Water Quality Improvement Plan for

Lake of Three Fires

Taylor County, Iowa

Total Maximum Daily Load
For Pathogen Indicators

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Watershed Improvement Section
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Report Summary

What is the purpose of this report?

This Water Quality Improvement Plan (WQIP) has two purposes. First, it is a resource to be used by watershed planners, water quality action groups, individual citizens, and local and state government staff. It serves as a guide to help these groups understand and identify the cause of Lake of Three Fires water quality problems and to guide locally driven water quality improvements in the lake. The problem to be addressed in this plan is the high concentrations of bacteria that have been measured at the beach. Secondly, this report satisfies the Federal Clean Water Act obligation to establish a Total Maximum Daily Load (TMDL) for waterbodies on the 303(d) impaired waters list.

A WQIP was previously developed for Lake of Three Fires to address algae blooms, turbidity, and siltation. EPA approved it on January 30, 2003. A Diagnostic/Feasibility Study performed by Iowa State University for IDNR was completed in the 2001 to 2002 period. Several of the watershed improvements recommended in those documents have since been implemented and/or constructed.

What is wrong with Lake of Three Fires?

Lake of Three Fires is impaired for pathogen indicator bacteria counts that exceed the Water Quality Standards (WQS) criteria. This problem impairs recreational use of the lake.

What is causing the problem?

Lake of Three Fires is impaired for bacteria at the lake's swimming beach. The bacteria problem, measured by *E. coli* concentration, is caused by wildlife, livestock manure, including that resulting from equestrian activities in the state park, and poorly functioning septic systems.

What can be done to improve Lake of Three Fires?

To improve Lake of Three Fires water quality, bacteria loads to the lake must be reduced. A combination of the following management practices can be implemented to achieve these reductions:

- management of geese population and removal of feces from the beach and lawn areas adjacent to the lake,
- management of horse manure from equestrian activities in the park,
- restricting cattle from streams,
- adoption of manure application strategies that reduce loss in runoff,
- inspection, repair, and maintenance of septic systems.

Who is responsible for a cleaner Lake of Three Fires?

Everyone who lives, works, or plays in the Lake of Three Fires watershed has a role in water quality improvement. Because there are no regulated point sources in the watershed, voluntary management of land and animals will be required to see positive results. Improving water quality will require the collaboration of citizens and agencies with an interest in protecting the lake now and in the future.

Required Elements of the TMDL

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

Table 1-1 Required TMDL Elements

Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:	Lake of Three Fires, Taylor County Section 7 T68N R33W Latitude 40.7122 N Longitude 94.6902 W
Use designation classes:	Class A1 Primary Contact Recreation Class B (LW) Aquatic Life Class C Drinking Water Source Class HH (Human Health)
Impaired beneficial uses:	Class A1 Primary Contact Recreation
Identification of the pollutants and applicable water quality standards:	Primary contact recreational use (Class A1) is not supported due to violation of the *E. coli* Water Quality Standard criteria of 126 organisms/100 ml for the geometric mean (GM) and 235 organisms/100 ml for the single sample maximum (SSM).
Quantification of the pollutant loads that may be present in the waterbody and still allow attainment and maintenance of water quality standards:	The *E. coli* load capacity has been calculated for five flow recurrence intervals. Tables 3-4 and 3-5 list the load capacities.
Quantification of the amount or degree by which the current pollutant loads in the water body deviate from the pollutant loads that attain water quality standards:	The *E. coli* load departure from capacity has been calculated for five flow recurrence intervals. Table 3-7 lists these departures.
Identification of pollution source categories:	Nonpoint watershed *E. coli* sources are identified as the cause of the Lake of Three Fires pathogen indicator impairment.
Wasteload allocations for pollutants from point sources:	There are not any permitted point sources in the watershed and the WLA summation is zero.
Load allocations for pollutants from nonpoint sources:	The *E. coli* load allocations have been calculated for five design flow recurrence intervals. Tables 3-9 and 3-10 list the load allocations.
Margin of safety (MOS):	The margin of safety for this TMDL is an explicit 10 percent of the load capacity. Tables 3-9 and 3-10 list the MOS.

Consideration of seasonal variation:	The recreation season as defined in the Iowa Water Quality Standards runs from March 15 through November 15. This is the season used in the development of this pathogen indicator TMDL.
Allowance for reasonably foreseeable increases in pollutant loads:	An allowance for increased pathogen indicator loading was not included in this TMDL. The Iowa Department of Natural Resources owns and maintains the shoreline around Lake of Three Fires. Much of the nearby watershed is state owned forest, grass, and wetlands. The rest is in agricultural production with row-crop predominating. A significant change in watershed land use is unlikely.
Implementation plan:	An implementation plan is provided in Section 4 of this document to guide local citizens, government, and water quality improvement planning groups.

1. Introduction

The Federal Clean Water Act requires states to assess their waterbodies every even numbered year and incorporate these assessments into the 305(b) Water Quality Assessment Report. Assessed lakes and streams that do not meet the Iowa Water Quality Standards criteria are placed on the 303(d) Impaired Waters List. Subsequently, a Total Maximum Daily Load (TMDL) for each pollutant must be calculated and a Water Quality Improvement Plan written for each impaired waterbody.

A TMDL is a calculation of the daily maximum amount of a pollutant a waterbody can receive without exceeding the water quality standards. The total maximum daily load is allocated to permitted point sources (wasteload allocations), nonpoint sources (load allocations), and a margin of safety that accounts for uncertainty in the calculations.

This TMDL report is for Lake of Three Fires in Taylor County, Iowa. Lake of Three Fires is on the 2008 impaired waters list for *E. coli*, a pathogen indicator.

There are two primary purposes of this report: 1) Satisfy federal TMDL requirements for impaired waters, and 2) Serve as a resource for guiding water quality improvement projects in the Lake of Three Fires watershed that address bacteria problems. Local citizens, water quality groups, and government agencies will find it a useful description of the causes and solutions to Lake of Three Fires water quality concerns.

A TMDL report has some limitations:

- The 305(b) water quality assessment is made with available data that may not adequately describe lake water quality. Additional targeted monitoring is often expensive and requires time. Assumptions and simplifications on the nature, extent, and causes of impairment can create uncertainty in calculated values.
- A TMDL may not easily handle unregulated nonpoint sources of pollutants. It can be challenging to reduce pollutant loads when nonpoint sources are significant contributors.

This document can guide local water quality improvement projects that are targeted at pollutant sources in the watershed. The lake water quality mirrors the land that drains to it and reflects how well that land is managed. Local landowners, tenants, and other stakeholders often have the greatest influence on water quality.

2. Description and History of Lake of Three Fires

Lake of Three Fires is located in southwest Iowa in Taylor County three miles north of Bedford and is a significant publicly owned lake. It is the central feature of Lake of Three Fires State Park, a popular outdoor recreation area. Several small streams that discharge into the East Fork One Hundred and Two River were impounded to create the lake in 1935. The state park was established at that time.

The lake and park activities include boating, fishing, and swimming. There are equestrian and standard campgrounds, boat ramps, a swimming beach and ten miles of multi-use trails. Park use averages 71,500 visits per year. The lake lies entirely within 694 acres that is owned and managed by the IDNR. Lake of Three Fires has designated uses of Class A1 (primary contact recreation), Class B(LW) (aquatic life), Class C (drinking water source), and Class HH (human health). Table 2-1 lists basic lake information.

Table 2-1 Lake of Three Fires

Waterbody Name	Lake of Three Fires
12 Digit Hydrologic Unit Code (HUC):	102400130104
IDNR Waterbody ID	IA 05-PLA-00335-L_0
Location	Section 12 T68N R34W
Latitude	40.7122° N
Longitude	94.6902° W
Water Quality Standard Designated Uses	Class A1 Primary Contact Recreation Class B (LW) Aquatic Life Class C Drinking water source HH Human Health
Tributaries	Unnamed streams
Receiving Waterbody	East Fork One Hundred and Two River
Lake Surface area	97 acres
Maximum Depth	27.8 feet
Mean Depth	9.9 feet
Volume	960 acre-feet
Length of Shoreline	3.6 miles
Watershed Area (with lake)	3723 acres
Watershed/Lake Area Ratio	38
Lake Detention Time (outlet)[1]	131 days

1. Lake detention time is based on modeled flow developed from 11 years of precipitation data, from 1998 to 2009.

2.1. Lake of Three Fires

Lake of Three Fires has undergone a great deal of restoration activity in the last ten years. This work has included:

- a major dredging project,
- construction of new and rehabilitation of existing sediment detention ponds and grade stabilization structures,

- drawing down the lake level to rehabilitate the fishery and reestablish shoreline aquatic plants, and
- the establishment of a wetland upstream of the lake to buffer it from impacts of watershed pollutants.

A timeline of Lake of Three Fires water quality improvement activities is shown in Figure 2-1.

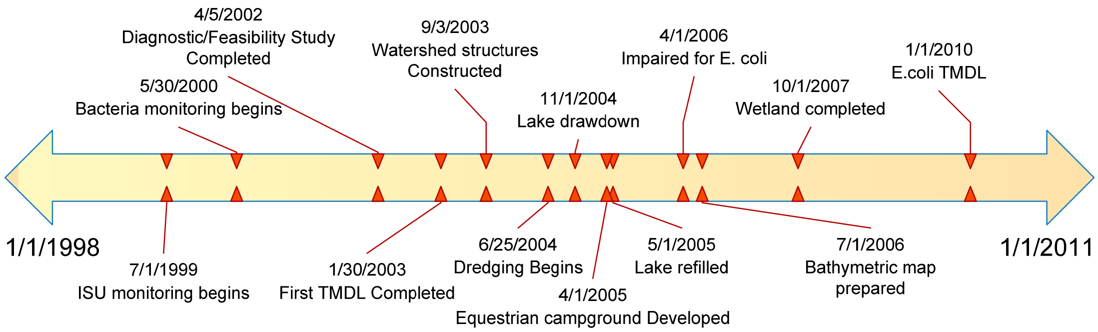

Figure 2-1 Timeline of lake restoration activities since 1998.

Hydrology.
Lake of Three Fires has one major unnamed surface tributary that discharges into the northeast end of the lake and a smaller tributary that discharges to the lake from the west. The lake outlet is in the south end at the dam. An adjacent large spillway drains the lake at an elevation of 1,143 feet MSL. A hydrologic budget was developed for the ISU Diagnostic/Feasibility Study using data collected in 1999 and 2000. The average annual precipitation is 35.0 inches/year and the average lake retention time is 131 days based on recent modeling of estimated flow.

Morphometry.
In 2002 a bathymetric map of Lake of Three Fires was completed for the ISU D/F Study. After the dredging and other work in the lake was completed in 2004 and 2005, IDNR constructed a new bathymetric map using data collected in 2006 and this is shown in Figure 2-2. Table 2-2 shows the difference in basic lake data between these two mapping efforts.

Table 2-2 Pre and post dredging lake characteristics

Characteristic	Pre-dredging (2002)	Post dredging (2006)
Lake Surface area	86 acres	97 acres
Maximum Depth	13.0 feet	27.8 feet
Mean Depth	8.3 feet	9.9 feet
Volume	716 acre-feet	960 acre-feet
Watershed Area (with lake)	3719 acres	3723 acres

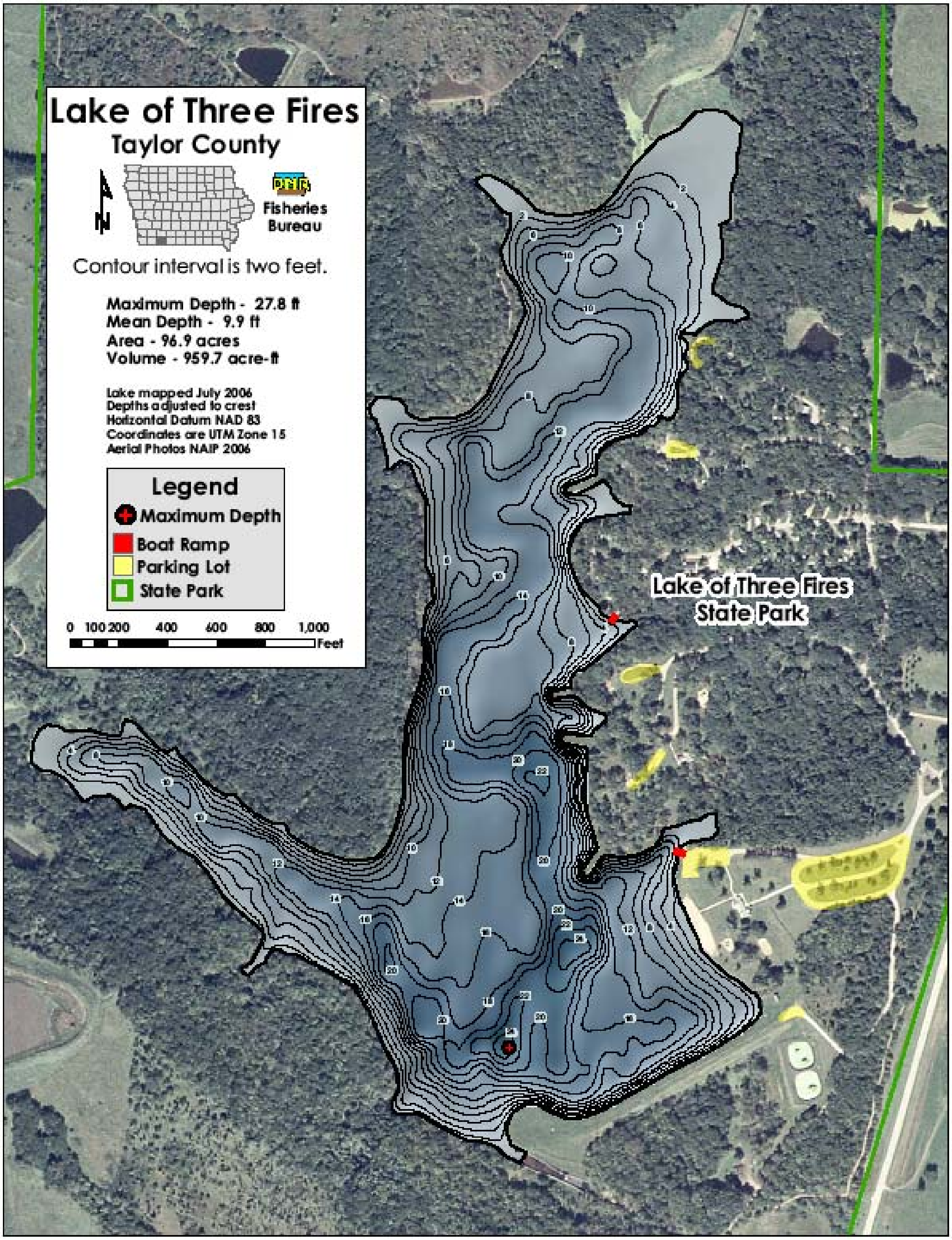

Figure 2-2 Lake of Three Fires bathymetric map

2.2. The Lake of Three Fires Watershed

The Lake of Three Fires watershed has an area of 3,723 acres including the lake. Without the lake, the watershed has a drainage area of 3,626 acres and a watershed to lake ratio of 38:1. This watershed to lake area ratio is high. IDNR Fisheries and lake restoration staff consider the maximum ideal ratio for a high quality lake to be less than or equal to 20:1. Figure 2-3 shows the lake and its watershed.

There are no cities or NPDES permitted point sources in the watershed, but there are eight occupied residences. The residences use onsite septic tank systems for wastewater treatment and it is assumed that some are not functioning properly and may be discharging directly to surface drainage. Lake of Three Fires State Park has recently constructed wastewater collection and treatment facilities. The new wastewater treatment lagoons discharge downstream of the lake outlet.

Land Use.
Land uses and associated areas for the watershed are listed in Table 2-3. Figure E-1 in Appendix E displays a land use map. Row crop agriculture is the predominant land use in the watershed. There is one animal feeding operation. IDNR owns or maintains the entire shoreline around the lake.

Table 2-3 Land use in the Lake of Three Fires Watershed

Land Uses from 2009 Assessment	Area, acres	Percent of total
Beans	501	13.5%
CAFO[1]	4	0.1%
Cemetery	2	0.1%
Corn	1,056	28.3%
Farmstead	43	1.1%
Feedlot	1	0.0%
Grass	521	14.0%
Hay	246	6.6%
Pasture	395	10.6%
Roads	73	2.0%
Timber	681	18.3%
Water[2]	200	5.4%
Total	**3,723**	**100%**

1. Confined Animal Feeding Operation
2. Includes lake surface area of 97 acres.

Soils and topography.
Lake of Three Fires is located in the Southern Iowa Drift Plain ecoregion. This region is characterized by loess capped glacial till plains with well developed dendritic drainage. The loess cover is silty and sometimes sandy in texture and ranges in thickness from 5 feet to 33 feet. The drift plain typically includes level upland divides and alluvial lowlands. Individual hill slopes in this plain have ridge and swale features giving the landscape a furrowed appearance. Most land surfaces are sloping with level areas in the uplands and stream bottoms. The slopes range from moderate to steep with grades from

five to twenty-five percent. The watershed soils are prairie and forest-derived and are developed from glacial till, a paleosol derived from glacial till, and loess. Twenty six percent of the soils in the watershed are derived from glacial till, thirty percent are paleosol-based, twenty eight percent are derived from loess and the remainder is a mix of rock and other soil types.

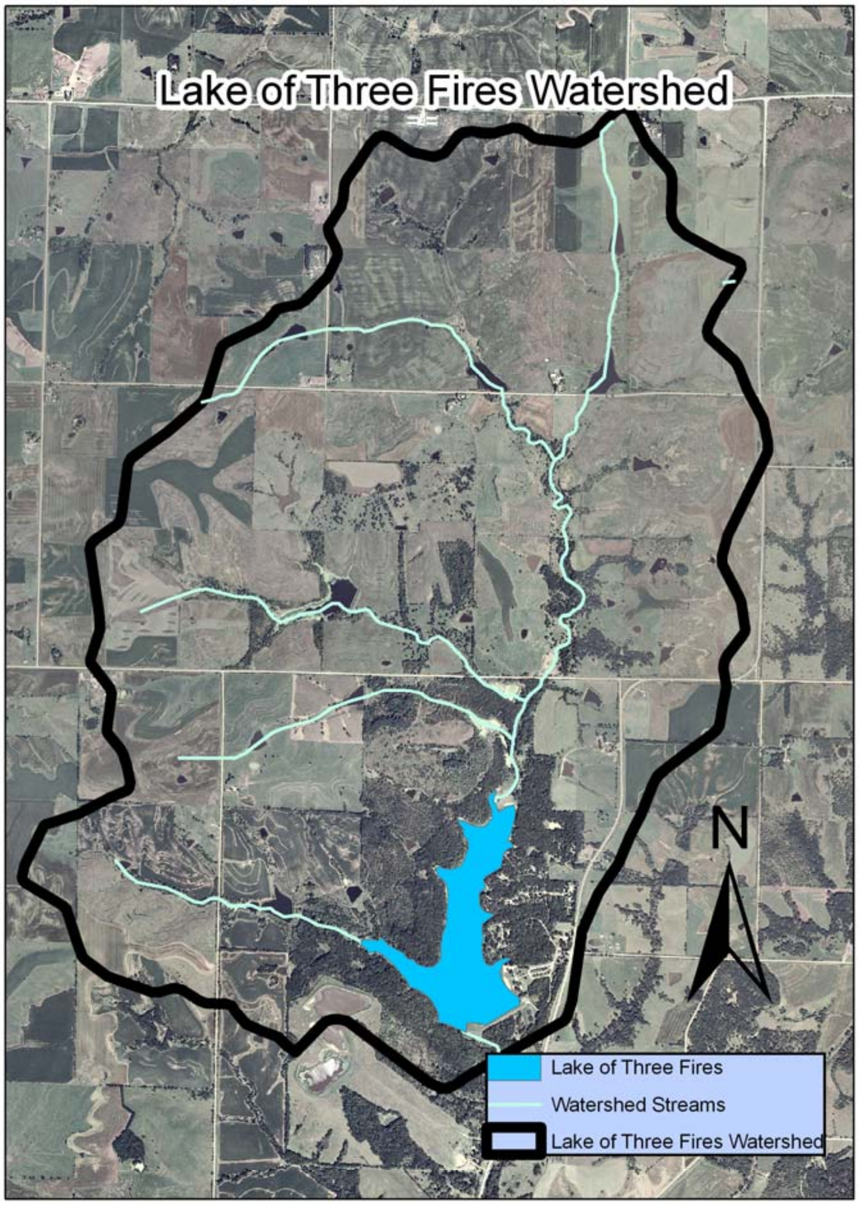

Figure 2-3 Lake of Three Fires and its watershed

3. Total Maximum Daily Load for Pathogen Indicators (*E. coli*)

A Total Maximum Daily Load (TMDL) for the pathogen indicator *E. coli* is required for Lake of Three Fires by the Federal Clean Water Act. This section quantifies the maximum daily *E. coli* load that can be delivered to Lake of Three Fires without exceeding the Iowa water quality standards.

3.1. Problem Identification

Applicable water quality standards.
The applicable designated uses and water quality standards for pathogen indicators are found in *Iowa Administrative Code 567, Chapter 61, Water Quality Standards.* Table 3.1 summarizes the water quality standards for pathogen indicators for the Class A1 use.

Table 3-1 *E. coli* bacteria criteria (organisms/100 ml of water) for Class A1 Uses

Use *Class A1 - Primary Contact Recreational Use.*	***Geometric Mean Concentration***	***Sample Maximum Concentration***
Class A1		
3/15 – 11/15	*126*	*235*
11/16 – 3/14	*Does not apply*	*Does not apply*

Problem statement.
The full 2008 305(b) water quality assessment for Lake of Three Fires is included in Appendix F. For Lake of Three Fires, Class A1 uses are assessed as "not supported" based on results of monitoring for indicator bacteria (*E. coli*). According to IDNR assessment and impaired listing methodology, if monitoring shows that greater than ten percent of samples exceed the single sample maximum, a lake is partially supported for Class A1 use and is impaired.

The basis for impairing Lake of Three Fires is the 2008 305(b) water quality report that the Class A1 uses are assessed (monitored) as "not supporting" due to levels of indicator bacteria (*E. coli*) that exceed state water quality standards. The assessment is based on beach water quality monitoring conducted by IDNR.

Data sources.
The assessment of the pathogen indicator impacts on the Class A1 use is based on the results of the IDNR-UHL summer beach monitoring program that collected bacteria samples from Lake of Three Fires from 2000 through 2008. Samples were collected at the lake’s beach once a week, usually from mid-April to mid-October. Watershed model output (BasinSims/GWLF) was used to simulate flows to the lake based on precipitation and temperature data from the nearby Bedford weather station.

Interpreting Lake of Three Fires E. coli data.
Flow and load duration curves were used to establish the occurrence of water quality standards violations and compliance targets and to set pollutant allocations and margins of safety. Flow duration curves are derived from flow plotted as a percentage of recurrence. *E. coli* loads are calculated from *E. coli* concentrations and flow volume. Load duration methods have been applied to the Lake of Three Fires *E. coli* data and modeled flow to establish existing and target *E. coli* loads for five flow conditions (see Appendix D). The five flow intervals represent conditions that can be used to interpret sources of *E. coli*. These flow interval midpoints are the quartiles (25, 50, and 75 percent) and the 5 and 95 percent values of flow recurrences and are values frequently used with flow and load duration analysis. The five flow conditions are described in Table 3-2.

Table 3-2 Five flow conditions used to establish existing and target loads

Flow condition	Description
High flow - zero to ten percent recurrence interval	Runoff conditions predominate here and the flows and loads are the greatest primarily from nonpoint sources available for washoff.
Moist conditions - ten to forty percent recurrence interval	Runoff conditions are gradually decreasing in volume as is their contribution to bacteria loading.
Mid-range flow - forty to sixty percent recurrence interval	Impacts from runoff in this flow recurrence interval are still a an important fraction but flow from groundwater and interflow are a growing part of the total. Loads originate from minor occurrences of local runoff and from the continuous septic tank, and cattle in the stream.
Dry conditions - sixty to ninety percent recurrence interval	Runoff loads at this flow recurrence interval are a shrinking fraction of the total. Flow from groundwater and interflow are a growing part of the total. Loads originate from minor occurrences of local runoff and increasingly from failed septic tanks, and cattle in the stream.
Low flow - ninety to one hundred percent recurrence interval	This is the low flow to no flow condition. Loads in this flow condition are nearly all from local continuous sources although the delivery of these continuous loads can be greatly reduced in the driest conditions.

The flow and load duration curves were developed using eleven years (1998 to 2009) of recreation season (March 15 to November 15) precipitation data from the weather station in Bedford to simulate flows to the lake using BasinSims/GWLF watershed modeling.

To construct the flow duration curves, the bacteria monitoring data and the Water Quality Standard (WQS) single sample maximum criteria (SSM, 235 *E. coli* organisms/100 ml) were plotted with the flow duration percentile. Figure 3-1 shows the flow duration curve for Lake of Three Fires with SSM data exceeding the criteria at three of the five flow conditions. High flow violations indicate that the problem occurs during run-off conditions when nearly all bacteria are washing off from nonpoint sources. Criteria exceeded during low or base flow, when runoff is generally not occurring, indicate that continuous sources such as septic tanks, wildlife and livestock in or near the lake and its tributary streams are the problem.

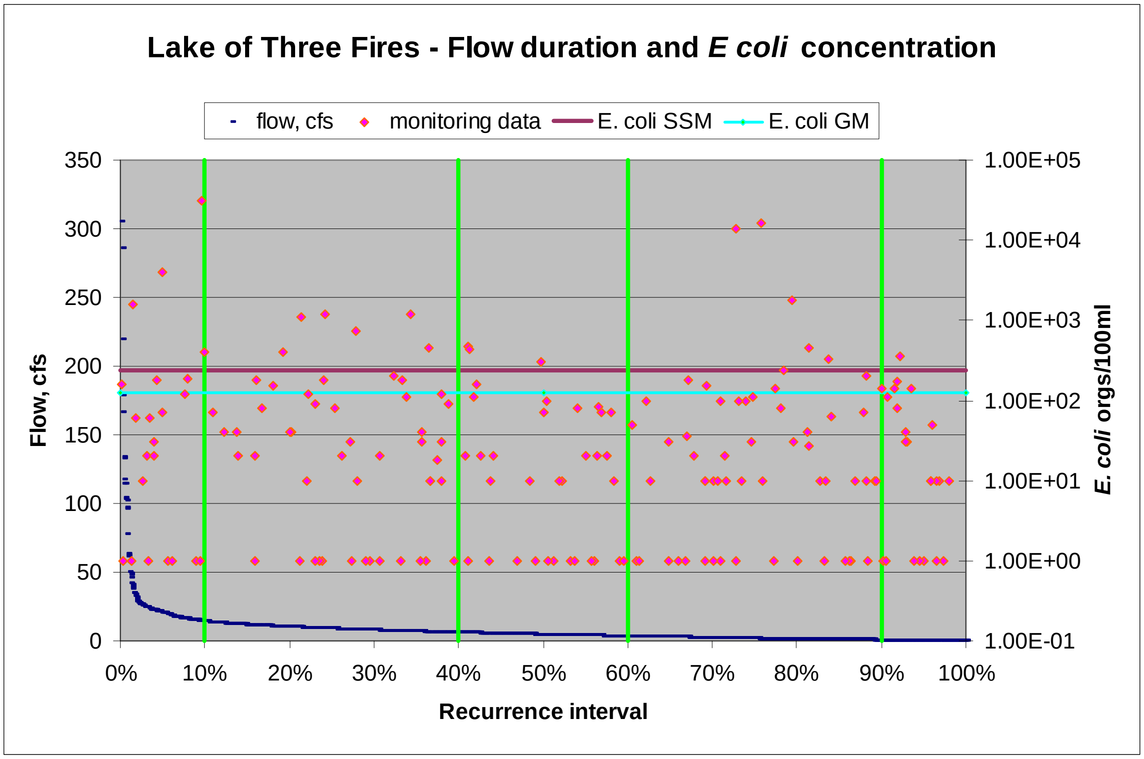

Figure 3-1 Lake of Three Fires Flow Duration Curve

3.2. TMDL Target

The target for this TMDL is the water quality standard for Class A1, Primary Contact Recreational Use. The criteria are a geometric mean (GM) of 126 *E. coli* organisms/100ml and a single sample maximum (SSM) of 235 *E. coli* organisms/100ml. The loads associated with these concentrations are based on the average daily flow through the lake. The criteria used to determine attainment of the water quality standards are explained in the 305(b) report assessment protocol in Appendix F.

General description of the pollutant.

The nonpoint source (NPS) pollutants in the watershed have two components. One is episodic and comprised of livestock and wildlife fecal material that is periodically transported during precipitation events. The other is relatively continuous loading from leaking septic tank systems, cattle manure in and near watershed streams, horse manure on the trails adjacent to the lake, and feces from geese in and near the lake. Horse manure and goose feces near the lake can be carried in by beachgoers and horses entering the water. Waves and brief rains that cause only very local runoff can also transport these to the lake.

Selection of environmental conditions.
The recreation season as defined in the Iowa WQS runs from March 15 through November 15. This is the season used in the development of this *E. coli* TMDL and only recreation season flow and monitoring data have been used to develop the duration curves.

Waterbody pollutant loading capacity (TMDL).
The *E. coli* load capacity for Lake of Three Fires is the number of organisms for a flow volume that can be in the lake and still meet the water quality criteria. The loading capacity for each of the five flow conditions is calculated by multiplying the midpoint flow and *E. coli* criteria concentrations. Table 3.3 shows the median, maximum, and minimum flows for the five recurrence intervals.

Table 3-3 Maximum, minimum and median flows for recurrence intervals

Flow description	Recurrence interval range (mid %)	Midpoint of flow range, cfs	Maximum of flow range, cfs	Minimum of flow range, cfs
High flow	**0 to 10% (5)**	20.5	305.3	14.0
Moist conditions	**10% to 40% (25)**	8.7	14.0	6.0
Mid-range	**40% to 60% (50)**	4.4	6.0	3.3
Dry conditions	**60% to 90% (75)**	1.6	3.3	0.5
Low flow	**90% to 100% (95)**	0.2	0.5	0.1

A load duration curve based on the modeled flows from BasinSims/GWLF has been used to establish the target loads for Lake of Three Fires and is shown in Figure 3-2. The lower curve shows the *E. coli* count for the geometric mean criteria and the upper curve shows the *E. coli* count for the single sample maximum (SSM) criteria. The points on the chart represent observed (monitored) *E. coli* concentrations converted to loads using simulated flow for the sampling date. Points above the load duration curves are violations of the WQS criteria.

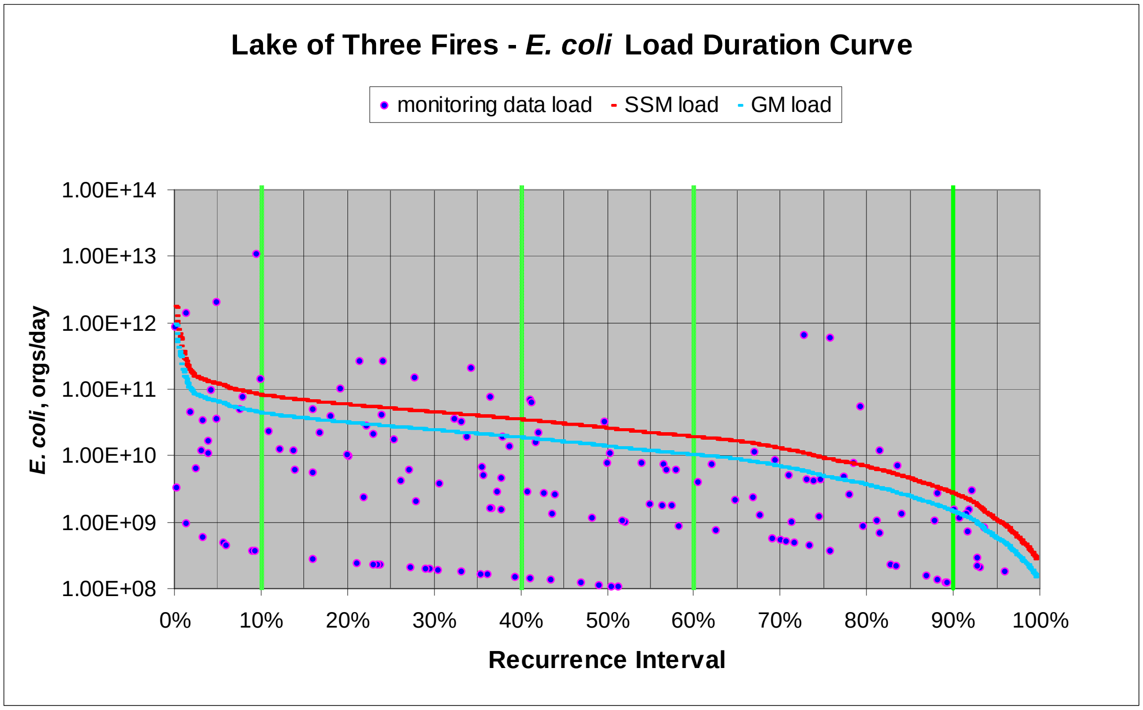

Figure 3-2 Lake of Three Fires Load Duration Curve

Tables 3-4 and 3-5 show the load capacities (targets) for each of the midpoint flow conditions at the GM and SSM criteria, respectively.

Table 3-4 Lake of Three Fires GM load capacity at five recurrence intervals

Flow condition	Recurrence interval	Associated midpoint flow, cfs	Estimated flow interval load capacity, *E. coli* orgs/day
High flow	**0 to 10%**	20.5	6.3E+10
Moist conditions	**10% to 40%**	8.7	2.7E+10
Mid-range	**40% to 60%**	4.4	1.4E+10
Dry conditions	**60% to 90%**	1.6	4.9E+09
Low flow	**90% to 100%**	0.2	6.2E+08

Table 3-5 Lake of Three Fires SSM load capacity at five recurrence intervals

Flow condition	Recurrence interval	Associated midpoint flow, cfs	Estimated flow interval load capacity, *E. coli* orgs/day
High flow	**0 to 10%**	20.5	1.2E+11
Moist conditions	**10% to 40%**	8.7	5.0E+10
Mid-range	**40% to 60%**	4.4	2.5E+10
Dry conditions	**60% to 90%**	1.6	9.2E+09
Low flow	**90% to 100%**	0.2	1.2E+09

Decision criteria for water quality standards attainment.
Water Quality Standards will be attained in Lake of Three Fires when the monitored *E. coli* concentrations meet the criteria of a geometric mean of 126 org/100 ml and a single sample maximum concentration of 235 org/100 ml.

3.3. Pollution Source Assessment

There are two mechanisms of *E. coli* transport to Lake of Three Fires. The first is the wash-off load from bacteria accumulation on watershed land surfaces when it rains. The other is wildlife and livestock in tributary streams and adjacent to the lakeshore and in the lake. As previously noted, horse manure and deer and goose feces near the lake are tracked in by beachgoers and horses or are delivered by wave action or brief rainfall events that do not show up as runoff in the duration curves but that carry bacteria because of proximity to the lake. These latter sources are delivered at low flow.

Existing load.
The existing loads are derived from the observed data for each flow interval. These data are the monitored points shown in the flow and load duration curves. The monitored *E. coli* concentrations are multiplied by the average daily flow to get the daily loads that are plotted with the load duration curves. The maximum allowable load for a recurrence percentage is the flow multiplied by the GM or SSM. Observed data that exceed the WQS criteria are above the GM and SSM curves.

The maximum existing load occurs during storms when maximum runoff and bacteria concentrations are highest. These elevated loads and flows cause bacteria concentration to exceed the criteria. The other situation leading to criteria violations occurs during dry and low flow periods when loads from livestock and wildlife in streams and other local lakeshore bacteria sources are delivered to the lake. These two situations can be observed in Figure 3-2, where most peak loads occur during high and moist flow conditions and a few elevated load samples were collected in dry flow conditions.

The assessment methodology used to evaluate pathogen indicator criteria assume that if 10 percent or more of samples exceed the *E. coli* criteria then the waterbody is not supporting recreational use. The 90^{th} percentile of observed concentrations within each flow condition is multiplied by the median flow for each condition to estimate existing loads. Table 3-6 shows the existing loads for each flow condition.

Table 3-6 Existing loads at the five recurrence intervals

Flow condition	Recurrence interval	Associated midpoint flow, cfs	Existing 90^{th} percentile conc., orgs/100ml	Existing *E. coli* load, orgs/day
High flow	**0 to 10%**	20.5	1600	8.03E+11
Moist conditions	**10% to 40%**	8.7	400	8.52E+10
Mid-range	**40% to 60%**	4.4	145	1.56E+10
Dry conditions	**60% to 90%**	1.6	216	8.46E+09
Low flow	**90% to 100%**	0.2	140	6.85E+08

Departure from load capacity.
The departure from load capacity is the difference between the existing load and the load capacity. This varies for each of the five flow conditions. Table 3-7 shows this difference. At high flow runoff conditions loads are elevated, since this is when watershed bacteria are washed off by storm events. In high flow runoff conditions, the concentration is usually higher than when runoff is not occurring. This high runoff bacteria concentration combined with high flow results in very high bacteria counts. The difference between the load capacity (target) and existing loads for each of the flow intervals is displayed graphically in Figure 3-6.

Table 3-7 Departure from load capacity, SSM loads

Flow condition	Recurrence interval	Existing *E. coli* orgs/day	Load capacity[1], orgs/day	Departure from capacity, orgs/day[2]
High flow	**0 to 10%**	8.03E+11	1.2E+11	6.85E+11
Moist conditions	**10% to 40%**	8.52E+10	5.0E+10	3.51E+10
Mid-range	**40% to 60%**	1.56E+10	2.5E+10	-9.69E+09
Dry conditions	**60% to 90%**	8.46E+09	9.2E+09	-7.44E+08
Low flow	**90% to 100%**	6.85E+08	1.2E+09	-4.65E+08

1. This is calculated using the single sample maximum of 235 organisms/100 ml.
2. Negative departure from load capacity indicates that the existing load for the flow interval is less than the load capacity.

Identification of pollutant sources.
The two types of bacteria sources that are evaluated for TMDL development are point and nonpoint sources. Point sources are permitted discharges that are usually municipal wastewater treatment facilities. The second category is nonpoint sources that include all other discharges. Nonpoint sources are usually of a diffuse nature such as runoff from agricultural areas.

Point Sources: There are no permitted point sources in the Lake of Three Fires watershed. The state park has a relatively new wastewater collection and treatment system that discharges downstream of the lake. Construction was completed and it began operation in 2000. The facilities include a two-celled aerated lagoon and two lift stations that receive wastewater from six cabins, two bath houses, a dump station, and the park ranger's house. These facilities are not bacteria sources since wastewater is collected, treated and discharged downstream of the lake.

Nonpoint Sources: All sources of *E. coli* in the lake and watershed originate from the feces of warm blooded animals. In the Lake of Three Fires the sources are:

- Wildlife (primarily geese and deer in the park).
- Horses on the park trails and in the equestrian campground.
- Grazing animals in pastures.
- Cattle manure directly deposited in tributary streams.

- Land application of manure.
- Faulty septic tank systems in the watershed.

The contributions from each of these sources have been estimated using information from:

- IDNR State Park staff that are on site everyday.
- IDNR Wildlife and Fisheries biologists who work in the area and are familiar with lake and watershed aquatic and wildlife populations.
- IDNR GIS staff who performed a watershed assessment in September 2009 that estimated numbers of cattle and hogs and manure application locations and timing.
- IDNR Field Office staff familiar with manure problems in the watershed.
- IDNR Lake Restoration Program staff familiar with past efforts to improve water quality in Lake of Three Fires.
- IDNR Beach Monitoring staff responsible for collecting bacteria data.

The six nonpoint source categories listed below have been evaluated for their potential for lake bacteria contamination. These assessments have been integrated into the source model (EPA Bacteria Indicator Tool, BIT) that quantifies bacteria sources and their potential to contribute to the impairment.

In general, the bacteria sources have been estimated for the peak five month recreation season, May through September. Though the statutory recreational season runs from March 15 to November 15, violations have been monitored only during the peak season, partly because that is when samples are collected. This has little impact on the analysis because it is based on worst case monthly accumulation available for washoff for any day in that month by a rainfall event. Bacteria loads are not cumulative in the lake. For the BIT evaluation, the month of June has been selected as representative of maximum potential loads. In June there is an accumulation of bacteria available for washoff that is greater than or equal to that of any other month.

1. Wildlife: Geese and deer.
    - Geese estimates are 15 geese per day in the summer with higher numbers during fall migration. The geese are present daily. 15 geese * 30 days/month * 5 months = 2250 goose days per season.
    - Geese proximity and source potential is high since they are often on the beach and the clipped lawns in the vicinity of the beach (See Figure 4-1).
    - Deer estimates range from 75 to 100 animals in the state park. The deer are in the park year round with an assumed average of ninety deer per day. 90 deer * 30 days/month * 5 months = 13,500 deer days
    - Deer proximity and source potential is high since they are in the timbered areas of the state park close to the lake.
2. Horses in the equestrian campground and on the park trails.
    - Horse estimates in the park are twenty per day mostly on the weekends. Assume four weekends a month. 4.3 weekends * 2 days * 20 horses = 172 horse days per month. Assume horses are present from mid-May to mid-

October giving five months plus three holidays. 5 months * 172 horse days/month + 3 holidays * 20 horses = 920 horse days per recreation season

- Horse proximity and source potential is high since the equestrian campground is on the same side of the lake and is upstream of the beach. The campground is drained by two ditches, one on the north and one on the south. The discharge from these areas enters the lake upstream of the beach. The distances overland to the shoreline and the water distances from the ditch discharges to the beach are shown in Table 3-8.

Table 3-8 Distances from equestrian campground to beach

Travel Segment	Distance, feet
North ditch overland to water	1,060
North ditch outlet over water to beach	2,410
South ditch overland to water	1,420
South ditch outlet over water to beach	1,750

3. Grazing livestock.
   - Cattle estimates are 150 beef cows on pasture throughout the recreation season.
   - Cattle proximity and source potential is medium. The pastures are from 0.5 to 1.5 miles from the lake and the livestock are in four separate pastures with 40 to 50 animals in each.

4. Cattle in streams.
   - Of the 150 cattle in pastures, two to six are assumed to be in the stream on a given day during the recreation season.
   - Cattle proximity is medium, however the source potential is high since bacteria deposited directly in the stream are transported to the lake with or without rainfall.

5. Field applications of manure and storage leaks.
   - It is estimated that there are 3,840 hogs in one confinement in the watershed. The manure management plan states that manure is spread over 100 acres at a rate of 2,500 to 3,500 gallons per acre and is applied in the fall. Weather or storage requirements can lead to spring application.
   - The proximity of manure application is low to medium. Application fields and manure storage are 2.5 miles from the north end of the lake and the potential for recreation season *E. coli* impacts is reduced by the fall and spring timing of manure application.

6. Non functional septic tank systems.
   - There are eight houses in the watershed and it is estimated by IDNR field staff that half or more of the onsite systems are functioning properly. It is also assumed that these are continuous year round discharges.
   - The houses are not close to the lake so potential impact is reduced.

Watershed E. coli source analysis.

There are two mechanisms of *E. coli* transport to Lake of Three Fires. The first is the wash-off load from bacteria accumulation on watershed land surfaces when it rains. The other is wildlife and livestock in tributary streams and adjacent to the lakeshore and in the lake. As previously noted, horse manure and deer and goose feces near the lake are carried into the water by beachgoers and horses or are delivered by wave action or brief rainfall events. These latter sources are delivered at low flow.

The Lake of Three Fires watershed has been divided into two sub watersheds to characterize potential bacteria sources. The first is the area near the lake and is designated the Lakeshore sub watershed. It is the forested landuse and most of it is contained in the State Park. The Lakeshore sub watershed is 681 acres and the bacteria sources are wildlife and horses in the state park. The second sub watershed has been designated the Three Fires sub watershed and consists of four landuses of 2,843 acres and 102 acres of water (ponds, settling basins, streams) for a total subwatershed area of 2,945 acres. The sources here are primarily grazing cattle on pastureland and wildlife on all landuses. Instances of both transport mechanisms occur in both of the sub watersheds. The bacteria source evaluations for these sub watersheds can be found in Appendix D. Figure 3.3 shows the moist flow load distribution by animal source for the Lakeshore sub watershed and by landuse for the Three Fires sub watershed.

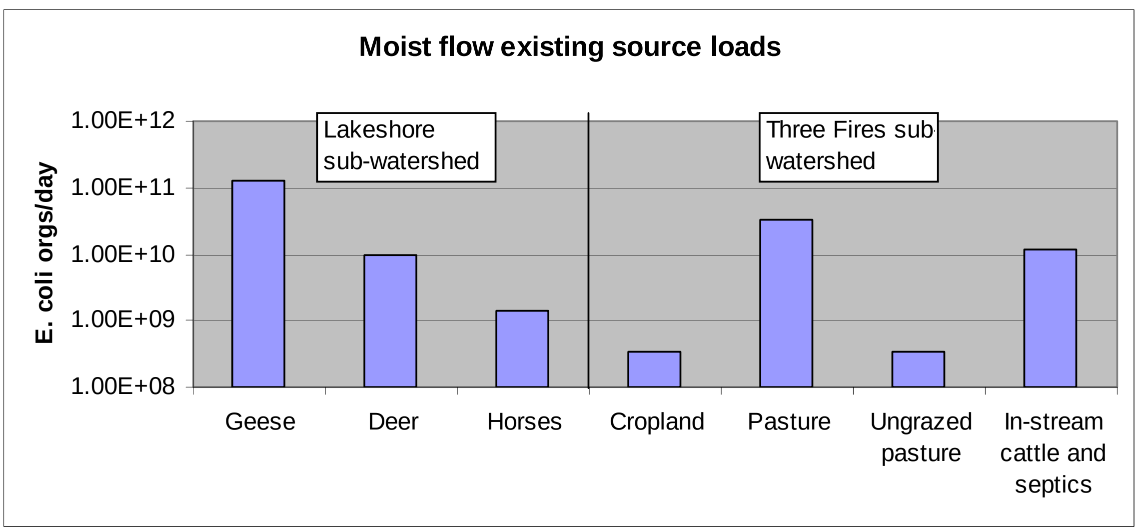

Figure 3-3 *E. coli* loads by source during moist flow conditions

Figure 3-4 shows the high flow load distribution by animal source for the Lakeshore sub watershed and by land use for the Three Fires sub watershed. The in-stream cattle and septics source is included as part of the pasture load.

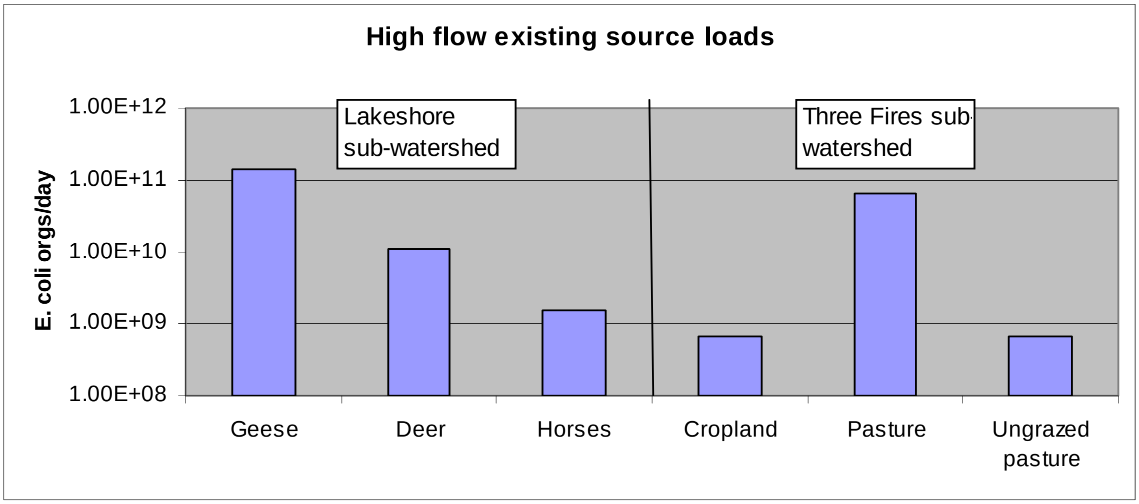

Figure 3-4 *E. coli* loads by source during high flow conditions

Linkage of E. coli *sources to the lake: flow and load analysis.*
The loads delivered to the lake vary with runoff conditions in the watershed. During peak runoff conditions the loads are dominated by washed off bacteria. The BIT model estimates the maximum bacteria available for wash off by landuse. Only a fraction of the bacteria available for wash off is actually delivered to the lake. The flow and load duration curves estimate existing loads at each of the five flow conditions. The fraction delivered by precipitation is the existing observed load during runoff conditions divided by the maximum load available for washoff.

Figure 3-5 shows the runoff duration curve, the SSM load duration curve and the observed loads from the monitoring data. It also illustrates that:

- Runoff is a decreasing fraction of total flow as recurrence increases, approaching zero between 30 and 40 percent recurrence.
- Interflow and baseflow increase as a fraction of total flow until they make up the entire flow.

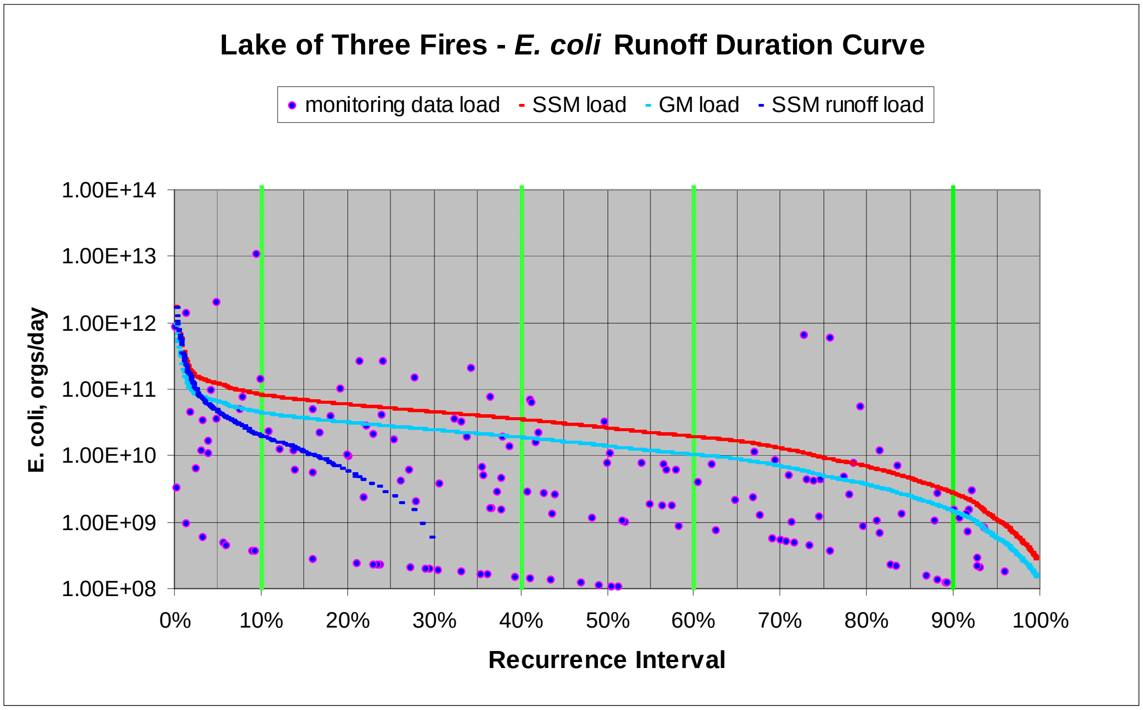

Figure 3-5 Lake of Three Fires total flow and runoff duration curves

Examination of the runoff duration curve shows that the largest part of modeled runoff occurs at recurrence intervals that are less than 30 percent. It also shows that 75 percent of samples exceeding the SSM criteria (15 out of 20) were taken when flows were at less than 33 percent recurrence. This is about the same recurrence interval as for runoff flows. The other five samples that exceeded the SSM criteria occurred between 69 and 82 percent recurrence. Two of these five samples, the second and third highest in the entire data set, were collected a week apart at the end of July 2007. This means that for the high bacteria loads at dry conditions are not a chronic problem but rather are the result of a single episode.

It is also useful to examine Figure 3-6, which shows the existing and SSM criteria target loads for each of the five flow conditions. As previously explained, the load duration analysis is used to obtain the median target load for each recurrence interval. The existing load is the 90th percentile of all the observed data for the same recurrence interval. It can be seen that the lowest two recurrence intervals, from zero to ten and from ten to forty percent recurrence, have existing loads that exceed the target loads. At midrange to low flows, forty to one hundred percent recurrence, the target loads are higher than the existing loads, i.e., the existing loads meet the SSM criteria.

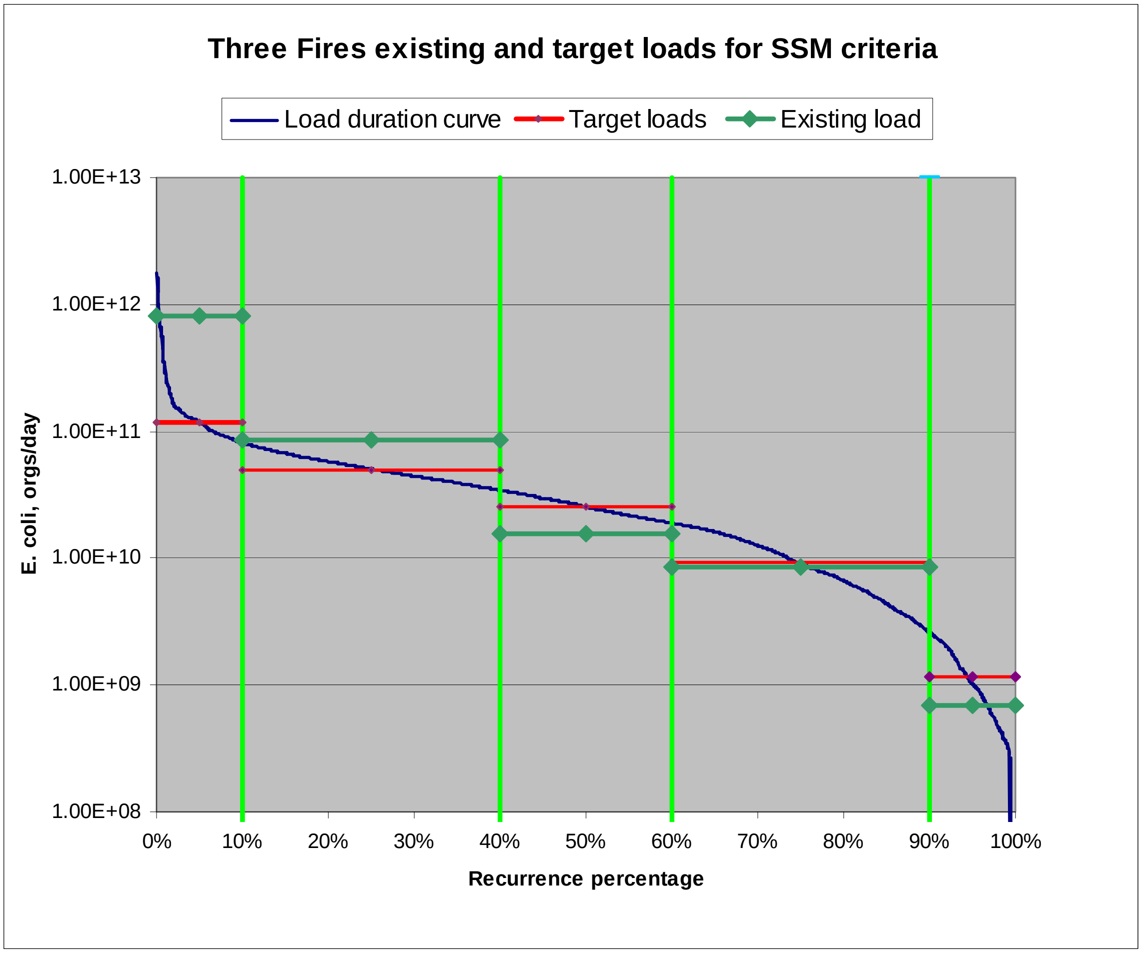

Figure 3-6 Existing and SSM criteria target loads

Allowance for increases in pollutant loads.
An allowance for increased pathogen indicator loading was not included in this TMDL. The Iowa Department of Natural Resources owns and maintains all of the shoreline around Lake of Three Fires. Some of the nearby watershed is in state owned forest, grass, and wetlands and most of the rest is in agricultural production with row-crop predominating. A significant change in watershed land use is unlikely.

3.4. Pollutant Allocation

Wasteload allocation.
There are no permitted point sources in the Lake of Three Fires watershed and, therefore, there are no *E. coli* wasteload allocations and the sum of the wasteload allocations is zero.

Load allocation.
The load allocations for this *E. coli* TMDL are the load capacity less an explicit ten percent margin of safety (MOS). There are separate load allocations set for the geometric

mean and single sample maximum criteria for each recurrence interval target. These load allocations and margins of safety are shown in Tables 3-9 and 3-10.

Table 3-9 Lake of Three Fires load allocations, geometric mean

Flow condition	Recurrence interval	Load capacity, orgs/day[1]	MOS, explicit 10%, orgs/day	Load Allocation, orgs/day
High flows	**0 to 10%**	6.3E+10	6.3E+09	5.7E+10
Moist conditions	**10% to 40%**	2.7E+10	2.7E+09	2.4E+10
Mid-range	**40% to 60%**	1.4E+10	1.4E+09	1.2E+10
Dry conditions	**60% to 90%**	4.9E+09	4.9E+08	4.4E+09
Low flow	**90% to 100%**	6.2E+08	6.2E+07	5.5E+08

1. Based on geometric mean criteria, 126 *E. coli* organisms/100 ml

Table 3-10 Lake of Three Fires load allocations, single sample maximum

Flow condition	Recurrence interval	Load capacity, orgs/day[1]	MOS, explicit 10%, orgs/day	Load Allocation, orgs/day
High flows	**0 to 10%**	1.2E+11	1.2E+10	1.1E+11
Moist conditions	**10% to 40%**	5.0E+10	5.0E+09	4.5E+10
Mid-range	**40% to 60%**	2.5E+10	2.5E+09	2.3E+10
Dry conditions	**60% to 90%**	9.2E+09	9.2E+08	8.3E+09
Low flow	**90% to 100%**	1.2E+09	1.2E+08	1.0E+09

1. Based on single sample maximum criteria, 235 *E. coli* organisms/100 ml

Margin of safety.
The margin of safety for *E. coli* is an explicit ten percent of the load capacity for the geometric mean and single sample maximum criteria for each recurrence interval target as shown in Tables 3-9 and 3-10.

3.5. TMDL Summary

The following equation represents the TMDL and its components for Lake of Three Fires.

Total Maximum Daily Load = Σ Load Allocations + Σ Wasteload Allocations +MOS

A Total Maximum Daily Load has been calculated for the geometric mean and single sample maximum criteria for each recurrence interval target. These TMDLs, load allocations and margins of safety are shown in Tables 3-11 and 3-12. Figures 3-7 and 3-8 show the results of these calculations in the load duration curves.

Table 3-11 TMDL calculation, geometric mean criteria

Flow condition	Recurrence interval	Σ LA, orgs/day	Σ WLA, orgs/day	MOS, orgs/day	TMDL, orgs/day
High flows	0 to 10%	5.7E+10	zero	6.3E+09	6.3E+10
Moist conditions	10 to 40%	2.4E+10	zero	2.7E+09	2.7E+10
Mid-range	40 to 60%	1.2E+10	zero	1.4E+09	1.4E+10
Dry conditions	60 to 90%	4.4E+09	zero	4.9E+08	4.9E+09
Low flow	90 to 100%	5.5E+08	zero	6.2E+07	6.2E+08

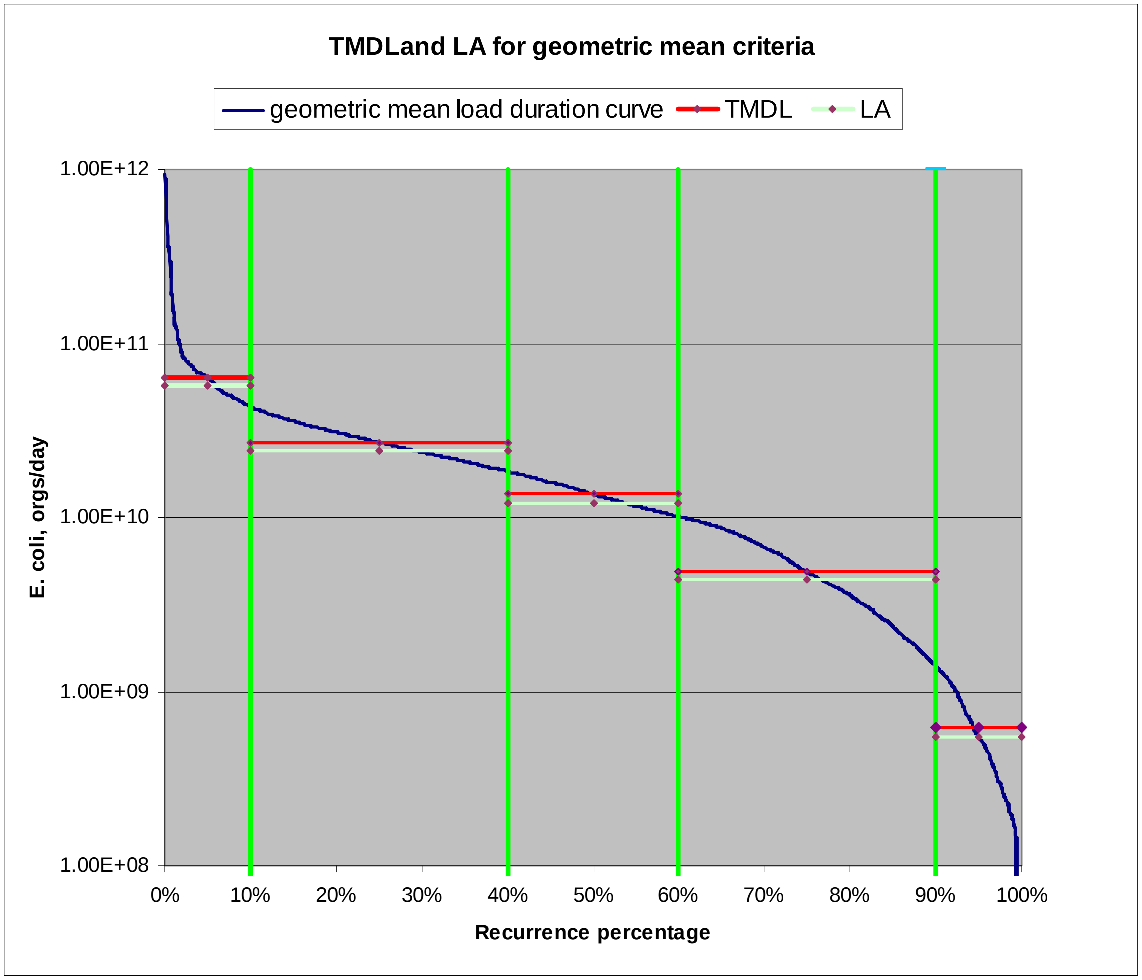

Figure 3-7 TMDL at the geometric mean WQS of 126 orgs/100 ml for the five flow conditions

Table 3-12 TMDL calculation, single sample maximum criteria

Flow condition	Recurrence interval	Σ LA, orgs/day	Σ WLA, orgs/day	MOS, orgs/day	TMDL, orgs/day
High flows	**0 to 10%**	1.1E+11	zero	1.2E+10	1.2E+11
Moist conditions	**10 to 40%**	4.5E+10	zero	5.0E+09	5.0E+10
Mid-range	**40 to 60%**	2.3E+10	zero	2.5E+09	2.5E+10
Dry conditions	**60 to 90%**	8.3E+09	zero	9.2E+08	9.2E+09
Low flow	**90 to 100%**	1.0E+09	zero	1.2E+08	1.2E+09

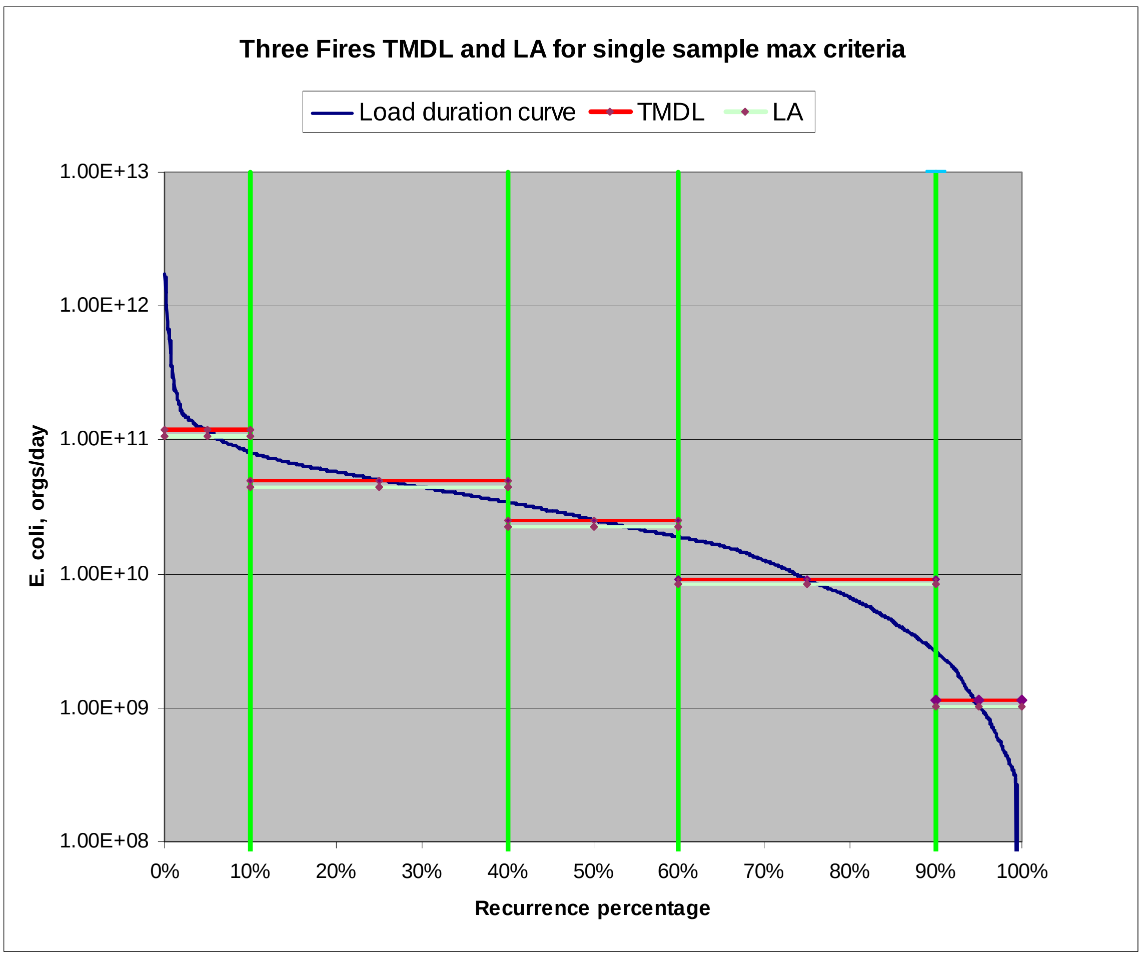

Figure 3-8 TMDL at the maximum single sample WQS of 235 orgs/100 ml for the five flow conditions

4. Implementation Plan

This implementation plan is not a requirement of the Federal Clean Water Act. However, the Iowa Department of Natural Resources recognizes that implementation guidance is important for the attainment of TMDL goals. Local watershed managers and citizens can use this report as a general guide for planning and decision making. The management practices discussed below may direct watershed activities toward achievement of water quality goals. Ultimately, it is up to land managers, citizens, and local conservation professionals to determine which management practices to use and how best to apply them.

4.1. Implementation Goals

Over the last decade, water quality improvement projects have been ongoing in the Lake of Three Fires watershed as shown in Figure 2-1. Most of these projects have focused on reducing sediment and nutrient delivery to the lake. Reducing bacteria delivery requires management practices that may differ from those already used, although sediment basins and wetlands constructed to reduce sediment and nutrients also reduce bacteria transport.

While the problem of *E. coli* bacteria at the beach has benefited from the management practices already in place, beach monitoring has shown that a problem persists. The bacteria sources that have the most impact on beach bacteria concentrations are those that are closest and have the most direct and shortest path to the lake when it rains. These are geese, deer, and horses in the immediate vicinity.

Table 4.1 shows the estimated departures of existing loads from target loads for the five flow condition as a percent load reduction required. At the geometric mean there are three flow conditions requiring a load reduction. At the single sample maximum there are two flow conditions requiring a load reduction. Negative values mean the existing load is less than the criteria load.

Table 4-1 Load reductions from existing conditions needed to meet *E. coli* targets

Flow percent recurrence	Geometric mean departure from capacity, orgs/day	Single sample max departure from capacity, orgs/day	Geometric mean percent reduction needed	Single sample max percent reduction needed
0 to 10 %	7.39E+11	6.85E+11	92.1%	85.3%
10 to 40 %	5.83E+10	3.51E+10	68.5%	41.3%
40 to 60 %	2.05E+09	-9.69E+09	13.1%	No reduction needed
60 to 90 %	3.52E+09	-7.44E+08	41.7%	No reduction needed
90 to 100 %	6.85E+07	-4.65E+08	10.0%	No reduction needed

Tables 4-2 and 4-3 list the loads by category as well as suggested load reduction distribution by source for the two critical flow conditions when runoff is occurring. The delivery for each of the two sub watersheds is different as discussed in Appendix D. As a result, reductions in the Lakeshore sub watershed sources have a much greater impact on beach *E. coli* concentrations.

Table 4-2 Existing bacteria loads, load reductions, and target loads for the moist flow condition (10 to 40% recurrence interval)

Load source	Existing load, orgs/day	Target load orgs/day,	Load reduction, orgs/day	Suggested reduction
Geese[1]	6.22E+10	2.49E+10	3.73E+10	60.00%
Deer[1]	4.73E+09	3.78E+09	9.46E+08	20.00%
Horses[1]	6.76E+08	3.38E+08	3.38E+08	50.00%
Pasture[2]	1.66E+10	9.93E+09	6.62E+09	40.00%
Ungrazed pasture[2]	1.69E+08	1.69E+08	0.00E+00	0.00%
Cropland[2]	1.69E+08	1.35E+08	3.38E+07	20.00%
In-stream cattle and septics[3]	6.85E+08	6.85E+07	6.17E+08	90%
Implementation total[4]	8.52E+10	4.56E+10	3.96E+10	46.5%
Target total[4]	**8.52E+10**	**5.0E+10**	**3.51E+10**	**41.25%**

1. Lakeshore sub watershed loads available for washoff are from geese, deer, and horses. The delivered load is the existing load.
2. Three Fires sub watershed loads available for wash off are from the cropland, pasture, and ungrazed pasture land uses. The delivered load is the existing load.
3. Three Fires sub watershed continuous loads have a bacteria loss factor of 5 and a time of travel of 0.85 day.
4. The implementation total reduction is the sum of the recommended load reductions as a percentage of the existing total load. The target total reduction is the load capacity as a percentage of the existing load as calculated in Section 3 LDC procedures.

Table 4-3 Existing bacteria loads, load reductions, and target loads for the high flow condition (zero to 10% recurrence interval)

Load source	Existing load, orgs/day	Target load, orgs/day	Load reduction, orgs/day	Suggested reduction
Geese[1]	4.43E+11	4.43E+10	3.99E+11	90.00%
Deer[1]	3.37E+10	1.69E+10	1.69E+10	50.00%
Horses[1]	4.82E+09	2.89E+09	1.93E+09	40.00%
Cropland[2]	3.15E+11	4.72E+10	2.67E+11	85.00%
Pasture[2]	3.21E+09	2.57E+09	6.42E+08	20.00%
Ungrazed pasture[2]	3.21E+09	1.93E+09	1.28E+09	40.00%
Implementation total[3]	**8.03E+11**	**1.16E+11**	**6.87E+11**	**85.6%**
Target total[3]	**8.03E+11**	**1.18E+11**	**6.85E+11**	**85.3%**

1. Lakeshore sub watershed loads available for wash off are from geese, deer, and horses. The delivered load is the existing load.
2. Three Fires sub watershed loads available for wash off are from the cropland, pasture, and ungrazed pasture land uses. The delivered load is the existing load. At high flow the in-stream cattle and septic loads have been included in the pasture washoff loads.
3. The implementation total reduction is the sum of the recommended load reductions as a percentage of the existing total load. The target total reduction is the load capacity as a percentage of the existing load as calculated in Section 3 LDC procedures

4.2. Implementation Design and Timeline

This water quality improvement plan sets targets and load allocations for *E. coli* concentrations in Lake of Three Fires. To be effective at improving water quality, watershed stakeholders will need to participate in the implementation of bacteria controls and continuing water quality evaluations.

A great deal of work has been completed both in-lake and in the watershed that has resulted in measurable water quality improvements and increased park usage. However, over the last few years *E. coli* concentrations exceeding the state criteria have raised concerns. The bacteria sources are animal feces and Figure 4-1 shows just how close to the lake goose feces have been found.

Figure 4-1 Goose feces on the beach and in the water at Lake of Three Fires

Figures 4-2 and 4-3 show the equestrian impacts on the park. Figure 4-2 shows horse manure in the equestrian campgrounds in the areas around the hitching rails and corrals. There are two drainages on either side of the campground that discharge to the lake that are 1,000 and 1,400 feet away from the lake. Figure 4-3 shows a trail near the campground that has been churned into mud and manure and has been post holed by horse traffic. Many of the impacted trails are near the lake and become conduits for runoff.

Figure 4-2 Manure in the equestrian campground

Figure 4-3 Multi-use trail impacted by horse manure and hooves

Some management practices can be identified for implementation. Since the impairment occurs mostly during high and moist flow runoff conditions, practices must address washoff when it rains. The primary focus needs to be on nearby sources in the Lakeshore sub watershed. These sources include geese on the beach and nearby locations, deer throughout the forested park, and horses in the equestrian campground and on park trails. Reductions in these loads will require changes in the way wildlife and horse manure are managed. Best management practices for reducing pathogen indicators in the Lakeshore sub watershed include:

- Reduce the geese numbers and time spent on and near the lake, especially the beach area.
- Remove goose feces from the beach area daily and remove it outside of the watershed.
- Reduce the deer population in the park.
- Slow down the runoff from the equestrian campground with detention basins in drainage ways.
- Remove horse manure from the equestrian campground outside of the watershed daily.
- Limit horses on trails near the lake and remove trail manure daily outside of the watershed.

There are other bacteria sources in the Three Fires sub-watershed but distance, time, sedimentation basins, ponds, and wetlands dampen their impacts. These sources include the continuous septic tank and cattle in the stream sources and the pasture and applied manure sources that are available for washoff when it rains. Best management practices for reducing pathogen indicators in the Three Fires sub watershed include:

- Limit livestock access to waterways in pastures and provide alternate watering sources.
- Control manure in runoff using incorporation or subsurface application to physically separate fecal material from surface runoff.
- Place buffer strips along tributaries to slow and divert runoff.
- Repair or replace improperly connected and malfunctioning septic tank systems.

Most of the management practices listed for the Lakeshore sub watershed are more about housekeeping than construction. Daily removal of goose feces and horse manure can be accomplished as soon as resources are available to do it. Managing geese and deer populations might take more time. Below are objectives and a suggested schedule to reduce *E. coli* in Lake of Three Fires.

- Identify, assess, and rank the potential sources within a quarter mile of the lakeshore. Select best management practices for each source. Complete by May 2011.

- Begin implementation of the best management practices by priority ranking for the sources identified in step 1. Reduce the identified source pathogen loading 25 percent by May 2012.
- In 2012, begin the process of identifying, assessing and ranking watershed bacteria sources and selecting BMPs outward from the tributary streams in quarter-mile increments every year.

5. Future Monitoring

These monitoring recommendations for Lake of Three Fires and its watershed are based on accomplishing the water quality goals identified in this bacteria TMDL and the 2003 nutrient and siltation TMDL, and for understanding the lake's water quality trends.

5.1. Existing Monitoring to Support Lake Water Quality Assessment

Existing Lake of Three Fires monitoring consists of two separate programs supported by IDNR. In one, the University of Iowa Hygienic Lab (UHL) collects three to six samples between April and October. These samples are analyzed for nutrients, suspended solids, temperature, pH, chlorophyll, and transparency. The other effort is the separate IDNR beach monitoring program in which samples are collected weekly at the park beach and analyzed for *E. coli*.

These two monitoring efforts provide the information used in the biannual 305(b) water quality assessment and currently form the foundation of Lake of Three Fires monitoring activities. This data is sufficient to assess lake water quality because, over time, it can detect impairments. However, evaluation of pollutant sources, the impacts of specific implemented best management practices, and trends over time requires a more detailed and comprehensive monitoring approach.

5.2. Lake of Three Fires Monitoring Recommendations

Watershed and in-lake water quality monitoring are important elements for support of water quality improvement efforts. They play key roles in the analysis and modeling of pollutant sources and water quality. Watershed stream monitoring provides information for several purposes related to Lake of Three Fires water quality improvement. Table 5-1 outlines the purposes, periods, and general procedures for engaging in this type of monitoring.

Table 5-1 Watershed stream monitoring

Type ID	Purpose	Time frame	General procedure
W1[1].	Measure continuous flow. Required for calculating loads, baseflow separation, flow and load duration curves, model calibration, etc.	Stage measured hourly, April to October.	Requires continuous stage monitoring, monthly or biweekly field measurement of flow, and the development of a hydrograph from these.
W2[1].	Event sampling for phosphorus, nitrogen, suspended solids, and *E. coli*. Provides information on loads during runoff conditions.	Once an hour for at least 24 hours.	Auto-sampler set to begin sampling as stage increases. Samples at preset interval to capture most of hydrograph rise and fall. Operates in conjunction with flow measurement.
W3[1].	Grab sampling for phosphorus, nitrogen, suspended solids, and *E. coli*. Also, field measurements of pH, DO and flow. Provides data for watershed and lake model parameterization.	Once or twice a month, April to October.	Grab samples, field pH, DO, flow. These need to be collected at a range of flow conditions to be most useful.
W4[1].	Long term sampling for phosphorus, nitrogen, suspended solids, and *E. coli* to evaluate long term trends and BMP effectiveness	Once or twice a month for 5 to 10 years, April to October.	Determine confidence required, usually 95%, and calculate number of samples needed to detect a long term trend. Design a statistical model that uses event and monthly sampling data to evaluate watershed loads and detect trends.

1. These are watershed monitoring type identifications used in Table 5-3.

In-lake monitoring is used to assess Lake of Three Fires water quality and support lake eutrophication modeling. Table 5-2 outlines the purposes, periods, and general procedures for in-lake monitoring.

Table 5-2 In-lake monitoring

Type ID	Purpose	Time frame	General procedure
L1[1].	Measure continuous discharge from the lake. Required for estimating total flow into the lake and doing a water balance, developing flow and load duration curves, and providing lake model input and calibration.	Stage measured hourly, ice out to ice in.	Requires continuous stage monitoring, at the discharge weir.
L2[1].	Daily precipitation near the lake. Needed for both watershed and lake models.	Long term and year round.	Well maintained automatic rain gage.
L3[1].	Beach *E. coli* samples collected at the lake swimming beach to determine if water is safe for swimming. It is also needed for load duration curve evaluation.	Sampling done once a week May through October.	Consists of grab samples collected at the swimming beach and analyzed for *E. coli*.

1. These are lake monitoring type identifications used in Table 5-3.

Many lake water quality improvement activities require or can benefit from monitoring. Table 5-3 provides a framework for the monitoring that is necessary or is recommended for each of these.

Table 5-3 Monitoring for future watershed and water quality evaluation and improvement activities

Activity	Time frame and site locations	Necessary monitoring types	Recommended monitoring types
Erosion and sediment control - BMP effectiveness	Two years before and five years after BMP installation, at tributary sites	W1, W2, W4	W3
Watershed BasinSims/GWLF modeling	Ten years of precipitation data and two years of lake discharge.	L1, L2	W1, W2, W3
Load duration curves for bacteria	Five years of precipitation and discharge data.	L1, L3	L2

6. Public Participation

Public involvement is important in the TMDL process since it is the land owners, tenants, and citizens who directly manage land and live in the watershed that will determine Lake of Three Fires water quality. During the development of this TMDL, efforts were made to ensure local stakeholder involvement.

6.1. Public and Stakeholder Meetings

An initial stakeholders meeting was held at 11:00 am on November 3, 2009 at the state park. Lake water quality issues and bacteria sources were identified and discussed. Information obtained at this meeting was used to support development of this WQIP.

Attending:
William Graham, Meeting organizer, IDNR TMDL Program; Jason McCurdy, IDNR Beach Monitoring; Mike McGhee, IDNR Lake Restoration; Doug Sleep, IDNR Lake of Three Fires Park Manager; Chad Paup, IDNR Regional Wildlife Biologist; Gary Sobatka, IDNR Regional Fisheries Biologist; Bob Schierbaum, IDNR State Parks District 3 Supervisor.

A public meeting was held on March 15th, 2010 at the Bedford Fire Station from 6:00 to 8:00 pm. Over one hundred people attending the meeting comprised mostly of people concerned with the horse trails. Staff from the DNR Watershed Improvement Section led the meeting to discuss the results of the Water Quality Improvement Plan and to invite comments on the document.

6.2. Written Comments

A press release was issued on February 25, 2010 notifying the public comment period for the Lake of Three Fires. The public comment period was open from February 25th, 2010 to March 29th, 2010. No public comments with regards to the plan were received during the public comment period.

7. References

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9. Appendices

Appendix A --- Glossary of Terms, Abbreviations, and Acronyms

303(d) list: Refers to section 303(d) of the Federal Clean Water Act, which requires a listing of all public surface waterbodies (creeks, rivers, wetlands, and lakes) that do not support their general and/or designated uses. Also called the state's "Impaired Waters List."

305(b) assessment: Refers to section 305(b) of the Federal Clean Water Act, it is a comprehensive assessment of the state's public waterbodies' ability to support their general and designated uses. Those bodies of water which are found to be not supporting or only partially supporting their uses are placed on the 303(d) list.

319: Refers to Section 319 of the Federal Clean Water Act, the Nonpoint Source Management Program. Under this amendment, States receive grant money from EPA to provide technical & financial assistance, education, & monitoring to implement local nonpoint source water quality projects.

AFO: Animal Feeding Operation. A lot, yard, corral, building, or other area in which animals are confined and fed and maintained for 45 days or more in any 12-month period, and all structures used for the storage of manure from animals in the operation. Open feedlots and confinement feeding operations are considered to be separate animal feeding operations.

AU: Animal Unit. A unit of measure used to compare manure production between animal types or varying sizes of the same animal. For example, one 1,000 pound steer constitutes one AU, while one mature hog weighing 200 pounds constitutes 0.2 AU.

Benthic: Associated with or located at the bottom (in this context, "bottom" refers to the bottom of streams, lakes, or wetlands). Usually refers to algae or other aquatic organisms that reside at the bottom of a wetland, lake, or stream (see periphyton).

Benthic macroinvertebrates: Animals larger than 0.5 mm that do not have backbones. These animals live on rocks, logs, sediment, debris and aquatic plants during some period in their life. They include crayfish, mussels, snails, aquatic worms, and the immature forms of aquatic insects such as stonefly and mayfly nymphs.

Base flow: Sustained flow of a stream in the absence of direct runoff. It can include natural and human-induced stream flows. Natural base flow is sustained largely by groundwater discharges.

Biological impairment: A stream segment is classified as biologically impaired if one or more of the following occurs, the FIBI and or BMIBI scores fall below biological reference conditions, a fish kill has occurred on the segment, or the segment has seen a > 50% reduction in mussel species.

Biological reference condition: Biological reference sites represent the least disturbed (ie. most natural) streams in the ecoregion. The biological data from these sites are used to derive least impacted BMIBI and FIBI scores for each ecoregion. These scores are used to develop Biological Impairment Criteria (BIC) scores for each ecoregion. The BIC is used to determine the impairment status for other stream segments within an ecoregion.

BMIBI: Benthic Macroinvertebrate Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of bottom-dwelling invertebrates.

BMP: Best Management Practice. A general term for any structural or upland soil or water conservation practice. For example terraces, grass waterways, sediment retention ponds, reduced tillage systems, etc.

CAFO: Concentrated Animal Feeding Operation. A federal term defined as any animal feeding operation (AFO) with more than 1000 animal units confined on site, or an AFO of any size that discharges pollutants (e.g. manure, wastewater) into any ditch, stream, or other water conveyance system, whether man-made or natural.

CBOD5: 5-day Carbonaceous Biochemical Oxygen Demand. Measures the amount of oxygen used by microorganisms to oxidize hydrocarbons in a sample of water at a temperature of 20°C and over an elapsed period of five days in the dark.

CFU: A Colony Forming Unit is a cell or cluster of cells capable of multiplying to form a colony of cells. Used as a unit of bacteria concentration when a traditional membrane filter method of analysis is used. Though not necessarily equivalent to most probably number (MPN), the two terms are often used interchangeably.

Confinement feeding operation:	An animal feeding operation (AFO) in which animals are confined to areas which are totally roofed.
Credible data law:	Refers to 455B.193 of the Iowa Administrative Code, which ensures that water quality data used for all purposes of the Federal Clean Water Act are sufficiently up-to-date and accurate. To be considered "credible," data must be collected and analyzed using methods and protocols outlined in an approved Quality Assurance Project Plan (QAPP).
Cyanobacteria (blue-green algae):	Members of the phytoplankton community that are not true algae but are capable of photosynthesis. Some species produce toxic substances that can be harmful to humans and pets.
Designated use(s):	Refer to the type of economic, social, or ecological activities that a specific waterbody is intended to support. See Appendix B for a description of all general and designated uses.
DNR (or IDNR):	Iowa Department of Natural Resources.
Ecoregion:	Areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources based on geology, vegetation, climate, soils, land use, wildlife, and hydrology.
EPA (or USEPA):	United States Environmental Protection Agency.
Ephemeral gully erosion:	Ephemeral gullies occur where runoff from adjacent slopes forms concentrated flow in drainage ways. Ephemerals are void of vegetation and occur in the same location every year. They are crossable with farm equipment and are often partially filled in by tillage.
FIBI:	Fish Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of fish species.
FSA:	Farm Service Agency (United States Department of Agriculture). Federal agency responsible for implementing farm policy, commodity, and conservation programs.
General use(s):	Refer to narrative water quality criteria that all public waterbodies must meet to satisfy public needs and expectations. See Appendix B for a description of all general and designated uses.

Geometric Mean (GM):	A statistic that is a type of mean or average (different from arithmetic mean or average) that measures central tendancy of data. It is often used to summarize highly skewed data or data with extreme values such as wastewater discharges and bacteria concentrations in surface waters. In Iowa's water quality standards and assessment procedures, the geometric mean criteria for *E. coli* is measured using at least five samples collected over a 30-day period.
GIS:	Geographic Information System(s). A collection of map-based data and tools for creating, managing, and analyzing spatial information.
Groundwater:	Subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated.
Gully erosion:	Soil movement (loss) that occurs in defined upland channels and ravines that are typically too wide and deep to fill in with traditional tillage methods.
HEL:	Highly Erodible Land. Defined by the USDA Natural Resources Conservation Service (NRCS), it is land which has the potential for long term annual soil losses to exceed the tolerable amount by eight times for a given agricultural field.
IDALS:	Iowa Department of Agriculture and Land Stewardship
Integrated report:	Refers to a comprehensive document which combines the 305(b) assessment with the 303(d) list, as well as narratives and discussion of overall water quality trends in the state's public waterbodies. The Iowa Department of Natural Resources submits an integrated report to the EPA biennially in even numbered years.
LA:	Load Allocation. The portion of the loading capacity attributed to (1) the existing or future nonpoint sources of pollution and (2) natural background sources. Wherever possible, nonpoint source loads and natural loads should be distinguished. (The total pollutant load is the sum of the wasteload and load allocations.)
LiDAR:	Light Detection and Ranging. Remote sensing technology that uses laser scanning to collect height or elevation data for the earth's surface.

Load: The total amount of pollutants entering a waterbody from one or multiple sources, measured as a rate, as in weight per unit time or per unit area.

Macrophyte: An aquatic plant that is large enough to be seen with the naked eye and grows either in or near water. It can be floating, completely submerged (underwater), or partially submerged.

MOS: Margin of Safety. A required component of the TMDL that accounts for the uncertainty in the response of the water quality of a waterbody to pollutant loads.

MPN: Most Probable Number. Used as a unit of bacteria concentration when a more rapid method of analysis (such as Colisure or Colilert) is utilized. Though not necessarily equivalent to colony forming units (CFU), the two terms are often used interchangeably.

MS4: Municipal Separate Storm Sewer System. A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains) owned and operated by a state, city, town, borough, county, parish, district, association, or other public body (created by or pursuant to state law) having jurisdiction over disposal of sewage, industrial wastes, stormwater, or other wastes, including special districts under state law such as a sewer district, flood control district or drainage district, or similar entity, or an Indian tribe or an authorized Indian tribal organization, or a designated and approved management agency under section 208 of the Clean Water Act (CWA) that discharges to waters of the United States.

Nonpoint source pollution: Pollution that is not released through pipes but rather originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related either to land or water use including failing septic tanks, improper animal-keeping practices, forestry practices, and urban and rural runoff.

NPDES: National Pollution Discharge Elimination System. The national program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under Section 307, 402, 318, and 405 of the Clean Water Act. Facilities subjected to NPDES permitting regulations include operations such as municipal wastewater treatment plants and industrial waste treatment facilities, as well as some MS4s.

NRCS:	Natural Resources Conservation Service (United States Department of Agriculture). Federal agency which provides technical assistance for the conservation and enhancement of natural resources.
Open feedlot:	An unroofed or partially roofed animal feeding operation (AFO) in which no crop, vegetation, or forage growth or residue cover is maintained during the period that animals are confined in the operation.
Periphyton:	Algae that are attached to substrates (rocks, sediment, wood, and other living organisms). Are often located at the bottom of a wetland, lake, or stream.
Phytoplankton:	Collective term for all photosynthetic organisms suspended in the water column. Includes many types of algae and cyanobacteria.
Point source pollution:	Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources are generally regulated by a federal NPDES permit.
Pollutant:	As defined in Clean Water Act section 502(6), a pollutant means dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water.
Pollution:	The man-made or man-induced alteration of the chemical, physical, biological, and/or radiological integrity of water.
PPB:	Parts per Billion. A measure of concentration which is the same as micrograms per liter (µg/L).
PPM:	Parts per Million. A measure of concentration which is the same as milligrams per liter (mg/L).
RASCAL:	Rapid Assessment of Stream Conditions Along Length. RASCAL is a global positioning system (GPS) based assessment procedure designed to provide continuous stream and riparian condition data at a watershed scale.
Riparian:	Refers to areas near the banks of natural courses of water. Features of riparian areas include specific physical, chemical, and

biological characteristics that differ from upland (dry) sites. Usually refers to the area near a bank of a stream or river.

RUSLE: Revised Universal Soil Loss Equation. An empirical model for estimating long term, average annual soil losses due to sheet and rill erosion.

Secchi disk: A device used to measure transparency in waterbodies. The greater the Secchi depth (typically measured in meters), the more transparent the water.

Sediment delivery ratio: A value, expressed as a percent, which is used to describe the fraction of gross soil erosion that is delivered to the waterbody of concern.

Seston: All particulate matter (organic and inorganic) suspended in the water column.

Sheet & rill erosion: Sheet and rill erosion is the detachment and removal of soil from the land surface by raindrop impact, and/or overland runoff. It occurs on slopes with overland flow and where runoff is not concentrated.

Single-Sample Maximum (SSM): A water quality standard criterion used to quantify *E. coli* levels. The single-sample maximum is the maximum allowable concentration measured at a specific point in time in a waterbody.

SI: Stressor Identification. A process by which the specific cause(s) of a biological impairment to a waterbody can be determined from cause-and-effect relationships.

Storm flow (or stormwater): The discharge (flow) from surface runoff generated by a precipitation event. *Stormwater* generally refers to runoff which is routed through some artificial channel or structure, often in urban areas.

STP: Sewage Treatment Plant. General term for a facility that treats municipal sewage prior to discharge to a waterbody according to the conditions of an NPDES permit.

SWCD: Soil and Water Conservation District. Agency which provides local assistance for soil conservation and water quality project implementation, with support from the Iowa Department of Agriculture and Land Stewardship.

TDS: Total Dissolved Solids: The quantitative measure of matter (organic and inorganic material) dissolved, rather than suspended, in the water column. TDS is analyzed in a laboratory and quantifies the material passing through a filter and dried at 180 degrees Celsius.

TMDL: Total Maximum Daily Load. As required by the Federal Clean Water Act, a comprehensive analysis and quantification of the maximum amount of a particular pollutant that a waterbody can tolerate while still meeting its general and designated uses. A TMDL is mathematically defined as the sum of all individual wasteload allocations (WLAs), load allocations (LAs), and a margin of safety (MOS).

Trophic state: The level of ecosystem productivity, typically measured in terms of algal biomass.

TSI (or Carlson's TSI): Trophic State Index. A standardized scoring system developed by Carlson (1977) that places trophic state on an exponential scale of Secchi depth, chlorophyll, and total phosphorus. TSI ranges between 0 and 100, with 10 scale units representing a doubling of algal biomass.

TSS: Total Suspended Solids. The quantitative measure of matter (organic and inorganic material) suspended, rather than dissolved, in the water column. TSS is analyzed in a laboratory and quantifies the material retained by a filter and dried at 103 to 105 degrees Celsius.

Turbidity: A term used to indicate water transparency (or lack thereof). Turbidity is the degree to which light is scattered or absorbed by a fluid. In practical terms, highly turbid waters have a high degree of cloudiness or murkiness caused by suspended particles.

UAA: Use Attainability Analysis. A protocol used to determine which (if any) designated uses apply to a particular waterbody. (See Appendix B for a description of all general and designated uses.)

UHL: University Hygienic Laboratory (University of Iowa). Provides physical, biological, and chemical sampling for water quality purposes in support of beach monitoring, ambient monitoring, biological reference monitoring and impaired water assessments.

USDA: United States Department of Agriculture

USGS: United States Geologic Survey (United States Department of the Interior). Federal agency responsible for implementation and maintenance of discharge (flow) gauging stations on the nation's waterbodies.

Watershed: The land area that drains water (usually surface water) to a particular waterbody or outlet.

WLA: Wasteload Allocation. The portion of a receiving waterbody's loading capacity that is allocated to one of its existing or future point sources of pollution (e.g., permitted waste treatment facilities).

WQS: Water Quality Standards. Defined in Chapter 61 of Environmental Protection Commission [567] of the Iowa Administrative Code, they are the specific criteria by which water quality is gauged in Iowa.

WWTP: Wastewater Treatment Plant. General term for a facility which treats municipal, industrial, or agricultural wastewater for discharge to public waters according to the conditions of the facility's NPDES permit.

Zooplankton: Collective term for all animal plankton suspended in the water column which serve as secondary producers in the aquatic food chain and the primary food source for larger aquatic organisms.

Scientific Notation: Scientific notation is the way that scientists easily handle very large numbers or very small numbers. For example, instead of writing 45,000,000,000 we write 4.5E+10. So, how does this work?

We can think of 4.5E+10 as the product of two numbers: 4.5 (the digit term) and E+10 (the exponential term). Here are some examples of scientific notation.

10,000 = 1E+4	24,327 = 2.4327E+4
1,000 = 1E+3	7,354 = 7.354E+3
100 = 1E+2	482 = 4.82E+2
1/100 = 0.01 = 1E-2	0.053 = 5.3E-2
1/1,000 = 0.001 = 1E-3	0.0078 = 7.8E-3
1/10,000 = 0.0001 = 1E-4	0.00044 = 4.4E-4

As you can see, the exponent is the number of places the decimal point must be shifted to give the number in long form. A **positive** exponent shows that the decimal point is shifted that number of places to the right. A **negative** exponent shows that the decimal point is shifted that number of places to the left.

Appendix B --- General and Designated Uses of Iowa's Waters

Introduction

Iowa's Water Quality Standards (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code) provide the narrative and numerical criteria used to assess water bodies for support of their aquatic life, recreational, and drinking water uses. There are different criteria for different waterbodies depending on their designated uses. All waterbodies must support the general use criteria.

General Use Segments

A general use water body does not have perennial flow or permanent pools of water in most years, i.e. ephemeral or intermittent waterways. General use water bodies are defined in IAC 567-61.3(1) and 61.3(2). General use waters are protected for livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and industrial, agricultural, domestic and other incidental water withdrawal uses.

Designated Use Segments

Designated use water bodies maintain year-round flow or pools of water sufficient to support a viable aquatic community. In addition to being protected for general use, perennial waters are protected for three specific uses, primary contact recreation (Class A), aquatic life (Class B), and drinking water supply (Class C). Within these categories there are thirteen designated use classes as shown in Table B1. Water bodies can have more than one designated use. The designated uses are found in IAC 567-61.3(1).

Table B1 Designated use classes for Iowa water bodies.

Class prefix	Class	Designated use	Brief comments
A	A1	Primary contact recreation	Supports swimming, water skiing, etc.
	A2	Secondary contact recreation	Limited/incidental contact occurs, such as boating
	A3	Children's contact recreation	Urban/residential waters that are attractive to children
B	B(CW1)	Cold water aquatic life – Type 2	Able to support coldwater fish (e.g. trout) populations
	B(CW2)	Cold water aquatic life – Type 2	Typically unable to support consistent trout populations
	B(WW-1)	Warm water aquatic life – Type 1	Suitable for game and nongame fish populations
	B(WW-2)	Warm water aquatic life – Type 2	Smaller streams where game fish populations are limited by physical conditions & flow
	B(WW-3)	Warm water aquatic life – Type 3	Streams that only hold small perennial pools which extremely limit aquatic life
	B(LW)	Warm water aquatic life – Lakes and Wetlands	Artificial and natural impoundments with "lake-like" conditions
C	C	Drinking water supply	Used for raw potable water
Other	HQ	High quality water	Waters with exceptional water quality
	HQR	High quality resource	Waters with unique or outstanding features
	HH	Human health	Fish are routinely harvested for human consumption

Appendix C --- Lake of Three Fires Water Quality Data

The following tables contain the beach monitoring data collected in 2000 when beach monitoring at Lake of Three Fires began subsequent years through 2008.

Table C-1 IDNR 2000 *E. coli* beach data for Lake of Three Fires

Collection date	Result, orgs/100ml	Simulated GWLF daily flow, cfs	Percent rank
5/30/2000	1	9.0	78.3%
6/5/2000	10	9.0	78.1%
6/12/2000	1	13.9	48.1%
6/19/2000	1	18.9	24.9%
6/26/2000	180	27.7	5.6%
7/3/2000	1	26.9	6.2%
7/10/2000	1	23.7	11.0%
7/17/2000	30	20.2	20.8%
7/24/2000	1	17.8	29.2%
7/31/2000	10	19.3	23.5%
8/7/2000	1	16.6	34.6%
8/14/2000	1	13.4	50.5%
8/21/2000	10	19.1	24.2%
8/28/2000	10	17.7	30.0%
9/5/2000	1	13.9	48.0%
9/11/2000	1	11.6	62.0%
9/18/2000	10	9.3	75.9%

Table C-2 IDNR 2001 *E. coli* beach data for Lake of Three Fires

Collection date	Result, orgs/100ml	Simulated GWLF daily flow, cfs	Percent rank
5/21/2001	70	19.2	23.9%
6/4/2001	120	23.7	10.9%
6/6/2001	150	18.7	26.0%
6/11/2001	1	16.0	37.4%
6/18/2001	40	19.6	22.4%
6/25/2001	1	18.5	26.6%
7/2/2001	20	15.9	38.0%
7/9/2001	1	13.6	49.8%
7/16/2001	1	11.0	65.6%
7/19/2001	18	15.6	39.7%
7/23/2001	1	12.5	56.4%
7/26/2001	82	15.1	42.3%
7/30/2001	1	15.6	39.6%
8/6/2001	36	12.6	55.6%
8/13/2001	1	10.2	70.8%
8/20/2001	100	10.3	69.9%
8/27/2001	140	8.3	82.1%
9/5/2001	27	6.3	91.5%
9/10/2001	1	15.0	42.3%

Table C-3 IDNR 2002 E. coli beach data for Lake of Three Fires

Collection date	Result, orgs/100ml	Simulated GWLF daily flow, cfs	Percent rank
4/15/2002	1	10.4	98.4%
4/22/2002	10	14.2	94.1%
4/29/2002	1	22.5	77.2%
5/6/2002	20	32.8	51.4%
5/13/2002	40	44.9	27.7%
5/20/2002	1	37.6	41.4%
5/27/2002	400	42.0	33.2%
6/3/2002	1	33.9	48.8%
6/10/2002	1	30.4	57.2%
6/17/2002	10	28.6	61.6%
6/24/2002	1	23.1	75.8%
7/1/2002	20	19.6	84.4%
7/8/2002	1	21.0	81.2%
7/15/2002	10	17.0	89.1%
7/22/2002	1	13.8	94.8%
7/29/2002	10	31.8	54.1%
8/5/2002	1800	25.7	69.3%
8/12/2002	1	33.2	50.6%
8/19/2002	50	39.5	37.6%
8/26/2002	10	39.1	38.3%
9/3/2002	10	30.7	56.4%
9/9/2002	110	25.5	69.5%
9/16/2002	350	22.2	78.0%
9/23/2002	30	24.6	72.0%
9/30/2002	10	20.7	81.8%
10/7/2002	1	26.0	68.5%
10/14/2002	50	21.0	81.0%
10/21/2002	10	20.2	83.2%
10/28/2002	1	27.7	64.2%

Table C-4 IDNR 2003 *E. coli* beach data for Lake of Three Fires

Collection date	Result, orgs/100ml	Simulated GWLF daily flow, cfs	Percent rank
4/15/2003	1	6.2	92.0%
4/22/2003	1	8.8	79.4%
4/29/2003	200	12.0	58.9%
5/6/2003	10	12.1	58.6%
5/13/2003	10	30.9	3.7%
5/20/2003	81	18.2	27.5%
5/27/2003	10	16.2	36.3%
6/3/2003	1	15.0	42.4%
6/10/2003	1	14.8	43.3%
6/17/2003	10	12.2	57.8%
7/1/2003	10	10.6	67.7%
7/8/2003	10	9.6	74.6%
7/15/2003	10	6.9	89.0%
7/22/2003	30	5.6	94.6%
7/29/2003	81	9.6	74.7%
8/5/2003	40	8.2	83.3%
8/12/2003	330	10.3	69.7%
8/19/2003	72	11.1	64.9%
8/26/2003	200	7.1	88.2%
9/2/2003	140	6.5	90.7%
9/9/2003	80	5.3	95.8%
9/16/2003	40	9.5	74.9%
9/23/2003	140	9.0	78.0%
9/30/2003	1	7.5	86.4%
10/7/2003	10	6.1	92.6%
10/14/2003	10	8.4	81.7%
10/21/2003	1	6.8	89.4%
10/28/2003	10	5.8	93.7%

Table C-5 IDNR 2004 *E. coli* beach data for Lake of Three Fires

Collection date	Result, orgs/100ml	Simulated GWLF daily flow, cfs	Percent rank
5/25/2004	400	23.6	11.1%
6/1/2004	190	25.0	8.8%
6/8/2004	40	20.2	20.8%
6/15/2004	180	23.5	11.3%
6/22/2004	81	20.5	19.8%
6/29/2004	110	16.5	35.1%
7/6/2004	110	14.9	43.0%
7/13/2004	480	19.2	23.7%
7/20/2004	180	19.8	21.9%
7/27/2004	430	17.3	31.7%
8/3/2004	180	32.9	3.3%
8/10/2004	300	17.8	29.3%
8/17/2004	70	14.4	45.4%
8/24/2004	70	35.5	2.4%

Table C-6 IDNR 2005 *E. coli* beach data for Lake of Three Fires

Collection date	Result, orgs/100ml	Simulated GWLF daily flow, cfs	Percent rank
8/2/2005	110	21.7	15.9%
8/9/2005	240	17.5	30.9%
8/16/2005	460	22.8	12.7%
8/23/2005	63	18.8	25.5%
8/30/2005	1	16.4	35.5%
9/6/2005	1	13.3	51.5%
9/13/2005	1	14.0	47.3%
9/20/2005	170	9.6	74.3%
9/27/2005	30	7.8	85.2%
10/4/2005	1	9.2	76.7%
10/11/2005	20	9.7	74.1%
10/18/2005	10	7.0	88.8%
10/25/2005	1	8.8	79.1%

Table C-7 IDNR 2006 *E. coli* beach data for Lake of Three Fires

Collection date	Result, orgs/100ml	Simulated GWLF daily flow, cfs	Percent rank
4/17/2006	20	7.6	86.0%
4/24/2006	80	7.0	88.7%
5/1/2006	90	17.3	31.9%
5/8/2006	20	18.0	28.5%
5/15/2006	40	13.5	50.5%
5/23/2006	10	11.8	60.0%
5/30/2006	1	13.7	48.8%
6/6/2006	1	11.1	65.0%
6/13/2006	180	18.1	28.0%
6/20/2006	100	14.6	44.2%
6/27/2006	1	17.1	32.9%
7/3/2006	70	16.8	34.0%
7/11/2006	30	12.7	55.3%
7/18/2006	10	11.1	64.8%
7/25/2006	1	10.4	69.3%
8/1/2006	72	8.9	78.7%
8/8/2006	160	238.4	0.1%
8/15/2006	140	22.7	13.4%
8/22/2006	20	26.3	6.9%
8/29/2006	720	29.2	4.5%
9/5/2006	460	23.9	10.6%
9/11/2006	1200	25.5	8.1%
9/18/2006	160	22.4	14.0%
9/25/2006	20	20.0	21.3%

Table C-8 IDNR 2007 *E. coli* beach data for Lake of Three Fires

Collection date	Result, orgs/100ml	Simulated GWLF daily flow, cfs	Percent rank
5/22/2007	20	16.4	35.7%
5/30/2007	41	19.9	21.6%
6/5/2007	30	16.7	34.3%
6/12/2007	31	13.5	50.3%
6/19/2007	1	10.9	66.2%
6/26/2007	100	10.6	68.2%
7/2/2007	20	15.6	39.3%
7/10/2007	31	12.3	57.4%
7/17/2007	10	10.6	67.8%
7/24/2007	14136	8.9	78.5%
7/25/2007	97	8.7	80.1%
7/31/2007	16000	8.4	81.7%
8/1/2007	152	9.0	78.2%
8/7/2007	1	138.5	0.3%
8/14/2007	98	25.1	8.5%
8/21/2007	20	20.3	20.6%
8/28/2007	1100	29.5	4.3%
8/29/2007	1200	28.2	5.3%

Table C-9 IDNR 2008 *E. coli* beach data for Lake of Three Fires

Collection date	Result, orgs/100ml	Simulated GWLF daily flow, cfs	Percent rank
5/19/2008	1	10.2	70.7%
5/27/2008	120	13.5	50.0%
6/3/2008	31000	22.7	13.3%
6/4/2008	1600	42.9	1.6%
6/9/2008	4000	28.2	5.2%
6/18/2008	60	32.2	3.4%
6/23/2008	20	33.7	3.0%
6/26/2008	60	41.7	1.7%
6/30/2008	1	34.0	2.9%
7/2/2008	30	32.0	3.4%
7/7/2008	1	27.9	5.4%
7/9/2008	1	29.2	4.5%
7/15/2008	1	24.3	9.9%
7/16/2008	1	23.6	11.2%
7/21/2008	1	46.2	1.4%
7/23/2008	20	37.9	2.1%
7/28/2008	1	27.3	5.9%
7/30/2008	120	24.6	9.4%
8/4/2008	10	21.1	17.7%
8/6/2008	1	19.8	21.7%
8/11/2008	10	17.0	33.0%
8/13/2008	90	16.0	37.4%
8/18/2008	20	13.8	48.7%
8/26/2008	10	10.8	67.0%

IDNR collected additional monitoring data for *E. coli* at six different locations in the watershed and three different locations in the lake in 2004 and 2007. Tables C-10 and C-11 show the data from the beach monitoring and Table C-12 shows the data from the sampling at sites in the watershed.

Table C-10 IDNR 2004 *E. coli* intensive beach data

Lake location	date	ankle	knee	chest
North	6/15/2004	150	130	190
North	7/7/2004	160	30	60
North	7/24/2004	4000	200	63
Center	6/15/2004	660	72	50
Center	7/7/2004	540	40	10
Center	7/24/2004	1600	50	30
South	6/15/2004	610	160	90
South	7/7/2004	1100	140	20
South	7/24/2004	470	30	27
mean		**1032**	**95**	**60**
median		**610**	**72**	**50**

Table C-11 IDNR 2007 *E. coli* intensive beach data

Lake location	date	ankle	knee	chest
North	7/10/2007	40	10	10
North	7/25/2007	160	20	10
North	8/1/2007	10	20	10
North	8/29/2007	160	40	10
Center	7/10/2007	30	10	10
Center	7/25/2007	40	20	10
Center	8/1/2007	510	10	10
Center	8/29/2007	13000	10	100
South	7/10/2007	240	10	10
South	7/25/2007	750	30	10
South	8/1/2007	350	10	10
South	8/29/2007	1900	660	60
mean		**1432.5**	**70.8**	**21.7**
median		**200**	**15.0**	**10.0**

Table C-12 IDNR 2007 *E. coli* intensive watershed data

Site[1]	E. coli, orgs/100ml	E. coli, orgs/100ml	E. coli, orgs/100ml
	6/15/2004	**7/7/2004**	**7/24/2004**
3F1	8300	230	160
3F2	520	390	140
3F3	330		
3F4	280	50	50
3F5	480	36	120
3F6	30	30	50
	7/10/2007	**8/29/2007**	**12/17/2007**
3F1	760	620	120
3F2	120	160	
3F3		400	60
3F4		1200	60
3F5		30	190
3F6		40	80

1.

Appendix D --- Watershed Hydrology, Water Quality Analysis, and Modeling

This water quality plan was developed using a watershed model to simulate hydrology called *BasinSims/ Generalized Watershed Loading Function (GWLF)*, a bacteria source evaluation spreadsheet called the *EPA Bacteria Indicator Tool (BIT)*, and flow and load duration curve analysis spreadsheets. These are listed in Table D-1.

Table D-1 Descriptions of the models used for Lake of Three Fires

Model	Type and purpose	Time frame	Description
BasinSims/GWLF	Watershed model used to simulate hydrology	Annual, monthly, daily	Provides estimates of daily flow to generate recurrence intervals for duration curves.
EPA Bacteria Indicator Tool (BIT)	Bacteria source loads available for washoff or continuous discharged.	Multi-year	Estimates bacteria loads from watershed sources and estimates output.
Flow and load duration curves	Multi-year flow and load analysis for *E. coli*	Multi-year	Transforms daily flow to recurrence intervals and inputs monitored E. coli data to calculate loads and evaluate source contributions and critical flow intervals.

Watershed Modeling – BasinSims/GWLF

The BasinSims/GWLF watershed model uses precipitation and temperature data from the nearby Bedford National Weather Service COOP station (IA0576), land use information from a DNR GIS coverage created from a 2009 watershed assessment. Soil information is from an IDNR GIS coverage based on SSURGO data. The procedures used to simulate watershed hydrology for Lake of Three Fires consist of:

- Obtaining the daily precipitation and temperature data from the Bedford weather station and using to create a weather input file for BasinSims/GWLF.
- Estimating curve numbers based on a recent watershed assessment and SSURGO soils data.
- Running the BasinSims/GWLF model in the **flow only mode** to obtain simulated flow into the lake from the watershed.
- Using this simulated flow to generate flow and load duration curves.

It should be noted that several factors are unnecessary model inputs when erosion, sediment delivery, and nutrients are not required output.

Weather File

As noted, the watershed hydrology is based on BasinSims/GWLF modeling using temperature and precipitation data from a weather station in the City of Bedford, three miles south of Lake of Three Fires. The period used as weather input to the model was April 1, 1998 to March 31, 2009. The watershed was modeled as a single basin.

Transport and Nutrient Files
A Lake of Three Fires watershed field assessment was done in September 2009. The data from the assessment was then used to generate GIS landuse coverage. The BasinSims/GWLF modeling created for this TMDL incorporates this coverage as well as GIS coverages based on aerial photography and satellite imagery. The landuse and soils information has been incorporated into the in the spreadsheet *ThreeFires_CN_Worksheet by weighted LU area.xls* where it has been sorted by land use and soil hydrologic group. A curve number estimate for each land use and soil hydrologic group has been made based on soils data.

The land uses have been weighted by area and a curve number assigned to each. These have been put into the model transport file. The factors in the evapotranspiration tab of the transport file are from the tables in the GWLF User Manual and are typical for Iowa. Table D-2 shows the land uses and parameters for the Land Use Type tab. Table D-3 shows the factors used in the Evapotranspiration tab.

Table D-2 Watershed land use and curve numbers

Land use	Area, acres	Area weighted curve number	Estimated KLSCP
Beans	501	74	0.02
CAFO	4	74	0.004
Cemetery	2	58	0.003
Corn	1,056	74	0.01
Farmstead	43	77	0.001
Feedlot	1	79	0.01
Grass	521	64	0.001
Hay	246	73	0.002
Pasture	395	67	0.005
Roads	74	86	0
Timber	681	66	0.005
Water	200	100	0
Total	**3,723**		

Table D-3 Monthly GWLF parameters for all subbasins

Month	Cover coefficient	Day length	Growing season (1 = yes)	Erosivity coefficient
Apr	0.95	13.2	1	0.3
May	0.95	14.4	1	0.3
Jun	0.95	14.9	1	0.3
Jul	0.95	14.7	1	0.3
Aug	0.95	13.7	1	0.3
Sep	0.95	12.2	1	0.3
Oct	0.95	10.8	1	0.12
Nov	0.45	9.6	0	0.12
Dec	0.45	9.1	0	0.12
Jan	0.45	9.3	0	0.12
Feb	0.45	10.3	0	0.12
Mar	0.45	11.7	0	0.12

The nutrient file has been created based on general Iowa values for phosphorus (sediment P=750 mg/kg and groundwater P=0.04 mg/l) and nitrogen (sediment N=1000 mg/kg and groundwater N=3 mg/l) although these do not play a role in generating flow from the model. The BasinSims/GWLF model does not simulate bacteria so *E. coli* loading cannot be included. Bacteria loads continuously discharged or available for washoff are estimated using the EPA BIT model.

Flow and Load Duration Curves

The simulated flow data from the BasinSims/GWLF modeling has been used to create the flow, load, and runoff duration curves found in this document. The observed concentration data is matched to the modeled flow for the day the sample was collected to calculate the estimated daily load. Similarly, multiplying daily flow values times the GM and SSM of 126 and 235 *E. coli* orgs/100 ml generates the criteria target loads for each day. In general, it is assumed that bacteria are distributed evenly through the stream and lake volumes.

Flows are converted to percent recurrence to create the flow duration curve. The flows at the percent recurrence are multiplied by the relevant *E. coli* concentration to construct the load duration curve. The flow and load duration curves have been divided into five flow conditions that are represented as the percent recurrence of a flow. These five flow conditions are described in Table 3-2 of the main report and are shown in Table D-4.

Table D-4 Flow conditions for recurrence intervals

Recurrence Interval	Flow condition
0-10%	High flows - runoff dominated
10-40%	Moist conditions
40-60%	Mid-range flow
60-90%	Dry conditions - mostly base flow
90-100%	Low (base) flow

Inspection of the sampled concentrations that exceed the criteria at these recurrence intervals provides insight into bacteria sources. In general, monitored bacteria concentrations exceeding the criteria at high flows are from the washoff of nonpoint sources and criteria exceeded at low flows are from continuous discharges sources such as septic tanks and wildlife and livestock in or near the tributary streams and the lake. Between these two extreme flow conditions, there is a continuum of sources from moist conditions when bacteria are delivered by runoff from rainfall, to dry low flow conditions when bacteria are delivered by continuous sources.

The midpoints of the five flow conditions occur at recurrences of 95%, 75%, 50%, 25%, and 5%. The median *E. coli* count for each flow condition is calculated at the two criteria concentrations (126 and 235 orgs/100 ml) for each interval median flow. This calculation becomes the target for the flow condition interval. Figure D-1 (aka Figure 3-5) shows the load and runoff duration curves plotted with the five recurrence intervals. The runoff flows are from the BasinSims/GWLF output converted to a percent recurrence. Two-thirds of the time there is little simulated runoff occurring.

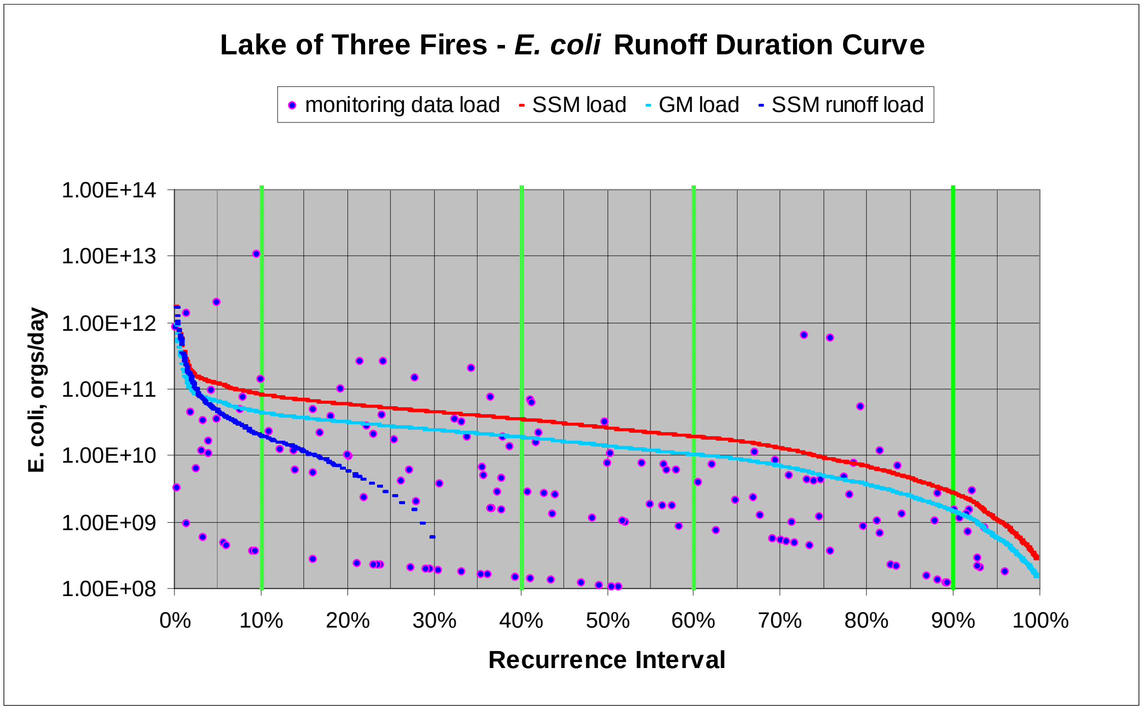

Figure D-1 Load and runoff duration curves

The recurrence interval TMDL targets for GM and SSM are listed in Tables 3-4 and 3-5, respectively. The SSM existing and target loads for the five intervals are shown graphically in Figure 3-7. The existing loads are estimated by multiplying the 90th concentration percentile of all of the monitored *E. coli* values in a flow condition by the midpoint flow.

Pathogen Indicator Analysis and Modeling

In 2004, the Iowa Department of Natural Resources converted from fecal coliform to *E. coli* bacteria as the indicator for primary contact recreation assessment. *E. coli* is now used as the pathogen indicator in the water quality standards but previously fecal coliform was used. There are a few instances in the development of this report where fecal coliform was used in the analysis because some reference materials, particularly for the Bacteria Indicator Tool (BIT) spreadsheet calculations, use fecal coliform as the pathogen indicator.

The fecal coliform/*E. coli* relationship used in this TMDL is based on the WQS geometric mean for fecal coliform that was used before the *E. coli* standard was adopted. The values, respectively, for these geometric means are 200 fecal coliform organisms/100 ml and 126 *E. coli* organisms/100 ml for a ratio of 1.6 for this document. Until November 2006, IDNR used this ratio to convert NPDES permits for wastewater treatment plants from *E. coli* to fecal coliform. BIT model fecal coliform output has been converted to *E. coli* using this ratio.

EPA Bacteria Indicator Tool
EPA's Bacteria Indicator Tool (USEPA, 2001) estimates watershed bacteria accumulation available for washoff when it rains. It is a spreadsheet model that estimates the bacteria contribution from multiple sources based on land use, livestock and wildlife populations, septic tanks, and built up area contributions. The BIT is a model used to estimate bacteria loading to a stream. This model may be used for a lake, depending upon the location of sampling sites and morphology of the lake. For this TMDL, the BIT was used to estimate bacteria source potential for delivery to the lake

It approximates the monthly accumulation rate of bacteria on each of five land uses; cropland, pastureland, forest, ungrazed pasture, and built-up (farmsteads). From this accumulation, the upper limit of the load available for washoff when it rains is derived.

A field survey and watershed assessment in September 2009 by IDNR staff resulted in the livestock numbers and land uses that have been used in the development of this document. The livestock field report is shown below.

> One hog confinement is located in the watershed and it houses 3,840 hogs. According to the manure management plan (MMP) for this confinement, manure is fall applied to all of the SW ¼ of section 29. About 100 acres of this quarter section are in the Lake of Three Fires watershed. The MMP states manure is knifed in at a rate of 2,500-3,200 gallons per acre depending on the crop. In the MMP file there were complaints that the manure application rates were extremely high and the pond located in the SE corner of section 30 was negatively impacted.
>
> Livestock: The survey of the watershed found approximately 150 mature beef cows with calves on pasture and 5 horses on pasture. The horses were on pasture about a half mile west of the state park.

The BIT used the following assumptions for estimates of livestock bacteria contributions:

- Access to pastureland for grazing cattle varies during the year. According to researchers at Iowa State University (Jim Russell, Dept. of Animal Science, Iowa State University. December 2005. Personal communication) cattle are:
- 80 percent confined from January through March.
- During the spring and summer months (April through October) they spend 100% of their time grazing.
- In November and December, they have slightly reduced access and spend approximately 80 percent of their time grazing.

Estimating bacteria loss
In this section the delivery from continuous flow sources at low flow is estimated, as is the ratio of load available for washoff to the load that is delivered at the high and moist flow conditions. The delivered load is approximated as the midpoint existing loads

derived from the LDC procedures. Bacteria loss from the source to the monitored location is often estimated using the following equation where C_x is delivered bacteria load.

$$C_x = C_o / e^{k*t}$$

Where: **Co** = Initial bacteria count, as a concentration of organisms per 100 milliliters or liters or as a daily load, organisms per day at the source.
C_x = Concentration or daily load at a point distance "x" downstream of the discharge.
k = first order decay coefficient, 1/day
t = time of travel, days

The decay coefficient (k) as used here represents the rate at which bacteria loss occurs over time. It is generally between 0.5 and 5 depending on environmental characteristics. The time of travel (t) is the length of time the loss rate is applied between the source and the impacted waterbody. The time of travel can be estimated using the Manning equation.

Estimating time of travel using the Manning equation method:

Solve for:
d = mean depth = hydraulic radius, meters
A= x-section area, m^2
v = stream velocity, meters/second
ToT = time of travel, days

$$Q = \left(\sqrt{S/n}\right)(w)\left(d^{5/3}\right)$$
$$d = \left[Q\left(n/\sqrt{S}\right)(1/w)\right]^{(3/5)}$$
$$A = w*d$$
$$v = Q/A$$
$$ToT = v*L$$

<u>Known</u>
Q = flow, m^3/s
S = slope, meter/meter
n, roughness, unitless
W = channel width, meter
L = segment length, m

Since there are many ponds, detention basins and constructed wetlands in the watershed tributary streams, time of travel is difficult to estimate in the Lake of Three Fires drainage basin. The same factors that make it difficult to approximate time of travel make the decay rate hard to estimate.

There are many mechanisms that increase bacteria decay and removal and extend time of travel in the watershed. Bacteria delivery to the impaired waterbody is affected by the fraction of organisms that are actually washed off from the source. Bacteria loss is affected by natural die off, settling, and predation in detention basins and constructed wetlands. Time of travel is extended by circuitous routing of flow and the many watershed detention basins, ponds, and constructed wetlands. Decay, loss, and travel time are difficult to estimate because of the washoff and transport unknowns. Because of these uncertainties, bacteria loss from the source to the lake has been adjusted upward until the result approximates the existing load for the recurrence interval.

The existing load for each flow interval is predictable using load duration procedures and the loads available for washoff and continuous loads can be estimated using procedures previously described. For each flow interval, there is a ratio of the estimated potential loads at the sources and the existing loads in the lake. The bacteria loss factor have been used to adjust the potential loads from the two sub watersheds to the existing measured loads for the flow intervals in which the impairments have occurred.

At low flow time of travel has been estimated using the average distance of the pasture areas (source for most continuous loads) from the lake along the length of the main tributary. Using aerial photography in GIS the channel length (L) and width (W) have been estimated and are 3 km and 1 meter, respectively. The average elevation change (7.6 meters) over the length of the channel (S) has been determined by counting the number of contour lines from the lake surface upstream and dividing this by the length of the channel. The slope is 7.6/3,000 = 0.0025 m/m

Flow recurrence interval analysis
Three of the five flow intervals have been evaluated; low flow, moist condition flow, and high flow. The primary bacteria impairments occur at moist and high flow conditions and have been evaluated. Continuous flows and loads are separated from precipitation runoff at low flow and so this condition has been evaluated. The median SSM loads at the dry (60 to 90 percent) and mid-range (40 to 60 percent) flow recurrence intervals do not exceed the SSM criteria. Two elevated samples were collected the same week in July 2007 causing the GM criteria to be exceeded (176 *E. coli* orgs/100 ml) for the dry flow condition. This is an isolated episode, probably caused by a nearby source such as geese on the beach or a local rain not captured by the Bedford weather station.

Flow recurrence interval analysis – low flow
The time of travel and the bacteria loss coefficient for low flow conditions has been approximated based on the method outlined above. The only sources of bacteria during low flow conditions are continuous loads. These sources are cattle in the tributary streams, failed septic tanks, and geese in the lake itself.

The estimated delivered continuous load is the midpoint existing load at the low flow recurrence interval (90 to 100 percent) and is 6.85 E+08E+10 *E. coli* orgs/day. The estimated continuous load from the watershed, primarily from cattle in the stream during the summer, is 3.92 E+11 *E. coli* orgs/day. Assuming that septic tanks and cattle in the stream are the entire low flow load, the ratio of delivered to available load is 0.2 percent, not surprising since this watershed has many sediment control basins, farm ponds and wetlands reducing the transported bacteria loads.

Figure D-2 is aerial photography showing the Lake of Three Fires watershed. The large number of sedimentation basins and ponds can be seen along the lake tributaries. Some of these basins are large and have significant detention time, even at high flow. Basins are on both major and minor tributaries with some being in series on the same stream. The basins and their relationship to pasture are displayed in the land use map, Figure F-1, in Appendix F.

Figure D-2 Lake of Three Fires watershed showing the many sedimentation basins (dark areas) on the tributaries that significantly reduce bacteria delivery.

A spreadsheet has been used to work out the delivery of bacteria to the lake at low flow. Using the Manning and bacteria loss equations, Figure D-3 was created to estimate the impact of bacteria loss and time of travel on continuous bacteria load delivery to the lake. A bacteria loss coefficient of five has been selected to incorporate bacteria loss, sedimentation loss, and zooplankton predation. The travel time is controlled by velocity and distance. The velocity has been fixed at 0.18 ft/s so that delivered load matches the existing low flow midpoint load. The resulting time of travel is 0.85 day.

In Figure D-3 the existing and target loads are plotted and, as previously shown, the existing load is less than the target load. This means that the continuous bacteria sources, cattle in the stream and septic tank systems, are not primary sources of the bacteria impairment. Figure D-3 also shows the potential watershed load from continuous sources as estimated by the BIT model plotted with the existing and target loads. The available watershed load is much higher than the existing load in the lake at low flow. The difference between the available and delivered existing loads results from reduced velocities and subsequent longer travel times at low flow during dry periods allowing for significant bacteria loss and loss. There is only one minor criteria exceedance at low flow conditions indicating that cattle in the stream and failed septic tank systems are not important sources at the other four higher flow conditions.

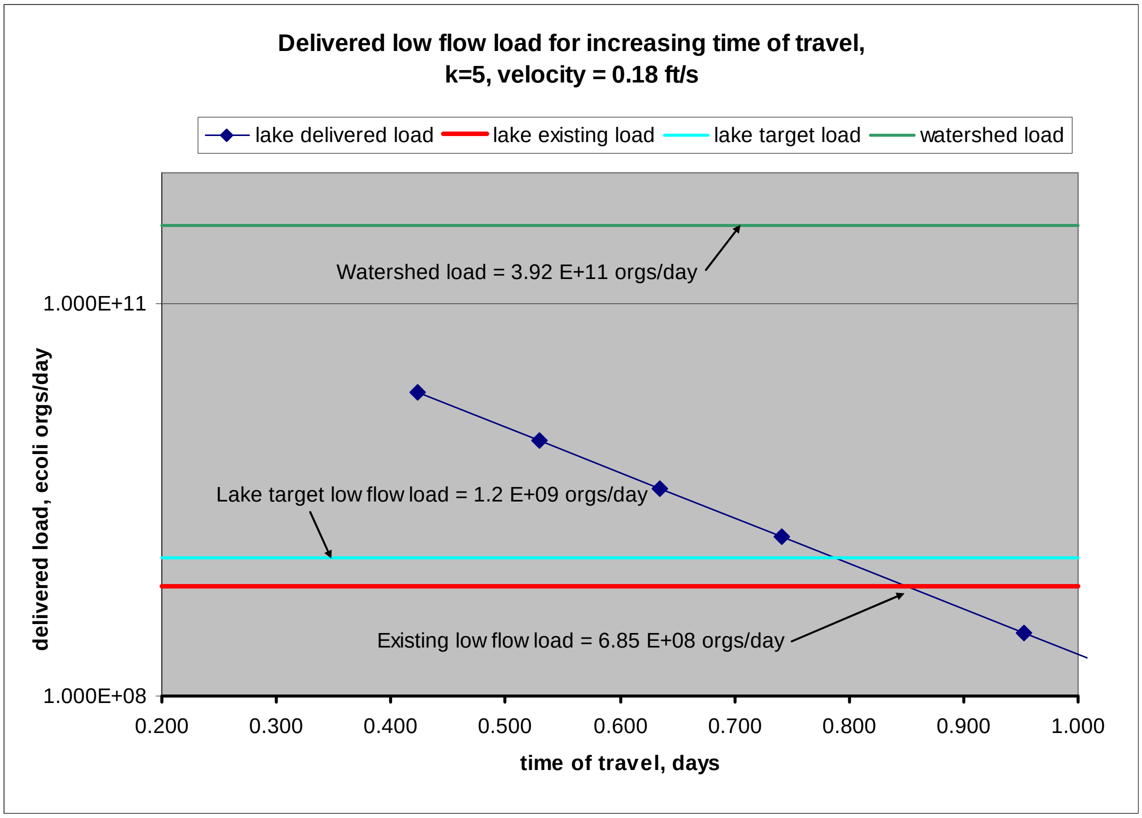

Figure D-3 Watershed continuous load estimate and delivered load

Moist flow recurrence interval analysis
At the moist flow condition (ten to forty percent recurrence), the existing load at midpoint flow is 8.52 E+10 *E. coli* orgs/day and this delivered load is divided between the Lakeshore and the Three Fires sub watersheds. The load available for washoff from both sub watersheds has been estimated using the BIT source model. The analysis assumes the Lakeshore sub watershed is the primary source of bacteria during moist flow runoff conditions based on:

- the close proximity of the sources to the beach,
- the brief to non-existent time of travel when it rains for runoff from the Lakeshore sub watershed to get to the lake,
- the results of intensive sampling in 2007 show *E. coli* concentrations decreasing with distance from the beach shoreline, and

- the size of the available load and the timing of the criteria violations.

The Lakeshore sub watershed load available for washoff is 5.28 E+11 orgs/day. Figure D-4 shows how the bacteria load decreases with increasing distance from the source to the lake at moist flow conditions when bacteria loss is set at 20 and the velocity is set at 0.02 ft/s. This bacteria loss factor (k) and velocity give a typical distance of 92 feet from source to the beach where the samples are collected. This seems reasonable.

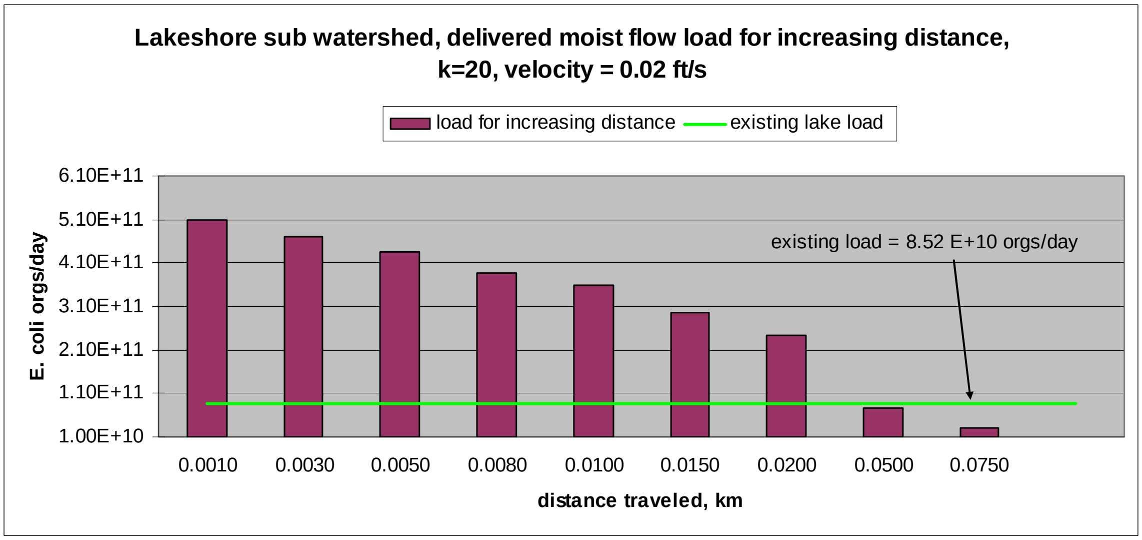

Figure D-4 Lakeshore sub watershed load estimates at moist flow for increasing distance from the lake

Figure D-5 shows similar information with the distance replaced by time of travel on the x-axis. In addition to the existing load, the figure shows the delivered and available (watershed) loads for the same bacteria loss rate (k=20) and velocity (0.02 ft/s).

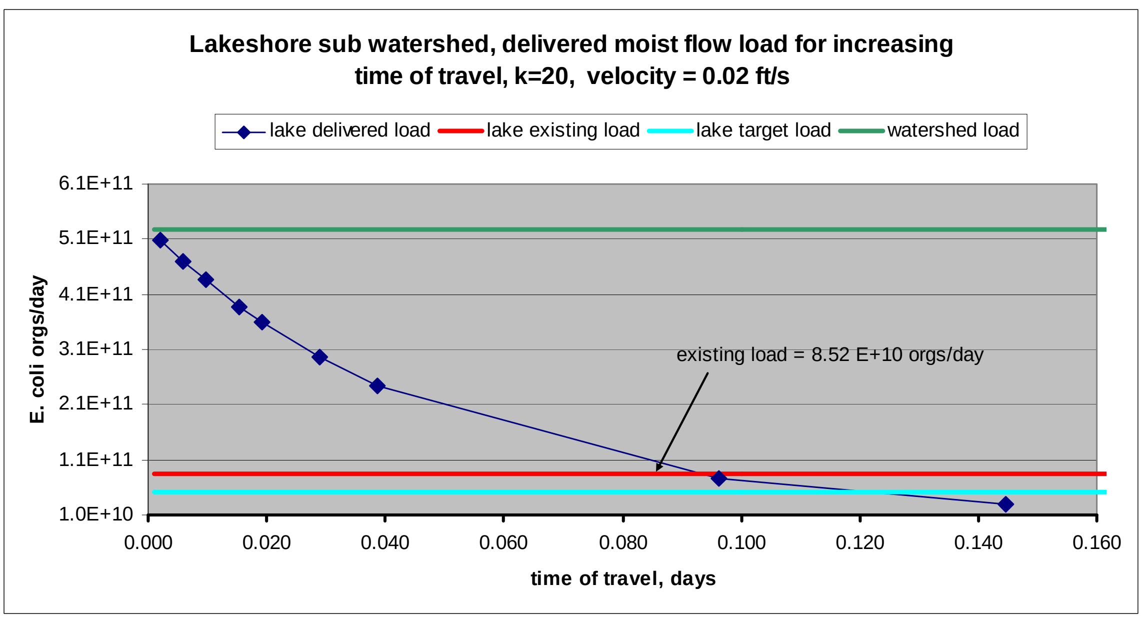

Figure D-5 Lakeshore sub watershed load estimates at moist flow for increasing time of travel to the lake

The delivered loads from the two sub watersheds, Lakeshore and Three Fires, add up to the existing load. That means that the delivered load in the Lakeshore sub watershed lies somewhere below the existing load line along the delivered load line in Figure D-5.

The Three Fires sub watershed load available for washoff is 9.43 E+12 *E. coli* orgs/day. The BIT indicates that most of the Three Fires sub watershed load comes from the grazed pasture land use.

Figure D-6 shows how the bacteria load decreases with increasing distance from the sources to the lake at moist flow conditions when the bacteria loss is set at 30 and the velocity is set at 1.1 ft/s. The velocity is higher than in the Lakeshore watershed since the flow is concentrated from the much larger surface area of the Three Fires watershed. The bacteria loss rate (k) is adjusted so that the delivered load is less than the total existing load at the selected velocity. This velocity and decay signify a typical distance of 15,000 feet from source to the beach where the samples are collected to get from the available load to the delivered load.

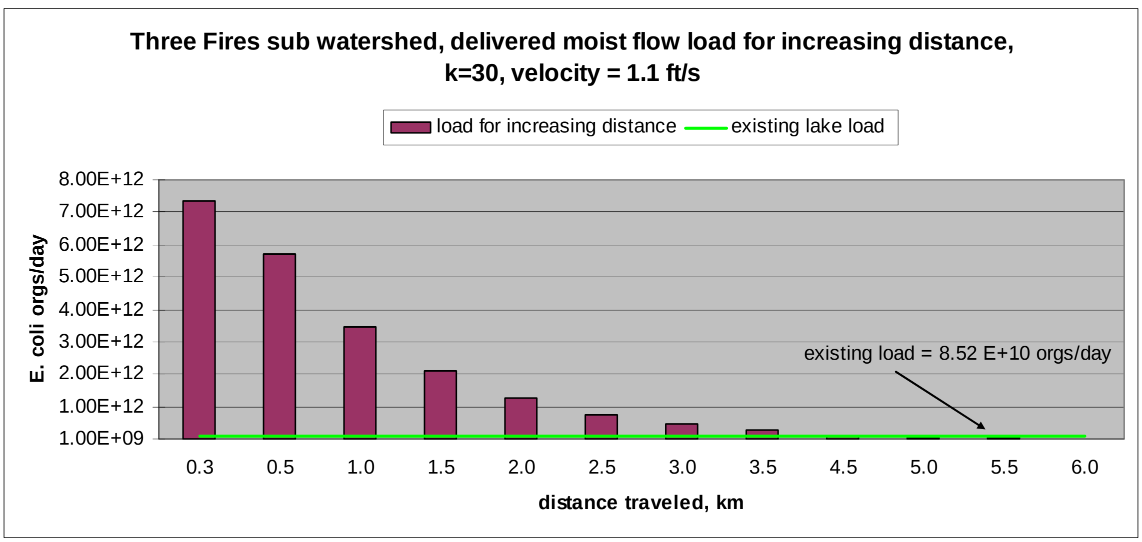

Figure D-6 Three Fires sub watershed load estimates at moist flow for increasing distance from the lake

Figure D-7 shows similar information with the distance replaced by time of travel on the x-axis. In addition to the existing load, the figure shows the delivered and available (watershed) loads for the same bacteria loss factor (30) and velocity (1.1 ft/s). There are about two orders of magnitude difference between estimated load available for washoff and the delivered existing load.

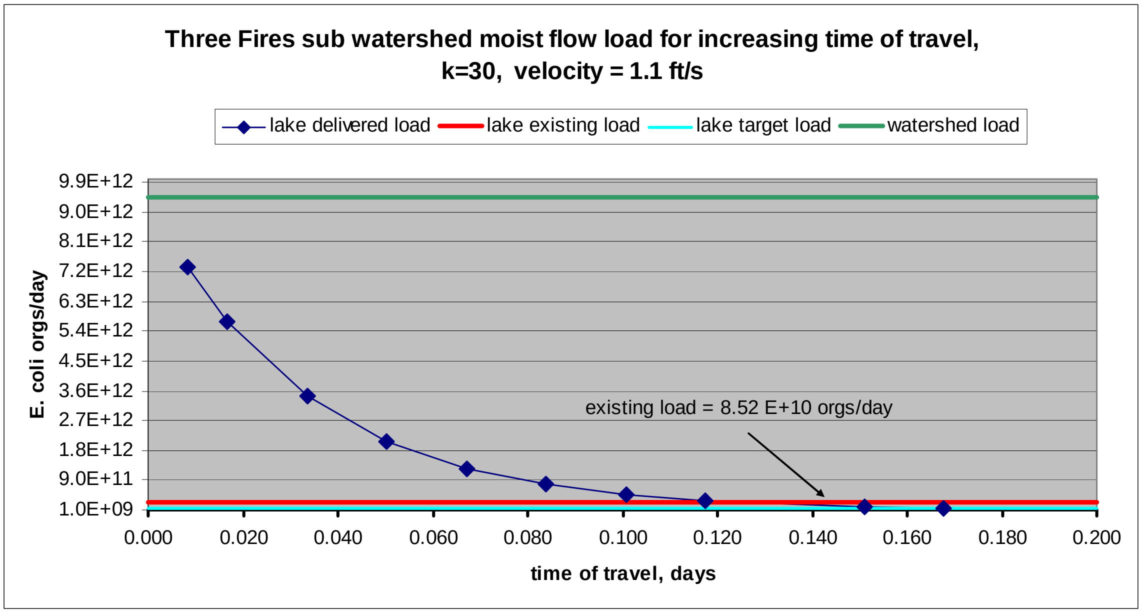

Figure D-7 Three Fires sub watershed load estimates at moist flow for increasing time of travel to the lake

The total load at moist flow is 8.52 E+10 E. coli orgs/day. This load consists of the summed loads from the two sub watersheds. Table D-5 shows the load for five load fraction combinations. It is assumed for this report that the Lakeshore load at moist flow is 80 percent of the total load or 6.76 E+10 orgs/day. The corresponding Three Fires sub watershed load is 1.69 E+10 orgs/day. This load division between the two watersheds is based on the close proximity of the Lakeshore sub watershed sources and the many detention basins that intercept flows from the Three Fires sub watershed reducing bacteria concentrations.

Table D-5 Moist flow fraction of total load for the two sub watersheds

Lakeshore load fraction	Lakeshore load, orgs/day	Three Fires load fraction	Three Fires load, orgs/day
0.5	4.22E+10	0.5	4.22E+10
0.6	5.07E+10	0.4	3.38E+10
0.7	5.91E+10	0.3	2.53E+10
0.8[1]	6.76E+10	0.2	1.69E+10
0.9	7.60E+10	0.1	8.45E+09

1. Estimated fraction of load originating in the Lakeshore sub watershed.

High flow recurrence interval analysis

At the high flow condition (zero to ten percent recurrence interval), the existing load at midpoint flow is 8.03 E+11 orgs/day. This is a large increase in the midpoint load over the moist flow condition. As with the moist conditions analysis, the delivered load is divided between the Lakeshore and Three Fires sub watersheds and again it is assumed that the Lakeshore sub watershed is the primary source of bacteria during high flow runoff conditions.

The load available for washoff from both sub watersheds has been estimated using the BIT source model. The analysis assumes the Lakeshore sub watershed is the primary source of bacteria during moist flow runoff conditions based on:

- the close proximity of the sources to the beach,
- the brief to non-existent time of travel when it rains for runoff from the Lakeshore sub watershed to get to the lake,
- the results of intensive sampling in 2007 show *E. coli* concentrations decreasing with distance from the beach shoreline, and
- the size of the available load and the timing of the criteria violations.

The Lakeshore sub watershed load available for washoff is 5.28 E+11 orgs/day. Figure D-8 shows how the bacteria load decreases with increasing distance from the source to the lake at high flow conditions when the bacteria loss factor (k) set at 20 and the velocity is set at 0.04 ft/s. This bacteria loss factor and velocity give a typical distance of 92 feet from source to the beach where the samples are collected.

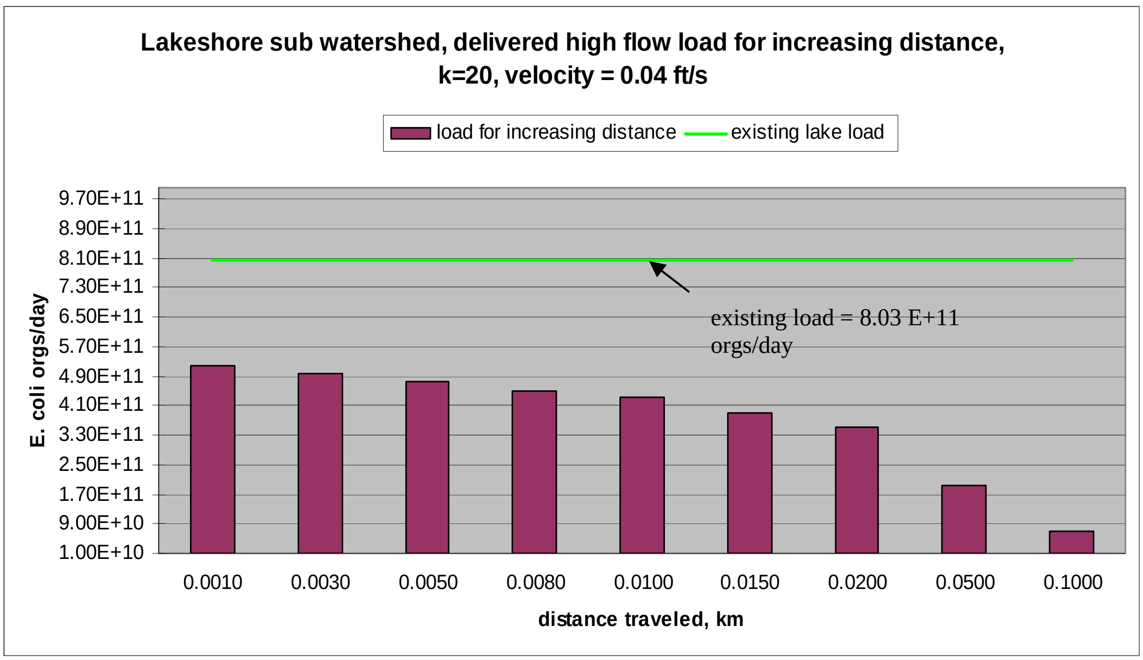

Figure D-8 Lakeshore sub watershed load estimates at high flow for increasing distance from the lake

Figure D-9 shows similar information with the distance replaced by time of travel on the x-axis. In addition to the existing load, the figure shows the delivered and available (watershed) loads for the same bacteria loss rate (k=20) and velocity (0.04 ft/s).

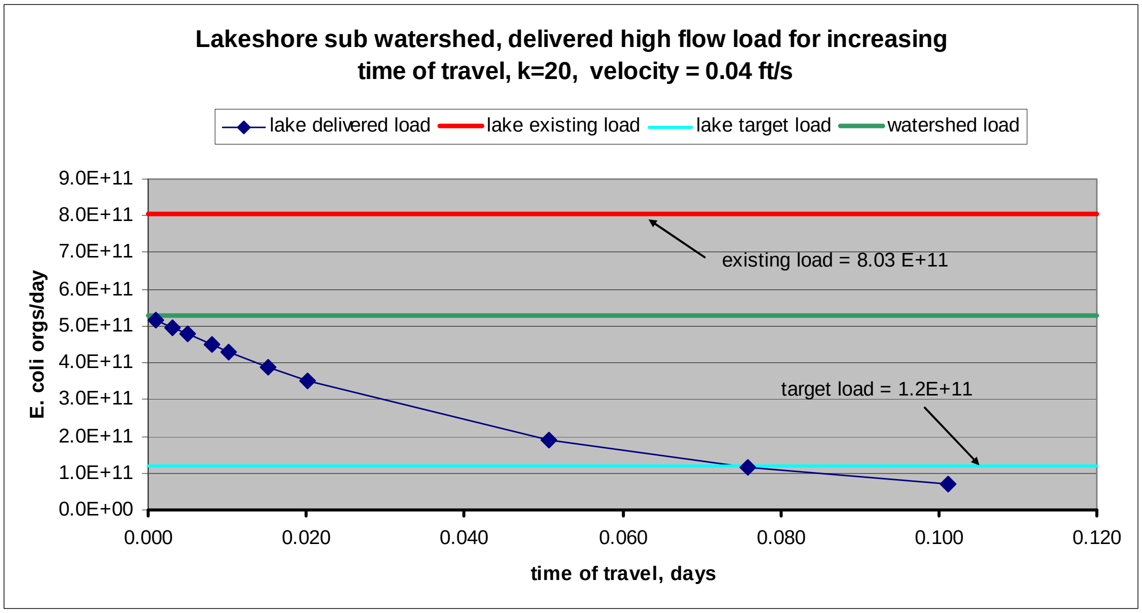

Figure D-9 Lakeshore sub watershed load estimates at high flow for increasing time of travel to the lake

As with the moist flow condition, the high flow delivered loads from the two sub watersheds, Lakeshore and Three Fires, add up to the existing load. That means that the delivered load in the Lakeshore sub watershed lies somewhere along the delivered load curve in Figure D-9, below the existing load line.

The Three Fires sub watershed load available for washoff is the same for both the moist and high flow conditions, 9.43 E+12 orgs/day. Most of the Three Fires sub watershed load comes from the grazed pasture land use and includes the continuous cattle in the stream load seen at the low flow condition.

Figure D-10 shows bacteria load decreasing with increasing distance from the sources to the lake at high flow conditions. The bacteria loss factor is set at 20 and the velocity is set at 0.04 ft/s. As noted for the moist flow condition, the velocity is higher than in the Lakeshore watershed. The flow is concentrated from the greater surface area of the Three Fires watershed. The bacteria loss rate is adjusted so that the delivered load is less than the total existing load at the selected velocity. This velocity and loss rate suggest a typical distance of 13,000 feet from source to the beach where the samples are collected to get from the available load to the delivered load.

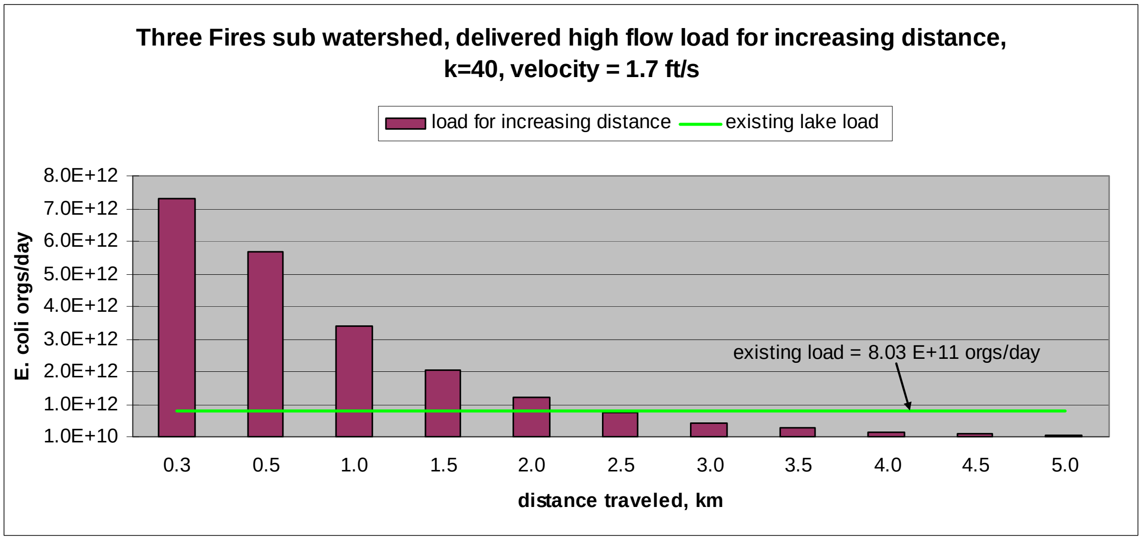

Figure D-10 Three Fires sub watershed load estimates at high flow for increasing distance from the lake

Figure D-11 shows similar information with the distance replaced by time of travel on the x-axis. In addition to the existing load, the figure shows the delivered and available (watershed) loads for the same bacteria loss rate (k=40) and velocity (1.7 ft/s). The load available for washoff is the same at both the moist and high flow conditions but the existing load is higher for the high flow condition.

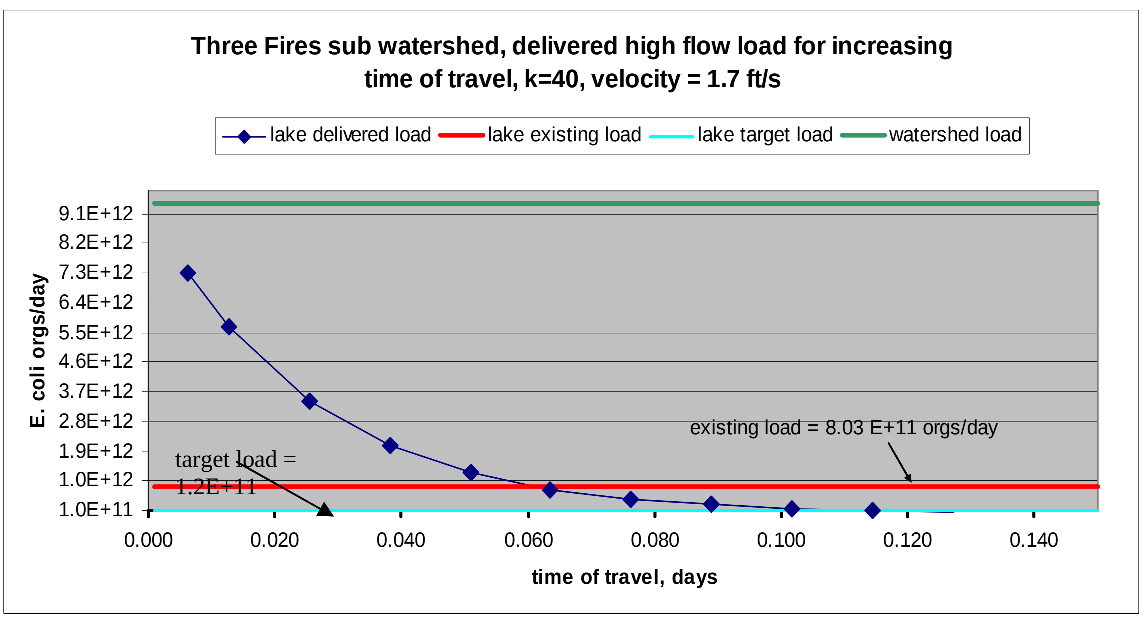

Figure D-11 Three Fires sub watershed load estimates at high flow for increasing time of travel to the lake

The total load at high flow is 8.03 E+11 E. coli orgs/day. This load consists of the summed loads from the two sub watersheds. Table D-6 shows the load at for five load fraction combinations. It is assumed for this report that the Lakeshore load at high flow is 60 percent of the total load or 4.82 E+11 orgs/day. The corresponding Three Fires sub watershed load is 3.21 E+11 orgs/day.

The total load at high flow is 8.03 E+11 E. coli orgs/day. This load consists of the summed loads from the two sub watersheds. Table D-6 shows the load for five load fraction combinations. It is assumed for this report that the Lakeshore load at high flow is 60 percent of the total load or 4.82 E+11 orgs/day. The corresponding Three Fires sub watershed load is 3.21 E+10 orgs/day. This division between the two watersheds is based on the proximity of the Lakeshore sub watershed sources and the many detention basins that intercept flows from the Three Fires sub watershed reducing bacteria concentrations.

Table D-6 High flow fraction of total load for the two sub watersheds

Lakeshore load fraction	Lakeshore load, orgs/day	Three Fires load fraction	Three Fires load, orgs/day
0.5	4.01E+11	0.5	4.01E+11
0.6[1]	4.82E+11	0.4	3.21E+11
0.7	5.62E+11	0.3	2.41E+11
0.8	6.42E+11	0.2	1.61E+11
0.9	7.22E+11	0.1	8.03E+10

1. Estimated fraction of load originating in the Lakeshore sub watershed.

Analysis and Model Documentation

The data analysis and modeling for the Lake of Three Fires TMDL are contained in the spreadsheet and model input files listed below in Tables D-7 to D-10. These folders, spreadsheets, and model input files are located in the folder S*upport Documentation*. The spreadsheets contain the data and information used to develop this water quality improvement plan, the BasinSims/GWLF model input and output files, and the BIT bacteria sourcing. These models and related documentation can be downloaded from the internet. The model files can be directly loaded into the downloaded model software.

Table D-7 Data and analysis spreadsheets for *E. coli*

Folder and file name	Description of contents
Data and analysis (folder)	**Spreadsheet files with data, data analysis and modeling for bacteria**
3 fires bacteria data.xls	Original *E. coli* data
weather and rain vs ecoli 2.xls	Temperature and precipitation data from the Bedford weather station.
Lake_of_Three_Fires_Intensive2.xls	2004 and 2007 E. coli data from the beach at different depths and in the watershed at six tributary sites.

Table D-8 BasinSims/GWLF watershed model folders and files

Folder and file name	Description of contents
GWLF model (folder)	GWLF model files used for duration curve development.
Input development (subfolder)	Spreadsheet files used in the development and parameterization of the GWLF model.
ThreeFires_CN_Worksheet by weighted LU area.xls	Land uses and estimates of curve numbers
Input (subfolder)	The GWLF model transport, nutrient, and weather files are here
threefires EPA.prj	Files with the prj extension are GWLF project files and load input files into the model.
3fires weather 2.dat	The 11 year GWLF weather file used for the model.
EPA3fires1transport.dat	The GWLF transport file for the model.
test1nutrient.dat	The GWLF nutrient file for the model.
Output (subfolder)	The GWLF model output files are here
EPA 3fires Results.dat	The monthly mean results for each year of the 11 used in this GWLF model
EPA 3fires Summary.dat	The summarized mean results for the 11 years of weather data used in this GWLF model.
EPA3firesStream.xls	This spreadsheet contains the daily flow and runoff output from the GWLF model.

Table D-9 BIT and duration curve folders and files

Folder and file name	Description of contents
BIT and duration curves(folder)	**Spreadsheet files with BIT model and flow and load duration curves**
3fires 2009 BIT landuses.xls	Field assessment landuses adapted for use in the BIT
Three Fires BIT6.xls	Bacteria Indicator Tool used to evaluate watershed sources of bacteria.
EPA 3fires flow and load curves.xls	Flow and load duration curves using GWLF hydrology and E. coli data
EPA 3fires new load calcs.xls	Calculation of target and existing loads

Table D-10 TMDL, LA, and MOS calculation folders and files

Folder and file name	Description of contents
TMDL calcs (folder)	**Spreadsheet files with BIT model and flow and load duration curves**
EPA 3fires TMDL and loads3.xls	Spreadsheet calculations and charts showing TMDL, LA, and existing loads in charts.
EPA load delivery calcs3.xls	Loads delivered by animal and land use sources.

Appendix E --- Maps

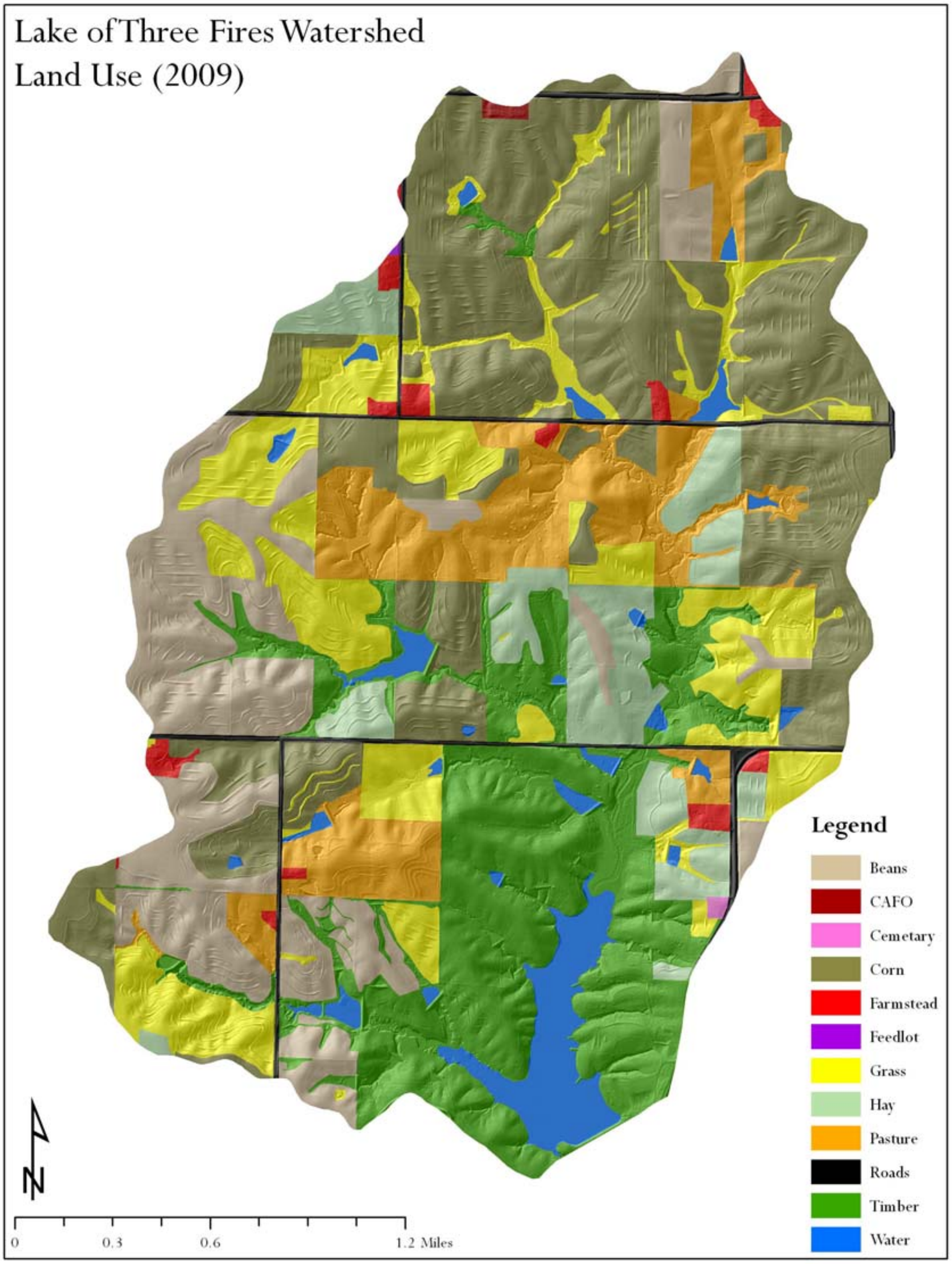

Figure E-1 Lake of Three Fires land use map based on 2009 assessment

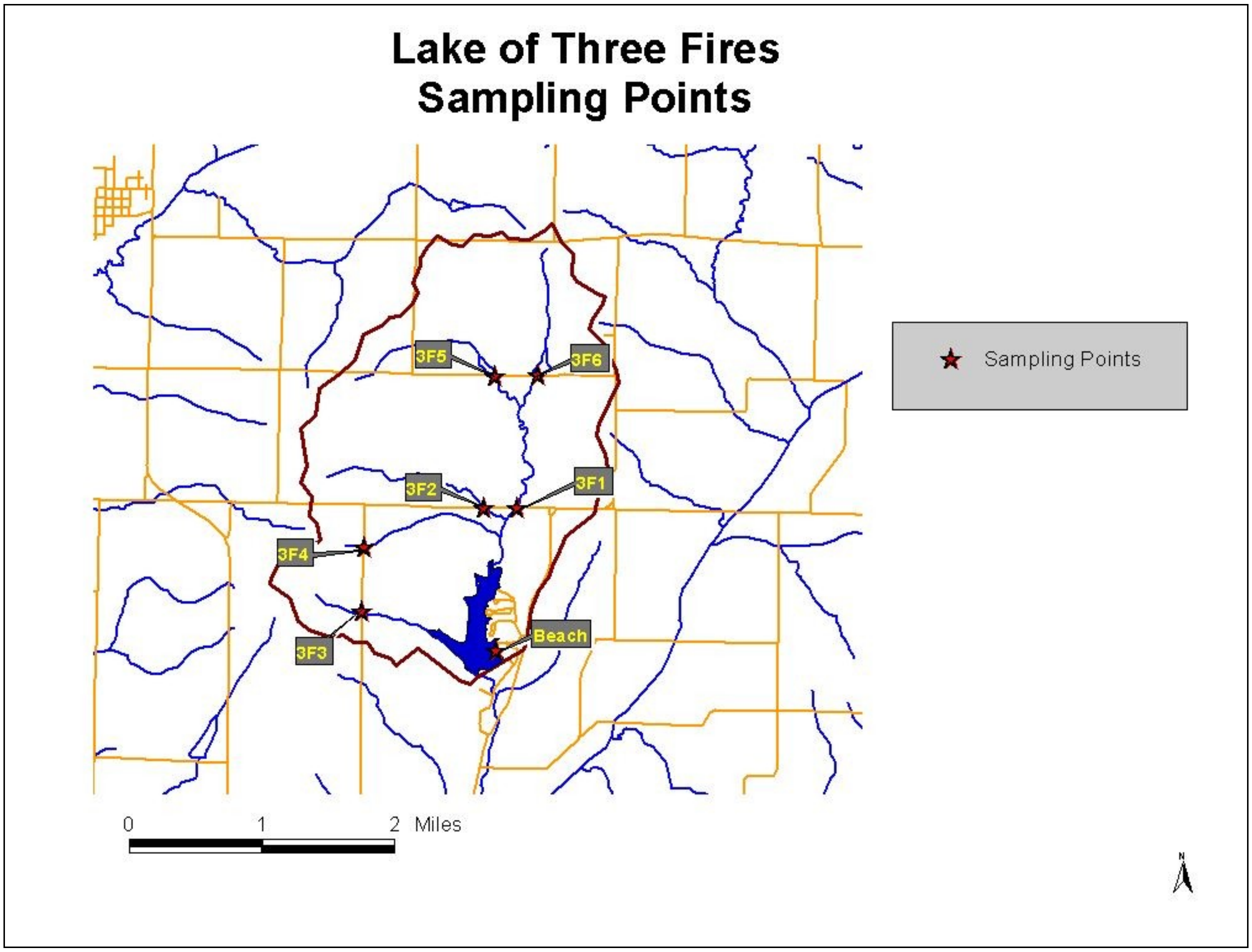

Figure E-2 Locations for watershed E. coli intensive sampling in 2004 and 2007

Appendix F --- Water Quality Assessments – 2008 305(b) Report

The 2008 305(b) water quality assessments for Lake of Three Fires are found below. They describe the rationales behind the finding that the primary contact recreation use is not fully supported.

2008 Water Quality Assessment: Assessment results from 2004 through 2006

Assessment Comments
Assessment is based on: (1) results of the IDNR-UHL beach monitoring program in the summers of 2004, 2005, and 2006 (2) results of the statewide survey of Iowa lakes conducted from 2002 through 2006 by Iowa State University (ISU), (3) results of the statewide ambient lake monitoring program conducted in 2005 and 2006 by University Hygienic Laboratory (UHL), (4) information from the IDNR Fisheries Bureau, and (5) IDNR/EPA fish tissue (RAFT) monitoring in 1998 and 2006.

Assessment Summary and Beneficial Use Support

- Overall Use Support - Not supporting
- Aquatic Life Support – Partial
- Fish Consumption – Fully
- Primary Contact Recreation - Not supporting
- Drinking Water - Not assessed
- Assessment Type: Monitored
- Integrated Report Category: 5a
- Water is impaired or a declining water quality trend is evident, and a TMDL is needed.
- Trend: Stable
- Trophic Level: Eutrophic

Basis for Assessment and Comments
SUMMARY: The Class A1 (primary contact recreation) uses are assessed (monitored) as “not supported” due to levels of indicator bacteria that exceed Iowa’s water quality standard. High levels of cyanobacteria are also a concern at this lake. The Class B(LW) (aquatic life) uses are assessed (evaluated) as “partially supported” due to high levels of non-algal turbidity. Fish consumption uses are assessed (monitored) as “fully supported.” Sources of data for this assessment include (1) results of the IDNR-UHL beach monitoring program in the summers of 2004, 2005, and 2006 (2) results of the statewide survey of Iowa lakes conducted from 2002 through 2006 by Iowa State University (ISU), (3) results of the statewide ambient lake monitoring program conducted in 2005 and 2006 by University Hygienic Laboratory (UHL), (4) information from the IDNR Fisheries Bureau, and (5) IDNR/EPA fish tissue (RAFT) monitoring in 1998 and 2006.

Note: A TMDL for impacts of siltation and nutrients at Lake of Three Fires was prepared by IDNR and approved by EPA in 2002; thus, this lake was placed into IR Category 4a (TMDL approved) for the 2004 assessment/listing cycle. Not all Section 303(d) impairments identified for the 2006 assessment/listing cycle and the current (2008) assessment/listing cycle (indicator bacteria), however, are addressed in the TMDL. Thus, this waterbody remains in Category 5a (impaired; TMDL required) for the 2008 assessment/listing cycle.

EXPLANATION: Results of IDNR-UHL beach monitoring from 2004 through 2006 suggest that the Class A1 uses are "not supported." Levels of indicator bacteria at Lake of Three Fires beach were monitored once per week during the primary contact recreation seasons (May through September) of 2004 (14 samples), 2005 (12 samples), and 2006 (27 samples) as part of the IDNR-UHL beach monitoring program. According to IDNR's assessment methodology, two conditions need to be met for results of beach monitoring to indicate "full support" of the Class A1 (primary contact recreation) uses: (1) all thirty-day geometric means for the three-year assessment period are less than the state's geometric mean criterion of 126 E. coli orgs/100 ml and (2) not more than 10 % of the samples during any one recreation season exceeds the state's single-sample maximum value of 235 E. coli orgs/100 ml. If a 5-sample, 30-day geometric mean exceeds the state criterion of 126 orgs/100 ml during the three-year assessment period, the Class A1 uses should be assessed as "not supported." Also, if significantly more than 10% of the samples in any one of the three recreation seasons exceed Iowa's single-sample maximum value of 235 E. coli orgs/100 ml, the Class A1 uses should be assessed as "partially supported." This assessment approach is based on U.S. EPA guidelines (see pgs 3-33 to 3-35 of U.S. EPA 1997b).

At Lake of Three Fires beach, the geometric means of 13 thirty-day periods during the summer recreation seasons of 2004, 2005 and 2006 exceeded the Iowa water quality standard of 126 E. coli orgs/100 ml: 8 of 10 geometric means violated in 2004, 0 of 8 geometric means violated in 2005, and 5 of 23 geometric means violated in 2006. Also, the percentage of samples exceeding Iowa's single-sample maximum criterion (235 E. coli orgs/100 ml) was significantly greater than 10% in the 2004 recreation season (29%). The percentages of samples exceeding Iowa's single-sample maximum criterion in 2005 (17%) and 2006 (11%) were not significantly greater than 10% and therefore do not suggest impairment of the Class A1 uses. According to IDNR's assessment methodology and U.S. EPA guidelines, these results suggest impairment (nonsupport) of the Class A1 (primary contact recreation) uses.

Lake of Three Fires was sampled as part of IDNR's Safe Lakes Program, which aims to identify sources of bacteria to selected beaches where bacteria levels have consistently violated the state water quality criteria. The Safe Lakes Program found that wildlife (mainly geese) were the likely source of bacteria to Lake of Three Fires. Geese were noted regularly during sampling. Also, bacteria levels throughout the watershed were found to be consistently low, while bacteria levels in the sand were very high suggesting that inputs from the watershed were less significant than bacteria inputs at the beach.

Results from the ISU lake survey and the UHL ambient lake monitoring program suggest that the Class A1 (primary contact recreation) uses for Lake of Three Fires be assessed (monitored) as "partially supported" for the 2008 reporting cycle. Using the median values from these surveys from 2002 through 2006 (approximately 18 samples), Carlson's (1977) trophic state indices for Secchi depth, chlorophyll a, and total phosphorus were 64, 63, and 68 respectively for Lake of Three Fires. According to Carlson (1977) the Secchi depth, chlorophyll a, and total phosphorus values all place Lake of Three Fires in between the eutrophic and the hypereutrophic categories. While these values show improvement over the 2006 listing/assessment cycle (Secchi depth TSI 69, chlorophyll a TSI 64, total phosphorus TSI 73), the TSI scores from the 2008 listing/assessment cycle are not sufficiently less than 65 to propose delisting of this lake. The 2008 values suggest moderately high levels of chlorophyll a and suspended algae in the water, moderately poor water transparency, and high levels of phosphorus in the water column.

Based on data from the ISU and UHL surveys in 2002 through 2006, the median concentration of inorganic suspended solids was 6.0 mg/L, which was the 46th highest concentration of the 132 lakes monitored by these programs. These moderately high levels suggest potential problems related to in-lake turbidity.

Data from the 2002-2006 ISU and UHL surveys suggest a large population of cyanobacteria exists at Lake of Three Fires, which contributes to impairment at this lake. These data show that cyanobacteria comprised 98% of the phytoplankton wet mass at this lake. The median cyanobacteria wet mass (80.7 mg/L) was also the 12th highest of the 132 lakes sampled. This median is in the worst 25% of the 132 lakes sampled. The presence of a large population of cyanobacteria at this lake suggests a potential violation of Iowa's narrative water quality standard protecting against the occurrence of nuisance aquatic life. This assessment is based strictly on the distribution of the lake-specific median cyanobacteria values from 2002-2006. Median levels greater than the 75th percentile of this distribution were arbitrarily considered to represent potential impairment. No other criteria exist, however, upon which to base a more accurate identification of impairments due to cyanobacteria. Assessments based on level of cyanobacteria will be considered "evaluated" (indicating an assessment with relatively lower confidence) as opposed to "monitored" (indicating an assessment with relatively higher confidence) to account for this lower level of confidence.

The Class B (LW) (aquatic life) uses are assessed (evaluated) as "partially supported." Information from the IDNR Fisheries Bureau suggests that water clarity and fish populations have improved at Lake of Three Fires following a dredging project and fishery renovation initiated in 2004. However, high levels of algal and non-algal turbidity remain concerns at this lake.

Results from the ISU and UHL lake surveys and physical/chemical monitoring associated with the IDNR-UHL beach monitoring program show good chemical water quality at Lake of Three Fires. The ISU and UHL lake surveys data from 2002-2006 show no violations of the Class B (LW) criteria for ammonia in 11 samples and only one violation of the Class B(LW) criterion for pH in 18 samples. The data show 2 violations of the criterion for dissolved oxygen in 18 samples (11%). Based on IDNR's assessment methodology, however, these violations are not significantly greater than 10% of the samples necessary to suggest impairment of the Class B (LW) uses. Results of physical/chemical monitoring as part of IDNR's beach monitoring program also suggest good water quality at Lake of Three Fires. Data from the beach monitoring program from 2004 through 2006 show 4 violations of the Class B (LW) criterion for dissolved oxygen in 51 samples. These violations are less than 10% of the samples and therefore do not constitute an impairment of the Class B (LW) uses of Lake of Three Fires. The pH data from the beach monitoring program (2004-2006) show 8 violations of Iowa's criterion for pH in 51 samples (13%). These violations are not significantly greater than 10% of the samples and therefore suggest full support of the Class B (LW) uses of Lake of Three Fires.

The Class C (drinking water) uses remain "not assessed" due to lack of information upon which to base an assessment. The only parameter collected as part of the ISU and UHL lake surveys relevant to support of Class C (drinking water) uses is nitrate. While the results of the ISU and UHL surveys from 2002-06 show that nitrate levels are very low at this lake (maximum value = 3.0 mg/l; median = 0.1 mg/l in 17 samples) compared to the MCL for nitrate (10 mg/L), these data are not sufficient for developing a valid assessment of support of the Class C uses.

Fish consumption uses are assessed (monitored) as "fully supported" based on results of U.S.EPA/IDNR fish contaminant (RAFT) monitoring at Lake of Three Fires in 1998 and 2006. Although the composite samples of fillets from channel catfish contained low levels of most contaminants in both the 1998 and 2006 samplings, the samples of largemouth bass had elevated levels of mercury. Levels of mercury in the composite sample of largemouth bass fillets were 0.235 ppm in the 1998 sample and 0.37 ppm in the 2006 sample. The level of mercury in the 2006 sample exceeds the IDNR/IDPH trigger level of 0.3 ppm for a one meal/week advisory. The existence of, or potential for, a fish consumption advisory is the basis for Section 305(b) assessments of support of fish consumption uses in Iowa's rivers and lakes. According to IDNR's assessment methodology, the single occurrence of contaminant above an advisory trigger level neither warrants issuance of an advisory nor indicates impairment of the fish consumption uses: two consecutive samplings that show contaminant levels are above the trigger level in fillet samples are needed to justify issuance of an advisory. But, this elevated level does indicate a concern and the need to conduct additional monitoring to better define contaminant levels in fish from this river segment. Thus, follow-up monitoring will be conducted in 2008 to better determine whether a one-meal-per-week consumption advisory needs to be issued.

Monitoring and Methods

Assessment Key Dates

- 7/20/1998 Fish Tissue Monitoring
- 5/28/2002 Fixed Monitoring Start Date
- 9/11/2006 Fish Tissue Monitoring

- 10/3/2006 Fixed Monitoring End Date

Methods

- Surveys of fish and game biologists/other professionals
- Non-fixed-station monitoring (conventional during key seasons and flows)
- Primary producer surveys (phytoplankton/periphyton/macrophyton)
- Water column surveys (e.g. fecal coliform)
- Fish tissue analysis

Causes and Sources of Impairment

Causes	Use Support	Cause Magnitude	Sources	Source Magnitude
Pathogens	Primary Contact Recreation	High	Source Unknown	High
Noxious aquatic plants	Primary Contact Recreation	Moderate	Internal nutrient cycling (primarily lakes)	Moderate
Turbidity	Aquatic Life Support	Moderate	Sediment resuspension	Moderate
Algal Grwth/Chlorophyll a	Primary Contact Recreation	Moderate	Internal nutrient cycling (primarily lakes)	Moderate
Turbidity	Primary Contact Recreation	Not Impairing	Sediment resuspension	Moderate
Siltation	Aquatic Life Support	Not Impairing	Agriculture Natural Sources	Moderate Slight
Nutrients	Aquatic Life Support	Not Impairing	Agriculture Internal nutrient cycling (primarily lakes) Natural Sources	Moderate Moderate Slight

Appendix G --- Public Comments

No public comments with regards to the plan were received during the public comment period.