Total Maximum Daily Load
For Siltation and Nutrients
Lake of Three Fires
Taylor County, Iowa

December 2002

Iowa Department of Natural Resources
TMDL & Water Quality Assessment Section

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TMDL for Siltation and Nutrients
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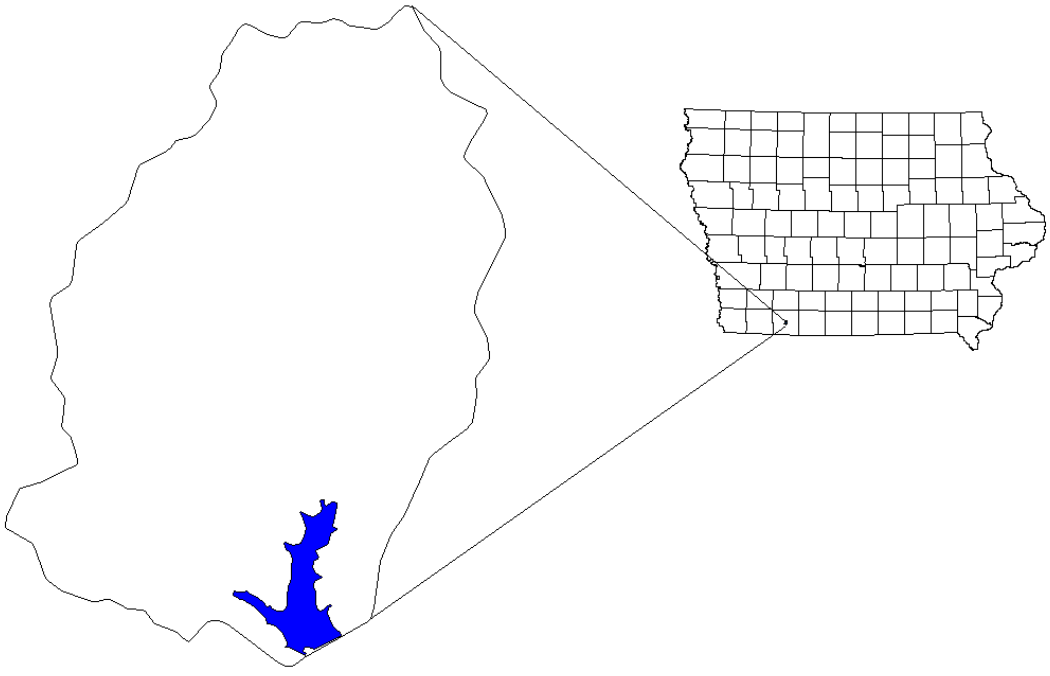
Waterbody Name:	Lake of Three Fires
IDNR Waterbody ID:	IA 05-PLA-00335-L
Hydrologic Unit Code:	102400130104
Location:	Section 7 T68N R33W
Latitude:	40.7122° N
Longitude:	94.6902° W
Use Designation Class:	A (primary contact recreation) B(LW) (aquatic life) C (potable water source
Watershed:	3,633 acres
Lake Area:	86 acres
Major River Basin:	Southern Iowa River Basin
Receiving Water Body:	East Fork One Hundred and Two River
Pollutant:	Siltation and Nutrients
Pollutant Sources:	Agricultural NPS
Impaired Use	Aquatic Life
1998 303d Priority:	High



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. Lake of Three Fires has been identified as impaired by siltation and nutrients. The purpose of these TMDLs for Lake of Three Fires 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 these TMDLs for Lake of Three Fires will:

- Identify the adverse impact that siltation and nutrients are having on the designated use of the lake and how the excess sediment and nutrient loads are impairing the water quality standards,
- Identify a target by which the waterbody can be assured to maintain its designated uses,
- Calculate acceptable sediment and nutrient loads, including a margin of safety, and allocate to the sources, and
- Present a brief implementation plan to offer guidance to Department staff, IDNR partners, and watershed stakeholders in an effort to achieve the goals of the TMDL and maintain the lake's intended uses.

The IDNR believes that sufficient evidence and information is available to protect Lake of Three Fires from further degradation by siltation and nutrients. The Department acknowledges, however, that additional information will likely be necessary. Therefore, in order to accomplish the goals of these TMDLs, a phased approach will be used. This will allow feedback from future assessments to be incorporated into the plan.

Phase I of this TMDL for Lake of Three Fires will be to reduce the sediment and nutrient loads that are impairing the aquatic life uses. Phase II will evaluate the effect that the sediment and nutrient load targets have on the intended results. In Phase II, monitoring of Lake of Three Fires will continue and the allocation of sediment and nutrients will be reassessed. The phased approach allows IDNR to utilize a feedback loop to determine if the initial sediment and nutrient load targets have been effective.

2. Description of Waterbody and Watershed

2.1 General Information

Lake of Three Fires was built by the Civilian Conservation Corps in 1935 as an impoundment on several small streams that discharge into the East Fork One Hundred and Two River. Lake of Three Fires is located 3 miles north of Bedford in southwest Iowa. The lake has a surface area of 86 acres, a mean depth of 8 feet, a maximum depth of 13 feet, a storage volume of 716 acre-feet.

Lake of Three Fires lies within the 694 acre park and is owned and managed by the IDNR. Lake of Three Fires has designated uses of Class A (primary contact recreation), Class B(LW) (aquatic life), and Class C (potable water source). The lake and park areas provide facilities for fishing, camping, swimming, boating and picnicking. Park use is approximately 71,500 visits per year.

The Lake of Three Fires watershed has an area of approximately 3,633 acres and has a watershed to lake ratio of 42:1. The landuses and associated areas for the watershed are shown in the table below.

Table 1. Landuse in the Lake of Three Fires watershed (2002)

Landuse	Area in Acres	Percent of Total Area
Cropland	758	21
Grass and CRP	1,878	52
Timber	563	16
Pasture and Hay	310	8
Ponds	65	2
Other (Roads Farmsteads, etc.)	59	1
Total	3,633	100

The 2002 landuse in the Lake of Three Fires watershed is currently dominated by grass and CRP. This landuse currently accounts for 52% of the watershed (1,878 acres). Cropland comprised 21 percent of the watershed (758 acres), and pasture and hay account for 8 percent of the watershed (310 acres). The remaining area includes timber, ponds, farmsteads, and roads.

2.2 Current Watershed Conditions

The current watershed characteristics were identified through a cooperative effort between the Taylor County Soil and Water Conservation District, the local NRCS office, and the IDNR Water Quality Bureau as part of the Lake of Three Fires Watershed Assessment (IDNR, 2002).

As is the case in most Iowa watersheds, agricultural interest dominates the landscape of the Lake of Three Fires watershed. However, the water quality threat that these activities pose has been reduced drastically over the years. The amount of land planted to row crop probably peaked in the late 1970's with an estimated 70% of the watershed planted to corn and beans. Currently, less than 20% of the watershed is annually planted to corn or soybeans, and of these acres, over 80% are no tilled.

Presently, 40% of the watershed is enrolled in the Conservation Reserve Program (CRP). If and when these acres are brought back into row crop production could have a profound impact upon the water quality of the Lake of Three Fires. If the CRP ground is not re-enrolled and planted to a commodity crop, the sediment delivery rates from this ground are expected to increase and will be largely dependent upon the best management practices adopted, and whether portions of the vegetative cover are maintained.

In the late 1970's to early 1980's, the Taylor SWCD provided special funding to encourage BMP implementation within the Lake of Three Fires watershed. Through this program, numerous practices such as grade stabilization structures and terraces were installed throughout the watershed.

The watershed assessment completed in 2002 determined that the average soil loss in the Lake of Three Fires watershed is 0.94 t/ac/yr. This equates to 569 t/yr (0.16 t/ac/yr) delivered to the Lake of Three Fires. This represents a loss of 0.29 acre-feet per year

from the lake (IDNR, 2002). EUTROMOD modeling calculated a sediment delivery of 517 tons/year, which correlates very well with the field level watershed assessment.

3. Applicable Water Quality Standards

The *Iowa Water Quality Standards* (Iowa, 2000) list the designated uses for Lake of Three Fires as Primary Contact Recreation (Class A), Aquatic Life (Class B(LW)), and Potable Water Source (Class C). Lake of Three Fires also has general uses of secondary contact recreation, domestic uses, and wildlife watering.

The State of Iowa does not have numeric water quality criteria for siltation or nutrients that apply to Lake of Three Fires. Lake of Three Fires was included on the list of Iowa impaired waters based on the best professional judgment of IDNR field staff regarding the water quality. Lake of Three Fires has been assessed as "partially supported" since 1992. The IDNR Fisheries Bureau indicated that siltation and nutrients were impairing the Class B(LW) designated use. The Class B(LW) designated use states that the physical and chemical characteristics are suitable to maintain a balanced community normally associated with lake-like conditions (IAC 567-61.3(1)b(7)). Excess siltation and nutrients are altering the physical and chemical characteristics of the lake so that a balanced community normally associated with lake-like conditions is not maintained. Excess siltation and nutrients are impairing the beneficial uses of aquatic habitat, spawning and reproduction, and sport fishing.

4. Water Quality Conditions

4.1 Water Quality Studies

Water quality surveys have been conducted on Lake of Three Fires in 1979, 1989, 1990, 1999-2000, and 2000-01 (Bachmann et al., 1980; Kennedy and Miller, 1990; Bachmann et al., 1994; Downing et al., 2001; Downing and Ramstack, 2002). In addition, a watershed assessment was completed in 2002 by the IDNR in cooperation with the Taylor County SWCD and the local NRCS office (IDNR, 2002), and also in 1991 by the Division of Soil Conservation (IDALS-DSC, 1991).

Samples were collected three times each summer for the lake studies conducted in 1979 and 1990 (Bachmann et al., 1980, Bachmann et al., 1994). This data is shown in Tables 2 and 4 in the Appendix.

The University Hygienic lab sampled Lake of Three Fires on three occasions in 1989 (Kennedy and Miller, 1990). This data is shown in Table 3 (Appendix).

A diagnostic/feasibility study was completed for Lake of Three Fires in 2002 (Downing, et al., 2002). Water quality monitoring was completed on the lake and tributaries from July 1999 – July 2000.

Lake of Three Fires 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 5 and 6 (Appendix).

Lake of Three Fires was modeled using CNET and EUTROMOD to determine the current phosphorous delivery to the lake. This modeling predicted the current phosphorous loading is 2,235 lbs/year.

4.2 Angling

Fishery analysis. (Mike McGhee, Fisheries Biologist, IDNR)
Lake of Three Fires was impounded in the late 1930's. The earliest fish surveys in the IDNR archives are 1948. Fisheries survey information and anecdotal records for over 50 years have always indicated a fishery that has had problems due to extended periods of poor water quality. This has then resulted in a below average fishery dominated by slow growing, substandard crappie populations and significant carp numbers. The only "bright spots" have been an average channel catfish fishery and an occasional trophy largemouth bass available to fisherman.

The fish population was totally renovated for the first time in 1962 and again in 1980 in an attempt to improve the fisheries. However, just as the desired fishery starts to develop, carp reenter the lake up the spillway and the fishery deteriorates. The current spillway design allows movement of fish up from the stream below the dam into the lake during high water discharge events.

Flathead catfish were stocked beginning in 1993 to control a high density, slow growing bullhead population, and it has proved successful. However, the rest of the fishery can best be described as marginal. An intensive mark and recapture fish population estimate was undertaken by Mt. Ayr DNR fisheries management in the spring of 2000. Results indicated white and black crappie represented 82% of the fish in the lake by number and 36% by weight, with only 1% of the crappie greater than 9 inches in total length. Carp were 2% of the fish population by number, but represented 36% of the fishery by weight. Bluegill, largemouth bass and channel catfish collectively contributed 16% of the population by number and only 17% by weight. Flathead catfish were sampled, but no recaptures were detected. Total fish biomass was 358 lbs/acre, with less than 60 lbs/acre of crappie, bluegill, channel catfish and largemouth bass of a size that anglers would keep.

A late August 2001 fisheries survey indicated that gizzard shad were now part of the Lake of Three Fires fisheries component. Shad had never been documented in over 50 years of sampling effort. It is likely that they accessed the lake swimming up the concrete spillway. Thousands of 5.5 to 7.5 inch gizzard shad were observed in the summer electrofishing survey. The only bright spot was the largemouth bass population sampled during electrofishing, at a rate of 56 fish/hour, with the majority of the bass twelve to eighteen inches in length.

A workplan is being developed that will ultimately result in an improved fishery. A combination of dredging, additional soil conservation practices in the watershed, spillway modification, total fishery renovation and a fish habitat enhancement project will improve water quality and allow a quality fishery to develop.

5. Desired Target

The listing of Lake of Three Fires is based on narrative criteria. Lake of Three Fires 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 Lake of Three Fires or its sources in Chapter 61 of the Iowa Water Quality Standards (Iowa, 2000). The targets for Lake of Three Fires 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 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.

Gross sheet and rill erosion for the watershed was calculated using the Revised Universal Soil Loss Equation (RUSLE) and sediment delivery to Lake of Three Fires was determined using the erosion and sediment delivery worksheet (USDA-NRCS, 1998). The watershed assessment completed in 2002 determined that the average soil loss in the Lake of Three Fires watershed is 0.94 t/ac/yr. This equates to 569 t/yr delivered to the Lake of Three Fires. This represents a loss of 0.29 acre-feet per year from the lake. EUTROMOD modeling calculated a current sediment delivery of 517 tons/year, which correlates very well with the field level watershed assessment.

A watershed assessment completed in 1991 by the Division of Soil Conservation indicated that the sediment delivery rate under the existing (1991) conditions was 5,704 tons/year. This assessment also indicated that when all conservation plans were fully implemented in accordance with the Food Security Act (FSA), the sediment delivery rate to Lake of Three Fires would be reduced to 1,342 tons/year. The Taylor SWCD and local NRCS office have worked to implement the FSA conservation requirements, and the watershed assessment completed in 2002 indicates that the current sediment delivery rate to Lake of Three Fires is 569 tons/year. This equates to a 90% reduction since 1991.

The recent watershed improvements have resulted in a large (90%) reduction in sediment delivered to the lake. However, large amounts of sediment have historically been delivered to the lake, and continue to cause problems from loss of habitat, and resuspension. The sediment target is to maintain or reduce current sediment delivery rates to the lake. The sediment delivery target is set as the estimated current sediment delivery rate to Lake of Three Fires of 569 tons/year (based on the 2002 watershed assessment).

5.2 Nutrients

As discussed in section 3, the State of Iowa does not have numeric water quality criteria for nutrients applicable to Lake of Three Fires. 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 the Lake of Three Fires to below hypereutrophic. This would be reflected in a TSI of 70. Recent TSI for Lake of Three Fires are in the table below. The nutrient target for Lake of Three Fires will be measured by a Carlson TSI for total phosphorous of 70 or below. While the chlorophyll-a TSI and transparency TSI are already at or below 70, as sediment and phosphorous delivery to the lake is reduced, transparency may improve and algae blooms may become more prominent and begin to express the excess nutrients in the water column. Therefore, the desired phase I target is to reduce the total phosphorous TSI to 70 or below, and maintain the chlorophyll-a TSI and transparency TSI at or below 70.

TSI values for Lake of Three Fires

Year	Chl-a	Total Phosphorous	Transparency
1999-2000*	62	76	73
2000**	63	84	69
2001**	63	72	69

* Lake of Three Fires Diagnostic Feasibility Study (Downing, et al., 2002).
** Iowa Lakes Survey (Downing and Ramstack, 2002).

The CNET and EUTROMOD modeling completed on Lake of Three Fires indicate the current phosphorous load to the lake is 2,235 lbs/year. EUTROMOD predicted an in lake total phosphorous concentration of 99 µg/L. This is half of the observed in lake average. This discrepancy can be explained by internal loading of phosphorous through resuspension of sediment and nutrients within the lake. This is due in part to the large carp population, which thrives in the shallow areas of the lake.

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 2,146 pounds/year (4% reduction). This loading represents the allowable amount of phosphorous delivered from internal and external sources. The internal loading will be reduced by a combination of in-lake measures, including dredging, spillway design renovation, and fish population renovation. These measures can be expected to significantly reduce the internal nutrient loading.

5.3 Aquatic Life

The Phase II aquatic life target for this TMDL will be achieved when the fishery of Lake of Three Fires 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 Lake of Three Fires assessment will be compared with the benchmarks being developed. These

assessments will include age, growth, size structure, body condition, relative abundance, and species.

Lake of Three Fires will not be considered restored until the Phase II target is achieved. If the aquatic life target is achieved prior to the nutrient delivery target, 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 Lake of Three Fires. Lake of Three Fires 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 use.

The implementation of ag best management practices in the last 10-20 years has resulted in a 90% sediment delivery reduction from 1991 to 2002. The sediment impairment to Lake of Three Fires is an historic problem, with very little sediment currently moving through the system. Therefore, the loading capacity for Lake of Three Fires is to maintain or reduce the current level of sediment delivery of 569 tons/year.

The Phase I nutrient target for Lake of Three Fires is to achieve a Carlson TSI for total phosphorous of 70, and to maintain the Carlson TSI for chlorophyll-a and transparency at or below 70. This initial target will bring the lake below hypereutrophy and result in an initial step towards restoring the aquatic life uses. The Phase I total phosphorous target of a TSI value of 70 results in a loading capacity of 2,146 pounds/year of phosphorous.

7. Pollutant Sources

Water quality in Lake of Three Fires is influenced only by nonpoint sources. There are no point source discharges in the watershed.

The watershed assessment completed in 2002 documented current landuse and potential non-point source pollutant sources. As described in section 2.2, the majority of the watershed is currently seeded to grass or CRP. Overall, very little sediment is moving through the watershed and into Lake of Three Fires. The existing cropland does provide a source of sediment and nutrients to the lake, especially when manure or commercial fertilizers are applied in excess.

A hog confinement is located in the northernmost portion of the watershed has the highest potential for causing water quality problems in Lake of Three Fires. This confinement applies manure to row crop ground in the watershed. An investigation of the operation's manure management plan and soil tests of the row crop ground are ongoing. Terraces are being installed post-harvest 2002 on the land in the watershed that receives manure application. This will substantially improve the soil conservation practices on this tract.

Very few active gullies or sites of streambank erosion were observed within the Lake of Three Fires watershed. This is likely due in part to the large number of structural BMP's and CRP acres in the watershed.

The Diagnostic/Feasibility study indicated that approximately 950 feet of shoreline was in need of stabilization (Downing, et al., 2002). However, no quantities or estimates of the amount of sediment were provided.

8. Pollutant Allocation

8.1 Point Sources

There are no point source discharges in the Lake of Three Fires watershed. Therefore, the Wasteload Allocation for siltation and nutrients established under this TMDL is zero.

8.2 Non-Point Sources

Historically, the majority of the watershed has been used for agriculture production, either row crop, hay, or pasture. Currently the majority of the watershed is being idled in grassland or CRP. Sheet and rill erosion from the agricultural ground is still the main source of sediment and nutrients to the lake. The Load Allocation established under this TMDL is 569 tons of sediment delivered to the lake from the watershed each year. The Load Allocation for nutrients is 2,146 pounds per year of phosphorous.

8.3 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 Lake of Three Fires 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. The IDNR Fisheries Bureau will begin additional watershed monitoring in 2003 to monitor watershed improvements and continuing sources of sediment and nutrients. In addition, the IDNR Fisheries Bureau will conduct an assessment of the fishery of Lake of Three Fires 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 Lake of Three Fires.

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 Lake of Three Fires.

This TMDL is being designed as a Phased TMDL. In Phase I, the amount of sediment and nutrients delivered to the lake will be reduced so that the TMDL is met. In-lake restoration and an assessment of the fishery will be completed during Phase II.

In Phase I of this TMDL, the amount of sediment delivered to Lake of Three Fires will be maintained or reduced. Although a sediment reduction is not called for at this time, future work will likely be done in the watershed to continue to reduce sediment and nutrient delivery to the lake. Modeling of sediment and nutrient delivery to Lake of Three Fires has been completed as part of the 2002 watershed assessment (IDNR, 2002).

Phosphorus and sediment delivery to the lake can be reduced through several best management practices in the watershed. Fencing of the riparian corridors would limit cattle access to streams and reduce sediment and nutrient delivery from the stream corridor. Perhaps the greatest threat to the future water quality is the expiration of CRP contracts on approximately 1,350 acres in the watershed. It is important to limit these areas for sediment and nutrient delivery to the lake, either by re-enrollment into CRP, permanent vegetation (perhaps through a conservation easement), or proper best management practices if the land is placed back into production agriculture.

During Phase II of the TMDL, in-lake restoration work will be completed to improve the fishery and overall water quality of the lake. As discussed previously, agricultural practices have changed significantly in the last 20 years. Prior to these improved practices, the delivery of sediment and nutrients to the lake was significantly higher than it is today. Once sediment and nutrients get into a lake they are retained and may be recycled within the system. This internal nutrient recycling is a major contributor to the continued poor water quality of Lake of Three Fires. The 2002 watershed assessment identified the current sediment delivery rates in the watershed, and when compared to a similar assessment completed in 1991, sediment delivery rates have been reduced by 90%. Because of the internal component to the degradation of the lake's water quality, improvements in water quality may not be realized without substantial in-lake work, including shoreline rip-rapping, establishment of aquatic vegetation, removal of rough fish, and dredging to remove nutrient laden sediments and deepen the lake.

Also as part of Phase II, monitoring will be completed at Lake of Three Fires. This includes the Iowa Lakes Survey, watershed monitoring by the IDNR Fisheries Bureau, and a fishery assessment completed by the IDNR Fisheries Bureau. 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 Lake of Three Fires.

12. Public Participation

Public meetings were held in Des Moines and Bedford regarding the proposed TMDL for siltation and nutrients for Lake of Three Fires on January 14 and January 29, 2002. A draft version of the TMDL was available for public notice from November 14 through

December 6, 2002. Comments received were reviewed and given consideration and, where appropriate, incorporated into the TMDL.

13. References

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14. Appendix

Table 2. Data collected in 1979 by Iowa State University (Bachmann, et al, 1980).

Date Collected	7/17/1979				8/8/1979			9/5/1979		
Depth (meters)	0	3	6	9	0	3	6	0	3	6
Secchi (meters)	.5				.6			.5		
Suspended Solids (mg/L)	17.5	15.3	15.8	43.6	15.4	14.0	16.0	12.2	15.1	17.4
Dissolved Oxygen (mg/L)	7.5	7.5	7.2	4.0	7.9	7.8	7.9	6.8	6.6	4.0
Ammonia Nitrogen (mg/L)								2.6		
Nitrate-Nitrite Nitrogen (mg/L)								.15		
Total Phosphorus (mg/L) po4	.207	.232	.204	.245	.192	.212	.234	.194	.208	.221
Chlorophyll a (ug/L) Corrected	43.4	45.7	47.9	17.2	43.4	37.0	22.8	25.1	22.1	23.2

Table 3. Data collected in 1989 by the University of Iowa Hygienic Laboratory (Kennedy and Miller, 1990).

Date Collected	6/14/89			7/26/89			10/4/89		
Depth (meters)	0	1.2	2.1	0	1.2	2.1	0	1.8	3.6
Secchi (meters)	0.3			0.2			0.4		
Suspended Solids (mg/L)	38	62	48	60	58	61	31	29	210
Dissolved Oxygen (mg/L)	7.0	7.0	1.7	9.8	5.8	1.1	7.8	7.7	7.7
Ammonia Nitrogen (mg/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.2	0.2
Nitrate-Nitrite Nitrogen (mg/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.1	0.1
Total Phosphorus (mg/L)	0.1	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.5
Chlorophyll a (ug/L) Corrected	46	72	61	95	79	63	23	31	<1

Table 4. Data collected in 1990 by Iowa State University (Bachmann, et al, 1994).

Date Collected	6/6/1990			7/7/1990			8/5/1990		
Sample Number	1	2	3	1	2	3	1	2	3
Secchi (m)	0.4			0.6			0.4		
Suspended Solids (mg/L)	31	34.5	29.4	20	20.1	19.5	55.1	47.9	48.1
Total Nitrogen (mg/L)	1.4	1.5	1.2	1.7	2	1.7	1.8	1.7	1.6
Total Phosphorus (mg/L)	103	103	96	115	132	126	171	186	183
Chlorophyll a (ug/L) Corrected	23	20	20	129	132	131	79	78	81

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

Table 5. Data collected in 2000 by Iowa State University (Downing and Ramstack, 2001)

Parameter	6/20/2000	7/17/2000	8/8/2000
Secchi Depth m	0.4	0.6	1.3
Chlorophyll (ug/L)	28	30	11
NH_3+NH_4^+ -N (ug/L)	818	857	1203
NH_3 –N (un-ionized) (ug/L)	6	48	11
NO_3+NO_2-N (mg/L)	0.16	0.11	0.11
Total Nitrogen (mg/L as N)	1.19	1.68	1.99
Total Phosphorus (ug/l as P)	126	278	255
Silica (mg/L as SiO_2)	31	27	24
pH	7.2	7.9	7.2
Alkalinity (mg/L)	95	97	181
Total Suspended Solids (mg/L)	23.7	17.7	23.3
Inorganic Suspended Solids (mg/L)	18.0	7.7	14.2
Volatile Suspended Solids (mg/L)	5.8	10.0	9.2

Table 6. Data collected in 2001 by Iowa State University (Downing and Ramstack, 2002)

Parameter	5/21/2001	6/18/2001	7/23/2001
Secchi Depth m	0.6	0.7	0.6
Chlorophyll (ug/L)	--	29	26
NH_3+NH_4^+ -N (ug/L)	853	771	702
NH_3 –N (un-ionized) (ug/L)	9	14	42
NO_3+NO_2-N (mg/L)	1.27	1.11	0.28
Total Nitrogen (mg/L as N)	2.40	1.92	1.35
Total Phosphorus (ug/l as P)	115	110	107
Silica (mg/L as SiO_2)	16	11	7
pH	7.5	7.6	8.0
Alkalinity (mg/L)	50	90	93
Total Suspended Solids (mg/L)	23.9	21.1	7.7
Inorganic Suspended Solids (mg/L)	17.8	15.2	6.6
Volatile Suspended Solids (mg/L)	6.1	5.9	1.1