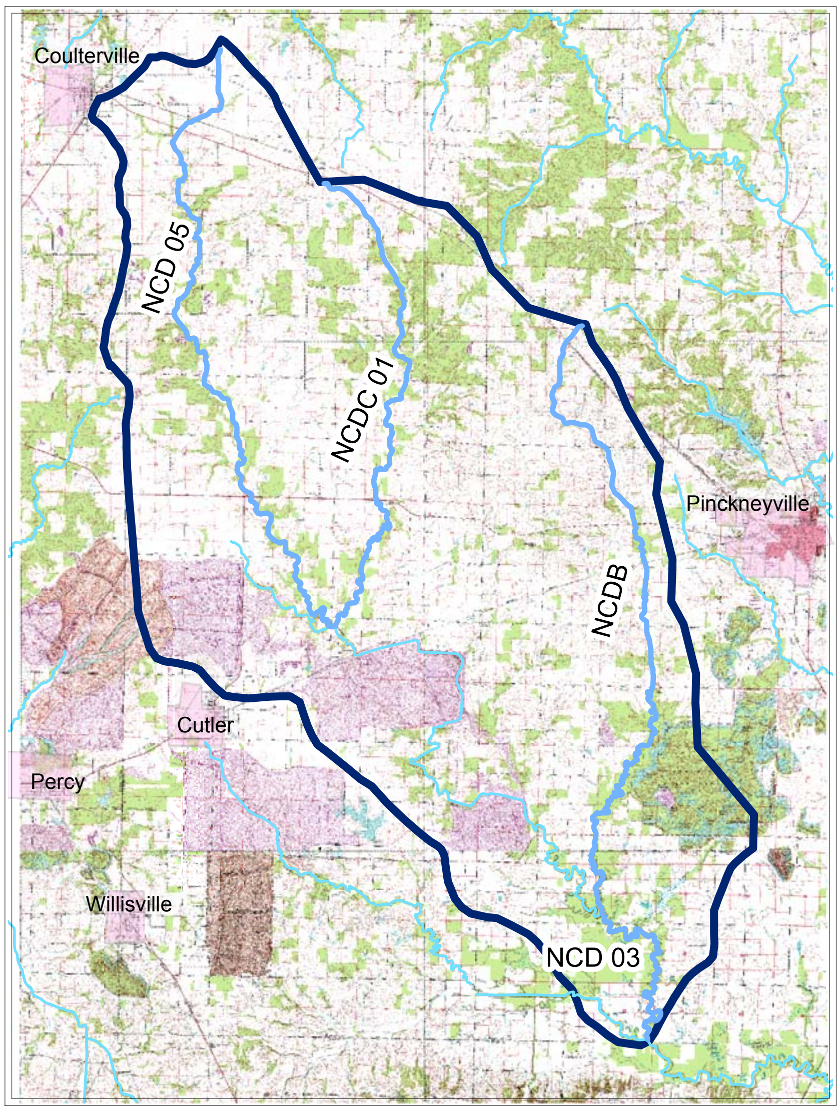
Illinois
Environmental
Protection Agency

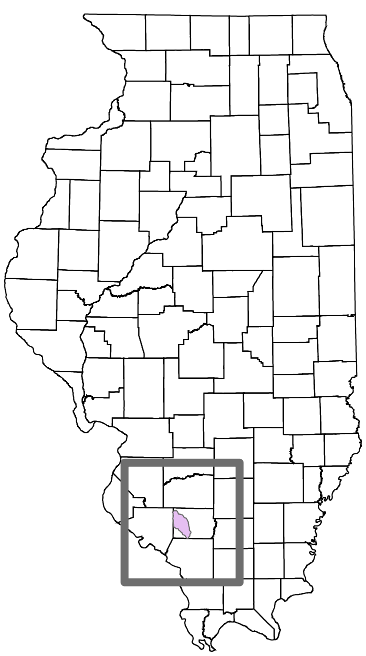
Bureau of Water
P.O. Box 19276
Springfield, IL 62794-9276

June 2004

IEPA/BOW/04-014

BONNIE CREEK TMDL REPORT





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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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REPLY TO THE ATTENTION OF:

WW-16J

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09 JUN 2004

Ms. Marcia T. Willhite
IEPA Bureau of Water
1021 North Grand Avenue East
Springfield, IL 62794-9276

Dear Ms. Willhite:

The United States Environmental Protection Agency (U.S. EPA) has reviewed the final Total Maximum Daily Load (TMDL) submittal for the Bonnie Creek Watershed, including supporting documentation and follow up information. IEPA's submitted TMDLs address four stream segments impaired for General Use on the 2002 303(d) list by sulfates, Total Dissolved Solids (TDS), manganese, and silver. Based on this review, U.S. EPA has determined that Illinois' submittal of the Bonnie Creek Watershed TMDLs (segments NCDC01, NCD05, NCD03, NCDB) including Galum Creek and Little Galum Creek, meets the requirements of Section 303(d) of the Clean Water Act (CWA) and U.S. EPA's implementing regulations at 40 C.F.R. Part 130. Therefore, U.S. EPA hereby approves Illinois' 8 TMDLs for the Bonnie 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 this submitted TMDL, and look forward to future TMDL submissions by the State of Illinois. If you have any questions, please contact Mr. Kevin Pierard, Chief of the Watersheds and Wetlands Branch at 312-886-4448.

Sincerely yours,

Jo Lynn Traub
Director, Water Division

Enclosure

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Parameter changes for developing TMDLs

In May 2001, Illinois EPA entered into a contract with Camp Dresser & McKee to develop Total Maximum Daily Loads (TMDLs) for Bonnie Creek (NCDC01), Galum Creek (NCD03), Galum Creek (NCD05), and Little Galum Creek (NCDB). In the 1998 Section 303(d) List, Bonnie Creek (NCDC01) was listed as impaired for sulfates and other habitat alterations; Galum Creek (NCD03) was listed for silver, sulfates, siltation, TDS, and other habitat alterations; Galum Creek (NCD05) was listed for manganese, low dissolved oxygen (DO), and other habitat alterations; and Little Galum Creek (NCDB) was listed for manganese, sulfates, TDS, and other habitat alterations.

Illinois EPA has since determined that at this time TMDLs will only be developed for those parameters with numeric water quality standards. These numeric water quality standards will serve as the target endpoints for TMDL development and provide a greater degree of clarity and certainty about the TMDL and implementation plan. As a result, TMDL development for Bonnie Creek (NCDC01) will only focus on the parameter of sulfates; Galum Creek (NCD03) will address silver, sulfates, and TDS; Galum Creek (NCD05) will address manganese and low DO; and Little Galum Creek (NCDB) will address manganese, sulfates, and TDS. Numeric water quality standards exist for the parameters being addressed in this TMDL.

Causes of impairment not based on numeric water quality standards will be assigned a lower priority for TMDL development. Pending the development of numeric water quality standards for these parameters, as may be proposed by the Agency and adopted by the Illinois Pollution Control Board, Illinois EPA will continue to work toward improving water quality throughout the state by promoting and administering existing programs and working toward creating new methods for treating these potential causes of impairment.

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Contents

Figures

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Tables

Acronyms

°C	degrees Celsius
°F	degrees Fahrenheit
µg/L	micrograms per liter
µmho/cm	microSiemens per centimeter
AMLRD	Abandoned Mined Lands Reclamation Division
AWQMN	Ambient Water Quality Monitoring Network
BMP	best management practices
BOD	biochemical oxygen demand
BOD_5	5-day biochemical oxygen demand
$CBOD_{20}$	20-Day Carbonaceous Biochemical Oxygen Demand
CCC	Commodity Credit Corporation
cfs	cubic feet per second
CPP	Conservation Practices Program
CRP	Conservation Reserve Program
CWA	Clean Water Act
DEM	Digital Elevation Model
DO	dissolved oxygen
EMC	event mean concentration
EQIP	Environmental Quality Incentive Program
FSA	Farm Service Agency
GIS	geographic information system
IBI	Index of Biotic Integrity
IDA	Illinois Department of Agriculture
IDNR	Illinois Department of Natural Resources
Illinois EPA	Illinois Environmental Protection Agency
IPCB	Illinois Pollution Control Board
LA	Load Allocation
LC	Loading Capacity
LTA	long-term average
MBI	Macroinvertebrate Biotic Index
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MOS	Margin of Safety
NCDC	National Climatic Data Center

NCSU	North Carolina State University
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resource Conservation Service
NWIS	National Water Inventory System
SOD	sediment oxygen demand
SSRP	Streambank Stabilization and Restoration Practice
STORET	*Storage and Retrieval* (USEPA database)
TDS	total dissolved solids
TMDL	Total Maximum Daily Load
TOC	total organic carbon
TSS	total suspended solids
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WERF	Water Environment Research Foundation
WHIP	Wildlife Habitat Incentives Program
WLA	Waste Load Allocation
WMM	Watershed Management Model
WRP	Wetlands Reserve Program

Executive Summary
Bonnie Creek Watershed

TMDL Fact Sheet

Watershed Name:	Bonnie Creek	Bonnie Creek	Bonnie Creek	Bonnie Creek
Segment Name:	Bonnie Creek	Galum Creek	Galum Creek	Little Galum Creek
Impaired Segments:	NCDC01	NCD05	NCD03	NCDB
Location:	Perry County, IL	Perry County, IL	Perry County, IL	Perry County, IL
Size:	10.0 miles	13.2 miles	4.5 miles	13.4 miles
Primary Watershed Land Uses:	Agriculture, grassland, and forest	Agriculture, grassland, and forest	Agriculture, grassland, and forest	Agriculture, grassland, and forest
Criteria of Concern:	Sulfates	Manganese (Mn) and Dissolved Oxygen (DO)	Silver, Sulfates, and TDS	Manganese, Sulfates, and TDS
Designated Uses Affected:	General use	General use	General use	General use
Environmental Indicators:	Sulfates monitoring	Manganese and DO monitoring	Silver, Sulfates, and TDS monitoring	Manganese, Sulfates, and TDS monitoring
Major Sources:	Potentially contaminated groundwater	Potentially contaminated groundwater, stagnant stream conditions, elevated instream temperatures, and nonpoint source loading from agriculture	Potentially contaminated groundwater	Potentially contaminated groundwater
Loading Capacity:	Sulfates = 32,026 lb/day	Mn = 91 lb/day DO = No allocation	Silver = 1.1 lb/day Sulfates = 257,557 lb/day TDS = 506,942 lb/day	Mn = 52 lb/day Sulfates = 37,675 lb/day TDS = 97,826 lb/day
Waste Load Allocation:	Zero; no significant point sources	Zero; no significant point sources	Zero; no significant point sources	Zero; no significant point sources
Margin of Safety:	Implicit through data selected for development of TMDL; additional explicit of 10%	Implicit through data selected for development of TMDL; additional explicit of 10%	Implicit through data selected for development of TMDL; additional explicit of 10%	Implicit through data selected for development of TMDL; additional explicit of 10%

This Total Maximum Daily Load (TMDL) assessment for impaired water bodies in the Bonnie Creek Watershed addresses the sources of water body impairments, reductions in source loading necessary to comply with water quality standards, and the implementation of procedures to mitigate the impairment.

The TMDLs for manganese, silver, sulfates, and TDS in Bonnie Creek segment NCDC01, Galum Creek segments NCD03 and NCD05, and Little Galum Creek segment NCDB were based on analyses performed in a Monte Carlo simulation. The simulation for manganese in segments NCD05 and NCDB showed a manganese reduction of 40 percent and 78 percent, respectively, necessary to achieve water quality standards. Results of the Monte Carlo simulation showed a 70 percent reduction of silver for segment NCD03 and sulfates reductions of 25 percent, 71 percent, and 52 percent for segments NCDC01, NCD03, and NCDB, respectively, necessary to achieve water quality standards. The potential source of manganese, silver, sulfates, and TDS in the Bonnie Creek Watershed is contaminated groundwater. The groundwater is potentially contaminated by abandoned coal and non-coal mines; however, further source identification is recommended. Confirmation that abandoned mines are a source of manganese, silver, sulfates, and TDS in the watershed would require reclamation of the mines. Passive treatment for mine reclamation is recommended.

The TMDL analysis for DO in segment NCD05 in the Bonnie Creek Watershed was made through investigation of the relationship between DO, total organic carbon (TOC), 5-day biochemical oxygen demand (BOD_5), and reaeration in the creek. The likely source of DO impairments in the segment is primarily a lack of aeration caused by stagnant stream conditions and elevated instream temperatures. BOD loadings in runoff from nonpoint source loads may also contribute to DO impairments. However, examination of BOD in the stream segment showed that the concentrations of BOD are low and likely represent ambient conditions in the stream; therefore, reductions in BOD concentrations are not recommended at this time. Due to data limitations and technical considerations of implementation difficulties, a load allocation cannot be developed for reaeration or temperature, so allocations were not developed for the Bonnie Creek Watershed. Procedures to alleviate low DO caused by stagnant flows can be addressed with in-stream mitigation methods such as reaeration. Additionally, riparian buffer strips aid in decreasing instream temperatures, which could help to alleviate the DO impairment. Excess nutrients can cause excessive algal growth that can also deplete DO in streams; however, analytical tools were not used to assess nutrients, algae, and DO as no algal data was available for impaired segments. Methods to control nutrients were still included in the implementation plan such as buffer strips along the stream banks, which prevent nutrients in surface runoff from reaching the stream. The potential contributions to BOD from nonpoint source loads are attributed to agricultural land uses requiring mitigation methods to control nutrients in sediment erosion and surface runoff from the land contributing to impaired segments. Watershed controls include filter strips, which are similar to buffer strips in their ability to remove nutrients from surface runoff, and development of nutrient management plans to ensure that excess nutrients are not applied to agricultural fields.

Section 1
Goals and Objectives for Bonnie Creek Watershed (ILNCD01)

1.1 Total Maximum Daily Load 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 (U.S. Environmental Protection Agency [USEPA] 1998).

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 swimming, 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 Bonnie Creek Watershed

The TMDL goals and objectives for the Bonnie Creek Watershed 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 Bonnie Creek Watershed, which are also shown in Figure 1-1:

- Bonnie Creek (NCDC01)
- Galum Creek (NCD05)
- Galum Creek (NCD03)
- Little Galum Creek (NCDB)

The TMDL for each of 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:

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

Each 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 TMDLs will be achieved is described in the implementation plan. The implementation plan for the Bonnie Creek Watershed describes how water quality standards will be attained. This implementation plan includes recommendations for implementing best management practices (BMP), 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 Bonnie Creek Watershed Description** provides a description of the impaired water bodies and general watershed characteristics;
- **Section 3 Public Participation and Involvement** discusses public participation activities that occurred throughout the TMDL development;
- **Section 4 Bonnie Creek Watershed Water Quality Standards** defines the water quality standards for the impaired water bodies. Pollution sources will also be discussed in this section;
- **Section 5 Bonnie Creek Watershed Data Review** provides an overview of available data for the Bonnie Creek Watershed;
- **Section 6 Methodologies to Complete TMDLs for the Bonnie Creek Watershed** discusses the models and analyses needed for TMDL development;
- **Section 7 Methodology Development for Bonnie Creek** describes the analytical procedures used to examine Bonnie Creek Watershed;
- **Section 8 Total Maximum Daily Load for the Bonnie Creek** discusses the allowable loadings to water bodies to meet water quality standards and the reduction in existing loadings needed to meet allowable loads;
- **Section 9 Implementation Plan for Bonnie Creek Watershed** provides methods to reduce loadings to impaired water bodies;
- **Section 10 References** lists references used in this report.

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Figure 1-1
Bonnie Creek Watershed (ILNCD01)
Impaired Water Bodies
CDM

Section 2
Bonnie Creek Watershed Description

2.1 Bonnie Creek Watershed Overview

Bonnie Creek originates in Perry County and flows southward where it merges with Galum Creek. Little Galum Creek is a tributary to Galum Creek. The Bonnie Creek watershed (ILNCD01) encompasses an area of approximately 102 square miles and is located in U.S. Geological Survey (USGS) Big Muddy Basin (Hydrologic Unit Code 07140106). Figure 1-1 shows the impaired river segments within the watershed. Impaired segments are shown in red. Table 2-1 lists the water body segments, water body size, and potential causes of impairment for each water body. Illinois EPA has determined that at this time TMDLs will only be developed for those parameters with numeric water quality standards; therefore, several parameters listed for the Bonnie Creek watershed in the 1998 and 2002 303(d) lists, such as siltation and habitat alternation, will not be addressed with this TMDL.

Table 2-1 Impaired Water Bodies in Bonnie Creek Watershed

Water Body Segment ID	Water Body Name	Size	Potential Causes of Impairment
NCDC01	Bonnie Creek	10.0 miles	Sulfates
NCD05	Galum Creek	13.2 miles	Manganese, dissolved oxygen (DO)
NCD03	Galum Creek	4.5 miles	Silver, sulfates, total dissolved solids (TDS)
NCDB	Little Galum Creek	13.4 miles	Manganese, sulfates, TDS

Land use data was obtained from the Critical Trends Assessment Land Cover Database of Illinois (Illinois Department of Natural Resources [IDNR] 1996). Land use in the watershed is predominantly agricultural followed by grassed and forested land. Strip mining also is a land use type found within the watershed. Farmers in the area primarily raise cash crops, such as corn, soybeans, and alfalfa.

Soils within the Bonnie Creek Watershed are primarily somewhat poorly drained to moderately well drained soils. The surface layer is typically five to seven inches thick and is brown silt loam. The subsurface layer ranges from three to seven inches and consists of a yellowish brown silt loam. The underlying subsoil layer is silty clay loam and extends below a depth of 60 inches (U.S. Department of Agriculture [USDA] 1988).

The climate in the watershed is cold in the winter and warm in the summer. In the winter, October through March, the average temperature is 43 degrees Fahrenheit (°F) and the average daily minimum temperature is 32°F according to data collected at DuQuoin, Illinois. Summer temperatures are typically 70°F with an average daily maximum of 82°F. Annual precipitation is 45 inches of which 25 inches, approximately 55 percent, usually falls in April through September (National Climatic Data Center [NCDC] 2002).

2.2 Stream Segments Site Reconnaissance of Bonnie Creek Watershed

The project team conducted a site reconnaissance of the Bonnie Creek Watershed on June 19, 2001. This section briefly describes the stream segments and the site reconnaissance.

Table 2-1 lists the impaired stream segments in the Bonnie Creek Watershed. Based on the 1998 and 2002 303(d) lists, Illinois EPA determined that one segment of Bonnie Creek, two segments of Galum Creek, and one segment of Little Galum Creek were impaired. These segments are shown in Figure 1-1.

Looking north at Bonnie Creek, riprap and other bank stabilization efforts are visible.

Segment NCDC01 of Bonnie Creek flows from north to south and is located within Perry County, Illinois. During the site reconnaissance, this segment was observed from the bridge on Illinois Route 154. A strip mine observed in the area north of Bonnie Creek appears to be undergoing reclamation. The area of the creek south of the bridge has undergone several attempts at bank stabilization. It was littered with grout and other riprap and appeared disturbed. The creek north of the bridge was not as disturbed and had a noticeable riparian buffer strip. Agricultural lands surrounded the creek.

Galum Creek at the intersection of Illinois Rts. 150 and 154, looking northeast from the bridge.

Two segments of Galum Creek, NCD05 and NCD03, were identified as impaired. NCD03, flows northwest to southeast, and is located downstream from segment NCD05 as shown in Figure 1-1. Segment NCD05 was observed from the bridge near the intersection of Illinois Routes 150 and 154. The land to the north and east of the creek had a sign noting that they were part of the Conservation 2000 program. The creek had a slow flow velocity and was observed to be turbid or silty in this area. The creek northeast of the bridge appears to have flooded recently, and erosion was evident where a drainage channel from the field into the creek had been created.

Conservation 2000 sign and Galum Creek bank on the northeast side of the road and creek.

Segment NCDB of Little Galum Creek was identified as impaired, and this segment flows from north to south and is located within Perry County, Illinois. Little Galum Creek flows into Galum Creek segment NCD03 as shown in Figure 1-1.

Section 3
Public Participation and Involvement

3.1 Bonnie Creek Watershed Public Participation and Involvement

Public knowledge, acceptance, and follow through are necessary to implement a plan to meet recommended TMDLs. It was 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 the recommendations. A public meeting was held to discuss the Bonnie Creek Watershed at 6:30 p.m. on December 13, 2001 at the Pinckneyville Lions Club in Pinckneyville, Illinois. A total of 56 interested citizens, including public officials and organizations other than Illinois EPA, attended the public meeting. A final public meeting was held to discuss the Bonnie Creek Watershed TMDL draft final report at 8:00 p.m. on February 25, 2004. It was attended by approximately 10 people and concluded at 9:25 p.m. with the meeting record remaining open until midnight, March 29, 2004.

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Section 4
Bonnie Creek 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 2000). The only designated uses applicable to the Bonnie Creek Watershed are General Use.

The General Use classification provides for the protection of indigenous aquatic life, primary and secondary contact recreation (e.g., swimming or boating), and agricultural and industrial uses. The General Use is applicable to the majority of Illinois streams and lakes (Illinois EPA 2000).

4.3 Illinois Water Quality Standards

To make 303(d) listing determinations, Illinois EPA compares collected data for the water body to the available water quality standards developed by Illinois EPA for assessing water body impairment. Table 4-1 presents the water quality standards of the potential causes of impairment for TMDLs that will be developed in the Bonnie Creek Watershed. These water quality standards are further discussed in the remainder of the section.

Table 4-1 Summary of General Use Water Quality Standards for Bonnie Creek Watershed

Parameter	General Use Water Quality Standard
DO	Greater than 5.0 milligrams per liter (mg/L) Greater than 6.0 mg/L (16 hours of any 24-hour period)
Manganese	1.0 mg/L
Silver	5.0 micrograms per liter (µg/L)
TDS	TDS = 1,000 mg/L
Sulfates	500 mg/L

4.3.1 Dissolved Oxygen

DO is listed as a cause of impairment for Galum Creek segment NCD05. The General Use water quality standard for DO is based on a minimum value of 5.0 mg/L. Therefore, DO levels shall not be less than 5.0 mg/L at any time. In addition, DO levels should not be less than 6.0 mg/L for more than 16 hours of any 24-hour period.

DO is listed as a cause of less than full support use attainment in streams if there is at least one General Use water quality violation based on the last three years of Ambient Water Quality Monitoring Network (AWQMN) data, or at least one violation determined from the most recent basin survey or facility survey data.

4.3.2 Manganese

Manganese is listed as a cause of impairment for Galum Creek segment NCD05 and Little Galum Creek. The general use water quality standard for manganese is 1.0 mg/L and is based on total manganese.

Manganese is listed as a cause of less than full support use attainment in streams if there is at least one general use water quality violation based on the last three years of AWQMN data, or at least one violation determined from the most recent basin survey or facility survey data. Manganese is also listed as a cause of less than full support if the manganese concentration in the sediment is 2,800 milligrams per kilogram (mg/kg) or higher (Illinois EPA 2000).

4.3.3 Silver

Silver is listed as a cause of impairment for Galum Creek segment NCD03. The general use water quality standard for silver is 5.0 µg/L based on total silver. Silver is listed as a cause of less than full support use attainment in streams if there is at least one general use water quality violation based on the last three years of AWQMN data, or at least one violation from the most recent basin survey or facility survey data. Silver is also listed as a cause of less than full support if the sediment data indicate highly elevated levels (Illinois EPA 2000). The intensive survey for the watershed does not list the level considered to be highly elevated.

4.3.4 Total Dissolved Solids

TDS is listed as a cause of impairment for Galum Creek segment NCD03 and Little Galum Creek segment NCDB. The general use water quality standard for TDS is 1,000 mg/L.

TDS is listed as a cause of less than full support use attainment in streams if there is at least one general use water quality violation of TDS in the last three years based on AWQMN data, or at least one violation determined from the most recent basin survey or facility survey data. Conductivity measurements are used to determine the relative TDS level. If conductivity levels are greater than 1,667 microSiemens per centimeter (µmho/cm), TDS is estimated to be a cause of impairment.

4.3.5 Sulfates

Sulfates are listed as a cause of impairment for Bonnie Creek segment NCDC01, Galum Creek segment NCD03, and Little Galum Creek segment NCDB. The general use water quality standard for sulfates is 500 mg/L. Sulfate is listed as a cause of a less than full support use attainment in streams if there is at least one general use water quality violation based on the last three years of AWQMN data, or at least one violation from the most recent basin survey or facility survey data.

4.3.6 Parameters without Water Quality Standards

It should be noted that although formal TMDLs will not be developed for parameters without water quality standards in the Bonnie Creek Watershed, many of the management measures discussed in Section 9 of this report will result in reductions of the parameters listed in the 1998 and 2002 303(d) lists that do not currently have adopted water quality standards. For example, many of the management measures that will be discussed in Section 9 address the other parameters of concern for the watershed. For siltation and habitat alterations management measures that control erosion, such as filter strips and wetlands, will reduce sediment from entering the waterways thereby reducing siltation and habitat alterations caused by eroding stream banks.

4.4 Pollutant Sources

As part of the Illinois EPA use assessment presented in the annual Illinois Water Quality Report, the causes of the pollutants resulting in a less than full support use attainment are associated with a potential source, based on data, observations, and other existing information. The following is a summary of the sources associated with the listed causes for the TMDL listed segments in this watershed. They are summarized in Table 4-2.

Table 4-2 Summary of Potential Sources of Pollutants

Potential Source	Cause of Impairment
Agriculture Nonirrigated crop production Pasture Lane Animal Holding/Management Areas	DO
Resource Extraction Mining Mine Tailings	TDS Sulfates Manganese Silver
Contaminated Sediments	Manganese Silver DO
Urban Runoff/Storm Sewers	TDS DO

4.4.1 Agriculture

The southern Illinois area is largely agriculture land use. Row crop agriculture is the largest single category land use in the basin. Agricultural land uses contribute sediment, total suspended solids (TSS), nutrients, and biochemical oxygen demand (BOD) loads to the water resource loading. The amount that is contributed is a function of the soil type, slope, crop management, precipitation, total amount of cropland, and the distance to the water resource (Muir et al. 1995).

Erosion of the land and streambanks carries sediment to the streams and lakes, resulting in higher levels of BOD which impacts DO concentrations. This can also be caused by livestock on pastures and feedlots. Wastes from livestock can enter streams and impact DO.

4.4.2 Resource Extraction

Resource extraction consists of both active mining and abandoned mine lands. Runoff and discharges from mines can contain sulfates, TDS, metals, TSS, and can affect the pH of the stream. There are currently 47 permitted coal mines with 169 authorized discharges in the Big Muddy River basin. In addition, 1,177 inactive or abandoned mines have been identified. There are 4 permitted, active coal mines located in the Bonnie Creek Watershed and 4 permitted, inactive coal mines. Mining is most concentrated in Beaucoup Creek, Galum Creek, Little Muddy River, Pond Creek, Hurricane Creek, and Rend Lake watersheds (Muir et al. 1997).

Drainage from the mines can be impacted by contact with exposed soil, spoil piles, or pumped water from pits. Acid mine drainage occurs when water and oxygen come in contact with iron pyrite material. This combination makes ferrous iron and sulfuric acid, creating acidic runoff and impacting the stream pH. Although acid mine drainage may come from active mines, most acid mine drainage entering streams is from abandoned mine lands.

4.4.3 Contaminated Sediments

Sediments are carried to streams, lakes, and reservoirs during runoff conditions and are generally deposited in streambeds or lake bottoms. Constituents contained in sediment may include nutrients, which can impact BOD loads, and metals. Both agricultural lands and urban areas contribute to the nutrient loading in the sediment.

Suspended sediments settle out to stream bottoms during periods of low flow. During periods of high flow, sediments are resuspended and carried downstream to be deposited in another location. Once the sediment reaches a lake or reservoir, the sediments are deposited and typically accumulate in these areas. The source of the contaminated sediment can therefore be located much farther upstream than the location detected.

Contaminated sediments can slowly leach contaminants to the water column, thereby being a continual source of impact to the waterbody. Phosphorous is commonly released from sediment into the water column especially when anoxic conditions persist.

4.4.4 Urban Runoff/Storm Sewers

Urban areas in the Bonnie Creek Watershed constitute a small percentage of land use in the watershed; however, polluted runoff from urban sections can be significant. Runoff from urban areas reaches streams or lakes either by sheet flow runoff or through storm sewer discharges. The runoff can originate from any number of areas including highways; roadways; parking lots; industrial, commercial, or residential areas; or undeveloped lands. Phosphorous, which can influence BOD loads, can originate from fertilizer use, natural phosphorous levels in sediment, and from sanitary waste where combined sewer overflows are present.

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Section 5
Bonnie Creek Watershed Data Review

5.1 Existing Data Review

The following data sources were reviewed for model selection and analysis:

- mapping data
- topography data
- flow data
- precipitation data
- temperature data
- existing water quality data
- land use
- point sources
- dairy and animal confinement locations
- septic systems

5.1.1 Mapping Data

USGS quadrangle maps (scale 1:24,000) were collected for the watershed in paper and electronic form. These were utilized for base mapping.

5.1.2 Topography Data

A Digital Elevation Model (DEM) was used to delineate watersheds in a geographic information system (GIS) for impaired segments NCD03, NCD05, NCDB, and NCDC01. A DEM is a digital representation of the landscape as a GIS-compatible grid in which each grid cell is assigned an elevation. DEMs of 90-meter resolution were downloaded from the *BASINS* database (USEPA 2002a) for watershed delineation. GIS watershed delineation defines the boundaries of a watershed by computing flow directions from elevations and locating elevation peaks on the DEM. The GIS-delineated watershed was checked against USGS 7.5-minute topographic maps to ensure agreement between the watershed boundaries and natural topographic boundaries. Figure 5-1 at the end of this section shows the location of historic water quality gages for the Bonnie Creek Watershed and the subwatershed boundaries for each impaired segment in the watershed. The subwatershed boundaries define the area investigated for causes of impairments in each segment. Purple areas in Figure 5-1 represent features of the topographic maps that have been updated through aerial photography, but have not been field verified.

Surface mining activities in the Bonnie Creek Watershed have significantly altered the natural landscape through changes in topography and the creation of inclined lakes and final cut lakes. Figure 5-2 shows an aerial photograph of the area surrounding the confluence of Bonnie Creek and Galum Creek and the GIS-delineated watersheds. The inclined and final cut lakes are visible in Figure 5-2. These lakes were originally strip-mined areas and roads dug to the mine floor that were left to become impoundments once mining activities ceased. From Figure 5-2, it is likely that the GIS watershed delineation is not correct through the mined areas. The possible reasons for the discrepancy is that the DEM resolution is too coarse to capture rapid elevation changes created by strip mines or that the DEM was completed prior to mining activities. An accurate delineation would require elevation data throughout the mined regions, which is not presently available. Without this data or detailed knowledge of flow patterns in the watershed, the GIS-delineated watersheds were used to model the impaired segments. An alteration was made to the segment NCD05 subwatershed based on knowledge of a stream relocation in the southwest section of the subwatershed. The discrepancy between the GIS-delineated watersheds and the physical landscape will be discussed further in Section 9.

5.1.3 Flow Data

Analyses of the Bonnie Creek Watershed require an understanding of flow through the impaired stream segments. There is no active stream gage within the impaired segments of the Bonnie Creek Watershed. Therefore, the drainage area ratio method, represented by the following equation, was used to estimate flows within the subwatersheds.

$$Q_{gaged}\left(\frac{Area_{ungaged}}{Area_{gaged}}\right) = Q_{ungaged}$$

where:

Q_{gaged}	=	Streamflow of the gaged basin
$Q_{ungaged}$	=	Streamflow of the ungaged basin
$Area_{gaged}$	=	Area of the gaged basin
$Area_{ungaged}$	=	Area of the ungaged basin

The assumption behind the equation is that the flow per unit area is equivalent in watersheds with similar characteristics. Therefore, the flow per unit area in the gaged watershed times the area of the ungaged watershed will result in a flow for the ungaged watershed.

UGSG gage 05595730 (Rayse Creek near Waltonville, Illinois) was chosen as an appropriate gage from which to compute flow through segments NCDC01, NCD03, NCD05, and NCDB. Gage 05595730 captures flow from a drainage area of 88 square miles and is located approximately 30 miles northeast of the Bonnie Creek Watershed. Daily streamflow data for the gage were downloaded from the USGS National Water Inventory System (NWIS) for the entire period of record from September 11, 1979 to September 30, 2001 (USGS 2002a). Figure 5-3 shows average monthly flows over the period of record through segments NCDC01, NCD03, NCD05, and NCDB calculated from the drainage area ratio method using gage 05595730. Flows are higher in the spring months of March through May. For Bonnie Creek segment NCDC01, average monthly flows range from 1.2 to 37.5 cubic feet per second (cfs) with a mean annual flow of 19.5 cfs. For lower Galum Creek segment NCD03, average monthly flows range from 6.4 to 203 cfs with a mean annual flow of 105 cfs. For upper Galum Creek segment NCD05, average monthly flows range from 1.7 to 54.4 cfs with a mean annual flow of 28.3 cfs. For Little Galum Creek segment NCDB, average monthly flows range from 1.2 to 37.7 cfs with a mean annual flow of 19.6 cfs. The 7Q10 flow (lowest average seven consecutive day low flow with an average recurrence frequency of once in 10 years) is typically utilized as the critical low flow for National Pollutant Discharge Elimination System (NPDES) permitting and is estimated to be zero for segments NCDC01, NCD03, NCD05, and NCDB (ISWS 2002).

5.1.4 Precipitation and Temperature Data

As discussed in Section 2.1, the Bonnie Creek Watershed is located within Perry County. Two sites with historical temperature and precipitation data were identified in Perry County through the NCDC database. The data from gage 2483 were used for analysis. Daily precipitation and temperature data for gage 2483 were extracted from the NCDC database for the years of 1985 through 2001. Table 5-1 lists the station details for the Perry County gages.

Table 5-1 Historical Precipitation Data for the Bonnie Creek Watershed

NCDC Gage Number	Station Location	Period Record
2483	Perry County (Du Quoin)	1901-present
6779	Perry County (Pinckneyville)	1990-present

Table 5-2 Average Monthly Precipitation for Perry County from 1985 to 2001

Month	Average Precipitation (in)
January	3.2
February	2.8
March	3.5
April	4.3
May	4.7
June	5.1
July	3.8
August	3.2
September	3.5
October	3.1
November	4.5
December	3.0
Average Annual Precipitation	**44.7**

Table 5-2 shows the average monthly precipitation of the dataset developed for Perry County for the years 1985 to 2001. The average annual precipitation over the same period is approximately 48 inches for Perry County.

5.1.5 Water Quality Data

Four historic water quality stations exist within the Bonnie Creek Watershed and are presented in Table 5-3. This table provides the location, station identification number, and the agency that collected the water quality data. Location and station identification number are also shown in Figure 5-1.

Table 5-3 Historical Water Quality Stations for the Bonnie Creek Watershed

Location (Segment ID)	Station Identification Number	Data Collection Agency
Bonnie Creek (NCDC01)	NCDC01	Illinois EPA Division of Water Pollution Control
Galum Creek (NCD03)	NCD03	Illinois EPA Division of Water Pollution Control
Galum Creek (NCD05)	NCD05	Illinois EPA Division of Water Pollution Control
Little Galum Creek (NCDB)	NCDB01	Illinois EPA Division of Water Pollution Control

The impaired water body segments in the Bonnie Creek Watershed were presented in Section 2. For Bonnie Creek segment NCDC01, Galum Creek segments NCD03 and NCD05, and Little Galum Creek segment NCDB, there is one historic water quality station within each segment. Table 5-4 summarizes available historic water quality data since 1990 from the USEPA *Storage and Retrieval (STORET)* database associated with impairments discussed in Section 2 for the Bonnie Creek Watershed.

Table 5-4 Water Quality Data for the Bonnie Creek Watershed

Sample Location and Parameter	Period of Record Examined for Samples	Number of Samples
Bonnie Creek Segment NCDC01; Sample Location NCDC01		
Sulfates	8/2/95-3/4/96	2
Galum Creek Segment NCD03; Sample Location NCD03		
Silver	7/26/95-3/5/96	2
Sulfates	7/26/95-3/5/96	2
TDS	7/26/95-3/5/96	2
Galum Creek Segment NCD05; Sample Location NCD05		
Manganese	8/2/95-3/4/96	2
DO	8/2/95-3/4/96	2
Little Galum Creek Segment NCDB; Sample Location NCDB01		
Manganese	7/17/95-3/4/96	2
Sulfates	7/17/95-3/4/96	2
TDS	7/17/95-3/4/96	2

5.1.5.1 Bonnie Creek Water Quality Data

There is one active water quality station in each impaired stream segment in the Bonnie Creek Watershed as shown in Figure 5-1. The water quality station data for each segment were downloaded from the *STORET* on-line database for the years of 1990 to 1998 (USEPA 2002b). The data summarized in this section include water quality data for impaired constituents in the Bonnie Creek Watershed, as well as constituents used in modeling efforts. The raw data are contained in Appendix A.

5.1.5.1.1 Manganese, Sulfates, Silver, and TDS

Table 5-5 summarizes historical manganese, sulfates, silver, and TDS data since 1990 from the USEPA *STORET* database and recent data not yet entered into the *STORET* database for impaired segments in the Bonnie Creek Watershed. The raw historical water quality data is contained in Appendix A. For some constituents, the average of the data sets is below the water quality standard, but the maximum values observed do exceed the water quality standards. The historical water quality samples were also taken during months with historically varying flow conditions.

Table 5-5 Existing Water Quality Data and TMDL Endpoints (USEPA 2002b)

Sample Location and Parameter	Endpoint (mg/L)	Period of Record Examined and Number of Data Points	Mean	Maximum	Minimum
Bonnie Creek Segment NCDC01; Sample Location NCDC01					
Sulfates	500	8/2/95-3/4/96; 2	370	616	124
Galum Creek Segment NCD03; Sample Location NCD03					
Silver	0.005	7/26/95-3/5/96; 2	0.0055	0.008	0.003
Sulfates	500	7/26/95-3/5/96; 2	1,440	1,580	1,300
TDS	1,000	7/26/95-3/5/96; 2	2,455	2,740	2,170
Galum Creek Segment NCD05; Sample Location NCD05					
Manganese	1.0	8/2/95-3/4/96; 2	0.9	1.5	0.3
Little Galum Creek Segment NCDB; Sample Location NCDB01					
Manganese	1.0	7/17/95-3/4/96; 2	2.0	3.8	0.2
Sulfates	500	7/17/95-3/4/96; 2	671	952	390
TDS	1,000	7/17/95-3/4/96; 2	1,100	1,180	1,020

Historical flow data were presented in Section 5.1.3. The flow values during the historical sampling events for manganese, sulfates, silver, and TDS are presented in Table 5-6. As discussed in Section 5.1.3, the flow data were calculated from USGS gage 05595730. The flow for each sample date was compared to the monthly average flow shown in Figure 5-3 for the month the sample was taken. Based on this comparison, all samples were taken at below average flow values except for the samples taken on August 2, 1995 in segments NCDC01 and NCD05. This suggests that most historical samples were taken under baseflow conditions in the Bonnie Creek Watershed. The above average flow values during the August sampling in segments NCDC01 and NCD05 suggest a portion of the constituents may be attributed to runoff.

Table 5-6 Manganese, Sulfates, Silver, and TDS Sampling Events and Associated Flow Values

Sample Location	Date	Flow (cfs)	Mn (mg/L)	Total Sulfates (mg/L)	Silver (mg/L)	TDS (mg/L)	Average Monthly Flow (cfs)
Bonnie Creek (NCDC01)	8/2/95	3.7	–	124	–	–	1
Bonnie Creek (NCDC01)	3/4/96	0.6	–	616	–	–	32
Galum Creek (NCD03)	7/26/95	4.2	–	1,300	0.008	2,740	
Galum Creek (NCD03)	3/5/96	1.6	–	1,580	0.003	2,170	173
Galum Creek (NCD05)	8/2/95	5.3	1.5	–	–	–	2
Galum Creek (NCD05)	3/4/96	0.4	0.27	–-	–	–	47
Little Galum Creek (NCDB)	7/17/95	0.1	3,800	390	–	1,020	6
Little Galum Creek (NCDB)	3/4/96	0.3	220	952	–	1,180	32

5.1.5.1.2 DO and TOC

Table 5-7 summarizes the available historic DO and total organic carbon (TOC) data since 1990 from the USEPA *STORET* database and recent data not yet entered into the *STORET* database for Galum Creek segment NCD05 in the Bonnie Creek Watershed (raw data contained in Appendix A). TOC data are presented here because they are used in the DO analysis. DO and TOC concentrations for the remaining segments are not included because only segment NCD05 is impaired for DO in the Bonnie Creek Watershed. The average DO concentration for the segment is above the water quality standard of 6.0 mg/L (16 hours of any 24-hour period), but the minimum value observed is less than the water quality standard of 6.0 mg/L.

Table 5-7 Existing DO Water Quality Data and TMDL Endpoints for Bonnie Creek Watershed Segment NCD05 (USEPA 2002b and Illinois EPA 2000)

Sample Location and Parameter	Endpoint (mg/L)	Period of Record Examined for Samples and Number of Data Points	Mean (mg/L)	Maximum (mg/L)	Minimum (mg/L)
Galum Creek Segment NCD05; Sample Location NCD05					
DO	6.0 (16 hours of any 24-hour period	8/2/95 - 3/4/96; 2	9.5	14.9	4.1
TOC	–	8/2/95 - 3/4/96; 2	11.0	14.8	7.1

Historical flow data were presented in Section 5.1.3. The flow values during the historical sampling events for DO are presented in Table 5-8. As discussed in Section 5.1.5.1.1, the flow for each sample date was compared to the monthly average flow shown in Figure 5-3 for the month the sample was taken. As mentioned in Section 5.1.5.1.1, based on this comparison, the August 2, 1995 sample for Segment NCD05 was taken at above average flow conditions, and the March 4, 1996 sample was taken at below average flow values. Although the flow value for the August sampling was above average, the flow of 5.3 cfs is still considered a slow-moving stream. Slow-moving waters within the stream segment result in stagnant conditions, which could decrease the amount of aeration occurring in the stream. In addition, the day with DO impairment (August 2, 1995) occurred during a warm weather month. Elevated stream temperatures affect the aquatic environment by limiting the concentration of DO in the water column. For example, the DO concentration for 100 percent air saturated water at sea level is 14.6 mg O_2/L at 0 degrees Celsius (°C) (32°F) and decreases to 8.6 mg O_2/L at 25°C (77°F) (Brown and Brazier 1972).

Table 5-8 DO Sampling Events and Associated Flow Values

Sample Location	Date	Flow (cfs)	DO (mg/L)
Galum Creek (NCD05)	8/2/1995	5.3	4.1
Galum Creek (NCD05)	3/4/1996	0.4	14.9

5.1.6 Land Use

The Illinois Natural Resources Geospatial Clearinghouse distributes the Critical Trends Assessment Land Cover Database of Illinois. This database represents 23 land use classes created by satellite imagery captured between 1991 and 1995. The data were published in 1996 and are distributed by county in grid format for use in GIS.

The GIS-delineated watershed for Galum Creek segment NCD05 was used to obtain the land use from the Critical Trends Assessment Land Cover grid. Only the land use for segment NCD05 was developed because land use is utilized only in the DO analysis, which will be discussed in Section 7. Table 5-9 lists the land uses contributing to the Galum Creek segment NCD05 subwatershed, as well as each land use area and percent of total area.

Table 5-9 Land Use for the Segment NCD05 Watershed

Land Use	Area (Acres)	Percent of Total
Row Crop	8,942	41%
Rural Grassland	7,324	34%
Small Grains	2,369	11%
Deciduous	2,086	10%
Forested Wetland	456	2%
Open Water	205	1%
Shallow Water/Wetlands	197	1%
Medium Density	58	0%
Deep Marsh	40	0%
Shallow Marsh/Wetlands	25	0%
Urban Grassland	7	0%
High Density	5	0%
Barren Land	1	0%
TOTAL	**21,715**	**100%**

5.1.7 Point Sources and Animal Confinement Operations

5.1.7.1 Coal Mines and Oil and Gas Fields

Acid mine drainage from coal mines could contribute to manganese, sulfates, and TDS concentrations in a watershed, and runoff from other mining activity could potentially contribute to silver concentrations. Data from the Illinois Natural Resources Geospatial Data Clearinghouse was reviewed for coal mines, oil fields, and non-coal mines within the Bonnie Creek Watershed from the following references (full citation provided in Section 10):

- Chenoweth, Cheri, 1998, Areas Mined for the Springfield (No. 5) Coal in Illinois
- Stiff, Barbara J., 1997, Areas Mined for Coal in Illinois - Part 1
- Stiff, Barbara J., 1997, Areas Mined for Coal in Illinois - Part 2
- Coal Section, Illinois State Geological Survey, 1991, Point Locations of Active and Abandoned Coal Mines in Illinois
- Illinois Office of Mines and Minerals, 1998, Coal Mine Permits Boundaries in Illinois
- Staff, ISGS, 1996, Non-coal Underground Mines of Illinois
- Staff, ISGS, 1996, Non-coal Underground Mines of Illinois - Points
- Illinois State Geological Survey, not published, Oil and Gas Fields in Illinois

Figure 5-4 presents the findings from these databases for extraction operations in the Bonnie Creek Watershed. Multiple coal mines were identified within the watershed and labeled on Figure 5-4. The mine names and dates of operation are listed in Appendix B. Figure 5-4 also shows which coal mines are permitted. A comparison of the existing and permitted mine databases suggests that non-permitted mines are likely abandoned or closed. No oil or gas fields or non-coal mines were located in the Bonnie Creek Watershed; however, the non-coal mine database contains only 20 percent of the non-coal mines in Illinois due to the lack of a legal filing requirement.

Table 5-10 lists water discharge permits for mines in the Bonnie Creek Watershed, the date the most recent permit was issued, and the permit expiration date. Each permit represents multiple pipe outfalls, which are depicted in Figure 5-5 at the end of this section. Figure 5-5 also shows the facility location for each active mine listed in Table 5-10.

Table 5-10 Water Discharge Permits for Mines within Bonnie Creek Watershed (USEPA 2002c)

Permit ID	Facility Name	Status	Receiving Waters	Permit Issued	Permit Expiration
IL0026492	Consolidation Coal - Burning Star #4 Mine	Inactive		2/27/95	1/1/00
IL0033723	Apogee Coal - Captain Mine #1	Active	Galum Creek (NCD03)	10/4/00	7/31/05
IL0047716	Consolidation Coal - Burning Star Mine	Inactive		11/16/81	7/31/85
IL0048623	Consolidation Coal - Pyramid Mine	Active	Chicken Creek	10/29/97	9/30/02
IL0052795	Consolidation Coal - Burning Star #4 Mine	Active	Galum Creek (NCD05)	9/1/99	6/30/04
IL0064718	Apogee Coal - Horse Creek Mine	Active	Unnamed Tributary of Bonnie Creek (NCD03)	1/13/00	10/31/04
IL0066559	Apogee Coal - Captain Mine #2	Inactive	Rattlesnake Creek (NCD03)	5/13/96	10/1/00
IL0068454	Apogee Coal - Conant Mine	Inactive	Unnamed Tributary of Galum Creek	7/21/95	6/1/00

Sulfate and chloride water quality data are available for selected pipe outfalls from the Apogee Coal Captain #1 (IL0033723) and Captain #2 Mines (IL0066599), Apogee Coal Horse Creek Mine (IL0064718), which potentially impact Galum Creek segment NCD03; and the active Consolidation Coal Burning Star #4 Mine (IL0052795), which potentially impacts Galum Creek segment NCD05. These data are summarized in Table 5-11.

Table 5-11 Sulfate and Chloride Pipe Outfall Concentrations

Permit ID and Sample Dates	Pipe Outfall	Flow (cfs)				Sulfate (mg/L)				Chloride (mg/L)			
		# of Samples	Minimum	Maximum	Average	# of Samples	Minimum	Maximum	Average	# of Samples	Minimum	Maximum	Average
IL0033723 01/99 – 06/02	Outfall 009	11	0.109	3.55	1.34	10	1334	2537	2315	11	2.5	30.6	25.3
	Outfall 022	28	0.020	6.26	2.44	33	891	1760	1395	33	45	132	79.5
	Outfall 023	9	0.002	1.07	0.20	10	68	1824	639	10	4	243	61.7
	Outfall 025	5	0.016	1.43	0.60	7	65	165	135	7	10	23	17.8
	Outfall 028	25	0.003	1.39	0.30	32	1998	2704	2437	32	5.9	22.9	11.7
IL0066559 01/99 – 06/02	Outfall 001	21	0.002	0.23	0.08	25	72	375	245	25	5	125	34
	Outfall 002	10	0.006	1.27	0.24	14	111	2460	1119	14	23	436	195
	Outfall 003	8	0.005	0.36	0.10	11	130	620	396	11	19	457	88
	Outfall 008	14	0.003	0.48	0.14	14	83	313	181	15	6	26	9
IL0064718 01/00 – 03/02	Outfall 004	16	0.016	1.66	0.29	16	8	314	84	16	4	21	9
	Outfall 009	4	0.078	0.62	0.30	4	174	242	204	4	23	25.3	23.7
IL0052795 05/99 – 06/02	Outfall 002	25	0.002	2.13	0.37	1	84	84	84	1	9.8	9.8	9.8
	Outfall 040	25	0.002	5.01	0.39	1	233	233	233	1	8.7	8.7	9
	Outfall 046	19	0.005	6.01	1.55	18	318	739	593	4	28	37.7	34.2

Permitted discharges are regulated by Title 35 of the Illinois Administrative Code (IPCB 1999b). The effluent standards for mine discharges are listed in Table 5-12.

Table 5-12 Effluent Standards for Mine Discharges in Illinois (IPCB 1999b)

Constituent	Limit
Acidity	Shall not exceed total alkalinity
Iron (total)	3.5 mg/L
Lead (total)	1 mg/L
Ammonia Nitrogen (as N)	5 mg/L
pH	6 - 9 s.u.
Zinc (total)	5 mg/L
Fluoride (total)	15 mg/L
Total Suspended Solids	35 mg/L
Manganese	2 mg/L[a]
Sulfate	3,500 mg/L [a]
Chloride	1,000 mg/L [a]
TDS	– [a]

[a] Utilize good mining practices to minimize discharge of pollutant.

All sulfate and chloride samples in Table 5-11 are below the effluent standards complying with Title 35; however, sulfate concentrations in half of the pipe outfalls exceed the water quality standards as evidenced by effluent concentrations greater than 500 mg/L.

Both the Illinois EPA and IDNR Office of Mines and Minerals have responsibilities relating to the permitting of active coal mines and the regulation of mine drainage. Mine drainage is any groundwater, surface water, or rainwater that flows through, or in any way contacts an area affected by mining. Mine drainage from sites in Illinois are either non-acid drainage or acid drainage and can be classified as pre-law and post-law. Pre-law mines are those mines operated prior to 1977 that are abandoned and not permitted and are typically acid drainage mines (Muir et al. 1997).

Acid mine drainage is formed when three essential components combine: iron pyrite material, oxygen, and water. Pyritic material may come in several different forms, some of which are very stable and difficult to break down while others are very reactive and break down readily. Iron pyrite is commonly found associated with coal and coal refuse materials. As water contacts iron pyrite in the presence of oxygen, a chemical reaction occurs that forms ferrous iron and sulfuric acid. The ferrous iron then undergoes oxidation to form ferric iron. With the presence of ferrous iron, ferric iron, pyrite, oxygen, and water, several chemical reactions occur that produce additional acidity, further lowering the pH of the water. The formation of new acid is practically continuous when erosion of the refuse material exposes unreacted pyrite in the presence of oxygen and water. The negative impacts of acid mine drainage are high levels of dissolved solids, especially iron, sulfates, chlorides, and manganese associated with the mine drainage (Muir et al. 1997).

Table 5-13 shows constituents or "tracers" typically examined when analyzing whether sources of pollutants in a water body are from mining or oil and gas activities. For acid mine drainage, generally elevated concentrations of iron would be observed. For oil and gas contributions, chloride or sodium tracers can be used to assess impacts from brine waste generated in the production of oil and gas. As mentioned previously, the sampling data shown in Table 5-13 were under low-flow conditions except for the August 2, 1995 sample in segments NCDC01 and NCD05. The absence of exceedences of the water quality standards for manganese, sulfates, silver, and TDS at higher flows in Table 5-13 supports the conclusion that manganese and sulfates from the remaining segments could have leached into the groundwater from pools within mine sites. Therefore, groundwater could be the source of manganese, sulfates, silver, and TDS for the Bonnie Creek Watershed. It is possible that surface runoff from mine sites is the source of elevated concentrations in segments NCDC01 and NCD05. In addition, no data is available to assess the natural background of manganese, sulfates, silver, and TDS in the watershed. Natural background concentrations typically are attributed to what occurs naturally in groundwater due to mineral conditions of the soils (Water Environment Research Foundation [WERF] 1997).

Table 5-13 Historical Water Chemistry in Bonnie Creek Watershed (USEPA 2002b)

Sample Location	Date	Flow (cfs)	Total Mn (mg/L)	Sulfates (mg/L)	TDS (mg/L)	Ag (µg/L)	Total Fe (µg/L)	Total Ca (mg/L)	Total Cl (mg/L)	Total Na (mg/L)	Total K (mg/L)	Total Mg (mg/L)
Bonnie Creek (NCDC01)	8/2/95	3.7	–	124	–	3	670	58	31.4	42	10	22
Bonnie Creek (NCDC01)	3/4/96	0.6	–	616	–	3	390	130	40.1	83	7	74
Galum Creek (NCD03)	7/26/95	4.2	–	1,300	2,740	8	1,200	200	181	720	12	91
Galum Creek (NCD03)	3/5/96	1.6	–	1,580	2,170	3	930	210	118	570	11	93
Galum Creek (NCD05)	8/2/95	5.3	1.5	–	–	3	1,400	47	22.4	25	14	15
Galum Creek (NCD05)	3/4/96	0.4	0.3	–	–	3	580	100	40.2	76	6.4	49
Little Galum Creek (NCDB)	7/17/95	0.1	3,800	390	1,020	3	910	130	32.1	74	10	55
Little Galum Creek (NCDB)	3/4/96	0.3	220	952	1,180	3	200	200	44.8	120	7.3	110

5.1.7.2 Animal Confinement Operations

The Illinois EPA provided a GIS shapefile illustrating the location of livestock facilities in the Big Muddy River Basin, which contains the Bonnie Creek Watershed. The 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. Only facilities in the segment NCD05 subwatershed were investigated because it is the only segment impaired for DO, and animal confinement operations may contribute to DO impairments. Four animal management operations were located within the segment NCD05 subwatershed. Of the four operations, two feedlots were listed as having no impact on receiving waters, one feedlot is listed as having a slight impact on receiving waters, and one facility was not assessed and may be empty. Figure 5-6 shows the animal management operations within the segment NCD05 subwatershed.

5.1.7.3 Wastewater Treatment Plants

The Coulterville wastewater treatment plant is located near Galum Creek Segment NCD05. The flow and associated load from this wastewater treatment is negligible and therefore will not be considered in the TMDL analyses for DO.

5.1.8 Septic Systems

Typically, septic systems near lake waters have greater potential for impacting water quality than systems near streams due to their proximity to the water body of concern. The number of septic systems within the watersheds could not be confirmed from available data sources. It is anticipated that failing septic systems are a negligible source of pollutant loads in this watershed.

5.1.9 Aerial Photography

Aerial photographs of the Bonnie Creek Watershed were obtained from the Illinois Natural Resources Geospatial Data Clearinghouse. The photographs were used to supplement the USGS quadrangle maps when locating facilities.

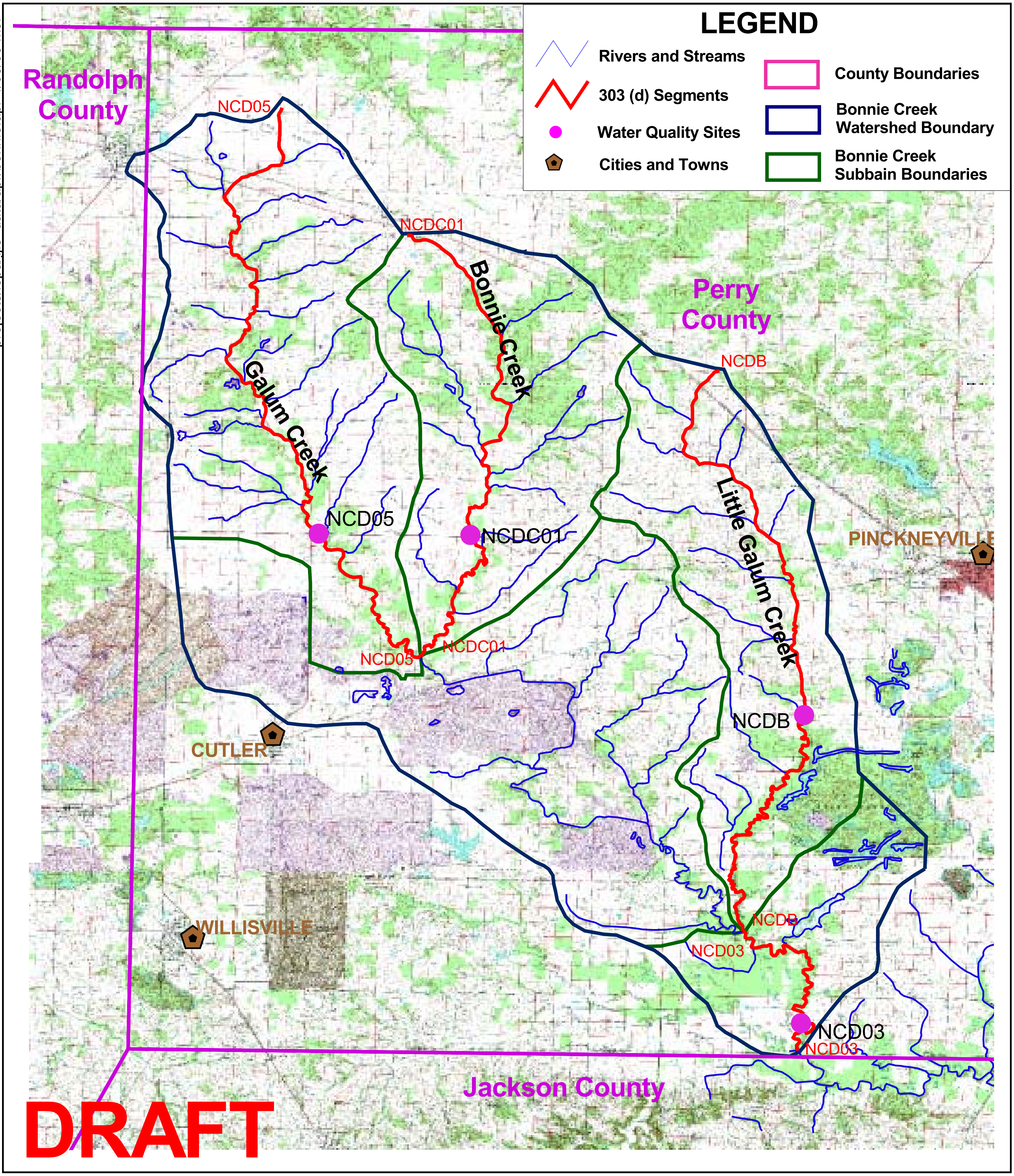

Figure 5-1
Bonnie Creek Watershed and Historic Sampling Locations

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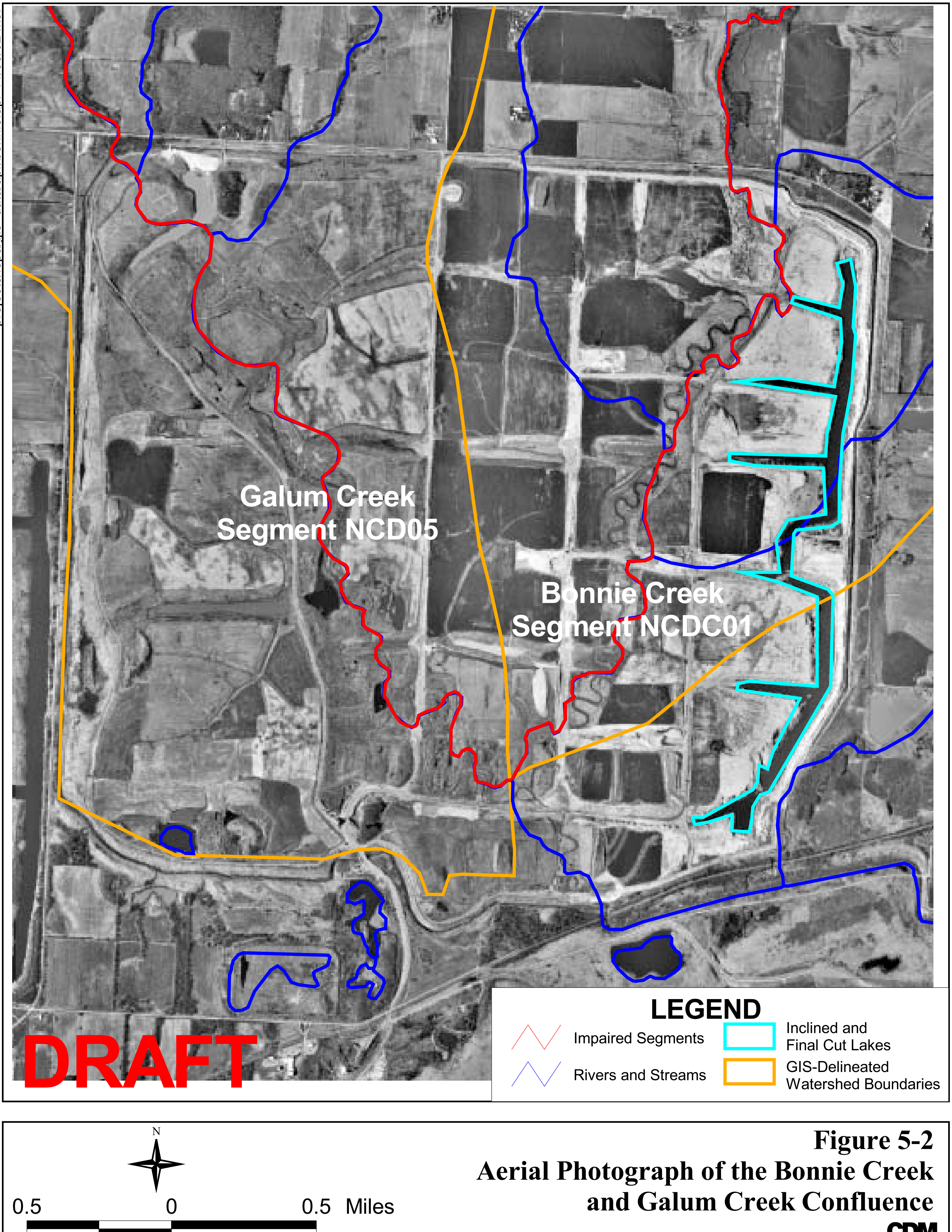

Figure 5-2
Aerial Photograph of the Bonnie Creek and Galum Creek Confluence

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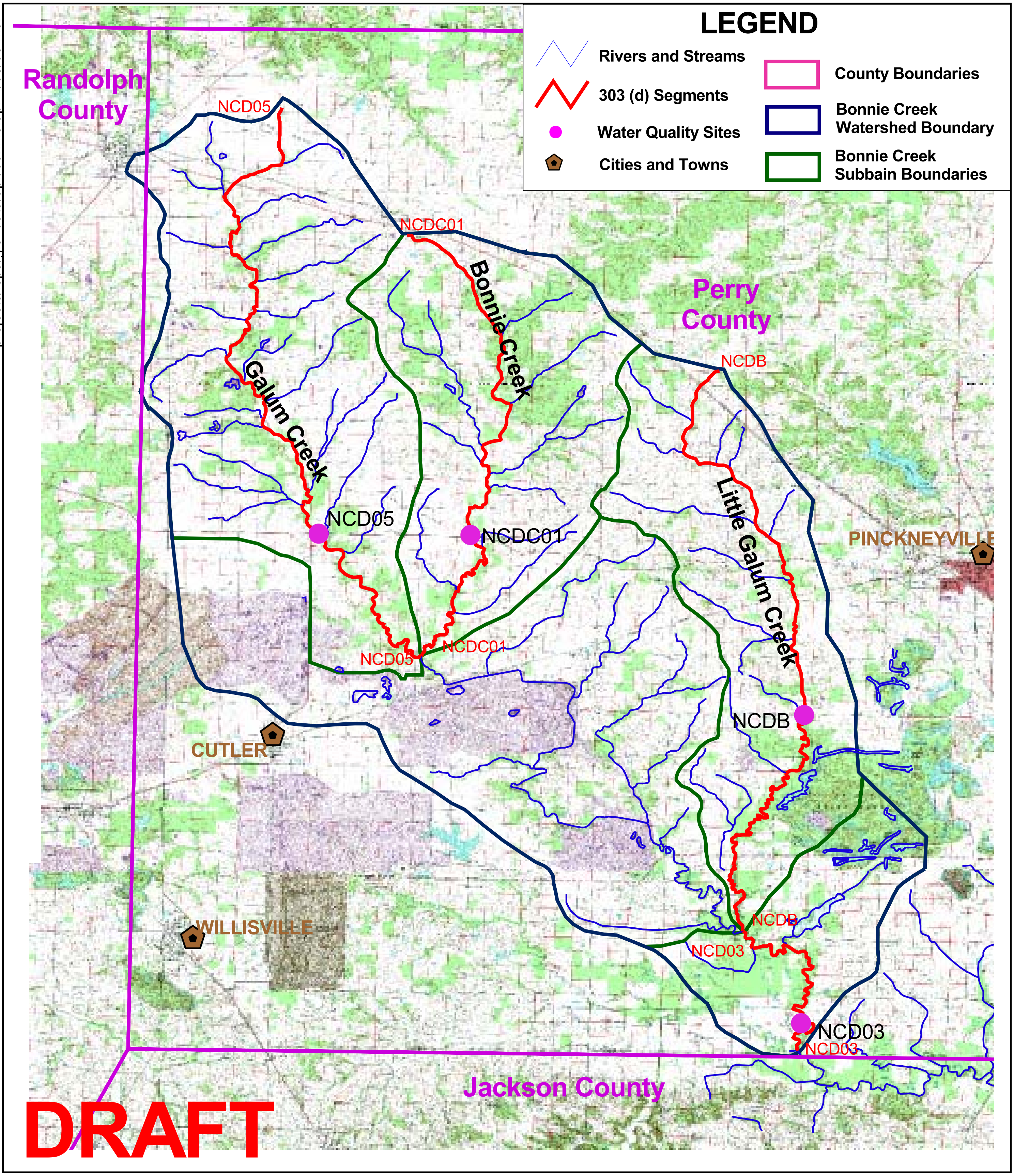

Figure 5-1
Bonnie Creek Watershed and Historic Sampling Locations

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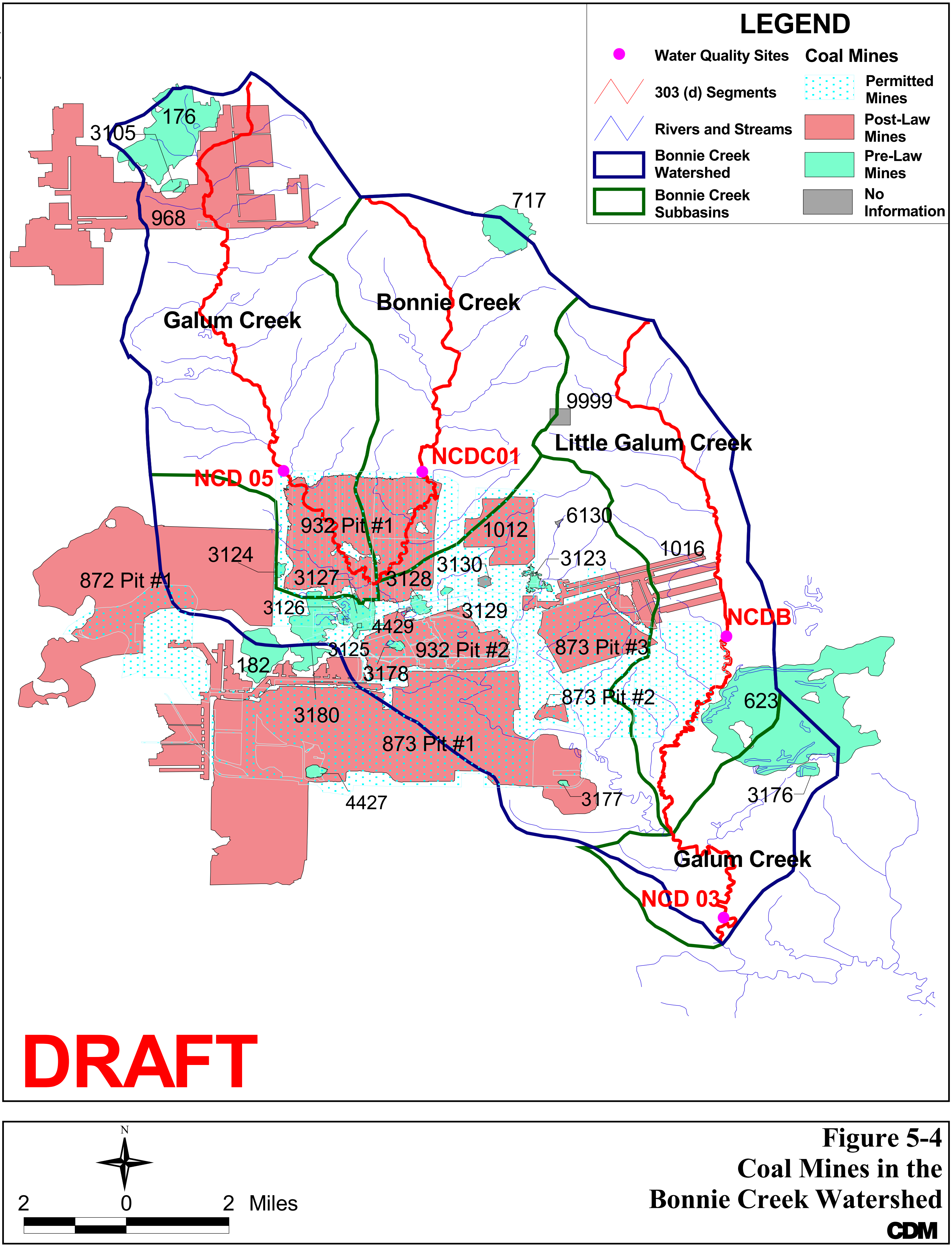

Figure 5-4
Coal Mines in the Bonnie Creek Watershed

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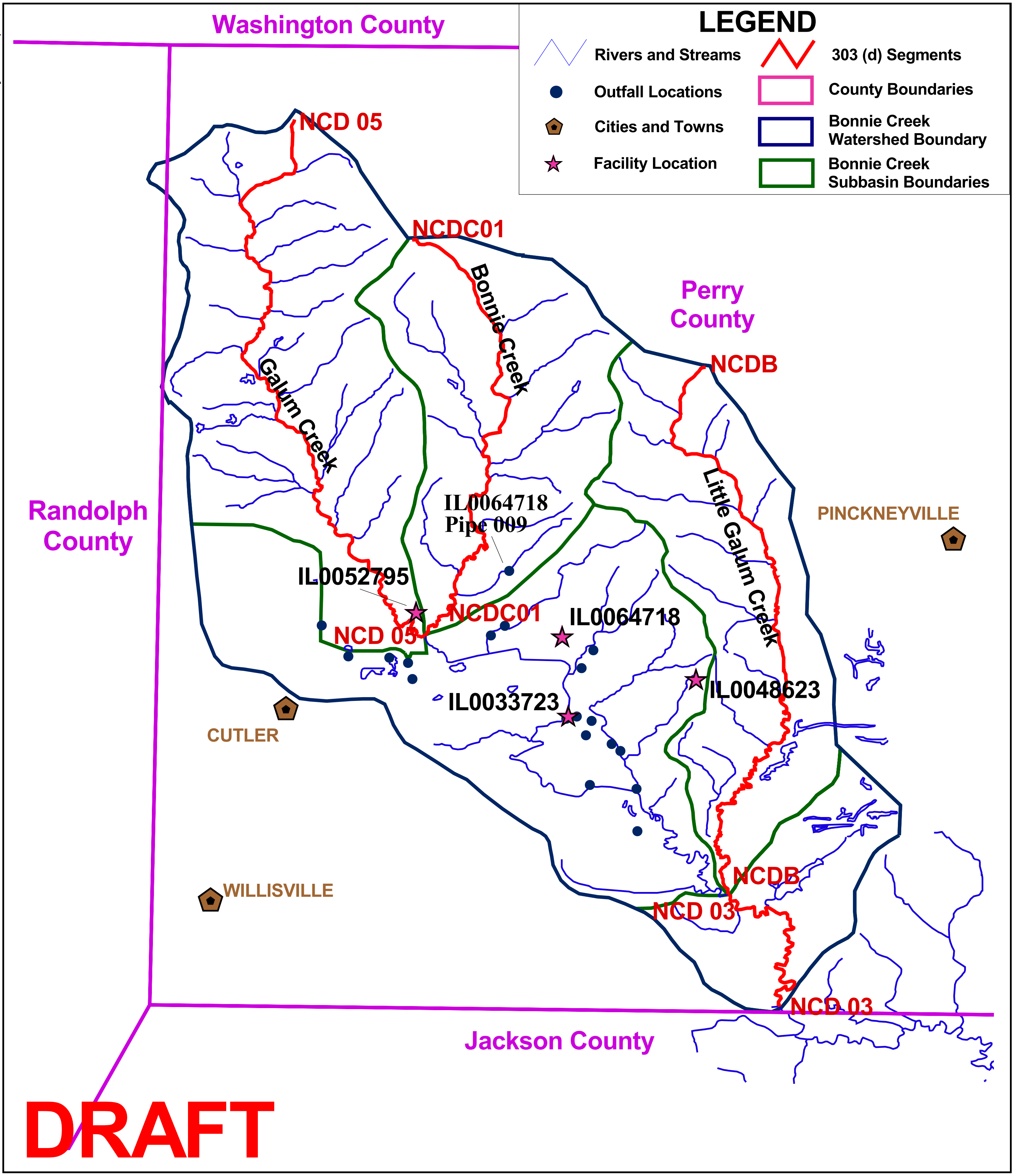

Figure 5-5
Mine Effluent Outfalls in the Bonnie Creek Watershed

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Figure 5-6
Animal Management Operations in the Segment NCD05 Watershed

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Section 6
Methodologies and Models to Complete TMDLs for the Bonnie Creek Watershed

6.1 Set Endpoints for TMDLs

TMDLs are used to define the total amount of pollutants that may be discharged into a particular water body within any given day based on a particular use of that water body. Developing TMDLs must, therefore, account for both present and future stream users, habitat, flow variability, and current and future point and nonpoint pollutant loadings that may impact the water body. Defining a TMDL for any particular stream segment must take into account not only the science related to physical, chemical, and biological processes that may impact water body water quality, but must also be responsive to temporal changes in the watershed, and likely influences of potential solutions to water quality impairments on entities that reside in the watershed.

Stream and lake water quality standards were presented in Section 4, specifically in Table 4-1. Biological data, such as the Index of Biotic Integrity (IBI) and the Macroinvertebrate Biotic Index (MBI), are used to support 305(b) and 303(d) listing decisions; however, TMDLs were not developed specifically to meet biological endpoints for the Bonnie Creek Watershed. The endpoints presented in Section 4, which are chemical and physical endpoints of the following constituents, were targeted: manganese, sulfates, TDS, and DO.

6.2 Methodologies and Models to Assess TMDL Endpoints

Methodologies and models were examined to assess their applicability for addressing TMDL endpoints for the Bonnie Creek Watershed. Model development is more data intensive than using simpler methodologies or mathematical relationships for the basis of TMDL development. In situations where only limited or qualitative data exist to characterize impairments, methodologies were used to develop TMDLs and implementation plans as appropriate.

In addition to methodologies, watershed and receiving water computer models are available for TMDL development. Most models have similar overall capabilities, but operate at different time and spatial scales and were developed for varying conditions. The available models range between empirical and physically based. However, all existing watershed and receiving water computer models simplify processes and often include obviously empirical components that omit the general physical laws. They are, in reality, a representation of data.

Each model has its own set of limitations on its use, applicability, and predictive capabilities. For example, watershed models may be designed to project loads within annual, seasonal, monthly, or storm event time scales with spatial scales ranging from large watersheds to small subbasins to individual parcels such, as construction sites. With regard to time, receiving water models can be steady state, quasi dynamic, or fully dynamic. As the level of temporal and spatial detail increases, the data requirements and level of modeling effort increase.

6.2.1 Watershed Models

Watershed or loading models can be divided into categories based on complexity, operation, time step, and simulation technique. USEPA has grouped existing watershed-scale models for TMDL development into three categories based on the number of processes they incorporate and the level of detail they provide (USEPA 1997a):

- simple models
- mid-range models
- detailed models

Simple models primarily implement empirical relationships between physiographic characteristics of the watershed and pollutant runoff. A list of simple category models with an indication of the capabilities of each model is shown in Table 6-1. Simple models may be used to support an assessment of the relative significance of different nonpoint sources, guide decisions for management plans, and focus continuing monitoring efforts. Generally, simple models aggregate watershed physiographic data spatially at a large-scale and provide pollutant loading estimates on large time-scales. Although they can easily be adopted to estimate storm event loading, their accuracy decreases since they cannot capture the large fluctuations of pollutant concentrations observed over smaller time-scales.

Table 6-1 Evaluation of Watershed Model Capabilities - Simple Models (USEPA 1997a)

Criteria		USEPA Screening[1]	Simple Method[1]	Regression Method[1]	SLOSS-PHOSPH[2]	Watershed	FHWA	WMM
Land Uses	Urban	○	◒	◒	–	◒	○[3]	●
	Rural	◒	–	○	◒	◒	○	●
	Point Sources	–	–	–	–	○	–	○
Time Scale	Annual	●	●	●	●	●	●	●
	Single Event	○	○	○	–	–	○	–
	Continuous	–	–	–	–	–	–	–
Hydrology	Runoff	–[4]	◒	–	–	–	○	○
	Baseflow	–	–	–	–	–	–	○
Pollutant Loading	Sediment	◒	◒	◒	◒	◒	–	–
	Nutrients	◒	◒	◒	◒	◒	◒	◒
	Others	○	◒	◒	–	◒	◒	◒
Pollutant Routing	Transport	–	–	–	–	–	–	–
	Transformation	–	–	–	–	–	–	○
Model Output	Statistics	–	–	–	–	◒	○	○
	Graphics	–	–	–	–	◒	–	○
	Format Options	–	–	–	–	◒	–	○
Input Data	Requirements	○	○	○	○	○	○	○
	Calibration	–	–	–	○	◒	–	◒
	Default Data	●	●	◒	◒	○	◒	◒
	User Interface	–	–	–	–	◒	○	◒
BMPs	Evaluation	○	○	–	○	◒	◒	◒
	Design Criteria	–	–	–	–	–	–	–
Documentation		●	●	●	●	●	●	◒

[1] Not a computer program
[2] Coupled with GIS
[3] Highway drainage basins
[4] Extended Versions recommended use of SCS-curve number method for runoff estimation

● High ◒ Medium ○ Low – Not Incorporated

Mid-range models attempt a compromise between the empiricism of the simple models and complexity of detailed mechanistic models. Mid-range models are designed to estimate the importance of pollutant contributions from multiple land uses and many individual source areas in a watershed. Therefore, they require less aggregation of the watershed physiographic characteristics than the simple models. Mid-range models may be used to define large areas for pollution migration programs on a watershed basis and make qualitative evaluations of BMP alternatives. A list of models within the mid-range category and their capabilities is shown in Table 6-2.

Table 6-2 Evaluation of Watershed Model Capabilities - Mid-Range Models (USEPA 1997a)

Criteria		SITEMAP	GWLF	P8-UCM	Auto-QI	AGNPS	SLAMM
Land Uses	Urban	●	●	●	●	–	●
	Rural	●	●	–	–	●	–
	Point Sources	◒	◒	●	–	●	●
Time Scale	Annual	–	–	–	–	–	–
	Single Event	○	–	●	–	●	–
	Continuous	●	●	●	●	–	●
Hydrology	Runoff	●	●	●	●	●	●
	Baseflow	○	●	○	○	–	○
Pollutant Loading	Sediment	–	●	●	●	●	●
	Nutrients	●	●	●	●	●	●
	Others	–	–	●	●	–	●
Pollutant Routing	Transport	○	○	○	◒	●	◒
	Transformation	–	–	–	–	–	–
Model Output	Statistics	◒	○	–	–	–	○
	Graphics	◒	◒	●	–	●	○
	Format Options	●	●	●	○	●	●
Input Data	Requirements	◒	◒	◒	◒	◒	◒
	Calibration	○	○	○	◒	○	◒
	Default Data	●	●	◒	○	◒	◒
	User Interface	●	●	●	◒	◒	●
BMPs	Evaluation	○	○	●	◒	◒	◒
	Design Criteria	–	–	●	◒	◒	○
Documentation		●	●	●	◒	●	◒

● High ◒ Medium ○ Low – Not Incorporated

Detailed models use storm event or continuous simulation to predict flow and pollutant concentrations for a range of flow conditions. These models explicitly simulate the physical processes of infiltration, runoff, pollutant accumulation, instream effects, and groundwater/surface water interaction. These models are complex and were not designed with emphasis on their potential use by the typical state or local planner. Many of these models were developed for research into the fundamental land surface and instream processes that influence runoff and pollutant generation rather than to communicate information to decisionmakers faced with planning watershed management (USEPA 1997a). Although detailed or complex models provide a comparatively high degree of realism in form and function, complexity does not come without a price of data requirements for model construction, calibration, verification, and operation. If the necessary data are not available, and many inputs must be based upon professional judgment or taken from literature, the resulting uncertainty in predicted values undermine the potential benefits from greater realism. Based on the available data for the Bonnie Creek Watershed, a detailed model could not be constructed, calibrated, and verified with certainty, and the watershed model selection should focus on the simple or mid-range models.

6.2.1.1 Watershed Model Recommendation

For the Bonnie Creek Watershed, the Watershed Management Model (WMM) will be utilized in screening mode for the DO TMDL in the watershed. For manganese, silver, sulfates, and TDS, a Monte Carlo simulation will be utilized as discussed in Section 7.

6.2.2 Receiving Water Quality Models

Receiving water quality models differ in many ways, but some important dimensions of discrimination include conceptual basis, input conditions, process characteristics, and output. Table 6-3 presents extremes of simplicity and complexity for each condition as a point of reference. Most receiving water quality models have some mix of simple and complex characteristics that reflect tradeoffs made in optimizing performance for a particular task.

Table 6-3 General Receiving Water Quality Model Characteristics

Model Characteristic	Simple Models	Complex Models
Conceptual Basis	Empirical	Mechanistic
Input Conditions	Steady State	Dynamic
Process	Conservative	Nonconservative
Output Conditions	Deterministic	Stochastic

The concept behind a receiving water quality model may reflect an effort to represent major processes individually and realistically in a formal mathematical manner (mechanistic), or it may simply be a "black-box" system (empirical) wherein the output is determined by a single equation, perhaps incorporating several input variables, but without attempting to portray constituent processes mechanistically.

In any natural system, important inputs such as flow in the river change over time. Most receiving water quality models assume that the change occurs sufficiently slowly so that the parameter (for example, flow) can be treated as a constant (steady state). A dynamic receiving water quality model, which can handle unsteady flow conditions, provides a more realistic representation of hydraulics, especially those conditions associated with short duration storm flows, than a steady state model. However, the price of greater realism is an increase in model complexity that may be neither justified nor supportable.

The manner in which input data are processed varies greatly according to the purpose of the receiving water quality model. The simplest conditions involve conservative substances where the model need only calculate a new flow-weighted concentration when a new flow is added (conservation of mass). Such an approach is unsatisfactory for constituents such as DO or labile nutrients, such as nitrogen and phosphorus, which will change in concentration due to biological processes occurring in the stream.

Whereas the watershed nonpoint model's focus is the generation of flows and pollutant loads from the watershed, the receiving water models simulate the fate and transport of the pollutant in the water body. Table 6-4 presents the steady state (constant flow and loads) models applicable for this watershed. The steady state models are less complex than the dynamic models. Also, as discussed above, the dynamic models require significantly more data to develop and calibrate an accurate simulation of a water body.

Table 6-4 Descriptive List of Model Components - Steady State Water Quality Models

Model	Water Body Type	Parameters Simulated	Process Simulated	
			Physical	Chemical/Biological
USEPA Screening Methods	River, lake/ reservoir, estuary, coastal	Water body nitrogen, phosphorus, chlorophyll "a," or chemical concentrations	Dilution, advection, dispersion	First order decay - empirical relationships between nutrient loading and eutrophication indices
EUTROMOD	Lake/reservoir	DO, nitrogen, phosphorus, chlorophyll "a"	Dilution	Empirical relationships between nutrient loading and eutrophication indices
BATHTUB	Lake/reservoir	DO, nitrogen, phosphorus, chlorophyll "a"	Dilution	Empirical relationships between nutrient loading and eutrophication indices
QUAL2E	Rivers (well mixed/shallow lakes or estuaries)	DO, CBOD, arbitrary, nonconservative substances, three conservative substances	Dilution, advection, dispersion	First order decay, DO-BOD cycle, nutrient-algal cycle
EXAMSII	Rivers	Conservative and nonconservative substances	Dilution, advection, dispersion	First order decay, process kinetics, daughter products, exposure assessment
SYMPTOX3	River/reservoir	Conservative and nonconservative substances	Dilution, advection, dispersion	First order decay, sediment exchange
STREAMDO	Rivers	DO, CBOD, and ammonium	Dilution	First order decay, BOD-DO cycle, limited algal component

6.2.2.1 Receiving Water Model Recommendation

Because of the lack of spatial data sets for the stream segments within the Bonnie Creek Watershed, methodologies based on the USEPA Screening Methods and Monte Carlo simulations will be utilized for stream TMDL development as discussed in the following section.

6.2.3 Stream TMDLs for the Bonnie Creek Watershed

Because of limited data available for watershed and receiving water model development for the Bonnie Creek Watershed, TMDLs for the following constituents will be completed using methodologies: manganese, silver, sulfates, TDS, and DO. For DO, a Streeter-Phelps analysis based on the USEPA Screening Procedures was developed. In addition, a screening level WMM analysis was conducted. These analyses are described in Section 7. For manganese, silver, sulfates, and TDS, a Monte Carlo simulation was conducted and the description of this analysis is also contained in Section 7.

6.2.4 Calibration and Validation of Models

The results of loading and receiving water simulations are more meaningful when they are accompanied by some sort of confirmatory analysis. The capability of any model to accurately depict water quality conditions is directly related to the accuracy of input data and the level of expertise required to operate the model. It is also largely dependent on the amount of data available. Calibration involves minimization of deviation between measured field conditions and model output by adjusting parameters of the model. Data required for this step are a set of known input values along with corresponding field observation results. Validation involves the use of a second set of independent information to check the model calibration. The data used for validation should consist of field measurements of the same type as the data output from the model. Specific features such as mean values, variability, extreme values, or all predicted values may be of interest to the modeler and require testing. Models are tested based on the levels of their predictions, whether descriptive or predictive. More accuracy is required of a model designed for absolute versus relative predictions. If the model is calibrated properly, the model predictions will be acceptably close to the field predictions. Because methodologies will be utilized for the Bonnie Creek Watershed, a detailed calibration and verification cannot be completed for the watershed.

6.2.5 Seasonal Variation

Consideration of seasonal variation, such that water quality standards for the allocated pollutant will be met during all seasons of the year, is a requirement of a TMDL submittal. TMDLs must maintain or attain water quality standards throughout the year and consider variations in the water body's assimilative capacity caused by seasonal changes in temperature and flow (USEPA 1999). Seasonal variation for the Bonnie Creek Watershed is discussed in Section 8.

6.2.6 Allocation

Establishing a TMDL requires the determination of the LC of each stream segment. The models or methodologies were used to establish what the LC is for each segment for each pollutant. The next step was to determine the appropriate MOS for each segment. After setting the MOS, WLA of point sources and LA from the nonpoint sources were set.

The MOS can be set explicitly as a portion of the LC or implicitly through applying conservative assumptions in data analysis and modeling approaches. Data analyses and modeling limitations were taken into account when recommending a MOS. The allocation scheme (both LA and WLA) demonstrates that water quality standards will be attained and maintained and that the load reductions are technically achievable. The allocation is the foundation for the implementation and monitoring plan. Further discussion on the allocation is presented in Section 8.

6.2.7 Implementation and Monitoring

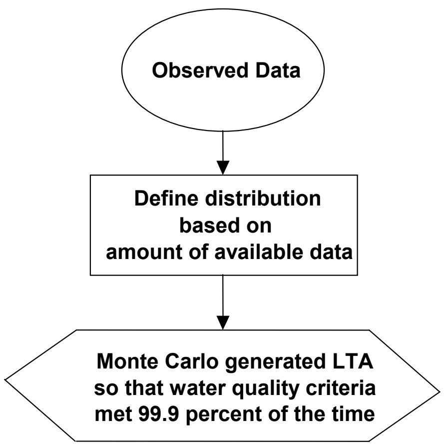
For the Bonnie Creek Watershed, a plan of implementation was produced to support the developed TMDL. The plan of implementation has reasonable assurance of being achieved. The plan provides the framework for the identification of the actions that must be taken on point and nonpoint sources to achieve the desired TMDLs. The accomplishment of the necessary actions to reach these targets may involve substantial efforts and expenditures by a large number of parties within the watershed. Depending upon the specific issues and their complexity in the Bonnie Creek Watershed, the timeframe for achieving water quality standards has been developed.

The implementation plan delineates a recommended list of the sources of stressors that are contributing to the water quality impairments. The amount of the reduction needed from various sources to achieve the water quality limiting parameter was then delineated. For nonpoint sources, the use of BMPs is one way to proceed to get the desired reduction in loading. The effectiveness of various BMPs was factored into the modeling and methodologies to develop the range of options of BMPs to use. Associated with those BMPs is cost information, as available. Also, reductions from point sources through waste stream management, which involves the treatment of point source waste streams in order to decrease potential water quality impacts; pretreatment controls; and other structural and nonstructural programs, were identified as applicable. The implementation plan for the Bonnie Creek Watershed is presented in Section 9.

Section 7
Methodology Development for the Bonnie Creek Watershed

7.1 Methodology Overview

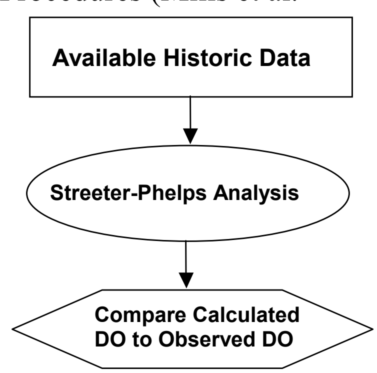
Methodologies were utilized in the TMDL analysis of the Bonnie Creek Watershed. For manganese, silver, sulfates, and TDS, a Monte Carlo simulation was utilized to estimate a long-term average instream concentration needed to meet water quality standards. Investigation of DO required a Streeter-Phelps analysis.



Schematic 1

The schematic to the left shows how the Monte Carlo analysis was utilized to analyze manganese, silver, sulfates, and TDS. A distribution based on existing data is entered in the Monte Carlo simulation program. This distribution is based on the amount of existing data available. Using this defined distribution, the computer simulation program randomly generates values to determine what long-term average (LTA) would be needed in the stream segment so that water quality criteria are met 99.9 percent of the time, or so that water quality criteria are exceeded less than once every three years. The TMDL for manganese, silver, sulfates, and TDS will be based on this LTA. The randomly generated values generated by the Monte Carlo simulation are available in Appendix C.

The Streeter-Phelps analysis was conducted as illustrated in the schematic to the right. Observed data were utilized to set up a Streeter-Phelps analysis to predict stream coefficients that would be required to result in observed DO concentrations. This Streeter-Phelps analysis was based on USEPA's Screening Procedures (Mills et al. 1985). The 5-day biochemical oxygen demand (BOD_5) load and reaeration coefficient (k_a) utilized in the Streeter-Phelps analysis were examined in the TMDL for DO for segment NCD05.



Schematic 2

7.2 Watershed Delineation

Subwatersheds for Bonnie Creek segment NCDC01, Galum Creek segments NCD03 and NCD05, and Little Galum Creek segment NCDB were delineated with GIS analyses through use of the DEM as discussed in Section 5.1.2. The delineation suggests that Bonnie Creek segment NCDC01, Galum Creek segment NCD05, and Little Galum Creek segment NCDB capture flows from watersheds of approximately 19 square miles, 27 square miles, and 19 square miles, respectively. Galum Creek segment NCD03 captures flows from a watershed of approximately 102 square miles, which includes segments NCDC01, NCD05, and NCDB. Figure 7-1 at the end of this section shows the location of the water quality stations in the Bonnie Creek Watershed and the boundary of the GIS-delineated watershed contributing to the impaired segments in the Bonnie Creek Watershed.

7.3 Methodology Development and Results

This section discusses the methodologies utilized to examine manganese, silver, sulfates, TDS, and DO levels in the Bonnie Creek Watershed.

7.3.1 Monte Carlo Analysis Development and Results

For each constituent exceeding water quality standards, the available data was analyzed and an appropriate distribution was chosen to represent the data. A triangle distribution was chosen to analyze segments NCDC01, NCD03, NCD05, and NCDB since data for these sites was extremely limited.

Each constituent was evaluated separately using @RISK, which is a Microsoft® *Excel* add-in for the Monte Carlo analysis. The @RISK analysis package performed 10,000 iterations to determine the required percent reduction such that the water quality criteria would be met at least 99.9 percent of the time. The 99.9 percent of time value matches the Illinois EPA's 303(d) listing criteria of less than once in a three-year allowable excursion of water quality standards. For each simulation, the required percent reduction is:

$$PR = \text{maximum } \{0, (1 - Cc/Cd)\}$$

where: PR = required percent reduction for the current iteration
Cc = water quality criterion in mg/L
Cd = randomly generated pollutant source concentration in mg/L based on the triangular distribution with the observed data's minimum, mode, and maximum values

A triangular distribution assumes that the values of a given data set are most often at or near the mode and linearly distributed to the minimum and maximum values. The minimum is the smallest concentration of the sample data set. The maximum value is the largest sample in the sample data set. The mode is the value that is most likely to be observed in a long time series of sample data. In the case where available water quality data is limited, a triangular distribution was used to describe the observed data. Since the available observed data is not sufficient to truly predict the mode, the mode was assumed to be the mean as shown in Table 5-5.

In order to define a more appropriate distribution than triangular, more data needs to be collected. In the absence of any drift, or non-random error, 10 samples can be used to define a distribution. As the data set increases, so does the ability to define an appropriate distribution, such a lognormal, normal, etc. The number of samples needed to define the true data distribution depends upon the severity of the drift.

An allowable LTA instream concentration was determined for each impaired constituent. The Monte Carlo simulation analysis is designed to identify a LTA value that will meet the water quality criterion for that parameter 99.9 percent of the time. The Monte Carlo simulation was run using 10,000 iterations with the triangular distribution. For each iteration, a concentration, Cd, is randomly generated according to a specified distribution determined by observed data. For each concentration generated, a percent reduction was calculated, if necessary, to meet water quality criteria. The mean concentration value is multiplied by the inverse of the required percent reduction to compute the long-term daily average concentration that needs to be met to achieve the water quality standard.

The overall percent reduction required is the 99.9th percentile value of the probability distribution generated by the 10,000 iterations, so that the allowable LTA concentration is:

$$\mathbf{LTA = Mean * (1 - PR99.9)}$$

7.3.1.1 Monte Carlo Results for Bonnie Creek Segment NCDC01

Segment NCDC01 is located in Bonnie Creek upstream of the confluence with Galum Creek. Sample data for this section was very limited. Sulfates values ranged from 124 to 616 mg/L as shown in Table 5-5. As discussed previously, a triangular distribution was chosen for the reason that only two samples were available for sulfates.

Two of the output model concentrations are significant to the TMDL analysis of segment NCDC01. The first is the average concentration calculated from the triangular distribution of the observed data. The second concentration is the LTA, which represents the average concentration that should be observed over the long term to ensure that the water quality standard is exceeded fewer than once every three years. Table 7-1 shows the average concentration calculated from the distribution utilized in the Monte Carlo analysis and the LTA concentration needed so that water quality standards will be achieved in Bonnie Creek segment NCDC01. Calculation details are presented in Appendix C.

Table 7-1 LTA Concentration Determined through Analysis to Meet Water Quality Standards in Bonnie Creek Segment NCDC01

Constituent	Average Concentration Calculated from Distribution (mg/L)	LTA Concentration (mg/L)
Sulfates	370	307

Table 7-1 shows that the concentration determined through analysis to meet water quality reductions, the LTA, is lower than the observed average concentration for sulfates; therefore, the TMDL for Bonnie Creek segment NCDC01 requires that a load reduction be made for sulfates based upon the available data. The TMDL will be discussed in Section 8.

7.3.1.2 Monte Carlo Results for Galum Creek Segment NCD03

Segment NCD03 is the lower section of Galum Creek in the Bonnie Creek Watershed starting at the confluence of Galum Creek and Little Galum Creek. Sample data for this section was very limited. Sulfates values ranged from 1,300 to 1,580 mg/L and TDS values ranged from 2,170 to 2,740 mg/L as shown in Table 5-5. A triangular distribution was chosen for the reason that only two samples were available for both sulfates and TDS.

Two of the output model concentrations are significant to the TMDL analysis of segment NCD03. The first is the average concentration calculated from the triangular distribution of the observed data. The second concentration is the LTA, which represents the average concentration that should be observed over the long term to ensure that the water quality standard is exceeded fewer than once every three years. Table 7-2 shows the average concentration calculated from the distribution utilized in the Monte Carlo analysis and the LTA concentration needed so that water quality standards will be achieved in Galum Creek segment NCD03. Calculation details are presented in Appendix C.

Table 7-2 LTA Concentrations Determined through Analysis to Meet Water Quality Standards in Galum Creek Segment NCD03

Constituent	Average Concentration Calculated from Distribution (mg/L)	LTA Concentration (mg/L)
Silver	0.006	0.002
Sulfates	1,440	457
TDS	2,456	900

Table 7-2 shows that the concentration determined through analysis to meet water quality reductions, the LTA, is lower than the observed average concentration for silver, sulfates, and TDS; therefore, the TMDL for Galum Creek segment NCD03 requires that a load reduction be made for silver, sulfates, and TDS based upon the available data. The TMDL will be discussed in Section 8.

7.3.1.3 Monte Carlo Results for Galum Creek Segment NCD05

Segment NCD05 is the upper section of Galum Creek in the Bonnie Creek Watershed starting at headwaters and continuing until the confluence of Galum Creek and Bonnie Creek. Sample data for this section were very limited. Manganese values ranged from 0.3 to 1.5 mg/L shown in Table 5-5. A triangular distribution was chosen for the reason that only two samples were available for manganese.

Two of the output model concentrations are significant to the TMDL analysis of segment NCD05. The first is the average concentration calculated from the triangular distribution of the observed data. The second concentration is the LTA, which represents the average concentration that should be observed over the long term to ensure that the water quality standard is exceeded fewer than once every three years. Table 7-3 shows the average concentration calculated from the distribution utilized in the Monte Carlo analysis and the LTA concentration needed so that water quality standards will be achieved in Galum Creek segment NCD05. Calculation details are presented in Appendix C.

Table 7-3 LTA Concentrations Determined through Analysis to Meet Water Quality Standards in Galum Creek Segment NCD05

Constituent	Average Concentration Calculated from Distribution (mg/L)	LTA Concentration (mg/L)
Manganese	0.9	0.6

Table 7-3 shows that the concentration determined through analysis to meet water quality reductions, the LTA, is lower than the observed average concentration for manganese; therefore, the TMDL for Galum Creek segment NCD05 requires that a load reduction be made for manganese based upon the available data. The TMDL will be discussed in Section 8.

7.3.1.4 Monte Carlo Results for Little Galum Creek Segment NCDB

Segment NCDB is the Little Galum Creek of the Bonnie Creek Watershed starting at the headwaters and ending at the confluence with Galum Creek. Sample data for this section were very limited. Manganese values ranged from 0.2 to 3.8 mg/L, sulfates values ranged from 390 to 952 mg/L, and TDS values ranged from 1,020 to 1,180 mg/L as shown in Table 5-5. A triangular distribution was chosen for the reason that only two samples were available for sulfates, TDS, and manganese.

Two of the output model concentrations are significant to the TMDL analysis of segment NCDB. The first is the average concentration calculated from the triangular distribution of the observed data. The second concentration is the LTA, which represents the average concentration that should be observed over the long term to ensure that the water quality standard is exceeded fewer than once every three years. Table 7-4 shows the average concentration calculated from the distribution utilized in the Monte Carlo analysis and the LTA concentration needed so that water quality standards will be achieved in Little Galum Creek segment NCDB. Calculation details are presented in Appendix C.

Table 7-4 LTA Concentrations Determined through Analysis to Meet Water Quality Standards in Little Galum Segment NCDB

Constituent	Average Concentration Calculated from Distribution (mg/L)	LTA Concentration (mg/L)
Manganese	2.0	0.5
Sulfates	672	360
TDS	1,099	935

Table 7-4 shows that the concentration determined through analysis to meet water quality reductions, the LTA, is lower than the observed average concentration for manganese, sulfates, and TDS; therefore, the TMDL for Little Galum Creek segment NCDB requires that a load reduction be made for manganese, sulfates, and TDS based upon the available data. The TMDL will be discussed in Section 8.

7.3.1.5 Loading Analysis from Permitted Mines

Because the analyses presented in the previous sections focus on total load reduction needed and does not focus on the sources of the load (point or nonpoint), a loading analysis based on available discharge mine data was completed. The goal of the analyses was to determine whether permitted discharges from mining activity could be causing water body impairments, and if so what appropriate reductions would be needed to be incorporated in the mine permits.

To assess the relative loading from the mines in relation to loading in the stream, the average loading in stream versus loading from the mine was estimated. Results for Galum Creek Segment NCD05 are shown in Table 7-5. Results for NCDB and NCDC01 are not shown as no permitted mine discharges to these segments. The concentration of manganese in the effluent was not reported for IL0052795, however iron was used as an acceptable surrogate constituent for calculation purpose. Table 7-5 shows that percent of manganese loading from the mine is likely insignificant in comparison to nonpoint sources or background loads of manganese

Table 7-5 Comparison of Loadings for Stream vs Permitted Mine for Manganese

Mine	Average River Flow (cfs)	Average River Concentration (mg/L)	Average River Manganese Load (lb/day)	Average Mine Flow (cfs)	Average Mine Concentration (mg/L)	Average Mine Manganese Load (lb/day)	Percent of Manganese Load from Mine (%)
IL0052795	28	0.9	136	1	0.6	3	2

Results for Galum Creek Segment NCD03 are shown in Table 7-6. Galum Creek is listed for sulfate, silver, and TDS. The discharge monitoring data for each of the mines discharging to this segment report discharge for sulfates, but not silver or TDS. None of the data reported by the DMRs provided an acceptable surrogate for silver or TDS; therefore, the analysis only estimated the target effluent concentration for sulfate, and similar results are assumed to apply to silver and TDS. Similar to Galum Creek NCD05, the mine effluent comprises a small portion of the total load. Therefore, it is not recommended that mine point sources reduce concentrations of manganese, sulfates, TDS, and silver in their discharges.

Table 7-6 Comparison of Loadings for Stream vs Permitted Mine for Sulfates

Mine	Average River Flow (cfs)	Average River Concentration (mg/L)	Average River Sulfates Load (lb/day)	Average Mine Flow (cfs)	Average Mine Concentration (mg/L)	Average Mine Sulfates Load (lb/day)	Percent of Sulfates Load from Mine (%)
IL00033723	105	**1440**	815000	1	**1614**	5600	1
IL00064718	105	1440	815000	0.3	107	173	0.02
IL00066559	105	1440	815000	0.2	440	474	0.1

7.3.2 DO Analysis Development and Results

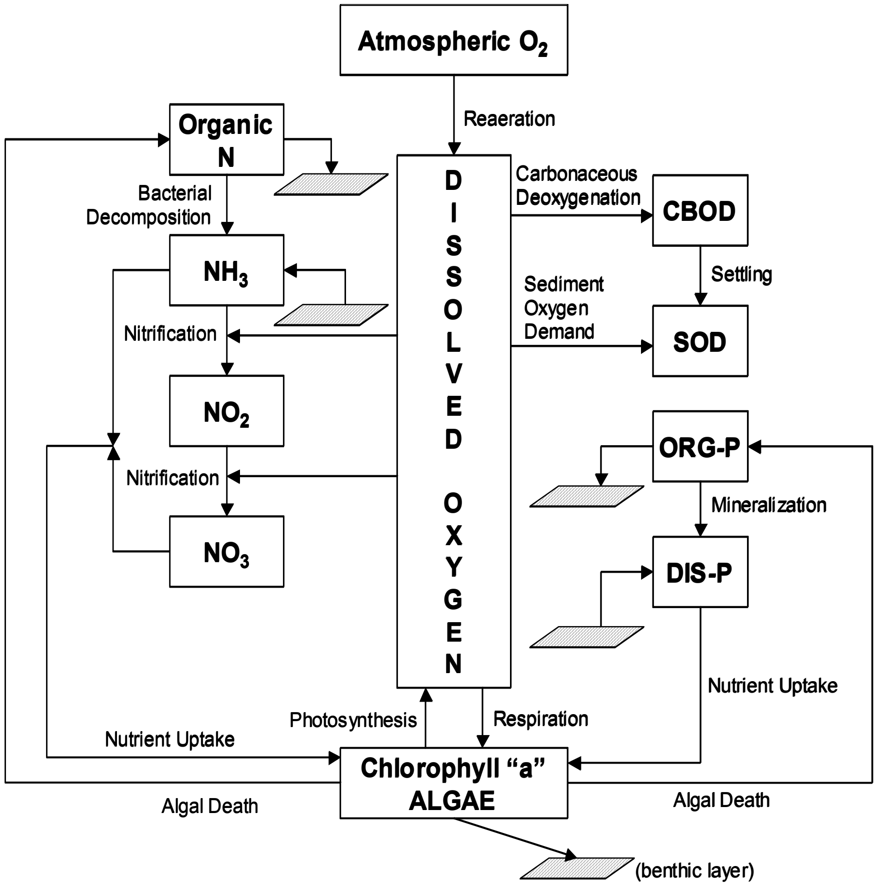
A Streeter-Phelps analysis was utilized for investigation of DO in the Bonnie Creek Watershed. Data availability useful for analyzing DO for this watershed is described in Table 7-7. The historic water quality data were investigated from 1990 to 2000.

Table 7-7 Data Availability from 1990 to 2000

Model Parameter	Historic Data Available (Yes/No)
Flow	Yes
Stream Temperature	Yes
DO	Yes
Carbonaceous BOD_5	No
BOD_5	No
Total Nitrogen	Yes
Total Organic Carbon	No
Ammonia	Yes
Nitrate + Nitrite	Yes
Total Kjeldahl Nitrogen	Yes
Total Phosphorus	Yes
Dissolved Phosphorus	Yes
Orthophosphate	No
pH	Yes
20-Day Carbonaceous Biochemical Oxygen Demand ($CBOD_{20}$)	No
Daily Minimum and Maximum DO	No
Chlorophyll "a" / algae	No
Stream Depth	Yes

The lack of various constituent samples from historic data sites in the Bonnie Creek Watershed limits the modeling tools available for DO. Therefore, a Streeter-Phelps analysis was developed to examine the DO relationship with BOD_5 in Galum Creek segment NCD05. The diagram below shows the interactions of DO with different processes within the water column of the stream (USEPA 1997b). The consumers of DO include:

- deoxygenation of biodegradable organics whereby bacteria and fungi (decomposers) utilize oxygen in the bioxidation-decomposition process
- sediment oxygen demand (SOD), where oxygen is utilized by organisms inhabiting the upper layers of the bottom sediment deposits
- nitrification, in which oxygen is utilized during oxidation of ammonia and organic nitrogen to nitrates
- respiration by algae and aquatic vascular plants that use oxygen during night and early morning hours to sustain their living processes

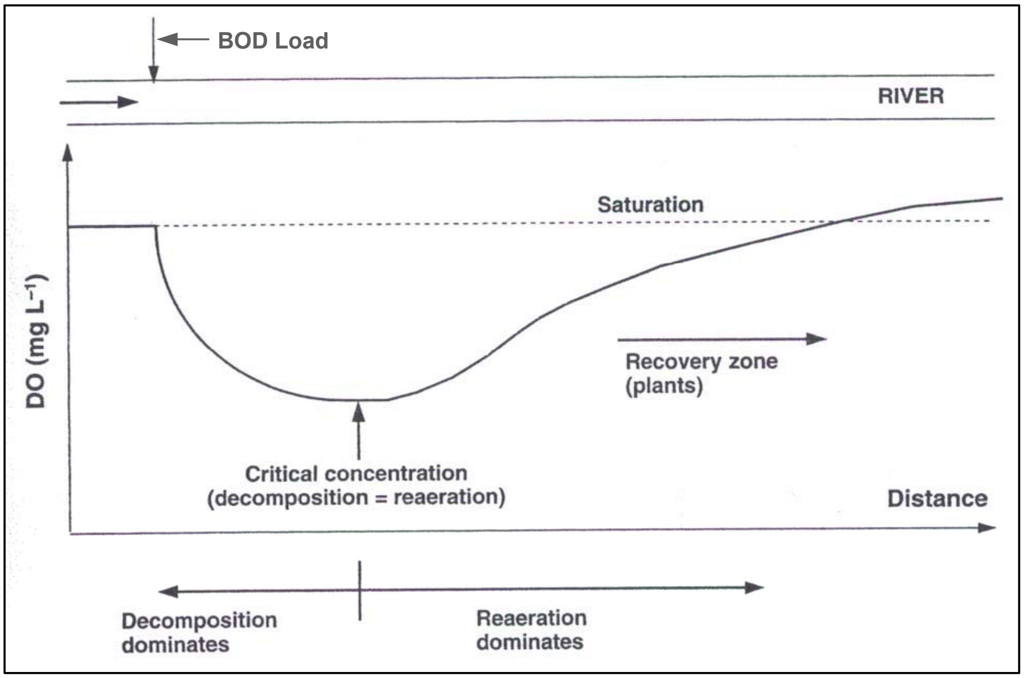


Major oxygen sources are:

- atmospheric reaeration, where oxygen is transported from the air into the water through turbulence at the air-water interface
- photosynthesis, where chlorophyll-containing organisms (producers such as algae and aquatic plants) convert carbon dioxide to organic matter with a consequent production of oxygen

Streeter and Phelps (1925) proposed the basic concept of the DO balance in streams. The Streeter-Phelps equation predicts the DO "sag" that occurs after biodegradable constituents are discharged into streams. A biodegradable constituent is anything that can be broken down by microorganisms. BOD is the measure of the quantity of oxygen consumed by microorganisms during the decomposition of organic matter. When nutrients such as nitrate and phosphate are released into the water, growth of algae and aquatic plants is stimulated. The result is an increase in microbial populations, higher levels of BOD, and increased oxygen demand from the photosynthetic organisms during the dark hours. This results in a reduction in DO concentrations, especially during the early morning hours just before dawn.

In addition to natural sources of BOD, such as leaf fall from vegetation near the water's edge and aquatic plants, there are also anthropogenic (human) sources of organic matter. Point sources, which may contribute high levels of BOD, include wastewater treatment facilities, pulp and paper mills, and meat and food processing plants. Organic matter also comes from nonpoint sources such as agricultural runoff, urban runoff, and livestock operations. Both point and nonpoint sources can contribute significantly to the oxygen demand in a water body. The DO sag is shown in the following figure (Chapra 1997):



Water quality models have built upon the Streeter-Phelps equation to evaluate the DO balance in streams. The analysis for Galum Creek segment NCD05 is based on BOD_5 and reaeration only. There is not enough coincident nutrient and algal historical data from this site to assess impacts of nutrient loads on algal growth that also impact DO levels. Free floating and attached algae as well as aquatic plants are of concern. The extent to which algae impact the DO resources of a river is dependent on many factors, such as turbidity, which can decrease light transmittance through the water column. Additionally, the photosynthetic rate constantly changes in response to variations in sunlight intensity and is not constant. This results in diurnal fluctuations in DO levels (Mills et al. 1985). In addition, there is not enough data available to estimate the impacts of SOD at these sites.

The Streeter-Phelps analysis was based on the following equation (Mills et al. 1985):

$$\mathbf{D} = \mathbf{D_o}\mathbf{exp}\left[\frac{-\mathbf{k_a\,x}}{\mathbf{v}}\right] + \frac{\mathbf{L_0 k_d}}{\mathbf{k_a - k_d}}\left[\mathbf{exp}\left(\frac{-\mathbf{k_d\,x}}{\mathbf{v}}\right) - \mathbf{exp}\left(\frac{-\mathbf{k_d\,x}}{\mathbf{v}}\right)\right]$$

where: DO_o = Calculated DO concentration(mg/L)
D_S = DO at saturation (mg/L)
D_o = Initial DO deficit (mg/L)
k_a = Reaeration rate (1/day)
k_d = BOD_5 decay rate (1/day)
x = Distance downstream of discharge (ft)
v = Stream velocity (ft/day)
L_0 = Initial BOD_5 (mg/L) at x = 0

The initial BOD_5 concentration (L_o) was calculated from observed TOC data. Literature states that the ratio of BOD_5 to TOC is typically between 1.0 and 1.6 (Metcalf and Eddy, Inc. 1991). For analysis, a ratio of 1.3 was used to calculate BOD_5 for each sample date.

Literature provides equations to calculate both the BOD_5 decay rate coefficient (k_d) and reaeration rate coefficient (k_a). The decay rate coefficient is dependent on stream depth, and the reaeration coefficient is dependent on depth and velocity. Due to the limits of the data set shown in Table 7-7, the decay rate coefficient was calculated from either known depths or rating curves allowing the reaeration coefficient to be calculated from the Streeter-Phelps equation presented above as the only unknown variable. The rating curves used to determine depths are available in Appendix D.

The BOD_5 decay rate coefficient (k_d)at 20°C was calculated based on the following equation (USEPA 1997b):

$$\mathbf{k_d = 0.3\left[\frac{H}{8}\right]^{-0.434} \text{ for } 0 < H < 8}$$
$$\mathbf{= 0.3 \text{ for } H > 8}$$

The BOD_5 decay rate coefficient was corrected for temperature with the following equation (Novotny and Olem 1994):

$$\mathbf{k_{dT} = k_{d20}\theta^{(T-20)}}$$

where k_{dT} = BOD_5 decay rate coefficient at temperature T; T in °C
θ = Thermal factor

The thermal factor (θ) in the above equation has an accepted value of 1.047 for the BOD_5 decay rate coefficient (Novotny and Olem 1994). The decay rate coefficient typically falls between 0.02 and 3.4 day^{-1}. The reaeration rate coefficient typically ranges between 0 and 100 day^{-1} (USEPA 1997b). For comparison purposes, the reaeration coefficient (k_a) was calculated based on the following equation (USEPA 1997b):

$$\mathbf{k_a = \frac{12.9\ v^{0.5}}{H^{1.5}} \text{ at } 20^\circ C}$$

where v = Stream velocity (feet/s)
H = Stream depth (feet)

Like the BOD_5 decay rate coefficient, the reaeration coefficient is corrected for temperature with the following equation (Novotny and Olem 1994):

$$\mathbf{k_{aT}} = \mathbf{k_{a20}} \boldsymbol{\theta}^{(T-20)}$$

where k_{dT} = Reaeration rate coefficient at temperature T; T in °C
θ = Thermal factor

The thermal factor (θ) for the reaeration coefficient has an accepted value of 1.025 (Novotny and Olem 1994).

Since no point sources were identified as contributing significantly to either segment, it was assumed that the BOD_5 load from all nonpoint sources is evenly distributed throughout each segment as shown in the following figure:

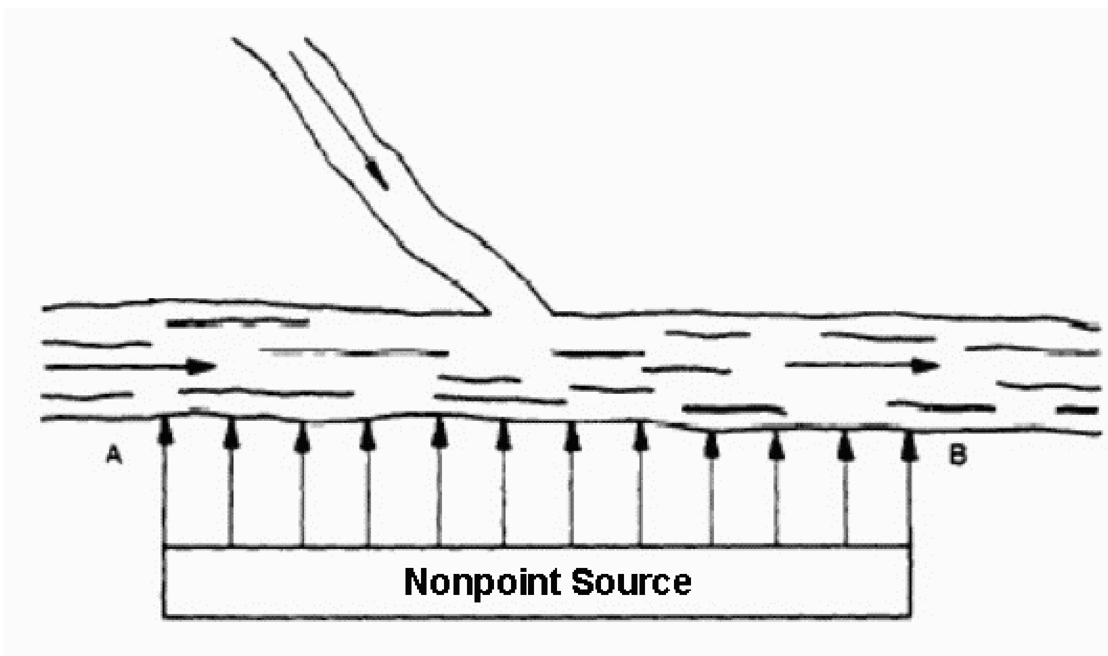


Table 7-8 shows the observed TOC data and the BOD_5 concentrations (L_0) calculated from observed TOC data. BOD loads were not calculated for March 4, 1996 because the observed DO was above saturation. Table 7-8 also shows the k_a and k_d coefficients calculated with the above equations. In addition, the estimated BOD_5 load was calculated based on the calculated BOD_5 concentration and average daily flow on the day the sample was taken. Revised k_a and k_d values are also shown in Table 7-8. These values were utilized in the Streeter-Phelps equation described above, and the resulting calculated DO was compared to observed DO readings. If there was not a match between the calculated DO and observed DO, k_a and k_d were revised within their accepted ranges so that calculated DO more closely matched observed DO. If possible, only k_a was revised as it was calculated based on estimated depth and flow, while k_d was based on estimated depth. Table 7-8 also includes precipitation values near or on the sampling date, so that estimates of pollutant loads from runoff can be compared to loads estimated based on the BOD_5/TOC ratio. Analysis details are contained in Appendix E. An error analysis was run on the literature ranges of values for k_a and k_d for each sample date to validate their use for the Streeter-Phelps analysis. This analysis is contained in Appendix F.

Table 7-8 Streeter-Phelps Calculated BOD_5 Concentrations (L_0) and Loads Associated with DO Concentrations

Sample Location and Date	NCD05 8/2/95	NCD05 3/4/96
Measured DO (mg/L)	2.9	11.1
Measured TOC (mg/L)	14.8	7.1
Calculated BOD_5 Concentration (mg/L)	19.2	9.2
Calculated BOD_5 Load (lb/day)	670	—
Calculated k_a (1/day)	23.1	—
Revised k_a (1/day)	5.9	—
Calculated k_d (1/day)	1.2	—
Revised k_d (1/day)	1.2	—
Precipitation (in)	0.1 – 0.8	0.32
Dates Precipitation Occurred	10 to 13 days before sample date	7 days before sample date
Flow (cfs)	6.5	0.5

As discussed in Section 6.2.1.1, the WMM model was run as a screening tool to assess the BOD_5 loads that are typically generated annually for the watershed. The major inputs to the model are land use, precipitation, and event mean concentration (EMC). Land use for the watershed was presented in Table 5-9. The average monthly and annual precipitation for Perry County was presented in Table 5-2. The EMCs used for each land use type are shown in Table 7-9.

Table 7-9 EMC by Land Use Type for Segment NCD05 Watershed

Land Use	Area (acres)	Percent of Total	BOD EMC (mg/L)	Source
Row Crop	8,942	41	8.0	2
Rural Grassland	7,324	34	2.0	1
Small Grains	2,369	11	8.0	2
Deciduous	2,086	10	2.0	1
Forested Wetland	456	2	0.0	1
Open Water	205	1	0.0	1
Shallow Water/Wetlands	197	1	0.0	1
Medium Density	58	0	14.1	1
Deep Marsh	40	0	0.0	1
Shallow Marsh/Wetlands	25	0	0.0	1
Urban Grassland	7	0	2.0	1
High Density	5	0	14.1	1
Barren Land	1	0	2.0	1

1 Smullen 1999
2 Denison and Tilton 1998

Results of the WMM screening are shown in Table 7-10. The results are for the watershed contributing to segment NCD05. Results shown are an estimate of annual loads and loads from the precipitation events provided in Table 7-8. The loads estimated from WMM generated based on precipitation events near the sampling events are all greater than those shown in Table 7-8. The WMM model files are contained in Appendix G. This analysis indicates that loading from runoff events is not the sole source of DO impairments. Other factors that could contribute to low DO levels include stagnant flow conditions occurring during low flows, elevated stream temperatures during summer months, and nutrient loads from nonpoint sources in the watershed. The implementation plan in Section 9 will address other factors that could also cause decreased DO levels in the Bonnie Creek Watershed.

Table 7-10 Results of WMM Screening Analysis for the Segment NCD05 Watershed

Event	Total BOD_5 Load (lb/event)	Precipitation (inches)
Annual	521,942	44.7
8/2/1995	1,168	0.1
8/2/1995	4,671	0.4
8/2/1995	9,341	0.8
3/4/1996	3,736	0.32

The estimated BOD_5 loads in Table 7-8 are low in comparison to the WMM loads predicted suggesting that they represent loadings occurring during ambient conditions. Therefore, it is likely that further reductions in BOD concentrations could be achieved. The WMM results represent loadings from precipitation events shown in Table 7-10 that occurred before the sample date. On the impaired date shown in Table 7-8, the precipitation occurred between 10 and 13 days prior to the sampling date, and it is likely that the loads from the event passed through the stream system before the sample was taken. As discussed in Section 5.1.5.1.2, although the flow on the impaired sample date (August 2, 1995) was above average, the flow is considered a slow-moving flow suggesting that slow flows may be the cause of DO impairments. In slow-moving flows, conditions in a stream can become stagnant (lack of aeration) where water pools in slow-moving sections of the stream. The streams in this watershed have very low gradient, and when low flows occur, pools can form which have extremely low velocity. Therefore, the TMDL described in Section 8 and the implementation plan outlined in Section 9 will focus on increases in reaeration needed to meet the TMDL endpoint of 6.0 mg/L DO (16 hours of any 24-hour period). The implementation plan in Section 9 will also address methods to reduce the BOD_5 loading to the stream and other factors that could also cause decreased DO levels in the segment NCD05 subwatershed, such as elevated stream temperatures during summer months and nutrient loads from nonpoint sources in the watershed.

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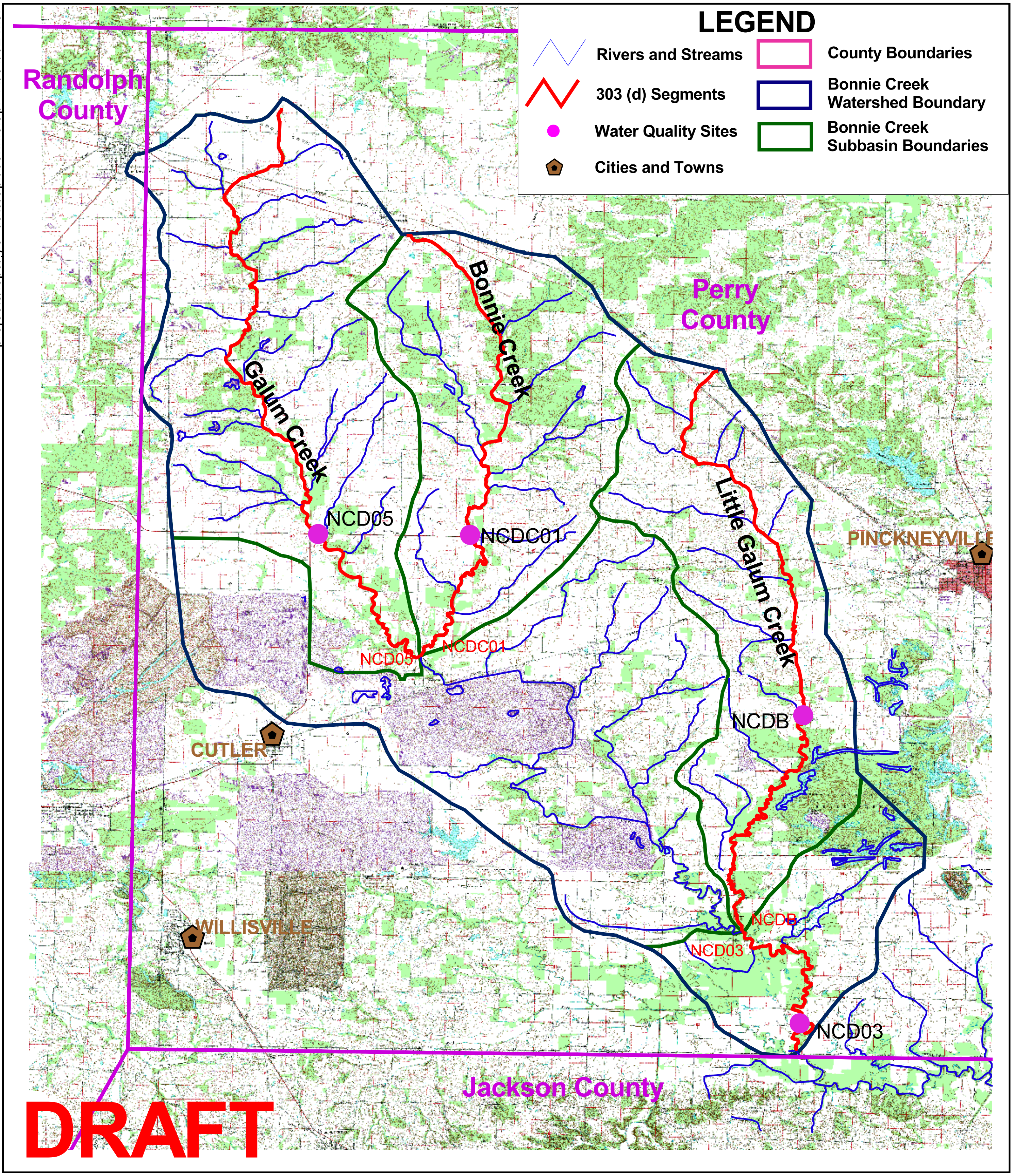

Figure 7-1
Bonnie Creek Watershed and Historic Sampling Locations

CDM

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Section 8
Total Maximum Daily Load for the Bonnie Creek Watershed

8.1 TMDL Endpoints

The TMDL endpoints for manganese, silver, sulfates, TDS, and DO in a stream segment are summarized in Table 8-1. For manganese, silver, sulfates, and TDS, the desired concentration must be below the TMDL endpoint. For DO, concentrations must be greater than 6.0 mg/L for 16 hours of any 24-hour period. These endpoints are based on protection of aquatic life in Bonnie Creek, Little Galum Creek, Galum Creek, and their tributaries. Some of the average concentrations in Table 8-1, which are based on a limited data set, meet the desired endpoints. However, for those constituents, the data set has maximum or minimum values, presented in Sections 5.1.5.1.1 and 5.1.5.1.2, that do not meet the desired endpoints, and this was the basis for TMDL analysis. Further monitoring, as outlined in the monitoring plan presented in Section 9, will help further define when impairments are occurring in the watershed and support the TMDL allocations outlined in the remainder of this section.

Table 8-1 TMDL Endpoints and Average Observed Concentrations for Impaired Constituents in the Bonnie Creek Watershed

Constituent	TMDL Endpoint (mg/L)	Average Observed Concentration for NCDC01 (mg/L)	Average Observed Concentration for NCD03 (mg/L)	Average Observed Concentration for NCD05 (mg/L)	Average Observed Concentration for NCDB (mg/L)
Manganese	1.0	–	–	0.9	2.0
Silver	0.005	–	0.0055	–	–
Sulfates	500	370	1,440	–	671
TDS	1,000	–	2,455	–	1,100
DO	6.0 (16 hours of any 24-hour period)	–	–	9.5	–

8.2 Pollutant Source and Linkages

Pollutant sources for the Bonnie Creek Watershed were identified through the existing data review described in Section 5. Based on the data review, the source of manganese, sulfates, and TDS in the impaired Bonnie Creek, Galum Creek, and Little Galum Creek segments is groundwater potentially contaminated by abandoned coal mines. The source of silver is unknown, but could potentially be from runoff from non-coal mines that are not listed in the dataset. The likely source of oxygen demanding constituents is primarily factors occurring during low flow conditions, such as stagnant flows and increased water temperatures promoting algal growth. Nonpoint source loads in the watershed may also contribute to low DO in the stream.

8.3 Allocation

As explained in Section 1, the TMDL for Bonnie Creek, Little Galum Creek, and Galum Creek segments will address the following equation:

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

where:
- LC = Maximum amount of pollutant loading a water body can receive without violating water quality standards
- WLA = The portion of the TMDL allocated to existing or future point sources
- LA = Portion of the TMDL allocated to existing or future nonpoint sources and natural background
- MOS = An accounting of uncertainty about the relationship between pollutant loads and receiving water quality

Each of these elements will be discussed in this section as well as consideration of seasonal variation in the TMDL calculation.

8.3.1 Manganese, Silver, Sulfates, and TDS TMDL

8.3.1.1 Loading Capacity

The loading capacity for manganese, silver, sulfates, and TDS for impaired segments NCDC01, NCD03, NCD05, and NCDB was based on the Monte Carlo analysis described in Section 7. The LTA, determined by analysis to meet water quality standards generated from the Monte Carlo analysis, is the basis for loading capacity for Bonnie Creek, Little Galum Creek, and Galum Creek. This LTA was multiplied by average flow in each segment to determine an average load. These average loads are shown in Table 8-2.

Table 8-2 Average Loads Based on LTA for Manganese, Silver, Sulfates, and TDS

	NCDC01		NCD03		NCD05		NCDB	
Constituent	LTA Concentration (mg/L)	Allowable Load (lb/day)	LTA Concentration (mg/L)	Allowable Load (lb/day)	LTA Concentration (mg/L)	Allowable Load (lb/day)	LTA Concentration (mg/L)	Allowable Load (lb/day)
Manganese	–	–	–	–	0.6	91	0.5	52
Silver	–	–	0.002	1.13	–	–	–	–
Sulfates	307	32,026	457	257,557	–	–	360	37,675
TDS	–	–	900	506,942	–	–	935	97,826

8.3.1.2 Seasonal Variation

A season is represented by changes in weather; for example, a season can be classified as warm or cold as well as wet or dry. Seasonal variation is represented in the Bonnie Creek TMDL as conditions were investigated during all seasons of the year. Section

5.1.3 discusses the flow data available for the Beaucoup Creek watershed, and Section 5.1.5 and Appendix A contain the water quality data available for manganese, silver, sulfates, and TDS. A review of the flow data (Figure 5-3) shows seasonal variations. Since the various pollutant sources are expected to contribute loadings in different quantities during different time periods (e.g., spring run-off loads), the loadings for this TMDL will focus on a LTA loading rather than specifying different loadings by season. As more data is gathered, further refinement of the seasonal variation may be possible.

8.3.1.3 Margin of Safety

The MOS can be implicit (incorporated into the TMDL analysis through conservative assumptions) or explicit (expressed in the TMDL as a portion of the loadings) or a combination of both. An explicit MOS of 10 percent is recommended for manganese, silver, sulfates, and TDS in the Bonnie Creek Watershed because of the limited data set available for analysis and because Monte Carlo analysis incorporates uncertainty to some degree into the LTA.

Uncertainty in water quality is accounted for in the Monte Carlo analysis based upon how the analysis is done. The distribution of the water quality data is estimated and numerous iterations are run to determine the reduction needed to meet the target of one exceedence in three years. A data set with significant variation will result in a final target (LTA) that is significantly lower than the water quality standard, as compared to a data set with little variation that would likely result in a LTA being slightly lower than the water quality standard. By this process, uncertainty in the data is addressed. For these reasons, an explicit 10 percent MOS is considered appropriate based upon the data available. As more data become available such as a regression analysis between flow and in-stream concentrations, the MOS could be revisited and revised if appropriate.

8.3.1.4 Waste Load Allocation

Mine effluent from three permitted mines (IL033723, IL0066559, and IL0067418) is discharged into Galum Creek segment NCD03 and from one permitted mine (IL0052795) into Galum Creek segment NCD05. However, the loads from the mines are negligible in comparison to loading in the river from nonpoint sources or background loads. Hence, no WLA is recommended at this time.

8.3.1.5 Load Allocation and Summary TMDLs

Table 8-3 shows a summary of the TMDL for manganese, silver, sulfates, and TDS in the Bonnie Creek Watershed. The calculated allowable loads (LC) necessary to maintain the water quality standard are reduced by the MOS, representing the uncertainty in the data analysis, to determine the allowable loading from the watershed, the LA. The LC was calculated from the LTA presented in Section 7.3.1.

Table 8-3 TMDL Summary for Manganese, Silver, Sulfates, and TDS in the Bonnie Creek Watershed

Segment and Constituent	LC (lb/day)	WLA (lb/day)	LA (lb/day)	MOS (lb/day)	Reduction Needed (lb/day)	Reduction Needed (percent)
NCDC01 - sulfates	32,026	0	28,823	3,203	9,782	25%
NCD03 - silver	1.13	0	1.0	0.1	2.4	70%
NCD03 - sulfates	257,557	0	231,801	25,756	579,701	71%
NCD03 - TDS	506,942	0	456,248	50,694	928,079	67%
NCD05 - manganese	91	0	82	9	54	40%
NCDB - manganese	52	0	47	5.2	163	78%
NCDB - sulfates	37,675	0	33,908	3,768	36,471	52%
NCDB - TDS	97,826	0	88,043	9,783	27,035	23%

The calculated LTAs presented in Section 7 and in Table 8-2 were reduced because of the applied MOS and are presented in Table 8-4. The recalculated LTA represents the LA in Table 8-3. Methods to meet these LTAs will be outlined in Section 9.

Table 8-4 LTAs Adjusted by TMDL MOS

Segment and Constituent	Monte Carlo LTA (mg/L)	Recalculated LTA (mg/L)
NCDC01 - sulfates	307	276
NCD03 - silver	0.002	0.0018
NCD03 - sulfates	457	411
NCD03 - TDS	900	810
NCD05 - manganese	0.6	0.5
NCDB - manganese	0.5	0.45
NCDB - sulfates	360	324
NCDB - TDS	935	841

8.3.2 DO TMDL

As discussed in Section 7.3.2, the BOD_5 loads in segment NCD05 likely represents background loadings, which suggests that the principle cause of DO impairments in these segments is a lack of aeration caused by slow-moving flows and stagnant pools. Table 8-5 shows the aeration coefficient calculated from the observed DO in Section 7.3.2 for the sample date that did not meet the TMDL endpoint, and the coefficient that would be required to meet the TMDL endpoint of 6.0 mg/L DO (16 hours of any 24-hour period) for sampling event that had a DO measurement less than 6.0 mg/L. Increasing aeration in the stream is not a parameter for which a TMDL can be developed. Therefore, no TMDL will be developed at this time. Methods to achieve elevated reaeration coefficients will be outlined in Section 9.

Table 8-5 Calculated Reaeration Coefficients and Required Reaeration Coefficients in the Segment NCD05 Subwatershed Based on TMDL Endpoint for DO

Segment	Date	Measured DO Concentration (mg/L)	Modeled k_a (1/day)	Required k_a (1/day)
NCD05	8/2/95	4.1	5.9	16.7

Based on the data analysis, increases of aeration would be required in summer months but not during winter conditions. Monitoring data to make the analysis more robust will be discussed in Section 9, as well as management measures to increase aeration and reduce nonpoint source loads contributing to non-attainment of the DO water quality standard.

To confirm that reductions in BOD_5 loads to meet the water quality standard are not an appropriate measure for controlling DO in this watershed, the Streeter-Phelps equations, presented in Section 7.3.2, were used to estimate the BOD_5 loading required to meet the water quality standard on each sample date impaired for DO. Table 8-6 shows the BOD_5 loads estimated from TOC as discussed in Section 7.3.2 and the BOD_5 loading that would be necessary to meet water quality standards.

Table 8-6 Calculated BOD_5 Loads and Required BOD_5 Loads in the Segment NCD05 Subwatershed Based on TMDL Endpoint for DO

Segment	Date	Measured DO Concentration (mg/L)	Calculated BOD_5 (lb/d)	Required BOD_5 (lb/d)
NCD05	8/2/95	4.1	670	0

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Section 9
Implementation Plan for Bonnie Creek Watershed

9.1 Implementation Actions and Management Measures for Manganese, Silver, Sulfates, and TDS

An adaptive management or phased approach is recommended for the TMDL for this watershed because of the limited amount of data available for the TMDL analysis of Bonnie Creek Watershed. Adaptive management is a systematic process for continually improving management policies and practices through learning from the outcomes of operational programs. Some of the differentiating characteristics of adaptive management are:

1. acknowledgement of uncertainty about what policy or practice is "best" for the particular management issue;

2. thoughtful selection of the policies or practices to be applied (the assessment and design stages of the cycle);

3. careful implementation of a plan of action designed to reveal the critical knowledge that is currently lacking;

4. monitoring of key response indicators;

5. analysis of the management outcomes in consideration of the original objectives, and incorporation of the results into future decisions (British Columbia Ministry of Forests 2000).

Based on existing data review, presented in Section 5, the likely sources of manganese, sulfates, silver, and TDS in the Bonnie Creek Watershed are from active and abandoned mining activity. Further source identification is required as outlined in the next section.

9.1.1 Source Identification for Manganese, Silver, Sulfates, and TDS

It is recommended that further source identification activities take place within the watershed because the current data regarding sources of manganese, silver, sulfates, and TDS in Bonnie Creek Watershed is limited. The TMDL analysis for each impaired segment in the Bonnie Creek Watershed was conducted on two data points taken after 1990 for each impaired constituent. Five of the eight TMDL analyses for manganese, sulfates, silver, and TDS were based on sample data containing one sample violating the water quality standard and one sample in compliance. A longer period of record with an increased sampling frequency would enhance understanding of impairments in the watershed. The GIS data and mapping provided in Section 5 (Figure 5-4) should be the basis for the start of the source investigation. Collection of data during various flow conditions may also be beneficial in determining the source of these constituents. Once potential sources are identified and located, sampling stations should be placed in appropriate locations to assess water quality downstream of these sources. The potential source identification and station sampling placement should be the result of field investigations.

The difficulty of using GIS to delineate watersheds through areas with surface mining was discussed in Section 5.1.2. Although the watershed delineation through mined areas may not be exact, the implementation actions and management measures remain applicable to the entire Bonnie Creek Watershed.

9.1.2 Manganese, Silver, Sulfates, and TDS Management Measures

For the active mine sites, current NPDES permits were examined to confirm current effluent limitations are being met and that effluent limits are appropriate. Mine effluent limitations are provided in Part 406 of the Illinois Administrative Code. Section 406.202 states:

> In addition to the other requirements of this Part, no mine discharge or non-point source mine discharge shall, alone or in combination with other sources, cause a violation of any water quality standards of 35 Ill. Adm. Code 302 or 303. When the Agency finds that a discharge which would comply with effluent standards contained in this Part would cause or is causing a violation of water quality standards, the Agency shall take appropriate action under Section 31 or 39 of the Environmental Protection Act to require the discharge to meet whatever effluent limits are necessary to ensure compliance with the water quality standards. When such a violation is caused by the cumulative effect of more than one source, several sources may be joined in an enforcement or variance proceeding and measures for necessary effluent reductions will be determined on the basis of technical feasibility, economic reasonableness and fairness to all discharges (1999b).

It is likely that the main contributors to impairments within the watershed are abandoned mine sites. If the major source of manganese, sulfates, silver, and TDS in the Bonnie Creek Watershed is attributed to abandoned mining, active chemical treatment methods, passive treatment methods, and mine reclamation are available. Active chemical treatment typically involves the addition of alkaline chemicals, such as calcium carbonate, sodium hydroxide, sodium bicarbonate and anhydrous ammonia to acid mine drainage. These chemicals raise the pH to acceptable levels and decrease the solubility of dissolved metals. Metal precipitates form and settle out of the solution. Active chemical treatment is not a viable option for the Bonnie Creek Watershed because the chemicals are expensive, and the treatment system requires additional costs associated with operation and maintenance as well as the disposal of metal-laden sludges (PDEP 2002).

Reclamation of abandoned mines is another method of controlling pollutants. Reclamation of abandon mine land involves clearing site vegetation, removing contaminated topsoil and coal, and restoring functionality of the site for recreational, agricultural, or wildlife habitat purposes. The environmental benefits realized from abandoned mine reclamation projects are numerous and significant, including restoring land for future use and improving water quality. Restoration of the land can result in increased and enhanced pasture land, recreational areas, or wildlife habitat (PDEP 2002). However, reclamation projects tend to be costly and resource intensive and may not be appropriate for abandoned mine sites in Bonnie Creek Watershed.

Passive methods could be utilized until full reclamation of a mine occurs. Chemical addition and energy consuming treatment processes are virtually eliminated with passive treatment systems. The operation and maintenance requirements of passive systems are considerably less than active treatment systems (PDEP 2002). Therefore, passive treatment systems would be the best solution for controlling manganese from abandoned coal mines in the Bonnie Creek Watershed.

Following are examples of the passive treatment technologies:

- aerobic wetland
- compost or anaerobic wetland
- open limestone channels
- diversion wells
- anoxic limestone drains
- vertical flow reactors
- pyroclastic process

The remainder of this section discusses these technologies.

9.1.2.1 Aerobic Wetland

An aerobic wetland consists of a large surface area pond with horizontal surface flow. The pond may be planted with cattails and other wetland species. Aerobic wetlands can only effectively treat water that is net alkaline (pH greater than 7). In aerobic wetland systems, metals are precipitated through oxidation reactions to form oxides and hydroxides. A typical aerobic wetland will have a water depth of six to 18 inches (PDEP 2002).

9.1.2.2 Compost or Anaerobic Wetland

Compost wetlands, or anaerobic wetlands as they are sometimes called, consist of a large pond with a lower layer of organic substrate. The flow is horizontal within the substrate layer of the basin. Piling the compost a little higher than the free water surface can encourage the flow within the substrate. Typically, the compost layer consists of spent mushroom compost that contains about 10 percent calcium carbonate. Other compost materials include peat moss, wood chips, sawdust, or hay. A typical compost wetland will have 12 to 24 inches of organic substrate and be planted with cattails or other emergent vegetation (PDEP 2002).

9.1.2.3 Open Limestone Channels

Open limestone channels may be the simplest passive treatment method. Open limestone channels are constructed in two ways. In the first method, a drainage ditch constructed of limestone collects contaminated acid mine drainage water. The other method consists of placing limestone fragments directly in a contaminated stream. Dissolution of the limestone adds alkalinity to the water and raises the pH. This treatment requires large quantities of limestone for long-term success (PDEP 2002).

9.1.2.4 Diversion Wells

Diversion wells are another simple way to increase the alkalinity of contaminated waters. Acidic water is conveyed by a pipe to a downstream "well," which contains crushed limestone aggregate. The hydraulic force of the pipe flow causes the limestone to turbulently mix and abrade into fine particles preventing armoring (PDEP 2002).

9.1.2.5 Anoxic Limestone Drains

An anoxic limestone drain is a buried bed of limestone constructed to intercept subsurface mine water flow and prevent contact with atmospheric oxygen. Keeping oxygen out of the water prevents oxidation of metals and armoring of the limestone. An anoxic limestone drain can be considered a pretreatment step to increase alkalinity and raise pH before the water enters a constructed aerobic wetland (PDEP 2002).

9.1.2.6 Vertical Flow Reactors

Vertical flow reactors were conceived as a way to overcome the alkalinity producing limitations of anoxic limestone drains and the large area requirements of compost wetlands. The vertical flow reactor consists of a treatment cell with an underdrained limestone base topped with a layer of organic substrate and standing water. The water flows vertically through the compost and limestone and is collected and discharged through a system of pipes. The vertical flow reactor increases alkalinity by limestone dissolution and bacterial sulfate reduction (PDEP 2002).

9.1.2.7 Pyrolusite Process

This is a patented process, which utilizes site-specific cultured microbes to remove iron, manganese, and aluminum from acid mine drainage. The treatment process consists of a shallow bed of limestone aggregate inundated with acid mine drainage. After laboratory testing determines the proper combination, microorganisms are introduced to the limestone bed by inoculation ports located throughout the bed. The microorganisms grow on the surface of the limestone chips and oxidize the metal contaminants while etching away limestone, which in turn increases the alkalinity and raises the pH of water. This process has been used on several sites in western Pennsylvania with promising results (PDEP 2002).

9.2 Implementation Actions and Management Measures for Dissolved Oxygen

DO impairments are addressed by focusing on organic loads that consume oxygen through decomposition and nutrient loads that can cause algal growth, which can also deplete DO. Analysis provided in Section 7 established a relationship between reaeration, BOD_5, and DO concentrations in Galum Creek segment NCD05, so management measures for segment NCD05 will focus on increasing reaeration and decreasing BOD_5 loads to increase DO concentrations. Although it was shown that based on current data, BOD_5 loads do not need to be reduced, it is likely that during storm events, high BOD_5 loads are transported to the stream, and therefore reducing these loads will also help increase DO concentrations.

DO impairments in Galum Creek segment NCD05 are mostly attributed to low flow or stagnant conditions within the creek. Runoff from nonpoint sources may also contribute a BOD_5 load in Galum Creek segment NCD05. An additional contributor to low DO is increased water temperatures. Therefore, management measures for segment NCD05 will focus on reducing nonpoint source loading through sediment and surface runoff controls, reducing stream temperatures, and reducing stagnant conditions through reaeration.

Implementation actions, management measures, or BMPs are used to control the generation or distribution of pollutants. BMPs are either structural, such as wetlands, sediment basins, fencing, reaeration structures, or filter strips; or managerial, such as conservation tillage, nutrient management plans, or crop rotation. Both types require good management to be effective in reducing pollutant loading to water resources (Osmond et al. 1995).

It is generally more effective to install a combination of BMPs or a BMP system. A BMP system is a combination of two or more individual BMPs that are used to control a pollutant from the same critical source. In other words, if the watershed has more than one identified pollutant, but the transport mechanism is the same, then a BMP system that establishes controls for the transport mechanism can be employed. (Osmond et al. 1995).

Implementation actions and management measures are described for each nonpoint source in the watershed. Nonpoint sources include cropland, rural grassland, and animal management facilities.

9.2.1 DO Concentration Management

The sources of nonpoint source pollution in the Bonnie Creek TMDL are divided between agricultural cropland, rural grasslands, and animal management facilities. BMPs evaluated for treatment of these nonpoint sources are:

- filter strips
- wetlands

- Nutrient Management Plan
- reaeration

Organic and nutrient loads originating from cropland is most efficiently treated with a combination of riparian buffer or grass filter strips and wetlands. Nutrient management focuses on source control of nonpoint source contributions to Galum Creek. Instream management measures for DO focus on reaeration techniques. The Streeter-Phelps equations presented in Section 7 utilizes a reaeration coefficient. Increasing the reaeration coefficient by physical means will increase DO in Galum Creek segment NCD05.

9.2.1.1 Filter Strips

Filter strips can be used as a structural control to reduce pollutant loads, including nutrients and sediment, to Galum Creek segment NCD05. Filter strips implemented along stream segments slow and filter nutrients and sediment out of runoff, help reduce stream water temperatures thereby increasing the water body DO saturation level, and provide bank stabilization decreasing erosion and deposition. The following paragraphs focus on the implementation of filter strips in Galum Creek segment NCD05 subwatershed. Finally, design criteria and size selection of filter strips are detailed.

Organic debris in topsoil contributes to the BOD_5 load to water bodies (USEPA 1997b). Increasing the length of stream bordered by grass and riparian buffer strips will decrease the amount of BOD_5 and nutrient load associated with sediment loads to Galum Creek segment NCD05. Nutrient criteria, currently being developed and expected to be adopted around 2007 by the Illinois EPA, will assess the instream nutrient concentrations required for the watershed. As stated previously, excess nutrients in streams can cause excessive algal growth, which can deplete DO in streams. Adoption of nutrient criteria will affect this DO TMDL and would be expected to also help control exceedences of DO water quality criteria in Galum Creek segment NCD05.

Filter strips will help control BOD_5 levels by removing organic loads associated with sediment from runoff; however, no studies were identified as providing an estimate of removal efficiency. Grass filter strips can remove as much as 75 percent of sediment and 45 percent of total phosphorus from runoff, so it is assumed that the removal of BOD_5 falls within this range (North Carolina State University [NCSU] 2000). Riparian buffer strips also help reduce water temperatures increasing the water body DO saturation level as explained in Section 7.

Riparian vegetation, specifically shade, plays a significant role in controlling stream temperature change. The shade provided will reduce solar radiation loading to the stream. Furthermore, riparian vegetation provides bank stability that reduces sediment loading to the stream and the stream width-to-depth ratio. Research in California (Ledwith 1996), Washington (Dong et al. 1998), and Maine (Hagan and Whitman 2000) show that riparian buffers effect microclimate factors such as air temperature and relative humidity proximal to the stream. Ledwith (1996) found that a 500-foot buffer had an air temperature decrease of 12°F at the stream over a zero-foot buffer. The greatest change occurred in the first 100 feet of the 500-foot buffer where the temperature decreased 2°F per 30 feet from the stream bank. A decrease in the air temperature proximal to the stream would result in a smaller convective flux to the stream during the day.

Filter strip widths for the segment NCD05 TMDL were estimated based on the slope. According to the National Resource Conservation Service (NRCS) Planning and Design Manual, the majority of sediment is removed in the first 25 percent of the width (NRCS 1994). Table 9-1 outlines the guidance for filter strip flow length by slope (NRCS 1999). Based on slope estimates near tributaries within the watershed, filter strips widths of 72 to 144 feet could be incorporated in locations throughout the watershed. The total acreage examined was 470 acres.

Table 9-1 Filter Strip Flow Lengths Based on Land Slope

Percent Slope	0.5%	1.0%	2.0%	3.0%	4.0%	5.0% or greater
Minimum	36	54	72	90	108	117
Maximum	72	108	144	180	216	234

The acreages provided above are used to calculate an approximation of BMP cost in Section 9.3 and should only be used as a guideline for watershed planning. It is recommended that landowners evaluate their land near streams and lakes and create or extend filter strips according to the NRCS guidance presented in Table 9-1. Programs available to fund the construction of these buffer strips are discussed in Section 9.3.

9.2.1.2 Wetlands

Wetlands can be used as a structural control to treat loads from animal management operations located in the Bonnie Creek Watershed. Wetlands are an effective BMP for sediment, nutrient, and organic load control because they function to:

- prevent floods by temporarily storing water, allowing the water to evaporate or percolate into the ground;
- improve water quality through natural pollution control such as plant nutrient uptake;
- filter sediment;
- slow overland flow of water thereby reducing soil erosion (USDA 1996).

While constructed wetlands have been demonstrated to effectively reduce nitrogen and sediment, literature shows mixed results for phosphorus removal. Studies have shown that artificial wetlands, designed and constructed specifically to remove pollutants from surface water runoff, have removal rates for suspended solids of greater than 90 percent, for total phosphorus of 0 to 90 percent, and for nitrogen species from 10 to 75 percent (Johnson, Evans, and Bass 1996; Moore 1993; USEPA 1993; Kovosic et al.

2000). In some cases, wetlands can be sources of phosphorus. Over the long term, it is generally thought that wetlands are neither sources nor sinks of phosphorus (Kovosic et al. 2000).

Efficiency of pollutant removal in wetlands can be addressed in the design and maintenance of the constructed wetland. Location, hydraulic retention time and space requirements should be considered in design. To maintain removal efficiency, sheet flow should be maintained and substrate should be monitored to assess whether the wetland is operating optimally. Sediment or vegetation removal may be necessary if the wetland removal efficiency is lessened over a period of time (USEPA 1993; NCSU 1994).

It is recommended that further investigation take place within the watershed to determine the impact of animal management facilities on Galum Creek segment NCD05. Due to the lack of data on the impacts of nonpoint source runoff from these facilities, wetlands were not analyzed as part of a treatment for this TMDL. However, it is recommended that animal control facility managers consider wetlands to treat nonpoint source runoff from control facilities.

9.2.1.3 Nutrient Management

Nutrient management could result in reduced nutrient loads to segment NCD05. Crop management of nitrogen and phosphorus can be accomplished through Nutrient Management Plans, which focus on increasing the efficiency with which applied nutrients are used by crops, thereby reducing the amount available to be transported to both surface and groundwater. In the past, nutrient management focused on application rates designed to meet crop nitrogen requirements but avoid groundwater quality problems created by excess nitrogen leaching. This results in buildup of soil phosphorus above amounts sufficient for optimal crop yields. Illinois, along with most Midwestern states, demonstrates high soil test phosphorus in greater than 50 percent of soil samples analyzed (Sharpley et al. 1999).

The overall goal of nutrient reduction from agriculture should increase the efficiency of phosphorus use by balancing phosphorus inputs in feed and fertilizer with intakes of crops and animal produce, as well as managing the level of phosphorus in the soil. Reducing nutrient loss in agricultural runoff may be brought about by source and transport control measures, such as filter strips or grassed waterways. The Nutrient Management Plans account for all inputs and outputs of phosphorus to determine reductions. Elements of a Nutrient Management Plan include:

- plan summary
- manure summary, including annual manure generation, use, and export
- nutrient application rates by field and crop
- summary of excess manure utilization procedures
- implementation schedule
- manure management and stormwater BMPs

In Illinois, Nutrient Management Plans have successfully reduced phosphorus application to agricultural lands by 36-lb/acre. National reductions range from 11- to 106-lb/acre, with an average of 35-lb/acre (NCSU 2000).

9.2.1.4 Reaeration

The purpose of reaeration is to increase DO concentrations in streams. Physical measures that will assist in increasing reaeration of a stream include bank stabilization, channel modifications, and the addition of riprap or pool and riffle sequences. Bank stabilization reduces erosion by planting vegetation along the bank or modification of the channel to decrease the slope of the bank. Riprap or pool and riffle sequences would increase reaeration by increasing turbulence. Turbulence creates an increase in the interaction between air and water, which draws air into the river increasing aeration. Expanding monitoring to several locations along the impaired segments could help identify reaches that would benefit the most from an increase of turbulence.

9.3 Reasonable Assurance

Reasonable assurance means that a demonstration is given that the pollutant reductions in this watershed will be implemented. It should be noted that all programs discussed in this section are voluntary. The discussions in Sections 9.1 and 9.2 provided a means for obtaining the reductions necessary. The remainder of this section discusses the programs available to assist with funding and an estimate of costs to the watershed for implementing these practices.

9.3.1 Available Programs for Manganese, Silver, Sulfates, and TDS TMDL

As mentioned previously, the Illinois EPA is responsible for regulating permitted coal mines in Illinois. As outlined in Section 9.1, the Illinois EPA has the authority to revise permit limits to protect water quality standards. It is recommended that additional data on abandoned mine sites and their contribution to impairments be further examined prior to revision of permit limits in Bonnie Creek Watershed.

The state agency primarily responsible for reclamation of pre-law coal mine areas is the IDNR, Office of Mines and Minerals, Abandoned Mined Lands Reclamation Division (AMLRD). The AMLRD contracts or oversees reclamation of pre-law mine sites utilizing funds from a "reclamation fee" (tax) on every ton of coal mined in Illinois since the implementation of the Surface Mining Control and Reclamation Act of 1977. The fee monies are sent to the U.S. Department of Interior and are then partially reallocated back to the states for several purposes, which include the reclamation of pre-law abandoned mined lands. This reclamation fee funds almost all the reclamation of pre-law mine sites in Illinois. The AMLRD also has the responsibility to reclaim permitted mine sites where the operator has deserted the site and all of the bond money has been forfeited. This adds to the overall number of projects that the AMLRD has to complete (Muir et al. 1997).

Abandoned mine sites are reclaimed through the ALMRD according to a priority list as monies become available. Because the federally designated first priority for ALMRD projects is safety, most of the early reclamation projects were not environmentally oriented. Even so, the AMLRD has completed a large number of environmentally oriented reclamation projects (Muir et al. 1997). Due to the uncertainty of sources of manganese, sulfates, silver, and TDS in the Bonnie Creek Watershed, no cost estimates were developed for mitigation of the potential sources provided in this report. If the abandoned mines in the Bonnie Creek Watershed are shown to contribute to impairment of segments within the watershed, funds from the ALMRD focused on environmental projects should be directed towards water bodies with TMDLs.

9.3.2 Available Programs for DO TMDL

Approximately 86 percent of the Galum Creek segment NCD05 subwatershed is classified as rural grassland (pasture land, Conservation Reserve Program [CRP], waterways, buffer strips, etc.), row crop, and small grains land. There are several voluntary conservation programs established through the 2002 U.S. Farm Bill, which encourage landowners to implement resource-conserving practices for water quality and erosion control purposes. These programs would apply to crop fields and rural grasslands that are presently used as pasture land. Each program is discussed separately in the following sections.

9.3.2.1 Illinois Department of Agriculture and Illinois EPA Nutrient Management Plan Project

The Illinois Department of Agriculture (IDA) and Illinois EPA are presently co-sponsoring a cropland Nutrient Management Plan project in watersheds that have or are developing a TMDL. Under this project, 11,311 acres of cropland have been targeted in the Bonnie Creek segment NCD05 subwatershed. This voluntary project will supply incentive payments to producers to have Nutrient Management Plans developed and implemented. Additionally, if sediments or phosphorus has been identified as a cause for impairment in the watershed, then traditional erosion control practices will be eligible for cost-share assistance through the Nutrient Management Plan project as well.

9.3.2.2 Clean Water Act Section 319 Grants

Section 319 was added to the CWA to establish a national program to address nonpoint sources of water pollution. Through this program, each state is allocated section 319 funds on an annual basis according to a national allocation formula based on the total annual appropriation for the section 319 grant program. The total award consists of two categories of funding; incremental funds and base funds. A state is eligible to receive EPA 319(h) grants upon USEPA's approval of the state's Nonpoint Source Assessment Report and Nonpoint Source Management Program. States may reallocate funds through subawards (e.g., contracts, subgrants) to both public and private entities, including local governments, tribal authorities, cities, counties, regional development centers, local school systems, colleges and universities, local nonprofit organizations, state agencies, federal agencies, watershed groups, for-profit groups, and individuals. Subawards to individuals are limited to demonstration projects (USEPA 2003, 2002).

USEPA designates incremental funds, a $100-million award, for the restoration of impaired water through the development and implementation of watershed-based plans and TMDLs for impaired waters. Base funds, funds other than incremental funds, are used to provide staffing and support to manage and implement the state Nonpoint Source Management Program. Section 319 funding can be used to implement activities which improve water quality, such as filter strips, streambank stabilization, etc. (USEPA 2003, 2002).

9.3.2.3 Streambank Stabilization and Restoration Practice

The Streambank Stabilization and Restoration Practice (SSRP) was established to address problems associated with streambank erosion; such as loss or damage to valuable farmland, wildlife habitat, roads; stream capacity reduction through sediment deposition; and degraded water quality, fish, and wildlife habitat. The primary goals of the SSRP are to develop and demonstrate vegetative, stone structure and other low cost bio-engineering techniques for stabilizing streambanks and to encourage the adoption of low-cost streambank stabilization practices by making available financial incentives, technical assistance, and educational information to landowners with critically eroding streambanks. A cost share of 75 percent is available for approved project components, such as willow post installation, bendway weirs, rock riffles, stream barbs/rock, vanes, lunker structures, gabion baskets, and stone toe protection techniques. There is no limit on the total program payment for cost-share projects that a landowner can receive in a fiscal year. However, maximum cost per foot of bank treated is used to cap the payment assistance on a per foot basis and maintain the program's objectives of funding low-cost techniques (IDA 2000).

9.3.2.4 Conservation Reserve Program (CRP)

This voluntary program encourages landowners to plant long-term resource-conserving cover to improve soils, water, and wildlife resources. CRP is the USDA's single largest environmental improvement program and one of its most productive and cost-efficient. It is administered through the Farm Service Agency (FSA) by USDA's Commodity Credit Corporation (CCC). The program was initially established in the Food & Security Act of 1985. The duration of the contracts under CRP range from 10 to 15 years.

Eligible land must be one of the following:

1. cropland that is planted or considered planted to an agricultural commodity two of the five most recent crop years (including field margins), and must be physically and legally capable of being planted in a normal manner to an agricultural commodity.

2. certain marginal pastureland enrolled in the Water Bank Program.

The CCC bases rental rates on the relative productivity of soils within each county and the average of the past three years of local dryland cash rent or cash-rent equivalent. The maximum rental rate is calculated in advance of enrollment. Producers may offer land at the maximum rate or at a lower rental rate to increase likelihood of offer acceptance. In addition, the CCC provides cost-share assistance for up to 50 percent of the participant's costs in establishing approved conservation practices. CCC also encourages restoration of wetlands by offering a one-time incentive payment equal to 25 percent of the costs incurred. This incentive is in addition to the 50 percent cost share provided to establish cover (USDA 1999).

Finally, CCC offers additional financial incentives of up to 20 percent of the annual payment for certain continuous sign-up practices. Continuous sign-up provides management flexibility to farmers and ranchers to implement certain high-priority conservation practices on eligible land. The land must be determined by NRCS to be eligible and suitable for any of the following practices:

- riparian buffers
- filter strips
- grass waterways
- shelter belts
- field windbreaks
- living snow fences
- contour grass strips
- salt tolerant vegetation
- shallow water areas for wildlife
- eligible acreage within an USEPA-designated wellhead protection area (FSA 1997)

9.3.2.5 Wetlands Reserve Program (WRP)

The Wetlands Reserve Program (WRP) is a voluntary program that provides technical and financial assistance to eligible landowners to restore, enhance, and protect wetlands. The goal of WRP is to achieve the greatest wetland functions and values, along with optimum wildlife habitat, on every acre enrolled in the program. At least 70 percent of each project area will be restored to the original natural condition, to the extent practicable. The remaining 30 percent of each area may be restored to other than natural conditions. Landowners have the option of enrolling eligible lands through permanent easements, 30-year easements, or restoration cost-share agreements. The program is offered on a continuous sign-up basis and is available nationwide. WRP offers landowners an opportunity to establish, at minimal cost, long-term conservation and wildlife habitat enhancement practices and protection. It is administered through the NRCS (2002a).

The 2002 Farm Bill reauthorized the program through 2007. Increasing the acreage enrollment cap to 2,275,000 acres with an annual enrollment of 250,000 acres per calendar year. The program is limited by the acreage cap and not by program funding. The program offers three enrollment options: permanent easements, 30-year conservation easements, and 10-year restoration cost-share agreements. Since the program began in 1985, the average cost per acre is $1,100 in restorative costs, and the average project size is 177 acres. The costs for each enrollment option follows in Table 9-2 (USDA 1996).

Table 9-2 Costs for Enrollment Options of WRP Program

Option	Permanent Easement	30-year Easement	Restoration Agreement
Payment for Easement	100% Agricultural Value (Max of $1,200 Acre)	75% Agricultural Value (Max of $900 Acre)	NA
Payment Options	1. Lump Sum 2. 5-30 Annual Payments 3. No Annual Cap	1. Lump Sum if less than $50,000 2. 5-30 Annual Payments 3. Annual Cap of $50,000	NA
Restoration Payments	100% Restoration Cost Reimbursements	75% Restoration Cost Reimbursements	75% Restoration Cost Reimbursements

9.3.2.6 Environmental Quality Incentive Program (EQIP)

The Environmental Quality Incentive Program (EQIP) is a voluntary USDA conservation program for farmers and private landowners engaged in livestock or agricultural production who are faced with serious threats to soil, water, and related natural resources. It provides technical, financial, and educational assistance primarily in designated "priority areas." Priority areas are defined as watershed, regions, or areas of special environmental sensitivity that have significant soil, water, or natural resource related concerns. The program goal is to maximize environmental benefits per dollar expended and provides "(1) flexible technical and financial assistance to farmers and ranchers that face the most serious natural resource problems; (2) assistance to farmers and ranchers in complying with federal, state, and tribal environmental laws, and encourage environmental enhancement; (3) assistance to farmers and ranchers in making beneficial, cost-effective changes to measures needed to conserve and improve natural resources; and (4) for the consolidation and simplification of the conservation planning process." As of 2001, 379,000 acres have been protected in Illinois using EQIP (NRCS 2002c,d).

Landowners, with the assistance of a local NRCS or other service provider, are responsible for development of a site-specific conservation plan, which addresses the primary natural resource concerns of the priority area. Conservation practices include but are not limited to erosion control, filter strips, buffers, and grassed waterways. If the plan is approved by NRCS, a five- to 10-year contract that provides cost-share and incentive payments is developed.

Cost-share assistance may pay landowners up to 75 percent of the costs of conservation practices, such as grassed waterways, filter strips, manure management, capping abandoned wells, and other practices important to improving and maintaining the health of natural resources in the area. Total incentive and cost-share payments are limited to $10,000 per person per year and $50,000 over the life of the contract.

9.3.2.7 Conservation Practices Program

The Conservation Practices Program (CPP) is a 10-year program. The practices consist of waterways, water and sediment control basins (WASCOBS), pasture/hayland establishment, critical area, terrace system, no-till system, diversions, and grade stabilization structures. The CPP is state funded through the Department of Agriculture. There is a project cap of $5,000 per landowner and costs per acre vary significantly from project to project.

9.3.2.8 Wildlife Habitat Incentives Program (WHIP)

The Wildlife Habitat Incentives Program (WHIP) is a voluntary program that encourages the creation of high quality wildlife habitat of national, state, tribal, or local significance. WHIP is administered through NRCS, which provides technical and financial assistance to landowners for development of upland, riparian, and aquatic habitat areas on their property. NRCS works with the participant to develop a wildlife habitat development plan, which becomes the basis of the cost-share agreement between NRCS and the participant. Most contracts are five to 10 years in duration, depending upon the practices to be installed. However, longer term contracts of 15 years or greater may also be funded. Under the agreement:

- The landowner agrees to maintain the cost-shared practices and allow NRCS or its agent access to monitor its effectiveness.

NRCS agrees to provide technical assistance and pay up to 75 percent of the cost of installing the wildlife habitat practices. Additional financial or technical assistance may be available through cooperating partners (NRCS 2002b).

The FSA administers the CRP. NRCS administers the EQIP, WRP, and WHIP. Local NRCS and FSA contact information in Perry County are listed in Table 9-3 below.

Table 9-3 Local NRCS and FSA Contact Information

Contact	Address	Phone
Local NRCS Office		
Robert L. Spencer	Hwy 127 North PO Box 146 Pickneyville, Illinois 62274	618-357-6016 x 3
Local FSA Office		
Pickneyville Service Center	Hwy 127 North PO Box 146 Pickneyville, Illinois 62274	618-357-6016 x 3

9.3.3 Cost Estimates for BMPs

Cost estimates for different BMPs and individual practice prices such as filter strip installation are detailed in the following sections. Table 9-4 outlines the cost of implementation measures per acre. Finally, an estimate of the total order of magnitude costs for implementation measures in the Galum Creek segment NCD05 Watershed are presented in Section 9.3.3.6 and Table 9-5.

9.3.3.1 Streambank Stabilization

Cost information of streambank stabilization was taken from Johnson County NRCS. Johnson County NRCS estimates an average cost per foot to implement streambank stabilization measures at $40.00/foot. This price includes grading and shaping of the bank and critical area and dormant stub planting.

9.3.3.2 Nutrient Management Plan - IDA and Illinois EPA

The costs associated with development of Nutrient Management Plans co-sponsored by the IDA and the Illinois EPA is estimated as $5/acre paid to the producer and $2/acre for a third party vendor who develops the plans. The total plan development cost is estimated at $7/acre.

9.3.3.3 Filter Strips and Riparian Buffers

The Perry County NRCS estimates an average cost per acre to install a grass filter strip with a 15-year life span at $260/acre. A riparian buffer strip established with bare root stock has a life span of 15 years and an installation cost of $280/acre. Based on this preliminary estimate, it appears that grass filter strips would be a more cost-effective way to control BOD and nutrient loads in the watershed.

9.3.3.4 Nutrient Management Plan - NRCS

Generally, agricultural land in Perry County is comprised of cropland and rural grassland. Few Nutrient Management Plans have been established. The Perry County Extension Service estimates the average plan to cost $5 to $15/acre.

9.3.3.5 Planning Level Cost Estimates for Implementation Measures

Cost estimates for different implementation actions are presented in Table 9-4. The column labeled *Program* lists the financial assistance program available for various BMPs. The programs represented in the table are the WRP and the CRP.

Table 9-4 Cost Estimate of Various BMP Measures in the Bonnie Creek Watershed

Source	Program or Sponsor	BMP	Life Span	Installation Mean $/acre	Maintenance $/ac/yr
Nonpoint	CRP	Grass Filter Strips	15	$90.00	$9.00
	CRP	Riparian Buffer	10	$384.00	$40.00
	319 or SSRP	Streambank Stabilization*	10	$40.00	$4.00
	IDA and Illinois EPA	Nutrient Management Plan		$7.00	

* Streambank Stabilization cost calculated on linear foot basis.

The total order of magnitude capital costs for implementation measures in the watershed were estimated to be $3,192,000. The total cost is calculated as the number of acres over which a BMP or structural measure is applied by the cost per acre. Table 9-5 summarizes the number of acres each measure is applied to in the basin and the corresponding cost. The acreages reported in Table 9-5 are a preliminary estimate in order to provide an overall understanding of cost of implementation in the watershed.

The total only represents capital costs and annual maintenance costs. These do not represent the total costs of operating the measure over its life cycle.

Table 9-5 Cost Estimate of Implementation Measures for the Bonnie Creek Watershed

BMP	Treated Acres	Capital Costs		Maintenance Costs	
		Mean $/acre	Watershed $	$/ac/yr	Watershed $/yr
Grass Filter Strips	470	$260.00	$122,000.00	$26.00	$12,200.00
Nutrient Management Plan	11,311	$7.00	$79,000.00		
Streambank Stabilization*	69,700	$40.00	$2,788,000.00	4.00	$278,800.00
Total			**$2,981,000.00**		**$291,000.00**

* Streambank Stabilization cost calculated on linear foot basis.

9.4 Monitoring Plan

The purpose of the monitoring plan for the Bonnie Creek Watershed is to assess the overall implementation of management actions outlined in this section. This can be accomplished by conducting the following monitoring programs:

- track implementation of management measures in the watershed
- estimate effectiveness of management measures
- continued ambient monitoring
- monitoring of permitted mine discharge

Tracking the implementation of management measures can be used to address the following goals (NCSU 2000):

- determine the extent to which management measures and practices have been implemented compared to action needed to meet TMDL endpoints
- establish a baseline from which decisions can be made regarding the need for additional incentives for implementation efforts
- measure the extent of voluntary implementation efforts
- support workload and cost analysis for assistance or regulatory programs
- determine the extent to which management measures are properly maintained and operated

Estimating the effectiveness of the BMPs implemented in the watershed could be completed by monitoring before and after the BMP is incorporated into the watershed. Additional monitoring could be conducted on specific structural systems, such as a constructed wetland. Inflow and outflow measurements could be conducted to determine site-specific removal efficiency.

Segments within the Bonnie Creek Watershed are monitored approximately every five years as part of the Big Muddy River Basin Intensive Survey. Continuation of this monitoring will assess instream water quality as improvements in the watershed are completed. This data will also be used to assess whether water quality standards in the watershed are being attained. To further support DO modeling and to plan for future nutrient criteria in the watershed, the following parameters should be added to the monitoring list:

- BOD_5
- BOD_{20}
- Chlorophyll "a" or algae monitoring

Monitoring discharge from permitted mines within the Bonnie Creek Watershed will help further assess sources of contaminants in the watershed. Permit limits should be reviewed based on source identification and mine discharge concentrations. Permit discharges may need to be decreased to maintain water quality standards. Decreases in discharges may result only after further review and study.

9.5 Implementation Time Line

Implementing the actions outlined in this section for the Bonnie Creek Watershed should occur in phases, and the effectiveness of the management actions should be assessed as improvements are made. It is assumed that it may take up to one to two years for further source identification in the watershed. It is also assumed that it may take up to five years to secure funding for actions needed in the watershed and five to seven years after funding to implement the measures. The length of time required to meet water quality standards will be based on the types of BMPs implemented in the watershed. In summary, to meet water quality standards in the Bonnie Creek Watershed may take 15 to 20 years to complete.

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Section 10
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Appendix A
Historic Water Quality Data

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Segment	Name	Size Miles	Primary Station ID	Organization Code	Start Date	Parameter Code	Parameter Long Name	Result Value
NCDC 01	Bonnie Cr.	10.0	NCDC01	21ILL	8/2/1995	945	SULFATE, TOTAL (MG/L AS SO4)	124
NCDC 01	Bonnie Cr.	10.0	NCDC01	21ILL	3/4/1996	945	SULFATE, TOTAL (MG/L AS SO4)	616

Segment	Name	Size Miles	Primary Station ID	Organization Code	Start Date	Parameter Code	Parameter Long Name	Result Value
NCD 03	GALUM CR RD 6 MI NNE AVA T6SR3WNE33	4.5	NCD 03	ILL-EPA	7/26/1995	1077	SILVER, TOTAL (UG/L AS AG)	8
NCD 03	GALUM CR RD 6 MI NNE AVA T6SR3WNE33	4.5	NCD 03	ILL-EPA	3/5/1996	1077	SILVER, TOTAL (UG/L AS AG)	3

Segment	Name	Size Miles	Primary Station ID	Organization Code	Start Date	Parameter Code	Parameter Long Name	Result Value
NCD 03	GALUM CR RD 6 MI NNE AVA T6SR3WNE33	4.5	NCD 03	ILL-EPA	7/26/1995	945	SULFATE, TOTAL (MG/L AS SO4)	1300
NCD 03	GALUM CR RD 6 MI NNE AVA T6SR3WNE33	4.5	NCD 03	ILL-EPA	3/5/1996	945	SULFATE, TOTAL (MG/L AS SO4)	1580

Segment	Name	Size Miles	Primary Station ID	Organization Code	Start Date	Parameter Code	Parameter Long Name	Result Value
NCD 03	GALUM CR RD 6 MI NNE AVA T6SR3WNE33	4.5	NCD 03	ILL-EPA	7/26/1995	70300	RESIDUE,TOTAL FILTRABLE (DRIED AT 180C),MG/L	2740
NCD 03	GALUM CR RD 6 MI NNE AVA T6SR3WNE33	4.5	NCD 03	ILL-EPA	3/5/1996	70300	RESIDUE,TOTAL FILTRABLE (DRIED AT 180C),MG/L	2170

Segment	Name	Size Miles	Primary Station ID	Organization Code	Start Date	Parameter Code	Parameter Long Name	Result Value
NCD05	GALUM CR RT 154 3.5 MI N CUTLER T5SR4WSW16	13.2	NCD 05	ILL-EPA	8/2/1995	1055	MANGANESE, TOTAL (UG/L AS MN)	1500.00
NCD05	GALUM CR RT 154 3.5 MI N CUTLER T5SR4WSW16	13.2	NCD 05	ILL-EPA	3/4/1996	1055	MANGANESE, TOTAL (UG/L AS MN)	270.00

Segment	Name	Size Miles	Primary Station ID	Organization Code	Start Date	Parameter Code	Parameter Long Name	Result Value
NCD05	GALUM CR RT 154 3.5 MI N CUTLER T5SR4WSW16	13.2	NCD 05	ILL-EPA	8/2/1995	299	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.10
NCD05	GALUM CR RT 154 3.5 MI N CUTLER T5SR4WSW16	13.2	NCD 05	ILL-EPA	3/4/1996	299	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	14.90

Segment	Name	Size Miles	Primary Station ID	Organization Code	Start Date	Parameter Code	Parameter Long Name	Result Value
NCDB	Little Galum Cr.	13.4	NCDB01	21ILL	7/17/1995	1055	MANGANESE, TOTAL (UG/L AS MN)	3800
NCDB	Little Galum Cr.	13.4	NCDB01	21ILL	3/4/1996	1055	MANGANESE, TOTAL (UG/L AS MN)	220

Segment	Name	Size Miles	Primary Station ID	Organization Code	Start Date	Parameter Code	Parameter Long Name	Result Value
NCDB	Little Galum Cr.	13.4	NCDB01	21ILL	7/17/1995	945	SULFATE, TOTAL (MG/L AS SO4)	390
NCDB	Little Galum Cr.	13.4	NCDB01	21ILL	3/4/1996	945	SULFATE, TOTAL (MG/L AS SO4)	952

Segment	Name	Size Miles	Primary Station ID	Organization Code	Start Date	Parameter Code	Parameter Long Name	Result Value
NCDB	Little Galum Cr.	13.4	NCDB01	21ILL	7/17/1995	70300	SOLIDS, RESIDUE ON EVAPORATION AT 180 DEG C, DISSOLVED (MG/L)	1020
NCDB	Little Galum Cr.	13.4	NCDB01	21ILL	3/4/1996	70300	SOLIDS, RESIDUE ON EVAPORATION AT 180 DEG C, DISSOLVED (MG/L)	1180

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Appendix B
Directory of Selected Coal Mines for Perry County, Illinois

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APPENDIX B

DIRECTORY OF SELECTED COAL MINES FOR PERRY COUNTY, ILLINOIS (IDNR 2000)
MAY 4, 2000

ISGS INDEX	COMPANY NAME	MINE NAME	MINE NO.	MINE TYPE	METHOD	YEARS OPERATED	SEAM MINED	COUNTY	LOCATION TWP	LOCATION RGE	LOCATION SEC
176	CHICAGO & COULTERVILLE C C	CHICAGO & COULTERVILLE		SHAFT	MRP	1901-04	HERRIN	PERRY	4S	4W	18
176	WEST MUDDY C C	WEST MUDDY		SHAFT		1904-05	HERRIN	PERRY	4S	4W	18
176	HIPPARD C C	VULCAN		SHAFT		1905-06	HERRIN	PERRY	4S	4W	18
176	VULCAN COAL & MNG CO	VULCAN		SHAFT		1906-07	HERRIN	PERRY	4S	4W	18
176	ST LOUIS-COULTERVILLE C C	VULCAN		SHAFT		1907-17	HERRIN	PERRY	4S	4W	18
176	PERRY C C	VULCAN		SHAFT		1917-19	HERRIN	PERRY	4S	4W	18
176	PERRY C C	PERCO		SHAFT		1919-31	HERRIN	PERRY	4S	4W	18
176	COULTERVILLE C C	COULTERVILLE		SHAFT		1931-40	HERRIN	PERRY	4S	4W	18
176	WEIR, PAUL	VULCAN		SHAFT		1940-44	HERRIN	PERRY	4S	4W	18
182	WILSON C C	G		SHAFT	MRP	1913-18	HERRIN	PERRY	6S	4W	5
182	SOPER C C	BARNARD	2	SHAFT		1918-20	HERRIN	PERRY	6S	4W	5
182	ALLADIN COAL MNG CO	ALLADIN	2	SHAFT		1920-22	HERRIN	PERRY	6S	4W	5
182	SOUTHERN GEM C C	SOUTHERN GEM	10	SHAFT		1922-23	HERRIN	PERRY	6S	4W	5
182	CHICAGO FUEL CO	CHICAGO	2	SHAFT		1923-34	HERRIN	PERRY	6S	4W	5
182	WHIP POOR WILL C C	WHIPPOORWILL		SHAFT		1934-39	HERRIN	PERRY	6S	4W	5
182	C & R C C	C & R		SHAFT		1939-42	HERRIN	PERRY	6S	4W	5
182	J & T C C	J & T		SHAFT		1942-44	HERRIN	PERRY	6S	4W	5
182	SMITH BROS (WHIP C C)	SMITH		SHAFT		1944-45	HERRIN	PERRY	6S	4W	5
182	WHIP COAL CO	WHIP		SHAFT		1945-46	HERRIN	PERRY	6S	4W	5
623	PYRAMID C C	PYRAMID		STRIP		1926-52	HERRIN	PERRY	6S	3W	10
623	PYRAMID C C	PYRAMID STRIP		STRIP		1926-52	HERRIN	PERRY	5S	3W	35
623	PYRAMID C C	PYRAMID STRIP		STRIP		1926-52	HERRIN	PERRY	5S	3W	26
623	PYRAMID C C	PYRAMID STRIP		STRIP		1926-52	HERRIN	PERRY	6S	3S	1
623	PYRAMID C C	PYRAMID STRIP		STRIP		1926-52	HERRIN	PERRY	6S	2W	6
623	PYRAMID C C	PYRAMID STRIP		STRIP		1926-52	HERRIN	PERRY	6S	2W	6
623	PYRAMID C C	PYRAMID STRIP		STRIP		1926-52	HERRIN	PERRY	6S	2W	7
623	PYRAMID C C	PYRAMID STRIP		STRIP		1926-52	HERRIN	PERRY	5S	3W	35
623	PYRAMID C C	PYRAMID STRIP		STRIP		1926-52	HERRIN	PERRY	6S	3W	13
623	BINKLEY C C	PYRAMID PIT		STRIP		1934-34	HERRIN	PERRY	6S	3W	10
623	TRUAX TRAER C C	PYRAMID		STRIP		1952-60	HERRIN	PERRY	5S	3W	35
717	AVERY C & MNG CO	BALD EAGLE		SHAFT	RPB	1906-10	DANVILLE	PERRY	4S	4W	25
717	AVERY COAL & MNG CO	BALD EAGLE		SHAFT		1906-10	HERRIN	PERRY	4S	4W	25
717	BALD EAGLE MNG CO	BALD EAGLE		SHAFT		1910-14	DANVILLE	PERRY	4S	4W	25
717	BALD EAGLE MNG CO	BALD EAGLE		SHAFT		1910-14	HERRIN	PERRY	4S	4W	25
717	CHIME COAL CO	BALD EAGLE		SHAFT		1914-15	DANVILLE	PERRY	4S	4W	25
717	CHIME COAL CO	BALD EAGLE		SHAFT		1914-15	HERRIN	PERRY	4S	4W	25
717	GRANGER C C	BALD EAGLE		SHAFT		1915-17	HERRIN	PERRY	4S	4W	25
717	CROWN C C	BALD EAGLE		SHAFT		1917-20	HERRIN	PERRY	4S	4W	25

APPENDIX B

DIRECTORY OF SELECTED COAL MINES FOR PERRY COUNTY, ILLINOIS (IDNR 2000)
MAY 4, 2000

ISGS INDEX	COMPANY NAME	MINE NAME	MINE NO.	MINE TYPE	METHOD	YEARS OPERATED	SEAM MINED	COUNTY	LOCATION TWP	RGE	SEC
717	COLUMBIA COLLIERY	BALD EAGLE		SHAFT		1920-28	DANVILLE	PERRY	4S	4W	25
717	COLUMBIA COLLIERY CO	BALD EAGLE		SHAFT		1920-28	HERRIN	PERRY	4S	4W	25
717	DELCO MNG CO	BALD EAGLE		SHAFT		1928-30	DANVILLE	PERRY	4S	4W	25
717	DELCO COAL MNG CO	BALD EAGLE		SHAFT		1928-30	HERRIN	PERRY	4S	4W	25
717	EGYPTIAN C C	EGYPTIAN		SHAFT		1930-32	DANVILLE	PERRY	4S	4W	25
717	EGYPTIAN COAL CO	BALD EAGLE		SHAFT		1930-32	HERRIN	PERRY	4S	4W	25
717	WINKLE COAL CO	WINKLE		SHAFT		1932-36	DANVILLE	PERRY	4S	4W	25
717	WINKLE COAL CO	BALD EAGLE		SHAFT		1932-36	HERRIN	PERRY	4S	4W	25
872	SOUTHWESTERN ILLINOIS C C	STREAMLINE		STRIP		1936-82	HERRIN	RANDOLPH	5S	5W	36
872	SOUTHWESTERN ILLINOIS C C	STREAMLINE		STRIP		1936-82	SPRINGFIELD	RANDOLPH	6S	5W	25
873	SOUTHWESTERN ILLINOIS C C	CAPTAIN		STRIP		1964-84	HERRIN	PERRY	6S	4W	15
873	SOUTHWESTERN ILLINOIS C C	CAPTAIN		STRIP		1964-84	SPRINGFIELD	PERRY	6S	4W	15
873	ARCH OF ILLINOIS	CAPTAIN		STRIP		1984-98	DANVILLE	PERRY	6S	4W	15
873	ARCH OF ILLINOIS	CAPTAIN		STRIP		1984-98	HERRIN	PERRY	6S	4W	15
873	ARCH OF ILLINOIS	CAPTAIN		STRIP		1984-98	SPRINGFIELD	PERRY	6S	4W	15
873	ARCH OF ILLINOIS	CAPTAIN		STRIP		1984-98	HERRIN	PERRY	6S	4W	15
873	ARCH OF ILLINOIS	CAPTAIN		STRIP		1984-98	SPRINGFIELD	PERRY	6S	4W	15
873	ARCH OF ILLINOIS	CAPTAIN		AUGER		1995-95	SPRINGFIELD	PERRY	6S	4W	8
932	CONSOLIDATION C C	BURNING STAR	4	STRIP		1973-97	HERRIN	PERRY	6S	4W	3
932	CONSOLIDATION C C	BURNING STAR	4	STRIP		1973-97	HERRIN	PERRY	6S	4W	3
932	CONSOLIDATION C C	BURNING STAR	4	STRIP		1973-97	SPRINGFIELD	PERRY	6S	4W	3
968*	ZEIGLER C C	ZEIGLER	11	SHAFT	CRP	1976-91	HERRIN	RANDOLPH	4S	5W	26
968*	OLD BEN C C	ZEIGLER	11	SHAFT	CRP	1992-	HERRIN	RANDOLPH	4S	5W	26
997	CARTER COAL CO	KATHLEEN		DRIFT		1984-88	HERRIN	PERRY	6S	4W	8
997	CUTLER CC (ARCH MINERALS)	KATHLEEN		UG		1988-95	HERRIN	PERRY	6S	4W	8
1012	ARCH OF ILLINOIS	HORSE CREEK		STRIP		1986-94	HERRIN	PERRY	5S	4W	25
1012	ARCH OF ILLINOIS	HORSE CREEK		AUGER		1994-94	SPRINGFIELD	PERRY	5S	4W	24
1012	ARCH OF ILLINOIS	HORSE CREEK		AUGER		1994-94	HERRIN	PERRY	5S	4W	24
1016	ARCH OF ILLINOIS	CONANT		DRIFT	PB	1991-99	HERRIN	PERRY	5S	3W	31
3105	HOLIDAY MINE	HOLIDAY		UG	RP	1886-86	HERRIN	PERRY	4S	4W	19
3123	CONANT C C	CONANT		SHAFT	MRP	1934-50	HERRIN	PERRY	5S	4W	25
3123	BIG 5 C C	BIG 5	1	SHAFT		1950-60	HERRIN	PERRY	5S	4W	25
3124	ELM GROVE C C, UNDERGROUND	ELM GROVE		UG	MRP	1933-55	HERRIN	PERRY	5S	4W	28
3125	ALLEN C C	ALLEN	1	SHAFT	MRP	1920-21	HERRIN	PERRY	5S	4W	34
3125	SOUTHERN GEM C C	SOUTH GEM	7	SHAFT		1921-25	HERRIN	PERRY	5S	4W	34
3126	GILLIS QUARRY MINE	MINE 1310				1940-40		PERRY	5S	4W	34
3127	SOUTHERN GEM C C	SOUTH GEM	8	SHAFT		1923-24	HERRIN	PERRY	5S	4W	34
3128	RING C C	RING	1	SHAFT	RPB	1933-35	HERRIN	PERRY	5S	4W	35
3128	NEW GALUM C C	NEW GALUM		SHAFT		1935-42	HERRIN	PERRY	5S	4W	35
3129	BARWELL & CARTER	GALUM		SHAFT	RPB	1882-84	HERRIN	PERRY	5S	4W	35
3129	CARTER & BARWELL,BEFORE 1883	GALUM		SHAFT		1883-84	HERRIN	PERRY	5S	4W	35

APPENDIX B

DIRECTORY OF SELECTED COAL MINES FOR PERRY COUNTY, ILLINOIS (IDNR 2000)
MAY 4, 2000

ISGS INDEX	COMPANY NAME	MINE NAME	MINE NO.	MINE TYPE	METHOD	YEARS OPERATED	SEAM MINED	COUNTY	LOCATION		
									TWP	RGE	SEC
3129	BARWELL MINE	BARWELL		SHAFT		1890-91	HERRIN	PERRY	5S	4W	35
3129	BRYDEN COAL & COKE	GALUM		SHAFT		1892-94	HERRIN	PERRY	5S	4W	35
3129	BARWELL MINE	BARWELL		SHAFT		1894-94	HERRIN	PERRY	5S	4W	35
3129	BROWN & BARWELL	BARWELL		SHAFT		1895-00	HERRIN	PERRY	5S	4W	35
3129	BARWELL COAL CO	BARWELL		SHAFT		1900-01	HERRIN	PERRY	5S	4W	35
3130	GORGEN MINE, BEFORE 1934	GORGEN					HERRIN	PERRY	5S	4W	36
3176	COAL STRIPPING CO	COAL STRIP	1	STRIP		1931-35	HERRIN	PERRY	6S	3W	14
3176	PYRAMID C C	PYRAMID	1	STRIP		1935-36	HERRIN	PERRY	6S	3W	14
3177	HIGGERSON C C	HIGGERSON		SHAFT		1934-43	HERRIN	PERRY	6S	3W	18
3178	FREEMAN C C	FREEMAN		SLOPE		1933-33		PERRY	6S	4W	2
3180	WILSON C C	WILSON		SHAFT	MRP	1922-32	HERRIN	PERRY	6S	4W	4
3180	CUTLER COAL & MNG CO	NEW WILSON		SHAFT		1932-61	HERRIN	PERRY	6S	4W	4
3180	NEW CUTLER C C,IDLE 56-61	NEW WILSON		SHAFT		1961-64	HERRIN	PERRY	6S	4W	4
4427	WHITENBORN SHAFT	WHITENBORN						PERRY	6S	4W	16
4427	CARTER C C	CARTER		SLOPE		1922-27	HERRIN	PERRY	6S	4W	16
4429	BROWERTON	BROWERTON						PERRY	5S	4W	35
6130	PATRICK MINE	PATRICK		UG				PERRY	5S	3W	19

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Appendix C
Monte Carlo Analyses

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IEPA
Watershed Load Reductions
7/18/2002

Monte Carlo Simulations using @RISK 3.5

Watershed : NCDC 01

Sulfate

Cc (Sulfate)	500	mg/L	- Water quality criterion
Cd (Sulfate)	#NAME?	mg/L	- Randomly generated pollutant source concentration based on the observed data

Percent Reduction

PR = Max{ 0, (1-Cc/Cd)}

PR (Sulfate) #NAME?

After Monte-Carlo Simulation:

Percent reduction at the 99th percentile

PR99 (Sulfate) 14.0% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

mean 370.2 mg/L

LTA = mean * (1 - PR99)

LTA (Sulfate) 318.581 mg/L

Percent reduction at the 99.9th percentile

PR99.9 (Sulfate) 17.1% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

mean 370.2 mg/L

LTA = mean * (1 - PR99.9)

LTA (Sulfate) 307.099 mg/L

Simulation Results for Book2

Iterations= 10000
Simulations= 1
# Input Variables= 3
# Output Variables= 1
Sampling Type= Monte Carlo
Runtime= 00:00:17
Run on 7/29/2002, 10:19:52 AM

Summary Statistics

Cell	Name	Minimum	Mean	Maximum
B56	PR (Sulfate)	0.00E+00	0.0074587	0.1878236
B12	(Input) Cd (Mn)	1.014909	1.939506	2.893846
B50	(Input) Cd (Sulfate)	125.5223	370.2349	615.6298
B88	(Input) Cd (TDS)	1730.073	1735.051	1739.963

@RISK Simulation of	Run on 7/29/2002, 10:42:50 AM	Simulations= 1	Iterations= 10000	
Name	PR (Sulfate)	Cd (Mn)	Cd (Sulfate)	Cd (TDS)
Description	Output	Triang(1,1.95,2.9)	Triang(124,370,616)	Triang(1730,1735,1740)
Cell	B56	B12	B50	B88
Minimum =	0.00E+00	1.01335	128.5838	1730.125
Maximum =	0.1842018	2.88205	612.8967	1739.963
Mean =	0.007339658	1.952144	368.0015	1735.033
Std Deviation =	0.0259476	3.95E-01	1.01E+02	2.055153
Variance =	6.73E-04	1.56E-01	1.01E+04	4.223654
Skewness =	4.004045	-0.01192721	3.66E-03	-0.03896119
Kurtosis =	19.21648	2.401075	2.378618	2.370514
Errors Calculated =	0	0	0	0
Mode =	0	1.5803	249.7478	1733.928
5% Perc =	0	1.290067	201.8402	1731.546
10% Perc =	0	1.414577	231.0843	1732.222
15% Perc =	0	1.515351	254.9502	1732.743
20% Perc =	0	1.597763	274.6851	1733.16
25% Perc =	0	1.672608	295.6113	1733.58
30% Perc =	0	1.735737	312.3884	1733.917
35% Perc =	0	1.795328	327.8362	1734.239
40% Perc =	0	1.850388	342.7962	1734.531
45% Perc =	0	1.901894	356.0299	1734.797
50% Perc =	0	1.952061	369.193	1735.04
55% Perc =	0	1.999932	381.4581	1735.304
60% Perc =	0	2.052984	394.3373	1735.583
65% Perc =	0	2.111595	408.3851	1735.888
70% Perc =	0	2.172494	423.2242	1736.183
75% Perc =	0	2.236128	439.6718	1736.515
80% Perc =	0	2.305632	458.4966	1736.891
85% Perc =	0	2.387269	479.9227	1737.348
90% Perc =	0.007731131	2.484694	503.8957	1737.82
95% Perc =	0.06567726	2.616839	535.147	1738.435
Filter Minimum =				
Filter Maximum =				
Type (1 or 2) =				
# Values Filtered =	0	0	0	0
Scenario #1 =	>75%			
Scenario #2 =	<25%			
Scenario #3 =	>90%			
Target #1 (Value)=	0.139515951	2.769023418	581.0682983	1739.228516
Target #1 (Perc%)=	99%	99%	99%	99%
Target #2 (Value)=	0.170530647	2.86338377	602.7950439	1739.739014
Target #2 (Perc%)=	99.90%	99.90%	99.90%	99.90%

Simulation Sensitivities for PR (Sulfate) in Cell B56
(From @RISK Simulation of Book2- Run on 7/29/2002, 10:19:52 AM, Simulations= 1, Iterations= 10000)

Rank	Cell	Name	Sensitivity (RSqr=0.2778062)	Rank Correlation Coefficient
#1	B50	Cd (Sulfate)	0.5270733	0.5394289
#2	B12	Cd (Mn)	0	3.14E-03
#3	B88	Cd (TDS)	0	2.32E-02

Simulation Variables for Book2
(From @RISK Simulation of Book2- Run on 7/29/2002, 10:19:52 AM, Simulations= 1, Iterations= 10000)
Outputs:

Cell	Name	Current
B56	PR (Sulfate)	0

Input Variables:

Cell	Name	Current	Worksheet	Formula in Cell
! B12	Cd (Mn)	Triang(1,1.95,2.9)	[IEPA_Monte_Carlo_NCDC01.xls]NCDC01	'=RiskTriang(1,1.95,2.9)
! B50	Cd (Sulfate)	Triang(124,370,616)	[IEPA_Monte_Carlo_NCDC01.xls]NCDC01	'=RiskTriang(124,370,616)
! B88	Cd (TDS)	Triang(1730,1735,1740)	[IEPA_Monte_Carlo_NCDC01.xls]NCDC01	'=RiskTriang(1730,1735,1740)

IEPA
Watershed Load Reductions
9/4/2002

Monte Carlo Simulations using @RISK 3.5

Watershed : NCD03

<u>Sulfate</u>

Cc (Sulfate)	500	mg/L	- Water quality criterion
Cd (Sulfate)	#NAME?	mg/L	- Randomly generated pollutant source concentration based on the observed data

Percent Reduction

PR = Max{ 0, (1-Cc/Cd)}

PR (Sulfate) #NAME?

<u>After Monte-Carlo Simulation:</u>

Percent reduction at the 99th percentile

PR99 (Sulfate) 67.9% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

mean 1439.9 mg/L

LTA = mean * (1 - PR99)

LTA (Sulfate) 461.863 mg/L

Percent reduction at the 99.9th percentile

PR99.9 (Sulfate) 68.3% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

mean 1439.9 mg/L

LTA = mean * (1 - PR99.9)

LTA (Sulfate) 457.134 mg/L

IEPA
Watershed Load Reductions
9/4/2002

Monte Carlo Simulations using @RISK 3.5

Watershed : NCD03

TDS

Cc (TDS)	1000	mg/L	- Water quality criterion
Cd (TDS)	#NAME?	mg/L	- Randomly generated pollutant source concentration based on the observed data

Percent Reduction

PR = Max{ 0, (1-Cc/Cd)}

PR (TDS) #NAME?

After Monte-Carlo Simulation:

Percent reduction at the 99th percentile

PR99 (TDS) 62.9% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

mean 2456.3 mg/L

LTA = mean * (1 - PR99)

LTA (TDS) 910.758 mg/L

Percent reduction at the 99.9th percentile

PR99.9 (TDS) 63.4% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

mean 2456.3 mg/L

LTA = mean * (1 - PR99.9)

LTA (TDS) 899.530 mg/L

Monte Carlo Simulations using @RISK 3.5

Watershed : NCD03

Silver

Cc (Silver)	0.1	mg/L	- Water quality criterion
Cd (Silver)	#NAME?	mg/L	- Randomly generated pollutant source concentration based on the observed data

Percent Reduction

PR = Max{ 0, (1-Cc/Cd)}

PR (Silver) #NAME?

After Monte-Carlo Simulation:

Percent reduction at the 99th percentile

PR99 (Silver) 63.0% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

mean 0.006 mg/L

LTA = mean * (1 - PR99)

LTA (Silver) 0.002 mg/L

Percent reduction at the 99.9th percentile

PR99.9 (Silver) 63.3% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

mean 0.006 mg/L

LTA = mean * (1 - PR99.9)

LTA (Silver) 0.002 mg/L

Simulation Results for Book1

Iterations= 10000
Simulations= 1
# Input Variables= 3
# Output Variables= 2
Sampling Type= Monte Carlo
Runtime= 00:00:19
Run on 8/12/2002, 12:52:34 PM

Summary Statistics

Cell	Name	Minimum	Mean	Maximum
B56	PR (Sulfate)	6.16E-01	0.6522163	0.6832606
B94	PR (TDS)	0.5401503	0.5919709	0.6347642
B132	PR (Silver)	0.5393892	0.5916654	0.633863
B12	(Input) Cd (Mn)	1.008954	1.950247	2.898032
B50	(Input) Cd (Sulfate)	1301.935	1439.923	1578.585
B88	(Input) Cd (TDS)	2174.624	2456.345	2737.957
B126	(Input) Cd (Silver)	3.05E-03	5.52E-03	7.97E-03

@RISK Simulation of	Run on 8/12/2002, 12:52:34 PM	Simulations= 1	Iterations= 10000				
Name	PR (Sulfate)	PR (TDS)	PR (Silver)	Cd (Mn)	Cd (Sulfate)	Cd (TDS)	Cd (Silver)
Description	Output	Output	Output	Triang(1,1.95,2.9)	Triang(1300,1440,1580)	Triang(2170,2455,2740)	Triang(0.003,0.0055,0.008)
Cell	B56	B94	B132	B12	B50	B88	B126
Minimum =	6.16E-01	0.5401503	0.5393892	1.008954	1301.935	2174.624	3.05E-03
Maximum =	0.6832606	0.6347642	0.633863	2.898032	1578.585	2737.957	7.97E-03
Mean =	0.6522163	0.5919709	0.5916654	1.950247	1439.923	2456.345	5.52E-03
Std Deviation =	0.01377303	1.94E-02	1.95E-02	3.89E-01	56.8274	116.4737	1.03E-03
Variance =	1.90E-04	3.78E-04	3.82E-04	1.52E-01	3229.353	13566.13	1.06E-06
Skewness =	-0.1709002	-0.1937089	-0.2055511	-1.57E-02	-0.004388506	9.84E-04	-3.81E-02
Kurtosis =	2.440964	2.413318	2.442044	2.402537	2.400083	2.360185	2.380943
Errors Calculated =	0	0	0	0	0	0	0
Mode =	0.6299853	0.5574053	0.5571359	1.627918	1351.297	2259.403	3.25E-03
5% Perc =	0.6282461	0.5578249	0.5572918	1.29304	1344.976	2261.547	3.78E-03
10% Perc =	0.6332225	0.564826	0.5644231	1.420066	1363.224	2297.932	4.10E-03
15% Perc =	0.6368099	0.5700677	0.5696515	1.514405	1376.689	2325.948	4.36E-03
20% Perc =	0.6399336	0.5746966	0.5740681	1.598293	1388.633	2351.263	4.58E-03
25% Perc =	0.6426572	0.5784995	0.578225	1.670959	1399.217	2372.477	4.77E-03
30% Perc =	0.6449159	0.5819063	0.5817363	1.736604	1408.117	2391.808	4.96E-03
35% Perc =	0.6471516	0.5850066	0.5847393	1.799237	1417.039	2409.677	5.12E-03
40% Perc =	0.6490865	0.5877166	0.5877001	1.857416	1424.853	2425.516	5.26E-03
45% Perc =	0.6509846	0.590253	0.5903959	1.906172	1432.602	2440.53	5.40E-03
50% Perc =	0.6528372	0.5926914	0.5928153	1.95279	1440.247	2455.141	5.54E-03
55% Perc =	0.6545925	0.5954137	0.5949445	2.000293	1447.566	2471.661	5.66E-03
60% Perc =	0.6562637	0.5979577	0.597569	2.050676	1454.604	2487.3	5.80E-03
65% Perc =	0.6582674	0.6004823	0.6002147	2.105186	1463.132	2503.018	5.94E-03
70% Perc =	0.6602374	0.6032713	0.6030515	2.165222	1471.616	2520.615	6.08E-03
75% Perc =	0.6622434	0.6064123	0.6060355	2.228619	1480.356	2540.73	6.25E-03
80% Perc =	0.6645473	0.6097381	0.6092867	2.297441	1490.523	2562.382	6.43E-03
85% Perc =	0.6672909	0.6133691	0.6128455	2.378109	1502.814	2586.446	6.64E-03
90% Perc =	0.6703402	0.6175707	0.6173064	2.47822	1516.715	2614.862	6.90E-03
95% Perc =	0.6742487	0.6228911	0.6227752	2.601214	1534.913	2651.754	7.23E-03
Filter Minimum =							
Filter Maximum =							
Type (1 or 2) =							
# Values Filtered =	0	0	0	0	0	0	0
Scenario #1 =	>75%	>75%	>75%				
Scenario #2 =	<25%	<25%	<25%				
Scenario #3 =	>90%	>90%	>90%				
Target #1 (Value)=	0.679244578	0.629222095	0.629544377	2.763859987	1558.820068	2697.032227	7.63E-03
Target #1 (Perc%)=	99%	99%	99%	99%	99%	99%	99%
Target #2 (Value)=	0.682528853	0.633793473	0.633066118	2.865254879	1574.946289	2730.699707	7.86E-03
Target #2 (Perc%)=	99.90%	99.90%	99.90%	99.90%	99.90%	99.90%	99.90%

Simulation Sensitivities for PR (Sulfate) in Cell B56
(From @RISK Simulation of Book1- Run on 8/12/2002, 12:52:34 PM, Simulations= 1, Iterations= 10000)

Rank	Cell	Name	Sensitivity (RSqr=0.997809)	Rank Correlation Coefficient
#1	B50	Cd (Sulfate)	0.9989039	1
#2	B12	Cd (Mn)	0	-8.99E-03
#3	B88	Cd (TDS)	0	6.26E-03

Simulation Sensitivities for PR (TDS) in Cell B94
(From @RISK Simulation of Book1- Run on 8/12/2002, 12:52:34 PM, Simulations= 1, Iterations= 10000)

Rank	Cell	Name	Sensitivity (RSqr=0.9969245)	Rank Correlation Coefficient
#1	B88	Cd (TDS)	0.9984541	1
#2	B12	Cd (Mn)	0.001575334	4.36E-03
#3	B50	Cd (Sulfate)	0	6.26E-03

Simulation Sensitivities for PR (Silver) in Cell B132
(From @RISK Simulation of IEPA_Monte_Carlo_NCD03.xls- Run on 9/4/2002, 7:29:57 AM, Simulations= 1, Ite

Rank	Cell	Name	Sensitivity (RSqr=0.9968359)	Rank Correlation Coefficient
#1	B88	Cd (TDS)	0.9984167	1
#2	B12	Cd (Mn)	0	-0.0229817
#3	B50	Cd (Sulfate)	0	-1.45E-02
#4	B126	Cd (Silver)	0	1.08E-02

Simulation Variables for Book1
(From @RISK Simulation of Book1- Run on 8/12/2002, 12:52:34 PM, Simulations= 1, Iterations= 10000)
Outputs:

Cell	Name	Current
B56	PR (Sulfate)	0.305555556
B94	PR (TDS)	0.84375
B132	PR (Silver)	0.594395468

Input Variables:

Cell	Name	Current	Worksheet	Formula in Cell
! B12	Cd (Mn)	Triang(1,1.95,2.9)	[IEPA_Monte_Carlo_NCD03.xls]NCD03	'=RiskTriang(1,1.95,2.9)
! B50	Cd (Sulfate)	Triang(1300,1440,1580)	[IEPA_Monte_Carlo_NCD03.xls]NCD03	'=RiskTriang(1300,1440,1580)
! B88	Cd (TDS)	Triang(2170,2455,2740)	[IEPA_Monte_Carlo_NCD03.xls]NCD03	'=RiskTriang(2170,2455,2740)
! B126	Cd (Silver)	Triang(0.003,0.0055,0.008)	[IEPA_Monte_Carlo_NCD03.xls]NCD03	'=RiskTriang(0.003,0.0055,0.008)

IEPA
Watershed Load Reductions
7/18/2002

Monte Carlo Simulations using @RISK 3.5

Watershed : NCD 05

Manganese

Cc (Mn)	1	mg/L	- Water quality criterion
Cd (Mn)	#NAME?	mg/L	- Randomly generated pollutant source concentration based on the observed data

Percent Reduction

PR = Max{ 0, (1-Cc/Cd)}

PR (Mn) #NAME?

After Monte-Carlo Simulation:

Percent reduction at the 99th percentile

PR99 (Mn) 29.2% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

mean 0.9 mg/L

LTA = mean * (1 - PR99)

LTA (Mn) 0.626 mg/L

Percent reduction at the 99.9th percentile

PR99.9 (Mn) 32.2% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

mean 0.9 mg/L

LTA = mean * (1 - PR99.9)

LTA (Mn) 0.600 mg/L

Simulation Results for Book1

Iterations= 10000
Simulations= 1
# Input Variables= 3
# Output Variables= 1
Sampling Type= Monte Carlo
Runtime= 00:00:18
Run on 8/28/2002, 3:29:56 PM

Summary Statistics

Cell	Name	Minimum	Mean	Maximum
B18	PR (Mn)	0.00E+00	0.0438305	0.3304964
B12	(Input) Cd (Mn)	0.2847387	0.8843908	1.493644
B50	(Input) Cd (Sulfate)	124.5628	369.5972	615.2793
B88	(Input) Cd (TDS)	1730.089	1735.017	1739.916

@RISK Simulation of	Run on 8/28/2002, 3:29:56 PM	Simulations= 1	Iterations= 10000	
Name	PR (Mn)	Cd (Mn)	Cd (Sulfate)	Cd (TDS)
Description	Output	Triang(0.27,0.885,1.5)	Triang(124,370,616)	Triang(1730,1735,1740)
Cell	B18	B12	B50	B88
Minimum =	0.00E+00	0.2847387	124.5628	1730.089
Maximum =	0.3304964	1.493644	615.2793	1739.916
Mean =	0.04383053	0.8843908	369.5972	1735.017
Std Deviation =	0.07851655	2.50E-01	1.01E+02	2.055324
Variance =	6.16E-03	6.23E-02	1.02E+04	4.224357
Skewness =	1.730357	-0.01474713	4.90E-03	0.01017349
Kurtosis =	4.821458	2.413383	2.386554	2.389534
Errors Calculated =	0	0	0	0
Mode =	0	0.9359429	270.008	1734.257
5% Perc =	0	0.4643449	201.4335	1731.588
10% Perc =	0	0.5444117	234.0155	1732.224
15% Perc =	0	0.6081992	257.6187	1732.717
20% Perc =	0	0.662121	278.1345	1733.181
25% Perc =	0	0.7073956	295.5607	1733.563
30% Perc =	0	0.748228	313.0963	1733.897
35% Perc =	0	0.7839046	329.2099	1734.193
40% Perc =	0	0.8190789	344.3938	1734.474
45% Perc =	0	0.8541285	357.5081	1734.737
50% Perc =	0	0.8864363	370.1134	1734.99
55% Perc =	0	0.9170353	383.115	1735.26
60% Perc =	0	0.9491075	395.5616	1735.536
65% Perc =	0	0.9857627	409.8639	1735.824
70% Perc =	0.02409158	1.024686	424.186	1736.166
75% Perc =	0.06081351	1.064751	441.4557	1736.516
80% Perc =	0.09781367	1.108418	460.2401	1736.897
85% Perc =	0.1378362	1.159872	481.3211	1737.293
90% Perc =	0.1804381	1.220164	506.8041	1737.785
95% Perc =	0.2289556	1.296942	540.0388	1738.478
Filter Minimum =				
Filter Maximum =				
Type (1 or 2) =				
# Values Filtered =	0	0	0	0
Scenario #1 =	>75%			
Scenario #2 =	<25%			
Scenario #3 =	>90%			
Target #1 (Value)=	0.292467564	1.413362741	579.888855	1739.350952
Target #1 (Perc%)=	99%	99%	99%	99%
Target #2 (Value)=	0.321724892	1.474328041	605.5002441	1739.805786
Target #2 (Perc%)=	99.90%	99.90%	99.90%	99.90%

Simulation Sensitivities for PR (Mn) in Cell B18
(From @RISK Simulation of Book1- Run on 8/28/2002, 3:29:56 PM, Simulations= 1, Iterations= 10000)

Rank	Cell	Name	Sensitivity (RSqr=0.6191396)	Rank Correlation Coefficient
#1	B12	Cd (Mn)	0.7868543	0.8381274
#2	B50	Cd (Sulfate)	0	-4.79E-03
#3	B88	Cd (TDS)	0	-4.40E-03

Simulation Variables for Book1
(From @RISK Simulation of Book1- Run on 8/28/2002, 3:29:56 PM, Simulations= 1, Iterations= 10000)
Outputs:

Cell	Name	Current
B18	PR (Mn)	0.487179487

Input Variables:

Cell	Name	Current	Worksheet	Formula in Cell
! B12	Cd (Mn)	Triang(0.27,0.885,1.5)	[IEPA_Monte_Carlo_NCD05.xls]NCD05	'=RiskTriang(0.27,0.885,1.5)
! B50	Cd (Sulfate)	Triang(124,370,616)	[IEPA_Monte_Carlo_NCD05.xls]NCD05	'=RiskTriang(124,370,616)
! B88	Cd (TDS)	Triang(1730,1735,1740)	[IEPA_Monte_Carlo_NCD05.xls]NCD05	'=RiskTriang(1730,1735,1740)

IEPA
Watershed Load Reductions
7/18/2002

Monte Carlo Simulations using @RISK 3.5

Watershed : NCDB

<u>Manganese</u>

Cc (Mn)	1	mg/L	- Water quality criterion
Cd (Mn)	#NAME?	mg/L	- Randomly generated pollutant source concentration based on the observed data

Percent Reduction

PR = Max{ 0, (1-Cc/Cd)}

PR (Mn) #NAME?

<u>After Monte-Carlo Simulation:</u>

Percent reduction at the 99th percentile

PR99 (Mn) 71.7% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

mean 2.0 mg/L

LTA = mean * (1 - PR99)

LTA (Mn) 0.568 mg/L

Percent reduction at the 99.9th percentile

PR99.9 (Mn) 73.2% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

mean 2.0 mg/L

LTA = mean * (1 - PR99.9)

LTA (Mn) 0.537 mg/L

Monte Carlo Simulations using @RISK 3.5

Watershed : NCDB

Sulfate

Cc (Sulfate)	500	mg/L	- Water quality criterion
Cd (Sulfate)	#NAME?	mg/L	- Randomly generated pollutant source concentration based on the observed data

Percent Reduction

PR = Max{ 0, (1-Cc/Cd)}

PR (Sulfate) #NAME?

After Monte-Carlo Simulation:

Percent reduction at the 99th percentile

PR99 (Sulfate) 45.2% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

mean 672.3 mg/L

LTA = mean * (1 - PR99)

LTA (Sulfate) 368.734 mg/L

Percent reduction at the 99.9th percentile

PR99.9 (Sulfate) 46.5% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

mean 672.3 mg/L

LTA = mean * (1 - PR99.9)

LTA (Sulfate) 359.881 mg/L

Monte Carlo Simulations using @RISK 3.5

Watershed : NCDB

TDS

Cc (TDS)	1000	mg/L	- Water quality criterion
Cd (TDS)	#NAME?	mg/L	- Randomly generated pollutant source concentration based on the observed data

Percent Reduction

PR = Max{ 0, (1-Cc/Cd)}

PR (TDS) #NAME?

After Monte-Carlo Simulation:

Percent reduction at the 99th percentile

PR99 (TDS) 14.4% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

mean 1099.3 mg/L

LTA = mean * (1 - PR99)

LTA (TDS) 941.269 mg/L

Percent reduction at the 99.9th percentile

PR99.9 (TDS) 15.0% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

mean 1099.3 mg/L

LTA = mean * (1 - PR99.9)

LTA (TDS) 934.452 mg/L

Simulation Results for Book1

Iterations= 10000
Simulations= 1
# Input Variables= 3
# Output Variables= 3
Sampling Type= Monte Carlo
Runtime= 00:00:21
Run on 8/28/2002, 7:03:31 AM

Summary Statistics

Cell	Name	Minimum	Mean	Maximum
B18	PR (Mn)	0.00E+00	0.4391932	0.7349734
B56	PR (Sulfate)	0	0.2394605	0.4712317
B94	PR (TDS)	0.020449	0.0895381	0.1518421
B12	(Input) Cd (Mn)	0.2431811	2.005475	3.773207
B50	(Input) Cd (Sulfate)	393.408	672.3365	945.5938
B88	(Input) Cd (TDS)	1020.876	1099.31	1179.026

@RISK Simulation of	Run on 8/28/2002, 7:03:31 AM	Simulations= 1	Iterations= 10000			
Name	PR (Mn)	PR (Sulfate)	PR (TDS)	Cd (Mn)	Cd (Sulfate)	Cd (TDS)
Description	Output	Output	Output	Triang(0.22,2,3.8)	Triang(390,671,952)	Triang(1020,1100,1180)
Cell	B18	B56	B94	B12	B50	B88
Minimum =	0.00E+00	0	0.02044898	0.2431811	393.408	1020.876
Maximum =	0.7349734	0.4712317	0.1518421	3.773207	945.5938	1179.026
Mean =	0.4391932	0.2394605	0.08953808	2.005475	672.3365	1099.31
Std Deviation =	0.214055	1.25E-01	2.70E-02	0.7315464	113.6029	32.57998
Variance =	4.58E-02	1.57E-02	7.30E-04	0.5351602	12905.61	1061.455
Skewness =	-0.8422275	-0.4068316	-1.06E-01	-0.008824988	-2.41E-02	1.98E-02
Kurtosis =	2.578306	2.25322	2.427757	2.36456	2.428046	2.412515
Errors Calculated =	0	0	0	0	0	0
Mode =	0	0	0.06263264	2.5837	628.9387	1038.463
5% Perc =	0	0	0.04246337	0.786069	480.3581	1044.346
10% Perc =	0.01273798	0.0326919	0.0528052	1.012902	516.8984	1055.749
15% Perc =	0.1582461	0.08406994	0.05987051	1.187996	545.8932	1063.683
20% Perc =	0.2513286	0.1232352	0.0650559	1.335699	570.2783	1069.583
25% Perc =	0.3223191	0.1554125	0.07038733	1.475621	592.0049	1075.717
30% Perc =	0.3746996	0.1816477	0.07511751	1.599231	610.9838	1081.218
35% Perc =	0.4145232	0.204528	0.07970165	1.70801	628.5577	1086.604
40% Perc =	0.4482921	0.2239712	0.08337976	1.812554	644.306	1090.964
45% Perc =	0.4780456	0.2418773	0.08682436	1.915876	659.5239	1095.08
50% Perc =	0.5013964	0.2580452	0.09024424	2.005601	673.8955	1099.196
55% Perc =	0.5231324	0.2725941	0.09361516	2.097018	687.3741	1103.284
60% Perc =	0.5460125	0.2892286	0.09728676	2.202704	703.461	1107.771
65% Perc =	0.5658649	0.3034706	0.1005942	2.303431	717.8448	1111.845
70% Perc =	0.5861862	0.3185615	0.1043762	2.416546	733.7419	1116.54
75% Perc =	0.6072755	0.3359984	0.1091518	2.546314	753.0103	1122.526
80% Perc =	0.6258823	0.3537021	0.1140551	2.672956	773.6371	1128.738
85% Perc =	0.6445302	0.3723257	0.1192119	2.813179	796.5915	1135.347
90% Perc =	0.665723	0.3942107	0.1256745	2.991531	825.3695	1143.739
95% Perc =	0.6892384	0.4196314	0.1339115	3.2179	861.5215	1154.616
Filter Minimum =						
Filter Maximum =						
Type (1 or 2) =						
# Values Filtered =	0	0	0	0	0	0
Scenario #1 =	>75%	>75%	>75%			
Scenario #2 =	<25%	<25%	<25%			
Scenario #3 =	>90%	>90%	>90%			
Target #1 (Value)=	0.716796279	0.451563239	0.143763736	3.531027079	911.6821289	1167.901978
Target #1 (Perc%)=	99%	99%	99%	99%	99%	99%
Target #2 (Value)=	0.732462227	0.464731514	0.149965346	3.737789869	934.1106567	1176.422607
Target #2 (Perc%)=	99.90%	99.90%	99.90%	99.90%	99.90%	99.90%

Simulation Sensitivities for PR (Mn) in Cell B18
(From @RISK Simulation of Book1- Run on 8/28/2002, 7:03:31 AM, Simulations= 1, Iterations= 10000)

Rank	Cell	Name	Sensitivity (RSqr=0.9100651)	Rank Correlation Coefficient
#1	B12	Cd (Mn)	0.9539733	0.9995435
#2	B50	Cd (Sulfate)	0	-1.19E-02
#3	B88	Cd (TDS)	0	-1.84E-03

Simulation Sensitivities for PR (Sulfate) in Cell B56
(From @RISK Simulation of Book1- Run on 8/28/2002, 7:03:31 AM, Simulations= 1, Iterations= 10000)

Rank	Cell	Name	Sensitivity (RSqr=0.9765774)	Rank Correlation Coefficient
#1	B50	Cd (Sulfate)	0.9882414	0.9997916
#2	B88	Cd (TDS)	0.002927656	-8.45E-03
#3	B12	Cd (Mn)	0	-1.18E-02

Simulation Sensitivities for PR (TDS) in Cell B94
(From @RISK Simulation of Book1- Run on 8/28/2002, 7:03:31 AM, Simulations= 1, Iterations= 10000)

Rank	Cell	Name	Sensitivity (RSqr=0.9987581)	Rank Correlation Coefficient
#1	B88	Cd (TDS)	0.9993789	1
#2	B12	Cd (Mn)	0.00E+00	-2.21E-03
#3	B50	Cd (Sulfate)	0.00E+00	-8.71E-03

Simulation Variables for Book1
(From @RISK Simulation of Book1- Run on 8/28/2002, 7:03:31 AM, Simulations= 1, Iterations= 10000)
Outputs:

Cell	Name	Current
B18	PR (Mn)	0.626865672
B56	PR (Sulfate)	0
B94	PR (TDS)	0.687108886

Input Variables:

Cell	Name	Current	Worksheet	Formula in Cell
! B12	Cd (Mn)	Triang(0.22,2,3.8)	[IEPA_Monte_Carlo_NCDB.xls]NCDB	'=RiskTriang(0.22,2,3.8)
! B50	Cd (Sulfate)	Triang(390,671,952)	[IEPA_Monte_Carlo_NCDB.xls]NCDB	'=RiskTriang(390,671,952)
! B88	Cd (TDS)	Triang(1020,1100,1180)	[IEPA_Monte_Carlo_NCDB.xls]NCDB	'=RiskTriang(1020,1100,1180)

Appendix D
Rating Curve for Stream Depth

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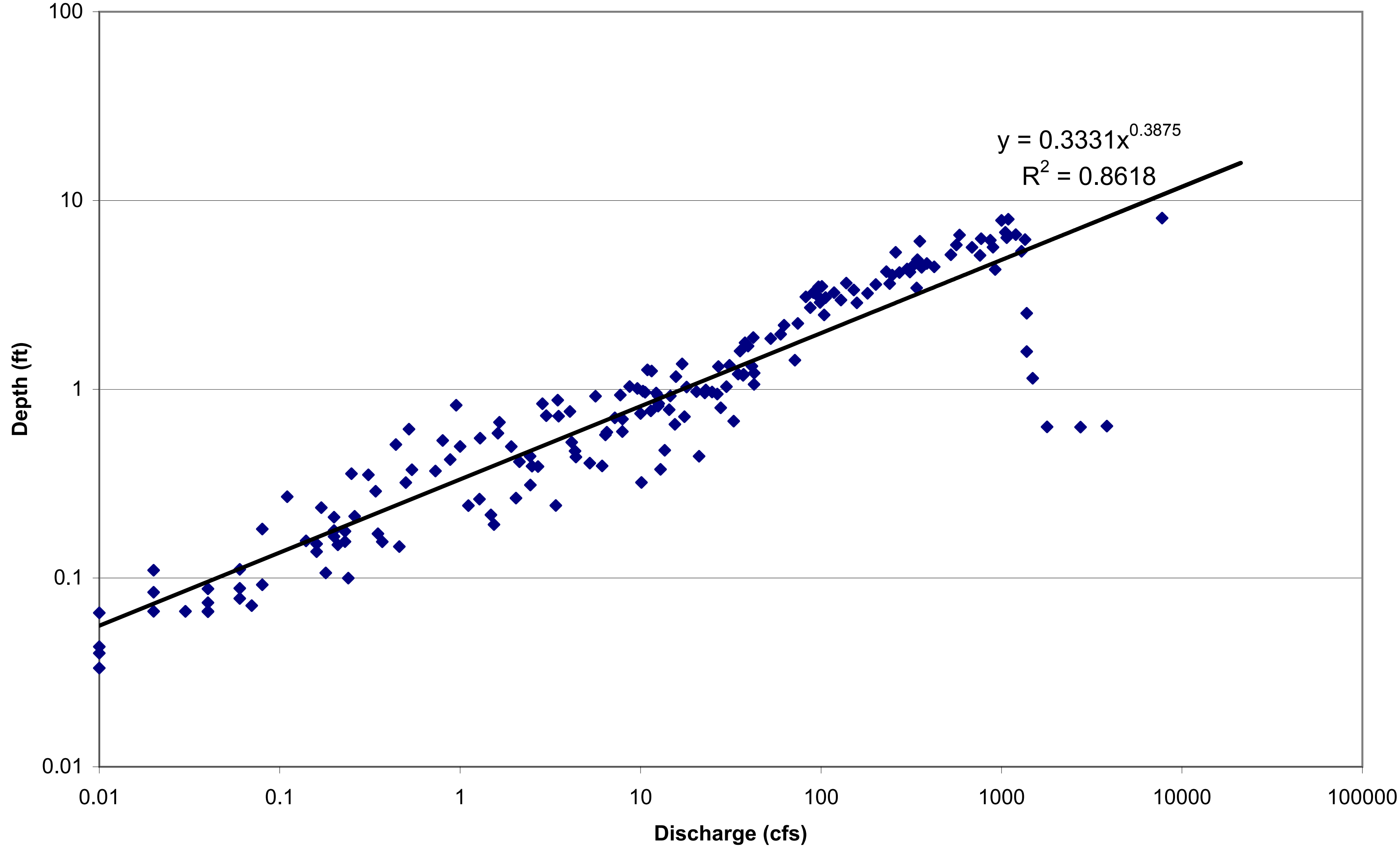
Depth Rating Curve for Bonnie Creek Watershed



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Appendix E
Streeter-Phelps Analyses

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Bonnie Creek Watershed
Aeration Coefficient Summary

Location	Date	DO observed	BOD @ DO observed	Ka @ DO observed	Ka at DO = 6 mg/L
NCD05	8/2/1995	4.1	19.2	5.9	16.74
NCD05	3/4/1996	14.9	---	---	---

Definitions

D	DO Deficit = DO at saturation minus observed DO
D_o	Initial DO deficit
k_a	Reaeration rate
k_d	BOD5 decay rate
x	Distance downstream of discharge
U	Stream velocity
L_o	Initial BOD5 at x=0
C_s	DO at saturation
C	Observed DO
H	Stream depth
T	Stream temperature
Q	Streamflow

Used Q from USGS Derived Flows and H calculated from Q. Kd is temp corrected and Ka is calibrated.

		20 °C	@ T									
D	D_o	k_a	k_a	k_d	x	U	L_o	C_s	C	H	T	Q
mg/L	mg/L	1/day	1/day	1/day	ft	ft/s	mg/L	mg/L	mg/L	ft	°C	cfs
3.88	4	19.65	5.90	1.19	5280	0.8	19.2	8.0	4.1	0.7	26.8	6.47
3.88												

x	y	m	b
25	8.4	-0.16	12.4
30	7.6		

DO @ Temp 8.1

x	y	m	b
0	8.4	-0.0003	8.4
2000	7.8		

Elevation	450	feet
DO @ Elev.	8.3	mg/L
DO Elev Factor	0.98	
DO @ Temp/Elev	8.0	mg/L

Used Q from USGS Derived Flows and H calculated from Q. Kd is temp corrected and Ka is calibrated.

D	D_o	20 °C k_a	@ T k_a	k_d	x	U	L_o	C_s	C	H	T	Q
mg/L	mg/L	1/day	1/day	1/day	ft	ft/s	mg/L	mg/L	mg/L	ft	°C	cfs
1.98	4	19.65	16.74	1.19	5280	0.8	19.2	8.0	6	0.7	26.8	6.47
1.98												

x	y	m	b	
	25	8.4	-0.16	12.4
	30	7.6		

DO @ Temp 8.1

x	y	m	b	
	0	8.4	-0.0003	8.4
	2000	7.8		

Elevation	450	feet
DO @ Elev.	8.3	mg/L
DO Elev Factor	0.98	
DO @ Temp/Elev	8.0	mg/L

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Appendix F
Error Analyses

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F.1 Monte Carlo Analysis Development and Results

This appendix provides the results of the Monte-Carlo DO error analysis. The analysis was run on the range of possible values for the BOD_5 decay rate coefficient (k_d) and the reaeration rate coefficient (k_a). The Monte-Carlo program requires a distribution of k_a and k_d values. For each impaired DO sample date, a triangle distribution was chosen to analyze segment NCD05 since data for this site was extremely limited.

Each impaired DO sample date was evaluated separately using @RISK, which is a Microsoft® *Excel* Add-in for the Monte-Carlo analysis. The @RISK analysis package performed 10,000 iterations to determine the range of possible DO predictions over 10,000 combinations of randomly selected k_a and k_d values.

A triangular distribution assumes that the values of a given data set are most often at or near the mode and linearly distributed to the minimum and maximum values. The minimum is the smallest concentration of the sample data set. The maximum value is the largest sample in the sample data set. The mode is the value that is most likely to be observed in a long time series of sample data. Water quality data were not available to determine the actual k_a and k_d, so the estimated values discussed in Section 7.3 and shown in Table 7-6 were used as the mode for each sample date.

In order to define a more appropriate distribution than triangular, more data needs to be collected. In the absence of any drift, or non-random error, 10 samples can be used to define a distribution. As the data set increases, so does the ability to define an appropriate distribution, such a lognormal, normal, etc. The number of samples needed to define the true data distribution depends upon the severity of the drift.

The Monte Carlo simulation was run using 10,000 iterations with the triangular distribution. For each iteration, a DO concentration is randomly generated according to random sampling of the triangular distribution of k_a and k_d. The output of the Monte-Carlo simulation is a population of 10,000 DO concentrations that could be observed across the literature range of k_a and k_d values. Statistics were performed on the Monte-Carlo output to determine the 95^{th} and 99.9^{th} percentile confidence intervals. A confidence interval means that the stated percent of the simulated concentrations fall within the low and high concentrations of the interval.

This appendix shows the set-up for the Monte-Carlo simulation for each impaired sample date, a summary of the output, and the 95^{th} and 99.9^{th} percentile confidence intervals for each impaired sample date.

	Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column I	Column J
	D	D_o	x	U	L_o	D_s	DO_{obs}	Q		
	mg/L	mg/L	ft	ft/s	mg/L	mg/L	mg/L	cfs	Ka	Kd
Row 3	=F3-G3	4	5280	0.8	19.2	8.0	4.1	6.5	=RiskTriang(0.01,5.9,100)	=RiskTriang(0.02,1.19,3.4)

DO= =$F$3-(($B$3*EXP((-$I$3*$C$3)/($D$3*86400)))+($E$3*$J$3/($I$3-$J$3))*(EXP(-$J$3*$C$3/($D$3*86400))-EXP(-$I$3*$C$3/($D$3*86400))))

Summary of Monte Carlo Results

	DO	Ka	Kd
Minimum =	-0.03	0.11	0.04
Maximum =	7.97	99.51	3.38
Mean =	6.36	35.17	1.55
Std Deviation =	1.40	23.06	0.70
Variance =	1.95	531.57	0.49
Skewness =	-1.26	0.56	0.28
Kurtosis =	3.99	2.39	2.41
Errors Calculated =	0.00	0.00	0.00
Mode =	6.21	16.49	1.18

95th Percent Confidence Interval

3.6	9.1

99.9th Percent Confidence Interval

1.7	11.0

Appendix G
Watershed Management Model (WMM) Analyses

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G.1 Watershed Management Model (WMM)

As discussed in Sections 6.2.1.1 and 7.3, the WMM model was run as a screening tool to assess the BOD_5 loads that are typically generated annually for the watershed. This appendix provides the output files from the WMM analysis for each sampled date in the Bonnie Creek Watershed and for the average annual precipitation event.

The output tables in this appendix use the following column headings. They are defined as follows:

Baseflow - Annual dry weather flow (cfs/sq. mile)
Point Source - Wastewater Treatment Plant or industrial process wastewater discharge
ISDS – Individual septic disposal system
Agriculture - Agriculture or pasture land
COM - Office or commercial land
Extractive - Mining type land use
Farm - Small or medium farm land
IND - Light to heavy industrial land
Institutional - University, school, or institution
Roads - Highways or surface roads
Water - Rivers, lakes, or wetlands
Forest - Forest land
Res High - High density residential land
Res Med - Medium density residential land
Urban Open - Urban open space
Vacant – Urban land with no development
LU1 - User defined land use
LU2 - User defined land use

TABLE 1-A
BONNIE CREEK WATERSHED
AVERAGE BONNIE CREEK LOADS BY SUBBASIN
ANNUAL

Constituent	(units)	Basin	Jurisdiction	Baseflow	Point Source	ISDS	Agriculture	COM	Extractive	Farm	IND	Institutional	Roads	Water	Forest	Res High	Res Med	Urban Open	Vacant	LU1	LU2	Total
Runoff	(ac-ft/yr)	Bonnie Creek	Perry	0	0	0	44	0	0	0	0	0	0	21	37	0	0	0	0	0	0	102
BOD	(lbs/yr)	Bonnie Creek	Perry	0	0	0	948	0	0	0	0	0	0	0	202	1	17	0	0	0	0	1,168
COD	(lbs/yr)	Bonnie Creek	Perry	0	0	0	6,040	0	0	0	0	0	0	0	5,147	7	99	3	0	0	0	11,298
TSS	(lbs/yr)	Bonnie Creek	Perry	0	0	0	37,901	0	0	0	0	0	0	0	8,801	3	38	6	0	0	0	46,748
TDS	(lbs/yr)	Bonnie Creek	Perry	0	0	0	11,844	0	0	0	0	0	0	0	10,093	9	120	7	0	0	0	22,072
Total-P	(lbs/yr)	Bonnie Creek	Perry	0	0	0	303	0	0	0	0	0	0	2	12	0	0	0	0	0	0	318
Dissolved-P	(lbs/yr)	Bonnie Creek	Perry	0	0	0	11	0	0	0	0	0	0	2	3	0	0	0	0	0	0	16
Total-N	(lbs/yr)	Bonnie Creek	Perry	0	0	0	1,090	0	0	0	0	0	0	58	131	0	1	0	0	0	0	1,280
TKN	(lbs/yr)	Bonnie Creek	Perry	0	0	0	550	0	0	0	0	0	0	34	36	0	1	0	0	0	0	620
NO2+NO3	(lbs/yr)	Bonnie Creek	Perry	0	0	0	540	0	0	0	0	0	0	25	94	0	0	0	0	0	0	659
Lead	(lbs/yr)	Bonnie Creek	Perry	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	3
Copper	(lbs/yr)	Bonnie Creek	Perry	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Zinc	(lbs/yr)	Bonnie Creek	Perry	0	0	0	0	0	0	0	0	0	0	3	9	0	0	0	0	0	0	12
Manganese	(lbs/yr)	Bonnie Creek	Perry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 1-A
BONNIE CREEK WATERSHED
AVERAGE BONNIE CREEK LOADS BY SUBBASIN
ANNUAL

Constituent	(units)	Basin	Jurisdiction	Baseflow	Point Source	ISDS	Agriculture	COM	Extractive	Farm	IND	Institutional	Roads	Water	Forest	Res High	Res Med	Urban Open	Vacant	LU1	LU2	Total
Runoff	(ac-ft/yr)	Bonnie Creek	Perry	0	0	0	139	0	0	0	0	0	0	67	119	0	1	0	0	0	0	326
BOD	(lbs/yr)	Bonnie Creek	Perry	0	0	0	3,032	0	0	0	0	0	0	0	646	4	54	0	0	0	0	3,736
COD	(lbs/yr)	Bonnie Creek	Perry	0	0	0	19,330	0	0	0	0	0	0	0	16,471	24	318	11	0	0	0	36,153
TSS	(lbs/yr)	Bonnie Creek	Perry	0	0	0	121,284	0	0	0	0	0	0	0	28,162	9	120	19	0	0	0	149,594
TDS	(lbs/yr)	Bonnie Creek	Perry	0	0	0	37,901	0	0	0	0	0	0	0	32,296	28	383	21	0	0	0	70,630
Total-P	(lbs/yr)	Bonnie Creek	Perry	0	0	0	970	0	0	0	0	0	0	7	39	0	0	0	0	0	0	1,017
Dissolved-P	(lbs/yr)	Bonnie Creek	Perry	0	0	0	34	0	0	0	0	0	0	7	10	0	1	0	0	0	0	52
Total-N	(lbs/yr)	Bonnie Creek	Perry	0	0	0	3,487	0	0	0	0	0	0	186	418	0	4	0	0	0	0	4,096
TKN	(lbs/yr)	Bonnie Creek	Perry	0	0	0	1,759	0	0	0	0	0	0	108	116	0	3	0	0	0	0	1,985
NO2+NO3	(lbs/yr)	Bonnie Creek	Perry	0	0	0	1,728	0	0	0	0	0	0	79	302	0	1	0	0	0	0	2,110
Lead	(lbs/yr)	Bonnie Creek	Perry	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	11
Copper	(lbs/yr)	Bonnie Creek	Perry	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	4
Zinc	(lbs/yr)	Bonnie Creek	Perry	0	0	0	0	0	0	0	0	0	0	10	27	0	0	0	0	0	0	37
Manganese	(lbs/yr)	Bonnie Creek	Perry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 1-A
BONNIE CREEK WATERSHED
AVERAGE BONNIE CREEK LOADS BY SUBBASIN
ANNUAL

Constituent	(units)	Basin	Jurisdiction	Baseflow	Point Source	ISDS	Agriculture	COM	Extractive	Farm	IND	Institutional	Roads	Water	Forest	Res High	Res Med	Urban Open	Vacant	LU1	LU2	Total
Runoff	(ac-ft/yr)	Bonnie Creek	Perry	0	0	0	174	0	0	0	0	0	0	83	148	0	2	0	0	0	0	408
BOD	(lbs/yr)	Bonnie Creek	Perry	0	0	0	3,790	0	0	0	0	0	0	0	807	5	68	1	0	0	0	4,671
COD	(lbs/yr)	Bonnie Creek	Perry	0	0	0	24,162	0	0	0	0	0	0	0	20,589	29	398	14	0	0	0	45,192
TSS	(lbs/yr)	Bonnie Creek	Perry	0	0	0	151,605	0	0	0	0	0	0	0	35,203	11	150	23	0	0	0	186,992
TDS	(lbs/yr)	Bonnie Creek	Perry	0	0	0	47,376	0	0	0	0	0	0	0	40,370	35	479	27	0	0	0	88,288
Total-P	(lbs/yr)	Bonnie Creek	Perry	0	0	0	1,213	0	0	0	0	0	0	9	49	0	1	0	0	0	0	1,271
Dissolved-P	(lbs/yr)	Bonnie Creek	Perry	0	0	0	43	0	0	0	0	0	0	9	12	0	1	0	0	0	0	65
Total-N	(lbs/yr)	Bonnie Creek	Perry	0	0	0	4,359	0	0	0	0	0	0	233	523	1	5	0	0	0	0	5,120
TKN	(lbs/yr)	Bonnie Creek	Perry	0	0	0	2,198	0	0	0	0	0	0	134	145	0	3	0	0	0	0	2,482
NO2+NO3	(lbs/yr)	Bonnie Creek	Perry	0	0	0	2,160	0	0	0	0	0	0	98	377	0	1	0	0	0	0	2,638
Lead	(lbs/yr)	Bonnie Creek	Perry	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	14
Copper	(lbs/yr)	Bonnie Creek	Perry	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	5
Zinc	(lbs/yr)	Bonnie Creek	Perry	0	0	0	0	0	0	0	0	0	0	12	34	0	0	0	0	0	0	47
Manganese	(lbs/yr)	Bonnie Creek	Perry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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ANNUAL

Constituent	(units)	Basin	Jurisdiction	Baseflow	Point Source	ISDS	Agriculture	COM	Extractive	Farm	IND	Institutional	Roads	Water	Forest	Res High	Res Med	Urban Open	Vacant	LU1	LU2	Total
Runoff	(ac-ft/yr)	Bonnie Creek	Perry	0	0	0	348	0	0	0	0	0	0	167	297	0	4	0	0	0	0	816
BOD	(lbs/yr)	Bonnie Creek	Perry	0	0	0	7,580	0	0	0	0	0	0	0	1,615	10	135	1	0	0	0	9,341
COD	(lbs/yr)	Bonnie Creek	Perry	0	0	0	48,324	0	0	0	0	0	0	0	41,178	59	795	27	0	0	0	90,383
TSS	(lbs/yr)	Bonnie Creek	Perry	0	0	0	303,209	0	0	0	0	0	0	0	70,406	22	301	46	0	0	0	373,984
TDS	(lbs/yr)	Bonnie Creek	Perry	0	0	0	94,753	0	0	0	0	0	0	0	80,741	71	958	53	0	0	0	176,576
Total-P	(lbs/yr)	Bonnie Creek	Perry	0	0	0	2,426	0	0	0	0	0	0	19	97	0	1	0	0	0	0	2,543
Dissolved-P	(lbs/yr)	Bonnie Creek	Perry	0	0	0	85	0	0	0	0	0	0	18	24	0	3	0	0	0	0	130
Total-N	(lbs/yr)	Bonnie Creek	Perry	0	0	0	8,717	0	0	0	0	0	0	466	1,045	1	9	1	0	0	0	10,239
TKN	(lbs/yr)	Bonnie Creek	Perry	0	0	0	4,397	0	0	0	0	0	0	269	290	1	7	0	0	0	0	4,963
NO2+NO3	(lbs/yr)	Bonnie Creek	Perry	0	0	0	4,321	0	0	0	0	0	0	197	755	0	3	0	0	0	0	5,276
Lead	(lbs/yr)	Bonnie Creek	Perry	0	0	0	0	0	0	0	0	0	0	1	27	0	0	0	0	0	0	28
Copper	(lbs/yr)	Bonnie Creek	Perry	0	0	0	0	0	0	0	0	0	0	1	10	0	0	0	0	0	0	11
Zinc	(lbs/yr)	Bonnie Creek	Perry	0	0	0	0	0	0	0	0	0	0	24	69	0	1	0	0	0	0	94
Manganese	(lbs/yr)	Bonnie Creek	Perry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 1-A
BONNIE CREEK WATERSHED
AVERAGE BONNIE CREEK LOADS BY SUBBASIN
ANNUAL

Constituent	(units)	Basin	Jurisdiction	Baseflow	Point Source	ISDS	Agriculture	COM	Extractive	Farm	IND	Institutional	Roads	Water	Forest	Res High	Res Med	Urban Open	Vacant	LU1	LU2	Total
Runoff	(ac-ft/yr)	Bonnie Creek	Perry	0	0	0	19,470	0	0	0	0	0	0	9,321	16,591	15	197	11	0	0	0	45,604
BOD	(lbs/yr)	Bonnie Creek	Perry	0	0	0	423,546	0	0	0	0	0	0	0	90,228	559	7,550	59	0	0	0	521,942
COD	(lbs/yr)	Bonnie Creek	Perry	0	0	0	2,700,103	0	0	0	0	0	0	0	2,300,806	3,292	44,443	1,517	0	0	0	5,050,161
TSS	(lbs/yr)	Bonnie Creek	Perry	0	0	0	16,941,821	0	0	0	0	0	0	0	3,933,928	1,244	16,792	2,594	0	0	0	20,896,378
TDS	(lbs/yr)	Bonnie Creek	Perry	0	0	0	5,294,319	0	0	0	0	0	0	0	4,511,385	3,966	53,546	2,975	0	0	0	9,866,191
Total-P	(lbs/yr)	Bonnie Creek	Perry	0	0	0	135,535	0	0	0	0	0	0	1,038	5,428	8	67	4	0	0	0	142,080
Dissolved-P	(lbs/yr)	Bonnie Creek	Perry	0	0	0	4,765	0	0	0	0	0	0	1,014	1,353	11	145	1	0	0	0	7,288
Total-N	(lbs/yr)	Bonnie Creek	Perry	0	0	0	487,077	0	0	0	0	0	0	26,022	58,395	60	511	39	0	0	0	572,105
TKN	(lbs/yr)	Bonnie Creek	Perry	0	0	0	245,656	0	0	0	0	0	0	15,024	16,223	40	371	11	0	0	0	277,324
NO2+NO3	(lbs/yr)	Bonnie Creek	Perry	0	0	0	241,421	0	0	0	0	0	0	10,999	42,172	20	141	28	0	0	0	294,781
Lead	(lbs/yr)	Bonnie Creek	Perry	0	0	0	0	0	0	0	0	0	0	31	1,511	1	14	1	0	0	0	1,558
Copper	(lbs/yr)	Bonnie Creek	Perry	0	0	0	0	0	0	0	0	0	0	36	569	0	3	0	0	0	0	608
Zinc	(lbs/yr)	Bonnie Creek	Perry	0	0	0	0	0	0	0	0	0	0	1,355	3,836	5	35	3	0	0	0	5,234
Manganese	(lbs/yr)	Bonnie Creek	Perry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix H
Responsiveness Summary

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Responsiveness Summary

This responsiveness summary responds to substantive questions and comments received during the public comment period from January 23 to March 29, 2004 postmarked, including those from the February 25, 2004 public meeting discussed below.

What is a TMDL?

A Total Maximum Daily Load (TMDL) is the sum of the allowable amount of a pollutant that a water body can receive from all contributing sources and still meet water quality standards or designated uses. The Bonnie Creek TMDL report contains a plan detailing the actions necessary to reduce pollutant loads to the impaired water bodies and ensure compliance with applicable water quality standards. The Illinois EPA implements the TMDL program in accordance with Section 303(d) of the federal Clean Water Act and regulations thereunder.

Background

The watershed targeted for TMDL development is Bonnie Creek (ILNCD01), which originates in western Perry County, Illinois. The watershed encompasses an area of approximately 102 square miles. Land use in the watershed is predominately agriculture followed by grasses and forested land uses. TMDLs developed for impaired waterbodies in the Bonnie Creek watershed include Bonnie Creek segment NCDC01, Galum Creek segments NCD05 and NCD03, and Little Galum Creek NCDB. In the 1998 Section 303(d) List, and subsequent 2002 303(d) List, Bonnie Creek (NCDC01) was listed as impaired for sulfates and other habitat alterations; Galum Creek (NCD03) was listed for silver, sulfates, siltation, total dissolved solids (TDS), and other habitat alterations; Galum Creek (NCD05) was listed for manganese, low dissolved oxygen (DO), and other habitat alterations; Little Galum Creek (NCDB) was listed for manganese, sulfates, TDS, and other habitat alterations. The Clean Water Act and USEPA regulations require that states develop TMDLs for waters on the Section 303(d) List. Illinois EPA is currently developing TMDLs for pollutants that have numeric water quality standards. Therefore, TMDLs were only developed for the following: Bonnie Creek (NCDC01): sulfates; Galum Creek (NCD03): silver, sulfates, and TDS; Galum Creek (NCD05): manganese, DO; Little Galum Creek (NCDB): manganese, sulfates, and TDS. The Illinois EPA contracted with Camp Dresser & McKee (CDM) to prepare a TMDL report for the Bonnie Creek watershed.

Public Meetings

Public meetings were held in the city of Springfield on June 5, 2001 and in the city of Pinkneyville on December 13, 2001 and February 25, 2004. The Illinois EPA provided public notice for the February 25, 2004 meeting by placing display ads in the Southern Illinoisan and DuQuoin Evening Call on January 27, 2004 and The Democrat and Sparta News Plaindealer on January 25, 2005. This notice gave the date, time, location, and purpose of the meeting. The notice also provided references to obtain additional information about this specific site, the TMDL Program and other related issues. Approximately 35 individuals and organizations were sent the public notice by first class mail. The draft TMDL Report was available for review at the Pinkneyville Community High School office and also on the Agency's web page at http://www.epa.state.il.us/water/tmdl .

The final public meeting started at 8:00 p.m. on Wednesday, February 25, 2004. It was attended by approximately 10 people and concluded at 9:25 p.m. with the meeting record remaining open until midnight, March 29, 2004.

Questions and Comments

1. The data used in the analysis were collected several years ago. The water quality could have changed since then. Haven't newer data been taken?

Response: In 2003, samples were collected at two stations on Galum Creek (NCD-05 and NCD-07), and one station on Pipestone Creek (NCDA-01). No new data has been collected on other streams in this watershed.

2. Do manganese, sulfates, and silver settle to the bottom of the stream or stay in the water and get flushed downstream?

Response: Both can occur as the metals bind to sediment within the water column or stay in a dissolved form and move downstream.

3. Did the impairments occur only during rainstorms or during low flow conditions?

Response: All of the impairments were based on samples taken during low flow conditions.

4. Some of the mines have pits that overflow and end up in nearby fields, leaving black sediment behind. Could this be a source of contamination?

Response: If the metals of concern are bound to the sediment, this could be a source of contamination within the watershed. However, the data submitted to the state on a monthly basis by the permitted mines suggest that the mines are in compliance with their effluent limits. And analysis shows that their effluent does not contribute the majority of the load of these metals within the watershed.

5. Were samples taken from the impaired segments before 1995?

Response: It is possible that other agencies or individuals collected data from these streams before 1995; however, the Illinois EPA did not. No data prior to 1995 were used in the assessment process which placed these impaired segments on the 303d List.

6. Studies have been done in the past for Bonnie Creek and Galum Creek when they were channelized. This channelization can impact water quality.

Response: We concur with this statement and as mining areas are reclaimed and stream segments restored this should improve water quality over time. Several segments in this watershed were identified as impaired due to habitat alteration (i.e. channelization). Since no standard exists for this, we believe that conducting a TMDL without a properly adopted standard would be problematic. We are interested in habitat improvement proposals that the Agency could participate in or fund.

7. What happens once this report is sent to USEPA?

Response: The report will be reviewed by USEPA. Once approved, a final version of the report will be printed and made available to the public. It is the Agency's hope that local groups will work together to begin implementing the management measures described in the Implementation Plan of the report and those dealing with related problems (see our response to #6).

8. The report is based on old data, and doesn't address changes that have since occurred within the watershed, such as re-channalization, mines closing, etc. How can this report be approved without taking new data?

Response: The scope of the TMDL study was to use readily available data. Maps provided by Illinois EPA mines program were used by the consultant to produce GIS maps. These maps represent the most recent re-channalization and incline/final cut lakes in the watershed. Land use data were not a component of the methodologies used to calculate the pollutant load reductions, so the location of channels would not have impacted the load analysis. Discharge data, currently available for permitted mines operating within the watershed, were reviewed. The Implementation Plan includes a monitoring plan listing additional data needs that could be taken to effectively identify locations for implementation activities.

9. Why does it take so long for the report to be generated from the time the data are taken?

Response: Once a water sample is taken it must be analyzed in a lab, with certain methods followed, to assure that the sample was taken and analyzed properly. The data are assessed every two years, so there is a lag between the time the data are taken to the time the data are assessed. The Agency's TMDL program has only been developing TMDLs for the last few years. The TMDL study for the Bonnie Creek watershed began in 2001 and was based on the 1998 303(d) List, which was based on data taken through 1996.

10. Pollutants that are caused by abandoned mines cannot be remedied by individual landowners, so how will the problems be taken care of?

Response: The Agency is willing to address the causes of impairment by cooperating with other agencies and landowners on projects that will reduce pollutant loads. As identified in the report, funds are available if local partners and projects can be identified.

11. The report fails to state that much of the abandoned mining land in the watershed is owned by the State of Illinois. Since it is owned by the State, is it exempt from regulations?

Response: If requested, Illinois EPA will work with local groups to identify areas of the watershed that are owned by the State. It is NOT correct, however, that State owned property is exempt from following State laws and regulations. State owned lands are subject to the same terms for meeting water quality standards as private property. In general, the discharges associated with these properties are not regulated. They are produced by rain-fall runoff and must be addressed by voluntary means.

12. Was it investigated whether manganese is naturally occurring and not caused by mines? Some farmers have naturally high manganese levels in their soil tests in areas that do not have mining.

Response: The report indicates that naturally occurring manganese could be a source of pollution within the watershed in addition to abandoned mine contribution and point sources of mine effluent.

DISTRIBUTION OF RESPONSIVENESS SUMMARY

Additional copies of this responsiveness summary are available from Mark Britton, Illinois EPA Office of Community Relations, phone 217-524-7342 or email Mark.Britton@epa.state.il.us

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Questions regarding the public record and access of the exhibits should be directed to Hearing Officer Sanjay Sofat, 217-782-5544.

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