Total Maximum Daily Load
For Siltation and Nutrients
Badger Creek Lake
Madison County, Iowa

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Iowa Department of Natural Resources
TMDL & Water Quality Assessment Section

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TMDL for Siltation and Nutrients
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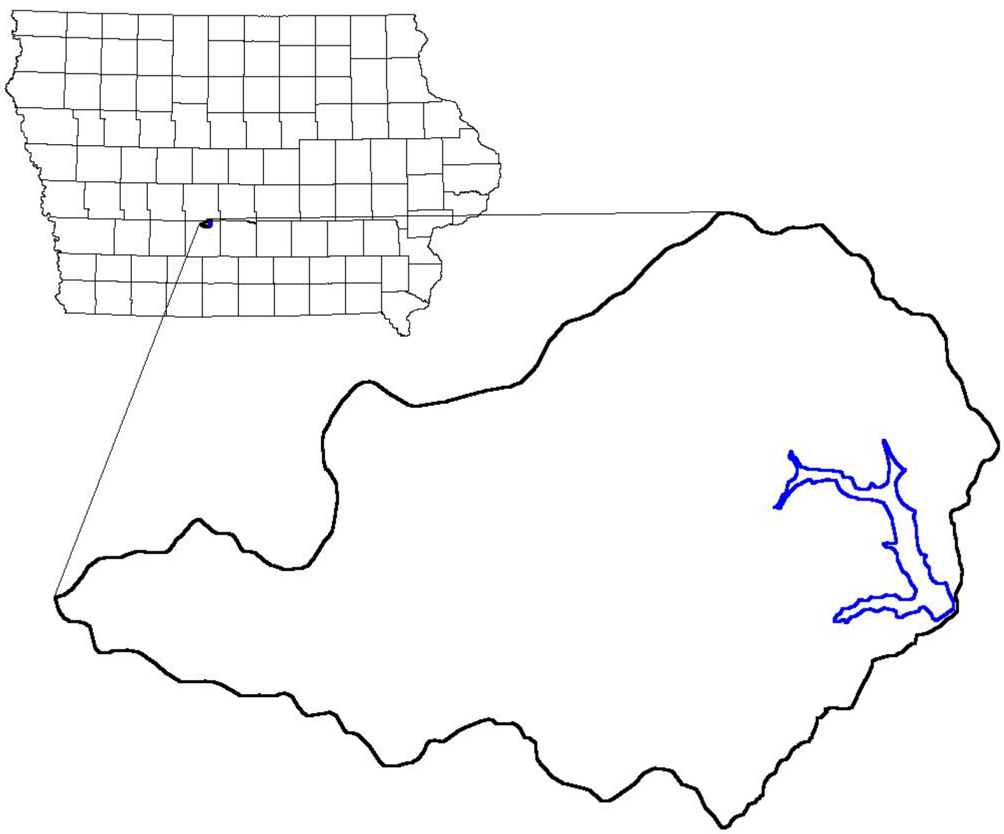
Waterbody Name:	Badger Creek Lake
IDNR Waterbody ID:	IA 04-LDM-03080-L
Hydrologic Unit Code:	HUC12 071000080403
Location:	Section 13 T77N R27W
Latitude:	41 Deg. 28 Min. 30 Sec N
Longitude:	93 Deg. 54 Min. 51 Sec W
Use Designation Class:	A (primary contact recreation) B(LW) (aquatic life)
Watershed:	11,700 acres
Lake Area:	269 acres
Major River Basin:	Des Moines River Basin
Tributaries	Badger Creek
Receiving Water Body:	Badger Creek to North River
Pollutant:	Siltation and Nutrients
Pollutant Sources:	Agricultural nonpoint source
Impaired Use	Aquatic Life
1998 303d Priority:	Low



1. Introduction

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. Badger Creek Lake has been identified as partially supporting its aquatic life uses due to excessive siltation and nutrients. The purpose of these TMDLs for Badger Creek Lake is to calculate the maximum amount of siltation and nutrients that the lake can receive and still meet water quality standards, and then develop an allocation of that amount of siltation and nutrients to the sources in the watershed.

Specifically this siltation and nutrient TMDLs for Badger Creek Lake will:

- Identify the adverse impact that siltation and nutrients are having on the designated uses of the lake.
- Describe how siltation and nutrient loads in the lake violate the water quality standards.
- Identify target conditions and loads that assure the designated uses will be achieved.
- Calculate acceptable siltation and nutrient limits, including a margin of safety, and allocate the loads to the sources.
- Provide implementation guidance for IDNR staff and watershed stakeholders to achieve designated use goals.

The IDNR believes that sufficient evidence and information is available to begin the process of restoring Badger Creek Lake. The Department acknowledges that to fully restore the aquatic life uses at Badger Creek Lake, additional information will likely be necessary. In order to accomplish the goals of these TMDLs, a phased approach will be used. By approaching the restoration process in phases, feedback from future assessments can be incorporated into the plan.

Phase I of these TMDLs for Badger Creek Lake will develop target siltation and nutrient limits based on a reduction of the current levels that will be protective of the aquatic life uses. Phase II will evaluate the effect those targets have on the intended results. Included in Phase II will be monitoring for results, reevaluating the extent of the siltation and nutrient impairments, and evaluating if the specific aquatic life impairments originally identified in the TMDL have been remedied.

2. Description of Waterbody and Watershed

Badger Creek Lake was constructed in 1980 and is located 9 miles east of Earlham, Iowa. It is a 269-acre lake with a mean depth of 10 feet, a maximum depth of 25 feet, and a storage volume of 2,616 acre-feet. The lake and park provide facilities for boating, fishing, camping, picnicking, and hiking. Park usage is estimated at approximately 68,000 visits per year.

The Badger Creek Lake watershed has an area of approximately 11,700 acres and has a watershed-to-lake ratio of 43:1. Land use data was collected in 2000 for Table 1.

Table 1. Landuse in the Badger Creek Lake watershed

Landuse	Area in Acres	Percent of Total Area
Cropland	4,914	42
Pasture/Hayland/Grass	6,201	53
Timber	468	4
Other (roads, etc)	117	1
Total	11,700	100

3. Applicable Water Quality Standards

The *Iowa Water Quality Standards* (IAC, 2000) list the designated uses for Badger Creek Lake as Primary Contact Recreation (Class A) and Aquatic Life (Class B(LW)). The State of Iowa does not have numeric water quality standards for siltation or nutrients. The aquatic life uses (Class B) for Badger Creek Lake have been assessed as partially supported due to excessive siltation and nutrients since 1992. The assessment of partially supporting of Class B(LW) has continued to be used in subsequent biennial reports. Excess siltation and nutrients impact the Class B(LW) designated use by altering the physical and chemical characteristics of the lake so that a balanced community normally associated with lake-like conditions is not maintained (IAC 567-61.3(1)b(7)).

The altering of the physical and chemical characteristics caused by excess siltation and nutrients include the following impacts to the beneficial uses: 1) interference with reproduction and growth of fish and other aquatic life; 2) creating a light-limiting environment that interferes with establishment of aquatic vegetation; and, 3) excessive suspension of siltation and nutrient rich water create poor water quality that inhibits proper functioning of aquatic life.

The primary impact of sediment at Badger Creek Lake is identified as interference with reproduction and growth of fish and other aquatic life. IDNR Fisheries biologists cited that siltation impacts aquatic life primarily in the upper portions of the lake. Although the entire lake was listed, it is the excessive sediment deposition in the upper arms of the lake that has lead to the lake being assessed as not meeting water quality standards. The upper arms of the lake are shallow and were ideal as an aquatic habitat. Those areas are now covered with fine silt that make successful spawning almost impossible. The deposition of sediment in these arms has severely limited the fishery in the entire lake.

Excess nutrients are causing the lake to become hypereutrophic, which has resulted in occasional fishkills. Excess nutrients are causing large algae blooms in the lake. When the algae die off, oxygen in the lake is consumed causing low dissolved oxygen levels and resulting in fish kills.

4. Water Quality Conditions

4.1 Water Quality Studies

Water Quality studies have been conducted at Badger Creek Lake in 1990 and 2000-present (Bachmann et al., 1994, Downing and Ramstack, 2002). Additional monitoring was completed by University Hygienic Laboratory under contract with the IDNR in 2002 in support of TMDL development. A feasibility study was completed by the IDNR Fisheries Bureau to determine possible options for raising the lake level.

Samples were collected three times each summer for the lake studies conducted in 1992 (Bachmann et al., 1994). This data is shown in Tables 2 in the Appendix.

Badger Creek Lake was sampled again in 2000-01 as part of the Iowa Lakes Survey (Downing and Ramstack, 2002). This survey will sample the lake three times each summer for five years. The data collected in 2000-01 is shown in Tables 3 and 4 (Appendix).

Badger Creek Lake was monitored from March 2002 to August 2002 by UHL under contract with the IDNR. This data is summarized in Tables 5-7 in the Appendix.

4.2 Angling (Mike McGhee, IDNR Fisheries Biologist)
Badger Creek was initially impounded in 1980. The fishery developed, but had problems. It was dominated by small, slow growing crappie (5-7") and big numbers of 6 to 8 inch bullhead. The lake was lowered and the fish population renovated (killed) and restocked in the fall of 1984. This time everything worked due to fall stocking of 5 inch largemouth bass instead of 2 inch bass the following spring. The lake continues to be a good fishery providing decent bass, bluegill and crappies. In fact, it is a very popular bass tournament fishing spot. The channel catfish population did not develop until we started stocking larger channel catfish (large mouth bass were preying on the small catfish).

This lake shouldn't have been a good fishing lake the last 15 years, but it is. However, we are on the edge. Highly eutrophic waters and severe summer algae blooms create problems. We have experienced several small summer kills and the frequency and length of the summer algae blooms seem to be on the increase. One saving grace is that the lake is missing a common carp population.

Grass carp were stocked into Badger Creek in 1987 in response to extensive aquatic vegetation development, but none have been stocked in over 10 years and no future stockings are planned. Some weedbed growth is returning to the lake, but more is needed. Severe shoreline erosion along 1.5 miles of shoreline is contributing to water quality problems.

In regards to the upper end of the lake above the bridge, it was always shallow, except for the creek channel. However continued siltation is making the area less accessible. This has resulted in loss of fishing habitat and fishing area; spawning areas have been diminished but plenty of spots remain. Turbidity has increased in the upper end and fewer people use this lake area. We probably need a combination of silt dikes, dredging, shoreline protection, watershed work and lake expansion to remedy the problem.

5. Desired Target

The listing of Badger Creek Lake is based on narrative criteria. Badger Creek Lake was included on the list of Iowa impaired waters based on the best professional judgment of IDNR field staff regarding the water quality. Badger Creek Lake has been assessed as "partially supported" since 1992. The IDNR Fisheries Bureau indicates that siltation and nutrients are impairing the Class B(LW) designated use. There are no numeric criteria for siltation or nutrients applicable to Badger Creek Lake or its sources in Chapter 61 of the Iowa Water Quality Standards (Iowa, 2000). The targets for Badger Creek Lake need to include siltation and nutrient loads as well as a measurement of the aquatic life.

This is a phased TMDL and each phase will incorporate a separate target. Phase I will include a target for siltation and nutrient delivery to the lake. Monitoring the water quality and the fishery of the lake will be included in both Phase I and Phase II.

5.1 Nutrients

As discussed in section 3, the State of Iowa does not have numeric water quality criteria for nutrients applicable to Badger Creek Lake. Therefore, an acceptable nutrient target needs to be identified.

Trophic State Indices (TSI) are an attempt to provide a single quantitative index for the purpose of classifying and ranking lakes, most often from the standpoint of assessing water quality. The Carlson Index is a measure of the trophic status of a body of water using several measures of water quality including: transparency or turbidity (Secchi disk depth), chlorophyll-a concentrations (algal biomass), and total phosphorous levels (usually the limiting nutrient in algal growth).

The Carlson TSI ranges along a scale from 0-100 that is based upon relationships between secchi depth and surface water concentrations of algal chlorophyll, and total phosphorous for a set of North American lakes. A TSI value above 70 indicates a very productive waterbody with hypereutrophic characteristics; low clarity, high chlorophyll and phosphorous concentrations, and noxious surface scums of algae.

Without numeric water quality standards to base a target on, the Carlson TSI will be used to determine the Phase I target for nutrients. The Phase I target is to reduce the trophic state of Badger Creek Lake to below hypereutrophic. This would be reflected in a TSI of 70. The current TSI based on chlorophyll-a is 77, for total phosphorous is 78, and based on transparency (secchi) is 60. The nutrient target for Badger Creek Lake will be measured by a Carlson TSI for chlorophyll-a and total phosphorous of 70 or below, and to maintain the TSI for transparency below 70.

TSI values for Badger Creek Lake

Year	Chl-a	Total Phosphorous	Transparency
2000*	65	87	71
2001*	74	70	62
2002**	77	78	60

* Iowa Lakes Survey (Downing and Ramstack, 2002).
** IDNR monitoring under contract with UHL

EUTROMOD modeling was completed on Badger Creek Lake and indicate the current phosphorous load to the lake is 25,229 lbs/year. To achieve a total phosphorous TSI of 70, the in-lake total phosphorous concentration needs to be at approximately 100 µg/L. To achieve this in-lake concentration, the phosphorous loading to the lake needs to be reduced to 7,487 pounds/year (70% reduction). This loading represents the allowable amount of phosphorous delivered from internal and external sources.

5.2 Siltation

The Phase I sediment delivery target will address the amount of sediment delivered to the lake from the watershed. A direct measure of the sediment load is difficult to make given seasonal variability and actual measurement tools. Acceptable estimates using established soil loss equations can be made to predict the erosion rates in the watershed, and subsequent delivery to the lake.

The EUTROMOD modeling completed for Badger Creek Lake and its watershed predicted a current sediment delivery of 12,696 tons/year based on landuse in the watershed. Since there are no numeric standards for sediment or siltation, an appropriate target for sediment needs to be identified. This is a phased TMDL, which allows for the targets to be revisited and adjusted as new data and information are available. Phosphorous is typically bound with soil and sediment delivery, and therefore the initial or Phase I target for sediment is to reduce sediment loading by the same percent reduction for phosphorous, a 70% reduction. This sets the Phase I siltation target at 3,809 tons/year delivered to the lake.

5.3 Aquatic Life

The Phase II aquatic life target for this TMDL will be achieved when the fishery of Badger Creek Lake is determined to be fully supporting the Class B aquatic life uses. This determination will be accomplished through an assessment conducted by the IDNR Fisheries Bureau. This assessment will be in accordance with the Statewide Biological Sampling Plan protocol (Larscheid, 2001). This protocol is currently being used to develop benchmarks for the fishery of Iowa's lakes. The results from the Badger Creek Lake assessment will be compared with the benchmarks being developed. These assessments will include age, growth, size structure, body condition, relative abundance, and species.

Badger Creek Lake will not be considered restored until the Phase II target is achieved. If the aquatic life target is achieved prior to the sediment and nutrient delivery targets, then the level of land practices may be maintained at a level at or above those in place at the time of the assessment. If however, after a reasonable time following the completion of the sediment and nutrient delivery practices the aquatic life has not been restored, then further study and practices may be necessary.

6. Loading Capacity

The State of Iowa does not have numeric water quality criteria for siltation or nutrients that apply to Badger Creek Lake. Badger Creek Lake was included on the list of Iowa impaired waters based on the best professional judgment of IDNR field staff regarding the water quality. Excess siltation and nutrients are causing impairment of the Class B(LW) designated uses.

The Phase I nutrient target for Badger Creek Lake is to achieve a Carlson TSI for total phosphorous and chlorophyll-a of 70. This initial target will bring the lake below hypereutrophy and result in an initial step towards restoring the impaired designated uses. The Phase I target of a TSI value of 70 results in a loading capacity of 7,487 pounds/year of phosphorous.

The Phase I sediment target for Badger Creek Lake is based on a reduction of the current modeled sediment delivery. This target results in a loading capacity of 3,809 tons/year of sediment delivered to the lake. This is an initial step towards improving water quality for the aquatic life by reducing the amount of sediment delivered to the lake.

7. Pollutant Sources
Water quality in Badger Creek Lake is influenced only by nonpoint sources. There are no point source discharges in the watershed.

There are no point source discharges in the watershed. Nonpoint source pollution is caused by material transported to the lake by runoff from the watershed. Gully, streambank/streambed, sheet and rill, and shoreline erosion can contribute significantly to poor water quality and deterioration of the lake. Shoreline erosion along approximately 1.5 miles of shoreline is contributing significant amounts of sediment to Badger Creek Lake. Internal resuspension of sediment and nutrients can be a significant source nutrients to the water column, and also contribute to the poor water clarity by maintaining sediments in suspension.

8. Pollutant Allocation
8.1 Point Sources
There are no point source discharges in the Badger Creek Lake watershed. Therefore, the Wasteload Allocation for siltation and nutrients established under this TMDL is zero.

8.2 Non-Point Sources
Production agriculture dominates the watershed of Badger Creek Lake. Sheet and rill erosion from the large watershed contributes both sediment and nutrients to the lake. Shoreline erosion has been identified as a direct source of sediment and nutrients to Badger Creek Lake. In addition, resuspension of sediment and nutrients from the lake bottom is a significant contributor to the poor water quality at Badger Creek Lake.

Badger Creek Lake was modeled using EUTROMOD to determine the reduction of nutrient inputs necessary to achieve the desired targets. In order to achieve a total phosphorous concentration of 100 µg/L, a 70% reduction in phosphorous loading is needed from a combination of internal and external sources. The current phosphorous load as determined by EUTROMOD is 25,229 lbs/year. Therefore, a 70% reduction from internal and external sources results in a Load Allocation for total phosphorous of 7,487 lbs/year. Reductions of total phosphorous from internal sources will be achieved by in-lake improvements, including rough fish removal and shoreline stabilization. The Load Allocation for sediment established under this TMDL is 3,809 tons/year.

8.3 Load Allocation and Margin of Safety
The margin of safety for this TMDL is implicit. The multiple targets for this TMDL assures that the aquatic life uses will be restored regardless of the accuracy of the Phase I siltation and nutrient delivery targets. Failure to achieve water quality standards will result in review of the TMDL, allocations, and/or sediment management approaches and probable revision. In addition, calculations were made using conservative estimates.

9. Seasonal Variation
This TMDL accounts for seasonal variation by recognizing that (1) loading varies substantially by season and between years, and (2) impacts are felt over multi-year timeframes. Sediment and nutrient loading and transport are predictable only over long timeframes. Moreover, in contrast to pollutants that cause short-term beneficial use impacts and are thus sensitive to seasonal variation and critical conditions, the sediment

and nutrient impacts in this watershed occur over much longer time scales. For these reasons, the longer timeframe (tons per year) used in this TMDL is appropriate.

10. Monitoring

Monitoring will be completed at Badger Creek Lake as part of the Iowa Lakes Survey. In-lake water monitoring will be completed three times per year for each of the field seasons 2000 – 2004. In addition, the IDNR Fisheries Bureau will conduct an assessment of the fishery of Badger Creek Lake in accordance with the Statewide Biological Sampling Plan protocol (Larscheid, 2001). This assessment will be completed after the lake restoration project is complete. At the completion of this assessment, the data will be evaluated to determine the listing status of Badger Creek Lake.

A lake mapping and sediment core study was undertaken by the IDNR and USGS in the fall of 2002. This data will provide a bathymetric map of Badger Creek Lake, estimates of sediment volume and location, and sediment core samples from the lake basin. This information will be used to determine more precisely the current amount and location of sediment in the lake, and also serve as a baseline for measuring TMDL implementation success. While this information is not available for the development of the TMDL, it will be very useful in Phase II of the TMDL.

11. Implementation

The Iowa Department of Natural Resources recognizes that an implementation plan is not a required component of a Total Maximum Daily Load. However, the IDNR offers the following implementation strategy to IDNR staff, partners, and watershed stakeholders as a guide to improving water quality at Badger Creek Lake.

Although a comprehensive watershed plan is not yet available for Badger Creek Lake, there are some pollutant sources identified that can be reduced and work towards overall water quality improvement at the lake. Shoreline erosion has been identified as a direct source of sediment and nutrients to the lake. Rip-rap or establishment of aquatic macrophytes along the shoreline can reduce or eliminate this source of sediment and nutrients. The establishment of aquatic macrophytes will also help to remove excess nutrients from the lake, and likely increase transparency. Upland conservation measures should continue to be promoted, reducing sediment and nutrient delivery from sheet and rill erosion. Streambank and streambed erosion can be reduced through the installation of riparian corridors, buffer strips, and livestock exclusion.

A Feasiblity study was completed for Badger Creek Lake in 2001. This study evaluated raising the height of the dam, which would increase the surface area and the mean depth. Generally deeper lakes in Iowa have better water quality and healthier aquatic communities than shallow lakes. A deeper mean depth would likely result in improved water quality, by allowing the lake to stratify and reducing the amount of nutrients being recycled within the lake. An increase in lake size would also provide more habitat within the lake, resulting in an improved fishery at Badger Creek Lake. This project has a large capital cost, and would result in facilities (boat ramps, roads, camping areas, etc.) being moved and reconstructed. This project would also require the cooperation of local landowners to willingly sell land to the IDNR for completion of the project.

As part of Phase II, monitoring will be completed at Badger Creek Lake. This includes the Iowa Lakes Survey and a fishery assessment completed by the IDNR Fisheries

Bureau. At the completion of this assessment, the data will be evaluated to determine the listing status of Badger Creek Lake.

12. Public Participation

Public meetings regarding the procedure and timetable for developing the Badger Creek Lake TMDL were held on January 14, 2002, in Des Moines, Iowa; and in Earlham, Iowa. A draft version of the TMDL was available for public notice from November 14 through December 6, 2002. Appropriate comments will be incorporated into the TMDL prior to submittal to EPA for final approval.

13. References

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14. Appendix

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

Date Collected	6/16/1992	7/16/1992	8/18/1992
Secchi (meters)	0.7	0.5	0.5
Suspended Solids (mg/L)	5.4	11.9	13.3
Total Nitrogen (mg/L)	1.34	1.3	1.34
Total Phosphorus (mg/L)	0.070	0.157	0.262
Chlorophyll a (ug/L) Corrected	12.6	49.7	63.2

Each sample was a composite water sample from all depths of the lake.

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

Parameter	**6/30/2000**	**7/26/2000**	**8/23/2000**
Secchi Depth m	0.6	0.5	0.4
Chlorophyll (ug/L)	22	50	32
NH_3+NH_4^+ -N (ug/L)	1047	1028	847
NH_3 –N (un-ionized) (ug/L)	14	11	--
NO_3+NO_2-N (mg/L)	0.19	0.13	0.25
Total Nitrogen (mg/L as N)	1.77	1.69	1.93
Total Phosphorus (ug/l as P)	344	181	305
Silica (mg/L as SiO_2)	24	18	32
pH	7.4	7.3	7.5
Alkalinity (mg/L)	224	113	111
Total Suspended Solids (mg/L)	16.0	6.6	9.2
Inorganic Suspended Solids (mg/L)	8.8	2.8	4.6
Volatile Suspended Solids (mg/L)	7.2	3.7	4.6

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

Parameter	**5/31/2001**	**6/28/2001**	**8/1/2001**
Secchi Depth m	2.1	0.9	0.5
Chlorophyll (ug/L)	12	105	85
NH_3+NH_4^+ -N (ug/L)	242	485	496
NH_3 –N (un-ionized) (ug/L)	11	153	52
NO_3+NO_2-N (mg/L)	0.40	0.04	0.20
Total Nitrogen (mg/L as N)	0.84	2.56	1.64
Total Phosphorus (ug/l as P)	69	96	443
Silica (mg/L as SiO_2)	4	12	16
pH	8.2	8.9	8.2
Alkalinity (mg/L)	127	88	108
Total Suspended Solids (mg/L)	11.1	33.2	11.5
Inorganic Suspended Solids (mg/L)	6.4	18.9	2.2
Volatile Suspended Solids (mg/L)	4.7	14.3	9.3

Table 5. Surface sample results from Badger Creek Lake, collected by UHL 3/2002 – 8/2002

Parameter	Min	Max	Median	St Dev
Secchi (m)	0.5	2	1.3	0.45
Ammonia Nitrogen as N (mg/L)	0.05	3.4	0.05	1.21
Chlorophyll a – corrected (ug/L)	5	140	7	56.91
Dissolved Oxygen (mg/L)	4	12	10	2.76
pH	8.3	9.1	8.4	0.34
Nitrate + Nitrite Nitrogen as N (mg/L)	0.1	0.1	0.1	0.0
Total Kjeldahl Nitrogen (mg/L)	0.68	2.6	1	0.77
Ortho Phosphate as P (ug/L)	50	280	50	80
Total Phosphate as P (ug/L)	50	450	80	140
Total Suspended Solids (mg/L)	4	58	9	16.79

Table 6. Mid-water column sample results from Badger Creek Lake, collected by UHL 3/2002 – 8/2002

Parameter	Min	Max	Median	St Dev
Ammonia Nitrogen as N (mg/L)	0.05	1.5	0.17	0.52
Chlorophyll a – corrected (ug/L)	4	70	7	30.05
Dissolved Oxygen (mg/L)	3.4	11.9	9.5	2.95
pH	8.3	8.8	8.4	0.16
Nitrate + Nitrite Nitrogen as N (mg/L)	0.1	0.1	0.1	0.0
Total Kjeldahl Nitrogen (mg/L)	0.65	2.5	0.99	0.66
Ortho Phosphate as P (ug/L)	50	270	50	80
Total Phosphate as P (ug/L)	50	420	80	140
Total Suspended Solids (mg/L)	5	90	7	29.19

Table 7. Bottom sample results from Badger Creek Lake, collected by UHL 3/2002 – 8/2002

Parameter	Min	Max	Median	St Dev
Ammonia Nitrogen as N (mg/L)	0.05	1.6	0.11	0.59
Chlorophyll a – corrected (ug/L)	4	27	7	7.99
Dissolved Oxygen (mg/L)	1.8	11.8	8.5	4.34
pH	7.9	8.5	8.3	0.25
Nitrate + Nitrite Nitrogen as N (mg/L)	0.1	0.1	0.1	0.0
Total Kjeldahl Nitrogen (mg/L)	0.73	2.4	1.1	0.64
Ortho Phosphate as P (ug/L)	0.05	0.71	0.05	0.25
Total Phosphate as P (ug/L)	0.05	0.42	0.11	0.15
Total Suspended Solids (mg/L)	4	90	6.5	29.35