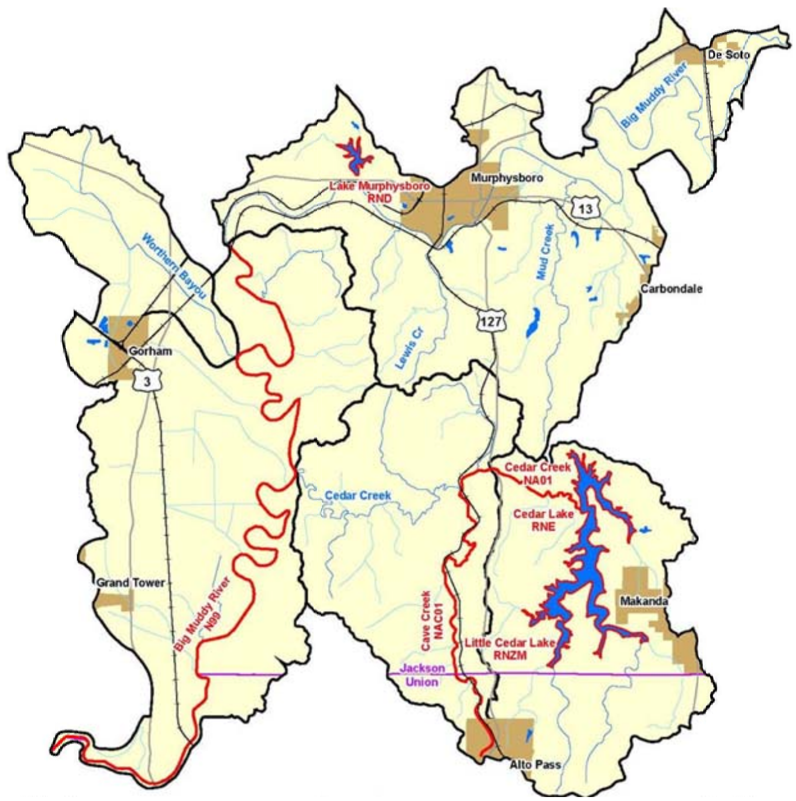
Illinois
Environmental
Protection Agency

Bureau of Water
P.O. Box 19276
Springfield, IL 62794-9276

June 2008

IEPA/BOW/07-025

Cedar Creek Watershed TMDL Report



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TMDL Development for the Cedar Creek/Cedar Lake Watershed, Illinois

This file contains the following documents:

1) U.S. EPA Approval letter for Stage Three TMDL Report

2) Stage One Report: Third Quarter Draft

3) Stage Two Report: Data Report

4) Stage Three Report: TMDL Development

5) Implementation Plan Report

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, IL 60604-3590

SEP 20 2007

REPLY TO THE ATTENTION OF:
WW-16J

Marcia Willhite, Chief
Bureau of Water
Illinois Environmental Protection Agency
P.O. Box 19276
Springfield, IL 62794-9276

Dear Ms. Willhite:

The United States Environmental Protection Agency (U.S. EPA) has reviewed the final Total Maximum Daily Loads (TMDLs) from the Illinois Environmental Protection Agency (IEPA) for the Cedar Creek Watershed in Illinois. The TMDLs are for pollutants contributing to low Dissolved Oxygen (DO) in the Big Muddy River (N-99) and Cave Creek (NAC-01), fecal coliform in Cedar Creek (NA-01), and phosphorus in Lake Murphysboro (RND) and Little Cedar Lake (RNZM), all located in HUC 0714010612. The Designated Uses impaired are for general use and public and food processing water supplies. Manganese, sedimentation/siltation, and Total Suspended Solids (TSS) impairments will also be addressed through surrogates.

Based on this review, U.S. EPA has determined that Illinois' 11 TMDLs addressing 7 impairments of low DO (2 segments), fecal coliform, sedimentation/siltation, TSS, manganese, and phosphorus meet the requirements of Section 303(d) of the Clean Water Act and U.S. EPA's implementing regulations at 40 C.F.R. Part 130. Therefore, U.S. EPA hereby approves 11 TMDLs for 7 impairments for the Cedar Creek Watershed. The statutory and regulatory requirements, and U.S. EPA's review of Illinois' compliance with each requirement, are described in the enclosed decision document.

We wish to acknowledge Illinois' effort in submitting these TMDLs and look forward to future TMDL submissions by the State of Illinois. If you have any questions, please contact Dean Maraldo, TMDL Program Manager, at 312-353-2098.

Sincerely yours,

Kevin M. Pierard
Acting Director, Water Division

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Watershed Management Section
BUREAU OF WATER

Enclosure
cc: Mike Eppley, IEPA

CDM

Illinois Environmental
Protection Agency

Cedar Creek/Cedar Lake Watershed TMDL
Stage One
Third Quarter Draft Report

June 2006

Draft Report

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Contents

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Acronyms

°F	degrees Fahrenheit
BMP	best management practice
cfu	Colony forming units
CWA	Clean Water Act
DMR	Discharge Monitoring Reports
DO	dissolved oxygen
ft	Foot or feet
GIS	geographic information system
HUC	Hydrologic Unit Code
IDA	Illinois Department of Agriculture
IDNR	Illinois Department of Natural Resources
IL-GAP	Illinois Gap Analysis Project
ILLCP	Illinois Interagency Landscape Classification Project
Illinois EPA	Illinois Environmental Protection Agency
INHS	Illinois Natural History Survey
IPCB	Illinois Pollution Control Board
LA	load allocation
LC	loading capacity
lb/d	pounds per day
mgd	Million gallons per day
mg/L	milligrams per liter
MOS	margin of safety
MUID	Map Unit Identification
NA	Not applicable
NASS	National Agricultural Statistics Service
NCDC	National Climatic Data Center
NED	National Elevation Dataset
NPDES	National Pollution Discharge Elimination System
NRCS	National Resource Conservation Service
PCS	Permit Compliance System
SSURGO	Soil Survey Geographic Database
STATSGO	State Soil Geographic
STORET	Storage and Retrieval
STP	Sanitary Treatment Plant

TMDL	total maximum daily load
ug/L	Micrograms per liter
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WLA	waste load allocation
WTP	Water Treatment Plant

Section 1
Goals and Objectives for Cedar Creek/Cedar Lake Watershed (0714010612)

1.1 Total Maximum Daily Load (TMDL) Overview

A Total Maximum Daily Load, or TMDL, is a calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards. TMDLs are a requirement of Section 303(d) of the Clean Water Act (CWA). To meet this requirement, the Illinois Environmental Protection Agency (Illinois EPA) must identify water bodies not meeting water quality standards and then establish TMDLs for restoration of water quality. Illinois EPA lists water bodies not meeting water quality standards every two years. This list is called the 303(d) list and water bodies on the list are then targeted for TMDL development.

In general, a TMDL is a quantitative assessment of water quality problems, contributing sources, and pollution reductions needed to attain water quality standards. The TMDL specifies the amount of pollution or other stressor that needs to be reduced to meet water quality standards, allocates pollution control or management responsibilities among sources in a watershed, and provides a scientific and policy basis for taking actions needed to restore a water body.

Water quality standards are laws or regulations that states authorize to enhance water quality and protect public health and welfare. Water quality standards provide the foundation for accomplishing two of the principal goals of the CWA. These goals are:

- Restore and maintain the chemical, physical, and biological integrity of the nation's waters
- Where attainable, to achieve water quality that promotes protection and propagation of fish, shellfish, and wildlife, and provides for recreation in and on the water

Water quality standards consist of three elements:

- The designated beneficial use or uses of a water body or segment of a water body
- The water quality criteria necessary to protect the use or uses of that particular water body
- An antidegradation policy

Examples of designated uses are recreation and protection of aquatic life. Water quality criteria describe the quality of water that will support a designated use. Water quality criteria can be expressed as numeric limits or as a narrative statement. Antidegradation policies are adopted so that water quality improvements are conserved, maintained, and protected.

1.2 TMDL Goals and Objectives for Cedar Creek/Cedar Lake Watershed

The Illinois EPA has a three-stage approach to TMDL development. The stages are:

- Stage 1 – Watershed Characterization, Data Analysis, Methodology Selection
- Stage 2 – Data Collection (optional)
- Stage 3 – Model Calibration, TMDL Scenarios, Implementation Plan

This report addresses Stage 1 TMDL development for the Cedar Creek/Cedar Lake watershed. Stage 2 and 3 will be conducted upon completion of Stage 1. Stage 2 is optional as data collection may not be necessary if additional data is not required to establish the TMDL.

Following this process, the TMDL goals and objectives for the Cedar Creek/Cedar Lake watershed will include developing TMDLs for all impaired water bodies within the watershed, describing all of the necessary elements of the TMDL, developing an implementation plan for each TMDL, and gaining public acceptance of the process. Following are the impaired water body segments in the Cedar Creek/Cedar Lake watershed for which a TMDL will be developed:

- Big Muddy River (N 99)
- Cedar Creek (NA 01)
- Cave Creek (NAC 01)
- Lake Murphysboro (RND)
- Cedar Lake (Jackson) (RNE)
- Little Cedar Lake (RNZM)

These impaired water body segments are shown on Figure 1-1. There are six impaired segments within the Cedar Creek/Cedar Lake watershed. Table 1-1 lists the water body segment, water body size, and potential causes of impairment for the water body.

Table 1-1 Impaired Water Bodies in Cedar Creek/Cedar Lake Watershed

Water Body Segment ID	Water Body Name	Size	Causes of Impairment with Numeric Water Quality Standards	Causes of Impairment with Assessment Guidelines
N 99	Big Muddy River	28.49 miles	Sulfates, dissolved oxygen	Sedimentation/siltation, total suspended solids (TSS)
NA 01	Cedar Creek	3.98 miles	Total Fecal Coliform	
NAC 01	Cave Creek	8.9 miles	Dissolved oxygen	Habitat alterations (streams)
RND	Lake Murphysboro	143 acres	Total phosphorus	Excess algal growth, total phosphorus
RNE	Cedar Lake (Jackson)	1,800 acres	Manganese	Mercury
RNZM	Little Cedar Lake	70 acres	Manganese	Excess algal growth

Illinois EPA is currently only developing TMDLs for parameters that have numeric water quality standards, and therefore the remaining sections of this report will focus on the manganese, sulfates, dissolved oxygen, total fecal coliform, and total phosphorus (numeric standard) impairments in the Cedar Creek/Cedar Lake watershed. For potential causes that do not have numeric water quality standards as noted in Table 1-1, TMDLs will not be developed at this time. However, in the implementation plans completed during Stage 3 of the TMDL, many of these potential causes may be addressed by implementation of controls for the pollutants with water quality standards.

The TMDL for the segments listed above will specify the following elements:

- Loading Capacity (LC) or the maximum amount of pollutant loading a water body can receive without violating water quality standards
- Waste Load Allocation (WLA) or the portion of the TMDL allocated to existing or future point sources
- Load Allocation (LA) or the portion of the TMDL allocated to existing or future nonpoint sources and natural background
- Margin of Safety (MOS) or an accounting of uncertainty about the relationship between pollutant loads and receiving water quality

These elements are combined into the following equation:

$$\mathbf{TMDL = LC = \Sigma WLA + \Sigma LA + MOS}$$

The TMDL developed must also take into account the seasonal variability of pollutant loads so that water quality standards are met during all seasons of the year. Also, reasonable assurance that the TMDL will be achieved will be described in the implementation plan. The implementation plan for the Cedar Creek/Cedar Lake watershed will describe how water quality standards will be attained. This implementation plan will include recommendations for implementing best management practices (BMPs), cost estimates, institutional needs to implement BMPs and controls throughout the watershed, and timeframe for completion of implementation activities.

1.3 Report Overview

The remaining sections of this report contain:

- **Section 2 Cedar Creek/Cedar Lake Watershed Characteristics** provides a description of the watershed's location, topography, geology, land use, soils, population, and hydrology
- **Section 3 Public Participation and Involvement** discusses public participation activities that occurred throughout the TMDL development

- **Section 4 Cedar Creek/Cedar Lake Watershed Water Quality Standards** defines the water quality standards for the impaired water body
- **Section 5 Cedar Creek/Cedar Lake Watershed Watershed Characterization** presents the available water quality data needed to develop TMDLs, discusses the characteristics of the impaired reservoirs in the watershed, and also describes the point and non-point sources with potential to contribute to the watershed load.
- **Section 6 Approach to Developing TMDL and Identification of Data Needs** makes recommendations for the models and analysis that will be needed for TMDL development and also suggests segments for Stage 2 data collection.

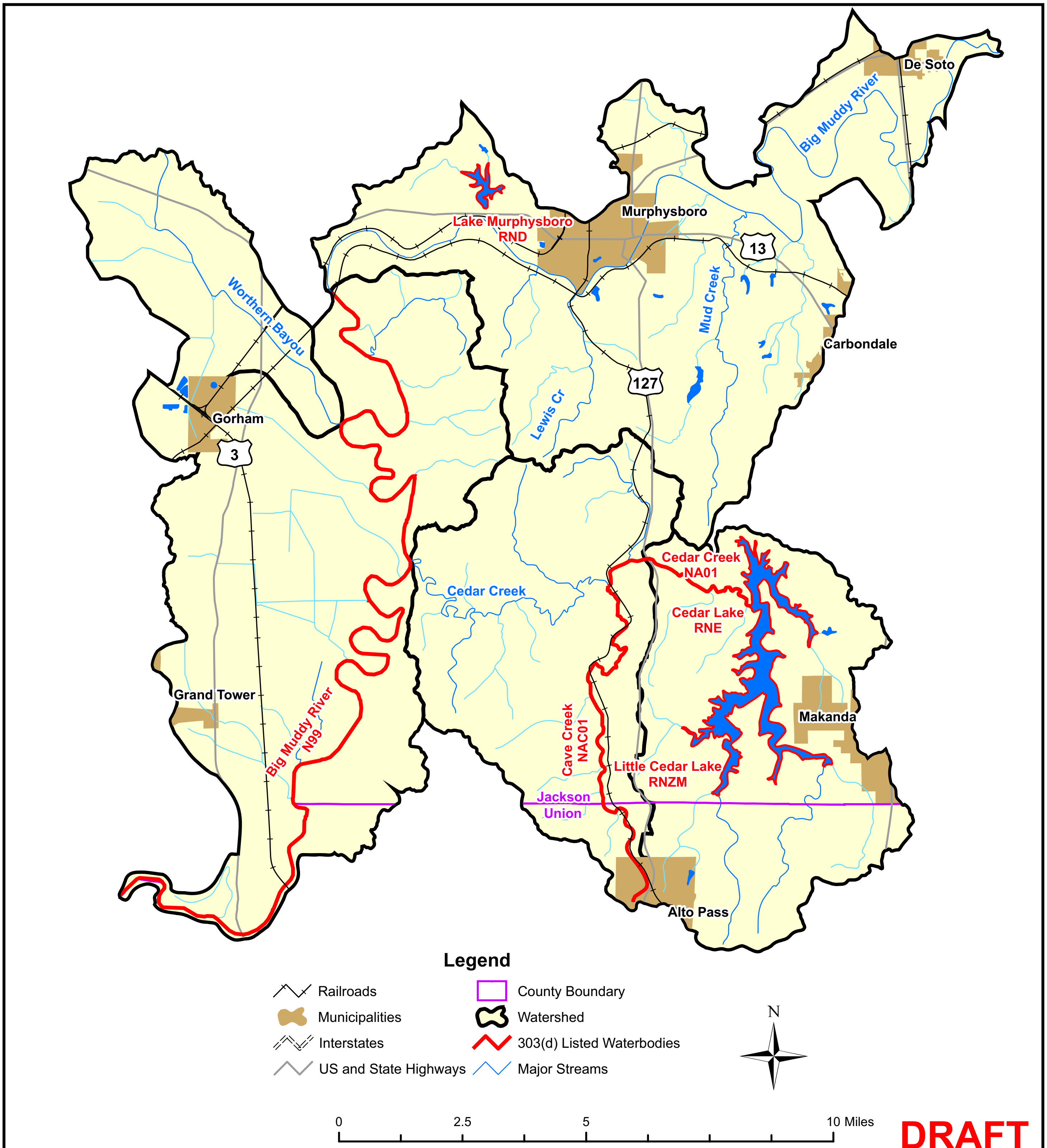

Figure 1-1
Cedar Creek - Cedar Lake Watershed

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Section 2
Cedar Creek/Cedar Lake Watershed Description

2.1 Cedar Creek/Cedar Lake Watershed Location

The Cedar Creek/Cedar Lake watershed (Figure 1-1) is located in southern Illinois, flows in a west-southwesterly direction, and drains approximately 127,000 acres within the state of Illinois. The watershed covers land within Jackson and Union Counties near the Missouri state line.

2.2 Topography

Topography is an important factor in watershed management because stream types, precipitation, and soil types can vary dramatically by elevation. National Elevation Dataset (NED) coverages containing 30-meter grid resolution elevation data are available from the USGS for each 1:24,000-topographic quadrangle in the United States. Elevation data for the Cedar Creek/Cedar Lake watershed was obtained by overlaying the NED grid onto the GIS-delineated watershed. Figure 2-1 shows the elevations found within the watershed.

Elevation in the Cedar Creek/Cedar Lake watershed ranges from 876 feet above sea level in the headwaters of the Cedar Creek to 367 feet in the Big Muddy River in the southwest corner of the watershed. The absolute elevation change is 82 feet over the approximately 12-mile stream length of Cedar Creek, which yields a stream gradient of approximately 6.7 feet per mile. The Big Muddy River yields an absolute elevation change of 33 feet over the approximately 55-mile stream length contained within the watershed boundary and a stream gradient of approximately 0.6 feet per mile.

2.3 Land Use

Land use data for the Cedar Creek/Cedar Lake watershed were extracted from the Illinois Gap Analysis Project (IL-GAP) Land Cover data layer. IL-GAP was started at the Illinois Natural History Survey (INHS) in 1996, and the land cover layer was the first component of the project. The IL-GAP Land Cover data layer is a product of the Illinois Interagency Landscape Classification Project (IILCP), an initiative to produce statewide land cover information on a recurring basis cooperatively managed by the United States Department of Agriculture National Agricultural Statistics Service (NASS), the Illinois Department of Agriculture (IDA), and the Illinois Department of Natural Resources (IDNR). The land cover data was generated using 30-meter grid resolution satellite imagery taken during 1999 and 2000. The IL-GAP Land Cover data layer contains 23 land cover categories, including detailed classification in the vegetated areas of Illinois. Appendix A contains a complete listing of land cover categories. (Source: IDNR, INHS, IDA, USDA NASS's 1:100,000 Scale Land Cover of Illinois 1999-2000, Raster Digital Data, Version 2.0, September 2003.)

The land use of the Cedar Creek/Cedar Lake watershed was determined by overlaying the IL-GAP Land Cover data layer onto the GIS-delineated watershed. Table 2-1 contains the land uses contributing to the Cedar Creek/Cedar Lake watershed, based on the IL-GAP land cover categories and also includes the area of each land cover category and percentage of the watershed area. Figure 2-2 illustrates the land uses of the watershed.

The land cover data reveal that approximately 56,753 acres, representing nearly 45 percent of the total watershed area, are devoted to agricultural activities. Corn and soybean farming account for about 9 percent and 11 percent of the watershed area, respectively and rural grassland accounts for about 20 percent. Upland forests occupy approximately 31 percent of the watershed and wetlands occupy approximately 15 percent. Other land cover categories represent less that 5 percent of the watershed area.

Table 2-1 Land Use in Cedar Creek/Cedar Lake Watershed

Land Cover Category	Area (Acres)	Percentage
Corn	11,389	9.0%
Soybeans	14,265	11.3%
Winter Wheat	2,143	1.7%
Other Small Grains & Hay	1,503	1.2%
Winter Wheat/Soybeans	2,353	1.9%
Other Agriculture	173	0.1%
Rural Grassland	24,928	19.6%
Upland	39,472	31.1%
Forested Areas	2,797	2.2%
High Density	843	0.7%
Low/Medium Density	835	0.6%
Urban Open Space	2,766	2.2%
Wetlands	18,759	14.8%
Surface Water	4,548	3.6%
Barren & Exposed Land	13	0.0%
Total	**126,787**	**100%**

1. Forested areas includes partial canopy/savannah upland and coniferous.
2. Wetlands includes shallow marsh/wet meadow, deep marsh, floodplain forest, swamp, and shallow water.

2.4 Soils

Two types of soil data are available for use within the state of Illinois through the National Resource Conservation Service (NRCS). General soils data and map unit delineations for the entire state are provided as part of the State Soil Geographic (STATSGO) database. Soil maps for the database are produced by generalizing detailed soil survey data. The mapping scale for STATSGO is 1:250,000. More detailed soils data and spatial coverages are available through the Soil Survey Geographic (SSURGO) database for a limited number of counties. For SSURGO data, field mapping methods using national standards are used to construct the soil maps. Mapping scales generally range from 1:12,000 to 1:63,360 making SSURGO the most detailed level of soil mapping done by the NRCS.

The Cedar Creek/Cedar Lake watershed falls within Jackson and Union Counties. At this time, SSURGO data are only available for Union county. STATSGO data have been used in lieu of SSURGO data for the portion of the watershed that lies within Jackson County. Figure 2-3 displays the STATSGO soil map units as well as the SSURGO soil series in the Cedar Creek/Cedar Lake watershed. Attributes of the spatial coverage can be linked to the STATSGO and SSURGO databases, which provide information on various chemical and physical soil characteristics for each map unit and soil series. Of particular interest for TMDL development are the hydrologic soil groups as well as the K-factor of the Universal Soil Loss Equation. The following sections describe and summarize the specified soil characteristics for the Cedar Creek/Cedar Lake watershed.

2.4.1 Cedar Creek/Cedar Lake Watershed Soil Characteristics

Appendix B contains the STATSGO Map Unit IDs (MUIDs) for the Cedar Creek/ Cedar Lake watershed as well as the SSURGO soil series. The table also contains the area, dominant hydrologic soil group, and k-factor range. Each of these characteristics is described in more detail in the following paragraphs. The predominant soil type in the watershed are soils categorized as a fine-grained and made up of silts and clays with a liquid limit of less than 50 percent that tend toward a lean clay and silt.

Hydrologic soil groups are used to estimate runoff from precipitation. Soils are assigned to one of four groups. They are grouped according to the infiltration of water when the soils are thoroughly wet and receive precipitation from long-duration storms. All hydrologic soil groups (A through D) are found within the Cedar Creek/Cedar Lake watershed with the majority of the watershed falling into category B. Category B soils are defined as "soils having a moderate infiltration rate when thoroughly wet." Category B soils "consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture." These soils have a moderate rate of water transmission. (NRCS 2005).

A commonly used soil attribute is the K-factor. The K-factor:

> *Indicates the susceptibility of a soil to sheet and rill erosion by water.* (The K-factor) *is one of six factors used in the Universal Soil Loss Equation (USLE) to predict the average annual rate of soil loss by sheet and rill erosion. Losses are expressed in tons per acre per year. These estimates are based primarily on percentage of silt, sand, and organic matter (up to 4 percent) and on soil structure and permeability. Values of K range from 0.02 to 0.69. The higher the value, the more susceptible the soil is to sheet and rill erosion by water (NRCS 2005).*

The distribution of K-factor values in the Cedar Creek/Cedar Lake watershed range from 0.02 to 0.64.

2.5 Population

Population data were retrieved from Census 2000 TIGER/Line Data from the U.S. Bureau of the Census. Geographic shape files of census blocks were downloaded for every county containing any portion of the watersheds. The block files were clipped to each watershed so that only block populations associated with the watershed would be counted. The census block demographic text file (PL94) containing population data was downloaded and linked to each watershed and summed. City populations were taken from the U.S. Bureau of the Census. For municipalities that are located across watershed borders, the population was estimated based on the percentage of area of municipality within the watershed boundary.

Approximately 53,995 people reside in the watershed. The major municipalities in the Cedar Creek/Cedar Lake watershed are shown in Figure 1-1. The city of Murphysboro is the largest population center in the watershed and contributes an estimated 8,854 people to total watershed population.

2.6 Climate and Streamflow

2.6.1 Climate

Southern Illinois has a temperate climate with hot summers and cold, snowy winters. Monthly precipitation and temperature data from the Carbondale Sewage Plant (station id. 1265) in Jackson County were extracted from the NCDC database for the years of 1910 through 2004. The western portion of Carbondale, Illinois is located within the basin. Due to the sewage plant's proximity to the area, it was deemed an adequate representation of climate throughout the watershed.

Table 2-2 contains the average monthly precipitation along with average high and low temperatures for the period of record. The average annual precipitation is approximately 44 inches.

Table 2-2 Average Monthly Climate Data in Carbondale, Illinois

Month	Total Precipitation (inches)	Maximum Temperature (degrees F)	Minimum Temperature (degrees F)
January	3.0	42	24
February	1.2	47	27
March	5.5	57	35
April	3.4	69	45
May	6.6	78	54
June	3.1	86	63
July	4.3	90	67
August	1.8	89	64
September	0.1	83	57
October	6.3	72	45
November	6.0	57	35
December	3.0	46	27
Total	**44.3**		

2.6.2 Streamflow

Analysis of the Cedar Creek/Cedar Lake watershed requires an understanding of flow throughout the drainage area. USGS gage 05599500 Big Muddy River at Murphysboro is the only gage within the watershed that has available data (Figure 2-4). It is located on the Big Muddy River along the southern edge of Murphysboro near the confluence with Lewis Creek. Data is available from 1916 to 2004. The average monthly flows recorded at the Big Muddy River at Murphysboro, Illinois gage range from 399 cubic feet per second (cfs) in September to 3720 cfs in April with a mean annual monthly flow of 1866 cfs (Figure 2-5).

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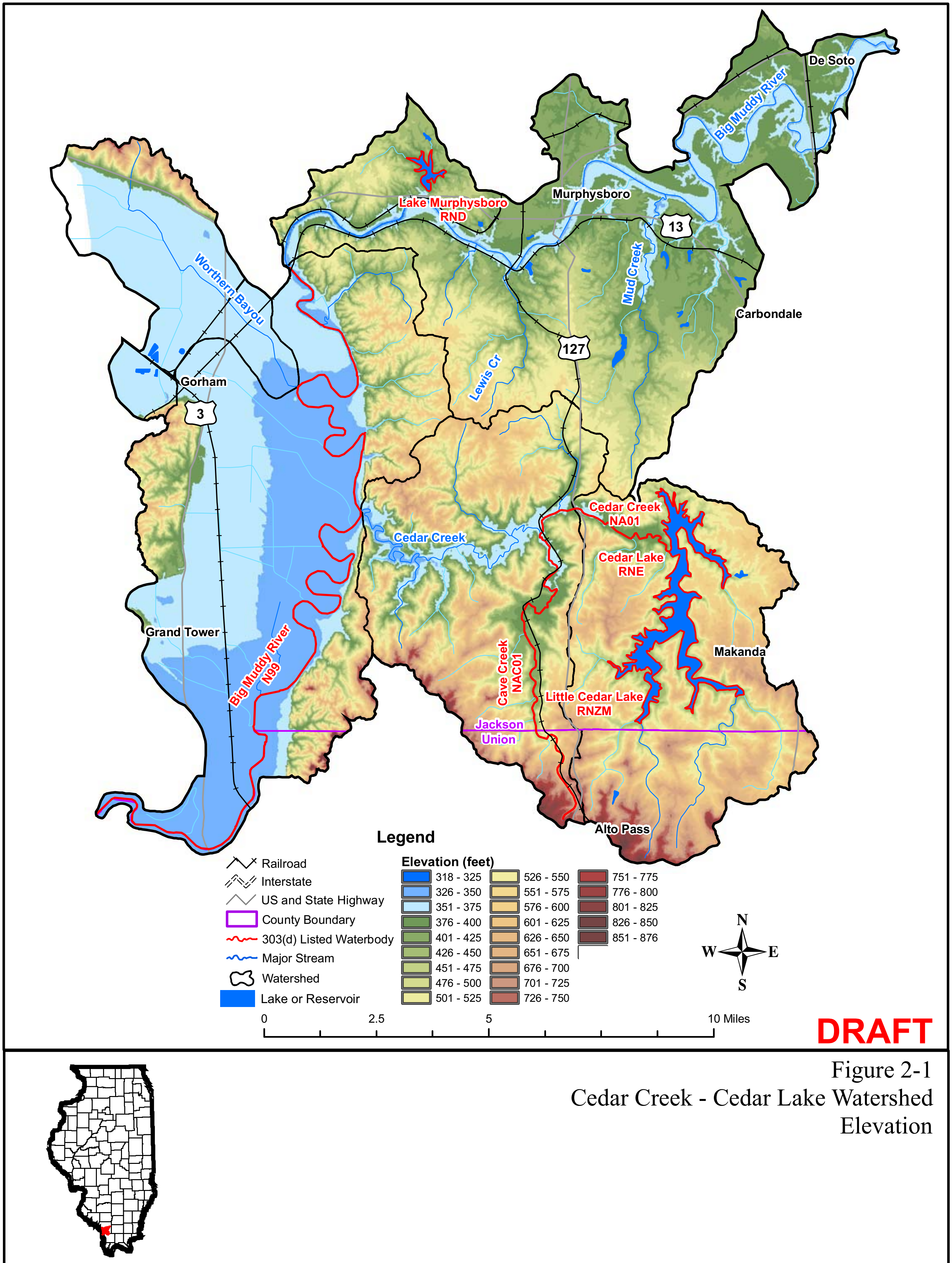

Figure 2-1
Cedar Creek - Cedar Lake Watershed
Elevation

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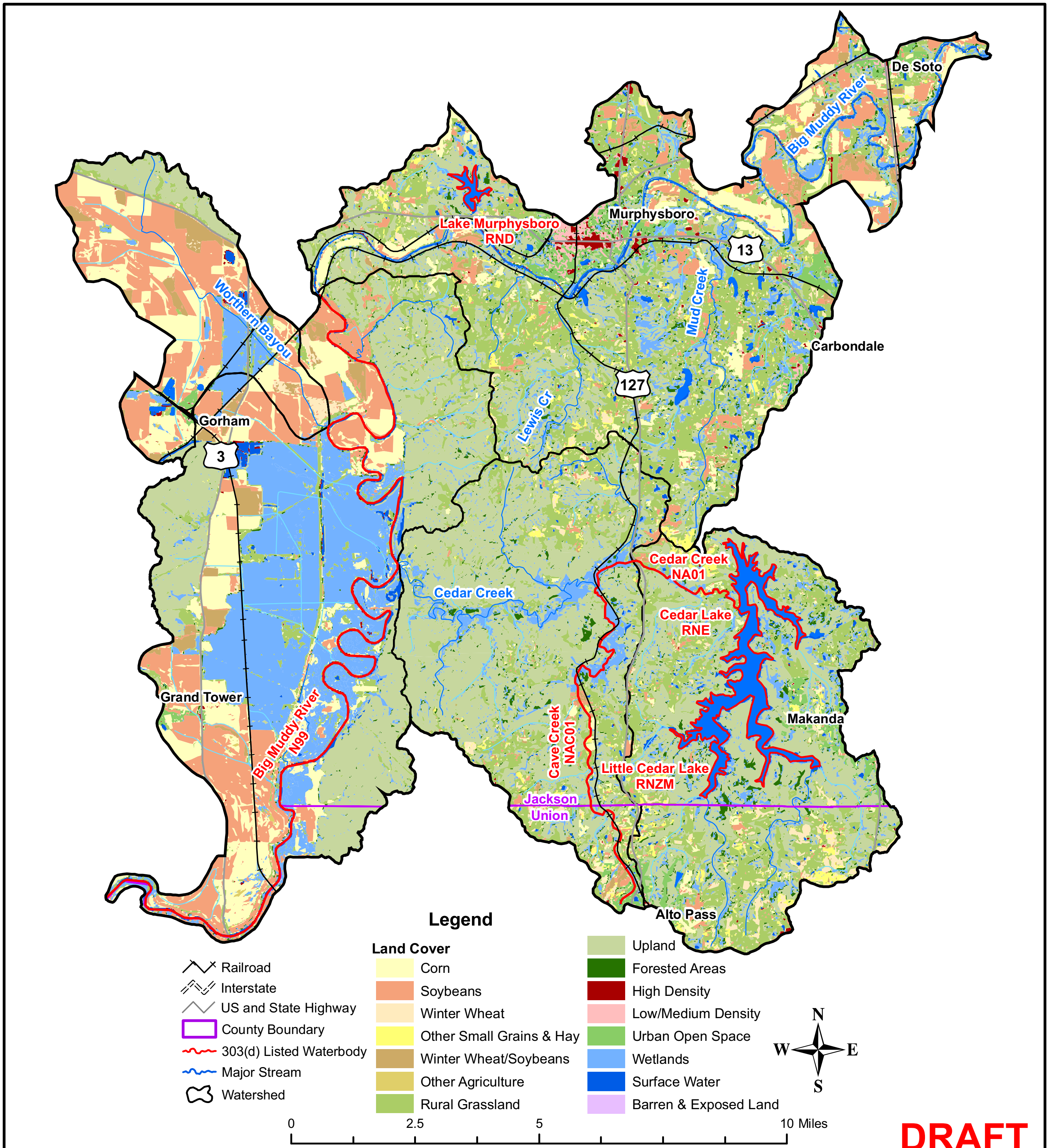

Figure 2-2
Cedar Creek - Cedar Lake Watershed
Land Use

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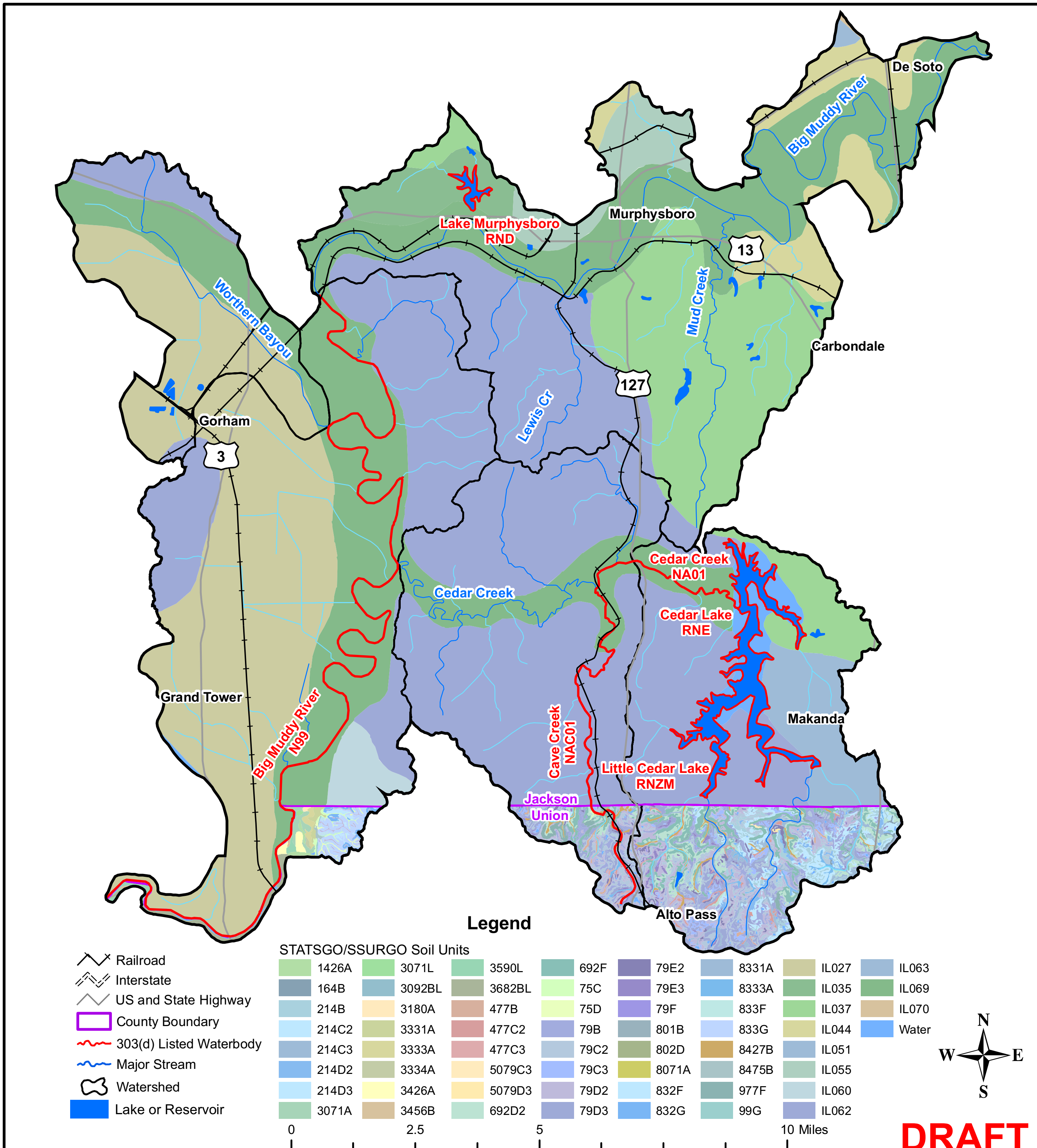

Figure 2-3
Cedar Creek - Cedar Lake Watershed
Soils

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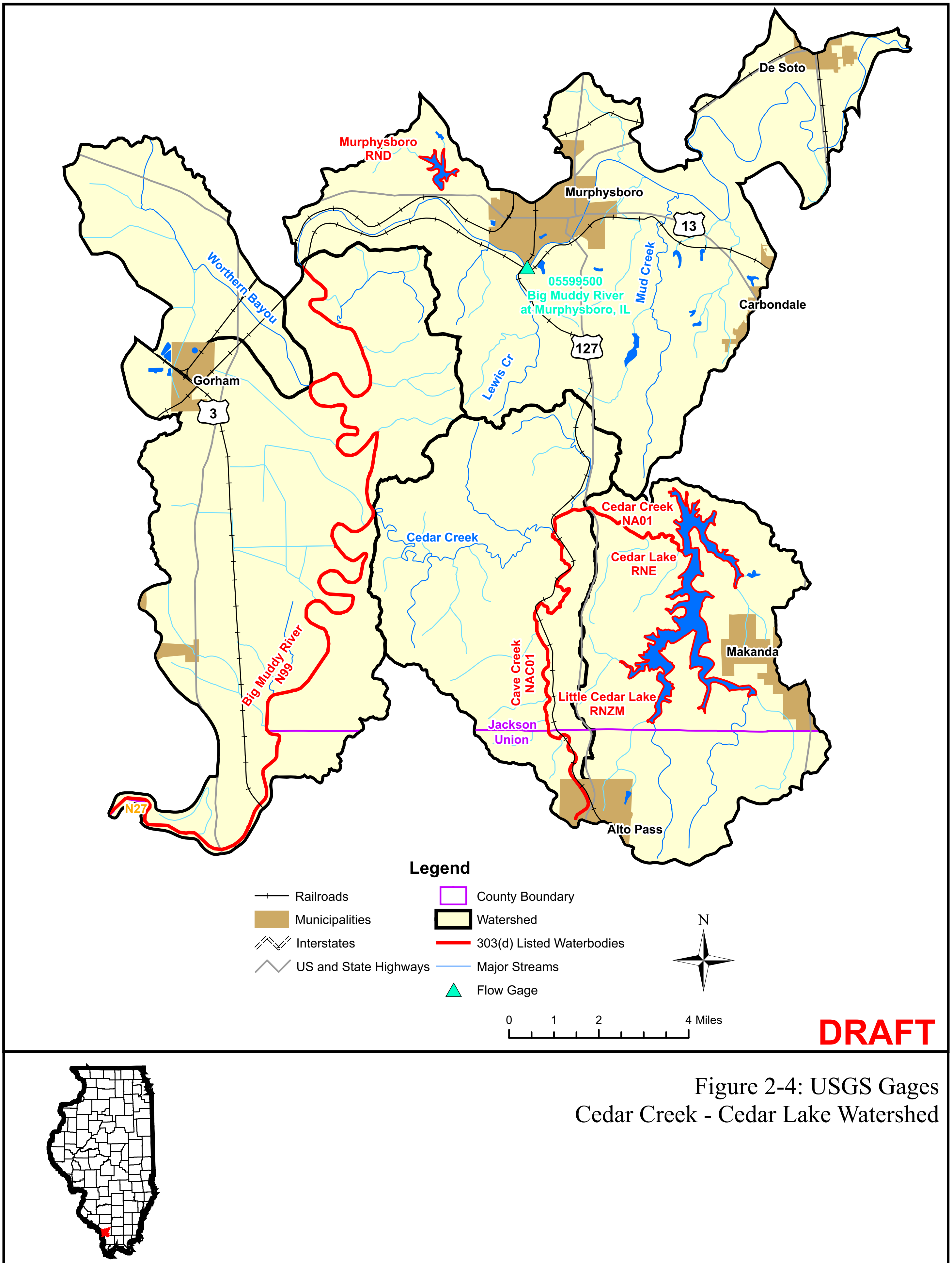

Figure 2-4: USGS Gages
Cedar Creek - Cedar Lake Watershed

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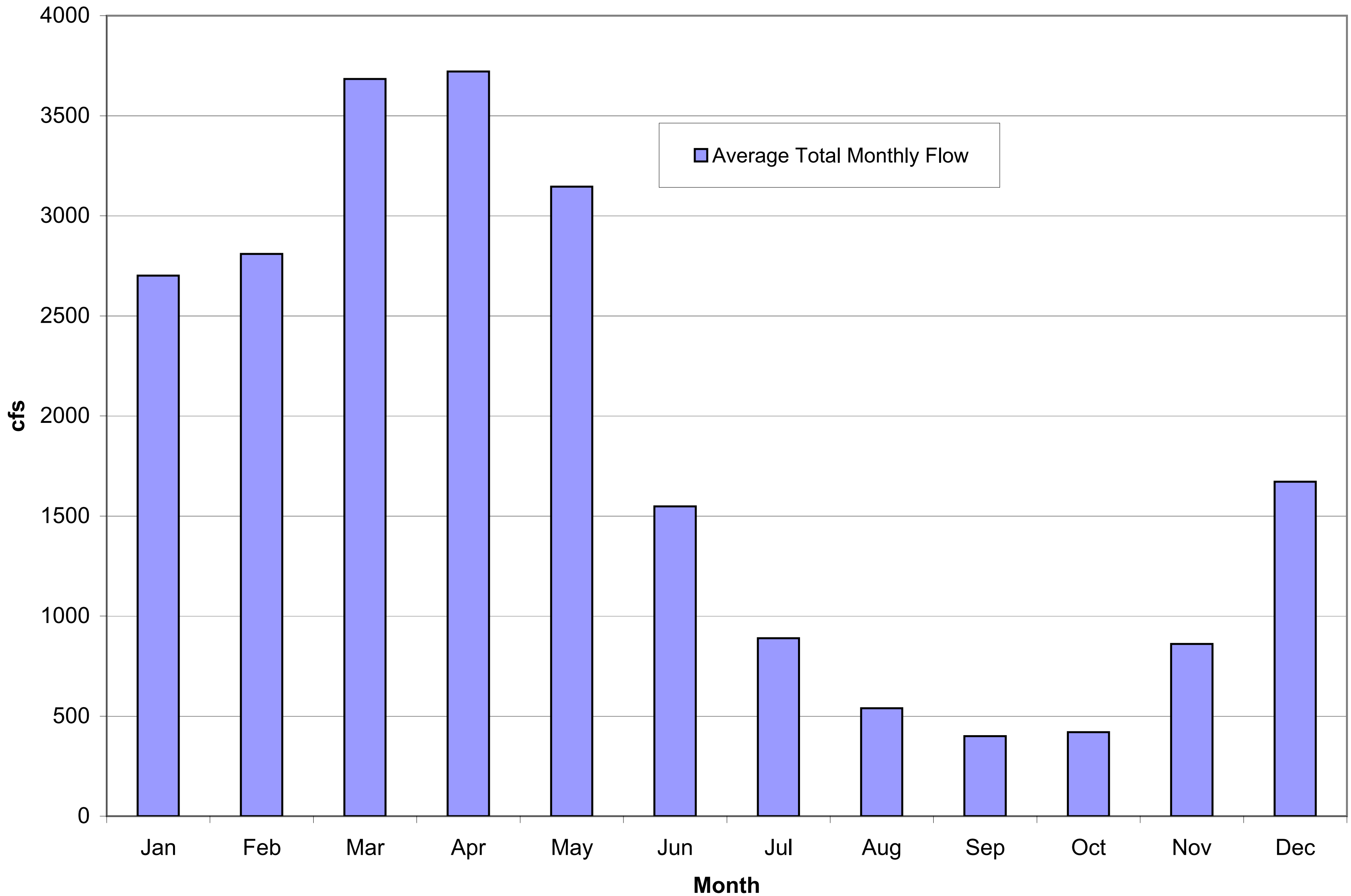

CDM

Figure 2-5:
Average Total Monthly Streamflow
at USGS gage 05599500
Big Muddy River at Murphysboro, IL

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Section 3
Public Participation and Involvement

3.1 Cedar Creek/Cedar Lake Watershed Public Participation and Involvement

Public knowledge, acceptance, and follow through are necessary to implement a plan to meet recommended TMDLs. It is important to involve the public as early in the process as possible to achieve maximum cooperation and counter concerns as to the purpose of the process and the regulatory authority to implement any recommendations.

Illinois EPA, along with CDM, will hold up to four public meetings within the watershed throughout the course of the TMDL development. This section will be updated once public meetings have occurred.

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Section 4
Cedar Creek/Cedar Lake Watershed Water Quality Standards

4.1 Illinois Water Quality Standards

Water quality standards are developed and enforced by the state to protect the "designated uses" of the state's waterways. In the state of Illinois, setting the water quality standards is the responsibility of the Illinois Pollution Control Board (IPCB). Illinois is required to update water quality standards every three years in accordance with the CWA. The standards requiring modifications are identified and prioritized by Illinois EPA, in conjunction with USEPA. New standards are then developed or revised during the three-year period.

Illinois EPA is also responsible for developing scientifically based water quality criteria and proposing them to the IPCB for adoption into state rules and regulations. The Illinois water quality standards are established in the Illinois Administrative Rules Title 35, Environmental Protection; Subtitle C, Water Pollution; Chapter I, Pollution Control Board; Part 302, Water Quality Standards.

4.2 Designated Uses

The waters of Illinois are classified by designated uses, which include: General Use, Public and Food Processing Water Supplies, Lake Michigan, and Secondary Contact and Indigenous Aquatic Life Use (Illinois EPA 2005). The designated uses applicable to the Cedar Creek/Cedar Lake watershed are the General Use and Public and Food Processing Water Supplies Use.

4.2.1 General Use

The General Use classification is defined by IPCB as standards that "will protect the state's water for aquatic life, wildlife, agricultural use, secondary contact use and most industrial uses and ensure the aesthetic quality of the state's aquatic environment." Primary contact uses are protected for all General Use waters whose physical configuration permits such use.

4.2.2 Public and Food Processing Water Supplies

The Public and Food Processing Water Supplies Use is defined by IPCB as standards that are "cumulative with the general use standards of Subpart B and must be met in all waters designated in Part 303 at any point at which water is withdrawn for treatment and distribution as a potable supply or for food processing."

4.3 Illinois Water Quality Standards

To make 303(d) listing determinations for aquatic life uses, Illinois EPA first collects biological data and if this data suggests that an impairment to aquatic life exists, a comparison of available water quality data with water quality standards will then occur. For public and food processing water supply waters, Illinois EPA compares available data with water quality standards to make impairment determinations. Tables 4-1 and 4-2 present the water quality standards of the potential causes of impairment for both lakes and streams in the Cedar Creek/Cedar Lake watershed. Only constituents with numeric water quality standards will have TMDLs developed at this time.

Table 4-1 Summary of Water Quality Standards for Potential Cedar Creek/Cedar Lake Watershed Lake Impairments

Parameter	Units	General Use Water Quality Standard	Public and Food Processing Water Supplies
Excess Algal Growth	NA	No numeric standard	No numeric standard
Manganese (total)	µg/L	1000	150
Mercury - Statistical Guideline	NA	No numeric standard	No numeric standard
Total Phosphorus	mg/L	0.05[1]	No numeric standard
Total Phosphorus - Statistical Guideline	NA	No numeric standard	No numeric standard

µg/L = micrograms per liter
mg/L = milligrams per liter
NA = Not Applicable

[1] Standard applies in particular inland lakes and reservoirs (greater than 20 acres) and in any stream at the point where it enters any such lake or reservoir.

Table 4-2 Summary of Water Quality Standards for Potential Cedar Creek/Cedar Lake Watershed Stream Impairments

Parameter	Units	General Use Water Quality Standard	Public and Food Processing Water Supplies
Habitat Alterations (Streams)	NA	No numeric standard	No numeric standard
Oxygen, Dissolved	mg/L	5.0 instantaneous minimum; 6.0 minimum during at least 16 hours of any 24 hour period	No numeric standard
Total Fecal Coliform	Count/ 100 mL	May through Oct – 200(3), 400(4) Nov though Apr – no numeric standard	2000(3)
Sedimentation/ Siltation	NA	No numeric standard	No numeric standard
Sulfates	mg/L	500	250
Total Suspended Solids	NA	No numeric standard	No numeric standard

µg/L = micrograms per liter exp(x) = base natural logarithms raised to the x- power

mg/L = milligrams per liter ln(H) = natural logarithm of hardness of the receiving water in mg/L

NA = Not Applicable * = conversion factor for multiplier for dissolved metals

(1) Not to be exceeded except as provided in 35 Ill. Adm. Code 302.208(d).

(2) Not to be exceeded by the average of at least four consecutive samples collected over any period of at least four days except as provided in 35 Ill. Adm. Code 302.208(d). The samples used to demonstrate attainment or lack of attainment with a chronic standard must be collected in a manner that assures an average representative of the sampling period. To calculate attainment status of chronic metals standards, the concentration of the metal in each sample is divided by the calculated water quality standard for the sample to determine a quotient. The water quality standard is attained if the mean of the sample quotients is less than or equal to one for the duration of the averaging period.

(3) Geometric mean based on a minimum of 5 samples taken over not more than a 30 day period.

(4) Standard shall not be exceeded by more than 10% of the samples collected during any 30 day period.

4.4 Potential Pollutant Sources

In order to properly address the conditions within the Cedar Creek/Cedar Lake watershed, potential pollution sources must be investigated for the pollutants where TMDLs will be developed. The following is a summary of the potential sources associated with the listed causes for the 303(d) listed segments in this watershed.

Table 4-3 Summary of Potential Sources for Cedar Creek/Cedar Lake Watershed

Segment ID	Segment Name	Potential Causes	Potential Sources
N 99	Big Muddy River	Sulfates, sedimentation/siltation, dissolved oxygen, total suspended solids	Agriculture, crop-related sources, nonirrigated crop production, resource extraction, surface mining, source unknown
NA 01	Cedar Creek	Total Fecal Coliform	Source unknown
NAC 01	Cave Creek	Dissolved oxygen, habitat alterations (streams)	Habitat modification (other than hydromodification), removal of riparian vegetation, bank or shoreline modification/destabilization, source unknown
RND	Lake Murphysboro	Total phosphorus, excess algal growth, total phosphorus	Contaminated sediments, lake fertilization, forest/grassland/parkland, source unknown
RNE	Cedar Lake (Jackson)	Manganese, mercury	Source unknown
RNZM	Little Cedar Lake	Manganese, excess algal growth	Forest/grassland/parkland, source unknown

Section 5
Cedar Creek/Cedar Lake Watershed Characterization

5.1 Water Quality Data

There are 15 historic water quality stations within the Cedar Creek/Cedar Lake watershed that were used for this report. Figure 5-1 shows the water quality data stations within the watershed that contain data relevant to the impaired segments.

The impaired water body segments in the Cedar Creek/Cedar Lake watershed were presented in Section 1. Refer to Table 1-1 for impairment information specific to each segment. The following sections address both stream and lake impairments. Data are summarized by impairment and discussed in relation to the relevant Illinois numeric water quality standard. Data analysis is focused on all available data collected since 1990. The information presented in this section is a combination of USEPA Storage and Retrieval (STORET) database and Illinois EPA database data. STORET data is available for stations sampled prior to January 1, 1999 while Illinois EPA data (electronic and hard copy) are available for stations sampled after that date. The following sections will first discuss Cedar Creek/Cedar Lake watershed stream data followed by Cedar Creek/Cedar Lake watershed lake/reservoir data.

5.1.1 Stream Water Quality Data

The Cedar Creek/Cedar Lake watershed has three impaired streams within its drainage area that are addressed in this report. There are three active water quality stations on the impaired segments (see Figure 5-1). The data summarized in this section include water quality data for impaired constituents as well as parameters that could be useful in future modeling and analysis efforts. All historic data are available in Appendix C.

5.1.1.1 Dissolved Oxygen

Big Muddy River segment N99 and Cave Creek segment NAC01 are listed for impairments caused by dissolved oxygen (DO). Table 5-1 summarizes the available historic DO data since 1990 for the impaired stream segments (raw data contained in Appendix C). The table also shows the number of violations for each segment. A sample was considered a violation if it was below 5.0 mg/L. The average DO concentration is above the standard (5.0 mg/L instantaneous minimum) on both of the impaired segments. Minimum values for each segment were below the DO standard.

Table 5-1 Existing Dissolved Oxygen Data for Cedar Creek Watershed Impaired Stream Segments

Sample Location and Parameter	Illinois WQ Standard (mg/L)	Period of Record and Number of Data Points	Mean	Maximum	Minimum	Number of Violations
Big Muddy River Segment N 99; Sample Locations N99						
DO	5.0[(1)]	2003; 3	6.2	7.2	4.2	1
Cave Creek Segment NAC 01; Sample Location NAC 01						
DO	5.0[(1)]	1995-1996; 2	8.3	12.2	4.3	1

(1) Instantaneous Minimum

Table 5-2 contains information on data availability for other parameters that may be useful in data needs analysis and future modeling efforts for DO. Where available, all nutrient, biological oxygen demand (BOD), and total organic carbon data have been collected for possible use in future analysis.

Table 5-2 Data Availability for DO Data Needs Analysis and Future Modeling Efforts

Sample Location and Parameter	Available Period of Record Post 1990	Number of Samples
Big Muddy River Segment N 99; Sample Location N01		
Depth (feet)	2003	3
Temperature , Water deg C	2003	3
Cave Creek Segment NAC 01; Sample Location NAC 01		
Ammonia, Unionized (Calc Fr Temp-pH-NH4) (mg/L)	1995-1996	2
Ammonia, Unionized (mg/L as N)	1995-1996	2
Carbon, Total Organic (mg/L as C)	1995	1
Nitrite plus Nitrate, Total 1 Det. (mg/L as N)	1995-1996	2
Nitrogen Kjeldahl Total Bottom Dep Dry Wt (mg/kg)	1995	1
Nitrogen, Ammonia, Total (mg/L as N)	1995-1996	2
Nitrogen, Kjeldahl, Total (mg/L as N)	1995-1996	2
Phosphorus, Dissolved (mg/L as P)	1995-1996	2
Phosphorus, Total (mg/L as P)	1995-1996	2
Phosphorus, Total, Bottom Deposit (mg/kg-P Dry Wgt)	1995	1
Sulfate, Total (mg/L as SO4)	1995-1996	2

5.1.1.2 Chemical Constituents: Sulfates

Big Muddy River segment N99 is listed for impairment caused by sulfates. The applicable water quality standard for sulfates is a maximum total concentration of 500 mg/L. Standards for general use waters cannot be exceeded except where mixing is allowed as provided in 35 Ill. Adm. Code 302.102.

The most recent sulfates data were collected at sampling location N13 on the Big Muddy River in 1988. There were no violations of the general use sulfates standard in this 1988 sample set. Table 5-3 summarizes this data.

Table 5-3 Most Recent Sulfates Data

Sample Location and Parameter	Illinois WQ Standard (µg/L)	Period of Record and Number of Data Points	Mean	Maximum	Minimum	Number of Violations
Big Muddy River Segment N 99; Sample Location N13						
Sulfates (mg/L)	500	1998; 3	324	481	234	0

5.1.1.3 Total Fecal Coliform

Segment NA01 of Cedar Creek is listed for impairment caused by total fecal coliform. The general use water quality standard for total fecal coliform is:

- 200 cfu/100 mL geometric mean based on a minimum of five samples taken over not more than a 30 day period during the months of May through October
- 400 cfu/100 mL which shall not be exceeded by more than 10 percent of the samples collected during any 30 day period during the months of May through October

There are no instances since 1990 where at least five samples have been collected during a 30 day period. The summary of data presented in Table 5-4 reflects single samples compared to the standards during the appropriate months. Figure 5-2 shows the total fecal coliform samples collected over time at NA01.

Table 5-4 Total Fecal Coliform Data for Cedar Creek/Cedar Lake Watershed Impaired Stream Segments

Sample Location and Parameter	Period of Record and Number of Data Points	Geometric mean of all samples	Maximum	Minimum	Number of samples > 200 (1)	Number of samples > 400 (1)
Cedar Creek Segment NA01; Sample Location NA01						
Total Fecal Coliform (cfu/100 mL)	1990-2004; 114	94.5	13300	2	29	18

5.1.2 Lake and Reservoir Water Quality Data

The Cedar Creek watershed has three impaired lakes within its drainage area that are addressed in this report. The data summarized in this section include water quality data for impaired constituents as well as parameters that could be useful in future modeling and analysis efforts. All historic data is available in Appendix C.

5.1.2.1 Lake Murphysboro

There are three active stations in Lake Murphysboro (see Figure 5-1). The lake is impaired for total phosphorous. An inventory of all available phosphorous data at all depths is presented in Table 5-5.

Table 5-5 Lake Murphysboro Data Inventory for Impairments

Lake Murphysboro Segment RND; Sample Locations RND-1, RND-2, and RND-3		
RND-1	**Period of Record**	**Number of Samples**
Total Phosphorus	1994-2000	27
RND-2		
Total Phosphorus	1994-2000	13
RND-3		
Total Phosphorus	1994-2000	13

Table 5-6 contains information on data availability for other parameters that may be useful in data needs analysis and future modeling efforts for manganese. DO at varying depths as well as chlorophyll-a data have been collected where available.

Table 5-6 Lake Murphysboro Data Availability for Data Needs Analysis and Future Modeling Efforts

Lake Murphysboro Segment RND; Sample Locations RND-1, RND-2, and RND-3		
RND-1	**Period of Record**	**Number of Samples**
Chlorophyll-a Corrected	1991-2000	5
Chlorophyll-a Uncorrected	1991-2000	5
Dissolved Oxygen	1991-2000	75
Temperature	1991-2000	75
RND-2		
Chlorophyll-a Corrected	1991-2000	5
Chlorophyll-a Uncorrected	1991-2000	5
Dissolved Oxygen	1991-2000	55
Temperature	1991-2000	55
RND-3		
Chlorophyll-a Corrected	1991-2000	5
Chlorophyll-a Uncorrected	1991-2000	5
Dissolved Oxygen	1991-2000	35
Temperature	1991-2000	35

5.1.2.1.1 Total Phosphorus

Compliance with the total phosphorus standard is based on samples collected at a one-foot depth from the lake surface. The average total phosphorus concentrations at a one-foot depth for each year of available data at each monitoring site in Lake Murphysboro are presented in Table 5-3. The water quality standard for total phosphorus is less than or equal to 0.05 mg/L.

Table 5-7 Average Total Phosphorus Concentrations (mg/L) in Lake Murphysboro at One-Foot Depth

	RND-1		RND-2		RND-3		Lake Average	
Year	**Data Count; Number of Violations**	**Average**	**Data Count; Number of Violations**	**Average**	**Data Count; Number of Violations**	**Average**	**Data Count; Number of Violations**	**Average**
1994	5; 3	0.05	5; 4	0.06	5; 3	0.06	15; 10	0.06
1997	3; 2	0.06	4; 3	0.06	4; 3	0.07	11; 8	0.06
2000	5; 1	0.04	4; 0	0.03	4; 0	0.03	–	–

Figure 5-6 shows the average total phosphorous concentrations annually in Lake Murphysboro.

5.1.2.2 Cedar Lake

There are five active stations in Cedar Lake. The lake is impaired for manganese. An inventory of all available manganese data is presented in Table 5-8. Manganese data were not available for sampling location RNE-2.

Table 5-8 Cedar Lake Data Inventory for Impairments

Cedar Lake Segment RNE; Sample Locations RNE-1, RNE-3, RNE-4, and RNE-5		
RNE-1	**Period of Record**	**Number of Samples**
Manganese Bottom Deposits	1990-2000	5
RNE-3		
Manganese Bottom Deposits	1994-1997	3
RNE-4		
Manganese Bottom Deposits	1990-2000	2
RNE-5		
Total Manganese	2000	5
Manganese Bottom Deposits	2000	1

Table 5-9 contains information on data availability for other parameters that may be useful in data needs analysis and future modeling efforts for manganese. DO at varying depths as well as phosphorus data has been collected where available.

Table 5-9 Cedar Lake Data Availability for Data Needs Analysis and Future Modeling Efforts

Cedar Lake Segment RNE- Sample Locations RNE-1, RNE-2, RNE-3, RNE-4, and RNE-5		
RNE-1	**Period of Record**	**Number of Samples**
Depth	1990-1998	146
Dissolved Oxygen	1990-2000	114
Temperature	1990-2000	552
RNE-2		
Depth	1990-1998	126
Dissolved Oxygen	1990-2000	90
Temperature	1990-2000	475
RNE-3		
Depth	1990-1998	124
Dissolved Oxygen	1990-2000	57
Temperature	1990-2000	286
RNE-4		
Depth	1990-1998	122
Dissolved Oxygen	1990-2000	46
Temperature	1990-2000	243
RNE-5		
Depth	1990-1998	86
Dissolved Oxygen	1990-2000	101
Temperature	1990-2000	101

5.1.2.2.1 Manganese

The applicable water quality standard for manganese is 1,000 µg/L for general use and 150 µg/L for public water supplies. Table 5-10 summarizes available manganese data for Cedar Lake. Samples collected in July and August of 2000 exceeded both standards.

Table 5-10 Average Total Manganese Concentrations in Cedar Lake

Sampling Location	Date	Depth (ft)	Result (ug/L)
RNE-5	4/28/2000	20	47
RNE-5	6/7/2000	20	82
RNE-5	7/13/2000	21	640
RNE-5	8/16/2000	22	1900
RNE-5	10/23/2000	19	110

5.1.2.3 Little Cedar Lake

There are three active stations on Little Cedar Lake. The lake is impaired for manganese. An inventory of all available manganese data is presented in Table 5-11. Manganese data were not available for sampling location RNZM-2.

Table 5-11 Little Cedar Lake Data Inventory for Impairments

Little Cedar Lake Segment RNZM; Sample Locations RNZM-1 and RNZM-3		
RNZM-1	**Period of Record**	**Number of Samples**
Total Manganese	2000	5
Manganese Bottom Deposits	1993-2000	3
RNZM-3		
Manganese Bottom Deposits	1997-2000	2

Table 5-12 contains information on data availability for other parameters that may be useful in data needs analysis and future modeling efforts for manganese. DO values at various depths have been collected where available.

Table 5-12 Little Cedar Lake Data Availability for Data Needs Analysis and Future Modeling Efforts

Little Cedar Lake Segment RNZM; Sample Locations RNZM-1, RNZM-2, and RNZM-3		
RNZM-1	**Period of Record**	**Number of Samples**
Depth	1997-2000	15
Dissolved Oxygen	1997-2000	64
Temperature	1997-2000	133
RNZM-2		
Depth	1997-2000	10
Dissolved Oxygen	1997-2000	40
Temperature	1997-2000	79
RNZM-3		
Depth	1997-2000	10
Dissolved Oxygen	1997-2000	17
Temperature	1997-2000	35

5.1.2.3.1 Manganese

The applicable water quality standard for manganese is 1,000 µg/L for general use and 150 µg/L for public water supplies. Table 5-13 summarizes available manganese data for Little Cedar Lake. all of the samples taken in 2000 violated the total manganese public water supply standard, and two samples (July and August) were above the general use standard.

Table 5-13 Average Total Manganese Concentrations in Little Cedar Lake

Sampling Location	Date	Depth (ft)	Result (ug/L)
RNZM-1	4/27/2000	12	170
RNZM-1	6/7/2000	13	730
RNZM-1	7/13/2000	13	1300
RNZM-1	8/16/2000	12	5400
RNZM-1	10/23/2000	13	350

5.2 Reservoir Characteristic

There are three impaired reservoirs in the Cedar Creek/Cedar Lake watershed. Reservoir information that can be used for future modeling efforts was collected from GIS analysis, Illinois EPA, and USEPA water quality data. The following sections will discuss the available data for each reservoir.

5.2.1 Little Cedar Lake and Cedar Lake

Cedar Lake and Little Cedar Lake are part of the same lake that is separated by a berm. The lake was created in 1974 by damming a branch of Cedar Creek. Cedar Lake has a surface area of 1,800 acres while Little Cedar Lake is 70 acres in area. The total shoreline length is 30 miles. Water is supplied to the Village of Alto Pass and the City of Carbondale for drinking water from intakes in both Little Cedar Lake and Cedar Lake. Table 5-14 contains dam information for Cedar Lake.

Table 5-14 Cedar Lake Dam Information (U.S. Army Corps of Engineers)

Dam Length	1,690 feet
Dam Height	74 feet
Maximum Discharge	10,234 cfs
Maximum Storage	49,336 acre-feet
Normal Storage	28,365 acre-feet
Spillway Width	33 feet
Outlet Gate Type	U

Tables 5-15 and 5-16 contain depth information for each sampling location on both lake segments. The average maximum depth in Cedar Lake is 41.7 feet while the maximum depth in Little Cedar Lake is 25.4 feet.

Table 5-15 Average Depths (ft) for Cedar Lake Segment RNE (Illinois EPA 2002 and USEPA 2002a)

Year	RNE-1	RNE-2	RNE-3	RNE-4	RNE-5
1990	39.5	35.0	21.2	16.9	14.7
1991	38.8	36.6	20.3	16.0	12.8
1992	34.7	34.9	16.0	16.4	16.4
1993	35.8	35.6	19.1	19.0	15.3
1994	41.7	35.5	19.4	17.8	16.5
1995	42.0	42.0	21.4	16.3	15.1
1996	39.0	39.0	19.5	16.9	15.1
1997	56.2	39.1	20.5	19.2	16.5
1998	44.6	33.0	20.4	16.0	23.9
2000	44.2	36.6	21.6	16.8	40.0
Average	41.7	36.7	19.9	17.1	18.6

Table 5-16 Average Depths (ft) for Little Cedar Lake Segment RNZM (Illinois EPA 2002 and USEPA 2002a)

Year	RNZM-1	RNZM-2	RNZM-3
1997	26.3	14.1	5.8
2000	24.4	14.2	5.5
Average	25.4	14.2	5.6

5.2.2 Lake Murphysboro

Lake Murphysboro is located in Jackson County, west of the City of Murphysboro and north of the Big Muddy River. The lake is part of Lake Murphysboro State Park, which is maintained by the Illinois Department of Natural Resources. The lake was built in 1950 by the Division of Fisheries. The lake has a surface area of 143 acres and has 7.5 miles of shoreline. Table 5-17 contains dam information.

Table 5-17 Lake Murphysboro Dam Information (U.S. Army Corps of Engineers)

Dam Length	590 feet
Dam Height	46 feet
Maximum Discharge	9,171 cfs
Maximum Storage	4,281 acre-feet
Normal Storage	2,375 acre-feet
Spillway Width	100 feet
Outlet Gate Type	U

Table 5-18 contains depth information for each sampling location on the lake. The maximum average water depth is 29 feet.

Table 5-18 Average Depths (ft) for Lake Murphysboro (Illinois EPA 2002 and USEPA 2002a)

Year	RND-1	RND-2	RND-3
1990	28	18	10
1992	30	23	16
1996	NA	19	6
1997	NA	24	14
1998	30	21	16
2000	28	21	12
Average	29	21	12

5.3 Point Sources

Point sources for the Cedar Creek watershed have been separated into municipal/ industrial sources and mining discharges. Available data have been summarized and are presented in the following sections.

5.3.1 Municipal and Industrial Point Sources

Permitted facilities must provide Discharge Monitoring Reports (DMRs) to Illinois EPA as part of their NPDES permit compliance. DMRs contain effluent discharge sampling results, which are then maintained in a database by the state. There are approximately 16 point sources located within the Cedar Creek and Lake watershed. Figure 5-3 shows the location of point sources in the watershed. In order to assess point source contributions to the watershed, the data have been examined by receiving water and then by the downstream impaired segment that has the potential to receive the discharge. Receiving waters were determined through information contained in the USEPA Permit Compliance System (PCS) database. Maps were used to determine downstream impaired receiving water information when PCS data were not available. The impairments for each segment or downstream segment were considered when reviewing DMR data. Data have been summarized for any sampled parameter that is associated with a downstream impairment (i.e., all available nutrient and BOD data was reviewed for segments that are impaired for DO). This will help in future model selection as well as source assessment and load allocation.

5.3.1.1 Little Cedar Lake Segment RNZM

There is one point source that discharges upstream of Little Cedar Lake Segment RNZM. Little Cedar Lake is listed as impaired for manganese. The Alto Pass Water Treatment Plant is permitted to discharge to an unnamed tributary to Little Cedar Lake. Table 5-19 contains a summary of available DMR data for this point source. No manganese data was available as it is not required by the discharge permit.

Table 5-19 Effluent Data from Point Sources Discharging Upstream of Little Cedar Lake Segment RNZM (Illinois EPA 2005)

Facility Name Period of Record Permit Number	Receiving Water/ Downstream Impaired Waterbody	Constituent	Average Value	Average Loading (lb/d)
Alto Pass WTP 2002-2004 IL0000914	NA/Little Cedar Lake Segment RNZM	Average Daily Flow	0.0112 mgd	NA

5.3.1.2 Big Muddy River Segment N 99

There are 16 point sources with the potential to contribute discharge to Big Muddy River Segment N 99 directly or through tributaries. Most of the facilities summarized in the table below are significantly upstream of this segment of the Big Muddy River. Segment N 99 is listed as impaired for sulfates and DO. Table 5-20 contains a summary of available DMR data for these point sources. No sulfates data were available because sampling for that parameter is not required by the discharge permits.

Table 5-20 Effluent Data from Point Sources Discharging Upstream of Big Muddy River Segment N 99 (Illinois EPA 2005)

Facility Name Period of Record Permit Number	Receiving Water/ Downstream Impaired Waterbody	Constituent	Average Value	Average Loading (lb/d)
Country Village MHP-Murphysboro 1994-2004 ILG551083, Il0038164	Unnamed Tributary to Carbon Lake/Big Muddy River Segment N 99	Average Daily Flow	0.016 mgd	NA
		CBOD, 5-Day	13.6 mg/L	0.22
Desoto STP 1994-2004 IL0024937	Big Muddy River/Big Muddy River Segment N 99	Average Daily Flow	0.24mgd	NA
		CBOD, 5-Day	41.4 mg/L	56.3
Fairway Mobile Home Park 1997-2004 IL0045306	Unnamed Tributary to Big Muddy River/Big Muddy River Segment N 99	Average Daily Flow	0.0071 mgd	NA
		CBOD, 5-Day	6.0 mg/L	0.32
Fairway Vista STP 2000-2003 ILG551064	Mud Creek to Big Muddy River/Big Muddy River Segment N 99	Average Daily Flow	0.01 mgd	NA
		CBOD, 5-Day	6.2 mg/L	0.67
Gorham SD STP 1998-2005 ILG580185	Worthen Bayou to Big Muddy River/Big Muddy River Segment N 99	Average Daily Flow	0.0735 mgd	NA
Grand Tower STP 1995-2005 ILG580079	Big Muddy River/Big Muddy River Segment N 99	Average Daily Flow	0.0845 mgd	NA
		CBOD, 5-Day	53.2 mg/L	8.83
Green Tree Mobile Home Park 1995-2004 IL0036935	Unnamed Tributary to Big Muddy River/Big Muddy River Segment N 99	Average Daily Flow	0.003 mgd	NA
		CBOD, 5-Day	6.30 mg/L	0.34
Happy Ours Trailer Park 1998-2004 IL0046299	Unnamed Tributary to Big Muddy River/Big Muddy River Segment N 99	Average Daily Flow	0.0043 mgd	NA
Jackson County Sand Company 1995-2005 IL0063797	Unnamed Tributary to Big Muddy River/Big Muddy River Segment N 99	Average Daily Flow	No Data	NA
Lake Chautauqua Home Assoc STP 2003-2005 ILG551046	Mud Creek/Big Muddy River Segment N 99	Average Daily Flow	0.05 mgd	NA
		CBOD, 5-Day	8.29 mg/L	0.23
Lone Oak Subdivision STP 1995-2004 IL0070904	Mud Creek/Big Muddy River Segment N 99	Average Daily Flow	0.0124 mgd	NA
		CBOD, 5-Day	10.5 mg/L	0.10
		Nitrogen, Ammonia	3.53 mg/L	0.03
Murphysboro STP 1989-2005 IL0023248	Big Muddy River/Big Muddy River Segment N 99	Average Daily Flow	1.27 mgd	NA
		CBOD, 5-Day	6.30 mg/L	0.34
		Manganese	–	0.41

Table 5-20 Effluent Data from Point Sources Discharging Upstream of Big Muddy River Segment N 99 (Illinois EPA 2005) continued

Facility Name Period of Record Permit Number	Receiving Water/ Downstream Impaired Waterbody	Constituent	Average Value	Average Loading (lb/d)
New Thompson Lake Fishing Club 1992-2004 IL0048569	Unnamed Tributary to Big Muddy River/Big Muddy River Segment N 99	Average Daily Flow	0.015 mgd	NA
		CBOD, 5-Day	8.58 mg/L	1.07
Orchard Hills Development Cntr 1993-2005 ILG550001, IL0050041	NA/Big Muddy River Segment N 99	Average Daily Flow	0.0026 mgd	NA
		CBOD, 5-Day	65.3 mg/L	0.074
		Ammonia, Nitrogen	5.73 mg/L	0.018
IL DNR-Lake Murphysboro St Pk 1996-2004 IL0051853	Unnamed Tributary to Big Muddy River/Big Muddy River Segment N 99	Average Daily Flow	0.01 mgd	NA
		CBOD, 5-Day	8.10 mg/L	0.203
		Ammonia, Nitrogen	1.99 mg/L	0.014

5.3.1.3 Cedar Lake Segment RNE

There is one point source with the potential to contribute discharge to Cedar Lake Segment RNE. Cedar Lake is listed as impaired for manganese. The Union Jackson Farm Labor Association is permitted to discharge to Mill Creek, which is a tributary to Cedar Lake. Table 5-21 contains a summary of available and pertinent DMR data for this point source. Data from the Union Jackson Farm Labor Association does not contain any information on manganese.

Table 5-21 Effluent Data from Point Sources Discharging Upstream of Cedar Lake Segment RNE (Illinois EPA 2005)

Facility Name Period of Record Permit Number	Receiving Water/ Downstream Impaired Waterbody	Constituent	Average Value	Average Loading (lb/d)
Union Jackson Farm Labor Assn 1994-2004 IL0047767, ILG551094	Mill Creek/Cedar Lake Segment RNE	Average Daily Flow	0.0122 mgd	NA

5.3.1.4 Other Impaired Segments

There are no permitted facilities or no data for facilities that discharge directly to or upstream of Lake Murphysboro RND, Cedar Creek segment NA 01, and Cave Creek segment NAC 01.

5.3.2 Mining Discharges

There are no permitted mine sites or recently abandoned mines within the Cedar Creek/Cedar Lake watershed.

5.4 Nonpoint Sources

There are many potential nonpoint sources of pollutant loading to the impaired segments in the Cedar Creek watershed. This section will discuss site-specific cropping practices, animal operations, and area septic systems. Data was collected through communication with local NRCS, Soil and Water Conservation District (SWCD), Public Health Department, and County Tax Department officials.

5.4.1 Crop Information

A portion of the land found within the Cedar Creek/Cedar Lake watershed is devoted to crops. Corn and soybean farming account for approximately 9 percent and 11 percent of the watershed, respectively. Tillage practices can be categorized as conventional till, reduced till, mulch-till, and no-till. The percentage of each tillage practice for corn, soybeans, and small grains by county are generated by the Illinois Department of Agriculture from County Transect Surveys. The most recent survey was conducted in 2004. Data specific to the Cedar Creek/Cedar Lake watershed was not available; however, the Jackson and Union County practices were available and are as shown. Communications with Union County have indicated that very little small grains or row crop agriculture takes place in the Union County portion of the watershed. The land in that part of Union County is mostly pasture and some orchards.

Table 5-22 Tillage Practices in Union County

Tillage System	Corn	Soybean	Small Grain
Conventional	15%	11%	0%
Reduced - Till	4%	4%	0%
Mulch – Till	4%	5%	40%
No – Till	77%	80%	60%

Table 5-23 Tillage Practices in Jackson County

Tillage System	Corn	Soybean	Small Grain
Conventional	57%	54%	59%
Reduced - Till	0%	0%	0%
Mulch – Till	17%	18%	41%
No – Till	26%	27%	0%

5.4.2 Animal Operations

Watershed specific animal numbers were not available for the Cedar Creek watershed. Data from the National Agricultural Statistics Service were reviewed and are presented below to show county-wide livestock numbers.

Table 5-24 Jackson County Animal Population (2002 Census of Agriculture)

	1997	2002	Percent Change
Cattle and Calves	16,066	16,566	3%
Beef	7,833	7,416	-5%
Dairy	542	1,183	118%
Hogs and Pigs	9,975	6,335	-36%
Poultry	510	715	40%
Sheep and Lambs	202	379	88%
Horses and Ponies	NA	864	NA

Table 5-25 Union County Animal Population (2002 Census of Agriculture)

	1997	2002	Percent Change
Cattle and Calves	17,453	14,002	-20%
Beef	8,340	7,162	-14%
Dairy	687	431	-37%
Hogs and Pigs	3,090	710	-77%
Poultry	319	331	4%
Sheep and Lambs	706	380	-46%
Horses and Ponies	NA	741	NA

Illinois EPA provided a GIS shapefile illustrating the location of livestock facilities in the Big Muddy River Basin, which contains the Cedar Creek watershed. In 2001, Illinois EPA assessed the potential impact of each facility on water quality with regard to the size of the facility, the site condition and management, pollutant transport efficiency, and water resources vulnerability. This GIS data have been used as reference since the surveys were conducted four years ago. Seven animal facilities existed at the time of the survey. One cattle facility was assessed to have a slight impact and was located along the northwestern border of the Lake Murphysboro subbasin. The other six facilities were not assessed or assessed to have no impact. Of the remaining six, only one was located in an area draining to an impaired segment. A hog facility that was not assessed was located in the Cave Creek subbasin.

5.4.3 Septic Systems

Many households in rural areas of Illinois, which are not connected to municipal sewers, make use of onsite sewage disposal systems, or septic systems. There are a variety of types of septic systems, but the most common septic system is composed of a septic tank draining to a septic field, where nutrient removal occurs. However, the degree of nutrient removal is limited by soils and system upkeep and maintenance.

Information on sewered and septic municipalities was obtained from Jackson and Union County health departments. Because the county health departments were unable to provide estimates of the number of septic systems, estimates of the number of existing residences within the watershed were obtained for the areas known to be served by septic systems. The tax assessor provided an estimated number of residences in Jackson County, and data from the U.S. Census Bureau were used to estimate the number of septic systems in Union County within the watershed. Table 5-26 is a summary of the available septic system data in the Cedar Creek watershed.

Table 5-26 Estimated Septic Systems in the Cedar Creek Watershed

County	Estimated No. of Septic Systems	Source of Septic Areas/ No. of Septic Systems
Jackson	4,529	Health Department/Tax Assessor
Union	82	Health Department/U.S. Census Bureau
Total	**4,611**	

There are approximately 4,600 septic systems in the watershed. In Jackson County, where the impaired Lake Murphysboro, Cedar Lake, and Little Cedar Lake are located, the municipalities are served by sewers. However, the rural areas are served by septic systems. Land use data (see Section 2.3) indicates that there are very few residences located near the impaired lakes.

5.5 Watershed Studies and Other Watershed Information

Previous planning efforts have been conducted within the Cedar Creek Watershed. An intensive survey of the Big Muddy River Basin was conducted in 2000. A Clean Lakes Study is currently being performed for Cedar Lake, which includes Little Cedar Lake. If data from these reports are available, they will be used as references during Stage 3 TMDL development and further investigation into watershed-specific groups and associated activities will be conducted.

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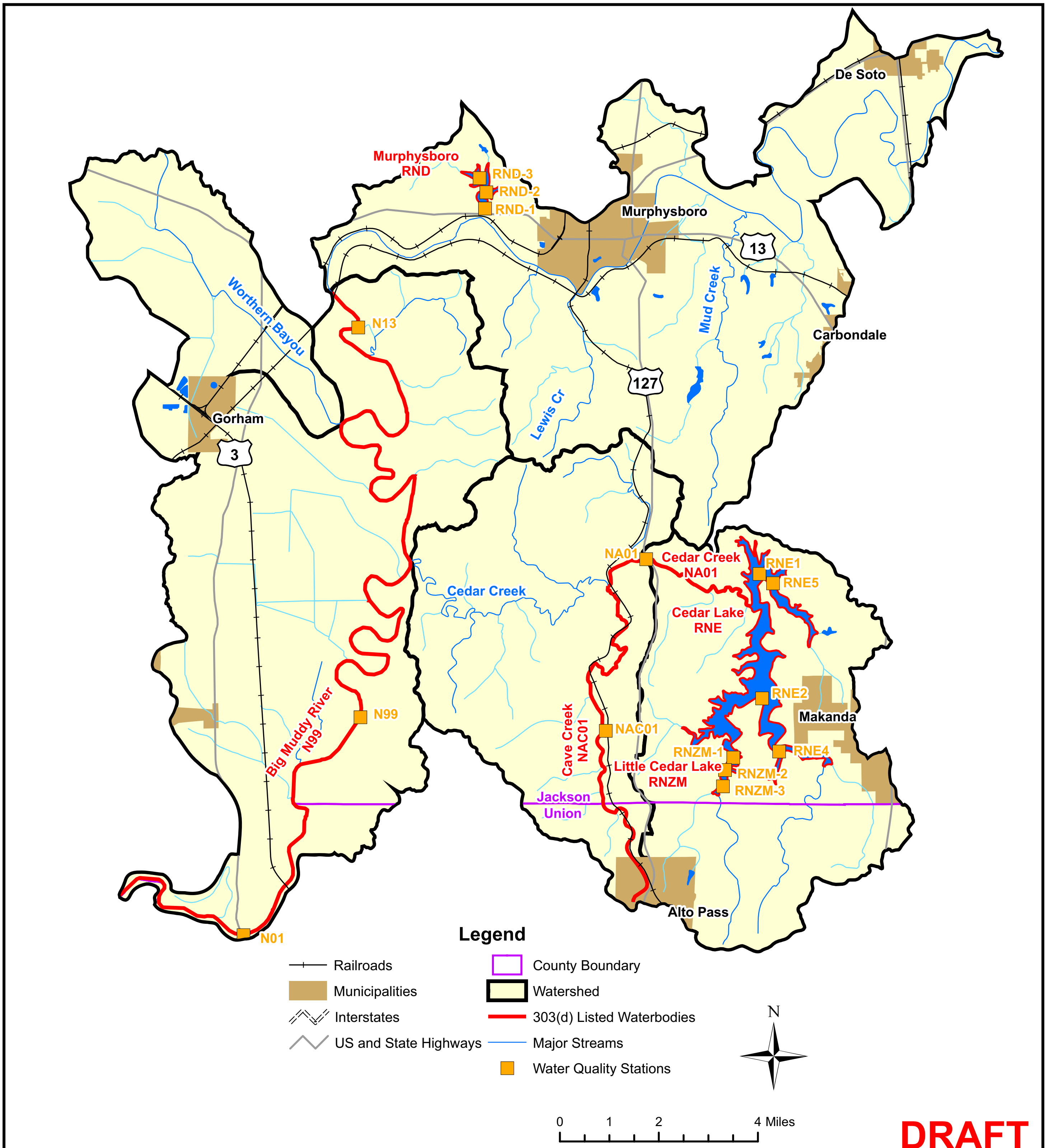

Figure 5-1
Water Quality Stations
Cedar Creek - Cedar Lake Watershed

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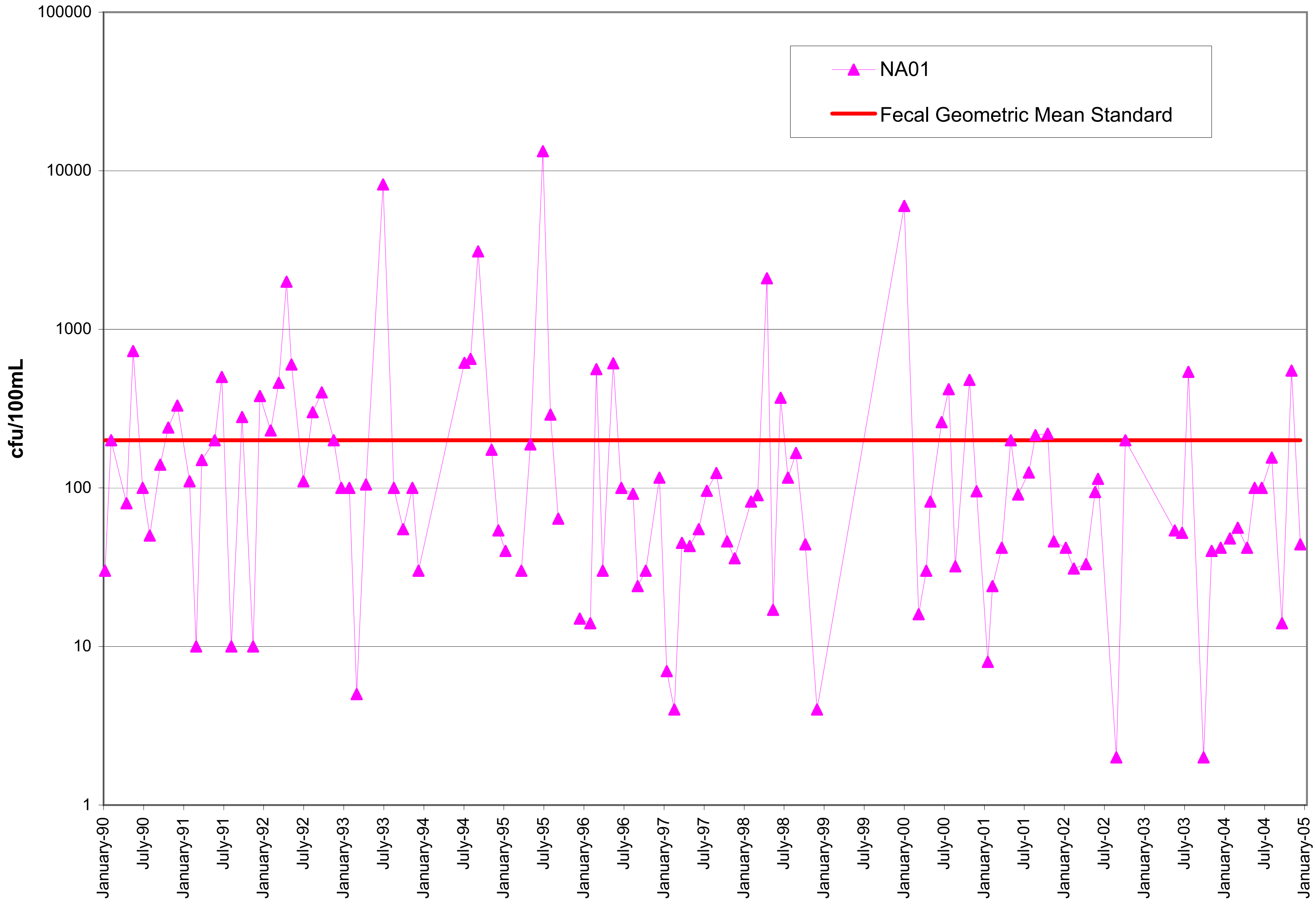

CDM

T:\GIS\4 Cedar Creek & Lake\Data\Cedar-stream-fecal.xlsCedar Fecal Chart

Figure 5-2:
Total Fecal Coliform
Cedar Creek NA01

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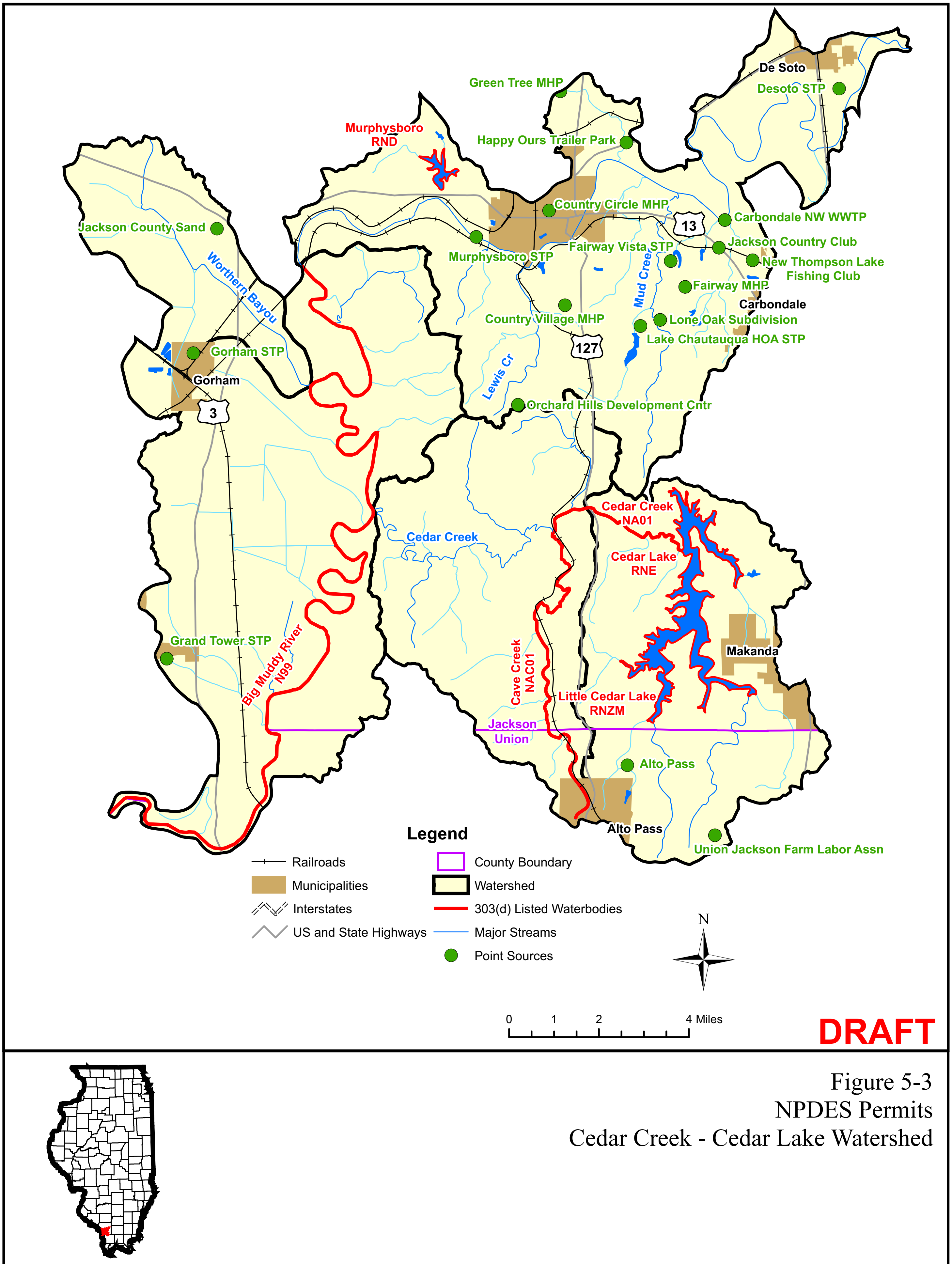

Figure 5-3
NPDES Permits
Cedar Creek - Cedar Lake Watershed

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Section 6
Approach to Developing TMDL and Identification of Data Needs

Illinois EPA is currently developing TMDLs for pollutants that have numeric water quality standards. Within the Cedar Creek/Cedar Lake watershed DO, sulfates, and total fecal coliform are the parameters with numeric water quality standards. For lakes and reservoirs in the watershed, total phosphorus and manganese are the only parameters a with numeric water quality standard. Illinois EPA believes that addressing these impairments should lead to an overall improvement in water quality due to the interrelated nature of the other listed pollutants. Refer to Table 1-1 for a list of all the impairments within the Cedar Creek/Cedar Lake watershed. Recommended technical approaches for developing TMDLs for streams and lakes are presented in this section. Additional data needs are also discussed.

6.1 Simple and Detailed Approaches for Developing TMDLs

The range of analyses used for developing TMDLs varies from simple to complex. Examples of a simple approach include mass-balance, load-duration, and simple watershed and receiving water models. Detailed approaches incorporate the use of complex watershed and receiving water models. Simple approaches typically require less data than detailed approaches and therefore these are the analyses recommended for the Cedar Creek/Cedar Lake watershed. Establishing a link between pollutant loads and resulting water quality is one of the most important steps in developing a TMDL. As discussed above, this link can be established through a variety of techniques. The objective of the remainder of this section is to recommend approaches for establishing these links for the constituents of concern in the Cedar Creek/Cedar Lake watershed.

6.2 Approaches for Developing TMDLs for Stream Segments in Cedar Creek/Cedar Lake Watershed

None of the impaired stream segments in the watershed have major point sources discharging to them. Approaches for developing TMDLs for areas without major point sources are described below.

6.2.1 Recommended Approach for DO TMDLs for Stream Segments without Major Point Sources

Data from segments N99 of the Big Muddy and NAC01 of Cave Creek indicate existing DO impairments on each of the segments, however, data are very limited. Therefore, it is recommended that more data be collected. If the collected data confirm that the impairments exist, a simplified approach that involves simulating pollutant oxidation and stream reaeration only within a spreadsheet model is recommended for DO TMDL development. This model simulates steady-state stream DO as a function of carbonaceous and nitrogenous pollutant oxidation and atmospheric reaeration. The model allows for non-uniform stream hydraulics, hydrology, and pollutant loadings at any level of segmentation. It is also free of numerical dispersion as it relies on well-known analytical solutions rather than numerical approximations of the fundamental equations. The model assumes plug flow (no hydrodynamic dispersion), which is likely an acceptable assumption for most small to medium sized streams. The model also does not incorporate the impacts of stream plant life, which generally require site-specific data for meaningful parameterization. A watershed model will not be used for these segments. Using the spreadsheet model iteratively, the BOD loads estimated to cause the DO impairments and to maintain a DO of 5.0 mg/L will be calculated. These calculated loads will become the basis for recommending TMDL reductions if necessary.

6.2.2 Recommended Approach for Sulfates TMDL

Segment N99 is listed for impairment caused by sulfates. No recent data have been available to indicate that sulfates are causing an impairment and no apparent sources of this constituent have been identified to date. It is recommended that more data be collected to confirm impairment. Once this occurs, it is recommended that an empirical loading and spreadsheet analysis be utilized to calculate this TMDL.

6.2.3 Recommended Approach for Fecal Coliform TMDL

Segment NA01 of Cedar Creek is listed as impaired for total fecal coliform. The standard is based on a geometric mean of at least 5 samples collected in a 30 day period during the months of May through October. There have been no instances when this is the case, however, the amount of data available is adequate for TMDL development. The recommended approach for developing TMDLs for these segments is use of the load-duration curve method. The load-duration methodology uses the cumulative frequency distribution of streamflow and pollutant concentration data to estimate the allowable loads for a waterbody.

6.3 Approaches for Developing TMDLs for Lake Segments in the Cedar Creek/Cedar Lake Watershed

It is assumed that for the lakes in the watershed, enough data exists to develop a simple model for use in TMDL development.

6.3.1 Recommended Approach for Total Phosphorus TMDLs

Lake Murphysboro is impaired for phosphorus. The BATHTUB model is recommended for phosphorus assessments in this reservoir. The BATHTUB model performs steady-state water and nutrient balance calculations in a spatially segmented hydraulic network that accounts for advective and diffusive transport, and nutrient sedimentation. The model relies on empirical relationships to predict lake trophic conditions and subsequent DO conditions as functions of total phosphorus and nitrogen loads, residence time, and mean depth. (USEPA 1997). Oxygen conditions in the model are simulated as meta and hypolimnetic depletion rates, rather than explicit concentrations. Watershed loadings to the lakes will be based on empirical data or tributary data available in the lake watersheds.

6.3.2 Recommended Approach for Manganese TMDLs

Cedar Lake and Little Cedar Lake have manganese impairments. The lakes are a source of public water and therefore, the applicable water quality standard for manganese in the lake is 150 µg/L. For this TMDL, manganese will not be analyzed because it is assumed that development of a DO TMDL will control the manganese concentrations. The TMDL will first investigate dissolved oxygen levels throughout the water column. The lake is not impaired for DO, however DO compliance is assessed at one-foot depth from the surface. A preliminary review of DO concentrations at greater depths shows that DO levels in the summer have been recorded as low as 0.0 mg/L (sampled at 39 feet in October 2000) in Cedar Lake and 0.2 mg/L (sampled at 17 feet in June 2000) in Little Cedar Lake. The manganese target will then be maintenance of hypolimnetic DO concentrations above zero, because the only controllable source of manganese to the lake is the release of manganese from lake sediments during periods when there is no DO in lake bottom waters. The cause of the lack of DO in lake bottom waters is unknown and it is recommended that a spreadsheet analysis be utilized to calculate this TMDL.

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Illinois Environmental
Protection Agency

Stage 2 Data Report

March 2007

Final Report

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Contents

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Figures

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Tables

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Section 1
Introduction

The Illinois Environmental Protection Agency (Illinois EPA) has a three-stage approach to total maximum daily load (TMDL) development. The stages are:

Stage 1 – Watershed Characterization, Data Analysis, Methodology Selection

Stage 2 – Data Collection (optional)

Stage 3 – Model Calibration, TMDL Scenarios, Implementation Plan

This report addresses data collection associated with Stage 2 TMDL development for the following watersheds:

- Bay Creek
- Cahokia Creek/Holiday Shores Lake
- Cedar Creek/Cedar Lake
- Crab Orchard Creek/Crab Orchard Lake
- Crooked Creek
- Little Wabash River
- Mary's River/North Fork Cox Creek
- Sangamon River/Lake Decatur
- Shoal Creek
- South Fork Saline River/Lake of Egypt
- South Fork Sangamon River/Lake Taylorville

Sampling has been completed based on the recommendations presented in Section 6 of each watershed's Stage 1 TMDL report and the sampling plan described within the quality assurance project plan (QAPP). The Stage 2 data will supplement existing data collected and assessed as part of Stage 1 of TMDL development and will support the development of TMDLs under Stage 3 of the process. Where adequate supporting data exist, data collected during Stage 2 activities may also be used to support the delisting of certain parameters from the state 303(d) list.

The remaining sections of this report contain:

- **Section 2 Field Activities** includes information on sampling locations as well as field parameter, grab sample and continuous monitoring data
- **Section 3 Quality Assurance Review** discusses changes in the sampling plan from the original QAPP, data verification and validity, and conformance to the data quality objectives
- **Section 4 Conclusions** summarizes the Stage 2 work and makes recommendations for moving forward

Section 2
Field Activities

TMDL streams were sampled by CDM twice during the fall of 2006 to collect data needed to support water quality modeling and TMDL development. The first round of Stage 2 data collection took place between August 28 and September 29, 2006. The second round of Stage 2 data collection took place between October 16 and November 17, 2006. In addition, three segments within the Little Wabash River watershed were sampled by Illinois EPA between April and August of 2006. Over the course the sampling project, 32 streams (out of a possible 33) and one lake were sampled within the eleven Stage 2 watersheds. Table 2-1 contains data collection dates for each watershed.

Table 2-1: Stage 2 Data Collection Field Dates

Watershed	First Round Dates (2006)	Second Round Dates (2006)
Bay Creek	9/25-9/29	10/30-11/6
Cahokia Creek/Holiday Shores Lake	8/28-9/6	10/16-10/20
Cedar Lake	9/5-9/14	10/30-11/6
Crab Orchard Lake	9/5-9/14	10/30-11/6
Crooked Creek	9/5-9/14	10/16-10/20
South Fork Saline River/Lake of Egypt	9/25-9/29	10/30-11/6
Little Wabash River - CDM	9/5-9/14	10/30-11/16
Little Wabash River – Illinois EPA	4/18-8/8	
Mary's River	9/5-9/14	10/16-10/20
Sangamon River/Lake Decatur	8/28-9/6	10/30-11/3
Shoal	8/28-9/6	10/16-10/20
South Fork Sangamon River/Lake Taylorville	8/28-9/6	10/30-11/3

Sampling was conducted in accordance with the QAPP by CDM personnel at stream and lake locations with sufficient water and access. When time permitted, alternate locations were investigated if water and/or access were limited at original locations. Figures 2-1 through 2-11 show sampling locations used for Stage 2 data collection for each watershed. Refer to section 3.1 for further information related to sampling location changes from the original QAPP. Appendix A contains pictures of each sampling location. The sampling and analysis activities conducted at each sampling location included:

- In-stream field parameterization
- Grab samples for laboratory analysis
- Continuous monitoring
- Stream gaging

2.1 Instream field parameters

Water quality measurements for pH, temperature, dissolved oxygen (DO), conductivity, and turbidity were taken at each accessible sampling location where water was present using an In-Situ 9500 Profiler water quality meter. In-Situ 9500 Profilers were calibrated each morning of field activity. Water quality readings were taken at each accessible site with adequate water at the center of flow and values were recorded in field books. These values are presented in Table 2-2. Table 2-2 also contains sample location latitude and longitude as well as explanatory information as to why a limited number of sites were not sampled.

At each site with adequate and safely wadeable streamflow, flow measurements were recorded using a Marsh McBirney 2000 flow meter. Appendix B contains flow meter data and stream discharge analysis for these sites.

2.2 Grab Samples

Grab samples were collected based on the causes of impairment identified in the 303(d) list as well as data needed to support TMDL development under Stage 3. Samples collected on Owl Creek and South Fork Sangamon River were analyzed by Prairie Analytical Laboratories in Springfield, IL and all other samples collected by CDM were analyzed by ARDL, Inc in Mt. Vernon, IL. Samples were delivered in person to the laboratory or exchanged with laboratory personnel in the field. Select segments in the Little Wabash watershed (Elm River segment CD01, and Little Wabash River segments C09 and C33) were sampled by Illinois EPA and analyzed by the Illinois EPA Laboratory in Champaign, IL.

Table 2-3 contains data collected at each location associated with impairment status. Values shown in bold face with gray background violated the applicable water quality standard. All data analyzed by the laboratories are contained in Appendix C. This appendix includes the data shown in Table 2-3 as well as all other parameters that were sampled in order to support Stage 3 TMDL development. In addition, Appendix C shows data qualifiers as well as detection limits for all samples.

2.3 Continuous Monitoring

In-Situ 9500 Professional XP multi-parameter data-logging sondes were used for continuous data measurements on streams impaired by low DO and/or pH. The sondes were calibrated prior to deployment then deployed for at least 3 days at select locations with adequate water and access. DO, pH, conductivity and temperature data were recorded at 15 minute intervals during sonde deployment, after which the sonde was removed and data were downloaded to a laptop computer. The continuous data associated with impairment causes are presented in Appendix D. Because sondes were not field checked at the time of retrieval, there is a possibility that some experienced times of drying or build-up of sedimentation during deployment. A column was added to the data presented in Appendix D to estimate acceptable or "suspect" data. Data were deemed suspect when low conductivity or high temperature values indicate that the meter was likely out of the water or also at times when field log books indicated that the sonde had not yet been deployed or had been pulled from the stream. The data that were deemed acceptable were plotted on Figures D-1 through D-26. The charts are grouped by watershed and show data collected during the first and second round of sampling at each location.

Violations of the instantaneous DO standard (5.0 mg/L minimum) were not recorded during either monitoring period on the following segments that are currently listed for impairment caused by low DO:

- Cedar Creek AJF16 (Figure D-1)
- Big Muddy River N99 (Figure D-4)
- Shoal Creek OI05 (Figures D-22 and D-23)
- South Fork Saline River ATH08 (Figure D-24)

According to Table B-2 of the Illinois Integrated Water Quality Report (2006), the aquatic life use may also be impaired if DO concentrations are below 6.0 mg/L for more than 16 hours of any 24 hour period. Appendix D also contains this analysis for the segments that did not violate the instantaneous minimum standard. The number of values recorded below 6.0 mg/L during any 24 hour period were counted and if any count was above 64 (64 values equates to 16 hours worth of data), the stream was considered to be potentially impaired by low DO. The following segments did not experience a violation of either the 5.0 mg/L instantaneous standard or the 6.0 mg/L standard as described above:

- Cedar Creek AJF16 (Figure D-1)
- Shoal Creek OI05 (Figures D-22 and D-23)
- South Fork Saline River ATH08 (Figure D-24)

Violations of the pH standard (6.5 minimum, 9.0 maximum) were not recorded during either monitoring period on the following segments that are currently listed for impairment caused by pH:

- Crab Orchard Creek ND12 (Figure D-5)
- Briers Creek ATHS01 (Figure D-25)

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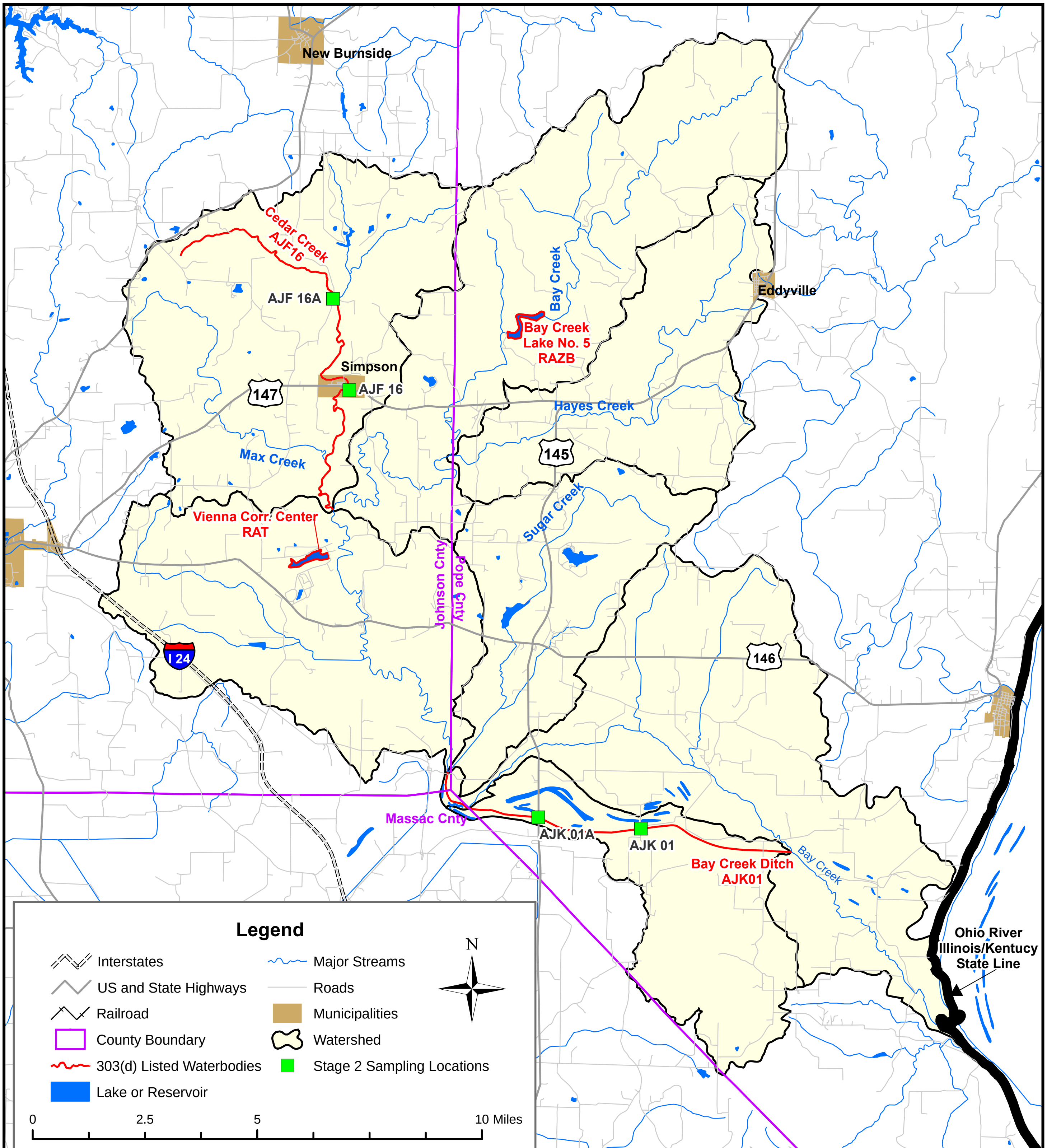

Figure 2-1
Stage 2 Sampling Locations
Bay Creek Watershed

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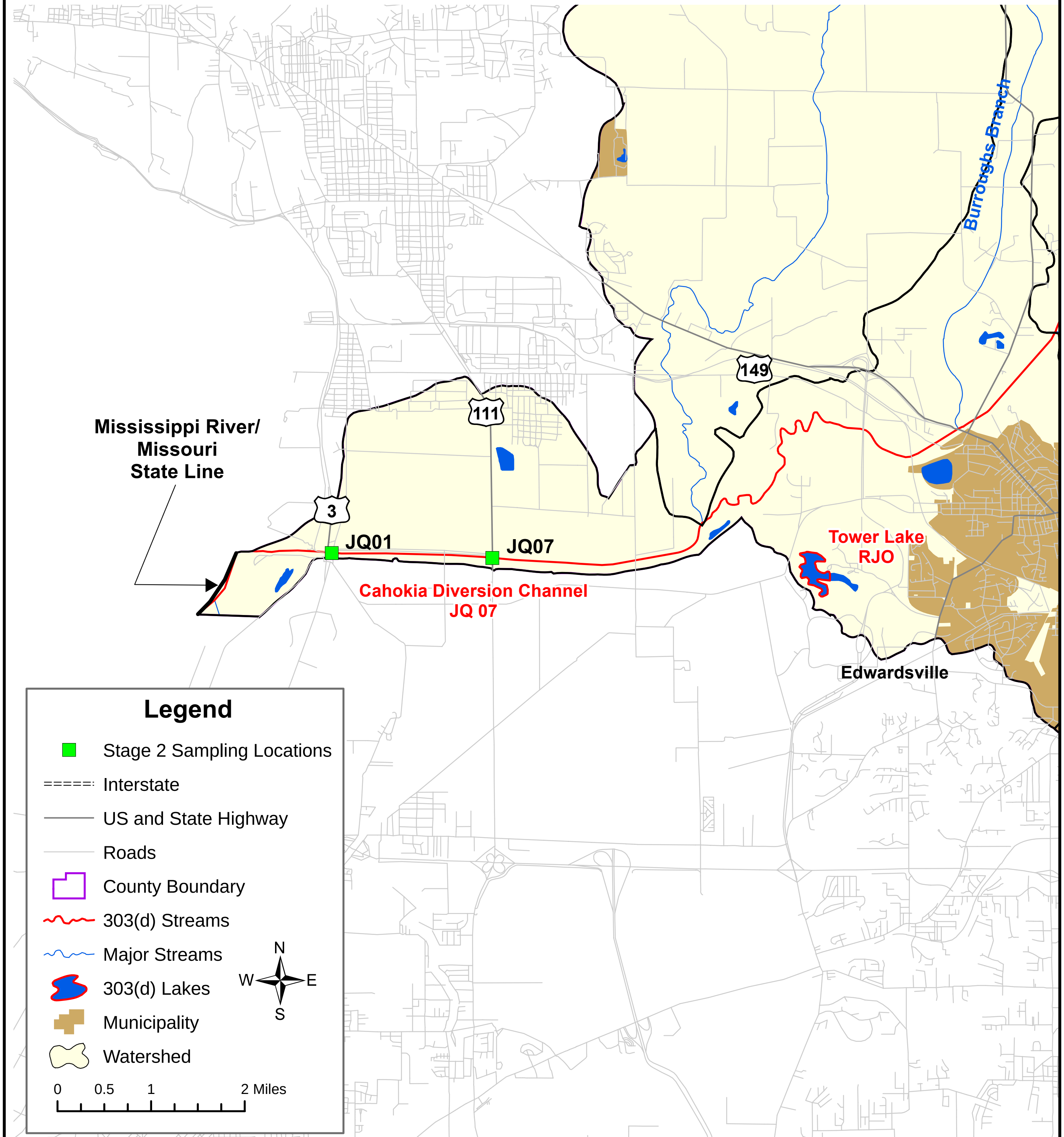

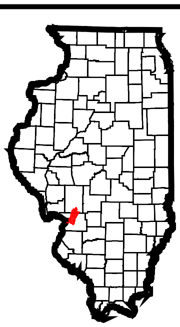

Figure 2-2:
Stage 2 Sampling Locations
Cahokia Creek/Holiday Shores Lake Watershed

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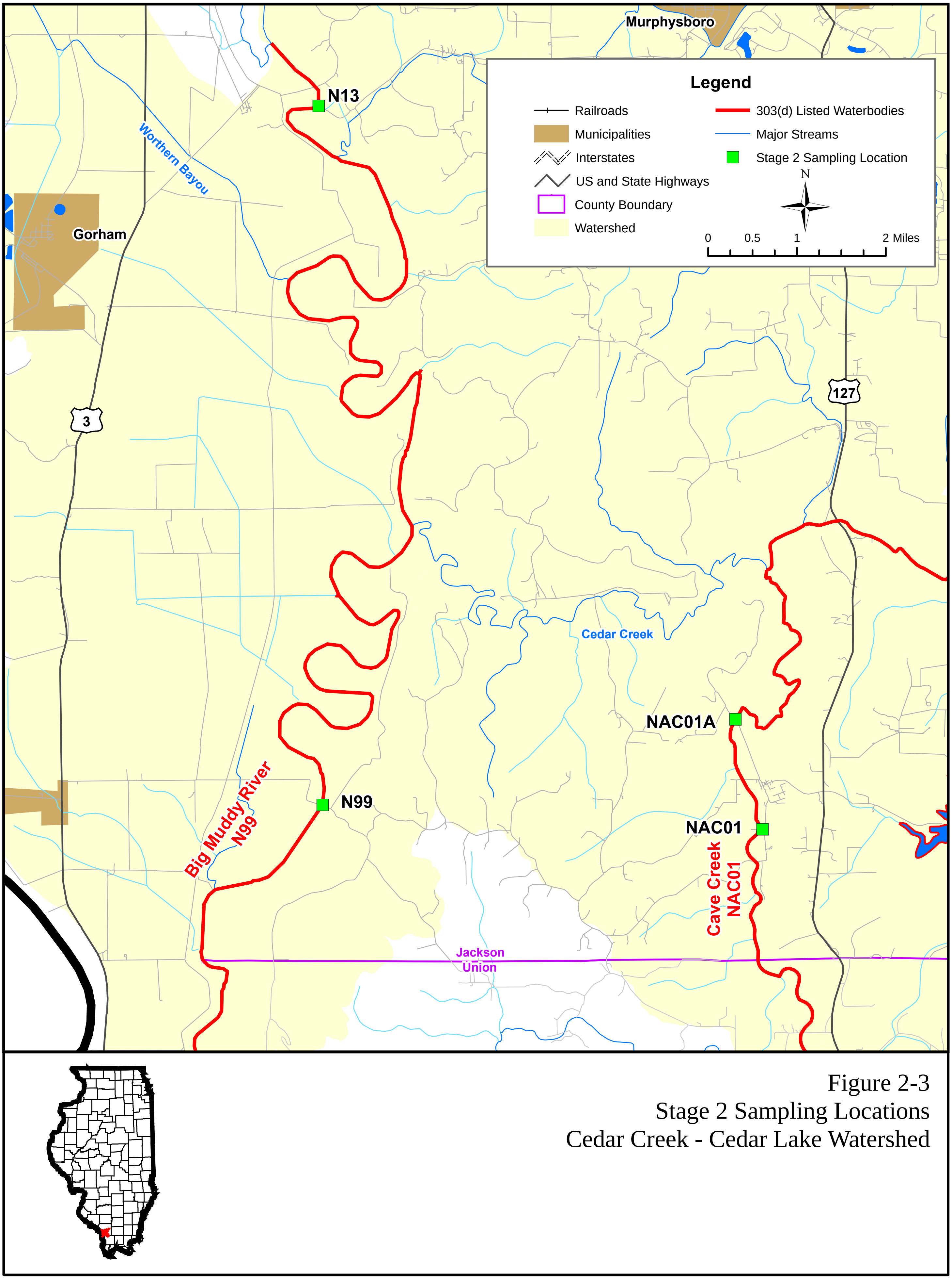

Figure 2-3
Stage 2 Sampling Locations
Cedar Creek - Cedar Lake Watershed

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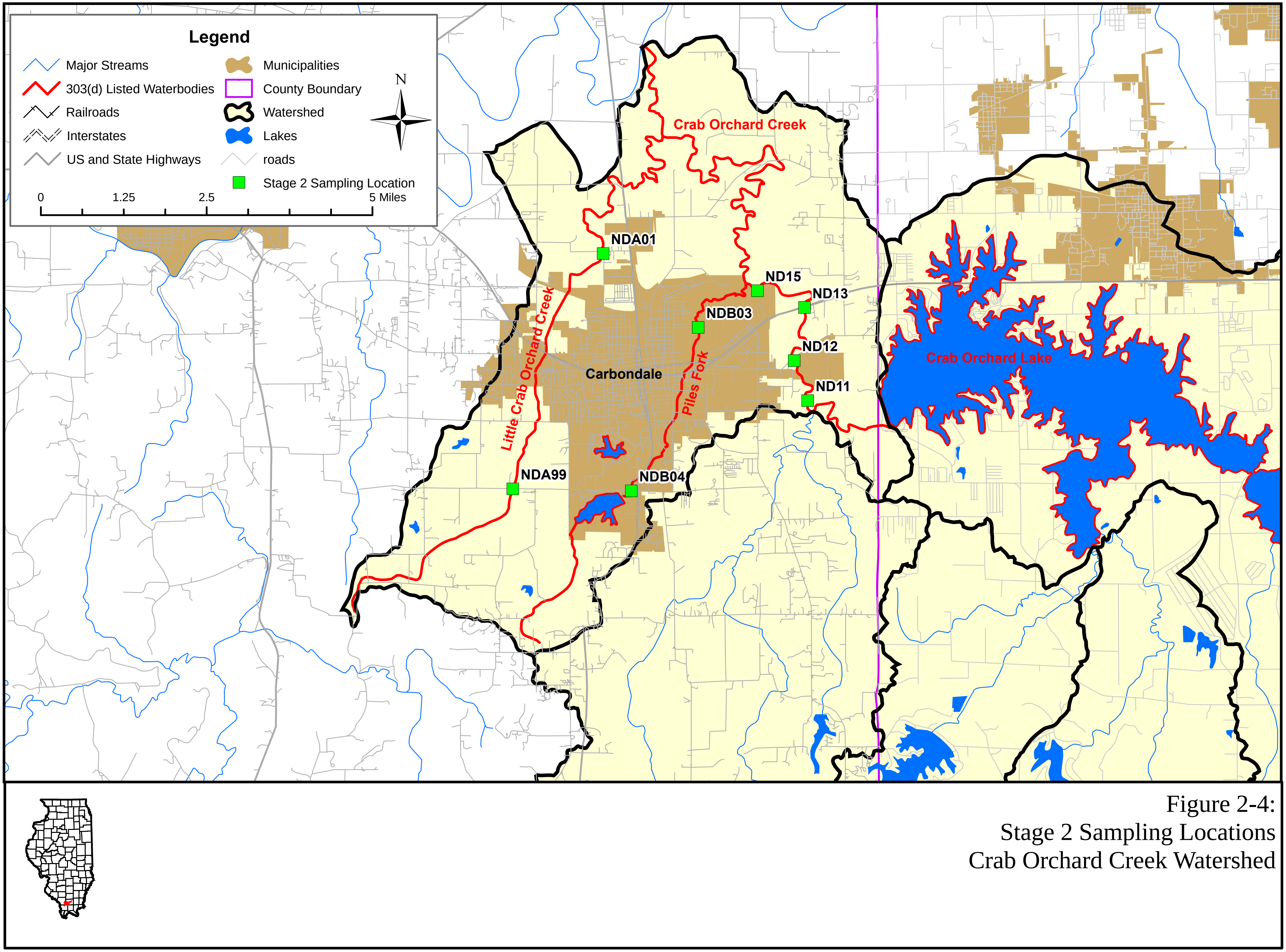

Figure 2-4:
Stage 2 Sampling Locations
Crab Orchard Creek Watershed

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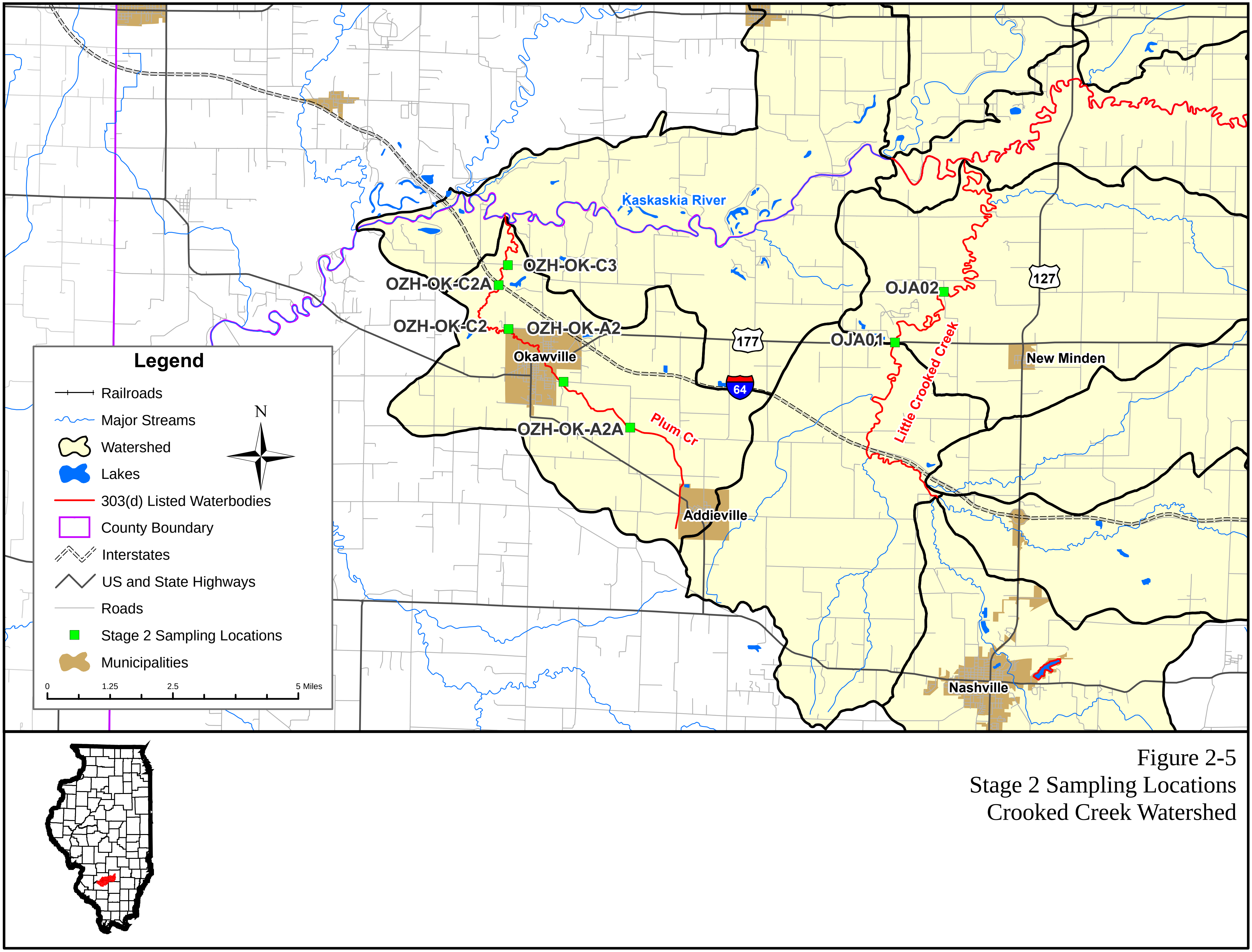

Figure 2-5
Stage 2 Sampling Locations
Crooked Creek Watershed

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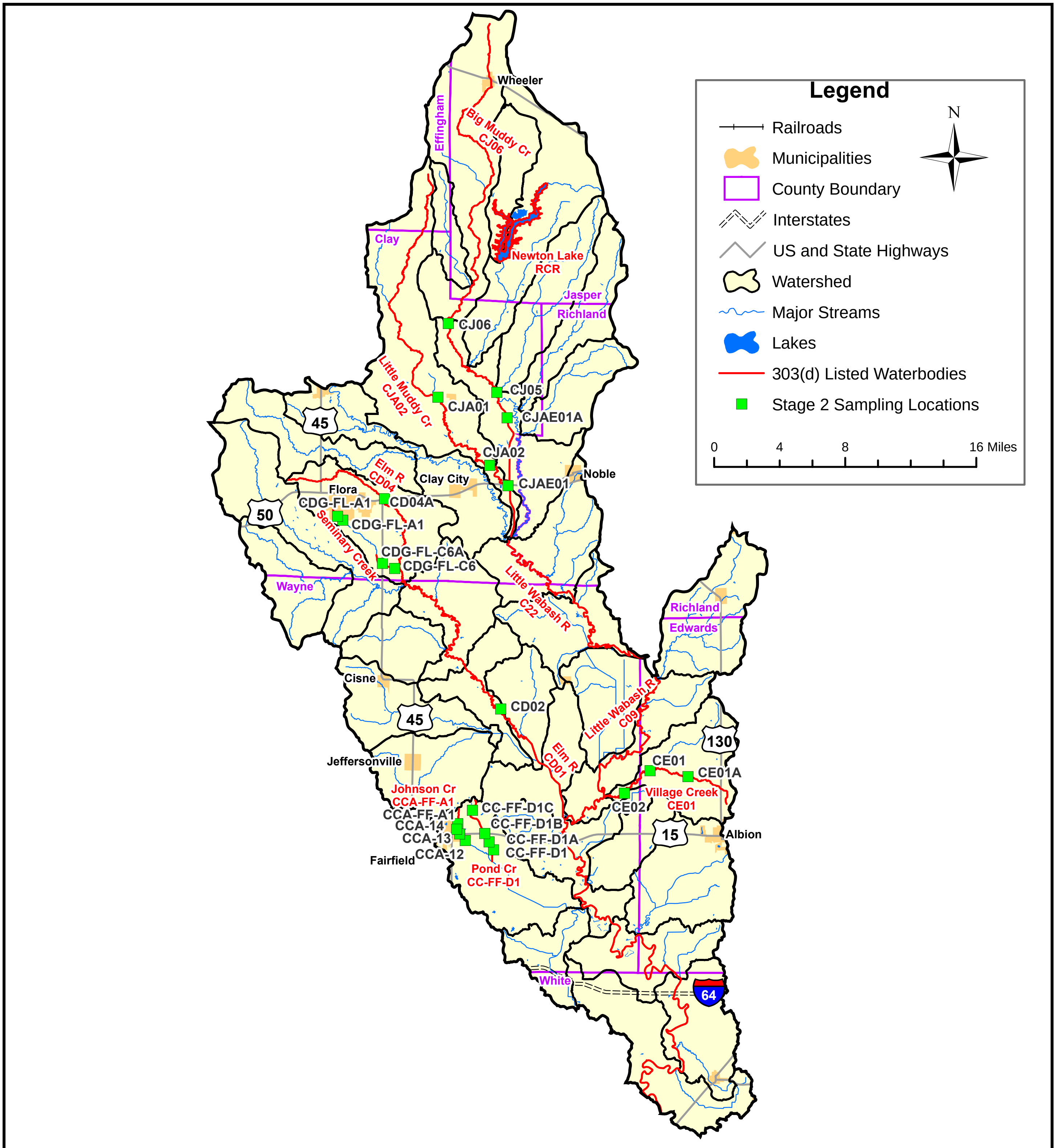

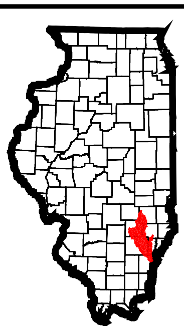

Figure 2-6:
Stage 2 Sampling Locations
Little Wabsash River Watershed

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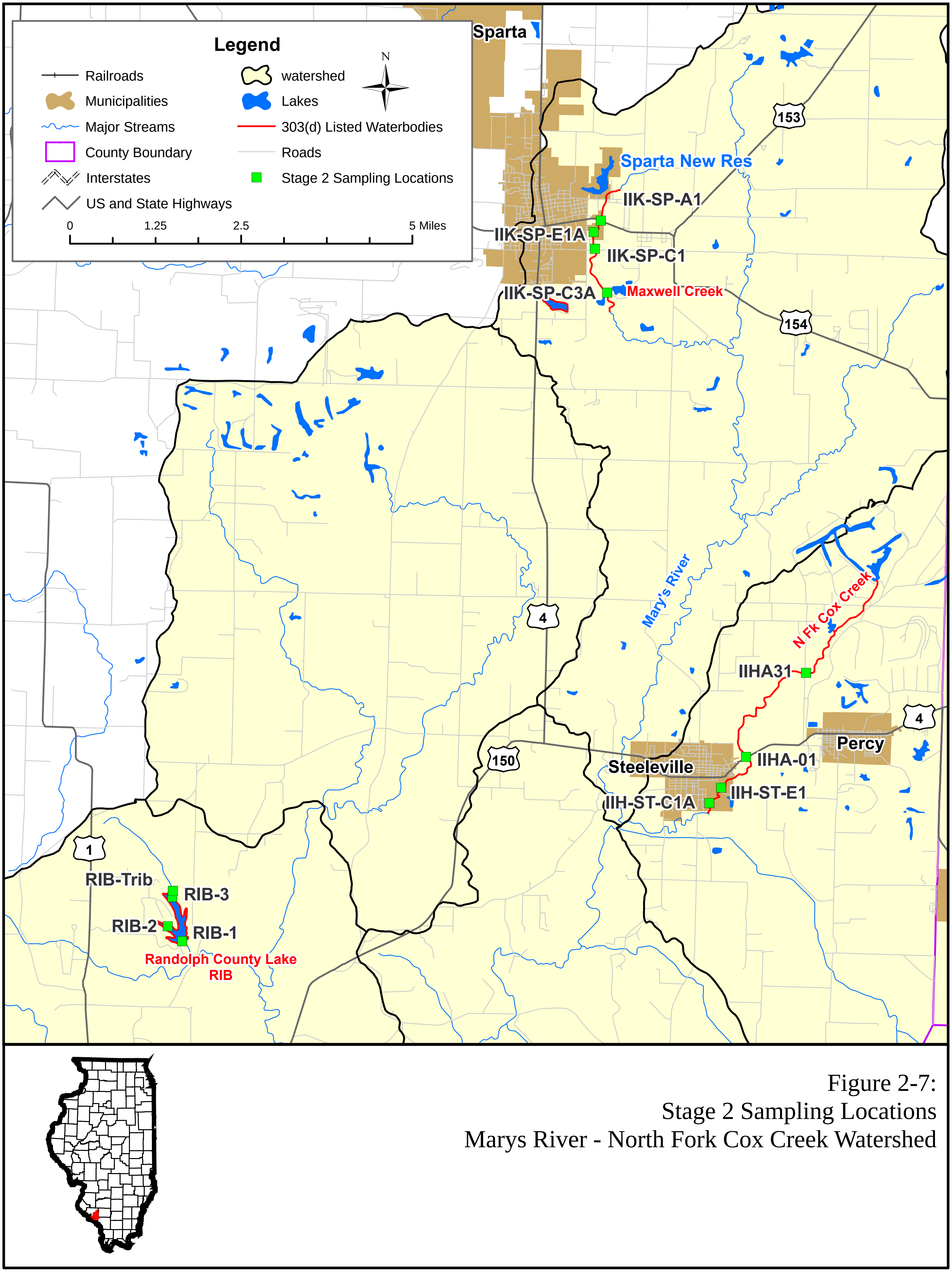

Figure 2-7:
Stage 2 Sampling Locations
Marys River - North Fork Cox Creek Watershed

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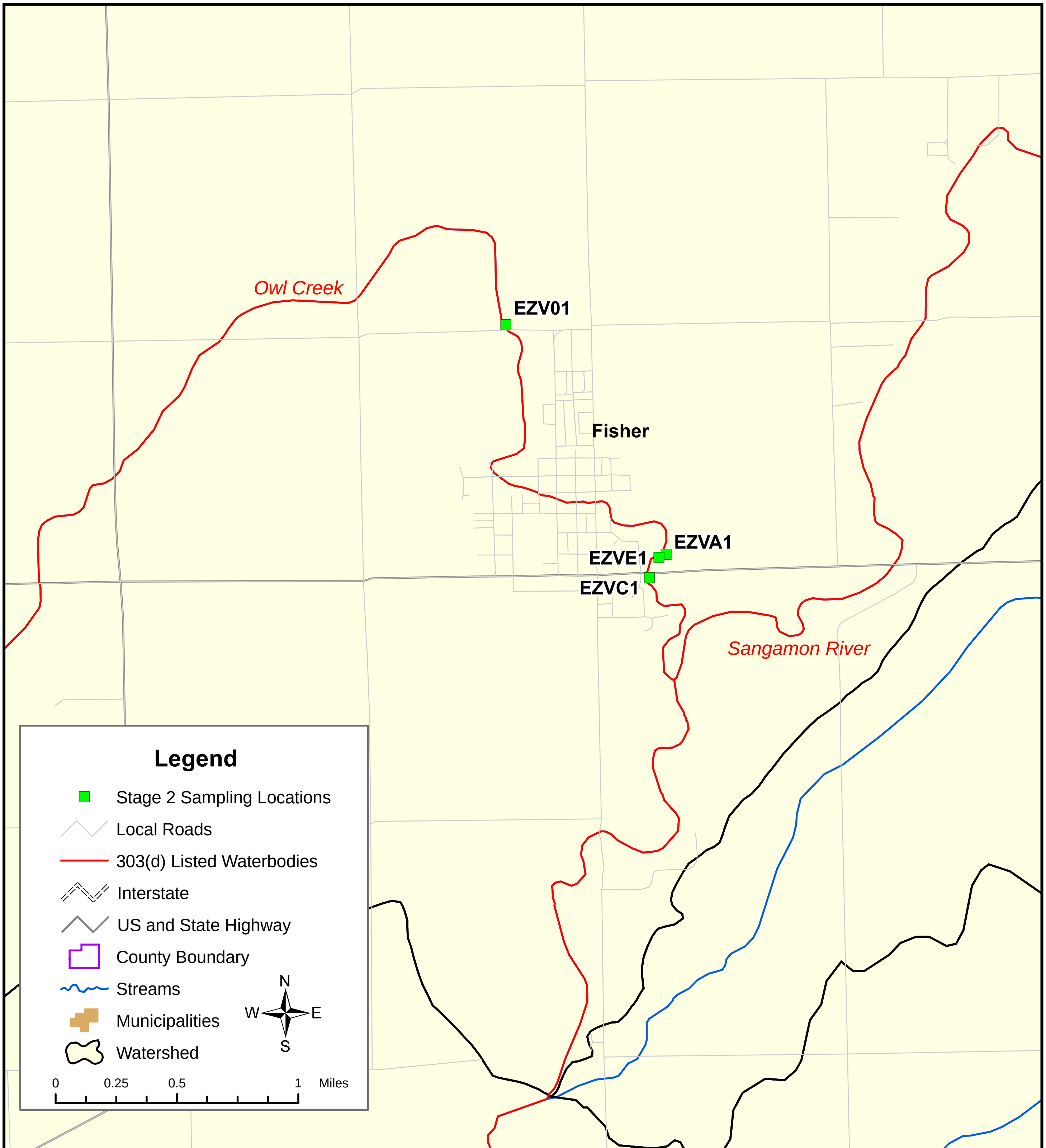

Figure 2-8:
Stage 2 Sampling Locations
Sangamon River - Lake Decatur Watershed

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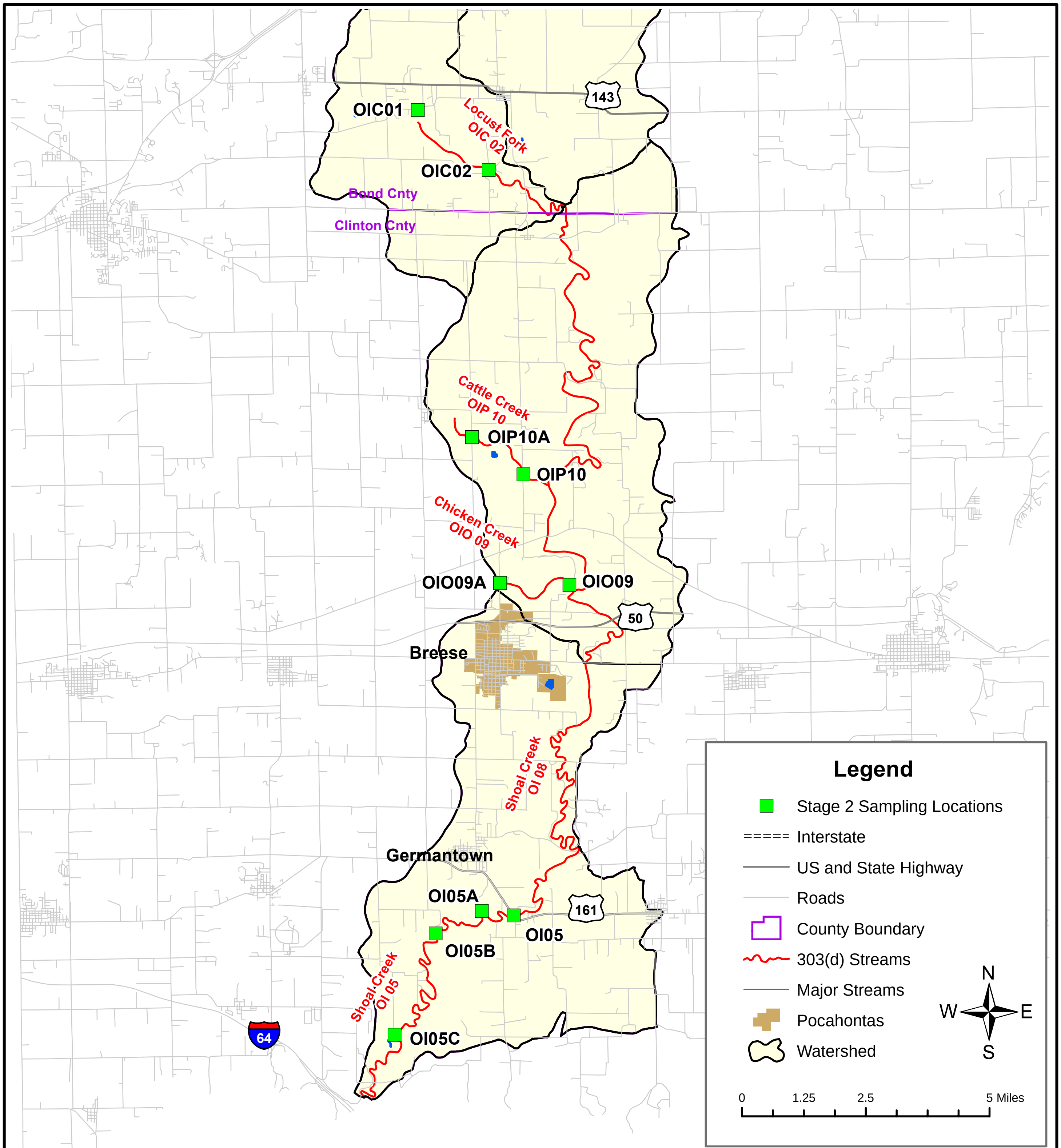

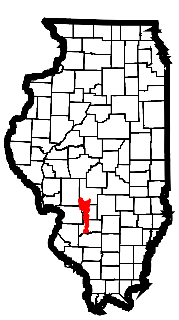

Figure 2-9:
Stage 2 Sampling Locations
Shoal Creek Watershed

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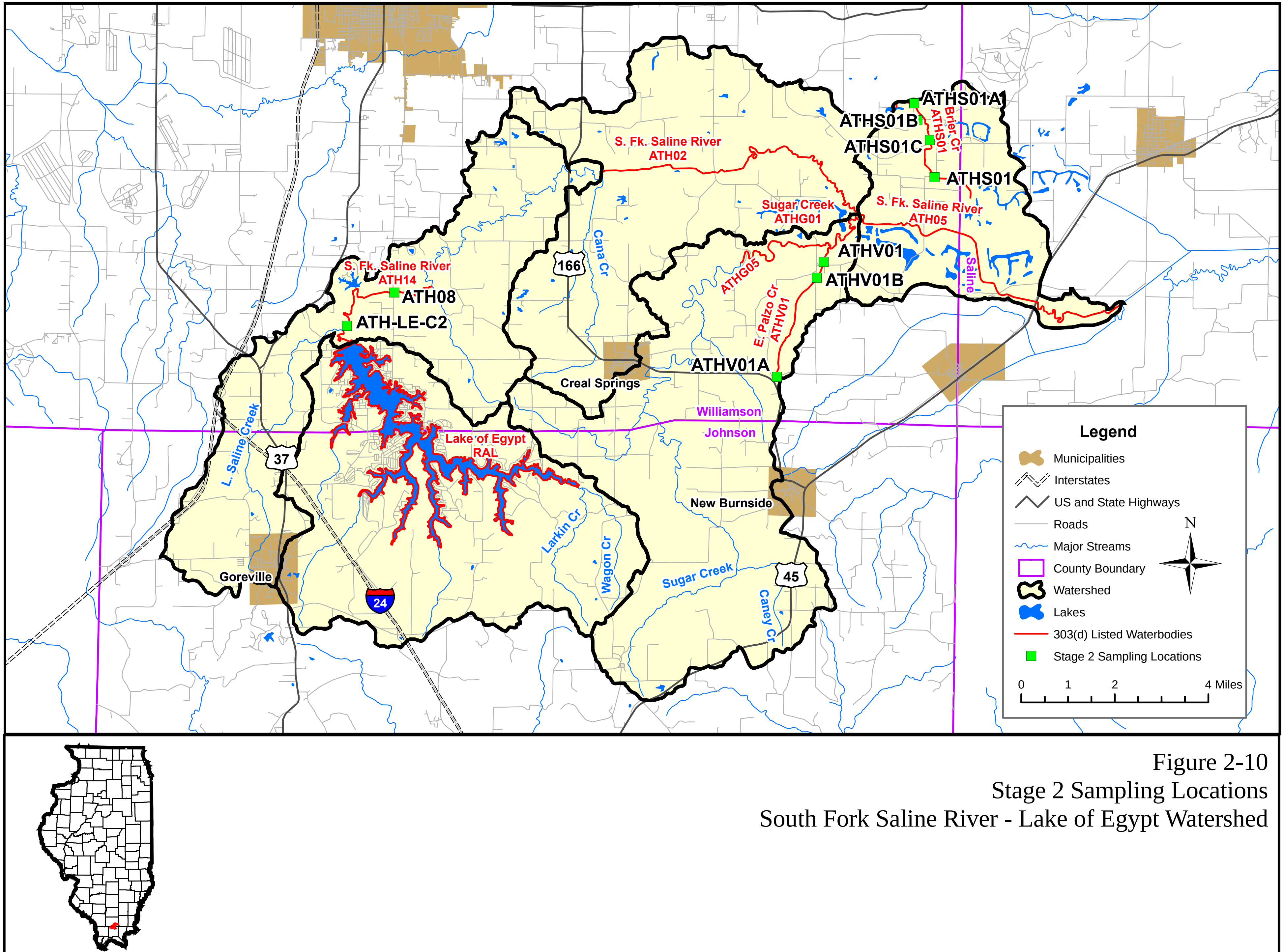

Figure 2-10
Stage 2 Sampling Locations
South Fork Saline River - Lake of Egypt Watershed

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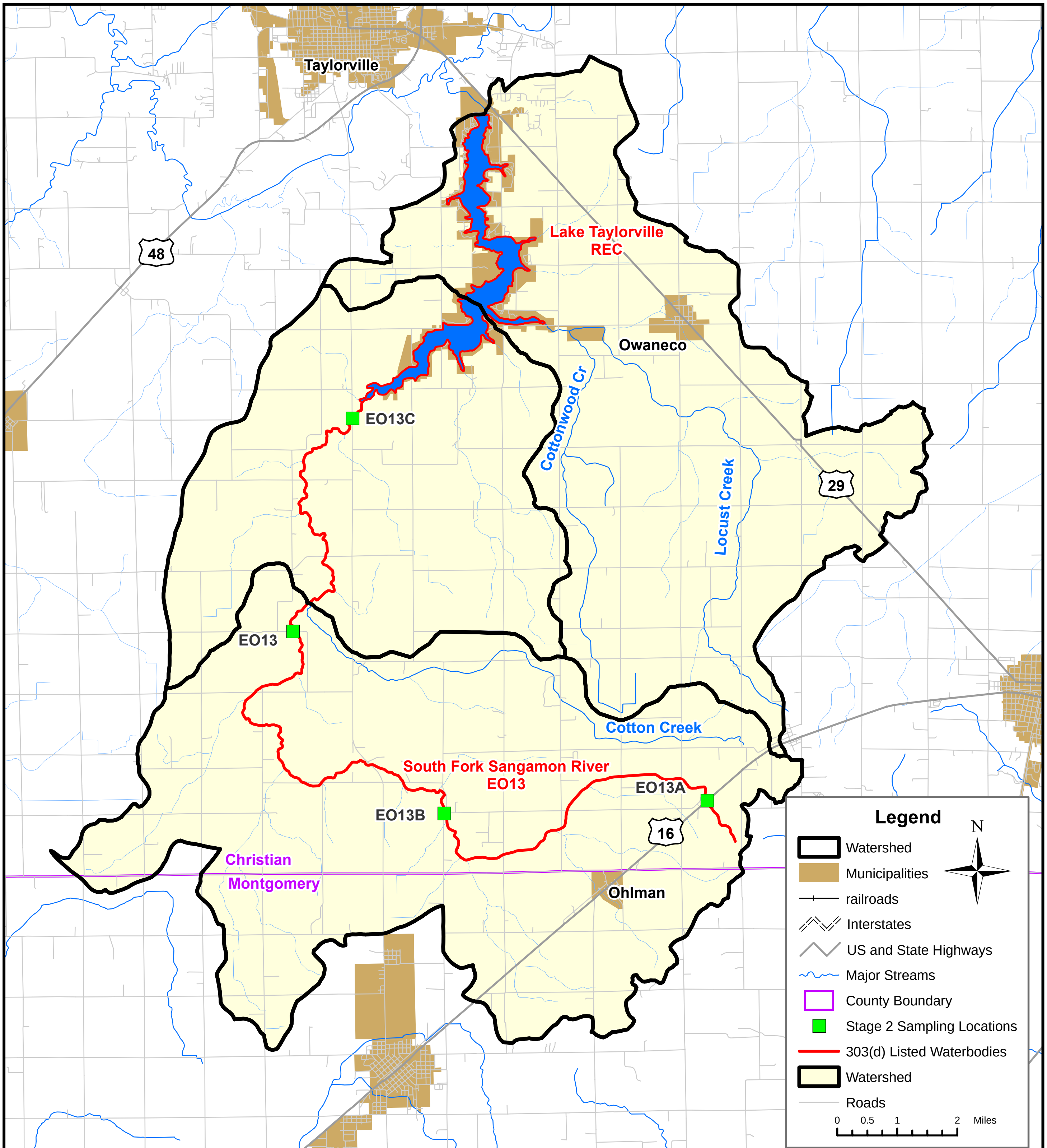

Figure 2-11:
Stage 2 Sampling Locations
South Fork Sangamon River - Lake Taylorville Watershed

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Table 2-2: Field Measurements

Watershed	Water body	Sample Site	Latitude	Longitude	Date	Time	pH (s.u.)	Conductivity (uS/cm)	Turbidity (NTU)	DO (mg/l)	Temp. °C	Depth (ft)
Bay Creek	Cedar Creek	AJF16	37.4661	88.7508	9/25/2006	18:00	6.5	117.0	7.8	8.9	63.9	NA
	Cedar Creek	AJF16	37.4661	88.7508	11/3/2006	11:05	7.2	164.5	8.6	11.0	7.0	NA
	Cedar Creek	AJF16A	37.4954	88.7592	9/25/2006	18:15	6.6	81.0	15.6	9.4	64.0	NA
	Cedar Creek	AJF16A	37.4954	88.7592	11/2/2006	13:30	7.3	101.8	5.4	11.6	9.2	NA
	Bay Creek Ditch	AJK01	37.3245	88.6337	9/25/2006	15:58	6.3	74.0	17.2	5.6	66.6	NA
	Bay Creek Ditch	AJK01	37.3245	88.6337	10/31/2006	8:15	7.2	91.6	20.4	8.2	12.8	NA
	Bay Creek Ditch	AJK01A	37.3282	88.6747	9/25/2006	NOT SAMPLED *Site flooded over banks into surrounding fields with no access/alternate site not located*						NA
	Bay Creek Ditch	AJK01A	37.3282	88.6747	10/31/2006	8:45	7.1	91.1	44.5	6.1	13.2	NA
Cahokia Creek/Holiday Shores Lake	Cahokia Diversion Ditch	JQ01	38.8054	90.1023	8/31/2006	13:40	7.4	606.7	62.3	3.4	23.9	NA
	Cahokia Diversion Ditch	JQ01	38.8054	90.1023	10/17/2006	14:45	8.3	459.8	92.9	9.6	12.6	NA
	Cahokia Diversion Ditch	JQ07	38.8050	90.0673	8/31/2006	14:45	7.4	498.6	68.0	5.3	23.0	NA
	Cahokia Diversion Ditch	JQ07	38.8050	90.0673	10/17/2006	14:15	8.3	427.0	115.8	9.4	12.8	NA
Cedar Creek	Big Muddy River	N13	37.7392	89.4284	9/7/2006	11:15	7.6	646.1	45.5	8.1	29.9	NA
	Big Muddy River	N13	37.7392	89.4284	11/1/2006	10:45	7.1	319.1	258.5	8.2	11.2	NA
	Big Muddy River	N99	37.6252	89.4284	9/7/2006	12:15	7.7	749.5	40.2	10.1	23.6	NA
	Big Muddy River	N99	37.6252	89.4284	11/1/2006	9:45	7.4	333.4	188.4	7.8	11.5	NA
	Cave Creek	NAC01	37.6154	89.3395	9/11/2006	11:45	7.8	288.4	N/A	7.6	20.4	NA
	Cave Creek	NAC01	37.6154	89.3395	11/1/2006	11:45	7.8	213.2	24.0	10.6	9.8	NA
	Cave Creek	NAC01A	37.6380	89.5660	9/11/2006	11:15	7.5	330.3	N/A	4.9	20.5	NA
	Cave Creek	NAC01A	37.6380	89.5660	11/1/2006	12:15	7.7	227.7	20.6	10.1	10.2	NA
Crab Orchard Creek	Crab Orchard Creek	ND11	37.7198	89.1717	9/6/2006	12:15	7.3	385.9	N/A	5.2	20.1	NA
	Crab Orchard Creek	ND11	37.7198	89.1717	11/1/2006	14:00	7.7	229.6	26.7	10.1	11.7	NA
	Crab Orchard Creek	ND12	37.7286	89.1753	9/6/2006	13:15	7.3	502.7	N/A	6.4	24.2	NA
	Crab Orchard Creek	ND12	37.7286	89.1753	11/1/2006	15:00	7.7	233.4	52.2	10.4	11.7	NA
	Crab Orchard Creek	ND13	37.7402	89.1723	9/6/2006	15:00	7.4	494.1	N/A	6.0	22.2	NA
	Crab Orchard Creek	ND13	37.7402	89.1723	11/1/2006	15:45	7.3	234.7	19.0	11.1	11.8	NA
	Crab Orchard Creek	ND15	37.7440	89.1852	9/6/2006	16:30	7.0	470.0	N/A	6.8	22.4	NA
	Crab Orchard Creek	ND15	37.7440	89.1852	11/1/2006	NOT SAMPLED *Site located behind Walmart parking lot and not accessible due to large chain link fence/no available alternate sites*						NA
	Little Crab Orchard Creek	NDA01	37.7525	89.2276	9/6/2006	18:00	7.3	242.5	N/A	2.1	19.2	NA
	Little Crab Orchard Creek	NDA01	37.7525	89.2276	11/2/2006	8:30	7.0	225.5	30.4	8.2	6.3	NA
	Little Crab Orchard Creek	NDA99	37.7011	89.2531	9/9/2006	NOT SAMPLED *Site dry and road crossings in the vacinity of site were also dry*						NA
	Little Crab Orchard Creek	NDA99	37.7011	89.2531	11/2/2006	10:30	8.7	190.5	17.0	12.3	5.5	NA
	Piles Fork	NDB03	37.7361	89.2016	9/7/2006	10:00	7.3	404.0	7.4	1.6	18.5	NA
	Piles Fork	NDB03	37.7361	89.2016	11/2/2006	9:15	7.7	240.7	25.5	10.3	7.3	NA
	Piles Fork	NDB04	37.7004	89.2205	9/9/2006	7:40	7.7	753.7	7.8	3.6	17.6	NA
	Piles Fork	NDB04	37.7004	89.2205	11/2/2006	11:00	8.1	154.9	56.5	11.5	10.2	NA
Crooked Creek	Little Crooked Creek	OJA-01	38.4416	89.4170	9/7/2006	17:45	7.0	274.0	22.5	3.7	20.3	NA
	Little Crooked Creek	OJA-01	38.4416	89.4170	10/19/2006	14:05	7.5	335.4	84.1	4.7	12.0	NA
	Little Crooked Creek	OJA-02	38.4564	89.3992	9/8/2006	11:15	7.0	284.8	20.2	3.1	19.7	NA
	Little Crooked Creek	OJA-02	38.4564	89.3992	10/19/2006	14:35	7.3	332.5	48.1	3.8	12.4	NA
	Plum Creek	OZH-OK-A2	38.4290	89.5387	9/8/2006	14:00	7.9	663.3	10.4	6.8	23.9	NA
	Plum Creek	OZH-OK-A2	38.4290	89.5387	10/19/2006	10:50	7.6	390.6	51.8	5.3	11.2	NA
	Plum Creek	OZH-OK-A2A	38.4160	89.5140	9/8/2006	16:45	7.8	503.2	56.9	8.5	22.3	NA
	Plum Creek	OZH-OK-A2A	38.4160	89.5140	10/19/2006	11:20	7.8	341.6	74.7	9.0	9.8	NA
	Plum Creek	OZH-OK-C2	38.4441	89.5592	9/8/2006	12:45	7.3	367.1	11.2	1.1	18.8	NA
	Plum Creek	OZH-OK-C2	38.4441	89.5592	10/19/2006	10:15	7.4	361.7	66.4	2.5	12.0	NA
	Plum Creek	OZH-OK-C2A	38.4568	89.5630	9/8/2006	17:30	7.8	977.9	13.4	4.6	20.7	NA
	Plum Creek	OZH-OK-C2A	38.4568	89.5630	10/19/2006	13:40	7.7	433.1	48.8	3.2	11.5	NA
	Plum Creek	OZH-OK-C3	38.4626	89.5598	9/8/2006	15:00	7.7	983.2	38.5	4.1	21.2	NA
	Plum Creek	OZH-OK-C3	38.4626	89.5598	10/19/2006	9:35	7.5	384.1	556.5	5.2	11.7	NA

Table 2-2: Field Measurements

Watershed	Water body	Sample Site	Latitude	Longitude	Date	Time	pH (s.u.)	Conductivity (uS/cm)	Turbidity (NTU)	DO (mg/l)	Temp. °C	Depth (ft)
Little Wabash	Little Wabash River	C09	38.4407	88.2581	1/25/2005	14:00	7.3	415	42	12.1	1.1	NA
	Little Wabash River	C09	38.4407	88.2581	3/17/2005	8:00	8.3	700	23	14.9	7	NA
	Little Wabash River	C09	38.4407	88.2581	4/19/2005	14:30	7.8	535	50	7.3	18.8	NA
	Little Wabash River	C09	38.4407	88.2581	5/9/2005	10:30	7.3	738	60	6.7	19.7	NA
	Little Wabash River	C09	38.4407	88.2581	6/23/2005	7:30	7.7	690	47	5.1	26	NA
	Little Wabash River	C09	38.4407	88.2581	8/23/2005	13:00	7.2	290	70	4.2	27.1	NA
	Little Wabash River	C09	38.4407	88.2581	9/27/2005	16:00	7.8	533	25	7.5	24.6	NA
	Little Wabash River	C09	38.4407	88.2581	10/27/2005	14:00	7.8	550	11	8.7	11.7	NA
	Little Wabash River	C09	38.4407	88.2581	12/6/2005	13:00	7.6	375	70	11.8	1.6	NA
	Little Wabash River	C09	38.4407	88.2581	2/1/2006	13:00	7.6	390	200	9.3	6.8	NA
	Little Wabash River	C09	38.4407	88.2581	3/15/2006	10:00	6.6	150	130	6.2	12.4	NA
	Little Wabash River	C09	38.4407	88.2581	4/18/2006	16:00	7.9	572	40	8.1	20.1	NA
	Little Wabash River	C09	38.4407	88.2581	4/26/2006	10:00	7.8	580	59	7.2	17.7	NA
	Little Wabash River	C09	38.4407	88.2581	5/1/2006	9:45	7.5	543	75	6.4	16.2	NA
	Little Wabash River	C09	38.4407	88.2581	5/10/2006	10:00	7.4	475		6.2	18.5	NA
	Little Wabash River	C09	38.4407	88.2581	5/17/2006	11:00	7.4	421	70	7.4	14.7	NA
	Little Wabash River	C09	38.4407	88.2581	5/24/2006	9:45	7.5	473		6.6	18.9	NA
	Little Wabash River	C09	38.4407	88.2581	5/31/2006	10:20	7.2	352		4	25.3	NA
	Little Wabash River	C09	38.4407	88.2581	6/7/2006	10:15	7.2	345		4.3	23.3	NA
	Little Wabash River	C09	38.4407	88.2581	6/15/2006	8:50	7.4	536	55	5.2	23.9	NA
	Little Wabash River	C09	38.4407	88.2581	6/22/2006	10:05	7.5	608	65	4.4	28.4	NA
	Little Wabash River	C09	38.4407	88.2581	6/27/2006	10:40	7.44	462	64	4.9	24.17	NA
	Little Wabash River	C09	38.4407	88.2581	7/5/2006	10:30	7.2	321		4.4	27.5	NA
	Little Wabash River	C09	38.4407	88.2581	7/12/2006	10:30	7.3	456		3.8	25.3	NA
	Little Wabash River	C09	38.4407	88.2581	7/20/2006	10:00	7.4	372		4.8	29.4	NA
	Little Wabash River	C09	38.4407	88.2581	7/27/2006	10:00	7.2	239		4.8	26.4	NA
	Little Wabash River	C09	38.4407	88.2581	8/1/2006	8:30	7.3	306	65	4.5	30.3	NA
	Little Wabash River	C09	38.4407	88.2581	8/8/2006	11:05	7.3	392	55	4.75	28.4	NA
	Little Wabash River	C33	38.2699	88.1377	4/18/2006	11:00	7.1	418	35	4.4	19.8	NA
	Little Wabash River	C33	38.2699	88.1377	4/26/2006	12:15	7.7	607	56	6	19	NA
	Little Wabash River	C33	38.2699	88.1377	5/1/2006	11:45	7.7	597	58	6.8	16.8	NA
	Little Wabash River	C33	38.2699	88.1377	5/10/2006	12:20	7.3	409		5.3	18.7	NA
	Little Wabash River	C33	38.2699	88.1377	5/17/2006	14:00	7.4	462	90	7.2	15.5	NA
	Little Wabash River	C33	38.2699	88.1377	5/24/2006	12:15	7.4	494		6.4	19.9	NA
	Little Wabash River	C33	38.2699	88.1377	5/31/2006	12:40	7.2	449		3.9	25.4	NA
	Little Wabash River	C33	38.2699	88.1377	6/7/2006	12:30	6.8	286		3	23.01	NA
	Little Wabash River	C33	38.2699	88.1377	6/15/2006	11:05	7.5	511	45	8.1	25.1	NA
	Little Wabash River	C33	38.2699	88.1377	6/22/2006	12:00	7.2	546	38	3	29.8	NA
	Little Wabash River	C33	38.2699	88.1377	6/27/2006	11:50	7.4	548	61	4.8	26.17	NA
	Little Wabash River	C33	38.2699	88.1377	7/5/2006	13:00	7.3	334		5.8	29	NA
	Little Wabash River	C33	38.2699	88.1377	7/12/2006	12:30	7.1	326		3.4	25.3	NA
	Little Wabash River	C33	38.2699	88.1377	7/20/2006	12:20	6.9	247		3.4	29.9	NA
	Little Wabash River	C33	38.2699	88.1377	7/27/2006	12:10	7.5	308		6.4	27.4	NA
	Little Wabash River	C33	38.2699	88.1377	8/1/2006	10:30	7.3	296	40	4.7	30.8	NA
	Little Wabash River	C33	38.2699	88.1377	8/8/2006	13:30	7.3	361	40	4.9	29.8	NA
	Johnson Creek	CCA12	38.3732	88.3449	9/9/2006	13:05	8.2	1402.0	13.4	14.2	28.4	NA
	Johnson Creek	CCA12	38.3732	88.3449	11/14/2006	9:45	7.5	651.4	645.5	7.7	7.0	NA
	Johnson Creek	CCA13	38.3789	88.3511	9/9/2006	14:30	8.6	1517.0	3.1	14.9	25.4	NA
	Johnson Creek	CCA13	38.3789	88.3511	11/14/2006	10:15	7.7	649.4	19.0	12.8	8.1	NA
	Johnson Creek	CCA14A	38.3830	88.3546	9/9/2006	15:25	7.6	836.0	3.6	5.7	21.6	NA

Table 2-2: Field Measurements

Watershed	Water body	Sample Site	Latitude	Longitude	Date	Time	pH (s.u.)	Conductivity (uS/cm)	Turbidity (NTU)	DO (mg/l)	Temp. °C	Depth (ft)
Little Wabash (cont.)	Johnson Creek	CCA14A	38.3830	88.3546	11/14/2006	10:25	7.7	694.2	2.4	12.5	8.0	NA
	Johnson Creek	CCAFFA1A	38.3881	88.3535	9/10/2006	10:50	7.4	788.0	5.9	3.8	19.8	NA
	Johnson Creek	CCAFFA1A	38.3881	88.3535	11/14/2006	10:45	7.4	789.8	4.3	12.3	7.5	NA
	Pond Creek	CCFFD1	38.3648	88.3130	9/9/2006	10:30	7.7	576.0	8.6	7.1	19.5	NA
	Pond Creek	CCFFD1	38.3648	88.3130	10/31/2006	10:10	7.6	8719.7	29.2	8.2	3.8	NA
	Pond Creek	CCFFD1A	38.3720	88.3181	9/9/2006	NOT SAMPLED *Site Dry/no available alternate sites*						NA
	Pond Creek	CCFFD1A	38.3720	88.3181	11/9/2006	12:15	7.3	742.5	9.1	11.2	13.6	NA
	Pond Creek	CCFFD1B	38.3793	88.3230	9/9/2006	11:45	7.5	784.0	10.0	8.6	22.9	NA
	Pond Creek	CCFFD1B	38.3793	88.3230	11/9/2006	11:35	7.3	827.9	4.1	12.1	12.7	NA
	Pond Creek	CCFFD1C	38.3999	88.3370	9/10/2006	12:10	8.0	3941.0	17.8	11.9	19.3	NA
	Pond Creek	CCFFD1C	38.3999	88.3370	10/31/2006	11:20	8.8	1394.0		14.4	4.4	NA
	Elm River	CD01	38.5184	88.1320	1/26/2005	13:00	7.1	388	36	9.1	1.4	NA
	Elm River	CD01	38.5184	88.1320	3/15/2005	11:30	8.4	950	7.2	14.6	6.2	NA
	Elm River	CD01	38.5184	88.1320	4/20/2005	11:30	7.4	670	60	6.7	20.1	NA
	Elm River	CD01	38.5184	88.1320	5/5/2005	13:00	7.5	625	27	7.6	13.8	NA
	Elm River	CD01	38.5184	88.1320	6/23/2005	10:00	7.5	1050	22	5.2	24.7	NA
	Elm River	CD01	38.5184	88.1320	8/18/2005	11:00	7.6	730	34	3.6	24.6	NA
	Elm River	CD01	38.5184	88.1320	9/29/2005	11:30	7.6	700	17	3.6	18.5	NA
	Elm River	CD01	38.5184	88.1320	10/18/2005	11:30	7.5	680	8.2	5.9	15	NA
	Elm River	CD01	38.5184	88.1320	12/8/2005	10:30	7.4	321	65	9.6	0.3	NA
	Elm River	CD01	38.5184	88.1320	2/1/2006	15:00	7.5	430	80	9.1	7	NA
	Elm River	CD01	38.5184	88.1320	3/1/2006	13:30	7.4	840	42	10.2	9.1	NA
	Elm River	CD01	38.5184	88.1320	4/6/2006	11:00	7.3	440	90	8.6	13.5	NA
	Elm River	CD01	38.5184	88.1320	4/18/2006	14:30	7.3	670	40	5.6	20.9	NA
	Elm River	CD01	38.5184	88.1320	4/26/2006	11:15	7.5	860		6.2	15.9	NA
	Elm River	CD01	38.5184	88.1320	5/1/2006	11:00	7.4	958		5.9	15.2	NA
	Elm River	CD01	38.5184	88.1320	5/10/2006	11:10	7.2	489		5	18.2	NA
	Elm River	CD01	38.5184	88.1320	5/17/2006	9:30	7.1	484	35	7	13.8	NA
	Elm River	CD01	38.5184	88.1320	5/24/2006	11:20	7.2	594		5.7	18.5	NA
	Elm River	CD01	38.5184	88.1320	5/31/2006	11:30	7.2	605		3.8	25.7	NA
	Elm River	CD01	38.5184	88.1320	6/7/2006	11:25	7	346		4.5	23.4	NA
	Elm River	CD01	38.5184	88.1320	6/15/2006	9:50	7.1	622		4.6	22.5	NA
	Elm River	CD01	38.5184	88.1320	6/22/2006	11:15	7.1	443		4.6	27.9	NA
	Elm River	CD01	38.5184	88.1320	6/27/2006	9:15	6.77	229	91	5	21.95	NA
	Elm River	CD01	38.5184	88.1320	7/5/2006	11:50	7.2	588		3.6	26.6	NA
	Elm River	CD01	38.5184	88.1320	7/12/2006	11:30	7.2	569		4.2	23.9	NA
	Elm River	CD01	38.5184	88.1320	7/20/2006	11:15	7	285		2.8	28.2	NA
	Elm River	CD01	38.5184	88.1320	7/27/2006	11:05	7.1	346		3.5	25.8	NA
	Elm River	CD01	38.5184	88.1320	8/1/2006	9:20	7.3	382		4	27.8	NA
	Elm River	CD01	38.5184	88.1320	8/8/2006	12:20	7.1	425		4.1	26.3	NA
	Elm River	CD02	38.6751	88.4362	9/8/2006	17:45	7.5	344.0	15.9	8.1	23.2	NA
	Elm River	CD02	38.6751	88.4362	11/8/2006	NOT SAMPLED *Miscommunication between field crews caused error in sampling*						NA
	Elm River	CD02A	38.4894	88.3051	9/12/2006	12:51	7.2	404.0	15.7	3.8	22.0	NA
	Elm River	CD02A	38.4894	88.3051	11/8/2006	NOT SAMPLED *Miscommunication between field crews caused error in sampling*						NA
	Seminary Creek	CDFGLC6	38.6180	88.4384	9/8/2006	12:25	7.7	708.0	4.2	6.6	19.5	NA
	Seminary Creek	CDFGLC6	38.6180	88.4384	11/8/2006	17:00	7.5	527.6	17.5	10.5	12.4	NA
	Seminary Creek	CDFGLC6A	38.6135	88.4245	9/8/2006	11:10	7.7	720.0	201.2	7.0	20.1	NA
	Seminary Creek	CDFGLC6A	38.6135	88.4245	11/8/2006	16:45	7.3	561.7	15.1	12.0	13.5	NA
	Seminary Creek	CDGFLA1	38.6561	88.4832	9/8/2006	15:40	7.9	558.0	7.0	10.0	22.0	NA
	Seminary Creek	CDGFLA1	38.6561	88.4832	11/8/2006	14:45	7.3	385.0	12.5	14.3	12.7	NA

Table 2-2: Field Measurements

Watershed	Water body	Sample Site	Latitude	Longitude	Date	Time	pH (s.u.)	Conductivity (uS/cm)	Turbidity (NTU)	DO (mg/l)	Temp. °C	Depth (ft)
Little Wabash (cont.)	Seminary Creek	CDGFLA1A	38.6595	88.4890	9/8/2006	13:45	7.4	362.0	22.7	2.6	19.0	NA
	Seminary Creek	CDGFLA1A	38.6595	88.4890	11/8/2006	15:50	7.2	429.8	16.8	15.1	12.7	NA
	Village Creek	CE01	38.4348	88.1369	9/6/2006	17:30	8.1	610.0	11.4	9.9	24.9	NA
	Village Creek	CE01	38.4348	88.1369	11/14/2006	8:45	7.5	697.9	8.0	10.6	6.8	NA
	Village Creek	CE01A	38.4294	88.0943	9/12/2006	17:05	7.2	327.0	145.2	5.8	22.6	NA
	Village Creek	CE01A	38.4294	88.0943	11/9/2006	13:45	7.2	607.2	8.7	11.2	14.2	NA
	Village Creek	CE02	38.4150	88.1659	9/6/2006	15:20	7.8	568.0	15.7	7.9	25.0	NA
	Village Creek	CE02	38.4150	88.1659	11/9/2006	12:55	7.5	587.4	14.1	10.7	13.1	NA
	Big Muddy Creek	CJ05	38.7693	88.3093	9/7/2006	16:45	8.2	63.1	11.4	10.5	23.6	NA
	Big Muddy Creek	CJ05	38.7693	88.3093	11/8/2006	11:30	7.4	457.0	32.5	12.4	8.3	NA
	Big Muddy Creek	CJ06	38.8298	88.3642	9/7/2006	18:10	7.5	588.0	34.6	4.9	21.8	NA
	Big Muddy Creek	CJ06	38.8298	88.3642	11/8/2006	11:00	7.3	455.1	15.8	11.6	10.6	NA
	Little Muddy Creek	CJA01	38.7647	88.3760	9/12/2006	10:20	7.0	321.0	9.5	3.4	20.9	NA
	Little Muddy Creek	CJA01	38.7647	88.3760	11/13/2006	12:00	7.0	267.9	113.2	10.1	7.4	NA
	Little Muddy Creek	CJA02	38.7047	88.3174	9/7/2006	14:20	6.8	554.0	45.9	2.8	20.4	NA
	Little Muddy Creek	CJA02	38.7047	88.3174	11/8/2006	12:30	7.0	497.0	35.8	9.3	10.4	NA
	Big Muddy Diversion Ditch	CJAE01	38.6865	88.2967	9/7/2006	12:10	7.1	1946.0	26.9	9.1	22.2	NA
	Big Muddy Diversion Ditch	CJAE01	38.6865	88.2967	11/8/2006	13:05	7.3	478.2	30.8	10.8	11.7	NA
	Big Muddy Diversion Ditch	CJAE01A	38.7467	88.2977	9/7/2006	15:45	8.1	908.0	6.5	10.3	24.3	NA
	Big Muddy Diversion Ditch	CJAE01A	38.7467	88.2977	11/13/2006	12:30	7.6	452.9	37.8	9.8	8.2	NA
Mary's River/North Fork Cox Creek	North Fork Cox Creek	IIHA01	38.0114	89.6460	9/9/2006	17:40	7.9	2073.0	N/A	10.0	22.0	NA
	North Fork Cox Creek	IIHA01	38.0114	89.6460	10/18/2006	14:25	8.3	2995.0	13.5	8.1	15.4	NA
	North Fork Cox Creek	IIHA31	38.0293	89.6303	9/9/2006	17:10	8.2	3491.0	N/A	9.6	23.9	NA
	North Fork Cox Creek	IIHA31	38.0293	89.6303	10/18/2006	14:45	8.4	3215.0	8.5	8.6	15.5	NA
	North Fork Cox Creek	IIHA-STC1	38.0015	89.6557	9/9/2006	16:15	7.8	3019.0	N/A	7.1	21.9	NA
	North Fork Cox Creek	IIHA-STC1	38.0015	89.6557	10/18/2006	14:00	8.1	1990.0	20.0	7.0	14.9	NA
	North Fork Cox Creek	IIHA-STE1	38.0048	89.6526	9/9/2006	15:45	7.8	3422.0	N/A	6.9	20.7	NA
	North Fork Cox Creek	IIHA-STE1	38.0048	89.6526	10/18/2006	13:40	8.0	2505.0	16.3	6.0	14.7	NA
	Maxwell Creek	IIKSPA1	38.1242	89.6870	9/7/2006	NOT SAMPLED *Site dry during both visits/available alternate locations also dry*						NA
	Maxwell Creek	IIKSPA1	38.1242	89.6870	10/17/2006							NA
	Maxwell Creek	IIKSPC1	38.1182	89.6885	9/7/2006	15:30	7.3	968.1	4.8	2.0	24.3	NA
	Maxwell Creek	IIKSPC1	38.1182	89.6885	10/17/2006	8:20	7.1	561.5	22.3	20.2	18.4	NA
	Maxwell Creek	IIKSPC3A	38.1090	89.6850	9/7/2006	15:00	7.5	997.0	4.4	2.6	21.6	NA
	Maxwell Creek	IIKSPC3A	38.1090	89.6850	10/17/2006	8:45	7.5	457.8	19.2	6.5	15.4	NA
	Maxwell Creek	IIKSPE1A	38.1218	89.6889	9/7/2006	NOT SAMPLED *Site dry during both visits/available alternate locations also dry*						NA
	Maxwell Creek	IIKSPE1A	38.1218	89.6889	10/17/2006							NA
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:00	9.1	279.7	N/A	13.9	25.6	1
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:02	9.1	279.5	N/A	13.9	24.9	2
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:04	9.1	279.2	N/A	13.8	24.7	3
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:06	9.1	278.8	N/A	13.9	24.6	4
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:08	9.0	279.3	N/A	13.2	24.4	5
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:10	9.0	279.7	N/A	12.6	24.3	6
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:12	8.9	280.4	N/A	11.8	24.2	7
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:14	8.2	286.0	N/A	6.2	23.9	8
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:16	7.8	287.4	N/A	4.4	23.7	9
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:18	7.6	288.9	N/A	2.5	23.5	10
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:20	7.3	290.3	N/A	0.3	23.1	11
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:22	7.3	296.0	N/A	0.1	22.7	12
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:24	7.1	317.6	N/A	0.0	21.2	13
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:26	7.1	332.7	N/A	0.0	18.5	14
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:28	7.1	330.3	N/A	0.0	17.1	15

Table 2-2: Field Measurements

Watershed	Water body	Sample Site	Latitude	Longitude	Date	Time	pH (s.u.)	Conductivity (uS/cm)	Turbidity (NTU)	DO (mg/l)	Temp. °C	Depth (ft)
Mary's River/North Fork Cox Creek (cont.)	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:30	7.1	329.6	N/A	0.0	16.1	16
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:32	7.1	329.9	N/A	0.0	14.7	17
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:34	7.1	330.0	N/A	0.0	13.6	18
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:36	7.1	332.4	N/A	0.0	12.4	19
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:38	7.1	335.4	N/A	0.0	11.8	20
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:40	7.1	341.7	N/A	0.0	11.3	21
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:42	7.1	347.9	N/A	0.0	10.9	22
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:44	7.1	350.1	N/A	0.0	10.8	23
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:46	7.1	352.6	N/A	0.0	10.6	24
	Randolph County Lake	RIB-1	37.9707	89.7962	9/9/2006	12:48	7.0	363.8	N/A	0.0	10.2	25
	Randolph County Lake	RIB-1	37.9707	89.7962	10/18/2006	10:25	8.0	306.1	5.6	7.1	15.8	0
	Randolph County Lake	RIB-1	37.9707	89.7962	10/18/2006	10:25	7.8	305.0	6.7	5.4	15.7	3.28
	Randolph County Lake	RIB-1	37.9707	89.7962	10/18/2006	10:25	7.8	304.9	5.9	5.4	15.7	6.56
	Randolph County Lake	RIB-1	37.9707	89.7962	10/18/2006	10:25	7.8	303.6	6.6	5.3	15.6	9.84
	Randolph County Lake	RIB-1	37.9707	89.7962	10/18/2006	10:25	7.7	303.5	7.1	5.3	15.6	13.12
	Randolph County Lake	RIB-1	37.9707	89.7962	10/18/2006	10:25	7.6	304.0	11.9	4.5	13.3	16.4
	Randolph County Lake	RIB-1	37.9707	89.7962	10/18/2006	10:25	7.5	371.4	9.8	0.6	12.7	19.68
	Randolph County Lake	RIB-1	37.9707	89.7962	10/18/2006	10:25	7.6	392.9	8.3	0.5	10.9	22.96
	Randolph County Lake	RIB-1	37.9707	89.7962	10/18/2006	10:25	7.5	435.0	63.4	0.3	10.1	26.24
	Randolph County Lake	RIB-2	37.9738	89.8000	9/9/2006	14:00	9.0	286.4	N/A	13.3	27.0	1
	Randolph County Lake	RIB-2	37.9738	89.8000	9/9/2006	14:02	9.0	282.2	N/A	13.8	26.8	2
	Randolph County Lake	RIB-2	37.9738	89.8000	9/9/2006	14:04	9.1	279.7	N/A	14.7	25.0	3
	Randolph County Lake	RIB-2	37.9738	89.8000	9/9/2006	14:06	9.0	280.2	N/A	14.3	24.7	4
	Randolph County Lake	RIB-2	37.9738	89.8000	9/9/2006	14:08	8.9	282.2	N/A	12.5	24.4	5
	Randolph County Lake	RIB-2	37.9738	89.8000	9/9/2006	14:10	8.6	286.3	N/A	9.0	24.1	6
	Randolph County Lake	RIB-2	37.9738	89.8000	9/9/2006	14:12	8.1	290.2	N/A	6.0	24.0	7
	Randolph County Lake	RIB-2	37.9738	89.8000	9/9/2006	14:14	7.8	292.2	N/A	4.0	23.9	8
	Randolph County Lake	RIB-2	37.9738	89.8000	9/9/2006	14:16	7.7	292.7	N/A	3.1	23.8	9
	Randolph County Lake	RIB-2	37.9738	89.8000	10/18/2006	12:05	8.0	304.9	10.3	7.1	16.0	0
	Randolph County Lake	RIB-2	37.9738	89.8000	10/18/2006	12:05	7.9	304.5	7.0	6.7	15.9	3.28
	Randolph County Lake	RIB-2	37.9738	89.8000	10/18/2006	12:05	7.8	304.5	6.6	6.4	15.9	6.56
	Randolph County Lake	RIB-2	37.9738	89.8000	10/18/2006	12:05	7.8	304.5	6.3	6.3	15.8	9.84
	Randolph County Lake	RIB-3	37.9800	89.7990	9/9/2006	13:00	9.0	283.0	N/A	13.2	26.4	1
	Randolph County Lake	RIB-3	37.9800	89.7990	9/9/2006	13:02	9.0	283.3	N/A	12.9	26.5	2
	Randolph County Lake	RIB-3	37.9800	89.7990	9/9/2006	13:04	9.0	281.0	N/A	12.8	25.8	3
	Randolph County Lake	RIB-3	37.9800	89.7990	9/9/2006	13:06	9.0	280.4	N/A	12.9	25.0	4
	Randolph County Lake	RIB-3	37.9800	89.7990	9/9/2006	13:08	9.0	279.7	N/A	12.9	24.6	5
	Randolph County Lake	RIB-3	37.9800	89.7990	9/9/2006	13:10	9.0	279.7	N/A	12.6	24.5	6
	Randolph County Lake	RIB-3	37.9800	89.7990	10/18/2006	11:15	8.0	305.0	8.8	7.9	16.0	0
	Randolph County Lake	RIB-3	37.9800	89.7990	10/18/2006	11:15	7.9	304.7	8.7	7.1	16.0	3.28
	Randolph County Lake	RIB-3	37.9800	89.7990	10/18/2006	11:15	7.8	304.7	10.4	6.7	16.0	6.56
	Randolph County Lake Tributary	RIB-Trib	37.9813	89.7988	9/9/2006	13:20	9.0	284.0	N/A	12.9	28.4	NA
	Randolph County Lake Tributary	RIB-Trib	37.9813	89.7988	10/18/2006	11:45	8.1	341.7	46.3	8.3	16.2	NA
Sangamon River/Lake Decatur	Owl Creek	EZV01	40.3254	88.3531	8/30/2006	12:50	7.4	669.0	50.8	8.5	21.2	NA
	Owl Creek	EZV01	40.3254	88.3531	11/2/2006	9:25	8.2	856.7		12.2	5.1	NA
	Owl Creek	EZVA1	40.3115	88.3409	8/30/2006	11:05	7.7	606.9	52.3	6.5	19.0	NA
	Owl Creek	EZVA1	40.3115	88.3409	11/2/2006	10:33	8.2	856.3		11.8	4.7	NA
	Owl Creek	EZVC1	40.3101	88.3423	8/30/2006	10:25	7.3	1450.0	25.6	5.0	21.0	NA
	Owl Creek	EZVC1	40.3101	88.3423	11/2/2006	12:20	8.1	990.7		11.7	6.0	NA
	Owl Creek	EZVE1	40.3113	88.3415	8/30/2006	10:45	7.5	1497.0	20.3	11.1	21.5	NA
	Owl Creek	EZVE1	40.3113	88.3415	11/2/2006	12:59	8.3	859.8		12.5	6.1	NA

Table 2-2: Field Measurements

Watershed	Water body	Sample Site	Latitude	Longitude	Date	Time	pH (s.u.)	Conductivity (uS/cm)	Turbidity (NTU)	DO (mg/l)	Temp. °C	Depth (ft)
Shoal Creek	Shoal Creek	OI05	38.5361	89.5213	9/1/2006	12:35	7.5	563.4	38.7	9.1	22.9	NA
	Shoal Creek	OI05	38.5361	89.5213	10/17/2006	11:30	7.9	604.4	39.7	8.5	12.0	NA
	Shoal Creek	OI05A	38.5370	89.5330	9/1/2006	NOT SAMPLED						NA
	Shoal Creek	OI05A	38.5370	89.5330	10/17/2006	*Site located at end of private road with chained fence/alternate location not located*						NA
	Shoal Creek	OI05B	38.5333	89.5496	9/1/2006	14:20	7.8	542.2	43.0	10.8	26.2	NA
	Shoal Creek	OI05B	38.5333	89.5496	10/17/2006	11:15	7.9	542.4	72.7	8.7	12.3	NA
	Shoal Creek	OI05C	38.5020	89.5661	9/1/2006	15:40	7.8	535.3	43.5	10.2	23.5	NA
	Shoal Creek	OI05C	38.5020	89.5661	10/16/2006	10:30	8.0	578.9	46.0	9.4	12.1	NA
	Locust Fork	OIC01	38.7715	89.5556	8/31/2006	NOT SAMPLED *Site dry/no other road crossings on segment*						NA
	Locust Fork	OIC01	38.7715	89.5556	10/19/2006	12:20	7.8	401.1	24.3	3.8	10.0	NA
	Locust Fork	OIC02	38.7536	89.5288	8/31/2006	17:50	8.0	499.6	23.2	9.4	24.2	NA
	Locust Fork	OIC02	38.7536	89.5288	10/17/2006	13:00	7.7	422.2	26.9	5.2	14.2	NA
	Chicken Creek	OIO09	38.6407	89.5025	9/1/2006							NA
	Chicken Creek	OIO09	38.6407	89.5025	10/17/2006	NOT SAMPLED						NA
	Chicken Creek	OIO09A	38.6373	89.5260	9/1/2006	*Sites dry during both visits/sites located at only two road crossings on segment*						NA
	Chicken Creek	OIO09A	38.6373	89.5260	10/17/2006							NA
	Cattle Creek	OIP10	38.6649	89.5170	8/31/2006	NOT SAMPLED *Site dry/no other road crossings on segment*						NA
	Cattle Creek	OIP10	38.6649	89.5170	10/17/2006	12:05	7.9	928.0	105.6	2.0	14.2	NA
	Cattle Creek	OIP10A	38.6744	89.5359	8/31/2006	NOT SAMPLED						NA
	Cattle Creek	OIP10A	38.6744	89.5359	10/17/2006	*Site dry/no other road crossings on segment*						NA
South Fork Saline River/Lake of Egypt	South Fork Saline River	ATH08	37.6399	88.9281	9/26/2006	10:20	7.1	165.0	0.6	8.7	23.6	NA
	South Fork Saline River	ATH08	37.6399	88.9281	10/31/2006	11:15	6.6	213.1	10.0	8.8	19.0	NA
	South Fork Saline River	ATH14	NA	NA	9/26/2006							NA
	South Fork Saline River	ATH14	NA	NA	10/31/2006	NOT SAMPLED						NA
	South Fork Saline River	ATHLEC1	NA	NA	9/26/2006	*Sites located on private property and/or not accessible by roads No other road crossings available on segment*						NA
	South Fork Saline River	ATHLEC1	NA	NA	10/31/2006							NA
	South Fork Saline River	ATHLEC2	37.6295	88.9465	9/26/2006	9:45	6.6	81.0	15.6	9.4	18.1	NA
	South Fork Saline River	ATHLEC2	37.6295	88.9465	10/31/2006	12:00	6.8	137.7	11.6	9.6	17.1	NA
	Briers Creek	ATHS01	37.6766	88.7178	9/11/2006	11:30	7.6	1997.0	2.0	9.1	21.3	NA
	Briers Creek	ATHS01	37.6766	88.7178	9/27/2006	9:00	7.3	1392.0	3.4	10.2	15.5	NA
	Briers Creek	ATHS01	37.6766	88.7178	10/30/2006	16:30	7.1	1281.0	19.6	9.4	13.7	NA
	Briers Creek	ATHS01	37.6766	88.7178	11/15/2006	10:25	7.0	700.1	185.3	4.6	9.4	NA
	Briers Creek	ATHS01A	37.6995	88.7257	9/11/2006	10:00	7.1	765.0	5.6	9.7	17.9	NA
	Briers Creek	ATHS01A	37.6995	88.7257	9/27/2006	11:30	7.5	817.0	1.9	9.7	17.0	NA
	Briers Creek	ATHS01A	37.6995	88.7257	11/2/2006	12:00	8.0	862.8	3.0	8.5	9.5	NA
	Briers Creek	ATHS01A	37.6995	88.7257	11/15/2006	11:10	6.8	226.1	36.3	5.4	10.2	NA
	Briers Creek	ATHS01B	37.6943	88.7245	9/11/2006	10:25	7.2	507.0	6.2	9.5	17.8	NA
	Briers Creek	ATHS01B	37.6943	88.7245	9/27/2006	10:35	6.7	500.0	0.5	9.7	17.3	NA
	Briers Creek	ATHS01B	37.6943	88.7245	11/2/2006	12:20	7.4	726.7	2.9	9.9	9.5	NA
	Briers Creek	ATHS01B	37.6943	89.7640	11/15/2006	11:30	6.8	198.9	69.1	4.0	10.0	NA
	Briers Creek	ATHS01C	37.6882	88.7195	9/11/2006	12:55	6.8	2071.0	21.5	6.3	19.0	NA
	Briers Creek	ATHS01C	37.6882	88.7195	9/27/2006	9:30	7.0	1571.0	2.2	9.8	15.1	NA
	Briers Creek	ATHS01C	37.6882	88.7195	10/31/2006	14:30	7.4	1296.0	4.5	9.4	12.0	NA
	Briers Creek	ATHS01C	37.6882	88.7195	11/15/2006	10:45	7.0	848.6	90.7	8.8	9.5	NA
	East Palzo Creek	ATHV01	37.6502	88.7608	9/11/2006	10:40	6.9	375.0	16.4	6.7	22.7	NA
	East Palzo Creek	ATHV01	37.6502	88.7608	9/27/2006	NOT SAMPLED *Site flooded over road with no safe access/no other road crossings on segment*						NA
	East Palzo Creek	ATHV01	37.6502	88.7608	10/31/2006	13:40	6.5	490.6	14.2	7.6	12.4	NA
	East Palzo Creek	ATHV01	37.6502	88.7608	11/15/2006	10:00	6.3	554.5	200.0	5.1	9.4	NA
	East Palzo Creek	ATHV01A	37.6143	88.7788	9/11/2006	8:25	7.2	1878.0	1.7	6.6	18.8	
	East Palzo Creek	ATHV01A	37.6143	88.7788	9/27/2006	NOT SAMPLED						NA
	East Palzo Creek	ATHV01A	37.6143	88.7788	10/31/2006	*Site dry/no other road crossings on segment*						NA
	East Palzo Creek	ATHV01A	37.6143	88.7788	11/15/2006	9:05	6.8	158.9	81.9	9.0	9.4	NA
	East Palzo Creek	ATHV01B	37.6452	88.7635	9/11/2006	8:55	6.9	481.0	28.8	6.0	19.1	NA
	East Palzo Creek	ATHV01B	37.6452	88.7635	9/26/2006	12:30	6.2	405.0	4.6	10.9	17.4	NA
	East Palzo Creek	ATHV01B	37.6452	88.7635	10/31/2006	13:00	6.4	498.2	23.8	8.7	12.4	NA
	East Palzo Creek	ATHV01B	37.6452	88.7635	11/15/2006	9:35	6.1	435.0	243.8	5.6	9.4	NA

Table 2-2: Field Measurements

Watershed	Water body	Sample Site	Latitude	Longitude	Date	Time	pH (s.u.)	Conductivity (uS/cm)	Turbidity (NTU)	DO (mg/l)	Temp. °C	Depth (ft)
South Fork Sangamon River/ Lake Taylorville	South Fork Sangamon River	EO13	39.4072	89.3164	8/30/2006	18:10	7.3	719.3	7.2	6.3	20.4	NA
	South Fork Sangamon River	EO13	39.4072	89.3164	11/2/2006	16:50	7.7	528.5		6.5	6.1	NA
	South Fork Sangamon River	EO13A	39.2700	89.1880	8/30/2006	19:55	7.3	754.7	7.6	9.7	21.6	NA
	South Fork Sangamon River	EO13A	39.2700	89.1880	11/2/2006	NOT SAMPLED *Miscommunication between field crews caused error in sampling*						NA
	South Fork Sangamon River	EO13B	39.3630	89.2700	8/30/2006	19:25	7.6	1112.0	60.1	8.3	21.6	NA
	South Fork Sangamon River	EO13B	39.3630	89.2700	11/2/2006	NOT SAMPLED *Miscommunication between field crews caused error in sampling*						NA
	South Fork Sangamon River	EO13C	39.4590	89.2970	8/30/2006	18:55	7.0	56.9	96.0	3.8	21.1	NA
	South Fork Sangamon River	EO13C	39.4590	89.2970	11/2/2006	16:25	8.2	954.1		5.8	6.4	NA

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Table 2-3: Data Associated with Impairment Status

Watershed	Water body	Sample Site	Date	Time	Causes of Impairment												
					pH[1]	DO[1]	Total Mn	Sulfates	TDS	Total Boron	Dissolved Zinc[6]	Dissolved Iron	Total Silver	Dissolved Copper[6]	TP	Atrazine[5]	Ammonia
					s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L
Bay Creek	Cedar Creek	AJF16	9/25/2006	18:00		8.9	0.25										
			11/3/2006	11:05		11.0	0.12										
		AJF16A	9/25/2006	18:15		9.4	0.23										
			11/2/2006	13:30		11.6	0.08										
	Bay Creek Ditch	AJK01	9/25/2006	15:58		5.6	0.16										
			10/31/2006	8:15		8.2	0.05										
		AJK01A	10/31/2006	8:45		6.1	0.06										
Cahokia Creek/Holiday Shores Lake	Cahokia Diversion Ditch	JQ07	10/4/2006	16:35		5.3								ND			
			10/17/2006	14:15		9.4								ND			
		JQ01	10/4/2006	16:20		**3.4**								ND			
			10/17/2006	14:45		9.6								ND			
Cedar Creek	Big Muddy River	N99	9/7/2006	12:15		10.1		186									
			11/1/2006	9:45		7.8		75									
		N13	9/7/2006	11:15		8.1		144									
			11/1/2006	10:45		8.2		68									
	Cave Creek	NAC01	9/11/2006	11:45		7.6											
			11/1/2006	11:45		10.6											
		NAC01A	9/11/2006	11:15		**4.9**											
			11/1/2006	12:15		10.1											
Crab Orchard Lake	Crab Orchard Creek	ND11	9/6/2006	12:15	7.3	5.2	1.00										
			11/1/2006	14:00	7.7	10.1	0.26										
		ND12	9/6/2006	13:15	7.3		0.17										
			11/1/2006	15:00	7.7		ND										
		ND13	9/6/2006	15:00		6.0											
			11/1/2006	15:45		11.1											
		ND15	9/6/2006	16:30		6.8											
	Little Crab Orchard Creek	NDA01	9/6/2006	18:00		**2.1**	**2.00**										
			11/2/2006	8:30		8.2	0.20										
		NDA99	11/2/2006	10:30		12.3	0.03										
	Piles Fork	NDB03	9/7/2006	10:00		**1.6**											
			11/2/2006	9:15		10.3											
		NDB04	9/9/2006	7:40		**3.6**											
			11/2/2006	11:00		11.5											
Crooked Creek	Plum Creek	OZH-OK-A2	9/8/2006	14:00		6.8	0.65										
			10/19/2006	10:50		5.3	0.33										
		OZH-OK-A2A	9/8/2006	16:25		8.5	0.20										
			10/19/2006	11:20		9.0	0.22										
		OZH-OK-C2	9/8/2006	12:45		**1.1**											
			10/19/2006	10:15		**2.5**											
		OZH-OK-C2A	9/8/2006	17:30		**4.6**											
			10/19/2006	13:40		**3.2**											
		OZH-OK-C3	9/9/2006	15:00		**4.1**	0.30										
			10/19/2006	9:35		5.2	0.77										
	Little Crooked Creek	OJA-01	9/7/2006	17:45		**3.7**	0.14										
			10/19/2006	14:05		**4.7**	0.17										
		OJA-02	9/8/2006	11:15		**3.1**	0.14										
			10/19/2006	14:35		**3.8**	0.17										

Table 2-3: Data Associated with Impairment Status

Watershed	Water body	Sample Site	Date	Time	Causes of Impairment												
					pH[1]	DO[1]	Total Mn	Sulfates	TDS	Total Boron	Dissolved Zinc [6]	Dissolved Iron	Total Silver	Dissolved Copper [6]	TP	Atrazine [5]	Ammonia
					s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L
Little Wabash	Village Creek	CE01	9/6/2006	17:30		9.9	0.17										
			11/14/2006	8:45		10.6	0.10										
		CE02	9/6/2006	15:20		7.9	0.80										
			11/9/2006	12:55		10.7	0.11										
		CE01A	9/12/2006	17:05		5.8	0.41										
			11/9/2006	13:45		11.2	0.08										
	Johnson Creek	CCAFFA1A	9/10/2006	10:50		**3.8**											
			11/14/2006	10:45		12.3											
		CCA12	9/9/2006	13:05		14.2											
			11/14/2006	9:45		7.7											
		CCA13	9/9/2006	14:30		14.9											
			11/14/2006	10:15		12.8											
		CCA14A	9/9/2006	15:25		5.7											
			11/14/2006	10:25		12.5											
	Pond Creek	CCFFD1	9/9/2006	10:30		7.1											
			10/31/2006	10:10		8.2											
		CCFFD1A	11/9/2006	12:15		11.2											
		CCFFD1B	9/9/2006	11:45		8.6											
			11/9/2006	11:35		12.1											
		CCFFD1C	9/10/2006	12:10		11.9											
			10/31/2006	11:20		14.4											
	Seminary Creek	CDGFLA1	9/8/2006	15:40		10.0											
			11/8/2006	14:45		14.3											
		CDGFLA1A	9/8/2006	13:45		**2.6**											
			11/8/2006	15:50		15.1											
		CDFGLC6	9/8/2006	12:25		6.6											
			11/8/2006	17:00		10.5											
		CDFGLC6A	9/8/2006	11:10		7.0											
			11/8/2006	16:45		12.0											
	Big Muddy Creek	CJ06	9/7/2006	18:10		**4.9**	0.54										
			11/8/2006	11:00		11.6	0.39										
		CJ05	9/7/2006	16:45		10.5	0.04										
			11/8/2006	11:30		12.4	0.07										
	Little Muddy Creek	CJA02	9/7/2006	4:20		**2.8**	**1.30**										
			11/8/2006	12:30		9.3	0.39										
		CJA01	9/12/2006	10:20		**3.4**	**1.30**										
			11/13/2006	12:00		10.1	0.17										
	Big Muddy Diversion Ditch	CJAE01	9/7/2006	12:10		9.1											
			11/8/2006	13:05		10.8											
		CJAE01A	9/7/2006	15:45		10.3											
			11/13/2006	12:30		9.8											

Table 2-3: Data Associated with Impairment Status

Watershed	Water body	Sample Site	Date	Time	Causes of Impairment												
					pH(1)	DO(1)	Total Mn	Sulfates	TDS	Total Boron	Dissolved Zinc (6)	Dissolved Iron	Total Silver	Dissolved Copper (6)	TP	Atrazine (5)	Ammonia
					s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L
Little Wabash	Elm River	CD02A	9/12/2006	12:51		**3.8**											
		CD02	9/8/2006	17:45		8.1											
		CD01	4/18/2006	14:30												0.12	
			4/26/2006	11:15												0.16	
			5/1/2006	11:00												0.27	
			5/17/2006	9:30												**19.00**	
			5/24/2006	11:20												**15.00**	
			5/31/2006	11:30												8.30	
			6/7/2006	11:25												5.70	
			6/15/2006	9:50												2.80	
			6/22/2006	11:15												1.20	
			6/27/2006	9:15												4.20	
			7/5/2006	11:50												2.40	
			7/12/2006	11:30												0.92	
			7/20/2006	11:15												2.40	
			7/27/2006	11:05												2.60	
			8/1/2006	9:20												2.60	
			8/8/2006	12:20												1.60	
	Little Wabash River	C33 (4)	4/18/2006	11:00												0.55	
			4/26/2006	12:15			**0.35**									1.10	
			5/1/2006	11:45			**0.50**									0.71	
			5/10/2006	12:20			**0.41**										
			5/17/2006	14:00												**19.00**	
			5/24/2006	12:15			**0.38**									8.10	
			5/31/2006	12:40			**0.37**									**13.00**	
			6/7/2006	12:30			**0.44**									6.30	
			6/15/2006	11:05												5.30	
			6/22/2006	12:00			**0.76**									2.60	
			6/27/2006	11:50												2.50	
			7/5/2006	13:00			**0.50**									1.70	
			7/12/2006	12:30			**0.54**									1.00	
			7/20/2006	12:20			**0.46**									2.30	
			7/27/2006	12:10												0.64	
			8/1/2006	10:30												0.66	
			8/8/2006	13:30												0.50	

Table 2-3: Data Associated with Impairment Status

Watershed	Water body	Sample Site	Date	Time	Causes of Impairment												
					pH[1]	DO[1]	Total Mn	Sulfates	TDS	Total Boron	Dissolved Zinc[6]	Dissolved Iron	Total Silver	Dissolved Copper[6]	TP	Atrazine[5]	Ammonia
					s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L
Little Wabash	Little Wabash River	C09	3/17/2005	8:00		14.9											
			4/19/2005	14:30		7.3											
			5/9/2005	10:30		6.7											
			6/23/2005	7:30		5.1											
			8/23/2005	13:00		**4.2**											
			9/27/2005	16:00		7.5											
			10/27/2005	14:00		8.7											
			12/6/2005	13:00		11.8											
			2/1/2006	12:30		9.3											
			3/15/2006	10:00		6.2											
			4/18/2006	16:00												0.27	
			4/26/2006	10:00									ND			0.62	
			5/1/2006	9:45									ND			0.59	
			5/10/2006	10:00									ND				
			5/17/2006	11:00									ND			**20.00**	
			5/24/2006	9:45									ND			6.30	
			5/31/2006	10:20									ND			**24.00**	
			6/7/2006	10:15									ND			4.20	
			6/15/2006	8:50									ND			1.80	
			6/22/2006	10:05									ND			1.20	
			6/27/2006	10:40									ND			1.50	
			7/5/2006	10:30									ND			1.20	
			7/12/2006	10:30									ND			0.96	
			7/20/2006	10:00									ND			1.60	
			7/27/2006	10:00									ND			0.72	
			8/1/2006	8:30									ND			0.63	
			8/8/2006	11:05									ND			0.40	
			8/18/2006	16:00									ND				
Mary's River/North Fork Cox Creek	North Fork Cox Creek	IIHA31	9/9/2006	17:10				**1610**	**3110**								
			10/18/2006	14:45				**1830**	**2830**								
		IIHA01	9/9/2006	17:40				**1850**	**3090**								
			10/18/2006	14:25				**1630**	**2540**								
		IIHA-STE1	9/9/2006	15:40					**3090**								
			10/18/2006	13:40					**1340**								
		IIHA-STC1	9/9/2006	16:15					**2530**								
			10/18/2006	14:00					**1400**								
	Maxwell Creek	IIKSPC1	9/7/2006	15:30		**2.0**											
			10/17/2006	8:20		20.2											
		IIKSPC3A	9/7/2006	15:00		**2.6**											
			10/17/2006	8:45		6.5											
	Randolph County Lake	RIB-1[3]	9/9/2006	12:00											0.04		
			10/18/2006	10:45											**0.130**		
		RIB-2[3]	9/9/2006	14:00											0.04		
			10/18/2006	12:05											**0.053**		
		RIB-3[3]	9/9/2006	13:00											0.04		
			10/18/2006	11:15											**0.100**		

Table 2-3: Data Associated with Impairment Status

Watershed	Water body	Sample Site	Date	Time	pH[1]	DO[1]	Total Mn	Sulfates	TDS	Total Boron	Dissolved Zinc[6]	Dissolved Iron	Total Silver	Dissolved Copper[6]	TP	Atrazine[5]	Ammonia
					Causes of Impairment												
					s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L
Sangamon River/ Lake Decatur	Owl Creek	EZV01	8/30/2006	12:50		8.5											
			11/2/2006	9:25		12.2											
		EZVA1	8/30/2006	11:05		6.5											
			11/2/2006	10:33		11.8											
		EZVE1	8/30/2006	10:45		11.1											
			11/2/2006	12:59		12.5											
		EZVC1	8/30/2006	10:25		**5.0**											
			11/2/2006	12:20		11.7											
Shoal Creek	Shoal Creek	OI05	9/1/2006	12:35		9.1											
			10/17/2006	11:30		8.5											
		OI05B	9/1/2006	14:20		10.8											
			10/17/2006	11:15		8.7											
		OI05C	9/1/2006	15:40		10.2											
			10/16/2006	10:30		9.4											
	Locust Fork	OIC01	10/19/2006	12:20		**3.8**	0.18										
		OIC02	8/31/2006	17:50		9.4	0.35										
			10/17/2006	13:00		5.2	0.08										
	Cattle Creek	OIP10	10/17/2006	12:05		**2.0**			928[2]					0.021			5.8
South Fork Saline River/ Lake of Egypt	Briers Creek	ATHS01	9/11/2006	11:30	7.6	9.1	0.65	**1250**	**1960**		0.020	0.310	ND				
			9/27/2006	9:00	7.3	10.2	**2.00**	**951**	**1490**		0.022	ND	ND				
			10//2006	11:30							ND	ND					
			10/30/2006	16:30			**1.50**	**656**	**1120**		0.035	ND	ND				
			11/15/2006	10:25			**1.40**	281	469		0.028	**1.10**	ND				
		ATHS01A	9/27/2006	11:30	7.5	9.7	0.10	294	678		ND	**1.10**	ND				
			10/4/2006	10:50							ND	ND					
			11/2/2006	12:00	8.0	8.5	0.11	219	597		0.012	ND	ND				
			11/15/2006	11:10	6.8	5.4	0.12	65	213		ND	**1.40**	ND				
		ATHS01B	9/13/2006	10:40			0.18	143	418			ND	ND				
			9/27/2006	10:35	6.7	9.7	0.17	196	414		ND	ND	ND				
			10/4/2006	11:05							0.013	ND					
			11/2/2006	12:20	7.4	9.9	0.22	373	608		0.018	ND	ND				
			11/15/2006	11:30	6.8	**4.0**						**2.10**					
		ATHS01C	9/11/2006	12:55			**8.70**	**1290**	**2150**			**5.00**	ND				
			9/27/2006	9:30	7.0	9.8	**4.10**	**1100**	**1660**		ND	0.78	ND				
			10/4/2006	11:20							ND	**2.20**					
			10/31/2006	14:30	7.4	9.4	**1.90**	**691**	**1190**		ND	0.17	ND				
			11/15/2006	10:45	7.0	8.8	0.93	338	667		ND	0.470	ND				

Table 2-3: Data Associated with Impairment Status

Watershed	Water body	Sample Site	Date	Time	pH[1]	DO[1]	Total Mn	Sulfates	TDS	Total Boron	Dissolved Zinc [6]	Dissolved Iron	Total Silver	Dissolved Copper [6]	TP	Atrazine [5]	Ammonia
					Causes of Impairment												
					s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L
South Fork Saline River/ Lake of Egypt	East Palzo Creek	ATHV01A	9/11/2006	10:40	6.9	6.7	**1.40**		**1560**			ND					
			10/31/2006	13:40	6.5	7.6	**1.80**		375			0.160		ND			
			11/15/2006	10:00	**6.3**	5.1	0.09		211			**2.60**		ND			
		ATHV01	9/11/2006	10:40	6.9	6.7	0.38		262			ND					
			10/4/2006	12:30								0.13		ND			
			10/31/2006	13:40	6.5	7.6	**1.80**		375			0.16		ND			
			11/15/2006	10:00	**6.3**	5.1	**2.10**		324			0.340		ND			
		ATHV01B	9/11/2006	8:55	6.9	6.0	0.41		388			ND					
			9/26/2006	12:30	**6.2**	10.9	1.00		323			ND		ND			
			10/4/2006	11:50								ND		ND			
			10/31/2006	13:00	**6.4**	8.7	**1.60**		341			ND		ND			
			11/15/2006	9:35	**6.1**	5.6	**1.60**		225			0.100		ND			
	South Fork Saline River	ATHLEC2	9/26/2006	9:45		9.4											
			10/31/2006	12:00		9.6											
		ATH08	9/26/2006	10:20		8.7											
			10/31/2006	11:15		8.8											
South Fork Sangamon River/ Lake Taylorville	South Fork Sangamon River	EO13A	8/30/2006	19:55		9.7	0.61			0.05							
		EO13	8/30/2006	18:10		6.3	0.49			0.20							
			11/2/2006	16:50		6.5	0.33			0.08							
		EO13B	8/30/2006	19:25		8.3	**1.18**			0.20							
		EO13C	8/30/2006	18:55		**3.8**	**5.49**			0.27							
			11/2/2006	16:25		5.8	0.38			0.13							

Shaded cells indicate exceedances of the applicable water quality standard

1 pH and DO values in this table represent field parameters sampled using the In-Site 9500 Profiler. Continuous DO and pH data are available in Appendix D.

2 Value shown is for conductivity. TDS standard corresponds to 1667 uS/cm specific conductance

3 Values shown were collected at one-foot depth.

4 Segment C33 is a source of public water. Therefore the applicable manganese standard is 150 ug/L.

5 Chronic criteria for atrazine is 9 ug/L and a single exceedance of this value indicates a potential cause of impairment

6 Corresponding hardness values were used to calculate standards. Analytical data can be found in Appendix C.

Section 3
Quality Assurance Review

A review was conducted to assess the quality and usability of data generated from Stage 2 work activities and to review compliance with the original sampling plan and objectives developed for the QAPP. Field and laboratory methods were deemed in accordance with the QAPP. Minor deviations from the original plan occurred and all are discussed below.

3.1 Deviations from original Sampling Plan (QAPP)

The following issues and/or concerns developed during the sampling events:

- Sampling during the week of September 25th followed a heavy precipitation event which resulted in high stream flows and flooding at Bay Creek Ditch segment AJK01A and East Palzo Creek segment ATHV01.
- In-field filtering was not performed for dissolved phosphorus or dissolved metal samples. Illinois EPA requested additional information on this procedure. CDM along with ARDL, Inc drafted text for Illinois EPA to validate this sampling practice. Total versus dissolved samples are discussed further in section 3.2.2.
- All locations on Chicken Creek (OIO09) were dry during both sample periods; therefore no samples were collected for this segment.
- The following sites had no water during either sampling event: Maxwell Creek IIKSPA1 and IIKSPE1A, and Cattle Creek OIP10A. Alternate locations were not found.
- Access was not available to the following sites during either sampling event: Shoal Creek OIO5A, South Fork Saline River sites ATH14 and ATHLEC1. Alternate locations were not found.
- Site EZVA1 on Owl Creek was moved from the location proposed in the QAPP to the intersection of Owl Creek and County Road 3100 due to better stream flow.
- Only one round of sampling was conducted at the following sites due to access or water volume issues (refer to Table 2-2 for specific dates and issues): Locust Fork OIC01, Cattle Creek OIP10, Crab Orchard Creek ND15, Little Crab Orchard Creek NDA99, Pond Creek CCFFD1A, East Palzo Creek ATHV01 and ATHV01A, and Bay Creek Ditch AJK01A.
- Due to field crew error only one round of sampling was conducted at South Fork Sangamon River EO13A and EO13B and Elm River locations CD02 and CD02A.

3.2 Data Verification and Validation

A data quality review was performed on all laboratory data. The review consisted of an evaluation of laboratory QC and field QC samples. Laboratory QC included an evaluation of method blanks, matrix spikes, matrix spike duplicates, laboratory control samples and holding times. Field QC included an evaluation of field duplicates. No decontamination rinsate blanks were collected.

No laboratory violation resulted in the qualification of CDM collected data. While some matrix spikes had percent recoveries outside of the established limits, all other QC associated with the samples were acceptable. When a matrix spike was reported outside of the control limits, the laboratory control samples had percent recoveries within the established control limits, indicating a matrix effect on the sample analysis and no need to qualify the data. All samples were analyzed within the control limits.

An evaluation of the phosphorus data (total versus dissolved) was performed to determine the effects of filtering the samples immediately versus waiting up to 48 to 64 hours. All samples were received by the laboratories on ice and at 4^0C (+/-). A total of 161 samples have been analyzed for both total and dissolved phosphorus by method 365.2. Of the 161 samples, a total of 10 samples sets had a phosphorus concentration of greater than 1 mg/L (100 times higher than the reporting limit and considered significant when controlling based on RPDs). One of these samples had relative percent difference (RPD) between the total and dissolved fraction of the sample of greater than 100. Precision values of less that 25 % RPD are considered acceptable for sample results reported significantly above the reporting limit. Sample EO13C had total phosphorus measured at 2.09 mg/L and dissolved phosphorus measured at 0.52 mg/L. The TSS measured in this sample was 159 mg/L. The suspended solids contained in this sample may have absorbed the available phosphorus, but all other results in samples with phosphorus concentrations above 1mg/L show that this reaction is not taking place. Sampling or analytical variations may explain the elevated RPD between the sample and the duplicate. Total phosphorus and dissolved phosphorus results for samples with phosphorus concentrations above 1 mg/L are not significantly different.

Looking at all other results, there does not appear to be a correlation between the difference of total and dissolved phosphorus and the TSS concentration. Suspended solids absorbing dissolved phosphorus would be the likely mechanism for lowering the dissolved phosphorus concentrations. Based on the lack of this correlation, dissolved phosphorus concentration would not be significantly different if the samples were filtered immediately versus filtering at the laboratory 48-hours after collection.

Finally, field and laboratory quality control data were collected to assess bias associated between field and laboratory methods. Positive sample results and relative percent difference (RPD) are presented in Table 3-1.

3.3 Data Quality Objectives

The data generated during the Stage 2 investigation conformed to the data quality objectives established in the QAPP. A completeness criterion of 90% was established and easily achieved. No data have been qualified that were collected by CDM personnel and analyzed by ARDL, Inc or Prairie Analytical laboratories. Data qualifiers were applied to some of the data collected by Illinois EPA personnel. All qualifiers are included with the laboratory data contained in Appendix C.

Table 3-1: Duplicate Pair Sample Results

SampleLocation	Parameter	Result	Units	Collection Date	RPD(%)
AJK01-DUP	Solids, total suspended	24.2	MG/L	9/25/2006	
AJK01	Solids, total suspended	25	MG/L	9/25/2006	3.252033
ATHS01A-DUP	Hardness (CA/MG)	435.1	MG CACO3/L	11/2/2006	
ATHS01A	Hardness (CA/MG)	445	MG CACO3/L	11/2/2006	2.249744
ATHS01A-DUP	Solids, total dissolved	604	MG/L	11/2/2006	
ATHS01A	Solids, total dissolved	597	MG/L	11/2/2006	-1.1657
ATHS01A-DUP	Chloride	5.13	MG/L	9/27/2006	
ATHS01A	Chloride	5.1	MG/L	9/27/2006	-0.64556
ATHS01A-DUP	Solids, total dissolved	675	MG/L	9/27/2006	
ATHS01A	Solids, total dissolved	678	MG/L	9/27/2006	0.443459
ATHS01A-DUP	Sulfate	290.63	MG/L	9/27/2006	
ATHS01A	Sulfate	294	MG/L	9/27/2006	1.154242
ATHS01C-DUP	Chloride	5.38	MG/L	9/11/2006	
ATHS01C	Chloride	5.4	MG/L	9/11/2006	0.388903
ATHS01C-DUP	Sulfate	1297.83	MG/L	9/11/2006	
ATHS01C	Sulfate	1290	MG/L	9/11/2006	-0.60514
ATHS01-FIELDDUP	Alkalinity	113	MG/L	10/30/2006	
ATHS01	Alkalinity	108	MG/L	10/30/2006	-4.52489
ATHS01-FIELDDUP	Chloride	4.9	MG/L	10/30/2006	
ATHS01	Chloride	4.9	MG/L	10/30/2006	0
ATHS01-FIELDDUP	Hardness (CA/MG)	673	MG CACO3/L	10/30/2006	
ATHS01	Hardness (CA/MG)	668	MG CACO3/L	10/30/2006	-0.74571
ATHS01-FIELDDUP	Iron	68200	MG/KG	10/30/2006	
ATHS01	Iron	93800	MG/KG	10/30/2006	31.60494
ATHS01-FIELDDUP	Manganese	1130	MG/KG	10/30/2006	
ATHS01	Manganese	1480	MG/KG	10/30/2006	26.81992
ATHS01-FIELDDUP	Manganese	1.5	MG/L	10/30/2006	
ATHS01	Manganese	1.5	MG/L	10/30/2006	0
ATHS01-FIELDDUP	Nitrate-Nitrite	0.06	MG/L	10/30/2006	
ATHS01	Nitrate-Nitrite	0.06	MG/L	10/30/2006	-11.9658
ATHS01-FIELDDUP	Phosphorus, diss	0.05	MG/L	10/30/2006	
ATHS01	Phosphorus, diss	0.05	MG/L	10/30/2006	8.163265
ATHS01-FIELDDUP	Phosphorus, total	0.04	MG/L	10/30/2006	
ATHS01	Phosphorus, total	0.03	MG/L	10/30/2006	-26.8657
ATHS01-FIELDDUP	Solids, total	69.7	%	10/30/2006	
ATHS01	Solids, total	74.5	%	10/30/2006	6.65742
ATHS01-FIELDDUP	Solids, total dissolved	1040	MG/L	10/30/2006	
ATHS01	Solids, total dissolved	1070	MG/L	10/30/2006	2.843602
ATHS01-FIELDDUP	Solids, total suspended	4.3	MG/L	10/30/2006	
ATHS01	Solids, total suspended	5.6	MG/L	10/30/2006	26.26263
ATHS01-FIELDDUP	Sulfate	662	MG/L	10/30/2006	
ATHS01	Sulfate	604	MG/L	10/30/2006	-9.16272
ATHS01-FIELDDUP	Zinc	106	MG/KG	10/30/2006	
ATHS01	Zinc	116	MG/KG	10/30/2006	9.009009
ATHS01-FIELDDUP	Zinc, diss	0.02	MG/L	10/30/2006	
ATHS01	Zinc, diss	0.03	MG/L	10/30/2006	8.333333
ATHS01-DUP	Alkalinity	60.9	MG/L	11/15/2006	
ATHS01	Alkalinity	56.8	MG/L	11/15/2006	-6.96686
ATHS01-DUP	Hardness (CA/MG)	340.14	MG CACO3/L	11/15/2006	
ATHS01	Hardness (CA/MG)	337	MG CACO3/L	11/15/2006	-0.92743
ATHS01-DUP	Solids, total dissolved	481	MG/L	11/15/2006	

Table 3-1: Duplicate Pair Sample Results (continued)

SampleLocation	Parameter	Result	Units	Collection Date	RPD(%)
ATHS01	Solids, total suspended	151	MG/L	11/15/2006	-104.43
ATHS01-DUP	Hardness (CA/MG)	1035.17	MG CACO3/L	9/27/2006	
ATHS01	Hardness (CA/MG)	1030	MG CACO3/L	9/27/2006	-0.50069
ATHV01B-DUP	Alkalinity	15.3	MG/L	9/26/2006	
ATHV01B	Alkalinity	15.3	MG/L	9/26/2006	0
ATHV01B-DUP	Solids, total	72.5	%	9/26/2006	
ATHV01B	Solids, total	71.9	%	9/26/2006	-0.83102
CCFFD1-DUP	Chlorophyll	5.5	MG/CU.M.	9/9/2006	
CCFFD1	Chlorophyll	5	MG/CU.M.	9/9/2006	-9.52381
CE01A-DUP	Solids, total suspended	134	MG/L	9/12/2006	
CE01A	Solids, total suspended	137	MG/L	9/12/2006	2.214022
CJA02-DUP	Biological Oxygen Demand	4	MG/L	11/8/2006	
CJA02	Biological Oxygen Demand	3.7	MG/L	11/8/2006	-7.79221
EO13-DUP	Biological Oxygen Demand	6.3	MG/L	11/2/2006	
EO13	Biological Oxygen Demand	6.3	MG/L	11/2/2006	0
EO13-DUP	Solids, total suspended	8.4	MG/L	11/2/2006	
EO13	Solids, total suspended	7.6	MG/L	11/2/2006	-10
IIAA01-DUP	Chloride	21.71	MG/L	9/9/2006	
IIAA01	Chloride	21.7	MG/L	9/9/2006	-0.0258
IIAA01-DUP	Sulfate	1832.11	MG/L	9/9/2006	
IIAA01	Sulfate	1850	MG/L	9/9/2006	0.971725
IIHA01-DUP	Chloride	21.71	MG/L	9/9/2006	
IIHA01	Chloride	21.7	MG/L	9/9/2006	-0.0258
IIHA01-DUP	Sulfate	1832.11	MG/L	9/9/2006	
IIHA01	Sulfate	1850	MG/L	9/9/2006	0.971725
IIHA31-DUP	Hardness (CA/MG)	1290.87	MG CACO3/L	9/9/2006	
IIHA31	Hardness (CA/MG)	1300	MG CACO3/L	9/9/2006	0.704783
IIHA31-DUP	Hardness (CA/MG)	1306.27	MG CACO3/L	10/18/2006	
IIHA31	Hardness (CA/MG)	1280	MG CACO3/L	10/18/2006	-2.0315
IIHA31-DUP	Chloride	19.5	MG/L	10/18/2006	
IIHA31	Chloride	19.4	MG/L	10/18/2006	-0.51363
IIHA31-DUP	Solids, total dissolved	2850	MG/L	10/18/2006	
IIHA31	Solids, total dissolved	2830	MG/L	10/18/2006	-0.70423
IIHA31-DUP	Sulfate	1783.35	MG/L	10/18/2006	
IIHA31	Sulfate	1830	MG/L	10/18/2006	2.582091
IIHA-STE1-DUP	Solids, total dissolved	3100	MG/L	9/9/2006	
IIHA-STE1	Solids, total dissolved	3090	MG/L	9/9/2006	-0.3231
IIKSPC3A-DUP	Biological Oxygen Demand	11	MG/L	9/7/2006	
IIKSPC3A	Biological Oxygen Demand	11	MG/L	9/7/2006	0
JQ01-DUP	Chlorophyll	11.8	MG/CU.M.	8/31/2006	
JQ-01	Chlorophyll	13.2	MG/CU.M.	8/31/2006	11.2
JQ01-DUP	Hardness (CA/MG)	221.3	MG CACO3/L	8/31/2006	
JQ-01	Hardness (CA/MG)	221	MG CACO3/L	8/31/2006	-0.13565
ND11-DUP	Solids, total suspended	16.2	MG/L	11/1/2006	
ND11	Solids, total suspended	15	MG/L	11/1/2006	-7.69231
ND11-DUP	Alkalinity	90.2	MG/L	9/6/2006	
ND11	Alkalinity	90.2	MG/L	9/6/2006	0
NDA01-DUP	Solids, total suspended	18.2	MG/L	9/6/2006	
NDA01	Solids, total suspended	16.6	MG/L	9/6/2006	-9.1954
NDB04-DUP	Chlorophyll	26.9	MG/CU.M.	11/2/2006	
NDB04	Chlorophyll	25.7	MG/CU.M.	11/2/2006	-4.56274
OI05C-DUP	Biological Oxygen Demand	4.6	MG/L	9/1/2006	
OI05C	Biological Oxygen Demand	5.1	MG/L	9/1/2006	10.30928
OIC02-DUP	Solids, total suspended	14	MG/L	8/31/2006	
OIC02	Solids, total suspended	13.7	MG/L	8/31/2006	-2.16606
OIC02-DUP	Solids, total suspended	18.5	MG/L	10/17/2006	

Table 3-1: Duplicate Pair Sample Results (continued)

SampleLocation	Parameter	Result	Units	Collection Date	RPD(%)
OIC02	Solids, total suspended	16.8	MG/L	10/17/2006	-9.63173
OIP10-DUP	Hardness (CA/MG)	278.52	MG CACO3/L	10/17/2006	
OIP10	Hardness (CA/MG)	286	MG CACO3/L	10/17/2006	2.650039
OZH-OK-A2A-DUP	Chlorophyll	155.4	MG/CU.M.	9/8/2006	
OZH-OK-A2A	Chlorophyll	126	MG/CU.M.	9/8/2006	-20.8955

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Section 4
Conclusions

Data collected during Stage 2 have been deemed adequate and usable for Stage 3 TMDL development (see discussion in Section 3). Table 4-1 contains information for each segment sampled during Stage 2 with regards to its impairment status. The table contains information on the number of historic samples available prior to Stage 2 data collection, the number of historic violations as well as the date of the last recorded violation. The intention of this table is to assist any future determination on the impairment status of the Stage 2 stream segments.

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Table 4-1: Impairment Status

Watershed	Stream Name	Segment	Parameter of Concern	Historic Data Count	Number of Historic Violations	Date of Last Recorded Violation	Stage 2 Data Count	Number of Violations	Suggested Status
Bay Creek	Cedar Creek	AJF16	Dissolved Oxygen	1	1	2000	Continuous	0	Delist
			Manganese	1	0	-	4	0	Delist
	Bay Creek Ditch	AJK01	Dissolved Oxygen	3	3	1987	Continuous	Multiple	Impaired
			Manganese	3	3	1987	3	0	Delist
Cahokia Creek/ Holiday Shores Lake	Cahokia Diversion Ditch	JQ07	Dissolved Oxygen	147	130	2005	Continuous	Multiple	Impaired
			Copper	5	1	1998	4	0	Delist
Cedar Creek	Big Muddy River	N99	Dissolved Oxygen	3	1	2002	Continuous	*	Impaired
			Sulfates	3	0	-	4	0	Delist
	Cave Creek	NAC01	Dissolved Oxygen	2	1	1995	Continuous	1	Impaired
Crab Orchard Lake	Crab Orchard Creek	ND11	Dissolved Oxygen	2	1	2000	Continuous	Multiple	Impaired
			Manganese	2	2	2000	2	0	Delist
			pH	3	2	2004	Continuous	Multiple	Impaired
	Crab Orchard Creek	ND12	pH	3	1	2004	Continuous	0	Delist
			Manganese	2	1	2000	2	0	Delist
	Crab Orchard Creek	ND13	Dissolved Oxygen	4	4	2000	Continuous	Multiple	Impaired
	Little Crab Orchard Creek	NDA01	Dissolved Oxygen	2	1	1995	Continuous	Multiple	Impaired
			Manganese	2	1	1995	3	1	Impaired
	Piles Fork	NDB03	Dissolved Oxygen	2	1	1995	Continuous	Multiple	Impaired
Crooked Creek	Plum Creek	OZH-OK-A2	Dissolved Oxygen	1	1	2002	Continuous	Multiple	Impaired
	Plum Creek		Manganese	1	1	2002	4	0	Delist
	Plum Creek	OZH-OK-C2	Dissolved Oxygen	1	1	2002	Continuous	Multiple	Impaired
	Plum Creek	OZH-OK-C3	Dissolved Oxygen	1	1	2002	Continuous	Multiple	Impaired
	Plum Creek		Manganese	1	1	2002	2	0	Delist
	Little Crooked Creek	OJA-01	Dissolved Oxygen	5	4	2002	Continuous	Multiple	Impaired
			Manganese	5	2	2002	4	0	Delist

Table 4-1: Impairment Status

Watershed	Stream Name	Segment	Parameter of Concern	Historic Data Count	Number of Historic Violations	Date of Last Recorded Violation	Stage 2 Data Count	Number of Violations	Suggested Status
Little Wabash	Little Wabash River	C09	Dissolved Oxygen	43	7	2003	Continuous	Multiple	Impaired
			Silver	43	1	2002	18	0	Delist
			Atrazine	2	1	1991	16	2	Impaired
		C33	Dissolved Oxygen	5	3	2002	Continuous	Multiple	Impaired
			Manganese	5	5	2002	10	10	Impaired
			Atrazine	NA	NA	NA	16	2	Impaired
	Village Creek	CE01	Dissolved Oxygen	1	0	NA	Continuous	Multiple	Impaired
			Manganese	1	1	2002	6	0	Delist
	Johnson Creek	CCAFFA1	Dissolved Oxygen	1	1	1997	Continuous	Multiple	Impaired
	Pond Creek	CCFFD1	Dissolved Oxygen	1	1	1997	Continuous	Multiple	Impaired
	Elm River	CD01	Atrazine	8	3	2002	16	2	Impaired
		CD02	Dissolved Oxygen	3	2	2003	Continuous	Multiple	Impaired
	Seminary Creek	CDGFLA1	Dissolved Oxygen	1	1	1998	Continuous	Multiple	Impaired
	Seminary Creek	CDFGLC6	Dissolved Oxygen	1	1	1998	Continuous	Multiple	Impaired
	Big Muddy Creek	CJ06	Dissolved Oxygen	3	1	2002	Continuous	Multiple	Impaired
			Manganese	2	1	2002	6	0	Delist
	Little Muddy Creek	CJA02	Dissolved Oxygen	4	3	2002	Continuous	Multiple	Impaired
			Manganese	4	3	2002	4	2	Impaired
	Big Muddy Diversion Ditch	CJAE01	Dissolved Oxygen	1	0	2000	Continuous	Multiple	Impaired
Mary's River/ North Fork Cox Creek	North Fork Cox Creek	IIHA31	Sulfates	2	2	1995	4	4	Impaired
			TDS	2	2	1995	4	4	Impaired
	North Fork Cox Creek	IIHA-STC1	TDS	1	1	1995	4	2	Impaired
	Maxwell Creek	IIKSPC1A	Dissolved Oxygen	2	2	19999	Continuous	Multiple	Impaired
	Randolph County Lake	RIB	Total Phosphorus	11	3	1993	6	2	Impaired
Sangamon River/ Lake Decatur	Owl Creek	EZV	Dissolved Oxygen	3	1	1998	Continuous	Multiple	Impaired

Table 4-1: Impairment Status

Watershed	Stream Name	Segment	Parameter of Concern	Historic Data Count	Number of Historic Violations	Date of Last Recorded Violation	Stage 2 Data Count	Number of Violations	Suggested Status
Shoal Creek	Shoal Creek	OI05	Dissolved Oxygen	3	1	2002	Continuous	0	Delist
	Locust Fork	OIC01	Dissolved Oxygen	3	1	1991	Continuous	Multiple	Impaired
			Manganese	3	1	1991	2	0	Delist
	Chicken Creek	OIO09	Dissolved Oxygen	2	1	1991	0	0	No Water
	Cattle Creek	OIP10	Dissolved Oxygen	3	2	1991	Continuous	Multiple	Impaired
			Ammonia	3	1	1991	1	0	Delist
			TDS	3	1	1991	1	0	Delist
South Fork Saline River/ Lake of Egypt	Briers Creek	ATHS01	Zinc	2	2	1993	13	0	Delist
			Iron	3	3	1993	16	3	Impaired
			Manganese	3	3	1993	8	4	Impaired
			Silver	3	1	1993	12	0	Delist
			Sulfates	3	3	1993	16	6	Impaired
			TDS	2	1	1993	16	9	Impaired
			pH	3	3	1993	Continuous	0	Delist
			Dissolved Oxygen	2	1	1993	Continuous	1	Impaired
	East Palzo Creek	ATHV01	Copper	3	2	1993	5	0	Delist
			Iron	3	3	1993	7	1	Impaired
			Manganese	3	3	1993	7	3	Impaired
			TDS	0		-	7	1	Impaired
			pH	3	3	1993	Continuous	Multiple	Impaired
	South Fork Saline River	ATH14	Dissolved Oxygen	8	1	2000	Continuous	0	Delist
South Fork Sangamon/ Lake Taylorville	South Fork Sangamon River	EO13	Dissolved Oxygen	1	1	1989	Continuous	Multiple	Impaired
			Boron	1	1	1989	6	0	Delist
			Manganese	1	1	1989	6	2	Impaired

* Continuous data did not violate the 5.0 mg/L instantaneous DO standard, however, continuous data collected at site N13 experienced more than 16 hours below 6.0 mg/L in a 24 hour period

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For Appendices, please contact Jennifer Clarke at the Illinois EPA for information.

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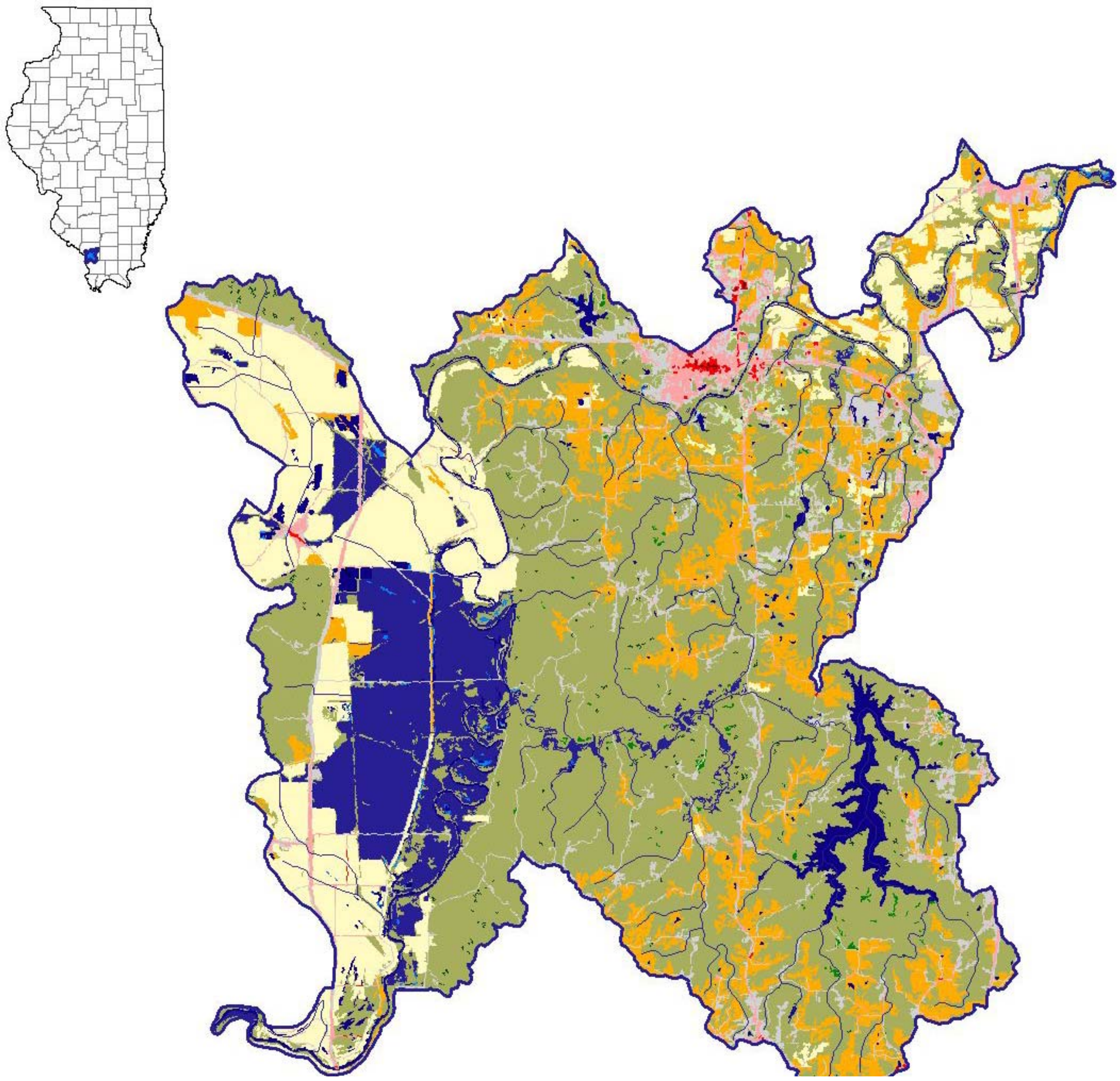
TMDL Development for the Cedar Creek/Cedar Lake Watershed, Illinois

FINAL REPORT
September 6, 2007



TETRA TECH

Illinois Environmental Protection Agency

TMDL Development for the Cedar Creek/Cedar Lake Watershed, Illinois

FINAL REPORT

September 6, 2007

Submitted to:
Illinois Environmental Protection Agency
1021 N. Grand Avenue East
Springfield, IL 62702

Submitted by:
Tetra Tech, Inc.
Water Resources TMDL Center

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1.0 INTRODUCTION

A total maximum daily load (TMDL) is defined as "the sum of the individual wasteload allocations for point sources and load allocations for nonpoint sources and natural background" such that the capacity of the waterbody to assimilate pollutant loadings is not exceeded. A TMDL is also required to be developed with seasonal variations and must include a margin of safety that addresses the uncertainty in the analysis. The overall goals and objectives in developing TMDLs for the listed waterbodies in the Cedar Creek watershed include:

- Assess the water quality of the impaired waterbodies and identify key issues associated with the impairments and potential pollutant sources.
- Use the best available science and available data to determine the maximum load the waterbodies can receive and fully support all of their designated uses.
- Use the best available science and available data to determine current loads of pollutants to the impaired waterbodies.
- If current loads exceed the maximum allowable load, determine the load reduction that is needed.
- Identify feasible and cost-effective actions that can be taken to reduce loads.
- Inform and involve the public throughout the project to ensure that key concerns are addressed and the best available information is used.
- Submit a final TMDL report to USEPA for review and approval.

The Illinois Environmental Protection Agency (IEPA) has a three-stage approach to TMDL development. The stages are:

1) Stage 1 was completed by the consulting firm Camp Dresser & McKee Inc. (CDM) in January 2007 and involved characterization of the watershed, assessment of the available water quality data, identification of additional data needs for the development of credible TMDLs and recommendation of potential technical approaches for TMDL development (Appendix D).
2) Stage 2 was completed by CDM in March 2007 and involved the collection of additional chemical water quality and continuous dissolved oxygen data as well channel morphology and discharge measurements at twenty-five monitoring locations (Figure 1 and Appendix E). One segment (Big Muddy River segment N99) has been delisted for sulfates since the Stage 1 report due to Stage 2 Data (Table 1). Additionally, the Cedar Lake manganese impairment is being recommended for de-listing as discussed in Section 2.0.
3) This report addresses Stage 3 of the project which involves modeling and TMDL analysis of the parameters of concern for the impaired segments. Stage 3 will also include the development of a project implementation plan, to be completed during Fall 2007.

Table 1. Delisted Cedar Creek/Cedar Lake Segment

Segment	Segment ID	Parameter	Standard	Original Listing Violation # exceed/#samples	2006 Stage 2 # exceed/# samples
Big Muddy River	N99	Sulfates	500 mg/l	0 of 3	0 of 4

2.0 BACKGROUND

The Big Muddy River watershed includes the Cedar Creek/Cedar Lake watershed and has a drainage area of approximately 2,360 square miles. The Cedar Creek/Cedar Lake watershed is made up of five 12 digit hydrologic unit codes (071401061201 through 071401061205) as defined by the U.S. Geological Survey (USGS). The watershed is located in south-western Illinois near the Missouri border (Figure 1). The portion of the watershed addressed in this report has an area of 200 square miles and encompasses two counties with Jackson County covering 92 percent of the watershed and Union County covering 8 percent. Forest is the dominant land cover in this watershed (Figure 2).

Table 2 identifies the Cedar Creek/Cedar Lake watershed's impaired segments for which TMDLs are addressed in this report. The watershed received a High priority ranking for TMDL development by IEPA because it contains one or more waterbodies that are less than full supporting for Public Water Supply (IEPA, 2006).

It should be noted that Cedar Lake was originally listed as impaired for the designated Public Water Supply use due to manganese. However, additional review of the data indicates that the samples causing the impairment were from below the depth of the raw water intake and thus cannot be directly assessed against the Public Water Supply criterion of 150 µg/L. 35 Illinois Administrative Code 302.301 indicates that the Public Water Supply criterion (of 150 µg/L for manganese) applies only at the point that water is withdrawn. Samples taken at this point (such as those collected in 2005) are below this criterion (Table 3). Because the samples are also below the General Use criterion of 1,000 µg/L (set to protect aquatic life), Cedar Lake will be recommended for de-listing in the 2008 Integrated Report and no TMDLs have been developed. Little Cedar Lake was confirmed as impaired for manganese and a TMDL is presented in Section 5.4.2.

Table 2. 2006 303(d) List Information for the Cedar Creek/Cedar Lake Watershed

Waterbody Name	Waterbody Segment	Segment and Lake Size (Segment Length in Miles, Lake Area in Acres)	Cause of Impairment	Impaired Designated Use
Big Muddy River	N-99	28.49	**Dissolved Oxygen**	Aquatic Life
			Sedimentation/Siltation	Aquatic Life
			Total Suspended Solids	Aquatic Life
Cedar Creek	NA-01	3.98	**Fecal Coliform**	Primary Contact Recreation
Cave Creek	NAC-01	8.9	**Dissolved Oxygen**	Aquatic Life
Murphysboro Lake	RND	143	**Phosphorus**	Aesthetic Quality
Cedar Lake	RNE	1800	Manganese[1]	Public Water Supplies
			Mercury	Fish Consumption
Little Cedar Lake	RNZM	70	**Manganese**	Public Water Supplies
			Impairment Unknown	Aesthetic Quality

Note: Bold font indicates cause will be addressed in this report.
[1] IEPA is recommending that Cedar Lake be de-listing for manganese in the 2008 Integrated Report; no TMDLs have been developed.

Table 3. Cedar Lake manganese data. The 2003 data represent mid-depth samples whereas the 2005 data represent intake depth samples.

Date	Manganese µg/L	Sample Depth
5/19/2003	47	19'
6/18/2003	34	19'
7/14/2003	73	18'
8/27/2003	880	19'
10/6/2003	97	19'
5/3/2005	37	15'
6/6/2005	36	15'
7/25/2005	28	15'
8/11/2005	36	14'
10/11/2005	140	13'

Table 4. 2005 Little Cedar Lake manganese data confirming impairment (3 of 5 samples exceed the water quality standard of 150 µg/L).

Date	Manganese µg/L	Sample Depth	Total Depth
5/11/2005	130	5.5'	23'
6/14/2005	140	5'	24'
8/1/2005	160	6'	23'
8/17/2005	280	5.5'	21'
10/19/2005	570	4.5'	24'

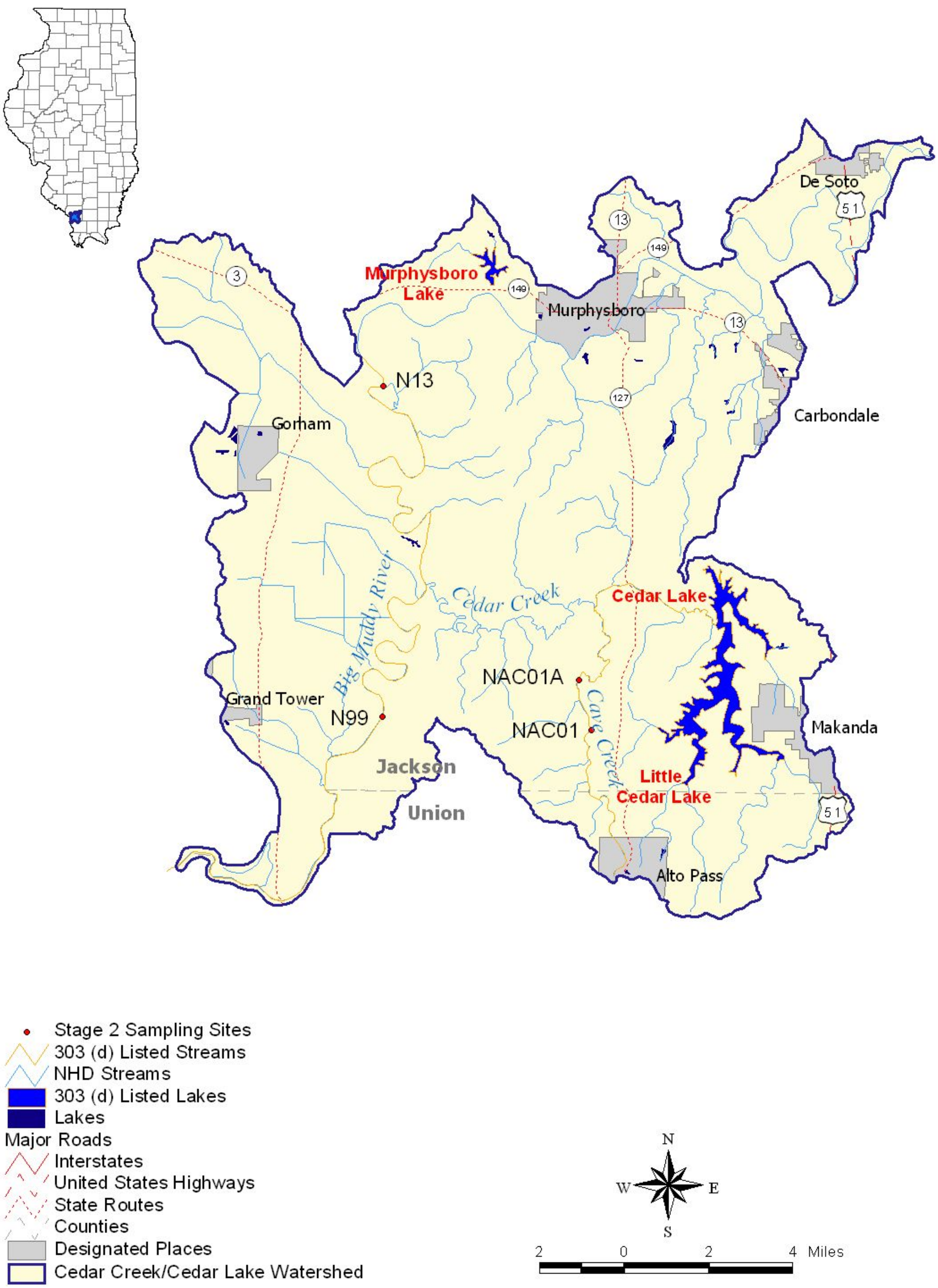

Figure 1. Location of the Cedar Creek/Cedar Lake Watershed

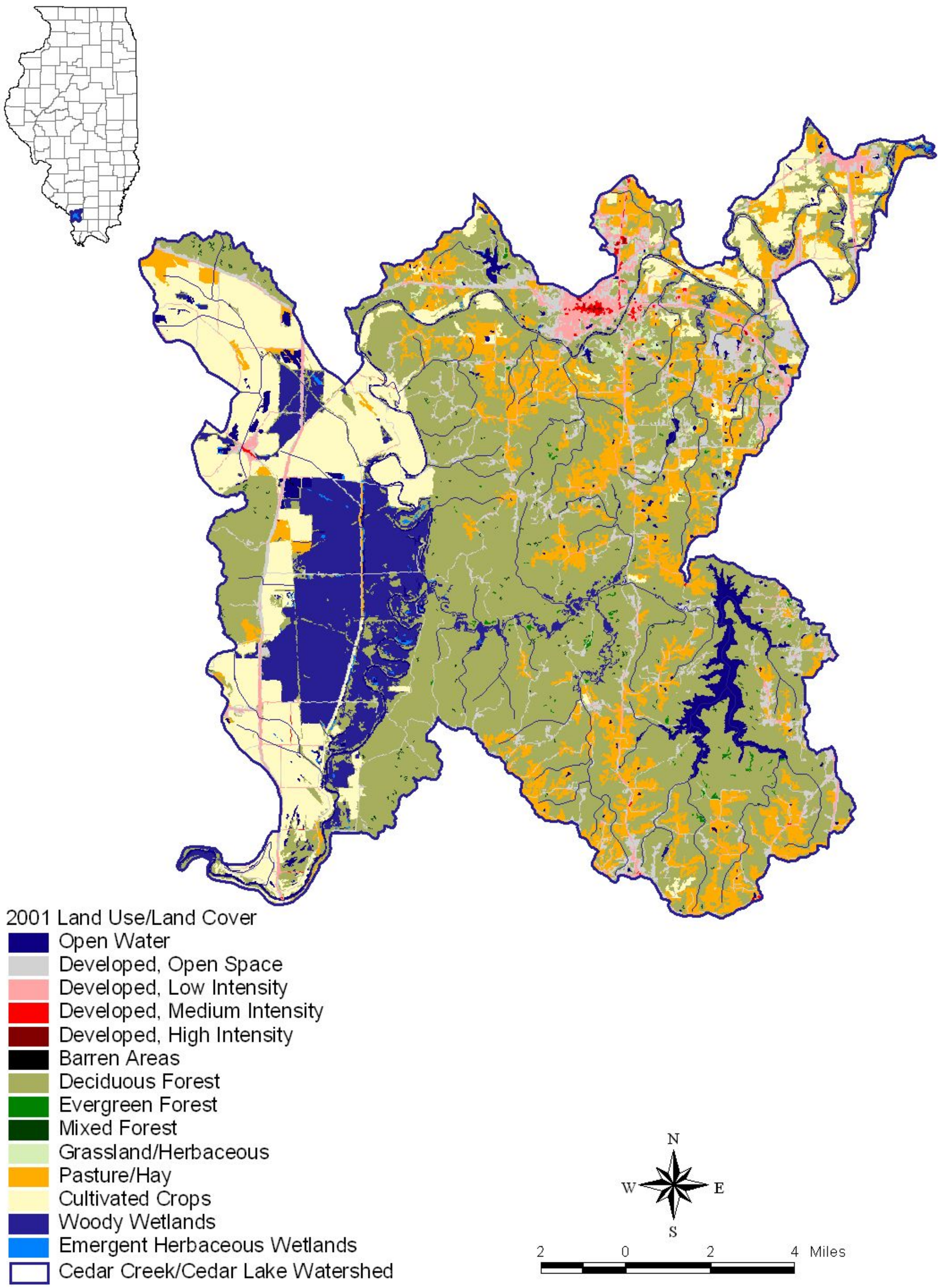

Figure 2. Land Use in the Cedar Creek/Cedar Lake Watershed

3.0 APPLICABLE WATER QUALITY STANDARDS

The purpose of developing a TMDL is to identify the pollutant loading that a waterbody can receive and still achieve water quality standards. Under the Clean Water Act, every state must adopt water quality standards to protect, maintain, and improve the quality of the nation's surface waters. These standards represent a level of water quality that will support the Clean Water Act's goal of "swimmable/fishable" waters. Water quality standards consist of three components: designated uses, numeric or narrative criteria, and an antidegradation policy. A description of the water quality standards that apply to this TMDL is presented below and detailed comparisons of the available water quality data to the standards are provided in Appendix D and Appendix E.

3.1 Use Support Guidelines

IEPA uses rules and regulations adopted by the Illinois Pollution Control Board (IPCB) to assess the designated use support for Illinois waterbodies. The following are the use support designations provided by the IPCB that apply to water bodies in the Cedar Creek/Cedar Lake watershed:

General Use Standards - These standards protect for aquatic life, wildlife, agricultural, primary contact (where physical configuration of the waterbody permits it, any recreational or other water use in which there is prolonged and intimate contact with the water involving considerable risk of ingesting water in quantities sufficient to pose a significant health hazard, such as swimming and water skiing), secondary contact (any recreational or other water use in which contact with the water is either incidental or accidental and in which the probability of ingesting appreciable quantities of water is minimal, such as fishing, commercial and recreational boating, and any limited contact incident to shoreline activity), and most industrial uses. These standards are also designed to ensure the aesthetic quality of the state's aquatic environment.

Public and food processing water supply standards – These standards are cumulative with the general use standards and apply to waters of the state at any point at which water is withdrawn for treatment and distribution as a potable supply to the public or for food processing.

Water quality standards used for TMDL development in the Cedar Creek/Cedar Lake watershed are listed below for lakes (Table 5) and streams (Table 6).

Table 5. Summary of Water Quality Standards for the Cedar Creek/Cedar Lake Watershed Lake Impairments.

Parameter	Units	General Use Water Quality Standard	Public and Food Processing Water Supplies	Section for Regulatory Citation[a]
Manganese	µg/L	1,000	150	General use: 302.208 Public Water Supply: 302.304
Total Phosphorus	mg/L	0.05[b]	No numeric standard	302.205

[a] All IEPA water quality standards are published by the Illinois Pollution Control Board under Title 35: Environmental Protection Subtitle C: Water Pollution Chapter I: Pollution Control Board. Part 302. Water Quality Standards. Subpart A: General Water Quality Provisions.
[b] Standard only applies in lakes/reservoirs that are greater than 20 acres in surface area and in any stream at the point where it enters such a lake/reservoir.

Table 6. Summary of Water Quality Standards for the Cedar Creek/Cedar Lake Watershed Stream Impairments.

Parameter	Units	General Use Water Quality Standard	Public and Food Processing Water Supplies	Section for Regulatory Citation[a]
Dissolved Oxygen	mg/L	5.0 instantaneous minimum	No numeric standard	302.206
		6.0 minimum during at least 16 hours of any 24 hour period		
Fecal coliform[b]	#/100 mL	400 in <10% of samples[c]	Geomean[d] <2,000	General use: 302.209 Public Water Supply: 302.306
		Geomean < 200[d]		

[a]All IEPA water quality standards are published by the Illinois Pollution Control Board under Title 35: Environmental Protection Subtitle C: Water Pollution Chapter I: Pollution Control Board. Part 302. Water Quality Standards. Subpart A: General Water Quality Provisions.
[b] Fecal coliform standards are for the recreation season only (May through October)
[c] Standard shall not be exceeded by more than 10% of the samples collected during a 30 day period
[d] Geometric mean based on minimum of 5 samples taken over not more than a 30 day period

4.0 TECHNICAL ANALYSIS

This section of the report addresses the technical approaches applied to calculate TMDLs for fecal coliform, phosphorus, and dissolved oxygen. Load duration curves were used to estimate the current and allowable loads of fecal coliform for impaired streams in the Cedar Creek/Cedar Lake watershed. QUAL2K modeling was used to simulate instream dissolved oxygen concentrations for impaired streams in the Cedar Creek/Cedar Lake watershed and pollutant load reductions that are needed to meet the water quality standards. BATHTUB was used to model total phosphorus in Murphysboro Lake and Little Cedar Lake. Table 7 presents the listed water bodies and the corresponding modeling approach used to address each TMDL.

Table 7. 303(d) List Information and Modeling Approaches for the Cedar Creek/Cedar Lake Watershed

Waterbody Name	Segment	Cause of Impairment	Modeling Approach
Big Muddy River	N-99	Dissolved Oxygen	QUAL2K
Cedar Creek	NA-01	Fecal Coliform	Load Duration Curve
Cave Creek	NAC-01	Dissolved Oxygen	QUAL2K
Murphysboro Lake	RND	Phosphorus	BATHTUB
Little Cedar Lake	RNZM	Manganese[a]	BATHTUB

[a] The Little Cedar Lake manganese impairment is believed to be related to eutrophication issues and therefore phosphorus was used as a surrogate pollutant as discussed further in Section 5.4.

4.1 Load Duration Curves

Load reductions for fecal coliform were determined through the use of load duration curves. The load duration curve demonstrates the allowable loadings of a pollutant at different flow regimes expected to occur in the impaired segment and still maintain the water quality standard. The following steps are taken:

1. A flow duration curve for the stream is developed by generating a flow frequency table and plotting the data points.

2. The flow curve is translated into a load duration (or TMDL) curve. To accomplish this, each flow value is multiplied by the water quality standard and by a conversion factor. The resulting points are graphed.

3. Each water quality sample is converted to a load by multiplying the water quality sample concentration by the average daily flow on the day the sample was collected and a conversion factor. Then, the individual loads are plotted on the TMDL graph.

4. Points plotting above the curve represent deviations from the water quality standard and the daily allowable load. Those plotting below the curve represent compliance with standards and the daily allowable load.

5. The area beneath the TMDL curve is interpreted as the loading capacity of the stream. The difference between this area and the area representing the current loading conditions is the load that must be reduced to meet water quality standards.

Fecal coliform loadings were calculated for Cedar Creek segment NA01. Segment NA01 starts at the northwestern area of Cedar Lake and ends at the confluence of the Big Muddy River (Figure 3).

Fecal coliform data from sampling stations NA-01 (Figure 3) were used to assess fecal coliform loadings to stream Segment NA01 as data for this station are representative of fecal coliform loadings to the segment. The necessary reductions for fecal coliform are presented in Section 5.1.

The stream flows displayed on a load duration curve may be grouped into various flow regimes to aid with interpretation of the load duration curves. The flow regimes are typically divided into 10 groups, which can be further categorized into the following five “hydrologic zones” (Cleland, 2005):

- High flow zone: stream flows that plot in the 0 to 10-percentile range, related to flood flows.
- Moist zone: flows in the 10 to 40-percentile range, related to wet weather conditions.
- Mid-range zone: flows in the 40 to 50 percentile range, median stream flow conditions;
- Dry zone: flows in the 60 to 90-percentile range, related to dry weather flows.
- Low flow zone: flows in the 90 to 100-percentile range, related to drought conditions.

The load duration approach helps to identify the issues surrounding the impairment and to roughly differentiate between sources. Table 8 summarizes the relationship between the five hydrologic zones and potentially contributing source areas.

The load reduction approach also considers critical conditions and seasonal variation in the TMDL development as required by the Clean Water Act and EPA’s implementing regulations. Because the approach establishes loads based on a representative flow regime, it inherently considers seasonal variations and critical conditions attributed to flow conditions.

Table 8. Relationship Between Load Duration Curve Zones and Contributing Sources.

Contributing Source Area	Duration Curve Zone				
	High	Moist	Mid-Range	Dry	Low
Point source				M	H
Livestock direct access to streams				M	H
On-site wastewater systems	M	M-H	H	H	H
Riparian areas		H	H	M	
Stormwater: Impervious		H	H	H	
Combined sewer overflow (CSO)	H	H	H		
Stormwater: Upland	H	H	M		
Field drainage: Natural condition	H	M			
Field drainage: Tile system	H	H	M-H	L-M	
Bank erosion	H	M			
Note: Potential relative importance of source area to contribute loads under given hydrologic condition (H: High; M: Medium; L: Low)					

4.1.1 Stream Flow Estimates

Daily stream flows are needed to apply the load duration curve. There is one USGS station with continuous flow data in the Cedar Creek/Cedar Lake watershed (Figure 3). USGS station 05599500 is located on the Big Muddy River near the city of Murphysboro.

Stream flows for monitoring station NA-01 were extrapolated from the USGS station 05599500, using a multiplier based upon a comparison of the two drainage areas. The drainage area of the water quality monitoring station NA-01 is 34.96 square miles and the drainage area of flow gage 05599500 is 2169 square miles. The drainage area ratio therefore equals 0.016 and the daily flows at the flow gage were multiplied by 0.016 to estimate the daily flows at station NA-01.

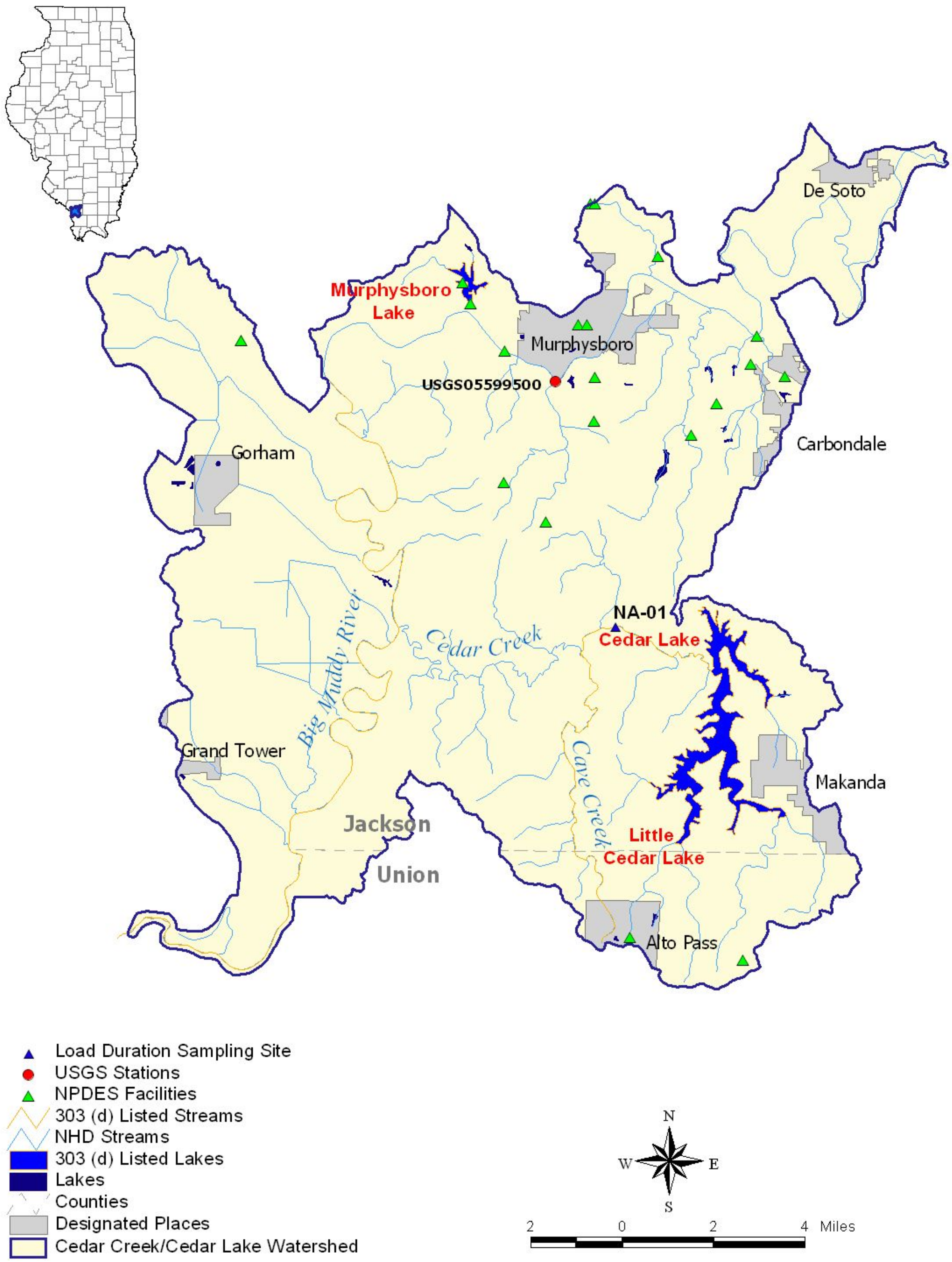

Figure 3. USGS and Load Duration Stations in the Cedar Creek/Cedar Lake Watershed

4.2 QUAL2K Model

The QUAL2K water quality model was selected for the development of Cedar Creek/Cedar Lake watershed dissolved oxygen TMDLs. QUAL2K is supported by U.S. EPA and has been used extensively for TMDL development and point source permitting issues across the country, especially for issues related to dissolved oxygen concentrations. The QUAL2K model is suitable for simulating hydraulics and water quality conditions of a small river. It is a one-dimensional model with the assumption of a completely mixed system for each computational cell. QUAL2K assumes that the major pollutant transport mechanisms, advection and dispersion, are significant only along the longitudinal direction of flow. The model allows for multiple waste discharges, water withdrawals, tributary flows, and incremental inflows and outflows. The processes employed in QUAL2K address nutrient cycles, algal growth, and dissolved oxygen dynamics. Two QUAL2K models were set up for each impaired stream to address low dissolved oxygen conditions. The impaired streams are Big Muddy River (segment N-99) and Cave Creek (segment NAC-01).

Illinois' water quality standard requires a minimum dissolved oxygen concentration of 5 mg/L at all times within the impaired streams and a 6.0 minimum during at least 16 hours of any 24 hour period. Once the model was setup and calibrated, a series of scenarios were run to evaluate the most likely cause of the observed low dissolved oxygen. These results are summarized in Section 5.2 and 5.3 and the QUAL2K modeling assumptions and results are provided in Appendix C.

4.3 BATHTUB Model

BATHTUB was selected for modeling water quality in Murphysboro Lake and Little Cedar Lake. BATHTUB performs steady-state water and phosphorus balance calculations in a spatially segmented hydraulic network, which accounts for pollutant transport and sedimentation. In addition, the BATHTUB model automatically incorporates internal phosphorus loadings into its calculations. Eutrophication-related water quality conditions (e.g., phosphorus, nitrogen, chlorophyll a, and transparency) are predicted using empirical relationships previously developed and tested for reservoir applications (Walker, 1987). BATHTUB was determined to be appropriate because it addresses the primary parameter of concern (phosphorus) and has been used previously for reservoir TMDLs in Illinois and elsewhere. USEPA also recommends the use of BATHTUB for phosphorus TMDLs (USEPA, 1999).

The BATHTUB model requires the following data to configure and calibrate: tributary flows and concentrations, reservoir bathymetry, in-lake water quality concentrations, and global parameters such as evaporation rates and annual average precipitation. Lake bathymetry data were available from IEPA's Stage 1 sampling data and maps of the lakes and are summarized in Table 9.

Table 9. Bathymetry Data for the Cedar Creek/Cedar Lake Watershed Lakes.

Lake	Parameter	Value
Murphysboro Lake	Normal Pool Volume (ac-ft)	2,375
	Normal Pool Surface Area (ac)	143
	Maximum Depth (ft)	29
	Mean Depth (ft)	16.6
Little Cedar Lake	Normal Pool Volume (ac-ft)	672
	Normal Pool Surface Area (ac)	70
	Maximum Depth (ft)	25
	Mean Depth (ft)	9.6

In a typical BATHTUB model application, tributary flows and corresponding phosphorus concentrations are input to the model, and simulated inlake concentrations are compared to a limited set of water quality samples. For Murphysboro Lake and Little Cedar Lake, watershed and tributary data were not available to estimate loads to the lake. As a result, watershed loads were not estimated and instead a “reverse” BATHTUB model was created where average inlake concentrations were used to estimate the load required given annual or summer season flow volume and lake bathymetry data. No adjustment of the phosphorus calibration factor was needed with this simulation because the loads were set by year to match average observed concentrations. An annual simulation was required for Murphysboro Lake to meet the BATHTUB turnover ratio criteria, while a summer (May through September) simulation was used for Little Cedar Lake.

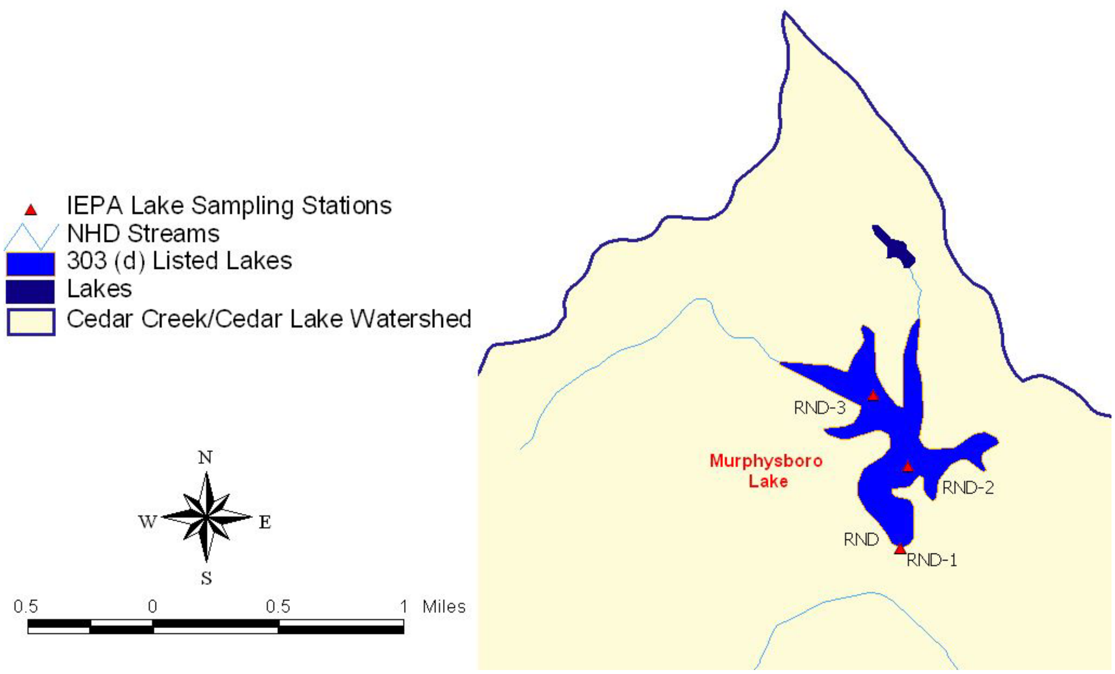

Figure 4. Murphysboro Lake Monitoring Stations

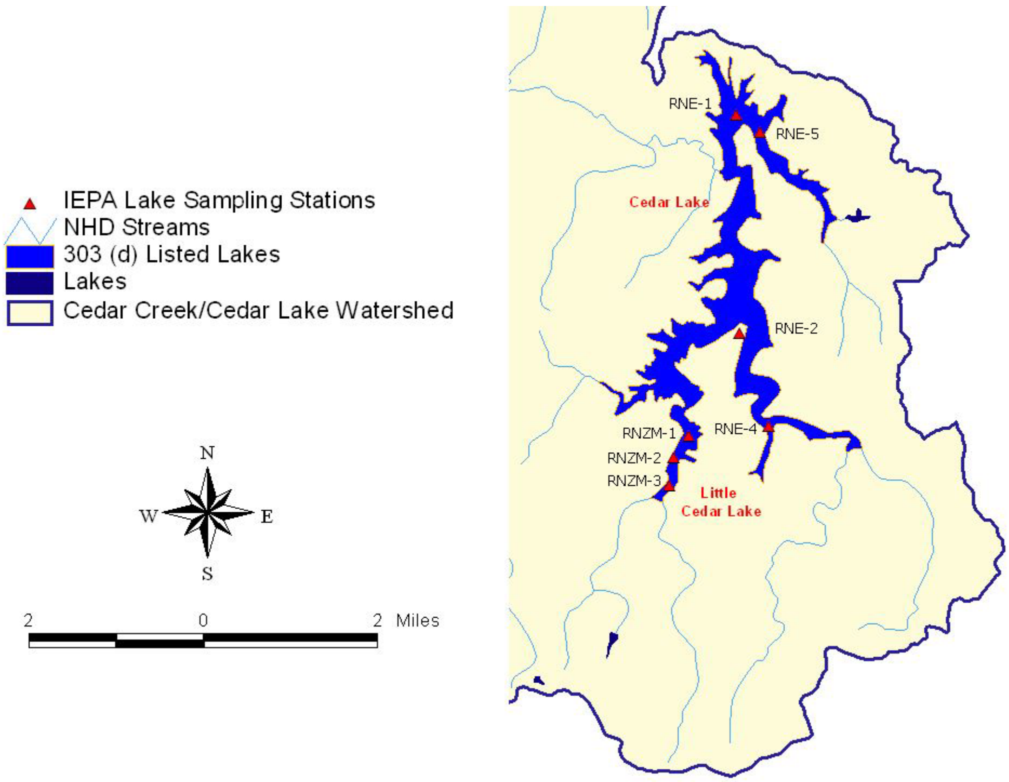

Figure 5. Cedar Lake and Little Cedar Lake Monitoring Stations

Flow rates to Murphysboro Lake and Little Cedar Lake were estimated by area weighting flows observed at USGS station 05599500 on the Big Muddy River near the city of Murphysboro, Illinois. Murphysboro Lake drains 7 square miles and Little Cedar Lake has a drainage area of 9 square miles.

Watershed loads and total flow volumes to the Cedar Creek/Cedar Lake Watershed lakes are summarized for the annual and summer season periods in Table 10 and Table 11.

Table 10. Annual Watershed Loading to Murphysboro Lake.

Lake	Year	Stream Flow (MG)	TP Load (ton)
Murphysboro Lake	1994	1,281	1.05
	1997	1,714	1.45
	2000	1,046	0.35
	2003	1,350	1.36

Table 11. Summer Season Watershed Loading to Cedar Lake and Little Cedar Lake.

Lake	Summer	Stream Flow (MG)	TP Load (ton)
Little Cedar Lake	1990	4,373	0.61
	1991	798	0.44
	1994	1,576	0.59
	1997	3,223	0.92
	2001	664	0.14
	2002	5,259	0.39
	2003	4,152	1.50
	2005	802	0.21

The BATHTUB model requires input of the fraction of inorganic nutrient load. Phosphate data were not available to estimate the inorganic phosphorus fraction, so a value of 0.3 was assumed based on similar lakes modeled previously in Illinois.

The USACOE BATHTUB model (Walker, 1987) was set up to simulate nutrient responses in Murphysboro Lake for the years 1994 to 2003 and from 1990 to 2005 in Little Cedar Lake to correspond with available water quality data. Second order, available nutrient models were used to simulate phosphorus in each lake.

Internal phosphorus loading is accounted for in BATHTUB by application of a net phosphorus sedimentation rate (settling minus resuspension). However, internal loads for both lakes were not calculated as tributary measurements were unavailable.

The BATHTUB model includes rates of direct deposition to the lake surface for total phosphorus. However, direct atmospheric deposition of phosphorus to a lake surface is generally considered insignificant compared to watershed loading rates. In studying phosphorus inputs to Lake Michigan, USGS determined that atmospheric deposition rates in agricultural areas were approximately 0.18 lb/ac/yr (Robertson, 1996). This rate was used for all simulation years in both lakes.

5.0 TMDL

A TMDL is the total amount of a pollutant that can be assimilated by the receiving water while still achieving water quality standards. TMDLs can be expressed in terms of mass per time or by other appropriate measures. TMDLs are composed of the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources (including natural background levels). In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this is defined by the equation:

$$\text{TMDL} = \sum \text{WLAs} + \sum \text{LAs} + \text{MOS}$$

A summary of the TMDL allocations for the Cedar Creek/Cedar Lake watershed is presented in this section of the report, organized according to pollutants and modeling analysis.

5.1 Loading Capacity for Fecal Coliform in Cedar Creek

A TMDL must identify the loading capacity of a waterbody for the applicable pollutant. USEPA regulations define loading capacity as the greatest amount of a pollutant that a waterbody can receive without violating water quality standards. The loading capacity is often referred to as the “allowable” load. The following sections provide load duration curve analysis for Segment NA 01 of Cedar Creek. Table 12 lists the fecal coliform load reductions required at the stream segment. Appendix A presents the entire load duration analysis performed for Cedar Creek at segment NA 01.

5.1.1 Loading Capacity of Stream Segment NA-01

Existing and allowable loads were calculated for Cedar Creek at station NA-01 located downstream of Cedar Lake. This location drains 35 square miles and land use/land cover is primarily forest (64%) followed by pasture/hay (17%), open water (9%), and developed/open land (8%). A total of 114 fecal coliform samples were available for the load duration analysis (Appendix B). There are two NPDES entities upstream of this point:

- Alto Pass WTP (permit number IL0000914)
- Union Jackson Farm Labor Assn (permit number IL0047767)

Both the geometric mean (200 cfu/100 mL) and the not-to-exceed (400 cfu/100 mL) components of Illinois’s water quality standard were evaluated as part of this study. The results of the load duration analysis based on the not-to-exceed 400 cfu/100 mL standard are presented in Appendix A for information purposes. The TMDL is based on meeting the geometric mean component of the standard because it is more restrictive and ensures both standards will be met. The Illinois fecal coliform standard is designated for the months of May to October and so only fecal coliform data collected during these months were used for load duration analysis.

Load duration analysis for this station was completed using only the data collected during the recreation season (May through October) and after December 31, 1999 (Appendix A). The load duration analysis is therefore reflective of current conditions to which the 200 cfu/100 mL geometric mean water quality standard is applicable.

Table 12 presents the TMDL summary for this assessment location. Results of the load duration analysis indicate that fecal coliform load reductions are needed in Cedar Creek during low flows (67 percent), moist flow condition (27 percent), and high flows (17 percent).

The specific sources of fecal coliform are listed as unknown for this segment, but the potential sources of fecal coliform may include livestock, private sewage systems, discharges from permitted point sources, and wildlife. Livestock and animal feeding operations are prevalent throughout Jackson and Union Counties (Illinois EPA, 2007). Private surface systems are also common in the area and if not treated properly can release untreated sewage to local waterways. It has been estimated that statewide between 20 and 60 percent of surface discharging systems are failing or have failed (Illinois EPA, 2004) suggesting that such systems may be a significant source of pollutants. The two NPDES dischargers in this watershed are not considered significant sources of fecal coliform upstream of this segment due to their low flows.

Table 12. Fecal Coliform TMDL Summary for Stream Segment NA 01

NA01 TMDL		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	**TMDL Component**	**0-10**	**10-40**	**40-60**	**60-90**	**90-100**
Fecal Coliform (Million/day)	Current Load	563,433	126,516	14,354	7,808	15,143
	TMDL= LA+WLA+MOS	**521,317**	**102,528**	**38,330**	**15,143**	**5,600**
	LA	469,008	92,098	34,320	13,452	4,863
	Future Growth Reserve (0%)	0	0	0	0	0
	WLA: Alto Pass WTP	85	85	85	85	85
	WLA: Union Jackson Farm Labors Assn	92	92	92	92	92
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	52,132	10,253	3,833	1,514	560
	TMDL Reduction (%)	17%	27%	0%	0%	67%

5.1.2 Waste Load Allocations

The following two NPDES permittees discharge upstream of the impaired segment of Cedar Creek:

- Alto Pass WTP (IL0000914)
- Union Jackson Farm Labors Assn (IL0047767)

No WLA is recommended for the Alto Pass WTP as no fecal coliform is associated with its effluent.

The Union Jackson facility is a sewage treatment plant and sewage from treatment plants treating domestic and/or municipal waste contain fecal coliform–it is indigenous to sanitary sewage. In Illinois, a number of these treatment plants, including the Union Jackson facility, have applied for and received disinfection exemptions which allow a facility to discharge wastewater without disinfection. All of these treatment facilities are required to comply with the geometric mean fecal coliform water quality standard of 200 cfu/100 mL at the closest point downstream where recreational use occurs in the receiving water or where the water flows into a fecal-impaired segment. The WLA for the Union Jackson facility was therefore based on its design flow multiplied by 200 cfu/100 mL and the resulting WLA (see Table 13) applies at the end of the disinfection exemption. Facilities with year-round disinfection exemptions may be required to provide IEPA with updated information to demonstrate compliance with these requirements and facilities directly discharging into a fecal-impaired segment may have their year-round disinfection exemption revoked through future NPDES permitting actions.

Table 13. Fecal Coliform Limits and WLA for NPDES Facilities Upstream of Segment NA 01

Facility name	Permit #	Design Average Flow (MGD)	Fecal Coliform Geomean Standard (#/100 mL)	Fecal Coliform WLA (million/day)	Outfall Pipes
Union Jackson Farm Labors Assn	IL0047767	0.0122	200	92	001 STP OUTFALL

5.1.3 Load Allocation

The load allocations are based on subtracting the allocations for WLAs and the MOS from allowable loads and are presented in Table 12. The control of fecal coliform from non point sources such as wildlife and agriculture will be explored during the development of the implementation plan.

5.1.4 Margin of Safety

The Clean Water Act requires that a TMDL include a margin of safety (MOS) to account for uncertainties in the relationship between pollutants loads and receiving water quality. USEPA guidance explains that the MOS may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit (i.e., expressed in the TMDL as loadings set aside for the MOS). The MOS for fecal coliform is an implicit one. Load duration analysis does not address die-off of pathogens therefore the TMDL has a built in margin of safety.

5.1.5 Critical Conditions and Seasonality

TMDLs should also take into account critical conditions and seasonal variations. Critical conditions refer to the periods when greatest reductions of pollutants are needed. The Clean Water Act requires that TMDLs take into account critical conditions for stream flow, loading, and water quality parameters as part of the analysis of loading capacity. From the load duration approach it has been determined that critical conditions for fecal coliform occur during high flow conditions. Both point and nonpoint sources are believed to contribute to fecal coliform loads during these critical periods and the specific sources will be further evaluated during the preparation of an implementation plan. The allocation of point source loads (i.e., the WLA) also takes into account critical conditions by assuming that the facilities will always discharge at their respective maximum design flows.

The Clean Water Act also requires that TMDLs be established with consideration of seasonal variations. Seasonal variations for fecal coliform TMDL are addressed by only assessing conditions during the season when the water quality standard applies (May through October). The load duration approach also accounts for seasonality by evaluating allowable loads on a daily basis over the entire range of observed flows and presenting daily allowable loads that vary by flow.

5.2 Loading Capacity for Dissolved Oxygen in Cave Creek

Cave Creek is listed as impaired due to low dissolved oxygen. The original listing was made based on 1 of 2 dissolved oxygen measurements from 1995 being below the aquatic life water quality criterion of 5 mg/L. The impairment was confirmed based on the Stage 2 sampling which resulted in an additional observation in September 2006 below 5 mg/L. The QUAL2K model was setup and calibrated to the September 2006 sampling data to further investigate the dissolved oxygen issues as explained in Section 4.2. Details of the QUAL2K modeling are provided in Appendix C.

The dissolved oxygen impairment in Cave Creek is believed to be due to an excessive loading of oxygen-consuming material that causes poor water quality during low flow and high temperature conditions. Table 14 indicates the load reductions of carbonaceous biochemical oxygen demand (CBOD) and total ammonia from nonpoint sources that would be needed to achieve both components of IEPA's dissolved oxygen water quality standards. CBOD measures the rate of oxygen uptake by micro-organisms in a sample of water and is an indication of the amount of biodegradable carbon in organic matter. Total ammonia is the sum of ammonia (NH_3) and ammonium (NH_4+) and is significant because the conversion of ammonium to nitrate by bacteria consumes dissolved oxygen. Human-related sources of organic material and ammonia could include runoff from manured areas, livestock operations, and failing household sewage treatment systems. Natural sources, such as leaf fall from vegetation near the water's edge, aquatic plants, and drainage from organically rich areas like swamps and bogs, can also contribute loads of oxygen-consuming material.

Table 14. Pollutant load reductions needed for Cave Creek to achieve dissolved oxygen water quality standards.

Pollutant	Existing Nonpoint Sources (lbs/day)	Reduced Nonpoint Sources (LA) (lbs/day)	Nonpoint Source Percent Reduction	Existing Point Sources (lbs/day)	Reduced Point Sources (lbs/day)	Point Source Percent Reduction	MOS (lb/day)
CBOD	383	256	26%	None	N/A	N/A	28
Total Ammonia	10	6.3	32%	None	N/A	N/A	0.7

N/A = Not Applicable

There is no WLA for the Cave Creek CBOD and total ammonia TMDLs because there are no NPDES facilities discharging to the stream segment. The LA is 256 lbs/day CBOD and 6.3 lbs/day total ammonia. The TMDL includes explicit MOS of 28 lbs/day CBOD and 0.7 lbs/day by reserving 10 percent of the loading capacity. A moderate MOS of ten percent is considered acceptable due to the good calibration of the QUAL2K model for certain parameters but the lack of data that precluded calibration of other parameters (see Appendix C).

5.3 Loading Capacity for Dissolved Oxygen in Big Muddy River

Big Muddy River is listed as impaired due to low dissolved oxygen. The original listing was made based on 1 of 3 dissolved oxygen measurements from 2003 being below the aquatic life water quality criterion of 5 mg/L. The impairment was confirmed based on the Stage 2 sampling from November 2006 which resulted in more than 16 hours below 6.0 mg/L in a 24 hour period. The QUAL2K model was setup and calibrated to the 2006 sampling data to further investigate the dissolved oxygen issues as explained in Section 4.2. Details of the QUAL2K modeling are provided in Appendix C.

The dissolved oxygen impairment in the Big Muddy River is believed to be due to loads of oxygen-consuming material in addition to excessive sediment oxygen demand caused by high algal growths. The excessive algal growths, in turn, are believed to be associated with excessive loadings of nitrogen and phosphorus. This relationship is further explained below.

Algae require a variety of inorganic elements to sustain life. Two of these elements, phosphorus and nitrogen, are needed in significant concentrations to sustain the production of organic plant material. Algae mostly obtain these nutrients from the water column (as opposed to from the air or soil). However, the amount of nitrogen and phosphorus an aquatic plant needs is often significantly higher than the naturally occurring concentrations found in water (Vallentyne, 1974). This phenomenon is referred to as the Limiting Nutrient law, because the concentration of nitrogen and phosphorus in a waterbody almost always limits algae growth (i.e., there simply isn't enough phosphorus or nitrogen present to further organic matter production). Therefore, increasing the amount of nitrogen and phosphorus in a waterbody tends to cause an increase in algae production (assuming all other variables remain the same). Given an infinite amount of nitrogen and phosphorus in the water column, production would increase until another element limited production (most likely carbon or silicon).

Algae produce and consume oxygen in water. During daylight hours, oxygen is produced by photosynthesis. Plants and algae then consume oxygen from the water column at night (respiration). The entire process is part of the natural cycle of most plants, and this cycle causes dissolved oxygen concentrations to fluctuate throughout the water column in a day. Various other processes also produce and consume dissolved oxygen in the water column. Processes that consume oxygen include organic decomposition, respiration by fish and invertebrates, and sediment oxygen demand. Additional dissolved oxygen is produced through atmospheric exchange. Excessive algae cause the diurnal oxygen cycle to expand. Dissolved oxygen becomes extremely high during the daytime, often resulting in oxygen supersaturation (Thomann and Mueller, 1987). This phenomenon was observed in the Big Muddy River during the September 2006 sampling (Figure 7) and indicates a large algal presence. The subsequent die-off of these algae are believed to have caused a large sediment oxygen demand, which contributed to the chronically low dissolved oxygen conditions observed in November 2006 that violated the 6 mg/L component of the state water quality standard (Figure 7).

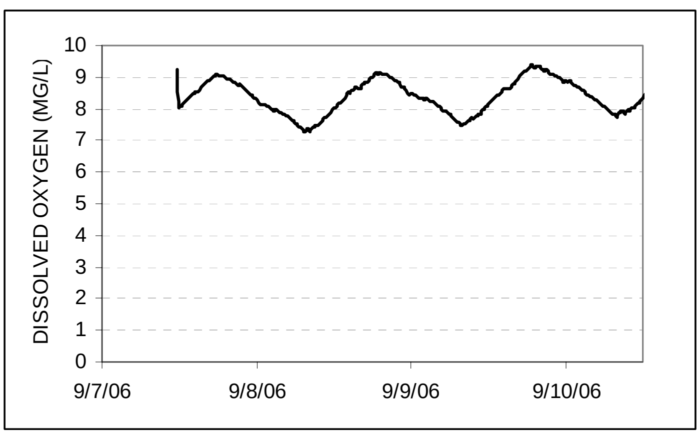

Figure 6. Dissolved oxygen sampling in the Big Muddy River during September 2006.

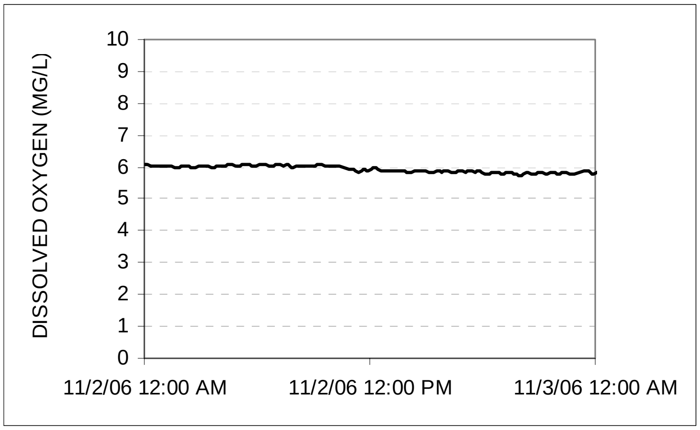

Figure 7. Dissolved oxygen sampling in the Big Muddy River during November 2006.

Table 15 indicates the load reductions of CBOD, total ammonia, organic nitrogen, nitrate, and organic and inorganic phosphorus that are needed to achieve both components of IEPA's dissolved oxygen water quality standards. The CBOD, total ammonia, and organic nitrogen reductions are needed to control the load of oxygen-consuming material, whereas the nitrate, organic phosphorus, and inorganic phosphorus reductions are needed to control the excessive algae growth.

Table 15. Pollutant load reductions needed for the Big Muddy River to achieve dissolved oxygen water quality standards.

Pollutant	Existing Nonpoint Sources (lbs/day)	Reduced Nonpoint Sources (LA) (lbs/day)	Nonpoint Source Percent Reduction	Existing Point Sources (lbs/day)	Reduced Point Sources (lbs/day)	Point Source Percent Reduction	MOS (lb/day)
CBOD	20071	18193	9%	144	144	0%	2021
Total Ammonia	803	508	37%	3	3	0%	57
Organic Nitrogen	531	338	36%	3	3	0%	37
Nitrate	945	595	37%	Unknown	N/A	N/A	66
Organic Phosphorus	165	104	37%	Unknown	N/A	N/A	12
Inorganic Phosphorus	130	82	37%	Unknown	N/A	N/A	9

N/A = Not Applicable

CBOD, total ammonia, and organic nitrogen WLAs for the Big Muddy River TMDL are based on the permitted loads from the Murphysboro Sewage Treatment Plant (NPDES ID IL0023248) that discharges to this segment (see Appendix D). WLAs for nitrate, organic phosphorus, and inorganic phosphorus were not established because there is no information on the current loads from these facilities and because nonpoint sources are considered to be much more significant. The TMDL includes explicit margins of safety by reserving 10 percent of the loading capacity (see last column in Table 15). A moderate MOS of ten percent is considered acceptable due to the good calibration of the QUAL2K model for certain parameters but the lack of data that precluded calibration of other parameters (see Appendix C). The load allocations are based on subtracting the WLA and MOS from the loading capacity of the stream and are shown in the third column of Table 15).

5.4 Loading Capacity for Murphysboro Lake and Little Cedar Lake

This section of the report presents the TMDL results for Murphysboro Lake and Little Cedar Lake.

5.4.1 Murphysboro Lake Loading Capacity

The BATHTUB model was used to identify the load reductions necessary to achieve the target concentration of 0.05 mg/L total phosphorus in Murphysboro Lake. The total phosphorus target for Murphysboro Lake is 0.05 mg/L. To meet the target during all years, a 42 percent reduction of phosphorus load is required. Table 16 shows the annual average total phosphorus concentrations if a 42 percent reduction is implemented.

Table 16. Average Total Phosphorus Concentration in Murphysboro Lake with 42 Percent Reduction in Loading

Year	Murphysboro Lake TP (mg/L)
1994	0.0437
1997	0.0464
2000	0.0255
2003	0.0496
Average	0.0413

5.4.2 Little Cedar Lake Loading Capacity

Little Cedar Lake is listed as being impaired due to manganese, which is considered to be related to the high phosphorus concentrations. Excessive phosphorus loadings are believed to be exerting negative effects on the aquatic ecosystem by increasing algal and aquatic plant life production (Sharpley et al., 1994). Excessive algal production is believed responsible for the manganese impairment because it is leading to anoxic (no dissolved oxygen) conditions in the bottom of the lake. These anoxic conditions, in turn, can lead to the release of manganese from the bottom sediments of the lake. IEPA believes that attaining a total phosphorus target of 0.05 mg/L (the state water quality standard for lakes) will result in shifting plant production back to natural levels, which in turn will result in manganese concentrations falling below the water quality standard of 150 µg/L.

To meet the 0.05 mg/L total phosphorus target during all years, a 76 percent reduction of phosphorus load is required. Table 17 shows the annual average total phosphorus concentrations if a 76 percent reduction is implemented.

Table 17. Average Total Phosphorus Concentration in Little Cedar Lake with 76 Percent Reduction in Loading

Year	Little Cedar Lake TP (mg/L)
1997	0.0492
2005	0.0462
Average	0.0477

5.4.3 Waste Load Allocations

There is one permitted discharger upstream of Little Cedar Lake (the Alto Pass Water Treatment Plant (IL0000914)). However, the Alto Pass Water Treatment Plant uses conventional water treatment whereby very little phosphorus would be expected in the effluent that would flow into Little Cedar Lake. Limited sampling from the plant effluent indicated a total phosphorus concentration of only 0.0065 mg/L, which equates to only 0.0003 kg/day at the plant's average maximum design flow of 0.0112 million gallons per day. Since this load is much less than one percent of the lake's loading capacity, no WLA is recommended as part of the TMDL. The Alto Pass Water Treatment Plant is not considered a significant source to Little Cedar Lake and implementation efforts should be focused on nonpoint source issues.

5.4.4 Load Allocation

The allocation of loads for the Cedar Creek/Cedar Lake watershed Lake TMDLs are summarized in Table 18. The existing loads for Murphysboro Lake are the annual loads to the lake and the loads calculated for Little Cedar Lake are the average summer loads to each lake for the period 1990 to 2005 (in years where observed data were available). The loading capacity was calculated based on the percent reduction from existing loads determined to be necessary from the modeling analysis. Five percent of the loading capacity is reserved for a margin of safety (as required by the Clean Water Act; see Section 5.4.5 for more information on the margin of safety).

Table 18. TMDL Summary for Murphysboro Lake.

Lake	Category	Phosphorus (kg/day)	Phosphorus (lb/day)
Murphysboro Lake[1]	Existing Load	2.88	6.35
	Loading Capacity	1.67	3.68
	Wasteload Allocation	0	0
	Margin of Safety	0.08	0.18
	Load Allocation	1.59	3.51
Little Cedar Lake[2]	Existing Load	5.72	12.61
	Loading Capacity	1.37	3.02
	Wasteload Allocation	0	0
	Margin of Safety	0.07	0.15
	Load Allocation	1.30	2.87

[1]Based on annual loading. .
[2]Based on summer season loads (May through September).

5.4.5 Margin of Safety

Section 303(d) of the Clean Water Act and USEPA's regulations at 40 CFR 130.7 require that "TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards with seasonal variations and a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality." The margin of safety can either be implicitly incorporated into conservative assumptions used to develop the TMDL or added as a separate explicit component of the TMDL (USEPA, 1991). A five percent explicit margin of safety has been incorporated into the Murphysboro Lake and Little Cedar Lake TMDLs by reserving a portion of the loading capacity.

A relatively low explicit margin of safety was selected because an implicit MOS is also associated with the recommended loading reductions resulting in lake water quality being significantly better than the water quality standard in all but the most critical years (see Table 16 and Table 17).

5.4.6 Critical Conditions and Seasonality

Section 303(d)(1)(C) of the Clean Water Act and USEPA's regulations at 40 CFR 130.7(c)(1) require that a TMDL be established that addresses seasonal variations normally found in natural systems. Lake nutrients are typically highest during the summer. The Little Cedar Lake TMDL is therefore expressed in terms of the summer average load. If the loading capacity identified for the summer months is achieved the beneficial use of the lakes are expected to be supported year-round. Although the Murphysboro Lake TMDL is expressed in terms of the annual average load, the loading capacity is specified based on meeting the water quality standard during the critical summer condition when the majority of the available data have been collected.

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Appendix A : Load Duration Analysis

Appendix B : Fecal Coliform Data for Load Duration Analysis

Table B-1. Available Fecal Coliform Data for Segment NA 01

Date	Fecal Coliform at station NA 01 (cfu/100ml)
1/8/1990	30
2/5/1990	200
4/16/1990	80
5/16/1990	730
6/28/1990	100
7/31/1990	50
9/17/1990	140
10/24/1990	240
12/4/1990	330
1/29/1991	110
2/28/1991	10
3/25/1991	150
5/23/1991	200
6/25/1991	500
8/7/1991	10
9/25/1991	280
11/14/1991	10
12/16/1991	380
2/3/1992	230
3/10/1992	460
4/15/1992	2000
5/7/1992	600
7/1/1992	110
8/12/1992	300
9/23/1992	400
11/16/1992	200
12/21/1992	100
1/27/1993	100
3/1/1993	5
4/12/1993	105
6/29/1993	8200
8/18/1993	100
9/29/1993	55
11/10/1993	100
12/8/1993	30
7/6/1994	616
8/3/1994	650
9/6/1994	3100
11/7/1994	174
12/8/1994	54
1/9/1995	40
3/23/1995	30
5/3/1995	188
6/29/1995	13300

Date	Fecal Coliform at station NA 01 (cfu/100ml)
8/2/1995	290
9/7/1995	64
12/14/1995	15
1/31/1996	14
2/28/1996	560
3/28/1996	30
5/15/1996	610
6/20/1996	100
8/13/1996	92
9/3/1996	24
10/10/1996	30
12/11/1996	116
1/14/1997	7
2/18/1997	4
3/24/1997	45
4/29/1997	43
6/9/1997	55
7/16/1997	96
8/28/1997	124
10/16/1997	46
11/20/1997	36
2/3/1998	82
3/5/1998	90
4/16/1998	2100
5/14/1998	17
6/17/1998	370
7/21/1998	116
8/27/1998	166
10/8/1998	44
12/1/1998	4
1/3/2000	6000
3/8/2000	16
4/12/2000	30
5/1/2000	82
6/21/2000	260
7/24/2000	420
8/23/2000	32
10/26/2000	480
11/28/2000	95
1/18/2001	8
2/8/2001	24
3/22/2001	42
5/3/2001	200
6/5/2001	91
7/24/2001	125

Date	Fecal Coliform at station NA 01 (cfu/100ml)
8/23/2001	215
10/18/2001	220
11/15/2001	46
1/9/2002	42
2/14/2002	31
4/11/2002	33
5/22/2002	94
6/5/2002	114
8/27/2002	2
10/8/2002	200
5/21/2003	54
6/23/2003	52
7/22/2003	540
9/29/2003	2
11/5/2003	40
12/16/2003	42
1/28/2004	48
3/3/2004	56
4/15/2004	42
5/19/2004	100
6/21/2004	100
8/5/2004	155
9/21/2004	14
11/4/2004	550
12/14/2004	44

Appendix C : QUAL2K Modeling

Appendix D : Stage 1 Report

Appendix E : Stage 2 Report

Appendix F : Responsiveness Summary

Cedar Creek/Cedar Lake TMDL Implementation Plan

FINAL REPORT

February 1, 2008

Submitted to:
Illinois Environmental Protection Agency
1021 N. Grand Avenue East
Springfield, IL 62702

Submitted by:
Tetra Tech

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KEY FINDINGS

As part of the Section 303(d) listing process, the Illinois Environmental Protection Agency (IEPA) identified six water bodies in the Cedar Creek/Cedar Lake watershed as impaired: Big Middy River, Cedar Creek, Cave Creek, Lake Murphysboro, Cedar Lake, and Little Cedar Lake (IEPA, 2006). Both the Big Muddy River and Cave Creek have dissolved oxygen levels less than the state standard of 5 mg/L. Cedar Creek exceeds the fecal coliform standard of 200 colony forming units (cfu)/100 mL, and Little Cedar Creek and Lake Murphysboro are impaired because of elevated manganese and phosphorus concentrations, respectively. The Little Cedar Lake manganese impairment is believed to be related to eutrophication issues (i.e., anoxic conditions that promote the release of manganese from lake bottom sediments), and therefore phosphorus was used as a surrogate pollutant for TMDL development. Details regarding the TMDLs can be found in the report titled, "TMDL Development for the Cedar Creek/Cedar Lake Watershed, Illinois" (also referred to as the "Stage 3" report) (IEPA, 2007).

The water quality impairments in the Cedar Creek/Cedar Lake watershed are due to a number of different sources. The largest source of phosphorus loading in the Lake Murphysboro and Little Cedar Lake watersheds is believed to be animal operations followed by crop production. Cedar Creek receives fecal coliform loadings from animal operations, failing onsite sewage treatment systems, and sewage treatment plants that operate under disinfection exemption. The dissolved oxygen impairments in Big Muddy River and Cave Creek are primarily the result of biodegradable organic matter and nutrients that are discharged from animal operations, failing septic systems, and sewage treatment plants.

Because of the variety of pollutant sources in the watershed, a number of different best management practices (BMPs) are recommended to reduce pollutant loading. The BMPs most likely to reduce loadings from animal operations include 1) proper manure management 2) vegetative controls such as grassed waterways, filter strips, and constructed wetlands, 3) manure composting, (4) cattle exclusion from streams, and 5) restoration of riparian areas and installation of riparian buffers. Additional water quality monitoring is recommended at the wastewater treatment facilities to quantify the nutrient, BOD, and fecal coliform loads. Once these loads are quantified, additional BMPs (i.e., disinfection or treatment upgrades) may be needed to reduce loads. Failing onsite septic systems should be identified and repaired to reduce nutrient and fecal coliform loads throughout the watershed.

1.0 INTRODUCTION

In 2006, six waterbodies in the Cedar Creek/Cedar Lake watershed were listed as impaired on Illinois' Section 303(d) list (Table 1-1). The Clean Water Act and USEPA regulations require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies listed as impaired. At this time, the Illinois Environmental Protection Agency is proceeding with TMDLs for pollutants that have numeric water quality standards. In the Cedar Creek/Cedar Lake watershed, these include:

- Big Muddy River (Dissolved Oxygen)
- Cedar Creek (Fecal Coliforms)
- Cave Creek (Dissolved Oxygen)
- Lake Murphysboro (Phosphorus)
- Little Cedar Lake (Manganese)

TMDLs for these five waterbody-pollutant combinations have been completed and are documented in the report titled, "TMDL Development for the Cedar Creek/Cedar Lake Watershed, Illinois," (also referred to as the "Stage 3" report) (IEPA, 2007).

This report builds on the 2007 TMDL report by recommending implementation measures to achieve the necessary load reductions. The remainder of this report provides a brief description of the watershed (Section 2.0), summarizes the TMDLs for each waterbody (Section 3.0), presents Best Management Practices (BMPs) to achieve water quality targets (Section 4.0), and discusses BMP priorities (Section 5.0). Sections 6.0 and 7.0 then discuss TMDL progress and the available programs to assist in BMP implementation, respectively.

Table 1-1. Illinois' 2006 303(d) List Information for the Cedar Creek/Cedar Lake Watershed

Waterbody Name	Segment ID	Segment or Lake Size (Miles or Acres)	Cause of Impairment	Impaired Designated Use
Big Muddy River	N-99	28.49	**Dissolved Oxygen**	Aquatic Life
			Sedimentation/Siltation	Aquatic Life
			Total Suspended Solids	Aquatic Life
Cedar Creek	NA-01	3.98	**Fecal Coliform**	Primary Contact Recreation
Cave Creek	NAC-01	8.9	**Dissolved Oxygen**	Aquatic Life
Lake Murphysboro	RND	143	**Phosphorus**	Aesthetic Quality
Cedar Lake	RNE	1800	Manganese[1]	Public Water Supplies
			Mercury	Fish Consumption
Little Cedar Lake	RNZM	70	**Manganese**	Public Water Supplies
			Impairment Unknown	Aesthetic Quality

Note: Bold font indicates pollutants that are addressed in this report.
[1] IEPA is recommending that Cedar Lake be delisted for manganese in the 2008 Integrated Report; no TMDLs have been developed.

2.0 DESCRIPTION OF WATERBODY AND WATERSHED CHARACTERISTICS

The purpose of this section of the report is to provide a basic understanding of the Cedar Creek/Cedar Lake watershed. More detailed information on the soils, topography, land use/land cover, climate and population of the watershed are available in the Stage One Watershed Characterization Report (IEPA, 2007b).

The Cedar Creek/Cedar Lake watershed is located in southern Illinois, flows in a west-southwesterly direction, and drains approximately 127,000 acres (198 square miles) within the state of Illinois (Figure 2-1). The watershed covers land within Jackson and Union Counties near the Missouri state line. The watershed encompasses all of the Cedar Creek drainage as well as portions of the Big Muddy River drainage (from the City of De Soto to the mouth).

The Illinois Gap Analysis Project Land Cover Data indicate that approximately 56,753 acres, representing nearly 45 percent of the total watershed area, are devoted to agricultural activities (Table 2-1). Corn and soybean farming account for about 9 percent and 11 percent of the watershed area, respectively and rural grassland accounts for about 20 percent. Upland forests occupy approximately 31 percent of the watershed and wetlands occupy approximately 15 percent. Other land cover categories represent less than 5 percent of the watershed area.

Soils in the watershed are typically categorized as fine-grained and are made up of silts and clays with a liquid limit of less than 50 percent that tend toward a lean clay and silt (NRCS, 2005). Most soils in the Cedar Creek/Cedar Lake watershed are categorized as B soils (i.e., moderately well drained soils).

Table 2-1. Land Use and Land Cover in the Cedar Creek/Cedar Lake Watershed.

Land Cover Category	Area (Acres)	Percentage
Corn	11,389	9.0%
Soybeans	14,265	11.3%
Winter Wheat	2,143	1.7%
Other Small Grains & Hay	1,503	1.2%
Winter Wheat/Soybeans	2,353	1.9%
Other Agriculture	173	0.1%
Rural Grassland	24,928	19.6%
Upland	39,472	31.1%
Forested Areas[1]	2,797	2.2%
High Density	843	0.7%
Low/Medium Density	835	0.6%
Urban Open Space	2,766	2.2%
Wetlands[2]	18,759	14.8%
Surface Water	4,548	3.6%
Barren & Exposed Land	13	0.0%
Total	**126,787**	**100%**

1. Forested areas include partial canopy/savannah upland and coniferous.
2. Wetlands includes shallow marsh/wet meadow, deep marsh, floodplain forest, swamp, and shallow water.

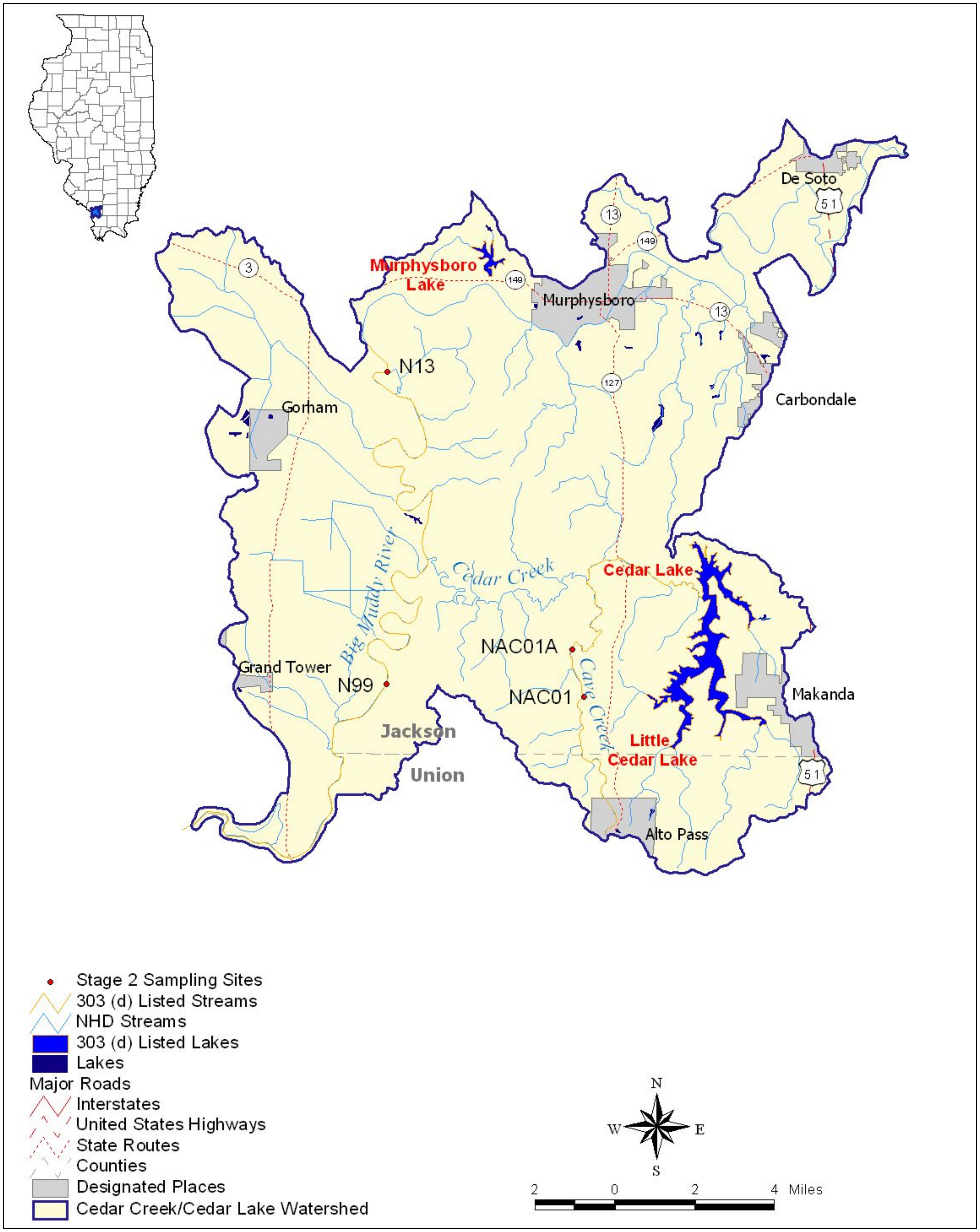


Figure 2-1. Location of the Cedar Creek/Cedar Lake Watershed

3.0 TMDLS AND SOURCES

TMDLs were completed for five waterbodies in the Cedar Creek/Cedar Lake watershed:

- Big Muddy River (Segment ID N-99) – Dissolved Oxygen
- Cave Creek (Segment ID NAC-01) – Dissolved Oxygen
- Cedar Creek (Segment ID NA-01) – Fecal Coliforms
- Lake Murphysboro (Segment ID RND) – Phosphorus
- Little Cedar Lake (Segment ID RNZM) – Manganese

The following sections summarize the TMDLs and the relevant sources for each waterbody. Source loads and BMP recommendations for each waterbody are presented in Section 5.0. Additional details regarding the TMDLs and sources for each waterbody can be found in the Stage 3 Report (IEPA, 2007).

3.1 Big Muddy River

The dissolved oxygen water quality standard is not being achieved in the Big Muddy River (Segment N-99). The impairment is believed to be due to excessive loads of oxygen-consuming material in addition to excessive oxygen demand caused by high algal growths. Based on QUAL2K modeling, load reductions are needed for Carbonaceous Biological Oxygen Demand (CBOD) and various forms of nutrients including total ammonia, organic nitrogen, nitrate, organic phosphorus, and inorganic phosphorus. Required load reductions range from 9 percent for CBOD to 37 percent for nutrients. Nonpoint sources (i.e., agriculture, septic systems, and animal operations) are the major source of nutrients and organic matter, and BMPs should focus on reducing loads from these sources. The Murphysboro Sewage Treatment Plant (NPDES ID IL0023248) is also a source of nutrients and organic matter, although no load reductions were recommended in the TMDL Report.

3.2 Cave Creek

The dissolved oxygen water quality standard is not being achieved in Cave Creek (NAC-01). The impairment is believed to be due to excessive loads of oxygen-consuming material in addition to excessive oxygen demand caused by high algal growths. Based on QUAL2K modeling, load reductions are needed for Carbonaceous Biological Oxygen Demand (CBOD) (26% reduction) and total ammonia (32% reduction). Nonpoint sources (i.e., agriculture, septic systems, and animal operations) are the major source of nutrients and organic matter, and BMPs should focus on reducing loads from these sources. There are no point sources in the Cave Creek watershed.

3.3 Cedar Creek

Fecal coliform concentrations in Cedar Creek (Segment NA-01) exceed Illinois' water quality standard. The TMDL analysis indicates that nonpoint sources are the largest contributor of fecal coliforms, and load reductions are needed during high flows, moist conditions, and low flows. Reductions range from 0 to 67 percent, depending on the flow condition. No point source load reductions were recommended in the TMDL. However, it should be noted that no fecal coliform data were available from the Union Jackson treatment plant, and sampling is recommended to quantify this load. Nonpoint sources in the watershed include animal operations, septic systems, wildlife, and domestic pets, and BMPs should focus on reducing the fecal coliform load from these sources.

3.4 Lake Murphysboro

Total phosphorus concentrations in Lake Murphysboro (Segment RND) exceed Illinois' water quality standard. The TMDL analysis indicates that nonpoint sources are the only contributor of phosphorus, and a 45 percent reduction in phosphorus loads is required. No point source load reductions were required in the TMDL. Nonpoint phosphorus sources in the watershed include agriculture, animal operations, septic systems, fertilizers, wildlife, and domestic pets, and BMPs should focus on reducing the phosphorus load from these sources. Streambank and overland sediment erosion is another potential source of phosphorus.

3.5 Little Cedar Lake

Manganese concentrations in Little Cedar Lake (Segment RNZM) exceed Illinois' water quality standard. The Little Cedar Lake manganese impairment is believed to be related to eutrophication issues – anoxic conditions caused by excess algae promote the release of manganese from lake-bottom sediments. Therefore, phosphorus was used as a surrogate pollutant for the manganese TMDL. The TMDL analysis indicates that nonpoint sources are the major contributor of phosphorus, and a 77 percent load reduction is required. No point source load reductions were required in the TMDL. Nonpoint phosphorus sources in the watershed include animal operations, septic systems, wildlife, and domestic pets, and BMPs should focus on reducing the phosphorus load from these sources. Streambank and overland sediment erosion is another potential source of phosphorus.

4.0 BEST MANAGEMENT PRACTICES

Controlling pollutant loading to the impaired reaches of the Cedar Creek/Cedar Lake watershed will require implementation of various BMPs depending on the pollutant(s) of concern and major sources of loading. This section describes the BMPs that may be used to reduce pollutant loading in the Cedar Creek/Cedar Lake watershed.

4.1 Disinfection of Primary Effluent from Sewage Treatment Plants

Sewage from treatment plants treating domestic and/or municipal waste contains fecal coliform bacteria, which is indigenous to sanitary sewage. In Illinois, a number of these treatment plants have applied for and received disinfection exemptions, which allow a facility to discharge wastewater without disinfection. All of these treatment facilities are required to comply with the geometric mean fecal coliform water quality standard of 200 cfu/100 mL at the closest point downstream where recreational use occurs in the receiving water or where the water flows into a fecal-impaired segment. Facilities with year-round disinfection exemptions may be required to provide the Agency with updated information to demonstrate compliance with these requirements. Facilities directly discharging into a fecal-impaired segment may have their year-round disinfection exemption revoked through future NPDES permitting actions.

Reducing the fecal coliform concentrations from a primary outfall of an exempt facility to 200 cfu/100 mL will require a permit change and disinfection of the effluent prior to discharge. Common disinfection techniques include chlorination, ozonation, and UV disinfection. In most cases, chlorination is the most cost-effective alternative, though residuals and oxidized compounds are toxic to aquatic life; subsequent dechlorination may be necessary prior to discharge which will increase costs similar to the other two options (USEPA, 1999a). The options most frequently employed are discussed below.

4.1.1 Chlorination

Chlorine compounds used for disinfection are usually either chlorine gas or hypochlorite solutions though other liquid and solid forms are available. Oxidation of cellular material destroys pathogenic organisms. The remaining chlorine residuals provide additional disinfection, but may also react with organic material to form harmful byproducts. To reduce the impacts on aquatic life from chlorine residuals and byproducts, a dechlorination step is often included in the treatment process (USEPA, 1999a).

The advantages of chlorine disinfection are

- Generally more cost-effective relative to UV disinfection or ozonation
- Residuals continue to provide disinfection after discharge
- Effective against a wide array of pathogens
- Capable of oxidizing some organic and inorganic compounds
- Provides some odor control
- Allows for flexible dosing

There are several disadvantages as well:

- Chlorine residuals are toxic to aquatic life and may require dechlorination, which may increase costs by 30 to 50 percent
- Highly corrosive and toxic with expensive shipping and handling costs
- Meeting Uniform Fire Code requirements can increase costs by 25 percent
- Oxidation of some organic compounds can produce toxic byproducts
- Effluent has increased concentrations of dissolved solids and chloride

More information about disinfection with chlorine is available online at
http://www.consolidatedtreatment.com/manuals/Fact_sheet_chlorine_disinfection.pdf

4.1.2 Ozonation

Ozone is generated onsite by passing a high voltage current through air or pure oxygen (USEPA, 1999b). The resulting gas (O_3) provides disinfection by destroying the cell wall, damaging DNA, and breaking carbon bonds. The advantages of ozonation include

- Ozone is more effective than chlorine and has no harmful residuals.
- Ozone is generated onsite so there are no hazardous transport issues.
- Short contact time of 10 to 30 minutes.
- Elevates the DO of the effluent.

Disadvantages are

- More complex technology than UV light or chlorine disinfection.
- Highly reactive and corrosive.
- Not economical for wastewater with high concentrations of BOD, TSS, COD, or TOC.
- Initial capital, maintenance, and operating costs are typically higher than for UV light or chlorine disinfection.

More information about ozonation is available online at
http://www.epa.gov/owmitnet/mtb/ozon.pdf

4.1.3 Ultraviolet Disinfection

UV radiation is generated by passing an electrical current through a lamp containing mercury vapor. The radiation attacks the genetic material of the organisms, destroying reproductive capabilities (NSFC, 1998).

The advantages of UV disinfection are

- Highly effective.
- Destruction of pathogens occurs by physical process, so no chemicals must be transported or stored.
- No harmful residuals.
- Easy to operate.
- Short contact time (20 to 30 min).
- Requires less space than chlorination or ozonation.

Disadvantages of UV disinfection are

- Organisms can sometimes regenerate
- Turbidity and TSS can interfere with disinfection at high concentrations
- Not as cost effective compared to chlorination alone, but when fire code regulations and dechlorination are considered, costs are comparable.

More information about disinfection with UV radiation is available online at
http://www.nsfc.wvu.edu/nsfc/pdf/eti/UV_Dis_tech.pdf

4.1.4 Effectiveness

The use of disinfection techniques in the sewage treatment plants that operate under a disinfection exemption will help in reducing in-stream fecal coliform concentrations to 200 cfu/100 mL.

4.1.5 Costs

Upgrading the existing STPs to include disinfection prior to discharge can be achieved with chlorination, ozonation, or UV radiation processes. The costs associated with these three techniques include upfront capital costs to construct additional process units, operating and maintenance costs for chemicals, electricity, labor, etc., as well as chemical storage and fire code requirements associated with the chlorination option. The USEPA compares the costs of chlorination, ozonation, and UV disinfection in a series of fact sheets available online. This information is summarized below as well as in Table 4-1. Prices in the fact sheets were listed in either 1995 or 1998 dollars. Prices have been converted to year 2004 dollars, assuming a 3 percent per year inflation rate, for comparison with the other BMPs discussed in this plan that must be described in year 2004 dollars.

Chlorine dosage usually ranges from 5 mg/L to 20 mg/L depending on the wastewater characteristics and desired level of disinfection. The cost of adding a chlorination/dechlorination system that meets fire code requirements and treats one million gallons per day (MGD) of wastewater with a chlorine dosage of 10 mg/L costs approximately $1,260,000 in 1995 with annual operation and maintenance costs of $59,200 (USEPA, 1999a). If a 3 percent per year inflation rate is assumed, these costs in 2004 dollars are $1,640,000 and $77,200, respectively.

Costs for ozonation were given by USEPA (1999b) in 1998 dollars. The capital costs in 1998 for treating one MGD of secondary wastewater with BOD and TSS concentrations each less than 30 mg/L was $300,000. The operating and maintenance costs were listed at $18,500 plus the costs of electricity. In 2004 dollars, these costs are $358,200 and $22,000, respectively.

Ultraviolet radiation costs were listed in 1995 dollars by USEPA (1995) relative to the cost per bulb. Based on vendor information available online, approximately 40 bulbs would be required to treat 1 MGD of secondary wastewater. Based on the information presented, the capital costs in 2004 for a 1 MGD facility would be approximately $750,000 and the annual operating and maintenance costs would range from $4,500 to $5,100.

Table 4-1 compares the costs for these three disinfection technologies. Annualized costs are calculated assuming a 20-year system life for each technology before major repairs or replacement would be required.

Table 4-1. Comparison of Disinfection Costs (2004) per 1 MGD of Sewage Treatment Plant Effluent.

Technology	Capital Cost	Annual Operating and Maintenance Cost	Annualized Cost
Chlorination (10 mg/L dosage), dechlorination, fire code regulations	$1,640,000	$77,200	$159,200
Ozonation	$358,200	$22,000	$39,900, plus cost of electricity
UV Disinfection	$750,000	$4,500 to $5,100	$42,000 to $42,600

4.2 Proper Maintenance of Onsite Systems

The most effective BMP for managing loads from septic systems is regular maintenance. Unfortunately, most people do not think about their wastewater systems until a major malfunction occurs (i.e., sewage backs up into the house or onto the lawn). When not maintained properly, septic systems can cause the release of pathogens and excess nutrients into surface water. Good housekeeping measures relating to septic systems are listed below (Goo, 2004; CWP, 2004):

- Inspect system annually and pump system every 3 to 5 years, depending on the tank size and number of residents per household.
- Refrain from trampling the ground or using heavy equipment above a septic system (to prevent collapse of pipes).
- Prevent septic system overflow by conserving water, not diverting storm drains or basement pumps into septic systems, and not disposing of trash through drains or toilets.

Education is a crucial component of reducing pollution from septic systems. Many owners are not familiar with USEPA recommendations concerning maintenance schedules. Education can occur through public meetings, mass mailings, and radio and television advertisements. The USEPA recommends that septic tanks be pumped every 3 to 5 years depending on the tank size and number of residents in the household (USEPA, 2002b). Annual inspections, in addition to regular maintenance, ensure that systems are functioning properly. An inspection program would help identify those systems that are currently connected to tile drain systems. All tanks discharging to tile drainage systems should be disconnected immediately.

Some communities choose to formally regulate septic systems by creating a database of all the systems in the area. This database usually contains information on the size, age, and type of system. All inspections and maintenance records are maintained in the database through cooperation with licensed maintenance and repair companies. These databases allow the communities to detect problem areas and ensure proper maintenance.

At this time, there is not a formal inspection and maintenance program in Jackson County. The County Health Department does issue permits for new onsite systems and major repairs

4.2.1 Effectiveness

The reductions in pollutant loading resulting from improved operation and maintenance of all systems in the watershed depends on the wastewater characteristics and the level of failure present in the watershed.

4.2.2 Costs

Septic tanks are designed to accumulate sludge in the bottom portion of the tank while allowing water to pass into the drain field. If the tank is not pumped out regularly, the sludge can accumulate and eventually become deep enough to enter the drain field. Pumping the tank every three to five years prolongs the life of the system by protecting the drain field from solid material that may cause clogs and system backups.

The cost to pump a septic tank ranges from $250 to $350 depending on how many gallons are pumped out and the disposal fee for the area. If a system is pumped once every three to five years, this expense averages out to less than $100 per year. Septic systems that are not maintained will likely require replacement which may cost between $2,000 and $10,000.

The cost of developing and maintaining a watershed-wide database of the onsite wastewater treatment systems in the Cedar Creek/Cedar Lake depends on the number of systems that need to be inspected. After the initial inspection of each system and creation of the database, only systems with no subsequent maintenance records would need to be inspected. A recent inspection program in South Carolina found that inspections cost approximately $160 per system (Hajjar, 2000).

Education of home and business owners that use onsite wastewater treatment systems should occur periodically. Public meetings, mass mailings, and radio, newspaper, and TV announcements can all be used to remind and inform owners of their responsibility to maintain their systems. The costs associated with education and inspection programs will vary depending on the level of effort required to communicate the importance of proper maintenance and the number of systems in the area.

The costs associated with inspecting and maintaining onsite wastewater treatment systems and educating owners of their responsibilities is summarized in Table 4-2.

Table 4-2. Costs Associated with Maintaining and Replacing an Onsite Wastewater Treatment System

Action	Cost per System	Frequency	Annual Cost per System
Pumping	$250 to $350	Once every 3 to 5 years	$70 to $85
Inspection	$160	Initially all systems should be inspected, followed by 5 year inspections for systems not on record as being maintained	Up to $32, assuming all systems have to be inspected once every five years, which is not likely
Replacement	$2,000 to $10,000	With proper maintenance, system life should be 30 years	$67 to $333
Education	$1	Public reminders should occur once per year	$1

4.3 Nutrient Management Plans

The primary BMP for reducing phosphorus loading from excessive fertilization is the development of a nutrient management plan. The plan should address fertilizer application rates, methods, and timing. Initial soil phosphorus concentrations are determined by onsite soil testing, which is available from local vendors. Losses through plant uptake are subtracted, and gains from organic sources such as manure application or industrial/municipal wastewater are added. The resulting phosphorus content is then compared to local guidelines to determine if fertilizer should be added to support crop growth and maintain current phosphorus levels. In some cases, the soil phosphorus content is too high, and no fertilizer should be added until stores are reduced by crop uptake to target levels.

The NRCS provides additional information on nutrient management planning at: *http://efotg.nrcs.usda.gov/references/public/IL/590.pdf*

The Illinois Agronomy Handbook may be found online at: http://iah.aces.uiuc.edu/

Soil phosphorus tests are used to measure the phosphorus available for crop growth. Test results reported in parts per million (ppm) can be converted to lb/ac by multiplying by 2 (USDA, 2003). Based on a survey of state soil testing laboratories in 1997, 64 percent of soils in Illinois had high soil phosphorus test concentrations (> 50 ppm). By 2000, the percentage of soils testing high decreased to 58 percent (USDA, 2003). Guidelines in the Illinois Agronomy Handbook (IAH) recommend maintaining a soil test phosphorus content in southeastern Illinois of 25 ppm (50 lb/ac). Soils that test at or above 35 ppm (70 lb/ac) should not be fertilized until subsequent crop uptake decreases the test to 25 ppm (50 lb/ac) (IAH, 2002). Soil phosphorus tests should be conducted once every three or four years to monitor accumulation or depletion of phosphorus (USDA, 2003).

Table 4-3 and Table 4-4 show buildup, maintenance, and total application rates for various starting soil test concentrations for sample corn and soybean yields, respectively. For a complete listing of buildup and maintenance rates for the three inherent availability zones and varying yields of corn, soybeans, oats, wheat, and grasses, see Chapter 11 of the IAH.

Starting Soil Test Phosphorus	***Fertilization Guidelines***
Less than 22.5 ppm:	*Buildup plus maintenance*
Between 22.5 and 32.5 ppm:	*Maintenance only*
Greater than 32.5 ppm:	*None*

Table 4-3. Suggested Buildup and Maintenance Application Rates of P_2O_5 for Corn Production in the Medium Inherent Phosphorus Availability Zone (IAH, 2002).

Starting Soil Test P ppm (lb/ac)	Buildup P_2O_5 (lb/ac)[1]	Maintenance P_2O_5 (lb/ac)[2]	Total P_2O_5 (lb/ac)
10 (20)	56	71	127
15 (30)	34	71	105
20 (40)	11	71	82
22.5 (45)	0	71	71
25 (50)	0	71	71
30 (60)	0	71	71
32.2 (65) or higher	0	0	0

[1] Rates are based on buildup for four years to achieve a target soil test phosphorus of 22.5 ppm (45 lb/ac).
[2] Maintenance rates assume a corn yield of 165 bushels per acre. The IAH lists maintenance rates discretely for yields of 90 to 200 bushels per acre.

Table 4-4. Production in the Low Inherent Phosphorus Availability Zone (IAH, 2002).

Starting Soil Test P ppm (lb/ac)	Buildup P_2O_5 (lb/ac)[1]	Maintenance P_2O_5 (lb/ac)[2]	Total P_2O_5 (lb/ac)
10 (20)	68	51	119
15 (30)	45	51	96
20 (40)	22	51	73
25 (50)	0	51	51
30 (60)	0	51	51
35 (70) or higher	0	0	0

[1] Rates are based on buildup for four years to achieve a target soil test phosphorus of 25 ppm (50 lb/ac).
[2] Maintenance rates assume a soybean yield of 60 bushels per acre. The IAH lists maintenance rates discretely for yields of 30 to 100 bushels per acre.

Nutrient management plans also address methods of application. Fertilizer may be applied directly to the surface, placed in bands below and to the side of seeds, or incorporated in the top several inches of the soil profile through drilled holes, injection, or tillage. Surface applications that are not followed by incorporation may result in accumulation of phosphorus at the soil surface and increased dissolved phosphorus concentrations in surface runoff (Mallarino, 2004).

Methods of phosphorus application have shown no impact on crop yield (Mallarino, 2004). The Champaign County Soil and Water Conservation District (CCSWCD) reports that deep placement of phosphorus in bands next to the seed zone requires only one-third to one-half the amount of phosphorus fertilizer to achieve the same yields and that on average, fertilizer application rates were decreased by 13 lb/ac (Stikkers, 2007). Thus, deep placement will not only reduce the amount of phosphorus available for transport, but will also result in lower fertilizer costs.

4.3.1 Effectiveness

The effectiveness of nutrient management plans (application rates, methods, and timing) in reducing phosphorus loading from agricultural land will be site specific. The following reductions are reported in the literature:

- 35 percent average reduction of total phosphorus load reported in Pennsylvania (USEPA, 2003).
- 20 to 50 percent total phosphorus load reductions with subsurface application at agronomic rates (HWRCI, 2005).
- 60 to 70 percent reduction in dissolved phosphorus concentrations and 20 percent reduction in total phosphorus concentrations when fertilizer is incorporated to a minimum depth of two inches prior to planting (HWRCI, 2005).
- 60 to 70 percent reduction in dissolved phosphorus concentrations and 20 to 50 percent reduction in total phosphorus with subsurface application, such as deep placement (HWRCI, 2005).
- 60 percent reduction in runoff concentrations of phosphorus when the following precipitation event occurred 10 days after fertilizer application, as opposed to 24 hours after application (HWRCI, 2005).
- Nutrient management plans will also reduce the dissolved oxygen impairments in the watershed by reducing the nutrients available to stimulate eutrophication.

4.3.2 Costs

A good nutrient management plan should address the rates, methods, and timing of fertilizer application. To determine the appropriate fertilizer rates, consultants in Illinois typically charge $6 to $18 per acre, which includes soil testing, manure analysis, scaled maps, and site specific recommendations for fertilizer management (USEPA, 2003). The Champaign County Soil and Water Conservation District (CCSWCD, 2003) estimates savings of approximately $10/ac during each plan cycle (4 years) by applying fertilizer at recommended rates. Actual savings (or costs) depend on the reduction (or increase) in fertilizer application rates required by the nutrient management plan as well as other farm management recommendations.

Placing the fertilizer below and to the side of the seed bed (referred to as banding) reduces the required application by one third to one half to achieve the same crop yields. In Champaign County, phosphorus application rates were reduced by approximately 13 lb/ac with this method. The equipment needed for deep placement costs up to $113,000 (Stikkers, 2007). Alternatively the equipment can be rented or the entire process hired out. The Heartland Regional Water Coordination Initiative lists the cost for deep placement of phosphorus fertilizer at $3.50/ac per application (HRWCI, 2005). Table 4-5 summarizes the assumptions used to develop the annualized cost for this BMP.

Table 4-5. Cost Calculations for Nutrient Management Plans.

Item	Costs and Frequency	Annualized Cost (Savings)
Soil Testing and Determination of Rates	Costs \$6/ac to \$18/ac Every four years	\$1.50/ac/yr to \$4.50/ac/yr
Savings on Fertilizer	Saves \$10/ac Every four years	(\$2.50/ac/yr)
Deep Placement of Phosphorus	Costs \$3.50/ac Every two years	\$1.75/ac/yr
Average Annual Costs		**\$0.75/ac/yr to \$3.75/ac/yr**

4.4 Tillage Practices

Conservation tillage practices and residue management are commonly used to control erosion and surface transport of pollutants from fields used for crop production. The IAH (2002) defines conservation tillage as any tillage practice that results in at least 30 percent coverage of the soil surface by crop residuals after planting. Tillage practices leaving 20 to 30 percent residual cover after planting can reduce erosion by approximately 50 percent compared to bare soil. Practices that result in 70 percent residual cover reduce erosion by approximately 90 percent (IAH, 2002). The residuals not only provide erosion control, but also provide a nutrient source to growing plants, and continued use of conservation tillage results in a more productive soil with higher organic and nutrient content. Increasing the organic content of soil has the added benefit of reducing the amount of carbon in the atmosphere by storing it in the soil. Researchers estimate that croplands and pasturelands could be managed to trap 5 to 17 percent of the greenhouse gases produced in the United States (Lewandrowski et al., 2004).

Several practices are commonly used to maintain the suggested 30 percent cover:

- No-till systems disturb only a small row of soil during planting, and typically use a drill or knife to plant seeds below the soil surface.
- Strip till operations leave the areas between rows undisturbed, but remove residual cover above the seed to allow for proper moisture and temperature conditions for seed germination.
- Ridge till systems leave the soil undisturbed between harvest and planting: cultivation during the growing season is used to form ridges around growing plants. During or prior to the next planting, the top half to two inches of soil, residuals, and weed seeds are removed, leaving a relatively moist seed bed.
- Mulch till systems are any practice that results in at least 30 percent residual surface cover, excluding no-till and ridge till systems.

The NRCS provides additional information on these conservation tillage practices:

no-till and strip till:	http://efotg.nrcs.usda.gov/references/public/IL/329a.pdf
ridge till:	http://efotg.nrcs.usda.gov/references/public/IL/329b.pdf
mulch till:	http://efotg.nrcs.usda.gov/references/public/IL/329c.pdf

Tillage system practices are not available specifically for the Cedar Creek/Cedar Lake watershed; however, county-wide tillage system surveys have been undertaken by the Illinois Department of Agriculture (2004). The results of these surveys are presented in Table 4-6. Mulch till and no-till are considered conservation tillage practices.

Table 4-6. Percentage of Agricultural Fields Surveyed with Indicated Tillage System in Union and Jackson Counties, Illinois, in 2004.

Union County 2004 Transect Survey				
Crop Field Type	Tillage Practice			
	Conventional	Reduced-till	Mulch-till	No-till
Corn	15	4	4	77
Soybean	11	4	5	80
Small Grain	0	0	40	60
Jackson County 2004 Transect Survey				
Crop Field Type	Tillage Practice			
	Conventional	Reduced-till	Mulch-till	No-till
Corn	57	0	17	26
Soybean	54	0	18	27
Small Grain	59	0	41	0

Source: Illinois Department of Agriculture, 2004.

Corn residues are more durable and capable of sustaining the required 30 percent cover required for conservation tillage. Soybeans generate less residue, the residue degrades more quickly, and supplemental measures or special care may be necessary to meet the 30 percent cover requirement (UME, 1996). Figure 4-1 shows a comparison of ground cover under conventional and conservation tillage practices.

Figure 4-1. Comparison of conventional (left) and conservation (right) tillage practices.

No-till systems typically concentrate phosphorus in the upper two inches of the soil profile due to surface application of fertilizer and decomposition of plant material (IAH, 2002; UME, 1996). This pool of phosphorus readily mixes with precipitation and can lead to increased concentrations of dissolved phosphorus in surface runoff. Chisel plowing may be required once every several years to reduce stratification of phosphorus in the soil profile.

Czapar et al. (2006) summarize past and present tillage practices and their impacts on erosion control and nutrient delivery. Historically, the mold board plow was used to prepare the field for planting. This practice disturbed 100 percent of the soil surface and resulted in basically no residual material. Today, conventional tillage typically employs the chisel plow, which is not as disruptive to the soil surface and tends to leave a small amount of residue on the field (0 to 15 percent). Mulch till systems were classified as leaving 30 percent residue; percent cover was not quantified for the no-till systems. The researchers used WEPP modeling to simulate changes in sediment and nutrient loading for these tillage practices. Relative to mold board plowing, chisel plowing reduced phosphorus loads leaving the field by 38 percent, strip tilling reduced loads by 80 percent, and no-till reduced loads by 85 percent. If chisel plowing is now considered conventional, then the strip till and no-till practices are capable of reducing phosphorus loads by 68 percent and 76 percent, respectively (Czapar et al., 2006).

4.4.1 Effectiveness

Czapar et al. (2006) summarize past and present tillage practices and their impacts on erosion control and nutrient delivery. Historically, the mold board plow was used to prepare the field for planting. This practice disturbed 100 percent of the soil surface and resulted in basically no residual material. Today, conventional tillage typically employs the chisel plow, which is not as disruptive to the soil surface and tends to leave a small amount of residue on the field (0 to 15 percent). Mulch till systems were classified as leaving 30 percent residue; percent cover was not quantified for the no-till systems in this study. The researchers used WEPP modeling to simulate changes in sediment and nutrient loading for these tillage practices. Relative to mold board plowing, chisel plowing reduced phosphorus loads leaving the field by 38 percent, strip tilling reduced loads by 80 percent, and no-till reduced loads by 85 percent. If chisel plowing is now considered conventional, then the strip till and no-till practices are capable of reducing phosphorus loads by 68 percent and 76 percent, respectively (Czapar et al., 2006).

USEPA (2003) reports the findings of several studies regarding the impacts of tillage practices on nutrient, sediment, and manganese loading. The reductions achieved by conservation tillage reported in these studies are summarized below:

- 68 to 76 percent reduction in total phosphorus.
- 50 percent reduction in sediment, and likely manganese, for practices leaving 20 to 30 percent residual cover.
- 90 percent reduction in sediment, and likely manganese, for practices leaving 70 percent residual cover.
- 69 percent reduction in runoff losses for no-till practices.

4.4.2 Costs

Conservation tillage practices generally require fewer trips to the field, saving on labor, fuel, and equipment repair costs, though increased weed production may result in higher pesticide costs relative to conventional till (USDA, 1999). In general, conservation tillage results in increased profits relative to conventional tillage (Olson and Senjem, 2002; Buman et al., 2004; Czapar, 2006). The HRWCI (2005) lists the cost for conservation tillage at $0/ac.

Hydrologic inputs are often the limiting factor for crop yields and farm profits. Conservation practices reduce evaporative losses by covering the soil surface. USDA (1999) reports a 30 percent reduction in evaporative losses when 30 percent ground cover is maintained. Harman et al. (2003) and the Southwest Farm Press (2001) report substantial yield increases during dry years on farms managed with conservation or no-till systems compared to conventional till systems.

Depending on the type of equipment currently used, replacing conventional till equipment with no-till equipment can either result in a net savings or slight cost to the producer. Al-Kaisi et al. (2000) estimated that converting conventional equipment to no-till equipment costs approximately $1.25 to $2.25/ac/yr, but that for new equipment, purchasing no-till equipment is less expensive than conventional equipment. Other researchers report a net gain when conventional equipment is sold to purchase no-till equipment (Harman et al., 2003).

Table 4-7 summarizes the available information for determining average annual cost for this BMP.

Table 4-7. Cost Calculations for Conservation Tillage.

Item	Costs and Frequency	Annualized Cost (Savings)
Conversion of Conventional Equipment to Conservation Equipment	Costs presented in literature were already averaged out to yearly per acre costs: $1.25/ac/yr to $2.25/ac/yr	$1.25/ac/yr to $2.25/ac/yr
Operating Costs of Conservation Tillage Relative to Conventional Costs	$0/ac/yr	$0/ac/yr
Average Annual Costs		**$1.25/ac/yr to $2.25/ac/yr**

4.5 Cover Crops

Grasses and legumes may be used as winter cover crops to reduce soil erosion and improve soil quality (IAH, 2002). These crops may also contribute nitrogen to the following crop. Grasses tend to have low seed costs and establish relatively quickly, but can impede cash crop development by drying out the soil surface or releasing chemicals during decomposition that may inhibit the growth of a following cash crop. Legumes take longer to establish, but are capable of fixing nitrogen from the atmosphere, thus reducing nitrogen fertilization required for the next cash crop. Legumes, however, are more susceptible to harsh winter environments and may not have adequate survival to offer sufficient erosion protection. Planting the cash crop in wet soil that is covered by heavy surface residue from the cover crop may impede emergence by prolonging wet, cool soil conditions. Cover crops should be killed off two or three weeks prior to planting the cash crop either by application of herbicide or mowing and incorporation, depending on the tillage practices used.

Cover crops alone may reduce soil and runoff losses by 50 percent, and when used with no-till systems may reduce soil loss by more than 90 percent (IAH, 2002). On naturally drained fields where surface runoff is the primary transport mechanism of phosphorus, reduction in phosphorus loading would be substantial as well. In Oklahoma, use of cover crops resulted in 70 to 85 percent reductions in total phosphorus loading (HRWCI, 2005) (cropping rotation was not described). Cover crops have the added benefit of reducing the need for pesticides and fertilizers (OSUE, 1999), and are also used in conservation tillage systems following low residue crops such as soybeans (USDA, 1999). Use of cover crops is illustrated in Figure 4-2.

(Photo Courtesy of CCSWCD)

Figure 4-2. Use of Cover Crops

The NRCS provides additional information on cover crops at:
http://efotg.nrcs.usda.gov/references/public/IL/340.pdf

4.5.1 Effectiveness

The effectiveness of cover crops in reducing pollutant loading has been reported by several agencies. In addition to these benefits, the reduction in runoff losses will reduce erosion from streambanks, further reducing manganese loads and allowing for the establishment of vegetation and canopy cover. The reported reductions are listed below:

- 50 percent reduction in soil and runoff losses with cover crops alone. When combined with no-till systems, may reduce soil loss by more than 90 percent (IAH, 2002). Manganese reductions will likely be similar.
- 70 to 85 percent reduction in phosphorus loading on naturally drained fields (HRWCI, 2005).
- Useful in conservation tillage systems following low-residue crops such as soybeans (USDA, 1999).

4.5.2 Costs

The National Sustainable Agriculture Information Service recommends planting ryegrass after corn harvest and hairy vetch after soybeans (Sullivan, 2003). Both seeds can be planted at a depth of ¼ to ½ inch at a rate of 20 lb/ac or broadcast at a rate of 25 to 30 lb/ac (Ebelhar and Plumer, 2007; OSUE, 1990).

Researchers at Purdue University estimate the seed cost of ryegrass and hairy vetch at $12 and $30/ac, respectively. Savings in nitrogen fertilizer (assuming nitrogen fertilizer cost of $0.30/lb (Sample, 2007)) are $3.75/ac for ryegrass and $28.50/ac for hairy vetch. Yield increases in the following crop, particularly during droughts, are reported at 10 percent and are expected to offset the cost of this practice (Mannering et al., 1998). Herbicide application is estimated to cost $14.25/ac.

Accounting for the seed cost, herbicide cost, and fertilizer offset results in an average net cost of approximately $19.25/ac assuming that cover crop planting recommendations for a typical 2 year corn/soybean rotation are followed (Mannering et al., 1998). These costs do not account for yield increases which may offset the costs completely. Table 4-8 summarizes the costs and savings associated with ryegrass and hairy vetch.

Table 4-8. Cost Calculations for Cover Crops.

Item	Ryegrass	Hairy Vetch
Seed Costs	$12/ac	$30/ac
Nitrogen Fertilizer Savings	($3.75/ac)	($28.50/ac)
Herbicide Costs	$14.25/ac	$14.25/ac
Annual Costs	$22.50/ac	$15.75/ac
Average Annual Cost Assuming Ryegrass Follows Corn and Hairy Vetch Follows Soybeans: $19.25/ac		

4.6 Filter Strips

Filter Strips are vegetative controls that are used to collect runoff from agricultural fields and treat it in small zone using infiltration, sedimentation, and plant uptake to remove phosphorus as well as fecal coliforms. Filter strips are used in agricultural and urban areas to intercept and treat runoff before it leaves the site. For small dairy operations, filter strips may also be used to treat milk house washings and runoff from the open lot (NRCS, 2003). Filter strips will require maintenance, including grading and seeding, to ensure distributed flow across the filter and protection from erosion. Periodic removal of vegetation will encourage plant growth and uptake, and will remove nutrients stored in the plant material. Filter strips are most effective on sites with mild slopes of generally less than 5 percent, and to prevent concentrated flow, the upstream edge of a filter strip should follow one elevation contour (NCDENR, 2005).

Filter strips also serve to reduce the quantity and velocity of runoff. Filter strip sizing is dependent on site specific features such as climate and topography, but at a minimum, the area of a filter strip should be no less than 2 percent of the drainage area for agricultural land (OSUE, 1994). The minimum filter strip width suggested by NRCS (2002a) is 30 ft. The strips are assumed to function properly with annual maintenance for 30 years before requiring replacement of soil and vegetation.

4.6.1 Effectiveness

Filter strips have been found to effectively remove pollutants from agricultural runoff. The following reductions are reported in the literature (USEPA, 2003; Kalita, 2000; Woerner et al., 2006):

- 65 percent reduction in total phosphorus
- 55 to 87 percent reduction in fecal coliform

4.6.2 Costs

Filter strips can either be seeded with grass or sodded for immediate function. The seeded filter strips cost approximately $0.30 per sq ft to construct, and sodded filter strips cost approximately $0.70 per sq ft to construct. Assuming that the required filter strip area is 2 percent of the drainage area (OSUE, 1994), 870 square feet of filter strips are required for each acre of agricultural land treated. The construction cost to treat one acre of land is therefore $261/ac for a seeded filter strip and $609/ac for a sodded strip. At an assumed system life of 20 years (Weiss et al., 2007), the annualized construction costs are $13/ac/yr for seeded and $30.50/ac/yr for sodded strips. Annual maintenance of filter strips is estimated at $0.01 per sq ft (USEPA, 2002b) for an additional cost of $8.70/ac/yr of agricultural land treated. In addition, the area converted from agricultural production to filter strip will result in a net annual income loss of $3.50. Table 4-9 summarizes the costs assumptions used to estimate the annualized cost to treat one acre of agricultural drainage using either a seeded or sodded filter strip.

Table 4-9. Cost Calculations for Seeded and Sodded Filter Strips in Agricultural Land.

Item	Costs of Seeded Filter Strip Required to Treat One Acre of Agricultural Land	Costs of Sodded Filter Strip Required to Treat One Acre of Agricultural Land
Costs per Square Foot		
Construction Costs	$0.30	$0.70
Annual Maintenance Costs	$0.01	$0.01
Costs to Treat One Acre of Agricultural Land (assuming 870 sq ft of filter strip)		
Construction Costs	$261	$609
System Life (years)	20	20
Annualized Construction Costs	$13	$30.50
Annual Maintenance Costs	$8.70	$8.70
Annual Income Loss	$3.50	$3.50
Average Annual Costs	**$25/ac treated**	**$43/ac treated**

Filter strips used in animal operations typically treat contaminated runoff from pastures or feedlot areas or washings from the milk houses of small dairy operations (NRCS, 2003). NRCS (2003) assumes that a filter strip area of 12,000 sq ft is required for small dairy operations (75 milk cows). For pasture operations, it is assumed that a filter strip area of 12,000 sq ft (30 ft wide and 400 ft long) would be required to treat runoff from a herd of 50 cattle (NRCS, 2003). The document does not explain why more animals can be treated by the same area of filter strip at the dairy operation compared to the pasture operation. Table 4-10 summarizes the capital, maintenance, and annualized costs for seeded and sodded filter strips used in animal operations.

Table 4-10. Cost Calculations for Filter Strips in Animal Operations.

	Capital Costs per Head	Annual Operation and Maintenance Costs per Head	Total Annualized Costs per Head
Seeded Filter Strips			
Small dairy operations (75 milking cows)	$48 per head of cattle	$1.50 per head of cattle	$4 per head of cattle
Pasture operations (50 cattle)	$72 per head of cattle	$2.50 per head of cattle	$6 per head of cattle
Sodded Filter Strips			
Small dairy operations (75 milking cows)	$112 per head of cattle	$1.50 per head of cattle	$7 per head of cattle
Pasture operations (50 cattle)	$168 per head of cattle	$2.50 per head of cattle	$11 per head of cattle

4.7 Grassed Waterways

Grassed waterways are stormwater conveyances lined with grass that prevent erosion of the transport channel. In addition, the grassed channel reduces runoff velocities, allows for some infiltration, and filters out some particulate pollutants. Grassed waterways are used in animal operations to divert clean water away from pastures, feedlots, and manure storage areas. A grassed waterway providing surface drainage for a corn field is shown in Figure 4-3.

(Photo Courtesy of CCSWCD)

Figure 4-3. Grassed Waterway.

The NRCS provides additional information on grassed waterways at:
http://efotg.nrcs.usda.gov/references/public/IL/412.pdf

4.7.1 Effectiveness

The effectiveness of grass swales for treating agricultural runoff has not been quantified. The Center for Watershed Protection reports the following reductions in urban settings (Winer, 2000):

- 30 percent reduction in total phosphorus
- 5 percent reduction in fecal coliform
- 68 percent reduction of total suspended solids

4.7.2 Cost

Grassed waterways cost approximately $0.50 per sq ft to construct (USEPA, 2002c). These stormwater conveyances are best constructed where existing bare ditches transport stormwater, so no income loss from land conversion is expected with this practice. It is assumed that the average area required for a grassed waterway is approximately 0.1 to 0.3 percent of the drainage area, or between 44 and 131 sq ft per acre. The range is based on examples in the Illinois Drainage Guide, information from the NRCS Engineering Field Handbook, and a range of waterway lengths (100 to 300 feet). Waterways are assumed to remove phosphorus effectively for 20 years before soil, vegetation, and drainage material need to be replaced (Weiss et al., 2007). The construction cost spread out over the life of the waterway is thus $2.25/yr for each acre of agriculture draining to a grassed waterway. Annual maintenance of grassed waterways is estimated at $0.02 per sq ft (Rouge River, 2001) for an additional cost of $1.75/ac/yr of agricultural land treated. Table 4-11 summarizes the annual costs assumptions for grassed waterways.

Table 4-11. Costs Calculations for Grassed Waterways in Agricultural Land.

Item	Costs Required to Treat One Acre of Agricultural Land
Costs per Square Foot	
Construction Costs	$0.50
Annual Maintenance Costs	$0.02
Costs to Treat One Acre of Agricultural Land (assuming 44 to 131 sq ft of filter strip)	
Construction Costs	$22 to $65.50
System Life (years)	20
Annualized Construction Costs	$1 to $3.25
Annual Maintenance Costs	$1 to $2.75
Annual Income Loss	$0
Average Annual Costs	**$2 to 6/ac treated**

Grassed waterways are primarily used in animal operations to divert clean water away from pastures, feedlots, and manure storage areas. Table 4-12 summarizes the capital, maintenance, and annualized costs of this practice per head of cattle as summarized by NRCS (2003).

Table 4-12. Costs Calculations for Grassed Waterways Used in Cattle Operations.

Capital Costs per Head	Annual Operation and Maintenance Costs per Head	Total Annualized Costs per Head
$0.50 to $1.50	$0.02 to $0.04	$0.05 to $0.12

4.8 Riparian Buffers

Riparian corridors, including both the stream channel and adjacent land areas, are important components of watershed ecology. The streamside forest slowly releases nutrients as twigs and leaves decompose. These nutrients are valuable to the fungi, bacteria, and invertebrates that form the basis of a stream's food chain. Tree canopies of riparian forests also cool the water in streams which can affect the composition of the fish species in the stream, as well as the rate of biological reactions. Channelization or widening of streams moves the canopy farther apart, decreasing the amount of shaded water surface and increasing water temperature.

Preserving natural vegetation along stream corridors can effectively reduce water quality degradation associated with development. The root structure of the vegetation in a buffer enhances infiltration of runoff and subsequent trapping of nonpoint source pollutants. However, the buffers are only effective in this manner when the runoff enters the buffer as a slow moving, shallow "sheet"; concentrated flow in a ditch or gully will quickly pass through the buffer offering minimal opportunity for retention and uptake of pollutants.

Even more important than the filtering capacity of the buffers is the protection they provide to streambanks. The rooting systems of the vegetation serve as reinforcements in streambank soils, which in turn helps to hold streambank material in place and minimize erosion. Due to the increase in stormwater runoff volume and peak rates of runoff associated with agriculture and development, stream channels are subject to greater erosional forces during stormflow events. Thus, preserving natural vegetation along stream channels minimizes the potential for water quality and habitat degradation due to streambank erosion and enhances the pollutant removal of sheet flow runoff from developed areas that passes through the buffer. Riparian buffers should consist of native species and may include grasses, forbs, shrubs, and trees.

Figure 4-4. Riparian Buffer Protecting the Stream from Adjacent Agricultural Fields.

4.8.1 Effectiveness

Riparian buffers should consist of native species and may include grasses, forbs, shrubs, and trees. Minimum buffer widths of 25 feet are required for water quality benefits. Higher removal rates are provided with greater buffer widths. Riparian corridors typically treat a maximum of 300 ft of adjacent land before runoff forms small channels that short circuit treatment. Buffer widths based on slope measurements and recommended plant species should conform to NRCS Field Office Technical Guidelines. The following reductions are reported in the literature:

- 25 to 30 percent reduction of total phosphorus for 30 ft wide buffers (NCSU, 2002)
- 70 to 80 percent reduction of total phosphorus for 60 to 90 ft wide buffers (NCSU, 2002)
- 34 to 74 percent reduction of fecal coliform for 30 ft wide buffers (Wenger, 1999)
- 87 percent reduction of fecal coliform for 200 ft wide buffers (Wenger, 1999)
- 62 percent reduction in BOD_5 for 200 ft wide buffers (Wenger, 1999)
- 70 to 90 percent reduction of sediment (and likely manganese) (NCSU, 2002)
- Increased canopy cover provides shading which may reduce water temperatures and improve dissolved oxygen concentrations (NCSU, 2002). Wenger (1999) suggests buffer width of at least 30 ft to maintain stream temperatures.
- Increased channel stability will reduce streambank erosion and manganese loads

4.8.2 Costs

Restoration of riparian areas costs approximately $100/ac to construct and $475/ac to maintain over the life of the buffer (Wossink and Osmond, 2001; NCEEP, 2004). Maintenance of a riparian buffer should be minimal, but may include items such as period inspection of the buffer, minor grading to prevent short circuiting, and replanting/reseeding dead vegetation following premature death or heavy storms. Assuming a buffer width of 90 ft on either side of the stream channel and an adjacent treated width of 300 ft of agricultural land, one acre of buffer will treat approximately 3.3 acres of adjacent agricultural land. The cost per treated area is thus $30/ac to construct and $142.50/ac to maintain over the life of the buffer. Assuming a system life of 30 years results in an annualized cost of $59.25/yr for each acre of agriculture land treated (Table 4-13).

The cost of restoring riparian areas to protect the stream corridor from cattle trampling and reduce the amount of fecal material entering the channel is shown in Table 4-14. The cost of this BMP depends more on the length of channel to be protected, rather than the number of animals having channel access. The costs of restoration is approximately $100/ac to construct and $475/ac to maintain over the life of the buffer (Wossink and Osmond, 2001; NCEEP, 2004). Fecal coliform reductions have been reported for buffers at least 30 ft wide (Wenger, 1999). Large reductions are reported for 200 ft wide buffers.

Table 4-13. Costs Calculations for Riparian Buffers in Agricultural Land.

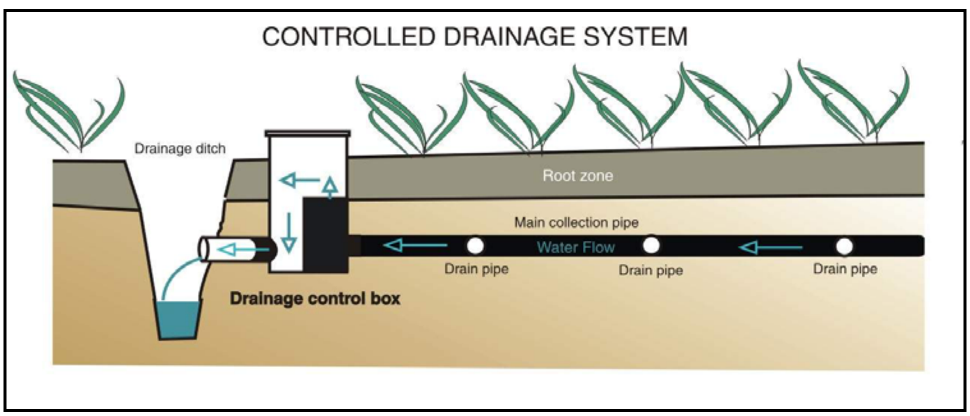
Item	Costs Required to Treat One Acre of Agricultural Land
Costs per Acre of Riparian Buffer	
Construction Costs	$100
Maintenance Costs Over System Life	$475
Costs to Treat One Acre of Agricultural Land (assuming 0.3 ac of buffer)	
Construction Costs	$30
Maintenance Costs Over System Life	$142.50
System Life (Years)	30
Annualized Construction Costs	$1
Annualized Maintenance Costs	$4.75
Annual Income Loss	$53.50
Average Annual Costs	**$59.25/ac treated**

Table 4-14. Costs Calculations for Riparian Buffers per Foot of Channel.

Width	Capital Costs per ft	Annual Operation and Maintenance Costs per ft	Total Annualized Costs per ft
30 ft on both sides of channel	$0.14	$0.02	$0.03
60 ft on both sides of channel	$0.28	$0.04	$0.05
90 ft on both sides of channel	$0.42	$0.06	$0.07
200 ft on both sides of channel	$0.93	$0.13	$0.16

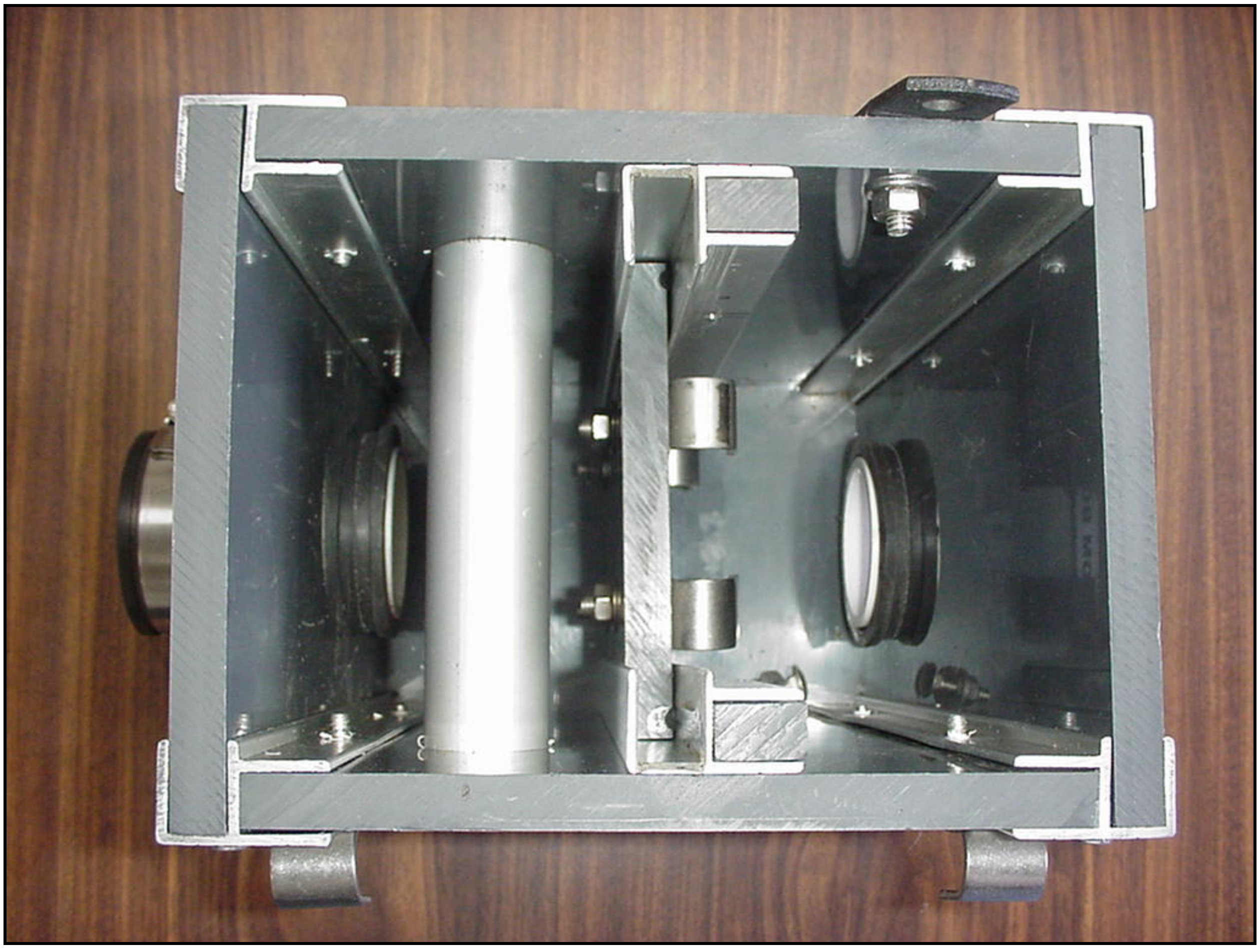
4.9 Controlled Drainage

A conventional tile drain system collects infiltrated water below the root zone and transports the water quickly to a down-gradient surface outlet. Placement of a water-level control structure at the outlet (Figure 4-5 and Figure 4-6) allows for storage of the collected water to a predefined elevation. The stored water becomes a source of moisture for plants during dry conditions and undergoes biological, chemical, and physical processes that result in lower nutrient concentrations in the final effluent.



(Illustration Courtesy of the Agricultural Research Service Information Division)

Figure 4-5. Controlled Drainage Structure for a Tile Drain System.



(Photo Courtesy of CCSWCD)

Figure 4-6. Interior View of a Drainage Control Structure with Adjustable Baffle Height.
The NRCS provides additional information on drainage management at: http://efotg.nrcs.usda.gov/references/public/IL/554.pdf.

4.9.1 Effectiveness

Researchers at the University of Illinois also report reductions in phosphorus loading with tile drainage control structures. Concentrations of phosphate were reduced by 82 percent, although total phosphorus reductions were not quantified in this study (Cooke, 2005). Going from a surface draining system to a tile drain system with outlet control reduces phosphorus loading by 65 percent (Gilliam et al., 1997).

Storage of drainage water for later use via subsurface irrigation has shown decreases in dissolved phosphorus loading of approximately 50 percent (Tan et al., 2003). However, accumulated salts in reuse water may eventually exceed plant tolerance and result in reduced crop yields. Mixing stored drain water with fresh water or alternating irrigation with natural precipitation events will reduce the negative impacts of reuse. Salinity thresholds for each crop should be considered and compared to irrigation water concentrations.

4.9.2 Costs

The Champaign County Soil and Water Conservation District currently offers tile mapping services for approximately $2.25/ac using color infrared photography to assist farmers in identifying the exact location of their tile drain lines. Cooke (2005) estimates that the cost of retrofitting tile drain systems with outlet control structures ranges from $20 to $40 per acre. Construction of new tile drain systems with outlet control is approximately $75/ac. The yield increases associated with installation of tile drain systems are expected to offset the cost of installation (Cooke, 2005). It is assumed that outlet control structures have a system life of 30 years. Cost assumptions for retrofitting and installation of new tile drain systems with outlet control devices are summarized in Table 4-15.

Table 4-15. Costs Calculations for Outlet Control Devices on Tile Drain Systems.

Item	Costs to Retrofit Existing Systems	Costs to Install a New System
Mapping Costs per Acre	$2.25	$0
Construction Costs	$20 to $40/ac	$75/ac
System Life (years)	30	30
Average Annual Costs	**$0.75 to $1.50/ac treated**	**$2.50/ac treated**

4.10 Proper Manure Handling, Collection and Disposal

Animal operations are typically either pasture-based or confined, or sometimes a combination of the two. The operation type dictates the practices needed to manage manure from the facility. A pasture or open lot system with a relatively low density of animals (1 to 2 head of cattle per acre (USEPA, 2002a)) may not produce manure in quantities that require management for the protection of water quality. If excess manure is produced, then the manure will typically be scraped with a tractor to a storage bin constructed on a concrete surface. Stored manure can then be land applied when ground is not frozen and precipitation forecasts are low. Rainfall runoff should be diverted around the storage facility with berms or grassed waterways. Runoff from the feedlot area is considered contaminated and is typically treated in a lagoon.

Confined facilities (typically dairy cattle, swine, and poultry operations) often collect manure in storage pits located under slatted floors. Wash water used to clean the floors and remove manure buildup combines with the solid manure to form a liquid or slurry in the pit. The mixture is usually land applied or transported offsite.

Final disposal of waste usually involves land application on the farm or transportation to another site. Manure is typically applied to the land once or twice per year. To maximize the amount of nutrients and organic material retained in the soil, application should not occur on frozen ground or when precipitation is forecast during the next several days.

An example of a waste storage lagoon is shown in Figure 4-7.

Figure 4-7. Waste Storage Lagoon.

The NRCS provides additional information on waste storage facilities and cover at
http://efotg.nrcs.usda.gov/treemenuFS.aspx
in Section IV B. Conservation Practices Number 313 and 367

and on anaerobic lagoons at
http://efotg.nrcs.usda.gov/references/public/IL/IL-365_2004_09.pdf
http://efotg.nrcs.usda.gov/references/public/IL/IL-366_2004_09.pdf

4.10.1 Effectiveness

Though little change in total phosphorus or organic content has been reported, reductions in fecal coliform as a result of manure storage have been documented in two studies:

- 97 percent reduction in fecal coliform concentrations in runoff when manure is stored for at least 30 days prior to land application (Meals and Braun, 2006).
- 90 percent reduction in fecal coliform loading with the use of waste storage structures, ponds, and lagoons (USEPA, 2003).

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4.10.2 Costs

NRCS (2003) has developed cost estimates for the various tasks and facilities typically used to transport, store, and dispose of manure. Table 4-16 summarizes the information contained in the NRCS report and lists the capital and operating/maintenance costs reported per head of animal. Annual maintenance costs were assumed to be 3 percent of capital costs except for gutter downspouts (assumed to be 10 percent to account for animals trampling the downspouts) and collection and transfer (assumed to be 15 percent to account for costs associated with additional fuel and labor). The costs presented as a range were given for various sizes of operations. The lower values reflect the costs per head for the larger operations which are able to spread out costs over more animals.

The full NRCS document can be viewed at
http://www.nrcs.usda.gov/Technical/land/pubs/cnmp1.html

The useful life for practices requiring construction is assumed to be 20 years. The total annualized costs were calculated by dividing the capital costs by 20 and adding the annual operation and maintenance costs. Prices are converted to year 2004 dollars.

Table 4-16. Costs Calculations for Manure Handling, Storage, and Treatment per Head.

Item	Application	Capital Costs per Head	Annual Operation and Maintenance Costs per Head	Total Annualized Costs per Head
Collection and Transfer of Solid Manure, Liquid/Slurry Manure, and Contaminated Runoff				
Collection and transfer of manure solids (assuming a tractor must be purchased)	All operations with outside access and solid collection systems for layer houses	$130.50 - dairy cattle $92.50 - beef cattle $0 - layer[1] $37.00 - swine	$19.50 - dairy cattle $13.75 - beef cattle $0.04 - layer $5.50 - swine	$26.00 - dairy cattle $18.25 - beef cattle $0.04 - layer $7.25 - swine
Collection and transfer of liquid/slurry manure	Dairy, swine, and layer operations using a flush system	$160 to $200 - dairy cattle $.50 - layer $5.75 to $4.50 - swine	$12.25 - dairy cattle $0.03 - layer $0.25 - swine	$20.25 to 22.25 - dairy cattle $0.05 - layer $0.50 - swine
Collection and transfer of contaminated runoff using a berm with pipe outlet	Fattened cattle and confined heifers	$4 to $9 - cattle	$0.12 to 0.25 - cattle	$0.25 to $0.75 - cattle
Feedlot Upgrades for Cattle Operations Using Concentrated Feeding Areas				
Grading and installation of a concrete pad	Cattle on feed (fattened cattle and confined heifers)	$35 - cattle	$1 - cattle	$2.75 - cattle
Clean Water Diversions				
Roof runoff management: gutters and downspouts	Dairy and swine operations that allow outside access	$16 - dairy cattle $2.25 - swine	$1.60 - dairy cattle $0.25 - swine	$2.50 - dairy cattle $0.50 - swine
Earthen berm with underground pipe outlet	Fattened cattle and dairy operations	$25.25 to $34.50 - cattle	$0.75 to $1.00 - cattle	$2 to $2.75 - cattle
Earthen berm with surface outlet	Swine operations that allow outside access	$1 - swine	$0.03 - swine	$0.08 - swine
Grassed waterway	Fattened cattle and confined heifer operations: scrape and stack system	$0.50 to $1.50 - cattle	$0.02 to $0.04 - cattle	$0.05 to $0.12 - cattle

[1] Costs presented by NRCS (2003) as operating and maintenance only.

Table 4-16. Costs Calculations for Manure Handling, Storage, and Treatment Per Head (continued).

Item	Application	Capital Costs per Head	Annual Operation and Maintenance Costs per Head	Total Annualized Costs per Head
Storage				
Liquid storage (contaminated runoff and wastewater)	Swine, dairy, and layer operations using flush systems (costs assume manure primarily managed as liquid)	$245 to $267 - dairy cattle $2 - layer $78.50 to $80 - swine	$7.25 - dairy cattle $0.06 - layer $2.50 - swine	$19.50 to $20.50 - dairy cattle $0.16 - layer $6.50 - swine
Slurry storage	Swine and dairy operations storing manure in pits beneath slatted floors (costs assume manure primarily managed as slurry)	$104 to $127 - dairy cattle $15.50 to $19.50 - swine	$3.25 to $3.75 - dairy cattle $0.50 - swine	$8.25 to $10.25 - dairy cattle $1.25 to $1.50 - swine
Runoff storage ponds (contaminated runoff)	All operations with outside access	$125.50 - dairy cattle $140 - beef cattle $23 - swine	$3.75 - dairy cattle $4.25 - beef cattle $0.75 - swine	$10 - dairy cattle $11.25 - beef cattle $2 - swine
Solid storage	All animal operations managing solid wastes (costs assume 100% of manure handled as solid)	$196 - dairy cattle $129 - beef cattle $1 - layer $14.25 - swine	$5.75 - dairy cattle $3.75 - beef cattle $0.03 - layer $0.50 - swine	$15.50 - dairy cattle $10.25 - beef cattle $0.25 - layer $1.25 - swine

Table 4-16. Costs Calculations for Manure Handling, Storage, and Treatment Per Head (continued).

Item	Application	Capital Costs per Head	Annual Operation and Maintenance Costs per Head	Total Annualized Costs per Head
Final Disposal				
Pumping and land application of liquid/slurry	Operations handling manure primarily as liquid or slurry.	Land application costs are listed as capital plus operating for final disposal and are listed as dollars per acre for the application system. The required number of acres per head was calculated for each animal type based on the phosphorus content of manure at the time of application. Pumping costs were added to the land application costs as described in the document.		\$19.50 - dairy cattle \$0.25 - layer \$2.75 - swine
Pumping and land application of contaminated runoff	Operations with outside feedlots and manure handled primarily as solid	Pumping costs and land application costs based on information in NRCS, 2003. Assuming a typical phosphorus concentration in contaminated runoff of 80 mg/L to determine acres of land required for agronomic application (Kizil and Lindley, 2000). Costs for beef cattle listed as range representing variations in number of animals and manure handling systems (NRCS, 2003). Only one type and size of dairy and swine operation were included in the NRCS document.		\$4 - dairy cattle \$3.75 - beef cattle \$4.50 - swine
Land application of solid manure	Operations handling manure primarily as solid	Land application costs are listed as capital plus operating for final disposal and are given as dollars per acre for the application system. The required number of acres per head was calculated for each animal type based on the phosphorus content of manure at the time of application. No pumping costs are required for solid manure.		\$11 - dairy cattle \$0.25 - layer \$1.50 - swine \$10.25 - fattened cattle

4.11 Composting

Composting is the biological decomposition and stabilization of organic material. The process produces heat that, in turn, produces a final product that is stable, free of pathogens and viable plant seeds, and can be beneficially applied to the land. Like manure storage areas, composting facilities should be located on dry, flat, elevated land at least 100 feet from streams. The landowner should coordinate with a USDA agricultural extension agent to determine the appropriate design for a composting facility based on the amount of manure generated. Extension agents can also help landowners achieve the ideal nutrient ratios, oxygen levels, and moisture conditions for composting on their site.

Composting can be accomplished by simply constructing a heap of the material, forming composting windrows, or by constructing one or more bins to hold the material. Heaps should be 3 feet wide and 5 feet high with the length depending on the amount of manure being composted. Compost does not have to be turned, but turning will facilitate the composting process (University of Missouri, 1993; PSU, 2005). Machinery required for composting includes a tractor, manure spreader, and front-end loader (Davis and Swinker, 2004). Figure 4-8 shows a poultry litter composting facility.

(Photo courtesy of USDA NRCS.)

Figure 4-8. Poultry Litter Composting Facility.

The NRCS provides additional information on composting facilities at
http://efotg.nrcs.usda.gov/references/public/IL/IL-317rev9-04.pdf
and
ftp://ftp.wcc.nrcs.usda.gov/downloads/wastemgmt/neh637c2.pdf

4.11.1 Effectiveness

Composting stabilizes the organic content of manure and reduces the volume that needs to be disposed of. In addition, the following reductions in loading are reported:

- 99 percent reduction of fecal coliform concentrations as a result of the heat produced during the composting process (Larney et. al., 2003).
- 56 percent reduction in runoff volumes and 68 percent reduction in sediment (and likely manganese) as a result of improved soil infiltration following application of composted manure (HRWCI, 2005).

4.11.2 Costs

The costs for developing a composting system include site development costs (storage sheds, concrete pads, runoff diversions, etc.), purchasing windrow turners if that system is chosen, and labor and fuel required to form and turn the piles. Cost estimates for composting systems have not been well documented and show a wide variation even for the same type of system. The NRCS is in the process of developing cost estimates for composting and other alternative manure applications in Part II of the document discussed in Section 5.10.2. Once published, these estimates should provide a good comparison with the costs summarized for the Midwest region in Table 4-16. For now, costs are presented in Table 4-17 based on studies conducted in Wisconsin, Canada, and Indiana.

Researchers in Wisconsin estimated the costs of a windrow composting system using four combinations of machinery and labor (CIAS, 1996). These costs include collection and transfer of excreted material, formation of the windrow pile, turning the pile, and reloading the compost for final disposal. The Wisconsin study was based on a small dairy operation (60 head). Costs for beef cattle, swine, and layer hens were calculated based on animal units and handling weights of solid manure (NRCS, 2003). Equipment life is assumed 20 years. The costs presented in the Wisconsin study are much higher than those presented in Table 4-16 for collection, transfer, and storage of solid manure. However, the Wisconsin study presented a cost comparison of the windrow system to stacking on a remote concrete slab, and these estimates were approximately four and half times higher than the values summarized by NRCS. It is likely that the single data set used for the Wisconsin study is not representative of typical costs.

The University of Alberta summarized the per ton costs of windrow composting with a front end load compared to a windrow turner (University of Alberta, 2000).

The Alberta Government presented a per ton estimate for a windrow system with turner: this estimate is quite different than the University of Alberta study. These per ton costs were converted to costs per head of dairy cattle, beef cattle, swine, and layer hens based on the manure generation and handling weights presented by NRCS (2003).

In 2001, the USEPA released a draft report titled “Alternative Technologies/Uses for Manure.” This report summarizes results from a Purdue University research farm operating a 400-cow dairy operation. This farm also utilizes a windrow system with turner.

Table 4-17 summarizes the cost estimates presented in each of the studies for the various composting systems. None of these estimates include the final costs of land application, which should be similar to those listed for disposal of solid manure in Table 4-16 as no phosphorus losses occur during the composting process.

Table 4-17. Costs Calculations for Manure Composting.

Equipment Used	Capital Costs per Head	Annual Operation and Maintenance Costs per Head	Total Annualized Costs per Head
2004 Costs Estimated from CIAS, 1996 – Wisconsin Study			
Windrow composting with front-end loader	$324.25 - dairy cattle $213.50 - beef cattle $1.75 - layer $23.75 - swine	$179.75 - dairy cattle $118.50 - beef cattle $1 - layer $13.25 - swine	$196 - dairy cattle $129.25 - beef cattle $1 - layer $14.25 - swine
Windrow composting with bulldozer	$266 - dairy cattle $175.25 - beef cattle $1.50 - layer $19.50 - swine	$179.75 - dairy cattle $118.50 - beef cattle $1 - layer $13.25 - swine	$193.25 - dairy cattle $127.25 - beef cattle $1 - layer $14.25 - swine
Windrow composting with custom-hire compost turner	$266 - dairy cattle $175.25 - beef cattle $1.50 - layer $19.50 - swine	$215.25 - dairy cattle $141.75 - beef cattle $1.25 - layer $15.75 - swine	$228.75 - dairy cattle $150.50 - beef cattle $1.25 - layer $16.75 - swine
Windrow composting with purchased compost turner	$617 - dairy cattle $406.25 - beef cattle $3.50 - layer $45.25 - swine	$234.25 - dairy cattle $154.25 - beef cattle $1.25 - layer $17.25 - swine	$265.25 - dairy cattle $174.75 - beef cattle $1.50 - layer $19.50 - swine
2004 Costs Estimated from University of Alberta, 2000			
Windrow composting with front-end loader	Study presented annualized costs per ton of manure composted.		$23.75 to $47.50 - dairy cattle $15.75 to $31.25 - beef cattle $0.13 to $0.25 - layer $1.75 to $3.50 - swine
Windrow composting with compost turner	Study presented annualized costs per ton of manure composted.		$71.25 to $142.50 - dairy cattle $47.00 to $94.00 - beef cattle $0.50 to $0.75 - layer $5.25 to $10.50 - swine
2004 Costs Estimated from Alberta Government, 2004			
Windrow composting with compost turner	Study presented annualized costs per ton of manure composted.		$31.50 - dairy cattle $20.75 - beef cattle $0.25 - layer $2.25 - swine
2004 Costs Estimated from USEPA, 2001a Draft			
Windrow composting with compost turner	Study presented annualized costs per dairy cow.		$15.50 - dairy cattle $10.25 - beef cattle $0.09 - layer $1.25 - swine

4.12 Constructed Wetlands

Constructed wetlands used to treat animal wastes are typically surface flowing systems comprised of cattails, bulrush, and reed plants. Wetland environments treat wastewater through sedimentation, filtration, plant uptake, biochemical transformations, and volatilization. Prior to treating animal waste in a constructed wetland, storage in a lagoon or pond is required to protect the wetland from high pollutant loads that may kill the vegetation or clog pore spaces. After treatment in the wetland, the effluent is typically held in another storage lagoon and then land applied (USEPA, 2002a). Alternatively, the stored effluent can be used to supplement flows to the wetland during dry periods. Constructed wetlands that ultimately discharge to a surface waterbody will require a permit, and the receiving stream must be capable of assimilating the effluent during low flow conditions (NRCS, 2002b). Figure 4-9 shows an example of a lagoon-wetland system.

(Photo courtesy of USDA NRCS.)

Figure 4-9. Constructed Wetland System for Animal Waste Treatment.

The NRCS provides additional information on constructed wetlands at
http://efotg.nrcs.usda.gov/references/public/IL/656.pdf
and
ftp://ftp.wcc.nrcs.usda.gov/downloads/wastemgmt/NEH637Ch3ConstructedWetlands.pdf

4.12.1 Effectiveness

Wetland environments treat wastewater through sedimentation, filtration, plant uptake, biochemical transformations, and volatilization. Reported pollutant reductions found in the literature are listed below:

- 42 percent reduction in total phosphorus (USEPA, 2003)
- 59 to 80 percent reduction in BOD_5 (USEPA, 2002a)
- 92 percent reduction in fecal coliform (USEPA, 2002a)
- 53 to 81 percent reduction in total suspended solids (USEPA, 2002a)

4.12.2 Costs

Researchers of the use of constructed wetlands for animal waste management generally agree that these systems are a lower cost alternative compared to conventional treatment and land application technologies. Few studies, however, actually report the costs of constructing and maintaining these systems. A Canadian study (CPAAC, 1999) evaluated the use of a constructed wetland system for treating milk house washings as well as contaminated runoff from the feedlot area and manure storage pile of a dairy operation containing 135 head of dairy cattle. The treatment system was comprised of a pond/wetland/pond/wetland/filter strip treatment train that cost $492 per head to construct. Annual operating and maintenance costs of $6.75 per head include electricity to run pumps, maintenance of pumps and berms, and dredging the wetland cells once every 10 years. Reductions in final disposal costs due to reduced phosphorus content of the final effluent were $20.75 per head and offset the costs of constructing and maintaining the wetland in seven years.

Another study evaluated the use of constructed wetlands for treatment of a 3,520-head swine operation in North Carolina. Waste removal from the swine facility occurs via slatted floors to an underlying pit that is flushed once per week. This new treatment system incorporated a settling basin, constructed wetland, and storage pond treatment system prior to land application or return to the pit for flushing.

Capital and maintenance costs reported in the literature for dairy and swine operations are summarized per head in Table 4-18. No example studies including costs were available for beef cattle operations, which should generate less liquid waste than the other two operations. It would therefore be expected that constructing a wetland for beef cattle operation would cost less than for a dairy or swine operation.

Table 4-18. Costs Calculations for Constructed Wetlands.

Example	Capital Costs per Head	Annual Operation and Maintenance Costs per Head	Total Annualized Costs per Head
Dairy farm	$492	-$14	$2.50
Swine operation	$103.75	$1.00	$4.50

4.13 Alternative Watering Systems

A primary management tool for pasture-based systems is supplying cattle with watering systems away from streams and riparian areas. Livestock producers who currently rely on streams to provide water for their animals must develop alternative watering systems, or controlled access systems, before they can exclude cattle from streams and riparian areas. One method of providing an alternative water source is the development of off-stream watering using wells with tank or trough systems. These systems are often highly successful, as cattle often prefer spring or well water to surface water sources.

Landowners should work with an agricultural extension agent to properly design and locate watering facilities. One option is to collect rainwater from building roofs (with gutters feeding into cisterns) and use this water for the animal watering system to reduce runoff and conserve water use (Tetra Tech, 2006). Whether or not animals are allowed access to streams, the landowner should provide an alternative shady location and water source so that animals are encouraged to stay away from riparian areas. Figure 4-10 shows a centralized watering tank allowing access from rotated grazing plots and a barn area.

(Photo courtesy of USDA NRCS.)

Figure 4-10. Centralized Watering Tank.

The NRCS provides additional information on these alternative watering components:

Spring development
http://efotg.nrcs.usda.gov/references/public/IL/IL-574.pdf,

Well development
http://efotg.nrcs.usda.gov/references/public/IL/IL-642.pdf,

Pipeline
http://efotg.nrcs.usda.gov/references/public/IL/516.pdf,

Watering facilities (trough, barrel, etc.)
http://efotg.nrcs.usda.gov/treemenuFS.aspx
in Section IV B. Conservation Practices Number 614

4.13.1 Effectiveness

The USEPA (2003) reports the following pollutant load reductions achieved by supplying cattle with alternative watering locations and excluding cattle from the stream channel by structural or vegetative barrier:

- 15 to 49 percent reductions in total phosphorus loading
- 29 to 46 percent reductions in fecal coliform loading.

4.13.2 Costs

Alternative drinking water can be supplied by installing a well in the pasture area, pumping water from a nearby stream to a storage tank, developing springs away from the stream corridor, or piping water from an existing water supply. For pasture areas without access to an existing water supply, the most reliable alternative is installation of a well, which ensures continuous flow and water quality for the cattle (NRCS, 2003). Assuming a well depth of 250 ft and a cost of installation of $22.50 per ft, the cost to install a well is approximately, $5,625 per well. The well pump would be sized to deliver adequate water supply for the existing herd size. For a herd of 150 cattle, the price per head for installation was estimated at $37.50.

After installation of the well or extension of the existing water supply, a water storage device is required to provide the cattle access to the water. Storage devices include troughs or tanks. NRCS (2003) lists the costs of storage devices at $23 per head.

Annual operating costs to run the well pump range from $9 to $22 per year for electricity (USEPA, 2003; Marsh, 2001), or up to $0.15 per head. Table 4-19 lists the capital, maintenance, and annualized costs for a well, pump, and storage system assuming a system life of 20 years.

Table 4-19. Costs Calculations for Alternative Watering Facilities.

Item	Capital Costs per Head	Annual Operation and Maintenance Costs per Head	Total Annualized Costs per Head
Installation of well	$37.50	$0	$2
Storage container	$23	$0	$1
Electricity for well pump	$0	$0.15	$0.15
Total system costs	**$60.50**	**$0.15**	**$3.15**

4.14 Cattle Exclusion from Streams

Cattle manure is a substantial source of nutrient and fecal coliform loading to streams, particularly where direct access is not restricted and/or where cattle feeding structures are located adjacent to riparian areas. Direct deposition of feces into streams may be a primary mechanism of fecal coliform loading during baseflow periods. During storm events, overbank and overland flow may entrain manure accumulated in riparian areas resulting in pulsed loads of nutrients, total organic carbon (TOC), biological oxygen demand (BOD), and fecal coliform bacteria into streams. In addition, cattle with unrestrained stream access typically cause severe streambank erosion. The impacts of cattle on stream ecosystems are shown in Figure 4-11and Figure 4-12.

Figure 4-11. Typical Stream Bank Erosion in Pastures with Cattle Access to Stream.

Figure 4-12. Cattle-induced Streambank Mass Wasting and Deposition of Manure into Stream.

An example of proper exclusion and the positive impacts on the stream channel are shown in Figure 4-13.

(Photo courtesy of USDA NRCS.)

Figure 4-13. Stream Protected from Sheep by Fencing.

The NRCS provides additional information on fencing at:
http://efotg.nrcs.usda.gov/treemenuFS.aspx
in Section IV B. Conservation Practices Number 382

Allowing limited or no animal access to streams will provide the greatest water quality protection. On properties where cattle need to cross streams to have access to pasture, stream crossings should be built so that cattle can travel across streams without degrading streambanks and contaminating streams with manure. Figure 4-14 shows an example of a reinforced cattle access point to minimize time spent in the stream and mass wasting of streambanks.

(Photo courtesy of USDA NRCS.)

Figure 4-14. Restricted Cattle Access Point with Reinforced Banks.

The NRCS provides additional information on use exclusion and controlled access at:
http://efotg.nrcs.usda.gov/treemenuFS.aspx
in Section IV B. Conservation Practices Number 472

4.14.1 Effectiveness

Fencing cattle from streams and riparian areas using vegetative or fencing materials will reduce streambank trampling and direct deposition of fecal material in the streams. As a result, manganese (associated with eroded sediment) and BOD_5 loads will decrease. The USEPA (2003) reports the following reductions in phosphorus and fecal coliform loading as a result of cattle exclusion practices:

- 15 to 49 percent reductions in total phosphorus loading
- 29 to 46 percent reductions in fecal coliform loading.

4.14.2 Costs

The costs of excluding cattle from streams depends more on the length of channel that needs to be protected than the number of animals on site. Fencing may also be used in a grazing land protection operation to control cattle access to individual plots. Costs were published by the Iowa State University Cooperative Extension Service in 1999 on the World Wide Web. The system life of the wire fences was reported as 20 years; the high tensile fence materials have a reported system life of 25 years. NRCS reports that the average operation needs approximately 35 ft of additional fencing per head to protect grazing lands and streams. Table 4-20 presents the capital, maintenance, and annualized costs for four fencing materials based on the NRCS assumptions.

Table 4-20. Installation and Maintenance Costs of Fencing Material.

Material	Capital Costs per Head	Annual Operation and Maintenance Costs per Head	Total Annualized Costs per Head
Woven Wire	$43.50	$3.50	$5.75
Barbed Wire	$33.50	$2.75	$4.50
High Tensile (non-electric) 8-strand	$30.75	$1.75	$3.00
High Tensile (electric) 5-strand	$23.00	$1.50	$2.50

4.15 Grazing Land Management

While erosion rates from pasture areas are generally lower than those from row-crop areas, a poorly managed pasture can approach or exceed a well-managed row-crop area in terms of erosion rates. Grazing land protection is intended to maximize ground cover on pasture, reduce soil compaction resulting from overuse, reduce runoff concentrations of nutrients and fecal coliform, and protect streambanks and riparian areas from erosion and fecal deposition. Figure 4-15 shows an example of a pasture managed for land protection. Cows graze the left lot while the right lot is allowed a resting period to revegetate.

(Photo courtesy of USDA NRCS.)

Figure 4-15. Example of a Well Managed Grazing System.

The NRCS provides additional information on prescribed grazing at
http://efotg.nrcs.usda.gov/treemenuFS.aspx
in Section IV B. Conservation Practices Number 528A
and on grazing practices in general at
http://www.glti.nrcs.usda.gov/technical/publications/nrph.html

4.15.1 Effectiveness

Maintaining sufficient ground cover on pasture lands requires a proper density of grazing animals and/or a rotational feeding pattern among grazing plots. Increased ground cover will also reduce transport of sediment-bound manganese. Dissolved oxygen concentrations in streams will likely improve as the concentrations of BOD_5 in runoff are reduced proportionally with the change in number of cattle per acre.

The following reductions in loading are reported in the literature:

- 49 to 60 percent reduction in total phosphorus loading
- 40 percent reduction in fecal coliform loading as a result of grazing land protection measures (USEPA, 2003)
- 90 percent reduction in fecal coliform loading with rotational grazing (Government of Alberta, 2007).

4.15.2 Costs

The costs associated with grazing land protection include acquiring additional land if current animal densities are too high (or reducing the number of animals maintained), fencing, and seeding costs, and developing alternative water sources. Establishment of vegetation for pasture areas costs from $39/ac to $69/ac based on data presented in the EPA nonpoint source guidance for agriculture (USEPA, 2003). Annual costs for maintaining vegetative cover will likely range from $6/ac to $11/ac (USEPA, 2003). If cattle are not allowed to graze plots to the point of requiring revegetation, the cost of grazing land protection may be covered by the fencing and alternative watering strategies discussed above.

4.16 Feeding Strategies

Use of dietary supplements, genetically enhanced feed, and specialized diets has been shown to reduce the nitrogen and phosphorus content of manure either by reducing the quantity of nutrients consumed or by increasing the digestibility of the nutrients. Manure with a lower nutrient content can be applied at higher rates to crop land, thus reducing transportation and disposal costs for excess manure.

Manure typically has a high phosphorus content relative to plant requirements, and also compared to its nitrogen content. Nitrogen losses due to ammonia volatilization begin immediately following waste excretion and continue throughout the stabilization process, whereas phosphorus remains conserved. In addition, most livestock animals are not capable of efficiently digesting phosphorus, so a large percentage passes through the animal undigested. Compounding the problem is over-supplementation of phosphorus additives relative to nutritional guidelines, particularly for dairy cattle (USEPA, 2002a).

4.16.1 Effectiveness

Most feeding strategies work to reduce the phosphorus content of manure such that the end product has a more balanced ratio of nitrogen and phosphorus. Reducing the phosphorus content of manure will result in lower phosphorus concentrations in runoff and stream systems. Feeding strategies will indirectly impact dissolved oxygen concentrations by reducing eutrophication in streams and lakes. The USEPA (2002a) reports the following reductions in phosphorus manure content:

- 40 percent reduction in the phosphorus content of swine manure if the animals are fed low-phytate corn or maize-soybean diets or given a phytase enzyme to increase assimilation by the animal.
- 30 to 50 percent reduction in the phosphorus content of poultry manure by supplementing feed with the phytase enzyme.

4.16.2 Costs

Several feeding strategies are available to reduce the phosphorus content of manure. Supplementing feed with the phytase enzyme increases the digestibility of phytate, which is difficult for animals to digest and is the form of phosphorus found in conventional feed products. Supplementing with phytase used to be expensive, but now is basically equivalent to the cost of the dietary phosphorus supplements that are required when animals are fed traditional grains (Wenzel, 2002).

Another strategy is to feed animals low-phytate corn or barley which contains more phosphorus in forms available to the animal. Most animals fed low-phytate feed do not require additional phosphorus supplementation; the additional cost of the feed is expected to offset the cost of supplements. The third strategy is to stop over-supplementing animals with phosphorus. Reducing intake to dietary requirements established by the USDA may save dairy farmers $25 per year per cow (USEPA, 2002a). Final disposal costs for manure will likely also decrease since less land will be required during the application process.

4.17 Streambank and Lake Shore Erosion

Streambanks in the Cedar Creek/Cedar Lake watershed should be inspected for signs of erosion. Banks showing moderate to high erosion rates (indicated by poorly vegetated reaches, exposed tree roots, steep banks, etc.) can be stabilized by engineering controls, vegetative stabilization, and restoration of riparian areas. Peak flows and velocities from runoff areas can be mitigated by infiltration in grassed waterways and passage of runoff through filter strips.

4.17.1 Effectiveness

Because the phosphorus loading from streambank erosion has not been quantified, it is not possible to estimate the additional phosphorus removed by these BMPs (over that assumed for agricultural load reductions). The benefits of filter strips, grassed waterways, and riparian buffers are therefore underestimated in this report.

4.17.2 Costs

Because the extent of streambank erosion in the watershed is not known, specialized BMPs, such as engineering controls, are not suggested. Rather, the agricultural BMPs that also address streambank stability are recommended (Table 4-21).

Table 4-21. Agricultural Phosphorus BMPs with Secondary Benefits for Streambank Stability.

BMP	Description	Annualized Cost Estimates
Filter Strips	Placement of vegetated strips in the path of field drainage to remove sediment and nutrients and reduce runoff velocities.	Seeded filter strips cost $25/ac treated Sodded strips cost $43/ac treated
Grassed Waterways	A runoff conveyance that removes phosphorus by sedimentation and plant uptake. Reduces peak flow velocities and subsequent erosion.	$2/ac to $6/ac
Restoration of Riparian Buffers	Conversion of land adjacent to stream channels to vegetated buffer zones. Removes phosphorus by sedimentation and plant uptake. Provides stream bank stability, stream shading, and aesthetic enhancement.	$59.25/ac treated

4.18 In-lake Controls

For lakes experiencing high rates of phosphorus or manganese inputs from bottom sediments, several management measures are available to control internal loading. Hypolimnetic (bottom water) aeration involves an aerator air-release that can be positioned at a selected depth or at multiple depths to increase oxygen transfer efficiencies in the water column and reduce internal loading by establishing aerobic conditions at the sediment-water interface.

4.18.1 Effectiveness

Hypolimnetic aeration effectiveness in reducing phosphorus concentration depends in part on the presence of sufficient iron to bind phosphorus in the oxygenated waters. A mean hypolimnetic iron:phosphorus ratio greater than 3.0 is optimal to promote iron phosphate precipitation (Stauffer, 1981). The iron:phosphorus ratio in the sediments should be greater than 15 to bind phosphorus (Welch, 1992). Aeration of bottom waters will also likely inhibit the release of manganese from bottom sediments in lakes.

Phosphorus inactivation by aluminum addition (specifically aluminum sulfate or alum) to lakes has been the most widely-used technique to control internal phosphorus loading. Alum forms a polymer that binds phosphorus and organic matter. The aluminum hydroxide-phosphate complex (commonly called alum floc) is insoluble and settles to the bottom, carrying suspended and colloidal particles with it. Once on the sediment surface, alum floc retards phosphate diffusion from the sediment to the water (Cooke et al., 1993).

Artificial circulation is the induced mixing of the lake, usually through the input of compressed air, which forms bubbles that act as airlift pumps. The increased circulation raises the temperature of the whole lake (Cooke et al., 1993) and chemically oxidizes substances throughout the water column (Pastorak et al., 1981 and 1982), reducing the release of phosphorus and manganese from the sediments to the overlying water, and enlarging the suitable habitat for aerobic animals.

If lake sediments are a significant source of phosphorus in Lake Murphysboro and Little Cedar Lake, then these in-lake controls should reduce the internal loading significantly. Without data to quantify the internal load for each lake, it is difficult to estimate the reduction in loading that may be seen with these controls.

4.18.2 Costs

In general, in-lake controls are expensive. For comparison with the agricultural cost estimates, the in-lake controls have been converted to year 2004 dollars assuming an average annual inflation rate of 3 percent.

Hypolimnetic aerators may decrease internal loading of both phosphorus and manganese. The number and size of hypolimnetic aerators used in a waterbody depend on lake morphology, bathymetry, and hypolimnetic oxygen demand. Total cost for successful systems has ranged from $170,000 to $1.7 million (Tetra Tech, 2002). USEPA (1993) reports initial costs ranging from $340,000 to $830,000 plus annual operating costs of $60,000. System life is assumed to be 20 years.

Alum treatments are effective on average for approximately 8 years per application and can reduce internal phosphorus loading by 80 percent. Treatment cost ranges from $290/ac to $720/ac (WIDNR, 2003).

Dierberg and Williams (1989) cite mean initial and annual costs for 13 artificial circulation projects in Florida of $440/ac and $190/ac/yr, respectively. The system life is assumed to be 20 years.

Table 4-22 summarizes the cost analyses for the three in-lake management measures. The final column lists the annualized cost per lake surface area treated.

Table 4-22. Cost Comparison of In-lake Controls.

Control	Construction or Application Cost	Annual Maintenance Cost	Annualized Costs $/ac/yr
Newton Lake (1,750 acres)			
Hypolimnetic Aeration	$340,000 to $830,000	$60,000	$45 to $58
Alum Treatment	$508,000 to $1,260,000	$0	$36 to $90
Artificial Circulation	$770,000	$333,000	$212
Fairfield Reservoir (16 acres)			
Hypolimnetic Aeration	$340,000 to $830,000	$60,000	$4,810 to $6,340
Artificial Circulation	$7,000	$3,000	$209

4.19 Stream Restoration

Stream restoration activities usually focus on improving aquatic habitat, but can also be used to increase the amount of reaeration from the atmosphere to the water. A proper restoration effort will involve an upfront design specific to the conditions of the reach being restored. Stagnant, slow moving, and deep waters typically have relatively low rates of reaeration. Restorations aimed at increasing reaeration must balance habitat needs (which include pools of deeper water) with sections of more shallow, faster flowing water. Adding structures to increase turbulence and removing excessive tree fall may be incorporated in the restoration plan.

Stream restoration differs from riparian buffer restoration in that the shape or features within the stream channel are altered, not the land adjacent to the stream channel. Stream restoration may also include restoration of the riparian corridor as well.

The effectiveness and cost of stream restorations is site specific and highly variable. Watershed planners and water resource engineers should be utilized to determine the reaches where restoration will result in the most benefit for the watershed as a whole.

4.20 BMP Summary

Table 4-23 summarizes the BMPs that are applicable to the sources in the Cedar Creek/Cedar Lake watershed.

Table 4-23. Summary of BMPs to reduce nutrient, fecal coliform, and BOD loadings in the Cedar Creek/Cedar Lake watershed.

BMP	Phosphorus Reduction (percent)	BOD_5 Reduction (percent)	Fecal Coliform Reduction (percent)	Additional Benefits for Stream Health and Dissolved Oxygen Impairments	Estimated Annualized Costs
Nutrient Management Plans	20 to 50	na	na	Reducing nutrient loads to streams may reduce algal growth and related dissolved oxygen problems.	\$0.75/ac/yr to \$3.75/ac/yr
Conservation Tillage	68 to 76	na	na	Reduces runoff losses by 69 percent, which may reduce rates of streambank erosion.	\$1.25/ac/yr to \$2.25/ac/yr
Cover Crops	70 to 85	na	na	Reduces runoff losses by 50 percent, which may reduce rates of streambank erosion.	\$19.25/ac
Filter Strips	65	unknown	55 to 87	Slows rates of runoff and may reduce volume via infiltration. May reduce rates of streambank erosion.	\$4 to \$6 per head of cattle/ or \$25/acre
Grassed Waterways	30	unknown	5	Slows rates of runoff and may reduce volume via infiltration. May reduce rates of streambank erosion.	\$0.05 to \$0.12 per head of cattle/ or \$2-\$6 per acre
Riparian Buffers (30 ft wide)	25 to 30	unknown	34 to 74	Slows runoff and may reduce quantity via infiltration.	\$0.03 per ft of channel
Riparian Buffers (60 to 90 ft wide)	70 to 80	unknown	unknown	Slows runoff and may reduce quantity via infiltration.	\$0.05 to \$0.07 per ft of channel
Riparian Buffers (200 ft wide)	unknown	62	87	Slows runoff and may reduce quantity via infiltration.	\$0.16 per ft of channel
Constructed Wetlands	42	59 to 80	92	Slows runoff and may reduce quantity via infiltration, evaporation, and transpiration.	\$2.50 per head of dairy cattle \$4.50 per head of swine
Controlled Drainage (new tile system)	65	na	na	Reduces peak flow volumes and velocities by storing water	\$2.50/ac
Controlled Drainage (retrofit tile system)	35	na	na	Reduces peak flow volumes and velocities by storing water	\$0.75 to \$1.50/ac

Table 4-23. Summary of BMPs to reduce nutrient, fecal coliform, and BOD loadings in the Cedar Creek/Cedar Lake watershed (cont.).

BMP	Phosphorus Reduction (percent)	BOD_5 Reduction (percent)	Fecal Coliform Reduction (percent)	Additional Benefits for Stream Health and Dissolved Oxygen Impairments	Estimated Annualized Costs
Proper Manure Handling, Collection, and Disposal	unknown	unknown	90 to 97	Reduces loads of nutrients and biodegradable organic material entering waterways which may improve dissolved oxygen concentrations.	Varies by operation and waste handling system (see Section 4.10)
Manure Composting	na	unknown	99	Stabilized manure that reaches waterbodies will degrade more slowly and not consume oxygen as quickly as conventional manure.	$1.25 to $10.50 per head of swine $15.50 to $142.50 per head of dairy cattle $10.25 to $94 per head of beef or other cattle
Feeding Strategies	30 to 50	na	na	Feeding strategies that reduce the phosphorus content of manure may improve dissolved oxygen conditions by reducing eutrophication in streams and lakes.	Variable – ranges from savings to net costs
Alternative Watering Systems with Cattle Exclusion	15 to 49	unknown	29 to 46	Prevents streambank trampling and therefore decreases loads of phosphorus to the stream. Reduces direct deposition of manure into stream channel, which reduces loads of BOD_5, nutrients, and fecal coliform.	$5.50 to $9 per head of beef or other pastured cattle
Grazing Land Management	49 to 60	unknown	40 to 90	Increased vegetative ground cover will reduce soil erosion and associated phosphorus and improve infiltration which should reduce runoff volumes. Improvements in dissolved oxygen concentrations should occur as a result of lower concentrations of BOD_5 in the runoff (reduced proportionally by the change in number of cattle per acre.)	Variable – costs may be covered by fencing and alternative watering locations
In-lake Controls	variable	unknown	na	May have impacts on dissolved oxygen balances downstream of water release structures.	$45 to $212/ac/yr
WWTP Disinfection	na	na	Variable		$42,000 to $159,200/yr
Septic System Maintenance	Variable	Variable	Variable		$170 to $451/yr

5.0 BMP PRIORITIZATION

This section discusses the pollutant sources in each of the impaired waterbodies, loads from those sources, and the various BMPs that could be used to reduce pollutant loads.

5.1 Lake Murphysboro

The Lake Murphysboro TMDL states that a 42 percent reduction in phosphorus loading is needed to achieve water quality standards. As reported in the Stage 1 watershed characterization, there are very few residences located near Lake Murphysboro and loads from these residences were estimated using typical loading rates and variable failure rates. A small portion of land is used for crop production, only 12 percent of the total land area, and average phosphorus loading rates for agricultural areas were used to estimate the load from this source. No information was available to estimate the loads from other sources, such as animal operations or internal loading from lake bottom sediments. Table 5-1 shows the estimated phosphorus loads in the Lake Murphysboro watershed.

BMPs that address these source of phosphorus are recommended to reduce loads to Lake Murphysboro. BMPs to address loads from animal operations include manure management, cattle exclusion from streams, constructed wetlands, feeding management, and grassed waterways (see Table 4-23). Riparian buffers would also help to keep phosphorus loads from entering the streams and lake. Nutrient management plans and conservation tillage could help to reduce loads from cropland. Finally, septic systems should be inspected and properly maintained to reduce loads from this source.

Table 5-1. Estimated Phosphorus Loads in the Lake Murphysboro Subwatershed.

Source	Estimated Load (lb/yr)
Onsite wastewater treatment systems	446 to 3,819
Crop production	2,265 to 6,795
Animal operations[1]	unknown
Stream bank and lake shore erosion[1]	unknown
Internal loading from lake bottom sediments[1]	unknown

[1]Not all sources could be quantified at the time of the TMDL report.

5.2 Little Cedar Lake

The TMDL for Little Cedar Lake stated that a 77 percent reduction in phosphorus loading is needed to achieve water quality standards. Table 5-2 shows the known phosphorus loads in the Little Cedar Lake watershed. BMP recommendations are similar to Lake Murphysboro and focus on reducing loads from animal operations, cropland, and septic systems.

Table 5-2. Estimated Phosphorus Loads in the Little Cedar Lake Subwatershed.

Source	Estimated Load (lb/yr)
Onsite wastewater treatment systems	264 to 2,265
Crop production	53 to 160
Animal operations[1]	unknown
Stream bank and lake shore erosion[1]	unknown
Internal loading from lake bottom sediments[1]	unknown

[1]Not all sources could be quantified at the time of the TMDL report.

5.3 Cedar Creek

The fecal coliform TMDL for Cedar Creek specified that load reductions are required during low flows (67 percent), moist flow conditions (27 percent), and high flows (17 percent). The potential sources of fecal coliforms in the Cedar Creek watershed are animal operations, failing septic systems, and sewage treatment plants (see Table 4-23). Table 5-3 shows the estimated fecal coliform loads in the Little Cedar Lake watershed.

Multiple BMPs are likely needed to achieve the fecal coliform water quality standard. Proper manure handling, collection, and disposal practices should be combined with composting manure, grazing land management, and/or alternative watering systems at animal operations located throughout the watershed. The following wastewater management practices are also suggested to meet the water quality standards in this segment: repairing or replacing failing onsite wastewater systems and disinfection of primary sewage treatment plant effluent at facilities that are not meeting permit requirements.

Table 5-3. Potential Estimated Loading of Fecal Coliform in the Cedar Creek Subwatershed.

Source	Estimated Load (cfu/day)
Exempt Point Source Dischargers	Unknown
Onsite Wastewater Treatment Systems	5.97E+7 to 5.11E+14
Animal operations	Unknown
Wildlife	Unknown

5.4 Big Muddy River (Segment N-99)

The dissolved oxygen impairment in Big Muddy River is believed to be caused by excessive oxygen consuming materials (i.e., BOD) and algae consumption. The TMDL for Big Muddy River recommends a 37 percent reduction in total ammonia, nitrate, organic phosphorus and inorganic phosphorus. Also, a 36 percent reduction in organic nitrogen was recommended to achieve the dissolved oxygen water quality standard. Animal operations and failing septic systems are the primary nonpoint sources of organic materials and nutrients. Treatment level BMPs such as filter strips, grassed waterways, constructed wetlands, and/or restoration of riparian buffers are recommended to mitigate organic and nutrient loads from animal operations (see Table 4-23). Proper manure handling, collection, and disposal practices combined with composting manure, grazing land management, and/or alternative watering systems are also recommended.

Table 5-4. Potential Estimated BOD_5 Loading in the Big Muddy River Subwatershed.

Source	Estimated Load (lb/day)
Exempt Point Source Dischargers	unknown
Onsite Wastewater Treatment Systems	197 to 1,108
Animal Operations	52,000

5.5 Cave Creek

The dissolved oxygen impairment in the Cave Creek is due to the excessive biodegradable organic material resulting from animal operations and failing septic systems. To achieve the 5.0 mg/L dissolved oxygen level in Cave Creek, a 32 percent ammonia reduction from nonpoint sources is needed. This target can be achieved by applying the same BMP measures proposed for Big Muddy River.

Table 5-5. Potential Estimated BOD_5 Loading in the Cave Creek Subwatershed.

Source	Estimated Load (lb/day)
Onsite Wastewater Treatment Systems	32 to 180
Animal Operations	unknown

6.0 MEASURING AND DOCUMENTING PROGRESS

Multiple agricultural BMPs will likely be needed to address the water quality impairments found in the Cedar Creek/Cedar Lake watershed. Water quality monitoring should be implemented to monitor BMP success, and to determine if additional BMPs are needed to achieve water quality standards. It may also be necessary to begin funding efforts for localized BMPs such as riparian buffer restoration.

7.0 REASONABLE ASSURANCE

USEPA requires reasonable assurance that TMDLs will be achieved and water quality standards will be met. For the Cedar Creek/Cedar Lake watershed, the primary strategy for attaining water quality standards is to implement agricultural BMPs. However, landowner participation may be limited due to resistance to change and upfront costs. Educational efforts and cost sharing programs will likely increase participation to levels needed to protect water quality. The following sections discuss the programs that are available to assist landowners and local entities in implementing BMPs.

7.1 Environmental Quality Incentives Program (EQIP)

Several cost share programs are available to landowners who voluntarily implement resource conservation practices in the Cedar Creek/Cedar Lake watershed. The most comprehensive is the NRCS Environmental Quality Incentives Program (EQIP) which offers cost sharing and incentives to farmers who utilize approved conservation practices to reduce pollutant loading from agricultural lands.

- The program will pay $10 for one year for each acre of farmland that is managed under a nutrient management plan (up to 400 acres per farm).
- Use of vegetated filter strips will earn the farmer $100/ac/yr for three years (up to 50 acres per farmer).
- The program will also pay 60 percent of the cost to construct grassed waterways, riparian buffers, and windbreaks.
- Use of residue management will earn the farmer $15/ac for three years (up to 400 acres per farm).
- Installation of drainage control structures on tile outlets will earn the farmer $5/ac/yr for three years for the effected drainage area as well as 60 percent of the cost of each structure.
- The program will pay 75 percent of the construction cost for a composting facility.
- Sixty percent of the fencing, controlled access points, spring and well development, pipeline, and watering facility costs are covered by the program.
- Waste storage facilities and covers for those facilities have a 50 percent cost share for construction.
- Prescribed grazing practices will earn the farmer $10/ac/yr for three years (up to 200 acres per farmer).

In order to participate in the EQIP cost share program, all BMPs must be constructed according to the specifications listed for each conservation practice.

The specifications and program information can be found online at:
http://www.il.nrcs.usda.gov/programs/eqip/cspractices.html.

7.2 Conservation Reserve Program (CRP)

The Farm Service Agency of the USDA supports the Conservation Reserve Program (CRP) which rents land that is converted from crop production to grass or forestland for the purposes of reducing erosion and protecting sensitive waters. This program is available to farmers who establish vegetated filter strips or grassed waterways. The program typically provides 50 percent of the upfront cost to establish vegetative cover and $185/ac/yr for up to 15 years.

More information about this program is available online at:
http://www.nrcs.usda.gov/programs/crp/

7.3 Conservation 2000

In 1995 the Illinois General Assembly passed the Conservation 2000 bill providing $100 million in funding over a 6-year period for the promotion of conservation efforts. In 1999, legislation was passed to extend the program through 2009. Conservation 2000 currently funds several programs applicable to the Cedar Creek/Cedar Lake watershed through the Illinois Department of Agriculture.

General information concerning the Conservation 2000 Program can be found online at:
http://www.agr.state.il.us/Environment/conserv/

7.3.1 Conservation Practices Program (CPP)

The Conservation Practices Cost Share Program provides monetary incentives for conservation practices implemented on land eroding at one and one-half times or more the tolerable soil loss rate. Payments of up to 60 percent of initial costs are paid through the local conservation districts. Of the BMPs discussed in this plan, the program will cost share cover crops, filter strips, grassed waterways, no-till systems, and pasture planting. Other sediment control options such as contour farming and installation of stormwater ponds are also covered. Practices funded through this program must be maintained for at least 10 years.

More information concerning the Conservation Practices Program can be found online at:
http://www.agr.state.il.us/Environment/conserv/

7.3.2 Streambank Stabilization Restoration Program

Conservation 2000 also funds a streambank stabilization and restoration program aimed at restoring highly eroding streambanks. Research efforts are also funded to assess the effectiveness of vegetative and bioengineering techniques.

More information about this program is available online at:
http://dnr.state.il.us/orep/c2000/grants/proginfo.asp?id=20

7.3.3 Sustainable Agriculture Grant Program (SARE)

The Sustainable Agricultural Grant Program funds research, education, and outreach efforts for sustainable agricultural practices. Private landowners, organizations, educational, and governmental institutions are all eligible for participation in this program.

More information concerning the Sustainable Agricultural Grant Program can be found online at:
http://www.sare.org/grants/

7.4 Nonpoint Source Management Program (NSMP)

Illinois EPA receives federal funds through Section 319(h) of the Clean Water Act to help implement Illinois' Nonpoint Source (NPS) Pollution Management Program. The purpose of the Program is to work cooperatively with local units of government and other organizations toward the mutual goal of protecting the quality of water in Illinois by controlling NPS pollution. The program emphasizes funding for implementing cost-effective corrective and preventative BMPs on a watershed scale; funding is also available for BMPs on a non-watershed scale and the development of information/education NPS pollution control programs.

The maximum federal funding available is 60 percent, with the remaining 40 percent coming from local match. The program period is two years unless otherwise approved. This is a reimbursement program.

Section 319(h) funds are awarded for the purpose of implementing approved NPS management projects. The funding will be directed toward activities that result in the implementation of appropriate BMPs for the control of NPS pollution or to enhance the public's awareness of NPS pollution. Applications are accepted June 1 through August 1.

More information about this program is available online at:
http://www.epa.state.il.us/water/financial-assistance/non-point.html

7.5 Agricultural Loan Program

The Agricultural Loan Program offered through the Illinois State Treasury office provides low-interest loans to assist farmers who implement soil and water conservation practices. These loans will provide assistance for the construction, equipment, and maintenance costs that are not covered by cost share programs.

More information about this program is available online at:
http://www.state.il.us/TREAS/ProgramsServices.aspx

7.6 Illinois Conservation and Climate Initiative (ICCI)

The Illinois Conservation and Climate Initiative (ICCI) is a joint project of the State of Illinois and the Delta Pollution Prevention and Energy Efficiency (P2/E2) Center that allows farmers and landowners to earn carbon credits when they use conservation practices. These credits are then sold to companies or agencies that are committed to reducing their greenhouse gas emissions. Conservation tillage earns 0.5 metric tons (1.1 US ton) of carbon per acre per year (mt/ac/yr), grass plantings (applicable to filter strips and grassed waterways) earn 0.75 mt/ac/yr, and trees planted at a density of at least 250 stems per acre earn somewhere between 3.5 to 5.4 mt/ac/yr, depending on the species planted and age of the stand.

Carbon credits are currently selling at around $2.50 per mt. Current exchange rates are available online at http://chicagoclimatex.com. Administrative fees of $0.14/mt plus 8 percent are subtracted from the sale price.

Program enrollment occurs through the P2/E2 Center which can be found online at http://p2e2center.org/. The requirements of the program are verified by a third party before credits can be earned.

More information about carbon trading can be found online at:
http://illinoisclimate.org/

7.7 Summary

Tables 7-1 and 7-2 summarize the cost sharing programs available to Illinois landowners.

Table 7-1. Summary of Assistance Programs Available for Farmers in the Cedar Creek/Cedar Lake Watershed.

Assistance Program	Program Description	Contact Information
NSMP	Provides grant funding for educational programs and implementation of nonpoint source pollution controls.	Illinois Environmental Protection Agency Bureau of Water Watershed Management Section, Nonpoint Source Unit P.O. Box 19276 Springfield, IL 62794-9276 Phone: (217) 782-3362
Agricultural Loan Program	Provides low-interest loans for the construction and implementation of agricultural BMPs. Loans apply to equipment purchase as well.	Office of State Treasurer Agricultural Loan Program 300 West Jefferson Springfield, Illinois 62702 Phone: (217) 782-2072 Fax: (217) 522-1217
NRCS EQIP	Offers cost sharing and rental incentives to farmers statewide who utilize approved conservation practices to reduce pollutant loading from agricultural lands. Applies to nutrient management plans, filter strips, grassed waterways, riparian buffers, and conservation tillage.	Jackson County SWCD 1213 N 14th St Murphysboro, IL 62966-2950 Phone: (618) 684-3471 Fax: (618) 684-3980
FSA CRP	Offsets income losses due to land conversion by rental agreements. Targets highly erodible land or land near sensitive waters. Provides up to 50 percent of the upfront cost to establish vegetative cover and $185/ac/yr for up to 15 years for converted land.	
Conservation 2000 CPP	Provides up to 60 percent cost share for several agricultural BMPs: cover crops, filter strips, grassed waterways.	
Conservation 2000 Streambank Stabilization Restoration Program	Provides 75 percent cost share for establishment of riparian corridors along severely eroding stream banks. Also provides technical assistance and educational information for interested parties.	
SARE	Funds educational programs for farmers concerning sustainable agricultural practices.	
Local SWCD	Provides incentives for individual components of nutrient management planning, use of strip tillage, and restoration of riparian buffers.	
ICCI	Allows farmers to earn carbon trading credits for use of conservation tillage, grass, and tree plantings.	

Table 7-2. Assistance Programs Available for Agricultural BMPs.

BMP	Cost Share Programs and Incentives
Education and Outreach	Conservation 2000 Streambank Stabilization Restoration Program SARE NSMP Local SWCD ULWREP
Nutrient Management Plan	EQIP: $10/ac for one year, 400 ac. max. Local SWCD: up to $30/ac for one year ULWREP: contact agency for individual resource allocations
Conservation Tillage	EQIP: $15/ac for three years, 400 ac. max. ICCI: earns 0.5 mt/ac/yr of carbon trading credit ULWREP: contact agency for individual resource allocations
Cover Crops	CPP: cost share of 60 percent ULWREP: contact agency for individual resource allocations
Filter Strips	EQIP: $100/ac for three years, 50 ac. max. CPP: 60 percent of construction costs CRP: 50 percent of the upfront cost to establish vegetative cover and $185/ac/yr for up to 15 years ICCI: earns 0.75 mt/ac/yr of carbon trading credit for each acre planted
Grassed Waterways	EQIP: 60 percent of construction costs CPP: 60 percent of construction costs CRP: 50 percent of the upfront cost to establish vegetative cover and $185/ac/yr for up to 15 years ICCI: earns 0.75 mt/ac/yr of carbon trading credit for each acre planted
Land Retirement of Highly Erodible Land or Land Near Sensitive Waters	CRP: 50 percent of the costs of establishing vegetative cover and cash incentive of $185/ac/yr for 15 years ICCI: earn between 0.75 and 5.4 mt/ac/yr of carbon trading credit depending on species planted ULWREP: contact agency for individual resource allocations
Restoration of Riparian Buffers	EQIP: 60 percent of construction of costs CRP: 50 percent of the costs of establishing vegetative cover and cash incentive of $185/ac/yr for 15 years ICCI: earn between 0.75 and 5.4 mt/ac/yr of carbon trading credit depending on species planted ULWREP: contact agency for individual resource allocations

Note: Cumulative cost shares from multiple programs will not exceed 100 percent of the cost of construction.

8.0 IMPLEMENTATION TIMELINE

This implementation plan for the Cedar Creek/Cedar Lake watershed defines a phased approach for achieving the water quality standards (Figure 8-1). Ideally, implementing control measures on nonpoint sources will be based on voluntary participation which will depend on 1) the effectiveness of the educational programs for farmers, landowners, and owners of onsite wastewater systems, and 2) the level of participation in the programs. In addition, point source dischargers operating under a disinfection exemption are required to comply with the geometric mean fecal coliform water quality standard of 200 cfu/100 mL at the closest point downstream where recreational use occurs in the receiving water or where the water flows into a fecal-impaired segment. Facilities with year-round disinfection exemptions may be required to provide the Agency with updated information to demonstrate compliance with these requirements. Facilities directly discharging into a fecal-impaired segment may have their year-round disinfection exemption revoked through future NPDES permitting actions. This section outlines a schedule for implementing the control measures and determining whether or not they are sufficient to meet the water quality standards.

Phase I of this implementation plan should focus on education of farm owners concerning the benefits of agricultural BMPs on crop yield, soil quality, and water quality as well as cost share programs available in the watershed. It is expected that initial education through public meetings, mass mailings, TV and radio announcements, and newspaper articles could be achieved in less than 6 months. As described in Section 7.0., assistance with educational programs is available through the following agencies: the Illinois Department of Agriculture Conservation 2000 Streambank Stabilization Restoration Program, the Illinois Department of Agriculture Sustainable Agriculture Grant Program (SARE), the Illinois Environmental Protection Agency Nonpoint Source Management Program (NSMP), and the local Soil and Water Conservation Districts. During this phase, the sewage treatment plants may be asked to submit fecal coliform data to IEPA to determine if a disinfection exemption is still appropriate.

Phase II of the implementation schedule will involve voluntary participation of landowners in BMPs such as proper management of manure and fertilizers, grazing land management, and use of filter strips, composting, constructed wetlands, conservation tillage, cattle exclusion from streams, and grassed waterways. The local Natural Resources Conservation Service office will be able to provide technical assistance and cost share information for these BMPs. In addition, initial inspections of all onsite wastewater treatment systems and necessary repairs may begin. Continued monitoring of water quality in the watershed should continue throughout this phase, which will likely take one to three years.

If pollutant concentrations measured during Phase II monitoring remain above the water quality standards, Phase III of the implementation plan will be necessary. The load reduction achieved during Phase II should be estimated by 1) summarizing the areas where BMPs are in use, 2) calculating the reductions in loading from BMPs, and 3) determining the impacts on pollutant concentrations measured before and after Phase II implementation. If BMPs are resulting in decreased concentrations, and additional areas could be incorporated, further efforts to include more stakeholders in the voluntary program will be needed. If the Phase II BMPs are not having the desired impacts on pollutant concentrations, or additional areas of incorporation are not available, supplemental BMPs, such as restoration of riparian areas and stream channels will be needed. In addition, sewage treatment plants may be required to add disinfection processes if fecal coliform standards in receiving and downstream segments are not being met. If required, this phase may last five to ten years.

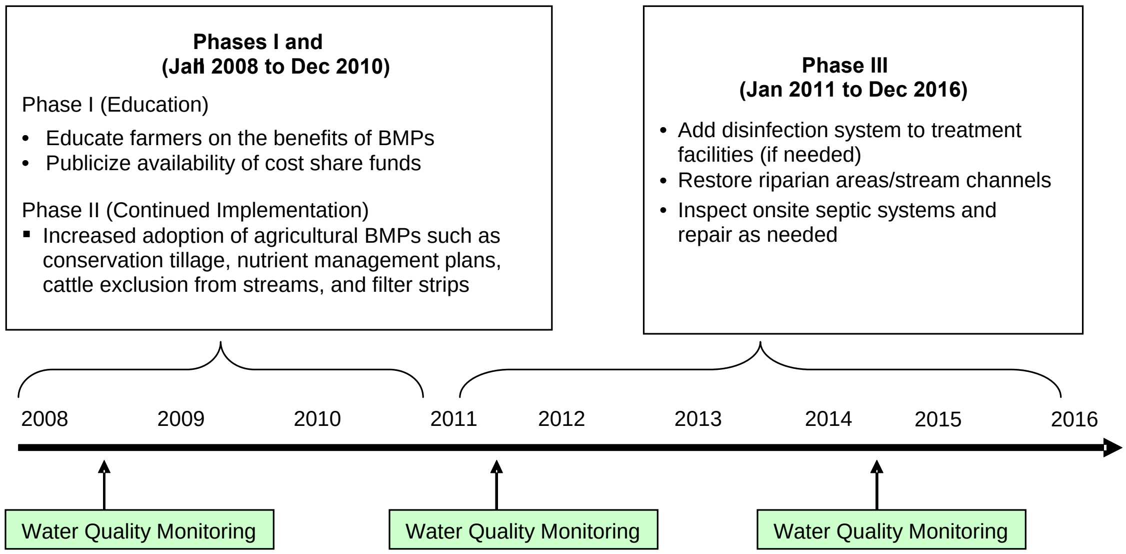

Figure 8-1. Timeline for the Cedar Creek/Cedar Lake TMDL Implementation Plan.

9.0 CONCLUSIONS

Phosphorus loading to Lake Murphysboro and Little Cedar Lake likely originates from animal operations, croplands, and failing onsite sewage treatment systems. Animal operations, failing onsite sewage treatment systems, and sewage treatment plants that operate under disinfection exemption are considered the most likely sources of fecal coliform in Cedar Creek. Animal operations and failing septic systems are also the potential sources of biodegradable organic matter in the Big Muddy river.

The implementation of BMPs in the Cedar Creek/Cedar Lake watershed should occur in a phased approach. Phase I of this implementation plan should provide education and financial incentives to farmers in the watershed to encourage the use of BMPs. Phase II should occur during and following Phase I and should involve voluntary participation of farmers in the watershed, and submittal of fecal coliform data for the STPs in the watershed. Future water quality monitoring will determine whether or not these BMPs are capable of achieving water quality standards.

Whether or not Phase III will be required depends on the results of future water quality sampling. If the water quality standards are not being met after implementation of the Phase II BMPs, then regional BMPs (such as restoration of stream channels and riparian areas) may be needed. Additional sewage treatment plant upgrades may also be considered.

As agricultural BMPs are implemented, water quality in the watershed should improve accordingly. Measuring the effectiveness of these BMPs will require continued sampling of water quality over the next several years.

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