollutant load needed to attain and maintain WQS:** Excessive levels of suspended solids and TP exist in the impaired water body primarily due to resuspension of bottom sediments by common carp. To meet the WQS and restore the beneficial uses of Ventura Marsh, ISS and TP must be reduced by 93% and 82%, respectively, from existing loads. Achieving these targeted reductions will result in turbidity and algae levels resulting in sufficient clarity to reach targeted beneficial uses. The ISS and TP targets are surrogates for the listed causes of turbidity and algae. These levels of ISS and TP have been shown to correlate with reduced algae and increased water clarity (Schrage and Downing, 2004).
5. **Identification of pollution source categories:** Ventura Marsh receives ISS and TP through nonpoint sources of pollution. Atmospheric deposition from rainfall is a significant source of TP (Downing et al., 2001). Groundwater also contributes TP to Ventura Marsh, while overland flow is a source of both ISS and TP (Downing et al., 2001). The shallow nature of the marsh and significant fetch causes wind driven waves, which contributes to resuspension of sediment and TP. Previous studies have also shown that excessive turbidity, suspended solids, and nutrients are a result of resuspension of sediment by exotic carp (Schrage and Downing, 2004). Schrage and Downing (2004) have demonstrated a link between benthivorous fish removal and the reduction of ISS and TP leading to an increase in water clarity and macrophyte growth.

6. **WLAs for pollutants from point sources**: No point sources have been identified in the Ventura Marsh watershed; therefore, the WLA is set to zero. In the absence of a National Pollutant Discharge Elimination System (NPDES) permit, the discharges associated with sources were applied to the LA, as opposed to the WLA, for purposes of this TMDL. The decision to allocate these sources to the LA does not reflect any determination by EPA as to whether these discharges are, in fact, unpermitted point source discharges within this watershed. In addition, by establishing this TMDL with some sources treated as LAs, EPA is not determining that these discharges are exempt from NPDES permitting requirements. If sources of the allocated pollutant in this TMDL are found to be, or become, NPDES-regulated discharges, their loads must be considered as part of the calculated WLA sum in this TMDL. WLA in addition to that allocated here is not available.
7. **LA for pollutants from nonpoint sources:** The LA for nonpoint sources is 3.6 tons/day (617 tons/year) of ISS and 241 lb/day (41,276 lb/year) TP.
8. **MOS:** This TMDL contains an implicit MOS. The TMDL targets are based on review and analysis of water quality data and the selection of a target clarity value that is greater than the mean clarity measured during periods when designated beneficial uses were being met. The TMDL targets were largely based upon a field investigation that directly reduced the levels of ISS and TP in Ventura Marsh and resulted in restored water quality conditions that supported designated beneficial uses in the marsh. This method of selecting water quality targets reduces uncertainty between pollutant loads and resulting water quality conditions.
9. **Consideration of seasonal variation:** This TMDL is based on daily ISS and TP loading that, when met throughout the course of the year, will result in the attainment of desirable macrophyte growth for the growing season (May through September).
10. **Allowance for reasonably foreseeable increases in pollutant loads:** An allowance for increased ISS and TP loading was not included in this TMDL. Increases in rough fish population or intensification of activities that add to marsh turbulence could increase resuspension 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.

2 VENTURA MARSH, DESCRIPTION AND HISTORY

Ventura Marsh, located in the headwaters of Clear Lake in Cerro Gordo and Hancock County, Iowa, has historically served as the prime spawning habitat for the fish population of Clear Lake. Clear Lake is the third largest of Iowa's 34 natural, glacial lakes and is managed for water based recreation and fishing (Downing et al., 2001). The water level in Ventura Marsh is regulated by IDNR via an outfall structure that includes a fish trap and rod barrier to keep carp out of the marsh. The fish trap has not been functional for the past 30 years, and as a result, carp have been able to move freely between the marsh and the lake.

Ventura Marsh was first listed as impaired in 1998 based on a 1994 IDNR Wildlife Bureau assessment that the marsh was impacted by exotic species (e.g., carp), algae, turbidity, and suspended solids. Ventura Marsh remained on the 2002 303(d) List based on results of the ISU Clear Lake Diagnostic and Feasibility Report (Downing et al., 2001), which showed Ventura Marsh impaired by exotic species that contributed to algal and turbidity problems. Consequently, in 2006 Ventura Marsh was listed as impaired by algae and turbidity. These listings are all related to the excessive turbidity from algal biomass and resuspension of bottom sediments primarily from common carp (but also by black bullhead) that have colonized the marsh since the fish trap failed.

Over the past decade, significant effort has been spent on understanding water quality conditions in the marsh. A study by Schrage and Downing (2004) described the effectiveness of benthivorous fish removal on water clarity. Three fish kills were conducted with applications of rotenone on August 17, 1999; February 13, 2000; and June 7, 2000. The study found a correlation between fish removal and increased water clarity through a reduction of suspended sediments and phytoplankton biomass. At the same time, the ISU Clear Lake Diagnostic and Feasibility Report named Ventura Marsh as a significant source of nutrients to Clear Lake (Downing et al., 2001). In addition, the 2005 Clear Lake TMDL for nutrients and algae identified Ventura Marsh as a major source of phosphorus to the lake (IDNR, 2005). Both of these reports discuss the adverse impacts of resuspension of bottom sediments by bioturbating carp on water quality in Ventura Marsh and Clear Lake. The Schrage and Downing (2004) study concludes that removal of the bioturbating fish population will lead to improved water quality and aquatic life functions in Ventura Marsh by improving light transmission to the entirety of Ventura Marsh's substrate resulting in increased macrophyte growth through reduction of sediment resuspension. The increase in macrophytes will benefit the zooplankton population, increasing grazing activities and lower phytoplankton levels.

2.1 VENTURA MARSH (IA 02-WIN-00456-L_0)

Ventura Marsh (IA 02-WIN-00456-L_0) is located on the border of Cerro Gordo County and Hancock County, Iowa. Ventura Marsh is a shallow marsh (mean depth 2.6 ft [0.79 m]) fed by three surface inflows and an outlet to Clear Lake on the eastern edge of the Marsh (Figure 1). Clear Lake, in turn, feeds into Clear Creek, which is part of the Winnebago River watershed.

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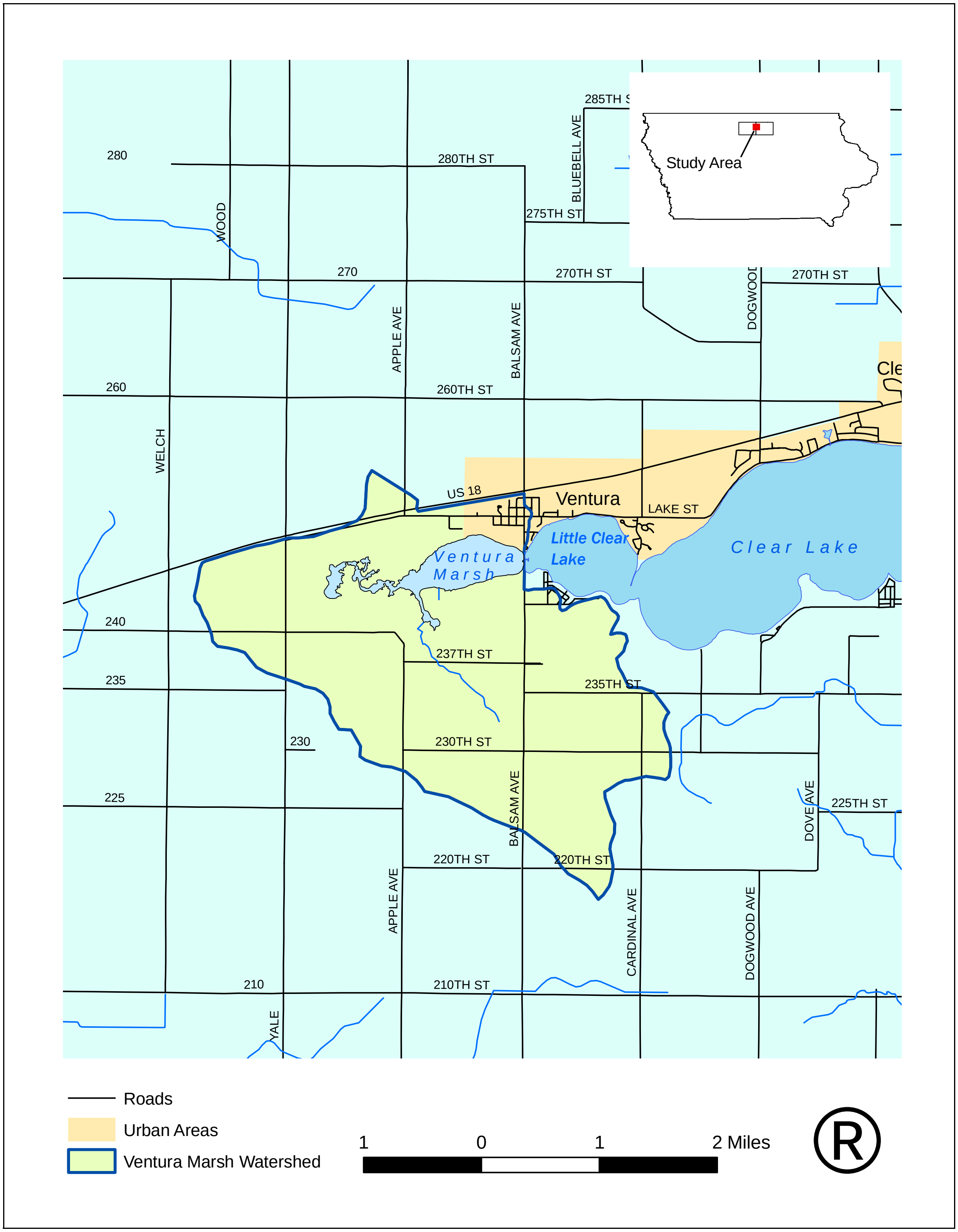

Figure 1. Ventura Marsh (IA 02-WIN-00456-L_0) Location and Watershed Boundary

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2.2 THE WATERSHED (IA 02-WIN-00456-L_0)

The Ventura Marsh watershed, located in Cerro Gordo County and Hancock County, Iowa, was delineated and used for assessment purposes to support TMDL development. The population of the Ventura Marsh watershed is not directly available. However, based on the population density of Census 2000 block groups, the population of the Ventura Marsh watershed is estimated at 350 people (United States Census Bureau, 2000).

The topography of the Ventura Marsh watershed includes slopes of 0 to 14%. Over half (54%) the soil formations in the watershed are Clarion, Canisteo, Harps, and Nicollet. Webster, Aquolls, and Histosols make up an additional 15% with all other soil formations being less than 5% of the watershed area (NRCS, 2009).

The Ventura Marsh watershed consists of predominantly agricultural land uses with an area of approximately 4,625 acres. Based on 2002 Iowa Geological Survey land use, the watershed consist primarily of corn (39.4%), soybeans (26.4%), and ungrazed, grazed and planted grassland (15.5%). The remaining categories each comprise less than ten percent of the watershed area. The Ventura Marsh water body is included in the water and wetland land use classifications. It comprises a portion of both of these land use classifications. Land use in the study area is presented in Table 2 and shown in Figure 2.

Table 2. Year 2002 Land Use within Ventura Marsh (IA 02-WIN-00456-L_0) Watershed (Cerro Gordo County and Hancock County, Iowa)

Land Use/Land Cover	Watershed Area		Percent
	Acres	Square Miles	
Corn	1823	2.8	39.4
Soybeans	1222	1.9	26.4
Ungrazed Grassland	513	0.8	11.1
Water	301	0.5	6.5
Deciduous Forest	178	0.3	3.9
Wetland	118	0.2	2.6
Grazed Grassland	104	0.2	2.3
Planted Grassland	96	0.1	2.1
Roads	93	0.1	2.0
Residential	83	0.1	1.8
Commercial / Industrial	42	0.1	0.9
Alfalfa / Hay	36	0.1	0.8
Bottomland Forest	9	0.0	0.2
Other Row Crop	6	0.0	0.1
Total	4,625	7.2	100.0

Source: Land Cover of the State of Iowa in the Year 2002 (IDNR, 2002). Available online at: ftp://ftp.igsb.uiowa.edu/gis_library/IA_State/Land_Description/Land_Cover_2002/lc_2002.zip

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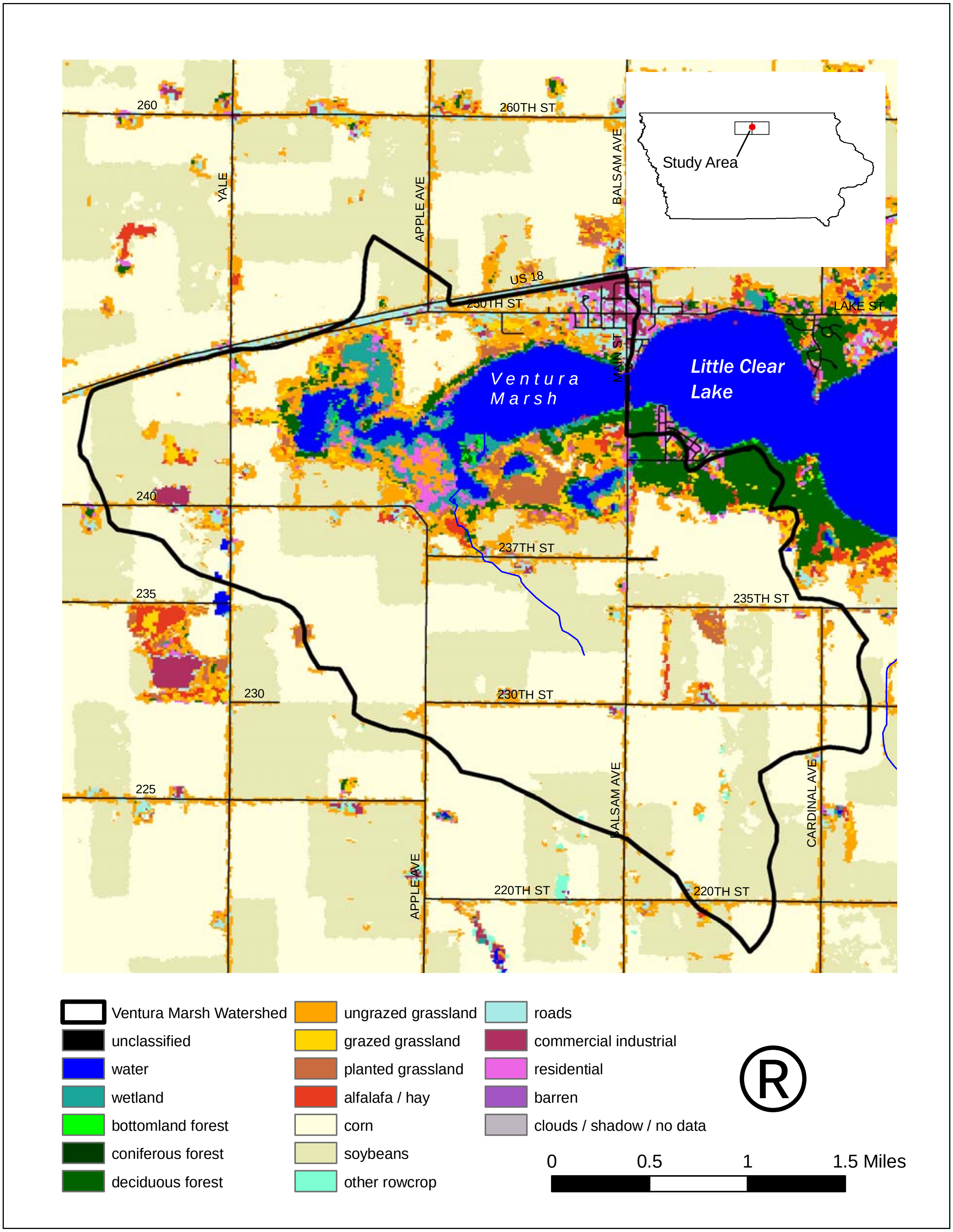

Figure 2. 2002 Land Cover, Cerro Gordo County and Hancock County, Iowa (IDNR, 2002)

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3 TMDL FOR TOTAL SUSPENDED SOLIDS AND TOTAL PHOSPHORUS

3.1 PROBLEM IDENTIFICATION

3.1.1 Impaired Beneficial Uses and Applicable Water Quality Standards

The IDNR 2006 Water Quality Assessment Database (IDNR, 2006b) specifies the following uses for Ventura Marsh (IA 02-WIN-00456-L_0):

- Aquatic Life [Class B (LW)], and
- Human Health (HH)

The impaired use is Aquatic Life. The designated use of Class B(LW) is defined as "…artificial and natural impoundments with hydraulic retention times and other physical and chemical characteristics suitable to maintain a balanced community normally associated with lake-like conditions" (IDNR, 2006b). Iowa general water quality criteria [567 IAC 61.3(2)] states, "…waters shall be free from substances, attributable to wastewater discharges or agricultural practices, in quantities which would produce undesirable or nuisance aquatic life..." and Section 61.3(3) states, "All Waters which are designated as …Class B(LW) are to be protected for wildlife, fish, aquatic and semi aquatic life." Ventura Marsh was listed as impaired based on the narrative criteria described above evidenced by excessive turbidity related to algal biomass and resuspension of bottom sediments that negatively impact water clarity, zooplankton composition, and macrophyte distribution in the wetland.

3.1.1.1 Interpreting Ventura Marsh Water Quality Data

Water quality samples collected for the ISU Diagnostic and Feasibility Study (Downing, et al., 2001) indicate Ventura Marsh "acts to decrease the concentration of nitrogen in water leaving the marsh, but it increases the concentrations of total phosphorus and total suspended solids exiting the marsh." Schrage and Downing (2004) studied fish removal in Ventura Marsh and identified bottom feeding fish (carp and bullhead) as a significant source of resuspended sediments and internal recycling of nutrients (phosphorus). In addition, Schrage and Downing (2004) found the limiting factor for phytoplankton was phosphorus. The combination of resuspended sediment and increased phytoplankton biomass (algal growth) did not allow enough light transmission for macrophyte growth. After reducing the fish population by more than 75%, Schrage and Downing (2004) noted a "clear water" phase in which resuspended sediment, phosphorus concentrations, and phytoplankton biomass all dropped. Reduced fish biomass led to "lower amounts of suspended sediment as a consequence of reduced fish foraging," and "lower total phosphorus concentrations due to reduced fish excretion." In addition Schrage and Downing concluded, "The increase in water clarity was sufficient to promote a dramatic increase in macrophyte diversity and abundance. The higher water clarity and the reduced fish foraging allowed macrophytes to establish at greater depths and in higher densities." The increase in macrophyte growth provided additional habitat for zooplankton and the "factor limiting phytoplankton biomass in Ventura Marsh switched between nutrients and zooplankton grazing."

Based on data from the ISU Diagnostic and Feasibility Study (Downing et al., 2001) and the Schrage and Downing (2004) study, target levels for ISS and TP will be set to promote water clarity through a reduction of phytoplankton biomass and increased macrophyte growth.

3.1.2 Key Sources of Data

The following data were acquired and assessed to support TMDL development:

- Schrage and Downing (2004) Study – "Pathways of Increased Water Clarity After Fish Removal from Ventura Marsh; A Shallow, Eutrophic Wetland."
- ISU Clear Lake Diagnostic and Feasibility Report (Downing et al., 2001).
- Clear Lake TMDL for Nutrients and Algae (IDNR, 2005).
- Ventura Marsh Water Quality Monitoring Data (1999-2000, 2005-2007, and 2008-2009) (IDNR, 2009).
- Land use, population, and other geographic information data in digital format for Iowa.

The Clear Lake Diagnostic and Feasibility Report (Downing et al., 2001) identified Ventura Marsh as a source of ISS and TP to Clear Lake, in part due to resuspension of sediments by an abundance of rough fish. Based on the research by Schrage and Downing (2004), the relationship between suspended solids and algae in the marsh will be used to define the TMDL target as ISS and TP concentrations that result in sufficient light transmission to allow rooted macrophyte growth. Water quality data used to develop numeric targets for ISS and TP were collected in Ventura Marsh during April 1999 through September 2000, May 2005 through August 2007, and April 2008 through September 2009 by ISU researchers and IDNR staff.

3.2 TMDL TARGET

Ventura Marsh's designated use [Class B(LW)] is to maintain a balanced community normally associated with lake-like conditions. The current condition of Ventura Marsh violates the Iowa general use narrative criteria [567 IAC 61.3(2)] and is not supporting the aquatic life use. Based on data from the ISU Diagnostic and Feasibility Study (Downing et el., 2001) and results of the Schrage and Downing (2004) study, ISS and TP concentrations in Ventura Marsh have contributed to reduced water clarity and increased algal growth. Reductions in ISS and TP will promote water clarity and increase macrophyte growth while providing habitat for zooplankton, which will reduce algal density. The goal of the TMDL is to establish scientifically valid targets for ISS and TP from nonpoint sources that improve water clarity and promote macrophyte growth in Ventura Marsh.

3.3 POLLUTION SOURCE ASSESSMENT

To support TMDL development, a pollutant source assessment is designed to characterize known and suspected sources of pollutant loading to the impaired water body. Pollutant sources within a watershed are characterized and quantified to the extent that information is available. ISS and TP sources that contribute to Ventura Marsh's impairment include internal and external nonpoint source loadings. Internal loadings include phosphorus cycling and resuspension of bottom sediments. External sources include atmospheric deposition and groundwater for TP and overland flow for both ISS and TP.

Because in-marsh mechanisms, such as settling, have an impact on the magnitude of internal sources of ISS and TP a simple computer model was developed to estimate the internal load of pollutants. The computer model provided a method of assessing and comparing internal and external pollutant loads that incorporated settling. The computer model predicts long term in-marsh averages to external and internal sources of pollutants.

3.3.1 Identification of Pollution Sources

3.3.1.1 Point Sources

There are no point sources identified in the Ventura Marsh Watershed. In the absence of an NPDES permit, the discharges associated with sources were applied to the LA, as opposed to the WLA for purposes of this TMDL. The decision to allocate these sources to the LA does not reflect any determination by EPA as to whether these discharges are, in fact, unpermitted point source discharges within this watershed. In addition, by establishing this TMDL with some sources treated as LAs, EPA is not determining that these discharges are exempt from NPDES permitting requirements. If sources of the allocated pollutant in this TMDL are found to be, or become, NPDES-regulated discharges, their loads must be considered as part of the calculated WLA sum in this TMDL. WLA in addition to that allocated here is not available.

3.3.1.2 Regulated Storm Water: MS4 Contributions

There are no MS4 contributions in the Ventura Marsh watershed.

3.3.1.3 Nonpoint Sources

The ISU Clear Lake Diagnostic and Feasibility Study (Downing et al., 2001) identified direct precipitation, groundwater, and internal loading from resuspension of sediment in Ventura Marsh as major sources of TP and resuspension as a major source of ISS. External nonpoint sources of ISS and TP include non-regulated storm water runoff from urban and agricultural land uses.

3.3.1.3.1 ISS Nonpoint Source Assessment

Sources of ISS to Ventura Marsh include watershed loads and internal loads, such as resuspension from bottom feeding fish and wind. Table 3 reports the annual average loads of ISS to Ventura Marsh from watershed and internal sources. The watershed load is the direct load delivered by overland runoff and tributaries. The internal load is contributed by internal resuspension of sediment from benthivorous fish and wind/ wave action. This table summarizes the loads of ISS to Ventura Marsh. The remainder of the section describes the methods used to estimate ISS loads using measured data and computer modeling, including a more refined breakdown of total internal loads and exported loads of ISS.

Table 3. Inorganic Suspended Solids (ISS) Annual Average Loads to Ventura Marsh

Source	ISS Load (%)	ISS Load (tons/year)
Watershed	1.8	154
Internal Sources	98.2	8,083
Total	100	8,237

ISS loading or concentration data from the watershed area contributing to Ventura Marsh was not collected. Therefore, ISS loads from the watershed were estimated from measured TSS data. The TSS watershed loads were converted to ISS equivalents based on the in-marsh linear relationship between ISS and TSS (Figure 3). Based on this linear regression, the TSS loads reported in the ISU Clear Lake Diagnostic Study (Downing et al., 2001) were converted to ISS loads. The original TSS loads and equivalent ISS loads are reported in Table 4.

Data from the ISU Clear Lake Diagnostic Study (Downing et al., 2001) was used to develop a linear relationship between ISS and TSS. Figure 3 depicts the linear relationship between these two parameters. Of 200 data points, 10 were deemed outliers and excluded from the graph. Outliers were determined by calculating upper and lower quartiles, inner fences, and outer fences. Any values outside the lower and upper outer fences were deemed extreme outliers and excluded. The upper and lower outer fences were (-0.08646 g/L, 0.197917 g/L) for ISS and (-0.06354 g/L, 0.117351 g/L) for TSS. Data used in this analysis are presented in Appendix A.

Excluding the outlying data points was logical because some of the values were negative or the ISS was greater than the TSS. Both of these scenarios are impossible, and the reported values are probably errors attributable to sampling technique, reporting, or laboratory methods. Seven of the ten outlying data points were collected over two consecutive sampling dates, making sampling error or equipment failure plausible. The linear regression equation was used to estimate ISS concentrations from TSS concentrations.

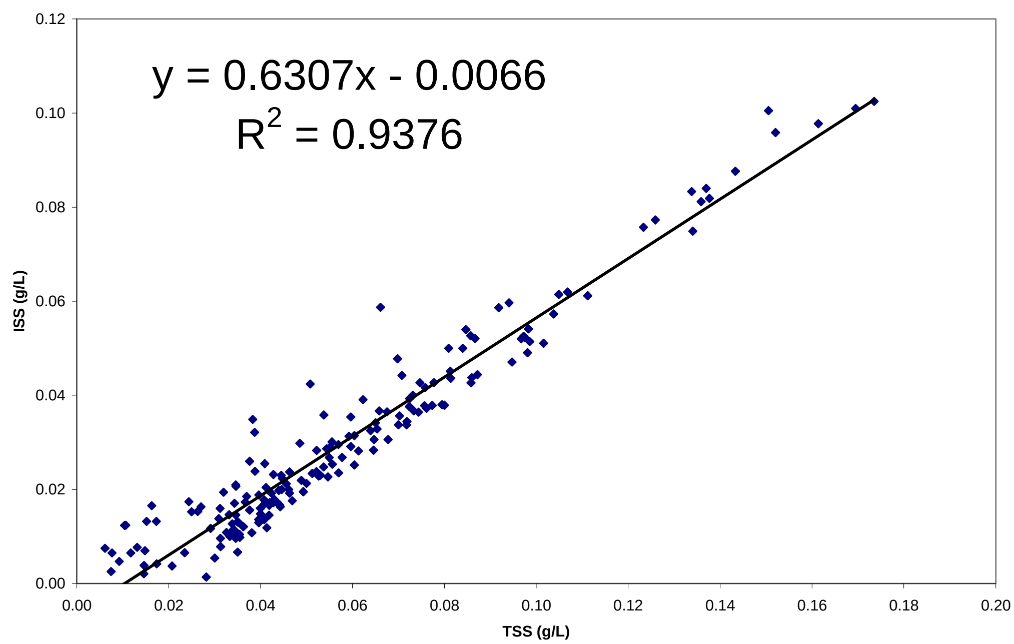

Figure 3. ISS and TSS Relationship (p-value 0.00)

The data reported in Table 4 was used to estimate watershed loads and net internal loads of ISS to Ventura Marsh. The TSS data for inflows into the marsh were collected from three main tributaries. This data provides estimates for total annual loads of TSS entering the marsh from August 1998 through July 2000. Outflow data was collected where the marsh connects with Clear Lake. The outflow data quantifies the amount of TSS leaving the marsh. The difference between the outflow and inflow provides an estimate of the net load from internal sources. Based on this information (Table 4), the average annual watershed load of TSS is 296 tons and the annual net internal TSS load is 101 tons. Based on the relationship between TSS and ISS, this is equivalent to 154 tons/year of ISS from the watershed and a net internal ISS load of 53 tons/year.

Table 4. Ventura Marsh TSS and ISS Watershed and Outflow Loads From Downing et al. (2001)

	Period 1: August 1998 – July 1999		**Period 2: August 1999 – July 2000**		**Average**	
Source	TSS (tons/yr)	ISS (tons/yr)	TSS (tons/yr)	ISS (tons/yr)	TSS (tons/yr)	ISS (tons/yr)
Ventura Marsh Inflow	519	277	72	31	296	154
Ventura Marsh Outflow	680	362	112	51	396	207
Average Watershed Load	519	277	72	31	296	154
Average Net Internal Load	161	86	40	21	101	53

The ISS and TSS loads from the watershed represent the material being delivered to Ventura Marsh by tributaries and overland flow. The net internal load represents the additional load that was generated in the marsh. The net internal load implicitly incorporates losses due to settling, while the watershed load estimates do not. A simple mass balance model was developed to better understand internal loads and the impact of settling within Ventura Marsh.

ISS concentrations in Ventura Marsh were estimated using a well-mixed lake spreadsheet model, such as the Simple Lake Model developed by Chapra (2001). The Simple Lake Model uses a Runge-Kutta fourth-order numerical integration method to simulate a completely mixed lake under variable loading conditions for a user-defined time step and first order reaction rate for settling.

The model was used to estimate total internal loading and the impact of particle settling on ISS concentrations. The area, mean depth, and average watershed flows for August 1998 through July 2000, measured during the Clear Lake Diagnostic Study (Downing et al., 2001), were used to estimate watershed hydrology, marsh volumes, and inflow ISS concentrations used in the Simple Lake Model (hereafter "Ventura Marsh Simple Model"). Internal loads of ISS were added until the Ventura Marsh Simple Model predicted ISS concentration values near the observed average outflow concentration from 1998 through 2000. The following assumptions and simplifications were made in order to model the Ventura Marsh system:

- Inflows and outflows were assumed to be equal. For the period simulated, the outflow was greater than the measured inflow; thus, the observed outflow was used in the model. The difference, approximately 25%, could be the result of measurement error or ungaged sources of inflow such as groundwater and precipitation.
- Inflow concentrations for ISS were calculated from measured TSS loads and total assumed inflow to the marsh (i.e., the observed outflow).
- Settling was set at 1 m/day (30 m/month) based on typical literature values (Chapra, 1997; EPA, 1985).
- The target predicted concentration was the observed average Ventura Marsh outfall concentration of TSS converted to ISS.
- All inflows and loading were assumed to be constant over time.

These assumptions limit the model predictive ability to long term averages and do not include seasonal variations; however, for its use to estimate internal loadings to Ventura Marsh it is appropriate.

The Clear Lake Diagnostic Study presented lake data for two distinct periods. Period 1, August 1998 through July 1999, was representative of typical environmental conditions, and Period 2, August 1999 through July 2000, was dryer than average (Downing et al., 2001). The Ventura Marsh Simple Model was used to simulate these two periods separately. Initial conditions for the Ventura Marsh Simple Model for these periods are provided in Table 5 and results of the model are in Table 6.

Table 5. Initial Conditions for ISS Ventura Marsh Simple Model

Parameter	**Period 1: August 1998 – July 1999**	**Period 2: August 1999 – July 2000**	**Units**
Area	187	187	acres
Depth	2.59	2.59	ft
Reaction Rate	0	0	/month
Settling Velocity	30	30	m/month
Initial Concentration and Watershed Inflow Concentration and Load	27.2 277	10.5 31	mg/L tons/year
Inflows/Outflows	10.5	3.0	CFS
Calculation Step	0.05	0.05	month
Print Step	1	1	month
Initial Time	1	1	month
Final Time	168	168	month

Table 6. ISS Results From Ventura Marsh Simple Model

Parameter	Period 1: August 1998 – July 1999	Period 2: August 1999 – July 2000	Average	Units
Predicted Average Marsh Concentration	35.7	17.6	26.7	mg/L
Measured Average Marsh Concentration	35.7	17.6	26.7	mg/L
Predicted Total Internal Load	10,840	5,325	8,083	tons/year
	12.9	6.4	9.7	$kg/m^2/yr$
Predicted Net Internal Load (exported)	85	21	53	tons/yr
Measured Net Internal Load (exported)	86	21	54	tons/yr
Predicted Marsh Concentration Without Internal Load	0.9	0.1	0.5	mg/L
TMDL Internal Load (in-marsh concentration 2 mg/L ISS)	356	569	463	tons/year
Measured Marsh Concentration Without Internal Load (Measured After Fish Kill)	2.0		NA	mg/L

NA = not applicable

The Ventura Marsh Simple Model matched the observed data well when a significant internal load was added to the model (Table 6).

Table 6 reports predicted and estimated ISS concentrations and net internal loads for both periods. The model was used to estimate the total internal load of ISS by adding internal load until the predicted average marsh concentration matched the measured average marsh concentration. The internal loading during Period 2 is most likely less than during Period 1 because it includes all three of the fish kills (thereby reducing bottom disturbances from fish). As a test of the computer models' predictive capability, the computer model was run without any internal loads. The resulting predicted in-marsh concentration was similar to that observed after the third and most successful fish kill.

The Schrage and Downing (2004) study showed considerable decrease in TSS when internal loadings from rough fish were removed. The low values predicted by the computer model are consistent with the Schrage and Downing (2004) paper. They reported ISS of 2 mg/L after the most successful fish kill event. The in-marsh concentration after the fish were removed should be slightly higher than predicted when all internal loads are removed from the model because other internal sources are present, such as wind, a few remaining fish, and other aquatic organisms. To develop the annual internal load that is allowable while still achieving high water clarity, the internal load was increased until a concentration of 2 mg/L ISS was achieved. This load represents the internal load allowed while still attaining the clarity levels achieved after the third fish kill when the marsh met water quality standards.

Schrage and Downing (2004) found that increased clarity was linked to benthivorous fish removal. During periods with benthivorous fish (termed the "turbid" phase), Secchi disk transparency was typically low (average clarity was approximately 0.35 m) and periods without benthivorous fish (termed the "clear" phase) was greater (average clarity was approximately 0.6 meters). Schrage and Downing (2004) concluded that the higher water clarity was partially due to "lower amounts of suspended sediment as a consequence of reduced fish foraging." In addition, the clarity achieved after fish were removed resulted in increased macrophyte growth consistent with the designated beneficial uses of Ventura Marsh. Therefore, removal of benthivorous fish resulted in a reduction in TSS that achieved WQS. This is consistent with the results of the Ventura Marsh Simple Model that showed reductions of internal loads resulted in significant reductions of in-marsh ISS concentrations.

Based on an analysis of ISS and Secchi disk transparency, ISS declined from an average of approximately 30 mg/L ISS during the turbid phase to 2 mg/L ISS during the clear phase. To calculate the ISS concentrations attributed to carp, Secchi disk measurements for both the clear and turbid phases were related to ISS concentrations. The turbid phase had an average Secchi disk concentration of 0.35 m, which can be related to ISS using the linear regression equation below (Schrage and Downing, 2004):

$$\text{Secchi disk clarity (m)} = -7.543074874\,[\text{ISS (g/L)}] + 0.579319064$$

The average ISS concentration from the turbid phase was then compared to the ISS concentration from the clear phase. The clear phase ISS value was calculated in a similar manner except a different regression was used to relate Secchi disk depth to ISS. The linear regression equation used in the Schrage and Downing (2004) paper could not be used for the clear phase data because of the high average transparency value. The average Secchi disk measurement during the clear phase was 0.59 m. Because of the linear relationship of the Schrage and Downing (2004) paper, it produces a negative ISS. When only the clear phase data is analyzed, the graph and regression equation reported in Figure 4 is produced.

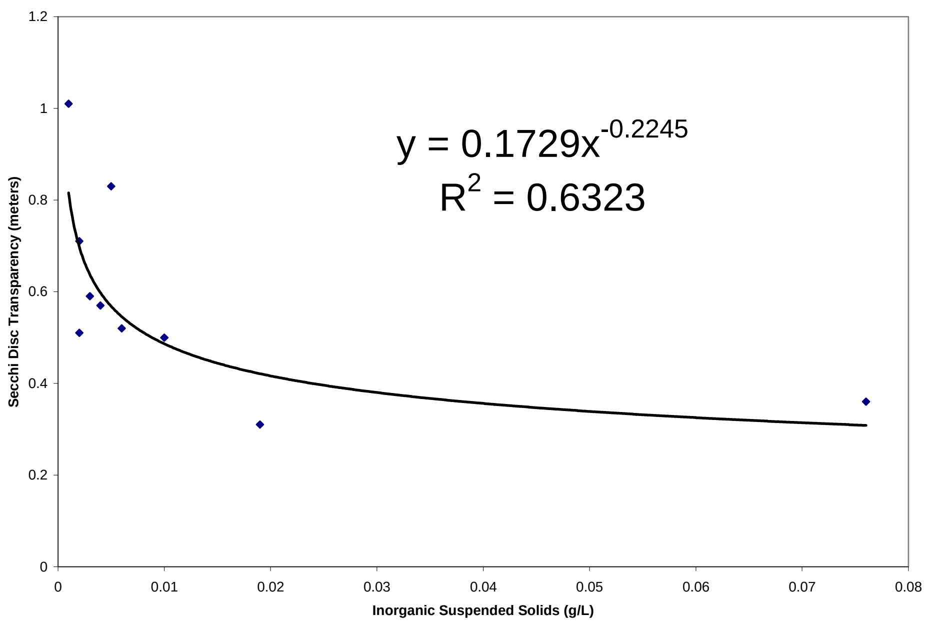

Figure 4. Transparency and ISS Relationship During Periods Without Bottom Feeding Fish During the "Clear" Phase (P-value is 0.0027)

This equation better represents the relationship between transparency and ISS during the clear phase because it incorporates the logarithmic distribution that is typical of environmental data sets. The difference in the ISS concentrations between the clear and turbid phase was approximately 30 mg/L. This difference in concentration is the result of the internal rough fish load.

3.3.1.3.2 TP Nonpoint Source Assessment

Sources of TP to Ventura Marsh include direct precipitation, groundwater inflow, watershed loads and internal loads. Table 7 reports the annual average loads to Ventura Marsh from several sources. The precipitation load reflects direct deposition of TP onto the marsh's surface. The groundwater load reflects subsurface TP loads that are contained within groundwater. The watershed load is the direct load delivered by overland runoff and tributaries. The internal load is contributed by resuspension of phosphorus from benthivorous fish and wind/ wave action and internal nutrient cycling. This table summarizes the loads of TP to Ventura Marsh. The remainder of the section describes the methods used to estimate TP loads using measured data and computer modeling, including a more refined breakdown of total internal loads and exported loads of TP.

Table 7. Total Phosphorus (TP) Annual Average Load to Ventura Marsh

Source	Load (%)	Load (lb/yr)
Precipitation	0.1	194
Groundwater	0.2	459
Watershed	1.6	3,611
Internal Sources	98.1	223,628
Total	100	227,892

Ventura Marsh has a watershed to wetland ratio of 20:1. This low watershed to wetland ratio suggests that loads from direct precipitation and internal sources likely play a significant role, compared to watershed sources of TP loading. As part of the ISU Diagnostic and Feasibility Study (Downing et al., 2001), TP concentrations in precipitation were measured in the Clear Lake watershed and found on average to be 169 µg/L. This value was used to estimate TP loads from direct precipitation in the Clear Lake TMDL for nutrients and algae and is also used to estimate phosphorus loads to the marsh for this TMDL. The annual average load from precipitation is 194 lb. Precipitation TP load was calculated from the average concentration, annual average precipitation, and marsh area.

The ISU Diagnostic and Feasibility Study (Downing et al., 2001) assessed three approaches to estimating groundwater flows and nutrient loads to Clear Lake. These approaches include the following:

- Direct measurements using seepage meters;
- Application of Darcy's Law using hydraulic head gradient and hydraulic conductivity data; and,
- Use of an analytic element groundwater model.

Darcy's Law and the analytic element model methods both recognize areas of inflow to and outflow from the lake and corroborate field measurements of hydraulic head. These models also resulted in groundwater flow similar to each other. In reviewing the three approaches, the ISU Study concluded that the analytical element groundwater model was likely the best estimate of groundwater discharge to Clear Lake. Using this model, the ISU Diagnostic and Feasibility Study estimated a TP groundwater load of 1.26 lb/day in Ventura Marsh. Estimates for groundwater flow and TP concentration for Ventura Marsh are presented in Table 8 (Downing et al., 2001).

Table 8. Groundwater Flows and TP Concentrations From the Analytical Element Groundwater Model Presented in the ISU Clear Lake Diagnostic and Feasibility Study for Clear Lake

Water Body	Flow Direction	Flow (CFS)	Nutrient or Contaminant	Median Concentration (mg/L)	Load (lb/yr)
Ventura Marsh	In	1.3	Total P	0.173	459

Source: Downing et al., 2001. Chapter 8, Table 7. Summary Calculations of nutrient and contaminant load to Clear Lake. Page 202.

The Clear Lake Diagnostic Feasibility Study (Downing, 2001) contains data concerning TP fluxes in and out of the lake. Included are watershed TP loads for Ventura Marsh. The TP data for inflows into the marsh was collected from three main tributaries. This data provides estimates for total annual loads of TP entering the marsh from 1998 to 2000. Outflow data was collected where the marsh connects with Clear Lake. This data set provides watershed loads to Ventura Marsh for 1998 through 2000, and the difference between the outflow and inflow provides an estimate of the net internal load. Average annual watershed load is 3,611 lb and the internal load is 1,304 lb (Table 9).

TP concentrations in Ventura Marsh were estimated using the Ventura Marsh Simple Model. The model was used to estimate internal loading and the impact of particle settling on TP concentrations. To estimate inflow TP concentrations, average Ventura Marsh inflow TP concentrations for August 1998 through July 1999 were used along with estimates of TP in precipitation and groundwater. Internal loads of TP were added until the Ventura Marsh Simple Model predicted TP concentration values near the observed average outflow concentration from August 1998 through July 2000. A settling rate of 1 m/day was used to represent settling of TP. Initial conditions and results for the Ventura Marsh Simple Model are provided in Table 10 and Table 11.

Table 9. Ventura Marsh TP Watershed and Outflow Loads from Downing et al. (2001)

Source	Period 1: August 1998 – July 1999	Period 2: August 1999 – July 2000	Average (lb/year)
Ventura Marsh Inflow	5,249	1,973	3,611
Ventura Marsh Outflow	7,767	2,064	4,915
Average Watershed Load	5,249	1,973	3,611
Average Net Internal Load	2,518	90	1,304

Table 10. Initial Conditions and Results for TP Ventura Marsh Simple Model

Parameter	Period 1: August 1998 – July 1999	Period 2: August 1999 – July 2000	Units
Area	187	187	acres
Depth	2.59	2.59	ft
Reaction Rate	0	0	/month
Settling Velocity	30	30	m/month
Initial Concentration	260	338	µg/L
Watershed Load	5,243	1,506	lb/ year
Inflows/ Outflows	10.5	3.0	CFS
Calculation Step	0.05	0.05	month
Print Step	1	1	month
Initial Time	1	1	month
Final Time	168	168	month

Table 11. TP Results of Ventura Marsh Simple Model

Parameter	Period 1: August 1998 – July 1999	Period 2: August 1999 – July 2000	Average	Units
Predicted Average Marsh Concentration	380	353	366.5	µg/L
Measured Average Marsh Concentration	380	353	366.5	µg/L
Predicted Total Internal Load	231,682 0.14	204,238 0.12	217,958 0.13	lb/year $kg/m^2/yr$
Measured Net Internal Load	2,544	555	1,549	lb/yr
Predicted Marsh Concentration Without Internal Load	8	2	5	µg/L
Measured Marsh Concentration Without Internal Load From Rough Fish	78		NA	µg/L
Predicted Internal Load for TMDL (in-marsh TP = 68 µg/L)	19	20	19.5	tons/year

NA = not applicable

The following assumptions and simplifications were made in order to model the Ventura Marsh system:

- Inflows and outflows were assumed to be equal. For the period simulated, the measured outflow was greater than the measured inflow; thus, the measured outflow was used in the model. The difference, approximately 25%, could be the result of measurement error or ungaged sources of inflow such as groundwater and precipitation.
- Inflow concentrations were calculated using the observed TP load and total assumed inflow to the marsh (i.e., the observed outflow), TP precipitation concentrations, and TP groundwater concentrations.
- Phosphorus was assumed to be attached to particulates and the settling rate was set at 1 m/day (30 m/month) based on typical literature values for particulate settling (EPA, 1985).
- Other losses due to plant uptake or hydrolysis were not included in the model.

- Target predicted concentration was observed average Ventura Marsh outfall concentration.
- All inflows and loading was assumed to be constant within each period.

These assumptions limit the model predictive ability to long term averages and do not include seasonal variations or differences due to dissolved, organic, inorganic and particulate phosphorus; however, it is a useful tool to estimate internal TP loadings to Ventura Marsh. To test the models predictive ability, the model was run under conditions in which internal loads were set to zero. The result was an in-marsh concentration of 8 µg/L. An internal load of 0.02 kilograms per square meter (kg/m^2) was required to match in marsh concentrations (74 µg/L) after fish removal. Some internal load after fish removal is expected due to decay of organic matter in the water column and sediment, excretions by aquatic organisms, and release of inorganic phosphorus from sediments.

Even with this simplification, the Ventura Marsh Simple Model matched the observed data well when a significant internal load was added to the model during both periods. Table 11 reports that the predicted average concentrations were the same as the average measured concentrations when an internal load was added. The model-predicted net internal loads were similar to the loads estimated from observed data (Table 11).

Schrage and Downing (2004) found a correlation between benthivorous fish removal and a 115-184 µg/L reduction in TP in the marsh as well as “high water clarity partially due to lower amounts of suspended sediment as a consequence of reduced fish foraging.” As part of the analysis conducted, concentrations of TP in Ventura Marsh were compared to Little Clear Lake, another embayment of Clear Lake that does not have the same water quality issues as Ventura Marsh. If Ventura Marsh was meeting established water quality standards its water quality would be similar to Little Clear Lake. “In the turbid phase the total phosphorus of Ventura Marsh was, on average, 147 µg/L higher than the TP concentration of the Little Clear Lake, whereas in the clear water phase the difference was an average of 32 µg/L.” Therefore, removal of benthivorous fish resulted in a reduction in TP that was much closer to the concentrations of Little Clear Lake, the first embayment in Clear Lake.

3.3.2 Linkage of Sources to Target

The target for transparency for Ventura Marsh is 0.7 m. This target is consistent with Clear Lake and other lakes in the Ventura Marsh region. In addition, it is 0.1 m greater clarity than the average clarity achieved after fish kills during periods when the marsh met aquatic life designated beneficial uses. Attaining this water clarity will increase macrophyte growth. The increased macrophyte growth will act as a positive feedback mechanism by providing habitat for zooplankton which will reduce the phytoplankton biomass, further increasing the water clarity, according to research by Schrage and Downing (2004). TMDL targets for ISS, TP, and chlorophyll-*a* were selected using Carlson’s Trophic Status Index (TSI) (Carlson and Simpson, 1995). TMDLs for ISS and TP are 2.0 mg/L and 68.0 µg/L respectively (Table 12) and should result in a Secchi disk measurement of 0.7 meters.

Table 12. TMDL Targets for Ventura Marsh

Parameter	TSI Value	Target
ISS	-	2.0 mg/L
Transparency	65	0.7 meters
Chlorophyll-*a*	65	33.3 µg/L
Algal Biomass*	-	1 – 3 mg/L
TP	65	68.0 µg/L

* Chlorophyll-*a* assumed to be between 1% and 3% of total biomass (EPA, 1985).

The TSI value was calculated based on a desired clarity of 0.7 meters. A TSI of 65 is representative of water bodies with macrophytes and centrarchids (sunfish), which is the desired condition of Ventura Marsh. Carlson's TSI is used for this TMDL to relate a desired level of water clarity to TP and chlorophyll-*a*. Appendix B includes an excerpt from the Clear Lake TMDL with an explanation of TSI, the associated equations, and their application to TMDL development.

The TMDL target for ISS was calculated using the desired transparency of 0.7 m and the regression equations developed for clarity and ISS. The regression equation (from Figure 4) produced an ISS concentration of 2 mg/L at a Secchi depth of 0.7 m.

$$\text{Secchi Disk Depth (m)} = 0.1729*[\text{ISS (mg/L)}]^{-0.2245}$$

Internal loading from resuspension of sediment is a major source of both ISS and TP to Ventura Marsh. Schrage and Downing (2004) showed a correlation between benthivorous fish removal in the marsh and reductions in ISS, TP, and phytoplankton biomass. This was done by comparing marsh conditions with fish and after fish kills. The fish kills resulted in increased water clarity that was conducive to increased macrophyte growth. The increased water clarity resulted in the marsh having conditions suitable to the expected aquatic life designated beneficial uses. The reduction in ISS and TP resulted in increased water clarity and increased macrophyte growth. The increased macrophyte growth acted as a positive feedback mechanism by providing refuge for zooplankton, which resulted in increased gazing and reduced the phytoplankton biomass further improving water clarity. The third rotenone treatment conducted in June 2000 resulted in the following marsh conditions:

- Clarity (measured by Secchi disk) of 0.75 m
- TP of 78 µg/L
- ISS of 2 mg/L
- Algal biomass of 2 mg/L

Based on these values, removing fish from Ventura Marsh will result in attainment of the clarity, ISS, and algal biomass goals. TP is above the desired target; therefore, additional reductions may be required. Because the ISS and TP targets are surrogates for algal biomass and clarity, the ultimate effectiveness of marsh restoration should be judged based on the water body's attainment of designated use.

3.4 POLLUTANT ALLOCATIONS

The pollutant allocations described below apply throughout the entire year. A daily maximum is included to meet the decision of the U.S. Court of Appeals for the D.C. Circuit in Friends of the Earth, Inc. v. EPA et.al., No. 05-5015 (April 25, 2006).

3.4.1 Wasteload Allocations

A WLA of zero ISS and TP is set for this TMDL. No wasteload reductions are required to achieve this allocation, because no existing sources were identified as contributing to the impairment. In the absence of an NPDES permit, the discharges associated with sources were applied to the LA, as opposed to the WLA for purposes of this TMDL. The decision to allocate these sources to the LA does not reflect any determination by EPA as to whether these discharges are, in fact, unpermitted point source discharges within this watershed. In addition, by establishing this TMDL with some sources treated as LAs, EPA is not determining that these discharges are exempt from NPDES permitting requirements. If sources of the allocated pollutant in this TMDL are found to be, or become, NPDES-regulated discharges, their loads must be considered as part of the calculated WLA sum in this TMDL. WLA in addition to that allocated here is not available.

3.4.2 Load Allocations

Because no point sources of ISS or TP discharge to Ventura Marsh or its watershed, all of the loading capacity has been allocated to the LA and MOS. The long term average LA for ISS and TP are 617 tons/year and 41,276 lb/year, respectively. The TMDL analysis used to develop these loads was based on data collected over a 2 year period; thus, they represent longer term loading values that result in attainment of WQS. The approach used to convert these loads to maximum daily values is based upon the maximum daily permit calculations provided in the *Technical Support Document (TSD) for Water Quality-Based Toxics Control* (EPA, 1991). These long-term averages were then converted to maximum daily limits using Table 5-2 of the TSD, assuming a coefficient of variation of 0.6 and a 95th percentile probability. This results in a multiplication factor of 2.13. A summary of long term and daily loads is provided in Table 13.

Table 13. Summary of Ventura Marsh Long Term and Daily Loads for ISS and TP

	ISS Average Annual Load	ISS Average Daily Load	TP Average Annual Load	TP Average Daily Load
Existing Condition (August 1998 – July 2000)	8,237 tons	22.6 tons	227,892 lb	624 lb
TMDL Condition	617 tons	1.7 tons	41,276 lb	113 lb
Required Reduction (load)	7,620 tons	20.9 tons	186,616 lb	511 lb
Required Reduction (percent)	93%	93%	82%	82%
Maximum Daily Limit (95th Percentile)[1]		3.6 tons		241 lb

[1] The maximum daily limit should only occur 5% of the time. The TMDL is based on an annual loading, the daily maximum is included to meet the decision of the U.S. Court of Appeals for the D.C. Circuit in Friends of the Earth, Inc. v. EPA et.al., No. 05-5015 (April 25, 2006).

The different sources that contribute loads to Ventura Marsh are reported in Table 14. These are provided to aid with implementation. The allocation for rough fish and other internal loads, such as wind resuspension, is the focus of all of the reductions because planned and ongoing restoration efforts focus on this area (Downing et al., 2001). It is expected that reduction to the internal sources of ISS and TP will be sufficient to meet water quality standards for the marsh. Reduction of ISS and TP to the levels described in Table 14 will result in increased water clarity and greater abundance of macrophytes and zooplankton, which will reduce phytoplankton through grazing.

As specified in Section 3.3.2 Linkage of Sources to Target, the ISS and TP targets are surrogates for the aquatic life impairment. If the ISS and TP targets are met, clarity will be improved, macrophyte and zooplankton growth will increase, and phytoplankton levels will decrease. The ultimate goal of the TMDL is to improve the conditions in Ventura Marsh to support the aquatic life designated beneficial use. Therefore, implementation success should be based on achieving WQS.

Table 14. Components of Ventura Marsh LA for ISS and TP

Source	ISS (tons/year)			TP (lb/year)		
	Existing Load	TMDL Load	Percent Reduction (%)	Existing Load	TMDL Load	Percent Reduction (%)
Groundwater	0	0		459	459	
Atmospheric Deposition	0	0		194	194	
Rough Fish and Other Internal Sources	8,083	463		223,628	36,983	
Surface Runoff	154	154		3,611	3,600	
Total	8,237	617	93	227,892	41,276	82
TMDL[1]		3.6 tons/day			241 lb/day	

[1] The TMDL is calculated using the long term average load and the method described in the EPA TSD (EPA, 1991), this does not imply that the daily maximum should occur every day. The default coefficient of variation of 0.6 is used because detailed time variable loading data is not available. The daily maximum is included to meet the decision of the U.S. Court of Appeals for the D.C. Circuit in Friends of the Earth, Inc. v. EPA et.al., No. 05-5015 (April 25, 2006).

3.4.3 Margin of Safety

The MOS for the Ventura Marsh TMDL is implicit through the use of empirical data and conservative assumptions. The TMDL was developed using empirical data collected within the water body during periods when WQS were achieved through ecosystem manipulation (e.g., fish kills). This method of setting numeric targets, because it is based on monitoring data collected during periods of acceptable water quality, results in a high level of certainty that recommended target concentrations will result in attainment of water quality standards. In addition, the target clarity of 0.7 m is greater than the median clarity value observed after the bottom feeding fish were removed. Thus, it is a conservative target because the ISS and TP surrogate targets are based on this clarity value either through direct relationship (ISS) or Carlson's TSI (TP).

4 PUBLIC PARTICIPATION

EPA regulations require that TMDLs be subject to public review (40 CFR 130.7). EPA is provided public notice of this TMDL for Ventura Marsh on the EPA, Region 7, TMDL website: http://www.epa.gov.region07/water/tmdl public_notice_htm. The response to comments and final TMDL will be available at: http://www.epa.gov/region07/water/apprtmdl.htm#Iowa.

This water quality limited segment of Ventura Marsh, Cerro Gordo/Hancock Counties, Iowa, is included on the EPA approved 1998 Section 303(d) List for Iowa. This TMDL is being produced by EPA to meet the requirements of the 2001 Consent Decree, *Sailors, Inc., Mississippi River Revival and Sierra Club v. EPA,* lawsuit No. 98-134-MJM. Iowa may submit and EPA may approve another TMDL for this water at a later time.

As part of the public notice process, IDNR assisted EPA by providing a link to this public notice on the Iowa TMDL Public Notice webpage at: http://www.iowadnr.gov/water/watershed/pubs.html. EPA responded to comments on the draft TMDL after the public notice comment period ended on March 10, 2010, and will post the response to comments on the EPA website: http://www.epa.gov/region07/water/apprtmdl.htm#Iowa.

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APPENDIX A - VENTURA MARSH WATER QUALITY DATA

Appendix A includes water quality data used in calculations presented in the TMDL. This appendix also includes data from the following:

- Clear phase data relating Secchi disk measurements and ISS concentrations. This data was used to develop the regression between clarity and ISS used to establish the TMDL targets.
- Water quality data from Ventura Marsh collected as part of the ISU Clear Lake Diagnostic Study (Downing et al., 2001).

The clear phase data is from periods of high clarity measured after fish kills. The data in Table A-1 was taken from the ISU Clear Lake Diagnostic Study (Downing et al., 2001) and reanalyzed as a unique data set to get a relationship between clarity and ISS for clear phase periods.

Table A-2 reports the sampling locations for the IDNR-collected data that was used to develop the linear relationship between ISS and TSS. Table A-3 reports the data used to develop the relationship between ISS and TSS.

Table A-1. Clear Phase ISS and Secchi Disk Clarity Data from Ventura Marsh

Analysis	Secchi Disc (meters)	Inorganic Suspended Solids (g/L)
	1.01	0.001
	0.83	0.005
	0.71	0.002
	0.59	0.003
	0.57	0.004
	0.52	0.006
	0.51	0.002
	0.5	0.01
	0.36	0.076
	0.31	0.019
Mean	0.591	0.0128
Median	0.545	0.005
Geometric Mean	0.559	0.005

Note: This data was taken from the ISU diagnostic study (Downing et al., 2001) and reanalyzed as a separate data set. No dates were given for this data and the location was identified as Ventura Marsh.

Table A-2. IDNR Sampling Locations for 2005 – 2009 Ventura Marsh Water Quality Data

STORET ID	Site Name	UTM - X	UTM - Y
29170001	Ventura Marsh West	462417	4773979
22170002	Ventura Marsh East	459736	4774011

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Table A-3. IDNR Ventura Marsh Data Used in TSS and ISS Calculations

Sampling Date	LakeName	Sampling method	SamplingSite	Depth	Total Suspended Solids (g/L)	Inorganic Suspended Solids (g/L)
04/12/1999	Clear Lake	Field	M1	0.5 m	0.06	0.03
04/12/1999	Clear Lake	Field	M1	0.0 m surface	0.05	0.03
04/12/1999	Clear Lake	Field	M2	0.5 m	0.06	0.03
04/12/1999	Clear Lake	Field	M2	0.0 m surface	0.05	0.03
04/12/1999	Clear Lake	Field	M3	0.5 m	0.06	0.03
04/12/1999	Clear Lake	Field	M3	0.0 m surface	0.05	0.02
04/29/1999	Clear Lake	Field	M1	0.0 m surface	0.08	0.04
04/29/1999	Clear Lake	Field	M1	0.5 m	0.09	0.04
04/29/1999	Clear Lake	Field	M2	0.5 m	0.08	0.04
04/29/1999	Clear Lake	Field	M2	0.0 m surface	0.07	0.03
04/29/1999	Clear Lake	Field	M3	0.5 m	0.07	0.04
04/29/1999	Clear Lake	Field	M3	0.0 m surface	0.08	0.04
05/13/1999	Clear Lake	Field	M1	0.0 m surface	0.07	0.03
05/13/1999	Clear Lake	Field	M1	0.5 m	0.17	0.10
05/13/1999	Clear Lake	Field	M2	0.0 m surface	0.07	0.04
05/13/1999	Clear Lake	Field	M2	0.5 m	0.06	0.03
05/13/1999	Clear Lake	Field	M3	0.5 m	0.02	0.02
05/13/1999	Clear Lake	Field	M3	0.0 m surface	0.02	0.01
05/25/1999	Clear Lake	Field	M1	0.5 m	0.03	0.02
05/25/1999	Clear Lake	Field	M1	0.0 m surface	0.03	0.02
05/25/1999	Clear Lake	Field	M2	0.5 m	0.04	0.02
05/25/1999	Clear Lake	Field	M2	0.0 m surface	0.04	0.02
05/25/1999	Clear Lake	Field	M3	0.0 m surface	0.04	0.02
05/25/1999	Clear Lake	Field	M3	0.5 m	0.03	0.02
06/08/1999	Clear Lake	Field	M1	0.5 m	3.38	0.05
06/08/1999	Clear Lake	Field	M1	0.0 m surface	0.08	0.05
06/08/1999	Clear Lake	Field	M2	0.0 m surface	3.32	0.04
06/08/1999	Clear Lake	Field	M2	0.5 m	2.88	0.03
06/08/1999	Clear Lake	Field	M3	0.5 m	1.57	0.01
06/08/1999	Clear Lake	Field	M3	0.0 m surface	1.31	0.01
06/23/1999	Clear Lake	Field	M1	0.0 m surface	0.07	0.05
06/23/1999	Clear Lake	Field	M1	0.5 m	0.80	0.52
06/23/1999	Clear Lake	Field	M2	0.0 m surface	0.06	0.04
06/23/1999	Clear Lake	Field	M2	0.5 m	0.09	0.05
06/23/1999	Clear Lake	Field	M3	0.5 m	0.48	0.28
06/23/1999	Clear Lake	Field	M3	0.0 m surface	0.08	0.05
07/06/1999	Clear Lake	Field	M1	0.0 m surface	0.10	0.05
07/06/1999	Clear Lake	Field	M1	0.5 m	0.13	0.07
07/06/1999	Clear Lake	Field	M2	0.5 m	0.09	0.04
07/06/1999	Clear Lake	Field	M2	0.0 m surface	0.07	0.03
07/06/1999	Clear Lake	Field	M3	0.0 m surface	0.07	0.04
07/06/1999	Clear Lake	Field	M3	0.5 m	0.09	0.06
07/21/1999	Clear Lake	Field	M1	0.5 m	0.04	0.02
07/21/1999	Clear Lake	Field	M1	0.0 m surface	0.04	0.02
07/21/1999	Clear Lake	Field	M2	0.5 m	0.05	0.02
07/21/1999	Clear Lake	Field	M2	0.0 m surface	0.04	0.02
07/21/1999	Clear Lake	Field	M3	0.5 m	0.05	0.04
07/21/1999	Clear Lake	Field	M3	0.0 m surface	0.04	0.03
08/03/1999	Clear Lake	Field	M1	0.5 m	0.06	0.03

Table A-3. IDNR Ventura Marsh Data Used in TSS and ISS Calculations (continued).

Sampling Date	LakeName	Sampling method	SamplingSite	Depth	Total Suspended Solids	Inorganic Suspended Solids
08/03/1999	Clear Lake	Field	M1	0.0 m surface	0.05	0.02
08/03/1999	Clear Lake	Field	M2	0.0 m surface	0.10	0.05
08/03/1999	Clear Lake	Field	M2	0.5 m	0.10	0.05
08/03/1999	Clear Lake	Field	M3	0.0 m surface	0.05	0.02
08/03/1999	Clear Lake	Field	M3	0.5 m	0.07	0.04
08/16/1999	Clear Lake	Field	M1	0.0 m surface	0.08	0.04
08/16/1999	Clear Lake	Field	M1	0.5 m	0.10	0.06
08/16/1999	Clear Lake	Field	M2	0.0 m surface	0.09	0.05
08/16/1999	Clear Lake	Field	M2	0.5 m	0.10	0.05
08/16/1999	Clear Lake	Field	M3	0.5 m	0.10	0.05
08/16/1999	Clear Lake	Field	M3	0.0 m surface	0.10	0.05
08/16/1999	Clear Lake	Field	VM01	0.0 m surface	0.05	0.02
08/16/1999	Clear Lake	Field	VM01	0.0 m surface	0.10	0.06
08/16/1999	Clear Lake	Field	VM02	0.0 m surface	0.06	0.03
08/16/1999	Clear Lake	Field	VM02	0.0 m surface	0.15	0.10
08/16/1999	Clear Lake	Field	VM03	0.0 m surface	0.05	0.02
08/16/1999	Clear Lake	Field	VM03	0.0 m surface	0.14	0.08
08/16/1999	Clear Lake	Field	VM04	0.0 m surface	0.13	0.08
08/16/1999	Clear Lake	Field	VM04	0.0 m surface	0.06	0.03
08/16/1999	Clear Lake	Field	VM05	0.0 m surface	0.17	0.10
08/16/1999	Clear Lake	Field	VM05	0.0 m surface	0.03	0.01
08/16/1999	Clear Lake	Field	VM06	0.0 m surface	0.03	0.01
08/16/1999	Clear Lake	Field	VM06	0.0 m surface	0.13	0.08
08/16/1999	Clear Lake	Field	VM07	0.0 m surface	0.12	0.08
08/16/1999	Clear Lake	Field	VM07	0.0 m surface	0.01	0.00
08/16/1999	Clear Lake	Field	VM08	0.0 m surface	0.14	3.94
08/16/1999	Clear Lake	Field	VM08	0.0 m surface	0.04	0.01
08/16/1999	Clear Lake	Field	VM09	0.0 m surface	0.02	0.00
08/16/1999	Clear Lake	Field	VM09	0.0 m surface	0.16	0.10
08/16/1999	Clear Lake	Field	VM10	0.0 m surface	0.01	0.00
08/16/1999	Clear Lake	Field	VM10	0.0 m surface	0.14	0.08
08/18/1999	Clear Lake	Field	VM01	0.0 m surface	0.04	0.01
08/18/1999	Clear Lake	Field	VM02	0.0 m surface	0.05	0.02
08/18/1999	Clear Lake	Field	VM03	0.0 m surface	0.04	0.01
08/18/1999	Clear Lake	Field	VM04	0.0 m surface	0.04	0.01
08/18/1999	Clear Lake	Field	VM05	0.0 m surface	0.04	0.01
08/18/1999	Clear Lake	Field	VM06	0.0 m surface	0.04	0.01
08/18/1999	Clear Lake	Field	VM07	0.0 m surface	0.04	0.02
08/18/1999	Clear Lake	Field	VM08	0.0 m surface	0.04	0.02
08/18/1999	Clear Lake	Field	VM09	0.0 m surface	0.04	0.02
08/18/1999	Clear Lake	Field	VM10	0.0 m surface	0.03	0.01
08/20/1999	Clear Lake	Field	M1	0.5 m	0.05	0.02
08/20/1999	Clear Lake	Field	M1	0.0 m surface	0.03	0.01
08/20/1999	Clear Lake	Field	M2	0.5 m	0.05	0.02
08/20/1999	Clear Lake	Field	M2	0.0 m surface	0.04	0.01
08/20/1999	Clear Lake	Field	M3	0.0 m surface	0.04	0.01
08/20/1999	Clear Lake	Field	M3	0.5 m	0.04	0.01
08/20/1999	Clear Lake	Field	VM01	0.0 m surface	0.04	0.01
08/20/1999	Clear Lake	Field	VM02	0.0 m surface	0.05	0.02
08/20/1999	Clear Lake	Field	VM03	0.0 m surface	0.04	0.01

Table A-3. IDNR Ventura Marsh Data Used in TSS and ISS Calculations (continued).

Sampling Date	LakeName	Sampling method	SamplingSite	Depth	Total Suspended Solids	Inorganic Suspended Solids
08/20/1999	Clear Lake	Field	VM04	0.0 m surface	0.04	0.01
08/20/1999	Clear Lake	Field	VM05	0.0 m surface	0.04	0.01
08/20/1999	Clear Lake	Field	VM06	0.0 m surface	0.04	0.01
08/20/1999	Clear Lake	Field	VM07	0.0 m surface	0.04	0.02
08/20/1999	Clear Lake	Field	VM08	0.0 m surface	0.04	0.02
08/20/1999	Clear Lake	Field	VM09	0.0 m surface	0.04	0.02
08/20/1999	Clear Lake	Field	VM10	0.0 m surface	0.03	0.01
08/24/1999	Clear Lake	Field	VM01	0.0 m surface	0.03	0.00
08/24/1999	Clear Lake	Field	VM02	0.0 m surface	0.03	0.01
08/24/1999	Clear Lake	Field	VM03	0.0 m surface	0.03	0.01
08/24/1999	Clear Lake	Field	VM04	0.0 m surface	0.03	0.01
08/24/1999	Clear Lake	Field	VM05	0.0 m surface	0.03	0.01
08/24/1999	Clear Lake	Field	VM06	0.0 m surface	0.03	0.01
08/24/1999	Clear Lake	Field	VM07	0.0 m surface	0.04	0.01
08/24/1999	Clear Lake	Field	VM08	0.0 m surface	0.03	3.00
08/24/1999	Clear Lake	Field	VM09	0.0 m surface	0.03	0.01
08/24/1999	Clear Lake	Field	VM10	0.0 m surface	0.03	0.01
08/27/1999	Clear Lake	Field	M1	0.0 m surface	0.04	0.02
08/27/1999	Clear Lake	Field	M1	0.5 m	0.04	0.02
08/27/1999	Clear Lake	Field	M2	0.5 m	0.03	0.01
08/27/1999	Clear Lake	Field	M2	0.0 m surface	0.03	0.01
08/27/1999	Clear Lake	Field	M3	0.0 m surface	0.02	0.01
08/27/1999	Clear Lake	Field	M3	0.5 m	0.02	0.00
08/27/1999	Clear Lake	Field	VM01	0.0 m surface	0.05	0.02
08/27/1999	Clear Lake	Field	VM02	0.0 m surface	0.09	0.05
08/27/1999	Clear Lake	Field	VM03	0.0 m surface	0.08	0.04
08/27/1999	Clear Lake	Field	VM04	0.0 m surface	0.08	0.05
08/27/1999	Clear Lake	Field	VM05	0.0 m surface	0.05	0.02
08/27/1999	Clear Lake	Field	VM06	0.0 m surface	0.04	0.02
08/27/1999	Clear Lake	Field	VM07	0.0 m surface	0.04	0.02
08/27/1999	Clear Lake	Field	VM08	0.0 m surface	0.04	0.02
08/27/1999	Clear Lake	Field	VM09	0.0 m surface	0.04	0.02
08/27/1999	Clear Lake	Field	VM10	0.0 m surface	0.04	0.01
09/03/1999	Clear Lake	Field	M1	0.5 m	0.04	0.02
09/03/1999	Clear Lake	Field	M1	0.0 m surface	0.04	0.02
09/03/1999	Clear Lake	Field	M2	0.5 m	0.04	0.01
09/03/1999	Clear Lake	Field	M2	0.0 m surface	0.04	0.01
09/03/1999	Clear Lake	Field	M3	0.5 m	0.04	0.02
09/03/1999	Clear Lake	Field	M3	0.0 m surface	0.04	0.01
09/07/1999	Clear Lake	Field	M1	0.5 m	0.09	0.06
09/07/1999	Clear Lake	Field	M1	0.0 m surface	0.08	0.05
09/07/1999	Clear Lake	Field	M2	0.5 m	0.05	0.04
09/07/1999	Clear Lake	Field	M2	0.0 m surface	0.06	0.04
09/07/1999	Clear Lake	Field	M3	0.0 m surface	0.14	0.09
09/07/1999	Clear Lake	Field	M3	0.5 m	0.11	0.06
09/17/1999	Clear Lake	Field	M1	0.5 m	0.14	0.08
09/17/1999	Clear Lake	Field	M1	0.0 m surface	0.07	0.04
09/17/1999	Clear Lake	Field	M2	0.0 m surface	0.07	0.03
09/17/1999	Clear Lake	Field	M2	0.5 m	0.08	0.04
09/17/1999	Clear Lake	Field	M3	0.5 m	0.06	0.03

Table A-3. IDNR Ventura Marsh Data Used in TSS and ISS Calculations (continued).

Sampling Date	LakeName	Sampling method	SamplingSite	Depth	Total Suspended Solids	Inorganic Suspended Solids
09/17/1999	Clear Lake	Field	M3	0.0 m surface	0.07	0.04
09/23/1999	Clear Lake	Field	M1	0.0 m surface	0.09	0.04
09/23/1999	Clear Lake	Field	M1	0.5 m	0.11	0.06
09/23/1999	Clear Lake	Field	M2	0.5 m	0.08	0.04
09/23/1999	Clear Lake	Field	M2	0.0 m surface	0.07	0.04
09/23/1999	Clear Lake	Field	M3	0.5 m	0.10	0.05
09/23/1999	Clear Lake	Field	M3	0.0 m surface	0.06	0.02
10/01/1999	Clear Lake	Field	M1	0.0 m surface	0.07	0.03
10/01/1999	Clear Lake	Field	M1	0.5 m	0.07	0.04
10/01/1999	Clear Lake	Field	M2	0.5 m	0.07	0.04
10/01/1999	Clear Lake	Field	M2	0.0 m surface	0.07	0.03
10/01/1999	Clear Lake	Field	M3	0.5 m	0.07	0.06
10/01/1999	Clear Lake	Field	M3	0.0 m surface	0.06	0.03
10/15/1999	Clear Lake	Field	M1	0.5 m	0.15	0.10
10/15/1999	Clear Lake	Field	M1	0.0 m surface	0.05	0.02
10/15/1999	Clear Lake	Field	M2	0.0 m surface	0.05	0.03
10/15/1999	Clear Lake	Field	M2	0.5 m	0.06	0.03
10/15/1999	Clear Lake	Field	M3	0.5 m	0.04	0.02
10/15/1999	Clear Lake	Field	M3	0.0 m surface	0.05	0.02
10/20/1999	Clear Lake	Field	M1	0.0 m surface	0.01	0.01
10/20/1999	Clear Lake	Field	M1	0.5 m	0.01	0.01
03/14/2000	Clear Lake	Field	M1	0.0 m surface	0.01	0.00
03/14/2000	Clear Lake	Field	M2	0.0 m surface	0.01	0.00
03/14/2000	Clear Lake	Field	M3	0.0 m surface	0.01	0.01
03/21/2000	Clear Lake	Field	M1	0.5 m	0.01	0.01
03/21/2000	Clear Lake	Field	M1	0.0 m surface	0.01	0.01
03/21/2000	Clear Lake	Field	M2	0.0 m surface	0.01	0.01
03/21/2000	Clear Lake	Field	M2	0.5 m	0.01	0.01
03/21/2000	Clear Lake	Field	M3	0.0 m surface	0.02	0.01
03/21/2000	Clear Lake	Field	M3	0.5 m	0.02	0.02
03/28/2000	Clear Lake	Field	M1	0.0 m surface	0.08	0.04
03/28/2000	Clear Lake	Field	M2	0.0 m surface	0.06	0.03
03/28/2000	Clear Lake	Field	M3	0.0 m surface	0.06	0.03
04/04/2000	Clear Lake	Other	M1	0.0 m surface	0.04	0.02
04/04/2000	Clear Lake	Other	M2	0.0 m surface	0.04	0.02
04/04/2000	Clear Lake	Other	M3	0.0 m surface	0.04	0.02
04/11/2000	Clear Lake	Field	M1	0.0 m surface	0.03	0.02
04/11/2000	Clear Lake	Field	M2	0.0 m surface	0.03	0.02
04/11/2000	Clear Lake	Field	M3	0.0 m surface	0.03	0.02
04/18/2000	Clear Lake	Other	M1	0.0 m surface	0.03	0.02
04/18/2000	Clear Lake	Other	M2	0.0 m surface	0.03	0.02
04/18/2000	Clear Lake	Other	M3	0.0 m surface	0.04	0.03
04/25/2000	Clear Lake	Field	M1	0.0 m surface	0.04	0.03
04/25/2000	Clear Lake	Field	M2	0.0 m surface	0.04	0.03
04/25/2000	Clear Lake	Field	M3	0.0 m surface	0.03	-0.04
05/04/2000	Clear Lake	Other	M1	0.0 m surface	0.05	0.02
05/04/2000	Clear Lake	Other	M1	0.5 m	0.05	0.03
05/04/2000	Clear Lake	Other	M2	0.5 m	0.03	0.01
05/04/2000	Clear Lake	Other	M2	0.0 m surface	0.03	0.01
05/04/2000	Clear Lake	Other	M3	0.5 m	0.06	0.03
05/04/2000	Clear Lake	Other	M3	0.0 m surface	0.07	0.04

Locations of the sampling sites are described in Schrage and Downing (2004). They include three primary sampling locations. M1 is located in the northeast third of the marsh. M2 is located approximately in the center of the marsh and M3 is located in the southwest third of the marsh. The other 10 sampling locations (named VM01 – VM10) are located throughout the marsh.

APPENDIX B - CARLSON'S TROPHIC STATE INDEX

Carlson's Trophic State Index (TSI) 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* (CHL). 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 listed below:

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

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

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

Where:

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

CHL = in-lake chlorophyll-*a* concentration, µg/L

SD = lake Secchi depth, meters

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

Table B-1. Changes in Temperate Lake Attributes According to Trophic State (Modified From Carlson, 1995; Oglesby et al., 1987; EPA, 2000)

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

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 B-1.

Table B-2. Summary of Ranges of TSI Values and Measurements for Chlorophyll-*a* and Secchi Depth Used to Define Section 305(b) Use Support Categories for the 2004 Reporting Cycle

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

Table B-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 (µg/l)	Chlorophyll-*a* Levels (µg/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

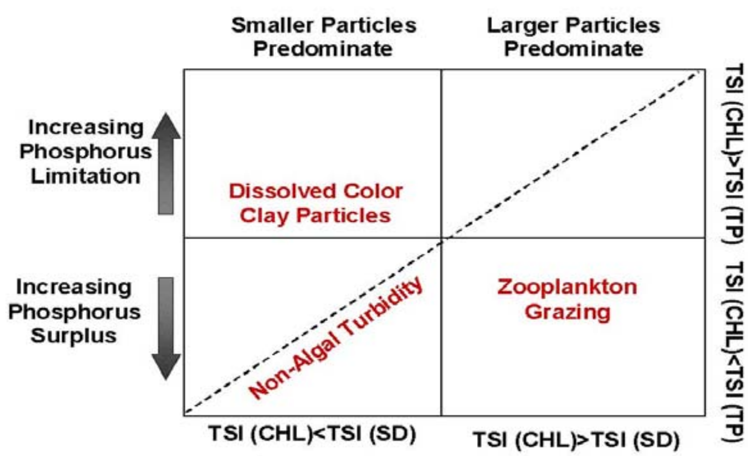

Figure B-1. Multivariate TSI Comparison Chart (Carlson)