Total Maximum Daily Loads
For Organic Enrichment and Siltation
Don Williams Lake
Boone County, Iowa

2005

Iowa Department of Natural Resources
TMDL & Water Quality Assessment Section

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1. Executive Summary

Table 1. Don Williams Lake Summary

Waterbody Name:	Don Williams Lake
County:	Boone
Use Designation Class:	A1 (primary contact recreation) B(LW) (aquatic life)
Major River Basin:	Des Moines River Basin
Pollutants:	Phosphorus, sediment
Pollutant Sources:	Nonpoint, internal recycle, atmospheric (background)
Impaired Use(s):	B(LW) (aquatic life)
2002 303d Priority:	Low
Watershed Area:	21,080 acres
Lake Area:	149 acres
Lake Volume:	2,296 acre-feet
Detention Time:	0.17 years
TSI Target(s):	Total Phosphorus less than 66 (existing); Chlorophyll-a less than 65; Secchi Depth less than 65
Total Phosphorus Load Capacity (TMDL):	12,440 pounds per year
Existing Total Phosphorus Load:	12,440 pounds per year
Total Phosphorus Load Reduction to Achieve TMDL:	N/A
Total Phosphorus Margin of Safety:	Implicit
Total Phosphorus Wasteload Allocation:	0 pounds per year
Total Phosphorus Load Allocation:	12,440 pounds per year
Sediment Load Capacity (TMDL):	11,600 tons per year
Existing Sediment Load:	14,200 tons per year
Sediment Load Reduction to Achieve TMDL:	2,600 tons per year
Sediment Margin of Safety:	1,160 tons per year
Sediment Wasteload Allocation:	0 tons per year
Sediment Load Allocation:	10,440 tons per year

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

This document consists of TMDLs for organic enrichment and siltation designed to provide Don Williams Lake water quality that fully supports its designated uses. Phosphorus, which is related through the Trophic State Index (TSI) to chlorophyll-and Secchi depth, is targeted to address the organic enrichment impairment. Sediment delivery is targeted to address the siltation impairment.

Phasing TMDLs is an iterative approach to managing water quality that becomes necessary when the origin, nature, and sources of water quality impairments are not well understood. In Phase 1, the waterbody load capacity, existing pollutant load in excess of this capacity, and the source load allocations are estimated based on the limited information available.

Phase 1 will consist of setting specific and quantifiable targets for total phosphorus, algal biomass, Secchi depth, and sediment delivery. The targets for total phosphorus, algal biomass, and Secchi depth will be related to the lake's trophic state through Carlson's Trophic State Index (TSI). A monitoring plan will be used to determine if prescribed load reductions result in attainment of water quality standards and whether or not the target values are sufficient to meet designated uses. Monitoring activities may include routine sampling and analysis, biological assessment, fisheries studies, and watershed and/or waterbody modeling.

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.

Phase 2 will consist of implementing the monitoring plan, evaluating collected data, and readjusting target values if needed. The additional data collected will be used to determine if the implemented TMDL and watershed management plan have been or are effective in addressing the identified water quality impairments. The data and information can also be used to determine if the TMDLs have accurately identified the required components (i.e. loading/assimilative capacity, load allocations, in-lake response to pollutant loads, etc.) and if revisions are appropriate.

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

1. **Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:** Don Williams Lake, S5, T84N, R27W, 2 miles west of Fraser, Boone County.

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

3. **Quantification of the pollutant load that may be present in the waterbody and still allow attainment and maintenance of water quality standards:** The Phase 1 nutrient target is a Carlson's Trophic State Index (TSI) value of less than 66 (existing) for total phosphorus, and TSI values of less than 65 for both

chlorophyll-a and Secchi depth. These values are equivalent to total phosphorus and chlorophyll concentrations of 75 and 33 ug/L, respectively, and a Secchi depth of 0.7 meters. The Phase 1 sediment target is a sediment delivery rate that will result in the loss of less than a third of the original lake volume within a 100-year design life.

4. **Quantification of the amount or degree by which the current pollutant load in the waterbody, including the pollutant from upstream sources that is being accounted for as background loading, deviates from the pollutant load needed to attain and maintain water quality standards:** The existing mean values for Secchi depth, chlorophyll-a, and total phosphorus based on 2000 - 2003 sampling are 1.6 meters, 27 ug/L, and 75 ug/L, respectively. Based on these values, all of the nutrient targets have been achieved. The estimated existing annual total phosphorus load to Don Williams Lake is 12,440 pounds per year. Since the nutrient targets are currently being met, the total phosphorus loading capacity has been set at the existing load.

   The estimated existing sediment load is 14,200 tons per year. The sediment load capacity is 11,600 tons per year. A sediment load reduction of 2,600 tons per year is required.

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

6. **Wasteload allocations for pollutants from point sources:** One NPDES-permitted facility is present in the watershed. The City of Pilot Mound owns and operates a municipal wastewater treatment facility (IA NPDES Permit # 0862001) consisting of a three-cell facultative lagoon system constructed in 1977. This facility has never discharged, reportedly due to low influent flows relative to the design volume (24). There are no other point source dischargers in the watershed. Therefore, the wasteload allocations will be set at zero.

7. **Load allocations for pollutants from nonpoint sources:** The total phosphorus load allocation for the nonpoint sources and internal recycle is 12,440 pounds per year including 50 pounds per year attributable to atmospheric deposition. The sediment load allocation for nonpoint sources is 10,440 tons per year.

8. **A margin of safety:** The nutrient targets for Don Williams Lake have already been achieved. Therefore, an explicit Margin of Safety (MOS) for nutrients has not been included in the load calculations. An implicit MOS is present in that existing TSI values for chlorophyll and Secchi depth are currently below their targets. An additional implicit MOS is present in that the lake response model

used to estimate the allowable loading results in a value that is 40% less than the watershed loading predicted by the Loading Function Model, which uses the most recent landuse assessment information to estimate watershed phosphorus delivery.

For sediment delivery, an explicit numerical MOS of 1,160 tons per year (a 10% reduction of the allowable load capacity) has been included to ensure that the load allocation will result in attainment of water quality targets.

9. **Consideration of seasonal variation:** The nutrient TMDL was developed based on the annual phosphorus loading that will result in attainment of TSI targets for the growing season (May through September). An annual loading period was used to define the sediment loading capacity. Sediment loads are actually the result of periodic precipitation events and the non-point source controls are targeted at times when high loading occurs.

10. **Allowance for reasonably foreseeable increases in pollutant loads:** An allowance for increased phosphorus or sediment loading was not included in the TMDLs. Significant changes in the Don Williams watershed landuses are unlikely. The majority of the watershed landuse is dedicated to agricultural production. The watershed includes the City of Pilot Mound, which has maintained a relatively stable population for the past 50 years (25). In addition, the City's treatment facility has never discharged in its 27 years of operation. The addition or deletion of grazing or livestock operations within the watershed could increase or decrease nutrient and sediment loading. Future increases in the rough fish population or intensification of activities that add to lake turbulence could increase re-suspension of settled solids and internal phosphorus loading. Such events cannot be predicted and at this time conditions are not expected to change, therefore, an allowance for their potential occurrence was not included in the TMDLs.

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

2. Don Williams Lake, Description and History

2.1 The Lake

Don Williams Lake was constructed in 1967 and is located in Boone County in central Iowa. The community of Pilot Mound is approximately 2.5 miles upstream of the lake along Bluff Creek. The lake is located 2 miles west of Fraser.

Public use for Don Williams Lake is estimated at approximately 91,000 visitors per year. Users of the lake and of the 600-acre Don Williams County Park enjoy fishing, swimming, boating, picnicking, hiking, camping, golf, and ice-skating. The beach at Don Williams Lake is located on the eastern shore.

Table 2. Don Williams Lake Features

Waterbody Name:	Don Williams Lake
Hydrologic Unit Code:	HUC10 0710000409
IDNR Waterbody ID:	IA 04-UDM-01650-L
Location:	Section 5 T84N R27W
Latitude:	42° 7’ N
Longitude:	94° 1’ W
Water Quality Standards Designated Uses:	1. Primary Contact Recreation (A1) 2. Aquatic Life Support (B(LW))
Tributaries:	Bluff Creek
Receiving Waterbody:	Bluff Creek
Lake Surface Area:	149 acres
Maximum Depth:	46 feet
Mean Depth:	15.4 feet
Volume:	2,296 acre-feet
Length of Shoreline:	29,700 feet
Watershed Area:	21,080 acres
Watershed/Lake Area Ratio:	141:1
Estimated Detention Time:	0.17 years

Morphometry

Don Williams Lake has a surface area of 149 acres. The lake has a mean depth of 15.4 feet and a maximum depth of 46 feet. Temperature and dissolved oxygen sampling indicate that Don Williams Lake is stratified throughout the growing season.

Hydrology

Don Williams Lake is fed by Bluff Creek and drainage ditch 107. Bluff Creek empties into the north end of the Don Williams Lake. A dam at the south end of Don Williams Lake feeds back into Bluff Creek. The estimated annual average detention time for Don Williams Lake is 0.17 years based on outflow. The methodology and calculations used to determine the detention time are shown in Appendix A.

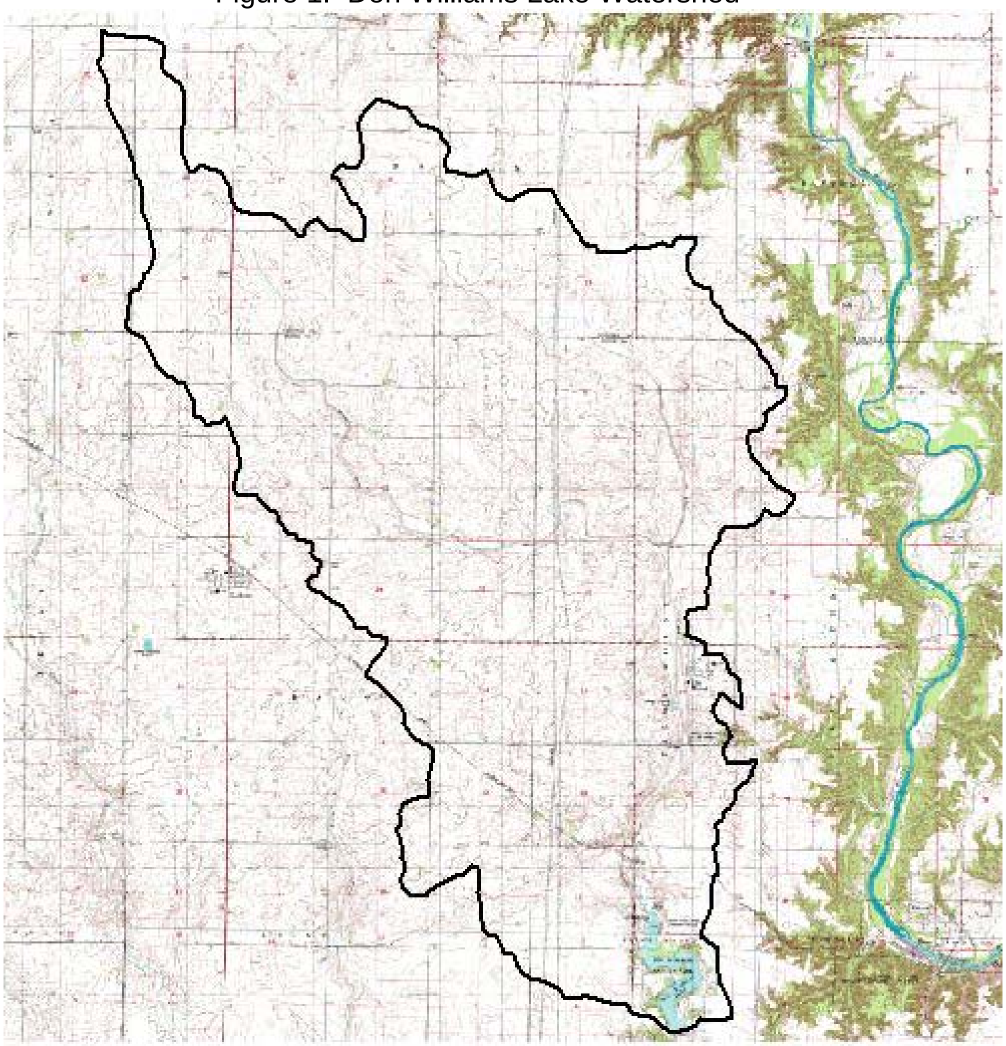
2.2 The Watershed

The Don Williams Lake watershed has an area of approximately 21,080 acres and has a watershed to lake ratio of 141:1. The 2002 landuses and associated areas for the watershed were obtained from satellite imagery and are shown in Table 3. For a landuse map based on the satellite imagery, see Figure D-1 in Appendix D.

Table 3. 2002 Landuse in Don Williams Lake watershed.

Landuse	Area in Acres	Percent of Total Area
Row Crop	18,060	85.7
Grassland	2,260	10.7
Alfalfa	340	1.6
Forest	130	0.6
Roads	130	0.6
Urban	110	0.5
Other	50	0.2
Total	21,080	100

Figure 1. Don Williams Lake Watershed



A more recent watershed assessment was completed in 2004 by IDNR to determine current landuses and associated cropping practice (CP) factors for use in calculating soil loss and delivery. A landuse map based on this assessment is found in Appendix D. The 2004 assessment also shows that the major landuse in the watershed is row crop, with 18,970 acres (90.0%) in either corn or soybeans. Other major landuses in the 2004 watershed assessment include ungrazed grass/CRP (3.9%), timber (1.5%), farmstead (1.4%), roads (1.3%), pasture (1.1%) and urban (0.4%). The 2004 assessment also noted the presence of four Confined Animal Feeding Operations (CAFOs) and seven open feedlots within the watershed. The estimated numbers of animal units associated with CAFOs and feedlots within the watershed are 1,400 swine animal units and 300 beef animal units.

Open feedlots are unroofed or partially roofed animal feeding operations in which no crop, vegetation, or forage growth or residue cover is maintained during the period that animals are confined in the operation. Runoff from open feedlots can deliver substantial quantities of nutrients to a waterbody dependent upon factors such as proximity to a water surface, number and type of livestock and manure controls. CAFOs are animal feeding operations in which animals are confined to areas that are totally roofed. CAFOs typically utilize earthen or concrete structures to contain and store manure prior to land application. Nutrients from CAFOs are delivered via runoff from land-applied manure or from leaking/failing storage structures.

Most of the City of Pilot Mound, including its wastewater treatment facility, is located within the watershed. The 2000 Census population of Pilot Mound was 214 (25). The treatment facility consists of a three-cell facultative lagoon system constructed in 1977 for a design population of 278. The lagoon system was designed as a controlled discharge system and has the capability to discharge treated effluent to Bluff Creek, which is tributary to Don Williams Lake. However, the facility has never discharged, reportedly due to low influent flows relative to the design volume (24).

The watershed is predominately level to gently sloping prairie-derived soils developed from Wisconsin till. Four soil associations encompass the watershed. The Clarion-Canisteo-Nicollet soil association dominates the watershed. Calcareous soils are common in the watershed.

3. TMDLs for Organic Enrichment and Siltation

3.1 TMDL for Organic Enrichment

3.1.1 Problem Identification

Impaired Beneficial Uses and Applicable Water Quality Standards

The Iowa Water Quality Standards (8) list the designated uses for Don Williams Lake as Primary Contact (Class A1) and Aquatic Life (Class B(LW)). In 1998, Don Williams Lake was included on the impaired waters list due to water quality impairments from organic enrichment and siltation.

Since 1994, the Class B aquatic life use at Don Williams Lake has been assessed as “partially supported” and the Class A primary contact recreation use has been assessed as “fully supported/threatened.” These assessments have been based primarily on information provided by the DNR Fisheries bureau. 2000 - 2003 monitoring data show that chlorophyll-a and Secchi depth TSI values are currently below the impairment threshold value of 65 (see Table C-2 in Appendix C).

Data Sources

Water quality surveys have been conducted on Don Williams Lake in 1979, 1990, and 2000-03 (1,2,3,4,5,20). The University of Iowa Hygenics Laboratory (UHL) collected additional water quality data from July through October of 2003. Data from the 1979, 1992, and 2000 - 2003 surveys is available in Appendix B. UHL sampling data from 2003 can be accessed at http://wqm.igsb.uiowa.edu/iastoret/.

Iowa State University Lake Study data from 2000 to 2003 and UHL monitoring data from 2003 were evaluated for this TMDL. The ISU study was completed in 2004 and approximates a sampling scheme used by Roger Bachman in earlier Iowa lake studies. Samples are collected at one location (maximum depth) three times during the early, middle and late summer. A number of water quality parameters are measured including Secchi disk depth, phosphorus series, nitrogen series, TSS, and VSS. The UHL monitoring includes samples taken six times during the growing season at each of three lake locations (shallow, mean and maximum depth) with measured water quality parameters similar to the ISU Lake Study.

Interpreting Don Williams Lake Water Quality Data

Based on mean values from ISU sampling during 2000 - 2003, the ratio of total nitrogen to total phosphorus for this lake is 161:1. Data on inorganic suspended solids from the ISU sampling indicate moderately high levels of non-algal turbidity. The median level of inorganic suspended solids in the 130 lakes sampled for the ISU lake survey from 2000 to 2001 was 5.3 mg/L. The median level of inorganic suspended solids at Don Williams Lake during the same time period was 8.1 mg/l, the 42nd highest of the 130 lakes.

Comparisons of the TSI values for chlorophyll, Secchi depth and total phosphorus for 2000 - 2003 in-lake sampling indicate some slight non-phosphorus limitation of algal growth potentially attributable to domination of the water column by larger particulates and/or zooplankton grazing (see Figure 2 and Appendix C).

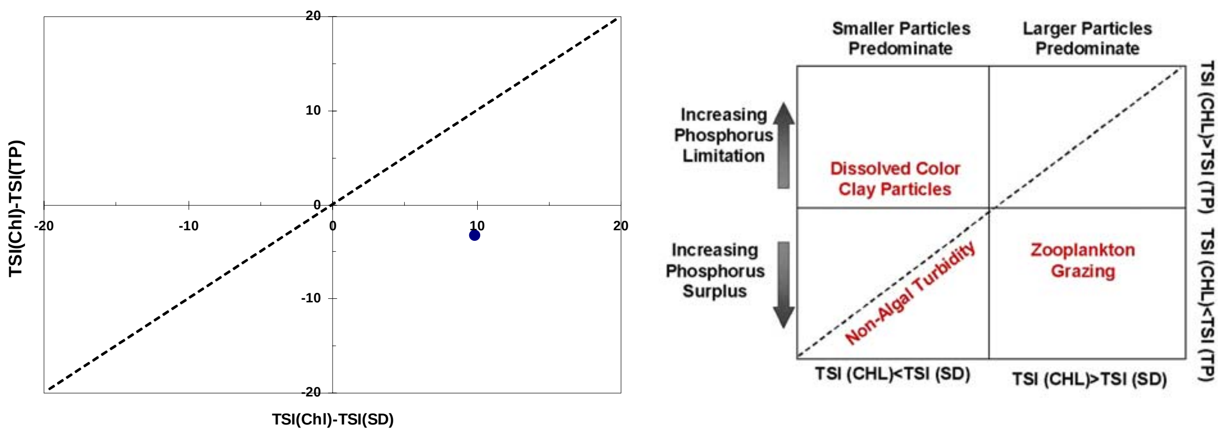
TSI values for 2000 - 2003 ISU and UHL maximum depth monitoring data are shown in Table 4. TSI values for all historical monitoring data and an explanation of Carlson's Trophic State Index are given in Appendix C.

Data from ISU phytoplankton sampling in 2000 and 2001 indicate that bluegreen algae (Cyanophyta) can sometimes comprise a relatively large portion of the summertime phytoplankton community. The number of available samples (three per summer) is insufficient to fully characterize the frequency of algal blooms. The 2000 average summer wet mass of bluegreen algae at this lake (4.3 mg/l) was the 39th lowest of 131 lakes sampled with bluegreens consisting of approximately 28% of the phytoplankton community. However, the 2001 average summer wet mass of bluegreen algae declined to 0.009 mg/L with bluegreens comprising a negligible portion of the phytoplankton community. Sampling for cyanobacterial toxins has not been conducted at Don Williams Lake for the 2000 - 2003 sampling period. 2000 and 2001 phytoplankton sampling results are given in Appendix B.

Table 4. Don Williams TSI Values (3,4,5,20)

Sample Date	Source	TSI (SD)	TSI (CHL)	TSI (TP)
6/23/2000	ISU	67	--	64
7/20/2000	ISU	65	65	68
8/10/2000	ISU	67	66	--
5/24/2001	ISU	60	31	80
6/22/2001	ISU	55	64	65
7/25/2001	ISU	40	48	62
5/30/2002	ISU	38	41	68
6/27/2002	ISU	50	52	47
8/1/2002	ISU	60	62	60
5/30/2003	ISU	60	61	55
6/26/2003	ISU	49	--	58
7/9/2003	UHL	63	72	69
7/21/2003	UHL	56	65	63
8/1/2003	ISU	56	63	67
8/4/2003	UHL	57	61	67
8/20/2003	UHL	54	58	47
9/11/2003	UHL	67	70	61
9/25/2003	UHL	70	75	73
10/7/2003	UHL	67	77	73

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



Potential Pollution Sources

The potential nutrient sources for Don Williams Lake are watershed nonpoint sources, internal recycling of pollutants from bottom sediments, and contributions from precipitation.

The only known potential point source in the watershed of Don Williams Lake is the municipal wastewater treatment facility for the City of Pilot Mound (IA NPDES Permit # 0862001). The treatment facility consists of a three-cell facultative lagoon system constructed in 1977. However, this facility has never discharged, reportedly due to low influent flows relative to the lagoon design volume (24).

Natural Background Conditions

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

3.1.2 TMDL Target

The Phase 1 targets for this TMDL is a TSI value of less than 66 (existing) for total phosphorus, and TSI values of less than 65 for both chlorophyll-a and Secchi depth. These values are equivalent to total phosphorus and chlorophyll concentrations of 75 and 33 ug/L, respectively, and a Secchi depth of 0.7 meters. Observed chlorophyll and Secchi depth values for Don Williams are currently below impairment threshold values. Therefore, the target for total phosphorus is set at the existing concentration.

Table 5. Don Williams Existing vs. Target TSI Values

Parameter	2000-2003 Mean TSI	2000-2003 Mean Value	Target TSI	Target Value	Minimum In-Lake Increase or Reduction Required
Chlorophyll	63	27 ug/L	<65	<33 ug/L	N/A
Secchi Depth	53	1.6 meters	<65	>0.7 meters	N/A
Total Phosphorus	66	75 ug/L	<66 (existing)	<75 ug/L	N/A

Criteria for Assessing Water Quality Standards Attainment

The State of Iowa does not have numeric water quality criteria for nutrients. The nutrient-loading objective is defined by a mean total phosphorus TSI of less than 66 (existing), which is related through the Trophic State Index to chlorophyll-a and Secchi depth. The TSI is not a standard, but is used as a guideline to relate phosphorus loading to chlorophyll and Secchi depth for TMDL development purposes and to describe water quality that will meet Iowa's narrative water quality standards.

Selection of Environmental Conditions

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

Modeling Approach

A number of different empirical models that predict annual phosphorus load based on measured in-lake phosphorus concentrations were evaluated. In addition, watershed phosphorus delivery using both export coefficients and an annual loading function model as outlined in Reckhow's EUTROMOD User's Manual (10) was calculated. Finally, the lake was segmented and Walker's BATHTUB (23) program was used with the Walker Reservoir Model to account for spatial variations in water quality with respect to sampling location. The results from all approaches were compared to select the best-fit empirical model.

Table 6. Model Results

Model	Predicted Existing Annual Total Phosphorus Load (lbs/yr) for in-lake GSM TP = ANN TP = 75 ug/L, SPO TP = 95 ug/L	Comments
Loading Function	20,630	Reckhow (10)
EPA Export	23,470	EPA/5-80-011 (21)
WILMS Export	17,760	"most likely" export coefficients
Reckhow 1991 EUTROMOD Equation	5,630	GSM model
Canfield-Bachmann 1981 Natural Lake	4,230	GSM model
Canfield-Bachmann 1981 Artificial Lake	5,680	GSM model
Reckhow 1977 Anoxic Lake	3,170	GSM model
Reckhow 1979 Natural Lake	4,430	GSM model.
Reckhow 1977 Oxic Lake (z/Tw < 50 m/yr)	4,560	GSM model. P out of range
Nurnberg 1984 Oxic Lake	4,080 (internal load = 0)	Annual model. P out of range
Walker 1977 General Lake	4,720	SPO model
Vollenweider 1982 Combined OECD	5,830	Annual model
Vollenweider 1982 Shallow Lake	6,800	Annual model
Walker Reservoir	6,970	GSM model
Walker Reservoir (BATHTUB)	12,440	GSM model. Segmented.

All of the empirical models evaluated gave results that were significantly below the watershed load estimates. Don Williams is elongated with a shoreline development ratio of approximately 3.2 and strongly stratifies. Also, the sampling location for the majority of available sampling data (maximum depth) is at the end of the lake opposite the main tributary channel. Therefore, it was concluded that the empirical models alone did not adequately account for spatial variations in water quality. The BATHTUB program, which uses empirical eutrophication models but also accounts for advective and diffusive transport in a segmented network, was used to address this issue.

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

The equation for the Walker Reservoir Model is:

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

where

$$A_1 = 0.17Q_s \big/ (Q_s + 13.3)$$

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

The predicted load from the BATHTUB program using the Walker Reservoir Model is greater than that of the empirical models but still below the range of watershed load estimates. Much of the discrepancy may be attributable to two factors. First, the estimated sediment delivery ratio for this watershed is low. The export estimates use typical phosphorus export coefficients weighted by land cover type and do not account for the sediment delivery ratio. Secondly, the low sediment delivery and large watershed to lake ratio weight the Loading Function estimate heavily towards the dissolved phosphorus component. Like the export estimates, the dissolved component of the Loading Function estimate is based on literature-based values lumped by land use and may vary substantially from actual site conditions.

Input and output from the BATHTUB program is shown in Appendix E.

Waterbody Pollutant Loading Capacity

The chlorophyll-a and Secchi depth objectives are related through the Trophic State Index to total phosphorus. The load capacity for this TMDL is the annual amount of phosphorus Don Williams Lake can receive and meet its designated uses. Based on the selected lake response model and a target TSI (TP) value of less than 66 (existing), the Phase 1 total phosphorus loading capacity for the lake is 12,440 pounds per year.

3.1.3 Pollution Source Assessment

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

Existing Load

The annual total phosphorus load to Don Williams Lake is estimated to be 12,440 pounds per year based on the selected lake response model. This estimate includes 12,390 pounds per year from a combination of nonpoint sources in the watershed and the internal phosphorus load recycled from the lake bottom sediment as well as an estimated load of 50 pounds per year from atmospheric deposition.

Departure from Load Capacity

Observed chlorophyll and Secchi depth values for Don Williams are currently below impairment threshold values. Therefore, the targeted load capacity for total phosphorus is set at the existing load. The Phase 1 targeted load capacity and estimated existing load for Don Williams Lake is 12,440 pounds per year or 0.6 pounds per year per acre of watershed area.

Identification of Pollutant Sources

As noted in *Section 3.1.1, Potential Pollutant Sources*, the only known potential point source in the watershed of Don Williams Lake is the municipal wastewater treatment facility for the City of Pilot Mound. Because this facility has never discharged in 27 years of operation and because the potential phosphorus load from it if it were to discharge is estimated to be less than 1% of the total target load to the lake, it is not identified as a significant pollutant source in this TMDL.

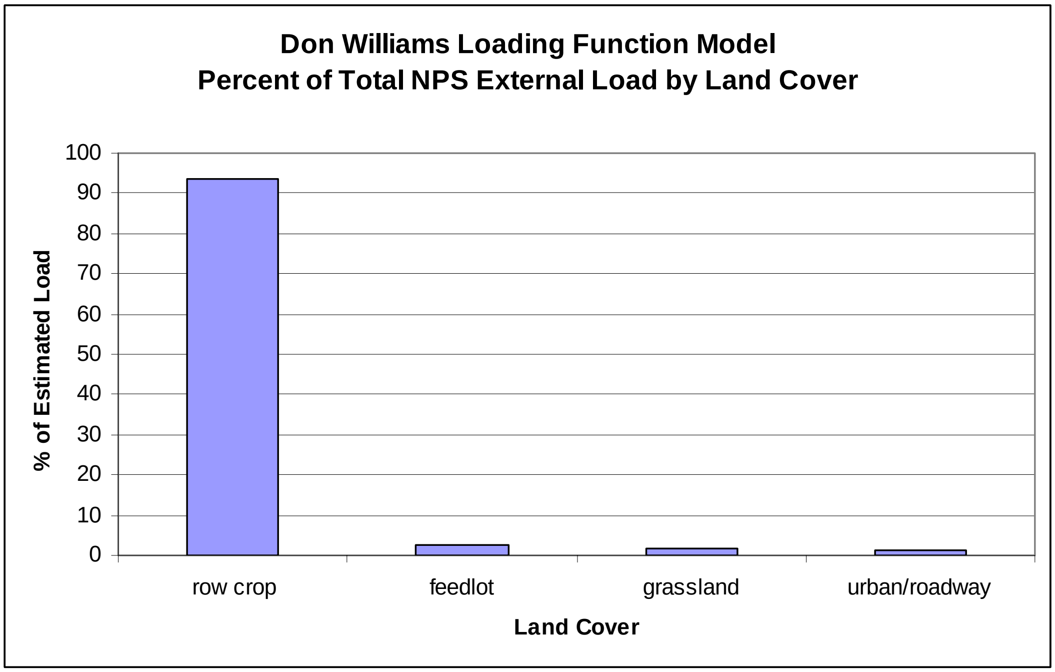
From the Loading Function Model, most of the nonpoint source phosphorus delivered to the lake is from row crop landuse as shown in Figure 3. The loading from feedlots was estimated based on an export coefficient of 200 lbs/acre/year (21). Actual loading from the feedlots may vary substantially from this estimate depending on the number of animals, extent of use and other factors. It should be noted that while the Loading Function Model provides estimates of the primary potential pollutant sources, it was used only for comparison purposes to select an empirical lake response model in the development of the target total phosphorus load identified in this TMDL. The target load was calculated from measured in-lake total phosphorus concentrations using the selected lake response model as described in *Section 3.1.2, Modeling Approach*.

Other sources of phosphorus capable of being delivered to the waterbody exist. These sources include septic systems and toilet pits from campsites and individual residences. Manure and waste from wildlife, pets, etc. also contribute to the phosphorus loading. Unfortunately, the potential phosphorus being contributed from these sources is difficult to quantify. These potential sources have been considered, but are deemed smaller contributors or have less impact than the sources previously identified. However, these sources will be evaluated and quantified as required in Phase 2 of this TMDL.

Linkage of Sources to Target

Excluding background sources, the average annual phosphorus load to Don Williams Lake originates entirely from nonpoint sources and internal recycling. To meet the TMDL, the annual nonpoint source and internal recycling total phosphorus contribution to Don Williams Lake needs to be limited to less than 12,440 pounds per year.

Figure 3. Loading Function Model Nonpoint Source Contributions



3.1.4 Pollutant Allocation

Wasteload Allocation

A single NPDES-permitted facility is present in the watershed. The City of Pilot Mound owns and operates a municipal wastewater treatment facility (IA NPDES Permit # 0862001) consisting of a three-cell facultative lagoon system constructed in 1977. This facility has never discharged, reportedly due to low influent flows relative to the design volume (24). There are no other point source dischargers in the watershed. Therefore, the wasteload allocation will be set at zero.

Load Allocation

The Load Allocation (LA) for this TMDL is 12,440 pounds per year of total phosphorus distributed as follows:

- 12,390 pounds per year allocated to the Don Williams Lake watershed and internal recycling of phosphorus from the lake bottom sediments.
- 50 pounds per year allocated to atmospheric deposition.

Margin of Safety

The nutrient targets for Don Williams Lake have already been achieved. Therefore, an explicit Margin of Safety (MOS) for nutrients has not been included in the load calculations. An implicit MOS is present in that existing TSI values for chlorophyll and Secchi depth are currently below their targets. An additional implicit MOS is present in that the lake response model used to estimate the allowable loading results in a value that is 40% less than the watershed loading predicted by the Loading Function Model, which uses the most recent landuse assessment information to estimate watershed phosphorus delivery.

3.1.5 Nutrient TMDL Summary

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

TMDL = Load Capacity (12,440 lbs/year) = WLA (0 lbs/year) + LA (12,440 lbs/year) + MOS (implicit)

3.2 TMDL for Siltation

3.2.1 Problem Identification

In 1998, Don Williams Lake was placed on the impaired water list for siltation. Excessive sediment deposition impairs recreation and aquatic life uses in many ways:

- Some of the most critical areas for feeding and reproduction of aquatic life are the upstream areas of tributary arms. This is also the area where most sediment settles as stream velocities rapidly decrease.
- As lakes lose depth, they are more susceptible to summer algal blooms and winter fish kills. There is a smaller volume of water under the winter ice that can provide dissolved oxygen.
- Shallow water favors the increase of the rough fish population such as bullheads and carp. Experience with temporarily drained Iowa lakes shows that populations of these species explode as shallower water predominates. These species also overgraze on macrophytes and stir up bottom sediments causing turbidity and nutrient recycling.

One of the biggest obstacles to assessing the nature and extent of a siltation problem is knowing how much silt has accumulated and how much volume has been lost. IDNR and US Geological Survey cooperated to develop a method to map the lake bottom and sediment volume using special sonar equipment. The USGS mapping and sediment estimating procedure are outlined in Appendix G. These estimates show that the lake has lost significant volume, depth and some surface area near the inlet. The Don Williams Lake siltation problem is not surprising; the watershed to lake area ratio of 141:1 is much higher than the desired maximum of 20:1.

Based on NRCS methods, the estimated sediment delivery ratio (SDR) is relatively low at 3.7%. A 1980 survey estimated that the SDR for the watershed was 8.8%. For the purposes of this TMDL, this SDR is rounded to 9%. Even at this higher SDR, the sediment delivered to the lake is only 20% of the directly measured silt mass. The watershed lies in the Des Moines lobe, which is level to gently rolling. The gentle slopes result in moderate sediment delivery of sheet and rill erosion in this region.

Data Sources

The Boone County Engineer made two detailed surveys of Don Williams Lake in 1974 and 1980. The estimated volume of Don Williams Lake in 1974 was 2603 acre-feet and in 1980 was 2516 acre-feet. During the 1980 survey, 14 sediment samples were taken and the volume weight of these ranged from 24 to 98 pounds per cubic foot. The average composition was 34% clay, 56% silt, and 10% sand. The 1980 survey estimated that the average annual sediment deposition from the watershed was 10,960 tons, or 0.53 tons/acre.

A bathymetric survey was conducted by the USGS under a cooperative agreement with the DNR in the summer of 2003. This data provides the current and original lake bottom and an estimate of the amount of sediment accumulated in the lake since 1967 when the dam was constructed. Data from this survey show that the current water volume in the lake is 2296 acre-feet and the sediment volume is 359 acre-feet. This represents a 7.4% loss in volume over the last 36 years.

A RUSLE erosion model using data from a watershed assessment and the IDNR geographical information system library evaluated the soil loss from the watershed. These estimates of erosion and watershed sediment delivery were used to evaluate current conditions. A description of this model can be found in Appendix F.

Interpreting Don Williams Water Quality Data

Volume Loss: The sedimentation impairment is expressed in the form of a loss of volume. For the 2003 USGS bathymetry and siltation estimate, the volume between the existing lake bottom and the sonar-derived original bottom was calculated. This volume is the estimate for the current siltation volume of 359 acre-feet. Table 7 summarizes Don Williams Lake sediment accumulation between 1967 and 2003.

Table 7. Estimated Sedimentation (from 2003 USGS mapping and siltation estimate, and 1974 and 1980 Surveys)

Bathymetry year	Lake water volume, acre-feet	Water volume change, acre- feet	Cumulative sedimentation, acre-feet	Average sedimentation rate, acre-feet / year
Original 1967 volume, USGS	2655	NA	NA	NA
January 1974 survey volume, Boone County	2603	52	52	7.43
January 1980 survey volume, Boone County	2516	87	139	14.5
August 2003 mapping volume, USGS	2296	220	359	9.97

The volume loss, or inversely, the sediment gain, between 1967 and 2003 was 359 acre-feet, a 7.4% volume loss over 36 years. The average annual sedimentation rate between 1967 and 2003 was 10 acre-feet per year.

Trap Efficiency: Another factor considered in this TMDL is how much of the sediment delivered to the lake settles out (i.e., sediment trap efficiency). The trap efficiency for Don Williams Lake was calculated using Brune's Curve (28):

Capacity-Inflow Method (Brune's Curve)
TE = 100*0.97^[0.19^(log C/I)]
C = Reservoir capacity, acre-ft = 2296 acre-feet
I = Mean annual flow, acre-ft = 14,725 acre-feet

The trap efficiency is 89% because of the relatively short detention time in the lake. Including the trap efficiency in the siltation estimate has the consequence of increasing the estimated sediment load to the lake. For the purposes of this TMDL, the delivered watershed sediment load is set the same as the deposited sediment load.

Siltation weight per volume (pounds per cubic foot): The mass associated with of the volume of silt in the bottom of the lake is very important in the estimation of lake sediment loading. For Don Williams Lake, the distribution of sediment particle size is available from the 1980 sediment core analysis. This information has been used to estimate the volume weight of the sediment using methods described in Appendix G of the US Army Corps of Engineers Engineering and Design Manual for Sedimentation Investigations of Rivers and Reservoirs (28). The methods incorporate a calculation for the composite weight of a mixture and the consolidation of deposits with time.

The specific weight in pounds per cubic foot was calculated based on a time of 36 years and average sand, silt and clay fractions of 0.10, 0.56, and 0.34, respectively.

- Calculations for the consolidated average specific weight for sand, silt, and clay:

  Specific Weight = w + k * [(t/t-1) * log (t) – 0.4343]

  Where w is initial specific weight, k is consolidation coefficient, and t is time in years. Values for w and k are taken from the Army Corps of Engineers (28).

  Sand: Wsand = 97 lb/cf
  Silt: Wsilt = 70 + 5.7 * [(36/35) * log(36) – 0.4343]
  = 82 lb/cf
  Clay: Wclay = 26 + 16 * [(36/35) * log(36) – 0.4343]
  = 45 lb/cf

- Calculation for the composite specific weight of the mixture:

  Wcomposite = 1/[(%sand / Wsand) + (%silt / Wsilt) + (%clay / Wclay)]
  = 1/[(0.10/97) + (0.56/82) + (0.34/45)]
  = 65 lb/cf

- Calculation for the annual load from the measured annual average sediment volume of 10 acre-feet and the calculated composite specific weight of 65 lb/cf:

  [(10 ac-ft) (43,560 cf/ac-ft) (65 lb/cf)] / (2000 tons/lb) = 14,200 tons per year

Potential Pollution Sources

No significant sediment point sources exist in the Don Williams Lake watershed. Two important potential non-point sediment sources in the Don Williams Lake watershed are:

- Stream bed, stream bank, and gully erosion, and
- Upland sheet and rill erosion in farmed fields.

Other less significant sources are runoff from construction and development activities, grasslands, and forest.

Natural Background Conditions

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

3.2.2 TMDL Target

The water quality target for this siltation TMDL is the volume of sediment that can be delivered to the lake annually and not cause an impairment of the lake's designated uses. The Phase 1 target for Don Williams Lake is the average annual siltation rate that equals the rate at which it would take to fill one third of the original volume over a design life of 100 years. The 100-year design life has been selected because it is frequently used by the U.S. Army Corps of Engineers for its reservoir projects. It is usually considered an economic parameter and not a physical limitation.

The original volume of the lake was 2655 acre-feet and one third of this is 885 acre-feet. Over 100 years, this results in an average annual allowable volume loss of 8.9 acre-feet per year. Over the past 36 years, 359 acre-feet have been lost, leaving an allowable volume loss for the next 64 years of 526 acre-feet or 8.2 acre-feet per year.

Criteria for Assessing Water Quality Standards Attainment

The State of Iowa does not have numeric water quality criteria for siltation. The loading objective is defined by a measurable loss of lake volume, area, and depth. For Don Williams Lake, the allowable sedimentation rate is that which is sustainable within the 100-year design life beginning in 1967. This rate is 8.9 acre-feet per year.

Selection of Environmental Conditions

The critical condition for which this sediment TMDL applies is the entire year. An annual loading period was used to define Don Williams Lake sediment loading capacity. However, sediment loads are actually the result of periodic precipitation events, so non-point source controls must be targeted at times when high loading occurs.

Waterbody Pollutant Loading Capacity

The load capacity for this siltation TMDL is the amount of deposited sediment Don Williams Lake can receive annually and not exceed the rate based on the design life of the lake. The silt storage volume at the impairment threshold is one third of the original lake volume, or 885 acre feet. The total storage volume spread over the 100-year design life of Don Williams Lake results in an allowable average annual sedimentation rate of 8.9 acre-feet per year. Accounting for volume loss over the past 36 years, for the next 64 years the allowable average annual sedimentation rate is reduced to 8.2 acre-feet per year.

The allowable sediment delivery to Don Williams Lake is 11,600 tons per year at an estimated dry weight of 65 pounds per cubic foot of volume.

3.2.3 Pollution Source Assessment

Don Williams Lake sediment sources fall into two categories. The first is upland sheet and rill erosion estimated using watershed erosion models. These models are also used to estimate impacts of implemented erosion control practices. The second category is gully, streambed, and stream bank erosion that are estimated for this TMDL by subtracting the upland erosion estimates from the measured 36-year average annual sedimentation rate in Don Williams Lake.

Existing Load

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

- 2004 IDNR estimates based on RUSLE equations and IDNR GIS coverages (see Appendix F),
- Estimates based on RUSLE modeling and assumptions about erosion control effectiveness, and
- Average annual sediment delivery based on the sediment volume in the lake.

The average annual volume loss of 10 acre-feet per year has been used to derive an average annual sediment delivery of 14,200 tons per year. This measured value is the starting point for source evaluation. Table 8 shows the total sheet and rill erosion based on an adjusted RUSLE, delivery using an SDR of 4% (NRCS method), delivery using an SDR of 9% (1980 survey estimate), the measured delivery, and an estimate of the bed and bank and gully erosion.

The estimated existing average annual sediment load is 14,200 tons per year, not including discharge losses (trap efficiency). Bluff Creek delivers most of this sediment to the lake. The remaining sediment comes from direct drainage of the land adjacent to the lake. This direct drainage is mostly forested.

Table 8. Sediment Delivery Estimates, IDNR RUSLE modeling, and measured in-lake volume

IDNR estimates, 2004 RUSLE modeling	Total estimated watershed erosion, tons/year	Unit basis, tons/acre/year
Current conditions, sheet and rill erosion, no delivery	99,600	4.7
Sediment delivery, SDR = 4% (NRCS method, land form and drainage area)	3,980	0.188
Sediment delivery, SDR = 9% (1980 survey estimate)	8,960	0.423
Measured sediment delivery from lake surveys	14,200	NA
In-stream bed and bank erosion, assuming SDR = 9%	5,240	NA

Departure from Load Capacity

The targeted total sediment loading capacity for Don Williams Lake is 11,600 tons per year. Estimated existing load to the lake is 14,200 tons per year. This is 2,600 tons per year over the sediment load capacity.

Identification of Pollutant Sources

There are no significant point source sediment discharges in the Don Williams Lake watershed. Non-point source identification and sediment quantification were established with data and modeling done for previous watershed projects and through the application of an IDNR-developed model based on the RUSLE and GIS data input in 2004.

Two categories of sediment sources have been identified in the Don Williams Lake watershed. Upland sources are sheet and rill erosion; non-upland sources are gully, streambed, and stream bank erosion.

Linkage of Sources to Target

The existing average annual sediment load of 14,200 tons per year to Don Williams Lake originates entirely from non-point sources. This sediment load needs to be reduced by 2,600 tons per year to reach the target of 11,600 tons per year. The target for this siltation TMDL is an average annual rate of sediment delivery that will not cause water quality impairments.

3.2.4 Pollutant Allocation

Wasteload Allocation

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

Load Allocation

The Load Allocation (LA) for this siltation TMDL is an annual average sediment load of 10,440 tons per year over a ten-year period distributed among the identified non-point sources.

Margin of Safety

The explicit margin of safety for this TMDL is a 10% reduction of the loading capacity of 11,600 tons per year. The MOS is 1,160 tons per year.

3.2.5 Siltation TMDL Summary

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

TMDL = Load Capacity (11,600 tons/year) = WLA (0 tons/year)+LA (10,440 tons/year)+MOS (1,160 tons/year)

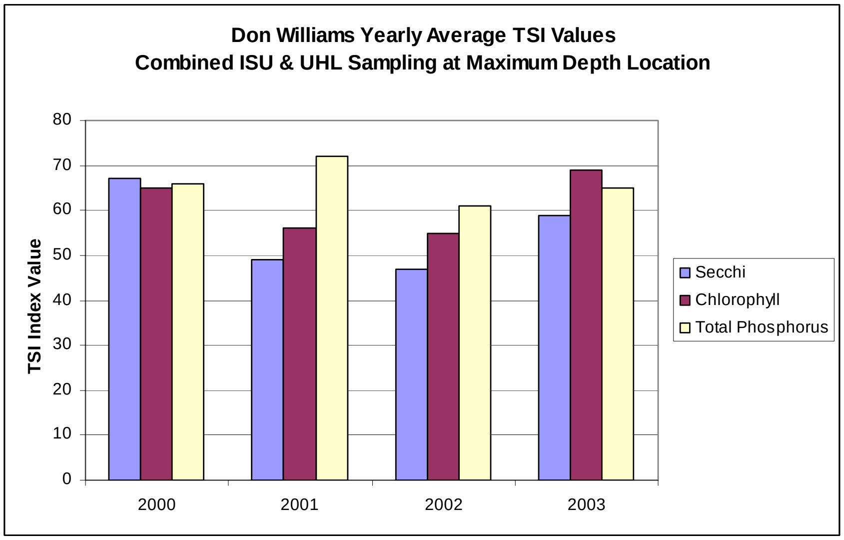
4. Implementation Plan

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

4.1 Organic Enrichment

Based on 2000 - 2003 monitoring data for chlorophyll and Secchi depth, the existing average annual nutrient loading to Don Williams Lake is below that which would cause impairment due to algal turbidity. The observed TSI values for these parameters do not show any obvious increasing or decreasing trend during the monitoring period as shown in Figure 4. However, this does not imply that continuation of existing and implementation of new management practices that will prevent degradation of water quality is not necessary.

Figure 4. Yearly Average TSI Values



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

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

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

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

Internal loading can be controlled through fish management to control rough fish (i.e., carp), rip rap along the shoreline to reduce shoreline erosion, and dredging to remove nutrients from the lake system.

4.2 Siltation

This siltation TMDL implementation plan provides guidance for agencies and stakeholders working to improve Don Williams Lake water quality. The emphasis is on non-point source reduction activities targeting sediment. These include:

Gully, streambed, and stream bank erosion: Bed and bank erosion have been identified as a significant sediment source now that so many upland erosion controls have been initiated. However, a rapid survey by the DSC showed minimal erosion from stream banks and gullies near the lake. Shoreline erosion also appeared to contribute little sediment.

Significant stream and gully sediment contributions should be identified and stream bank restoration work done. Identify problem locations and target restoration activities at eroding stream banks contributing significant sediment. Suggested controls are:

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

Overland sheet and rill erosion: Erosion control activities, including the maintenance of installed structures, need to continue in the watershed. The watershed should be periodically evaluated and erosion control activities focused on identified sediment contributors. Emphasis should be on row crop fields close to the lake or stream and having steeper slopes without effective management practices in place. An investigation of sediment contributed from tiles, particularly those fed by standpipes, would be of value. 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.

Sediment Reduction Goal: In addition to remediation of the water quality impairment in Don Williams Lake, the sediment reductions identified in this TMDL are necessary to protect the public investment in the lake and surrounding park. If future evaluations of the lake condition indicate that the sediment delivery goal is inadequate to prevent siltation impairment, the TMDL will be revised and new sediment allocations will be made.

5. Monitoring

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

Sources of gully, streambank, and streambed erosion in the Don Williams Lake watershed need to be more accurately quantified. This will be completed by working with the Division of Soil Conservation, the Natural Resources Conservation Service, and the Boone County Soil and Water Conservation District.

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

6. Public Participation

A public meeting was held at Swede Point Park regarding the proposed TMDL for Don Williams Lake on June 14, 2004. A second public meeting was held on January 12, 2005 to present the draft TMDL for public comment. Attendees at the meeting included representatives from IDNR, Boone County Conservation, NRCS, IDALS, and KWBG Radio. Comments received were reviewed and given consideration and, where appropriate, incorporated into the TMDL.

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8. Appendix A - Lake Hydrology

General Methodology

<u>Purpose</u>

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

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

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

<u>Data</u>

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

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

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

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

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

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

Methods

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

Equation Variables

Table A-2. Regression Equation Variables

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

Equations

Table A-3. Drainage Area Only Equations

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

Table A-4. Multiple Regression Equations

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

General Application

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

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

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

Application to Don Williams Lake - Calculations

Table A-5. Don Williams Lake Hydrology Calculations

Lake	Don Williams Lake	
Type	Impoundment	
Inlet(s)	Bluff Creek	
Outlet(s)	Bluff Creek	
Volume	2296	(acre-ft)
Lake Area	149	(acres)
Mean Depth	15.42	(ft)
Drainage Area	21076	(acres)
Mean Annual Precip	31.4	(inches)
Average Basin Slope	1.6	(%)
%Water	0.00	
%Forest	0.59	
%Grass/Hay	12.49	
%Corn	43.53	
%Beans	43.15	
%Urban/Artificial	0.17	
%Barren/Sparse	0.07	
Hydrologic Region	4	
Mean Annual Class A Pan Evap	50	(inches)
Mean Annual Lake Evap	37	(inches)
Est. Annual Average Inflow	13473.74	(acre-ft)
Direct Lake Precip	390.04	(acre-ft/yr)
Est. Annual Average Det. Time (inflow + precip)	0.1656	(yr)
Est. Annual Average Det. Time (outflow)	0.1713	(yr)

9. Appendix B - Sampling Data

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

Parameter	7/11/1979	8/02/1979	8/30/1979
Secchi Depth (m)	2.0	1.7	1.8
Chlorophyll (ug/L)	7.6	--	17.4
NO_3+NO_2-N (mg/L)	--	--	4.0
Total Phosphorus (ug/l as P)	16.4	36.2	37.2
Alkalinity (mg/L)	164	164	172

Data above is averaged over the upper 6 feet.

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

Parameter	6/01/1990	7/01/1990	7/29/1990
Secchi Depth (m)	0.4	0.8	0.1
Chlorophyll (ug/L)	6.1	15.6	11.7
Total Nitrogen (mg/L as N)	10.5	10.2	5.9
Total Phosphorus (ug/l as P)	381.6	198.7	394.9
Total Suspended Solids (mg/L)	33.1	14.7	103.6
Inorganic Suspended Solids (mg/L)	33.7	6.1	82.9

Data above is for surface depth.

TableB-3. Data collected in 2000 by Iowa State University (3)

Parameter	6/23/2000	7/20/2000	8/10/2000
Secchi Depth (m)	0.6	0.7	0.6
Chlorophyll (ug/L)	--	33	37
NH_3+NH_4^+ -N (ug/L)	468	289	680
NH_3 –N (un-ionized) (ug/L)		47	52
NO_3+NO_2-N (mg/L)	290	2.52	1.17
Total Nitrogen (mg/L as N)	4.02	3.72	2.62
Total Phosphorus (ug/l as P)	64	81	--
Silica (mg/L as SiO_2)	27	9	12
pH	7.2	8.5	8.1
Alkalinity (mg/L)	184	135	125
Total Suspended Solids (mg/L)	4.5	15.4	--
Inorganic Suspended Solids (mg/L)	1.1	9.2	--
Volatile Suspended Solids (mg/L)	3.4	6.3	--

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

Parameter	5/24/2001	6/22/2001	7/25/2001
Secchi Depth (m)	1.0	1.4	4.1
Chlorophyll (ug/L)	1	31	6
NH_3+NH_4^+ -N (ug/L)	797	222	234
NH_3 –N (un-ionized) (ug/L)	10	34	46
NO_3+NO_2-N (mg/L)	13.69	15.47	114.41
Total Nitrogen (mg/L as N)	14.92	20.57	14.77
Total Phosphorus (ug/l as P)	198	70	56
Silica (mg/L as SiO_2)	19	12	7
pH	7.7	8.6	8.6
Alkalinity (mg/L)	149	168	141
Total Suspended Solids (mg/L)	15.1	8.9	11.4
Inorganic Suspended Solids (mg/L)	10.5	3.6	8.1
Volatile Suspended Solids (mg/L)	4.6	5.3	3.3

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

Parameter	**5/30/2002**	**6/27/2002**	**8/01/2002**
Secchi Depth (m)	4.5	2.0	1.0
Chlorophyll (ug/L)	3	9	24
NH_3+NH_4^+ -N (ug/L)	323	130	324
NH_3 –N (un-ionized) (ug/L)	14	18	37
NO_3+NO_2-N (mg/L)	12.4	11.3	6.35
Total Nitrogen (mg/L as N)	14.25	12.48	7.48
Total Phosphorus (ug/l as P)	83	19	48
Silica (mg/L as SiO_2)	6	4	5
pH	8.2	8.4	8.3
Alkalinity (mg/L)	202	162	129
Total Suspended Solids (mg/L)	12.7	2.7	11.0
Inorganic Suspended Solids (mg/L)	4.0	--	4.0
Volatile Suspended Solids (mg/L)	8.7	--	7.0

Table B-6. Data collected in 2003 by Iowa State University (20)

Parameter	**5/30/2003**	**6/26/2003**	**8/01/2003**
Secchi Depth (m)	1.0	2.2	1.3
Chlorophyll (ug/L)	22.7	--	27.7
NH_3+NH_4^+ -N (ug/L)	196	126	206
NH_3 –N (un-ionized) (ug/L)	11	10	36
NO_3+NO_2-N (mg/L)	13.9	12.4	10.5
Total Nitrogen (mg/L as N)	14.8	13.8	11.6
Total Phosphorus (ug/l as P)	33	41	77
Silica (mg/L as SiO_2)	4	5	5
pH	8.2	8.3	8.5
Alkalinity (mg/L)	165	147	115
Total Suspended Solids (mg/L)	16	10	12
Inorganic Suspended Solids (mg/L)	11	6	7
Volatile Suspended Solids (mg/L)	5	5	6

Table B-7. 2000 and 2001 Phytoplankton Data (3,4)

	2000	**2001**
Division	**Wet Mass (mg/L)**	**Wet Mass (mg/L)**
Bacillariophyta Wet Mass	5.892	10.204
Chlorophyta Wet Mass	0.381	6.619
Chrysophyta Wet Mass	1.21	13.876
Cryptophyta Wet Mass	2.45	3.833
Cyanobacteria Wet Mass	4.249	0.009
Dinophyta Wet Mass	0.931	0.182
Euglenophyta Wet Mass	0.254	0
Total	15.368	34.723

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

10. Appendix C - Trophic State Index

Carlson's Trophic State Index

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

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

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

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

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

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

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

SD = lake Secchi depth, meters

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

Table C-1. Changes in temperate lake attributes according to trophic state (modified from 22,26,27).

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

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

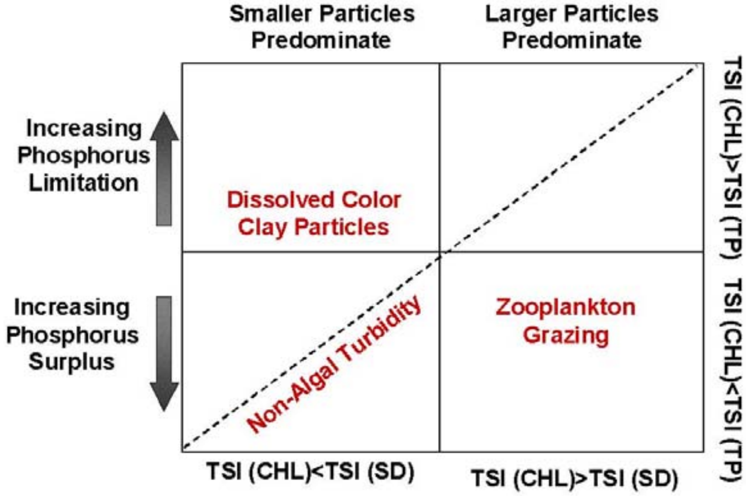
Level of Support	TSI value	Chlorophyll-a (ug/l)	Secchi Depth (m)
fully supported	<=55	*<=12*	*>1.4*
fully supported / threatened	55 ➔ 65	*12 ➔ 33*	*1.4 ➔ 0.7*
partially supported (evaluated: in need of further investigation)	65 ➔ 70	*33 ➔ 55*	*0.7 ➔ 0.5*
partially supported (monitored: candidates for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

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

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

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

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



Don Williams Lake TSI Values

Table C-4. 1979 Don Williams Lake TSI Values (1)

Sample Date	TSI (SD)	TSI (CHL)	TSI (TP)
7/11/1979	50	50	44
8/2/1979	52	--	56
8/30/1979	52	59	56

Table C-5. 1990 Don Williams Lake TSI Values (2)

Sample Date	TSI (SD)	TSI (CHL)	TSI (TP)
6/1/1990	73	48	90
7/1/1990	63	58	80
7/29/1990	93	55	90

Table C-6. 2000 - 2003 Don Williams Lake TSI Values (3,4,5,20)

Sample Date	TSI (SD)	TSI (CHL)	TSI (TP)
6/23/2000	67	--	64
7/20/2000	65	65	68
8/10/2000	67	66	--
5/24/2001	60	31	80
6/22/2001	55	64	65
7/25/2001	40	48	62
5/30/2002	38	41	68
6/27/2002	50	52	47
8/1/2002	60	62	60
5/30/2003	60	61	55
6/26/2003	49	--	58
8/1/2003	56	63	67

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

Sample Date	TSI (SD)	TSI (CHL)	TSI (TP)
7/9/2003	63	72	69
7/21/2003	56	65	63
8/4/2003	57	61	67
8/20/2003	54	58	47
9/11/2003	67	70	61
9/25/2003	70	75	73
10/7/2003	67	77	73

11. Appendix D - Land Use Maps

Figure D-1. Don Williams Lake watershed with 2002 landuse coverage based on satellite imagery.

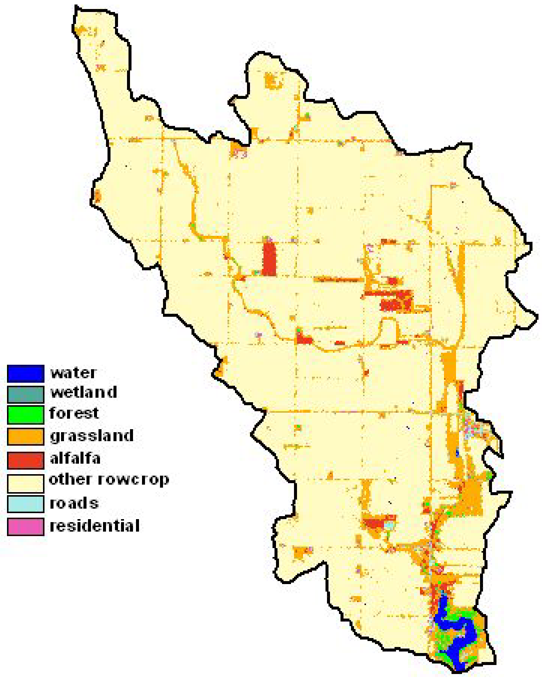
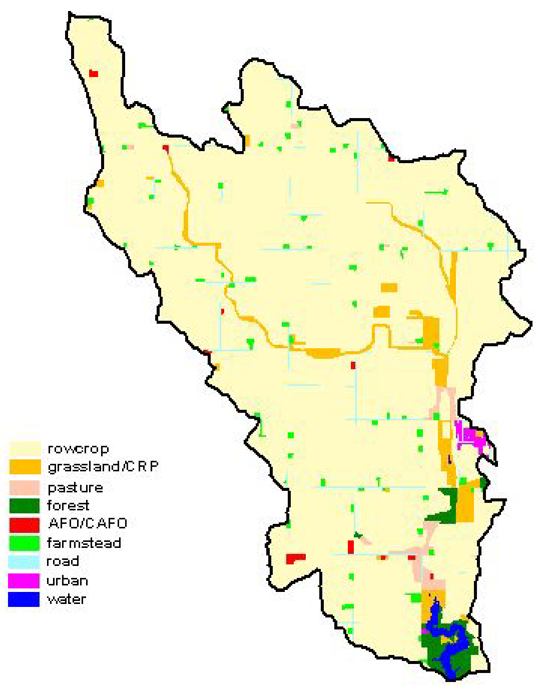


Figure D-2. Don Williams Lake watershed with 2004 landuse coverage based on a DNR field assessment.



12. Appendix E - Bathtub Program Input/Output

Don Williams
File: C:\Bathtubexe2\donwilliamsfinal.btb
Description:

three segments in series

suggested default values for model options & model coefficients

phosphorus budgets based upon total P only
availability factors ignored

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.798	0.1
Evaporation (m)	0.94	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	40	0.50
Total N	0	0.00
Ortho P	20	0.50
Inorganic N	0	0.00

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

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Upper Pool	2	1	0.2	3.2	0.96	3.1	0.12	0	0	0.28	2.22	0	0	0	0	0	0
2	Mid Pool	3	1	0.2	4.73	1.27	4.4	0.12	0	0	0.08	4.66	0	0	0	0	0	0
3	Near Dam	0	1	0.2	6.23	0.56	5.3	0.12	0	0	0.08	3.56	0	0	0	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	189	0.29	0	0	100	0.2	0.36	0.13	0	0	0	0	0	0	0	0
2	0	0	67	0.14	0	0	66	0.2	0.81	0.14	0	0	0	0	0	0	0	0
3	0	0	74.9	0.16	0	0	27	0.34	1.6	0.27	0	0	0	0	0	0	0	0

Segment Calibration Factors

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

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	stream a	1	1	85.3	16.62	0.1	0	0	338	0.2	0	0	0	0	0	0

Tributary Non-Point Source Drainage Areas (km^2)

		Land Use Category--->							
Trib	Trib Name	1	2	3	4	5	6	7	8
1	stream a	85.9	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.025	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Don Williams
File: C:\Bathtubexe2\donwilliamsfinal.btb

Segment & Tributary Network

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

Don Williams
File: C:\Bathtubexe2\donwilliamsfinal.btb

Hydraulic & Dispersion Parameters

Seg	Name	Outflow Seg	Net Inflow hm^3/yr	Resid Time years	Overflow Rate m/yr	Velocity km/yr	Dispersion--------> Estimated km^2/yr	Numeric km^2/yr	Exchange hm^3/yr
1	Upper Pool	2	16.6	0.0386	83.0	24.9	40.7	11.9	19.9
2	Mid Pool	3	16.6	0.0571	82.8	22.2	14.9	14.1	0.5
3	Near Dam	0	16.5	0.0754	82.7	7.4	20.4	2.1	0.0

Morphometry

Seg	Name	Area km^2	Zmean m	Zmix m	Length km	Volume hm^3	Width km	L/W -
1	Upper Pool	0.2	3.2	3.1	1.0	0.6	0.2	4.6
2	Mid Pool	0.2	4.7	4.4	1.3	0.9	0.2	8.1
3	Near Dam	0.2	6.2	5.3	0.6	1.2	0.4	1.6
Totals		0.6	4.7			2.8		

Don Williams
File: C:\Bathtubexe2\donwilliamsfinal.btb

Overall Water & Nutrient Balances

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

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	1	1	stream a	85.3	16.6	2.76E+00	0.10	0.19
PRECIPITATION				0.6	0.5	4.49E-03	0.14	0.80
TRIBUTARY INFLOW				85.3	16.6	2.76E+00	0.10	0.19
***TOTAL INFLOW				85.9	17.1	2.77E+00	0.10	0.20
ADVECTIVE OUTFLOW				85.9	16.5	2.80E+00	0.10	0.19
***TOTAL OUTFLOW				85.9	16.5	2.80E+00	0.10	0.19
***EVAPORATION					0.6	2.86E-02	0.30	

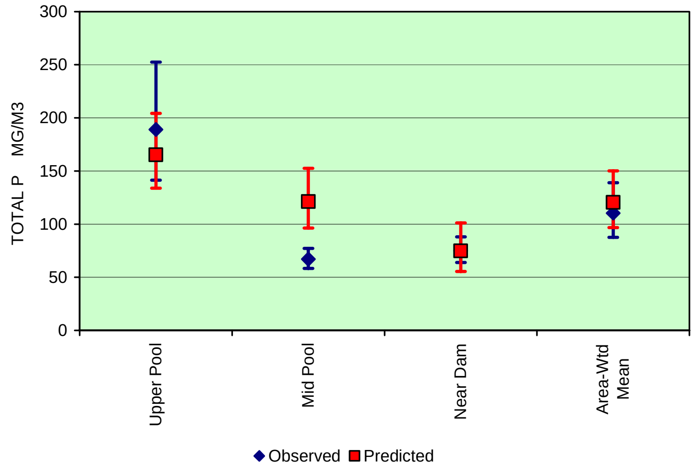
Overall Mass Balance Based Upon Component: **Predicted TOTAL P** — **Outflow & Reservoir Concentrations**

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	%Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	stream a	5617.6	99.6%	1.58E+06	100.0%	0.22	338.0	65.9
PRECIPITATION				24.0	0.4%	1.44E+02	0.0%	0.50	50.1	40.0
TRIBUTARY INFLOW				5617.6	99.6%	1.58E+06	100.0%	0.22	338.0	65.9
***TOTAL INFLOW				5641.6	100.0%	1.58E+06	100.0%	0.22	329.9	65.7
ADVECTIVE OUTFLOW				1238.4	22.0%	1.66E+05		0.33	74.9	14.4
***TOTAL OUTFLOW				1238.4	22.0%	1.66E+05		0.33	74.9	14.4
***RETENTION				4403.1	78.0%	1.33E+06		0.26		

Overflow Rate (m/yr)	27.6	Nutrient Resid. Time (yrs)	0.0605
Hydraulic Resid. Time (yrs)	0.1713	Turnover Ratio	16.5
Reservoir Conc (mg/m3)	121	Retention Coef.	0.780

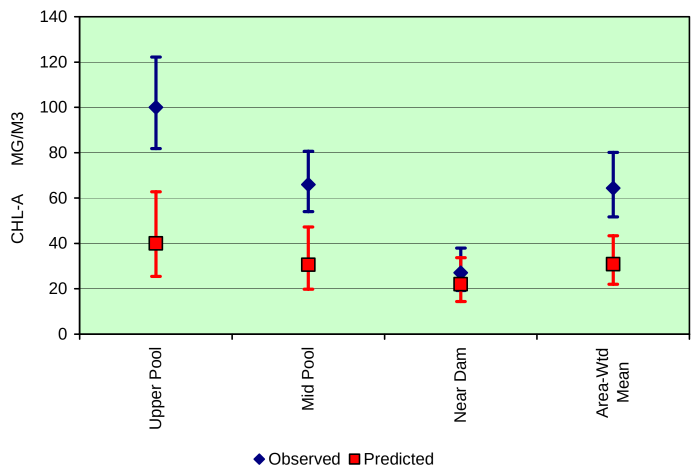
Don Williams
File: **C:\Bathtubexe2\donwilliamsfinal.btb**
Variable: **TOTAL P MG/M3**

Segment	Predicted Mean	CV	Observed Mean	CV
Upper Pool	165.3	0.21	189.0	0.29
Mid Pool	121.3	0.23	67.0	0.14
Near Dam	74.9	0.30	74.9	0.16
Area-Wtd Mean	120.5	0.22	110.3	0.23



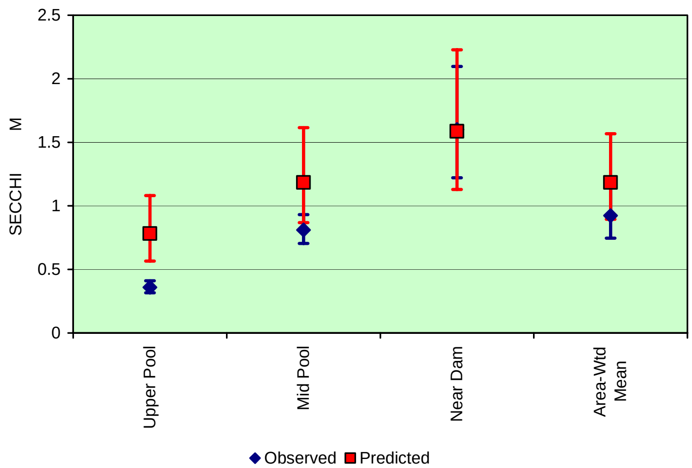
Don Williams
File: **C:\Bathtubexe2\donwilliamsfinal.btb**
Variable: **CHL-A MG/M3**

Segment	Predicted Mean	CV	Observed Mean	CV
Upper Pool	40.0	0.45	100.0	0.20
Mid Pool	30.6	0.43	66.0	0.20
Near Dam	22.0	0.42	27.0	0.34
Area-Wtd Mean	30.9	0.34	64.3	0.22



Don Williams
File: **C:\Bathtubexe2\donwilliamsfinal.btb**
Variable: **SECCHI M**

	Predicted		Observed	
Segment	**Mean**	**CV**	**Mean**	**CV**
Upper Pool	0.8	0.32	0.4	0.13
Mid Pool	1.2	0.31	0.8	0.14
Near Dam	1.6	0.34	1.6	0.27
Area-Wtd Mean	1.2	0.28	0.9	0.21



13. Appendix F - Erosion Model and Model inputs

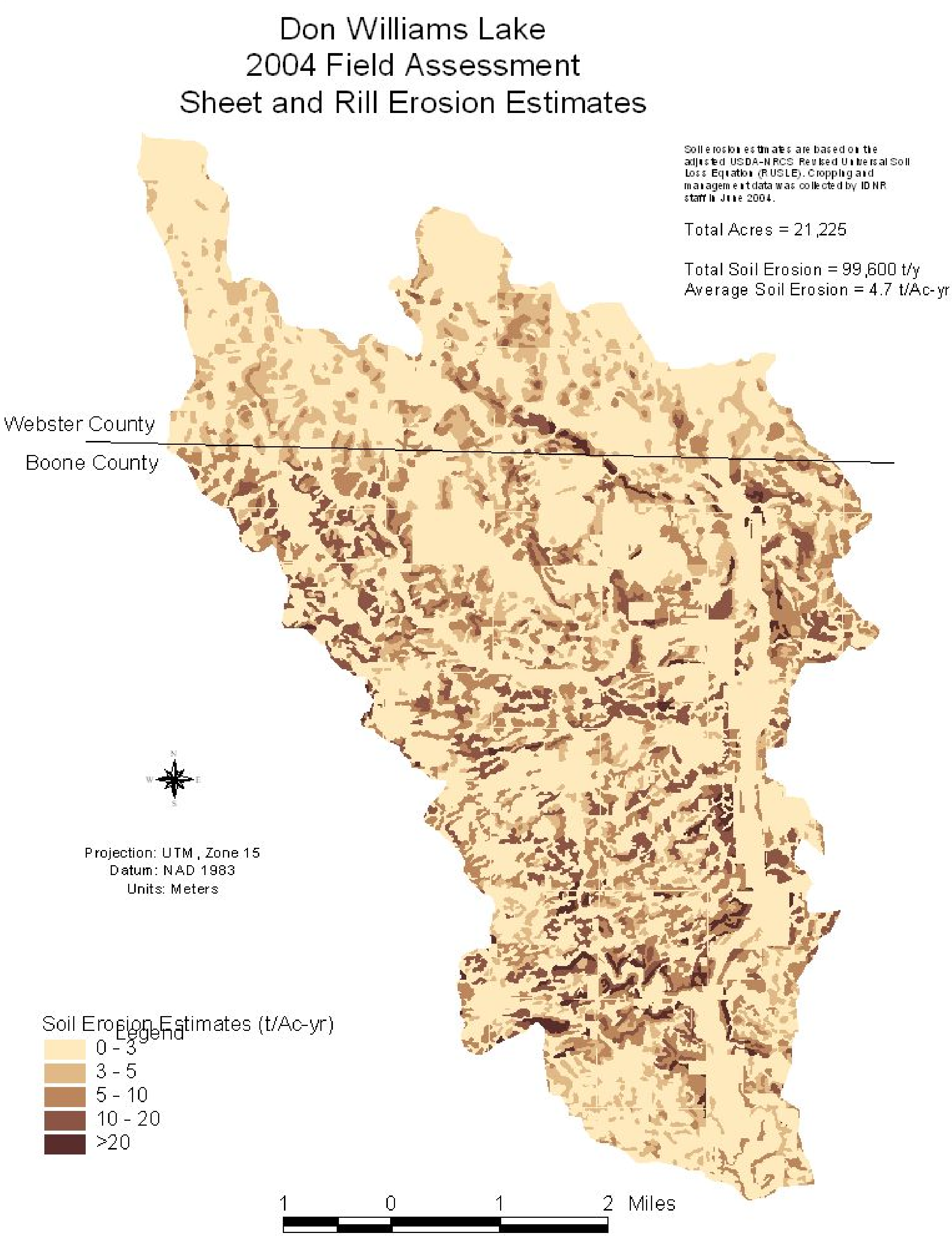
The Revised Universal Soil Loss Equation (RUSLE) (29) is an erosion model designed to predict the longtime annual average soil loss (A) carried by runoff from specific field slopes in specified cropping and management systems. The equation used by RUSLE is:

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

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

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

Figure F-1. Don Williams Lake RUSLE modeling results, sheet & rill erosion estimates



14. Appendix G - Lake Bed and Sediment Mapping

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

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

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

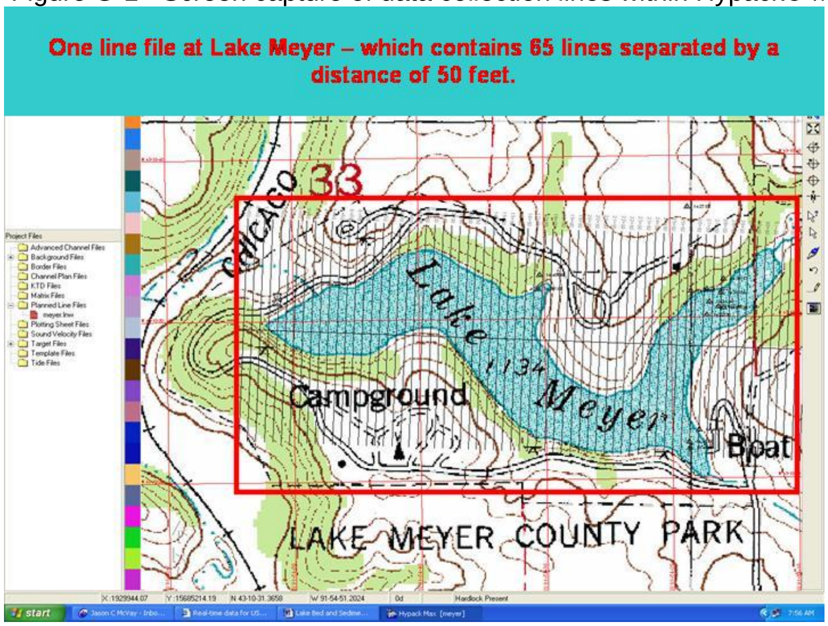
Computer Setup
Preparation includes computer setup and identifying the location of established benchmarks. Computer preparation work involves loading background maps (digital raster USGS topographic maps) in the file format. Background map files are used to help establish the lines that will be used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

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

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

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

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



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

Location of Benchmarks

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

Bathymetry Data Collection

GPS Accuracy

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

Lake Surface Elevation

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

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

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

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

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

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

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

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

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

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

Target and Calibration Cores

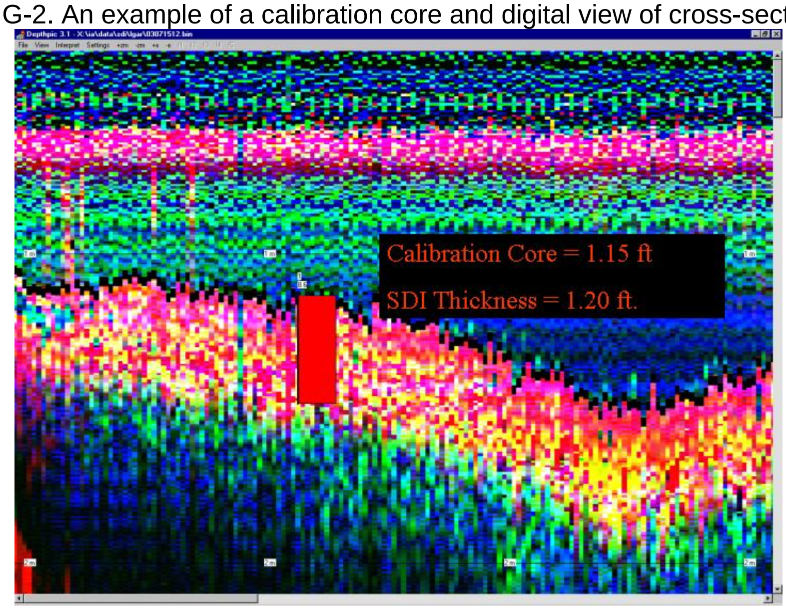
Sediment mapping has the same water depth limitations as the bathymetry. Collection of sediment cores is needed in lake areas where seismic data collection is not possible. Sediment cores are used to interpret sediment thickness during post-processing. Upon collection of the core samples, a visual determination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

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

Sediment thickness data processing

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

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



GIS Work

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

Water Quality

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

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

Summary

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