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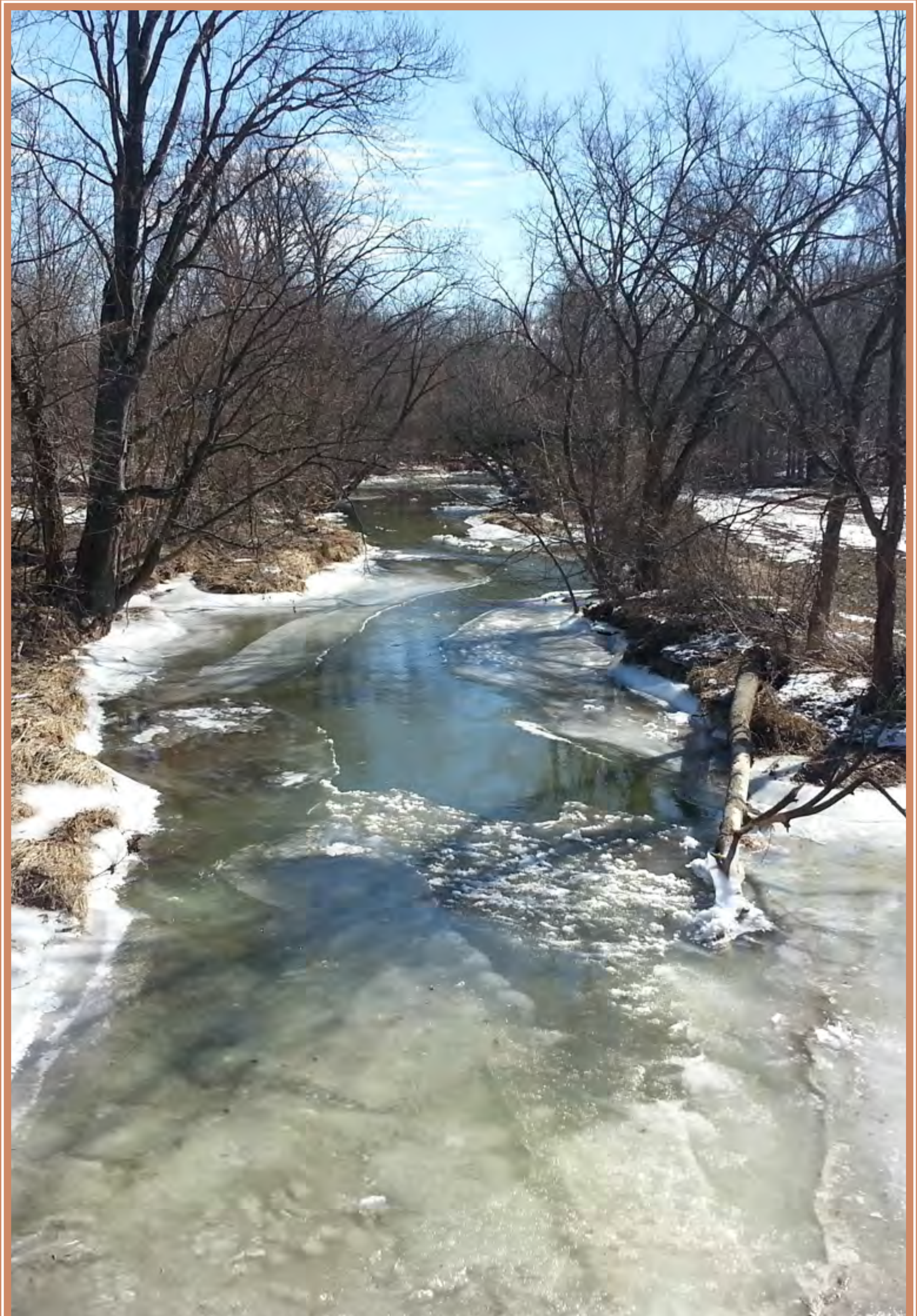

Watershed Management Plan for the Deer Creek-Sugar Creek Watershed

Carroll, Cass, Howard, Miami, & Tippecanoe Counties

December 2015

Project Contributors:

Carroll County Soil and Water Conservation District
The Wabash River Enhancement Corporation

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ACRONYM LIST

APC	Area Planning Commission
BFE	Base Flood Elevation
BMP	Best Management Practice
CFO	Confined Feeding Operation
CQHEI	Citizen Qualitative Habitat Evaluation Index
CR	County Road
CWP	Center for Watershed Protection
E. coli	*Escherichia coli*
FCA	Fish Consumption Advisory
GIS	Geographic Information Systems
HES	Highly Erodible Soils
HUC	Hydrologic Unit Code
IBI	Index of Biotic Integrity
IBC	Impaired Biotic Community
IDDE	Illicit Discharge Detection and Elimination
IDEM	Indiana Department of Environmental Management
IDNR	Indiana Department of Natural Resources
INDOT	Indiana Department of Transportation
ISDA	Indiana State Department of Agriculture
IWMA	Integrated Water Monitoring Assessment
kg	Kilograms
L	Liters
lb	Pounds
LUST	Leaking Underground Storage Tank
MCM	Minimum Control Measure
mg	Milligrams
MGD	Million Gallons per Day
NASS	National Agricultural Statistics Service
NRCS	Natural Resources Conservation Service
NWI	National Wetland Inventory
PCB	Polychlorinated Biphenyls
PHES	Potentially Highly Erodible Soils
ppm	Parts per million
QHEI	Qualitative Habitat Evaluation Index
RC&D	Resource Conservation and Development
STP	Sewage Treatment Plant
RM	River Mile
SWCD	Soil and Water Conservation District
µg	Micrograms
USGS	United States Geological Survey
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
WMP	Watershed Management Plan
WQS	Water Quality Standard
WREC	Wabash River Enhancement Corporation

1.0 WATERSHED COMMUNITY INITIATIVE

A watershed is the land area that drains to a common point, such as a location on a river. All of the water that falls on a watershed will move across the landscape collecting in low spots and drainage ways until it moves into the waterbody of choice. All activities that take place in a watershed can impact the water quality of the river that drains it. What we do on the land, such as constructing new buildings, fertilizing lawns, or growing crops, affects the water and the ecosystem that lives in it. A healthy watershed is vital for a healthy river, and a healthy river can enhance the community and helps maintain a healthy local economy. Watershed planning is especially important in that it will help communities and individuals determine how best to preserve water functions, prevent water quality impairment, and produce long-term economic, environmental, and political health.

The Deer Creek–Sugar Creek watershed includes portions of Carroll, Cass, Howard, Miami, and Tippecanoe Counties. All of the tributaries eventually drain into the Wabash River. The watershed of interest includes the area that drains into the Wabash River from Deer Creek, Sugar Creek, and Buck Creek. The Deer Creek watershed drains into the Wabash River approximately a mile before entering Tippecanoe County (from Carroll County). Sugar and Buck creeks flow into the Wabash River within Tippecanoe County. This watershed totals 345 square miles.

By managing and improving the Deer Creek-Sugar Creek watershed, we can do our part to improve water quality in the Wabash River. The following section details the history of the projects including funding details, project purposes, and stakeholder involvement as part of the Deer Creek – Sugar Creek Watershed Management Plan.

1.1 Project History

E. coli, impaired biotic communities, nutrients, PCBs, and mercury have been persistent problems in the Deer Creek-Sugar Creek watershed. The 2010 and the draft 2012 IDEM 303(d) lists identified several streams within the watershed with impairments: Buck Creek, Bachelor Run-Kuns Ditch, Deer Creek, Guckien-Cohee Ditch, Hughes Ditch, Little Deer Creek, Little Sugar Creek, Paint Creek, Price Plank Ditch, Shirar Ditch, Sugar Creek, and unnamed tributaries for *E. coli*; Buck Creek Ditch, Buck Creek and its tributaries, and the Wabash River for impaired biotic communities; Deer Creek, Little Deer Creek, and the Wabash River for nutrients; Deer Creek and the Wabash River for PCBs and mercury in fish tissue. Because of these impairments, a water management plan is needed to get the levels of these four parameters within state suggested ranges.

In the fall of 2010, the Carroll County Soil and Water Conservation District submitted a Section 319 Non-point Source Program grant application to the Indiana Department of Environmental Management (IDEM) watershed planning section. Concurrent with grant submission, identification of watershed partners occurred. Many of these initial partners became part of the project steering committee. The grant was awarded in April 2011 and signed in April 2012.The grant’s purpose was fivefold:

1. To produce a watershed management plan for the Deer Creek–Sugar Creek watershed (Figure 1);
2. To provide education and outreach to the watershed community;
3. To assess stakeholder opinions and provide educational opportunities;

4. To monitor water quality within Deer Creek, Sugar Creek, and their tributaries with hopes of showing a measurable improvement (change) in water quality during the implementation phase of the project; and
5. To develop and implement a cost-share program.

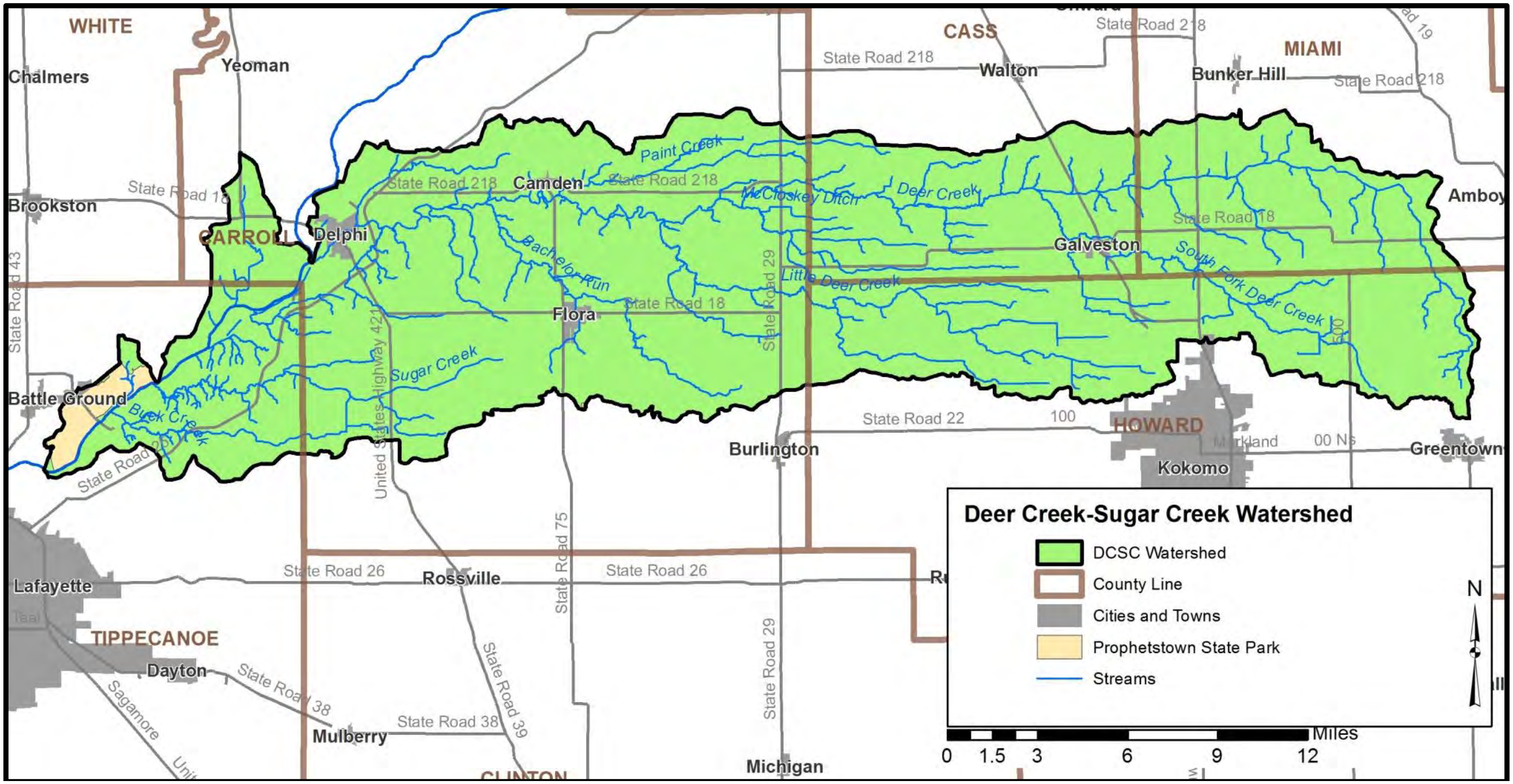

Figure 1. Deer Creek – Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

Once the contract was signed, the Carroll County Soil and Water Conservation District subcontracted with the Wabash River Enhancement Corporation to coordinate and complete all aspects of this grant. WREC staff was responsible for writing the watershed management plan with input and insight from the watershed partners and steering committee members. Additionally, WREC staff was responsible for guiding plan development, coordinating and facilitating committee meetings, and planning and implementing water quality and watershed information gathering. Purdue University was responsible for current water quality data collection and data analysis and stakeholder surveys.

Development of the Deer Creek–Sugar Creek watershed management plan was a community driven process and involved a diverse group of local citizens, experts, organizations, and community leaders. The following sections detail the committees created as part of this project, the work these committees completed, and the outcomes developed by the committees. Additionally, input from watershed stakeholders and the mechanisms in which this input was generated are also included in the following sections. All of these efforts were guided by the following mission and vision developed by public participants and committee members:

Mission: Communities working together to develop a roadmap of solutions to become better stewards of land, water, and wildlife in the Deer Creek-Sugar Creek watershed.

Vision: An improved watershed with healthy streams, diverse wildlife, and sustainable agricultural practices.

1.2 Stakeholder Involvement

Development of a watershed management plan requires input from interested citizens, local government leaders, and water resource professionals. These individuals are required to not only buy into the project and the process but must also become an integral part of identifying the solution(s) which will result in improved water quality. WREC involved stakeholders in the watershed management planning process through public meetings and a steering committee.

1.2.1 Steering Committee

Individuals representing the cities, towns, and counties within the watershed; neighborhood associations; environmental groups; natural resource and engineering professionals; and industrial and educational entities comprised the steering committee. The steering committee met bimonthly starting in May 2012. Table 1 identifies the steering committee members and their affiliation.

Table 1. Deer Creek-Sugar Creek watershed steering committee members and affiliations.

Steering Committee Member	Organization(s) Represented
Megan Benage	Tippecanoe County SWCD
Andrea Brown	Purdue Cooperative Extension, Carroll County
Judy Buttice	Cass County SWCD
Lynn Corson	Carroll County Chamber of Commerce; RC&D
Rick Duff	USDA/NRCS – Miami County
Larry Falk	Carroll County Resident
Jessica Fulgoni	Wabash River Enhancement Corporation
Angie Garcia-Miller	Tippecanoe County SWCD
Calvin Hartman	Howard County SWCD
Rhonda Hicks	Carroll County SWCD
Skyler Hill	DNR – Prophetstown State Park
Jerry Holsapple	Greater Lafayette Commerce; Carroll County Resident
Sarah Lake	Indiana State Department of Agriculture
Mary Lou Musselman	Miami County SWCD
Kathy Mylet	Carroll County Area Planning Commission
Allen Nail	Tippecanoe County Park & Recreation Department
Gus Nyberg	NICHES Land Trust
Joe O'Donnell	NRCS – Carroll County
Rick Parsons	Tippecanoe County Soil Waste District and SWCD
Sara Peel	Wabash River Enhancement Corporation
Donnie Shockley	Carroll County Survey
Evan Smith	NRCS – Howard County
Dale Snipes	Tippecanoe County Surveyor, MS4
Randy Strasser	Mayor, City of Delphi
Talia Tittelfitz	Wabash River Enhancement Corporation
Leanne Whitesell	Indiana Department of Environmental Management

1.2.2 Public Meetings

Public participation is necessary for the long-term success of any watershed planning and subsequent implementation effort. One component of public participation for this project was public meetings. Three public meetings have been held in Flora and Delphi, Indiana. Each has been organized and facilitated by Purdue University graduate and undergraduate students taking Dr. Linda Prokopy's class, *Community Involvement in Natural Resource Planning.* The meetings met class requirements and have also assisted in the development of the Deer Creek-Sugar Creek Watershed Management Plan (WMP). Additional annual public meetings, most likely in the fall towards the end of harvest season, will continue to be held as part of this project.

October 19, 2011

The purpose of the public meetings was to provide information on the overall planning effort and its process; solicit stakeholder input, opinions, and participation; and build support for future phases of the project.

The public meeting was advertised to the residents within the watershed in several ways. A "Save the Date" announcement was advertised in the local newspapers and posters and fliers were distributed throughout the community. Personal letters were mailed to key stakeholders that had been identified within the watershed. Additionally, information was e-mailed to involved residents in the area. The meeting was held at the 4-H Building in Flora, Indiana. Approximately 27 individuals attended the meeting, which included a BBQ, a public input session and children's activities. Attendees represented citizens, environmental groups, city and county employees, and local government agencies. During this meeting, the Carroll County SWCD detailed the history of the project; WREC described opportunities for individuals to volunteer as part of the project; and Purdue University students provided attendees with the opportunity to identify their concerns about the Deer Creek, Sugar Creek, and Buck Creek, their tributaries, and the watershed.

October 30, 2012

The purpose of the public meeting was to build on a list of issues and concerns started at the 2011 meeting.

The evening meeting was held in the Flora Community 4-H Building, and a BBQ dinner was provided. The meeting was attended by over 30 people from throughout the watershed, many of whom had lived here for over ten years. Meeting participants heard information about the grant, the Wabash River Enhancement Corporation, progress on the watershed management plan, and possible best management practices. They then had the opportunity to vote on their top concerns which could be addressed by the watershed management plan including agricultural, aesthetic and recreational, and industrial issues. Students also facilitated discussions of the problem areas in the watershed.

October 23, 2013

The purpose of this public meeting was to update the watershed communities on the progress of the watershed management plan, alert them to the upcoming cost share program, and solicit their feedback on critical components of the WMP.

The meeting was held in the evening at the United Methodist Church in Delphi, Indiana. Participants were served a church dinner and provided with a brief update on the progress of the WMP. Participants then moved into smaller breakout groups facilitated by Purdue students for smaller and more in-depth discussions on the draft goals statements of the WMP, the best means of conducting outreach and education in the watershed, and the specific feasibility and potential of selected best management practices.

1.3 Public Input

Throughout the planning process, project stakeholders, the steering committee, and the general public detailed concerns for the Wabash River, its tributaries, and its watershed. Public and committee meetings formed the primary mechanism for individual concerns to be recorded; however, concerns were also gathered at the county 4-H fairs and other education events. The committee and public's concerns voiced throughout the process are listed in Table 2. The order of concern listing does not reflect any prioritization by watershed stakeholders. Concerns have been consolidated and grouped in the right hand column for further analysis later in the plan.

Table 2. Stakeholder concerns identified during public input sessions and grouped for use in the planning process.

Stakeholder Concerns	Grouped Concerns
Agriculture run-off into Deer Creek	Agriculture run-off is contributing to the high nutrient concentrations and sedimentation (turbidity) within the Deer Creek Sugar Creek watershed.
Chemicals from farming	Pesticide concentrations in Deer Creek.
Loss of crops due to farms flooding	Flood prone ground is farmed causing additional sediment and nutrient loading to waterbodies in the Deer Creek-Sugar Creek watershed.
Too much till-farming of flood prone ground	
Use of cover crops to slow run off and erosion	Too few agricultural best management practices are located in the Deer Creek-Sugar Creek watershed.
Tree planting, shrubs, grasses to pressure stream banks, etc.	
Shallow wetland areas	
Implement filter strips	
Dead animals in Deer Creek (Hogs)	There are dead animals (hogs) in Deer Creek.
E. coli. from livestock	Waste from livestock is increasing the *E. coli* concentrations in watershed waterbodies.
Hog sewage in Little Deer Creek	Hog sewage (waste) is sitting/stagnate in Little Deer Creek.
Agriculture runoff sitting in Deer Creek because of low flow	
Livestock impact on water quality	Livestock is negatively impacting water quality.
	There are unregulated animal farms within the watershed.
	Livestock have access to the stream.
Decline in fish populations	Fish populations have been negatively affected by the water quality.
Decline in insect populations	Macroinvertebrate populations have been negatively affected by the water quality.
Wildlife areas encouraged and protected	Wildlife areas should be encouraged and protected within the watershed.
Decline in crawfish populations	There has been a decline in crawfish populations.

Stakeholder Concerns	Grouped Concerns
Want to see wetlands, water treatment systems, better systems, and rain barrels	Lack/decrease of wetlands within the watershed.
Lack of wetlands	
There are invasive species issues within the watershed.	There are invasive species issues within the watershed.
Safety of the consumption of fish caught within the watershed (Bass species)	Fish caught within the watershed are not safe for consumption.
The volume of manure produced in the Deer Creek-Sugar Creek watershed.	The volume of manure produced in the Deer Creek-Sugar Creek watershed.
There is a lack of manure management in areas of the watershed.	There is a lack of manure management in areas of the watershed.
Some CFO facilities are storing their manure too close to creeks.	Some CFO facilities are storing their manure too close to creeks.
There have been several manure spills/fish kills within the watershed.	There have been several manure spills/fish kills within the watershed.
Manure is being applied throughout the watershed.	Manure is being applied throughout the watershed.
Bio-solid issues	Bio-solid issues.
Nitrogen concentrations exceed suggested levels.	Nitrogen concentrations exceed suggested levels.
Phosphorus concentrations exceed suggested levels.	Phosphorus concentrations exceed suggested levels.
Turbidity/sediment exceeds recommended levels by USEPA.	Turbidity/sediment exceeds recommended levels by USEPA.
E. coli concentrations exceed the state of Indiana's suggested level.	*E. coli* concentrations exceed the state of Indiana's suggested level.
Monitoring stations on Deer Creek/Wabash River	Develop long term monitoring stations on Deer Creek/Wabash River.
There is no current monitoring on either stream	
Want clean, unpolluted water in Carroll County	
Want water quality to meet useable standards	
Implement filter strips	Limited buffers are located along watershed waterbodies causing poor water quality.
Soil erosion	Care of soil quality and erosion
Care of soil quality	
Down trees along Deer Creek due to erosion problems	Stream bank erosion occurs along the waterbodies within the watershed
No signs marking Sugar Creek	Education program programs addressing conservation practices, recycling, climate change, and disposing of chemicals need to be developed.
Target the editorial in newspapers that will inform others in the watershed	
Work around political system and act locally	
Tax plan dependent on political system	

Stakeholder Concerns	Grouped Concerns
Education	
Lack of recreation in the watershed	Limited recreation throughout the watershed.
Lack of hiking trails	
Southwest portion of the watershed has potential for recreational development	
Deer Creek – Low flow, less recreation	
Are there land use regulations of standards for these zones	Carroll County zoning regulations are not providing sufficient protection for sensitive and high quality areas.
Carroll County zoning regulations	
Ignoring a lot of sensitive areas due to agriculture interests and crops	
Problem with land value	Problem with land value.
Flooding concerns along Flora, IN residents (especially those with basements)	Flooding concerns within residential areas (Flora and Delphi).
Residential flooding/drainage	
Levees River Park – flooded homes	
Waste water treatment flooding outside of Delphi	
Deer Creek is too flashy	Instream flows are unpredictable.
Decreased water levels (lack of water)	
Interrupted flow by beavers (trees)	
Wells are low – waste contaminants	Wells are low and may be contaminated by nitrate.
Wells have to be dug deeper due to water quality issues (nitrate 70 ppm)	
Effects of highway construction on State Road 25	Effects of highway construction (State Road 25).
Illegal septic systems	Illegal septic systems.
Increased population of zooplankton species	Increased population of zooplankton species.
Waste water needs more conservation of water, don't use drinking water for other uses	Waste water needs more conservation of water, don't use drinking water for other uses.
Dredge river; make it deeper	Dredge river; make it deeper.
Reservoirs – effect on stream flow	Reservoirs – effect on stream flow
Engineering of tile drains in Carroll County	Engineering of tile drains in Carroll County.
Stone quarry being constructed outside of Americus.	Stone quarry being constructed outside of Americus.
Dumping/burying of chemical waste	Dumping/burying of chemical waste

1.4 Social Indicator Survey

The ability of WREC, Carroll County SWCD, and other stakeholders to conduct effective education and outreach depends on:

- understanding how people feel about local water resources
- how much they know about water quality concerns
- what practices they adopt on the land they manage
- what factors affect their land management decisions

Social indicator surveys provide one way to analyze these attitude, awareness, behavior, and constraint measures. The data obtained provide a snapshot of a given time, helping to direct outreach efforts and allowing for measurement of temporal change observed during future assessments. Education, urban, and rural committee members worked with a group of Purdue University social scientists to tailor an existing survey system that was originally developed for use in nonpoint source pollution projects by a regional team of researchers.

1.4.1 Survey Methods

Because the Deer Creek-Sugar Creek watershed is almost entirely agricultural, recipients for the survey were selected from a Farm Service Agency database of agricultural producers. In order to reach a representative variety of both crop and livestock producers, this list of recipients was supplemented by addresses listed on Confined Feeding Operation permits available through IDEM's virtual cabinet portal. The 12-page survey was sent to 612 addresses in the watershed, garnering an overall response rate of 47%.

A standardized delivery and collection method was used. In November 2013, a five-wave mail survey was utilized to collect the data (Dillman, 2000). An advance notice letter was sent to potential respondents to inform them of the survey's purpose and to notify them that they would be receiving a paper survey in the next week. This letter also included instructions on how to complete the survey online. The paper survey was sent the following week and included verbiage similar to the original advance letter, instructions for completing the survey online, and a summary of the survey's purpose. A postcard reminder was sent two weeks later, followed by a replacement survey the following week. After two more weeks, a third replacement survey was sent to all non-respondents.

The survey covered the social indicators developed for use in 319-funded watershed projects. The indicators are grouped into four categories: awareness, attitudes, constraints, and behaviors. Socio-demographic information was also collected. Descriptive summaries for the survey are included below. Detailed tables, including raw statistical data, are included in Appendix B.

1.4.2 Survey Results

As detailed above, the agricultural survey was sent to 612 producers and resulted in a 47% return rate.

Water as a Resource

Respondents were asked to rank the importance of a number of water-related activities. "Scenic beauty/enjoyment" and "fishing" were the highest ranked response categories, while "swimming" in the water received the lowest rating. "Picnicking" and "Canoeing, kayaking, and other boating" activities ranked in the middle. This suggests a prevalent "look but don't touch" attitude toward recreational use of the water, however clearly respondents seem comfortable with activities which bring them onto or in close proximity to the water. The vast majority of respondents stated that they know where the rainwater goes when it leaves their property and were able to name that body of water.

Water Quality Attitudes

Respondents were asked to rank their level of agreement with a number of statements related to their attitudes toward water quality, including its importance to the community, the financial ramifications of management practices, and levels of personal responsibility. This section assessed a baseline set of attitudes towards water quality that can be used as a basis for comparison in future social indicator surveys once practices, education, and outreach have been implemented. A 1-to-5 "strongly disagree" to "strongly agree" scale was used. In general, respondents believe that recommended agricultural practices can improve water quality and are willing to accept responsibility for improving water quality. They also lean favorably towards the ideas that personal actions can impact water quality, that it is important to protect water quality, and that the quality of life in their communities depends on good water quality in local rivers and streams.

Respondents were more ambivalent about their personal willingness to pay for improved water quality, neither agreeing nor disagreeing with the statement "I would be willing to pay more to improve water quality." In summary, producers recognize that water quality is important for the community and that their actions can affect it, but they are less committed to paying for water quality improvements, which is not an unusual attitude to encounter. Overall, their attitude towards water quality is fairly standard, if not leaning positively, for an agricultural community.

Familiarity with Water Impairments

Respondents were asked to rate the severity of numerous water impairments. Respondents demonstrated awareness of "trash and debris" and "sedimentation" as problematic water quality issues, rating both between slight and moderate problems. Respondents were less aware of water quality problems due to Bacteria, Phosphorus, Nitrogen, and Pesticides, with around 30% of respondents indicating that they "don't know" about the severity these issues. These responses suggest that the most visible water quality problems are the ones readily identified by the respondent community.

Consequences of Poor Water Quality

Respondents were asked to evaluate the consequences of poor water quality. Reduced beauty of streams, reduced quality of water recreation activities, and reduced opportunities for water recreation were seen as the most serious issues, ranked as "slight problems." Respondents were less aware of less visible issues, such as contaminated fish, excessive aquatic plants or algae, fish kills, and lower property values, however, those who were aware of these issues also ranked contaminated fish and excessive aquatic plants or algae as slight problems. Lower property values were ranked lowest by those aware of the issue: somewhere between "not a problem" and "slight problem." These responses suggest that respondents are most aware of visible and recreational-related issues, but for those that are aware of other issues, fish and algae blooms are the most serious issues. Though it is worth noting that less than a quarter of respondents deem any of the issues to be moderate to severe problems.

Sources of Water Pollution

Respondents were asked to rate the severity of 12 different sources of water pollution. Respondents ranked soil erosion from streambanks and farm fields and littering or illegal dumping of trash as the most serious contributors, ranking them as slight to moderate problems. Respondents were also aware of additional agricultural sources of pollution – such as manure from farm animals, excessive use of fertilizers, pasture grazing, and animal feeding operations – but ranked these lower: between not a problem and slight problem. Respondents were less aware of sources including septic systems, discharge from sewage treatment plants, industrial discharges, and urban stormwater runoff, though those that were aware considered stormwater runoff to be the highest ranked: a slight to moderate contributor. Overall, respondents in this watershed demonstrate the most awareness of agricultural and construction sources of pollution.

Practices to Improve Water Quality

Respondents were asked questions regarding specific land management practices to improve water quality (Figure 2 through Figure 5). An average of 87 respondents felt that questions related to livestock were relevant to their property. Of these, around 40% currently use manure in accordance with its nutrient content, and around 15% currently use animal composting facilities, approved grazing plans, and fences to exclude livestock from streams. An average of 210 respondents felt that questions related to crop agriculture were relevant to their property. Of these, around 70% of respondents currently use regular soil tests to determine nutrient application rates and retain crop residue and use grassed waterways to reduce erosion. Around 60% of respondents currently follow university recommendations for fertilization rates, use variable rate application technology, and consider location and soil characteristics to minimize leaching or runoff. Around 50% of respondents use conservation tillage, however, 20% of respondents said they know how to use conservation tillage but aren't currently using it. Respondents were the least familiar with regular servicing of septic systems; though nearly 50% of respondents currently use this practice, 30% of respondents were only slightly familiar with it or had never heard of it.

Constraints for Specific Practices

Respondents were asked detailed questions about their adoption of four specific conservation practices. Results from individual practices are included below:

Feedlot Runoff Diversion (built structures, filter strips, or grassed waterways)

A majority (73%) of respondents say this practice is not relevant for their operation. Nearly 13% currently use diversion of some kind to prevent surface water from flowing through feedlots, and around 10% had either never heard of this practice or were somewhat familiar with it. Nearly 60% said they might be willing to try this practice ("yes" or "maybe"). Desire to "keep things the way they are," property features which would make installation difficult, and cost were the highest ranking constraints preventing adoption of this practice.

Cover Crops
Around 30% of respondents currently use cover crops, and around 25% are somewhat familiar with this practice. Very few said they had never heard of it. Nearly half of respondents either said they know how to use cover crops but choose not to or feel they aren't relevant for their operation. Responses given for why the practice might not be relevant include “flat ground” and “no erosion,” demonstrating that many who are not using the practice feel the primary purpose of a cover crop is to prevent erosion on sloped fields. Over 80% said they might be willing to try this practice (“yes” or “maybe”). Cost, difficulty of using with existing farming equipment, and time required were the highest ranking constraints preventing adoption of this practice.

Two Stage Ditch
Few respondents (8%) currently use this practice. Over 30% know how to use two stage ditches but choose not to or do not feel they would be relevant for their operation. Almost 60% of respondents are only somewhat familiar with this practice or had never heard of it. Around 70% of respondents said they might be willing to try a two stage ditch (“yes” or “maybe”). Cost, time required, and lack of equipment were the highest ranking constraints preventing adoption of this practice.

Vegetated Riparian Buffer
Nearly 35% of respondents currently use this practice. Around 25% know how to use riparian buffers but choose not to or do not feel they would be relevant for their operation. Nearly 40% of respondents are only somewhat familiar with this practice or had never heard of it. Around 75% of respondents said they might be willing to try vegetated riparian buffers (“yes” or “maybe”). Cost and time required were the highest ranking constraints preventing adoption of this practice.

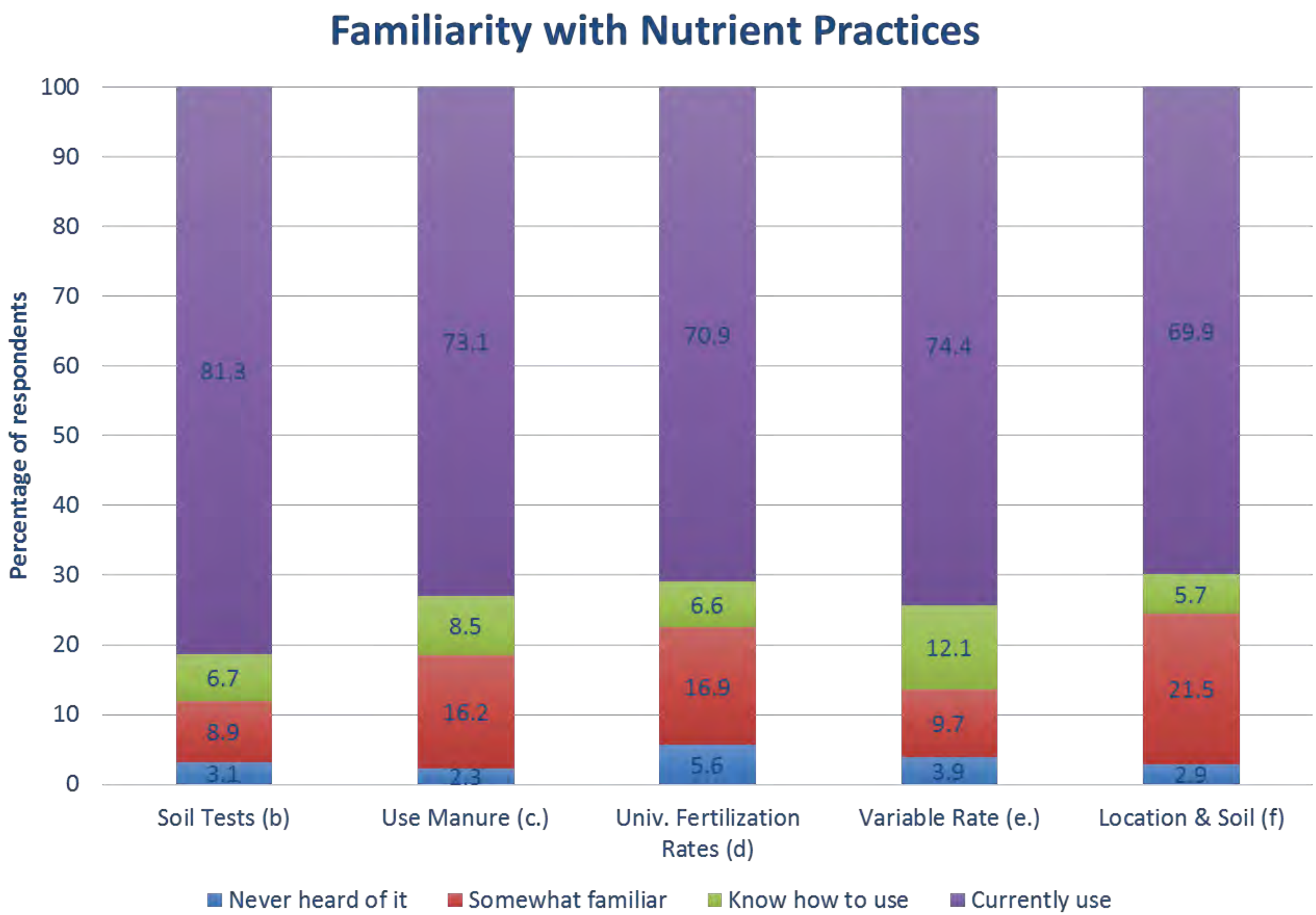

Figure 2. Survey respondents' familiarity with nutrient practices.

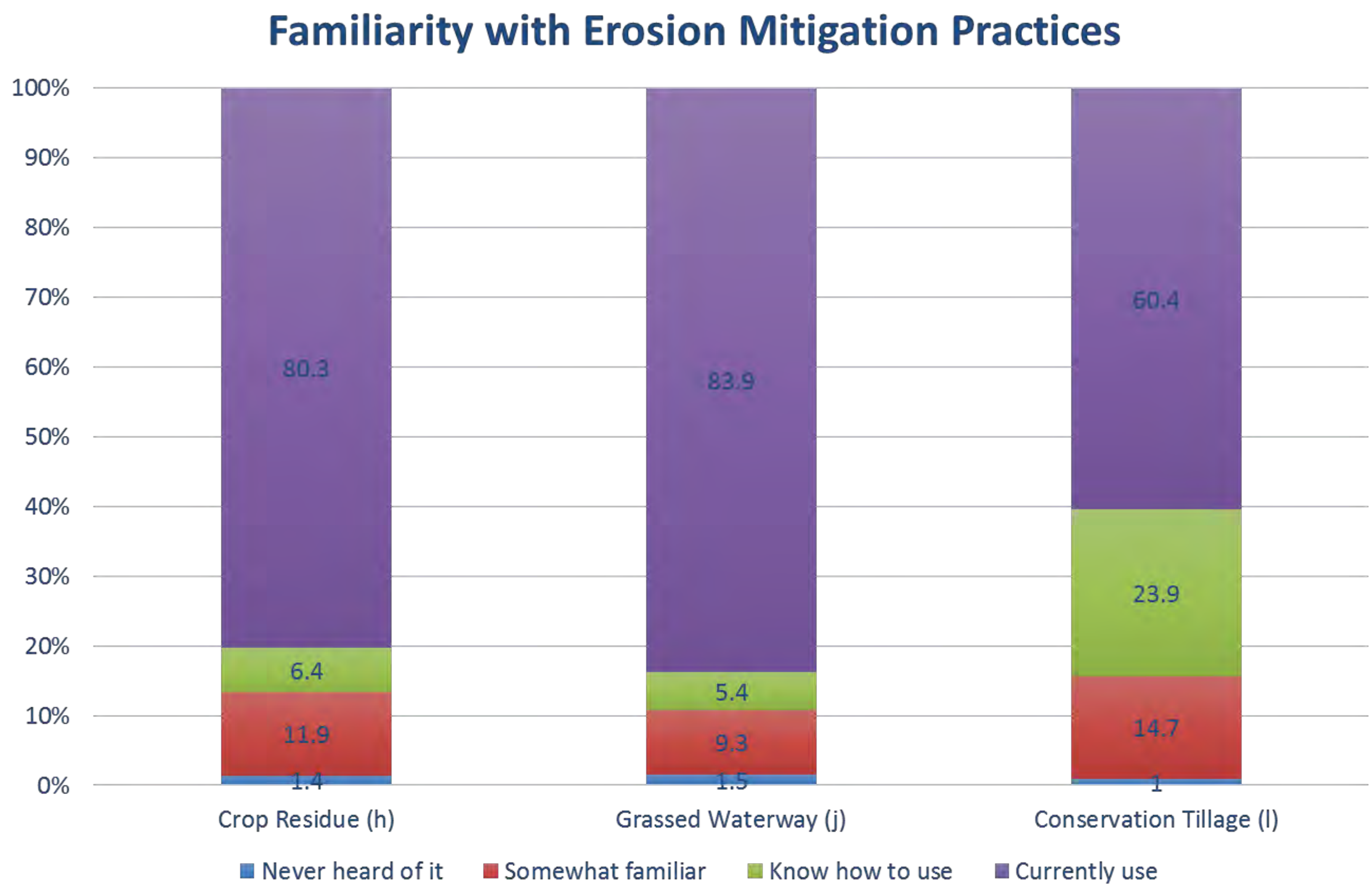

Figure 3. Survey respondents' familiarity with erosion mitigation.

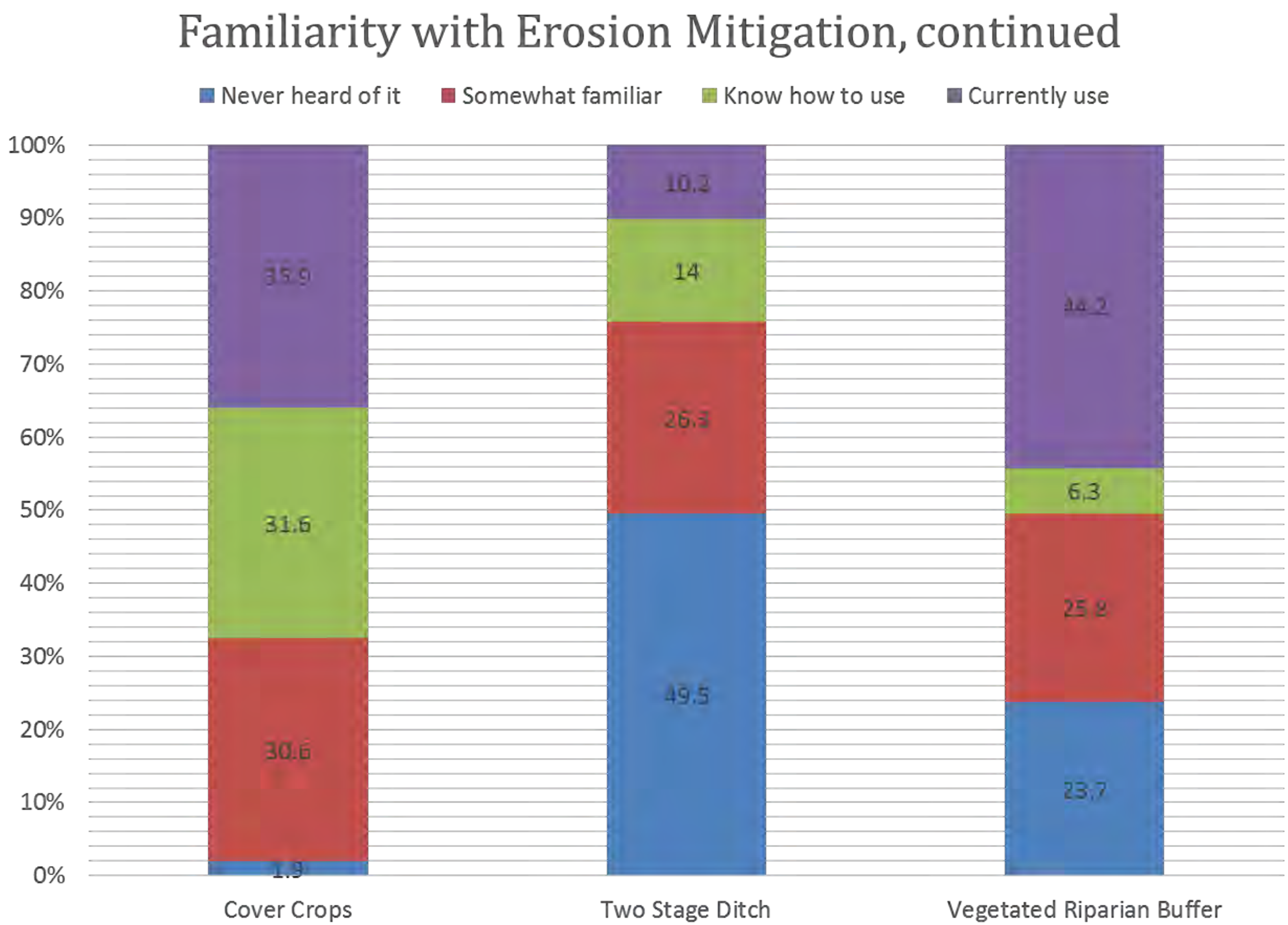

Figure 4. Survey respondents' familiarity with erosion mitigation, continued.

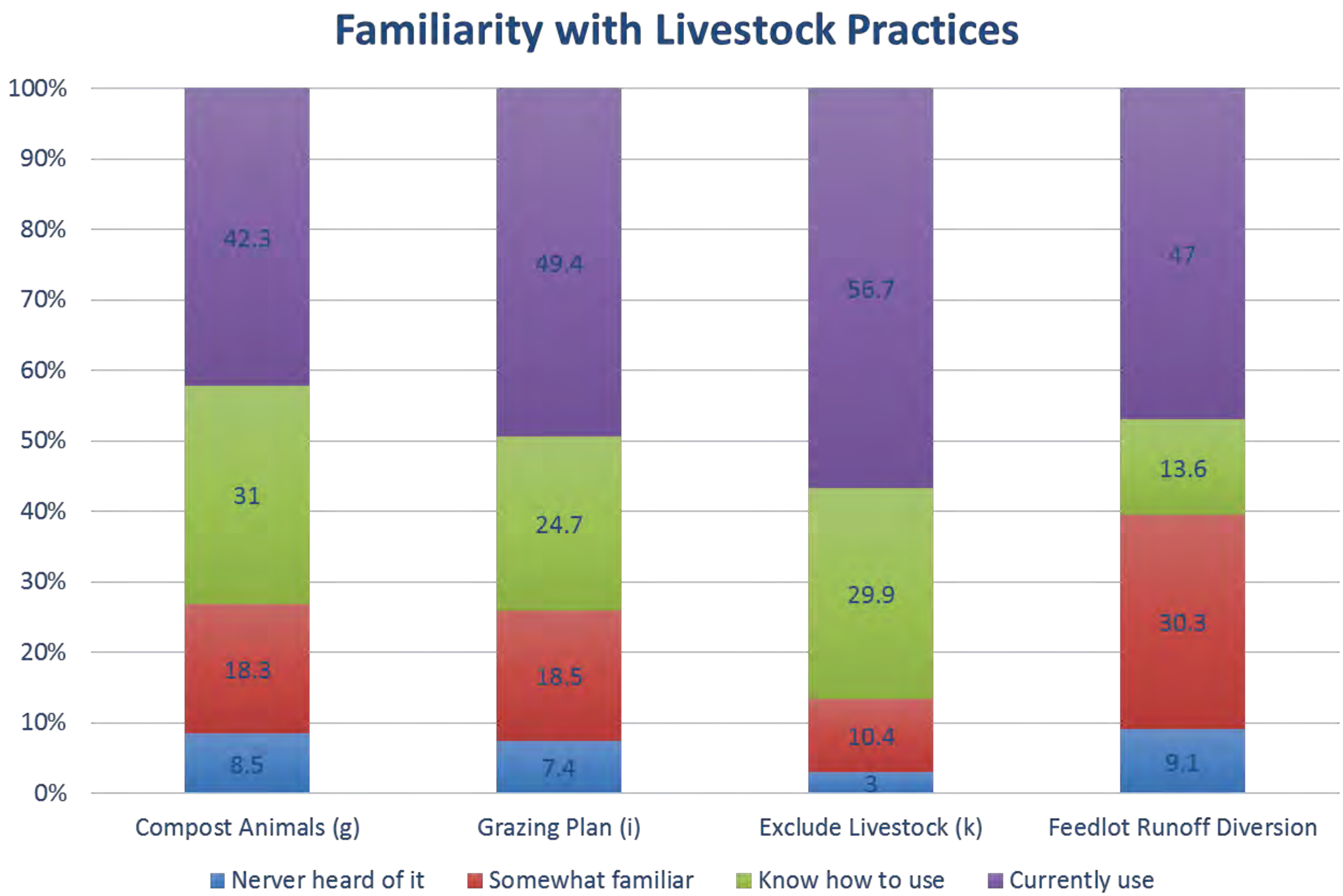

Figure 5. Survey respondents' familiarity with livestock practices.

General Constraints

Respondents were asked about the degree to which a number of constraints limited their ability to change their agricultural management practices. Personal expenses, lack of government funding, and inflexibility to change the practice were the top three constraints identified.

Socio-Demographics

The majority of respondents (over 85%) are male with a mean age of 64. Over 65% run their operation alone, with a spouse, or with family partners. Respondents have been farming for several decades (mean = 33 years), have had the farm in the family for generations (mean = 77 years), and a majority think it likely that family will continue the farming operations after they retire (over 70% said this will probably happen or will definitely happen). A majority of property managed (62%) touches a stream, river, or wetland. A majority of operations (nearly 70%) have a nutrient management plan; of those, 30% said the plan meets NRCS technical standard 590 and 70% said they didn't know. A majority (over 60%) of plans were developed by private sector agronomists or crop consultants.

Information Sources

Respondents were asked to select all the sources where they are likely to seek information about soil and water conservation issues. Newsletters, brochures, and fact sheets (46%); conversations with others (37%); and workshops, demonstrations and meetings (29%) were ranked highest. Respondents were also asked to select all the sources where they are likely to seek information about water quality issues. Newsletters, brochures, and fact sheets (45%); conversations with others (34%); and newspapers and magazines (28%) were ranked highest.

Respondents were also asked about the extent to which they know about or trust a number of conservation groups and related agricultural agencies. The three most trusted information sources were (in order) Soil and Water Conservation District, Purdue Extension, and Natural Resource Conservation Service – all ranked between "moderately" and "very much." These sources would thus be the best options for promotional and outreach materials. Hoosier Environmental Council, NICHES Land Trust, and the EPA garnered the least amount of trust, with all three scoring near the "slightly" trusted mark; though the majority of respondents were unfamiliar with both the Hoosier Environmental Council and NICHES. Respondents indicated that they "slightly" to "moderately" trust the Wabash River Enhancement Corporation, though over 40% reported that they were not familiar with the organization.

Septic Systems

Respondents were asked several questions related to septic systems. A majority of respondents (over 90%) indicated that they have a septic system (n=257). Most respondents with septic systems reported that they did not experience any problems with them in the last five years. Slow drains, toilet backups, and sewage backups in the house were the three most common problems reported if a system did malfunction. Most respondents (76%) said that they have a finger system, while 12% said they did not and 12% said they did not know.

1.4.3 Survey Summary

Most survey respondents, primarily agricultural landowners and producers, believe that good water quality is important for the communities that they live in for both economic and quality-of-life reasons. Most individuals feel a degree of personal responsibility for the actions they take that affect local water resources, though they may be unwilling to pay for improvements. It's clear that individuals frequently feel that they must compromise between desired environmental outcomes and their financial concerns.

In general, survey respondents readily identified visible water quality concerns such as littering and turbidity. Other problems, especially those related to nutrient loading and aquatic habitat alteration, have generated less awareness amongst respondents. Education and outreach efforts are needed across the board in order to effectively change management behaviors. Particularly successful campaigns may target those who have never heard of or are only slightly familiar with a given best management practice (Figure 2 through Figure 5). Respondents frequently identified financial factors as the primary constraint to adopting conservation practices.

Soil and Water Conservation District, Purdue Extension, and Natural Resource Conservation Service are the most trusted information sources for natural resource management concerns and would thus make excellent partners for outreach efforts. This survey indicates that WREC has a fairly low public profile; 42% of respondents were not familiar with the organization. WREC and Carroll County SWCD should take advantage of their partnerships with other well-known agencies in order to bolster its own name recognition and ability to achieve its goals.

2.0 WATERSHED INVENTORY I: WATERSHED DESCRIPTION

2.1 Watershed Location

The Deer Creek-Sugar Creek watershed is part of the Middle Wabash-Deer watershed and covers portions of Carroll, Cass, Howard, Miami, and Tippecanoe counties (Figure 6). The Middle Wabash-Deer watershed outlined in green, and the target watershed is outlined in black. The watershed has four distinct streams, Buck Creek, Deer Creek, Sugar Creek, and the Wabash River. Deer Creek has two headwater streams, the South Fork of Deer Creek and Little Deer Creek, while Sugar Creek has only one headwater stream, Little Sugar Creek. All of the streams drain into the Wabash River; from upstream to downstream, Deer Creek enters just below Delphi, IN, then Sugar Creek and finally Buck Creek. The Deer Creek-Sugar Creek watershed covers 375 square miles and includes all of Delphi, Flora, Camden, Galveston and portions of Battle Ground, Kokomo and Lafayette.

2.2 Subwatersheds

2.2.1 10-Digit Hydrologic Unit Watersheds

The Deer Creek-Sugar Creek watershed is a portion of the larger 8-digit Hydrologic Unit Code (HUC) watershed, the Middle Wabash-Deer watershed (05120105). Deer Creek-Sugar Creek is composed of three 10-digit HUC watersheds including Deer Creek (0512010505), South Fork of Deer Creek (0512010504), and Sugar Creek-Wabash River (0512010506) (Figure 6). The Deer Creek-Sugar Creek watershed is bordered to the north by the upper portion of the Middle Wabash-Deer watershed, to the north and east by the Upper Wabash watershed, to the south by the Wildcat Creek watershed, to the southwest by the Middle Wabash-Little Vermilion watershed, and to the northwest by the Tippecanoe watershed.

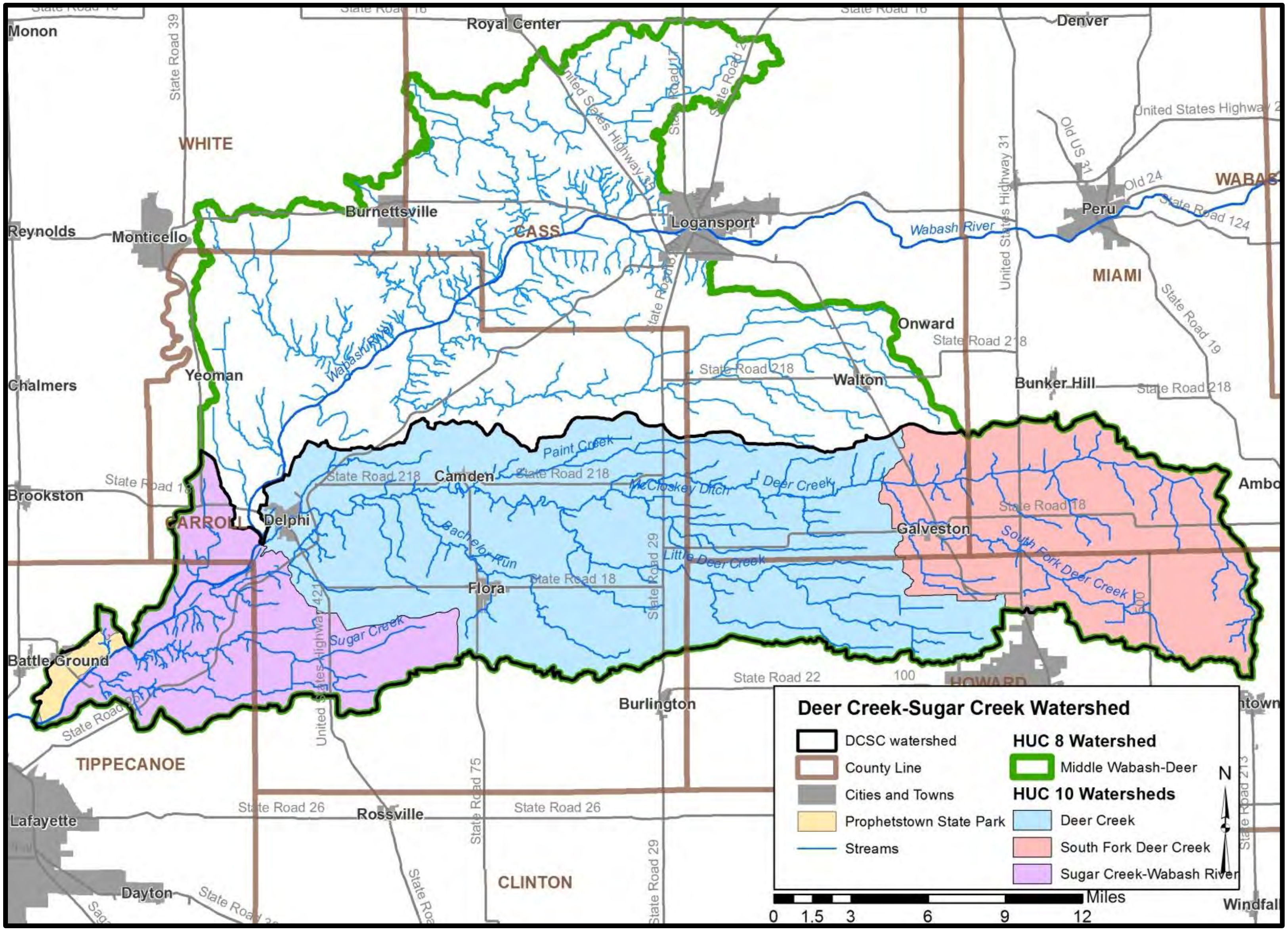

Figure 6. The Deer Creek-Sugar Creek watershed is located in the Wabash River-Deer watershed.
Data used to create this map are detailed in Appendix A.

2.2.2 Deer Creek-Sugar Creek Tributary Watersheds

Sixteen 12-digit HUC watersheds occur within the Deer Creek-Sugar Creek watershed (Figure 7, Table 3). The subwatersheds range in size from 10,301 to 25,532 acres or 16.1 to 39.9 square miles. Each of these drainages will be discussed in further detail under *Watershed Inventory II*.

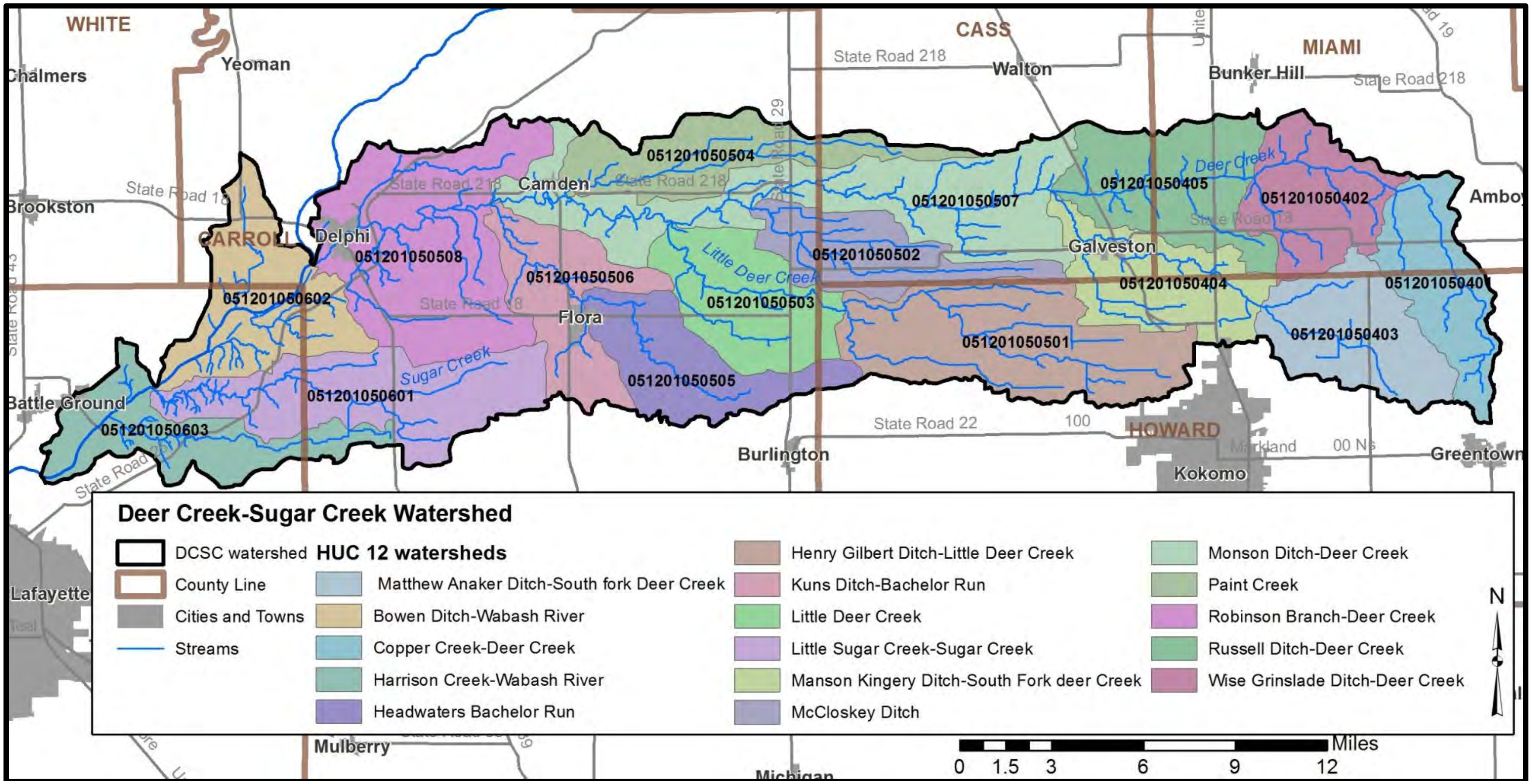

Figure 7. 12-digit Hydrologic Unit Codes in the Deer Creek-Sugar Creek watershed.

Data used to create this map are detailed in Appendix A.

Table 3. 12-digit Hydrologic Unit Code watersheds in the Deer Creek-Sugar Creek watershed.

Name	HUC	Area (Acres)	Area (sq mi.)	Counties
Copper Creek-Deer Creek	051201050401	11,149	17.4	Howard, Miami
Wise Grinslade Ditch-Deer Creek	051201050402	11,665	18.2	Howard, Miami
Matthew Anaker Ditch-South Fork of Deer Creek	051201050403	12,857	20.1	Howard, Miami
Manson Kingery Ditch-South Fork of Deer Creek	051201050404	12,583	19.7	Cass, Howard, Miami
Russell Ditch-Deer Creek	051201050405	14,692	23.0	Cass, Miami
Henry Gilbert Ditch-Little Deer Creek	051201050501	21,980	34.3	Cass, Howard
McCloskey Ditch	051201050502	10,301	16.1	Carroll, Cass, Howard
Little Deer Creek	051201050503	12,851	20.1	Carroll, Howard,
Paint Creek	051201050504	12,134	19.0	Carroll, Cass
Headwaters Bachelor Run	051201050505	11,666	18.2	Carroll, Howard
Kuns Ditch-Bachelor Run	051201050506	11,385	17.8	Carroll
Monson Ditch-Deer Creek	051201050507	25,196	39.4	Carroll, Cass
Robinson Branch-Deer Creek	051201050508	25,532	39.9	Carroll
Little Sugar Creek-Sugar Creek	051201050601	18,330	28.6	Carroll, Tippecanoe
Bowen Ditch-Wabash River	051201050602	15,112	23.6	Carroll, Tippecanoe
Harrison Creek-Wabash River	051201050603	12,608	19.7	Carroll, Tippecanoe

2.3 Climate

In general, Indiana has a temperate climate with warm summers and cool or cold winters. Climate in the Deer Creek-Sugar Creek watershed is no different than the rest of the state. There are four seasons throughout the year. The average temperatures measure approximately 72°F in the summer, while low temperatures measure below freezing (29°F) in the winter. The growing season typically extends from April through September. On average, 0.93 meters of precipitation occurs within the watershed per year; approximately 62% of this precipitation falls during the growing season (Carroll County Soil Survey, 1991).

2.4 Geology and Topography

The geology and topography of the Deer Creek-Sugar Creek watershed is influenced by the advance and retreat of the Huron-Erie and Saginaw lobes of the late Wisconsinan age (Fleming, 2011). Bedrock deposits are predominately from the Wisconsinan age, but there are also bedrock deposits from the Devonian, Holocene, Mississippian, and Silurian ages. Unconsolidated drift deposits overlie the bedrock with deposits ranging from a centimeter to 76 meters thick throughout the watershed. Bedrock consists of rocks from the Borden Group, Muscatatuck Group, New Albany Shale, and Wabash Formation. The Deer Creek-Sugar Creek watershed is dominated by the Wabash Formation; it covers approximately 72%, or 173,000 acres, of the watershed (Figure 8).The areas of the watershed where New Albany Shale or the Muscatatuck Group comprise the bedrock could be areas of concern due to the eroding nature of these bedrocks. This erosivity could cause steep stream banks and the loss of land.

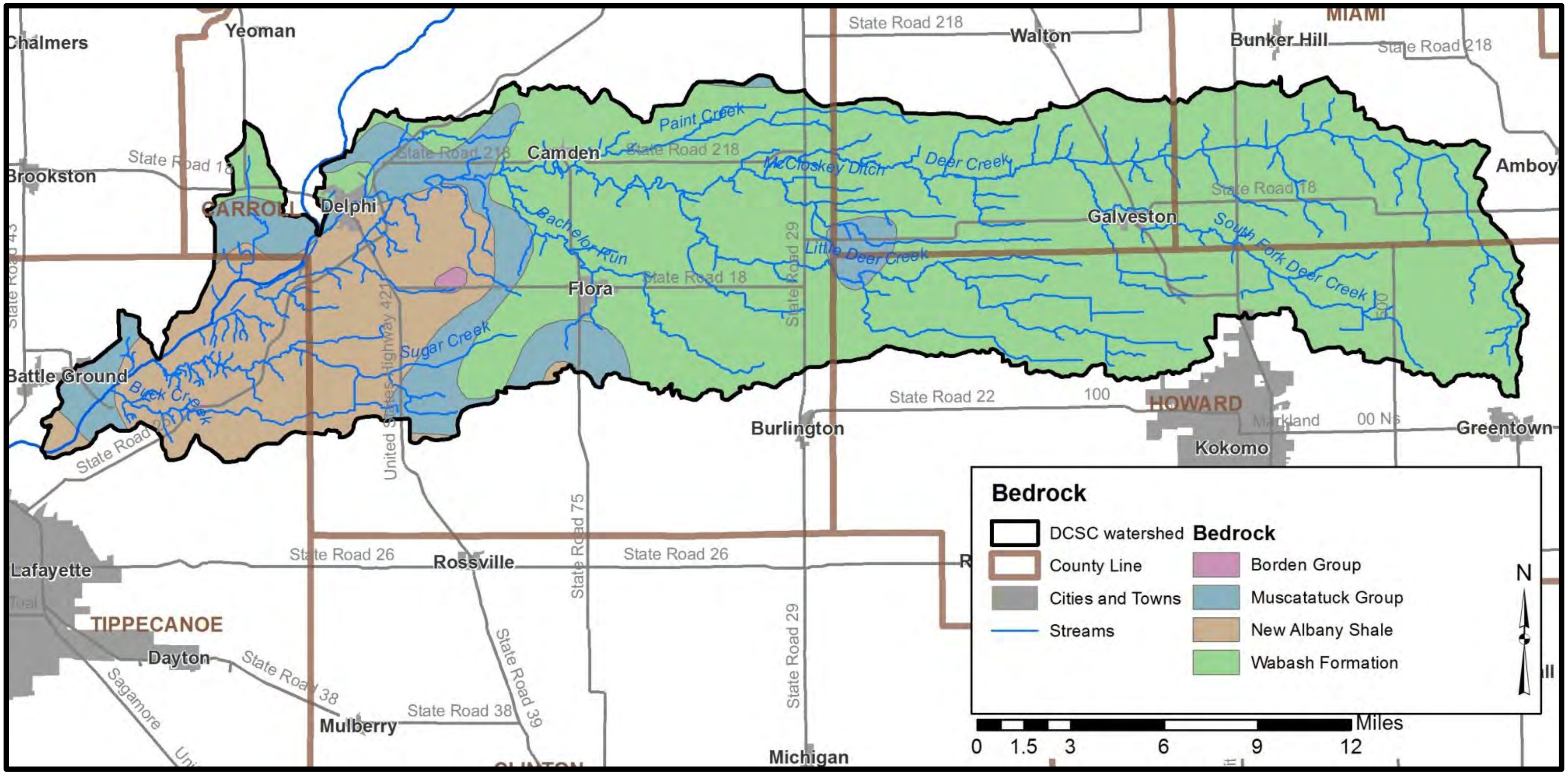

Figure 8. Bedrock in the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

The topography, surficial geology, soil development, and bedrock geology in the Deer Creek-Sugar Creek watershed is influenced by the advance and retreat of the Huron-Erie and Saginaw lobes of the late Wisconsinan age (Fleming, 2011). The surficial geology of the Deer Creek-Sugar Creek watershed is dominated by loam till (Figure 9). Approximately 171,500 acres or 71% of the watershed is loam till.

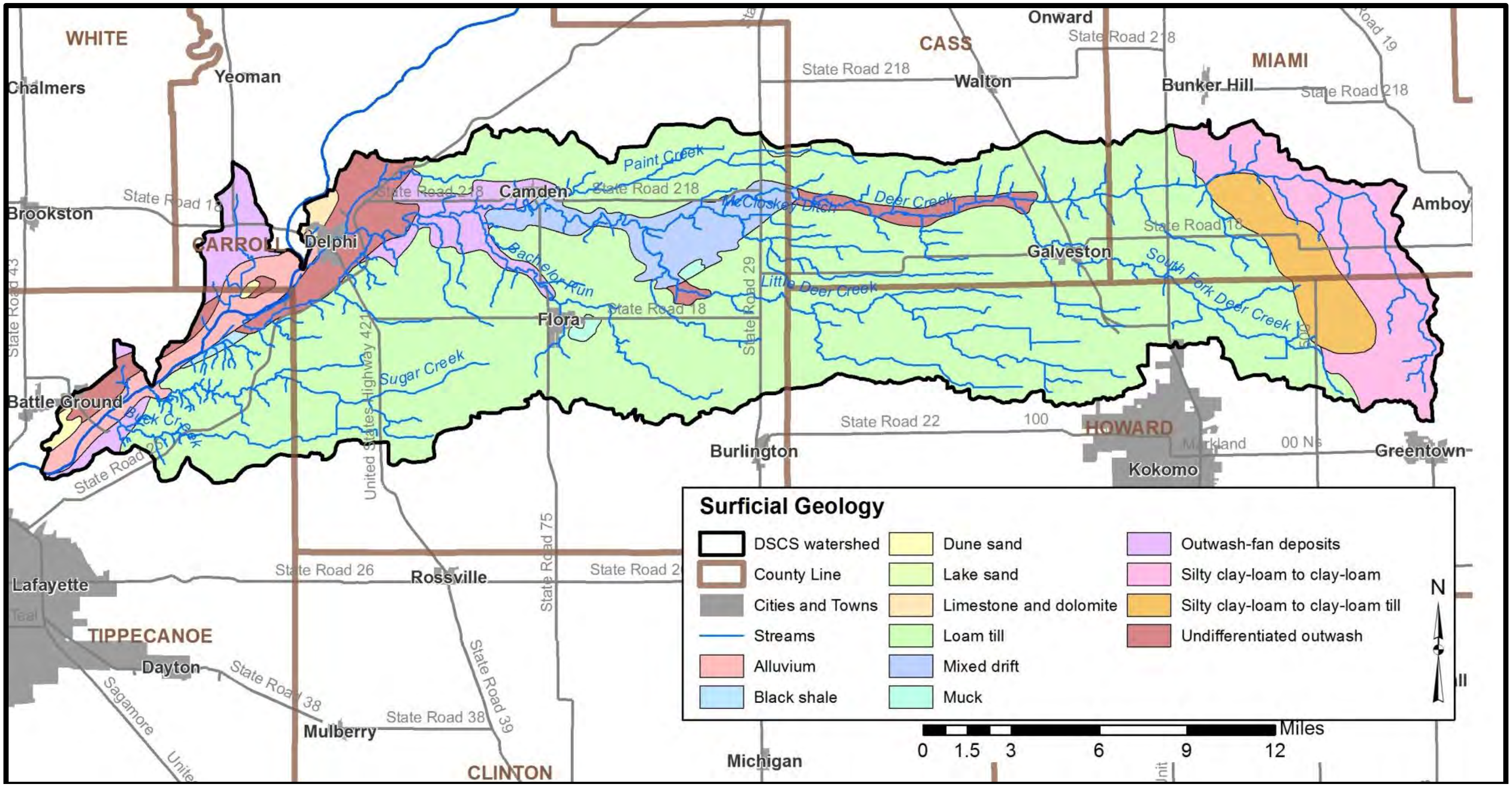

Figure 9. Surficial geology throughout the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

The highest point in the watershed is located in the eastern portion in Howard and Miami Counties (Figure 10). The area with the lowest elevation is located adjacent to the Wabash River. These areas intersect with bedrock that is New Albany Shale; this is most likely due to eroding of the layers of shale from weathering. The topography of the Deer Creek-Sugar Creek watershed is relatively flat. This is characteristic of the Central Till Plain Region where the majority of the watershed is located (Figure 11). The watershed slopes from east to west with the highest percent slope occurring around the streams located from the center of the western edge of the watershed.

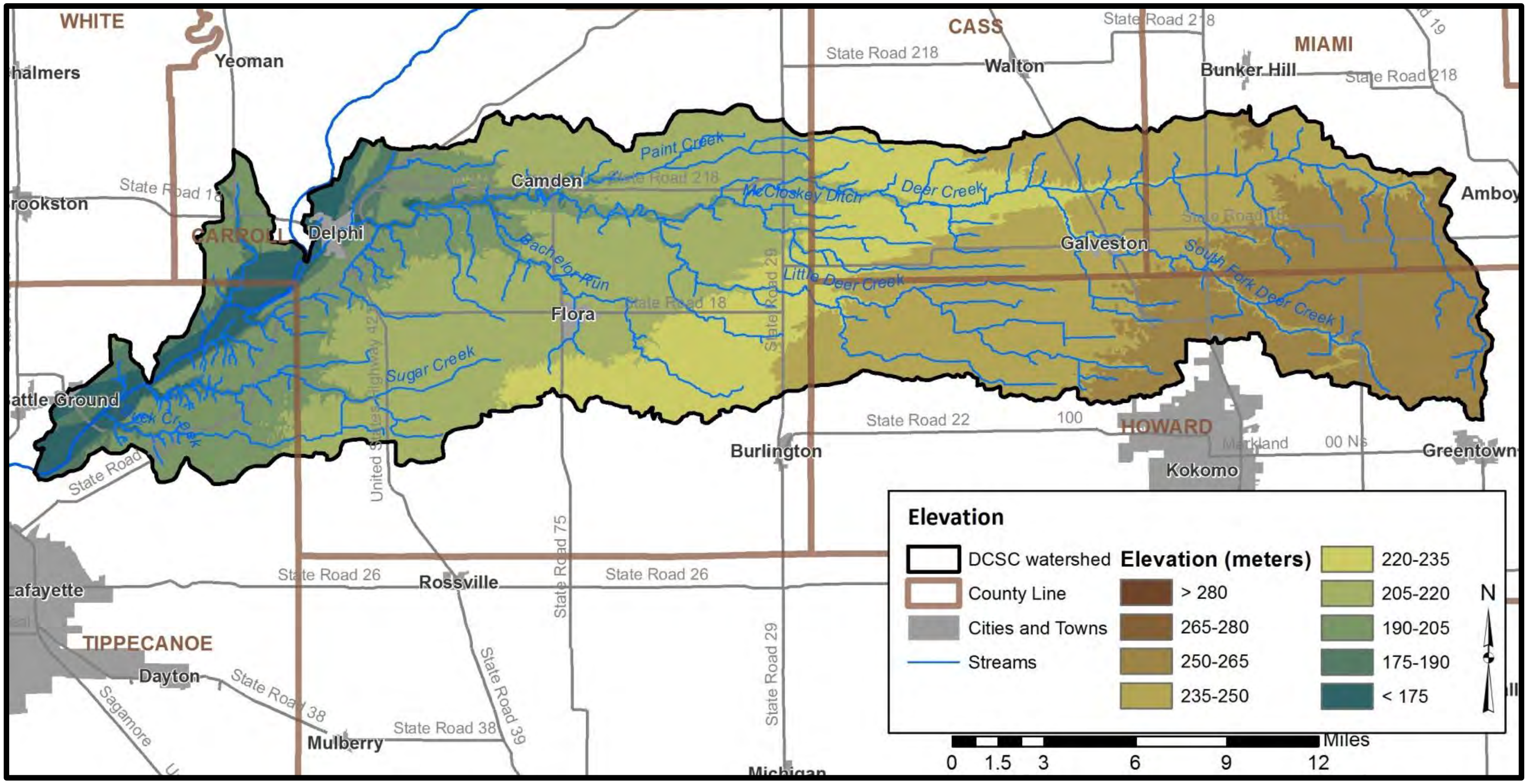

Figure 10. Surface elevation in the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

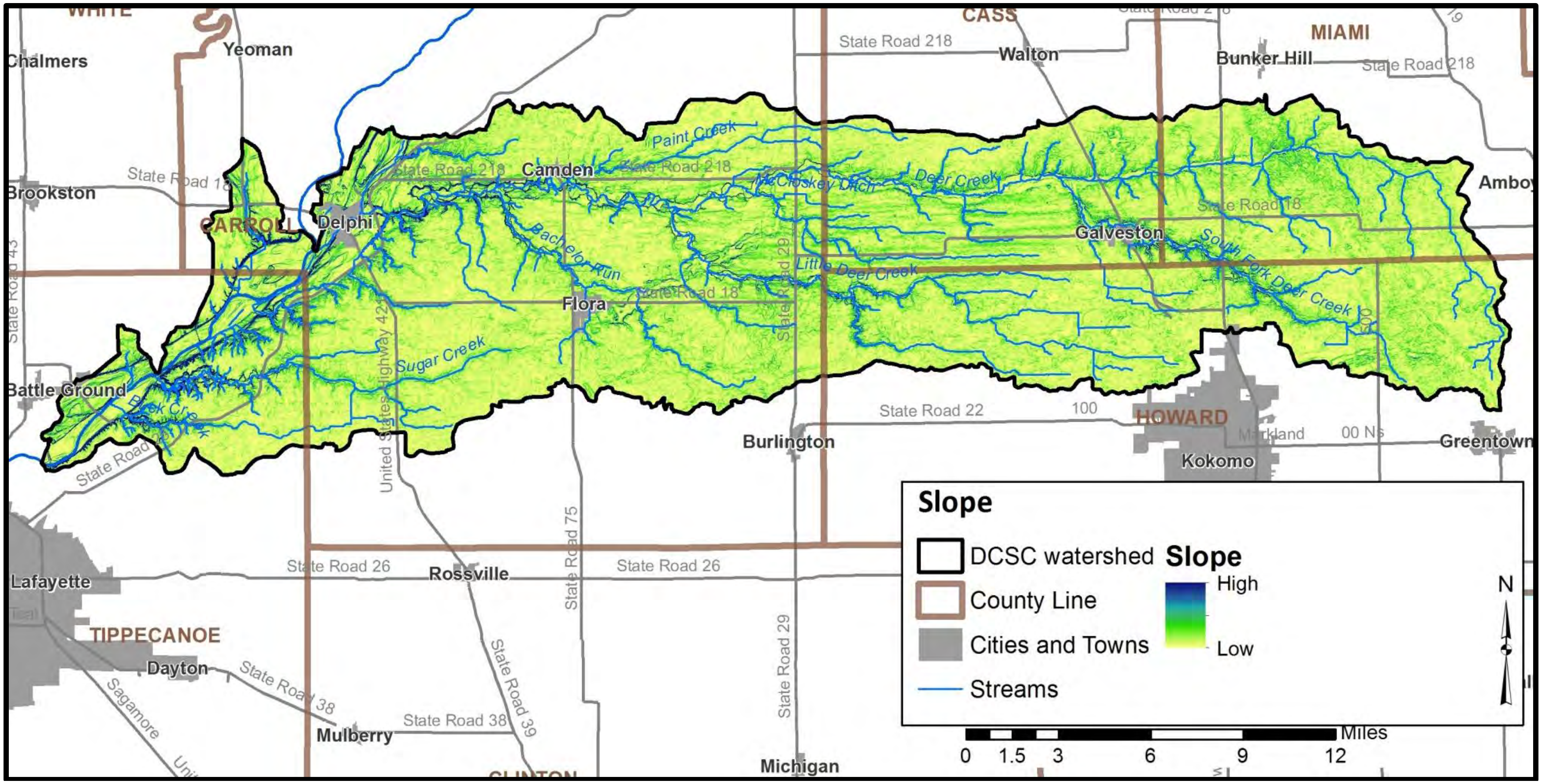

Figure 11. Surface slope of the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

2.5 Soil Characteristics

2.5.1 Soil Associations

The watershed is covered by 13 soil associations with six associations individually accounting for 5% or more of the total watershed area. The Fincastle-Brookston-Miamian soil association covers approximately half of the watershed (50.5% or 121,133 acres; Table 4). The Fincastle-Brookston-Miamian association lies within till deposits (loam till) and is somewhat poorly drained. This association is nearly level and is an upland soil. The Blount-Pewamo-Glynwood association covers 10.5% of the watershed. This association covers the eastern most part of the watershed in Howard and Miami counties, lies within till deposits, and a silty clay-loam to clay-loam. The Blount-Pewamo-Glynwood soil association is nearly level to gentle sloping. The Fox-Ockley-Westland association is the predominant soil association along Deer Creek's main section in Carroll County to where it enters the Wabash River. Fox-Ockley-Westland soil association lies on glacial outwash deposits and mixed drift. The Russell-Miami-Xenia, Patton-Starks-Kendall, and Rockfield-Fincastle-Camden soil associations are also common in the watershed. The Russell-Miami-Xenia soil association borders Deer Creek's main section in Cass County and also the majority of the South Fork of Deer Creek. In Carroll County, the Patton-Starks-Kendall association borders the eastern parts of the Fox-Ockley-Westland association while the Rockfield-Fincastle-Camden association borders the middle and western parts of the Fox-Ockley-Westland association (Figure 12).

Table 4. Soil Associations in the Deer Creek-Sugar Creek watershed.

Soil Name	Area (acres)	Percent of Watershed
Fincastle-Brookston-Miamian	121,133.0	50.5%
Blount-Pewamo-Glynwood	25,285.8	10.5%
Fox-Ockley-Westland	19,089.3	8.0%
Russell-Miami-Xenia	16,861.3	7.0%
Patton-Starks-Kendall	13,004.0	5.4%
Rockfield-Fincastle-Camden	12,076.7	5.0%
Crosby-Treaty-Miami	11,627.7	4.8%
Sawmill-Lawson-Genesee	6,874.4	2.9%
Miami-Crosby-Treaty	5,297.1	2.2%
Miami-Strawn-Hennepin	3,680.3	1.5%
Elston-Warsaw-Shipshe	3,029.8	1.3%
Millsdale-Newglarus-Randolph	1,635.2	0.7%
Mahalasville-Waynetown-Sleeth	447.0	0.2%
TOTAL	**240,041.6**	**100%**

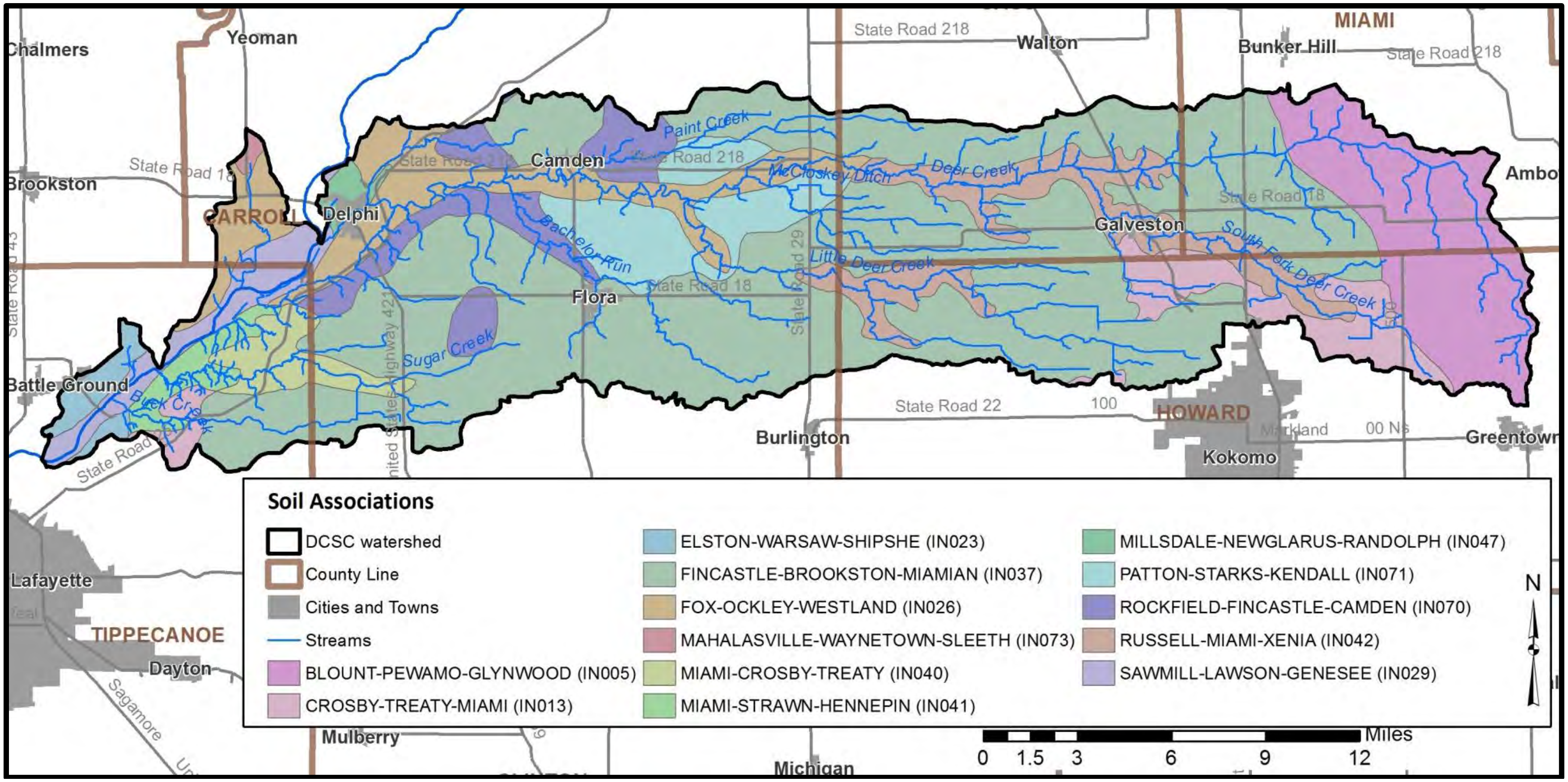

Figure 12. Soil Associations in the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

2.5.2 Soil Erodibility

Soils that move from the landscape to adjacent waterbodies result in degraded water quality, limited recreational use, and impaired aquatic habitat and health. Soils carry attached nutrients, pesticides, and herbicides. These can result in impaired water quality by increasing plant and algae growth, killing aquatic life or damaging water quality. The ability or likelihood for soils to move from the landscape to waterbodies are rated by the Natural Resources Conservation Service (NRCS). The NRCS uses soil texture and slope to classify soils into those that are considered highly erodible, potentially erodible, and non-erodible. The classification is based on an erodibility index which is determined by dividing the potential average annual rate of erosion by the soil unit's soil loss T (Tolerance) value. The T value is the maximum annual rate of erosion that can occur for a particular soil type without causing a decline in long-term productivity. The standard NRCS determination of potentially highly erodible soil is based on the steepness and the length of the underlying slope and erodibility index value. Highly and potentially highly erodible soils are mapped in Figure 13.

Watershed stakeholders are concerned with soil erosion. As detailed above, soils which have a high erodibility index value are those that are located on steep slopes and are easily moved by wind, water, or land uses. Figure 13 details locations of highly erodible and potentially highly erodible soils within the Deer Creek-Sugar Creek watershed. In total, highly erodible soils cover 4.7% of the watershed, or approximately 11,288 acres, while potentially highly erodible soils cover 9.7% of the watershed, or approximately 23,187 acres. Tippecanoe County contains the most highly erodible soil (3,461 acres) of the five counties despite only making up 9.6% the watershed (Table 5). Potentially highly erodible soils are concentrated in Carroll and Cass counties. Miami County does not contain any potentially highly erodible soils within the Deer Creek-Sugar Creek watershed.

Table 5. Highly erodible soils (HES) and potentially erodible soils (PHES) in the Deer Creek-Sugar Creek watershed.

County	Highly Erodible Soils (acres)	Potentially Highly Erodible Soils (acres)
Carroll	3,111.3	15,618.0
Cass	1,597.9	5,132.7
Howard	869.2	1,020.1
Miami	2,249.2	-
Tippecanoe	3,460.9	1,416.2

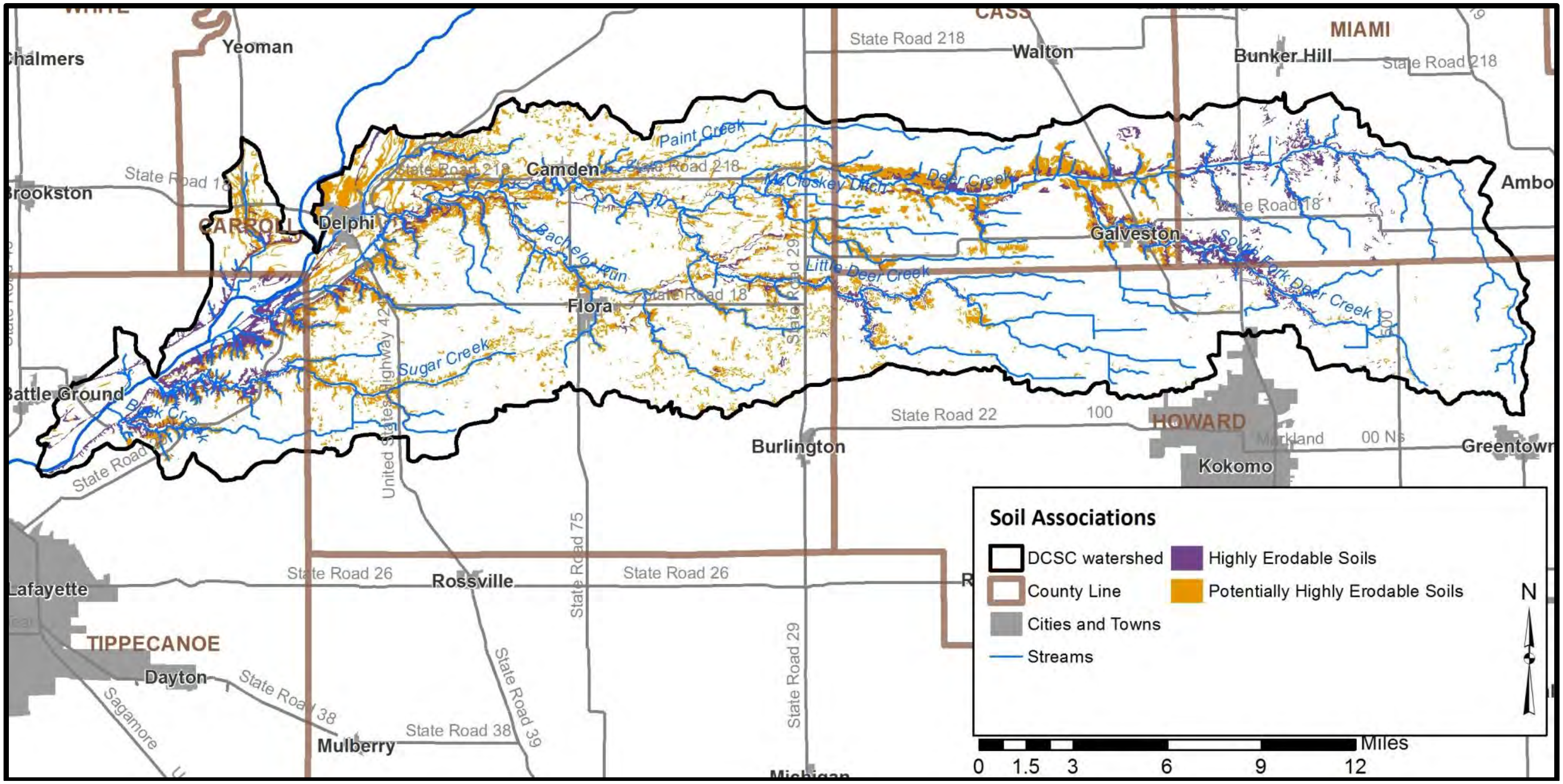

Figure 13. Highly erodible soils and potentially highly erodible soils in the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

2.5.3 Hydric Soils

Hydric soils are those which remain saturated for a sufficient period of time, thereby generating a series of chemical, biological, and physical processes. After undergoing these processes, the soils maintain the resultant characteristics even after draining or use modification occurs. Approximately 80,283 acres, or 33% of the watershed, is covered by hydric soils. The majority of the hydric soils are located in the headwaters of Deer Creek (northern Howard/southern Miami counties) and Little Deer Creek (northwest Howard/southeast Carroll counties; Figure 14). As these soils are considered to have developed under wetland conditions, they are a good indicator of historic wetland locations and therefore will be revisited in the land use section.

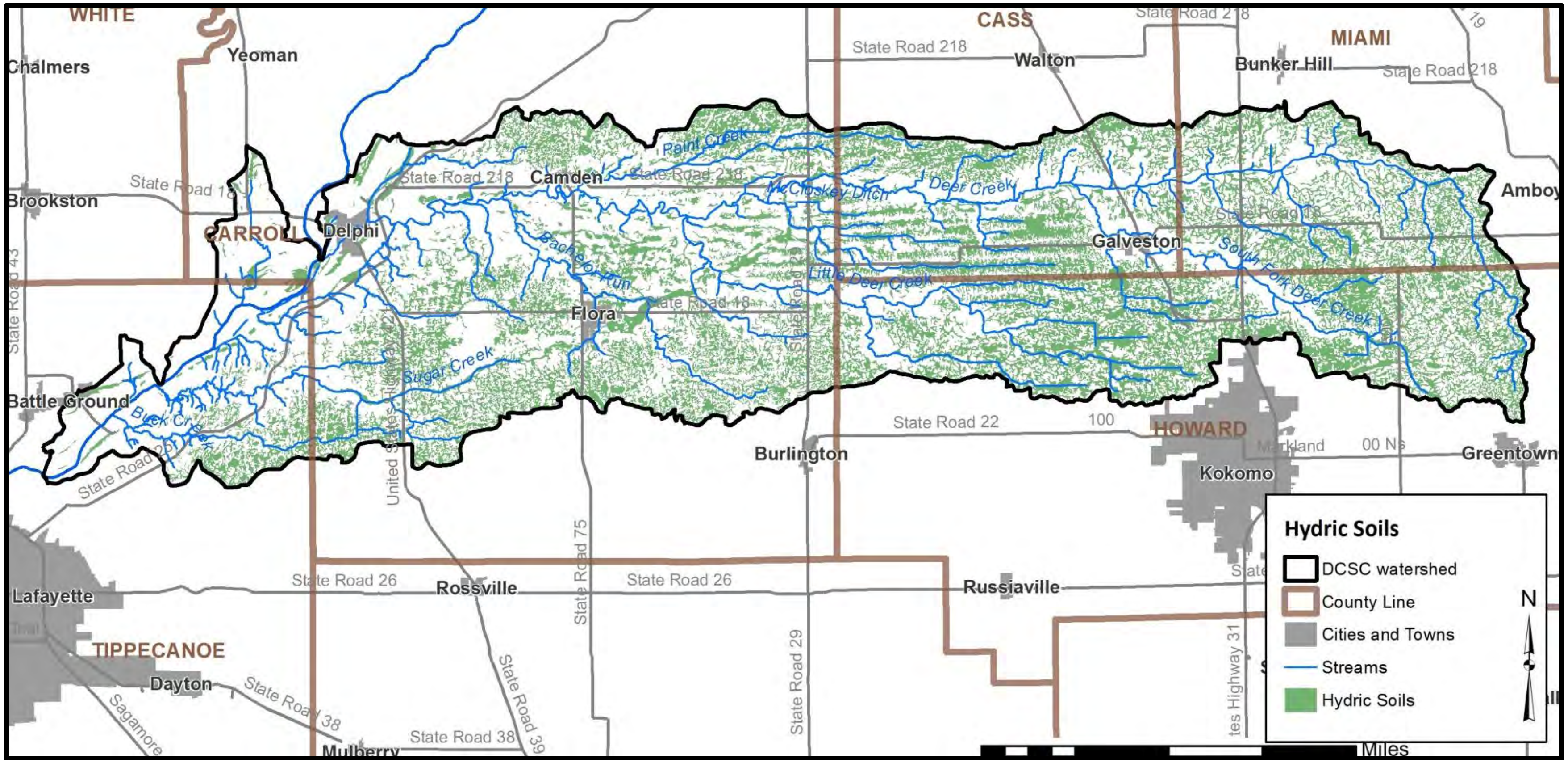

Figure 14. Hydric soils in the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

2.5.4 Tile Drained Soils

Soils drained by tile are common in the Deer Creek-Sugar Creek watershed. Tile drained soils are those soils located on cultivated cropland and classified as somewhat poorly, poorly, and very poorly drained. Using GIS data for calculations, tile drained soils cover approximately 65%, or 156,041 acres, of the watershed (Figure 15). Tile drained acres were not field verified. There are minimal tile drained soils west of the Wabash River; this is due to the large amount of outwash and silty-clay loam. The areas of the watershed that are not tile drained are the areas that have the greatest slope, thus the land would be able to drain without artificial assistance. Additionally, the area west of Flora that is not tile drained is covered by the Rockfield-Fincastle-Camden association, which is a very well-drained soil. In areas where the land is tile drained, the materials applied to agricultural soils are directly transported to waterbodies. Stakeholders are concerned about high *E. coli* concentrations and the volume of manure applied to agricultural land. Since the majority of the areas where manure is applied are tile drained, the nutrients and *E. coli* are likely being transported to the streams were the tiles discharge.

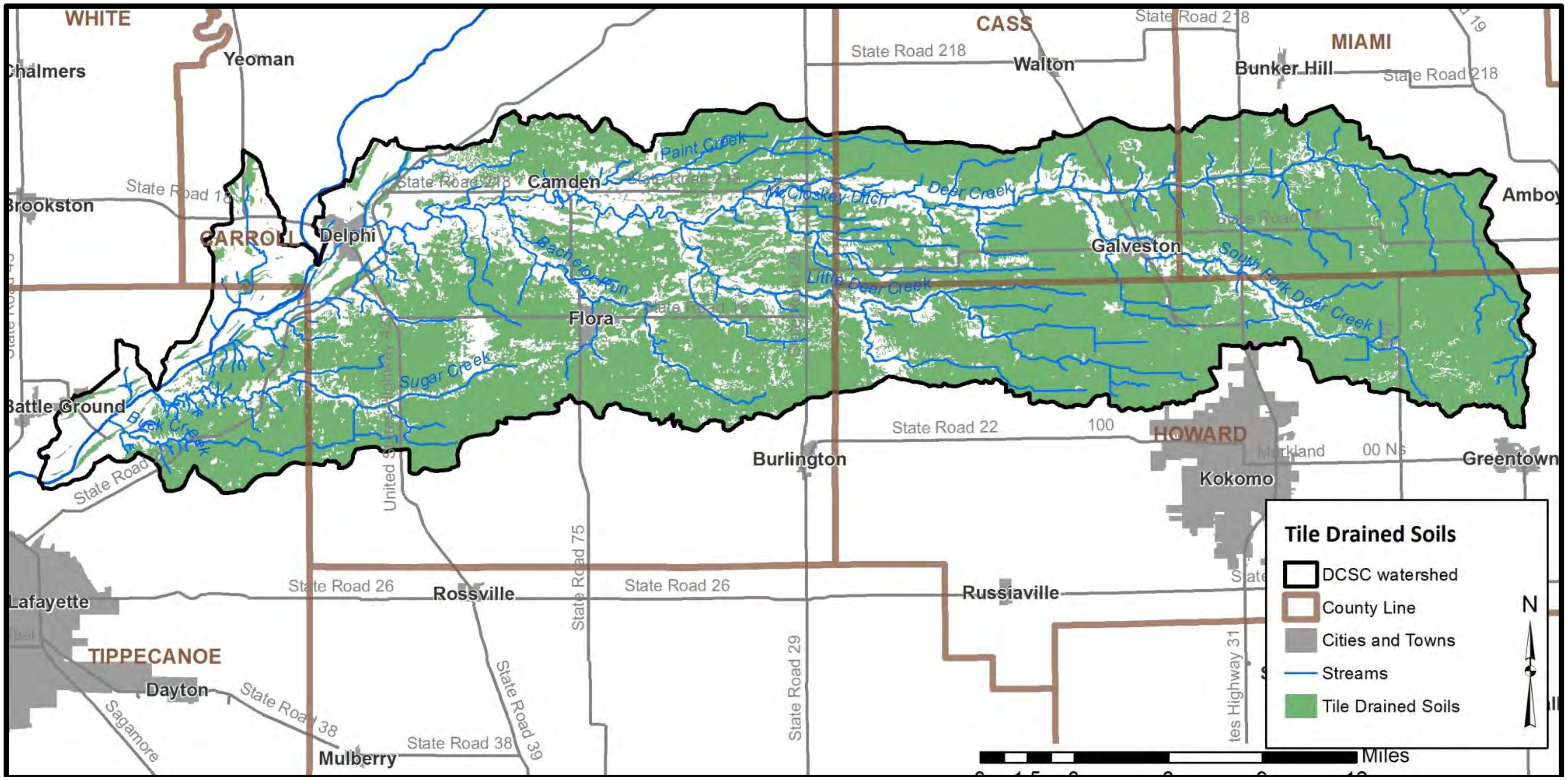

Figure 15. Tile-drained soils in the Deer Creek-Sugar Creek watershed.
Data used to create map is detailed in Appendix A.

2.6 Wastewater Treatment

2.6.1 Soil Septic Tank Suitability

The Natural Resources Conservation Service (NRCS) ranks each soil series in terms of its limitations for use as a septic tank absorption field. Each soil series is placed in one of three categories: severely limited, moderately limited, and slightly limited. Some soils are also unranked. Severe limitations delineate areas whose soil properties present serious restrictions to the successful operation of a septic tank tile disposal field. Using soils with a severe limitation increases the probability of the system's failure and increases the costs of installation and maintenance. Areas designated as having moderate limitations have soil qualities which present some drawbacks to the successful operation of a septic system; correcting these restrictions will increase the system's installation and maintenance costs. Slight limitations delineate locations whose soil properties present no known complications to the successful operation of a septic tank tile disposal field. Uses of soils that are rated moderately or severely limited generally require special design, planning, and/or maintenance to overcome limitations and ensure proper function.

In total, approximately 217,000 acres, or 90%, of the watershed, is covered by soils that are considered severely limited for use in septic tank absorption fields (Figure 16). An additional 7,700 acres, or 3%, of the watershed soils rate as moderately limited. The remaining 16,000 acres are slightly limited, covered by water, or not rated. The areas that are identified as slightly limited are similar to the surficial geology areas that are covered by outwash, drifts or fan deposits. Many of the unrated soils are located within the cities of Camden, Delphi, and Galveston where wastewater treatment plants handle septic waste.

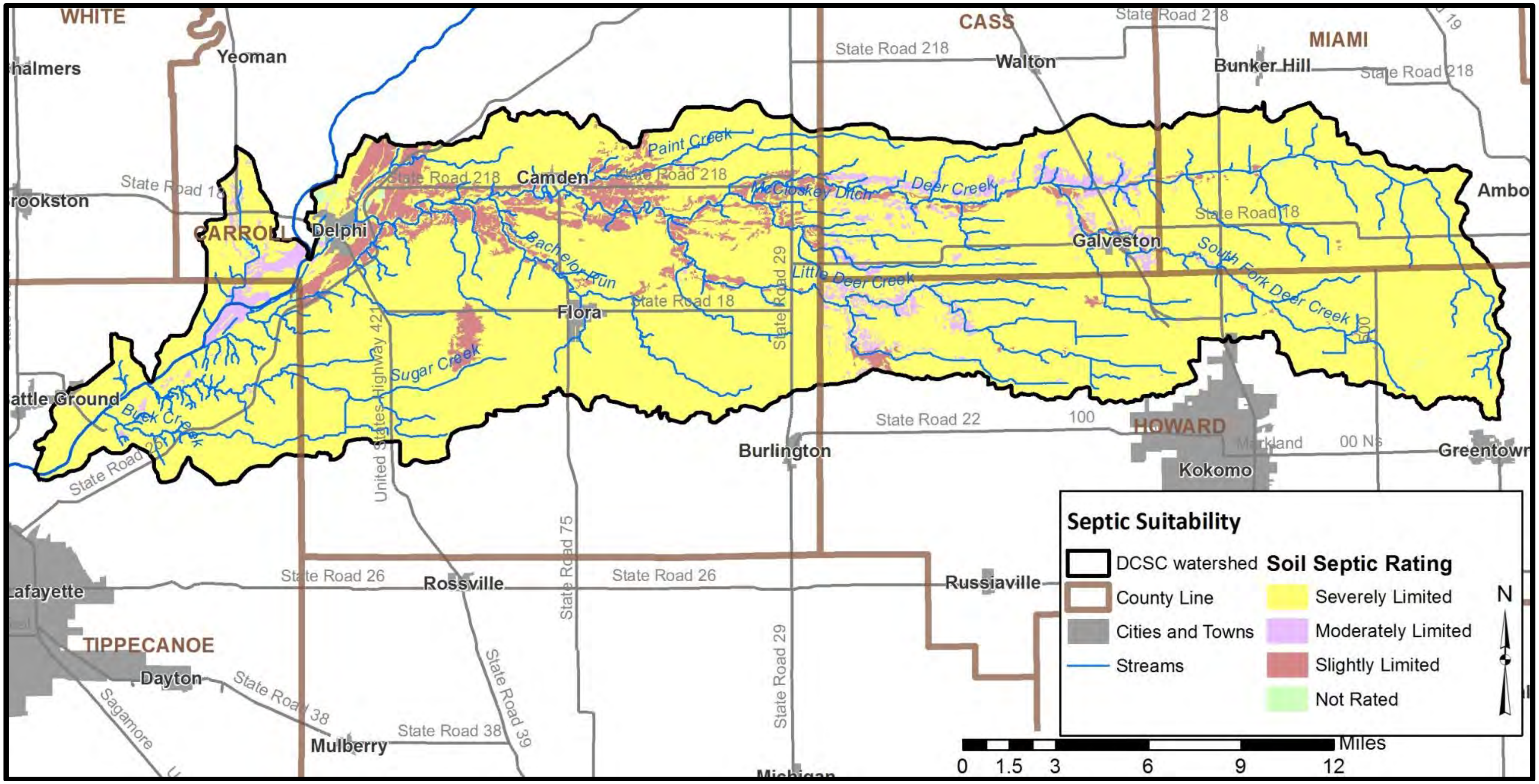

Figure 16. Suitability of soils for septic tank usage within the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

2.6.2 Wastewater Treatment and Solids Disposal

Several facilities which treat wastewater and are permitted to discharge the treated effluent are located within the watershed. These facilities are regulated by National Pollution Discharge Elimination System (NPDES) permits. These include several wastewater treatment plants ranging in size from small, local plants to publicly-owned facilities, industrial dischargers, commercial entities, and school facilities. In total, nine NPDES-regulated facilities are located within the watershed (Figure 17).Table 6 details the NPDES facility name, activity, and permit number. More detailed information for each facility will be discussed on a subwatershed basis in subsequent sections.

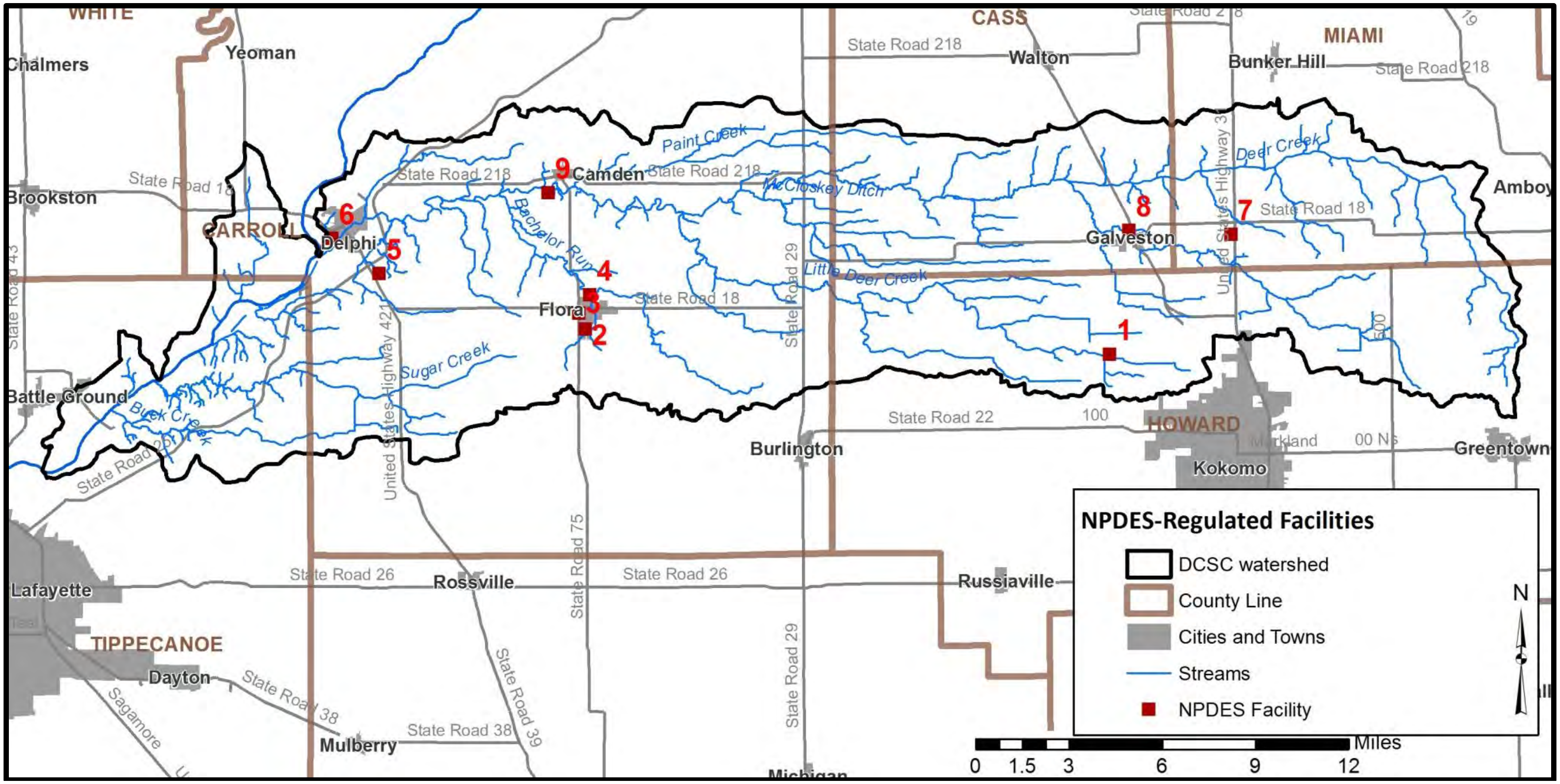

Figure 17. NPDES-regulated facilities in the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

Table 6. NPDES-regulated facility information.

Map ID	NPDES ID	Facility Name	Activity Description	Compliance Status	Past Violations	Flow Data	Discharges To
1	IN0034461	Northwestern Elementary and High School	Elementary and secondary schools	No violation	3 violations 2011-2013		Harrison-Harlan Ditch
2	IN0005029	Flora Public Water Supply	Water supply	No violation	None in past 12 quarters		Kuns Ditch
3	INP000011	Briggs Industries, INC., Sayco	Sanitary system	No violation	None is past 12 quarters		Flora Municipal STP
4	IN0020141	Flora Municipal STP	Sewage system	In violation	6 violations 2011-2013	0.428 MGD treated at secondary level	Bachelor Run
5	IN0059471	Indiana Packers Corp.	Pork processing and packaging	No violation	2 violations in 2011		Tributary of Bridge Creek
6	IN0021377	Delphi Municipal STP	Sewage system	No violation	8 violations 2011-2013	0.4 MGD treated at advanced level	Deer Creek
7	IN0052370	Maple Lawn Village M.H.P.	Residential mobile home sites	No violation	5 violations 2011-2013		Deer Creek
8	IN0021199	Galveston Municipal STP	Sewage system	No violation	5 violations 2011-2013	0.28 MGD treated at advanced level	South Fork of Deer Creek
9	IN0030562	Camden Municipal STP	Sewage system	No violation	1 violation in 2011	0.06 MGD treated at secondary level	Deer Creek

Data from USEPA 2008. Flow data for industrial permit holders not available.

2.6.3 Municipal Wastewater Treatment

In total, four municipal wastewater treatment plants service the areas within the Deer Creek-Sugar Creek watershed (Figure 18). The Camden and Delphi Municipal STP discharge to Deer Creek, the Flora Municipal STP discharges to Bachelor Run, and the Galveston Municipal STP discharges into the South Fork of Deer Creek. Sludge from municipal wastewater treatment plants is applied to 22.8 square miles throughout the watershed. The majority of the application sites are located with the 10-digit HUC Deer Creek watershed (Figure 19). Each of these treatment plants likely has some impact on water quality within the Deer Creek-Sugar Creek watershed. Watershed stakeholders are concerned about how the recent upgrades to the Camden sewage treatment plant (STP) affects nitrate levels in the streams.

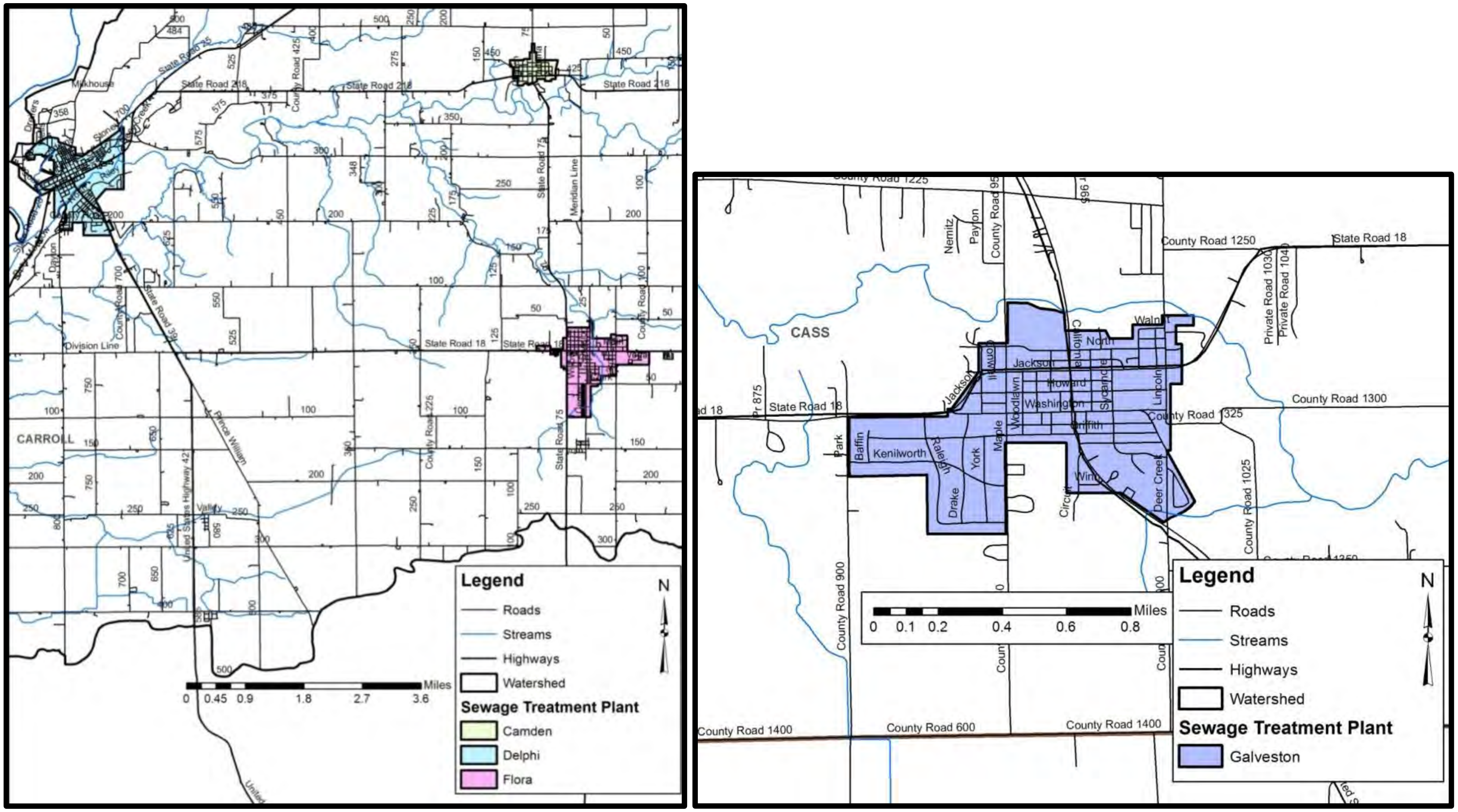

Figure 18. Carroll County sewage treatment areas.
Data used to create this map are detailed in Appendix A.

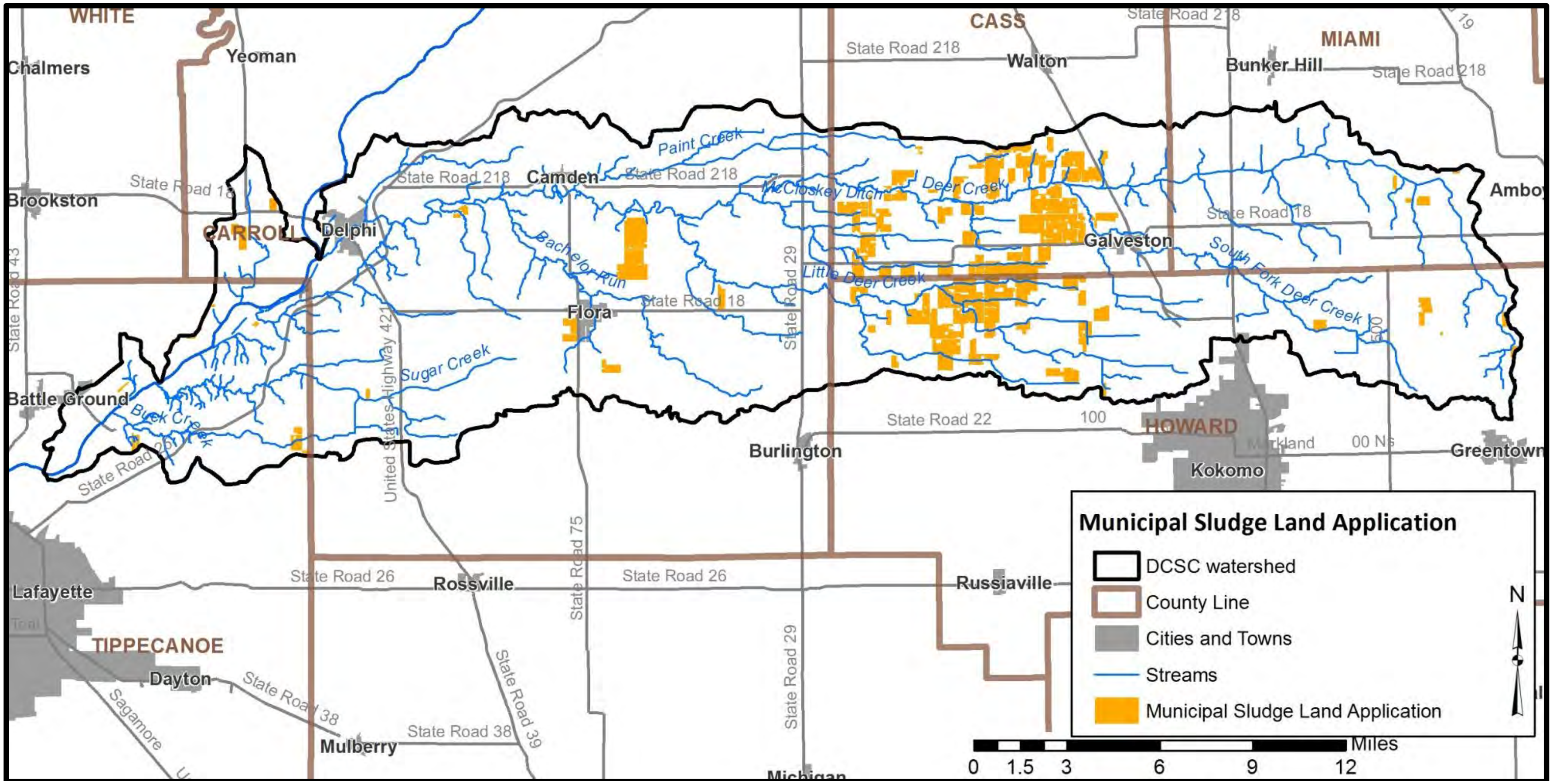

Figure 19. Municipal sludge land application sites within the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

Camden

The Town of Camden operates a sewage treatment plant which serves the town's 615 residents. In total, the plant treats 0.06 million gallons per day (MGD) to the secondary level; effluent is then discharged into Deer Creek (USEPA, 2008). The service area is shown in Figure 18.

Delphi

The Town of Delphi operates a sewage treatment plant which serves the town's 3,015 residents. In total, the plant treats 0.4 MGD to an advanced level; effluent is then discharged into Deer Creek (USEPA, 2008). The service area is shown in Figure 18.

Flora

The Town of Flora operates a sewage treatment plant which serves the town's approximately 2,227 residents. In total, the plant treats 0.428 MGD to the secondary level; effluent is then discharged into Bachelor Run (USEPA, 2008). The service area is shown in Figure 18.

Galveston

Galveston operates a sewage treatment plant which serves 1,884 residents. In total, the plant treats 0.28MGDtoan advanced level; effluent is then discharged into the South Fork of Deer Creek (USEPA, 2008). The service area is shown in Figure 19.

2.6.4 Unsewered Areas

Unsewered areas in the Deer Creek-Sugar Creek watershed were determined via desktop and windshield surveys. Areas that have at least 25 houses within a square mile outside of the incorporated areas were classified as dense, unsewered areas. In the watershed, 42 dense, unsewered areas were identified (Figure 20). Additionally, school buildings are mapped as there is typically high density use at these facilities throughout the year.

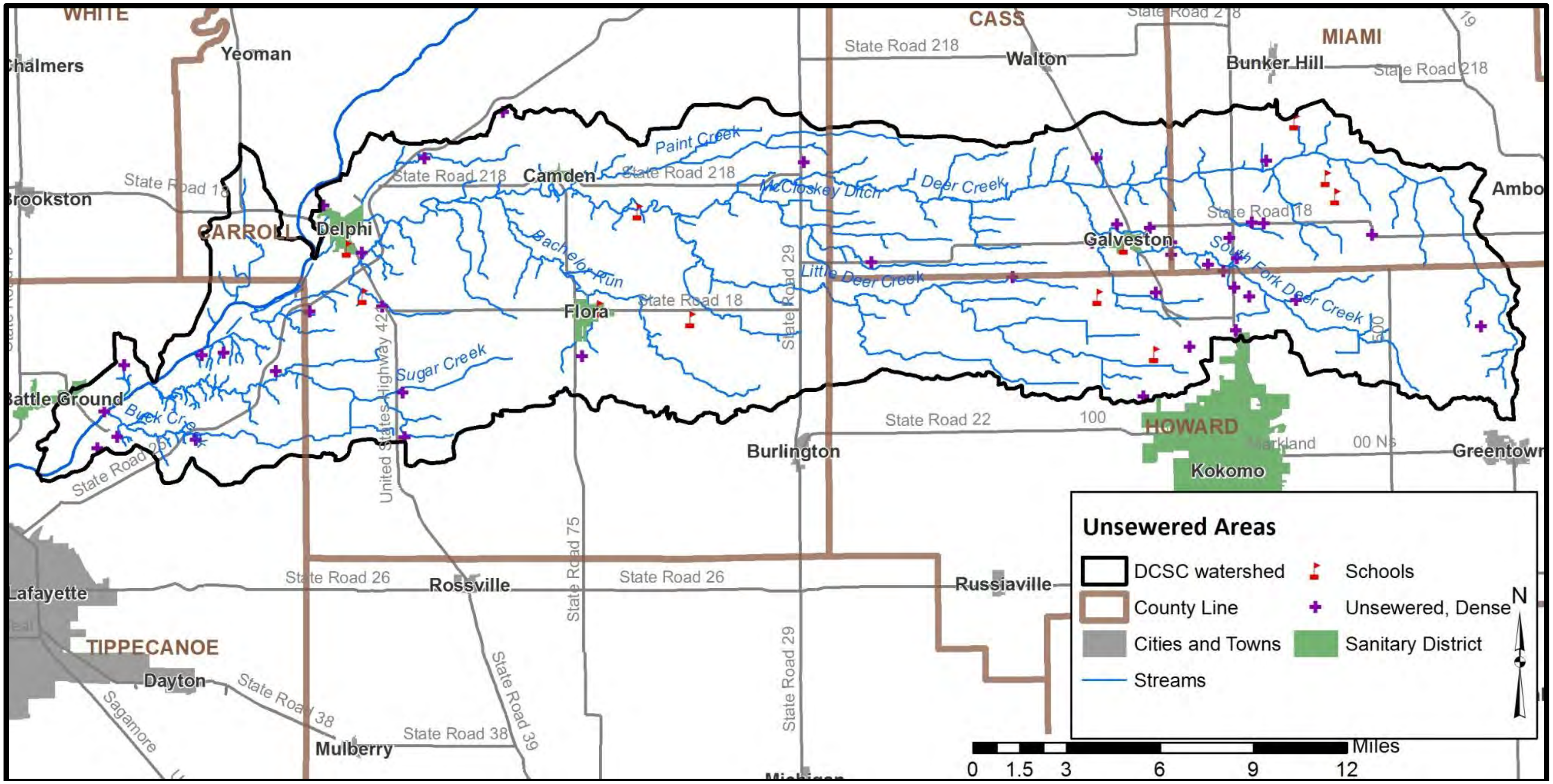

Figure 20. Unsewered areas in the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

2.7 Hydrology

Watershed streams, legal drains, floodplains, wetlands, storm drains, groundwater, subsurface conveyances, and manmade drainage channels all contribute to the watershed's hydrology. Each component moves water into, out of, or through the system. Their contributions will be covered in further details in subsequent sections.

WABASH RIVER
ENHANCEMENT CORPORATION

2.7.1 Watershed Streams

The Deer Creek-Sugar Creek watershed contains more than 600 miles of waterways (Figure 21 to Figure 23). The watershed has four distinct streams, Buck Creek, Deer Creek, Sugar Creek, and the Wabash River. Deer Creek has two headwater streams, the South Fork of Deer Creek and Little Deer Creek, while Sugar Creek has only one headwater stream, Little Sugar Creek. All of the streams drain into the Wabash River; Deer Creek enters just below Delphi, IN, then Sugar Creek and finally Buck Creek. Deer Creek, Sugar Creek, the Wabash River and their tributaries are used for fishing and full-body recreation. Individuals are concerned about consuming the fish from the waterbodies within the watershed. No beaches are located within the watershed; rather, access to the waterbodies is possible via public parks located adjacent to waterbodies such as Riley Park on Deer Creek.

In total, nearly 400 miles of regulated drains exist within the Deer Creek-Sugar Creek watershed. Drainage information was provided by each county surveyor's office (Figure 21 to Figure 23). It should be noted that some regulated drains are maintained by the county surveyor's office; however, some of the regulated drains within the watershed have neither a maintenance fund nor a maintenance schedule, and some maintained waterbodies and legal drains overlap the pre-existing stream system. In addition, definitions of regulated, legal, and maintained waterways differ from county to county. Maintenance practices can include dredging with large construction equipment to maintain flow, debris removal, and vegetation management both within the regulated drain and the riparian zone. As these waterbodies are subject to periodic cleaning, it is important to work with the county surveyor to establish priorities for these waterbodies in terms of water quality improvement and erosion control.

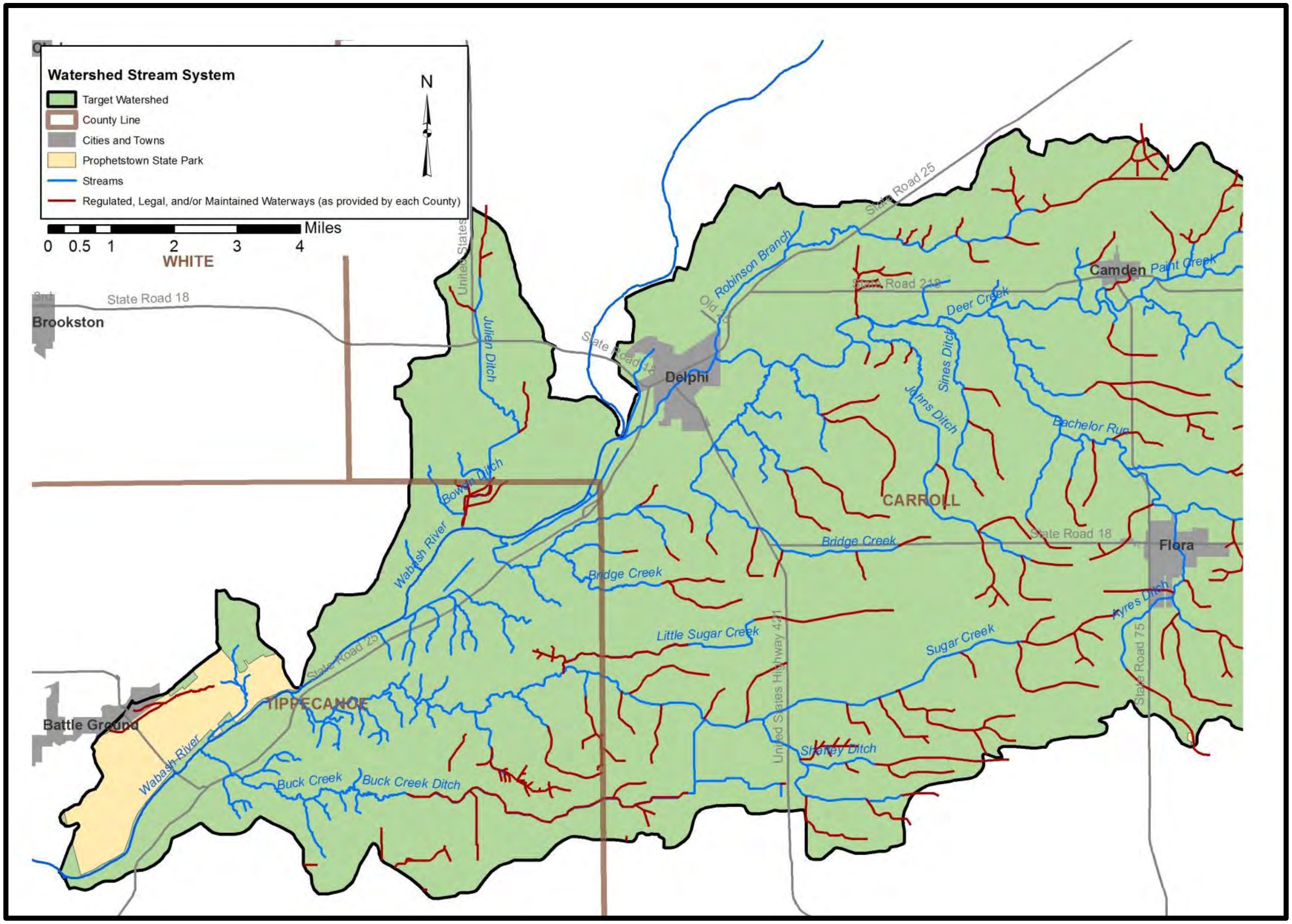

Figure 21. Waterways in the western third of the watershed.
Data used to create this map are detailed in Appendix A.

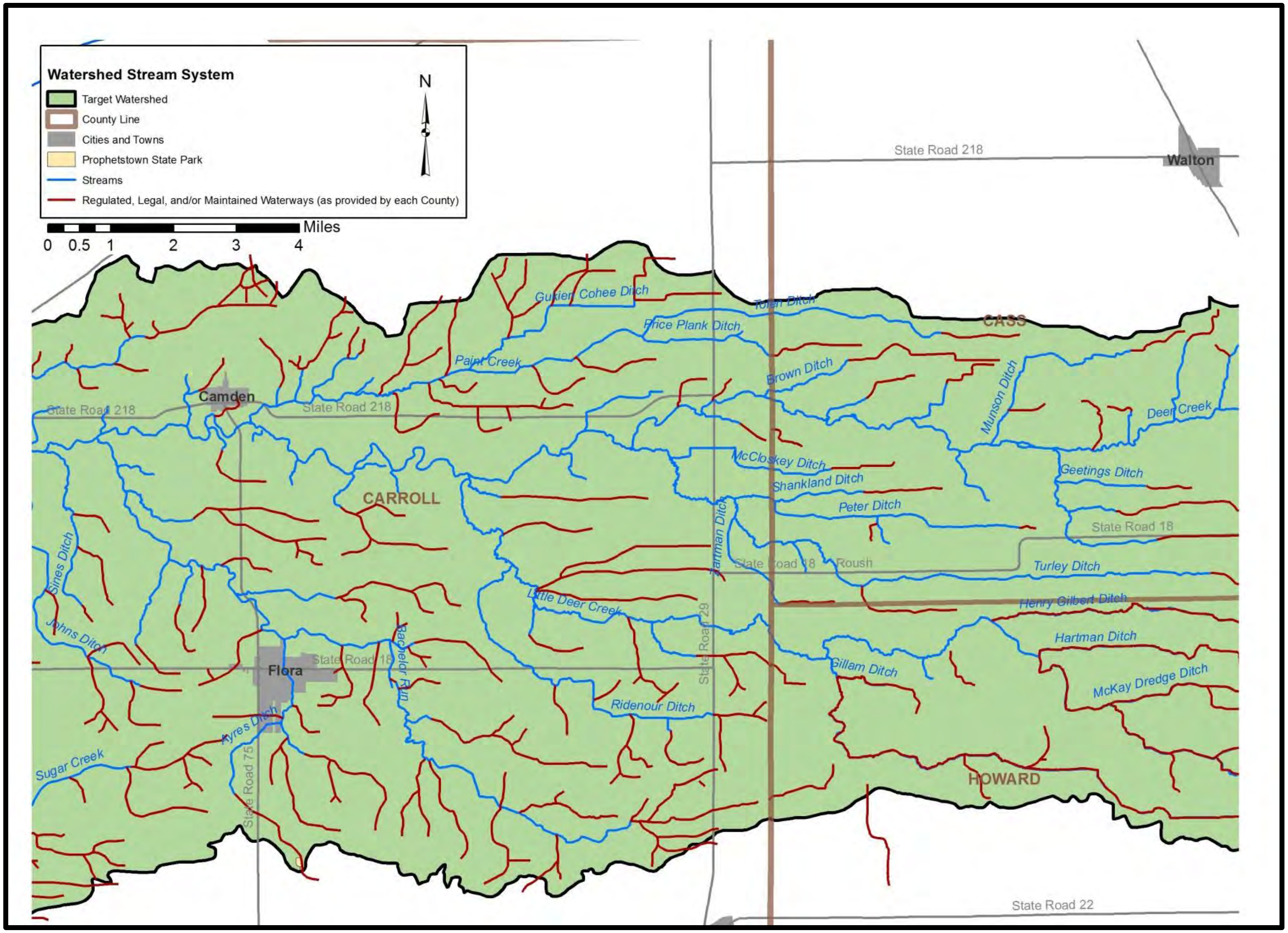

Figure 22. Waterways in the middle third of the watershed.
Data used to create this map are detailed in Appendix A.

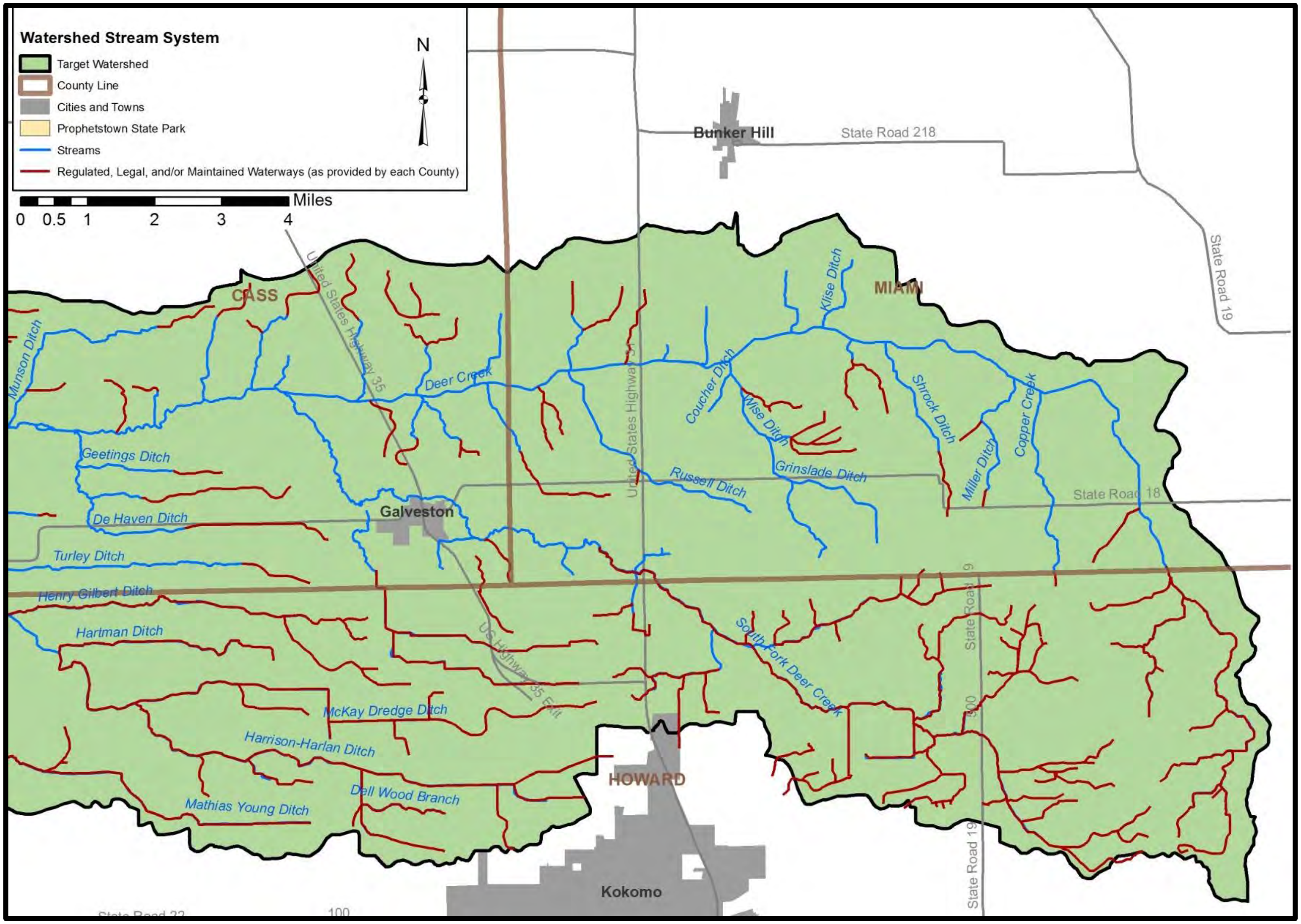

Figure 23. Waterways in the eastern third of the watershed.

2.7.2 Outstanding Rivers

In addition to various stream type classifications discussed above, the state of Indiana also imposes two designations on streams throughout the state. The first is the designation of outstanding rivers. Outstanding rivers or streams are those that are of particular environmental or aesthetic interest and qualify under one or more of 22 categories (NRC, 2007). As such, the 2,000 river miles representing less than 9% of rivers in Indiana were listed by the IDNR Division of Outdoor Recreation.

Only one stream in the Deer Creek-Sugar Creek watershed is designated as an outstanding river (Figure 24). The entire length of the Wabash River that is included in the Deer Creek-Sugar Creek watershed is designated as outstanding. The Wabash River is included as an outstanding river through legislation as part of the Wabash Heritage Corridor. This designation requires that these waterbodies be treated differently with regard to some state statutes and rules. Specifically, log jam removals and utility crossing requirements are more stringent within these waterbodies.

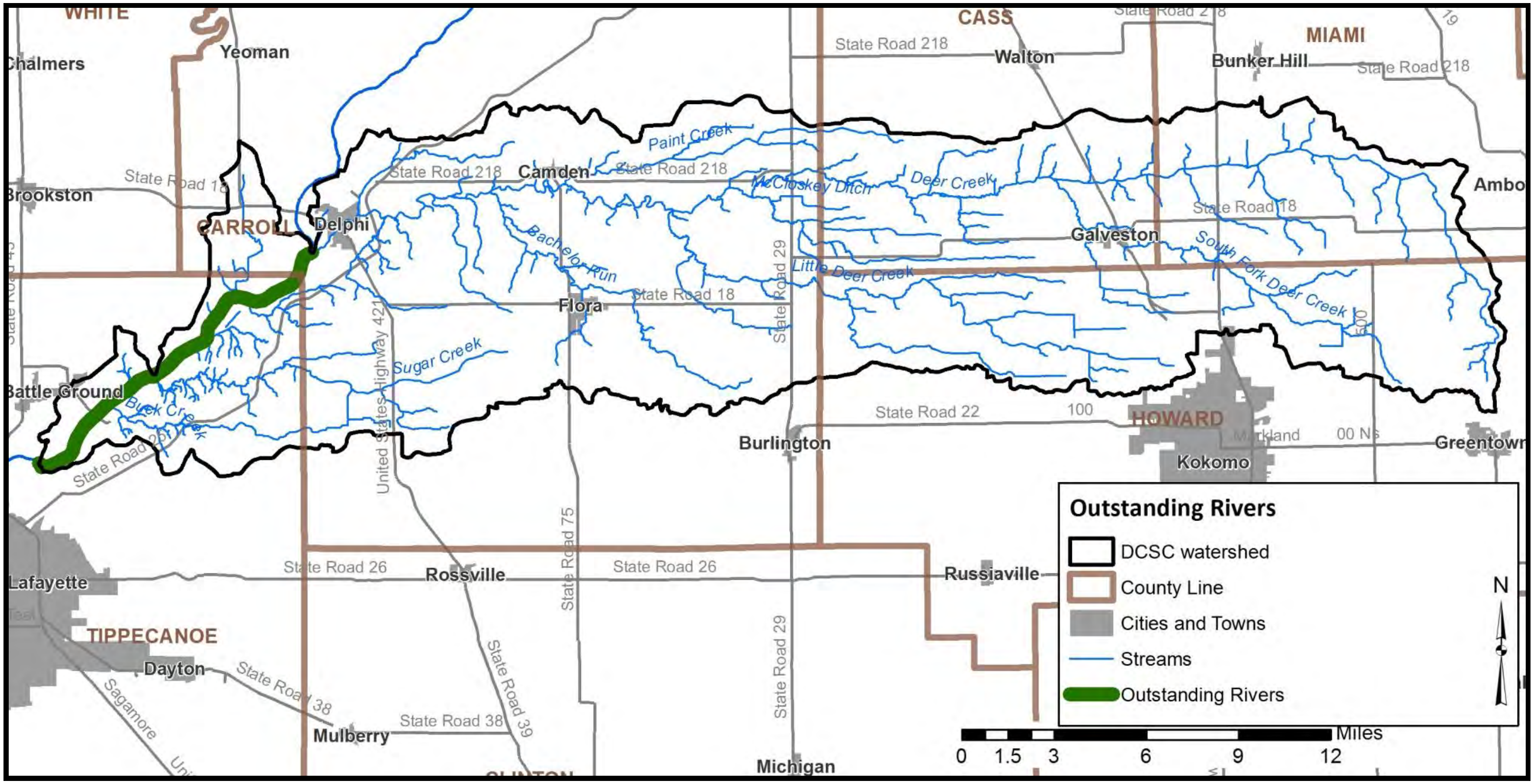

Figure 24. Outstanding river locations in the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

2.7.3 Impaired Waterbodies (303(d) List)

The second type of designation the state of Indiana uses on streams is impaired waterbodies. The impaired waterbodies list is prepared biannually by the Indiana Department of Environmental Management. Waterbodies are included on the list if they do not meet the state's water quality standards. Waterbodies are removed from the impaired waterbodies list once the waterbody again meets the state standards. In total, 45% of the watershed's streams have been assessed and are included on the 2012 Draft List of Impaired Waterbodies or the 303(d) list (Figure 25).

Table 7 details the listed impaired waterbodies in the Deer Creek-Sugar Creek watershed, while Figure 25 shows the segments and their locations within the watershed. Waterbodies are listed for *E. coli*, impaired biotic communities (IBC), and impairments based on fish tissue data including mercury, and polycarbonate biphenyls (PCBs). Based on these listings, the following conclusions can be drawn:

- The *E. coli* water quality standard is routinely exceeded along Buck Creek, Deer Creek, Sugar Creek, Wabash River and several of their tributaries, as well as Bachelor Run, Cohee Ditch, Kuns Ditch, Little Deer Creek, Munson Ditch, Paint Creek, Price Plank Ditch, and Shirar Ditch.
- PCB levels are elevated in Deer Creek and the Wabash River.
- Mercury levels are elevated in the Wabash River.
- Buck Creek, Deer Creek and Little Deer Creek are listed for impaired biotic communities.

Table 7. Impaired waterbodies as assessed and listed on the 2012 List of Impaired Waterbodies.

Assessment Unit Name	Cause of Impairment
Bachelor Run	*E. coli*
Bachelor Run – Unnamed Tributary	*E. coli*
Buck Creek	*E. coli,* IBC
Buck Creek – Unnamed Tributary	*E. coli*, IBC
Buck Creek Ditch	*E. coli*, IBC
Cohee Ditch	*E. coli*
Deer Creek	*E. coli,* IBC, Nutrients, PCBs in fish tissue
Deer Creek – Unnamed Tributary	*E. coli*
Hughes Ditch	*E. coli*
Kuns Ditch	*E. coli*
Little Deer Creek	*E. coli*, IBC, Nutrients
Little Sugar Creek	*E. coli*
Paint Creek	*E. coli*
Price Plank Ditch	*E. coli*
Shirar Ditch	*E. coli*
Sugar Creek	*E. coli*
Sugar Creek – Unnamed Tributary	*E. coli*
Sugar Creek, Branch One	*E. coli*
Wabash River	*E. coli,* IBC, Total Mercury and PCBs in fish tissue

Source: IDEM, 2012

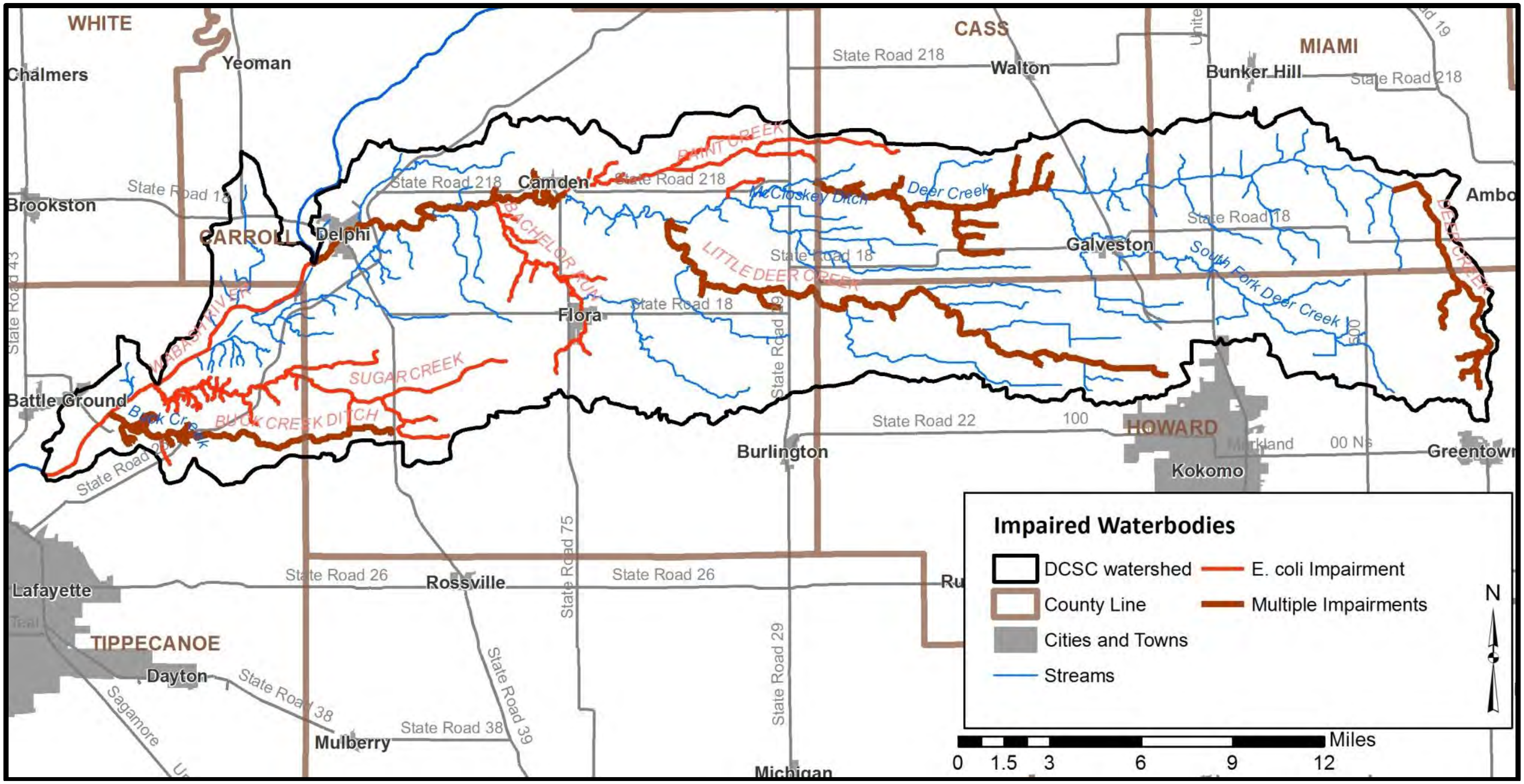

Figure 25. Waterbodies assessed as impaired in the Deer Creek-Sugar Creek watershed.

Data used to create this map are detailed in Appendix A. NOTE: Not all streams in the watershed were assessed; the current 303(d) list did not provide assessment data for the streams on this map which are not marked as impaired.

2.7.4 Floodplains

Flooding is a common hazard that can affect a local area or an entire river basin. Increased imperviousness, encroachment on the floodplain, deforestation, stream obstruction, tiling, or failure of a flood control structure all are mechanisms by which flooding occurs. Impacts of flooding include property and inventory damage, utility damage and service disruption, bridge or road impasses, streambank erosion and riparian vegetation loss, water quality degradation, and channel or riparian area modification.

Floodplains are lands adjacent to streams, rivers, and other waterbodies that provide temporary storage for water. These systems act as nurseries for wildlife, offer green space for humans and wildlife, improve water quality, and buffer the waterbody from adjacent land uses. Approximately 6.0% (14,475 acres) of the Deer Creek-Sugar Creek watershed lies within the 100-year floodplain (Figure 26). This 100-year floodplain is composed of three regions:

- Zone A is the area inundated during a 100-year flood event for which no base flood elevations (BFE) have been established. Zone A covers 72.5% of the Deer Creek-Sugar Creek watershed floodplain for 10,500 acres.
- Zone AE is the area inundated during a 100-year flood event for which BFEs have been determined. The chance of flooding in Zone AE is the same as the chance of flooding in Zone A; however, floodplain boundaries in Zone A are approximated, while those in Zone AE are based on detailed hydraulic models which allows Zone AE floodplains to be more accurate. Zone AE covers 3,742.8 acres or 25.9% of the Deer Creek-Sugar Creek watershed floodplain.
- Zone X includes areas outside the 100-year and 500-year floodplains which have a <1% chance of flooding to a depth of one foot of water. No BFEs are available for these areas and no flood insurance is required. Nearly 232 acres or less than 1.6% of the Deer Creek-Sugar Creek watershed floodplain is located within Zone X.

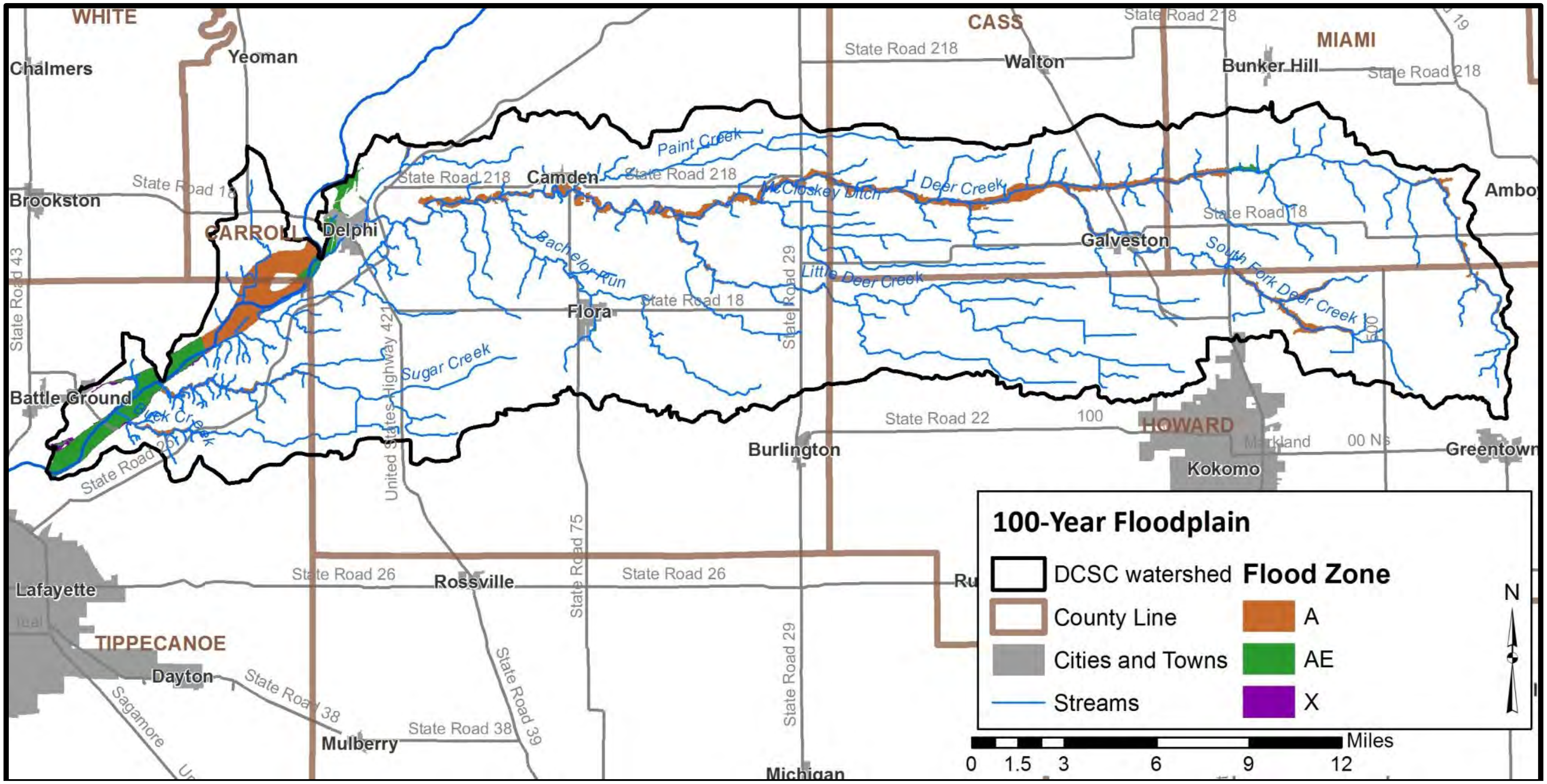

Figure 26. Floodplain locations within the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

2.7.5 Wetlands

Approximately 25% of Indiana was covered by wetlands prior to European settlement (IDEM, 2007). Overall, 85% of wetlands have been lost resulting in Indiana ranking fourth in the nation in terms of percentage of wetland loss. Wetlands provide numerous valuable functions that are necessary for the health of a watershed and waterbodies. Wetlands play critical roles in protecting water quality, moderating water quantity, and providing habitat. Wetland vegetation adjacent to waterways stabilizes shorelines and streambanks, prevents erosion, and limits sediment transport to waterbodies. Additionally, wetlands have the capacity to increase stormwater detention capacity, increase stormwater attenuation, and moderate low water levels or flow volumes by allowing groundwater to slowly seep back into waterbodies. These benefits help to reduce flooding and erosion. Wetlands also serve as high quality natural areas providing breeding grounds for a variety of wildlife. They are typically diverse ecosystems which can provide recreational opportunities, such as fishing, hiking, boating, and bird watching. It should be noted that wetlands are regulated through IDEM and the U.S. Army Corps of Engineers. Any modification to wetlands requires permits from these agencies.

The Deer Creek-Sugar Creek watershed contains approximately 7,202 acres (11.3 square miles) of wetlands. In total, wetlands cover 3.4% of the watershed. When hydric soil coverage is used as an estimate of historic wetland coverage, nearly 92% of wetlands have been modified or lost after European settlement. This represents over 125 square miles of wetland loss within the Deer Creek-Sugar Creek. Figure 27 details the current (pink) and historic (green) distribution of wetlands throughout the watershed. Wetlands displayed in Figure 27 are from compilation efforts by the U.S. Fish and Wildlife Service as part of the National Wetland Inventory (NWI). The NWI was not intended to map specific wetland boundaries that would compare exactly with boundaries derived from ground surveys. As such, NWI boundaries are not exact and should be considered to be estimates of wetland coverage.

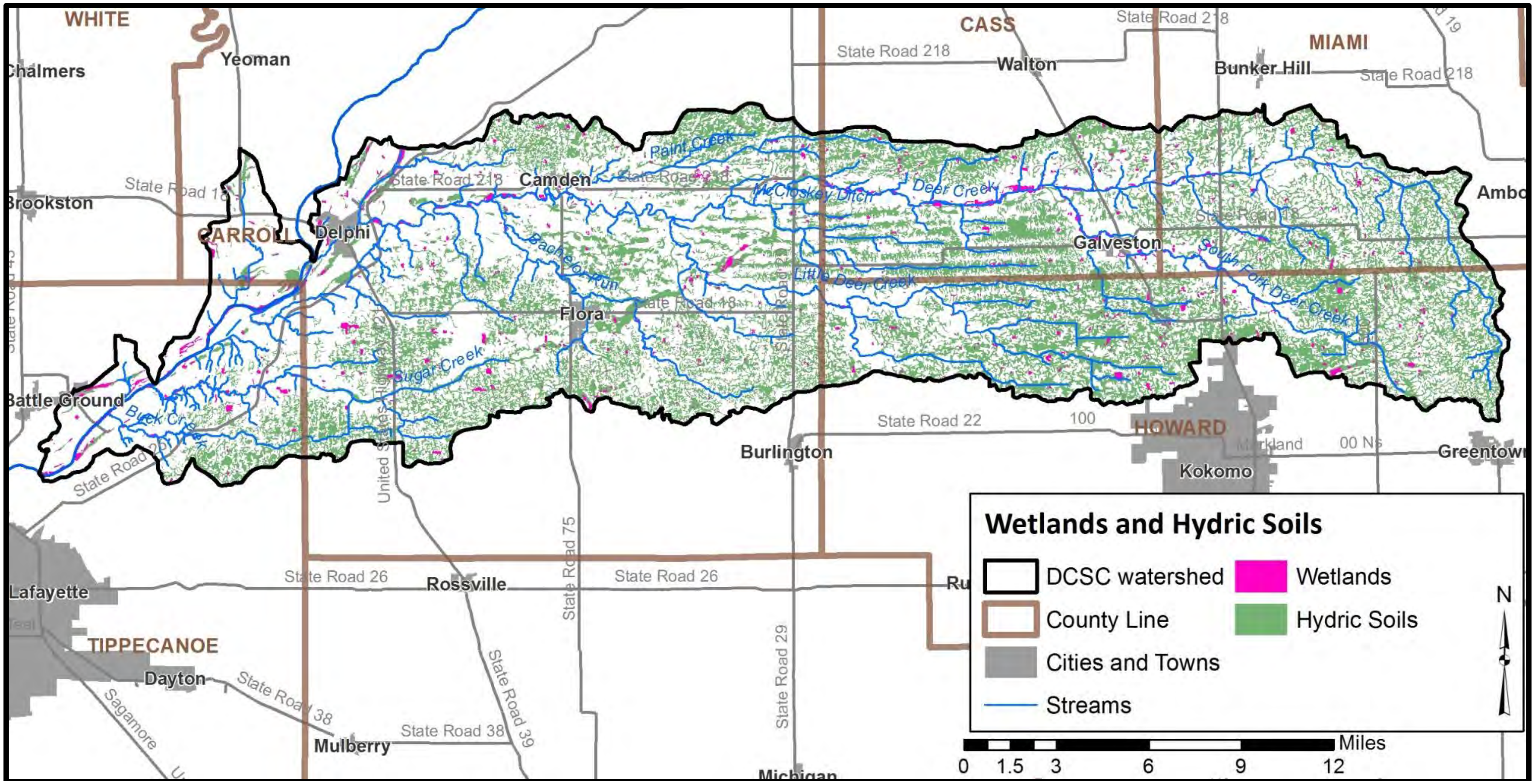

Figure 27. Wetlands and hydric soils located in the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

2.7.6 Stormwater and Storm Drains

Given the highly agricultural nature of the watershed, only a very small portion of land has infrastructure specifically to manage stormwater. Small parts of both the Howard County and Tippecanoe County Partnership for Water Quality Municipal Separate Storm Sewer Systems (MS4s) encroach into the watershed in Howard and Tippecanoe Counties, respectively (see sections 2.11.4 and 2.11.5), but neither discharge stormwater into the watershed. The City of Delphi, and the Towns of Flora, Camden, and Galveston also have infrastructure to collect and treat stormwater. Flora and Delphi have both separated their stormwater systems from their sewer systems and treat both separately. Only

Galveston has a combined sewer overflow (CSO) which would discharge into the South Fork of Deer Creek. Camden does not have any CSOs. Stormwater and storm drains are not presently a concern for this watershed.

2.7.7 Well Fields and Groundwater

The Silurian-Devonian aquifer (carbonate-rock), and other surficial sand and gravel aquifers may be utilized in the Deer Creek-Sugar Creek watershed by rural wells. Recharge of local aquifers occurs in the same manner as do many of the other aquifers in the state, namely by the downward percolation of local rainfall through the soil horizon and underlying formations. However, localized significant rainstorms can produce relatively quick response to recharge especially if adjacent areas did not receive the rainfall. Table 8 lists the wellhead protection areas within the Deer Creek-Sugar Creek watershed. Potential pollution from construction, sewage outfall, illegal dumping, agriculture, and storm water runoff must be avoided or controlled due to the recharge of these aquifers from runoff and river water. A map showing the location of the wellhead protection areas, generalized to within 2 miles to protect the specific location of drinking water wells, is located in Appendix G. Land use within the wellhead protection areas is primarily agricultural. The utility districts actively engage landowners within the protection areas and assist them in utilizing agricultural practices to protect water quality in the wells.

Table 8. Wellhead protection areas within the Deer Creek-Sugar Creek watershed.

ID Number	System Name	City
5208001	Camden Water Utility	Camden
5208002	Delphi Water Works	Delphi
5208003	Flora Water Works	Flora
5209003	Galveston Water Works	Galveston

2.7.8 Lakes

There are no lakes in the Deer Creek-Sugar Creek watershed.

2.8 Natural History

Geology, climate, geographic location, and soils all factor into shaping the native flora and fauna which occurs in a particular area. Categorization of these floral and faunal communities has been completed by a number of ecologists since the earliest efforts by Coulter in 1886. Since this time, Petty and Jackson (1966) identified regional communities; Homoya et al. (1985) classified Indiana into natural regions, while Omernik and Gallant (1988) categorized Indiana into ecoregions.

2.8.1 Natural and Eco-region Descriptions

The Deer Creek-Sugar Creek watershed mostly lies within the Central Tipton Till Plain natural region. The Central Tipton Till Plain is the largest natural region in Indiana. The Tipton Till Plain subregion of the Central Tipton Till Plain natural region covers approximately 82%, or 196,600 acres, of the watershed (Figure 28). It is characterized by a mix of poorly drained soils, which support a variety of oaks, maples, ash, elm, and sycamore, and better drained soils that are home to hickory, tulip tree, white ash, sugar maple, and beech (Jackson, 1997). The Bluffton Till Plain and Entrenched Valley subregions cover 28,905 acres (12%) and 14,191 acres (6%), respectively. The Bluffton Till Plain is composed of clay-rich soils with little to no slope, while the Entrenched Valley is identified by the deep entrenched valleys along drainages. Additionally, a very small area (328 acres) along the western edge of the watershed near Battle Ground lies within the Grand Prairie natural region. The Grand Prairie natural region is dominated by communities of tall prairies.

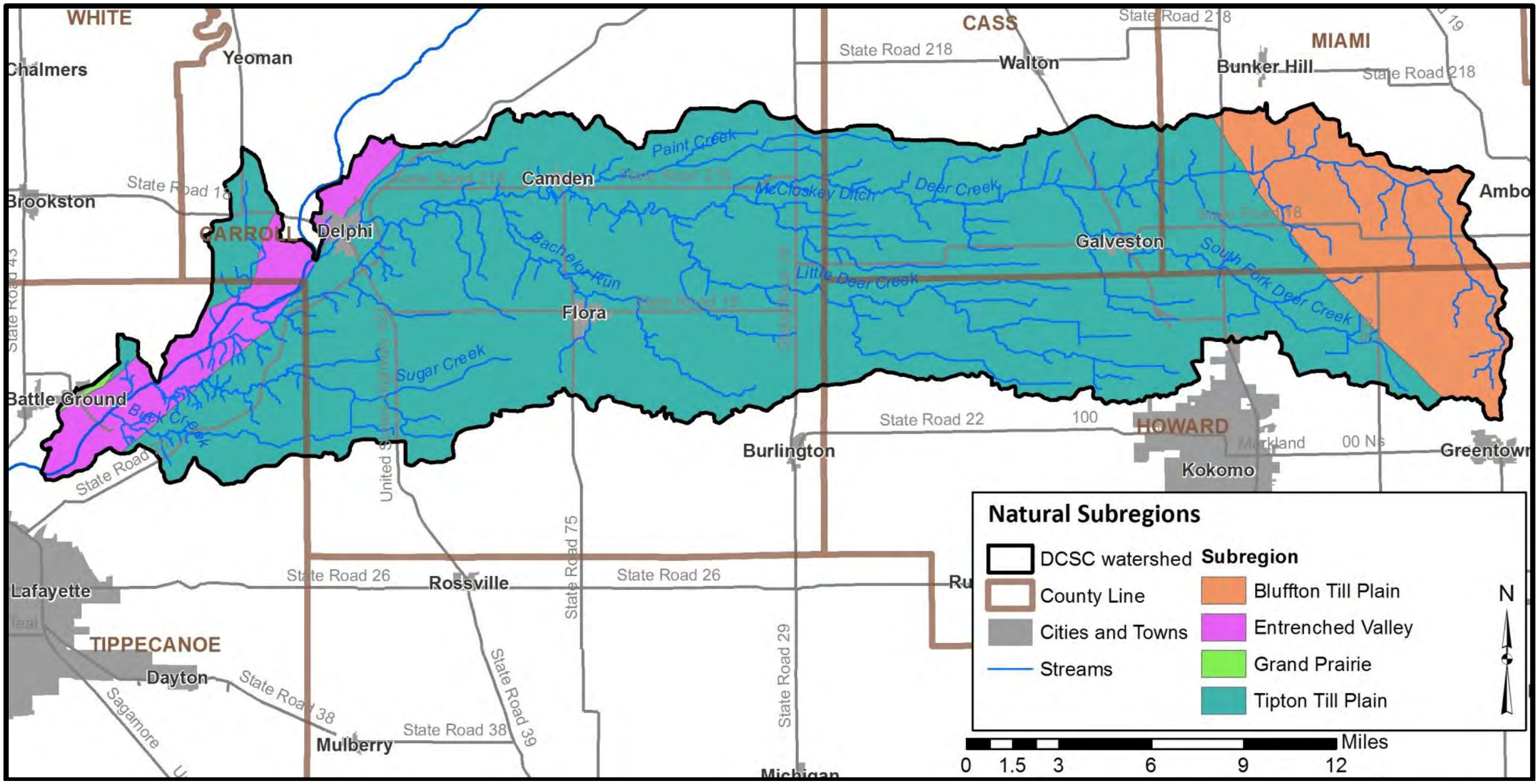

Figure 28. Natural subregions in the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

The watershed lies within the Eastern Corn Belt Plains level III eco-region. Omernik and Gallant (2008) describe the Eastern Corn Belt Plains as being primarily composed of gently rolling hills where tree cover occurs naturally. Additionally, soils are rich and well-drained and soybeans, corn and livestock production is common. In respect to level IV eco-regions, the watershed lies within the Clayey High Lime Till Plains and the Loamy High Lime Till Plains (Figure 29). The dividing line between the two eco-regions is located at the far eastern portion of the watershed. Griffith and Omernik (2008) describe the Clayey High Lime Till Plain as being level, having less production and the soils tend to need to be artificially drained. Conversely, the Loamy High Lime Till Plains tend to have descent natural drainage and more productive soils.

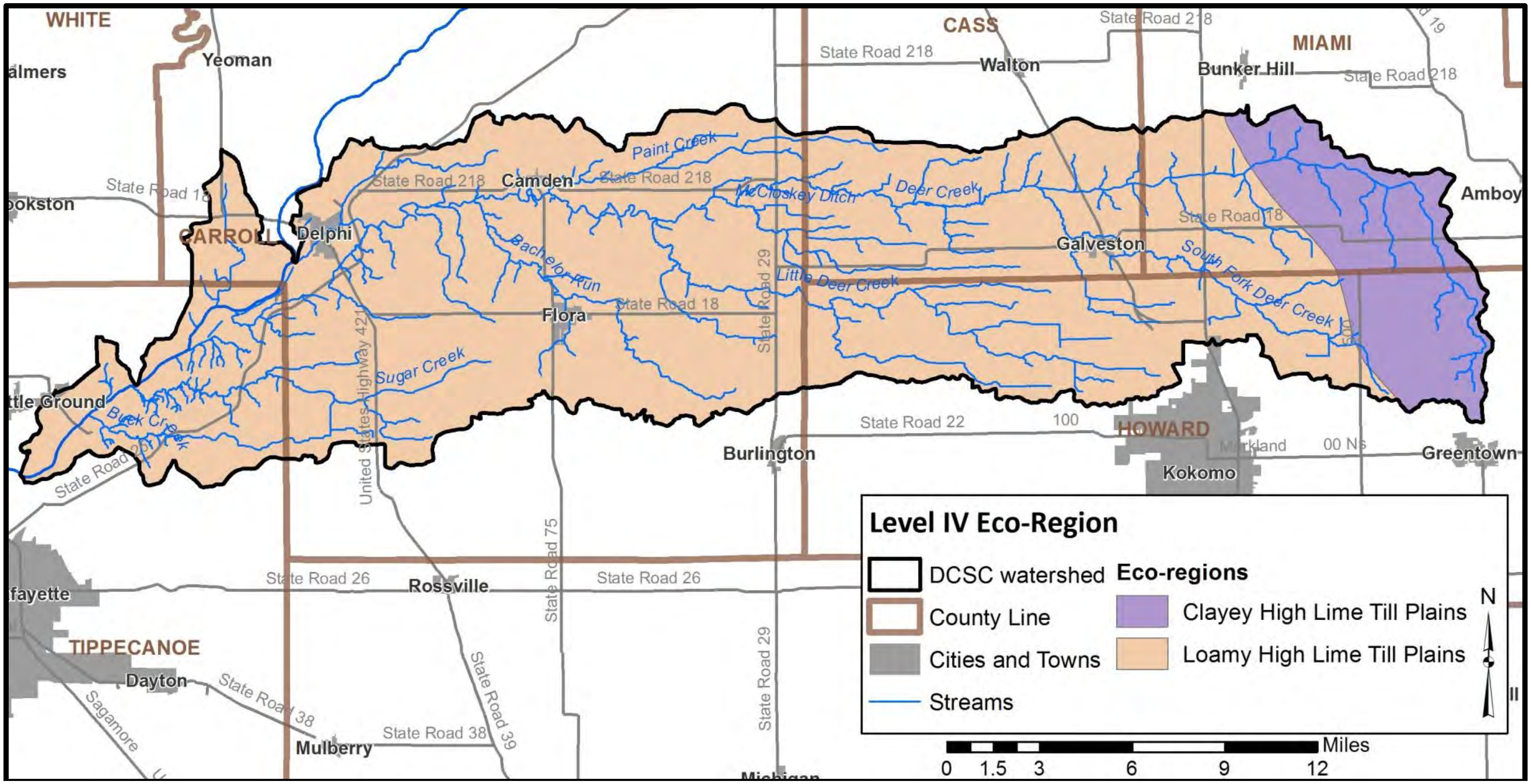

Figure 29. Level IV eco-regions in the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

2.8.2 Endangered Species

The Indiana Natural Heritage Data Center, part of the Indiana Department of Natural Resources, Division of Nature Preserves, maintains a database documenting the presence of endangered, threatened, or rare species; high quality natural communities; and natural areas in Indiana. The database originated as a tool to document the presence of special species and significant natural areas and to assist with management of said species and areas where high quality ecosystems are present. The database is populated using individual observations, which serve as historical documentation or as sightings occur; no systematic surveys occur to maintain the database.

The State of Indiana uses the following definitions to list species:

- *Endangered*: Any species whose prospects for survival or recruitment with the state are in immediate jeopardy and are in danger of disappearing from the state. This includes all species classified as endangered by the federal government which occur in Indiana. Plants currently known to occur on five or fewer sites in the state are considered endangered.
- *Threatened*: Any species likely to become endangered within the foreseeable future. This includes all species classified as threatened by the federal government which occur in Indiana. Plants currently known to occur on six to ten sites in the state are considered threatened.
- *Rare*: Plants and insects currently known to occur on eleven to twenty sites in the state are considered rare.

In total, 78 observations of special species occurred within the Deer Creek-Sugar Creek watershed (Figure 30). Of these observations, 13 federally listed species have historically been observed in the watershed. These listings include 11 mussel species, one reptile, and one bird. The following are federally endangered species: clubshell, eastern fanshell pearly mussel, fat pocketbook, northern riffleshell, rayed bean, ring pink, sheepnose, snuffbox, tubercled blossom, and white wartyback. The bald eagle, eastern massasauga and rabbitsfoot are federally threatened and are listed as candidates for the endangered, threatened, and rare species, respectively. The local community prioritizes preservation of habitat for endangered, threatened, or rare species. A county-based listing of species which occur within this watershed is included in Appendix C.

On a state listing basis, 20 species, which are listed in the Natural Heritage Database as state endangered, have been observed within the Deer Creek-Sugar Creek watershed including:

- **Mussels:** clubshell, eastern fanshell pearlymussel, fat pocketbook, longsolid, northern riffleshell, pyramid pigtoe, rabbitsfoot, sheepnose, snuffbox, tubercled blossom, and white wartyback;
- **Reptiles:** eastern massasauga, Kirtland's snake, and spotted turtle;
- **Fish:** gilt darter;
- **Birds:** cerulean warbler, peregrine falcon, and sedge wren; and
- **Vascular plants:** shaggy false-gromwell, and Canada burnet.

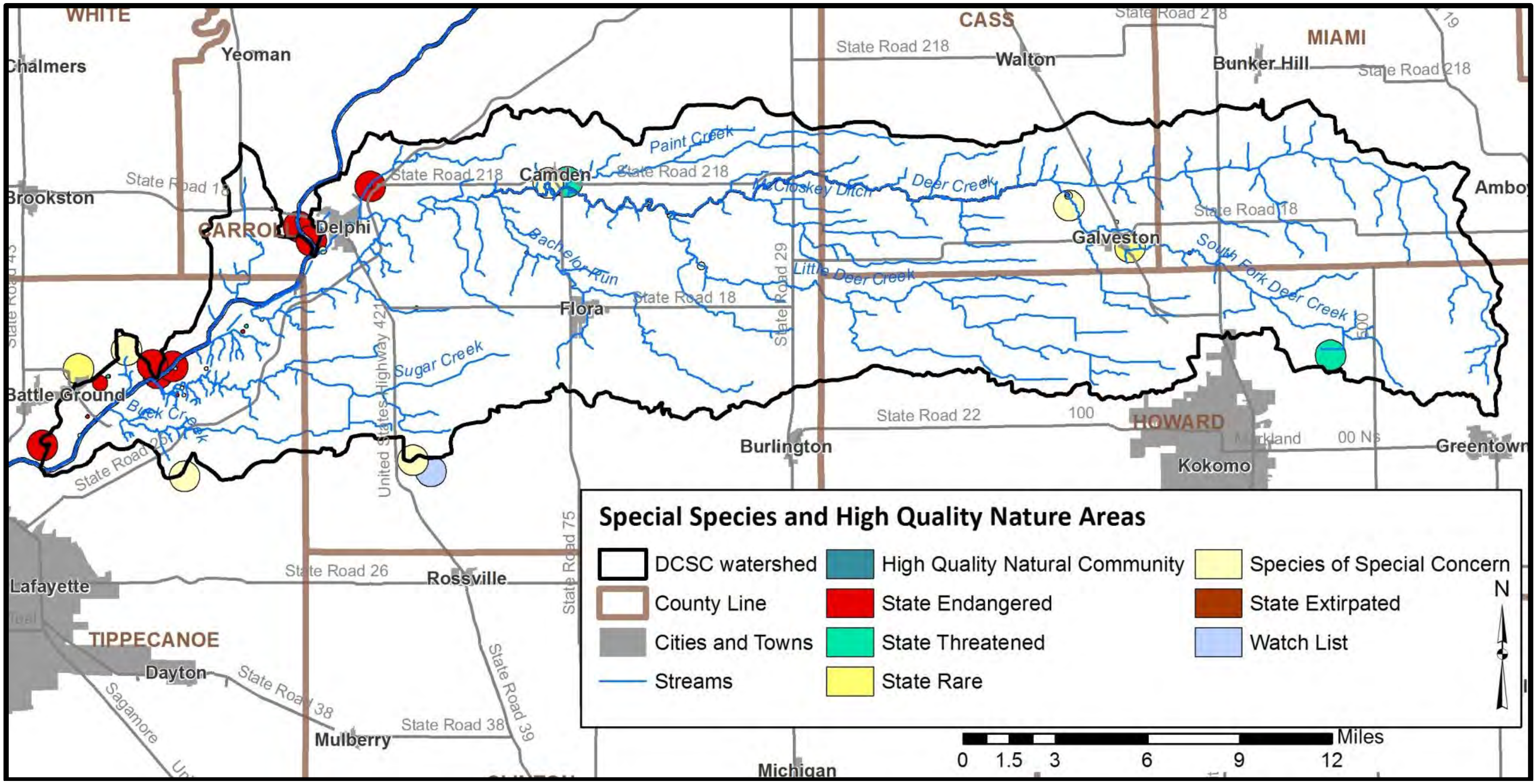

Figure 30. Locations of special species and high quality natural areas observed in the Deer Creek-Sugar Creek watershed.
Data used to create this map is detailed in Appendix A.
Note: Polygons reflect locational uncertainty associated with reported observations. A small circle indicates that there is less uncertainty of where the observation is mapped in relation to its real world location. A large circle reflects more uncertainty. Fish and mussels locations are mapped as linear polygon typically following river and stream stretches based on observational records along that stretch of the stream (R. Hellmich, personal communication November 7, 2012).

2.8.3 Exotic and Invasive Species

Stakeholders have expressed their concerns about the invasive species Japanese honeysuckle along Sugar Creek and Little Sugar Creek. The distribution of honeysuckle or other exotic and invasive species have not been mapped as part of this planning effort.

2.8.4 Recreational Resources and Significant Natural Areas

A limited variety of recreational opportunities exist within the Deer Creek-Sugar Creek watershed. Recreational opportunities include ball fields, campgrounds, a golf course, historical and cultural sites, and parks (Figure 31). Additionally, a few trails are located within the Deer Creek-Sugar Creek watershed. Trails are located in Prophetstown State Park, in the Delphi area, and east of Galveston (Figure 32). There are a variety of trail types such as park, forest, rail, riparian, and towpath. The trails in the Delphi area are managed by the Delphi Historic Trails and the Wabash Erie Canal Association, while the one east of Galveston is managed by the Indiana Trails Fund.

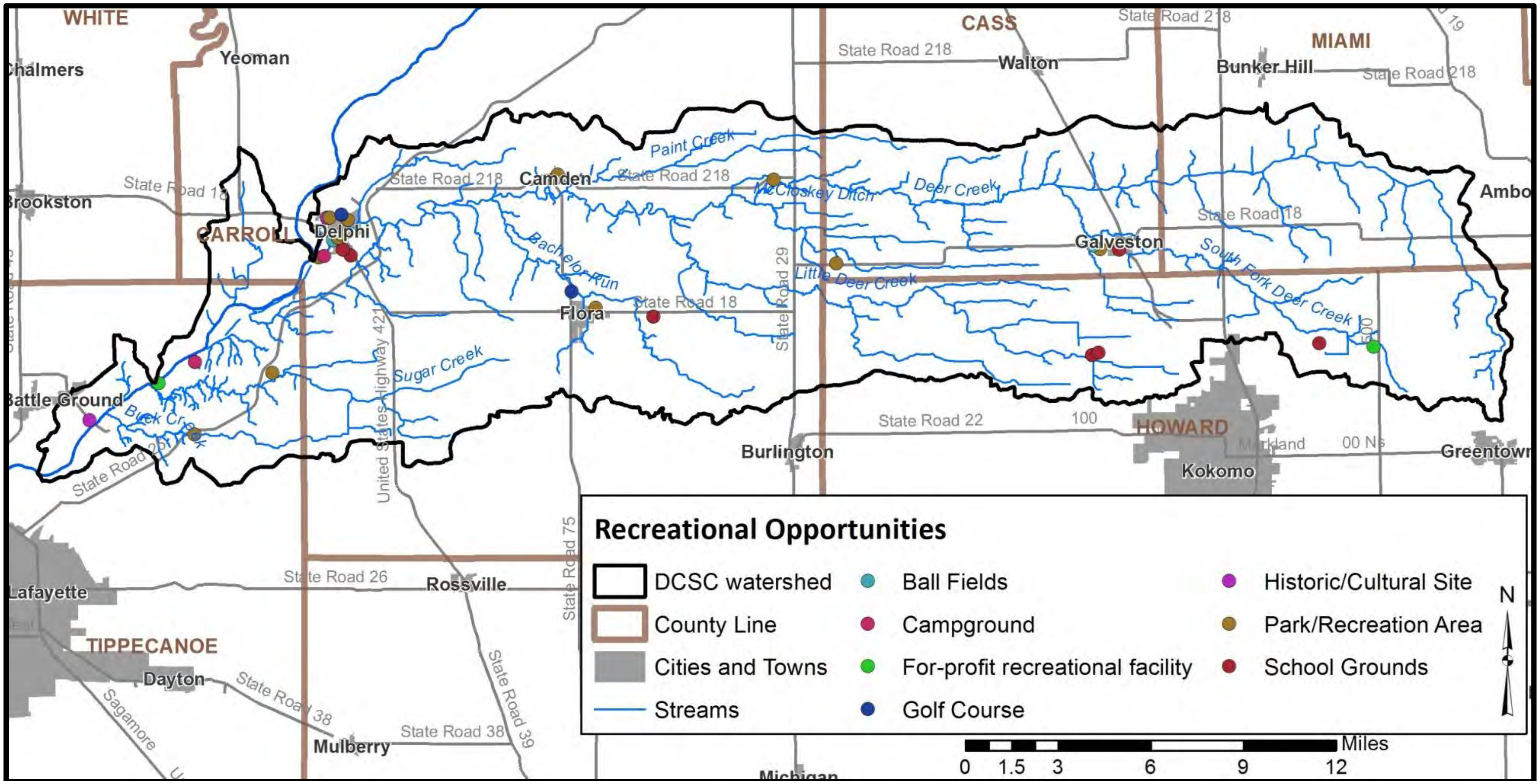

Figure 31. Recreational opportunities in the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

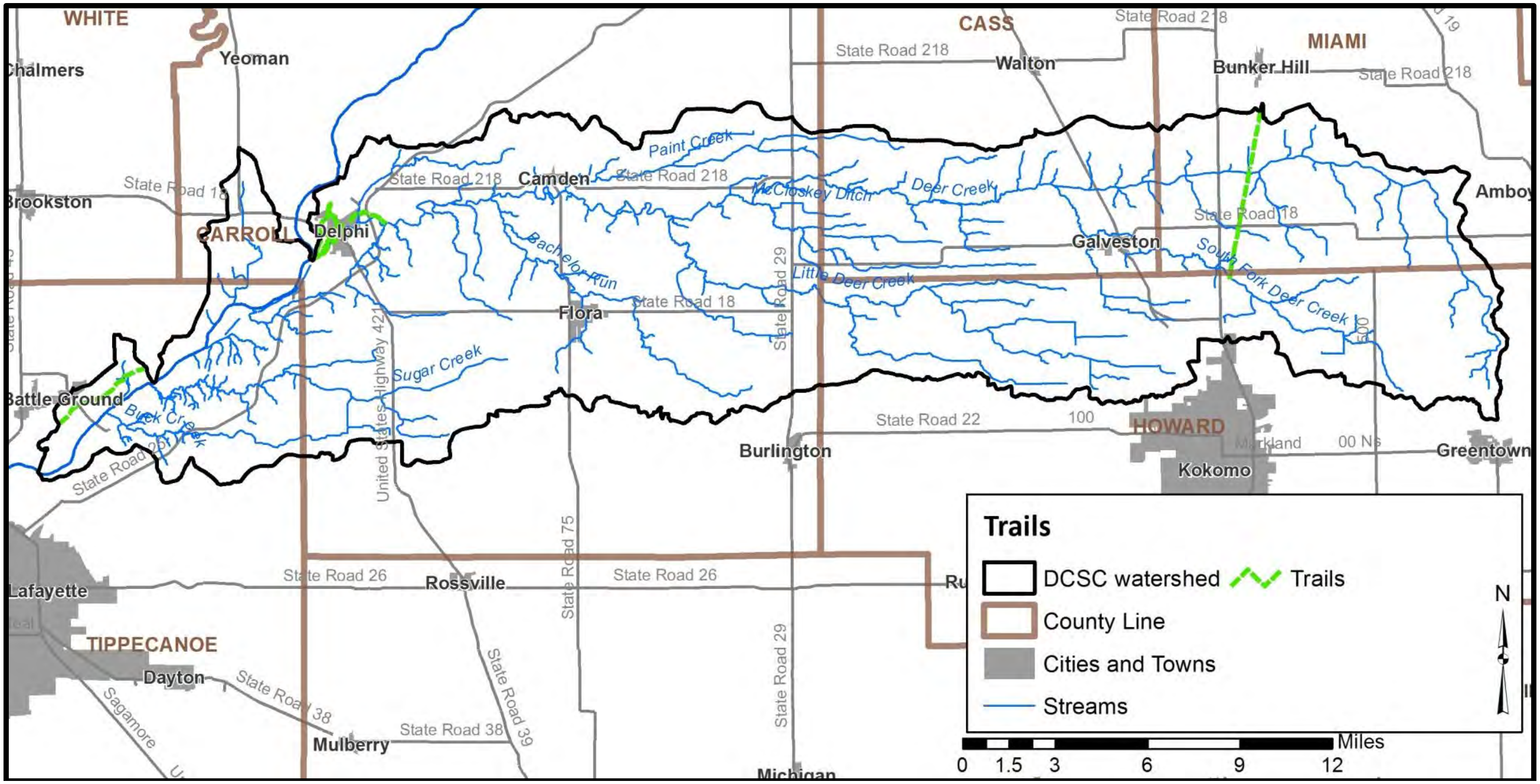

Figure 32. Trails in the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

2.9 <u>Land Use</u>

Water quality is greatly influenced by land use both past and present. Different land uses contribute different contaminants to surface waters. As water flows across agricultural lands, it can pick up pesticides, fertilizers, nutrients, sediment, pathogens, manure, and more. However, when water flows across parking lots or from roof tops, it not only picks up motor oil, grease, transmission fluid, sediment, and nutrients, but it reaches a waterbody faster than water flowing over natural or agricultural land. Hard or impervious surfaces present in parking lots or on rooftops create a barrier between surface and groundwater. This barrier limits the infiltration of surface water into the groundwater system resulting in increased rates of transport from the point of impact on the land to the nearest waterbody. A review of the historic land types present in the watershed will provide an idea of the types of restoration that could occur within the watershed and also a basis for the past uses of the land

2.9.1 Historic Land Use

During its early days, the watershed was described as being resplendent with large trees and prairies as far as the eye could see. Coulter (1886) described the region as part of the prairie region, noting the low water mark of the Wabash River - 504 feet above sea level - and detailing the numerous clear, cold streams and springs which carried water to the Wabash River. Deer Creek was so named for the numerous deer communities found along its bank in early settlement days (Helm, 1878).

The Deer Creek-Sugar Creek watershed is replete with historical significance. A major historically significant location within the watershed includes the Battle Field and Prophet's Rock near Battle Ground. A major skirmish occurred at this site between William Henry Harrison and the remaining Indians formerly led by Tecumseh and the Prophet. The battle occurred on the banks of Burnett Creek and was one of the bloodiest battles recorded in Indian history.

From the mid seventeenth century until well into the nineteenth century, the area was predominantly occupied by the Miami tribe. Nearly all of the land in the watershed belonged to the Great Miami Reservation by way of the St. Mary's Treaty, which was enacted between 1818 and 1840. The end of the treaty marked the end of any Miami land claims in Indiana (Helm 1878). European settlement patterns followed, starting in the 1830s. A sawmill was built along the south fork of Deer Creek in the late 1840s and Galveston was laid out in 1854 (Helm, 1878). Battle Ground was platted in 1858 and consolidated with the Town of Harrisonville nearly ten years later. The first settlements came to what was to become Delphi in 1824 (Helm, 1882).

A canal system was constructed throughout the state of Indiana, beginning in Fort Wayne in 1832 and coming to a close some forty years later. The waterway eventually expanded southward through Delphi in 1840 on its way to the Ohio River. The canal was built adjacent to the Wabash River in the eastern most part of the Deer Creek-Sugar Creek watershed. Though the railroad was in full swing, farmers and merchants searched for alternate and more accessible ways to ship goods. As railroad shipping costs grew, so did the appeal of building small, privately owned boats to cart cargo via the canal systems. Goods such as grain, lime, logs, pork and whisky were all moved along the Wabash-Erie Canal (Wabash and Erie Canal, 2014).

Along the route, a variety of innovations were used by canal engineers to compensate for the changing topography of the land. Swing bridges, systems of counterweights, tumbles, dams, locks, and development of a concrete that would harden under water were all employed for the canal's success (Wabash and Erie Canal, 2014). However, not long after its completion, many realized how inefficient the canal system was compared to the railroad. The canal's wooden structures often needed to be replaced, mosquitoes thrived in the stagnant canal waters, spring flooding, summer drought and freezing waters in the cold months constantly presented issues to farmers and merchants.

Presently, the remaining section of the canal can be seen in Delphi, IN. In recent years, efforts to revive the section of the canal in the Delphi area have been met with community support. Sections of land have been donated surrounding parts of the canal and the city has dedicated those lands to the parks system (Wabash and Erie Canal Park, 2009). Water exists in this part of the canal alone, and the town of Delphi has just completed a warehouse project along the side of the restored canal to house its newly built canal boat.

2.9.2 Current Land Use

In 2006, agricultural land uses dominated the Deer Creek-Sugar Creek watershed (Figure 33, Table 9). In total, 85.2% of the watershed is covered by agricultural row crop or pasture. Urban land uses, including urban open space and low, medium, and high intensity developed areas, account for 7% of the watershed land use, while forested lands and wetlands account for 6% of the watershed. Definitions for each land cover type are included in Appendix D.

Table 9. Detailed land use in the Deer Creek-Sugar Creek watershed.

Classification	Area (acres)	Percent of Watershed
Cultivated Crops	199,943.5	83.3%
Deciduous Forest	13,784.5	5.74%
Developed, Open Space	13,571.3	5.65%
Pasture/Hay	4,558.0	1.90%
Developed, Low Intensity	2,573.9	1.07%
Grassland/Herbaceous	2,501.2	1.04%
Woody Wetlands	1,082.6	0.45%
Open Water	732.5	0.31%
Developed, Medium Intensity	520.9	0.22%
Shrub/Scrub	417.7	0.17%
Developed, High Intensity	215.5	0.09%
Emergent Herbaceous Wetlands	111.1	0.05%
Barren Land	16.2	0.1%
Evergreen Forest	7.8	< 0.1%
Mixed Forest	4.9	< 0.1%
TOTAL	**240,041.9**	**100%**

Source: USGS 2006

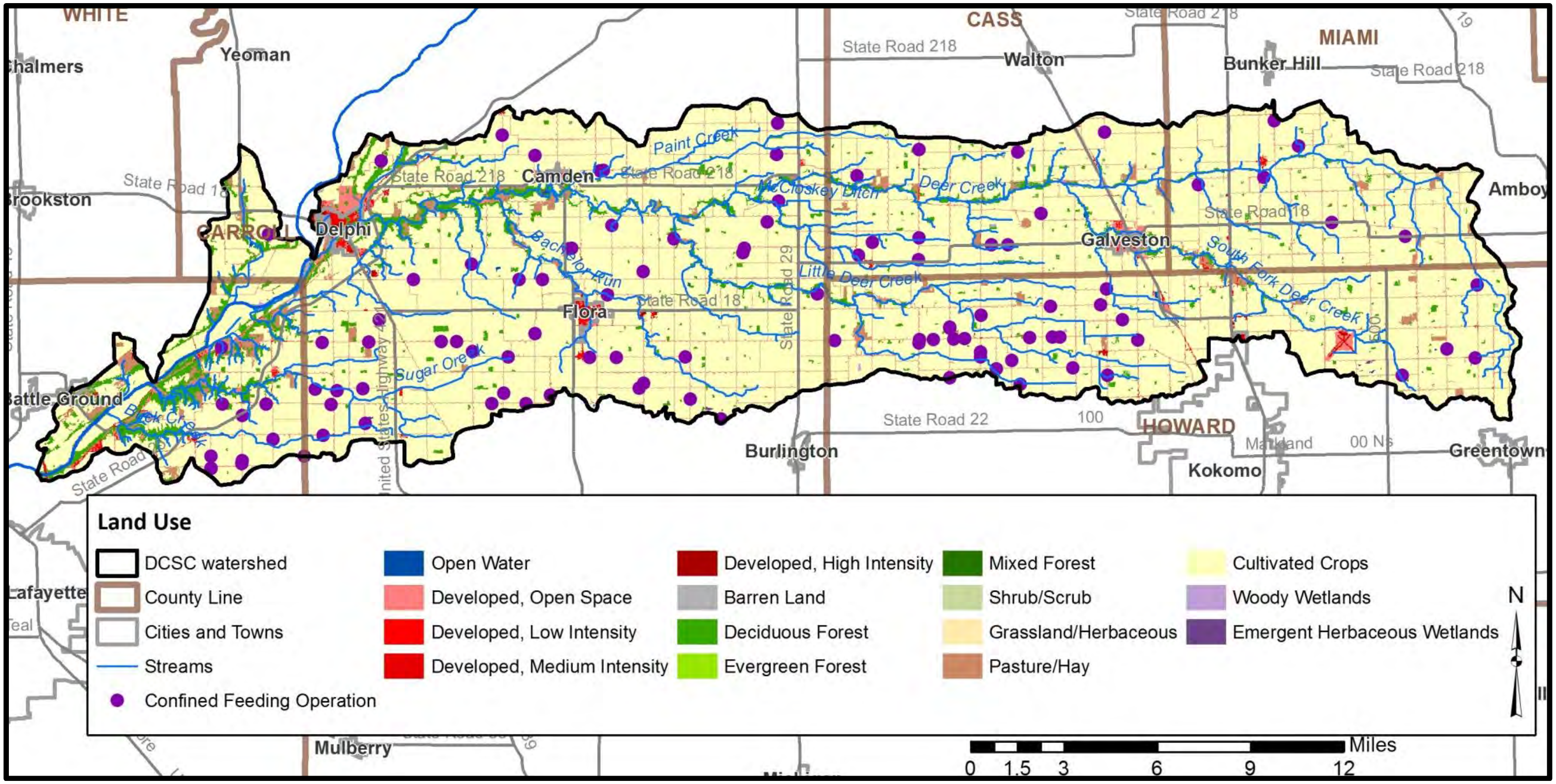

Figure 33. Land use in the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.
NOTE: 2006 is the most recent coverage.

2.9.3 Agricultural Land Use

Stakeholders are concerned about the impact of agricultural practices on water quality. Specifically, the volume of soil entering adjacent waterbodies, the use of agricultural chemicals, and the volume of manure applied via unregulated farms and through confined animal feeding operations concern stakeholders. Each of these issues will be discussed in further detail below. These concerns are especially important as according to the 2006 land classification effort, nearly 85.2% of the watershed is used for agricultural purposes. According to USDA data from

2004, cultivated areas cover approximately 99.4% of the watershed with 84.1% of cultivation occurring in densities greater than 75% (Table 10, Figure 34).

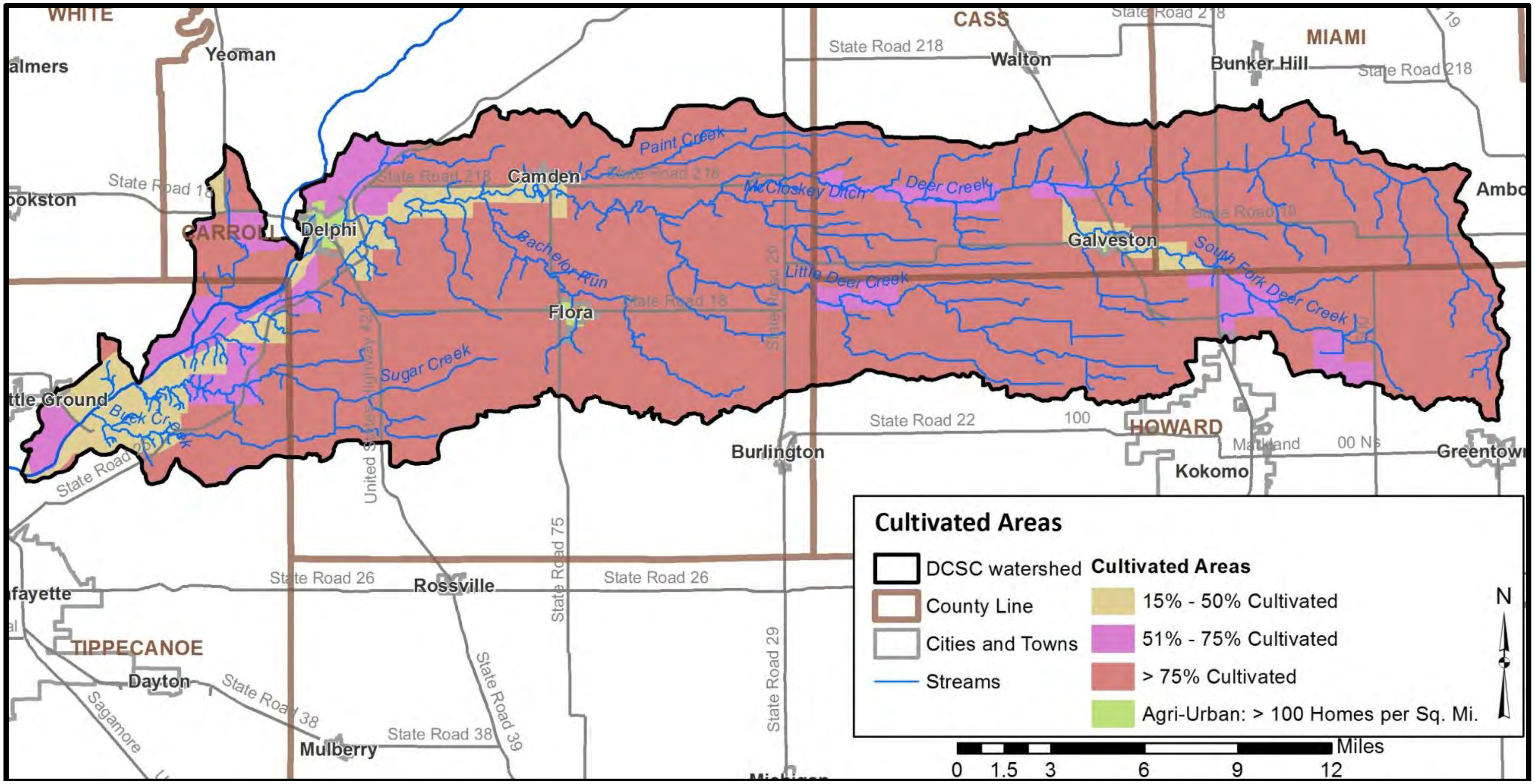

Figure 34. Cultivation density and type within the Deer Creek-Sugar Creek watershed.

Data used to create this map are detailed in Appendix A.

Table 10. Cultivation density and type within the Deer Creek-Sugar Creek watershed.

Cultivation Type and Density	Area (acres)	Percent of Watershed
15% - 50% Cultivated	16,872.3	7.0%
51% - 75% Cultivated	19,808.7	8.3%
> 75% Cultivated	201,975.0	84.1%
Agri-Urban: > 100 Homes per Sq. Mi.	1385.9	0.6%
TOTAL	**240,041.9**	**100%**

Source: USDA 2004.

Of the areas that are cultivated, corn and soybean production dominates crop production (Figure 35, Table 11). In total, corn production accounted for 44% of land cover in 2006, while soybeans accounted for 31% of land cover. Non-agricultural uses, such as woodland and developed areas, covered an additional 18% of the watershed. Pasture/hay, grass/pasture, winter wheat, alfalfa, and other crops covered the remaining crop production lands.

Table 11. Crop type (2008) in the Deer Creek Sugar Creek watershed.

Crop	Total Acreage	Percent of Watershed
Corn	105,345.3	43.9%
Soybeans	74,326.4	31.0%
Developed	21,831.3	9.1%
Woodlands	20,657.3	8.6%
Pasture/Hay	9,224.6	3.8%
Winter Wheat	3,946.7	1.6%
Grassland Herbaceous	2,669.1	1.1%
Water	714.0	0.3%
Alfalfa	415.0	0.2%
Grass/Pasture	301.0	< 0.1%
Wetlands	175.1	< 0.1%
Winter Wheat/Soybeans	148.9	< 0.1%
Barren/Fallow	135.8	< 0.1%
Shrubland	76.6	< 0.1%
Other Crops	74.5	< 0.1%
TOTAL	**240,041.6**	**100.0 %**

Source: NASS, 2008

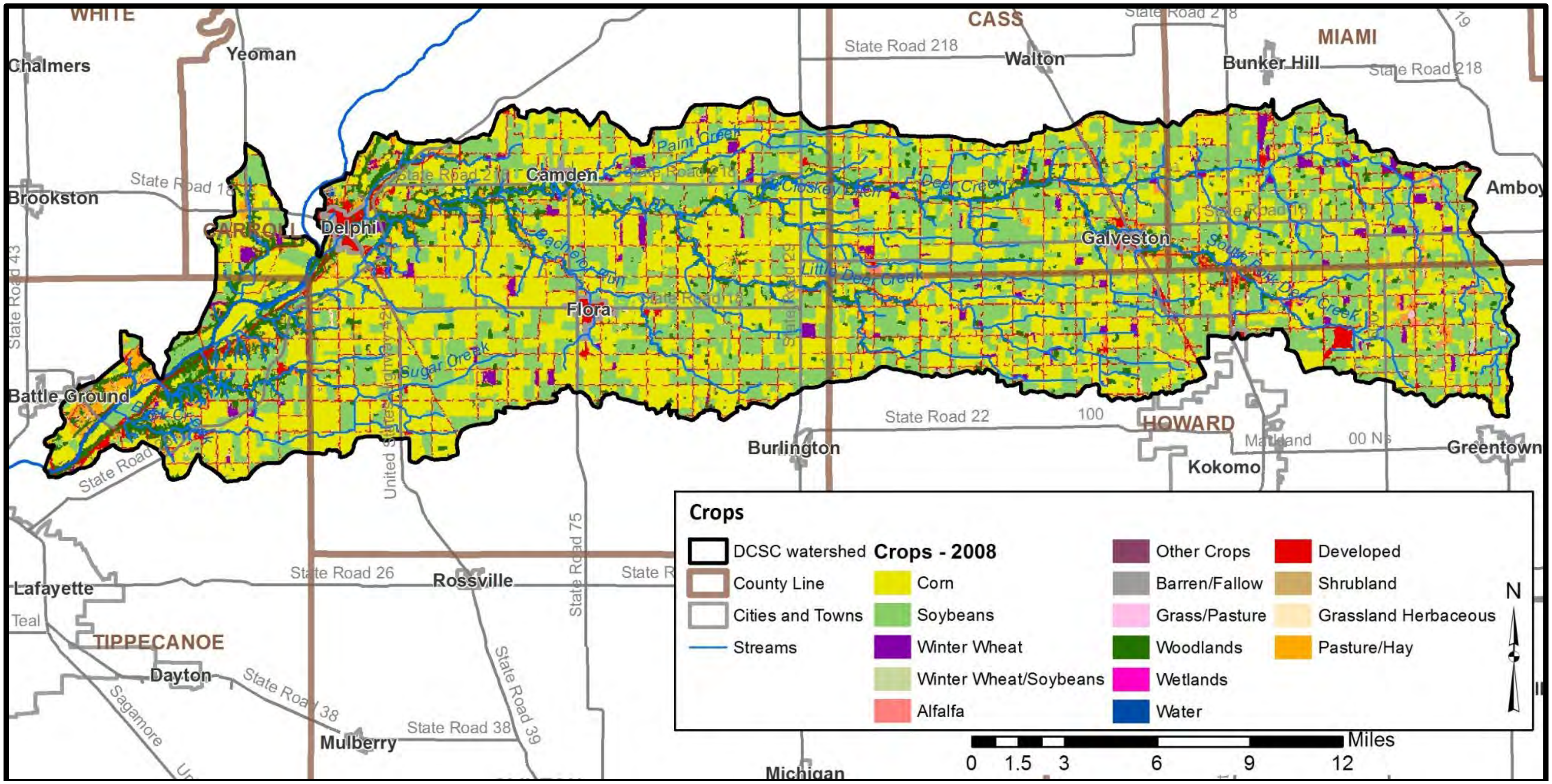

Figure 35. Crop type (2008) in the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.NOTE: 2008 is the most recent crop data that is available from Indianamap.org

According to the 2007 Census of Agriculture, Cass, Carroll, and Tippecanoe counties rank in the top 20 statewide for corn production (8th, 15th and 17th, respectively). Tippecanoe County also ranks 15th in soybean production, while the remaining counties in the watershed are not in the top 20 statewide. Miami and Carroll counties rank 17th and 19thin wheat for grain production. Miami, Howard, and Carroll Counties rank 4th-6th, respectively, in popcorn production, though very little is located within the watershed. According to the 2007 survey, conservation tillage practices within the five counties that comprise the Deer Creek-Sugar Creek watershed are at or slightly higher than the average for the state of Indiana (Table 12). Howard County is the only county of the five that is at or below the state median for conventional tillage.

Table 12. Tillage practices in the Deer Creek-Sugar Creek watershed.

County	Conventional Tillage	Reduced Till	Mulch Till	No Till	No Till Acreage	Total Acreage
Corn						
Carroll	32%	52%	1%	15%	15,800	105,000
Cass	37%	27%	12%	24%	24,700	103,000
Howard	27%	60%	5%	7%	4,800	69,000
Miami	63%	20%	4%	13%	8,600	66,000
Tippecanoe	49%	18%	3%	29%	28,100	97,000
INDIANA	**36%**	**22%**	**18%**	**23%**	-	-
Soybeans						
Carroll	14%	56%	1%	27%	18,200	67,500
Cass	7%	16%	18%	58%	42,700	73,600
Howard	10%	17%	46%	27%	19,000	70,500
Miami	4%	17%	21%	59%	47,400	80,300
Tippecanoe	8%	9%	9%	74%	64,600	87,300
INDIANA	**10%**	**11%**	**20%**	**59%**	-	-

Source: ISDA, 2011.

Agricultural Chemical Usage

Agricultural herbicides, pesticides, and synthetic fertilizers are commonly applied to row crops in Indiana. These chemicals can be carried into adjacent waterbodies through surface runoff and via tile drainage. This is especially an issue if a storm occurs prior to the chemicals being broken down and used by the crops.

Data for chemical usage on an individual county or watershed level is not currently collected. Rather, data are collected for the state as a whole in two forms. First, the National Agricultural Statistics Survey (NASS) collects information on chemical usage, number of applications per year, type of chemical applied, and the application rate. This data was last collected in 2010 (NASS, 2010). Second, NASS collects farmland data for the number of acres in agricultural production by type (i.e. corn, soybeans, grains) every five years. The acreage of cropland in the watershed was estimated using 2008 cropland cover data (Table 13).

This data indicates that corn and soybeans are the two primary crops grown in Carroll, Cass, Howard, Miami, and Tippecanoe counties. Fertilizers are more typically applied to corn than to soybeans. This is due to soybeans acting as nitrogen fixers, in essence, they pull the nitrogen that they need from the atmosphere, and then convert it into a form which they can use. Corn does not fix nitrogen; therefore, nitrogen needs to be applied**.** Nitrogen is typically applied twice in Indiana – once at or before planting and a second time when corn reaches approximately one foot in height (NASS, 2007). Agricultural data indicates that 99% of the acres of corn receive nitrogen fertilizer and 90% receive phosphorus. Based on this data, it is estimated that 18.2 million pounds of nitrogen and 6.4 million pounds of phosphorus are applied annually within the Deer Creek-Sugar Creek watershed.

Table 13. Agricultural chemical usage for corn in the Deer Creek-Sugar Creek watershed.

Nutrient	Acres of Corn	% of Area Applied	Applications (#/year)	Rate/Application (lbs/acre)	Total Applied/Year (Million lbs)
Nitrogen	105,345	99	1.9	92	18.2
Phosphorus	105,345	90	1.2	56	6.4

Source: NASS, 2010.

Confined Feeding Operations and Unregulated Farms

There are over a hundred large, regulated livestock operations (confined feeding operations) located within the Deer Creek-Sugar Creek watershed. Farms that house large number of animals for longer than 45 days per year are regulated by IDEM. These regulations are based on the number and type of animals present. IDEM requires permit applications, which document animal housing, manure storage and disposal, and nutrient management plans for farms which maintain 300 or more cows, 600 or more hogs, or 30,000 or more fowl. These facilities are considered confined feeding operations (CFOs). In July 2012, larger concentrated animal feeding operations (CAFOs) in the watershed began operating under state CFO rule 327 IAC-19, rather than under individual NPDES permits, effectively reclassifying these operations as CFOs for the purposes of 319 funding.

There are 120 active CFOs and approximately 300 small, unregulated farms located within the watershed (Figure 36). The CFOs contain approximately 240,000 animals and are permitted to spread manure on approximately 42 square miles of the watershed. Additional lands likely to receive manure application, as observed during windshield surveys, were also added to the mapped dataset in Figure 36. The unregulated farms contain nearly 3,000 animals. Data for small, unregulated farms and animals were collected via windshield survey in 2012 and 2013.

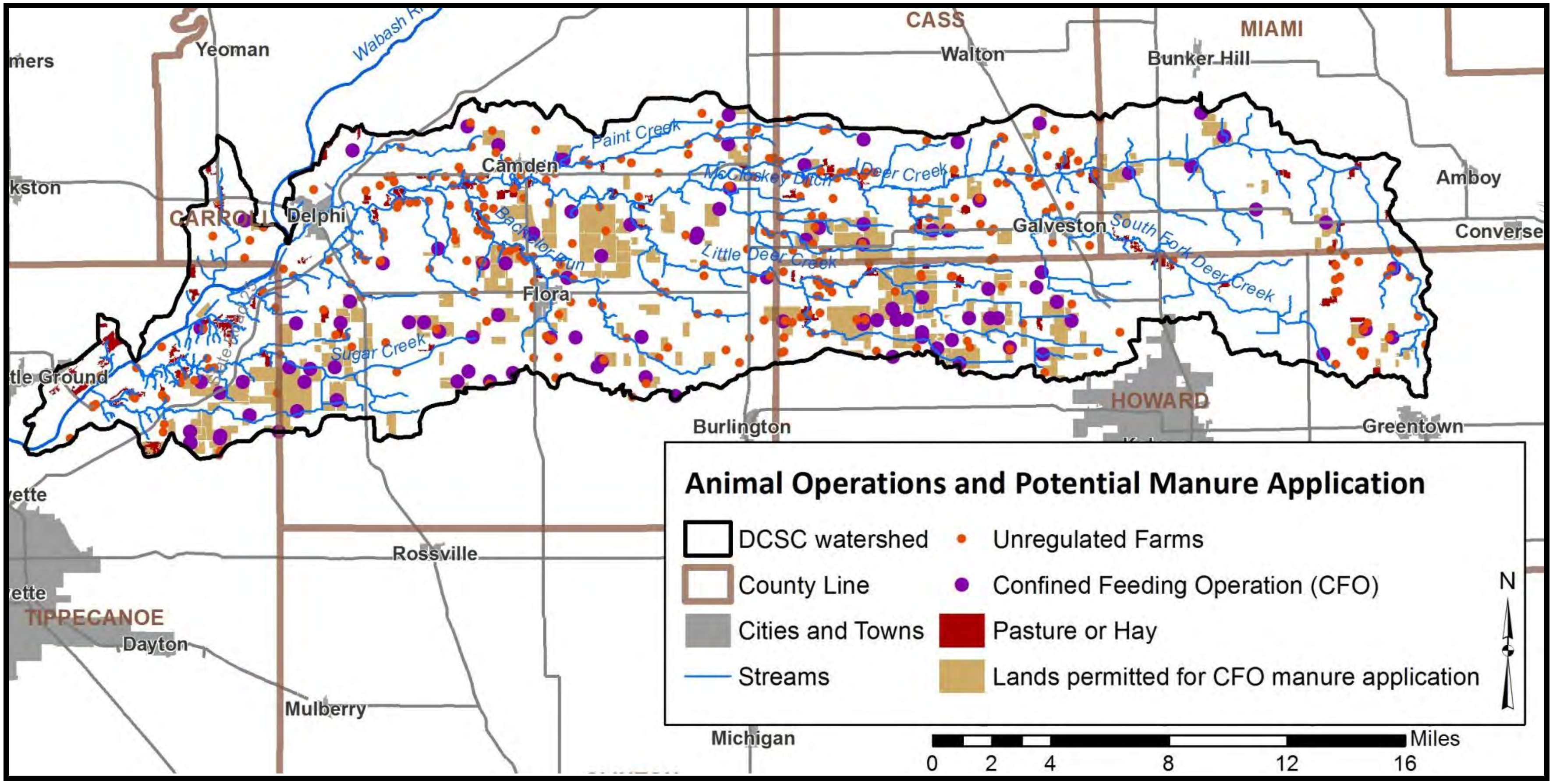

Figure 36. Active confined feeding operations and land permitted for manure application within the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

2.9.4 Natural Land Use

Natural land uses, including forests, wetlands, and open water, cover 9% of the watershed. Forest cover occurs adjacent to waterbodies throughout the watershed; however, these tracts are not contiguous (Figure 37). Large lengths of the watershed streams no longer contain intact riparian buffers. Specific areas of concern will be discussed in further detail in future sections.

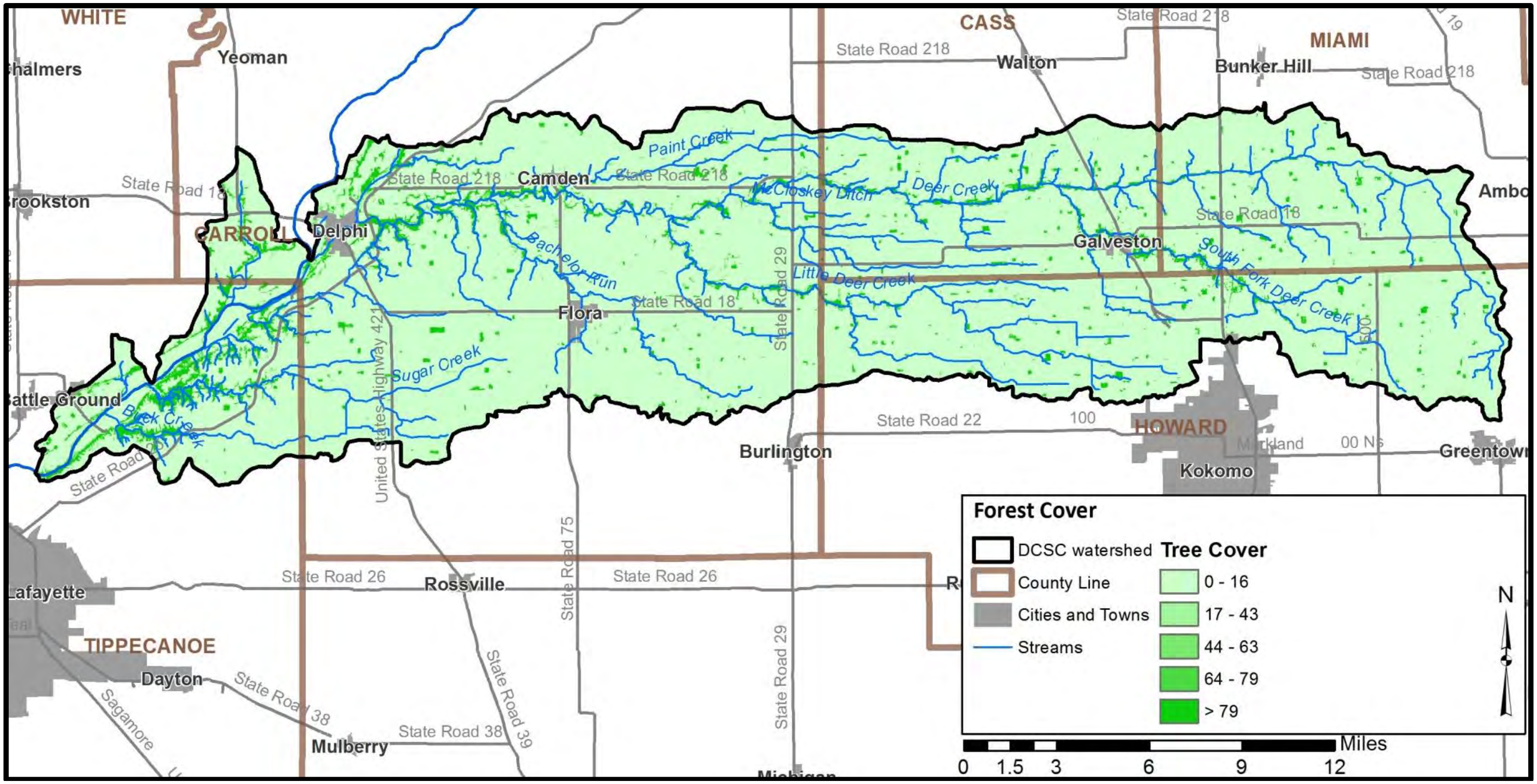

Figure 37. Percent forest cover in the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

2.9.5 Urban Land Use

Developed areas include over 7% of the watershed. These areas include low, medium, and high density residential and commercial development and urban grasslands. Camden, Delphi, Flora, and Galveston comprise the majority of the developed areas within the watershed.

Impervious Surfaces

Impervious surfaces are hard surfaces which limit water from infiltrating into the land to become groundwater, thereby creating high overland flow rates. Hard surfaces include concrete, asphalt, compacted soils, rooftops, and buildings or structures. In developed areas like Delphi, Flora, and Galveston, land which was once permeable has been covered by hard, impervious surfaces. This result in rain which is not absorbed into the surface, running off of rooftops and over pavement to enter Deer Creek with high quantities of pollutants. Figure 38 displays the impervious surface cover density within the Deer Creek-Sugar Creek watershed.

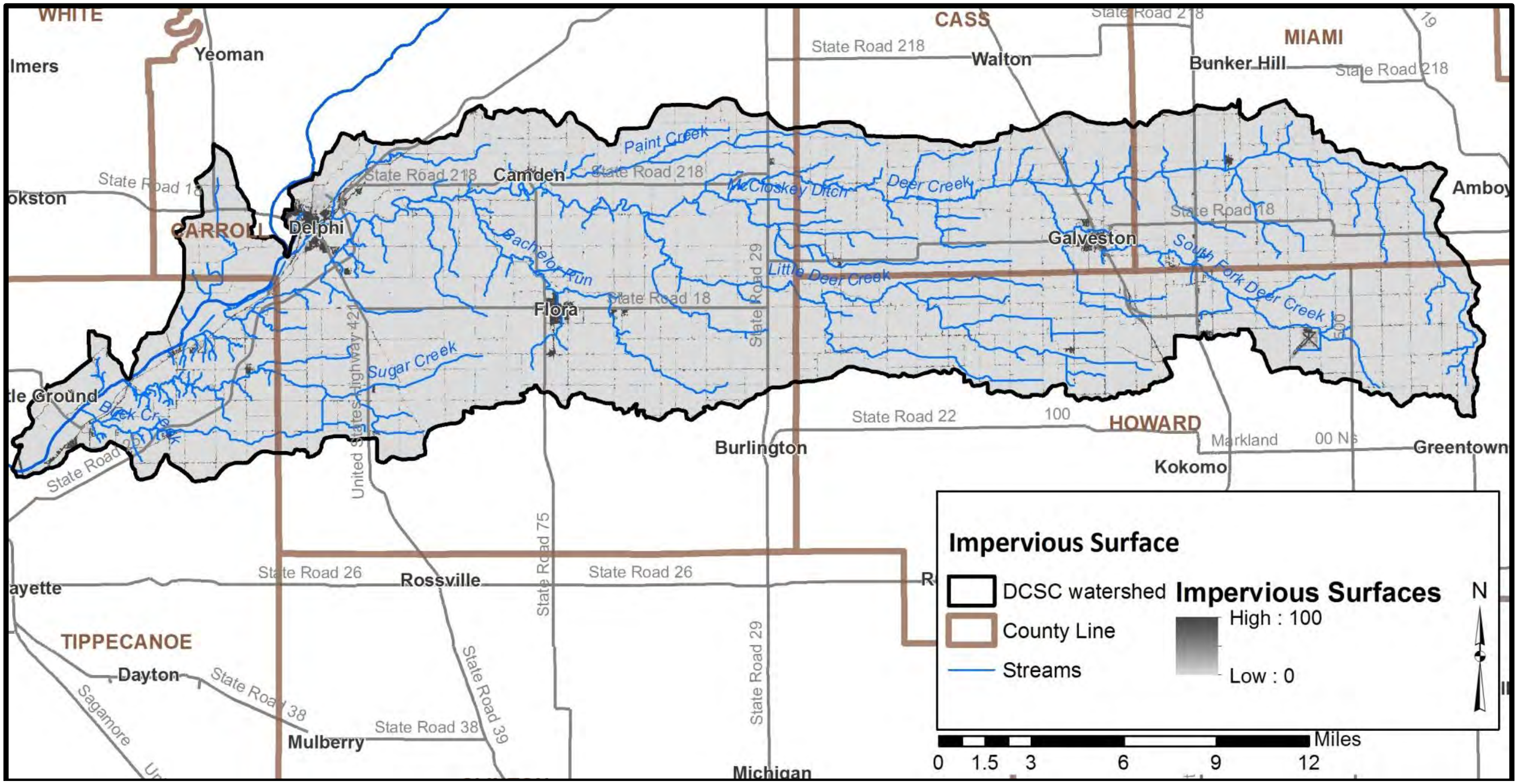

Figure 38. Impervious surface density within the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

Overall, the majority of the watershed is covered by low levels of impervious surfaces. However, high impervious densities are present in Delphi, Flora, and Galveston and along roads throughout the watershed. Estimates indicate that only 274 acres (<0.2%) of the watershed is 75% or more covered by hard surfaces, while 234,005 acres (97%) of the watershed is covered by 10% or less by hard surfaces. Elvidge et al. (2004) indicated that streams in watersheds with greater than 10% impervious surfaces clearly exhibited degradation. The Center for Watershed Protection (CWP) identified similar impacts from impervious surface density on water quality. The CWP study indicates that stream ecology degradation begins with only 10% impervious cover in a watershed (CWP. 2003). Since 97% of the watershed is 10% or less impervious surface, this is not something that will play a huge role in the watershed's implementation phase. The areas that it could play a role in are those that have a greater percentage of impervious surfaces like the tributaries of Deer Creek located near Delphi, Flora, and Galveston, such as Bachelor Run, Kuns Ditch, Robinson Branch, and the South Fork of Deer Creek.

Remediation Sites

Remediation sites including brownfields, industrial waste sites, leaking underground storage tanks (LUST), and open dumps are present throughout the Deer Creek-Sugar Creek watershed (Figure 39). Most of these sites are located near the urban areas around Delphi, Flora, and Galveston. In total, there are three brownfields, three industrial waste sites, 34 LUST facilities, and three open dumps present within the watershed.

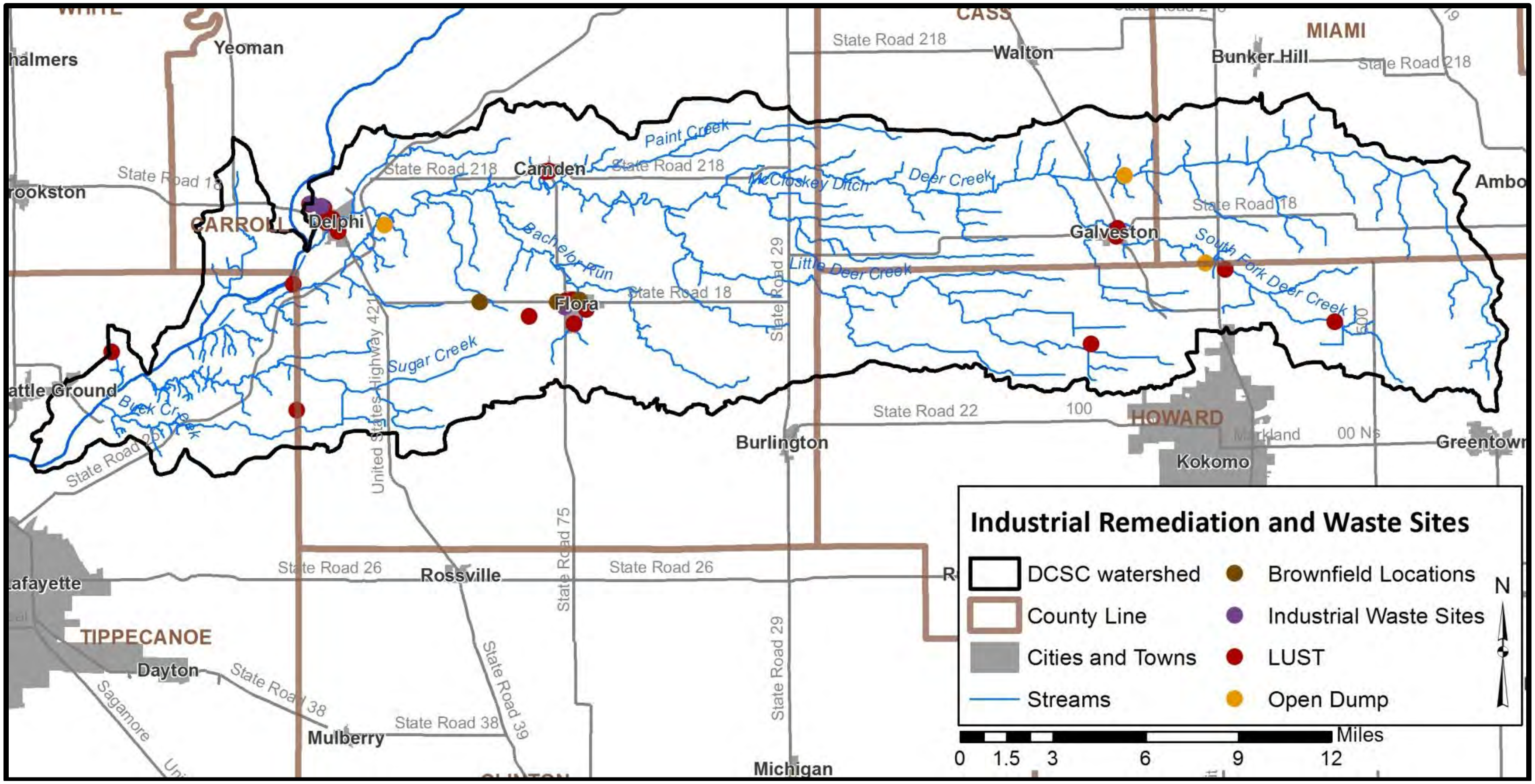

Figure 39. Industrial remediation and waste sites within the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

2.9.6 Industrial Land Use

The watershed is predominately rural in nature, and not much land is devoted to industrial use. Indiana Packers Corporation, a pork processing and packaging facility, is located just south of Delphi (see Figure 17 and Table 6). Additionally, numerous large-scale animal feeding operations exist throughout the watershed (see Figure 36).

2.9.7 Development Trends

Construction of the Hoosier Heartland Corridor began in 2008. Upon completion, it will connect Lafayette, IN to Fort Wayne, IN. This project will create an alternative to State Road 25 (now Old SR 25) by offering a four-lane, limited-access highway instead of a rural, two-lane highway (Figure 40, INDOT, 2012). The construction of the Hoosier Heartland Highway will have both economic and environmental impacts. Economically, there are both positive and negative aspects of the construction of the highway. The new highway will allow companies, such as The Andersons, Inc, “direct access to the new State Road 25 from a realigned State Road 218 (INDOT, 2004).” The new highway will also remove/decrease the semi-truck and the volume of traffic on the existing State Road 25. However, several businesses and companies will be displaced or need to be relocated due to the acquisition of the right-of-way of the new roadways. Tri-State Cob Limited, Watson Construction Co, J.W. Rentals will be displaced by the construction of new roadways. A potential loss of revenue might occur for the businesses located on Old State Road 25 and in Delphi because the highway will bypass them (INDOT, 2004).

As part of this construction, 1.7 miles of stream length will be crossed and 80.8 acres of riparian/forest and 2.7 acres of wetlands will be directly impacted. Bridge Creek, Buck Creek, Deer Creek, Robinson Branch, and Sugar Creek will be crossed and their riparian/forest will be impacted. All of the sites will have a combination of bridges and pipe/box culvert where the highway will cross the waterbody, except Robinson Branch, which will only have a pipe/box culvert (INDOT, 2004). The 2.7 acres of wetlands are divided up among seven sites. The existing wetland sites include 5.1 acres; after construction, only 2.4 acres of wetland will remain resulting in a 47% decrease in wetlands for this area. The FWS made the following two comments about the impacts of the construction:

- Bridge Creek, Buck Creek, and Sugar Creek crossings: “’Major forest fragmentation would occur’, but proposed plans to bridge the creeks would reduce channel impacts (INDOT, 2004).”
- “Bridge Creek tributary north of County Road 100 North, Bridge Creek near a tributary confluence, and Robinson Branch (two crossings): ‘Significant stream impacts may occur…’ (INDOT, 2004).”

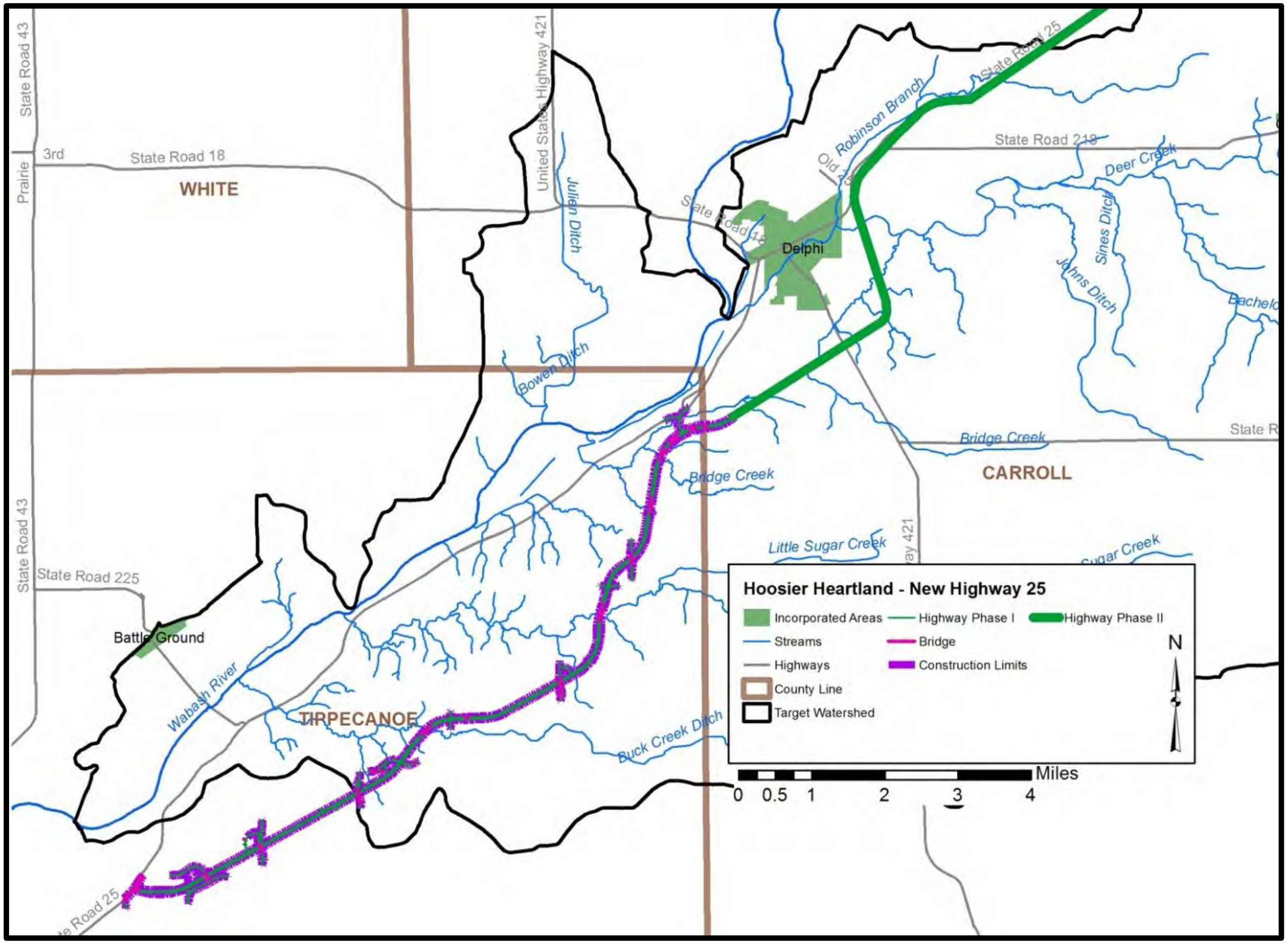

Figure 40. Construction extent of the Hoosier Heartland Corridor located in the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

2.10 Population Trends

As the land use discussion details above, the Deer Creek-Sugar Creek watershed supports a combination of sparsely and moderately dense populated areas. Tracking population changes within a watershed is difficult as watershed boundaries rarely align with the boundaries (townships, census tract, county) used to report populations. Reported data can be used to estimate current and projected populations, track population growth over the past century, and assist in identifying high and low density populations within the vicinity of the watershed.

The Deer Creek-Sugar Creek watershed lies within five counties. It drains 32% of Carroll County, 26% of Howard County, 12% of Cass and Miami counties, and 7% of Tippecanoe County. Population trends for these counties derived from the most recently completed census (2010) are shown in Table 14, while Table 15 displays estimated populations for the portion of the county located within the watershed. These data indicates considerable growth in Howard and Tippecanoe Counties over the past 110 years (190% and 347%, respectively). Populations decreased in Cass and Howard counties over the past decade.

Table 14. County demographics for counties within the Deer Creek-Sugar Creek watershed.

County	Area (acres)	Population (2010)	Population Change			Population Density (#/sq. mile)
			(1900-2010)	(1990-2010)	(2000-2010)	
Carroll	329,792	20,155	1.0%	7.2%	0.0%	53.8
Cass	265,341	38,966	12.8%	1.4%	-4.8%	94.0
Howard	187,945	82,752	189.6%	2.4%	-2.6%	281.8
Miami	241,305	36,903	30.2%	37.2%	2.3%	97.9
Tippecanoe	321,810	172,780	346.9%	32.3%	16.0%	343.6

Table 15. Estimated watershed demographics for the Deer Creek-Sugar Creek watershed.

County	Area of County in Watershed	Percent of County in Watershed	Population
Carroll	106,054	32.2%	6,481
Cass	32,893	12.3%	4,776
Howard	49,533	26.4%	21,809
Miami	28,397	11.8%	4,343
Tippecanoe	23,165	7.2%	12,437
Total Estimated Population			49,847

Based on the tracts the U.S. Census used in their most recent survey, there are approximately 2,000 tracts within the Deer Creek-Sugar Creek watershed. Population densities within the watershed are relatively low; 62% of the tracts have a population density of ten or less people per square kilometer (Figure 41). Additionally, 95% of the tracts have a population density of less than 50 people per square kilometer and only 19 tracts have a population density greater than 100 people per square kilometer. The highest density is located east of Galveston and has a population density of 324 people per square kilometer.

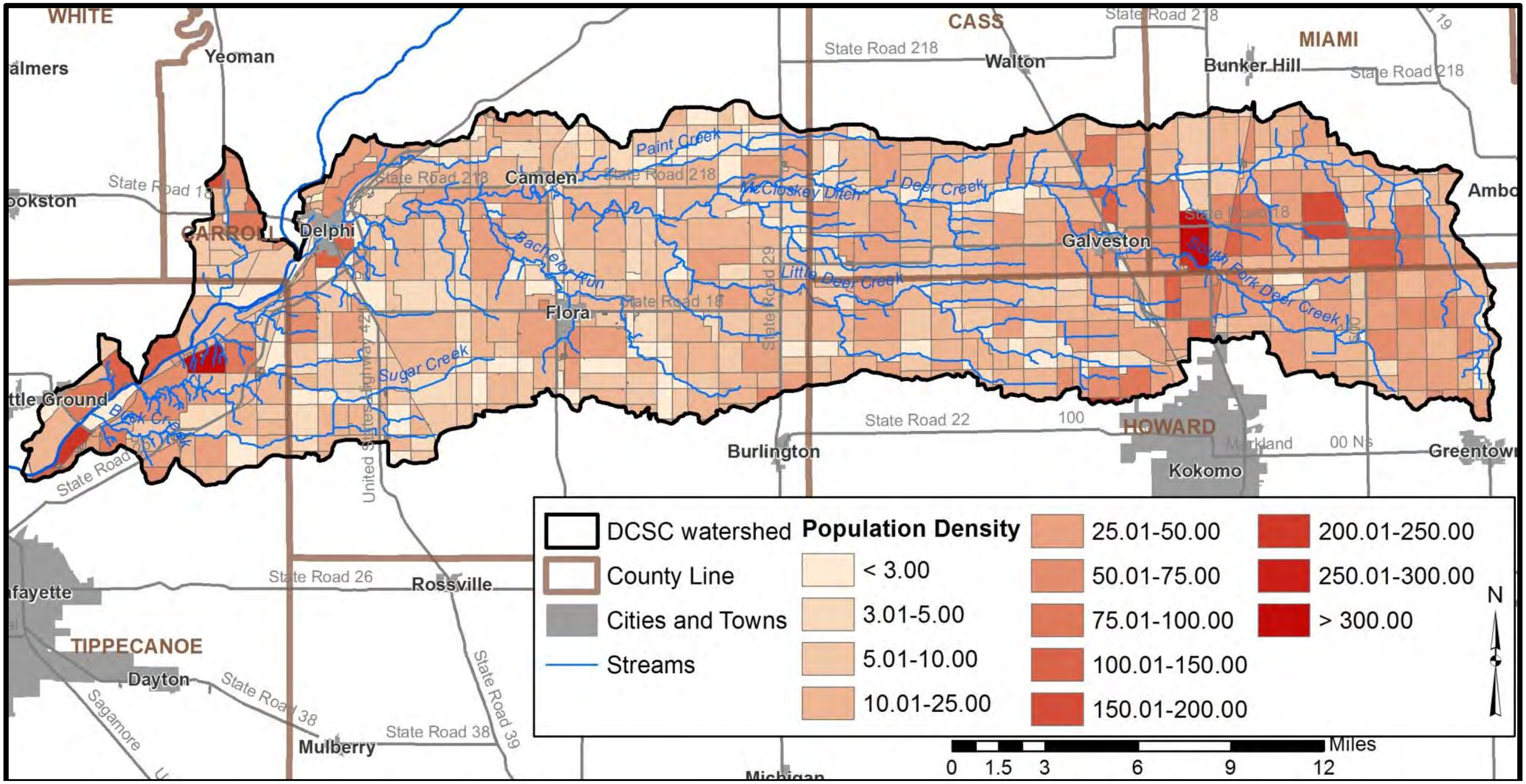

Figure 41. Population Density (#/square kilometers) within the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

2.11 Planning Efforts in the Watershed

2.11.1 Comprehensive Plans

Each county in the watershed maintains an adopted comprehensive plan. The following sections detail each county's comprehensive plan.

Carroll County

The Carroll County comprehensive plan was adopted in 1968. The first update to the 1968 comprehensive plan was made in 2001 and a new comprehensive planning initiative began in 2007. A draft plan was developed and is in the review process (Carroll County, 2008). Future Land Use Maps for Carroll County, the City of Delphi, and the Town of Camden can be found in Appendix G. The key highlights of the plan are described below:

- In terms of land use management, Carroll County's goal is to "provide opportunities for growth and development that enhance quality of life and economic vitality while preserving the County's rural character, agricultural industry, and environmentally sensitive areas (CPCC, 2008)." To achieve this goal two objectives were established:
    - Minimize land use conflicts between agricultural and industrial uses; and
    - To protect prime agricultural land.
- The transportation portion of the comprehensive plan detailed a goal of "providing a quality, safe, efficient, and fiscally responsible transportation network that serves the needs of [Carroll County] (CPCC, 2008)." Several objectives were identified as part of the comprehensive plan including:
    - Maintain and improve the condition of existing roadways;
    - Develop and enhance an efficient vehicular road network;
    - Encourage the expansion of the municipal airport;
    - Promote a safe and appropriate alternative transportation network throughout Carroll County; and
    - Provide opportunity for appropriate development of transportation options near the Hoosier Heartland Highway.
- The environmental goal of the comprehensive plan is to "preserve and enhance Carroll County's natural and historic/cultural resources and environmental features, and protect these features from development (CPCC, 2008)." To achieve this goal, seven objectives were developed as follows:
    - Protect the water quality in lakes, streams, and their watersheds;
    - Minimize conflicts between the natural environment and future development;
    - Conserve existing natural areas;
    - Focus growth in or near municipalities;
    - Preserve historical and cultural resources/amenities;
    - Initiate long-term planning related to the limestone quarry operations; and
    - Consider development of landfill facility to handle County generated wastes in an environmentally sound manner.

Proposed updates to the Carroll County Ordinance, pending County Commissioner approval, add a Rural-Residential (R-R) overlay adjacent to the banks of Deer Creek. This R-R district will not allow large scale feeding operations and restricts the number of animals to 1.2 animals per 1.5 acre lot. Passage of this ordinance would not allow large feeding operations to expand or for new large feeding operations to locate adjacent to Deer Creek in the R-R overlay. A map of the proposed R-R overlay is included in Appendix G.

Cass County

Cass County's comprehensive plan was adopted in July of 2009 (CPCC, 2009). Their plan focuses on the three requirements that are in Indiana Code 36-7-4-502; "a statement of objectives for the future development, a statement of policy for land use development, and a statement of policy for the development of public ways, public places, public lands, public structures, and public utilities" (1981). Maps from the plan, including an Existing Land Use Map, a Future Land Use Map, and a Parks, Recreation, and Connectivity Opportunities Map are in Appendix G. The highlights of the plan in terms of land use, transportation, and the environment are detailed below:

- In terms of land use, the Cass County Comprehensive Plan details goals and objectives that include the "planning principles of agricultural preservation and directing growth to existing communities (CPCC, 2009)." Three goals were identified as part of the plan including:
    - Recognize and strengthen existing communities;
    - Protect the viability of agricultural operations; and
    - Manage development along the Hoosier Heartland Corridor west of State Road 29.
- The transportation portion of the comprehensive plan addresses five goals for Cass County. Specifically, these goals are:
    - Provide a world-class county road system connecting economic development centers to the state road network;
    - Coordinate transportation systems at the "edges" where jurisdiction meets;
    - Encourage implementation and use of transportation alternatives to decrease growth of automobile use;
    - Promote walking, hiking, biking and other human powered transport by supporting walkways, paths and trails to tie existing communities together through a system of greenways and trails; and
    - Respond to the demands of new development without negatively impacting the existing road network.
- Cass County's policies related to the environment are focused on the surface and groundwater resources. That being said, four goals were created to address the surface, groundwater, and wastewater within the county including:
    - Support sustainable and natural systems for stormwater runoff and wastewater treatment;
    - Improve the quality of surface water and groundwater resources;
    - Ensure capacity of water and wastewater treatment facilities to accommodate growth; and
    - Coordinate services across jurisdictional boundaries to ensure efficiency and quality services.

Howard County

Howard County initiated a planning process to develop a comprehensive plan in February of 2003 (CPHC, 2003). "Howard County seeks to address growth, development, economic prosperity, environmental quality, agriculture, government services and quality-of-life issues (CPHC, 2003)." The Howard County Future Land Use Map can be found in Appendix G. The key highlights of the plan are detailed below:

- In terms of land use, Howard County's goal is to "provide opportunities for community growth and development which results in enhanced quality of life, a wide range of housing opportunities, economic vitality, and enhanced recreation while preserving environmental integrity (CPHC, 2003)." To achieve this goal, the following objectives were established:
    - Ensure adequate and suitable land exists for all uses and reflects the market demand;
    - Protect prime agricultural land;
    - Ensure that land uses are compatible with environmental features and surrounding land uses; and
    - Highly restrict development or filling-in of the floodplain.
- The transportation section of the comprehensive plan addresses both vehicular and alternative transportation. The goals and objectives are to "promote a fiscally responsible network of roads" and "provide a safe, appropriate and aesthetically pleasing alternative transportation system (CPHC, 2003)."
- The goal addressing the environment is to "promote an ecologically sound community by balancing the needs of the human, plant, and animal life forms and, to the fullest extent possible, protect and enhance the natural systems in Howard County (CPHC, 2003)." To achieve this goal several objectives were established:
    - Protect the quality and quantity of the water in groundwater, streams, and reservoirs;
    - Preserve and protect natural areas and drainage as well as the 100-year floodplain;
    - Protect and enhance streams and the natural environment;
    - Minimize conflicts between growth and the natural environment; and
    - Encourage the use of innovative methods of storm water management such as wetlands and swales.

Miami County

The Miami County comprehensive plan was adopted in 1967. Since the adoption of the plan several changes have occurred, but most specifically the realignment of Grissom Air Force Base (MCCP, 1999). The current comprehensive plan was readopted in 1999 and addresses constraints, goals, and opportunities in land use, environmental, and transportation. The land use map reflecting policy as of 2001 is included in Appendix G. The key highlights of the current plan are described below (though it is worth noting that Miami County is about to begin the process of updating the plan):

- The land use portion of the comprehensive plan addresses 10 goals for Miami County. The goals have been summarized into the following highlights:
    - Promote the orderly growth and development of Miami County;
    - Reserve sufficient land areas, in appropriate locations, for residential, commercial, and industrial growth and development that is forecasted in this Plan;

  - Foster and encourage a balance in housing opportunities and conserve existing housing;
  - Encourage the stabilization of existing commercial areas and the development of new commercial nodes;
  - Encourage continued expansion and development of industrial land uses;
  - Provide and foster compatibility and stability of land uses and an environment accepting of agricultural practices and lifestyles;
  - Enhance the visual appearance and living environment.
- The environmental portion of the comprehensive plan addresses four goals for Miami County. Specifically, these goals are:
  - Promote the preservation of sensitive natural areas within the county, especially areas prone to flooding;
  - Promote the preservation of historically significant structures, roadways, trails, and so on, within the County;
  - Promote the control and regulation of the adverse effects of development such as noise, light, odor, and so on, within the County;
  - Support farmland preservation and encourage cooperation between farm interest and development interests.
- The transportation section of the comprehensive plan addresses one main goal. The goal is "to ensure that the county's transportation system is adequate to support the growth and diversification of the county's population with minimal congestion and to enhance the ability of federal, state, and local governments to make needed transportation improvements (MCCP, 1999)."

Tippecanoe County

The Tippecanoe Area Plan Commission (APC) completed the comprehensive plan in 1981 (TCAPC, 1981). Multiple updates to the plan occurred since that time. The plan was intended to serve as a guidance document by which development and changes within the county could occur. The key planning pieces contained within the County Master Plan which are relevant to the watershed management plan include transportation and floodplain plans. The Plan's Existing and Future Land Use Map is included in Appendix G. The key highlights of each of these individual plans are described below:

- In terms of transportation, the plan addressed the current and future roadway plans and issues of the Hoosier Heartland Corridor (SR 25) from Lafayette to Logansport. Specific reviews of the Hoosier Heartland will be part of this planning process as should any development or redevelopment of other roads within the watershed.
- The portion of the plan that addresses floodplains is covered as part of the multi-hazard management plan which was updated in 2006 (TCAPC, 2006). The multi-hazard management plan is included as a portion of the County Master Plan. Flooding is noted as a significant concern within Tippecanoe County having occurred three times in the period of July 2003 through February 2005. In total, 14 flood events were recorded within the county from May 1943 through February 2005. These events resulted in more than $67 million in property damage and more than $58 million in crop damage. Flooding is typically limited to riverine flooding but has also historically been associated with flash, overland, lake, and urban flooding.

2.11.2 Soil and Water Conservation Districts (SWCD)

Carroll County

The mission statement of the Carroll County SWCD is "to develop, promote, and utilize current soil and water conservation programs that benefit both rural and urban citizens in Carroll County (CCSWCD, 2008)." The current business plan was adopted in 2008 and addressed issues through 2013. The SWCD identified four critical issues with natural resources: maintaining prime farm land, clean water, clean air, and surface water quality. Based on these issues the following actions were identified:

- Maintain current levels of conservation throughout the county until 2013.
- Installation of buffer strips along all creeks and tributaries by 2013.
- Educate landowners/producers on the practices of conservation tillage, no-tillage, and program opportunities.
- On an annual basis, ensure proper maintenance of conservation equipment.

The Deer Creek-Sugar Creek Watershed Management Plan will assist Carroll County in addressing their water and surface water quality concerns.

Cass County

The mission of the Cass County SWCD is "to provide leadership, education, and technical assistance to empower the citizens of Cass County to conserve and preserve our soil, water, and natural resources (CCSWCD, 2013)." The business plan was adopted in April of 2013 and as part of their plan, the SWCD identified the following areas of concern that will be addressed:

- Soil erosion and sedimentation
- Nutrient and pesticide applications
- Streambank stabilization
- Buffer and waterway protection
- Nutrient and sediment contamination
- Wildlife habitat loss and fragmentation
- Stormwater runoff

Even though only 12.4% of Cass County is within the Deer Creek-Sugar Creek watershed, the concerns identified by the SWCD still apply. These concerns closely parallel the stakeholder concerns listed in Table 2 and are addressed in subsequent analysis in the Deer Creek-Sugar Creek Watershed Management Plan. The following actions were identified by the SWCD to be completed by 2018:

- No-till practices shall be increased by 2,000 acres.
- Cover crops shall be increased by 2,000 acres.
- The SWCD will educate landowners in high manure application areas on best management practices for manure application.
- The SWCD will increase streambank stabilization awareness/education.
- 65 acres of buffers will be installed.
- Educate landowners about the benefits and installation of rain gardens.

- Provide educational and/or outreach opportunities on the environmentally wise use of nutrients and soil health.
- Educate landowners about beneficial native plants and the negative impact of invasive plants on our environment.
- Install 250 acres of wildlife habitat will be installed.
- Work to reduce stormwater runoff by facilitating programs to establish 100 best management practices.

Howard County

The mission of the Howard County SWCD is "to provide leadership and administer programs to help the people of Howard County improve and conserve the county's environment and natural resources (HCSWCD, 2009)." The current business plan was adopted in 2009 and addresses issues through 2015. The SWCD identified five critical natural resource issues: wildlife habitat, soil erosion, water quality, forestry, and land use development. The following actions, which relate to the Deer Creek-Sugar Creek planning efforts, were identified by the SWCD to be completed by 2015:

- Wildlife habitat shall be increased by 150 acres, 50 of those acres are to be reclaimed/restored
- Install 150 erosion control practices
- Increase low-till corn from 38% to 66%
- Increase no-till beans from 36% to 50%
- Increase riparian buffers and/or filter strips by 50% of eligible target areas
- Improve impaired waterbodies by removing five waterbodies from the EPA's impaired waterbody list.
- Establish 100 acres of trees and increase classified forest and wildlife habitat by 100 acres.
- Provide timber stand improvement for 150 acres of established woodlands.

Miami County

The mission of the Miami County SWCD is to "assist citizens in caring for soil, water, and related resources (MCSWCD, 2012)." In 2013, the Miami County SWCD will adopt a new district business plan. As part of their plan, the SWCD identified the following areas of concern that will be addressed beginning in 2013:

- Streams, rivers, and tributaries decreased quality due to sediment, *E. coli*, nutrients, pesticides, pollutants, and lack of buffers;
- Loss of woodlands and inadequacy of food and habitat for wildlife;
- Soil erosion in agricultural and non-agricultural settings;
- Excessive tillage and grading; and
- Noxious and invasive plants throughout the county.

The concerns identified by the SWCD apply to a small portion of the watershed; nevertheless, because these concerns closely parallel the stakeholder concerns listed in Table 2, this watershed management plan aligns with current planning efforts of the Miami County SWCD. The following actions were identified by the SWCD to be completed by 2018:

- No-till corn practices shall be increased from 13% to 25%.

- Install 75 additional miles of buffers.
- Cover crops shall be increased by 2,500 acres.
- Wildlife habitat shall be increased by an additional 500 acres with 250 acres of tree planting.
- Manure management plans used by an additional 2,000 acres and 4,000 acres using nutrient and pest management plans.
- Convert 400 acres from row crops to hay land.
- Install 7,500 feet of fencing for livestock exclusion.

Tippecanoe County

The mission of the Tippecanoe County SWCD is "to provide quality technical, educational, and informational resources for the community through leadership, service, and citizen involvement to foster natural resource conservation and environmental stewardship (TCSCWD)." As part of their plan the SWCD identified three visions for Tippecanoe County: stable soils, clean streams and water resources, and sustainable communities. These concerns closely parallel the concerns addressed by this plan. The following goals were identified by the SWCD to be completed by 2014:

- No till practices shall be increased by 2,500 acres in the Upper Wabash.
- Cover crops shall be increased by 2,500 acres in Tippecanoe County by 2014.
- The SWCD will educate 20 landowners in high manure application areas on best management practices for manure application by 2014.
- The SWCD will increase streambank stabilization awareness/education through 10 partnering opportunities by 2014.
- The SWCD will educate 150 landowners about the benefits and installation of two-stage ditches by 2014.
- The SWCD will provide 10 educational and/or outreach opportunities on the environmentally wise use of lawn fertilizers and pesticides by 2014.
- The SWCD will educate 750 landowners about beneficial native plants and the negative impact of invasive plants on the environment by 2014.
- 350 acres of wildlife habitat will be installed in Tippecanoe County by 2014.
- The SWCD will work to reduce stormwater runoff by facilitating programs to establish 250 best management practices by 2014.

2.11.3 Little Deer Creek Watershed Management Plan

In January 2003, the Howard County Soil and Water Conservation District received a 205j watershed planning grant for the Little Deer Creek Headwaters watershed (HCSWCD, 2005). The grant was funded by IDEM and the U.S. Environmental Protection Agency (USEPA). A combination of education and implementation of practices were used to meet the goals of the watershed management plan. Maps of the subwatersheds and the water quality results from the plan are in Appendix G. The goals of the plan are detailed below:

- Reduce animal waste contamination of surface water.
- Reduce nutrient and Atrazine loads at watershed outlet.
- Reduce soil loss.

To obtain these goals, an implementation strategy was outlined. The timeline for completing these tasks was approximately three years. The tasks that were identified as ways to reach the above goals are detailed below:

- Management of manure on approximately 3,500 acres or 40% of cropland received manure and ten manure storage units.
- Management of nutrients and pests on approximately 3,500 acres or 40% of cropland.
- Installation of riparian filter strips along five miles of ditches.
- Installation of 25 units of grade stabilization structures along ditches.
- Hosting of education meetings and distribution of educational materials.

The following practices have since been implemented:

- 4 auto guidance systems in accordance with Pest & Nutrient Management
- 2,118.63 acres in Pest & Nutrient Management planning
- 2,472,000 gallons of waste hauling
- 555.5 acres in Comprehensive Nutrient Management planning for waste utilization
- 3 waste utilization Injection Knives
- 2,829.75 acres in Comprehensive Nutrient Management planning for manure management
- 1 Animal Mortality Facility
- 1 Waste Storage pit
- 458 acres in Comprehensive Pest Management planning

2.11.4 Howard County Municipal Separate Storm Sewer System (MS4)

The Howard County Stormwater District was formed in response to a federal mandate by the Environmental Protection Agency (EPA) to obtain and maintain a permit from the Indiana Department of Environmental Management (IDEM) in an effort to reduce stormwater pollution. The District works to maintain this permit, makes capital improvements, does field inspections, and increases public awareness about stormwater pollution problems. Management of the District includes a mix of mandated and elected activities to provide education, coordination, maintenance, and development of a high quality stormwater system. The District's six minimum control measures include: public education, public participation, the elimination of polluted discharge from pipes, the cessation of construction site runoff both during and after construction, and the cessation of stormwater pollution on county facilities. The boundary of the Howard County Stormwater District has only a small overlap with the Deer Creek-Sugar Creek watershed (Figure 42). Within the watershed, the District has conducted de-trashing and clean-up efforts on the South Fork of Deer Creek.

Howard County has 2 two-stage ditches in the Deer Creek watershed, and the Howard County MS4 shares maintenance responsibility for the ditches with the Howard County Surveyor. The Rice-Bell ditch was installed as a mitigation project for the new US 31 bypass with funding from INDOT. The James Gallion ditch was installed by the Howard County Surveyor in cooperation with the Nature Conservancy with funding from the Nature Conservancy. Construction of the ditches was finished in March, 2013, and the District hosted a two-stage ditch workshop which was attended by The Nature Conservancy, NRCS, IDEM, Notre Dame, Ohio State University, and other participants. Together, the Surveyor and Stormwater staff cover the range of management issues for regulated drains. The Howard County Surveyor is responsible for maintaining the water flow in the ditches and for structural issues. The Howard County Stormwater District is responsible for maintaining water quality in the ditches including discharges from tiles or inflowing streams and dumping of trash or contaminants.

None of the District's CSOs are within the watershed boundary.

2.11.5 Tippecanoe County Partnership for Water Quality Plan

Tippecanoe County, Purdue University, Ivy Tech State College, and the Cities of Battle Ground, Dayton, Lafayette, and West Lafayette signed a joint agreement to collectively manage stormwater issues within the state designated Municipal Separate Storm Sewer System (MS4; Figure 42). This partnership is known as the Tippecanoe Partnership for Water Quality (TCPWQ). Collectively, TCPWQ submitted a notice of intent to accept responsibility for the management of the MS4 and the six designated minimal control measures (MCMs) which include: public education and outreach, public participation/involvement, illicit discharge detection and elimination (IDDE), construction site run-off control, post-construction run-off control, and municipal operations pollution prevention and good housekeeping.

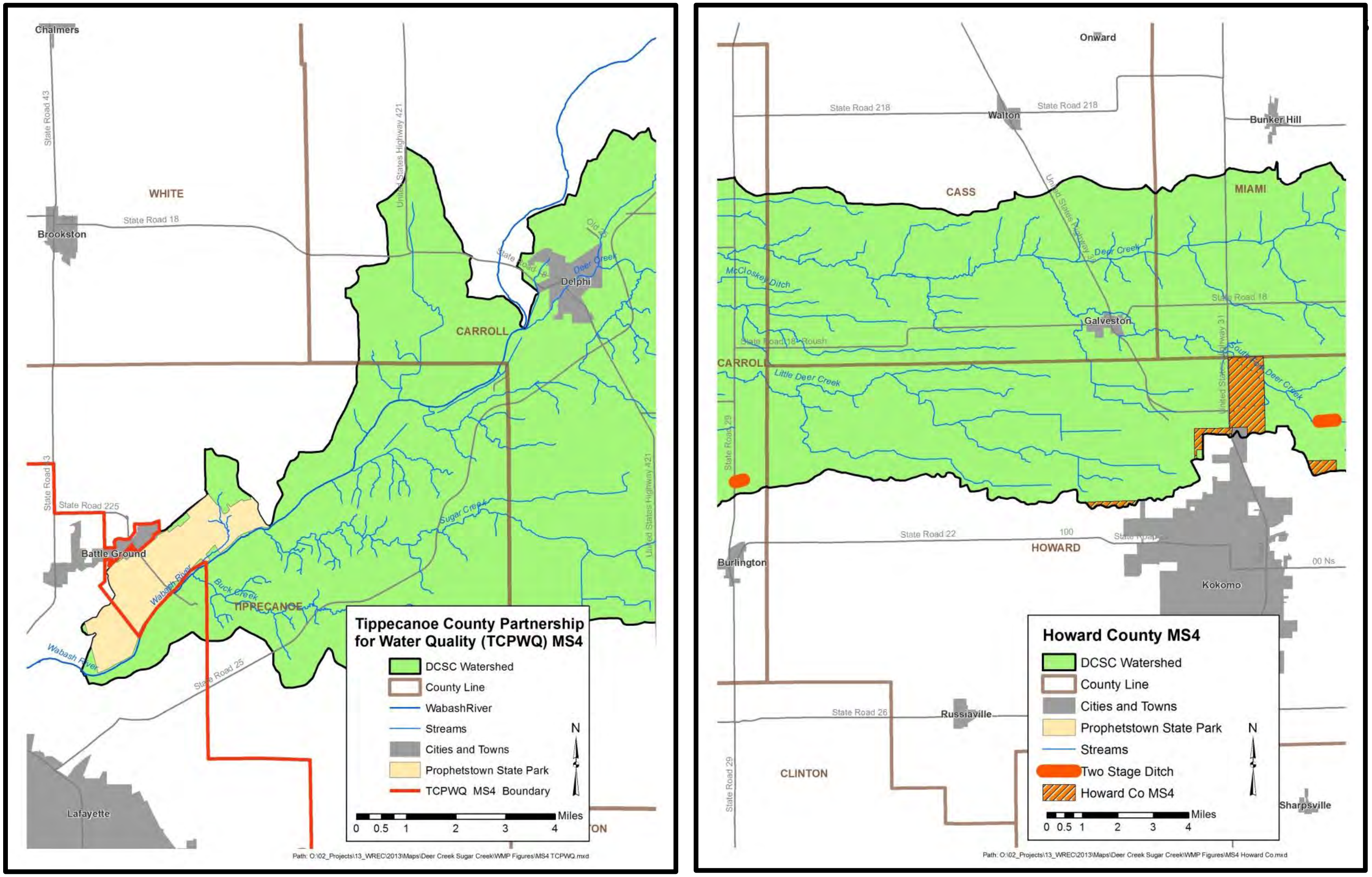

Figure 42. Two Municipal Separate Storm Sewer System (MS4) boundaries overlap the watershed boundary: the Tippecanoe County Partnership for Water Quality MS4 on the left and the Howard County MS4 on the right.
Data used to create this map are detailed in Appendix A.

In May 2004, the Baseline Characterization Report (or Part B) was submitted to IDEM as part of the MS4 permitting process (CBBEL, 2004). The report characterizes the land use and stormwater runoff, identifies sensitive areas and structural and non-structural best management practices, and specifies priority implementation areas within the MS4. Based on the fact that agricultural land uses dominate the MS4 area (60%), the implementation of agricultural best management practices focused on sediment and nutrient transport reduction are encouraged. The recommended best management practices include conservation tillage, nutrient and pesticide management, buffer strips, and wetland restoration. The implementation of these items will assist in addressing stakeholder concerns relating to sediment erosion and transport and high nutrient concentrations. Addressing the next highest land use as urban land use, accounting for 13% of the MS4 region, the baseline characterization report recommends adoption of a comprehensive stormwater ordinance and identifies urban best management practices for each MCM.

2.12 Watershed Summary: Parameter Relationships

Several relationships among watershed parameters become apparent when watershed-wide data are examined. These relationships are discussed here in general, while specific subwatershed related relationships are discussed in more detail in subsequent sections.

2.12.1 Bedrock, Topography, and Land Forms

Geology throughout the Deer Creek-Sugar Creek watershed is dominated by the Wabash Formation with the exception of the lower portions of Sugar, Buck, and Deer Creeks in Tippecanoe County and the eastern part of Carroll County. These areas are underlain by the New Albany Shale and Muscatatuck Group bedrocks. The erosive nature of these bedrocks paired with a concentration of highly erodible soils in these areas could increase the potential for steep banks and loss of land. The highest concentration of existing steep slopes is already in this portion of the watershed, adjacent to Sugar, Buck and lower Deer Creek. Any water quality improvements required in these areas of the watershed will need to target the unique soils, topography, and land uses associated with this area.

2.12.2 Unsewered Areas and Septic Soil Suitability

Nearly the entire watershed is covered by soils considered severely limited for use in septic tank absorption fields, yet only a small portion of the watershed is served by sewer infrastructure. Though the overall population of the watershed is small and sparsely distributed, 90% of survey respondents have septic systems, most with absorption systems. This presents a good opportunity for focused education and outreach on the importance of proper septic maintenance and the role it can have in impacting water quality.

2.12.3 Floodplains and Land Cover

Flooding is an issue for many farmers in the watershed, and a significant amount of the floodplains are currently used as crop lands. Mitigation measures to ease storm runoff and flooding are important on cropped floodplain areas and also upstream in order to reduce the potential for floods to have deleterious impacts to crop lands.

2.12.4 ETR Species and Recreational Opportunities

The large tract of historically significant and publicly-owned land at Prophetstown State coupled with the variety of endangered, threatened, and rare species in this part of the watershed creates a unique management opportunity. Publicly-owned land that is routinely visited by watershed stakeholders provides a great opportunity to positively impact water quality. This area could serve as a demonstration site which will allow stakeholders to view management options before enacting them on their own property. Stakeholder's love for this area, willingness to protect high quality species and habitat, and their desire to positively impact water quality and the environment will increase the opportunity present in the watershed to improve water quality.

2.12.5 Impaired Waterbodies

Public concern about water quality is supported by state impairment designations. State-assessed waterbodies in the watershed are listed as impaired because they routinely exceed the *E. coli* water quality standard. Four waterbodies are listed with multiple impairments in addition to *E. coli* such as nutrients, impaired biotic communities, mercury, and PCBs in fish tissue samples.

2.12.6 Manure Application and Farming in Floodplains

Most of the waterbodies in the watershed run through agricultural land that is intensely cultivated (greater than 75%). Many of the confined feeding operations and smaller unregulated farms are located adjacent to streams and tributaries. Some of the lands permitted for manure and municipal sludge application are also adjacent to creeks and streams in the watershed. The proximity of these activities to watershed waterbodies increases the chance for runoff to carry nutrients into the streams and eventually into the Wabash River.

2.12.7 Coordinated Efforts

Jurisdictions within the watershed are also actively working towards water quality improvement goals. The county comprehensive plans state broad goals to protect water quality and natural areas in the floodplains. Soil and Water Conservation Districts have all identified issues of concern which closely parallel the issues identified by watershed stakeholders including soil erosion, nutrient application, stormwater runoff, and loss of wildlife habitat. The SWCDs are each committed the installation of specific quantities of water quality improvement best management practices such as manure, nutrient, and pesticide management; filter strips; conservation and no till practices; habitat restoration; stormwater runoff reductions; education; cover crops; and livestock access exclusion. All of these practices will be included in this plan to further efforts to improve water quality, and each of the SWCDs are ideal partners for accessing watershed communities interested in conservation practices. Additional entities in Howard and Tippecanoe Counties (the Howard County MS4 and TCPWQ) are also already taking a proactive stance in promoting best management practices and also make ideal partners for the implementation of the WMP.

3.0 WATERSHED INVENTORY II-A: WATER QUALITY AND WATERSHED ASSESSMENT

In order to better understand the watershed, an inventory and assessment of the watershed and existing water quality studies conducted within the watershed is necessary. Examining previous efforts allowed the project participants to determine if sufficient data were available or if additional data needed to be collected in order to characterize water quality problems. The following sections detail the water quality and watershed assessment efforts on both the broad, watershed-wide scale and in a focused manner looking at each subwatershed within the Deer Creek-Sugar Creek watershed

3.1 Water Quality Targets

Many of the historic water quality assessments occurred using different techniques or goals. Several sites were sampled only one time and for a limited number of parameters. Steering committee members were reluctant to draw too many conclusions based on a single sampling event. Nonetheless, the available data are detailed below and compared in general with water quality targets. In order to compare the results of these assessments, the monitoring committee identified a standard suite of parameters and parameter benchmarks. Table 16 details the selected parameters and the benchmark utilized to evaluate collected water quality data.

Table 16. Water quality benchmarks used to assess water quality from historic and current water quality assessments.

Parameter	Water Quality Benchmark	Source
Dissolved Oxygen	Min: 4.0 mg/L Max: 12.0 mg/L	Indiana Administrative Code (327 IAC 2-1-6)
E. coli	Max: 235 CFU/ 100mL in a single sample Max Geometric Mean of 125 CFU/100 mL from 5 equally spaced samples over a 30-day period	Indiana Administrative Code (327 IAC 2-1.5-8)
Nitrate –Nitrogen	Max: 1.0 mg/L	Ohio EPA recommended criteria for Warm Water Habitat
pH	6 to 9	
Temperature	Dependent on time of year and whether stream is designated as a cold water fisheries	Indiana Administrative Code (327 IAC 2-1-6)
Total Phosphorus	Long Term Target Max: 0.08 mg/L	Dodds et al. 1998
	Short Term Target Max: 0.3 mg/L	IDEM TMDL target
Turbidity	Max: 9.89 NTU	U.S. EPA recommendation
Total Suspended Solids (TSS)	Max: 15.0 mg/L	Michigan DEQ
Qualitative Habitat Evaluation Index	> 51	IDEM
Macroinvertebrate Index of Biotic Integrity	> 2.2 (1990-2003 using rapid assessment single habitat method); >36 (2005-present scored using multi-habitat method)	IDEM
Index of Biotic Integrity	> 36 points	IDEM

3.2 Historic Water Quality Sampling Efforts

A variety of water quality assessment projects have been completed within the Deer Creek-Sugar Creek watershed (Figure 43). Statewide assessments and listings include the integrated water monitoring assessment, the impaired waterbodies assessment, and fish consumption advisories. Additionally, the Indiana Department of Natural Resources (IDNR) completed assessments within the watershed. Corridor-wide assessments of the fish community along the length of the Wabash River were completed by DePauw University and Ball State University. Regional water quality assessments were completed by the Tippecanoe County Soil and Water Conservation District (SWCD) and the Tippecanoe County Health Department (TCHD). Purdue University professors completed mussel and fish assessments throughout Tippecanoe County; additionally water quality data were collected. Prior to the construction of the Hoosier Heartland, a biological assessment was completed for the areas that will be impacted by the new highway. A summary of each assessment methodology and general results are discussed below. These are detailed within subwatershed discussions in subsequent section.

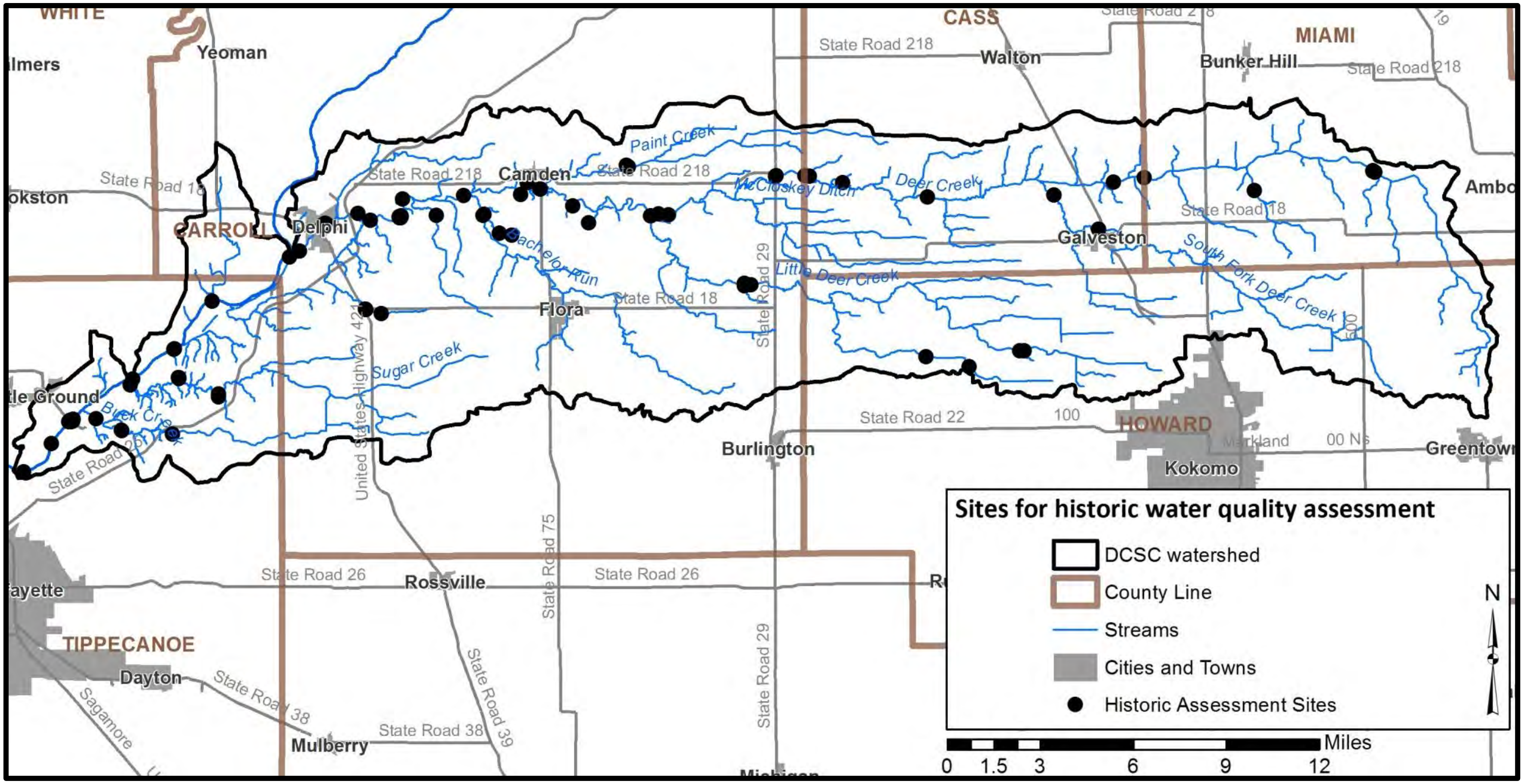

Figure 43. Historic water quality assessment locations.
Data used to create this map are detailed in Appendix A.

3.2.1 Integrated Water Monitoring Assessment (305(b) Report)

The Indiana Department of Environmental Management (IDEM) is the primary agency tasked with monitoring surface water quality within the state of Indiana. Chapter 305(b) of the Clean Water Act requires that the state report on the quality of waterbodies throughout the state on a biannual basis. These assessments are known as the Integrated Water Monitoring Assessment (IWMA) or the 305(b) Report (IDEM, 2012). To complete this report, the 305(b) coordinator reviews all data collected by IDEM and selected high-quality data collected by other organizations on a waterbody basis. Each assessed waterbody is then assigned a water quality rating based on its ability to meet Indiana's water quality standards (WQS). WQS are set at a level to protect Indiana waters' and their designated uses of swimmable, fishable, and drinkable. Waterbodies that do not meet their designated uses are proposed for listing on the Impaired Waterbodies List.

3.2.2 Impaired Waterbodies (303(d) List)

Waterbodies in the Deer Creek-Sugar Creek watershed which are included on the Impaired Waterbodies List are detailed in section 2.7.3 above.

3.2.3 Fish Consumption Advisory (FCA)

Three state agencies collaborate annually to compile the Indiana Fish Consumption Advisory (FCA). The Indiana Department of Natural Resources, Indiana Department of Environmental Management, and Indiana State Department of Health have worked together since 1972 on this effort. Samples are collected through IDEM's rotating basin assessment for bottom feeding, mid-water column feeding, and top feeding fish. Fish tissue samples are then analyzed for heavy metals, PCBs, and pesticides.

Table 17 details the advisories for the Deer Creek-Sugar Creek watershed from the 2011 report (IDEM, 2011). Advisory listings are as follows:

- Level 3 – limit consumption to one meal per month for adult males and females; women who are pregnant or breastfeeding; women who plan to have children; and children less than15 years of age should consume zero volume of these fish.
- Level 4 – limit consumption to one meal every two months for adult males and females; women and children detailed above having zero consumption.
- Level 5 – zero consumption or do not eat.

Based on these listings, the following conclusions can be drawn:

- No carp should be consumed from any waterbody within the watershed.
- Smallmouth bass longer than ten inches should only be consumed once a month.
- The Wabash River is under a fish consumption advisory for selected fish of select size within the length of the river in Carroll, Cass, Miami, and Tippecanoe counties up stream of Lafayette, IN.

Table 17. Fish Consumption Advisory listing for the Deer Creek-Sugar Creek watershed.

Waterbody	Fish Species	Fish Size	Advisory
All	Carp	15-20 inches	3
		20-25 inches	4
		25+ inches	5
Deer Creek	Smallmouth Bass	10+ inches	3
Wabash River	Black Redhorse	19+ inches	3
	Blue Sucker	21-26 inches	3
		26+ inches	4
	Carpsuckers	ALL	3
	Channel Catfish	15+ inches	3
	Freshwater Drum	16+ inches	3
	Sauger	13+ inches	3
	Shorthead Redhorse	15+ inches	3
	Smallmouth Buffalo	Up to 20 inches	3
		20+ inches	4

3.2.4 Wabash River Total Maximum Daily Load (TMDL) Study

Water quality data collected from the Wabash River indicated that the Wabash River did not consistently comply with the state's water quality standards. Based on these determinations, segments of the Wabash River have been included on the state's 303(d) list since its inception. The 2002 listing included segments of the Wabash River in non-compliance for pathogens (*E. coli* and fecal coliform), nutrients, pH, dissolved oxygen, and impaired biotic communities. Subsequent lists prepared in 2004, 2006, and 2008 replicate these listings. In order to cohesively address impairments, one TMDL was written for the entire length of the Wabash River including the 30 miles in Ohio and the 475 miles in Indiana and Illinois (Tetra Tech, 2006). Maps from the TMDL report showing the locations of impaired Wabash River segments, water quality sampling stations along the Wabash River, and verified nutrient impaired segments are included in Appendix G. Within the Deer Creek-Sugar Creek watershed, the TMDL addresses nutrient, dissolved oxygen, and *E. coli* impairments.

Data collected by several agencies were obtained for water quality model development and TMDL calculation. The following conclusions were drawn with regards to water quality in the Wabash River:

- Nitrate+nitrite concentrations routinely exceeded the Indiana benchmark (10 mg/L); however, median concentrations measured 5 mg/L. Concentrations were generally higher in the reach of the Wabash River included in the watershed than those observed both up and downstream.

- Median dissolved oxygen concentrations generally exceeded 8 mg/L with only a few stations measuring below the minimum benchmark (4 mg/L). However, several stations, including the stations within the watershed, routinely exceeded the upper benchmark (12 mg/L).
- Phosphorus concentrations routinely exceeded the long-term target and phosphorus benchmark (0.3 mg/L) used for impaired waterbody listing by the IDEM.
- Most station impairments resulted from a combination of phosphorus and nitrate+nitrite or dissolved oxygen exceedances.

Due to the routine nature of the listings, one TMDL was developed for the entire Wabash River. The TMDL was calibrated at six locations along the river where sufficient data were available for calculation. Specific information for the Deer Creek watershed was addressed as part of the TMDL. Based on the Wabash River TMDL, the following conclusions have been drawn:

- A monthly reduction in *E. coli* from April to October of 87% is needed in Deer Creek. This percent reduction results in a reduction of 52,700,000,000,000 *E. coli* colonies per year (TetraTech, 2007).
- Monthly reductions of total phosphorus of 4% are needed in Deer Creek. This results in an overall reduction of 0.64lb of phosphorus per day or 234 lbs. of phosphorus per year (TetraTech, 2007).
- No nitrate reductions are required in Deer Creek.

3.2.5 IDEM Fixed Station and Rotational Basin Assessments

Through IDEM's fixed station water quality monitoring program, IDEM scientists collect water quality samples once per month at 160 stream and river sample sites throughout the state. Three fixed sampling stations are located within the Deer Creek-Sugar Creek watershed, two on the Wabash River and one on Deer Creek. The sites on the Wabash River are located downstream of Americus (1991-2000) at State Road 225 and at Americus (2001 to present) at Americus Road. Based on the fixed station sampling data, the following conclusions can be drawn:

- Total phosphorus concentrations exceeded the recommended criteria during a majority of months sampled at both the upstream and downstream locations. Samples routinely exceeded the watershed short-term target of 0.3 mg/L resulting in these reaches of the Wabash River being listed on Indiana's Impaired Waterbodies List.
- Total Kjeldahl nitrogen and nitrate-nitrogen concentrations routinely exceeded the recommended criteria at both the upstream and downstream locations.
- Total suspended solids concentrations were elevated in a majority of the samples collected in both the up and downstream locations.
- *E. coli* concentrations varied over time but generally exceeded the state standard at both the upstream and downstream locations.

The fixed sampling station on Deer Creek is located at Country Road 300 Northeast of Delphi (1991-2012). Based on this fixed station's sampling data, the following conclusions can be drawn:

- Total phosphorus concentrations exceeded the long-term target of Dodds et al. (1998) of 0.08 mg/L during a third of sampling occasions.
- Total Kjeldahl nitrogen and nitrate-nitrogen concentrations routinely exceeded the recommended criteria and sometimes the EPA's drinking water standard (10 mg/L).

- Total suspended solids concentrations were elevated compared to the suggested concentration of 15 mg/L by Waters (1995) in a quarter of the samples collected.
- *E. coli* concentrations varied over time but only exceeded the state standard two of the eight sampling events.

In 1998, 2003, and 2008, IDEM sampled water chemistry at several locations in the Deer Creek-Sugar Creek watershed via their rotational basin assessment program. Sampling occurred on Bridge Creek, Deer Creek, Little Deer Creek, and Paint Creek in 1998. In 2003, Deer Creek was sampled at two locations. In 2008, IDEM sampled two additional sites on Deer Creek and one site each on Harrison-Harlan Ditch, Little Deer Creek, a tributary of Sugar Creek, and the Wabash River. A majority of these assessments included a single sampling event with some sites assessed three times. Based on the rotational basin water chemistry assessments, the following conclusions can be drawn:

- *E. coli* concentrations exceeded the state standard in Harrison-Harlan Ditch, at two of the four Deer Creek sites, in the tributary to Sugar Creek, and the Wabash River during at least one assessment.
- Nitrate-nitrite concentrations exceeded the recommended standard by Dodds et al. (1998) of 1 mg/L in Bridge Creek, in three of four Deer Creek sites, Harrison-Harlan Ditch, Little Deer Creek, Paint Creek, the tributary to Sugar Creek, and the Wabash River during at least one sampling event.
- Total phosphorus concentrations exceeded long term target of 0.08 mg/L by Dodds et al. (1998) in Bridge Creek, Deer Creek (all sites), Little Deer Creek, Paint Creek, and the Wabash River.
- Pesticide monitoring in Deer Creek occurred in 1998. Results indicate that pesticide concentrations are elevated especially acetochlor, alachlor, atrazine, clomazone, and metolachlor. Acetochlor and alachlor concentrations measured as high as 2.3 µg/L, while atrazine measured as high as 16 µg/L. Clomazone and metoachlor measured as high as 3.2 µg/L and 30 µg/L, respectively.

3.2.6 IDEM Biological and Habitat Assessments

IDEM completed biological and habitat assessments throughout the watershed. In 2004, a multi-habitat macroinvertebrate index of biotic integrity (mIBI) calibration study was completed at four sites: three on Deer Creek and one on Little Deer Creek. Fish sampling occurred at eight sites including, Bridge Creek, five sites at Deer Creek, Harrison-Harlan Ditch, and Little Deer Creek in 2003 and 2008. Macroinvertebrate communities were sampled at 17 sites Deer Creek-Sugar Creek subwatershed including sites on Bachelor Run, Bridge Creek, Buck Creek, nine sites on Deer Creek, Harrison-Harlan Ditch, Little Deer Creek, Sugar Creek, and the Wabash River. Fish and macroinvertebrate samples were collected and habitat was assessed using IDEM's standard methods. Based on these assessments, the following conclusions can be drawn:

- Habitat within Bachelor Run, Buck Creek, Bridge Creek, Deer Creek (County Road 1100 South in Miami County), Harrison-Harlan Ditch, and the Wabash River rated below the state standard indicating that the streams are not fully supporting the aquatic life use designation. Harrison-Harlan Ditch was rated the lowest with a score of 27.
- The macroinvertebrate communities rated as severely impaired in Bridge Creek, Buck Creek, Deer Creek (State Road 25, County Road 300 North in Cass County and County Road 1100 South in Miami County), Harrison-Harlan Ditch and the Wabash River at State Road 225 in Tippecanoe County.

3.2.7 IDEM Fisheries Assessment

Between July of 1998 and June of 2008, IDEM surveyed eight sites within the Deer Creek-Sugar Creek watershed. Five of the sampling locations were on located on Deer Creek, while the remaining three were on Harrison-Harlan Ditch, Bridge Creek, and Little Deer Creek. Based on these data, the following conclusions can be drawn:

- The most prevalent species at the Bridge Creek, Harrison-Harlan Ditch, and Little Deer Creek was the western blacknose dace, striped shiner, and central stoneroller, respectively.
- The most prevalent species at the five Deer Creek sites were not the same. The species that were most prevalent were the striped shiner, bluntnose minnow, black redhorse, longear sunfish, and central stoneroller.
- Of the nine sampling events, eight calculated Index of biotic integrity (IBIs) rated as fair or higher; the IBI calculated for Bridge Creek rated as poor.
- Of eight sites, habitat at six sites scored a QHEI greater than 51 indicating that the habitat was not negatively impacting the community. Habitat at one site on Deer Creek and at the Little Deer Creek site scored below 51 indicating that habitat could be negatively impacting the fish community.

3.2.8 Little Deer Creek Headwaters Watershed Management Project (2010)

As part of Little Deer Creek Headwaters 319 Program Watershed Management Project in Howard County, water quality data were collected (Howard County SWCD, 2010). The project occurred from November 2006 to May 2010. The headwaters of Little Deer Creek were sampled at County Road 800 West. Samples were collected a total of four times, three times in 2008 and once in 2009 using Hoosier Riverwatch methods. Based on the data collected, the following conclusions can be drawn:

- *E. coli* concentrations exceeded the Indiana state standard (235 colonies/100 mL) only once occurring in July of 2008 and was measured at 278 colonies/100 mL.
- Nitrate levels were greater than 1.0 mg/L during three of the four assessments, and exceed the EPA drinking water standard (10 mg/L) once in May of 2008 with a nitrate level of 17.6 mg/L
- The site's CQHEI was greater than 60, thus suggesting that the site is conducive of warm water fauna. The biological data indicated that the macroinvertebrate community's pollution tolerance was good to excellent at all four sampling events.

3.2.9 Wabash River Fishery Assessments: DePauw University (1973-1994)

Assessment and study of the Wabash River began in 1967. Initial studies focused on thermal effects on the fish community near Terre Haute and Cayuga. Research efforts extended to longer stretches of the river in 1973 and expanded north to include the river from Delphi (RM 330) downstream to Merom (RM 161). Extensive data collected via IDEM's fixed monitoring station network are also reported as part of Gammon's efforts (Gammon, 1995). Based on Gammon (1995), the following conclusions have been drawn:

- The average suspended sediment concentration in the Wabash River from 1977-1987 measured 64.9-157.2 mg/L.

- Mean nutrient concentrations calculated from measurements occurring from 1977-1987 indicate that nitrate-nitrogen (3.0-3.5 mg/L) and phosphate (0.170-0.300 mg/L) concentrations were elevated and need to be reduced. Higher concentrations were seen in the upper Wabash River, such as the reach from Delphi to Lafayette, which was probably due to agriculture and channelization.
- In Gammon's 1994 assessment of riparian conditions, 58 km of Wabash River bank from Delphi to Lafayette were examined. Bare banks were observed on 0.9 km, while banks with few trees occurred on 4.3 km. These data indicate that in 1994, the banks of the Wabash River had several short sections with limited bank protection.
- Carp was the fish in the community with the largest catch rate. A large population of carp can indicate degraded environmental conditions.
- Dominate species in the reach from Delphi to Lafayette include carpsucker species, hog suckers, longear sunfish, redhorse species, sauger, skipjack herring, smallmouth buffalo, and white bass.

3.2.10 Wabash River Fishery Assessment: Ball State University (2001-2008)

Ball State University continued Jim Gammon's Wabash River assessment efforts starting in 2001; samples were collected three times throughout the summer in 2001 and 2002 (Pyron and Lauer, 2004). Beginning in pre-summer of 2001, the assessment of the fish communities in 500 meter reaches from below Delphi, IN to Prairie Creek were conducted. The sampling was repeated during the summer of 2008. Sampling occurred along two reaches within the Deer Creek-Sugar Creek watershed; sites were located on the Wabash River, the first was below Delphi and the other was above Americus. During the six sampling times from 2001-2002, 68 species were collected, but in 2008 only 59 species were collected throughout the 230 km section of the Wabash River. Based on thiee data, the following conclusions can be drawn:

- The five most prevalent species in the upstream site were three redhorse and two minnow species (silver redhorse, river redhorse, short redhorse, sand shiner, and mimic shiner) while the downstream site was dominated by bluegill, spotted bass and two gar species.
- The sites below Delphi and above Americus were the most stable according to Gammon (1998) and these sites were made the reference sites to which all others were compared.
- Dissolved oxygen concentrations were lower at the two sites within the Deer Creek-Sugar Creek watershed than all of the other sites; however, none of the concentrations were low enough to cause concern.
- Conductivity was elevated at the site below Delphi (724 µmhos) but was below the highest recorded conductivity (741 µmhos).
- All sites possessed IBI scores which exceeded the score at which IDEM indicates streams are not meeting their aquatic life use designation (35); the IBI of the site below Delphi and above Americus were 59 and 51, respectively.

3.2.11 The Nature Conservancy Wabash River Study

The Nature Conservancy (TNC) compiled a database of biological stressor and threat data for the Wabash River and its tributaries (Armitage and Rankin, 2009). The data were then used to analyze water quality and fish community information on an 11-digit watershed level. Although no new data were collected as part of this study, their analysis methods allow conclusions to be drawn which can be used to compare this watershed with others along the length of the Wabash River. Based on existing data, the following conclusions can be drawn:

- An ideal habitat (QHEI) score for this portion of the Wabash River based on 1800s conditions is 93.5. At that time, habitat would have rated as excellent to near maximum scores for most metrics.
- This segment of the Wabash River was historically home to riffles and represents the most downstream reach where riffles occurred. TNC hypothesized that increased flashiness, increased peak flows, and modifications in meander patterns occur within this region of the Wabash River
- The fish community in this reach is generally lacking in sensitive species with common carp and freshwater drum dominating the population.
- Total phosphorus and nitrate-nitrogen concentrations are elevated within both the main stem and tributaries in this reach. The elevated nutrient concentrations present in the tributaries, coupled with the lack of buffers, increase the delivery of nutrients via drainage systems and tile drains, and degradation of in stream habitat due to altered hydrology.

3.2.12 Tippecanoe County SWCD Assessment (2002, 2003)

In 2002 and 2003, as part of the World Water Monitoring Day, the Soil and Water Conservation District (SWCD) and their volunteers monitored water quality at 44 sites throughout Tippecanoe County. Two of these sites were located within the Deer Creek-Sugar Creek watershed; sites were located on Buck Creek and Sugar Creek. Samples were analyzed for dissolved oxygen, pH, turbidity, and *E. coli*. Dissolved oxygen, pH, and turbidity measurements were completed using Hoosier Riverwatch methodologies, while *E. coli* was analyzed by IDEM's mobile laboratory. No flow data are available for these samples; however, it is assumed that since the samples were collected in late October that water levels and thus flow, were relatively low. Based on these data, the following conclusions can be drawn:

- Dissolved oxygen percent saturation was measured at or below 50% in both of the streams sampled within the watershed. Dissolved oxygen concentration was at the state standard (4 mg/L) in Buck Creek.
- *E. coli* concentrations exceeded the Indiana state standard (235 colonies/100 mL) in Buck Creek in 2002, but not in 2003.

3.2.13 USGS – Concentrations of *Escherichia Coli* in Streams in the Upper Wabash River Watershed in Indiana, June-September 1998

In 1998, the USGS assessed four sites within the Deer Creek-Sugar Creek watershed five times during a 30-day period during the recreational season (April-October). The assessment included collection of field data and *E. coli* samples. Sites were located on Deer Creek and the Wabash River. The sites on Deer Creek were located at State Road 29 and County Road 300 North near Delphi. The sites on the Wabash River were located at State Road 225 near Battle Ground and County Road 200 North near Delphi. The sample collection was designed for the calculation of geometric means following IDEM's standards. Based on these data, the following conclusions can be drawn:

- All four of the sites' five sample geometric mean *E. coli* concentrations were higher than the water-quality standard for full-body contact.
- *E.* coli concentrations exceeded the state standard four of the five times at both of the Wabash River sites.
- Of the five samples collected at the Deer Creek site at State Road 29, *E. coli* concentrations were greater than the state standard four of the five times. The Deer Creek site near Delphi only had two of the five samples greater than the state standard for full-body contact.

3.2.14 Purdue University Sturgeon Sampling (2003-2004, 2007-2008)

Shovelnose sturgeon populations within the Wabash River were assessed by Kennedy et al. (2007) from April 2003 through November 2004. Sturgeons were assessed in two portions of the Wabash River: from Wabash to Lafayette and from Lafayette to Terre Haute to determine relative abundance, size, age structure, growth, mortality rate, condition, and gender ratio. Two of the six sampling areas within the upper reach are located within the Deer Creek-Sugar Creek watershed. Based on this data, the following conclusions can be drawn:

- Relative abundance of shovelnose sturgeon measured greater in the upper reach during the spring than abundances measured in the lower reach. This is likely due to upstream migration associated with spawning activities. This migration suggests that the upper reach contains suitable spawning habitat that may significantly contribute to sustaining the overall shovelnose sturgeon population.
- Population characteristics observed by Kennedy et al. (2007) indicate that the Wabash River shovelnose sturgeon population is similar to populations reported in other river systems. However, despite shovelnose sturgeon attaining larger body sizes, reaching older age classes, and experiencing lower mortality rates, growth rates and relative weights were lower than those observed in other river systems.

3.2.15 Tippecanoe County-wide Mussel Assessment (1995)

Purdue University researchers conducted mussel surveys at 52 stream sites throughout Tippecanoe County from June to August 1995 (Myers-Kinzie et al., 2001). In total, six of these sites are located within the Deer Creek-Sugar Creek watershed; sites were located on Bowen Ditch, Bridge Creek, Buck Creek, and Sugar Creek. Based on the results of these studies, the following conclusions can be drawn:

- Four mussel species were observed in watershed streams. Only weathered shells (dead mussels) were identified in Buck Creek and Sugar Creek. The existence of weathered shells suggests that mussels once existed within these streams, but that conditions no longer allow them to do so.
- Sugar Creek contained the highest mussel diversity with three species identified, while Bridge Creek had the lowest with zero species (alive or weathered).
- A new species to Tippecanoe County records was found in Bowen Ditch. The *Toxolasmaparvus* or Lilliput was only found in three other sites in Tippecanoe County.
- Mussel species diversity was highly correlated with stream drainage, indicating that the volume of water, and thus remnant pool depths, is highly indicative of mussel diversity. The six sites within the watershed had the smallest drainage area and also the least number of species of all sample sites assessed by Myers-Kinzie et al (2001).

3.2.16 IDNR Mussel Assessment

From November 2001 to September 2005, the Indiana Department of Natural Resources identified and documented mussel species at 16 sites within the Deer Creek-Sugar Creek watershed. Twelve of these sites were located on the mainstem of Deer Creek, two sites on Little Deer Creek, and the remaining two sites on the South Fork of Deer Creek. Based on the information collected the following conclusions have been drawn:

- Within the Deer Creek-Sugar Creek watershed, a total of 28 species of mussels were identified. The only species found at all 16 sites was the *Lampsilis siliquoidea* (fatmucket)

- The average number of species found across all the sites was 13. The number of species found at the sites, including live, weathered dead, fresh dead, and subfossil shell material, ranged from 3-25 species. The sites with the lowest and highest number of species were on Deer Creek at Strawtown Pike in Miami County and Deer Creek at County Road 325 East in Carroll County, respectively.
- Three state species of special concern were identified at these sites; the *Lampsilis fasciola* (wavy-rayed lampmussel), *Toxoplasma lividus* (purple lilliput), and the *Ptychobranchusfasciolaris* (kidney shell). The purple lilliput was found at ten of the sites, the wavy-rayed lampmussel at nine sites, and the kidney shell at six sites.
- The Asian clam (*Corbicula fluminea*), an invasive species, was found at ten of the 16 sites.

3.2.17 Tippecanoe County Fish Assessment (1971-1977, 1994)

Purdue University researchers conducted fish surveys at 39 steam sites throughout Tippecanoe County annually from 1971 through 1977 (Curry and Spacie, 1978). These sites and 31 additional sites were sampled between June and December 1994. A variety of sampling methods were used during both assessments with species lists generated for each site. Three of the sites included within these studies are in the Deer Creek-Sugar Creek watershed. The sites were located on the Wabash River at the mouth of Sugar Creek, Americus, and near Battle Ground. Based on the results of these studies, the following conclusions can be drawn:

- The site on the Wabash River at the mouth of Sugar Creek had the greatest diversity of fish of the three sites within the Deer Creek-Sugar Creek watershed with 49 species identified. The remaining two sites on the Wabash River near Battle Ground and Americus had 37 and 39 species, respectively.

3.2.18 Hoosier Heartland Biologic Assessment

Prior to the construction of the State Road 25 Hoosier Heartland Highway a biological impact assessment had to be completed. The biological assessment addressed issues such as water quality impacts, floodplains, wetlands, endangered/threatened species, and wildlife impacts. A series of surveys of the area from Lafayette to Logansport were completed to evaluate the impacts and/or problems the highway will have on the environment. Based on the information collected the following conclusions have been drawn:

- Due to the construction of the Hoosier Heartland Highway, 1.7 miles of stream length will be crossed, 80.8 acres of riparian/forest and 2.7 acres of wetlands will be directly impacted.
- Along Sugar Creek where the highway will be crossing, federally endangered Indiana bats (*Myotis sodalist*) were captured. Additionally, the area along Sugar Creek is suitable habitat for maternity colonies of the bats.
- Six state protected, endangered, threatened species have been documented in the two natural areas which might be impacted by the construction of the highway, Americus Fern and Delphi Swamp. These include the spotted turtle, yellow sedge, hairy-fruited sedge, eastern Massasauga rattlesnake, Kirkland's snake, and the small yellow lady's slipper.
- To assess the fish and mussel communities, 11 sampling sites were selected along Buck Creek, Sugar Creek, Bridge Creek, Deer Creek, and Rock Creek (outside of watershed). From these sites, 36 species of fish and 11 species of mussels were identified. All mussels found within the watershed were found as weathered dead or subfossil shell material.

3.2.19 Summary of Historic Water Quality Sampling Efforts

Historically, the IDEM, the IDNR, The Nature Conservancy, Purdue University, DePauw University, Ball State University, the Tippecanoe County and Howard County SWCDs, and the Indiana Department of Transportation have sampled water quality at 47 locations throughout the Deer Creek-Sugar Creek watershed. These assessments indicated that waterbodies throughout the Deer Creek-Sugar Creek watershed generally contain elevated nutrient and sediment concentrations with *E. coli* levels that exceed state standards. In total, *e. coli* exceedances were observed in more than 50% of samples collected at 14 sites, total nitrogen exceedances were observed in more than 50% of samples collected at 7 sites, total phosphorus concentration exceedances were observed in more than 50% of samples collected at 8 sites, and total suspended solids concentrations exceedances were observed in more than 50% of samples collected at 24 sites within the Deer Creek- Sugar Creek watershed (Figure 44). IDEM identified *E. coli* impairments in 12 streams assessed from 1991 through 2008 as well as elevated PCB concentrations in Deer Creek and the Wabash River, and impaired biotic communities in Deer Creek, Little Deer Creek and Buck Creek. Fixed station and random sampling events indicate that total phosphorus generally exceeds both the short (0.3 mg/L) and long-term (0.08 mg/L) total phosphorus targets, nitrate-nitrogen targets (1.0 mg/L), and total suspended solids targets (15 mg/L). The Wabash River Nutrient and Pathogen TMDL (TetraTech, 2007) indicates a need to reduce *E. coli* by 87% and total phosphorus by 4% in Deer Creek. This reduction will assist the Wabash River in meeting its target *E. coli* and total phosphorus concentrations.

Biotic community assessments suggest that both water chemistry and habitat impair macroinvertebrate and fish communities within the Deer Creek-Sugar Creek watershed. Habitat generally measured below aquatic life use standards in channelized portions of the watershed, while habitat assessments in the more natural reaches indicated sufficient habitat quality to support high quality biotic communities. In general, macroinvertebrate population assessments reflect the elevated nutrient and sediment levels and poor habitat present within most assessment reaches with most communities rating as moderately to severely impaired. The fish communities rated fair to good suggesting that water chemistry rather than habitat limits their community. Mussel assessments completed by the DNR and Purdue University indicated relatively high diversity with 28 species collected at 16 sites. These collections include three species of special concern as well as the invasive Asian clam. These assessments collected throughout the Deer Creek-Sugar Creek watershed reflect fish community assessments completed within the mainstem of the Wabash River. Historic assessments (1970s to 1990s) indicate that the Wabash River contained elevated sediment and nutrient concentrations with the carp possessing the highest catch rate. More recent assessments (2000s) indicate an improvement in sediment and nutrient concentrations and a switch to a more balanced community which still lacks sensitive species.

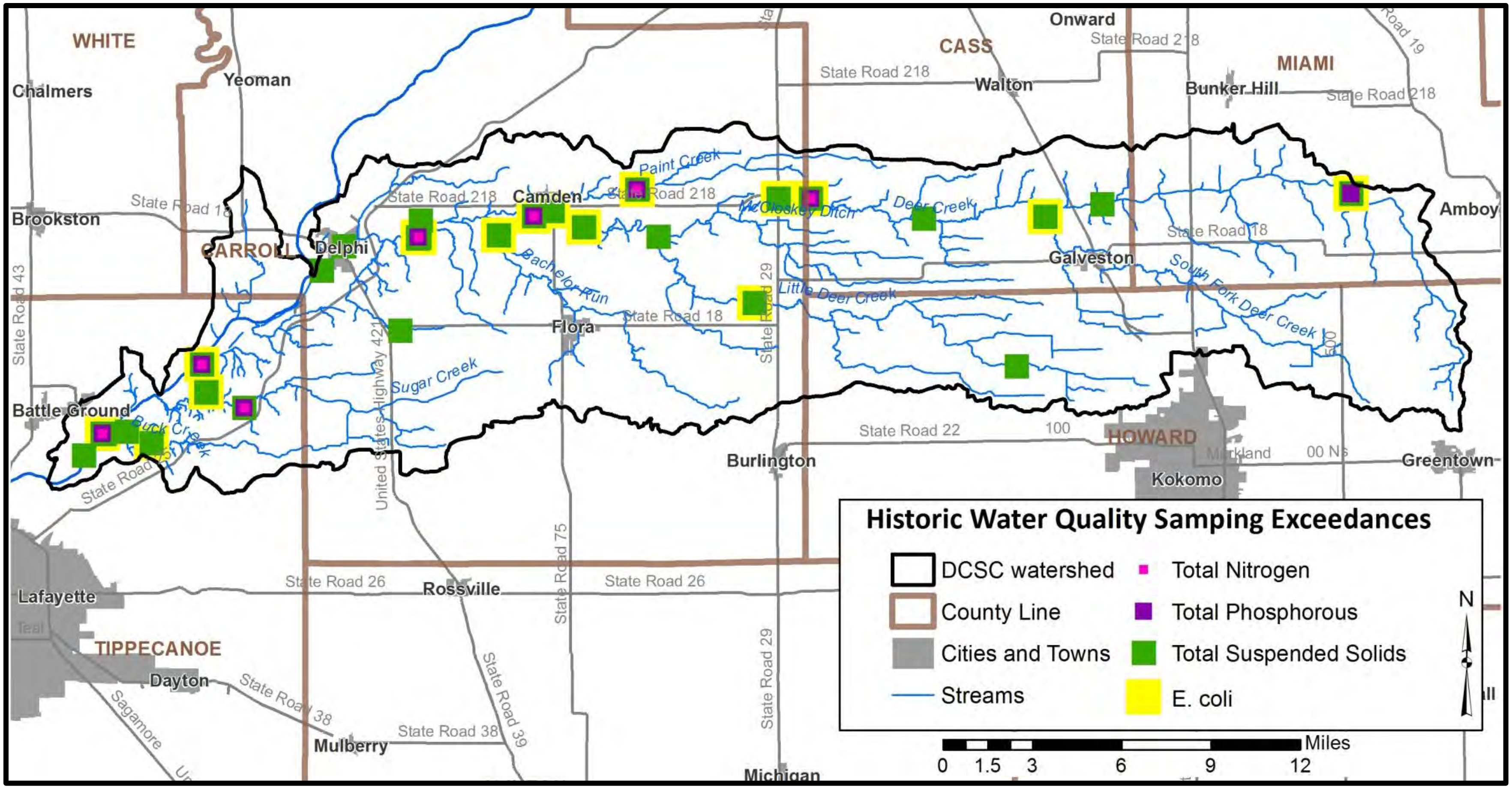

Figure 44. Historic Water Quality Sampling - Exceedances in Nitrogen, Phosphorus, Total Suspended Solids, and *E. coli.*
Data used to create this map are detailed in Appendix A.

3.3 Current Water Quality Assessment

3.3.1 Water Quality Sampling Methodologies

As part of the current project, Purdue University implemented a one year professional water quality monitoring program. The program included water chemistry, fish and macroinvertebrate community, and habitat assessments. Additionally, WREC and Carroll County SWCD implemented a volunteer monitoring program. The program is detailed below and in the Quality Assurance Project Plan for Deer Creek-Sugar Creek Watershed Management Plan approved on July 18, 2012 (WREC, 2012). Sites sampled through this program are displayed in Figure 45. Sample sites were selected based on land use and watershed drainage. The twelve sites represent each major tributary to Deer Creek or the Wabash River as well as important subwatershed areas. The biweekly sampling regimen was enacted to create a baseline of water quality data.

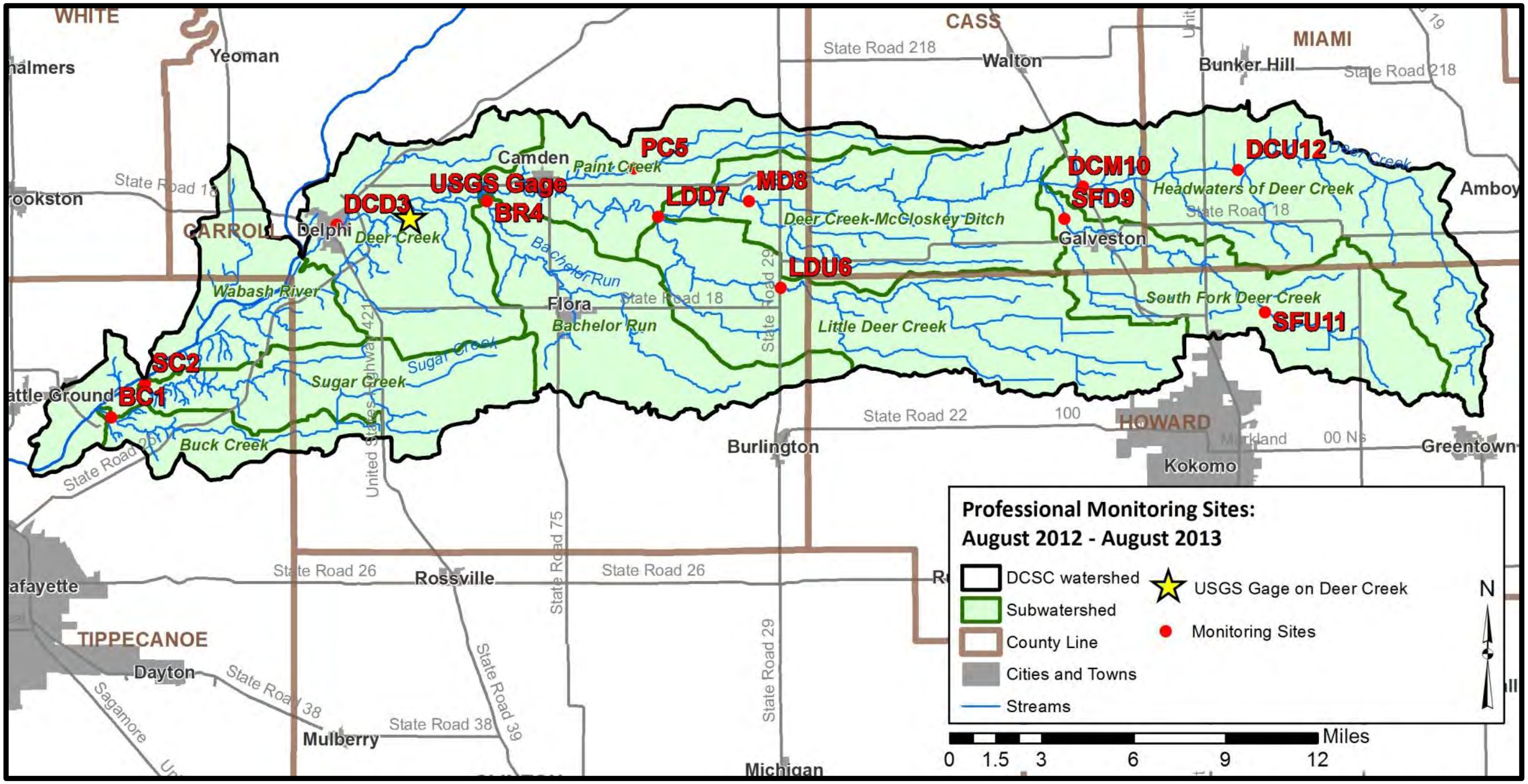

Figure 45. Sites sampled as part of the Deer Creek-Sugar Creek River Watershed Management Plan.
Data used to create this map are detailed in Appendix A.

Stream Flow

Stream flow was measured *in situ* when grab samples were collected. Stream flow was also calculated by scaling stream flow measured at the U.S. Geological Survey (USGS) stream gages to subwatershed drainage area. Based on a similar drainage area, the gage on Pine Creek near Montmorenci (USGS Gage #LPCI3) was used as a proxy for stream flow for the monitoring sites on Buck Creek (site BC1) and Sugar Creek (SC1). The gage on Deer Creek near Delphi (USGS Gage #DCDI3, mapped in Figure 45) was used to as a proxy for stream flow for the remaining monitoring sites.

Field Chemistry Parameters

Purdue University established twelve chemistry monitoring stations as part of the monitoring program. Stations are located on Buck Creek, Sugar Creek, Deer Creek, Paint Creek, Little Deer Creek, Bachelor Run and McCloskey Ditch. Dissolved oxygen, temperature, pH, turbidity, and conductivity were measured biweekly at the sampling stations from August 2012 to August 2013. Appendix E details the parameters measured and potential impacts to particular parameters.

Laboratory Chemistry Parameters

Like the field parameters, biweekly laboratory sample collection and analysis occurred throughout the one year sampling program. Samples were analyzed for nitrate-nitrogen, total phosphorus, total suspended solids, and *E. coli*. Appendix E details the parameters measured and potential impacts to particular parameters.

Habitat

The physical habitat at each of the biological sample sites was evaluated using the Qualitative Habitat Evaluation Index (QHEI). The Ohio EPA developed the QHEI for streams and rivers in Ohio (Rankin, 1989, 1995) and the IDEM adapted the QHEI for use in Indiana. Purdue University assessed habitat at all twelve sites in the summer of 2012. Appendix E details the QHEI and its individual metrics.

Fish Community

The fish community within the Deer Creek-Sugar Creek watershed was assessed at twelve sites once in 2012 Sampling. Methods followed Simon (1991). Index of Biotic Integrity (IBI) scores were calculated for each sampling event. Appendix E details the IBI metrics used to calculated Index of Biotic Integrity values for these samples.

Macroinvertebrate Community

The macroinvertebrate community within the Deer Creek-Sugar Creek watershed was assessed at twelve sites once in 2012. Samples were collected concurrent with fish community sampling. The 2012 samples consisted of six Surbers collected on each sample date. Surber samplers are used to collect aquatic invertebrate samples in moving water habitats with larger sediment particles (i.e., gravels and cobbles). The sampler is composed of a 0.0625 square meter quadrat that lays flat against the bottom and a wedge-shaped net suspended in the water column behind the quadrat. Samples are collected by disturbing the sediments within the quadrat and allowing the dislodged organisms to be carried by the current into the net. Surber samples were then 100% sorted for aquatic macroinvertebrates and one Surber sample for each sample date was randomly selected for 100% family level identification.

The 2010 samples consisted of D-frame kicknet samples as described in Barbour et al. (1999). While D-frame nets can be used in the same fashion as Surber samplers, they are more commonly used in slow-moving habitats with fine sediments to collect aquatic invertebrates. Many of the invertebrates in such habitats are clinging to overhanging vegetation and root wads, and the dip net is "jabbed" into these habitats to loosen and collect the invertebrates. Data in this case are more qualitative and are collected by making the same number of jabs from these habitats at each sample site. D-net samples were 100% sorted and aquatic macroinvertebrates were identified to family level. The macroinvertebrate Index of Biotic Integrity (mIBI) scores were calculated for each sampling event. The mIBI averages a series of ten metric scores resulting in an overall score rating the macroinvertebrate community in terms of impairment. The HBI which ranks species tolerance on a scale of 0-10 with 0 being intolerant and 10 being tolerant of pollution. Appendix E details the mIBI and its scoring methodologies.

3.3.2 Field Chemistry Results

Figure 46 through Figure 50 display results for field chemistry data collected every week at the twelve sample sites. At each of the stream sites, a multi parameter probe is deployed. The probe collects data for temperature, dissolved oxygen, specific conductivity, pH and turbidity.

Temperature

Figure 46 illustrates the biweekly temperature measurements in Deer Creek-Sugar Creek watershed stream. As shown, temperatures measure approximately the same at each of the stream sites with seasonal changes in temperature creating major differences in temperature throughout the sampling period. Temperatures measured near 0 ^{o}C in all streams from December 2012 through February 2013. The highest temperatures occurred during the August 2013 assessments.

Dissolved Oxygen

Dissolved oxygen concentrations also display seasonal changes like those observed for temperature. However, as shown in Figure 47, dissolved oxygen concentrations are opposite those measured for temperature. This is as expected as colder water holds more dissolved oxygen than warmer water; therefore, when water temperatures are low, dissolved oxygen concentrations are high and vice-versa. As such, the dissolved oxygen graph shows a general pattern where dissolved oxygen concentrations are higher in winter and lower in summer. All streams display variation in dissolved oxygen concentration due to individual conditions present within each system. The lowest dissolved oxygen concentrations occurred in May 2013. During this sampling event, Deer Creek at Riley Park (DCD3), Paint Creek (PC4), Little Deer Creek at SR 29 (LDCU7), McCloskey Ditch (MD8), South Fork Deer Creek at CR 1225 South (SFD9), Creek Deer Creek at SR 35 (DCM10), South Fork Deer Creek at Touby Road (SFU11) and Deer Creek at Elm Street (DCU12) contained dissolved oxygen concentrations below the state standard (5 mg/L). These low dissolved oxygen levels are likely due to elevated production within the streams.

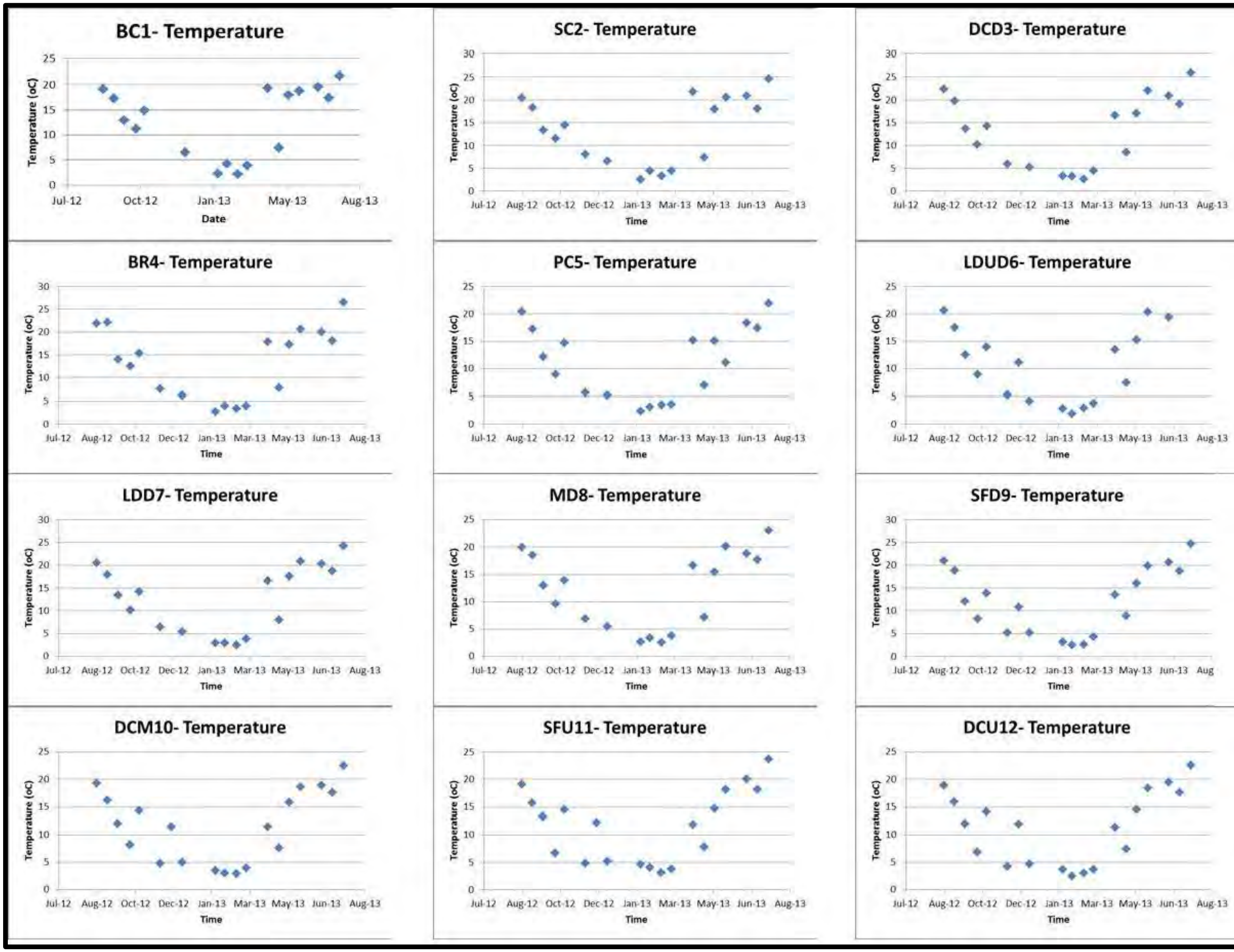

Figure 46. Temperature measurements in Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

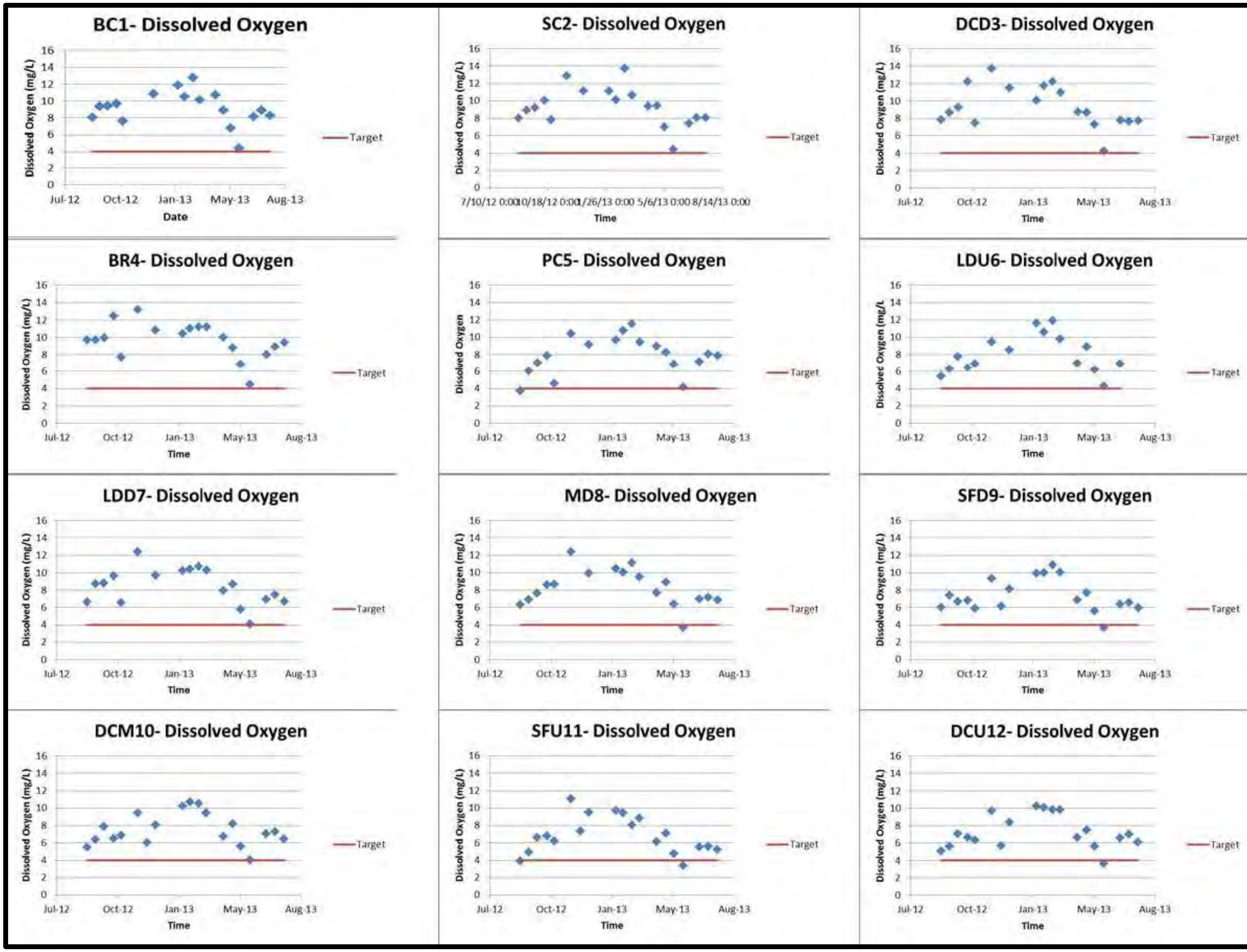

Figure 47. Dissolved oxygen measurements in Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

pH

Throughout the sampling period, pH generally remained in an acceptable range in all three streams. No discernible pattern can be found in pH levels in any of the monitored streams (Figure 48). During the December 2012 sampling, Buck Creek (BC1), Sugar Creek (SC2), Deer Creek at Riley Park (DCD3), and Bachelor Run (BR4) contained pH measurements above the upper pH target (9.0). Elevated pH levels suggest that elevated phytoplankton populations may be present at these sites. High plankton densities result in high photosynthesis levels which can elevate pH.

Specific Conductivity

Figure 49 displays conductivity measurements in Deer Creek-Sugar Creek watershed streams. Conductivity measurements varied greatly over the sampling period. Conductivity never exceeded state standards.

Turbidity

Turbidity measurements for Deer Creek-Sugar Creek watershed streams are displayed in Figure 50. Turbidity concentrations exceeded the target in 60% of collected samples. Turbidity tends to spike during high flow events and this can be observed at several sites throughout the sampling season. Most exceedances in the Deer Creek-Sugar Creek watershed measured just above the target (15 NTU). The highest turbidity levels occurred in Deer Creek at Riley Park (DCD3) and Deer Creek at SR35 (DCM10) with turbidities as high at 700 NTU observed in May 2013.

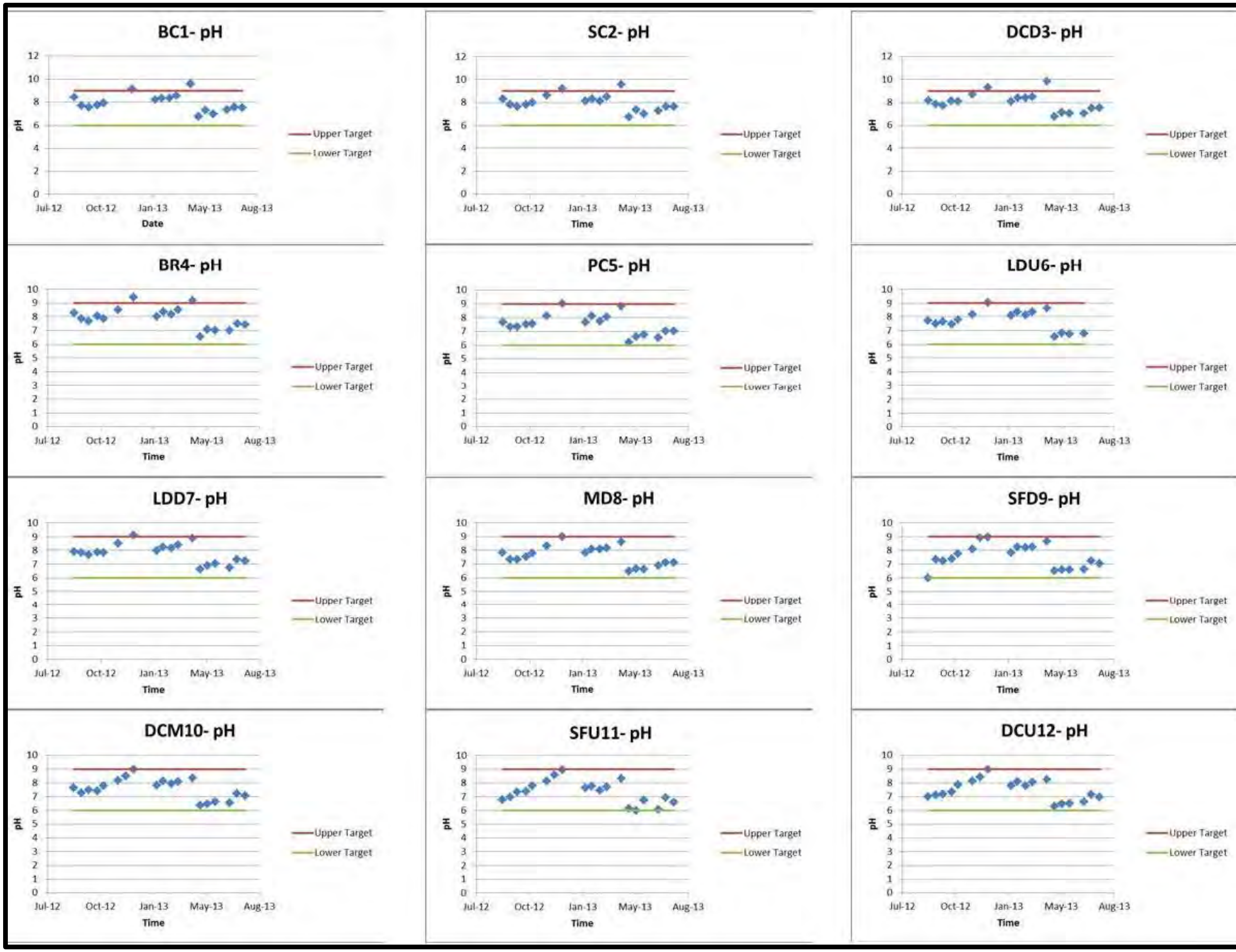

Figure 48. pH measurements in Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

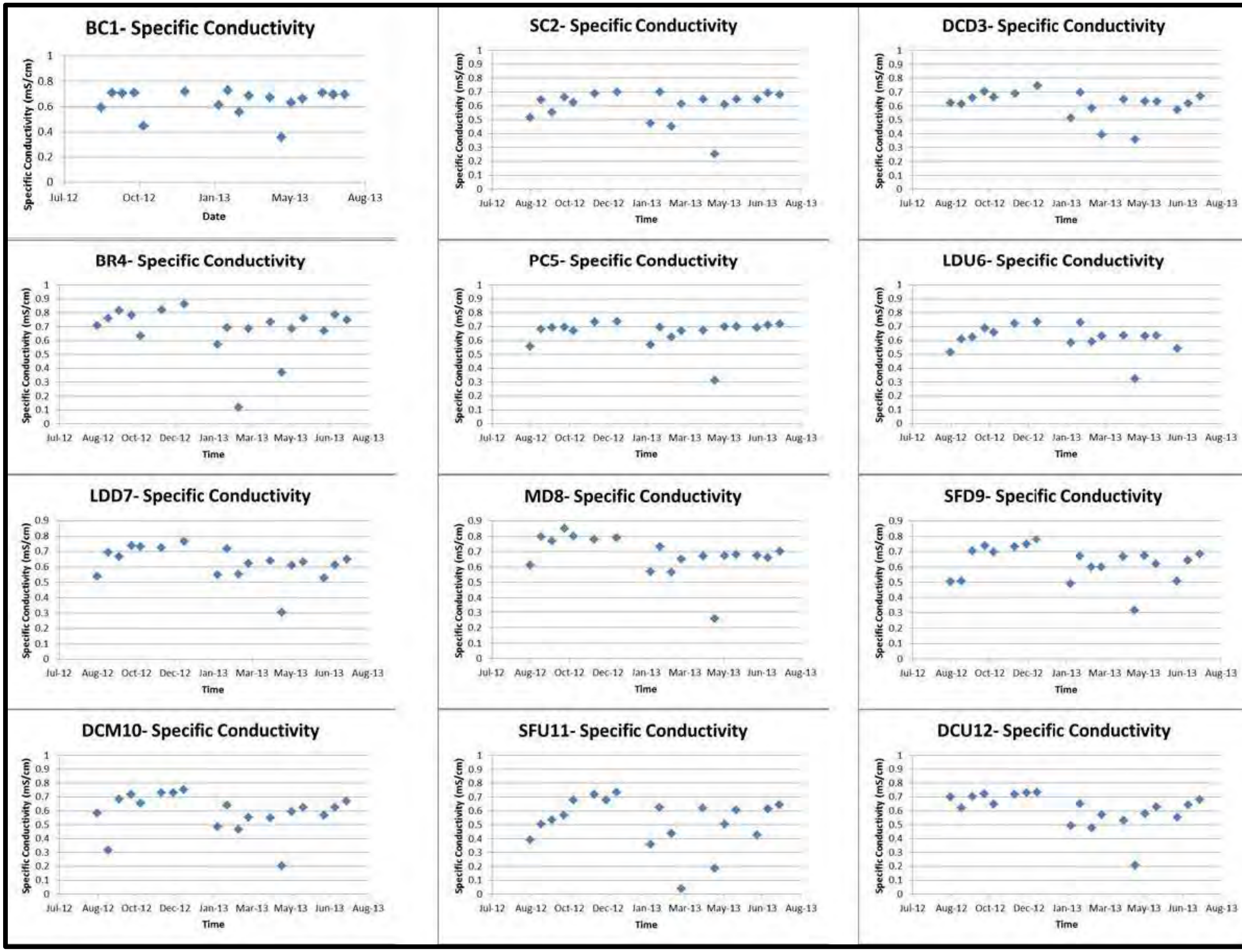

Figure 49. Conductivity measurements in Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

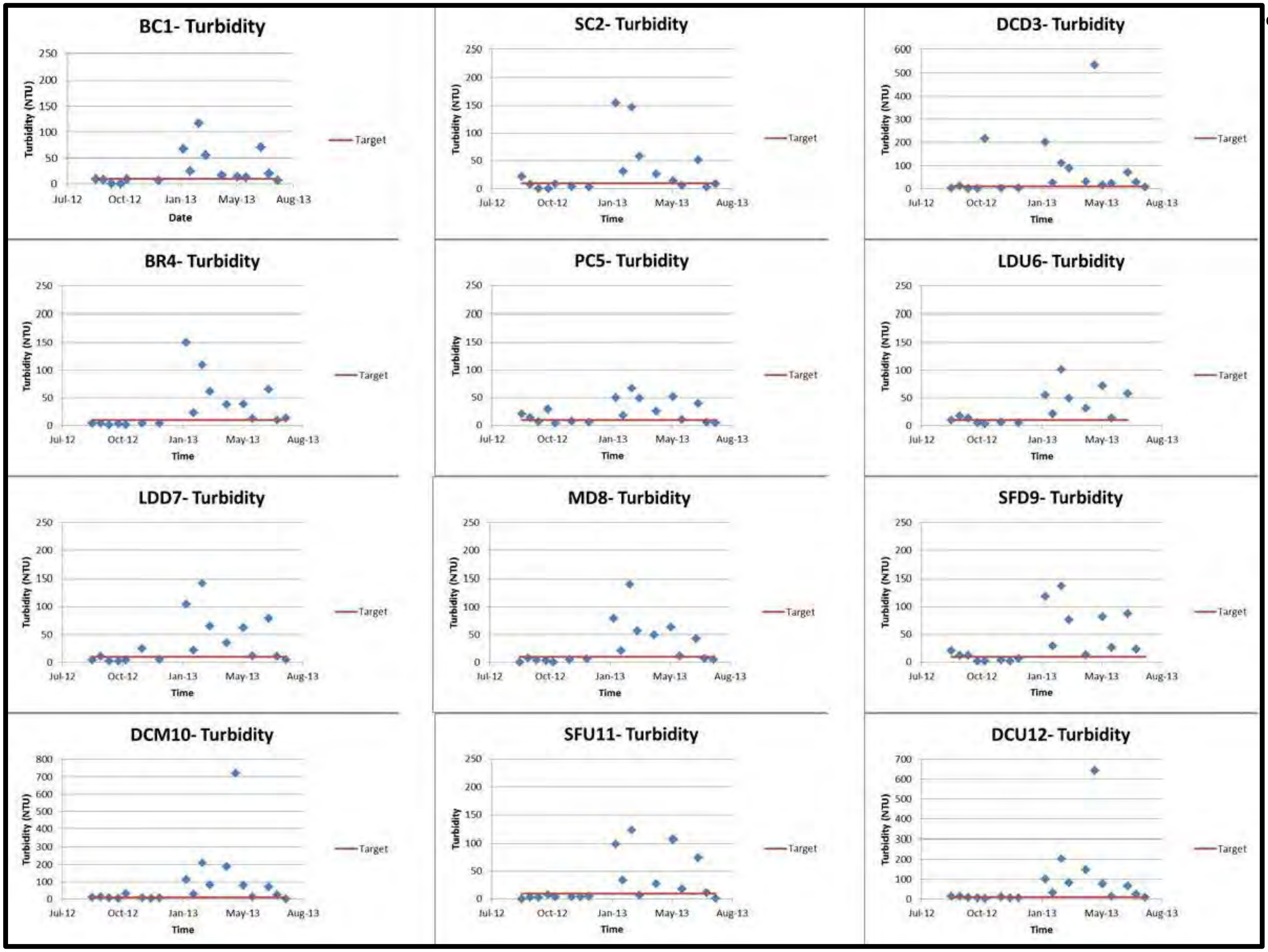

Figure 50. Turbidity measurements in Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

3.3.3 Water Chemistry Results

Figure 51 to Figure 59 display results for nitrate-nitrogen, total phosphorus, total suspended solids, and *E. coli* collected biweekly from twelve locations in the Deer Creek-Sugar Creek watershed. Data are displayed in comparison to target concentration and on load duration curves during the sample period. Appendix E details individual measurements collected throughout the sampling period.

Nitrate-nitrogen

Figure 51 displays nitrate-nitrogen concentrations compared to target levels (2 mg/L). As shown below, nitrate-nitrogen concentrations measured in 2013 almost always exceeded target levels, while 2012 concentrations are below target levels. This is likely due to the severe drought conditions which occurred through the Deer Creek-Sugar Creek watershed in 2012. Nitrate-nitrogen was held by plants or within the soil until the soil was saturated. When the ground was sufficiently saturated, runoff carried excess nitrate-nitrogen not used within the system into adjacent streams. Levels did begin to drop at the end of our study when flow conditions lessened and plants had used up nitrogen applied in the spring. In Deer Creek, nitrate-nitrogen concentrations exceed targets 57% of the time at the most upstream location (DCU12) and 57% of the time midstream (DCM10) but then increases to 83% exceedances in Deer Creek at Riley Park (DCD3). This suggests that there are limited sources of nitrate-nitrogen between the headwaters and middle Deer Creek site, but that nitrate-nitrogen sources are present between DCM10 and DCD3. In Little Deer Creek, nitrate-nitrogen exceeds targets 62% of the time at the headwaters site (LDU7) and 70% of the time at the mouth (LDD6). These data suggest that sources of nitrate-nitrogen may increase slightly between sites. Buck Creek (BC1) and Bachelor Run (BR4) exceeded targets in more than 90% of collected samples suggesting that flow condition does not impact sources of nitrate-nitrogen in Buck Creek and Bachelor Run. Buck Creek (BC1) and Paint Creek (PC5) contained the highest average nitrate-nitrogen concentrations.

Total Phosphorus

Total phosphorus concentrations rarely exceed target concentrations (Figure 52). However, when exceedances do occur, they measure up to three times that target concentration (0.3 mg/L). Concentrations measured in both Little Deer Creek (LDU6 and LDD7) and both Headwaters Deer Creek (DCM10 and DCU12) sites exceeded 1 mg/L during December 2012 sampling events. Buck Creek contained the highest percentage of exceedances with more than 25% of samples measuring higher than target concentrations and the third highest average total phosphorus concentration. Deer Creek Headwaters (DCU12) and Paint Creek (PC5) contained the highest average total phosphorus concentrations respectively. Neither average concentration exceeded the target concentration.

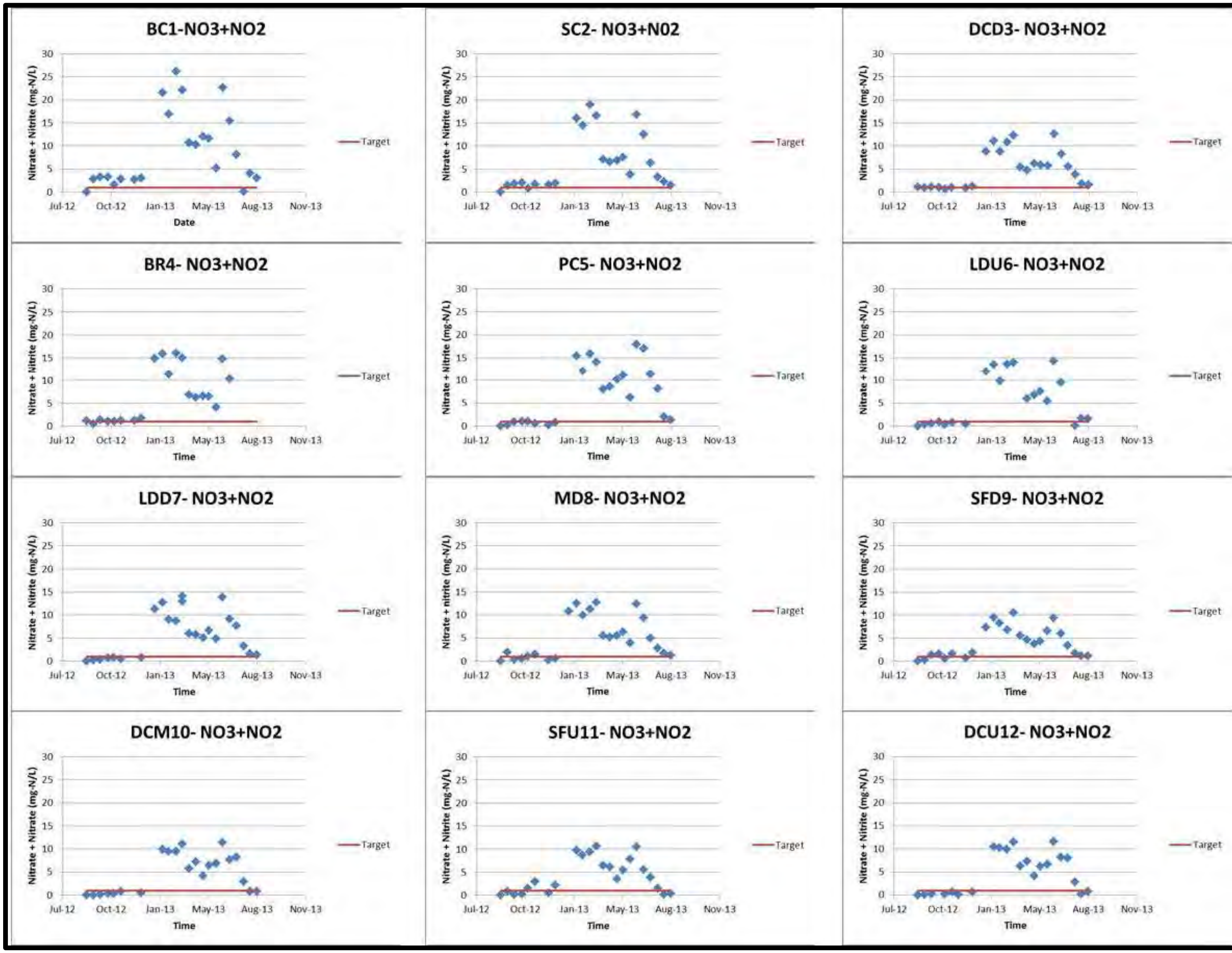

Figure 51. Nitrate-nitrogen concentrations measured in Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

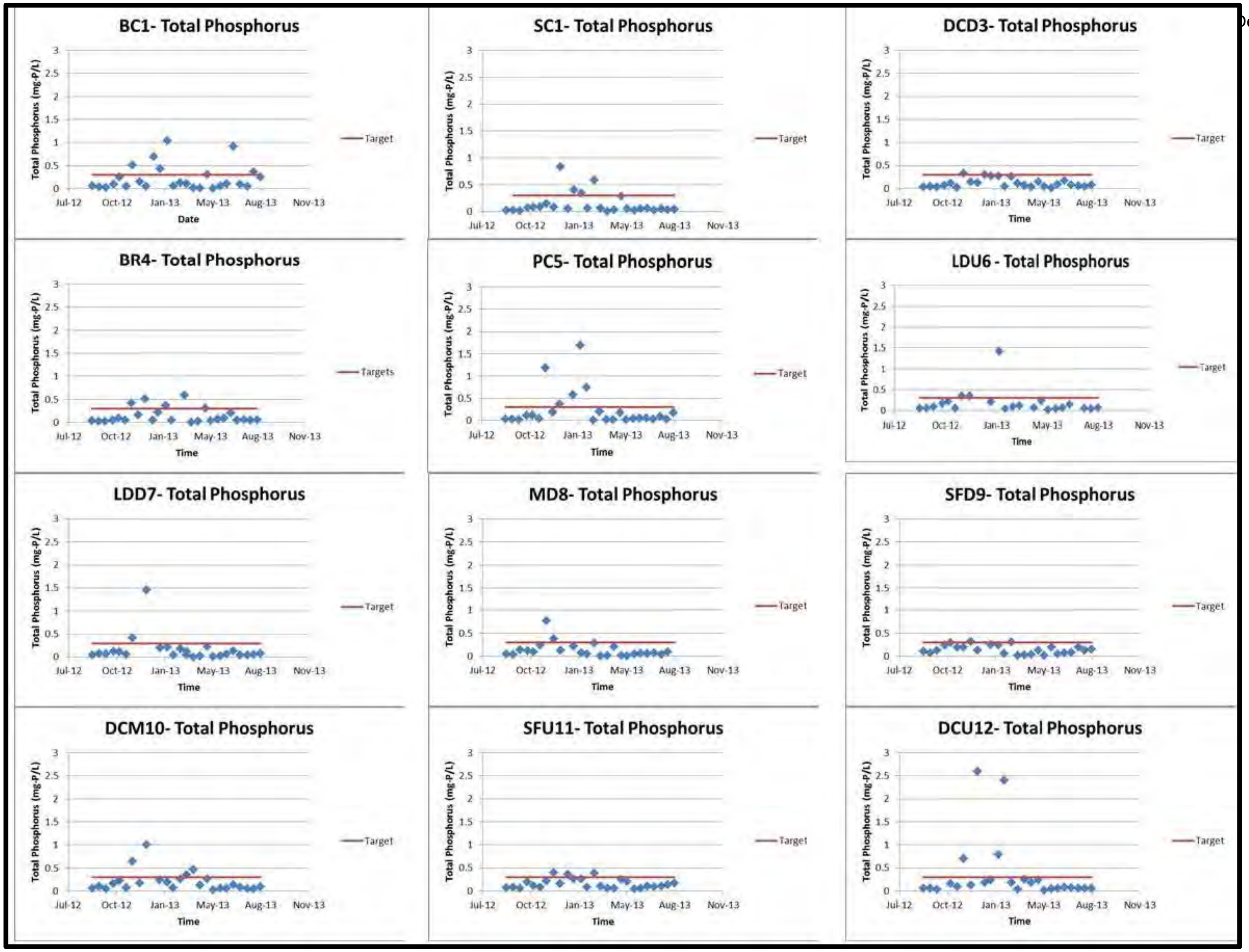

Figure 52. Total phosphorus concentrations measured in Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

Total Suspended Solids

Total suspended solids (TSS) levels generally measured above target levels during high flow events (Figure 53). Little Deer Creek at CR 300 N (LDD7) and Deer Creek at Riley Park (DCD3) contained the highest average TSS concentrations. These sites also contained the highest percentage of exceedances with each exceeding targets in more than nine collected samples. TSS concentrations exceeded 300 mg/L in Deer Creek (DCD3, DCM10, DCU12), Little Deer Creek (LDU7), Bachelor Run (BR4) and Sugar Creek (SC2).

E. coli

E. coli concentrations observed at Deer Creek-Sugar Creek sites are shown in Figure 54. *E. coli* concentrations exceed state standards during a majority of samples. In Buck Creek, *E. coli* concentrations are elevated during various flow conditions. Deer Creek (DCU12) and Buck Creek (BC1) contained the highest average *E. coli* concentrations, respectively. All Deer Creek-Sugar Creek watershed sites possessed average *E. coli* concentrations in excess of state standards (235 col/100 mL). Deer Creek at Riley Park (DCD3) and Bachelor Run (BR4) contained the lowest average *E. coli* concentrations with concentrations greater than 300 col/100 mL. *E. coli* exceedances appear to coincide with flow conditions with many sites containing elevated *E. coli* concentrations under elevated flow conditions.

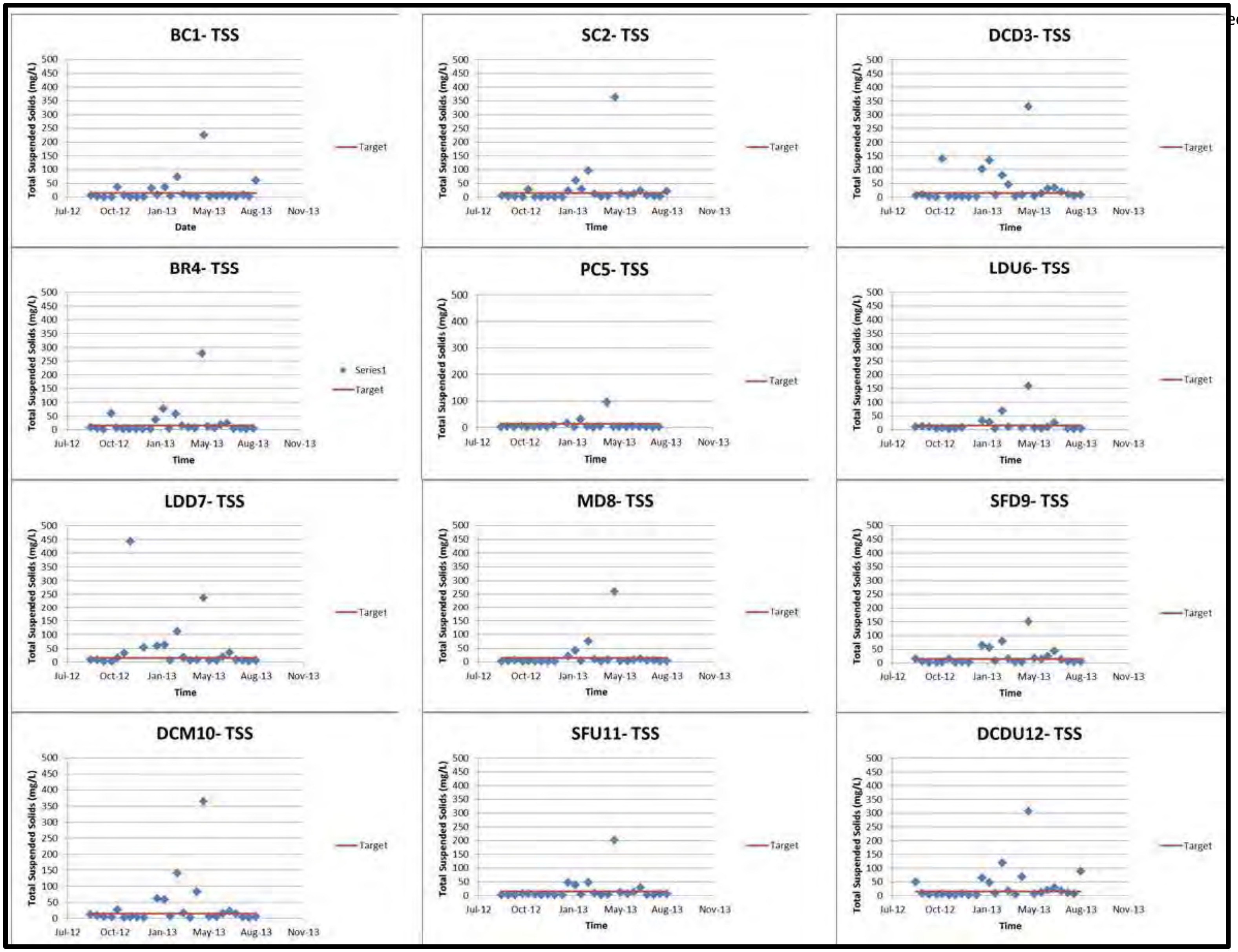

Figure 53. Total suspended solids concentrations measured in Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

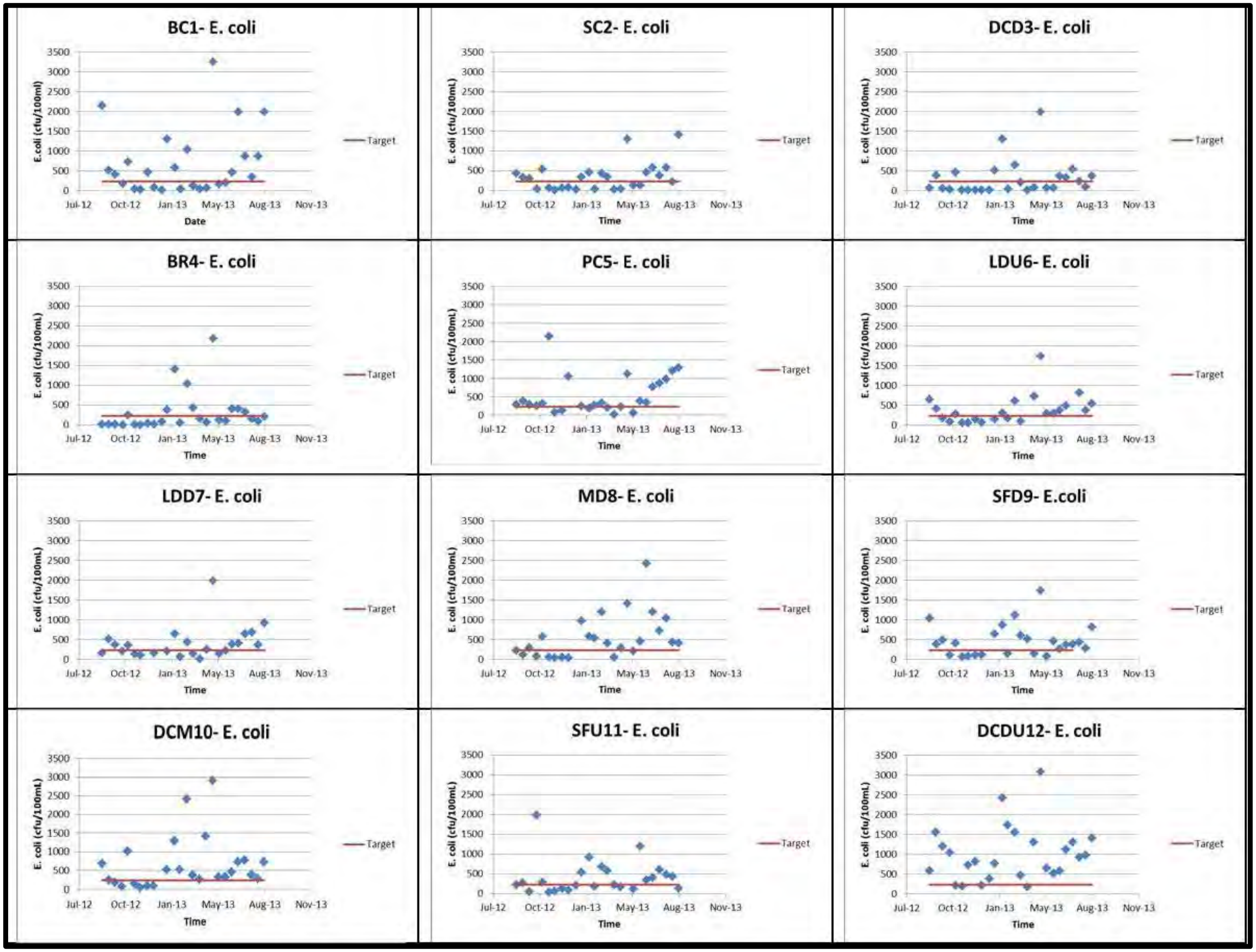

Figure 54. *E. coli* concentrations measured in Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

3.3.4 Flow Duration Curves

Flow duration curves allow characterization of flow conditions within a particular stream. Instead of plotting individual flows as a time series, they are plotted as a percent of time that a given flow occurs within the stream. The resultant curve indicates the percent of time that a given flow is equaled or exceeded within the system. For instance, the median flow (Q50) is the flow observed in the stream 50% of the time. Flows below Q50 indicate base flow conditions within the stream. If this portion of the curve contains a steep slope, a relatively small contribution from natural storage sources like groundwater is suggested. Other indices can be used to characterize low flow conditions within the stream. The ratio of discharge observed 90% of the time compared to that observed 50% of the time (Q90/ Q50) is commonly used to determine the portion of flow which is contributed from groundwater storage. Of additional importance is calculation of the percentage of time that zero-flow conditions occur.

The flow duration curves present the flow characteristics for the twelve systems during the time of study from August 28, 2012 to August 27, 2013 (Figure 55). Data used for the curves were calculated by scaling flow measured at two gauges; one on Deer Creek and the other on Little Pine Creek. Headwater stream flows were scaled using watershed size to the sample point in comparison with Little Pine Creek's watershed size. For downstream locations, Deer Creek stream flow measured at the U.S. Geological Survey gage was scaled to watershed size.

Drainage ratio = (sample site drainage area) / (gauge site drainage area)
*Estimated flow = (drainage ratio) * (flow at gauge)*

Buck Creek (BC1), Paint Creek (PC4), McCloskey Ditch (MD8) and the headwaters of South Fork Deer Creek (SFU11) contain the lowest maximum flows (<200 cfs). Deer Creek at Riley Park (DCD3) contains the highest maximum flow measuring greater than 10,000 cfs. Flow intensities increase from the headwaters to the mouth of Deer Creek as is typical for streams (Figure 55).

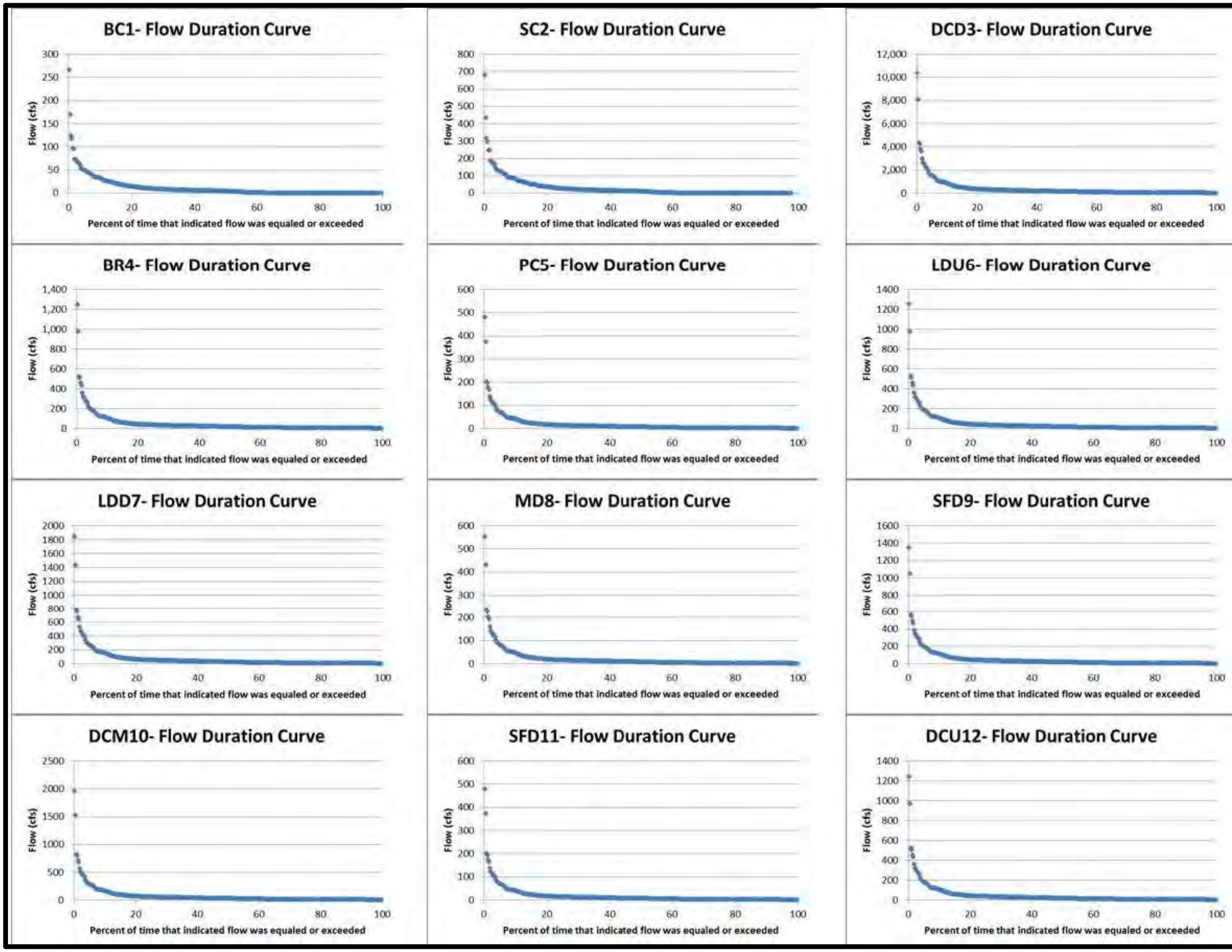

Figure 55. Flow duration curves for Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

3.3.5 Load Duration Curves

Load duration curves allows for comparison of instream loading with stream flow so that conditions of concern can be identified. The load duration curves present the flow characteristics for the twelve systems during the time of study from August 28, 2012 to August 27, 2013. Data used for the curves were calculated by scaling flow measured at two gauges; one on Little Pine Creek (for monitoring sites BC1 and SC2), and one on Deer Creek (for the other monitoring sites). The difference in measured flow from these two gages becomes apparent because the load duration curves are plotted on a logarithmic scale to enhance the visibility of the data, and the low flow data due to drought conditions are particularly apparent in the Pine Creek gage data (sites BC1 and SC2). Headwater stream flows were scaled using watershed size to the sample point in comparison with Little Pine Creek's watershed size. For downstream locations, Deer Creek stream flow measured at the U.S. Geological Survey gauge was scaled to watershed size.

observed flow (cfs)) x (conversion factor) x (target concentration or state criteria) = total load /day

The individual load duration curves, also known as the allowable load curves, are displayed below (Figure 56 to Figure 59). In the graphs, the total daily load of each contaminant sample result (points) is plotted against the "percent time exceeded" for the day of sampling (curve). Those points above the curve exceed the state criterion or target concentration. Values on a load duration curve can be grouped by hydrologic condition to help identify possible sources and conditions that result in the material being present in the system under those flow conditions. Most often, the flow ranges fall in High (0 to 10), Moist (10-40), Mid-Range (40-60), Wet (60-90), and Low (90-100). Exceedances falling in the moist range (10-40) are typically associated surface runoff or stormwater loads, while exceedances associated with the dry zone are most often associated with dry conditions. These exceedances are suggested to result from point sources that are the most likely source.

Nitrate + Nitrite-nitrogen Load Duration Curves

Nitrate + Nitrite loads tend to measure higher than target concentrations at most sites during all conditions (Figure 56). Buck Creek (BC1), Sugar Creek (SC2), Bachelor Run (BR4) and South Fork Deer Creek (SFD9, SFU11) nitrate-nitrogen concentrations measured above target levels more than 70% of the time. This suggests that a steady stream of nitrate-nitrogen is available within these subwatersheds. Deer Creek (DCD3, DCM10 and DCU12), McCloskey Ditch, Little Deer Creek (LDD6 and LDU7) and McCloskey Ditch (MD8) typically contain elevated nitrate-nitrogen during high flow conditions only. This suggests that under normal flow conditions, nitrogen is washed into the stream and that it may enter when sediment enters. During high flow conditions, nitrate-nitrogen concentrations in Buck Creek (BC1) measure below the target suggesting that higher volumes of nitrate-nitrogen being present in the watershed at all times like those from livestock or fertilizers.

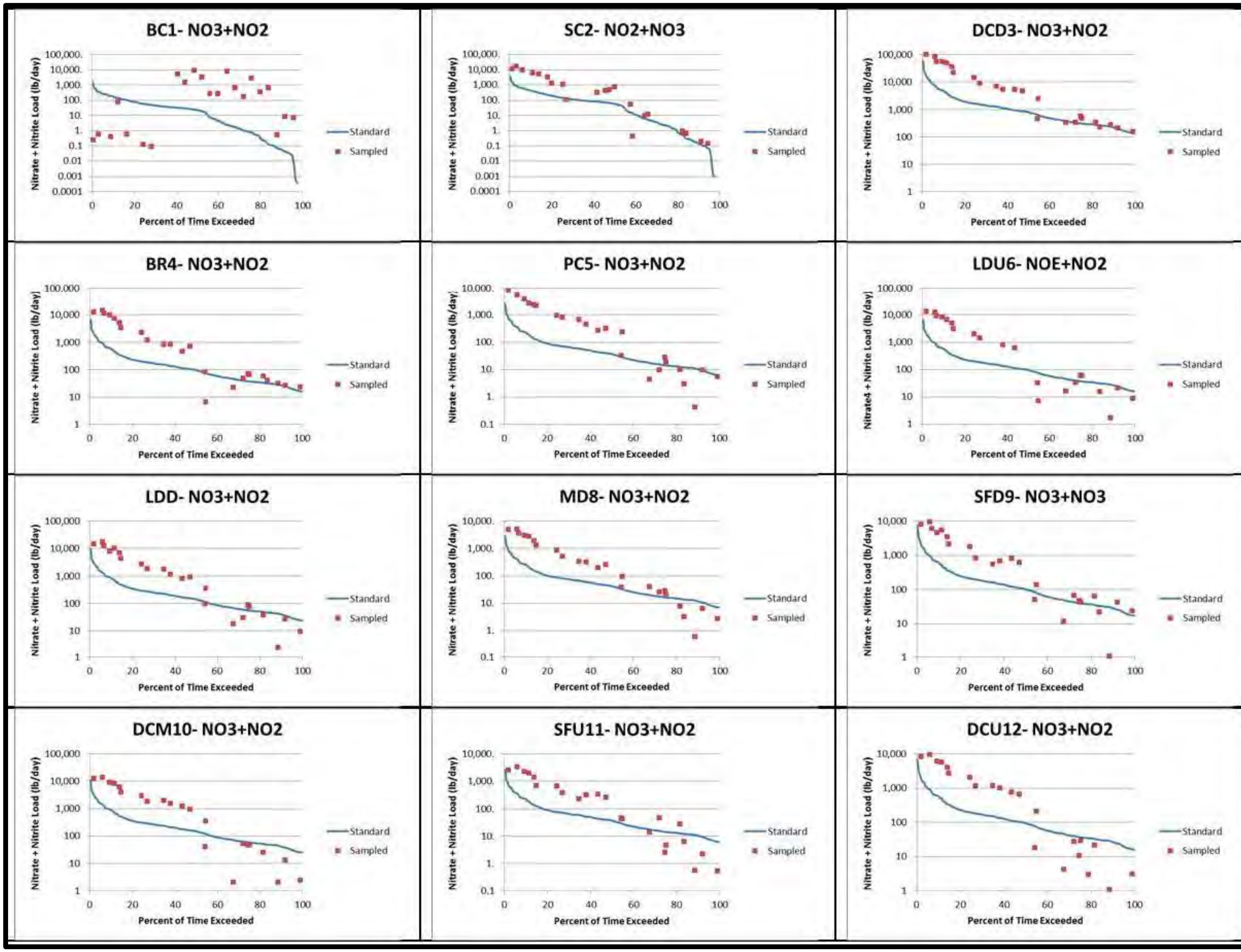

Figure 56. Nitrate-nitrogen load duration curves for Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

Total Phosphorus Load Duration Curves

Total phosphorus (TP) levels generally measured below target levels under all flow conditions (Figure 57). This is somewhat surprising considering that most total phosphorus enters streams attached to suspended solids. Exceedances of the target concentrations occurred only a few times in Sugar Creek (SC2), Deer Creek (DCD3, DCM10 and DCU12), Little Deer Creek (LDU6 and LDD7), Bachelor Run (BR4) and McCloskey Ditch (MD8). Most exceedances occurred in Sugar Creek (SC1), Bachelor Run (BR4) and Paint Creek (PC5) during storm flow events suggesting erosion or runoff is the cause of these values. Buck Creek (BC1) exceeded target levels under low flow conditions more than under high flow conditions. This suggests that a steady stream of total phosphorus is present in Buck Creek under all conditions.

Total Suspended Solids Load Duration Curves

Total suspended solids (TSS) levels generally measured above target levels during high flow events, which typically occurred under the wet conditions (Figure 58). Most exceedances occurred in Sugar Creek (SC2), Deer Creek (DCD3, DCM10 and DCU12), Little Deer Creek (LDD6 and LDU7), Bachelor Run (BR4), Paint Creek (PC5), McCloskey Ditch (MD8) and South Fork Deer Creek (SFU9 and SFD11) during storm flow events suggesting erosion or runoff is the cause of these values. Buck Creek exhibited a converse pattern for high flow event and several exceedances occurred during lower flow conditions as well. Possible sources of total suspended solids include the livestock access or stream bank erosion, both of which can provide a continuous source of total suspended solids to Buck Creek.

***E. coli* Load Duration Curves**

E. coli load duration curves display completely different conditions than those presented by nitrate-nitrogen, total phosphorus and total suspended solids curves (Figure 59). E. coli curves indicate that *E. coli* concentrations exceed targets in Buck Creek (BC1), Paint Creek (PC4), Little Deer Creek (LDU6 and LDD7), McCloskey Ditch (MD8), Headwaters of Deer Creek (DCM10 and DCU12), and South Fork Deer Creek (SFD9 and SFU11) during all flow conditions. These data suggest a nearly continuous source of *E. coli* within these streams. When flows are at their lowest, most of these sites contain *E. coli* concentrations below target levels suggesting that during wet or low exceedance conditions (60-100), there are limited sources of *E. coli* within these streams. Deer Creek at Riley Park (DCD3) and Bachelor Run (BR4) load duration curves indicate that *E. coli* concentrations exceed targets only during high flow conditions.

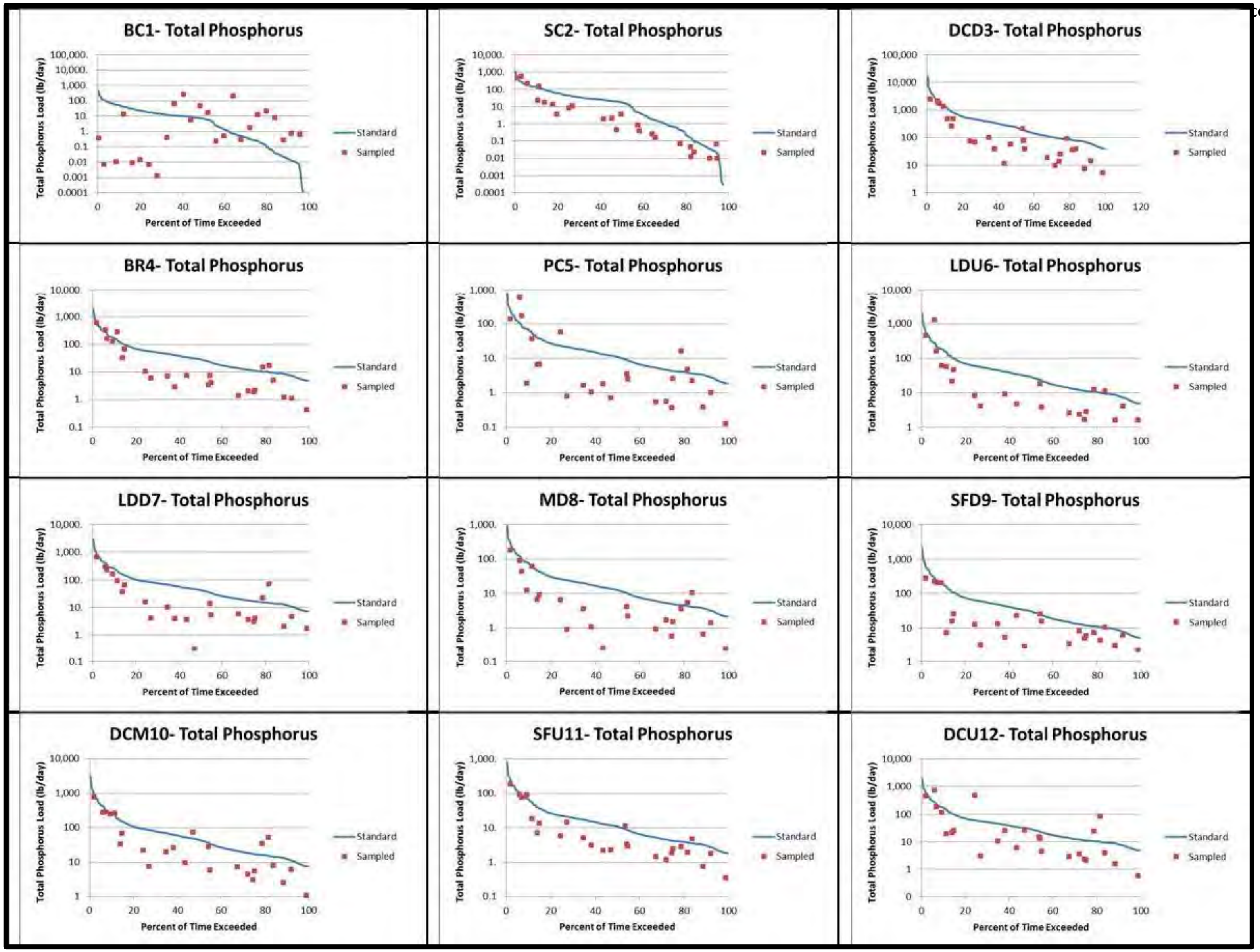

Figure 57. Total phosphorus load duration curves for Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

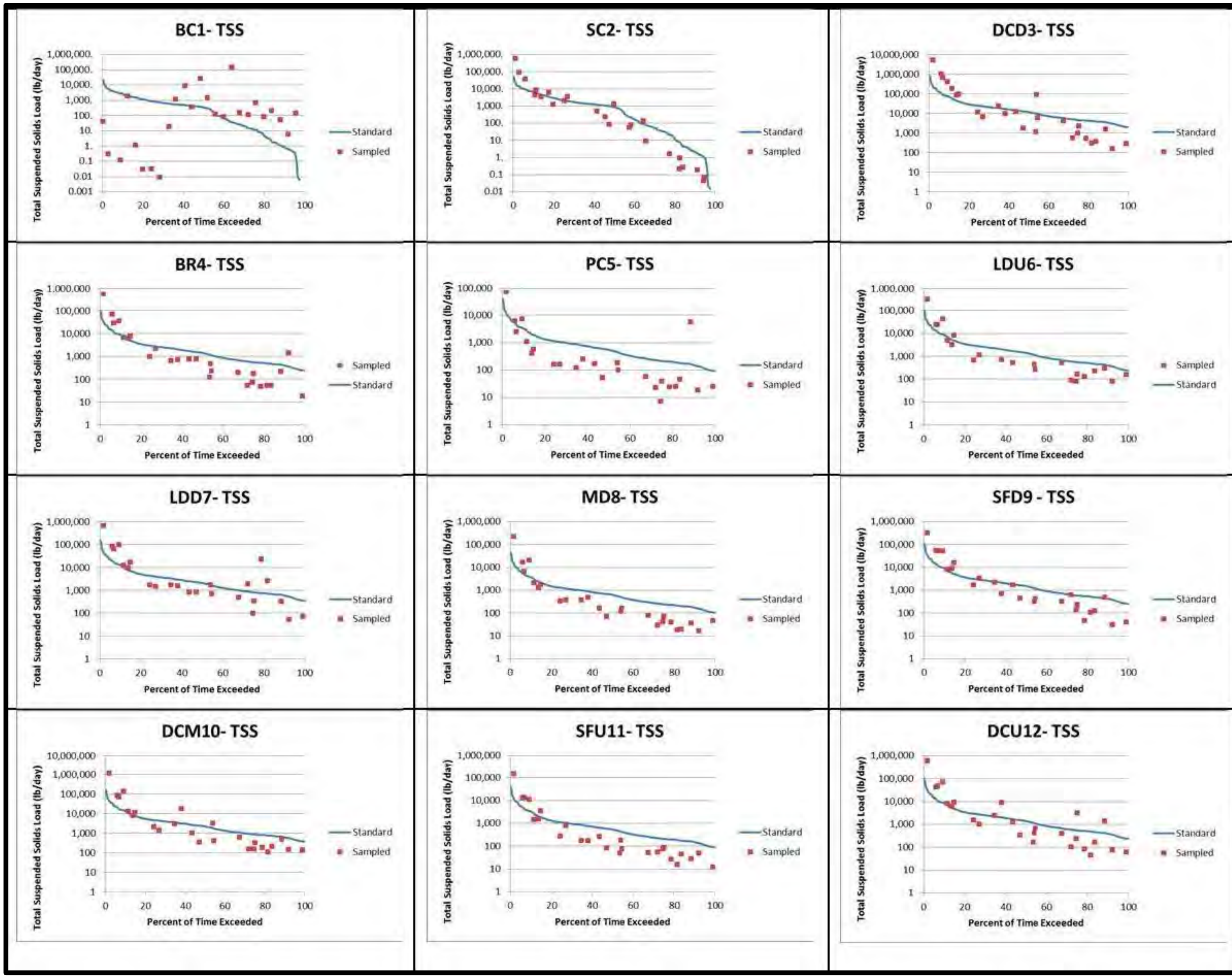

Figure 58. Total suspended solids load curves for Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

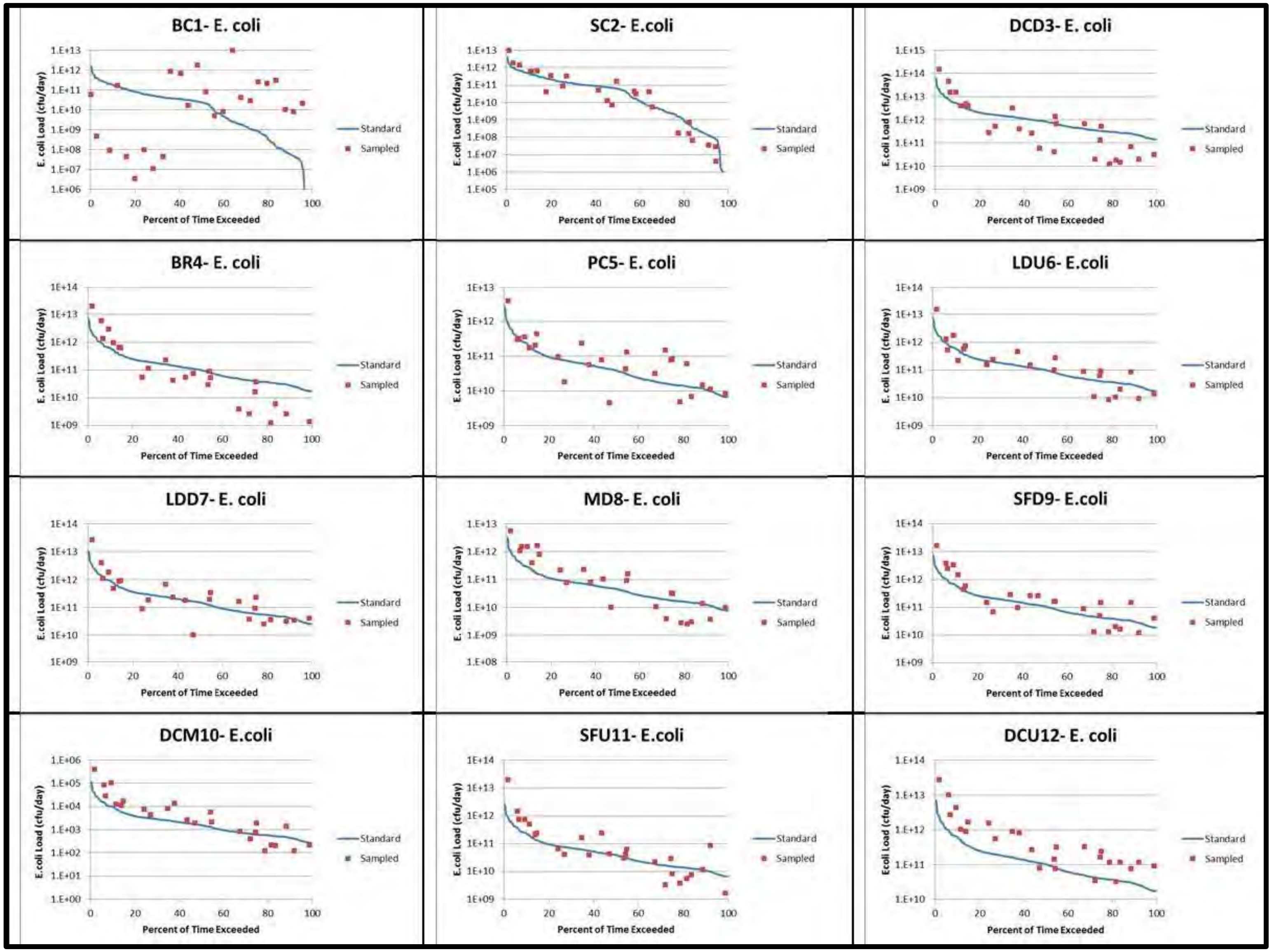

Figure 59. *E. coli* concentrations load duration curves for Deer Creek-Sugar Creek sample sites, August 2012 to August 2013.

3.3.6 Habitat Results

Stream water quality and available habitat influence the quality of a biological community in a stream, and it is necessary to assess both factors when reviewing biological data. Table 18 presents the results of QHEI assessments at each of the 12 stream sites sampled in the Deer Creek-Sugar Creek watershed during the summer of 2012. Figure 60 details metric and total scores for all sites. Among all the sites, riparian scores were relatively low and many sites had low pool/riffle development scores, contributing to overall lower QHEI scores. The lowest scores occurred at the South Fork Deer Creek upstream (SFU11) and Deer Creek upstream (DCU12) sites. These sites were representative of ditched streams present throughout Indiana. With high banks, narrow riparian zones, and limited pool and riffle development, it is not surprising that these sites scored poorly relative to other stream sites. The highest scores occurred at Little Deer Creek downstream (LDD7) and McCloskey Ditch (MD8) where comparatively high amounts of instream cover and larger substrates contributed strongly to the higher scores at these sites.

Table 18. Qualitative Habitat Evaluation Index (QHEI) scores measured in the Deer Creek-Sugar Creek watershed.

Study Site	Substrate	Cover	Channel	Riparian	Pool/Riffle	Gradient	Total
Buck Creek (BC1)	16.5	15	9	3.5	13.25	8	65.25
Sugar Creek (SC2)	15	13.5	10.75	6.5	8.5	10	64.25
Deer Creek Downstream (DCD3)	16	12.5	12.5	4.25	11.5	10	66.75
Bachelor Run (BC4)	17	10	6.5	5.25	12	8	58.75
Paint Creek (PC5)	17	13	8.5	3	4	10	55.5
Little Deer Creek Upstream (LDU6)	6	15	11	11	10	10	64
Little Deer Creek Downstream (LDD7)	18	16.5	14.25	6.5	10.5	8	73.75
McCloskey Ditch (MD8)	17	18.5	12	7.75	5	10	70.25
South Fork Deer Creek (SFD9)	10.5	15.5	12.5	7.75	9	10	65.25
Deer Creek Middle (DCM10)	14	15	9.5	4.75	7	6	56.25
South Fork Deer Creek (SFU11)	14	9.5	6	5.25	4	6	44.75
Deer Creek Upstream (DCU12)	6	11.5	7.5	4.25	12.5	6	47.75

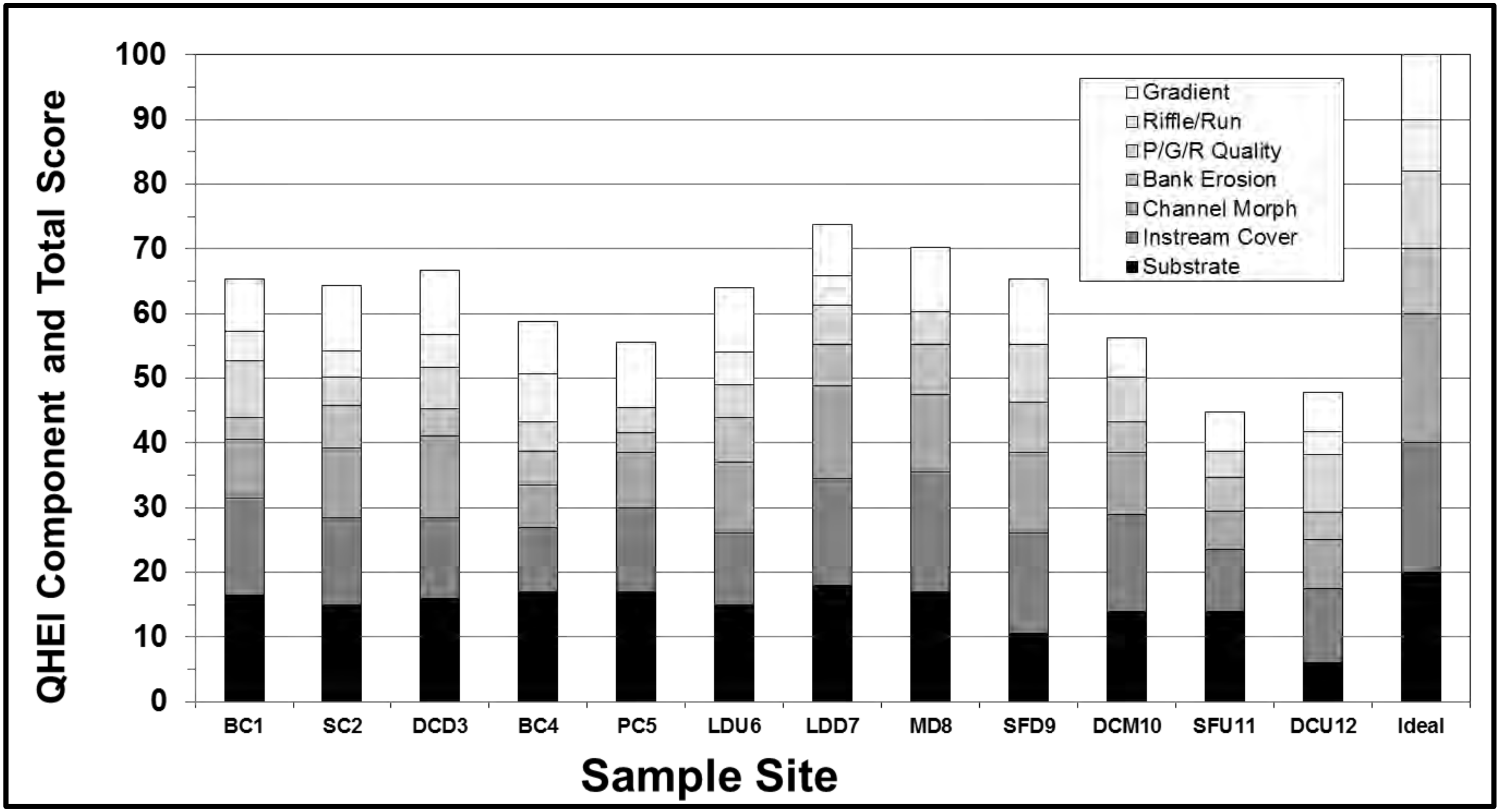

Figure 60. Qualitative Habitat Evaluation Index (QHEI) total and component scores measured for stream sites in the Deer Creek-Sugar Creek watershed.

3.3.7 Fish Community Results

A total of 50 fish species was collected over the sampling period from the Deer Creek-Sugar Creek watershed sample sites. Fish community data collected during sampling indicate that fish communities present in the Deer and Sugar Creek watersheds generally rate as poor to fair (scores of 30-40; Figure 61, Table 19). Only two sites along Deer Creek rated good condition, Deer Creek downstream (DCD3) and Deer Creek middle (DCM10). The lowest fish IBI scores (34 or less) occurred in Buck Creek (BC1), Paint Creek (PC5), Little Deer Creek upstream (LDU6), McCloskey Ditch (MD8), and South Fork Deer Creek downstream (SFD9). These sites represent streams impacted by changing water conditions and poor instream habitat. The highest fish IBI scores at Deer Creek downstream (DCD3) and Deer Creek middle (DCM10) reflect the presence of copious instream cover at the sites.

Table 19. Fish Index of Biotic Integrity (IBI) raw data used to score metrics and IBI scores for Deer Creek-Sugar Creek streams.

Fish IBI Metric	BC1	SC2	DCD3	BC4	PC5	LDU6	LDD7	MD8	SFD9	DCM10	SFU11	DCU12
Species Richness	18	26	28	20	18	20	31	28	13	31	24	27
#DMS species*	4	N/A	N/A	N/A	5	N/A	N/A	5	N/A	N/A	6	N/A
#Darter species	2	1	3	3	3	5	6	4	1	4	5	6
%Headwater species	27	2	0	17	17	5	0	0	0	0	0	2
#Sunfish species	4	4	7	3	3	3	7	5	6	6	5	5
#Minnow species	N/A	N/A	N/A	N/A	N/A	N/A	N/A	12	1	11	9	10
#Sucker species	1	2	2	1	2	1	3	4	3	4	1	2
#Sensitive species	3	8	12	11	2	7	11	9	3	12	7	9
%Tolerant species	45	19	6	17	31	25	23	42	18	21	27	38
%Omnivorous species	17	11	17	17	7	2	31	31	1	23	21	39
%Insectivorous species	41	75	72	50	48	55	46	39	84	54	49	39
%Pioneer species	N/A	N/A	N/A	N/A	N/A	N/A	N/A	55	19	15	57	21
%Carnivorous species	1	0	7	2	0	3	3	3	3	16	0	4
CPUE (#individuals/hour)	146	613	249	108	129	76	138	204	49	109	344	103
% Simple Lithophilic species	17	4	40	19	15	7	25	28	5	37	11	47
Total Fish IBI Score	**34**	**40**	**48**	**36**	**34**	**34**	**40**	**34**	**30**	**50**	**36**	**38**

*Darter, Madtom and Sculpin species

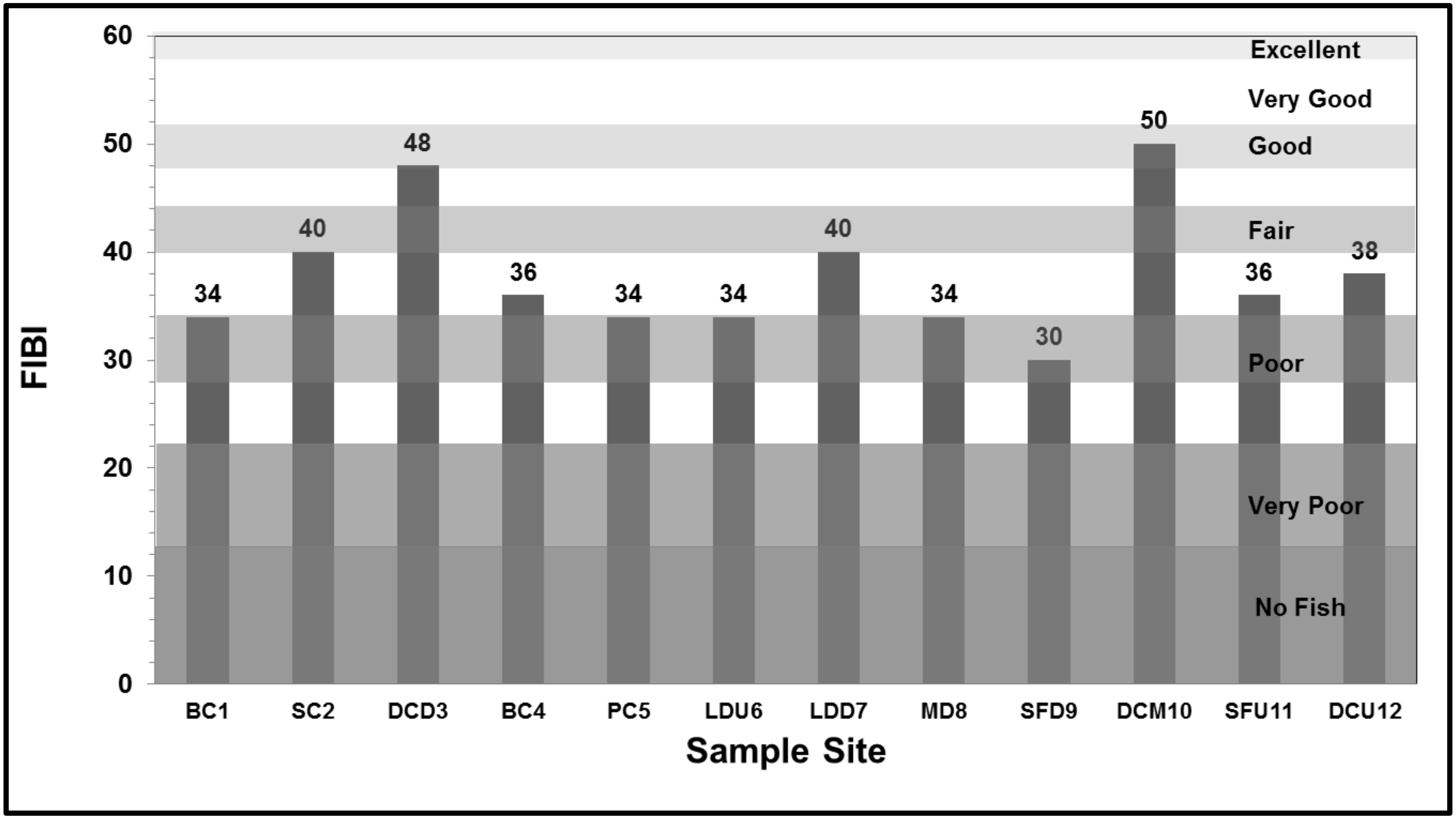

Figure 61. Fish Index of Biotic Integrity (IBI) scores calculated based on stream samples collected in the Deer Creek-Sugar Creek watershed streams during summer 2012. Condition classifications are indicated by shaded areas and associated descriptions provided on the right side of the graph.

3.3.8 Macroinvertebrate Results

Macroinvertebrate community data collected from sample sites in the Deer Creek-Sugar Creek watershed streams indicated a wide range of benthic macroinvertebrate Index of Biotic Integrity (mIBI) scores (Table 20 and Figure 62). The lowest mIBI scores occurred at McCloskey Ditch (MD8) and Deer Creek (DCM10) where the benthic macroinvertebrate communities rated as being severely impaired. The remainder of the sites contained mIBI scores that were higher than the threshold value (36) that separates impaired and unimpaired sites. However, four sites were just above this threshold, including Buck Creek (BC1), South Fork Deer Creek downstream (SFD9), South Fork Deer Creek upstream (SFU11), and Deer Creek upstream (DCU12). The highest mIBI scores occurred at Sugar Creek (SC2), Little Deer Creek upstream (LDU6), and Little Deer Creek downstream (LDD7).

Table 20. Benthic macroinvertebrate Index of Biotic Integrity (mIBI) raw data and mIBI scores for Deer Creek-Sugar Creek watershed streams.

mIBI Metric	**BC1**	**SC2**	**DCD3**	**BC4**	**PC5**	**LDU6**	**LDD7**	**MD8**	**SFD9**	**DCM10**	**SFU11**	**DCU12**
Total #Taxa	33	59	25	24	17	82	28	10	25	11	12	27
Total #Indiv	292	408	370	266	239	2019	233	314	222	147	251	307
Total EPT	12	35	11	13	3	50	15	2	4	3	3	10
Total #Diptera Taxa	14	12	3	2	5	15	4	1	10	4	1	8
%Chironomidae	0.64	0.18	0.25	0.15	0.21	0.15	0.22	0.49	0.46	0.52	0.18	0.57
%Non-insect Indiv. Excl. Crayfish	0.02	0.05	0.11	0.11	0.12	0.02	0.08	0.38	0.05	0.34	0.18	0.18
%Intolerant Individuals	0.15	0.58	0.61	0.62	0.15	0.52	0.56	0.08	0.09	0.10	0.40	0.12
%Tolerant Individuals	0.03	0.05	0.10	0.10	0.08	0.01	0.07	0.41	0.14	0.31	0.23	0.17
%Predators	0.10	0.09	0.01	0.01	0.41	0.06	0.01	0.03	0.16	0.03	0.12	0.02
%Shredders and/or Scrapers	0.04	0.49	0.10	0.20	0.07	0.44	0.32	0.01	0.03	0.03	0.02	0.06
%Collectors-Filterers	0.23	0.12	0.01	0.06	0.02	0.14	0.06	0.00	0.01	0.04	0.00	0.03
%Sprawlers	0.24	0.50	0.59	0.52	0.15	0.34	0.47	0.09	0.09	0.10	0.37	0.10
Total Benthic IBI Score	**38**	**52**	**44**	**48**	**40**	**54**	**50**	**24**	**38**	**24**	**38**	**38**

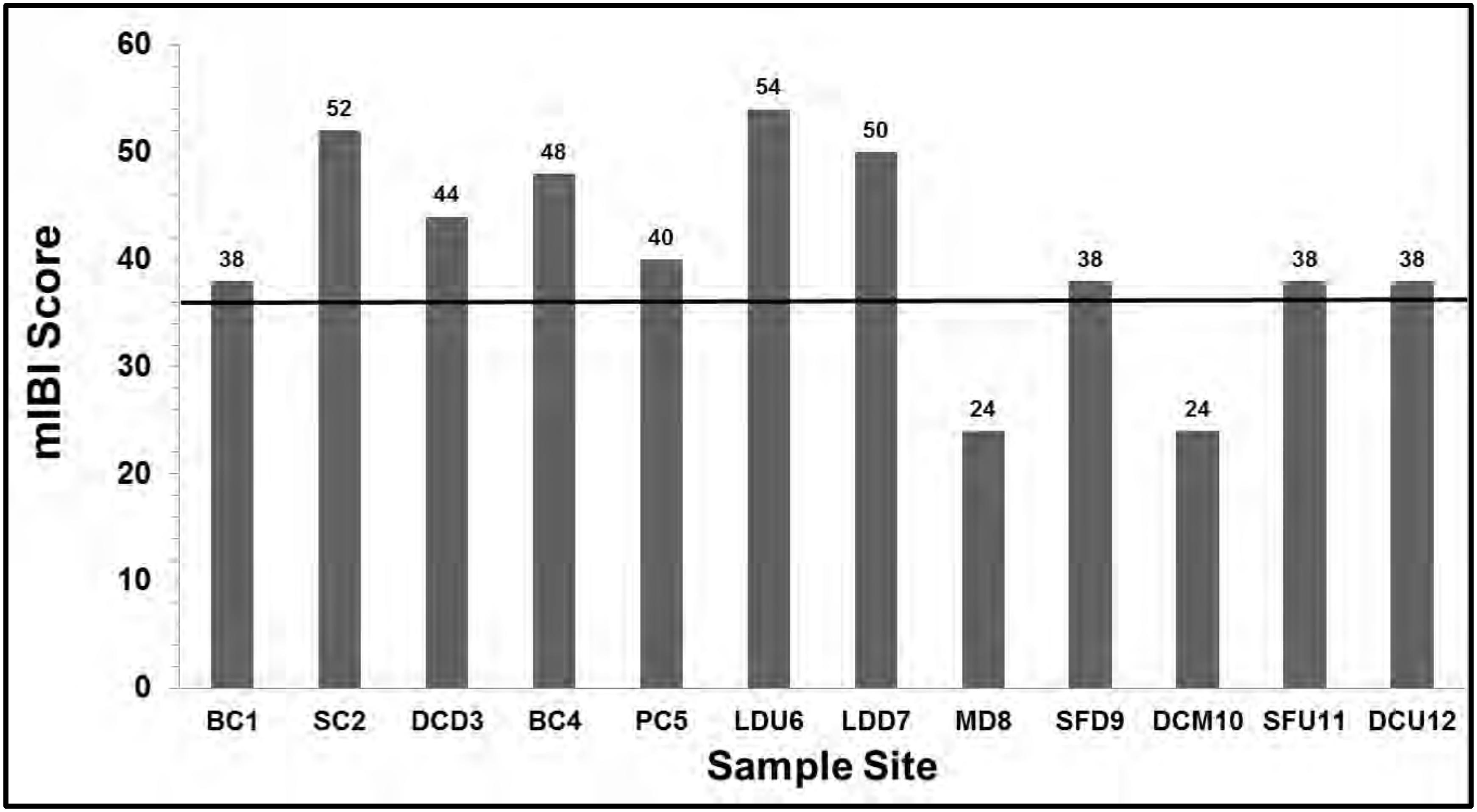

Figure 62. Total benthic macroinvertebrate (mIBI) scores for stream sites sampled in the Deer Creek-Sugar Creek watershed in summer 2012. Scores below the solid line were considered impaired.

3.3.9 Summary and Conclusions

The fish, macroinvertebrate, and QHEI data all indicated some degree of stream degradation for the stream sites assessed in the Deer and Sugar Creek watersheds, although there was a great amount of variation among sites. There were few cases where all assessment techniques yielded completely consistent results with regard to characterizations of site quality. This is not uncommon because each assessed group (i.e., fish, benthic macroinvertebrates, and habitat) does respond differently to environmental stressors.

QHEI and mIBI scores for South Fork Deer Creek Headwaters (SFU12) and Deer Creek Headwaters (DCU11) indicate that stream conditions were impaired. This is likely due to the low gradient of the channel and high amounts of sedimentation associated with these waterways. There was little to no discernible riffle habitat in the streams, and large sections of the stream bottom were covered in loose sand, which likely contributed to the low mIBI and QHEI scores. Buck Creek (BC1) biotic integrity and QHEI scores were lower than most of the other streams despite the fact the sample sites contained high quality habitat. Poor water quality in Buck Creek and substrates covered by silt during sampling events likely impair biological communities. The QHEI score for McCloskey Ditch (MD8) was among the highest observed in our assessments. However, the biological components of McCloskey Ditch did not score as high in those assessments. This suggested that physical habitat was not a limiting factor for reduced stream health in this stream. The sites with lower mean IBI scores (SFU12 and DCU11) also typically had lower mean QHEI scores.

The biological data for the ten sites that were consistently sampled suggested that many of these streams are impacted by either poor instream conditions (reduced QHEI); elevated nitrate-nitrogen, total suspended solids, and *E. coli* concentrations; or some other unknown impairment leading to compromised biological integrity. McCloskey Ditch and Buck Creek would be expected to exhibit high environmental quality based solely on the QHEI scores, although the biota at these sites suggested that there were likely other issues not related to physical habitat that influenced the biological communities and overall environmental quality. Conversely, Sugar Creek (SC2) and Deer Creek (DCD3) would be considered to be of relatively high environmental quality based on its mIBI and IBI scores, but their moderate QHEI scores suggested that the physical habitat of these sites may be degraded and of moderate environmental quality. It is obvious that incorporating biology, chemistry and habitat in site assessments is critical for making truly informed environmental evaluations of sites, and it is likely that a range of restoration actions will be necessary to address the impairments reported herein.

3.4 <u>Watershed Inventory Assessment</u>

3.4.1 Watershed Inventory Methodologies

Volunteers and Wabash River Enhancement Corporation staff completed windshield surveys throughout the Deer Creek-Sugar Creek watershed in spring 2013. Individuals conducted surveys by driving all accessible roads throughout the watershed. Large maps with aerial photographs, road and stream names, and public property labels were provided to each volunteer group. Volunteers recorded observations on the provided maps and data sheets, documented field conditions with photographs, and provided all notes to the Urban and/or Rural Committees for review. The windshield surveys were also used to confirm GIS map layer data throughout the watershed. Items targeted during the surveys included, but were not limited to the following:

- Aerial land use category
- Field or gully erosion
- Pasture locations and condition
- Livestock access and impact to streams
- Buffer condition and width
- Bank erosion or head-cutting
- Environmental site confirmation (NPDES, CFO, open dump, Superfund, etc.)

3.4.2 Watershed Inventory Results

The Deer Creek- Sugar Creek watershed was inventoried by watershed inventory volunteers and staff in the spring of 2013. A majority of the issues identified fall into two categories: stream buffers limited in width or lacking altogether and streambank erosion. Figure 63 details locations throughout the Deer Creek-Sugar Creek watershed where problems were identified. Additional assessments will be on-going; therefore, those areas identified in Figure 63 should not be considered exhaustive. Nearly 104 miles of tributary streambanks possessed limited buffers, nearly 70 miles of stream bank were eroded, and livestock had access to over 26 miles of streambanks. Additionally, nearly 40 of 42 miles of the Wabash River require stabilization and nearly 6.25 acres of land require buffering within 30 feet of the Wabash River.

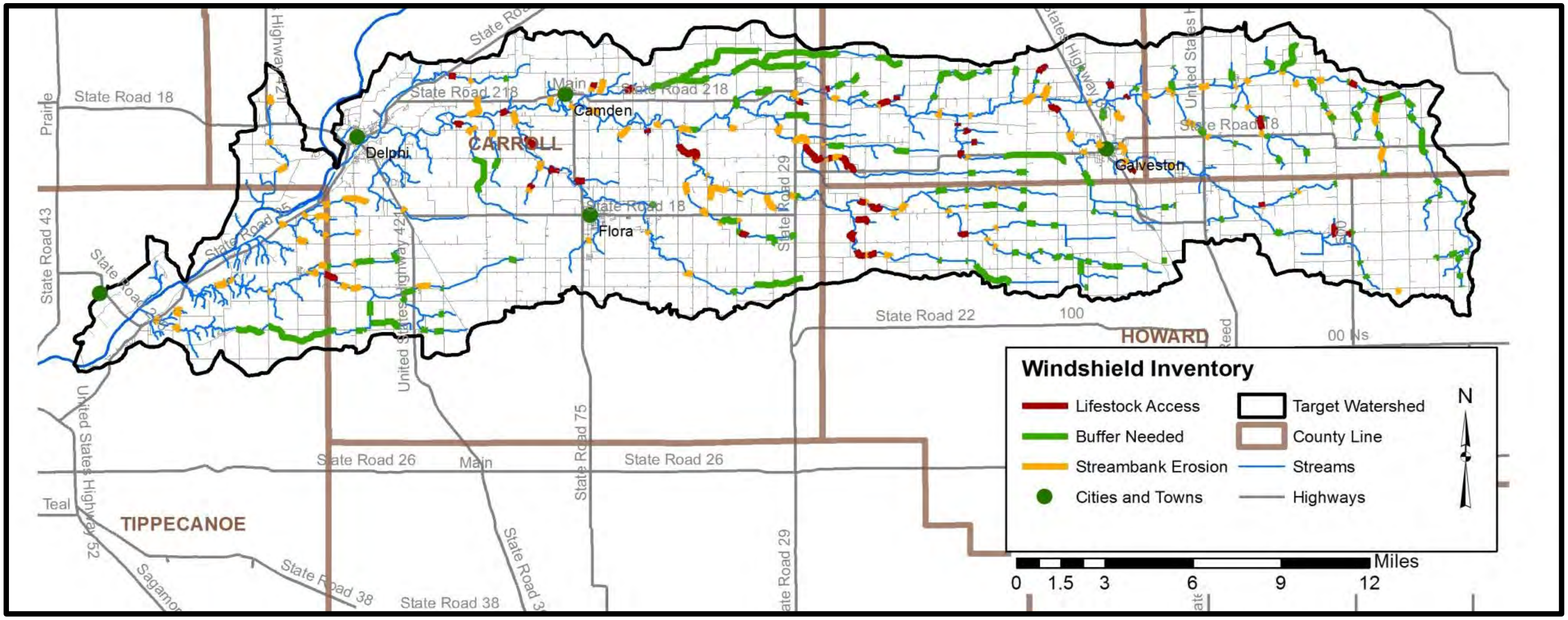

Figure 63. Stream-related watershed concerns identified during watershed inventory efforts, spring 2013.
Data used to create this map are detailed in Appendix A.

4.0 WATERSHED INVENTORY II-B SUBWATERSHED DISCUSSIONS

To gather more specific, localized data, the Deer Creek-Sugar Creek watershed was divided into ten subwatersheds (Figure 64). These subwatersheds reflect specific tributary drainages, similar land uses, and hydrology. Land uses, soil types, point and non-point watershed concern areas, and historic and current water quality sampling locations are detailed below for each watershed.

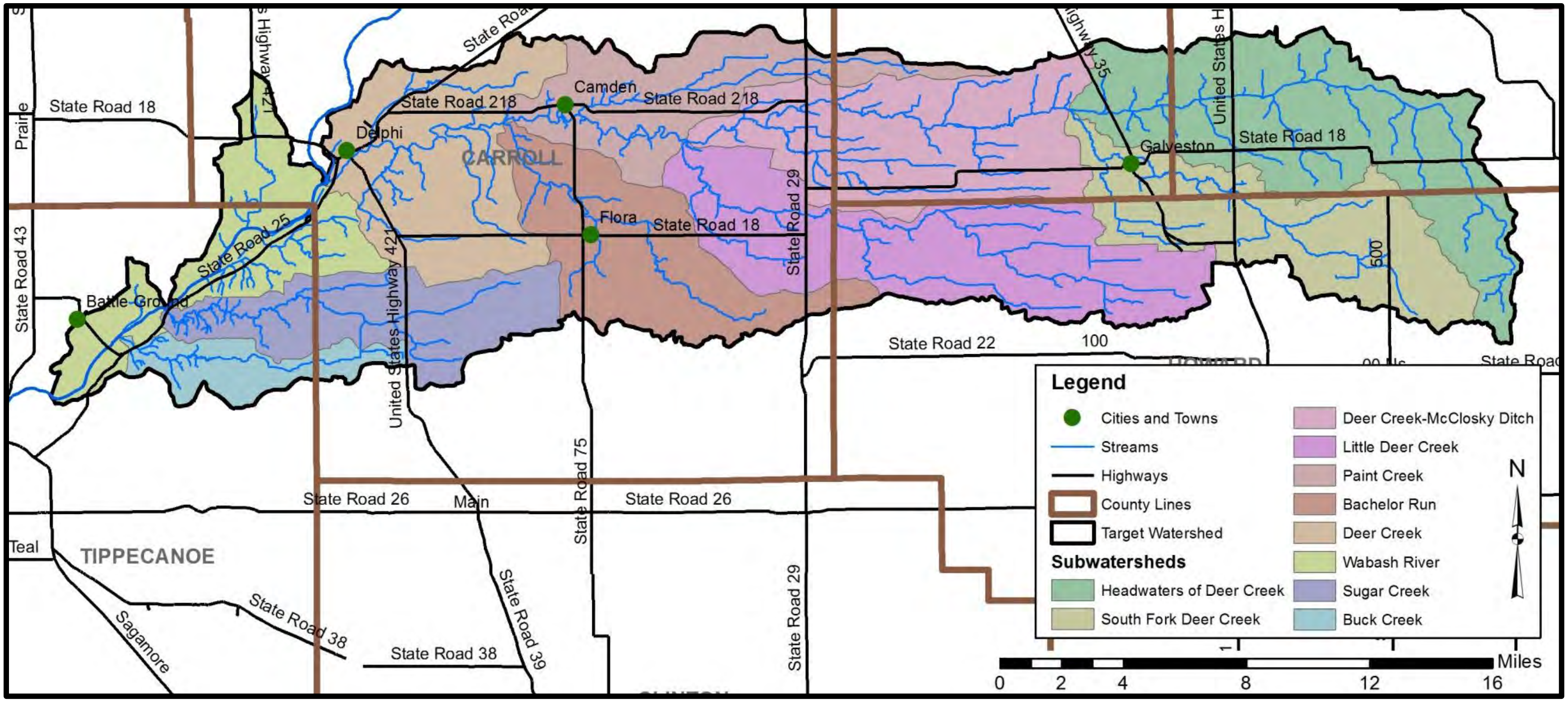

Figure 64. Ten subwatersheds in the Deer Creek-Sugar Creek watershed.

Data used to create this map are detailed in Appendix A.

4.1 Headwaters of Deer Creek

The Headwaters of Deer Creek subwatershed is located in the eastern part of the Deer Creek-Sugar Creek watershed forming the northeastern boundary. The Headwaters of Deer Creek subwatershed spans three counties including, Cass, Howard, and Miami, with the majority the subwatershed located in Miami County. The watershed includes three 12-digit watersheds, Copper Creek-Deer Creek (051201050401), Wise Grinslade Ditch-Deer Creek (051201050402), and Russell Ditch-Deer Creek (051201050405) and drains 37,499 acres or 58.6 square miles. In total, 54.7 miles of stream are present within the Headwaters of Deer Creek subwatershed. Of those, 13.4 miles are considered impaired for *E. coli*, biotic communities, and nutrients according to IDEM's draft 2012 303(d) list (Figure 65, IDEM, 2012).

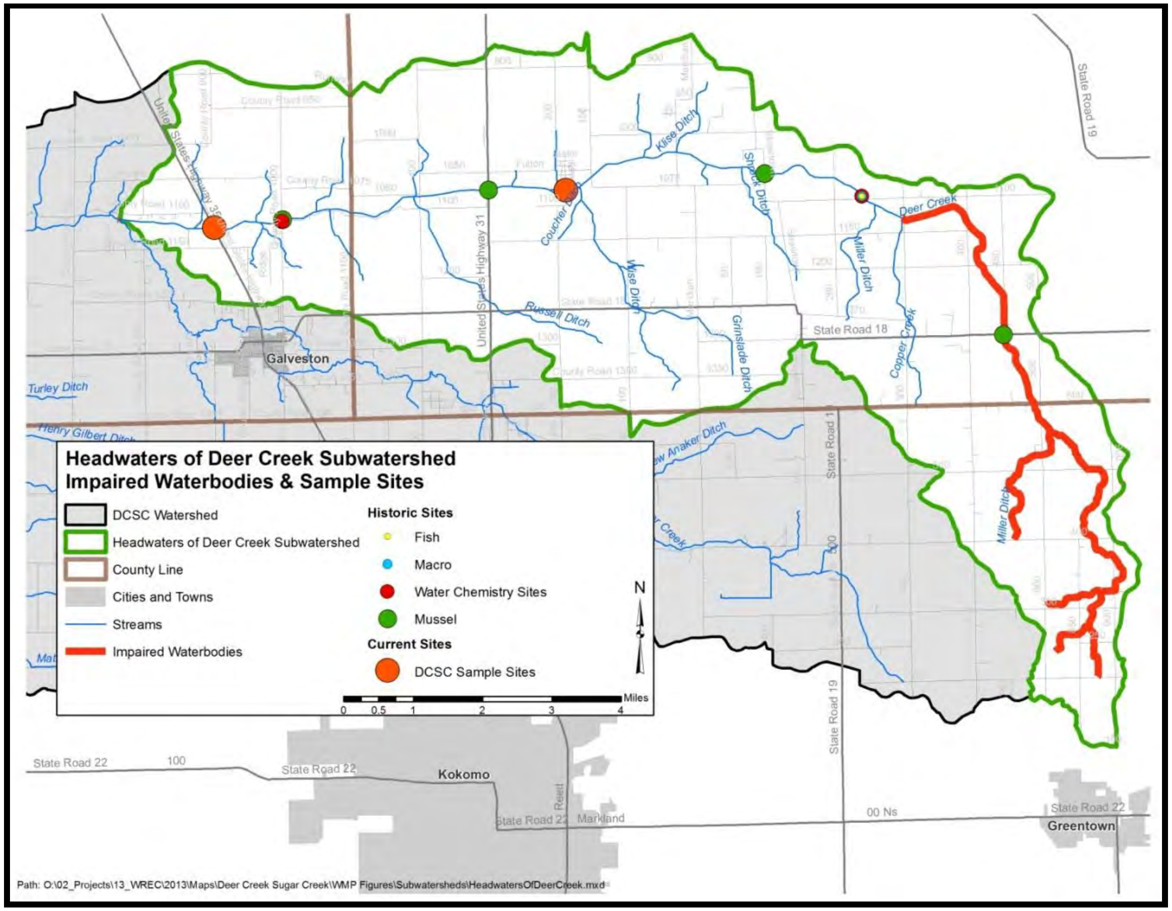

Figure 65. Impaired waterbodies and sample sites in the Headwaters of Deer Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.1.1 Soils

Hydric soils dominate the Headwaters of Deer Creek subwatershed (Figure 66). Hydric soils cover 14,977 acres, or approximately 40%, of the subwatershed. The hydric soils are equally dispersed throughout the watershed. Highly and potentially highly erodible soils cover 1,844 and 790 acres (4.9% and 2.1%), respectively. Highly erodible soils are isolated in the Miami County (eastern) portion of the watershed bordering Deer Creek and a few of its smaller tributaries. Potentially highly erodible soils are located predominantly along Deer Creek and its minor tributaries within the Cass County portion of the subwatershed. The Headwaters of Deer Creek subwatershed has the lowest percentage of potentially highly erodible soils of the ten subwatersheds.

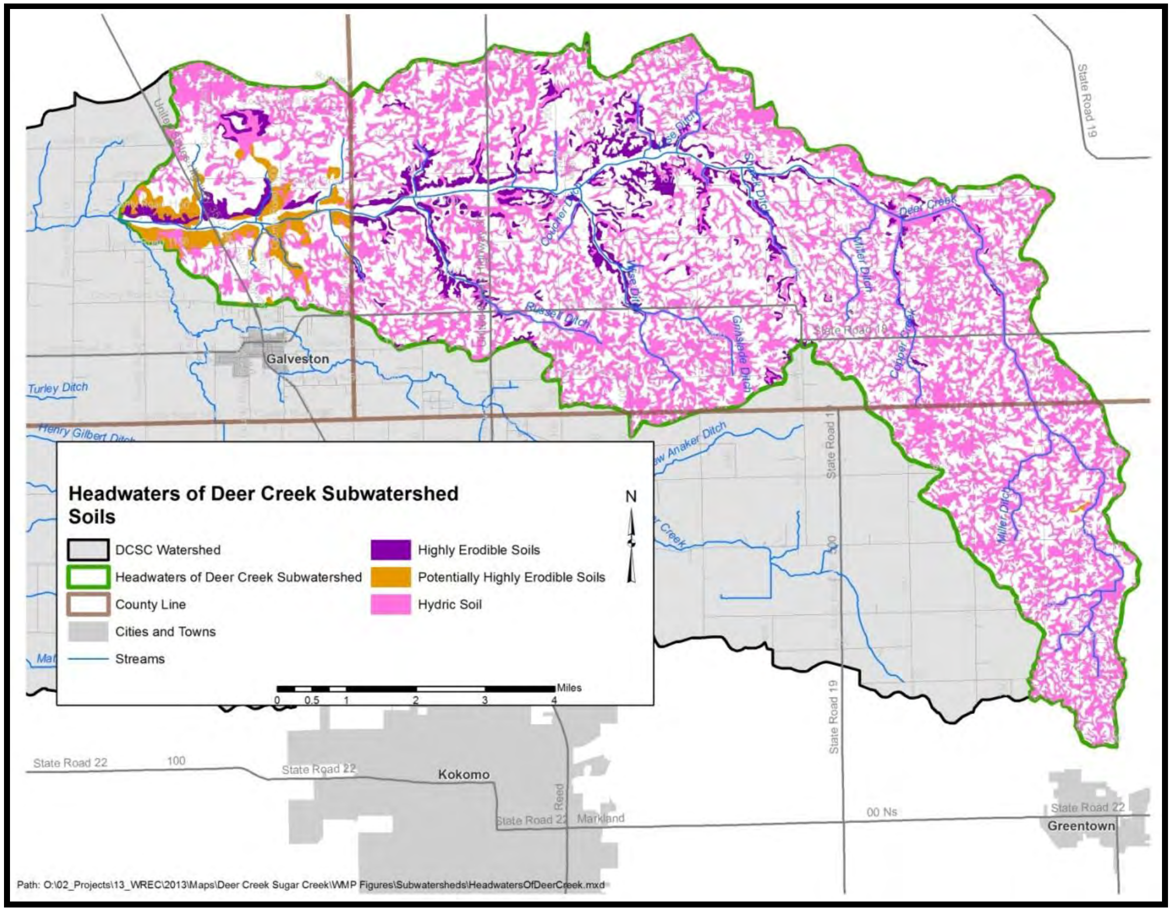

Figure 66. Properties of soils located in the Headwaters of Deer Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.1.2 Land Use

Agricultural land uses dominate the Headwaters of Deer Creek subwatershed. Agricultural land uses covers approximately 90% of the subwatershed. This subwatershed and the Little Deer Creek subwatershed are tied for the highest percentage of agriculture land use in the watershed. Developed open spaces and deciduous forests are the only other land uses making up greater than 1% of the watershed, comprising 5.7% and 1.6% of the watershed, respectively. The Headwaters of Deer Creek subwatershed has the lowest percentage of open water and forest in the watershed.

4.1.3 Point Source Water Quality Issues

As detailed above, the majority of the Headwaters of Deer Creek subwatershed is in agricultural land uses. There is one NPDES permitted facility within the subwatershed: the Maple Lawn Village mobile home park located on US Highway 31 North (Figure 67). The facility discharges into Deer Creek. There is one open dump within the subwatershed; it is located approximately two miles north of Galveston. There are no brownfields, industrial waste, or LUST sites within the Headwaters of Deer Creek subwatershed.

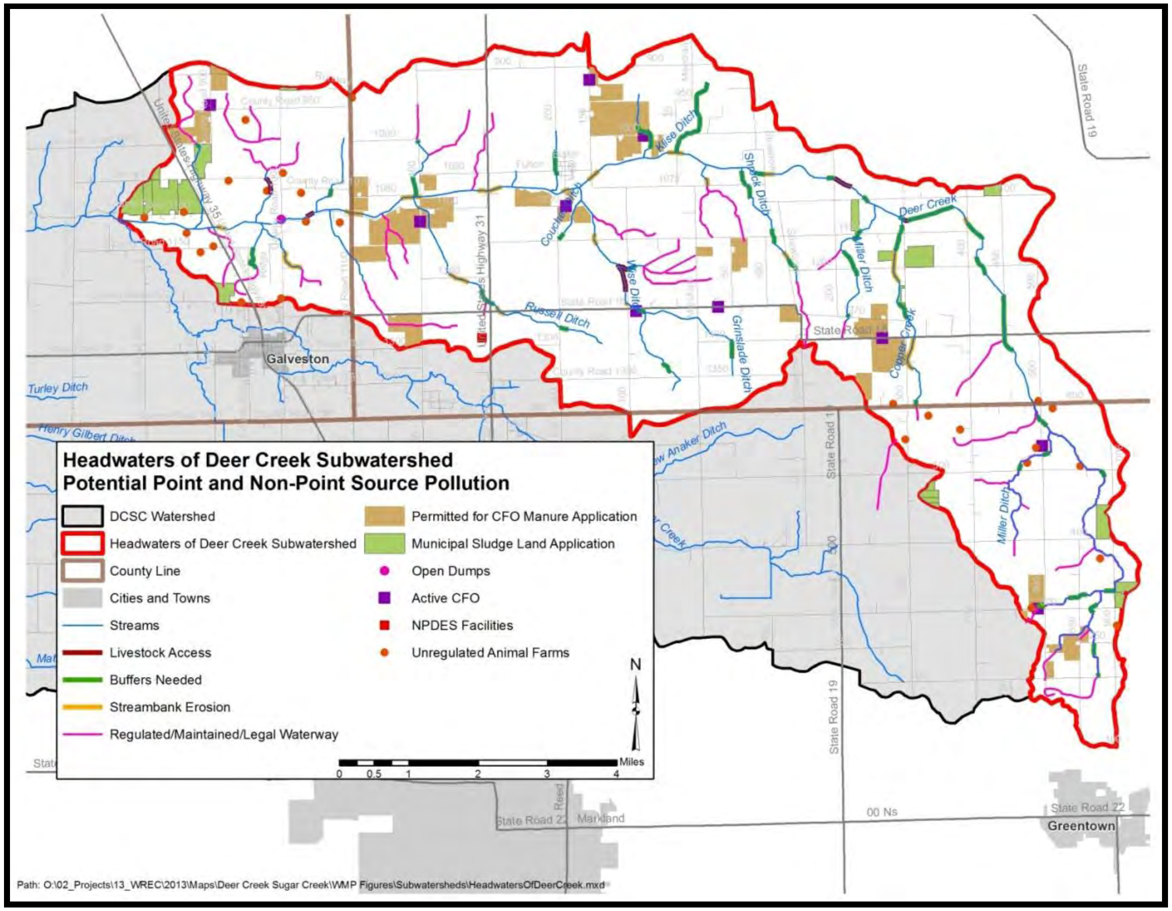

Figure 67. Point and non-point sources of pollution in the Headwaters of Deer Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.1.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the Headwaters of Deer Creek subwatershed and a corn-soybean rotation predominates in these areas. Nearly 30 unregulated animal farms are located within the Headwaters of Deer Creek subwatershed. Approximately, 208 cattle, 2 hogs, 20 sheep, 11 goats, and 40 horses are located on 27 farms. There are ten active CFOs in the Headwaters of Deer Creek subwatershed. CFOs in the Headwaters of Deer Creek subwatershed contain approximately 5,950 nursery pigs, 5,048 finishing pigs, and 1,565 sows. The CFO permits allow for distribution of manure on approximately 1,956 acres. Estimated conservatively, the livestock in this subwatershed produce upwards of 13 thousand tons of manure per year. Hypothetically, if this manure were applied entirely to the 1,956 acres of permitted receiving land, total Nitrogen and Phosphorus Pentoxide loads would not exceed recommended fertilizer rates (conservatively estimated for maximum yield and averaged across corn and soy crops) (Sutton et al., 2001).

Municipal sludge is being applied to 708 acres within the subwatershed. The sludge is transported from three facilities located outside the Deer Creek-Sugar Creek watershed, including the Greentown Municipal STP, Grissom Redevelopment Authority, and the Merrell Brothers Regional Bio-solids Center. Livestock have access to approximately 2.5 miles of stream within the subwatershed. Streambank erosion and the need for stream buffering are also of concern within the Headwaters of Deer Creek subwatershed. In total, 19 miles of stream buffers and 16.4 miles of streambank stabilization are needed within the subwatershed.

4.1.5 Water Quality Assessment

IDEM and the IDNR sampled waterbodies within the Headwaters of Deer Creek subwatershed at five locations (Figure 65). The first sample site is on Deer Creek at its intersection with Miami County Road 1100 South. This site has been sampled by IDEM for fish, macroinvertebrates, and water chemistry. The second site is also on Deer Creek in Cass County at the intersection of County Road 1000 East and County Road 1100 South. IDEM sampled *E. coli* and the IDNR sampled the mussel community at this site. The remaining three sites are also on Deer Creek in Miami County at Strawtown Pike, US Highway 31, and State Road 18. The IDNR also surveyed the mussel communities are these sites. As part of the current planning project, Purdue University sampled Deer Creek at State Road 35 (site DCM10) and Deer Creek at Elm Street (site DCU12) (Figure 45). Sampling for water chemistry occurred biweekly for one year (26 samples), while fish and macroinvertebrates were surveyed twice and habitat assessed once from August 2012 through August 2013.

Water Chemistry

E. coli was sampled five times over a 30 day period on Deer Creek located at the intersection of County Road 1100 South and 1000 East during September and October of 2003. *E. coli* levels exceed the state standard during three of the five sampling times. Of the samples that exceeded the state standard concentrations ranged from 435 to 1,300 colonies/100 mL. In the summer and fall of 2008, nutrient and field parameters collection occurred at Deer Creek's intersection with County Road 1100 South. *E. coli* was analyzed five times over a 30 day period and exceeded the state standard during four of the times measuring365 to920 colonies/100mL. Dissolved oxygen measured below the state standard (4.0 mg/L) with 0.42 mg/L measured during one of the sampling events. During all other times dissolved oxygen was measured, it measured above the state standard. Inorganic nitrogen (nitrate+nitrite) measured unusually high during a June sampling event with a concentration of 9.57 mg/L recorded. This is nearly four times the suggested benchmark of Dodds et al (1998) of 2 mg/L. Total phosphorus exceeded the benchmark of Dodds (1998) of 0.08 mg/L during two of the four samples measuring 0.178 and 0.474 mg/L.

In total, 19 field measurements and 25 samples were collected at Deer Creek at State Road 35 (site DCM10). All temperature, conductivity, dissolved oxygen, and pH measurements were within standards or recommendations. Turbidity measured above recommended levels during 12 of 19 assessments measuring from 12.1 to 209 NTU. Most high turbidities occurred during elevated flow conditions. Nitrate-nitrogen concentrations exceeded the target (2.0 mg/L; Dodds, 1998) during 13 of 19 sampling events. Most of these exceedances occurred during 2013. This is likely due to the severe drought conditions which occurred through the Deer Creek-Sugar Creek watershed in 2012. Nitrate-nitrogen was held by plants or within the soil until the soil was saturated. When the ground was sufficiently saturated, runoff carried excess nitrate-nitrogen not used within the system into adjacent streams. Concentrations exceeded the state drinking water standard (10 mg/L) during two events measuring as high at 11.5 mg/L. Total phosphorus concentrations exceeded the 0.08 mg/L target during 16 of 25 sampling events with concentrations measuring as high as 1.01 mg/L in December 2012. Total suspended solids concentrations measured above target levels during 8 of 25 sampling events. Exceedances generally coincided with elevated turbidity measurements and high flow events with concentrations ranging from 17.3 to 365 mg/L. *E. coli* concentrations measured above the state standard during 19 of 25 sampling events. Concentrations in exceedance ranged from 249 cfu/100 mL to 2909 cfu/100 mL. During the more typical flow conditions observed in 2013, *E. coli* concentrations never measured below the detection level.

Deer Creek at Elm Street (site DCU12) exhibited similar conditions to Deer Creek at State Road 35 during the sampling period. Temperature, conductivity and pH measured within standards or recommendations throughout the sampling period. Dissolved oxygen typically measured above the state standard (4 mg/L); however in May 2013 dissolved oxygen was low measuring 3.6 mg/L. Turbidities exceeded targets during 13 of 19 sampling events ranging from 11.1 to 202 NTU while in exceedance. Like Deer Creek at SR 35, nitrate-nitrogen concentrations in Deer Creek at Elm Street exceeded targets during 13 of 23 sampling events with all exceedances occurring in 2013 under more typical flow conditions. Total phosphorus concentrations exceeded the 0.08 mg/L target during 13 of 25 sampling events with concentrations in excess ranging from 0.089 to 2.59 mg/L. Concentrations measured greater than 2.0 mg/L during two events occurring in December 2012 and again in February 2013. Total suspended solids concentrations measured in excess of targets during 11 of 26 sampling events. As with the downstream site, TSS exceedances typically occurred under high flow conditions and coincided with elevated turbidity measurements. TSS concentrations in excess of the target ranged from 17 to 306 mg/L. *E. coli* concentrations measured above the state standard during 22 of 26 sampling events with concentrations in excess ranging from 387 cfu/100 mL to 3075 cfu/100 mL. Furthermore, total phosphorus and *E. coli* concentrations measured the highest on average of all streams monitored during the planning process.

Habitat

IDEM used the Qualitative Habitat Evaluation Index (QHEI) to evaluate habitat at one site (Country Road 1100 South in Miami County) during two assessments, while Purdue University assessed habitat once at two locations. The QHEI scores the habitat in a stream reach based on the presence or absence of specific characteristics. Streams with QHEI scores greater than 51 are considered to be fully supporting of their aquatic life use designation. IDEM assessments occurred in June and July of 2008, while Purdue University assessments occurred in 2012. Scores showed mixed results, in June 2008 the stream was fully in support of the aquatic life scoring 56, but in July 2008 it was no longer considered to support the aquatic life use designation scoring 41. In 2012, habitat rated fair with the two Headwaters of Deer Creek streams scoring two of the poorest habitat scores within the watershed (DCM10 scored 56; DCU12 scored 48). Poor instream cover, limited pool and riffle development and low stream gradients limit habitat in the Headwaters of Deer Creek streams.

Fish

In June of 2008, IDEM assessed the fish community in Deer Creek at its intersection with Miami County County Road 1100 South. The three most prevalent species by count were the striped shiner, longear sunfish, and the bluntnose minnow (19, 13, and 10, respectively). The IBI score was 38, rating this section of stream as poor to fair. Purdue University assessed Deer Creek at State Road 35 (DCM10) and Elm Street (DCU12) in 2012. Despite the relatively poor habitat present in the Headwaters of Deer Creek watershed streams, fish communities present at these two sites contained relatively high quality fish communities. Both sites contained high species diversity, low number of tolerant species and high percentages of intolerant species. Deer Creek at State Road 35 (DCM10) scored the highest IBI of all sites (tie).

Macroinvertebrates

The macroinvertebrate community was sampled once by IDEM in the summer of 2008 and at two sites by Purdue University in the Headwaters of Deer Creek subwatershed. The IDEM sampling event occurred at County Road 1100 South in Miami County. The mIBI score indicated that this segment was not supporting for aquatic life use rating as very poor scoring 20 using the new IDEM mIBI scoring method. The most prevalent species was Sphaerium, a moderately pollution tolerant clam species. The Purdue University events occurred at State Road 35 (DCM10) and Elm Street (DCU12). The macroinvertebrate community at State Road 35 (DCM10) contained high taxa richness but was dominated by tolerant taxa. The benthic taxa richness was very, very low (at least 11 taxa) and the sample was dominated by taxa considered tolerant of poor conditions. The mIBI (24) was tied for the lowest valued observed among sites. Deer Creek at Elm Street (DCU12) contained low benthic taxa richness and contained high densities of relatively tolerant species. The mIBI score (38) was just above the threshold (36) between impaired and unimpaired. Benthic taxa richness was moderate (at least 27 taxa), and comprised of primarily tolerant taxa.

Mussels

The INDR surveyed the mussel communities of Deer Creek at County Road 1000 East, Strawtown Pike, US Highway 31, and State Road 18. At the County Road 1000 East site, a total of nine species were identified; eight as weathered dead shell material and the other as live. Three species of mussels, two live and one weathered dead were identified at the Strawtown Pike site. The site located on US Highway 31 contained eight species of mussels; five were weathered dead shell material, one was fresh dead shell material and two live species were identified. Of the weathered dead mussel species, a state species of special concern was identified, the purple lilliput (*Toxolasmalividus*). At State Road 18, the IDNR identified 20 live mussels, the most live mussels within this subwatershed. Of those live mussels, four species were identified. Additionally, two more species were found as fresh dead shell material.

4.1.6 Headwaters of Deer Creek Subwatershed Summary

The Headwaters of Deer Creek subwatershed is comprised of 90% agricultural land, and, along with the Little Deer Creek subwatershed, has the highest percentage of agriculture land use in the watershed. Although agricultural land use is high, Headwaters of Deer Creek has the lowest percentage of potentially highly erodible soils of the ten subwatersheds. Stream bank stabilization and stream buffers are still a concern for this subwatershed, as turbidity levels were in exceedance in all sampled locations. Though fish communities consisted of low tolerance species, macroinvertebrate communities were comprised of high tolerance species, coinciding with poor to fair habitat evaluation scores. Overall water quality is poor to fair in this subwatershed due to elevated measurements of pathogens, sediment, and nutrient levels.

4.2 South Fork of Deer Creek

The South Fork of Deer Creek subwatershed is located immediately south of the Headwaters of Deer Creek subwatershed forming the southeast border of the Deer Creek-Sugar Creek watershed. The South Fork of Deer Creek subwatershed is located in Cass, Howard, and Miami counties with the majority within Howard County. The South Fork of Deer Creek subwatershed includes the Town of Galveston. The subwatershed includes two 12-digit watersheds, Matthew Anaker Ditch-South Fork of Deer Creek (051201050403) and Manson Kingery Ditch-South Fork of Deer Creek (051201050404) and drains 25,440 acres or 40 square miles. In total, 36.1 miles of stream are present within the South Fork of Deer Creek subwatershed. None of the stream lengths within this subwatershed are listed as impaired according to IDEM's 2012 draft 303(d) list (Figure 68).

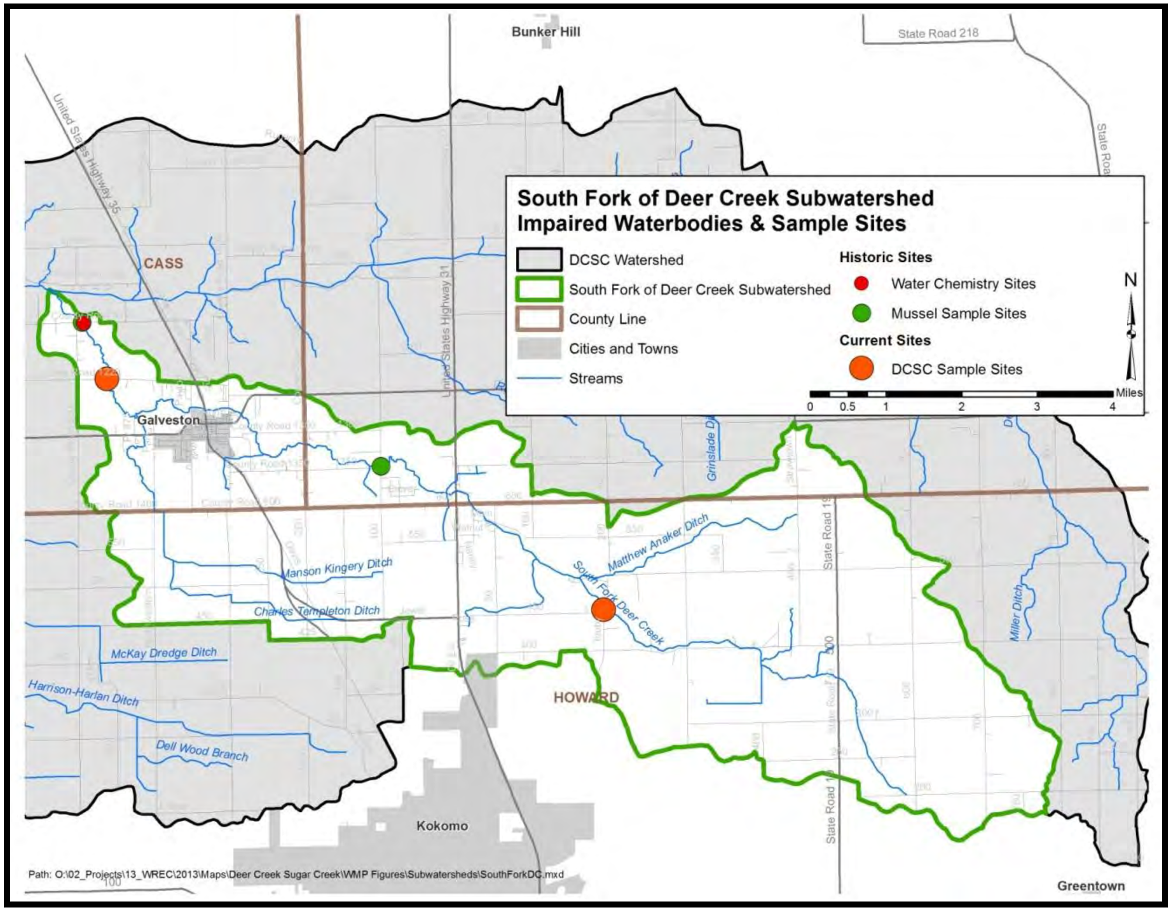

Figure 68. Impaired waterbodies and sample sites in the South Fork Deer Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.2.1 Soils

Highly erodible soils cover 1,697 acres or 6.7% of the South Fork of Deer Creek subwatershed (Figure 69). Most of these soils are located adjacent to the Deer Creek stream channel within Cass County. An additional 10,458 acres, or 41% of the subwatershed, are covered by hydric soils. This indicates that the soils in the South Fork of Deer Creek subwatershed were historically in wetland uses with nearly 41% of the subwatershed soils developing under wetland conditions. Currently, less than 1% of South Fork of Deer Creek subwatershed is covered by wetlands; this suggests that less than 8% of historic wetlands are still present. The South Fork of Deer Creek has the highest percentage of hydric soils of the ten subwatersheds.

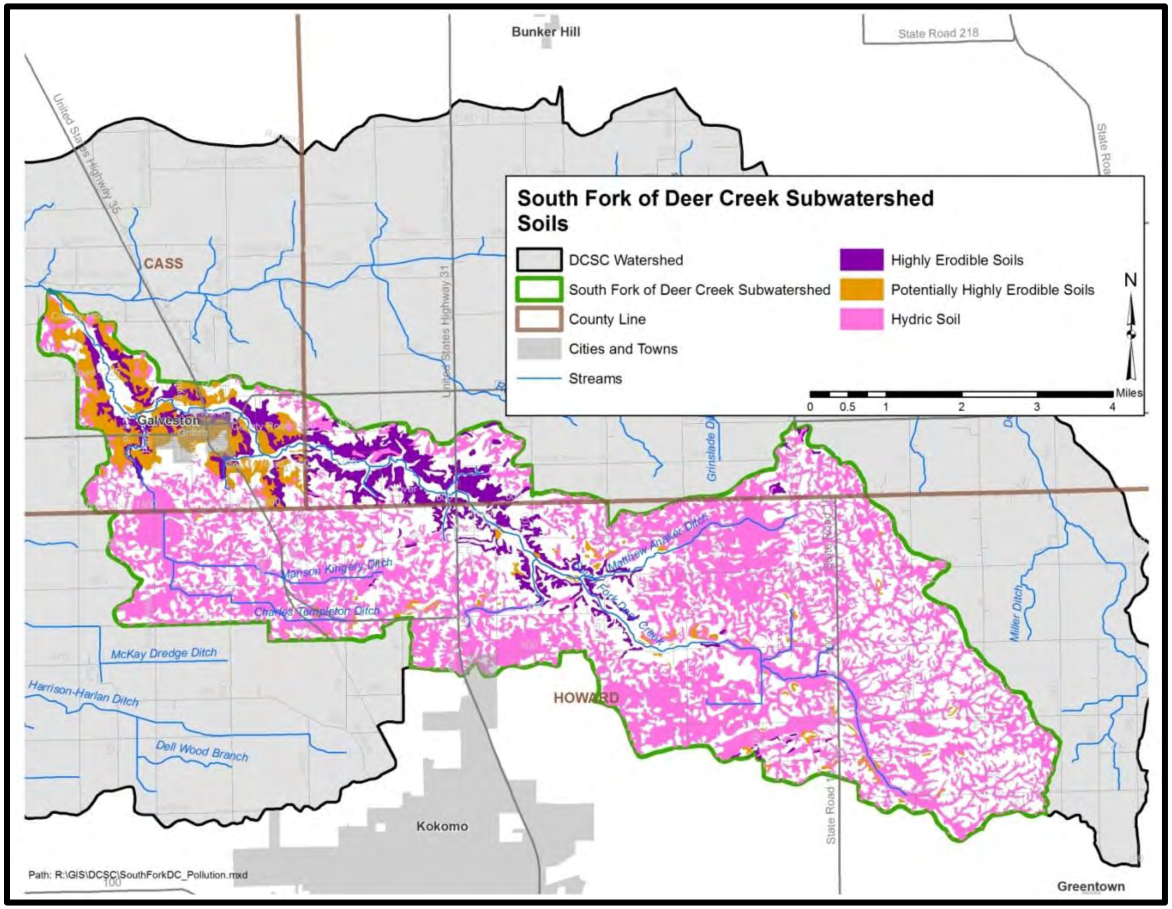

Figure 69. Properties of soils located in the South Fork of Deer Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.2.2 Land Use

Agriculture land uses dominates the South Fork of Deer Creek subwatershed accounting for 84% of land use. Urban land uses, including the city of Galveston, accounts for 10% of the subwatershed land use. Forest and wetland land uses account for approximately 7% of the subwatershed (3.6% and 3.1%, respectively), while open water covers less than 1% of the South Fork of Deer Creek subwatershed.

4.2.3 Point Source Water Quality Issues

As detailed above, the South Fork of Deer Creek subwatershed is predominately in agricultural land uses. There is one NPDES-permitted facility located within the subwatershed, the Galveston Municipal STP (Figure 70). Galveston operates a sewage treatment plant which serves 1,884 residents. In total, the plant treats 0.28MGD, which is treated at an advanced level, and is then discharged into the South Fork of Deer Creek (USEPA, 2008). Six leaking underground storage tanks (LUST) are located throughout the subwatershed. There is also an open dump on County Road 600 North near the Miami County-Howard County line.

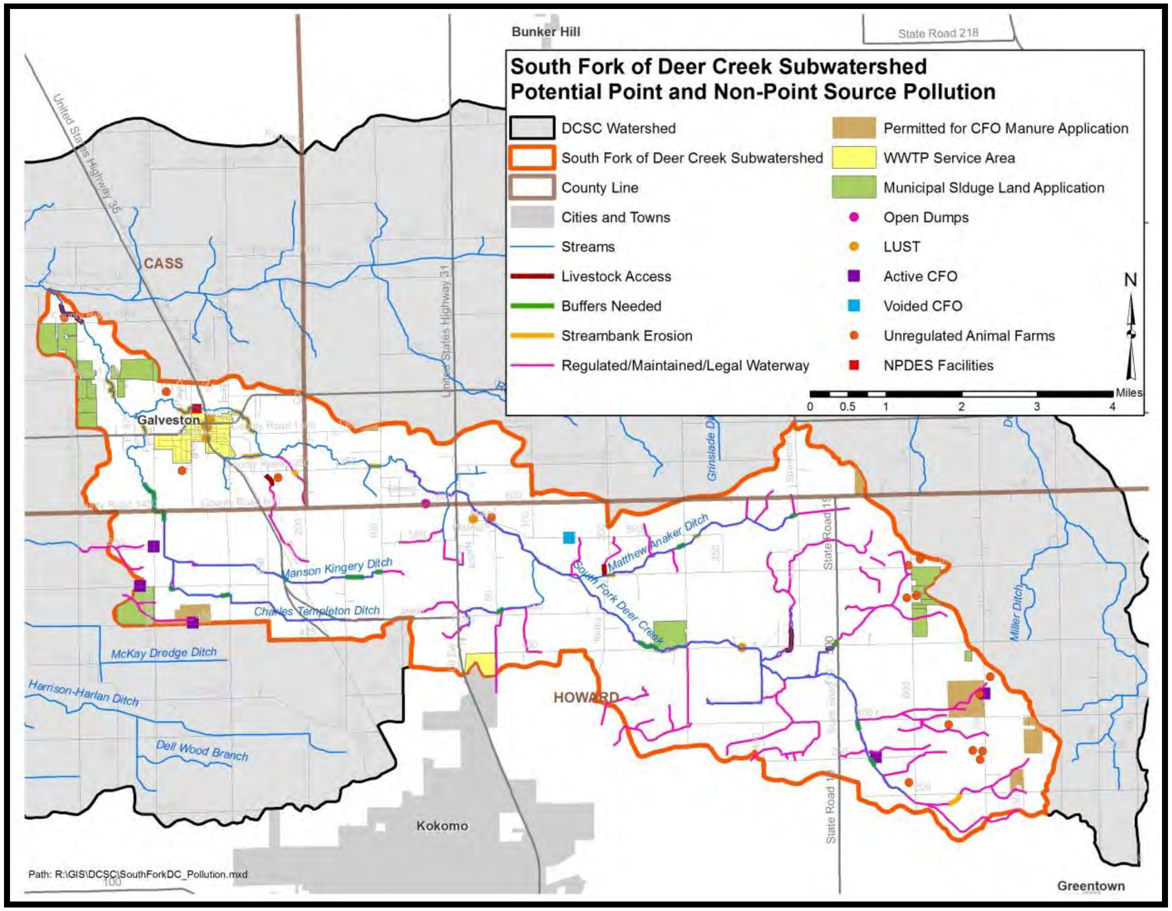

Figure 70. Point and non-point sources of pollution in the South Fork of Deer Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.2.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the South Fork of Deer Creek subwatershed and a corn-soybean rotation predominates in these areas. A number of unregulated animal farms are located within the South Fork of Deer Creek subwatershed. A number of unregulated animal farms are located within the Wabash River subwatershed. Approximately, 195 cattle, 20 sheep, and 23 horses are located on 17 farms. In the South Fork of Deer Creek subwatershed, there are five active CFOs. The South Fork of Deer Creek contains the lowest number of animals on CFOs. There are approximately 5,635 animals housed within this subwatershed. The South Fork of Deer Creek is also the only subwatershed to have veal calves;

there are 1,492 calves in the subwatershed. The remaining animals in the subwatershed are nursery pigs (830), finishing pigs (2,883), and sows (430). CFO permits allow for distribution of manure on approximately 348 acres. Estimated conservatively, the livestock in this subwatershed produce upwards of 9 thousand tons of manure per year. Hypothetically, if this manure were applied entirely to the 348 acres of permitted receiving land, total Nitrogen and Phosphorus Pentoxide loads would exceed recommended fertilizer rates (conservatively estimated for maximum yield and averaged across corn and soy crops) (Sutton et al., 2001).

Municipal sludge is being applied to 716 acres within the subwatershed. The sludge is transported from three facilities located outside the Deer Creek-Sugar Creek watershed, including the Greentown Municipal STP, Grissom Redevelopment Authority, and the Merrell Brothers Regional Bio-solids Center. Livestock have access to approximately 2.4 miles of stream within the subwatershed. Streambank erosion and the need for stream buffering are also of concern within the South Fork of Deer Creek subwatershed. In total, nearly 4.5 miles of stream buffers and 4 miles of streambank stabilization are needed within the subwatershed.

4.2.5 Water Quality Assessment

Waterbodies within the South Fork of Deer Creek subwatershed were sampled at two locations (Figure 68). IDEM and the IDNR sampled the South Fork of Deer Creek in Cass County at County Road 1150 South for *E. coli* and mussel communities, respectively. The IDNR sampled the mussel community at a second site at County Road 400 West in Miami County. As part of the current planning project, Purdue University sampled the South Fork of Deer Creek at County Road 1125 South (site SFD9) and at Touby Road (site SFU11) (Figure 45). Sampling for water chemistry occurred biweekly for one year (26 samples), while fish and macroinvertebrates were surveyed twice and habitat assessed once from August 2012 through August 2013.

Water Chemistry

In the fall of 2003, IDEM sampled the South Fork of Deer Creek in Cass County on County Road 1150 South for *E. coli.* Five samples were collected over a 30 day period. *E. coli* was higher than the Indiana state standard during three of the five sampling events. *E. coli* ranged from 191.8 to 1,986.3 colonies/100 mL of sample.

In total, 19 field measurements and 25 samples were collected at South Fork Deer Creek at County Road 1125 South (SFD9). All temperature, conductivity, dissolved oxygen, and pH measurements were within standards or recommendations. Turbidity measured above recommended levels during 13 of 19 assessments measuring from 12 to 354 NTU. Most high turbidities occurred during elevated flow conditions. Nitrate-nitrogen concentrations exceeded the target (2.0 mg/L; Dodds, 1998) during 20 of 24 sampling events. Most of these exceedances occurred during 2013. This is likely due to the severe drought conditions which occurred through the Deer Creek-Sugar Creek watershed in 2012. Nitrate-nitrogen was held by plants or within the soil until the soil was saturated. When the ground was sufficiently saturated, runoff carried excess nitrate-nitrogen not used within the system into adjacent streams. Concentrations exceeded the state drinking water standard (10 mg/L) during one event in March 2013 measuring as high as 10.5 mg/L. Total phosphorus concentrations exceeded the 0.08 mg/L target during 16 of 25 sampling events with concentrations measuring as high as 0.312 mg/L in December 2012. Total suspended solids concentrations measured above target levels during 8 of 25 sampling events. Exceedances generally coincided with elevated turbidity measurements and high flow events with concentrations ranging from 15.2 to 63.6 mg/L. *E. coli* concentrations measured above the state standard during 17 of 25 sampling events. Concentrations in exceedance ranged from 261 cfu/100 mL to 1732 cfu/100 mL. During the more typical flow conditions observed in 2013, *E. coli* concentrations measured below the detection level only once.

South Fork Deer Creek at Touby Road (SFU11) exhibited similar conditions to South Fork Deer Creek at County Road 1125 South during the sampling period. Temperature, conductivity and pH measured within standards or recommendations throughout the sampling period. Dissolved oxygen typically measured above the state standard (4 mg/L); however in August 2012 and again in May 2013 dissolved oxygen was low measuring less than 4 mg/L. Turbidities exceeded targets during 9 of 19 sampling events ranging from 11.2 to 502 NTU while in exceedance. Like South Fork Deer Creek at County Road 1125 South, nitrate-nitrogen concentrations in South Fork Deer Creek at Touby Road exceeded targets during 16 of 23 sampling events. Nitrate-nitrogen concentrations were generally elevated throughout the sampling period with the two sampling events exceeding the state standard for drinking water (10 mg/L). Total phosphorus concentrations exceeded the 0.08 mg/L target during 18 of 26 sampling events with concentrations in excess ranging from 0.083 to 0.389 mg/L. Total suspended solids concentrations measured in excess of targets during 5 of 26 sampling events. As with the downstream site, TSS exceedances typically occurred under high flow conditions and coincided with elevated turbidity measurements. TSS concentrations in excess of the target ranged from 28.7 to 202 mg/L. *E. coli* concentrations measured above the state standard during 14 of26 sampling events with concentrations in excess ranging from 272 cfu/100 mL to 5794 cfu/100 mL.

Habitat

Purdue University assessed habitat in the South Fork Deer Creek at County Road 1125 (SFD9) and Touby Road (SFU11) in 2012. Habitat rated fully supporting in South Fork Deer Creek at Touby Road (SFU11); however, South Fork Deer Creek at County Road 1125 (SFD9) contained the poorest rated habitat of any of the Deer Creek-Sugar Creek watershed sites. South Fork Deer Creek at County Road 1125 (SFD9) score 44.75 indicating this site was not fully supporting for aquatic life. Generally, both sites contained poorly developed riffles, limited instream habitat and poor cover.

Macroinvertebrates and Fish

Purdue University assessed the macroinvertebrate and fish communities in South Fork Deer Creek at County Road 1125 (SFD9) and at Touby Road (SFU11). Macroinvertebrate community was moderate at SFU11 with low taxa richness with highly tolerant species present. The mIBI score (38) was just above the threshold (36) between impaired and unimpaired. Benthic taxa richness was very low (at least 12 taxa), and comprised of primarily tolerant taxa. Benthic taxa richness was moderate (at least 25 taxa) at SFD9, and the community was dominated by taxa considered tolerant of degraded stream conditions. The mIBI score (38) was just above the threshold (36) between impaired and unimpaired. South Fork Deer Creek at County Road 1125 (SFD9) scored the poorest IBI of all sites (30) containing low species diversity; low number of darters, minnows and sensitive species; and high percentages of tolerant species. South Fork Deer Creek at Touby Road (SFU11) also rated relatively low (36) containing poor headwater species diversity, low number of suckers, and high densities of tolerant species.

Mussels

The IDNR surveyed the mussel communities at two locations within the South Fork of Deer Creek subwatershed, County Road 1150 South (Cass) and County Road 400 West (Miami). At County Road 1150 South, a total of 17 mussel species were identified, including 13 as live samples, three as fresh dead shell materials and one as weathered dead shell material. The site located on County Road 400 West contained eight mussel species, including five alive and one of each of fresh dead, weathered dead, and subfossil shell material. Of the weathered dead mussel species, the purple Lilliput, a state species of special concern, was identified at both sites as weathered dead. Additionally, IDNR identified a second species of special concern, the wavyayed lampmussel (*Lampsilis fasciola*), as a fresh dead shell material at the County Road 1150 South site.

4.2.6 South Fork of Deer Creek Subwatershed Summary

The South Fork of Deer Creek subwatershed is dominated by 84% agricultural land use. Urban land use represents 10% of the subwatershed, mainly in the City of Galveston. This subwatershed has the highest amount of hydric soils of the ten subwatersheds; 41% of the soil is anaerobic in the upper sediment layers. South Fork of Deer Creek has the lowest number of regulated animals present and a relatively smallest amount of acreage permitted for manure distribution. Streambank erosion and stream buffering remain a concern for both the Headwaters of Deer Creek and South Fork Deer Creek subwatersheds. South Fork of Deer Creek had the lowest scoring habitat assessment of all sites sampled during water monitoring, indicating that water quality is impaired. Overall water quality is relatively poor as suspended solids, pathogen levels, and nitrogen levels all exceed state target concentrations, particularly during high flow storm events.

4.3 Deer Creek-McCloskey Ditch

The Deer Creek-McCloskey Ditch subwatershed is located immediately downstream of and receives water from the Headwaters of Deer Creek and South Fork of Deer Creek subwatersheds. The majority of its drainage area is located in Cass County with portions in Carroll and Howard counties. The watershed includes two 12-digit watersheds, Monson Ditch-Deer Creek (051201050507) and McCloskey Ditch (051201050502) and drains 28,764 acres or 45 square miles. In total, 61.6 miles of stream are present within the Deer Creek-McCloskey Ditch subwatershed. Of these, approximately 7.4 miles are considered impaired for *E. coli* and 6.1 miles are considered impaired for PCBs and mercury in fish tissue (Figure 71; IDEM, 2012).

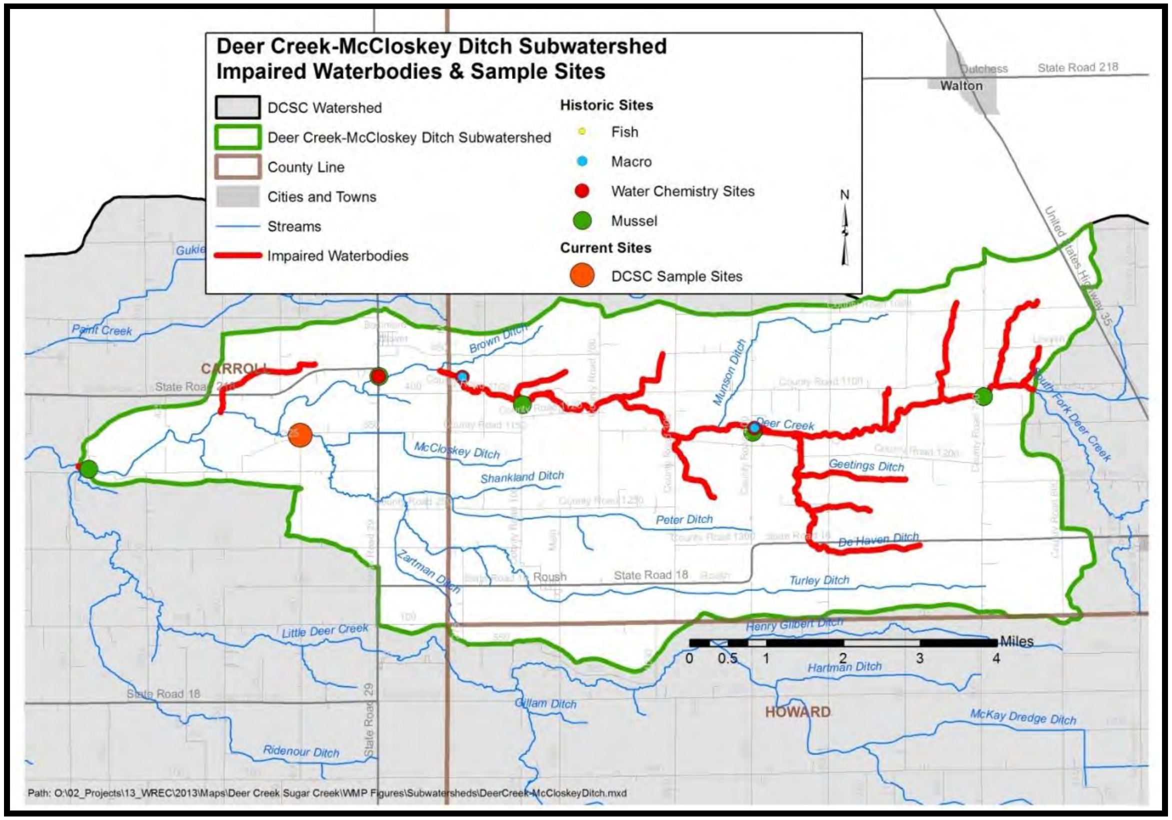

Figure 71. Impaired waterbodies and sample sites in the Deer Creek-McCloskey Ditch subwatershed.
Data used to create this map are detailed in Appendix A.

4.3.1 Soils

Hydric soils cover approximately 36%, or 10,310 acres, of the Deer Creek-McCloskey Ditch subwatershed (Figure 72). Highly erodible and potentially highly erodible soils cover 3% and 15% of the watershed, respectively. These soils are located primarily along the mainstem of Deer Creek and its minor tributaries within Cass County. The Deer Creek-McCloskey Ditch subwatershed has the second highest percentage of potentially highly erodible soil in the watershed; these soils cover a total of 4,362 acres of the subwatershed. The soils in the subwatershed are rated as severely limited for septic system usage for approximately 95% of the watershed. Only about 2,060 acres or 1.5% of the watershed is actually suitable for septic tank absorption fields.

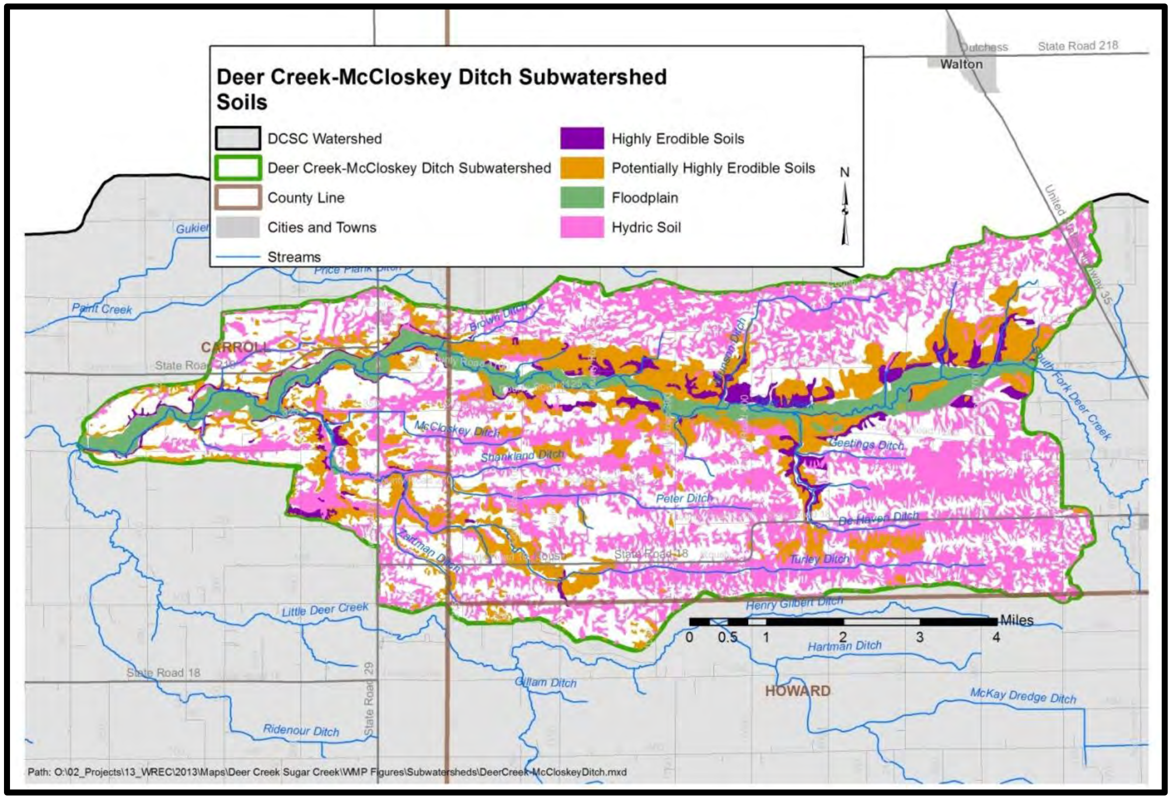

Figure 72. Properties of soils located in the Deer Creek-McCloskey Ditch subwatershed.
Data used to create this map are detailed in Appendix A.

4.3.2 Land Use

Agricultural land uses dominates the Deer Creek-McCloskey Ditch subwatershed at 87%. Forests and urban land uses account for 5.6% and 5.4%, respectively. The Deer Creek-McCloskey Ditch subwatershed has approximately 3%, or 807 acres, classified as woody or emergent wetlands.

4.3.3 Point Source Water Quality Issues

There are no point source water quality issues in the Deer Creek-McCloskey Ditch subwatershed.

4.3.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the Deer Creek-McCloskey subwatershed and a corn-soybean rotation dominates the agricultural land use. A number of unregulated animal farms are located within the Deer Creek-McCloskey Ditch subwatershed. Approximately, 341 cattle, 33 hogs, 65 sheep, 36 goats, and 53 horses are located on 55 farms. There are currently 12 active permitted CFOs in the subwatershed (Figure 73). The CFOs in the Deer Creek-McCloskey Ditch subwatershed contain approximately 6,130 nursery pigs, 5,534 finishing pigs, 30 sows in farrowing, 70 gestation sows, six boars, 222 sows, 3,300 swine greater than 55 pounds, and 1,200 swine less than 55 pounds. There are a total of 16,492 animals on CFOs in the Deer Creek-McCloskey Ditch subwatershed. CFO permits allow for distribution of manure on approximately 3,666 acres. Estimated conservatively, the livestock in this subwatershed produce upwards of 22 thousand tons of manure per year. Hypothetically, if this manure were applied entirely to the 3,666 acres of permitted receiving land, total Nitrogen and Phosphorus Pentoxide loads would not exceed recommended fertilizer rates (conservatively estimated for maximum yield and averaged across corn and soy crops) (Sutton et al., 2001).

Municipal sludge is applied to approximately 6,367 acres, or 22%, of the subwatershed. The sludge is transported from three facilities located outside the Deer Creek-Sugar Creek watershed, including the Greentown Municipal STP, Grissom Redevelopment Authority, and the Merrell Brothers Regional Bio-solids Center. Livestock have access to approximately 7 miles of stream within the subwatershed. Streambank erosion and lack of stream buffering are also of concern within the Deer Creek-McCloskey Ditch subwatershed. In total, 17.2 miles of stream buffers and 9.5 miles of streambank stabilization are needed within the subwatershed.

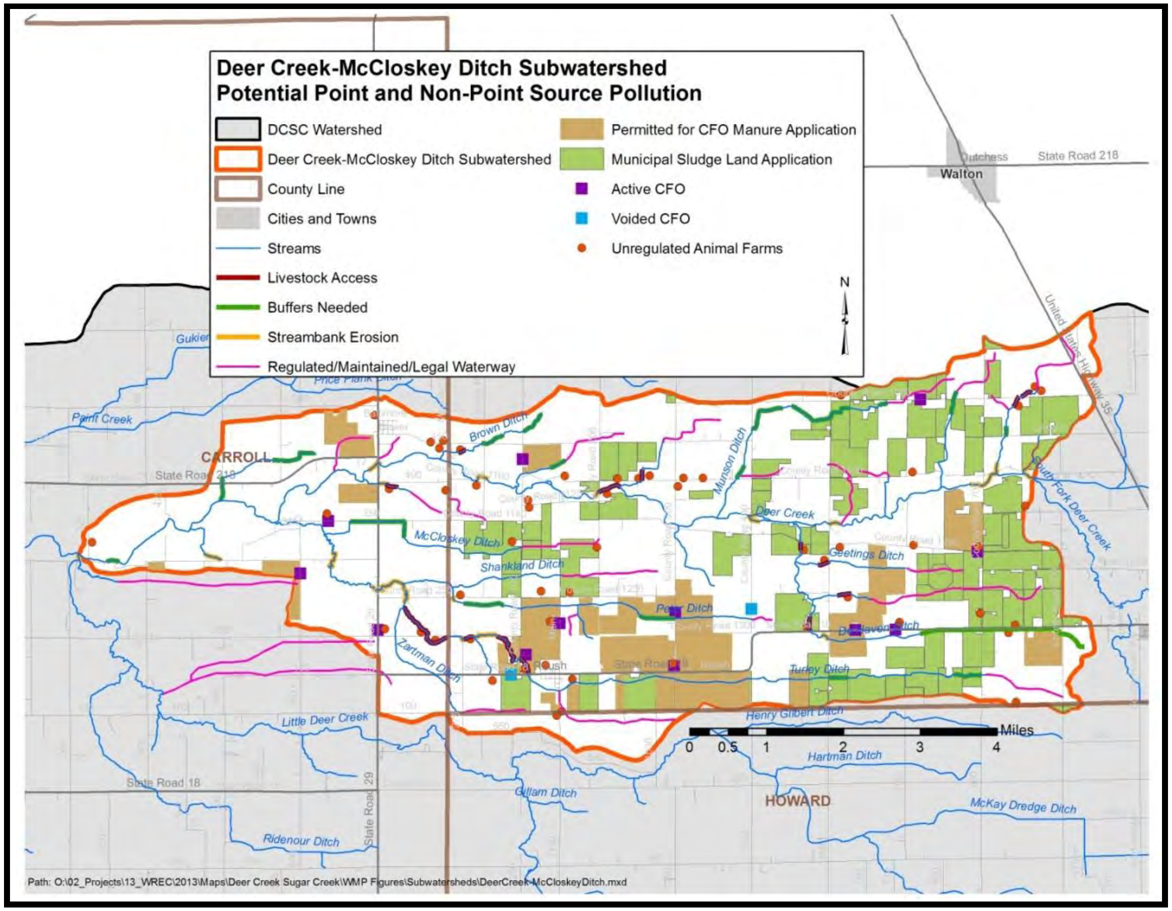

Figure 73. Non-point sources of pollution in the Deer Creek-McCloskey Ditch subwatershed.
Data used to create this map are detailed in Appendix A.

4.3.5 Water Quality Assessment

Waterbodies within the Deer Creek-McCloskey Ditch subwatershed were sampled at three locations (Figure 71). Historic assessments include analysis of *E. coli* concentrations and evaluating the habitat and fish and macroinvertebrate communities in Deer Creek. The sampling sites were all located on the mainstem of Deer Creek less than six miles apart. *E. coli* samples were collected at State Road 29 in Carroll County and County Road 1100 South in Cass County. The fish and macroinvertebrate communities were also assessed at the County Road 1100 South location, while only macroinvertebrates were sampled at County Road 400 East. As part of the current planning project, Purdue University sampled McCloskey

Ditch at County Road 600 East (site MD8, Figure 45). Sampling for water chemistry occurred biweekly for one year (26 samples), while fish and macroinvertebrates were surveyed twice and habitat assessed once from August 2012 through August 2013.

Water Chemistry

E. coli concentrations were measure twice at State Road 29 in Carroll County, once in 1998 and then again in 2003. In 1998, five samples were collected over a 30-day period. Four of the five samples exceeded the Indiana state standard of 235 colonies/100 mL; concentrations ranged from 220-780 colonies/100 mL. In 2003, six samples were collected with a duplicate being processed on one of the dates. Three of the six concentrations exceeded the state standard. One of the concentrations measured more than ten times the state standard measuring 2,419 colonies/100 mL. In 2008, IDEM assessed *E. coli* in Deer Creek at County Road 1100 South in Cass County. *E. coli* concentrations ranged from 192 to 2,419 colonies/100 mL; concentrations exceed state standards during three of the five times. During this assessment, IDEM collected field and nutrient water chemistry as well; parameters of concern during this sampling event included nitrogen (nitrate + nitrite) and total phosphorus. During the June sampling event, nitrogen concentrations measured almost four times the standard suggested by Dodds et al. (1998) with a concentrations of 7.4 mg/L. Total phosphorus also exceed Dodds et al (1998) suggested standard (less than 0.08 mg/L) in two of the three total phosphorus samplesmeasurering0.137 and 0.157 mg/L.

In total, 18 field measurements and 25 samples were collected at McCloskey Ditch at County Road 600 East (MD8). All temperature, conductivity, and pH measurements were within standards or recommendations. One dissolved oxygen sample in May 2013 measured below the detection level. Turbidity measured above recommended levels during 9 of 18 assessments measuring from 11.5 to 427 NTU. Most high turbidities occurred during elevated flow conditions. Nitrate-nitrogen concentrations exceeded the target (2.0 mg/L; Dodds, 1998) during 18 of 24 sampling events. Most of these exceedances occurred during 2013. This is likely due to the severe drought conditions which occurred through the Deer Creek-Sugar Creek watershed in 2012. Nitrate-nitrogen was held by plants or within the soil until the soil was saturated. When the ground was sufficiently saturated, runoff carried excess nitrate-nitrogen not used within the system into adjacent streams. Concentrations exceeded the state drinking water standard (10 mg/L) during five events in January, February, March and June 2013 measuring as high as 12.5 mg/L. Total phosphorus concentrations exceeded the 0.08 mg/L target during 11 of 25 sampling events with concentrations measuring as high as 0.769 mg/L in December 2012. Total suspended solids concentrations measured above target levels during 4 of 25 sampling events. Exceedances generally coincided with elevated turbidity measurements and high flow events with concentrations ranging from 20 to 260 mg/L. *E. coli* concentrations measured above the state standard during 16 of 25 sampling events. Concentrations in exceedance ranged from 290 cfu/100 mL to 2420 cfu/100 mL. During the more typical flow conditions observed in 2013, *E. coli* concentrations measured below the detection level only twice.

Habitat

Habitat assessments occurred twice at each location sampled by IDEM and once by Purdue University within the Deer Creek-McCloskey Ditch subwatershed using the Qualitative Habitat Evaluation Index (QHEI). IDEM assessed the site located on County Road 400 East in 1991 and 2003. The habitat was scored at 72 and 76, respectively. Deer Creek at SR 29 was assessed in June and July of 2008 scoring 82 in June and 72 in July. All four of these scores suggest that Deer Creek within the Deer Creek-McCloskey Ditch subwatershed are fully supporting the designated aquatic life uses. Purdue University's assessment of McCloskey Ditch rated the second highest of all Deer Creek-Sugar Creek watershed sites scoring 70.24. This score indicates a high quality habitat; however, there was limited pool/riffle development. All five of these scores suggest that Deer Creek within the Deer Creek-McCloskey Ditch subwatershed are fully supporting the designated aquatic life uses.

Macroinvertebrates

The macroinvertebrate communities within the Deer Creek-McCloskey Ditch subwatershed were sampled three times by IDEM. The site located at County Road 400 East was sampled twice, once in 1991 and again in 2003. The macroinvertebrate community rated as slightly impaired during both assessments scoring 5.0 and 5.4, respectively. The community was dominated by *Philopotamidae*, a relatively-intolerant caddisfly family in 1991 and *Simuliidae* (fairly tolerant to pollution) in 2003. The other site sampled was IDEM assessed the macroinvertebrate community in Deer Creek County Road 1100 South in 2008. The macroinvertebrate community rated as moderately impaired on IDEM's new mIBI scoring system (score = 42) and was dominated by *Boyeriavinosa*, a moderately tolerant to pollution dragonfly. Purdue University assessed the macroinvertebrate community in McCloskey Ditch in 2012. The taxa richness of the community was one of the poorest and was dominated by taxa considered tolerant of poor conditions. The benthic taxa richness was very, very low (at least 10 taxa) and the sample was dominated by taxa considered tolerant of poor conditions. The mIBI (24) was tied for the lowest valued observed among sites. This community suggests that something other than water quality is limiting the macroinvertebrate community in McCloskey Ditch.

Fish

IDEM assessed the fish community once in the Deer Creek-McCloskey Ditch subwatershed sampling Deer Creek at County Road 1100 South in Cass County in June 2008. The IBI score rated this portion of stream as good to excellent (IBI score = 54), indicating that there was exceptional assemblage of species including some of the more intolerant species. Twenty-six species of fish were identified within this section of Deer Creek; the two most prevalent species were the central stoneroller and the northern hog sucker. Purdue University assessed the fish community in McCloskey Ditch in 2012 with the community rating as fair. The fish community contained low percentages of headwater species, high percentage of tolerant species and low percentages of carnivores and pioneer species.

4.3.6 Deer Creek-McCloskey Ditch Subwatershed Summary

Deer Creek-McCloskey Ditch is made up of 87% agricultural land use, whereas urban land use makes up a 5.4% of the total land usage. Point source pollution is not a concern in this subwatershed, as no permitted point source discharge points currently exist. Measured at 15%, this subwatershed has the second highest percentage of potentially highly erodible soil in the entire watershed, most of which is located along the mainstem of Deer Creek and its tributaries. Consequently, stream bank erosion and lack of stream buffering are issues of concern for this subwatershed. Overall water quality is fair for Deer Creek-McCloskey Ditch. In addition, habitat assessments determined this subwatershed was the second highest for fully supporting its aquatic life. However, one of the poorest taxa richness scores was measured at this location. This could indicate that something other than water quality is affecting the macroinvertebrate community at this particular sampling location.

Nutrient levels, total suspended solids, and pathogen levels all measured below detection levels for more than half of the samples and measurements taken.

4.4 Little Deer Creek

The Little Deer Creek subwatershed is located immediately south of the Deer Creek-McCloskey Ditch subwatershed forming the southern boundary of the watershed in western Howard County. The subwatershed is located in Carroll and Howard counties with a sliver in Cass County. The watershed includes two 12-digit watersheds, Henry Gilbert Ditch-Little Deer Creek (051201050501) and Little Deer Creek (051201050503) and drains 34,814 acres or 54 square miles. In total, 59.7 miles of stream are present within the Little Deer Creek subwatershed. Of these, approximately 6.4 miles are considered impaired for *E. coli* (Figure 74; IDEM, 2012).

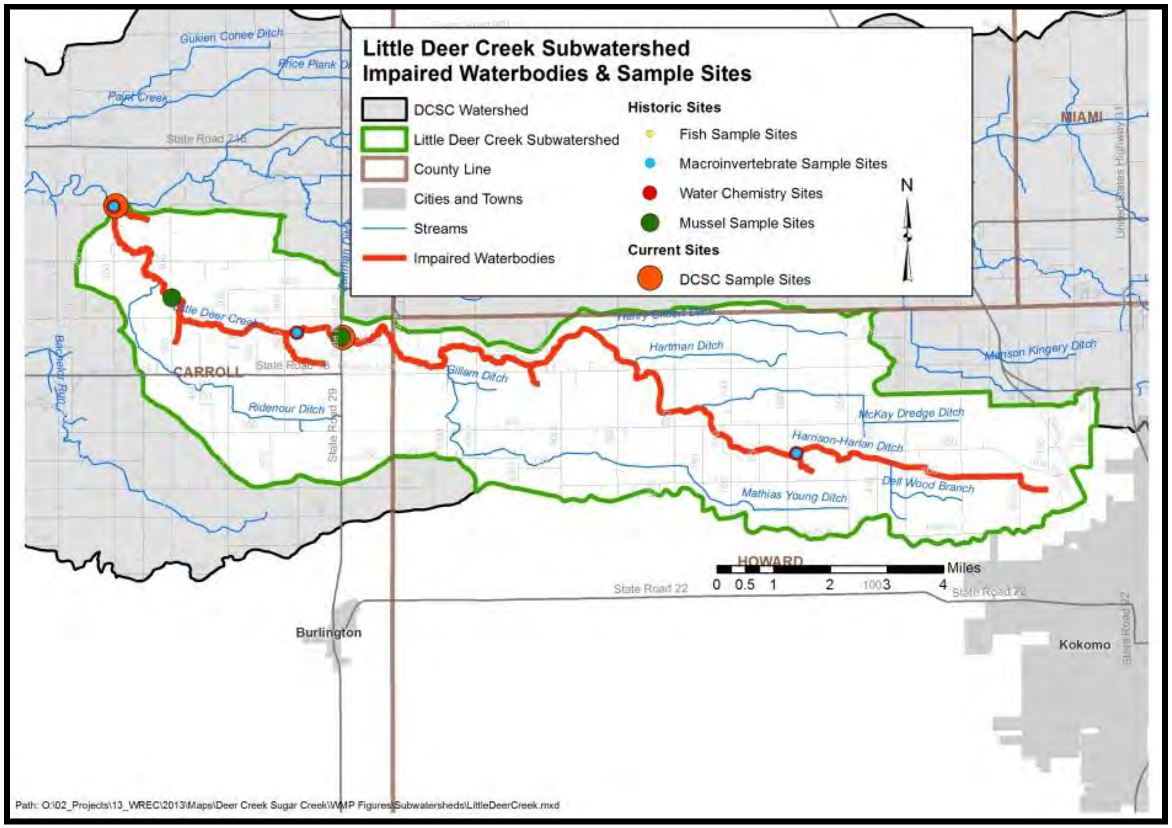

Figure 74. Impaired waterbodies and sample sites in the Little Deer Creek subwatershed.
Data used to create this map are detailed in Appendix A.

WABASH RIVER ENHANCEMENT CORPORATION

4.4.1 Soils

Soils in the Little Deer Creek subwatershed are dominated by those that are unsuitable for use in septic treatment. Nearly 92% of the soils in the subwatershed are rated as severely limited for use in septic tank absorption fields. Highly erodible soils cover only 2.7% or 943 acres of the Little Deer Creek subwatershed, while potentially highly erodible soils cover 2,358 acres or 6.7% of the subwatershed (Figure 75). A majority of the erodible soils are located adjacent to the mainstem of Little Deer Creek. Hydric soils cover nearly 40% of this subwatershed.

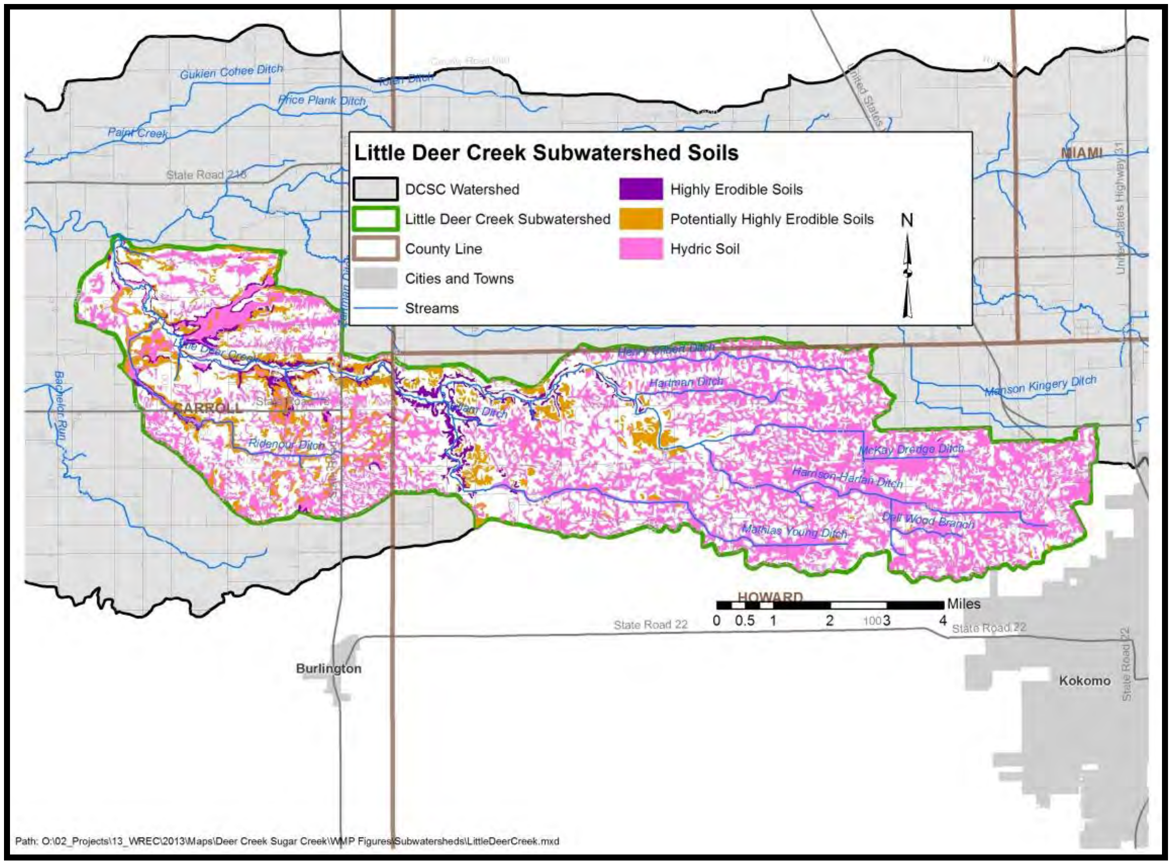

Figure 75. Properties of soils located in the Little Deer Creek subwatershed.
Data used to create this map is detailed in Appendix A

4.4.2 Land Use

Agricultural land uses account for approximately 90%, or 31,489 acres, of the subwatershed. Agricultural land uses in the Little Deer Creek subwatershed are tied for dominance with the Headwaters of Deer Creek subwatershed for the highest percent agriculture for all subwatersheds. The Little Deer Creek subwatershed also has the lowest percentage of urban land in the watershed; only 5.2% of the subwatershed is classified as developed. Natural land accounts for approximately 5% of the subwatershed.

4.4.3 Point Source Water Quality Issues

As detailed above, almost 90% of the Little Deer Creek subwatershed is classified as row crops according to land use data. There is one NPDES-permitted facility located within the subwatershed (Figure 76). The NPDES facility is Northwestern Elementary and High School located northwest of Kokomo. This facility discharges into Harrison-Harlan Ditch. There is one LUST within the subwatershed; it is located on County Road 350 North in Howard County at Northwestern Jr. Sr. High School.

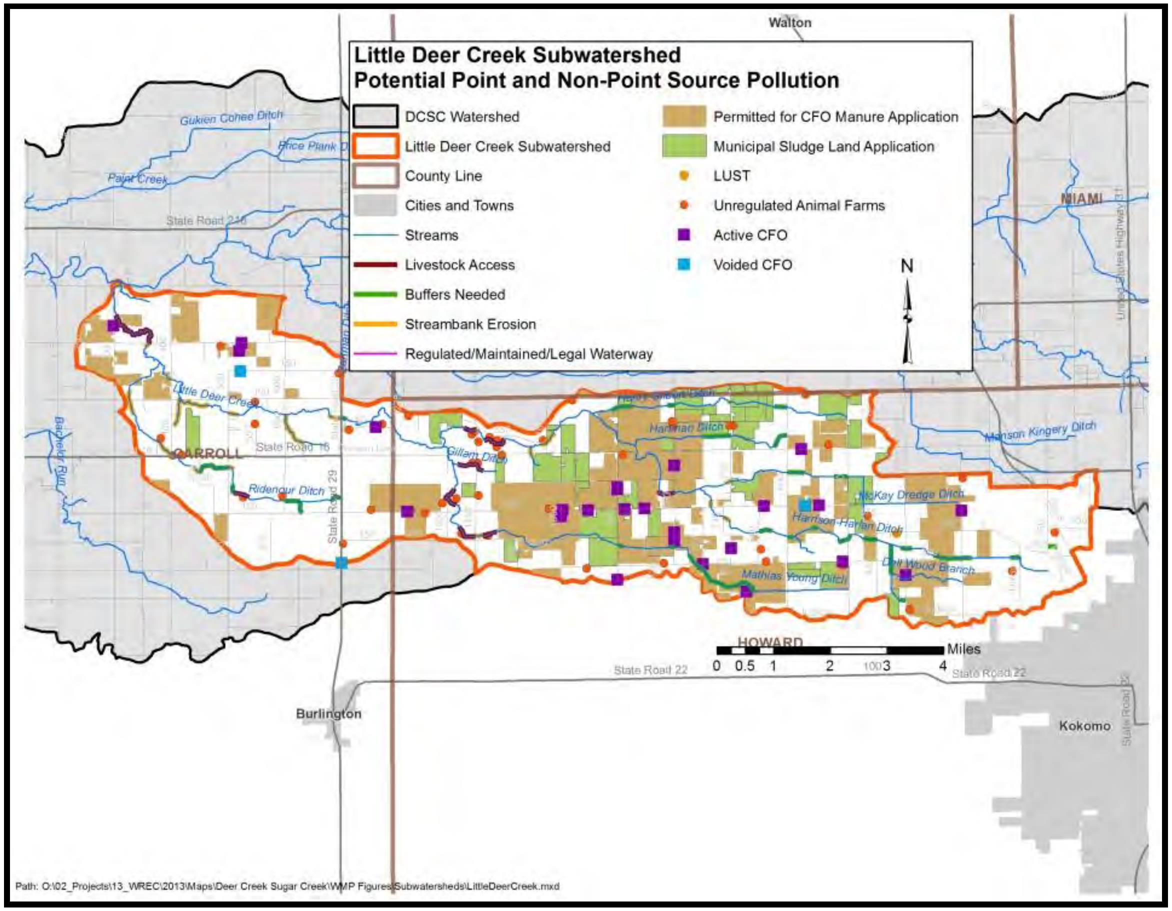

Figure 76. Point and non-point sources of pollution in the Little Deer Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.4.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the Little Deer Creek subwatershed and a corn-soybean rotation predominates in these areas. Approximately 50 unregulated animal farms are located within the Little Deer Creek subwatershed. Approximately, 193 cattle, 41 hogs, 18 sheep, 60 goats, and 70 horses are located on 51 farms in the Little Deer Creek subwatershed. There are 27 active confined feeding operations (CFO) located within the Little Deer Creek subwatershed. The Little Deer Creek subwatershed contains the third highest number of animals on confined feeding operations with approximately 39,080 animals housed in CFOs. This subwatershed is also the only one where beef cattle are housed and contains the highest number of sows in farrowing. The Little Deer Creek subwatershed also contains nursery pigs (6,880), finishing pigs (14,378), sows (978), swine greater than 55 lbs (8,900), and swine less than 55 lbs (1,200). CFO permits allow for distribution of manure on approximately 9,553 acres or 27% of the subwatershed. Estimated conservatively, the livestock in this subwatershed produce upwards of 44 thousand tons of manure per year. Hypothetically, if this manure were applied entirely to the 9,553 acres of permitted receiving land, total Nitrogen and Phosphorus Pentoxide loads would not exceed recommended fertilizer rates (conservatively estimated for maximum yield and averaged across corn and soy crops) (Sutton et al., 2001).

Municipal sludge is being applied to 4,840 acres or 14% of the subwatershed. The sludge is transported from three facilities located outside the Deer Creek-Sugar Creek watershed including the Grissom Redevelopment Authority, Merrell Bros Regional Bio-solids Center, and Walton Municipal STP and from two facilities within the watershed: the A. E. Staley Manufacturing Company and the Flora Municipal STP. Livestock have access to approximately 8.4 miles of stream within the subwatershed. Streambank erosion and the need for stream buffering are also of concern within the Little Deer Creek subwatershed. In total, 14.6 miles of stream buffers and 12 miles of streambank stabilization are needed within the subwatershed.

4.4.5 Water Quality Assessment

Waterbodies within the Little Deer Creek subwatershed were sampled at three locations by IDEM (Figure 74). Harrison-Harlan Ditch in Howard County on County Road 600 West was sampled for fish and macroinvertebrate communities and nutrients and field chemistry. IDEM sampled two sites on Little Deer Creek in Carroll County. Little Deer Creek at County Road 600 East was sampled as part of the rotational basin assessment and the macroinvertebrate community was evaluated. IDEM also evaluated the fish and macroinvertebrate communities, as well *E. coli* at Little Deer Creek at County Road 300 North. As part of the current planning project, Purdue University sampled water chemistry at Little Deer Creek at State Road 29 (site LDU6) and at County Road 300 North (site LDD7) Figure 45. Sampling for water chemistry occurred biweekly for one year (26 samples), while fish and macroinvertebrates were surveyed twice and habitat assessed once from August 2012 through August 2013.

Water Chemistry

E. coli was sampled five times over a 30 day period at Harrison-Harlan Ditch at County Road 600 West during September and October of 2008. *E. coli* levels exceed the state standard during all five assessments with concentrations ranging from 307.6 to 1,414 colonies/100 mL. In 2003, *E. coli* was measured by IDEM in Little Deer Creek at County Road 300 North. *E. coli* concentrations exceeded the state standard during five of the six sampling events; however, one of the duplicates collected on September 16th (209.8 colonies/100 mL) measured below the state standard. The remaining samples ranged from 365.4 to 1,414 colonies/100 mL. As part of IDEM's watershed assessment, Little Deer Creek at County Road 600 East was sampled in July 1998. Atrazine and metolachlor both were measured at 0.4 µg/L. Nitrogen, as nitrate and nitrite, measured 6.7 mg/L which is more than three times the standard (2 mg/L) suggested by Dodds et al. (1998).

In total, 17 field measurements and 23 samples were collected at Little Deer Creek at State Road 29 (LDU6). All temperature, conductivity, dissolved oxygen, and dissolved oxygen measurements were within standards or recommendations. One pH measured at the high end of the state standard range (9) suggesting high photosynthesis rate within the stream during the December 2012 sampling event. Turbidity measured above recommended levels during 11 of 17 assessments measuring from 12.9 to 309 NTU. Most high turbidities occurred during elevated flow conditions. Nitrate-nitrogen concentrations exceeded the target (2.0 mg/L; Dodds, 1998) during 13 of 21 sampling events. Most of these exceedances occurred during 2013. This is likely due to the severe drought conditions which occurred through the Deer Creek-Sugar Creek watershed in 2012. Nitrate-nitrogen was held by plants or within the soil until the soil was saturated. When the ground was sufficiently saturated, runoff carried excess nitrate-nitrogen not used within the system into adjacent streams. Concentrations exceeded the state drinking water standard (10 mg/L) during five events measuring as high at 14.3 mg/L. Total phosphorus concentrations exceeded the 0.08 mg/L target during 11 of 22 sampling events with concentrations measuring as high as 1.42 mg/L in January 2013. Total suspended solids concentrations measured above target levels during 5 of 22 sampling events measuring as high as 159 mg/L. *E. coli* concentrations measured above the state standard during 14 of 23 sampling events. Concentrations in exceedance ranged from 281 cfu/100 mL to 1733 cfu/100 mL. During the more typical flow conditions observed in 2013, *E. coli* concentrations never measured below the standard.

Little Deer Creek at County Road 300 North (LDD7) exhibited similar conditions to Little Deer Creek at State Road 29 during the sampling period. Temperature, conductivity and dissolved oxygen measured within standards or recommendations throughout the sampling period. pH measured above the state standard (9.0) during the December 2012 sampling event. This suggests that high levels of photosynthesis occurred in the stream during this sampling event. Turbidities exceeded targets during 11 of 17 sampling events ranging from 10.9 to 104 NTU while in exceedance. Like Little Deer Creek at SR 29, nitrate-nitrogen concentrations in Little Deer Creek at CR 300 North exceeded targets during 16 of 23 sampling events with all exceedances occurring in 2013 under more typical flow conditions. Nitrate-nitrogen concentrations exceeded the state drinking water standard (10 mg/L) during four sampling events with concentrations as high as 13.8 mg/L. Total phosphorus concentrations exceeded the 0.08 mg/L target during 11 of 24 sampling events with concentrations in excess ranging from 0.083 to 1.45 mg/L. Total suspended solids concentrations measured in excess of targets during 10 of 24 sampling events. As with the downstream site, TSS exceedances typically occurred under high flow conditions and coincided with elevated turbidity measurements. TSS concentrations in excess of the target ranged from 17 to 442 mg/L. *E. coli* concentrations measured above the state standard during 13 of 24 sampling events with concentrations in excess ranging from 248 cfu/100 mL to 1986 cfu/100 mL.

Habitat

IDEM used the QHEI to evaluate habitat at the same three sites detailed above during five assessments. Little Deer Creek's habitat was assessed at two sites in Carroll County, Country Road 300 North and Country Road 600 East, while Harrison-Harlan Ditch was assessed at County Road 600 West in Howard County. Little Deer Creek at County Road 300 North was evaluated twice, once in 1991 and again in 2004. The QHEI at this site scored 79 and 77 in 1991 and 2004, respectively. Little Deer Creek at County Road 600 East was assessed once in 1998 scoring 87. These are the highest QHEI scores recorded within the watershed. The scores from the two Little Deer Creek sites suggest that the stream was fully in support of the aquatic life. The site located on Harrison-Harlan Ditch was evaluated twice, once in June2008 and again in July of 2008. The QHEI scores for this site suggest that the stream is not supporting of the aquatic life use designation scoring 43 and 27, respectively.

Little Deer Creek at State Road 29 (LDU6) and at County Road 300 North (LDD7) contained some of the highest quality habitat observed by Purdue University in 2012 scoring 65 and 74, respectively. Diverse instream habitat and well developed pool and riffle habitat characterized both sites. The most notable negative aspect of the QHEI was that the stream habitats were not as well developed and stable in the downstream site (LDD7). At the upstream site, the lower instream cover and channel morphology scores indicate unstable habitats.

Macroinvertebrates
The macroinvertebrate communities within the Little Deer Creek subwatershed were sampled three times by IDEM at the same sites detailed above. In 1991 and 2004, IDEM assessed the macroinvertebrate community in Little Deer Creek at County Road 300 North. In 1991, the macroinvertebrate community rated as slightly impaired scoring 4.2 using the old scoring method. However, in 2004 the macroinvertebrate community rated as moderately impaired with a score of 38 using the new scoring method. The community was dominated by *Elmidae* and *Hetaerinaamericana* in 1991 and 2004, respectively. *Elmidae* is a riffle beetle that is intolerant to pollution while *Hetaerinaamericana* is a dragonfly that is moderately tolerant to pollution. In 1998, IDEM assessed the macroinvertebrate community of Little Deer Creek at County Road 600 East. During this assessment, the community rated as slightly impaired scoring 5.6 using the old scoring method. The dominant specie was *Elmidae*. The macroinvertebrate community at Harrison-Harlan Ditch was sampled in 2008. The site rated as very poor and scoring 30 using the new mIBI scoring method. The dominate species collected was *Physella*, a freshwater snail which is very tolerant of pollution.

Purdue University assessed the macroinvertebrate community in Little Deer Creek at State Road 29 (LDU6) and County Road 300 North (LDD7) in 2012. The community near Little Deer Creek's mouth (LDD7) contained a high quality macroinvertebrate community with very high taxa richness. Most of the taxa observed at this site are considered intolerant to degraded conditions. The macroinvertebrate community present in Little Deer Creek at State Road 29 contained a species with modest species richness including taxa that are typically indicative of higher quality instream conditions. At the upstream site (LDU6), the mIBI score was the highest observed (54), in part reflecting the especially high benthic taxa richness (at least 82) compared to most sites. Most taxa present are considered to be intolerant of degraded conditions.

Fish
IDEM assessed the fish communities in the Little Deer Creek subwatershed twice. The first assessment occurred in 1998 at County Road 600 East in Carroll County and IDEM assessed a second site in 2008 at County Road 600 West in Howard County. During the 1998 assessment, the dominant species was the central stoneroller. The IBI score measured 40 during this assessment, which is rated as fair. In 2008, the fish community of Harrison-Harlan Ditch, a tributary of Little Deer Creek was assessed. The striped shiner was the dominant species and the IBI score was 46, which is rated as fair to good.

Purdue University assessed the macroinvertebrate community in Little Deer Creek at State Road 29 (LDU6) and County Road 300 North (LDD7) in 2012. In general, fish IBIs rated relatively moderately scoring 40 and 34, respectively. Little Deer Creek at State Road 29 contained a more modest number of species and lower numbers of sunfish and sucker species. The fish community in Little Deer Creek at State Road 29 rated as fair, while the fish community in Little Deer Creek at County Road 300 North rated as fair.

Mussels

The INDR surveyed the mussel communities at five locations within the Little Deer Creek subwatershed. Two sites were located in Carroll County at State Road 29 and County Road 325 East, while three were in Cass County at County Road 100 East, County Road 400 East, and County Road 700 East. At the State Road 29 site, a total of 17 species were identified; 13 species were found alive, two as fresh dead, and one of each weathered dead and subfossil shell material. At the Carroll County County Road 325 East site, 25 species of mussels were identified. Sixteen species were found alive, five as fresh dead and four as weathered dead shell material. Twenty species of mussels, twelve live, six fresh dead, and two weathered dead were identified at the County Road 100 East in Cass County. The site located on County Road 400 East contained 18 species of mussels; 14 live, three weathered dead, and one fresh dead shell material. The County Road 700 East site contained15 species of mussels and seven were found alive. The remaining mussels were found as weathered dead (5), subfossil (2), and fresh dead (1) shell material. All five of the sites contained at least two state species of special concern, the wavy-rayed lampmussel and purple lilliput. A third species of special concern, the kidneyshell, was found at all sites except at Deer Creek at County Road 700 East.

4.4.6 Little Deer Creek Subwatershed Summary

Little Deer Creek subwatershed is the largest subwatershed comprised of 90% agricultural land use and has the lowest urban land use percentage at 5.2% of the subwatershed. Highly erodible soils and potentially highly erodible soils make up roughly 9% of the soil portrait in the subwatershed. These soils are typically found alongside Little Deer Creek. Though temperature, conductivity and dissolved oxygen were all within standards for the sampling period, pH was elevated in two of the three sampling locations. This could suggest that increased levels of photosynthesis were occurring at the time of sampling. This subwatershed had varied results in terms of overall water quality. Two of the sites had the highest habitat assessment scores in the watershed, while Harrison-Harlan Ditch sampling site had one of the lowest. In addition, high taxa richness and species diversity were observed at the two locations other than Harrison-Harlan Ditch. Measurements suggested Harrison-Harlan Ditch also had a majority of high-tolerance macroinvertebrate communities, reinforcing the assumption that the water quality is relatively impaired at this location. Despite major discrepancies among the habitat assessments and macrointertebrate populations, the fish communities were more or less similar and all three were given a fair score. Turbidity, nutrient levels and pathogens were in exceedance in close to 50% of the samples and measurements.

4.5 Paint Creek

The Paint Creek subwatershed is located immediately north of the Deer Creek-McCloskey Ditch subwatershed forming the northern boundary of the watershed in eastern Carroll County. The majority of its drainage area is located in Carroll County with a small section in Cass County. The Paint Creek subwatershed includes the Town of Camden. The watershed includes two 12-digit watersheds, Paint Creek (051201050504) and

Monson Ditch-Deer Creek (051201050507) and drains 18,866 acres or 29 square miles. In total, 34.7 miles of stream are present within the Paint Creek subwatershed. Of these, approximately 19.4 miles are considered impaired for *E. coli* and 5.9 miles are considered impaired due to PCBs and mercury in fish tissue (Figure 77; IDEM, 2012).

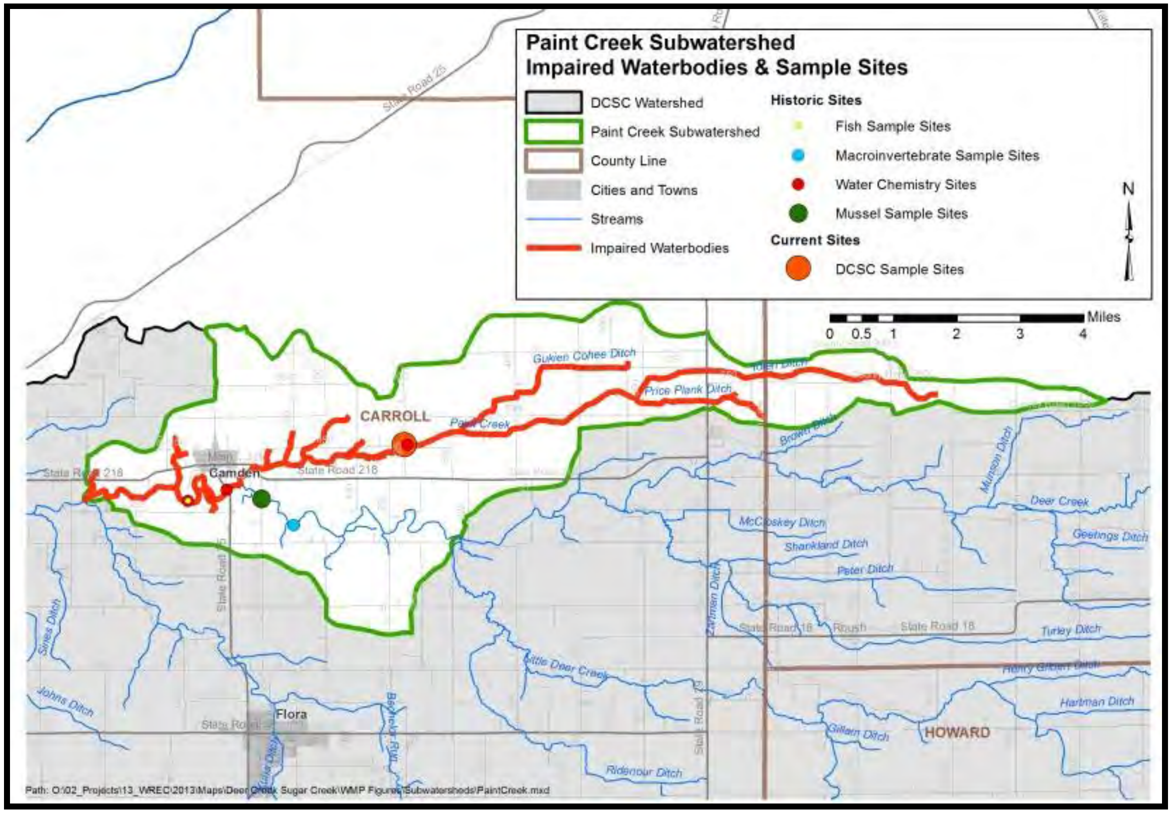

Figure 77. Impaired waterbodies and sample sites in the Paint Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.5.1 Soils

The Paint Creek subwatershed has the second highest percentage of soil that is suitable for septic treatment, approximately 17% or 3,175 acres. However, the remaining 82% of the subwatershed is classified as severely limited and is unsuitable for septic treatment. Approximately 34% of the Paint Creek subwatershed is hydric soil. Potentially highly erodible soils cover 12% of the subwatershed and are primarily located around the mainstem of Deer Creek and where Paint Creek enters Deer Creek (Figure 78).

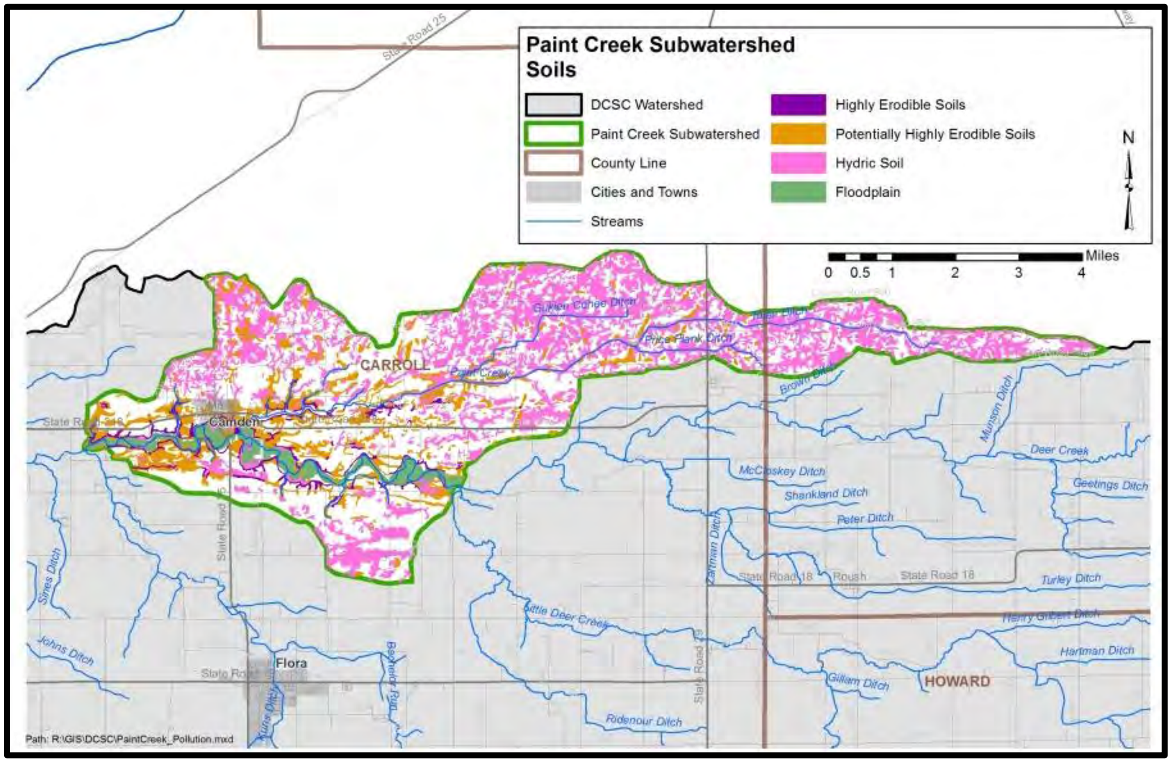

Figure 78. Properties of soils located in the Paint Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.5.2 Land Use

Agriculture is the dominate land use in the Paint Creek subwatershed accounting for 89% of the land use. Urban land uses, including the Town of Camden, accounts for 6.3% of the subwatershed land use. Forest and wetland land uses account for 7% of the subwatershed, while open water comprises less than 1% of the subwatershed's land use.

4.5.3 Point Source Water Quality Issues

Approximately 85% of the Paint Creek subwatershed is in agricultural land uses. There is one NPDES-permitted facility located within the subwatershed, the Camden Municipal STP (Figure 79). The Town of Camden operates a sewage treatment plant which serves the town's 615 residents. In total, the plant treats 0.06 million gallons per day (MGD), which is treated at the secondary level, and is then discharged into Deer

Creek (USEPA, 2008). Two LUSTs are located throughout the subwatershed. There are no brownfields, industrial waste, or open dumps within the Paint Creek subwatershed.

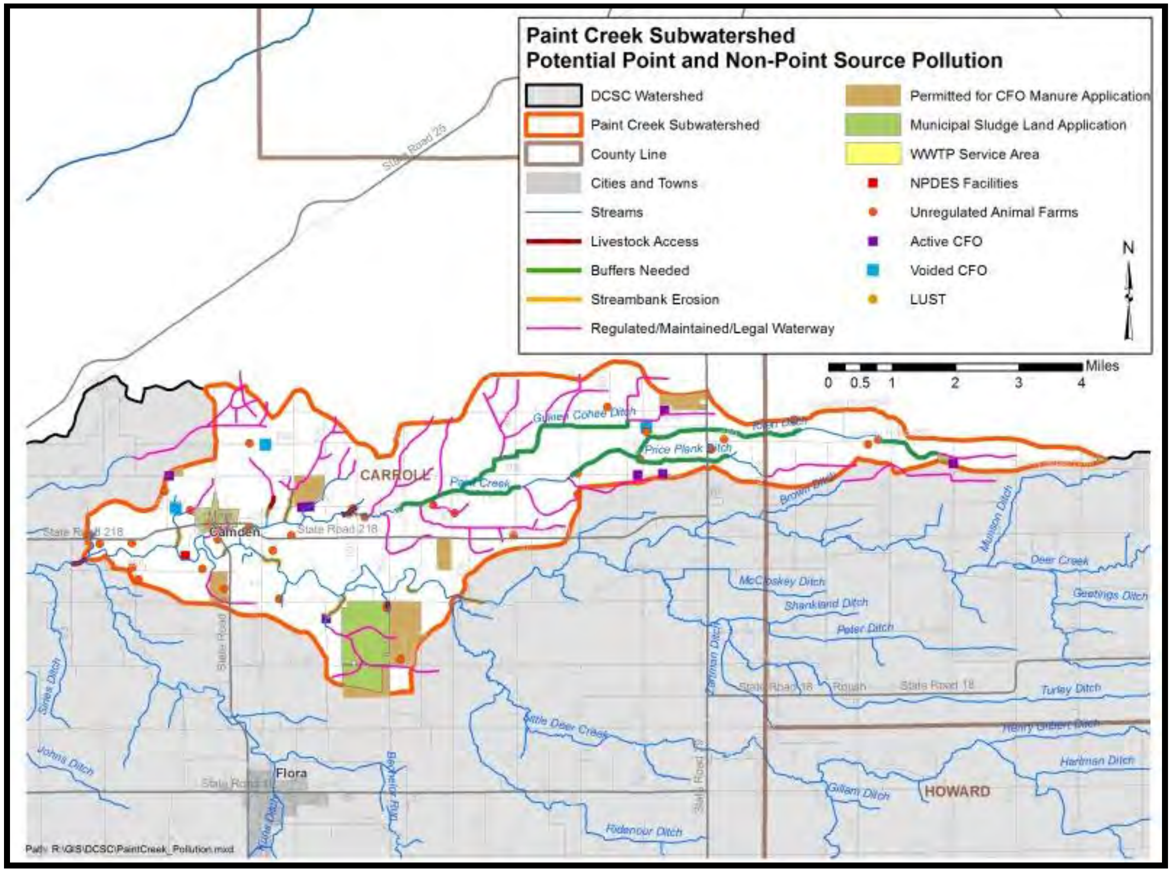

Figure 79. Point and non-point sources of pollution in the Paint Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.5.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the Paint Creek subwatershed and a corn-soybean rotation predominates in these areas. A number of unregulated animal farms are located within the Paint Creek subwatershed. Approximately, 141 cattle, 28 hogs, 50 sheep, 60 goats, and 32 horses are located on 33 farms. There are eight active CFOs within the subwatershed. The Paint Creek subwatershed contains approximately

11,082 animals housed in the CFOs. There are 6,050 nursery pigs, 4,650 finishing pigs, and 382 sows. The CFO manure is being distributed on approximately 488 acres. CFO permits allow for distribution of manure on approximately 488 acres. Estimated conservatively, the livestock in this subwatershed produce upwards of 9 thousand tons of manure per year. Hypothetically, if this manure were applied entirely to the 488 acres of permitted receiving land, total Nitrogen and Phosphorus Pentoxide loads would exceed recommended fertilizer rates (conservatively estimated for maximum yield and averaged across corn and soy crops) (Sutton et al., 2001).

In the Paint Creek subwatershed, municipal sludge is applied to 627 acres; the majority of the sludge is applied southwest of Camden. The only industry that is permitted to apply municipal sludge within the Paint Creek subwatershed is the Grissom Redevelopment Authority. Livestock have access to approximately 1.2 miles of stream within the subwatershed. Streambank erosion and the need for stream buffering are also of concern within the Paint Creek subwatershed. In total, 24.2 miles of stream buffers and 5.7 miles of streambank stabilization are needed within the subwatershed.

4.5.5 Water Quality Assessment

Within the Paint Creek subwatershed, samples have been collected at five locations within Carroll County (Figure 77). Three of the sites were located on the mainstem of Deer Creek, while two were located on Paint Creek. Historic assessments included the collection of *E. coli*, fish, and macroinvertebrates by IDEM and mussel communities by the IDNR. *E. coli* samples were collected in Paint Creek at County Road 225 East and in Deer Creek at County Road 300 North, Cemetery Road, and State Road 75. The fish and macroinvertebrate communities were also assessed in Deer Creek at County Road 300 North, while only fish were sampled in Deer Creek at Cemetery Road. The mussel community of Deer Creek was surveyed at County Road 00 in Carroll County. As part of the current planning project, Purdue University sampled water chemistry in Paint Creek at County Road 450 North (site PC5, Figure 45) biweekly for one year (26 samples), while fish and macroinvertebrates were surveyed twice and habitat assessed once from August 2012 through August 2013.

Water Chemistry

As part of the basin assessment program performed by IDEM, three sites within the Paint Creek subwatershed were sampled and only additional site was sampled for *E. coli.* In 1998, a variety of water chemistry parameters were assessed in Paint Creek located on County Road 225 East; concerning parameters include pesticides, nitrogen, and total phosphorus. A variety of pesticides measured above the detection limit including atrazine, clomazone, and metolachlor. Atrazine levels were at or exceed the maximum contaminant level (MCL) for finished drinking water (0.3 µg/L).The MCL for finished drinking water is used as a guide since there is not a standard for surface water. Nitrogen and total phosphorus measured higher than suggested standard concentration. Nitrogen measured more than three times the suggested standard at 6.2 mg/L and total phosphorus was measure approximately 0.04 mg/L greater than the standard at0.12 mg/L. In 2003, Deer Creek at County Road 300 North and at Cemetery Road were sampled as part of the basin assessment for various water chemistry parameters. The only parameter of concern for both sites was nitrogen. In Deer Creek at County Road 300 North in Carroll County, nitrogen concentrations exceed the suggested standard during every sampling event with concentrations ranging from 2.4 to 3.5 mg/L. In Deer Creek at Cemetery Road, nitrogen concentrations also exceeded the standard during every sampling event. Concentrations ranged from 2.5 to3.7 mg/L. In 2003, *E. coli* concentrations were measure five times over a 30-day period in Deer Creek at State Road 75.*E. coli* concentrations exceed the state of Indiana's standard during three of the five times with concentrations ranging from 308 to 1,203 colonies/100mL.

In total, 18 field measurements and 25 samples were collected in Paint Creek at County Road 450 North (PC5). All temperature, conductivity, and pH measurements were within standards or recommendations. One dissolved oxygen sample in August 2012 measured below the detection level. Turbidity measured above recommended levels during 12 of 18 assessments measuring from 10.9 to 67.1 NTU. Most high turbidities occurred during elevated flow conditions. Nitrate-nitrogen concentrations exceeded the target (2.0 mg/L; Dodds, 1998) during 15 of 23 sampling events. All of these exceedances occurred during 2013. This is likely due to the severe drought conditions which occurred through the Deer Creek-Sugar Creek watershed in 2012. Nitrate-nitrogen was held by plants or within the soil until the soil was saturated. When the ground was sufficiently saturated, runoff carried excess nitrate-nitrogen not used within the system into adjacent streams. Concentrations exceeded the state drinking water standard (10 mg/L) during six events in January, February, March, April, and June 2013 measuring as high as 17.9 mg/L. Total phosphorus concentrations exceeded the 0.08 mg/L target during 11 of 25 sampling events with concentrations measuring as high as 1.69 mg/L in January 2013. Total suspended solids concentrations measured above target levels during 4 of 25 sampling events. Exceedances generally coincided with elevated turbidity measurements and high flow events with concentrations ranging from 17.2 to 504 mg/L. *E. coli* concentrations measured above the state standard during 19 of 25 sampling events. Concentrations in exceedance ranged from 275 cfu/100 mL to 2196 cfu/100 mL. Nitrate-nitrogen and total suspended solids concentrations in Paint Creek were the second highest average concentrations at all sites within the Deer Creek-Sugar Creek watershed.

Habitat

In 2003, habitat was assessed three times by IDEM and once by Purdue University within the Paint Creek subwatershed using the QHEI. Deer Creek at County Road 300 rated as excellent with a score of 95. Deer Creek at Cemetery Road was sampled twice on back-to-back days in August 2003. The QHEI scored 95 on the first day and dropped to 87 on the second day. Paint Creek at County Road 450 North (PC5) rated 55.5. All four scores suggest that the waterbodies within the Paint Creek subwatershed are fully supporting the designated aquatic life uses. During the most recent assessment, the overall QHEI score (56) was on the low side of good, and bank erosion and riparian development at the site are both poor. Further, there was little to no development of riffle and run habitat.

Macroinvertebrates

The macroinvertebrate community within the Paint Creek subwatershed was sampled once by IDEM and once by Purdue University. Sampling occurred once in at Deer Creek at County Road 300 North by IDEM and once by Purdue University in Paint Creek at County Road 450 North (PC5). The Deer Creek macroinvertebrate community rated as moderately impaired rating a mIBI score of 2.4. The community was dominated by other *Chironomidae* whose tolerance for pollution ranges from fairly tolerant to very tolerant. The Paint Creek macroinvertebrate community was dominated by very tolerant taxa and contained low taxa richness. The community rated very poor. The mIBI score (40) was moderate compared to all other sites, although the benthic community was very taxa poor (at least 17) and dominated by taxa that are more typical of low quality sites.

Fish

IDEM assessed the fish communities of Deer Creek within the Paint Creek subwatershed three times at two locations during 2003. Sampling occurred once at County Road 300 North and twice at Cemetery Road. IBI scores ranged from 48 to 50 during all three events indicating a good fish community that is diverse, contains many trophic levels, and possesses pollution intolerant species. The most prevalent species at the Cemetery Road site was the longear sunfish, while the black redhorse was most prevalent at the County Road 300 North site.

Purdue University assessed the fish community in Paint Creek at County Road 450 North in 2012. The community contained low numbers of suckers, high percentages of tolerant species and low percent pioneer species. This site tied for the second lowest IBI score (34) and overall contained one of the poorest communities. The percent tolerance was elevated with tolerant species comprising 31% of the community in this reach of Paint Creek.

Mussels

The IDNR surveyed the mussel community at one site within the Paint Creek subwatershed. The site was located on Deer Creek at County Road 00. A total of 18 species were identified at this site; 16 were found dead as weathered dead (8), fresh dead (4), or subfossil (4) shell material and two species were found alive. Three state species of special concern were identified at this location. Weathered dead shell material of the wavy-rayed lampmussel and the purple lilliput and subfossil shell material of the kidney shell were collected.

4.5.6 Paint Creek Subwatershed Summary

Paint Creek subwatershed is comprised of 89% agricultural lands. Urban land usage is the second most prevalent practice, as it forms 6.3% of the remaining land and includes the Town of Camden. Highly erodible soils cover 12% of the subwatershed and are typically located alongside the mainstem of Deer Creek in addition to where Paint Creek enters Deer Creek. All temperature, conductivity, pH, and dissolved oxygen measurements were within standards or recommendations. Problem areas for Paint Creek subwatershed include turbidity and *E. coli*, which exceeded targets in close to 50% of the samples and measurements. Additional concerns include nitrogen and pesticides. Nitrogen levels were measured at three times the suggested standard in one event, and were measured above the suggested standard in all sampling events. Three pesticides also tested above the maximum containment level for drinking water in this subwatershed. Habitat assessments suggest that the waterbodies of Paint Creek are fully supporting aquatic life, though macroinvertebrate samples were dominated by very tolerant taxa and low taxa richness. Further fish samples reinforced the macroinvertebrate sample findings. This site tied for second for lowest mIBI score and contained one of the poorest macroinvertebrate communities in the watershed. Contrary to the macroinvertebrate data, the fish community scored high IBI numbers and contained high species richness and very intolerant fish species.

4.6 Bachelor Run

The Bachelor Run subwatershed is the most western subwatershed that drains into Deer Creek. It drains portions of Carroll and Howard counties. The Bachelor Run subwatershed forms part of the southern border of the Deer Creek-Sugar Creek watershed and includes the Town of Flora. The subwatershed includes two 12-digit watersheds, Headwaters Bachelor Run (051201050505) and Kuns Ditch-Bachelor Run (051201050506) and drains 23,032 acres or 36 square miles. In total, 25.4 miles of stream are present within the Bachelor Run subwatershed. Of these, approximately 16 miles have been listed on the 2012 draft 303(d) Impaired Waterbodies List for E. coli (Figure 80).

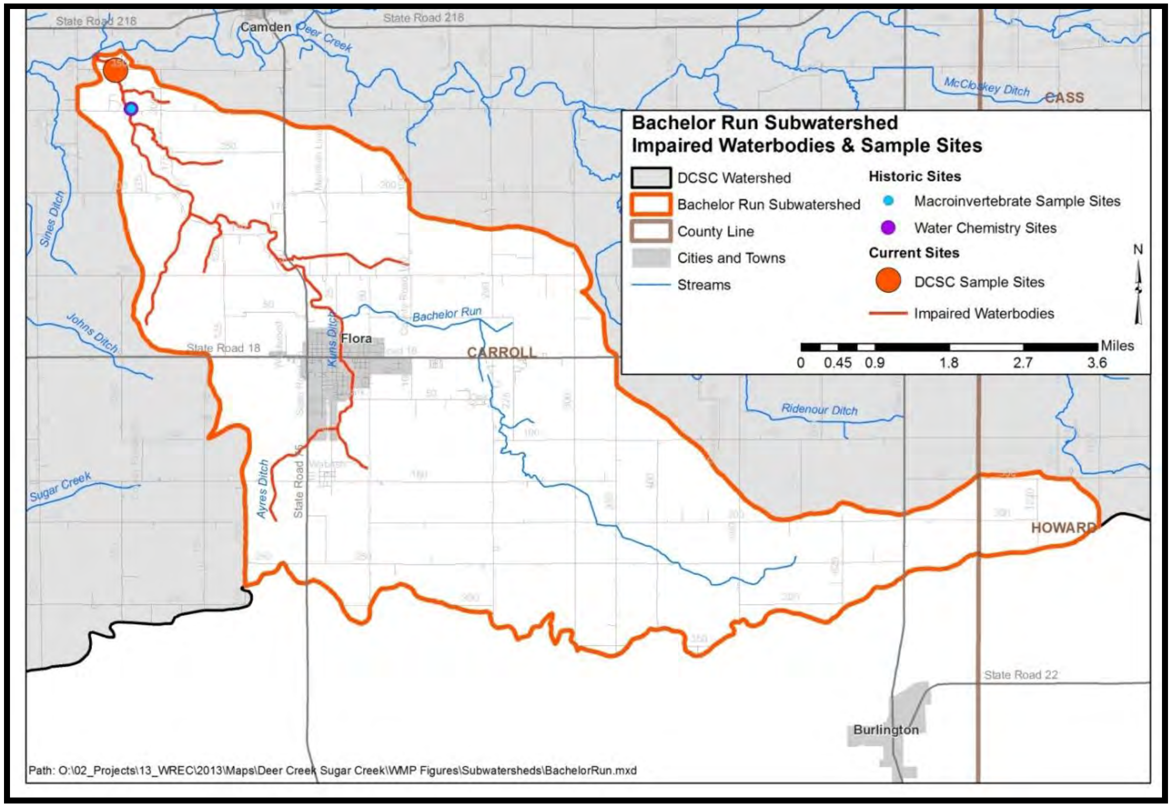

Figure 80. Impaired waterbodies and sample sites in the Bachelor Run subwatershed.

Data used to create this map are detailed in Appendix A.

4.6.1 Soils

Soils in the Bachelor Run subwatershed are dominated by areas formed under wetland conditions. In total, 8,263 acres or 35.8% of the subwatershed are covered by hydric soils. This indicates that the soils in the Bachelor Run subwatershed were historically in wetland uses. Currently, only 1% of the subwatershed is covered by wetlands; this suggests that less than 3% of historic wetlands are still present in the Bachelor Run subwatershed. Highly erodible soils cover 320 acres or 1.4% of the Bachelor Run subwatershed; this is the lowest percentage of highly erodible soils in the ten subwatersheds (Figure 81). The highly erodible soils are primarily located along Bachelor Run and Kuns Ditch.

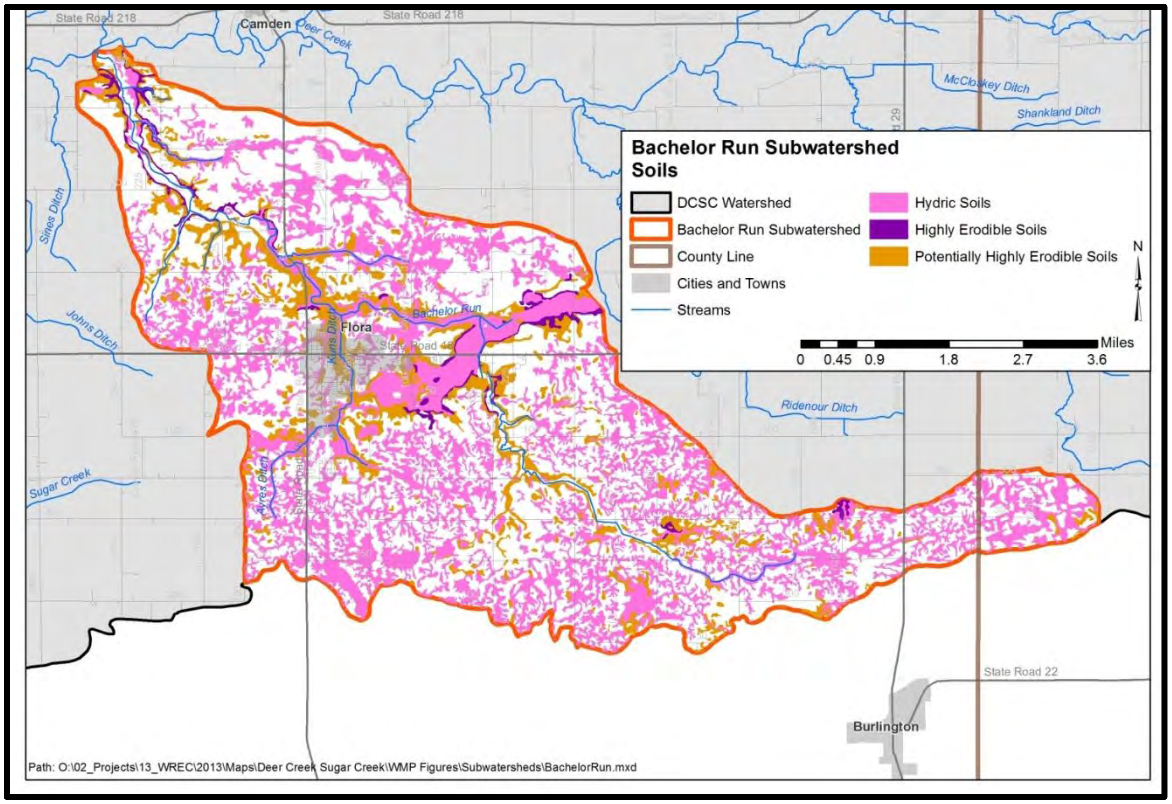

Figure 81. Properties of soils located in the Bachelor Run subwatershed.
Data used to create this map are detailed in Appendix A.

4.6.2 Land Use

Agriculture land uses dominate the Bachelor Run subwatershed. Cultivated crops and pasture/hay account for 87% of land use. Urban land uses including the Town of Flora account for 7.8% of the subwatershed land use. Forest and wetland land uses account for only 3% of the subwatershed, while open water covers less than 0.1% of the Bachelor Run subwatershed.

4.6.3 Point Source Water Quality Issues

As detailed above, much of the Bachelor Run subwatershed is in agricultural land uses. Three NPDES-permitted facilities are located within the subwatershed (Figure 82). Two of the sites service the Town of Flora, Flora Municipal STP and the Flora Water Works. The Flora Municipal STP serves the town's approximately 2,227 residents. In total, the plant treats 0.428 MGD, which is treated at the secondary level, and is then discharged into Bachelor Run, while the Flora Water Works discharges into Kuns Ditch (USEPA 2008). The third NPDES-permitted facility is the Briggs Industries, INC (SAYCO); this facility discharges to the Flora Municipal STP. Seven leaking underground storage tanks (LUST) are located within the Town of Flora. There are also two brownfields are located on or adjacent to State Road 18 in Flora. Additionally, there is also an industrial waste site located on State Road 75 within the limits of the Town of Flora.

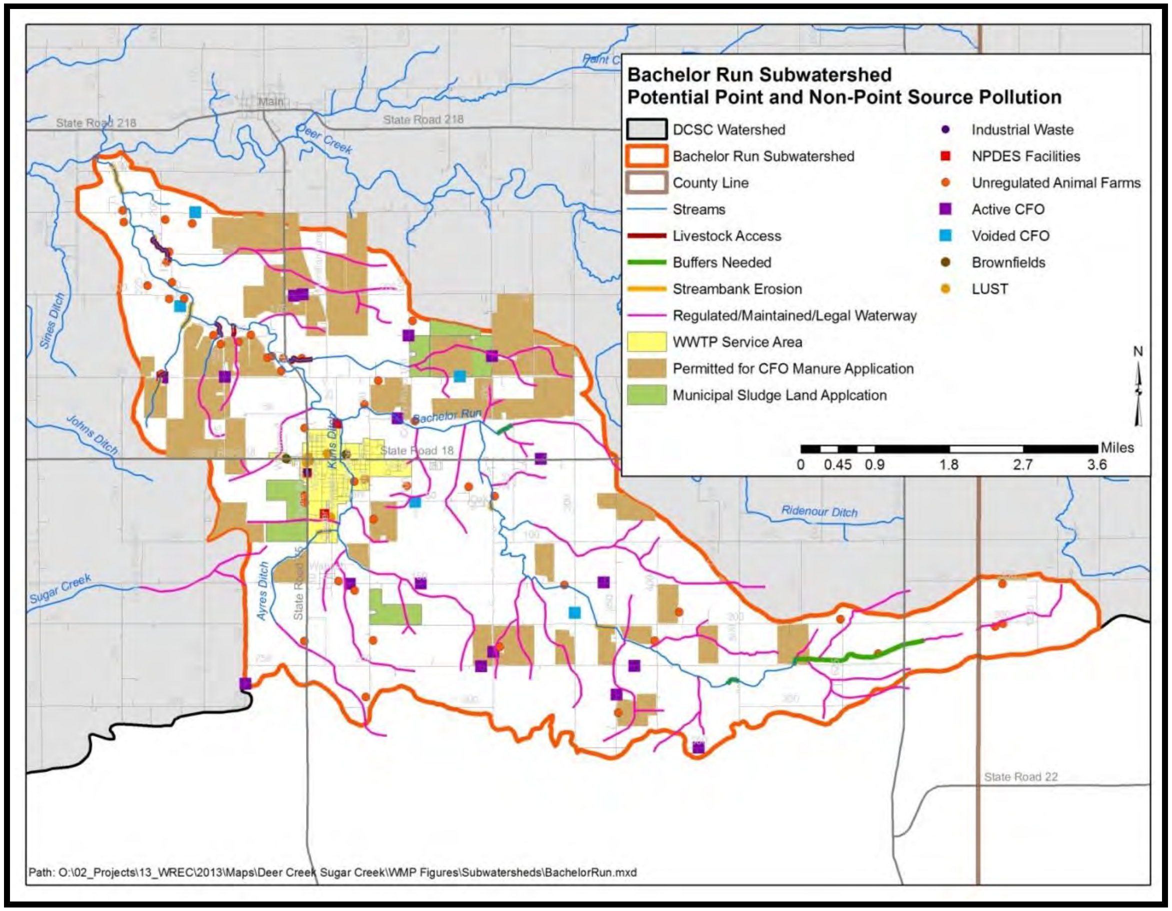

Figure 82. Point and non-point sources of pollution in the Bachelor Run subwatershed.
Data used to create this map are detailed in Appendix A.

4.6.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the Bachelor Run subwatershed and a corn-soybean rotation predominates in these areas. A number of unregulated animal farms are located within the Bachelor Run subwatershed. Approximately, 184 cattle, 30 hogs, 51 sheep, 31 goats, and 55 horses are located on 47 farms. Agricultural land uses dominates the Bachelor Run subwatershed and a corn-soybean rotation predominates in the agricultural land use. Additionally, 17 CFOs are scattered throughout the subwatershed. The CFOs in the Bachelor Run subwatershed contain approximately 28,025 animals. The remaining animals are nursery pigs (2,820), sows (744), and swine greater than 55 pounds (21,800). The CFO manure is being distributed on approximately 1,938 acres. CFO permits allow for distribution of manure on approximately 1,938 acres. Estimated conservatively, the livestock in this subwatershed produce upwards of 55 thousand tons of manure per year. Hypothetically, if this manure were applied entirely to the 1,938 acres of permitted receiving land, total Nitrogen and Phosphorus Pentoxide loads would exceed recommended fertilizer rates (conservatively estimated for maximum yield and averaged across corn and soy crops) (Sutton et al., 2001).

Livestock have access to approximately 2.4 miles of stream within the subwatershed. Streambank erosion and the need for stream buffering are also of concern within the Bachelor Run subwatershed. In total, 4.2 miles of stream buffers and 3 miles of streambank stabilization are needed within the subwatershed.

4.6.5 Water Quality Assessment

Within the Bachelor Run subwatershed, IDEM assessed water quality at one location, County Road 300 North. Historic assessments included the collection of *E. coli* and macroinvertebrates. *E. coli* was sampled five times from September to October in 2003. Macroinvertebrates were sampled twice, once in 1991 and again in 1998. As part of the current planning project, Purdue University sampled water chemistry in Bachelor Run at County Road 350 North (site BR4, Figure 45) biweekly for one year (26 samples), while fish and macroinvertebrates were surveyed twice and habitat assessed once from August 2012 through August 2013.

Water Chemistry

E. coli concentrations measured in excess of the state standard for more than 50% of samples collected at Bachelor Run. Dissolved oxygen, total coliform, pH, specific conductivity, temperature, and turbidity were also measured when samples were collected for *E. coli* analysis. Turbidity was the only parameter that exceeded the target level during one of the four sampling events.

In total, 18 field measurements and 26 samples were collected at Bachelor Run at County Road 350 North (BR4). All temperature, conductivity, and dissolved oxygen measurements were within standards or recommendations. Two pH samples measured outside the state standard range (9.0 mg/L) suggesting that high levels of photosynthesis occurred during the December 2012 and April 2013 sampling events. Turbidity measured above recommended levels during 11 of 18 assessments measuring from 12.8 to 150 NTU. The highest turbidity measurements occurred during elevated flow conditions. Nitrate-nitrogen concentrations exceeded the target (2.0 mg/L; Dodds, 1998) during 22 of 24 sampling events. Concentrations exceeded the state drinking water standard (10 mg/L) during seven events in January, February, March and June 2013 measuring as high as 15.9 mg/L. Total phosphorus concentrations exceeded the 0.08 mg/L target during 10 of 25 sampling events with concentrations measuring as high as 0.589 mg/L in March 2013. Total suspended solids concentrations measured above target levels during 7 of 26 sampling events. Exceedances generally coincided with elevated turbidity measurements and high flow events with concentrations ranging from 17.4 to 59.3 mg/L. *E. coli* concentrations measured above the state standard during 9 of 26 sampling events. Concentrations in exceedance ranged from 248 cfu/100 mL to 2187 cfu/100 mL.

Habitat

Habitat was assessed twice by the IDEM and once by Purdue University within the Bachelor Run subwatershed using the Qualitative Habitat Evaluation Index (QHEI). The QHEI scores habitat within a reach based on the presence or absence of specific characteristic. Streams with QHEI scores greater than 51 are considered to be fully supporting of their aquatic life use designation. IDEM assessments occurred in 1991 and 1998 with both conducted in Bachelor Run at County Road 300 North, while Purdue University assessed habitat at County Road 350 North (BR4). Scores of 48 and 57, respectively, indicate that the habitat in 1991 was not fully supporting the stream's designated aquatic life use; however, scores recorded in 1998 and 2012 indicate that the quality of habitat was good and the stream was supporting the designated aquatic life use. During the most recent assessment, the QHEI score (59) was good, although the channel morphology portion of the index was scored low, suggesting low microhabitat stability. There was also little instream cover at the site based on this portion of the QHEI.

Macroinvertebrates and Fish

The macroinvertebrate community within Bachelor Run was sampled twice by IDEM and once by Purdue University. IDEM sampling occurred once in 1991 and again in 1998 with both sampling events occurring at County Road 300 North; Purdue University sampling occurred in 2012 at County Road 350 North (BR4). The macroinvertebrate community rated as slightly impaired during both IDEM assessments scoring 4.6 and 4.2, respectively. The community was dominated by *Hydroptilidae*, a relatively-tolerant caddisfly family in 1991 and *Baetidae* (intolerant to pollution) and other *Chironomidae* (fairly-very tolerant to pollution) in 1998. The 2012 assessment utilized IDEM's new scoring method. The macroinvertebrate community was low in taxa richness, possessing 30 species of macroinvertebrates. Most identified taxa represented ubiquitous taxa that are common to sites of moderate water quality. The mIBI score was moderately high (48), although the benthic invertebrate community exhibited low taxa richness (at least 24) and there were only a few taxa considered to be typical of higher quality sites.

Purdue University assessed the fish community in 2012. The fish community rated fair scoring 36 points. Low numbers of suckers, high percentage of tolerant individuals and moderate species diversity suggest that the fish community in Bachelor Run is fair.

4.6.6 Bachelor Run Subwatershed Summary

Bachelor Run subwatershed is comprised of 87% agricultural land. Urban land use makes up 7.8% of the remaining land. The Town of Flora is situated in the middle of the subwatershed and contains 3 NPDES facilities and numerous other potential point source pollution sources. This subwatershed also has the greatest number of CFOs and regulated animals. Overall, temperature, conductivity, and dissolved oxygen measurements were within standards or recommendations. Two measurements of pH were elevated during two separate sampling events. This could suggest that photosynthesis was increased at the time of sampling. Additionally, turbidity was measured above state standards more than 50% of the sampling events. Nitrogen could be a cause of particular concern in this subwatershed. Of 24 sampling events, 22 samples measured nitrogen levels to exceed target levels. During seven sampling events, the nitrogen levels were found to exceed state drinking levels. Phosphorus, on the other hand, is not of particular concern in this subwatershed. Though Bachelor Run contains numerous points of pollution concern, it remains comparable, if not less impaired, than surrounding subwatersheds. The habitat was scored as slightly impaired due to a mix of not tolerant and high tolerance macroinvertebrates. The fish community reflects the macroinvertebrate community, as it also has a mix of moderate and tolerant species.

4.7 Deer Creek

The Deer Creek subwatershed represents the mainstem of Deer Creek, Robinson Branch, and these converge into the Wabash River. The Deer Creek subwatershed is located in the western portion of the watershed. The entire subwatershed's drainage area is located in Carroll County. The Deer Creek subwatershed includes the Town of Delphi. The subwatershed drains one 12-digit watershed, Robinson Branch-Deer Creek (051201050508) and covers 25,530 acres or 39 square miles. In total, 42.3 miles of stream are present within the Deer Creek subwatershed. Of these, approximately nine miles are considered impaired for *E. coli and* PCBs in fish tissue (Figure 83).

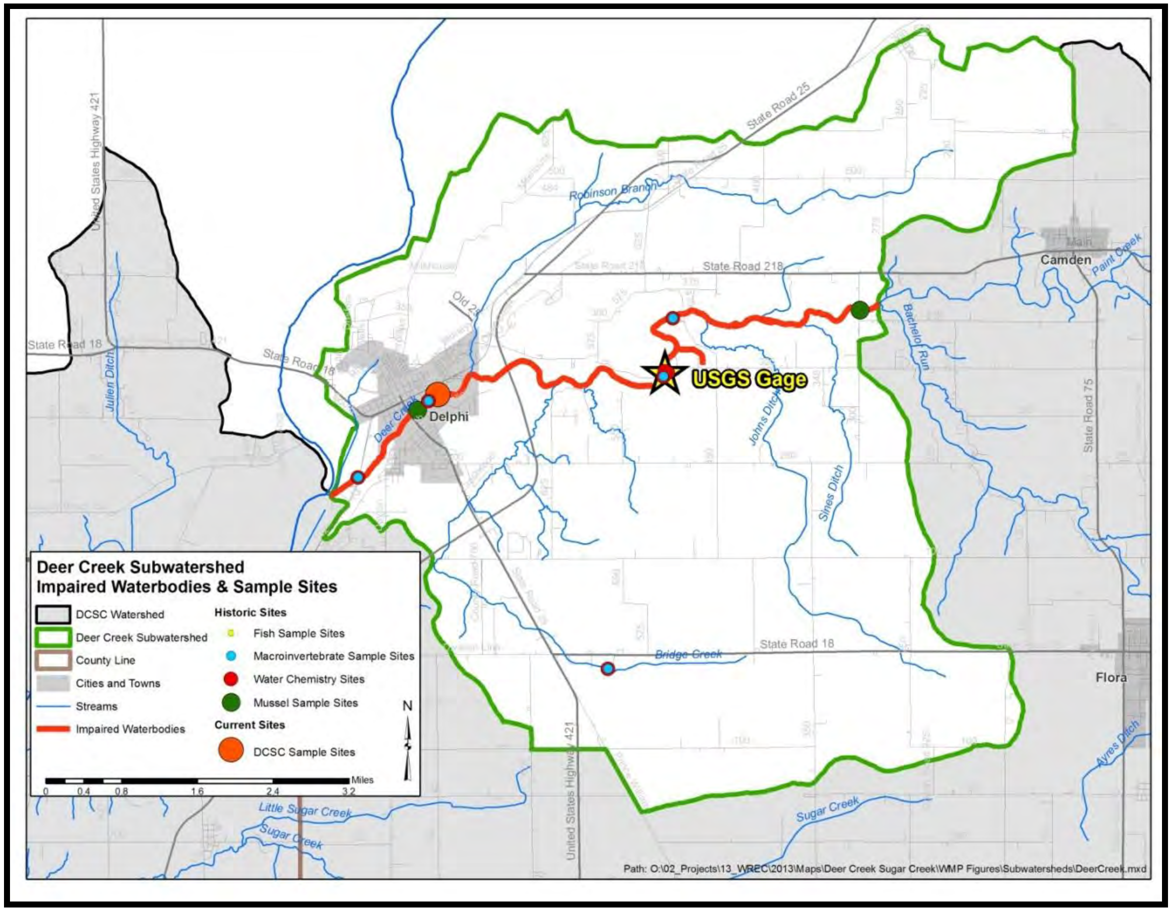

Figure 83. Impaired waterbodies and sample sites in the Deer Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.7.1 Soils

Hydric soils comprise approximately 23%, or 5,929 acres, of the Deer Creek subwatershed (Figure 84). The Deer Creek subwatershed has the lowest percentage of soils that are rated as severely limited for septic treatment, and has the highest percentage of soils that are only slightly impaired for septic treatment of the ten watersheds. Severely and slightly impaired soils for septic treatment cover 77% and 20% of the subwatershed, respectively. Highly and potentially highly erodible soils cover 1,845 and 5,394 acres (4.6% and 21.3%), respectively. The Deer

Creek subwatershed contains the highest percentage of potentially highly erodible soils in the watershed. These soils are primary located adjacent to Deer Creek and its tributaries.

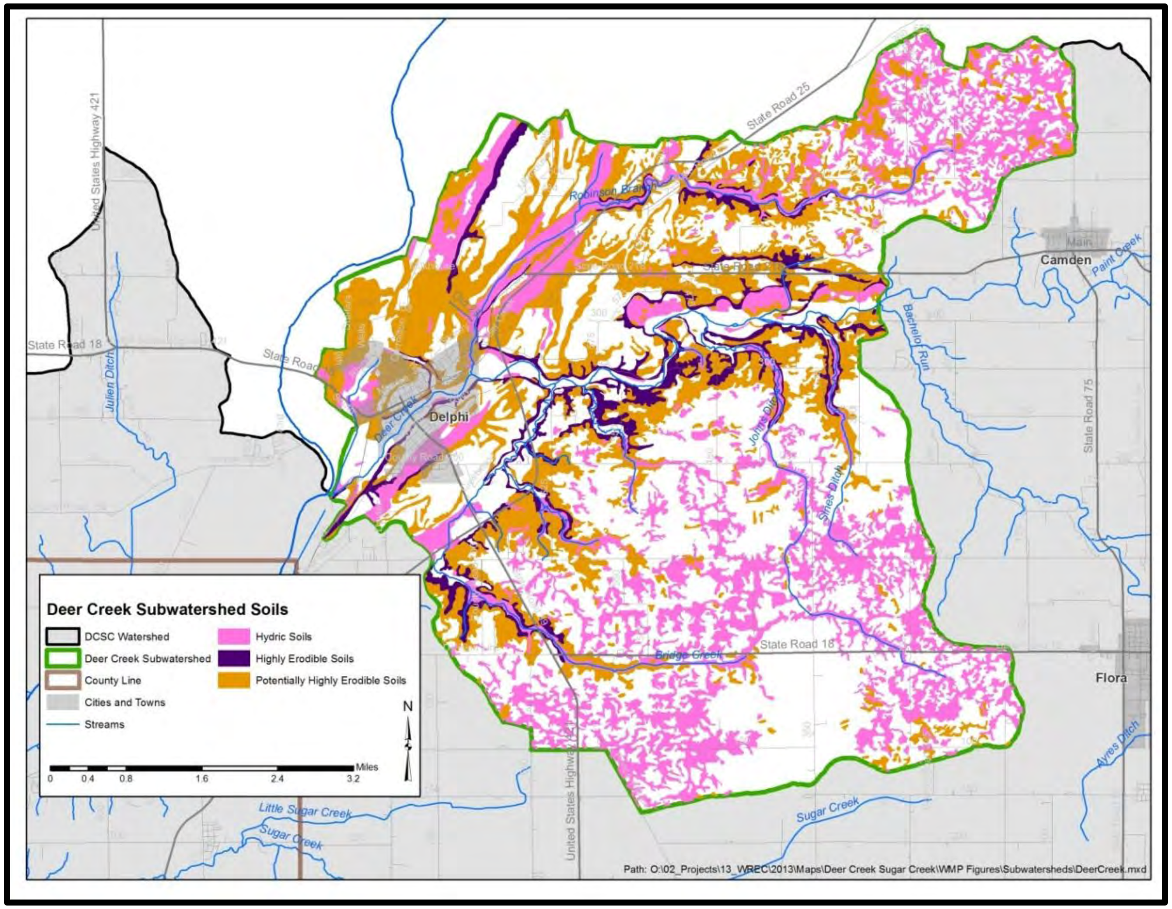

Figure 84. Properties of soils located in the Deer Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.7.2 Land Use

Agricultural land uses dominate the Deer Creek subwatershed. Agricultural land uses covers approximately 77% of the subwatershed. Developed or urban land uses, including the Town of Delphi, accounts for 10.3% or 2,625 acres of the subwatershed. Urban land uses within the subwatershed accounts for the highest percentage of any subwatershed. Natural areas comprise approximately 14% of the subwatershed, with forest accounting for 10.4% of the natural areas.

4.7.3 Point Source Water Quality Issues

As detailed above, the Deer Creek subwatershed is dominated by agricultural land uses. Two NPDES-permitted facilities are located within the subwatershed (Figure 85). The Town of Delphi operates the Delphi Municipal STP that serves the town's 3,015 residents. In total, the plant treats 0.4 MGD, which is treated at an advanced level, and is then discharged, into Deer Creek (USEPA, 2008). The second facility is the Indiana Packers Corporation located off Highway 421 South. This facility discharges into a tributary of Bridge Creek. Fifteen of the 34 LUST within the Deer Creek-Sugar Creek watershed are located within this subwatershed. There are also two industrial waste sites located on Washington Street southwest of Delphi. Additionally, there is one open dump and a brownfield located on County Road 625 West and State Road 18, respectively.

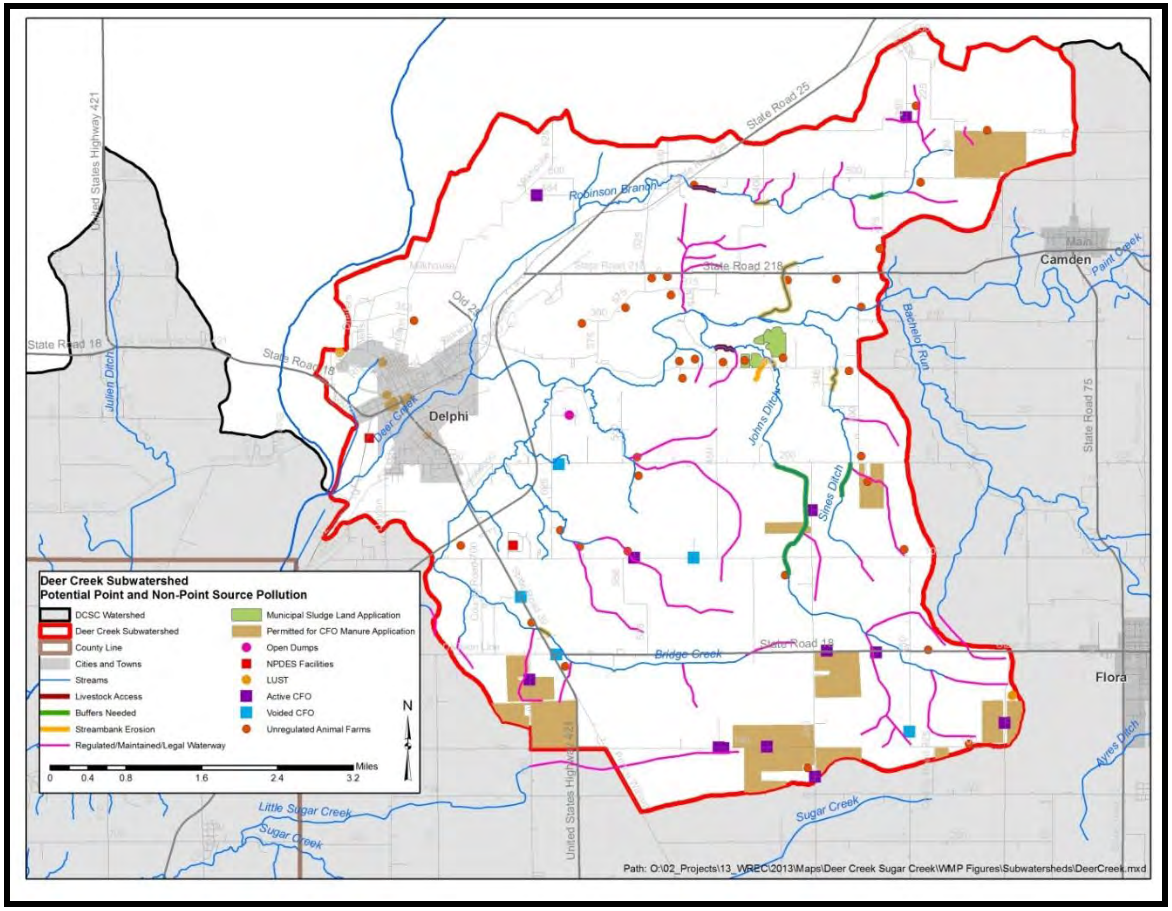

Figure 85. Point and non-point sources of pollution in the Deer Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.7.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the Deer Creek subwatershed and a corn-soybean rotation predominates in these areas. Nearly 40 unregulated animal farms are located within the Deer Creek subwatershed. Approximately, 152 cattle, 30 hogs, 51 sheep, 31 goats, and 55 horses are located on 36 farms. There are 12 active CFOs in the Deer Creek subwatershed. CFOs in the Deer Creek subwatershed contain approximately 2,820 nursery pigs, 35,035 finishing pigs, 744 sows, 21,800 swine greater than 55 pounds, and 6,600 swine less than 55 pounds. The Deer Creek subwatershed contains the highest number of nursery pigs of any of the Deer Creek-Sugar Creek subwatersheds. There are a total of 66,999 animals. CFO permits allow for distribution of manure on approximately 1,220 acres. Estimated conservatively, the livestock in this subwatershed produce upwards of 93 thousand tons of manure per year. Hypothetically, if this manure were applied entirely to the 1,220 acres of permitted receiving land, total Nitrogen and Phosphorus Pentoxide loads would exceed recommended fertilizer rates (conservatively estimated for maximum yield and averaged across corn and soy crops) (Sutton et al., 2001).

Municipal sludge is being applied to 64.3 acres within the subwatershed, which comprises 5% of the watershed when combined with CFO manure coverage. The municipal sludge is coming from the A.E. Staley Manufacturing Company. Livestock have access to approximately 1.4 miles of stream within the subwatershed. Streambank erosion and the need for stream buffering are also of concern within the Deer Creek subwatershed. In total, 4 miles of stream buffers and 4.2 miles of streambank stabilization are needed within the subwatershed.

4.7.5 Water Quality Assessment

Waterbodies within the Deer Creek subwatershed were sampled at six locations (Figure 83). The mainstem of Deer Creek was sampled at five locations; County Road 300 North, US Highway 421 (Riley Park), State Road 18, State Road 25, and approximately 0.3 miles South of County Road 375 North. The sixth site was located on Bridge Creek on State Road 18. The sites were assessed for one or multiple parameters by IDEM, including fish and macroinvertebrate communities, *E. coli*, pesticides, and water chemistry. As part of the current planning project, Purdue University sampled water chemistry in Deer Creek at Riley Park (site DCD3, Figure 45) biweekly for one year (26 samples), while fish and macroinvertebrates were surveyed twice and habitat assessed once from August 2012 through August 2013.

Water Chemistry

In 1998, the USGS assessed *E. coli* levels in Deer Creek at County Road 300 North. *E. coli* samples were collected five times over a 30-day period. *E. coli* levels exceeded the state standard two times in this period measuring 650 and 1,500 colonies/100 mL. As part of the 2003 sampling events, Deer Creek sites located on State Road 25 and US Highway 421 were assessed. *E. coli* samples were collected five times over a 30-day period. *E. coli* levels at the State Road 25 site exceeded the state standard four times in this period measuring 309 to 980 colonies/100 mL. *E. coli* levels at Deer Creek on US Highway 421 exceeded the state standard three times in the 30-day period measuring 361 to 866 colonies/100 mL.

As part of the 1998 basin assessment, IDEM assess Deer Creek approximately 0.3 miles from County Road 375 North and Bridge Creek at State Road 18. Nitrogen concentrations exceed Dodds et al. (1998) suggest standard at both sites; Deer Creek measured 3.7 mg/L and Bridge Creek measured 6.2 mg/L. Total phosphorus at the Deer Creek site measured approximately twice the suggested standard of 0.08 mg/L by Dodds et al. (1998)at 0.14 mg/L.

IDEM assessed the pesticide levels in Deer Creek in the summer of 1998 at County Road 300 North. Three pesticides had levels that raise concern, including acetorchlor, atrazine, and metolachlor. The MCL for acetochloris 0.2 µg/L. Levels in Deer Creek measured nearly 12 times the MCL ranging from 0.1 to 2.3 µg/L. The highest atrazine level measured over 50 times the atrazine MCL of 0.3 µg/L with concentrations ranging from 0.3 to 16 µg/L. Metolachlor does not have a MCL, but its detection level is 0.1 µg/L. Concentrations ranged from detection to 30 µg/L.

Turbidity was also measured during the pesticide sampling events and exceeded the USEPA's recommended standard of 9.89 NTU all 15 times it was measured. Turbidity ranged from 11-410 NTU in Deer Creek (2001).

In total, 18 field measurements and 26 samples were collected at Deer Creek at Trail Head Park (DCD3). All temperature, conductivity, and dissolved oxygen measurements were within standards or recommendations. Two pH measurements were above state standards (9.0) during two sampling events in December 2012 and April 2013. pH measured as high as 9.9 suggesting elevated levels of photosynthesis during these two sampling events. Turbidity measured above recommended levels during 12 of 18 assessments measuring from 11.1 to 217 NTU. Most high turbidities occurred during elevated flow conditions. Nitrate-nitrogen concentrations exceeded the target (2.0 mg/L; Dodds, 1998) during 20 of 24 sampling events. Concentrations exceeded the state drinking water standard (10 mg/L) during three events in February, March and June 2013 measuring as high as 12.6 mg/L. Total phosphorus concentrations exceeded the 0.08 mg/L target during 12 of 26 sampling events with concentrations measuring as high as 0.324 mg/L in November 2012. Total suspended solids concentrations measured above target levels during 9 of 26 sampling events. Exceedances generally coincided with elevated turbidity measurements and high flow events with concentrations ranging from 30.8 to 329 mg/L. *E. coli* concentrations measured above the state standard during 11 of 26 sampling events. Concentrations in exceedance ranged from 235.9 cfu/100 mL to 1988 cfu/100 mL.

Habitat

Habitat was assessed nine times by IDEM within the Deer Creek subwatershed using the QHEI, while Purdue University assessed habitat once in 2012; all sites previously listed were evaluated. Streams with QHEI scores greater than 51 are considered to be fully supporting of their aquatic life use designation. IDEM assessments occurred in 1991, 1998, 2003, and 2004. Deer Creek's habitat was evaluated nine times, including the most recent assessment by Purdue University, with scores ranging from 62 to 82, suggesting that the habitat is fully supporting the aquatic life. Bridge Creek was only evaluated once in 1998. It was scored at 49, indicating that it is not fully supporting its aquatic life use designation.

Macroinvertebrates

The macroinvertebrate communities within the Deer Creek subwatershed were sampled at fives site along Deer Creek by IDEM including intersections with US Highway 421 (Riley Park), State Road 18, South of County Road 375 North, State Road 25, and Country Road 300 North. The macroinvertebrate communities in Deer Creek were assessed by IDEM at Riley Park on US Highway 421 in 1991 and 2004 and by Purdue University in 2012. In 1991, the community rated as not impaired and was dominated by *Philopotamidae*. *Philopotamidae* is a family of caddisflies that is intolerant to pollution. In 2004, the community was reassessed and rated as moderately impaired with a score of 44 using the new mIBI scoring system. The community was still dominated by a caddisfly specie, *Ceratopsyche cheilonis*, which is not particularly intolerant of degraded environmental conditions. During the 2012 assessment, the macroinvertebrate community was fairly simple being dominated by two taxa. The macroinvertebrate community suggests poorer quality than the fish community and habitat.

In 1998, Deer Creek at State Road 18 was sampled by IDEM. The mIBI score indicated that this segment is not supporting the aquatic life use rating as moderately to severely impaired, scoring 2.0. The most prevalent family of macroinvertebrates was *Chironomidae*, which are fairly tolerant to tolerant to pollution.

In 1998, IDEM assessed Deer Creek approximately 0.3 miles South of County Road 375 North. The mIBI score indicated that this segment was supporting for aquatic life use rating as moderately impaired scoring 4.4. The most prevalent family of macroinvertebrates was *Heptageniidae*, an intolerant to pollution mayfly species.

In 1991 and 2004, IDEM assessed the macroinvertebrate community in Deer Creek at Trail Head Park on State Road 25. Purdue University assessed the macroinvertebrate community at the same site in 2012. In 1991, the macroinvertebrate community rated as severely impaired scoring 1.8 using the old mIBI scoring method and in 2004 it improved to moderately impaired with a score of 40 using the new mIBI scoring system. During both sampling events, the macroinvertebrate community was dominated by *Chironomidae*, a family of flies that are fairly tolerant to tolerant to pollution. In 2004, IDEM identified the *Chironomidae* family to the species level, *Orthocladiusobumbratus.* During the 2013 assessment, Purdue University identified a highly diverse benthic macroinvertebrate community which was dominated by stoneflies. Stoneflies typically indicate high quality communities suggesting that the macroinvertebrate community in Deer Creek at Trail Head Park (DCD3) is of higher quality than other macroinvertebrate communities throughout the watershed.

IDEM assessed macroinvertebrate communities in Deer Creek at the County Road 300 North three times. In 1991 and 2003, the macroinvertebrate community was dominated by *Chironomidae*, a family of flies that are fairly tolerant to tolerant to pollution. The site was rated as moderately impaired in 1991 and then improved to slightly impaired in 2003. The third assessment was completed in 2004 after a new mIBI scoring system was introduced. The site rated as moderately impaired scoring a 38. The community was dominated by *Ceratopsychachielonis*, a net spinning, caddisfly species.

During Purdue University's assessment, the benthic community was fairly simple, not very taxa rich, and was dominated by two taxa. The mIBI (44) was moderate compared to the other sampled sites. Overall, the site should be considered in good to very good condition based on the biological community and QHEI data.

Fish

In 1998, IDEM assessed fish communities on the mainstem of Deer Creek and Bridge Creek at County Road 300 North and State Road 18, respectively. The Deer Creek site was rated as fair suggesting that species that are intolerant to pollution were absent and the trophic levels are skewed. The IBI score was 42. The dominate species were the bluntnose minnow and spotfin shiner. Bridge Creek was rated as poor scoring 32 suggesting that many species that should have been present were absent and omnivores and tolerant species dominated the fish community. All of the fish collected at this site were the western blacknose dace.

In 2012, Purdue University assessed the fish community along the mainstem of Deer Creek at Riley Park (DCD3). The fish IBI in Deer Creek at Riley Park tied for the highest IBI among all sites rating "very good." High species diversity, high diversity of sunfish, and high diversity of insectivores and omnivores are characteristic of this community. The IBI was the second highest among all sites (48) and the fish species richness was among the highest of all sites.

Mussels

Mussel communities were assessed by Myers-Kinzie and the IDNR at four sites in the Deer Creek subwatershed. Myers-Kinzie assessed the mussel community at two locations, Bowen Creek at County Road 950 North and Bridge Creek at State Road 25. During the surveys, one mussel species, the purple lilliput, was found in Bowen Creek as weathered dead shells. This was the first discovery of this species in Tippecanoe County. The lilliput is typically found in mud, sand, or fine gravel in small creeks. In Bridge Creek, there was no evidence of mussels.

The INDR surveyed the mussel community at two locations along Deer Creek at County Road 300 West and US Highway 421. At the County Road 300 West site, a total of 16 species were identified; however, only two were found alive. The remaining were found as weathered dead (8), fresh dead (5), or subfossil (1) shell material. Weathered dead shell material of two state species of special concern were identified, including the wavy-rayed lampmussel and the kidneyshell. The Riley Park (US Highway 421) site contained 12 mussel species; four species were found alive, while the remaining eight species were found as weathered dead (3), subfossil (3), or fresh dead (2) shell material.

4.7.6 Deer Creek Subwatershed Summary

Deer Creek subwatershed is comprised of 77% agricultural land. Urban land use in this subwatershed accounts for 10.3%, in part due to the presence of the Town of Delphi. This subwatershed has the highest amount of urban land use among all of the subwatersheds. Deer Creek subwatershed houses two NPDES permitted facilities and numerous other potential point source pollution sources. Pesticides, pathogens, turbidity, and nitrogen levels all exceeded recommended levels or state drinking water standards. Phosphorus and pH were elevated in nearly 50% of the samples taken. Additionally, potential manure application could be problematic in this watershed. However, temperature, conductivity and dissolved oxygen were all within recommended levels. QHEI habitat assessments suggested the waterbody was fully supporting aquatic life. However historically, Deer Creek scored relatively low on the mIBI and IBI assessments. Macroinvertebrate data suggested that Deer Creek was moderately impaired and fish data rated the creek at fair-poor, in part due to only one fish species being found present. Presently, Deer Creek has the highest mIBI score in the watershed, and also is tied for the highest IBI score, rating “very good”.

4.8 <u>Sugar Creek</u>

The Sugar Creek subwatershed is located in the southwest portion of the watershed and drains directly to the Wabash River. The drainage area is located in Carroll and Tippecanoe Counties. The Sugar Creek subwatershed includes the Town of Colburn. The watershed is within the 12-HUC watershed Little Sugar Creek-Sugar Creek (051201050601) and drains 18,360 acres or 29 square miles. In total, 34.2 miles of stream are present within the Sugar Creek subwatershed. Of these, approximately 24.6 miles are considered impaired for *E. coli* and less than a quarter of a mile is considered impaired due to *E. coli,* nutrients, and PCBs and mercury in fish tissue (Figure 86).

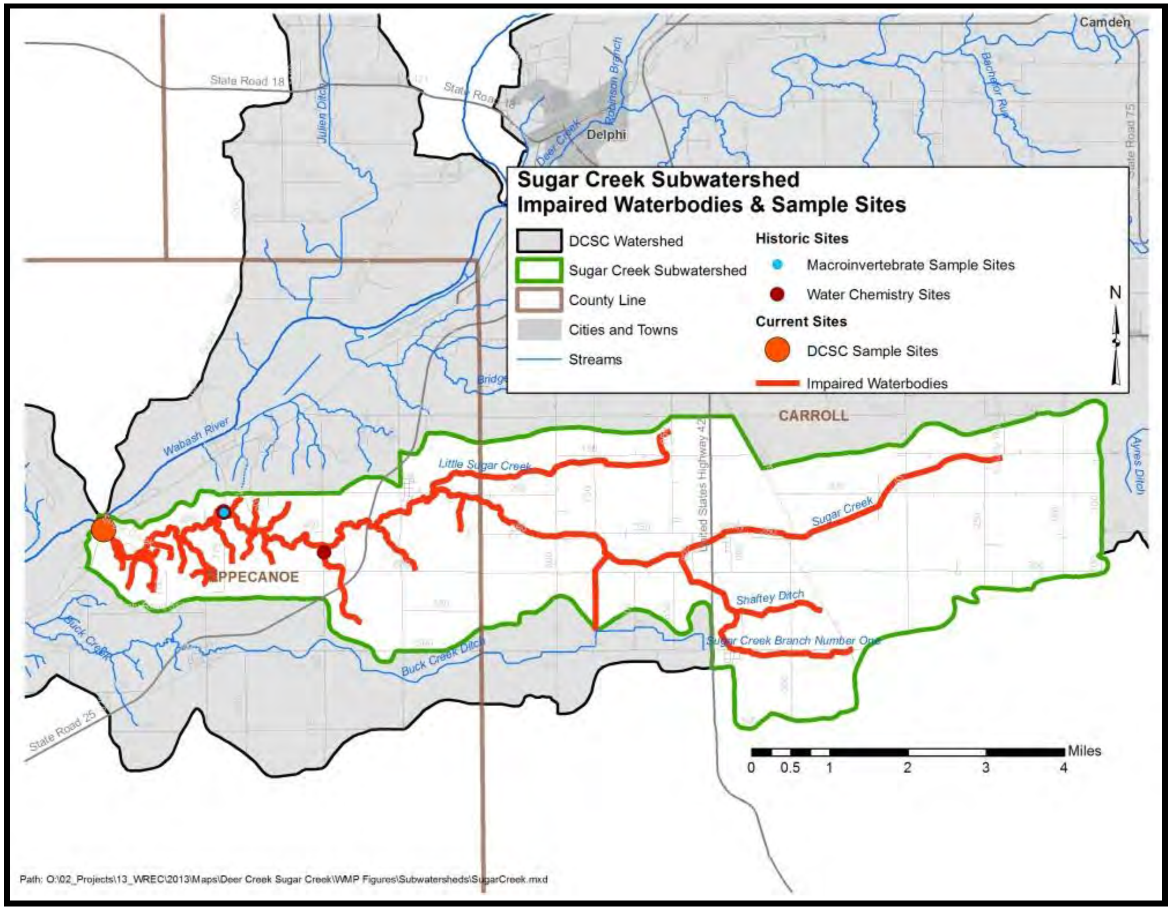

Figure 86. Impaired waterbodies and sample sites in the Sugar Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.8.1 Soils

Soils in the Sugar Creek subwatershed are dominated by those that are not suitable for use in septic treatment. Over 98% of the soils in the subwatershed are rated as severely limited for use in septic treatment. Easily erodible soils are located adjacent to the Sugar Creek from the Town of Colburn to the mouth of Sugar Creek (Figure 87). Potentially highly erodible soils cover 9.5% of 1,748 acres of the subwatershed. Highly erodible soils account for 939 acres of 5.1% of the subwatershed.

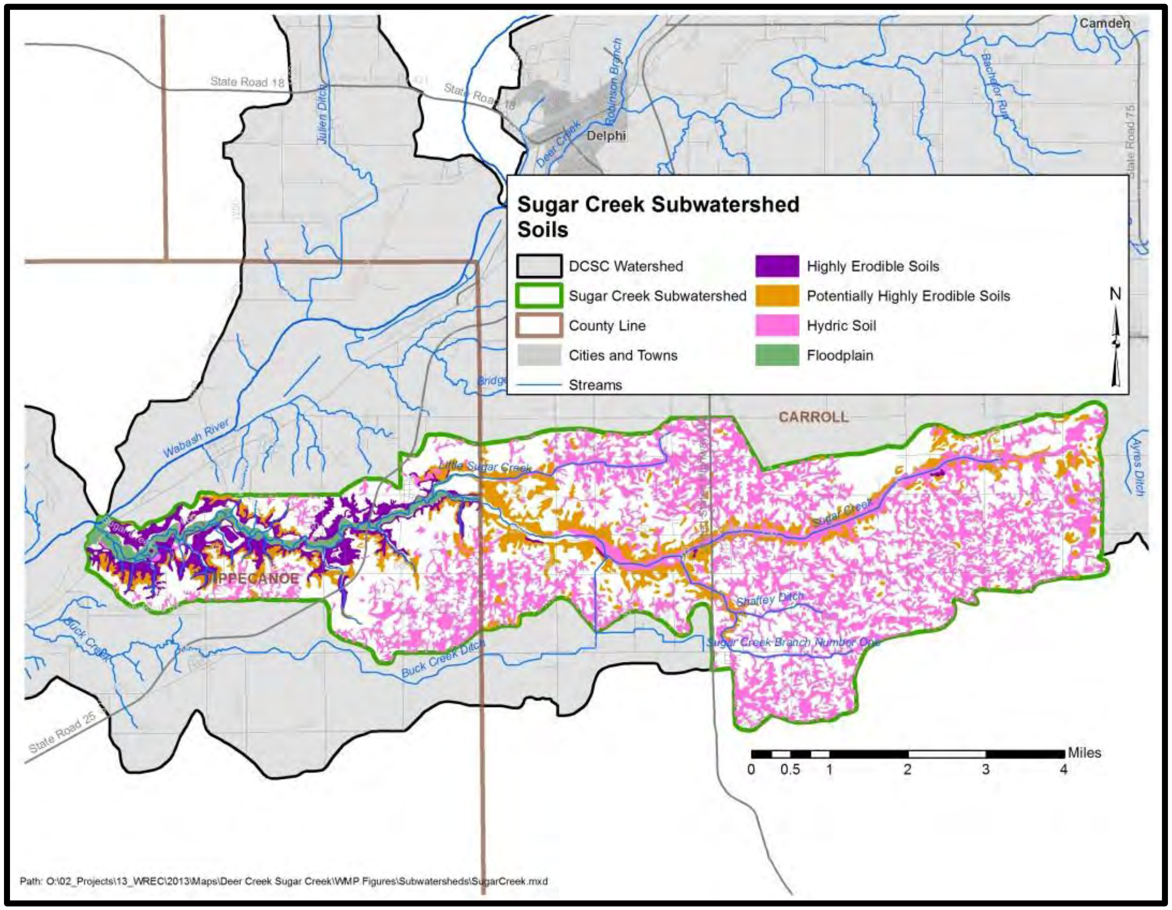

Figure 87. Properties of soils located in the Sugar Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.8.2 Land Use

Similar to the other subwatersheds in the Deer Creek-Sugar Creek watershed, the Sugar Creek subwatershed is dominated by agricultural land use which accounts for 85% of the land use. Urban land uses, including the Town of Colburn, account for 6% of the subwatershed land use. Deciduous forests accounts for approximately 8% of the subwatershed. These forests are located predominantly in the same areas as the potentially highly erodible soils. These forested areas should be protected as they provide stability on the erodible soils. The Sugar Creek subwatershed has the lowest percentage of grassland/herbaceous land use in the watershed, only 0.7% of the subwatershed is classified as grassland/herbaceous.

4.8.3 Point Source Water Quality Issues

As detailed above, the majority of the Sugar Creek subwatershed is in agricultural land uses, more specifically row crops. There is one LUST within the subwatershed; it is located on East County Line Road at Southeastway Park (Figure 88). There are no brownfields, industrial waste, NPDES facilities, or open dump sites within the Wabash River subwatershed.

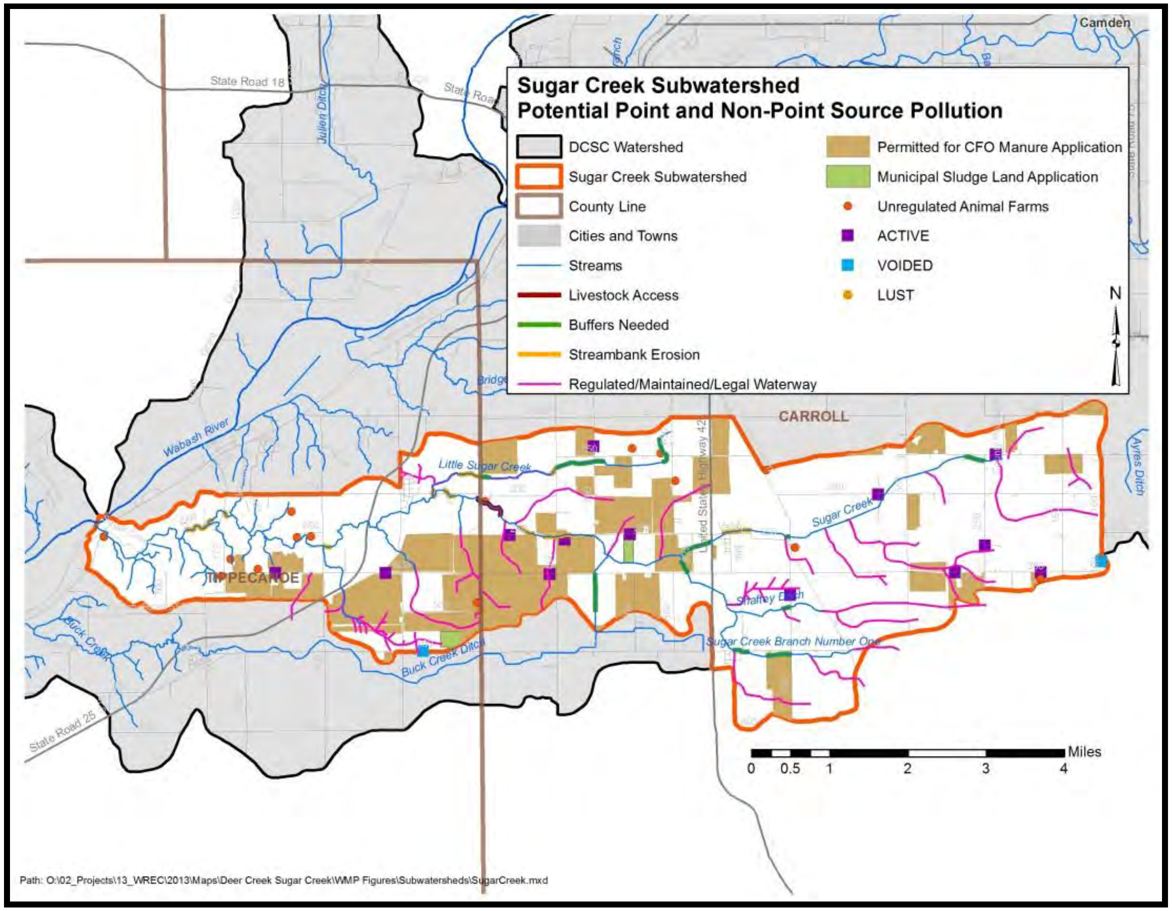

Figure 88. Point and non-point sources of pollution in the Sugar Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.8.4 Non-Point Source Water Quality Issues

Agricultural land uses dominate the Sugar Creek subwatershed and a corn-soybean rotation predominates in these areas. A number of unregulated animal farms are located within the Sugar Creek subwatershed. Approximately, 57 cattle and 24 horses are located on 14 farms. In, total, there are 13 active CFOs in the Sugar Creek subwatershed. The CFOs in the Sugar Creek subwatershed contain approximately 5,920 nursery pigs, 11,320 finishing pigs, 36 sows in farrowing, 221 gestation sows, five boars, 930 sows, 1,300 swine greater than 55 pounds, and 4,200 swine less than 55 pounds. There are a total of 23,932 animals in the Sugar Creek subwatershed. CFO permits allow for distribution of manure on approximately 4,698 acres or 26% of the subwatershed. Estimated conservatively, the livestock in this subwatershed produce upwards of 25 thousand tons of manure per year. Hypothetically, if this manure were applied entirely to the 4,698 acres of permitted receiving land, total Nitrogen and Phosphorus Pentoxide loads would not exceed recommended fertilizer rates (conservatively estimated for maximum yield and averaged across corn and soy crops) (Sutton et al., 2001).

Municipal sludge is being applied to 62 acres within the subwatershed. The sludge originates from two facilities that are located outside of the watershed including Frito-Lay, Inc. and the Lafayette Municipal STP. Livestock have access to approximately 1 mile of stream within the subwatershed. Streambank erosion and the need for stream buffering are also of concern within the Sugar Creek subwatershed. In total, 6.2 miles of stream buffers and 5.5 miles of streambank stabilization are needed within the subwatershed.

4.8.5 Water Quality Assessment

Waterbodies within the Sugar Creek subwatershed were sampled at two locations. Sugar Creek at County Road 900 East in Tippecanoe County was assessed in 2008 (Figure 86). *E.* coli and nutrient levels were measured at this site in the summer and fall. IDEM assessed macroinvertebrate communities at Sugar Creek at County Road 775 East (Tippecanoe County) in 1991 and *E. coli* levels were measured at this site in 2003. As part of the current planning project, Purdue University sampled water chemistry in Sugar Creek at State Road 25's intersection with Stair Road (site SC2, Figure 45) biweekly for one year (26 samples), while fish and macroinvertebrates were surveyed twice and habitat assessed once from August 2012 through August 2013

Water Chemistry

In the summer and fall of 2008, a tributary of Sugar Creek at County Road 900 East was sampled for *E. coli* and nutrients. *E. coli* was analyzed five times over a 30-day period and exceeded the state standard two of the five times. Overall, *E. coli* concentrations ranged from 54.6 to 488 colonies/100 mL. Other parameters of concern measured included nitrogen, as nitrate and nitrite, which measured 8.84 during a June sampling event. This is over four times the suggested benchmark of Dodds et al, 1998. In 2003, *E. coli* was measured by IDEM at Sugar Creek at County Road 775 East. *E. coli* levels exceeded the state standard during five of the six events; one of the duplicates collected on September 15th (98.5 colonies/100 mL) measured below the standard but its pair was above state standard (410.6 colonies/100 mL). The remaining samples ranged from 365.4 to 1,986 colonies/100 mL.

In total, 18 field measurements and 26 samples were collected at Sugar Creek at State Road 25's intersection with Stair Road (SC2). All temperature, conductivity, and dissolved oxygen measurements were within standards or recommendations. Two pH measurements exceeded the state standard measuring as high as 9.6. Turbidity measured above recommended levels during 9 of 18 assessments measuring from 13.9 to 154 NTU. Most high turbidities occurred during elevated flow conditions. Nitrate-nitrogen concentrations exceeded the target (2.0 mg/L; Dodds, 1998) during 21 of 23 sampling events. Concentrations exceeded the state drinking water standard (10 mg/L) during five events in January, February, March, May and June 2013 measuring as high as 18.9 mg/L. Total phosphorus concentrations exceeded the 0.08 mg/L target during 9 of 26 sampling events with concentrations measuring as high as 0.830 mg/L in December 2012. Total suspended solids concentrations measured above target levels during 8 of 26 sampling events. Exceedances generally coincided with elevated turbidity measurements and high flow events with concentrations ranging from 21.6 to 364 mg/L. *E. coli* concentrations measured above the state standard during 14 of 26 sampling events. Concentrations in exceedance ranged from 298 cfu/100 mL to 1413 cfu/100 mL.

Habitat

Habitat was assessed once by IDEM and once by Purdue University within the Sugar Creek subwatershed using the QHEI. IDEM assessment occurred in 1991 in Sugar Creek at County Road 775 East and in 2012 by Purdue University at Stair Road during the current Deer Creek-Sugar Creek planning project. IDEM scored Sugar Creek as 64, indicating the habitat was fully supporting the stream's designated aquatic life use. Purdue University scored Sugar Creek as fair (64) as well. The riffle/run score for the site was notably low, suggesting limited habitat diversity.

Macroinvertebrates and Fish

The macroinvertebrate community within Sugar Creek was sampled once by IDEM and macroinvertebrates and fish were sampled twice by Purdue University. IDEM sampling occurred in 1991 in Sugar Creek at County Road 775 East, while Purdue University sampled Sugar Creek at Stair Road (SC2). During the 1991 assessment, the macroinvertebrate community rated as slightly impaired during the assessment scoring 5.8. The community was dominated by *Hydropsychidae*, a caddisfly family which is relatively intolerant to pollution. During the current assessment, benthic macroinvertebrates were highly diverse and included a dominance by stoneflies, which both suggest higher quality benthic community. Benthic invertebrates were highly diverse at this site with at least 59 total taxa. The overall mIBI score (52) was the second highest of all sites. Of particular note is the dominance by stoneflies and other EPT taxa in the samples, which both suggest higher quality benthic community. The number of EPT taxa was at least 35 and was the second highest of all sites.

The fish community rated as fair during the Purdue University assessments. High numbers of species as well as high numbers of minnow species and sensitive species created the fair rating with the site scoring 40. The fish IBI score of 40 rated the site as fair, although the fish species richness was relatively high at 26 total species. However, there was only a single individual of one species of darter present, and this is unusual for this size stream. Overall, the Sugar Creek (SC2) site should be considered in good condition based on the biological community and physical habitat characteristics as scored using the QHEI.

Mussels

Myers-Kinzie assessed the mussel community at two locations within the Sugar Creek subwatershed. During the surveys, the creek heelsplitter (*Lasmigona compressa*), slippershell mussel (*Alasmidonta viridis),* and the cylindrical papershell (*Anodontoides ferussacianus)* were identified as weathered dead shells. The creek heelslitter and the cylindrical papershell are a headwater species typical of small streams and rivers, while the slippershell mussel was found by digging in the stream bed with hands.

4.8.6 Sugar Creek Subwatershed Summary

The land use of Sugar Creek subwatershed 85% agricultural, 6% urban, and 8% deciduous forest, which sits atop or adjacent to the majority of the subwatershed's potentially highly erodible soils. Conservation of these forests is critical, as the trees' root structures play a vital role in maintaining the stability of these PHES. Septic treatment is very limited in this subwatershed, as 98% of the soil is deemed severely limited for septic treatment. The Town of Colburn is situated in this subwatershed and houses only one leaky underground storage tank. Contrary to several of the other subwatersheds with higher urban land use, Sugar Creek subwatershed has no brownfields, industrial waste sites, NPDES facilities, or open dump sites. Temperature, conductivity, and dissolved oxygen were all within state standards or recommendations. Turbidity and E. coli were both elevated in almost 50% of the samples taken. Nitrogen is a cause of concern, as samples were in exceedance of state drinking standards in 21 out of 23 samples taken. Habitat assessments returned positive results for Sugar Creek subwatershed. Overall, the habitat was suggested to fully support aquatic life. Scores for mIBI and IBI were indicative of the same results as the habitat assessment. Intolerant and sensitive species were found in both assessments and both populations were highly diverse.

4.9 Buck Creek

The Buck Creek subwatershed is located in the southwest corner of the watershed and drains into the Wabash River. Buck Creek drains portions of Carroll and Tippecanoe Counties and includes the Town of Buck Creek. The subwatershed includes a portion of a 12-digit watershed, Harrison Creek-Wabash River (051201050603) and drains 7,480 acres or 17.7 square miles. In total, 11.7 miles of stream are present within the Buck Creek subwatershed. Nearly all of the 11.7 miles of stream are listed on the 2012 draft 303(d) Impaired Waterbodies List for *E. coli* and impaired biotic communities (Figure 89; IDEM, 2012).

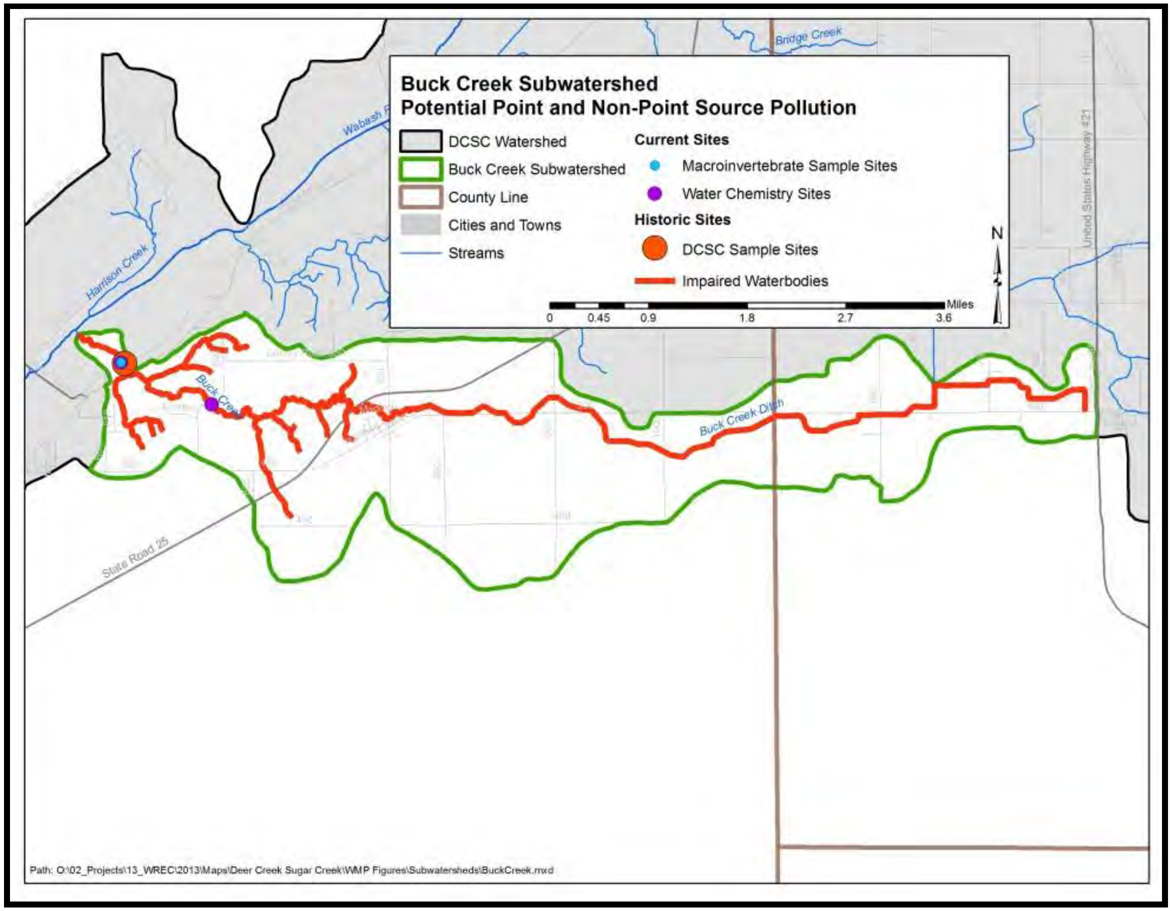

Figure 89. Impaired waterbodies and sample sites in the Buck Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.9.1 Soils

Hydric soils cover 2,583 acres or 34.5% of the subwatershed (Figure 90). Highly erodible soils and potentially highly erodible soils cover 414 acres or 5.5% and 494 acres or 6.6% of the Buck Creek subwatershed, respectively. HES and PHES are primarily localized adjacent to the floodplain and occur along nearly a third of the stream and its tributaries from the Town of Buck Creek to the mouth of Buck Creek. The Buck Creek subwatershed has the highest percentage of severely limited soils for septic treatment. Severely limited soils cover 99%, or 7,430 acres, of the subwatershed. Within the Buck Creek subwatershed, none of the soils are suitable for the use of septic treatment and only 0.5% of 40 acres that are considered as moderately limited for septic treatment.

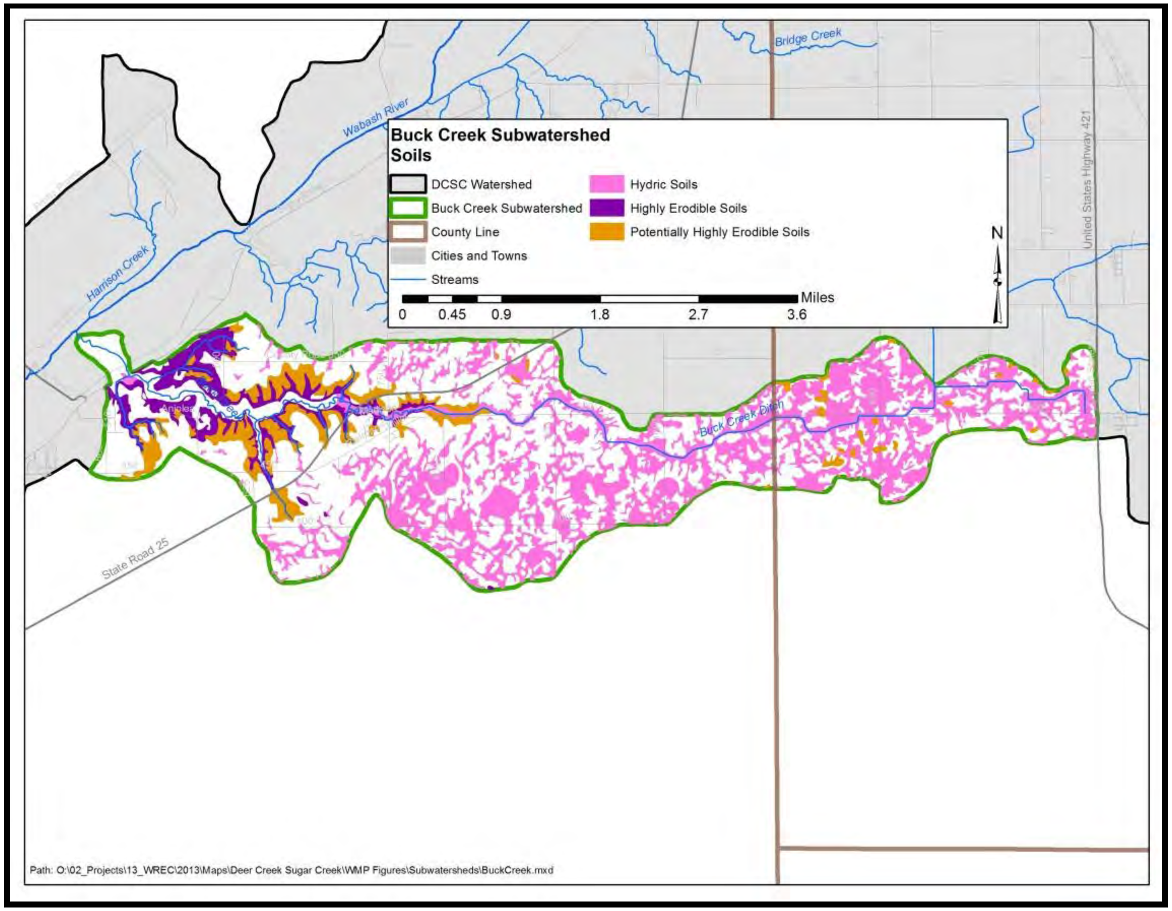

Figure 90. Properties of soils located in the Buck Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.9.2 Land Use

Agricultural land use dominates the Buck Creek subwatershed accounting for 84% of the land use. Urban land uses, including the Town of Buck Creek, accounts for 5% of the subwatershed. The Buck Creek subwatershed has the highest percentage of grassland/herbaceous land use of the ten subwatersheds with approximate 1.5% classified as grassland/herbaceous. Additionally, this subwatershed has the lowest percentage of wetlands (0.06%). Deciduous and mixed forests account for 9% of the land use in the subwatershed.

4.9.3 Point Source Water Quality Issues

There are no point source water quality issues in the Buck Creek subwatershed.

4.9.4 Non-Point Source Water Quality Issues

In the Buck Creek subwatershed, there are ten active CFOs. Seven unregulated animal farms are located within the Buck Creek subwatershed. Approximately, 57 cattle and 24 horses are located in the Buck Creek subwatershed. The Buck Creek subwatershed contains the second highest number of animals in confined feeding operations with are approximately 44,914 animals housed in CFOs. The subwatershed also contains the largest number of swine greater than 55 pounds, 24,575. The remaining animals in the subwatershed are nursery pigs (5,630), finishing pigs (9,144), sows (780), and swine less than 55 pounds (4,785). CFO permits allow for distribution of manure on approximately 2,929 acres or 39% of the subwatershed. Estimated conservatively, the livestock in this subwatershed produce upwards of 45 thousand tons of manure per year. Hypothetically, if this manure were applied entirely to the 2,929 acres of permitted receiving land, total Nitrogen would not exceed recommended fertilizer rates (conservatively estimated for maximum yield and averaged across corn and soy crops). However in this subwatershed, Phosphorus Pentoxide loads would exceed recommended fertilizer rates (Sutton et al., 2001).

Municipal sludge is being applied to 221 acres or 3% of the subwatershed (Figure 91). The sludge originates from the Lafayette Municipal STP which is located outside the watershed. Streambank erosion and lack of stream buffering are also of concern within the Buck Creek subwatershed. In total, 9.8 miles of stream buffers and 1.7 miles of streambank stabilization are needed within the Buck Creek subwatershed.

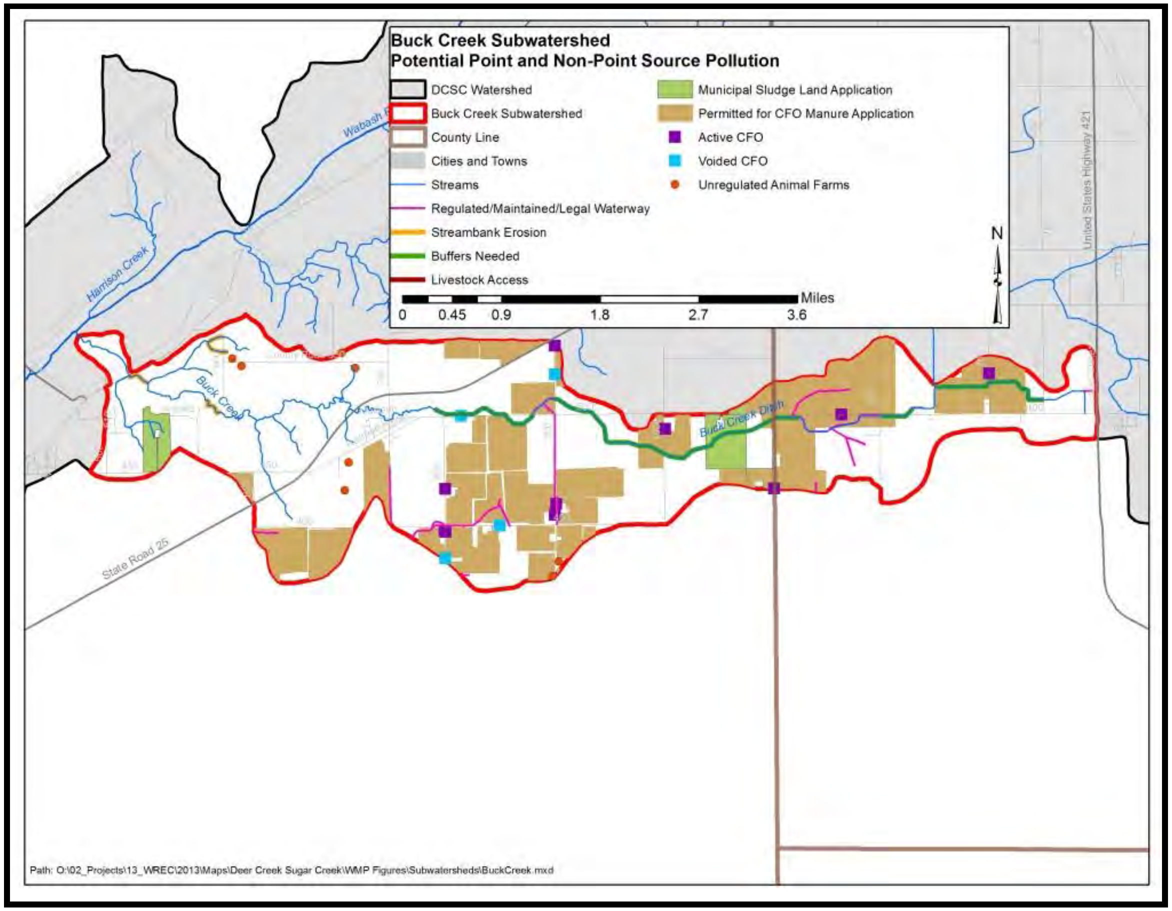

Figure 91. Non-point sources of pollution in the Buck Creek subwatershed.
Data used to create this map are detailed in Appendix A.

4.9.5 Water Quality Assessment

Waterbodies within the Buck Creek subwatershed were sampled at two locations. Historic assessments include analysis of *E. coli* concentrations and evaluation of habitat and macroinvertebrate communities in Buck Creek. The sampling sites were located less than two miles from the mouth of Buck Creek. *E. coli* samples were collected at County Road 600 East in Tippecanoe County and the habitat and macroinvertebrates were evaluated at 5 Northwest Road (also called Stair Road). As part of the current planning project, Purdue University sampled water chemistry in Buck Creek at Stair Road (site BC1, Figure 45) biweekly for one year (26 samples), while fish and macroinvertebrates were surveyed twice and habitat assessed once from August 2012 through August 2013.

Water Chemistry

In the fall of 2003, IDEM sampled Buck Creek in Tippecanoe County on County Road 600 East for *E. coli.* Five samples were collected over a 30 day period. *E. coli* measured higher than the Indiana state standard during four of the five sampling events. *E. coli* ranged from below detection to 1,203 colonies/100 mL of sample.

In total, 17 field measurements and 26 samples were collected at Buck Creek at Stair Road (BC1). All temperature, conductivity, dissolved oxygen, and pH measurements were within standards or recommendations. Turbidity measured above recommended levels during 10 of 17 assessments measuring from 16.8 to 361 NTU. Most high turbidities occurred during elevated flow conditions. Nitrate-nitrogen concentrations exceeded the target (2.0 mg/L; Dodds, 1998) during 21 of 23 sampling events. Concentrations exceeded the state drinking water standard (10 mg/L) during ten events in January, February, March and June 2013 measuring as high as 22.7 mg/L. Buck Creek contained the highest average nitrate-nitrogen concentration of all Deer Creek-Sugar Creek watershed sampling sites. Total phosphorus concentrations exceeded the 0.08 mg/L target during 15 of 26 sampling events with concentrations measuring as high as 1.044 mg/L in December 2012. Total suspended solids concentrations measured above target levels during 6 of 26 sampling events. Exceedances generally coincided with elevated turbidity measurements and high flow events with concentrations ranging from 23.4 to 226 mg/L. *E. coli* concentrations measured above the state standard during 15 of 26 sampling events. Concentrations in exceedance ranged from 344.8 cfu/100 mL to 3255 cfu/100 mL. On average, *E. coli* concentrations were the second highest of all sample sites in the Deer Creek-Sugar Creek watershed.

Habitat

Habitat was assessed twice by IDEM within the Buck Creek subwatershed using the QHEI and once by Purdue University during the current Deer Creek-Sugar Creek planning project. IDEM assessments occurred in 1991 and 2003 with both assessments conducted at Buck Creek at 5 Northwest Road in Tippecanoe County. Scores (56 and 48, respectively) indicate the habitat in 1991 was fully supporting the stream's designated aquatic life use, but in 2003 it was not supporting the designated aquatic life use in the stream. This change in QHEI is due to the decrease in the riparian/bank score (8 to 4) and the pool score (5 to 0). In 2003, there was no longer a pool present at the site. Purdue University scored Buck Creek at Stair Road (BC1) as good (65); habitat at this site within Buck Creek rated higher than habitat present at IDEM monitored sites. . Of particular note is the low score for bank erosion in Buck Creek indicating that bank erosion is a problem in this reach of Buck Creek.

Macroinvertebrates and Fish

The macroinvertebrate community within Buck Creek was sampled twice by IDEM and fish were sampled twice by Purdue University during the current Deer Creek-Sugar Creek planning project. Sampling occurred in 1991 and 2003 with both assessments at 5 Northeast Road. The macroinvertebrate community rated as slightly impaired in 1991 with a mIBI score of 4.8; however, during the 2003 assessment, the mIBI score rated as severely impaired with a score of 1.0. The community was dominated by *Elmidae*, an intolerant to pollution riffle beetle species in 1991 and all other *Chironomidae* families (fairly to very tolerant to pollution) in 2003. Benthic invertebrate assessments completed by Purdue University used the new IDEM monitoring method. Macroinvertebrates were fairly diverse with 41 taxa present during both assessments. Benthic invertebrates were dominated by midge larva (about a third of the total count) suggesting that the quality of the site is lower than desirable. The mIBI score was 38, which is just above the threshold value that designates sites as either impaired or unimpaired (36). Overall, the Buck Creek (BC1) site should be considered in fair condition.

Purdue University monitored the fish community in Buck Creek at Stair Road (BC1) during 2012 and 2013 with the community rating as fair scoring 34. Low percentages of carnivores, low number of suckers and moderate sensitive species populations generated the fair score.

Mussels

Myers-Kinzie assessed the mussel community at two locations within the Buck Creek subwatershed. Sites were located on County Road 600 East and Stair Road in Tippecanoe County. During the surveys, one species was identified as weathered dead shells. The mucket (*Actinonaias ligamentina*) is typically found in gravel, sand or a mixture of the two in medium to large rivers.

4.9.6 Buck Creek Subwatershed Summary

Buck Creek is the smallest subwatershed. Its agricultural land comprises 84% of the total land use, as urban land use accounts for 5%, in part due to the Town of Buck Creek. This subwatershed has no point source water quality issues. Temperature, conductivity, dissolved oxygen, and pH measurements were all within standards or recommendations. Turbidity and phosphorus were cause for some concern, as they were elevated in 10 out of 17 and 15 out of 26 water samples, respectively. Nitrogen was a recurring issue for Buck Creek, as levels exceeded recommendations in 21 out of 23 samples. *E. coli* concentrations in this subwatershed were the second highest of all sample sites in the watershed, as concentrations exceeded the state standard in 15 out of 26 samples. Habitat assessment scores indicated that Buck Creek is no longer fully supporting aquatic life. Scores from the mIBI and IBI suggested that the macroinvertebrate populations and fish populations were both “fair,” as a mix of sensitive to moderate species existed and the populations were fairly diverse as well.

4.10 <u>Wabash River</u>

The Wabash River subwatershed is located in the west edge of watershed. This subwatershed receives water from all upstream subwatersheds. The drainage for this subwatershed is located in Carroll and Tippecanoe Counties. The Wabash River subwatershed borders the Town of Battle Ground and includes portions of Prophetstown State Park. The subwatershed includes two 12-digit watersheds, Bowen Ditch-Wabash River (051201050602) and a portion of the Harrison Creek-Wabash River (051201050603), and drains 20,177 acres, or 31.5 square miles. In total, 10.7 miles of stream are present within the Wabash River subwatershed with the entire length considered impaired for *E. coli,* impaired biotic communities, PCBs in fish tissue, or a combination of the three impairments (Figure 92; IDEM, 2012).

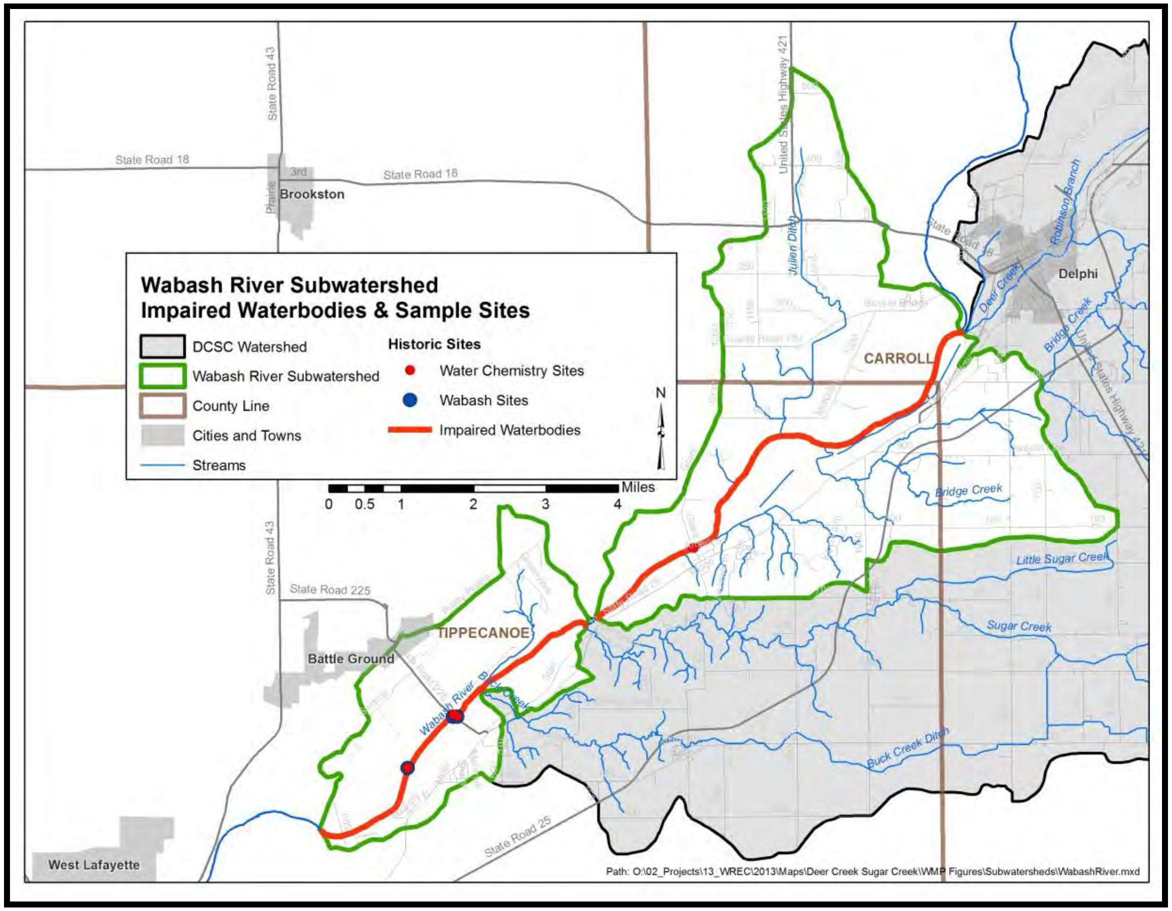

Figure 92. Impaired waterbodies and sample sites in the Wabash River subwatershed.
Data used to create this map are detailed in Appendix A.

4.10.1 Soils

The Wabash River subwatershed has the lowest percentage of hydric soil with approximately 8.9% or 1,789 acres in the watershed (Figure 93). However, the Wabash River subwatershed has the highest percentage of highly erodible soils out of the ten subwatersheds. Highly erodible soils cover 12.7%, or 2,564 acres, of the subwatershed and are primarily located adjacent to Julien Ditch, the Wabash River, and the Wabash River's smaller tributaries. Potentially highly erodible soils cover 10.8% of the subwatershed and are located in similar places as the highly erodible soils.

Approximately 84%, or 17,002 acres, of the Wabash River subwatershed are classified as severely limited in septic treatment and only 2%, or 429 acres, rate only slightly limited for septic treatment

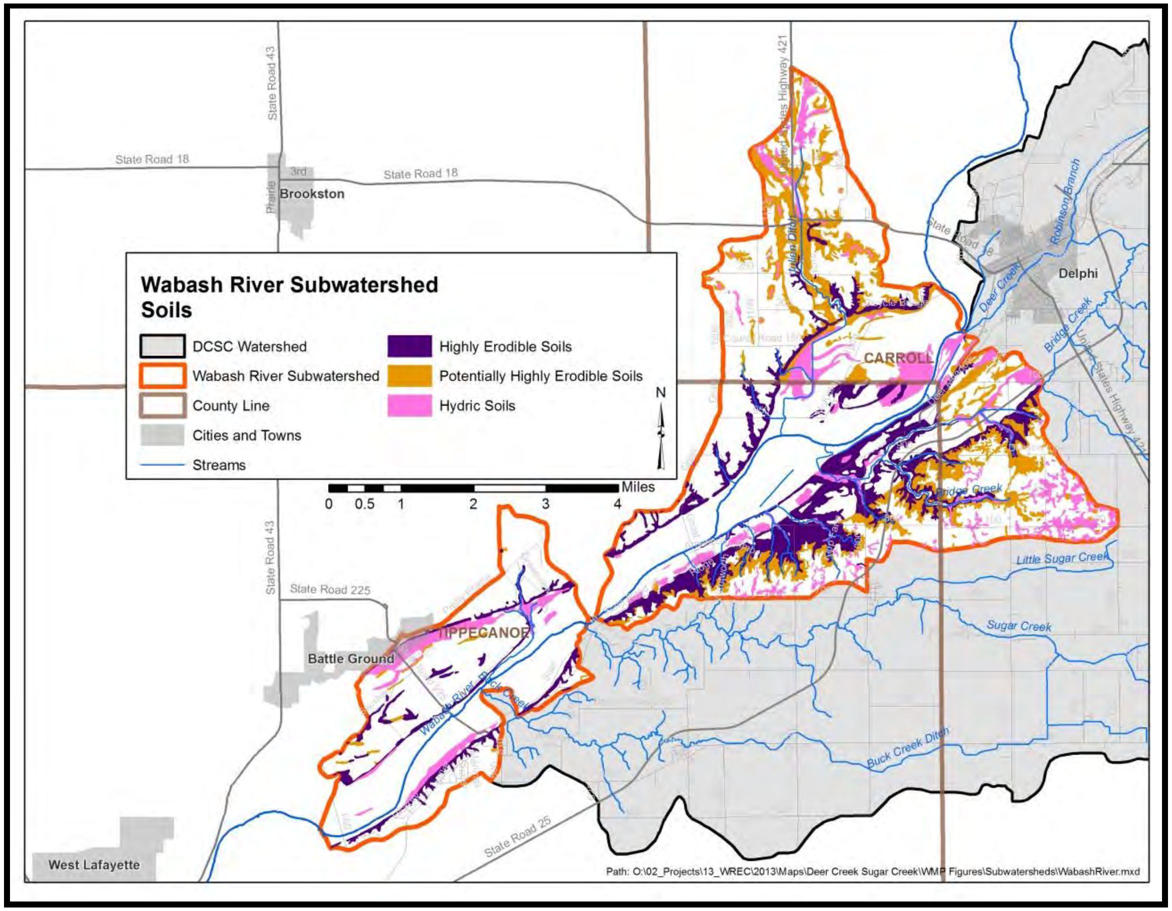

Figure 93. Properties of soils located in the Wabash River subwatershed.
Data used to create this map are detailed in Appendix A.

4.10.2 Land Use

Agricultural land use accounts for 71% of the Wabash River subwatershed; this is the lowest percentage of the ten subwatersheds. The Wabash River is different from the other subwatersheds in that while agriculture is the dominant land use, it covers a much smaller area of the watershed. This subwatershed has the highest percentage of open water, forest and wetlands in the watershed. Open water accounts for 2.8% of the subwatershed; that is greater than 12 times the next highest subwatershed. Deciduous forest accounts for 16.5% of 3,331 acres of the subwatershed, while wetlands account for another 6.8% or 1,380 acres.

4.10.3 Point Source Water Quality Issues

As detailed above, much of the Wabash River subwatershed is in agricultural land uses. The only point source water quality issue within this subwatershed is two leaking underground storage tanks (LUST) located on Pretty Prairie Road (Lafayette County Club) and State Road 25 (Lox Equipment Company, Figure 94). There are no brownfields, industrial waste, NPDES facilities, or open dump sites within the Wabash River subwatershed.

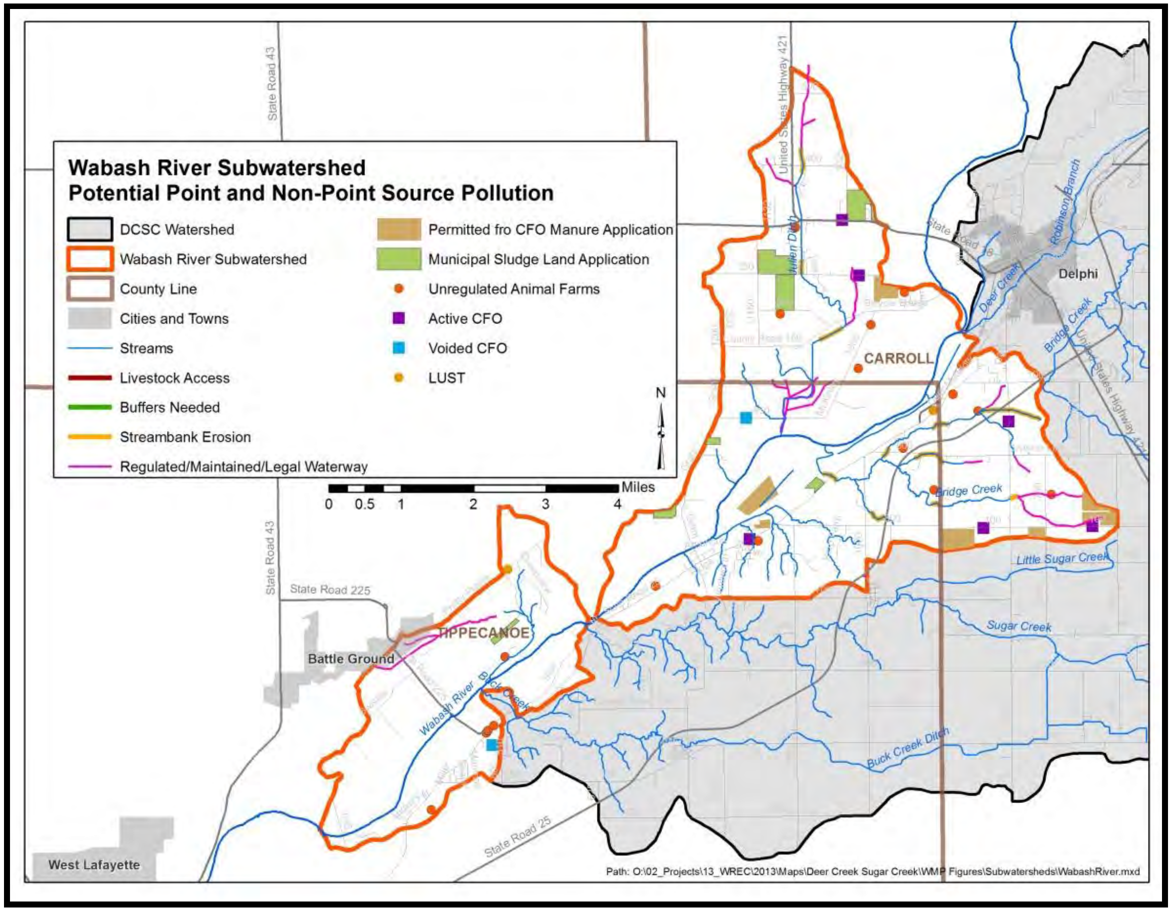

Figure 94.Point and non-point sources of pollution in the Wabash River subwatershed.
Data used to create this map are detailed in Appendix A.

4.10.4 Non-Point Source Water Quality Issues

Agricultural land uses account for the highest percentage of land uses in the Wabash River subwatershed. A number of unregulated animal farms are located within the Wabash River subwatershed. Approximately, 29 cattle, five goats, five sheep, and 36 horses are located on 17 farms. There are currently six active CFO scattered throughout the subwatershed. The Wabash River subwatershed contains the lowest number of animals in CFOs with only 7,640 animals. There are approximately 4,440 nursery pigs and 3,240 finishing pigs in the Wabash River subwatershed. CFO permits allow for distribution of manure on approximately 353 acres. Estimated conservatively, the livestock in this subwatershed produce upwards of 5 thousand tons of manure per year. Hypothetically, if this manure were applied entirely to the 353 acres of permitted receiving land, total Nitrogen would not exceed recommended fertilizer rates (conservatively estimated for maximum yield and averaged across corn and soy crops). However in this subwatershed, Phosphorus Pentoxide loads would exceed recommended fertilizer rates (Sutton et al., 2001).

Streambank erosion is also of concern within the Wabash River subwatershed. In total, 7 miles of streambank stabilization are needed along the tributaries which feed into the Wabash River. Additionally, nearly 40 miles of the Wabash River require stabilization and nearly 6.25 acres of land requires buffering within 30 feet of the Wabash River (along approximately 1.7 miles of riverbank).

4.10.5 Water Quality Assessment

Within the Wabash River subwatershed, IDEM assessed water quality and macroinvertebrate communities at four sites (Figure 92). Two of these sites are fixed monitoring stations on the Wabash River located on Grant Road and State Road 225. *E. coli* was measured at the two fixed stations. Macroinvertebrates in the Wabash River were sampled at State Road 225 and County Road 100 Northeast. Water chemistry samplers were also collected on the Wabash River downstream of the State Road 225 fixed station on the Wabash River.

Water Chemistry

IDEM assessed water chemistry in the Wabash River at SR 225 in 2008. *E. coli* samples were collected five times over a 30-day period. *E. coli* levels exceeded the state standard once in this period measuring 272.3 colonies/100 mL; the remaining four samples measured below 70 colonies/100 mL. Nitrogen and total phosphorus measured during this sampling event were also elevated. Nitrogen concentrations exceeded Dodds et al. (1998) suggested standard during one out of three sample events measuring 5.34 mg/L. Total phosphorus exceeded the suggested standard during two of the three events with concentrations of 0.125 and 0.202 mg/L. At both of the fixed stations, *E. coli*, nitrogen, and total phosphorus were parameters of concern. Nitrogen concentrations routinely exceeded the recommended criteria at both sites. Concentrations ranged from 0.2 to 12.0 mg/L. Total phosphorus concentrations also routinely exceeded the suggested standard (0.3 mg/L) at both sites. Concentrations ranged from 0.05 to 0.81 mg/L. *E. coli* concentrations varied over time, but generally exceeded the state standard at both sites. The maximum *E. coli* concentration measured 23,000 colonies/100 mL, nearly 100 times the state standard.

Habitat

IDEM assessed habitat twice within the Wabash River subwatershed using the QHEI. IDEM assessments occurred in 1995 and 2008; sites were located at State Road 225 and County Road 100 Northeast on the Wabash River in Tippecanoe County. In 1995, the State Road 225 site's habitat was evaluated receiving a score of 52. This is barely better than the cut off for whether a stream is fully supporting their aquatic life use designation. The Wabash River on County Road 100 Northeast was sampled in 2008 and rated as not being fully supportive of the aquatic life use designation scoring 49.

Macroinvertebrates

The macroinvertebrate communities within Wabash River subwatershed were sampled at two locations by IDEM. IDEM sampled the Wabash River at SR 225 in 1995 and 1999. Communities rated as severely impaired during both assessments scoring 0.2 and 1.8, respectively. The Wabash River at County Road 100 Northeast was evaluated in 2008. The macroinvertebrate community was dominated by *Pleurocera canaliculata*, a right-handed snail that is intolerant of pollution. The mIBI score for was a 34, which rates this site severely impaired according to IDEM's new mIBI scale.

4.10.6 Wabash River Subwatershed Summary

Wabash River subwatershed has the lowest percentage of agricultural land use in the Deer Creek-Sugar Creek watershed, as it accounts for 71% of total land. This watershed has no urban land use, instead the rest of the land is comprised of 2.8% open water, 16.5% deciduous forest, and 6.8% wetlands; some of these lands are within Prophetstown State Park. The only point source water quality issue in this subwatershed is two leaky underground storage tanks. Similar to Sugar Creek subwatershed, there are no brownfields, industrial waste sites, or NPDES permitted facilities. Nitrogen concentrations were in exceedance of suggested standards in close to 30% of the samples taken, while phosphorus exceeded standards in close to 65% of the samples taken. *E. coli* was cause for concern, as samples revealed concentrations of nearly 100 times the state standard. Overall, E. coli concentrations fluctuated from sample to sample, but regularly exceeded the state standard. The habitat assessment for the Wabash River subwatershed revealed a need for improvement. The QHEI score indicated the habitat is on the verge of not fully supporting the aquatic life in the river, and the mIBI score indicated that the macroinvertebrate population was severely impaired.

5.0 WATERSHED INVENTORY III: WATERSHED INVENTORY SUMMARY

Several important factors and relationships become apparent when the Deer Creek-Sugar Creek watershed is observed both as a whole and in part. Many of these were discussed in the individual subwatershed discussions above; therefore, those discussions are not repeated here. Rather, an overall summary of water quality impairments and a review of stakeholder concerns and any data which support these concerns are included herein.

5.1 Water Quality Summary

Based on historic data collected from IDEM, IDNR, previous water quality sampling and watershed projects, and current water quality assessment, water quality impairments were identified during the watershed inventory process. These include elevated nitrate-nitrogen, total phosphorus, total suspended solids or turbidity, and E. coli concentrations; high densities of small, unregulated animal farms and confined feeding operations; and large portions of the watershed where manure or wastewater treatment plant materials are applied.

Figure 95 highlights those locations within the Deer Creek-Sugar Creek watershed where current water quality assessment detected concentrations of these parameters measured higher than the target concentrations during high flow events, Figure 43 shows the locations of historic sampling locations, and Figure 44 shows which historic sampling sites exceeded state standards. Current water quality assessment sample sites in Figure 95 are mapped only if a majority of samples collected at those sites during 20% or higher flow events exceeded the target concentration based on a load duration curve analysis. These higher flow events produced elevated concentrations in the subwatersheds and creeks as described in Table 21.

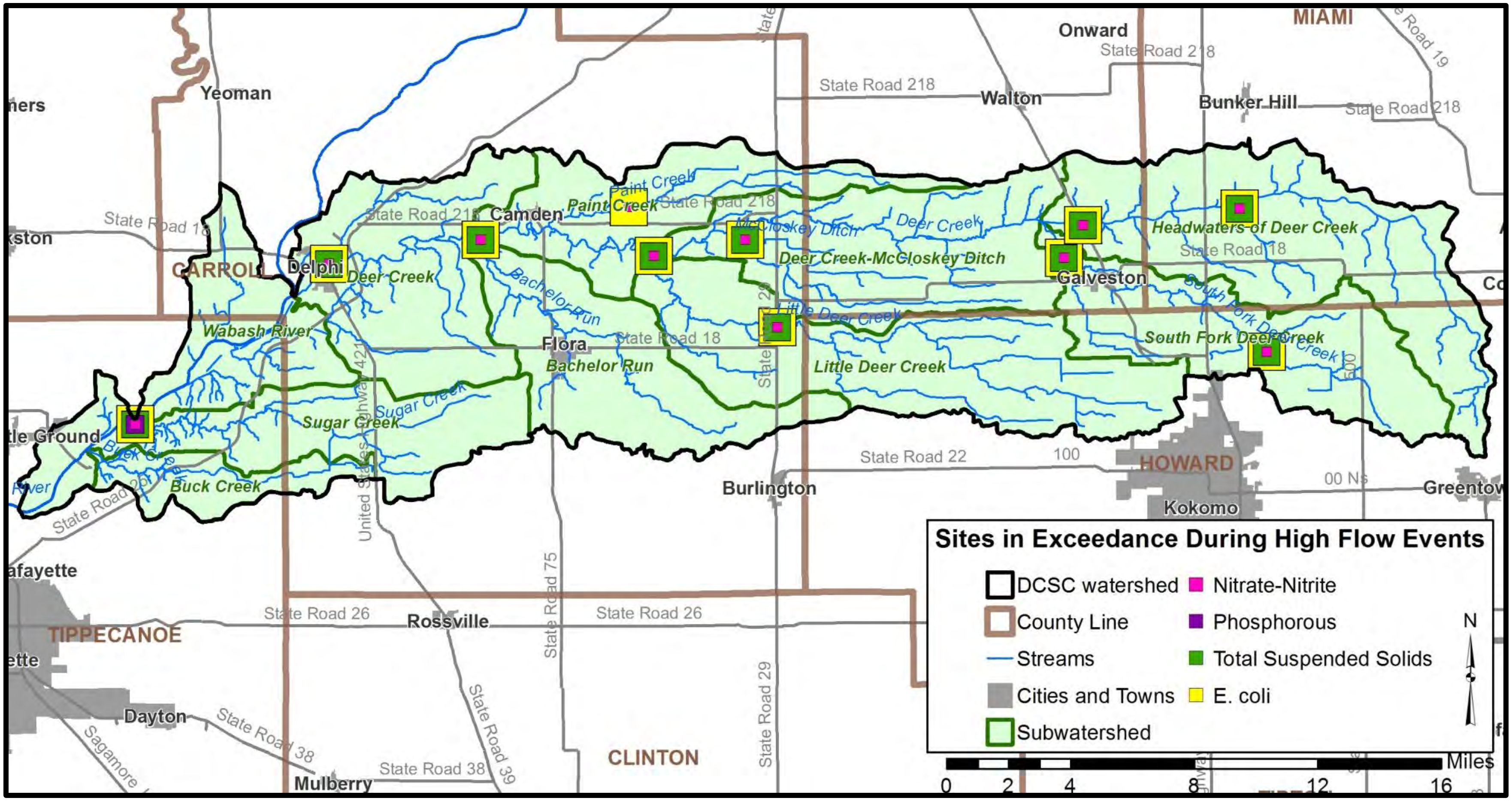

Figure 95. Locations where water chemistry concentrations exceed target concentrations during high flow events
Data used to create this map are detailed in Appendix A.

Table 21. Monitoring samples exceeding targets during high flow events

Subwatershed	E. coli	TSS	N	P
Headwaters of Deer Creek	●	●	●	
South Fork Deer Creek	●	●	●	
Deer Creek-McClosky Ditch	●	●	●	
Little Deer Creek	●	●	●	
Paint Creek	●		●	
Bachelor Run	●	●	●	
Deer Creek	●	●	●	
Sugar Creek	●	●	●	●
Buck Creek				
Wabash River	NA	NA	NA	NA
Stream	**E. coli**	**TSS**	**N**	**P**
South Fork Deer Creek	●	●	●	
Little Deer Creek	●	●	●	
McCloskey Ditch	●	●	●	
Paint Creek	●		●	
Bachelor Run	●	●	●	
Deer Creek	●	●	●	●
Sugar Creek	●	●	●	
Buck Creek				
Wabash River	NA	NA	NA	NA

5.2 Stakeholder Concern Analysis

All of the identified concerns generated both from stakeholder input and through water quality and watershed inventory efforts are detailed in Table 22. The steering committee rated each concern as to whether it is supported by watershed-based data, what evidence does or does not support the concerned, whether the concern is quantifiable, whether it is in the scope of the watershed management plan, and if it is something on which the committee wants to focus. Nearly all concerns were quantifiable and many were rated as being within the scope and items on which the committee wants to focus. If, in evaluating this table, the committee elected not to focus on a concern, the concern has been grayed out.

Table 22. Analysis of stakeholder concerns.

Grouped Stakeholder Concerns	Supported by data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
Agriculture run-off is contributing to the high nutrient concentrations and sedimentation (turbidity) within the Deer Creek Sugar Creek watershed.	Yes	• Cultivated crops accounts for 83.3% of the watershed's land use. Also, tile drained soils cover approximately 65% of the watershed. • Based on historic data, turbidity exceeded the USEPA's recommended standard of 9.89 NTU at 20 sites within the watershed (Bachelor Run, Deer Creek, Little Deer Creek, Paint Creek, South Fork of Deer Creek, Sugar Creek and the Wabash River). • Based on historic data, concentrations of nitrate-nitrite exceeded the recommended standard of 2 mg/L (Dodds et al., 1998) at 14 sites within the watershed (Bridge Creek, Deer Creek, Little Deer Creek, Sugar Creek and the Wabash River). During the current assessment, nitrate exceeded targets in 209 of 264 measurements. • Using historic data, concentrations of total phosphorus exceeded the recommended standard of 0.3 mg/l (Dodds et al., 1998) at 8 sites within the watershed (Bridge Creek, Deer Creek, Little Deer Creek, and the Wabash River). During the current assessment, total phosphorus concentrations exceeded targets in 43 of 264 measurements.	Yes	No	Yes
Pesticide concentrations in Deer Creek.	Yes	Based on historic IDEM data, there was evidence of pesticides in Deer Creek at CR 300 North in Carroll County. Pesticides detected include: Acetochlor – 0.1-2.3 µg/L; Alachlor – 0.1-2.3 µg/L; Atrazine – 0.3-16 µg/L; Benz[a]anthracene – 0.1 µg/L; Benzo[a]pyrene – 0.16 µg/L; Benzo(b)fluoranthene – 0.2 µg/L; Benzo[k]fluoranthene – 0.2 µg/L; Clomazone 0.1-3.2 µg/L; Cyanazine – 0.3 µg/L; Di(2-ethylhexyl) phthalate – 0.6-0.9 µg/L; Fluoranthene – 0.2-0.4 µg/L; Metolachlor – 0.1-30 µg/L. There is no data for the other waterbodies in the watershed.	Yes	No	Yes

Grouped Stakeholder Concerns	Supported by data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
Flood prone ground is farmed causing additional sediment and nutrient loading to waterbodies in the Deer Creek-Sugar Creek watershed.	Yes	Approximately 58% of the floodplain is classified as cultivated crops or hay/pasture (NLCD, 2006).	Yes	No	Yes
Too few agricultural best management practices are located in the Deer Creek-Sugar Creek watershed.	No data available at this time	Agricultural BMPs were identified during the watershed inventory; however, determination of whether “too few” are present did not occur. The committee agrees that increased usage of BMPs will improve water quality.	Yes	No	Yes
There are dead animals (hogs) in Deer Creek.	No	No data are available to support or refute this concern. The steering committee would like to address this issue if future evidence is found.	Yes	No	Yes
Waste from livestock is increasing the *E. coli* concentrations in watershed waterbodies.	No	The only way to definitively determine the actual source of *E. coli* is to perform DNA analysis of water quality samples. However, DNA analysis will not be done as part of this project. However, the steering committee would like to address the issue of livestock access in streams	Yes	No	Yes
Hog sewage (waste) is sitting/stagnate in Little Deer Creek.	No	No data are available to support or refute this concern. However the committee is interested in limiting the potential for sewage or waste to enter and stagnate in Little Deer Creek.	Yes	No	Yes
Livestock is negatively impacting water quality.	Yes	Livestock with stream access have the tendency to increase turbidity from entering and exiting the stream. Livestock have access to nearly 25 miles of watershed streams.	Yes	No	Yes
There are unregulated animal farms within the watershed.	Yes	There are 306 unregulated animal farms housing 259,000 animals.	Yes	No	Yes
Livestock access to the stream	Yes	Livestock have access to nearly 24 miles of watershed streams as observed during the watershed inventory.	Yes	No	Yes
Fish populations have been negatively affected by the water quality.	Yes	11 sites within the watershed were sampled for fish communities by IDEM; 7 sites were classified as below excellent using the IBI scale and 3 were not classified. Only one of the sites assessed during this planning process rated as excellent.	Yes	No	Yes

Grouped Stakeholder Concerns	Supported by data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
Macroinvertebrate populations have been negatively affected by the water quality.	Yes	Three sites assessed by IDEM using the current macroinvertebrate assessment method and five sites assessed by IDEM using the old assessment method rated below the IDEM standard. During this planning process, only the Headwaters of Deer Creek and McCloskey Ditch rated below the IDEM standard.	Yes	No	Yes
Wildlife areas should be encouraged and protected within the watershed.	Yes	IDNR manages 2,696 acres; Niches manages 64 acres within the watershed.	Yes	No	Yes
There has been a decline in crawfish populations.	No	Crawfish population surveys have not and will not be completed as part of this project.	Yes	No	No
Lack/decrease of wetlands within the watershed.	Yes	Based on the extent of hydric soils, nearly 92% of wetlands have been modified or lost. Approximately 3.4% of the watershed is classified as wetlands according to the National Wetland Inventory that updated in 2012 (NLCD, 2006 and NWI, 2012).	Yes	No	Yes
There are invasive species issues within the watershed.	No	Invasive species coverage will not be quantified as part of this project.	Yes	No	Yes
Fish caught within the watershed are not safe for consumption.	Yes	Fish consumption advisory exists for Deer Creek and the Wabash River (FCA, 2012):All waterbodies: Carp 15+ inches; Deer Creek – Smallmouth Bass 10+ inches; Wabash River – Black Redhorse 19+ inches; Blue Sucker 21+ inches; Carpsuckers ALL; Channel Catfish 15+ inches; Freshwater Drum 16+ inches; Sauger 13+ inches; Shorthead Redhorse 15+ inches; Smallmouth Buffalo 20+ inches	Yes	Yes	No
The volume of manure produced in the Deer Creek-Sugar Creek watershed.	Yes	Just over 42 square miles in the watershed are permitted for manure application. Based on average per head ton/year approximations, regulated animals from CFOs in the watershed are producing nearly 300,000 tons of manure per year. This does not include the additional waste produced by unregulated animal farms.	Yes	No	Yes

Grouped Stakeholder Concerns	Supported by data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
There is a lack of manure management in areas of the watershed.	No	Confined feeding operations have manure management plans on file with IDEM. Based on average per head ton/year approximations, regulated animals from CFOs in the watershed are producing nearly 300,000 tons of manure per year. This does not include the additional waste produced by unregulated animal farms. IDEM incident reports; newspaper articles indicate the following: •March 24th and April 18th of 1975: Fish kill in Little Sugar Creek and Sugar Creek due to a wastewater spill from a swine confined animal facility. • July 1981: Fish kill in Sugar Creek attributed to poor manure management on site resulting in manure inputs to the stream. •There are nine IDEM incident reports for CFO violations (IDEM virtual filing cabinet 1900-2013)	Yes	No	Yes
Some CFO facilities are storing their manure too close to creeks.	Undetermined at this time	Manure is being applied within the following distances from the creeks (determined using buffers along the streams and manure application sites):10 ft. – 64.3 acres; 50 ft. – 328.3 acres; 100 ft. – 689.3 acres; 200 ft. – 1,495 acres. CFO facility storage information will be updated upon the completion of the windshield survey	Yes	No	Yes
There have been several manure spills/fish kills within the watershed.	Yes	IDEM incident reports; newspaper articles indicate the following: •March 24th and April 18th of 1975: Fish kill in Little Sugar Creek and Sugar Creek due to a wastewater spill from a swine confined animal facility. • July 1981: Fish kill in Sugar Creek attributed to poor manure management on site resulting in manure inputs to the stream. •There are nine IDEM incident reports for CFO violations (IDEM virtual filing cabinet 1900-2013).	Yes	No	Yes

Grouped Stakeholder Concerns	Supported by data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
Manure is being applied throughout the watershed.	Yes	Manure is spread on 42.4 square miles of the watershed; this does not include manure from small producers and farms (IDEM and WREC, 2013).	Yes	No	Yes
Bio-solid issues	No	Municipal sludge (bio-solids) is being applied to approximately 14,596 acres. Application sites are predominately located in Cass and Howard Counties, 7,270 and 6,100 acres, respectively (IDEM, 2012).	Yes	No	Yes
Nitrogen concentrations exceed suggested levels.	Yes	Using historic data, concentrations of nitrate-nitrite exceeded the recommended standard of 2 mg/L (Dodds et al., 1998) at 14 sites within the watershed (Bridge Creek, Deer Creek, Little Deer Creek, Sugar Creek and the Wabash River). During the current assessment, nitrate exceeded targets in 209 of 264 measurements.	Yes	No	Yes
Phosphorus concentrations exceed suggested levels.	Yes	Using historic data, concentrations of total phosphorus exceeded the recommended standard of 0.3 mg/l (Dodds et al., 1998) at 8 sites within the watershed (Bridge Creek, Deer Creek, Little Deer Creek, and the Wabash River). During the current assessment, total phosphorus concentrations exceeded targets in 43 of 264 measurements.	Yes	No	Yes
Turbidity/sediment exceeds recommended levels by USEPA.	Yes	Using historic data, turbidity exceeded the USEPA's recommended standard of 9.89 NTU at 20 sites within the watershed (Bachelor Run, Deer Creek, Little Deer Creek, Paint Creek, South Fork of Deer Creek, Sugar Creek and the Wabash River). During the current assessment, turbidity measurements exceeded targets in 133 of 216 measurements.	Yes	No	Yes
E. coli concentrations exceed the state of Indiana's suggested level.	Yes	19 sites sampled by IDEM had *E. coli* concentrations exceeding Indiana's recommended standard of 235 colonies/100 mL. During the current assessment, *E. coli* concentrations exceeded targets during 188 of 216 measurements.	Yes	No	Yes
Develop long term monitoring stations on Deer Creek/Wabash River.	Yes/No	There are two USGS gauges within the watershed. One on Deer Creek and the other on the Wabash River.	Yes	No	Yes

Grouped Stakeholder Concerns	Supported by data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
There are limited buffers along Buck Creek which are contributing to poor water quality, and instable banks.	Yes	Insufficient or limited buffers are present along nearly 87 miles of watershed streams.	Yes	No	Yes
Care of soil quality and erosion.	Yes	Using historic data, turbidity concentrations were higher than the USEPA's suggested standard of 9.89 NTU at the majority of the historic sampling sites. During the current assessment, turbidity measurements exceeded targets in 133 of 216 measurements.	Yes	No	Yes
Stream bank erosion occurs along the waterbodies within the watershed.	Yes	Streambank erosion occurs along nearly 58 miles of watershed streams.	Yes	No	Yes
Educational programs addressing conservation practices, recycling, climate change, and disposing of chemicals need to be developed.	Yes/No	Educational programming and information is available throughout the watershed; however, additional programming and materials can always be useful.	Yes	No	Yes
Limited of recreation in the watershed.	Yes/No	Public access sites are available on Deer Creek and the Wabash River within the watershed. Efforts related to increasing recreation will be addressed via education and outreach efforts.	No	Yes	No
Carroll County zoning regulations are not providing sufficient protection for sensitive and high quality areas.	No	Carroll County is working to implement revised floodplain zoning which will most likely address these concerns.	No	Yes	No
Problem with land value.	No	No data could be identified to support or refute this issue with relationship to water quality.	No	Yes	No
Flooding concerns within residential areas (Flora and Delphi).	Yes/No	Documentation of historic flood events is available for both Flora and Delphi and both communities are making efforts to address these issues.	No	Yes	No
Instream flows are unpredictable	Yes/No	Flow data collected during this planning process indicate unpredictable flows; however, the committee will not address instream flows themselves but rather water retention and filtration efforts.	No	Yes	No
Wells are low and may be contaminated by nitrate.	No	No well data were collected as part of this planning effort.	No	Yes	No

Grouped Stakeholder Concerns	Supported by data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
Effects of highway construction (State Road 25).	No	A biological assessment occurred as part of the planning process for Hoosier Heartland. This document includes notation of streams that will be crossed but does not detail the communities present prior to construction.	No	Yes	No
Illegal septic systems	No	None of the county health departments have data on any illegal septic systems within the watershed. However, given the rural nature and development history, it is likely that some illegal septic systems exist within the watershed.	Yes	Yes	No
Increased population of zooplankton species	No	No zooplankton data were collected as part of the current or historic database.	No	Yes	No
Waste water needs more conservation of water, don't use drinking water for other uses	No	No water conservation data were collected as part of this planning process.	No	Yes	No
Dredge river; make it deeper	No	The need to dredge the Wabash River was not investigated as part of this planning process.	No	Yes	No
Reservoirs – effect on stream flow	No	The need for a reservoir within the Deer Creek-Sugar Creek watershed or the potential impact of such a waterbody was not investigated as part of this planning process.	No	Yes	No
Engineering of tile drains in Carroll County	No	Tile drains are present within the watershed including 65% of all soils and are engineered to increase the flow of water to surface waterbodies. This increase can impact water quality.	No	Yes	No
Stone quarry being constructed outside of Americus.	Yes	A stone quarry is planned outside of Americus within the Deer Creek-Sugar Creek watershed.	Yes	Yes	No
Dumping/burying of chemical waste	No	No evidence of dumping or burying of chemical waste was identified as part of this planning project.	No	Yes	No
Hydromodification of the stream system in the watershed	Yes	It appears that there are approximately 400 miles of regulated drains, indicating that the stream system is highly modified. More data need to be digitized, and variations in county definitions of legal, regulated, and maintained waterways need to be reconciled in order to review the exact mileage and locations of hydromodifications.	Yes	No	No

6.0 PROBLEM AND CAUSE IDENTIFICATION

6.1 Identifying Problems from Concerns & Inventory Analysis

Excluding concerns from Table 22 that the steering deemed outside the scope of the WMP (grayed out), Table 23 correlates public concerns and inventory analysis to problems in the watershed. Table 24 then addresses the potential causes of those problems.

Table 23. Problems identified for the Deer Creek-Sugar Creek watershed based on stakeholder and inventory concerns.

Public Concern and Inventory Analysis	Problems
• Agriculture run-off is contributing to the high nutrient concentrations and sedimentation (turbidity) within the Deer Creek Sugar Creek watershed. • Flood prone ground is farmed causing additional sediment and nutrient loading to waterbodies in the Deer Creek-Sugar Creek watershed. • Dead animals in Deer Creek (anecdotal). • Waste from livestock is increasing the *E. coli* concentrations in watershed bodies. • Hog sewage is stagnating in Little Deer Creek. • The volume of manure produced in the watershed. • There is a lack of manure management in areas of the watershed. • Some CFO facilities are storing manure too close to the creek. • There have been several manure spills/fish kills in the watershed. • Bio-solids issues. • Manure is being applied throughout the watershed. • Nitrogen concentrations exceed suggested levels. • Phosphorus concentrations exceed suggested levels. • There are limited buffers along Buck Creek which are contributing to poor water quality, and unstable banks.	Nutrient concentrations exceed target values set by this project.

<table>
<tr><th>Public Concern and Inventory Analysis</th><th>Problems</th></tr>
<tr><td>Agriculture run-off is contributing to the high nutrient concentrations and sedimentation (turbidity) within the Deer Creek Sugar Creek watershed.
Flood prone ground is farmed causing additional sediment and nutrient loading to waterbodies in the Deer Creek-Sugar Creek watershed.
Livestock is negatively impacting water quality.
There are unregulated animal farms within the watershed.
Turbidity/sediment exceeds recommended levels by USEPA.
Poor soil quality is present throughout the watershed.
Care of soil quality and erosion
Stream bank erosion occurs along the waterbodies within the watershed.
There are limited buffers along Buck Creek which are contributing to poor water quality, and unstable banks</td><td>Area streams are cloudy and turbid.</td></tr>
<tr><td>Fish populations have been negatively affected by the water quality.
Macroinvertebrate populations have been negatively affected by the water quality.
Wildlife areas should be encouraged and protected within the watershed.
Lack/decrease of wetlands within the watershed.
There are invasive species issues within the watershed.</td><td>Habitat is limited within watershed streams.</td></tr>
<tr><td>Fish populations have been negatively affected by the water quality.
Macroinvertebrate populations have been negatively affected by the water quality.
Nitrogen concentrations exceed suggested levels.
Phosphorus concentrations exceed suggested levels.
E. coli concentrations exceed the state of Indiana’s suggested level.</td><td>Area streams are listed by IDEM as impaired for recreational contact.</td></tr>
<tr><td>Educational programs addressing conservation practices, recycling, climate change, and disposing of chemicals need to be developed.</td><td>A unified education plan is not currently in place.</td></tr>
</table>

Public Concern and Inventory Analysis	Problems
• Pesticide concentrations in Deer Creek. • Too few agricultural best management practices are located in the Deer Creek-Sugar Creek watershed. • Develop long term monitoring stations on Deer Creek/Wabash River. • There are limited buffers along Buck Creek which are contributing to poor water quality, and instable banks. • Stream bank erosion occurs along the waterbodies within the watershed.	Individuals lack knowledge of about what they can do to improve the watershed.

6.2 Identifying Potential Causes of Problems

Table 24. Potential causes of identified problems in the Deer Creek-Sugar Creek watershed.

Problems	Potential Causes
Nutrient concentrations exceed target values set by this project.	Area streams have nutrient levels exceeding the suggested target levels of 1.0 mg/L for nitrate-nitrogen and 0.3 mg/L of total phosphorus.
Area streams are cloudy and turbid.	Turbidities exceed target standards of 9.89 NTU.
Habitat is limited within watershed streams.	Impaired biotic communities occur within the watershed.
Area streams are listed by IDEM as impaired for recreational contact.	*E. coli* concentrations exceed target values and the state standard.
A unified education plan is not currently in place.	Individuals lack knowledge of their impact on the watershed.
Individuals lack knowledge about what they can do to improve the watershed.	A targeted implementation program is lacking throughout the watershed.

6.3 Identifying Key Pollutants of Concern

Nonpoint pollution sources are varied, yet common, throughout almost any watershed. A summary of the key pollutants of concern in the Deer Creek-Sugar Creek watershed and their potential sources is listed below:

Nutrients (Nitrogen and Phosphorus):

- Conventional cropping practices
- Wastewater treatment discharges
- Industrial discharges (NPDES facilities permitted for nutrients)
- Agricultural and residential fertilizer
- Poor riparian buffers

- Streambank and bed erosion
- Construction activities
- Animal waste
- Confined feeding operations
- Human waste (failing septic systems, package plants, inadequately treated wastewater)
- Atmospheric deposition
- Altered hydrology (ditching and draining, fish passage limitations, altered stream courses)
- Flooding

E. coli:

- Human waste (failing septic systems, package plants, inadequately treated wastewater)
- Animal waste (livestock in streams, poor manure management, domestic and wildlife runoff)
- Urban runoff (pet waste, Combined Sewer Overflows)

Sediment:

- Conventional cropping practices
- Streambank and bed erosion
- Poor riparian buffers
- Need for floodplain restoration
- High velocities or increased urban runoff (impervious surfaces)
- Construction activities
- Livestock access to streams
- Altered hydrology (ditching and draining, fish passage limitations, altered stream courses)
- Flooding

6.4 Identifying Potential Sources of Pollutants

The steering committee used GIS, water quality data, and other available data to evaluate the potential sources of nonpoint pollution in the Deer Creek-Sugar Creek watershed. Table 25 to Table 30 detail the most significant potential sources of pollution for each of the problems identified in Table 23.

Table 25. Potential sources causing nutrient problems.

Problems:	Nutrient concentrations exceed target values set by this project.
Potential Causes:	Area streams have nutrient levels exceeding the suggested target levels of 2.0 mg/L for nitrate-nitrogen and 0.08 mg/L of total phosphorus.
Potential Sources:	• 48 livestock access areas were identified along more than 26 miles of streams. Livestock have access to streams in all subwatersheds except Buck Creek and Wabash River subwatersheds. Deer Creek-McCloskey Ditch, Little Deer Creek, Paint Creek, and South Fork of Deer Creek contain the highest percentage of streams with livestock access. • 1 (not recently problematic) Combined Sewer Overflow (CSO) identified in the South Fork of Deer Creek subwatersheds. • More than 256,000 animals are housed in confined feeding operations (CFOs) within the Deer Creek-Sugar Creek watershed. The highest density of animals occurs in the Buck Creek, Paint Creek, Sugar Creek, Deer Creek and Little Deer Creek subwatersheds. • 306 unregulated animal operations house nearly 2,725 animals throughout the watershed. The highest density of animals was observed in the Deer Creek-McCloskey Ditch, Buck Creek, Paint Creek and Bachelor Run subwatersheds. • 104 miles of stream lack adequate buffers or grassed waterways. Headwaters of Deer Creek, Deer Creek-McCloskey Ditch, Little Deer Creek, Sugar Creek, and Wabash River subwatersheds include streams which require improvement of more than 15% of their buffers. • 70 miles of stream lack adequate stabilization; all subwatersheds except Bachelor Run, Deer Creek, and Buck Creek have more than 10% of stream miles requiring stabilization. • 243 square miles of drained cropland are located throughout the watershed. Headwaters of Deer Creek, Bachelor Run, Buck Creek, South Fork of Deer Creek and Sugar Creek subwatersheds contain greater than 80% coverage by drained cropland. • Manure from confined feeding operations is applied on 42.4 square miles throughout the watershed. The highest density of manure application occurs in the Buck Creek, Sugar Creek, Little Deer Creek, Headwaters of Deer Creek, and Bachelor Run subwatersheds. • Four wastewater treatment plants and 42 unsewered dense housing areas are located within the Deer Creek-Sugar Creek watershed. South Fork of Deer Creek, Headwater of Deer Creek, Deer Creek, Sugar Creek and Buck Creek watersheds contain the highest densities of unsewered dense housing areas. • Wastewater treatment plant sludge is being applied to more than 22 square miles in the Deer Creek-McCloskey Ditch, Little Deer Creek, South Fork of Deer Creek, Paint Creek, Buck Creek and Headwaters of Deer Creek subwatersheds. • Unknown volumes of fertilizer and pesticides are applied on lawns adjacent to storm drains and streams within the urban and suburban portions of the watershed. • Pet and yard wastes are improperly disposed of within the urban and suburban portions of the watershed. • Failing septic systems add nutrients to the system within the rural portion of the watershed.

Table 26. Potential sources causing sediment problems.

Problems:	Area streams are cloudy and turbid.
Potential Causes:	Turbidities exceed target standards of 9.89 NTU.
Potential Sources:	• 48 livestock access areas were identified along more than 26 miles of streams. Livestock have access to streams in all subwatersheds except Buck Creek and Wabash River subwatersheds. Deer Creek-McCloskey Ditch, Little Deer Creek, Paint Creek, and South Fork of Deer Creek contain the highest percentage of streams with livestock access. • 104 miles of stream lack adequate buffers or grassed waterways. Headwaters of Deer Creek, Deer Creek-McCloskey Ditch, Little Deer Creek, Sugar Creek, and Wabash River subwatersheds include streams which require improvement of more than 15% of their buffers. • 70 miles of stream lack adequate stabilization; all subwatersheds except Bachelor Run, Deer Creek, and Buck Creek have more than 10% of stream miles requiring stabilization. • 243 square miles of drained cropland are located throughout the watershed. Headwaters of Deer Creek, Bachelor Run, Buck Creek, South Fork of Deer Creek and Sugar Creek subwatersheds contain greater than 80% coverage by drained cropland.

Table 27. Potential sources causing habitat problems.

Problems:	Habitat is limited within watershed streams.
Potential Causes:	Impaired biotic communities occur within the watershed.
Potential Sources:	• 104 miles of stream lack adequate buffers or grassed waterways. Headwaters of Deer Creek, Deer Creek-McCloskey Ditch, Little Deer Creek, Sugar Creek, and Wabash River subwatersheds include streams which require improvement of more than 15% of their buffers. • 70 miles of stream lack adequate stabilization; all subwatersheds except Bachelor Run, Deer Creek, and Buck Creek have more than 10% of stream miles requiring stabilization. • Poor IBI scores (<36) occurred in the Deer Creek subwatershed on tributaries to Deer Creek. • Poor mIBI scores (<2.2 old; <30 new) occurred in the Headwaters of Deer Creek, Little Deer Creek, Paint Creek, Deer Creek, Buck Creek and Wabash River subwatersheds. Although the scores are not a source, the fact that these scores occurred at these sites indicate a source of habitat issues within these streams. • Poor QHEI (<51) or CQHEI (<60) scores occurred in the Bachelor Run, Deer Creek, Buck Creek and Wabash River subwatersheds. Although the scores are not a source, the fact that these scores occurred at these sites indicate a source of habitat issues within these streams. • Many subwatersheds have undergone extensive hydromodification, including agricultural ditches and drains

Table 28. Potential sources causing *E. coli* problems.

Problems:	Area streams are listed by IDEM as impaired for recreational contact.
Potential Causes:	*E. coli* concentrations exceed target values and the state standard.
Potential Sources:	• 48 livestock access areas were identified along more than 26 miles of streams. Livestock have access to streams in all subwatersheds except Buck Creek and Wabash River subwatersheds. Deer Creek-McCloskey Ditch, Little Deer Creek, Paint Creek, and South Fork of Deer Creek contain the highest percentage of streams with livestock access. • 1 (not recently problematic) Combined Sewer Overflow (CSO) identified in the South Fork of Deer Creek subwatersheds. • Four wastewater treatment plants and 42 unsewered dense housing areas are located within the Deer Creek-Sugar Creek watershed. South Fork of Deer Creek, Headwater Deer Creek, Deer Creek, Sugar Creek and Buck Creek watersheds contain the highest densities of unsewered dense housing areas. • More than 256,000 animals are housed on confined feeding operations (CFOs) within the Deer Creek-Sugar Creek watershed. The highest density of animals occurs in the Buck Creek, Paint Creek, Sugar Creek, Deer Creek and Little Deer Creek subwatersheds. • 306 unregulated animal operations house nearly 2,725 animals throughout the watershed. The highest density of animals was observed in the Deer Creek-McCloskey Ditch, Buck Creek, Paint Creek and Bachelor Run subwatersheds. • 104 miles of stream lack adequate buffers or grassed waterways. Headwaters of Deer Creek, Deer Creek-McCloskey Ditch, Little Deer Creek, Sugar Creek, and Wabash River subwatersheds include streams which require improvement of more than 15% of their buffers. • 70 miles of stream lack adequate stabilization; all subwatersheds except Bachelor Run, Deer Creek, and Buck Creek have more than 10% of stream miles requiring stabilization. • Manure from confined feeding operations is applied on 42.4 square miles throughout the watershed. The highest density of manure application occurs in the Buck Creek, Sugar Creek, Little Deer Creek, Headwaters of Deer Creek, and Bachelor Run subwatersheds. • Wastewater treatment plant sludge is being applied to more than 22 square miles in the Deer Creek-McCloskey Ditch, Little Deer Creek, South Fork of Deer Creek, Paint Creek, Buck Creek and Headwaters of Deer Creek subwatersheds. • Failing septic systems add nutrients to waterbodies within the rural portion of the watershed.

Table 29. Potential sources causing education problems.

Problems:	A unified education plan is not currently in place.
Potential Causes:	Individuals lack knowledge of their impact on the watershed.
Potential Sources:	N/A

Table 30. Potential sources causing limited practice implementation.

Problems:	Individuals lack knowledge of about what they can do to improve the watershed.
Potential Causes:	A targeted implementation program is lacking.
Potential Sources:	N/A

7.0 LOAD ESTIMATES

Nonpoint source pollution is generated from diffuse sources found on public and private lands. The USEPA notes that sources of nonpoint source pollution include: urban runoff, construction activities, solid waste disposal, atmospheric deposition, streambank erosion, and more. Inventory data in Table 25 through Table 30 identify potential sources of nonpoint pollution within the watershed. These tables – generated using GIS, water quality data, windshield surveys, local knowledge, and other sources of data – are useful for generally identifying water quality problems. Two methods have been used to understand the loading of nutrients, sediment, and pathogens in waterbodies in the Deer Creek-Sugar Creek watershed: measured results from the monitoring regime and modeled results. Each method can estimate both the current load and the reduction in load needed to reach target concentrations. These methods each present advantages and disadvantages for understanding the loading in this watershed in particular. The steering committee considered the model results, available before the monitoring was completed, in order to draft long term goals and critical areas. When the measured results from the monitoring became available, the steering committee gave careful consideration to a comparison between the two before making final decisions about long term goals, short term goals, and critical areas.

7.1 Monitoring results

Results from monitoring data can be used to estimate loads of nonpoint source pollution. Concentrations of nutrients, sediments, and pathogens taken at sampling sites can be combined with flow data to estimate the current loads in those waterbodies. Target loads for those waterbodies can also be calculated using available flow data.

As discussed in section 3.3, twelve monitoring sites were sampled every other week from August 2012 through August 2013. There is clear value in using these measurements from the Deer Creek-Sugar Creek watershed to estimate loads and load reductions. However, there are some limitations in the measured dataset. Sampling methods did not allow for continuous flow measurements at each site, so data from several USGS gages were used to approximate flow. Samples collection began in a period of intense drought and was completed in a period of more normal precipitation. The dataset can therefore give us an interesting contrast between low flow and high flow conditions, but on the whole, it isn't representative of a typical annual precipitation and stream flow cycle.

7.2 L-THIA Model

Hydrologic simulation models, another mechanism to determine nonpoint pollution sources and estimate loads, can be used to model the transport of pollutants across the land surface as surface runoff. Rain water flows over the land and through the groundwater, collecting pollutants such as sediment and nutrients as it moves. Soil characteristics and land uses influence the way water moves through the system, and each hydrologic model simulates the movement in a different way. These computer models provide load estimates which can serve as a baseline against which to compare changes in land use and their impacts on water quality.

The Long Term Hydrologic Impact Analysis model, L-THIA, was used to assess the nonpoint source loading rates of three pollutants of concern in the watershed: total nitrogen, total phosphorus, and suspended solids. L-THIA combines land use and soil type inputs with a localized 30-year rainfall record (1963-1993) to produce estimates of runoff volume and pollutant loads. The Basic Spreadsheet L-THIA was loaded with the acreages of both land use and soil type within each subwatershed; thus L-THIA provides results ideal for comparing and determining which subwatersheds may require the most load reductions. The long-term rainfall assumptions made by L-THIA even out drought and flooding conditions. L-THIA is also widely available, free, easy to use, and recommended by IDEM for use in watershed management planning.

However, the model has its limitations as well. L-THIA does not model *E. coli* loads. The long-term rainfall assumptions are unable to predict loading that result from storms and turbulent runoff events. L-THIA assumes a nation-wide average contribution of a given pollutant from an acre of agricultural land; without calibration, L-THIA may over or under estimate the actual contributions of agricultural land in the watershed. In addition, the degree to which a particular acre of soil has been developed or compacted should ideally be fed into the model as a downgraded soil type with a higher runoff potential; however information this fine grained is not available on a watershed-wide basis. Thus the model may under-predict the runoff potential of certain soil types. Finally, L-THIA estimates runoff volumes only, and loading that result from tile drainage, streambank erosion, livestock access, nutrient application, or point source pollution will not be present in L-THIA's results. The L-THIA model results provide a broad picture of watershed loading, but they cannot provide a detailed prediction of loading in this watershed.

7.3 Annual Load Estimates

L-THIA-modeled runoff volume and nonpoint source pollutant loading based on total acreages of land use and soil types within each of Deer Creek-Sugar Creek's subwatersheds. In total, the model predicts that 696,000 pounds of nitrogen, 204,000 pounds of phosphorus, and 16.8 million pounds of sediment loading occurs within the Deer Creek-Sugar Creek watershed annually (Table 31). Little Deer Creek subwatershed is modeled as the largest contributor of nitrogen, phosphorus, and sediment loads to the watershed, followed by the South Fork of Deer Creek and the Buck Creek subwatersheds. When loading rates are normalized by area and represented in pounds per acre per year, Buck Creek is modeled as the highest contributor of nitrogen, phosphorus, and total suspended sediments per acre, followed by the Little Deer Creek and South Fork of Deer Creek subwatersheds (Table 32).

Concentration results from monitoring efforts can be multiplied by flow data to calculate loading measured between August 2012 and August 2013. The load at each sample site represents the loading from the land that drains to that site. Many sample sites are located close to the drainage point of a subwatershed, making possible a comparison between the measured load and the modeled load for a subwatershed. However, some sites only partially drain a subwatershed; in order to compare, measured results have been scaled up to match the drainage of the equivalent modeled subwatershed in Table 33 through Table 35.

Table 31. L-THIA-modeled annual load estimates for each subwatershed, ranked by total contributions – in pounds per year.

Ranked Contributions	Current Nitrogen Load		Current Phosphorus Load		Current Sediment Load	
	Subwatershed	*(lb/yr)*	Subwatershed	*(lb/yr)*	Subwatershed	*(lb/yr)*
Highest	Little Deer Creek	*136,497*	Little Deer Creek	*40,049*	Little Deer Creek	*3,297,033*
	South Fork of Deer Creek	*91,858*	South Fork of Deer Creek	*26,894*	South Fork of Deer Creek	*2,215,319*
	Buck Creek	*85,370*	Buck Creek	*25,146*	Buck Creek	*2,069,969*
	Bachelor Run	*77,346*	Bachelor Run	*22,729*	Bachelor Run	*1,868,415*
	Deer Creek	*68,028*	Deer Creek	*19,893*	Deer Creek	*1,634,413*
	Sugar Creek	*57,335*	Sugar Creek	*16,766*	Sugar Creek	*1,380,467*
	Headwaters of Deer Creek	*52,773*	Headwaters of Deer Creek	*15,319*	Headwaters of Deer Creek	*1,261,022*
	Paint Creek	*45,533*	Paint Creek	*13,361*	Paint Creek	*1,099,945*
	Deer Creek-McCloskey Ditch	*42,472*	Deer Creek-McCloskey Ditch	*12,495*	Deer Creek-McCloskey Ditch	*1,028,458*
Lowest	Wabash River	*38,956*	Wabash River	*11,307*	Wabash River	*931,603*
Totals		696,169		203,960		16,786,645

Table 32. L-THIA-modeled annual load estimates for each subwatershed, ranked by normalized contributions – in pounds per acre per year.

Ranked Contributions (Normalized)	Annual Nitrogen Load		Annual Phosphorus Load		Annual Sediment Load	
	Subwatershed	*(lb/acre/yr)*	Subwatershed	*(lb/acre/yr)*	Subwatershed	*(lb/acre/yr)*
Highest	Buck Creek	*11.41*	Buck Creek	*3.36*	Buck Creek	*276.73*
	Little Deer Creek	*3.92*	Little Deer Creek	*1.15*	Little Deer Creek	*94.70*
	South Fork of Deer Creek	*3.61*	South Fork of Deer Creek	*1.06*	South Fork of Deer Creek	*87.15*
	Bachelor Run	*3.36*	Bachelor Run	*0.99*	Bachelor Run	*81.12*
	Sugar Creek	*3.12*	Sugar Creek	*0.91*	Sugar Creek	*75.23*
	Deer Creek	*2.66*	Deer Creek	*0.78*	Deer Creek	*64.02*
	Paint Creek	*2.41*	Paint Creek	*0.71*	Paint Creek	*58.30*
	Wabash River	*1.93*	Wabash River	*0.56*	Wabash River	*46.17*
	Deer Creek-McCloskey Ditch	*1.48*	Deer Creek-McCloskey Ditch	*0.43*	Deer Creek-McCloskey Ditch	*35.76*
Lowest	Headwaters of Deer Creek	*1.41*	Headwaters of Deer Creek	*0.41*	Headwaters of Deer Creek	*33.63*

Table 33: Measured vs. Modeled Nitrogen Load Estimates

Monitoring Site	Equivalent Subwatershed(s)		Monitoring Drainage	Nitrogen: Measured Load*	Nitrogen: Modeled Load	Nitrogen: Comparison: monitor/model	Nitrogen: Measured Load*	Nitrogen: Modeled Load
	Name	Size (sq mi)	% of subwatershed(s)	lb/yr	lb/yr		lb/acre/year	lb/acre/year
DCM10	Headwaters of Deer Creek	58.59	96%	1,015,437	52,773	1924%	27.08	1.41
SFD9	South Fork Deer Creek	39.72	98%	620,118	91,858	675%	24.39	3.61
MD8	Deer Creek-McCloskey Ditch	44.94	35%	563,993	42,472	1328%	19.61	1.48
LDD7	Little Deer Creek	54.40	97%	1,164,669	136,497	853%	33.45	3.92
PC5	Paint Creek	29.48	47%	624,287	45,533	1371%	33.09	2.41
BR4	Bachelor Run	35.99	100%	1,028,934	77,346	1330%	44.67	3.36
DCD3	Deer Creek, Bachelor Run, Paint Creek, Little Deer Creek, Deer Creek-McCloskey Ditch, South Fork Deer Creek, Headwaters of Deer Creek	303.01	99%	6,562,910	514,508	1276%	33.84	2.65
SC2	Sugar Creek	28.67	100%	910,525	57,335	1588%	49.62	3.12
BC1	Buck Creek	11.69	96%	524,015	85,370	614%	70.06	11.41

*scaled to equivalent subwatershed size

from Monitoring

from L-THIA Model

Measured nitrogen loads are approximately ten times higher than modeled nitrogen loads. The surface water estimates for the L-THIA model do not allow for an accurate estimate of nitrogen transported by tile drainage or increased runoff over compacted or disturbed soils. The national average for nitrogen runoff per agricultural acre may underestimate local conditions. Additional spikes of nitrogen loading due to high flow runoff events, shown in Figure 56, may also go unaccounted for in the model. However, the measured and modeled results both point to the Buck Creek subwatershed as having the highest nitrogen load in pounds per acre per year.

Table 34: Measured vs. Modeled Phosphorus Load Estimates

Monitoring Site	Equivalent Subwatershed(s)		Monitoring Drainage	Phosphorous				
				Measured Load*	Modeled Load	Comparison: monitor/model	Measured Load*	Modeled Load
	Name	Size (sq mi)	% of subwatershed(s)	lb/yr	lb/yr		lb/acre/year	lb/acre/year
DCM10	Headwaters of Deer Creek	58.59	96%	32,921	15,319	215%	0.88	0.41
SFD9	South Fork Deer Creek	39.72	98%	15,470	26,894	58%	0.61	1.06
MD8	Deer Creek-McCloskey Ditch	44.94	35%	10,655	12,495	85%	0.37	0.43
LDD7	Little Deer Creek	54.40	97%	24,678	40,049	62%	0.71	1.15
PC5	Paint Creek	29.48	47%	20,858	13,361	156%	1.11	0.71
BR4	Bachelor Run	35.99	100%	24,700	22,729	109%	1.07	0.99
DCD3	Deer Creek, Bachelor Run, Paint Creek, Little Deer Creek, Deer Creek-McCloskey Ditch, South Fork Deer Creek, Headwaters of Deer Creek	303.01	99%	133,098	150,741	88%	0.69	0.78
SC2	Sugar Creek	28.67	100%	19,233	16,766	115%	1.05	0.91
BC1	Buck Creek	11.69	96%	8,737	25,146	35%	1.17	3.36

*scaled to equivalent subwatershed size

from Monitoring

from L-THIA Model

Measured phosphorus loads are in some cases lower than modeled phosphorus loads, but results for the subwatersheds are within the same order of magnitude.

Table 35: Measured vs. Modeled Sediment Load Estimates

Monitoring Site	Equivalent Subwatershed(s)		Monitoring Drainage	Total Suspendid Solids: Measured Load*	Modeled Load	Comparison: monitor/model	Measured Load*	Modeled Load
	Name	Size (sq mi)	% of subwatershed(s)	lb/yr	lb/yr		lb/acre/year	lb/acre/year
DCM10	Headwaters of Deer Creek	58.59	96%	20,010,763	1,261,022	1587%	533.63	33.63
SFD9	South Fork Deer Creek	39.72	98%	7,071,473	2,215,319	319%	278.19	87.15
MD8	Deer Creek-McCloskey Ditch	44.94	35%	5,901,862	1,028,458	574%	205.18	35.76
LDD7	Little Deer Creek	54.40	97%	13,977,532	3,297,033	424%	401.49	94.70
PC5	Paint Creek	29.48	47%	1,929,996	1,099,945	175%	102.30	58.30
BR4	Bachelor Run	35.99	100%	9,093,648	1,868,415	487%	394.83	81.12
DCD3	Deer Creek, Bachelor Run, Paint Creek, Little Deer Creek, Deer Creek-McCloskey Ditch, South Fork Deer Creek, Headwaters of Deer Creek	303.01	99%	105,712,210	12,404,605	852%	545.12	63.97
SC2	Sugar Creek	28.67	100%	9,731,940	1,380,467	705%	530.32	75.23
BC1	Buck Creek	11.69	96%	2,504,193	2,069,969	121%	334.79	276.73

*scaled to equivalent subwatershed size

from Monitoring

from L-THIA Model

Measured sediment loads are on average five times higher than modeled sediment loads. The national average for sediment runoff per agricultural acre may underestimate local conditions, and the model does not take into account streambank erosion or livestock access, which could be contributing to the higher loads measured. Additional spikes of sediment loading due to high flow runoff events, shown in Figure 58, may also go unaccounted for in the model.

Because the L-THIA does not model *E. coli*, our monitoring measurements are the only source of data to estimate annual *E. coli* concentrations in this watershed (Table 36). Annual concentrations are used instead of annual loading because it is difficult to determine the weight of bacteria cells. Annual concentrations, expressed as the number of colony forming units (cfu) are estimated by multiplying measured concentrations by stream flow.

Table 36: Measured *E. coli* Load Estimates

Monitoring Site	Equivalent Subwatershed(s)		Monitoring Drainage	E. coli	
				Measured Load*	Measured Load*
	Name	Size (sq mi)	% of subwatershed(s)	cfu/yr	cfu/acre/year
DCM10	Headwaters of Deer Creek	58.59	96%	971,091,275,103,353	25,896,457,908
SFD9	South Fork Deer Creek	39.72	98%	414,132,175,299,640	16,291,588,328
MD8	Deer Creek-McCloskey Ditch	44.94	35%	299,921,281,499,032	10,426,967,094
LDD7	Little Deer Creek	54.40	97%	504,186,355,449,550	14,482,287,455
PC5	Paint Creek	29.48	47%	137,768,217,723,814	7,302,460,390
BR4	Bachelor Run	35.99	100%	421,507,719,832,816	18,300,960,396
DCD3	Deer Creek, Bachelor Run, Paint Creek, Little Deer Creek, Deer Creek-McCloskey Ditch, South Fork Deer Creek, Headwaters of Deer Creek	303.01	99%	3,188,848,185,249,390	16,443,718,887
SC2	Sugar Creek	28.67	100%	206,920,604,130,396	11,275,712,720
BC1	Buck Creek	11.69	96%	190,152,613,424,739	25,421,472,383

*scaled to equivalent subwatershed size

7.4 Load Reduction Estimates

Water quality targets are used to calculate target loads, which are then subtracted from the annual loads to estimate the load reductions needed. Load reductions for each subwatershed play an important role in selecting critical areas and determining long-term goals. As discussed in section 3.1, the steering committee selected water quality target concentrations according to state recommended concentrations. Table 37 lists the target concentrations for our parameters of concern.

The difference between measurement- and model-derived target loads can be explained by the difference in flow estimates. L-THIA estimates runoff based on land use, soil type, and a localized 30-year rainfall average. However, it may underestimate runoff if soils have been compacted or disturbed; and the model does not account for tile drainage, which could contribute a significant amount to stream flow in this predominately agricultural watershed. Measured target loads are based on flow data from two local USGS gauges, giving a more accurate picture of localized stream flow for the timeframe during which samples were drawn. However, the extreme precipitation variations (drought year conditions) in a shorter timeframe (one year of data collection) weaken the reliability of the measured flow data as a baseline against which to measure future change.

Table 37. Target concentrations for parameters of interest in the Deer Creek-Sugar Creek Watershed.

Parameter of Concern	Water Quality Benchmark
Nitrate –Nitrogen	Max: 1.0 mg/L
Total Phosphorus	Short Term Target Max: 0.3 mg/L
Total Suspended Solids (TSS)	Max: 15.0 mg/L
E. coli	Max: 235 cfu/100mL in a single sample – OR – Max Geometric Mean of 125 cfu/100mL from 5 equally spaced samples over a 30 day period

L-THIA estimates target loads by multiplying predicted runoff by target concentrations. Measured data can also be used to estimate target loads by multiplying stream flow by target concentrations. Measured and modeled target loads are shown in Table 38. *E. coli* targets are calculated to the geometric mean concentration.

Table 38: Measured vs. Modeled Target Load Estimates

				Nitrogen		Phosphorous		Sediment		E. coli
Monitoring Site	**Equivalent Subwatershed(s)**		**Monitoring Drainage**	Measured Target Load*	Modeled Target Load	Measured Target Load*	Modeled Target Load	Measured Target Load*	Modeled Target Load	Measured Target Load*
	Name	Size (sq mi)	% of subwatershed(s)	lb/yr	lb/yr	lb/yr	lb/yr	lb/yr	lb/yr	cfu/yr
DCM10	Headwaters of Deer Creek	58.59	96%	144,880	13,265	43,464	3,979	2,173,204	198,969	82,203,299,280,285
SFD9	South Fork Deer Creek	39.72	98%	98,299	22,229	29,490	6,669	1,474,481	333,439	55,773,486,225,378
MD8	Deer Creek-McCloskey Ditch	44.94	35%	64,892	9,899	19,468	2,970	973,380	148,489	36,818,930,532,743
LDD7	Little Deer Creek	54.40	97%	134,608	32,250	40,382	9,675	2,019,118	483,748	76,374,834,692,956
PC5	Paint Creek	29.48	47%	52,381	10,718	15,714	3,215	785,711	160,771	29,720,178,305,490
BR4	Bachelor Run	35.99	100%	89,117	18,415	26,735	5,525	1,336,760	276,227	50,564,081,316,228
DCD3	Deer Creek, Bachelor Run, Paint Creek, Little Deer Creek, Deer Creek-McCloskey Ditch, South Fork Deer Creek, Headwaters of Deer Creek	303.01	99%	750,207	123,517	225,062	37,055	11,253,103	1,852,762	425,658,159,400,578
SC2	Sugar Creek	28.67	100%	53,979	13,734	16,194	4,120	809,692	206,008	30,627,276,664,203
BC1	Buck Creek	11.69	96%	21,961	19,713	6,588	5,914	329,414	295,689	12,460,369,555,105

*scaled to equivalent subwatershed size

from Monitoring

from L-THIA Model

Table 39 compares the load reductions derived from the measured data and the modeled data. The L-THIA model doesn't account for any subsurface runoff or in-stream erosion, thus it appears to underestimate suspended solids and water soluble nutrients such as nitrate. L-THIA appears to overestimate phosphorus, however, possibly because the model inputs for phosphorus runoff may not be calibrated to conditions in the watershed.

L-THIA's 30-year rainfall input assumes consistent flow conditions, whereas the monitoring spans nearly half a year of severe drought and includes a number of storm events. In examining the measured results from each sample site, (Figure 50 through Figure 54), it is interesting to note that the majority of the individual samples collected, particularly for total suspended solids and phosphorus, meet target concentrations. However, it appears that high flow events, likely the result of storm events, correspond with spikes in concentration, well above target levels. Concentrations sampled during these storm events seem to substantially contribute to the high loads represented in the monitoring results, offering an additional potential explanation for the disparity between the modeled and the measured data. Measured results suggest that on-the-ground practices which are already installed (Appendix F) maintain phosphorus concentrations below target levels during times of low to moderate flow, but additional practices are needed to prevent phosphorus loading spikes during high flow events.

The importance of storm or high flow events shown in these charts also reveals the necessity of using load duration curve analysis to determine which sites are in exceedance of their targets. Load duration curves model the target concentrations according to flow. Only those sites where a majority of the samples exceed the modeled target during a high flow event (i.e. those events greater than 20% normal flow) will be considered in exceedance (Figure 55 to Figure 59). Rather than lower the parameter targets, the steering committee selected this method to determine site exceedances in Figure 95.

Based on a thorough discussion of the discrepancies between the modeled and measured data, the steering committee decided to base the long-term load reduction goals on the L-THIA model. Additionally, the committee selected scaled goals to attempt to address the issues of substantial loading during storm events in the short term. Measured data were used to identify the storm-based exceedances measured as part of the water quality monitoring effort. L-THIA-derived reductions nitrogen, phosphorus, and sediment for each subwatershed are listed in Table 40 and mapped in Figure 96 through Figure 98. These reductions exceed the Wabash River TMDL reductions, which require a 4% reduction in phosphorus and no reduction in nitrate in Deer Creek (TetraTech, 2007).

Long term goals for *E. coli* reductions will be based on measured data. The average *E. coli* reduction for the watershed (averaged from sample sites DCD3, SC2, and BC1, which cover all drainage in the watershed except for the Wabash River subwatershed) is 88.3%, which exceeds the Wabash River TMDL required *E. coli* reduction of 87% for Deer Creek (TetraTech, 2007).

Table 39: Measured vs. Monitored Load Reduction Estimates

Monitoring Site	Equivalent Subwatershed(s)	Nitrogen Measured Reduction*		Nitrogen Modeled Reduction		Phosphorous Measured Reduction*		Phosphorous Modeled Reduction	
	Name	lb/yr	percent	lb/yr	percent	lb/yr	percent	lb/yr	percent
DCM10	Headwaters of Deer Creek	870,557	86%	39,509	75%	none	0%	11,339	74%
SFD9	South Fork Deer Creek	521,819	84%	69,629	76%	none	0%	20,225	75%
MD8	Deer Creek-McCloskey Ditch	499,101	88%	32,573	77%	none	0%	9,525	76%
LDD7	Little Deer Creek	1,030,061	88%	104,248	76%	none	0%	30,375	76%
PC5	Paint Creek	571,907	92%	34,815	76%	none	0%	10,146	76%
BR4	Bachelor Run	939,817	91%	58,931	76%	none	0%	17,205	76%
DCD3	Deer Creek, Bachelor Run, Paint Creek, Little Deer Creek, Deer Creek-McCloskey Ditch, South Fork Deer Creek, Headwaters of Deer Creek	5,812,703	89%	390,990	76%	none	0%	113,686	75%
SC2	Sugar Creek	856,546	94%	43,601	76%	3,039	16%	12,646	75%
BC1	Buck Creek	502,055	96%	65,657	77%	2,149	25%	19,232	76%

Monitoring Site	Equivalent Subwatershed(s)	Sediment Measured Reduction*		Sediment Modeled Reduction		*E. coli* Measured Reduction*	
	Name	lb/yr	percent	lb/yr	percent	cfu/yr	percent
DCM10	Headwaters of Deer Creek	17,837,559	89%	1,062,053	84%	888,887,975,823,068	92%
SFD9	South Fork Deer Creek	5,596,992	79%	1,881,880	85%	358,358,689,074,263	87%
MD8	Deer Creek-McCloskey Ditch	4,928,482	84%	879,969	86%	263,102,350,966,290	88%
LDD7	Little Deer Creek	11,958,414	86%	2,813,284	85%	427,811,520,756,594	85%
PC5	Paint Creek	1,144,285	59%	939,175	85%	108,048,039,418,325	78%
BR4	Bachelor Run	7,756,888	85%	1,592,189	85%	370,943,638,516,588	88%
DCD3	Deer Creek, Bachelor Run, Paint Creek, Little Deer Creek, Deer Creek-McCloskey Ditch, South Fork Deer Creek, Headwaters of Deer Creek	94,459,107	89%	10,551,843	85%	2,763,190,025,848,810	87%
SC2	Sugar Creek	8,922,249	92%	1,174,459	85%	176,293,327,466,192	85%
BC1	Buck Creek	2,174,779	87%	1,774,280	86%	177,692,243,869,634	93%

*scaled to equivalent subwatershed size

from Monitoring

from L-THIA Model

Table 40: L-THIA-derived load reductions for each subwatershed.

	Nitrogen			Phosphorous			Sediment		
Subwatershed	lb/yr	lb/acre/yr	percent	lb/yr	lb/acre/yr	percent	lb/yr	lb/acre/yr	percent
Headwaters of Deer Creek	39,509	1.05	75%	11,339	0.30	74%	1,062,053	28.32	84%
South Fork Deer Creek	69,629	2.74	76%	20,225	0.80	75%	1,881,880	74.03	85%
Deer Creek-McCloskey Ditch	32,573	1.13	77%	9,525	0.33	76%	879,969	30.59	86%
Little Deer Creek	104,248	2.99	76%	30,375	0.87	76%	2,813,284	80.81	85%
Paint Creek	34,815	1.85	76%	10,146	0.54	76%	939,175	49.78	85%
Bachelor Run	58,931	2.56	76%	17,205	0.75	76%	1,592,189	69.13	85%
Deer Creek	51,286	2.01	75%	14,871	0.58	75%	1,383,294	54.18	85%
Sugar Creek	43,601	2.38	76%	12,646	0.69	75%	1,174,459	64.00	85%
Buck Creek	65,657	8.78	77%	19,232	2.57	76%	1,774,280	237.20	86%
Wabash River	29,234	1.45	75%	8,391	0.42	74%	785,780	38.94	84%

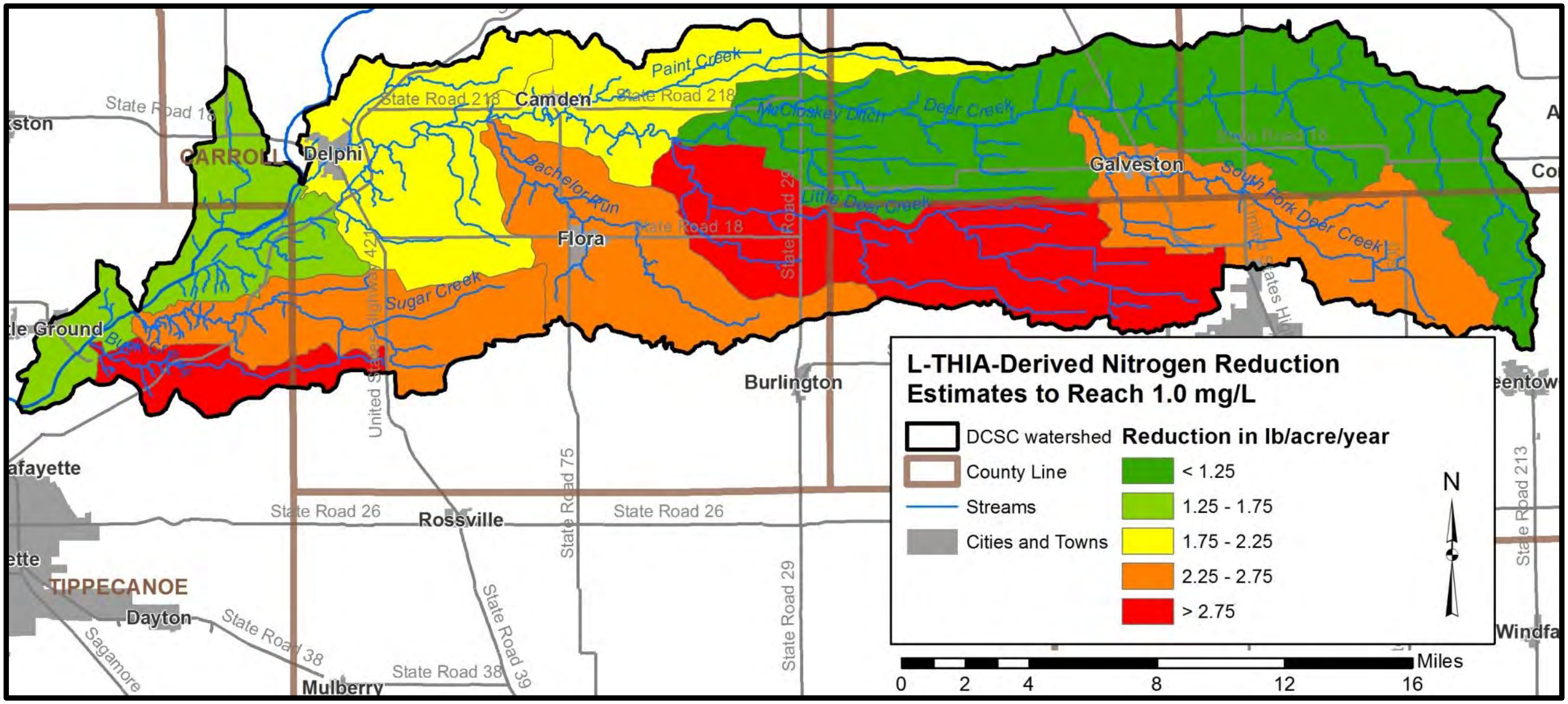

Figure 96. L-THIA-derived nitrogen reduction estimates by subwatershed.
Data used to create this map are detailed in Appendix A.

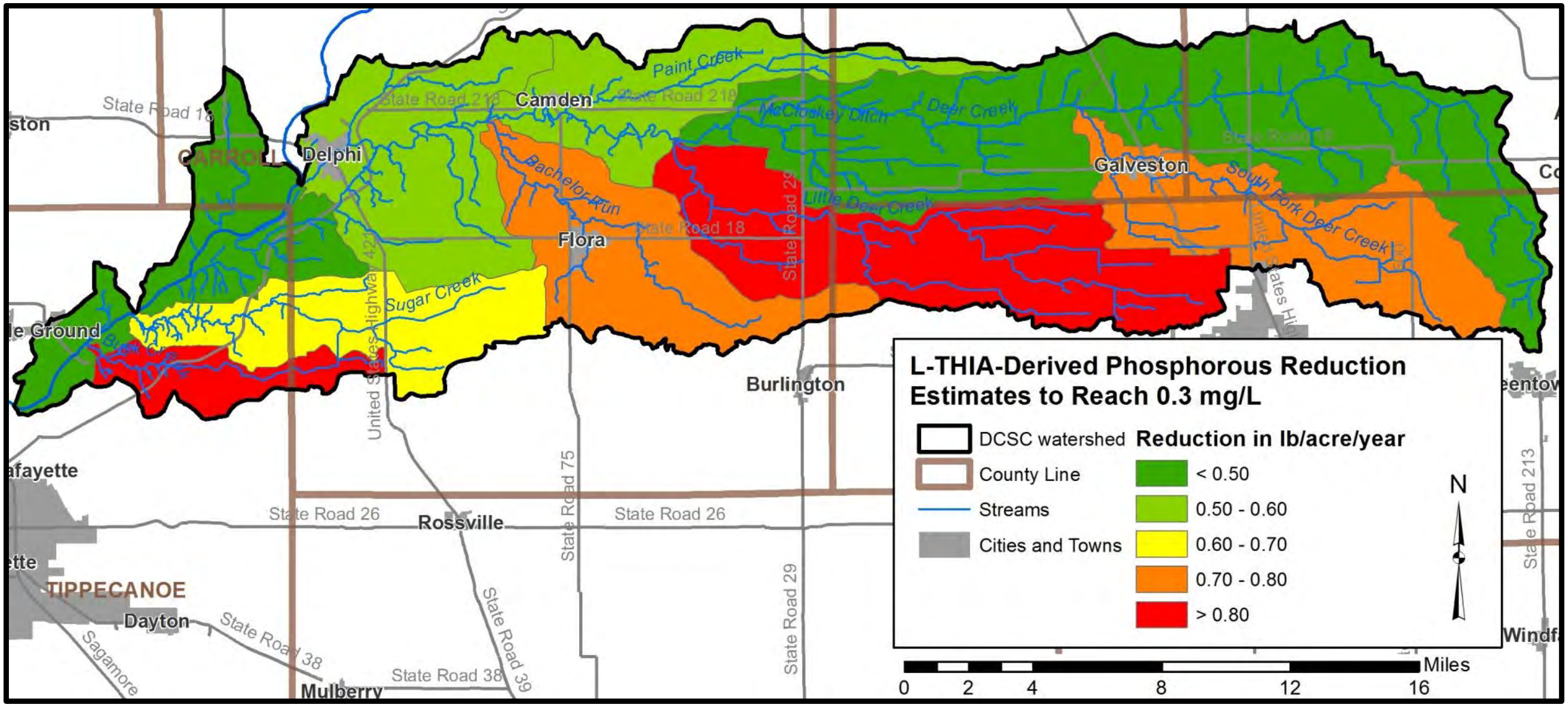

Figure 97. L-THIA-derived phosphorus reduction estimates by subwatershed.
Data used to create this map are detailed in Appendix A.

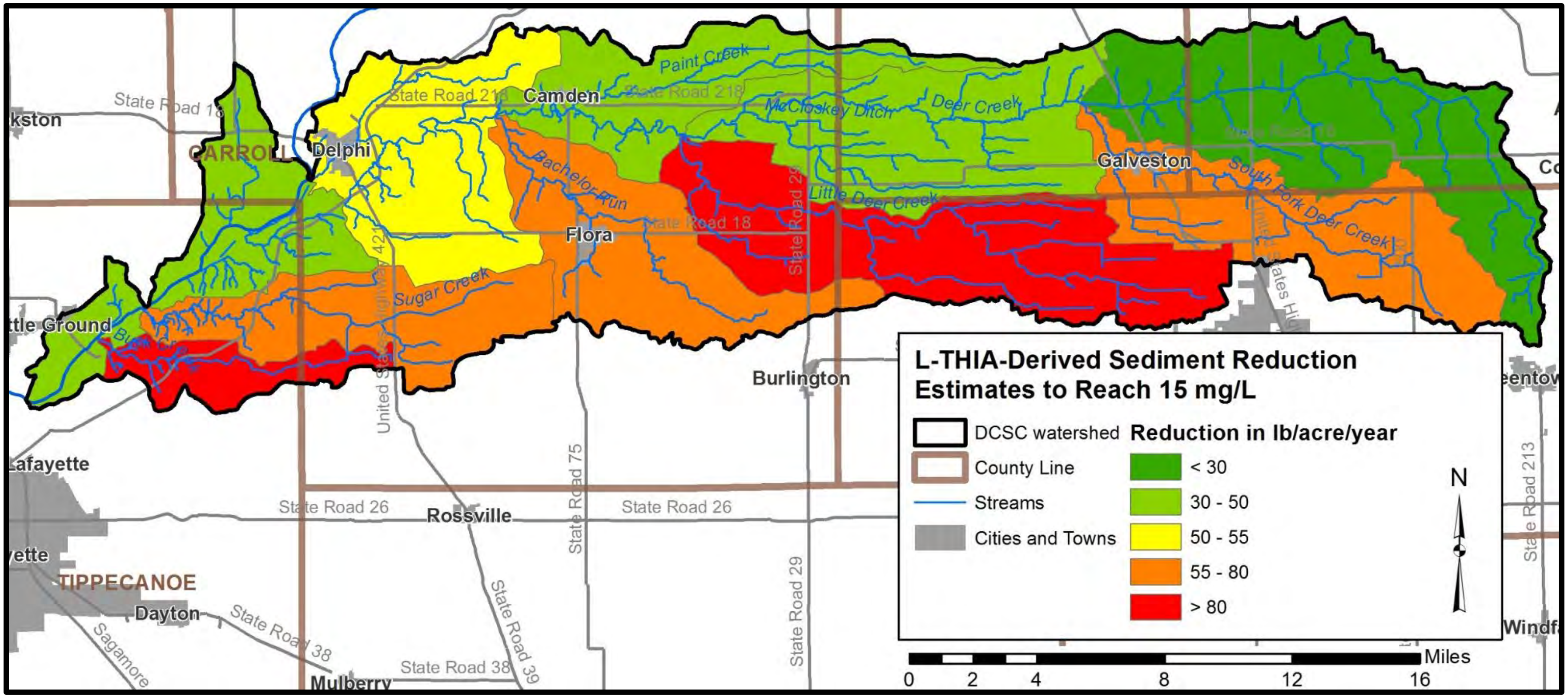

Figure 98. L-THIA-derived sediment reduction estimates by subwatershed.
Data used to create this map are detailed in Appendix A.

8.0 DEFINING CRITICAL AREAS

In order to focus conservation practice implementation, it is necessary to identify critical areas in the watershed which are experiencing the most problems and the worst impairments. Targeting the implementation of best management practices to these areas will help focus remediation where it is most needed.

Land use in Deer Creek-Sugar Creek is not varied, and many inventoried issues appear to be ubiquitous throughout the watershed, such as: agricultural land use, tile drained soils, soils used for septic treatment, hydric soils, and wetland loss. Though these issues contribute to pollution and degraded water quality throughout the watershed and need to be remedied, due to their widespread nature they cannot be used to narrow down critical areas which contribute the most loading and pollution.

However, the steering committee did identify inventoried issues of high concern, which include: total number of animals located on small, unregulated farms and confined feeding operations; acreage permitted for manure and sludge application; streambank erosion; water quality impairments; and concentrations which exceed targets for nutrients, sediment and *E. coli*. When tallied subwatershed-by-subwatershed, these issues illuminate the subwatersheds generating the most of each pollutant.

Critical areas are first determined one parameter at a time: for nutrients, sediment, and *E. coli*. The sections below summarize and tabulate the inventoried issues of high concern (listed above), monitored data, modeled data, and impaired waterbodies. To determine the final set of critical areas, the critical areas for each parameter are layered on top of one another to generate a tiered system: areas critical for 3 parameters are considered “high priority,” and areas critical for none of the parameters are considered “no priority.” The high, medium, and low critical areas are represented in Figure 102 in section 8.4, and these will guide the milestones and targets for the implementation plan and action registers in Chapters 10 and 11.

8.1 Critical Areas for by Nutrients

Based on the summarized data in Table 41, the yellow-highlighted subwatersheds are the most critical areas for nitrogen and phosphorus loading, including subwatersheds scoring 6 or greater out of 10 parameters. These subwatersheds are mapped in Figure 99.

Table 41. Critical Areas for Nutrients

	Headwaters of Deer Creek	South Fork of Deer Creek	Deer Creek-McCloskey Ditch	Little Deer Creek	Paint Creek	Bachelor Run	Deer Creek	Sugar Creek	Buck Creek	Wabash River
Summarized from Table 25. Potential sources causing nutrient problems.										
Highest density of regulated (CFO) animals				●	●		●	●	●	
Highest density of unregulated farm animals			●		●	●			●	
More than 10% of streams lack adequate stabilization	●	●	●	●	●			●		●
Highest density of manure application	●			●		●		●	●	
WWTP sludge applied to more than 22 sq mi	●	●	●	●	●				●	
From Table 21. Monitoring samples exceeding targets during high flow events.										
Nitrate-nitrogen	●	●	●	●	●	●	●	●		N/A
Total Phosphorus								●		N/A
From Table 40. L-THIA load reductions.										
Greater than 2.25 lb/acre/year load reduction needed to meet nitrogen target (orange and red in Table 44)		●		●		●		●	●	
Greater than 0.70 lb/acre/year load reduction needed to meet phosphorus target (orange and red)		●		●		●			●	
From Figure 25. Impaired waterbody locations										
Streams with nutrient impairments	●	N/A	●	●	●		●		●	
Score	5	5	5	8	6	5	3	6	7	1

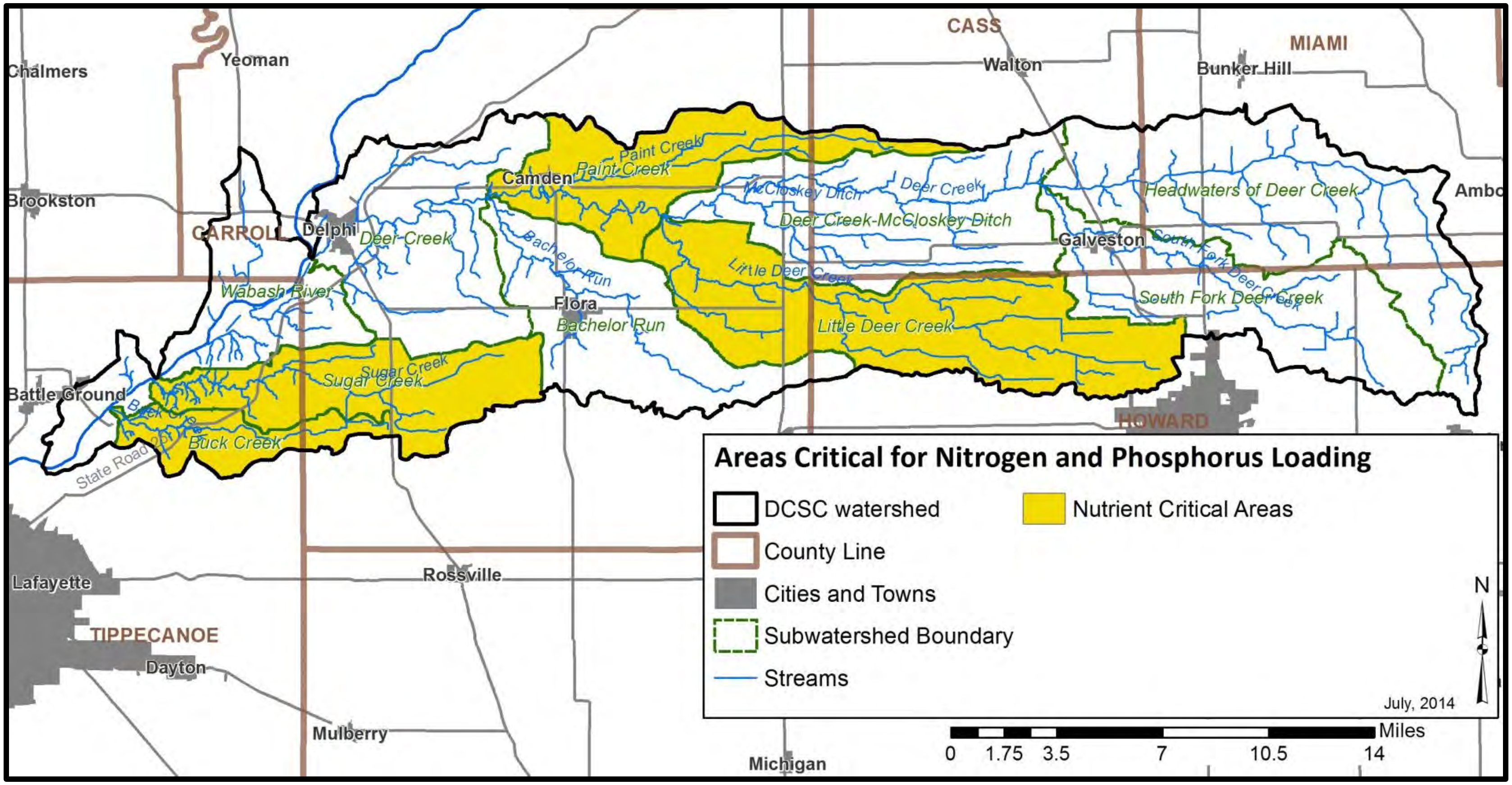

Figure 99. Areas Critical for Nutrients
Data used to create this map are detailed in Appendix A.

8.2 Critical Areas for *E. coli*

Based on the summarized data in Table 42, the green-highlighted subwatersheds are the most critical areas for *E. coli* loading, including subwatersheds scoring 4 or more out of 6 parameters. These subwatersheds are mapped in Figure 100.

Table 42. Critical areas for *E. coli*

	Headwaters of Deer Creek	South Fork of Deer Creek	Deer Creek-McCloskey Ditch	Little Deer Creek	Paint Creek	Bachelor Run	Deer Creek	Sugar Creek	Buck Creek	Wabash River
Summarized from Table 28. Potential sources causing *E. coli* problems.										
Highest density of regulated (CFO) animals				●	●		●	●	●	
Highest density of unregulated farm animals			●		●	●			●	
Highest density of manure application	●			●		●		●	●	
WWTP sludge applied to more than 22 sq mi	●	●	●	●	●				●	
From Table 21. Monitoring samples exceeding targets during high flow events.										
E. coli	●	●	●	●	●	●	●	●		N/A
From Figure 25. Impaired waterbody locations										
Streams with *E. coli* impairments	●	N/A	●	●	●	●	●	●	●	●
Score	4	2	4	5	5	4	3	4	5	1

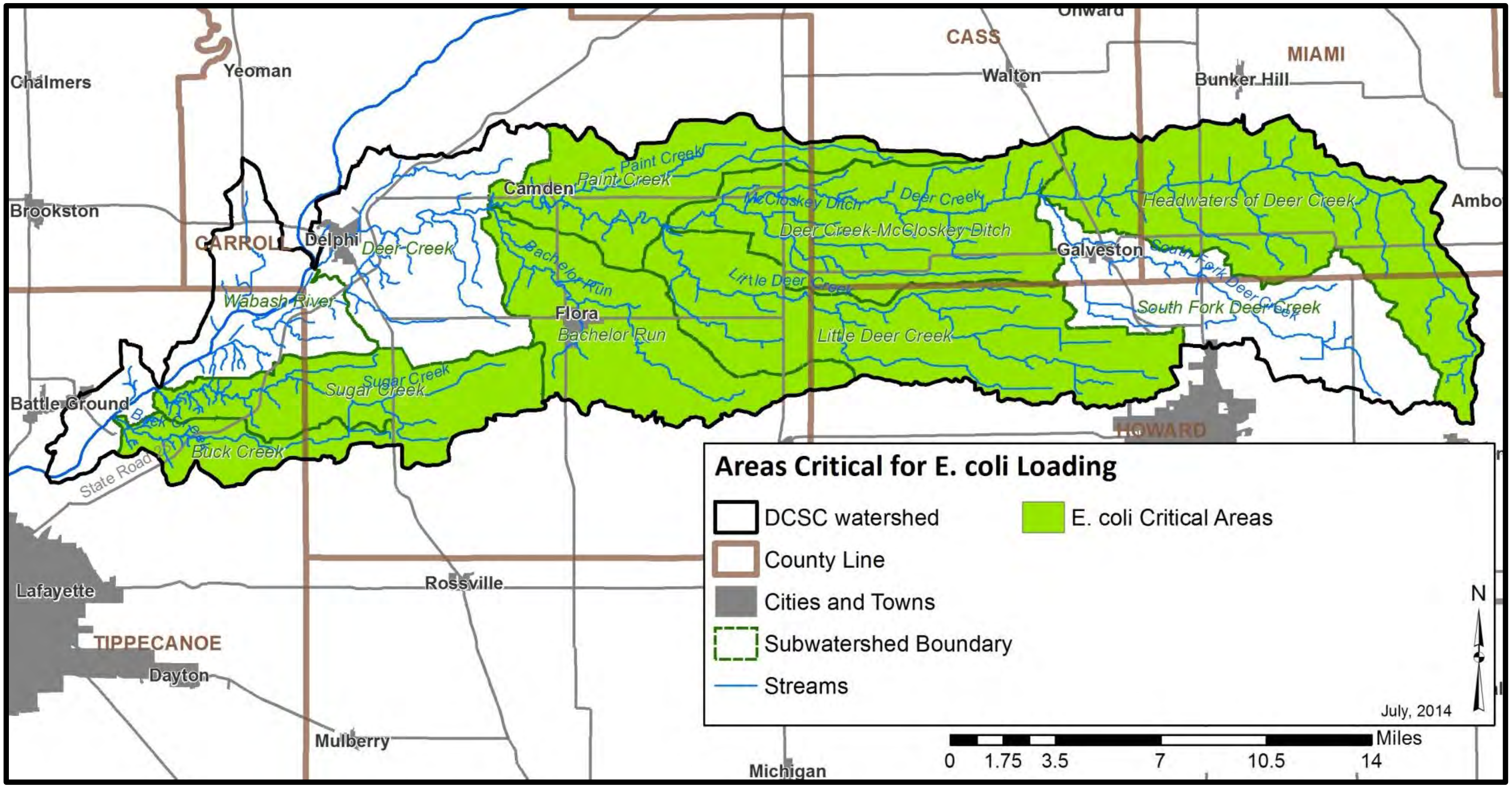

Figure 100. Areas Critical for *E. coli*

Data used to create this map are detailed in Appendix A.

8.3 Critical Areas for Sediment

Based on the summarized data in Table 43, the brown-highlighted subwatersheds are the most critical areas for sediment loading, including subwatersheds scoring 3 out of 3 parameters. These subwatersheds are mapped in Figure 101.

Table 43. Critical Areas for Sediment

	Headwaters of Deer Creek	South Fork of Deer Creek	Deer Creek-McCloskey Ditch	Little Deer Creek	Paint Creek	Bachelor Run	Deer Creek	Sugar Creek	Buck Creek	Wabash River
Summarized from Table 26. Potential sources causing sediment problems.										
More than 10% of streams lack adequate stabilization	●	●	●	●	●			●		●
From Table 21 Monitoring samples exceeding targets during high flow events.										
Sediment	●	●	●	●		●	●	●		N/A
From Table 40. L-THIA-derived load reductions										
Greater than 55 lb/acre/year load reduction needed to meet sediment target (red and orange in Table 44)		●		●		●		●	●	
Score	2	3	2	3	1	2	1	3	1	2

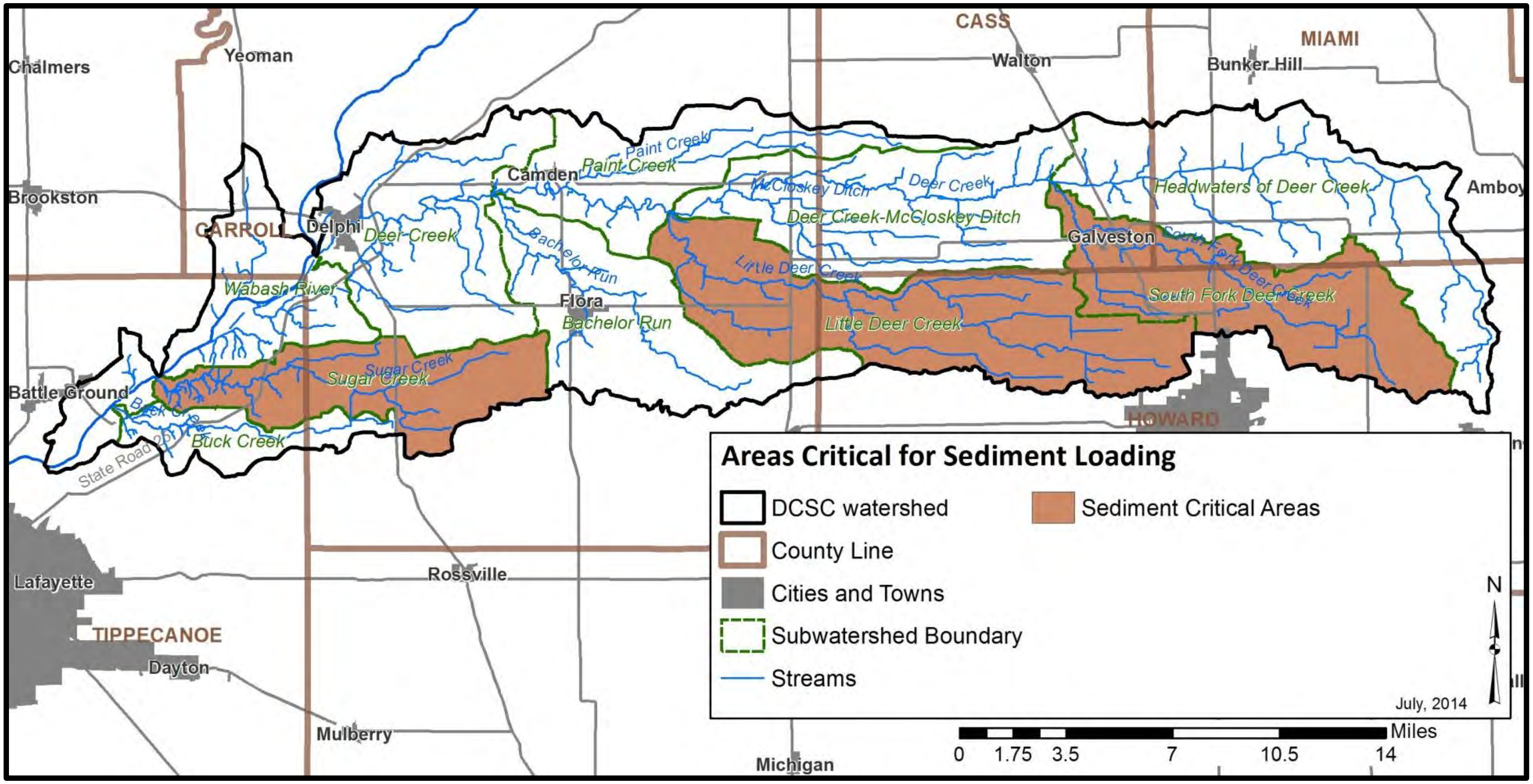

Figure 101. Areas Critical for Sediment
Data used to create this map are detailed in Appendix A.

8.4 Critical Areas for Impaired Natural Aquatic Habitat

Based on water quality data collected in 2012-2013, summarized in section 3.3.9, areas in the watershed most critically impaired natural habitat includes the Headwaters of Deer Creek, South Fork of Deer Creek, Deer Creek-McCloskey Ditch, and Buck Creek subwatersheds.

8.5 Critical Areas Summary

The steering committee elected to prioritize issues of water quality in an attempt to remedy sources of pollutants in the watershed before turning to natural habitat restoration. The combined extent of all areas critical for nutrients, *E. coli*, or sediment covers 8 of the 10 subwatersheds. In an effort to further prioritize and target an implementation plan, the three pollutant critical areas are stacked to create a tiered hierarchy of priority areas. Areas critical for all three parameters are considered high priority and will be the first to receive targeted actions. Implementation will then target areas critical for 2 parameters, and then areas critical for just 1 parameter. Table 44 shows the combined tally of parameters for each subwatershed, and the final critical areas in the Deer Creek-Sugar Creek watershed are mapped in Figure 102.

Table 44. Stacked Parameters to Determine Highest Priority Critical Areas

Subwatershed	Headwaters of Deer Creek	South Fork of Deer Creek	Deer Creek-McCloskey Ditch	**Little Deer Creek**	Paint Creek	Bachelor Run	Deer Creek	**Sugar Creek**	Buck Creek	Wabash River
Priority	*Low*	*Low*	*Low*	***High***	*Med*	*Low*	*0*	***High***	*Med*	*0*
Areas Critical for Nitrogen and Phosphorus (Table 41)										
Areas Critical for *E. coli* (Table 42)										
Areas Critical for Sediment (Table 43)										

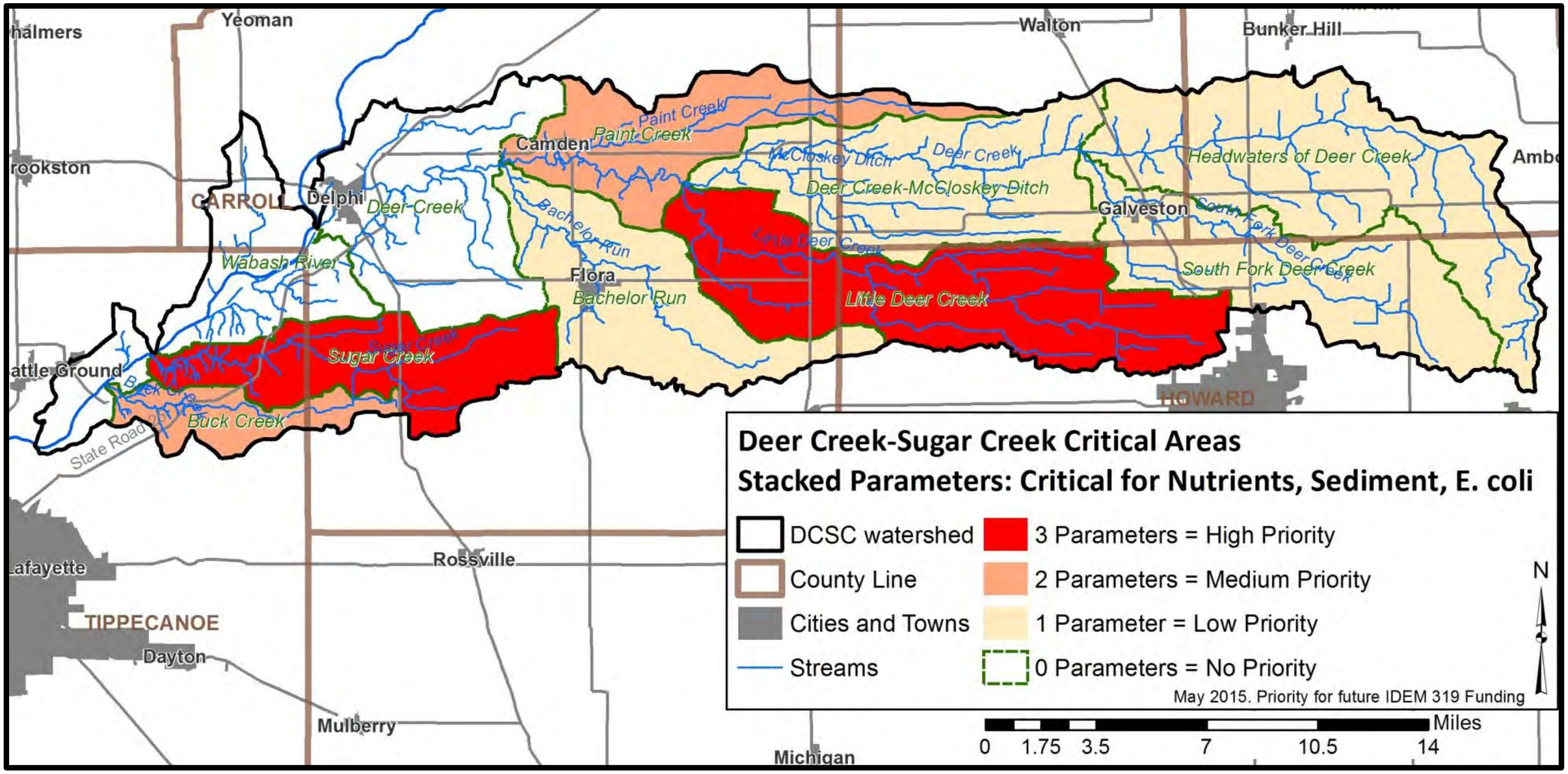

Figure 102. Critical Areas in the Deer Creek-Sugar Creek watershed.
Data used to create this map are detailed in Appendix A.

Table 45 summarizes data from Table 33 through Table 39 from Chapter 7.0, presenting current loads, reductions, and targets from the measured dataset, which the steering committee deemed to be a more conservative measure of current loading and needed reductions.

Table 45. Current loads, reductions and targets for high priority, medium priority and low priority subwatersheds.

HIGH PRIORITY AREA

	Nitrogen	Phosphorus	Sediment
	Load lb/yr		
Little Deer Creek	1,164,669	24,678	13,977,532
Sugar Creek	910,525	19,233	9,731,940
Total	**2,075,194**	**43,911**	**23,709,472**
	Reduction lb/yr		
Little Deer Creek	1,030,061	-15,704	11,958,414
Sugar Creek	856,546	3,039	8,922,248
Total	**1,886,607**	**-12,665**	**20,880,662**
	Target lb/yr		
Little Deer Creek	134,608	40,382	2,019,118
Sugar Creek	53,979	16,194	809,692
Total	**188,587**	**56,576**	**2,828,810**

MEDIUM PRIORITY AREA

	Nitrogen	Phosphorus	Sediment
	Load lb/yr		
Paint Creek	624,287	20,858	1,929,996
Buck Creek	524,015	8,737	2,504,193
Total	**1,148,302**	**29,595**	**4,434,189**
	Reduction lb/yr		
Paint Creek	571,906	5,144	1,144,285
Buck Creek	502,054	2,149	2,174,779
Total	**1,073,960**	**7,293**	**3,319,064**
	Target lb/yr		
Paint Creek	52,381	15,714	785,711
Buck Creek	21,961	6,588	329,414
Total	**74,342**	**22,302**	**1,115,125**

LOW PRIORITY AREA

	Nitrogen	Phosphorus	Sediment
	Load lb/yr		
Headwaters of Deer Creek	1,015,437	32,921	20,010,763
South Fork of Deer Creek	620,118	15,470	7,071,473
Deer Creek-McCloskey Ditch	563,993	10,655	5,901,862
Bachelor Run	1,028,934	24,700	9,093,648
Total	**3,228,482**	**83,746**	**42,077,746**
	Reduction lb/yr		
Headwaters of Deer Creek	870,557	-10,543	17,837,559
South Fork of Deer Creek	521,819	-14,020	5,596,992
Deer Creek-McCloskey Ditch	499,101	-8,813	4,928,482
Bachelor Run	939,817	-2,036	7,756,888
Total	**2,831,294**	**-35,411**	**36,119,921**
	Target lb/yr		
Headwaters of Deer Creek	144,880	43,464	2,173,204
South Fork of Deer Creek	98,299	29,490	1,474,481
Deer Creek-McCloskey Ditch	64,892	19,468	973,380
Bachelor Run	89,117	26,735	1,336,760
Total	**397,188**	**119,157**	**5,957,825**

9.0 GOAL SETTING

Based on thorough examination and comparison between water quality data measured results and modeled load estimates, the steering committee developed goals to address key pollutants of concern within the identified critical areas. Scaled goals serve as means for measuring progress towards the long-term goal. Because measurements were taken in partially low flow, drought conditions, the data in Table 45 suggest that no phosphorus reductions are needed in the short and long term. However, actions taken to reduce both nitrogen and sediment loading will necessarily have a positive impact on phosphorus loading as well and advance water quality towards the long term phosphorus reduction goal.

9.1 Reduce Nutrient Loading

Nitrogen Goals:

In the short term, by 2025, reduce nitrate-nitrogen loading from 2 million lb/yr to just under 190,000 lb/yr (a 91% reduction) in the high priority critical areas: the Little Deer Creek and Sugar Creek subwatersheds.

In the medium term, by 2035, reduce nitrate-nitrogen loading from 1.1 million lb/yr to 74,000 lb/yr (a 93% reduction) in the medium priority critical areas: the Paint Creek and Buck Creek subwatersheds.

In the long term, by 2045, reduce nitrate-nitrogen loading from 3.2 million lb/yr to 400,000 lb/yr (an 88% reduction) in the low priority critical areas: the Headwaters of Deer Creek, the South Fork of Deer Creek, the Deer Creek-McCloskey Ditch, and the Bachelor Run subwatersheds.

Phosphorus Goals

No short term goal for 2025, except for the reduction of phosphorus as a by-product of the implementation of nitrogen and sediment –reducing best management practices in the high priority critical areas: the Little Deer Creek and Sugar Creek subwatersheds.

In the medium term, by 2035, reduce phosphorus loading from 30,000 lb/yr to 22,000 lb/yr (a 25% reduction) in the medium priority critical areas: the Paint Creek and Buck Creek Subwatersheds.

No long term goal for 2045, except for the reduction of phosphorus as a by-product of the implementation of nitrogen and sediment –reducing best management practices in the low priority critical areas: the Headwaters of Deer Creek, the South Fork of Deer Creek, the Deer Creek-McCloskey Ditch, and the Bachelor Run subwatersheds.

9.2 Reduce Sediment Loading

In the short term, by 2025, reduce sediment loading from nearly 24 million lb/yr to 3 million lb/yr (an 88% reduction) in the high priority critical areas: the Little Deer Creek and Sugar Creek subwatersheds.

In the medium term, by 2035, reduce sediment loading from 4.4 million lb/yr to 1.1 million lb/yr (a 75% reduction) in the medium priority critical areas: the Paint Creek and Buck Creek subwatersheds.

In the long term, by 2045, reduce sediment loading from 42 million lb/yr to 6 million lb/yr (an 85% reduction) in the low priority critical areas: the Headwaters of Deer Creek, the South Fork of Deer Creek, the Deer Creek-McCloskey Ditch, and the Bachelor Run subwatersheds.

9.3 Improve Biological Communities

Goal: Improve water quality and restore natural aquatic habitat in the Deer Creek-Sugar Creek watershed so that streams meet their aquatic life use designation by the year 2035.

Scaled Goal: Implement goals 9.1, 9.2 and 9.4 to improve water quality before addressing natural aquatic habitat issues.

9.4 Reduce E. coli Loading

Long-term Goal: Reduce *E. coli* concentrations in the Deer Creek-Sugar Creek watershed critical areas by 87% by the year 2035.

Scaled Goal: Reduce *E. coli* concentrations such that the watershed streams exceed the state standard (235 cfu/100 mL) in no more than 20% of samples in 2020, particularly during storm events.

9.5 Increase Public Awareness and Participation

Long-Term Goal: Increase public awareness and knowledge about the waterways in the Deer Creek-Sugar Creek watershed and what individuals and communities can do to improve the quality of those waterways by the year 2035.

Scaled Goal: By 2020, improve community awareness of water quality issues specifically related to nutrient loading and aquatic habitat alteration; close the gap between watershed producers and landowners who are familiar with and would like to try conservation practices and those who put them into practice; and target established crop and animal producers and leaders in the farming community and foster farmer-to-farmer mentorship.

10.0 IMPROVEMENT MEASURE SELECTION

A wide variety of practices are available for on-the-ground implementation. Many of these practices will result in the reduction of sediment, nutrient, and *E. coli* loading into the Wabash River and its tributaries in the Deer Creek-Sugar Creek Watershed. A list of potential best management practices was reviewed by the steering committee with technical assistance from local NRCS agents. From this list, the practices which were deemed most appropriate and most likely to successfully meet loading reduction targets were identified. It should be noted that no practice list is exhaustive and that additional techniques may be both possible and necessary to reach water quality goals.

10.1 Best Management Practices

10.1.1 Agricultural Best Management Practices

Agricultural best management practices are implemented on agricultural lands, including row crop and animal feed lot facilities, in order to protect water resources and aquatic habitat while improving land resources and quality. These practices control nonpoint source pollutants, reducing their loading to the Wabash River by minimizing the volume of available pollutants. Potential agricultural best management practices designed to control and trap agricultural nonpoint sources of pollution include:

- Alternate Watering Systems
- Animal Mortality Facility
- Bioreactors
- Composting Facility
- Conservation Tillage
- Cover Crop
- Drainage Water Management
- Field Border or Filter Strip
- Forage and Biomass Planting
- Grade Stabilization Structure
- Grassed Waterway
- Livestock Restriction or Prescribed Grazing
- Manure Management Planning
- Mulching
- Nutrient and Pest Management
- Streambank Stabilization
- Tree & Shrub Establishment
- Two Stage Ditch
- Water and Sediment Control Basin
- Wetland Creation, Enhancement, and Restoration

Alternate Watering Systems

Alternative watering systems provide an alternate location for livestock to seek water rather than using a surface water source. This removes the negative impacts of livestock access to streams including direct deposit of manure and bank erosion and destabilization, while improving the health of livestock by providing a clean water source and better footing while drinking. This results in less *E. coli*, phosphorus, nitrogen, and sediment entering a surface waterbody. Two main types of alternative watering systems are used including pump systems and gravity systems. Livestock pipelines and lined waterways or outlets can also be included in this practice.

Animal Mortality Facility

An animal mortality facility is an on-farm facility for the treatment or disposal of livestock and poultry carcasses for routine and catastrophic mortality events. This practice can reduce impacts to surface and groundwater resources and decrease the spread of pathogens. This practice is applicable to operations where animal carcass treatment or disposal is needed. However, these facilities may not be used for catastrophic mortality resulting from disease. All runoff is diverted away from such facilities, which should be located down gradient from springs and wells and above the 100-year floodplain if possible to prevent contamination (FOTG Code 316, NRCS, 2011).

Bioreactors

Bioreactors use bacteria to digest organic materials, including manure, remnant plant material, and woody debris. Bioreactors typically generate energy, water, and fertilizer. Bioreactors use a series of tanks and treatment processes to separate cellulose-based materials from oils and gases. Materials are then broken down into carbon dioxide or methane gas and ethanol.

Composting Facility

A composting facility is a structure to facilitate the controlled anaerobic decomposition of manure or other organic material by microorganisms into a biologically stable organic material that is suitable for use as a soil amendment. It can reduce the pollution potential and improve the handling characteristics of organic waste solids and produce a soil amendment that adds organic matter and beneficial organisms, provides slow-release plant-available nutrients, and improves soil conditions (FOTG Code 317, NRCS, 2011).

Conservation Tillage

Conservation tillage refers to several different tillage methods or systems that leave at least 30% of the soil covered with crop residue after planting (Holdren et al., 2001). Tillage methods encompassed by conservation tillage include no-till, mulch-till, ridge-till, zero till, slot plant, row till, direct seeding, or strip till. The purpose of conservation tillage is to reduce sheet and rill erosion, maintain or improve soil organic matter content, conserve soil moisture, increase available moisture, reduce plant damage, and provide habitat and cover for wildlife. The remaining crop residue helps reduce soil erosion and runoff volume.

Several researchers have demonstrated the benefits of conservation tillage in reducing pollutant loading to streams and lakes. A comprehensive comparison of tillage systems showed that no-till results in 70% less herbicide runoff, 93% less erosion, and 69% less water runoff volume when compared to conventional tillage (Conservation Technology Information Center, 2000). Reductions in pesticide loading have also been reported (Olem and Flock, 1990). Conservation tillage is widely used throughout the watershed with 47% of survey respondents indicating that they currently use conservation tillage. Less than 1% of respondents indicate that they are unfamiliar with conservation tillage.

Cover Crop

Cover crops include legumes, such as clover, hairy vetch, field peas, and alfalfa and non-legumes, such as rye, oats, wheat, radishes, turnips, and buckwheat which are planted prior to or following crop harvest. Cover crops typically grow for one season to one year and are typically grown in non-cropping seasons. Cover crops are used to improve soil quality and future crop harvest by improving soil tilth, reducing wind and water erosion, increasing available nitrogen, suppressing weed cover, and encouraging beneficial insect growth. Cover crops reduce phosphorus transport by reducing soil erosion and runoff. Both wind and water erosion move soil particles that have phosphorus attached. Sediment that reaches water bodies may release phosphorus into the water. The cover crop vegetation recovers plant-available phosphorus in the soil and recycles it through the plant biomass for succeeding crops. Runoff water can wash soluble phosphorus from the surface soil and crop residue and carry it off the field. Cover crops are a fairly familiar conservation practice throughout the watershed with 30% of survey respondents indicating that they are currently using cover crops; however, 26% of survey respondents indicate that they are only somewhat familiar with this practice.

Drainage Water Management

Subsurface tile drainage is an essential water management practice on highly productive fields. As a result of tile drainage, nitrate carried in drainage water enters adjacent surface waterbodies. Drainage water management is necessary to reduce nitrate loads entering adjacent surface waterbodies from tile drainage networks. Drainage water management uses water control structures within lateral drains to vary the depth of tile outlets. Typically, the outlet is raised after harvest to limit outflow from the tile and reduce nitrate transport to adjacent waterbodies; lowered in the spring and fall to allow tile water to flow freely from the field to adjacent waterbodies; and raised in the summer to help store water making it available for crops (Frankenberger et al., 2006). Drainage water management can be used in concert with a suite of other conservation practices including cover crops and conservation tillage.

Field Borders and Filter Strip

Installing natural buffers or filters along major and minor drainages in the watershed helps reduce the nutrient and sediment loads reaching surface waterbodies. These practices are used throughout the Deer Creek-Sugar Creek Watershed with nearly 35% of survey respondents indicating that they currently use vegetated riparian buffers for agricultural operations. Buffers provide many benefits including restoring hydrologic connectivity, reduction nutrient and sediment transport, improving recreational opportunities and aesthetics, and providing wildlife habitat. Sediment, phosphorus, nitrogen, and *E. coli* are at least partly removed from water passing through a naturally vegetated buffer. The percentage of pollutants removed depends on the pollutant load, the type of vegetation, the amount of runoff, and the character of the buffer area. The most effective buffer width can vary along the length of a channel. Adjacent land uses, topography, runoff velocity, and soil and vegetation types are all factors used to determine the optimum buffer width.

Many researchers have verified the effectiveness of filter strips in removing sediment from runoff with reductions ranging from 56-97% (Arora et al., 1993; Mickelson and Baker, 1993; Schmitt et al., 1999; Lee et al, 2000; Lee et al., 2003). Most of the reduction in sediment load occurs within the first 15 feet of installed border. Smaller additional amounts of sediment are retained and infiltration is increased by increasing the width of the strip (Dillaha et al., 1989). Filter strips have been found to reduce sediment-bound nutrients like total phosphorus but to a lesser extent than they reduce sediment load itself. Phosphorus predominately associates with finer particles like silt and clay that remain suspended longer and are more likely to reach the strip's outfall (Hayes et al., 1984). Filter strips are least effective at reducing dissolved nutrients like those of nitrate and phosphorus, and atrazine and alachlor, although reductions of dissolved phosphorus, atrazine, and alachlor of up to 50% have been documented (Conservation Technology Information Center, 2000). Simpkins et al. (2003) demonstrated 20-93% nitrate-nitrogen removal in multispecies riparian buffers. Short groundwater flow paths, long residence times, and contact with fine-textured sediments favorably increased nitrate-nitrogen removal rates. Additionally, up to 60% of pathogens contained in runoff may be effectively removed. Computer modeling also indicates that over the long run (30 years), filter strips significantly reduce amounts of pollutants entering waterways.

Both filter strips and field borders should be designed as permanent plantings to treat runoff and should not be considered part of the annual rotation of adjacent cropland. Filter strips should receive only sheet flow and should be installed on stable banks. A mixture of grasses, forbs, and herbaceous plants should be used. In more permanent plantings, shrubs and trees should be intermingled to form a stable riparian community.

Forage and Biomass Planting

This practice establishes pasture, hay, or biomass production. In addition to maintaining livestock nutrition and health, it can reduce soil erosion and improve soil and water quality (FOTG Code 512, NRCS, 2011).

Grade Stabilization Structure

A grade stabilization structure is used to stabilize and control soil erosion in natural and artificial channels. It can prevent the formation or advance of gullies, enhance environmental quality, and reduce pollution hazards. Special attention is given to maintaining or improving habitat for fish and wildlife (FOTG Code 410, NRCS, 2011).

Grassed Waterway

Grassed waterways are natural or constructed channels established for transport of concentrated flow at safe velocities using adequate channel dimensions and proper vegetation. They are generally broad and shallow by design to move surface water across farmland without causing soil erosion. Grassed waterways are used as outlets to prevent rill and gully formation. The vegetative cover slows the water flow, minimizing channel surface erosion. When properly constructed, grassed waterways can safely transport large water flows downslope. These waterways can also be used as outlets for water released from contoured and terraced systems and from diverted channels. This BMP can reduce sediment concentrations of nearby waterbodies and pollutants in runoff. The vegetation improves the soil aeration and water quality due to its nutrient removal through plant uptake and absorption by soil. The waterways can also provide wildlife corridors and allows more land to be natural areas.

Livestock Restriction or Prescribed (Rotational) Grazing
Livestock that have unrestricted access to a stream or wetland have the potential to degrade the waterbody's water quality and biotic integrity. Only 30% of agricultural landowners responding to the social indicator survey indicate that they have livestock. Livestock can deliver nutrients and pathogens directly to a waterbody through defecation. Livestock also degrade stream ecosystems indirectly. Trampling and removal of vegetation through grazing of riparian zones can weaken banks and increase the potential for bank erosion. Trampling can also compact soils in a wetland or riparian zone decreasing the area's ability to infiltrate water runoff. Removal of vegetation in a wetland or riparian zone also limits the area's ability to filter pollutants in runoff. The degradation of a waterbody's water quality and habitat typically results in the impairment of the biota living in the waterbody.

Restoring areas impactied by livestock grazing often involves several steps. First, the livestock in these areas should be restricted from the wetland or stream to which they currently have access. If necessary an alternate source of water should be created for the livestock. Second, the wetland or riparian zone where the livestock have grazed should be restored. This may include stabilizing or reconstructing the banks using bioengineering techniques. Minimally, it involves installing filter strips along banks or wetland edge and replanting any denuded areas. Finally, if possible, drainage from the land where the livestock are pastured should be directed to flow through a constructed wetland to reduce pollutant loading, particularly nitrate-nitrogen loading, to the adjacent waterbody. Complete restoration of aquatic areas impacted by livestock will help reduce pollutant loading, particularly nitrate-nitrogen, sediment, and pathogens.

A livestock exclusion system is a system of permanent fencing (board, barbed, etc) installed to exclude livestock from streams and areas, not intended for grazing. This will reduce erosion, sediment, and nutrient loading, and improve the quality of surface water. Field office technical guide (FOTG) coded practices which can be included in a livestock exclusion system include Access Control (472), Fence (382), and Heavy Use Protection Area (561). Education and outreach programs focusing on rotational grazing and exclusionary fencing are important in the success of this BMP.

Manure Management Planning
Large volumes of manure are generated by both small, unregulated animal operations and by confined feeding operations located throughout the Deer Creek-Sugar Creek watershed. Many entities have manure management plans in place and are currently using these plans to manage the volume of manure produced on their facility. Manure management planning includes consideration of the volume and type of manure produced annually, crop rotations by field, the volume of manure and nutrients needed for each crop, field slope, soil type, and manure collection, transportation, storage, and distribution methods. Manure management planning uses similar techniques to nutrient management

planning with regards to nutrient budgets. Specific technical practices that can be included in manure management planning can include waste storage facilities and waste utilization.

Animal waste is a major source of pollution to waterbodies. To protect the health of aquatic ecosystems and meet water quality standards, manure must be safely managed. Good management of manure keeps livestock healthy, returns nutrients to the soil, improves pastures and gardens, and protects the environment, specifically water quality. Poor manure management may lead to sick livestock, unsanitary and unhealthy conditions for humans and other organisms, and increased insect and parasite populations. Proper management of animal waste can be done by implementing BMPs, through safe storage, by application as a fertilizer, and through composting. Proper manure management can effectively reduce E. coli concentrations, nutrient levels and sedimentation. Manure management can also be addressed in education and outreach to encourage farmers to participate in this BMP.

Mulching

Mulching is the application of plant residues to the land surface. This can help conserve soil moisture, moderate soil temperature, provide erosion control, facilitate the establishment of vegetative cover, improve soil quality, and reduce airborne particulates. This practice can be used alone or in combination with other practices (FOTG Code 484, NRCS, 2011).

Nutrient and Pest Management

Nutrient management is the management of the amount, source, placement, form, and timing of the application of plant nutrients and soil amendments to minimize the transport of applied nutrients into surface water or groundwater. This practice is used by roughly 60% of the watershed survey respondents. Nutrient management seeks to supply adequate nutrients for optimum crop yield and quantity, while also helping to sustain the physical, biological, and chemical properties of the soil. A nutrient budget for nitrogen, phosphorus, and potassium is developed considering all potential sources of nutrients including, but not limited to, animal manure, commercial fertilizer, crop residue, and legume credits. Realistic yields are based on soil productivity information, potential yield, or historical yield data based on a 5-year average. Nutrient management plans specify the form, source, amount, timing, and method of application of nutrients on each field in order to achieve realistic production levels while minimizing transport of nutrients to surface and/or groundwater.

Streambank Stabilization

Streambank stabilization or stream restoration techniques are used to improve stream conditions so they more closely mimic natural conditions. The most feasible restoration options return the stream to natural stream conditions without restoring the stream to its original condition. Restoration and stabilization options are limited by available floodplain, modifications to natural flows, and development structure locations. Reestablishment of riparian buffers, restoration of stream channels, stabilization of eroding stream banks, installation of riffle-pool complexes, and general maintenance can all improve stream function while reducing sediment and nutrient transport into and within the system.

Tree & Shrub Establishment

Tree & shrub establishment is the establishment of woody plants for forest products, wildlife habitat, long-term erosion control, water quality improvement, waste treatment, storage of carbon in biomass, improving or restoring natural diversity, or enhancing aesthetics. On a larger scale, reforestation can be used to restock existing forests and woodlands which have been depleted. This practice can be applied on any appropriately prepared site where woody plants can be grown (FOTG Code 612, NRCS, 2011).

Two Stage Ditch

When water is confined to stream or ditch channel it has the potential to cause bank erosion and channel down-cutting. Current ditch design generates narrow channels with steep sides. Water flowing through these systems often result in bank erosion, channel scour and flooding. A relatively new technique focuses on mitigating these issues through an in-stream restoration called a two-stage ditch. The design of a two-stage ditch incorporates a floodplain zone, called benches, into the ditch by removing the ditch banks roughly 2-3 feet above the bottom for a width of about 10 feet on each side. This allows the water to have more area to spread out on and decreases the velocity of the water. This not only improves the water quality, but also improves the biological conditions of the ditches where this is located.

The benefits of a two-stage ditch over the typical agricultural ditch include both improved drainage function and ecological function. The two-stage design improves ditch stability by reducing water flow and the need for maintenance, saving both labor and money. It also has the potential to create and maintain better habitat conditions. Better habitats for both terrestrial and marine species are a great plus when it comes to the two-stage ditch design. The transportation of sediment and nutrients is decreased considerably because the design allows the sorting of sediment, with finer silt depositing on the benches and coarser material forming the bed.

Water and Sediment Control Basin

A water and sediment control basin is an earthen embankment constructed across the slope of a minor watercourse to form a sediment trap and water detention basin with a stable outlet. This practice can reduce watercourse and gully erosion, trap sediment, and reduce downstream runoff. It is particularly applicable where watercourse or gully erosion is a problem and where sheet and rill erosion is controlled by other conservation practices. It can help in areas where sediment in runoff is severe, though it needs to be placed where adequate outlets can be provided (FOTG Code 638, NRCS, 2011).

Wetland Creation, Enhancement, and Restoration

Visual observation and historical records indicate at least a portion of the Deer Creek-Sugar Creek watershed has been altered to increase its drainage capacity. Riser tiles in low spots on the landscape and tile outlets along the waterways in the watershed confirm the fact that the landscape has been hydrologically altered. This hydrological alteration and subsequent loss of wetlands has implications for the watershed's water quality. Wetlands serve a vital role in storing water and recharging the groundwater. When wetlands are drained with tiles, the stormwater reaching these wetlands is directed immediately to nearby ditches and streams. This increases the peak flow velocities and volumes in the ditch. The increase in flow velocities and volumes can in turn lead to increased stream bed and bank erosion, ultimately increasing sediment delivery to downstream water bodies. Wetlands also serve as nutrient sinks at times. The loss of wetlands can increase pollutant loads reaching nearby streams and downstream waterbodies.

Restoring wetlands in the watershed could return many of the functions that were lost when these wetlands were drained. Through this process, a historic wetland site is restored to its historic status. These restored systems store nutrients, sediment, and E. coli while also increasing water storage and reducing flooding. Wetlands also provide additional habitat, stormwater mitigation, and recreational opportunities.

10.1.2 Preventative and System-Wide Practices

The protection of open space, preservation of habitat corridors, and mitigation of impacts from watershed-wide impacts are important management practices. These practices can be used throughout the Deer Creek-Sugar Creek watershed in locations where specific conditions occur. Potential management practices designed to address watershed impairment issues are as follows:

- Greenways and Trails
- Habitat Corridor Identification and Improvement
- Point Source Discharge Reduction
- Septic System Care and Maintenance
- Streambank Stabilization
- Threatened and Endangered Species Protection
- Urban Practices

Greenways and Trails

Greenways can provide a large number of functions and benefits to nature and the public. For plants and animals, greenways provide habitat, a buffer from development, and a corridor for migration. Greenways located along streams include riparian buffers that protect water quality by filtering sediments and nutrients from surface runoff and stabilizing streambanks. By buffering the stream from adjacent developed land use, riparian greenways offset some of the impacts associated with increased impervious surface in a watershed. Existing trails in the watershed are located in Prophetstown State Park, in the Delphi area, and east of Galveston (Figure 32).

Habitat Corridor Identification and Improvement

Protection of habitat corridors requires a multi-phase program including identification of appropriate habitat corridors, development of a corridor management plan, and creation of an improvement plan. Most long-term corridor protection will require land transfer into protected status. There are several options for land transfer ranging from donation to land purchase. Donations can be solicited and encouraged through incentive programs. Outright purchase of property is frequently the least complicated and most permanent protection technique; it is also the most costly. A conservation easement is a less expensive technique that does not require the transfer of land ownership but rather a transfer of use rights. Conservation easements might be attractive to property owners who do not want to sell their land at the present time but would support perpetual protection from further development. Conservation easements can be donated or purchased.

Several techniques can be used for protecting natural areas and open space in both public and private ownership. The first step is to identify and prioritize properties for protection. The highest priority natural areas should be permanently protected by the ownership or under the management of public agencies or private organizations dedicated to land conservation. Other open space can be protected using conservation design development techniques and is more likely to be managed by homeowner associations.

Point Source Discharge Reduction

Several point source permitted discharges are located throughout the Deer Creek-Sugar Creek watershed. These include municipal wastewater treatment plants, like those that service Galveston, Camden, Flora, and Delphi and several manufacturer-operated NPDES facilities such as the Indiana Packers Corporation, SAYCO, Northwestern Elementary and High School, and Maple Lawn Village mobile home park. A majority of the facilities permitted throughout the watershed operate within their permitted requirements with regards to water discharges. Although WREC and Carroll County SWCD cannot assist them with infrastructure changes, watershed stakeholders can lead the charge to reduce the volume of water entering the stormwater system, promote successes to improve water quality leaving any NPDES-permitted facility, and highlight efforts to reduce impacts to the Wabash River.

As detailed in the inventories for each subwatershed, there are a number of non-permitted point sources in the Deer Creek-Sugar Creek watershed as well. These include several dozen leaking underground storage tanks, industrial waste sites in Delphi and Flora, and a number of brownfields and open dumps.

Septic System Care and Maintenance

Septic, or on-site waste disposal systems, are the primary means of sanitary flow treatment throughout most of the watershed. Because of the prohibitive cost of providing centralized sewer systems to many areas, septic tank systems will remain the primary means of treatment into the future. Annual maintenance of septic systems is crucial for their operation, particularly the annual removal of accumulated sludge. The cost of replacing failed septic tanks is about $5,000-$15,000 per unit based on industry standards. Property owners are responsible for their septic systems under the regulation of the County Health Department. When septic systems fail, untreated sanitary flows are discharged into open watercourses that pollute the water and pose a potential public health risk. Septic systems discharging to the ground surface are a risk to public health directly through body contact or contamination of drinking water sources. Additionally, septic systems can contribute significant amounts of nitrogen and phosphorus to the watershed. Therefore, it is imperative for homeowners not to ignore septic failures. If plumbing fixtures back up or will not drain, the system is failing. Funding for this practice is limited.

Threatened and Endangered Species Protection

Threatened and endangered species are those plant and animal species whose survival is in peril. Federally and state listed species identified within the Deer Creek-Sugar Creek watershed are highlighted in the Watershed Inventory. Threatened species are those that are likely to become endangered in the foreseeable future. Federally endangered species are those that are in danger of extinction throughout all or a significant portion of their range. A state-endangered species is any species that is in danger of extinction as a breeding species in Indiana.

Protecting threatened and endangered species requires consideration of their habitat including food, water, and nesting and roosting living space for animals and preferred substrate for plants and mussels. Corridors for species movement are also necessary for long-term protection of these species. Protection of habitat can include providing clean water and available food but likely requires protection of the physical living space and associated corridor. Conservation management plans should be developed for each species, if they are not already in place. Such plans should consider habitat needs including purchase or protection of adjacent properties to current habitat locations, hydrologic needs, pollution reduction, outside impacts, and other techniques necessary to protect threatened and endangered species.

Urban Practices

Though only 10% of the watershed is classified as urban land use, there are some best management practices which could be considered for helping to improve water quality, particularly in areas, such as the City of Delphi and in the Towns of Flora, Camden, and Galveston, where development and impervious surfaces are more prevalent. The best way to mitigate the impacts of impervious surfaces is to infiltrate, store, and treat stormwater onsite before it can run off into nearby streams and tributaries.

- **Bioretention Practices** – Bioretention practices use biofiltration or bioinfiltration to filter runoff by storing it in shallow depressions. Bioretention uses plant uptake and soil permeability mechanisms in a variety of manners typically in combination. Potential practices include sand beds, pea gravel overflow structures, organic mulch layers, plant materials, gravel underdrains, and an overflow system to promote infiltration. Bioinfiltration can also be used to treat runoff from parking lots, roads, driveways and other areas in the urban environment. Bioretention should be used in areas where on-site storage space is available.

- **Infrastructure Retrofit** – Typical stormwater infrastructure includes pipe and storm drains, or hard infrastructure, to convey water away from hard surfaces and into the stormwater system. Retrofitting these structures to implement low impact development techniques, use green practices, and introduce plants and filters to reduce sediment and nutrient concentrations contained in stormwater.

- **Pervious Pavement** – Pervious pavement comes in many forms including porous pavement and modular block pavement. Both types of pervious pavement can be installed on most any travel surface with a slope of 5% or less.
  - Pervious pavement has the approximate strength characteristics of traditional pavement with the ability to percolate water into the groundwater system. The pavement reduces sediment and nutrient transmission into the groundwater as water moves through the pores in the pavement. When installed, porous pavement includes a stone layer, filter fabric, and a filter layer covered by porous pavement. Correctly mixed porous pavement eliminates fine aggregates found in typical pavements. Porous asphalt is a type of porous pavement which includes a mix of Portland cement, coarse aggregates, and water that results in the formation of interconnected voids.
  - Modular pavement consists of individual blocks made of pervious material such as sand, gravel, or sod interspersed with strong structural material such as concrete. The blocks are typically placed on a sand or gravel base and designed to provide a load-

bearing surface that is adequate to support personal vehicles, while allowing infiltration of surface water into the underlying soils. They usually are used in low-volume traffic areas such as overflow parking lots and lightly used access roads. An alternative to pervious and modular pavement for parking areas is a geotextile material installed as a framework to provide structural strength. Filled with sand and sodded, it provides a completely grassed parking area.

- **Phosphorus-free Fertilizers** – Phosphorus-free fertilizers are those fertilizers that supply nitrogen and minor nutrients without the addition of phosphorus. Phosphorus increases algae and plant growth which can cause negative impacts on water quality within aquatic systems. The Clear Choices, Clean Water (2010) program estimates that a one acre lawn fertilized with traditional fertilizer supplies 7.8 pounds of phosphorus to local waterbodies annually. Established lawns take their nutrients from the soil in which they grow and need little additional nutrients to continue plant growth. Fertilizers are manufactured in a variety of forms including that without phosphorus. Phosphorus-free fertilizer should be considered for use in areas where grass is already established.

- **Rain Garden** – Rain gardens are small-scale bioretention systems that be can be used as landscape features and small-scale stormwater management systems for single-family homes, townhouse units, some small commercial development, and to treat parking lot or building runoff. Rain gardens provide a landscape feature for the site and reduce the need for irrigation, and can be used to provide stormwater depression storage and treatment near the point of generation. These systems can be integrated into the stormwater management system since the components can be optimized to maximize depression storage, pretreatment of the stormwater runoff, promote evapotranspiration, and facilitate groundwater recharge. The combination of these benefits can result in decreased flooding due to a decrease in the peak flow and total volume of runoff generated by a storm event. Additionally, rain gardens can be designed to provide a significant improvement in the quality of the stormwater runoff.

10.2 Best Management Practice Measure Selection

The steering committee considered the list of best management practices (BMPs), and in an interactive exercise, identified which practices may best reduce the loading of nutrients, *E. coli*, and sediment and help improve aquatic habitat. Table 46 summarizes the results of this discussion, showing which BMPs would best address the parameters of concern in each of the Critical Areas. This selection process relied upon the technical expertise of the district conservationists on the steering committee, as well as local knowledge about which practices are currently installed in the watershed and which might be most easily adopted or expanded. A complete list of best management practices currently installed in the watershed can be found in Appendix F. Specific load reductions for these practices is discussed in the next section based on available data.

Table 45. Best Management Practices suggested for critical areas by parameter

Critical Areas	Reason for Being Critical	Suggested BMP
Little Deer Creek, Paint Creek, Sugar Creek, and Buck Creek subwatersheds & livestock access areas	Critical Areas for Nutrients (Nitrogen and Phosphorus) (refer to Table 41)	Alternate Watering Systems
		Animal Mortality Facility
		Bioreactor
		Composting Facility
		Consider soil characteristics to minimize runoff
		Cover Crops
		Diversion Structures
		Drainage Water Management
		Education and Outreach
		Filter Strips
		Forage and Biomass Planting
		Grassed waterway
		Livestock Restriction or Rotational Grazing
		Manure Management Planning
		Nutrient Management & Variable Rate Application
		Prescribed Grazing
		Residue and Tillage Management
		Service Septic Systems
		Tree/Shrub Establishment
		University Fertilization Recommendations
		Wetland Enhancement, Restoration

Critical Areas	Reason for Being Critical	Suggested BMP
Headwaters of Deer Creek, Deer Creek-McCloskey Ditch, Little Deer Creek, Paint Creek, Bachelor Run, Sugar Creek, and Buck Creek subwatersheds and livestock access areas	Critical Areas for *E. Coli* (refer to Table 42)	Alternate Watering Systems
		Animal Mortality Facility
		Composting Facility
		Diversion Structures
		Education and Outreach
		Livestock Restriction or Rotational Grazing
		Manure Management Planning
		Prescribed Grazing
		Service Septic Systems
		Wetland Creation
South Fork Deer Creek, Little Deer Creek, and Sugar Creek subwatersheds and livestock access areas	Critical Areas for Soil Erosion and Total Suspended Solids (refer to Table 43)	Consider soil characteristics to minimize runoff
		Cover Crops
		Education and Outreach
		Field Border
		Filter Strips
		Grade Stabilization Structure
		Grassed waterway
		Livestock Restriction or Rotational Grazing
		Prescribed Grazing
		Residue and Tillage Management
		Tree/Shrub Establishment
		Two Stage Ditch
		Water and Sediment Control Basin
		Wetland Enhancement, Restoration

Critical Areas	Reason for Being Critical	Suggested BMP
Headwaters of Deer Creek, South Fork Deer Creek, Deer Creek-McCloskey Ditch, Buck Creek	Impaired Natural Aquatic Habitat (refer to Section 4.3.9)	Alternate Watering Systems
		Cover Crops
		Education and Outreach
		Field Border
		Filter Strips
		Livestock Restriction or Rotational Grazing
		Nutrient and Pest Management & Variable Rate Application
		Service Septic Systems
		Tree/Shrub Establishment
		Wetland Enhancement, Restoration

10.3 Load Reduction by Best Management Practice

Load reduction calculations were estimated for nitrogen, phosphorus, and sediment based on estimated current loads in high, medium, and low priority areas and removal efficiencies from the EPA Region 5 model and the Spreadsheet Tool for Estimating Pollutant Load (STEPL). The load reductions shown in Table 46 are listed for practices which would directly reduce nitrogen, phosphorus or sediment loading, and assumptions are listed with each example. Load reductions are not available for all parameters for all BMPs.

Table 46. Load Reductions per Best Management Practice.

Best Management Practice	Assumptions	Estimated Load Reduction Per Practice			Unit of Reduction
		Nitrogen	Phosphorus	Sediment	
Animal Mortality Facility		16.25	0.09	0.00	lb/animal
Bioreactors	Applies to tile-drained soils only	20.31	0.00	0.00	lb/acres
Composting Facility		16.25	0.10	0.00	lb/animal
Conservation Tillage		22.34	0.44	86.36	lb/acre
Cover Crop		20.31	0.44	46.06	lb/acre
Drainage Water Management		13.65	0.00	101.33	lb/acre
Field Border	Buffers: 30' wide	28.43	0.73	74.85	lb/acre
Filter Strip (grass)	Buffers: 30' wide	28.43	0.73	74.85	lb/acre
Forage and Biomass Planting		28.43	0.73	74.85	lb/acre
Grade Stabilization Structure		8.94	0.87	103.63	lb/acre
Grassed Waterway		8.94	0.87	103.63	lb/acre
Livestock Restriction	Livestock Exclusion: 10' wide	30.46	0.73	86.36	lb/acre
Prescribed Grazing		11.08	0.25	16.31	lb/acre
Nutrient/Pest Management Planning					
Livestock Producers (Manure mgmt planning)	Manure management could be applied to approximately 25% of cropland	12.19	0.29	34.54	lb/acre
Non-livestock Producers (Nutrient mgmt planning)		8.12	0.19	34.54	lb/acre
Tree/Shrub Establishment		28.43	0.73	74.85	lb/acre
Two Stage Ditch	Two Stage Ditch: 30' wide	4.87	0.00	46.06	lb/acre
Water & Sediment Control Basin		28.43	0.68	80.60	lb/acre
Wetland Enhnancement, Restoration		8.96	0.26	89.24	lb/acre

11.0 INDICATORS, STRATEGIES, AND MILESTONES FOR REACHING GOALS

Implementation of policies, programs, and practices will improve water quality and watershed conditions within the Deer Creek-Sugar Creek watershed, helping reach goal statements (listed in Chapter 9.0) for high, medium, and low priority critical areas by 2045. Activities to be completed as part of this watershed management plan are identified in the action register in Table 47. Measurement of the success of implementation is a necessary part of any watershed project. Both social indicator and water quality data will be used to measure observable changes following implementation.

11.1 Indicators of Success

Water quality, social, and administrative indicators will be used to monitor progress towards successful achievement of the goals for the high, medium, and low priority critical areas. Water quality indicators will include monitoring orthophosphate, nitrate-nitrogen, and ammonia-nitrogen. Monitoring of total phosphorus, nitrate-nitrogen, turbidity, fish, macroinvertebrate, habitat, and *E. coli* will occur as part of the Hoosier Riverwatch volunteer program. Social indicator surveys will occur ten years after implementation begins, with results of these surveys compared to results observed during the planning phase of this project. Administrative indicators will be listed with each strategy below.

11.2 Action Register of Strategies, Milestones, and Cost Estimates

In addition to the long term strategy of continuing water quality monitoring, using both professional and volunteer monitoring options, Table 47 details strategies and milestones for implementing goals in the watershed, with strategies listed for meeting goals in high priority (by 2025), medium priority (by 2035), and low priority (2045) critical areas. Strategies for the high priority critical areas are particularly aggressive because of the large calculated load reduction, based on measured data from professional water quality monitoring, needed to meet target loads. Based on measured water quality conditions in 2012 and 2013, meeting target loads will require blanketing the critical areas with best management practices. These numbers are based on climatic conditions present at the time of water quality sampling, including severe drought and catastrophic rain events. Changes in climatic conditions based on subsequent water quality testing may result in the reduction of required BMPs to meet target loads. Strategies listed in the action register assume that BMPs will be installed in high priority areas first, or as much as is reasonably possible, before moving on to medium and low priority areas.

Table 47. Action Register for Strategies and Milestones in the Deer Creek-Sugar Creek Watershed.

Goal	Strategy	Target Audience	Milestone	Cost	Possible Partners	Technical Assistance
Nutrients, Sediment, *E.coli*	Increase cover crop acreage by 46,237 acres in high priority areas by 2025, by 10,000 acres in medium priority areas by 2035, and by 50,000 acres in low priority areas by 2045.	Agricultural landowners and operators	Develop cost-share program in 2015.	$12,500*	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension, Notre Dame, Howard County Surveyor	SWCDs, NRCS, RCPP
			Create a contractors list for specific cover crop seeding in 2015.	$500		
			Develop cover crop demonstration area highlighting various species by 2016.	$2,000		
			Host cover crop workshop in 2015 and biennially thereafter through 2045 at an appropriate location within the watershed.	$1,000		
			Annually, identify additional cover crop funding options.	$1,000		
			Annually from 2015-2025 implement 4,625 acres, from 2025-2035 implement 1,000, and from 2035-2045 implement 5,000 of cover crop in the appropriate critical areas.	$4.3 Million		
			Install 106,237 acres of cover crops by 2045.			
Nutrients, *E. coli*	Increase the use of manure management by 11,559 acres in high priority areas by 2025, 2,500 acres in medium priority areas by 2035, and 18,000 acres in low priority areas by 2045.	Agricultural landowners and operators	Develop cost-share program in 2015.	*see note	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension	SWCDs, NRCS
			Host annual tour or workshop highlighting the benefits of manure management planning. Tours will occur from 2015 to 2045 at an appropriate location in the watershed.	$2,500		
			Seek financial incentives for landowners to implement manure management (2016).	$1,000		
			Annually from 2015-2025 implement 1,156 acres, from 2025-2035 implement 250 acres and from 2035-2045 implement 1,800 acres of manure management in the appropriate critical areas.	$945,740		
			Implement 32,059 acres of manure management by 2045.			

Nutrients, Sediment, Habitat, *E. coli*	Increase conservation buffer (filter strips, field border, riparian buffer) by 152 acres in high priority areas by 2025, by 130 acres in medium priority areas by 2035, and by 190 acres in low priority areas by 2045.	Agricultural landowners and operators, Urban and rural landowners	Develop cost-share program in 2015.	*see note	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension DNR	SWCDs, NRCS, DNR
			Develop a field day highlighting management and development of buffer habitats and host annually from 2015 through 2045 at an appropriate location within the watershed .	$5,000		
			Submit grant application for restoration and easement purchase to increase zones of protection with emphasis on partners and water monitoring in 2015.	$1,000		
			Seek financial incentives for landowners to establish field borders/buffers as well as promote existing programs/incentives (2016).	$1,000		
			Identify and map areas for comprehensive watershed inventory of conservation practices.	$5,000		
			Annually from 2015-2025 implement 15.2 acres, from 2025-2035 implement 13 acres and from 2035-2045 implement 19 acres of conservation buffer in the appropriate critical areas.	$177,000		
			Install 472 acres of conservation buffer by 2045.			
Nutrients, *E. coli*	Increase the use of nutrient management by 34,678 acres in high priority areas by 2025, 5,313 acres in medium priority areas by 2035, and 15,000 acres in low priority areas by 2045.	Agricultural landowners and operators	Develop cost-share program in 2015.	*see note	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension	SWCDs, NRCS
			Host annual tour or workshop highlighting the benefits of nutrient management planning from 2015-2045 at an appropriate location in the watershed.	$2,500		
			Seek financial incentives for landowners to implement nutrient management (2016).	$1,000		
			Annually from 2015-2025 implement 3,468 acres, from 2025-2035 implement 531 acres and from 2035-2045 implement 1,500 acres of nutrient management in the appropriate critical areas.	$439,928		
			Implement 54,991 acres of nutrient management by 2045.			

Nutrients, Sediment, Habitat, *E. coli*	Increase wetland restoration by 19,504 acres in high priority areas by 2025, by 20 acres in medium priority areas by 2035, and by 55 acres in low priority areas by 2045.	Agricultural landowners and operators, Suburban and rural landowners	Develop cost-share program in 2015.	*see note	Wabash River RC&D, DNR, SWCDs, TNC, NRCS, USDA, IWF, NICHES, Purdue Extension	SWCDs, NRCS, IDNR
			Develop a list of potential wetland restoration sites and conduct 10 one-on-one meetings annually with individual landowners starting in 2015.	$5,000		
			Increase awareness about existing programs.	$1,000		
			Seek financial incentives for landowner to restore wetlands.	$1,000		
			Annually from 2015-2025 implement 1,950 acres, from 2025-2034 implement 2 acres and from 2035-2045 implement 5.5 acres of wetland restoration in the appropriate critical area.	$58.7 Million		
			Restore 19,579 acres of wetland by 2045.			
Nutrients	Increase landowner awareness on the use of drainage water management; install drainage management structures on 40,000 acres in high priority areas by 2025, by 50 acres in medium priority areas by 2035, and by 50 acres in low priority areas by 2045.	Agricultural landowners and operators	Identify and seek financial incentives for landowners to install drainage water management practices.	$1,000	Wabash River RC&D, SWCDs, DNR, TNC, NRCS, USDA, IWF, NICHES, Purdue Extension	SWCDs, NRCS, Purdue University
			Develop an education plan including demonstration day and printed materials targeting drainage water management, seeking farmer-to-farmer mentorship if possible.	*see note		
			Implement education plan (2015-2045).	**see note		
			Host annual workshop or presentation for landowners highlighting the benefits of drainage water management from 2015-2045 at an appropriate location in the watershed.	$1,000		
			Target installing a demonstration in 2017.	$3,000		
			Annually from 2015-2025 install drainage water management structures to treat 4,000 acres, from 2025-2035 implement treatment on 5 acres and from 2035-2045 implement treatment on 5 acres in appropriate critical areas.	$126,000		
			Install 1,002 structures treating no less than 40-50 acres by 2045.			

Nutrients, Sediment, Habitat, *E. coli*	Increase the use of a conservation system approach by 6,400 acres in high priority areas by 2025 and by 10,000 acres in medium priority areas by 2035, by 10,000 acres in low priority areas by 2045.	Agricultural landowners and operators	Develop cost-share program in 2015.	*see note	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension	SWCDs, NRCS
			Host annual tour or workshop highlighting the benefits of the conservation system in an operating area from 2015-2045 at an appropriate location in the watershed.	$1,000		
			Seek financial incentives for landowners to establish the system (2016).	$1,000		
			Implement 1,300 acres of the conservation system (includes cover crop, no till, nutrient management, pesticide management, and waste utilization) annually from 2015-2025, 1,000 acres annually from 2025-2035 in medium priority areas, and 1,000 acres annually in low priority areas.	$300,000		
Nutrients, Sediment, Habitat, *E. coli*	Restrict livestock access from watershed streams from 47,520 linear feet in high priority area by 2025, 4,400 linear feet in medium priority areas by 2035, and 17,600 linear feet in low priority areas by 2045.	Landowners with livestock access to watershed streams	Develop cost-share program in 2015.	*see note	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension
			Develop a targeted education program in 2015 based on areas observed to allow livestock access to streams. Conduct outreach to those landowners and provide technical and financial assistance for restricting access.	*see note		
			Implement education plan (2015-2045).	**see note		
			Develop individual livestock on-site restriction plans which may include provision of alternate water systems, livestock fencing, and rotational grazing.	$1,500		
			Annually from 2015-2025 restrict livestock access from 4,752 linear feet, annually from 2025-2035 restrict access from 440 lineal feet and annually from 2035-2045 restrict access from 1,760 lineal feet in appropriate critical areas.	$83,424		
			Restrict livestock from 69,520 linear feet by 2045.			

Nutrients	Increase landowner awareness on the use of bioreactors by 2025. Install bioreactors to treat tile-drained soils: 100 acres in high priority areas by 2025, 10 acres in medium priority areas by 2035, and 10 acres in low priority areas by 2045.	Agricultural landowners and operators, Urban and rural landowners	Identify and seek financial incentives for landowners to establish bioreactors.	$1,000	Wabash River RC&D, SWCDs, TNC, NRCS, USDA, IWF, NICHES, DNR, Purdue Extension	SWCDs, NRCS, Purdue Extension
			Develop an education plan including demonstration day and printed materials targeting the use of bioreactors.	*see note		
			Host annual workshop or presentation for landowners highlighting the benefits of bioreactors from 2015-2045 at an appropriate location in the watershed.	$1,000		
			Install bioreactors to treat 10 acres of tile drainage annually from 2015-2025, 1 acre of tile drainage annually from 2025-2035 and 1 acre of tile drainage annually from 2035-2045 in appropriate critical areas.	$54,000		
			Target demonstration areas to be installed in 2025 and install bioreactors to treat 120 acres of tile drained soils by 2045.			
Sediment	Increase conservation tillage acreage by 46,237 acres in high priority areas by 2025, by 6,375 acres in medium priority areas by 2035, and by 50,000 acres in low priority areas by 2045.	Agricultural landowners and operators	Host annual no till workshop from 2015-2045 in an appropriate location in the watershed..	$5,000	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension	SWCDs, NRCS
			Develop cost-share program in 2015.	*see note		
			Host annual no till breakfast (2015-2045) at an appropriate location in the watershed.	$6,000		
			Continue to perform annual tillage transect and promote results to watershed stakeholders.	$5,000		
			Conduct site visits with landowners to promote no till.	$1,000		
			Increase conservation tillage from 4,623 acres annually from 2015-2025, 635 acres annually from 2025-2035 and in 5,000 acres annually from 2035-2045 in appropriate critical areas.	$2.6 Million		
			Install 102,612 acres of conservation tillage by 2045.			

Sediment	Increase awareness of landowners on the use of two-stage ditches. Install 2 miles of two stage ditch in high priority areas by 2025, 2 miles in medium priority areas by 2035, and 7 miles in low priority areas by 2045.	Agricultural landowners and operators	Develop an education plan including demonstration day and printed materials targeting two stage ditches.	*see note	Wabash River RC&D, Howard County, SWCDs, DNR, TNC, NRCS, USDA, IWF, NICHES, Purdue Extension, Surveyors offices, Notre Dame, Howard County Surveyor	SWCDs, NRCS, Purdue University, RCPP
			Implement education plan (2015-2045).	$15,000		
			Host annual workshop or presentation for landowners highlighting the benefits of two stage ditches from 2015-2045 at an appropriate location in the watershed.	$5,000		
			Install 0.2 miles of two-stage ditch annually from 2015-2025, 0.2 miles of two-stage ditch annually from 2025-2035 and 0.7 miles of two-stage ditch annually from 2035-2045 in appropriate critical areas.	$709,632		
			Install 11 miles of two-stage ditches by 2045.			
Habitat, Sediment	Increase landowner awareness about streambank stabilization options and alternatives and stabilize streambanks as possible through 2045.	Agricultural landowners and operators, Urban and rural landowners	Identify potential demonstration sites where low and high cost stabilization techniques can be displayed.	$1,000	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension, Surveyors offices, DNR	SWCDs, NRCS, DNR
			Complete installation of demonstration site highlighting low and high cost streambank stabilization options.	$100,000		
			Host a series of field and demonstration days targeting streambank stabilization installation, completed projects, and maintenance issues.	$3,000		
			Develop a cost-share program as interest is generated.	*see note		
			Identify funding sources.	$1,000		
			Stabilize streambanks as possible through 2045.	$20-100/foot		

Sediment	Increase the use of grassed waterways by 76 acres in high priority areas by 2025, by 75 acres in medium priority areas by 2035, and by 75 acres in low priority areas by 2045.	Agricultural landowners and operators	Develop cost-share program in 2015.	*see note	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension	SWCDs, NRCS
			Develop a field day highlighting management and development of grassed waterways and host annually (2015-2045) at an appropriate location in the watershed.	$5,000		
			Seek financial incentives for landowners to establish grassed waterways (2016).	$1,000		
			Increase grassed waterway usage by 7.6 acres annually from 2015-2025, by 7.5 acres annually from 2025-2035 and by 7.5 acres annually from 2035-2045 in appropriate critical areas.	$39,550		
			Implement 226 acres grassed waterways by 2045.			
Sediment	Increase the use of prescribed grazing or grazing management practices on 876 acres in high priority areas by 2025, on 200 acres in medium priority areas by 2035, and on 500 acres in low priority areas by 2045.	Agricultural landowners and operators	In 2017, develop inventory of areas currently using prescribed grazing or grazing management practices.	$1,000	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension	SWCDs, NRCS
			In 2017, conduct targeted mailing highlighting conservation options to all identified livestock producers.	$1,000		
			In 2017, conduct one-on-one site visits with individual livestock producers, as possible, to discuss prescribed grazing.	$1,000		
			Implement 87.6 acres of prescribed grazing annually from 2015-2025, 20 acres annually from 2025-2035 and 50 acres annually from 2035-2045 in appropriate critical areas.	$55,160		
			Implement 1,576 acres of prescribed grazing or grazing management practices by 2045.			

Nutrients, *E. coli*	Install animal mortality/animal composting facilities to process 2000 animals in high priority areas by 2025, 2000 animals in medium priority areas by 2035, and 51,000 animals in low priority areas by 2045.	Livestock-producing agricultural landowners and operators	Develop cost-share program in 2015.	*see note	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension	SWCDs, NRCS
			Develop a field day highlighting animal mortality/composting facilities and host annually starting in 2015.	$5,000		
			Seek financial incentives for landowners to establish animal mortality/composting facilities (2015).	$1,000		
			Install 2 facilities from 2015-2025, 2 facilities from 2025-2035 and 5 facilities annually from 2035-2045 in appropriate critical areas.	$4.5 Million		
			Install 55 facilities (treating ~1,000 animals each) by 2045.			
Nutrients, Sediment	Increase the use of forage and biomass planting by 87 acres in high priority areas by 2025, by 50 acres in medium priority areas by 2035, and by 50 acres in low priority areas by 2045.	Agricultural landowners and operators	Develop cost-share program in 2015.	*see note	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension	SWCDs, NRCS
			Develop a field forage day and host annually (2015-2045) at an appropriate location in the watershed.	$5,000		
			Seek financial incentives for landowners for forage and biomass planting (2015).	$1,000		
			Increase forage and biomass planting by 9 acres annually from 2015-2025, 5 acre annually from 2025-2035 and 5 acres annually from 2035-2045 in appropriate critical areas.	$7,480		
			Install 187 acres of forage and biomass planting by 2045.			

Nutrients, Sediment	Increase use of grade stabilization structures by 11 acres in high priority areas by 2025, by 4 acres in medium priority areas in 2035, and by 20 acres in low priority areas by 2045.	Agricultural landowners and operators	Develop cost-share program in 2015.	*see note	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension	SWCDs, NRCS
			Develop a grade stabilization workshop and host annually (2015-2045) at an appropriate location in the watershed.	$5,000		
			Seek financial incentives for landowners for grade stabilization structures (2015).	$1,000		
			Increase the use of grade stabilization structures by 1.1 acres annually from 2015-2025, by 0.4 acres annually from 2025-2035 and by 2 acres annually from 2035-2045 in appropriate critical areas.	$122,500		
			Install 35 acres of grade stabilization structures by 2045.			
Nutrients, Sediment, Habitat	Increase tree and shrub establishment by 47,113 acres in high priority areas by 2025, by 500 acres in medium priority areas by 2035, and by 500 acres in low priority areas by 2045.	Agricultural landowners and operators, Stream/ditch-adjacent landowners	Develop cost-share program in 2015.	*see note	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension	SWCDs, NRCS
			Develop tree & shrub workshop and host annually (2015-2045) at an appropriate location in the watershed.	$5,000		
			Seek financial incentives for landowners for tree & shrub establishment (2015).	$1,000		
			Establish 4,711 acres of trees and shrubs annually from 2015-2025, 50 acres annually from 2025-2035 and 50 acres annually from 2035-2045 in appropriate critical areas.	$32.7 million		
			Install 48,113 acres of tree & shrub by 2045.			
Nutrients, Sediment, *E. coli*, Habitat	Increase water quality treatment via WASCOBs treating 21 acres in high priority areas by 2025, 5 acres in medium priority areas by 2035, and 5 acres in low priority areas by 2045.	Agricultural landowners and operators	Develop cost-share program in 2015.	*see note	Wabash River RC&D, SWCDs, NRCS, USDA, Purdue Extension	SWCDs, NRCS
			Develop water and sediment control basin field day and host biennially from 2015 through 2045 at an appropriate location within the watershed.	$5,000		
			Seek financial incentives for landowners for water and sediment control basins (2015).	$1,000		
			Install one structure annually from 2015-2025, from 2025-2035 and 2035-2045 in appropriate critical areas.			
			Install6 structures treating no less than 5.2 acres (31 acres treatment) each by 2045.	$24,500		

Public Awareness: Targeted Education Programs	Conduct a watershed-wide Sampling Blitz at least once annually through 2035.	Community volunteers, Businesses, Charter schools, Youth groups, Scout groups	Conduct annual sampling blitzes through 2035 ($2,000/year).	$40,000	Purdue University, City of Delphi, Town of Flora, Town of Camden, Town of Galveston, FFA, Community Organizations	Purdue University Soils Lab
			Develop education component for the sampling blitz (2015) and implement in concert with each sampling blitz.	$5,000		
			Develop annual planned dates for the sampling blitz to include it on annually-printed community calendars.	$500		
			Continue preparation of subwatershed maps following sampling to highlight results and changes in water quality.	$500		
			Develop a list of kid-friendly sample sites and ensure that sampling methods are adapted to encourage children's participation.	$500		
			Consider developing an adopt-a-site option for groups to sample during each event.	$1,000		
			Identify opportunities for businesses to participate in the blitz via employee sharing or other options.	$1,000		
			Evaluate event and determine continuation of the event annually and at the end of 2025.	$5,000		
Public Awareness: Targeted Education Programs	Host field days and demonstration events at least annually through 2035.	Community Volunteers, Producers	Host biennial water quality workshops from 2015-2045 to continue to educate stakeholders on watershed functions and emphasize individual impact on water quality. Workshops will move throughout the watershed.	$30,000	University of Purdue, County SWCDs, NRCS, Cover Crop Systems Initiatives (CCSI), CTIC, Seed and Equipment representatives, Producers	University of Purdue, County SWCDs, NRCS, CCSI, CTIC
			Host annual field days or partner with CCSI to demonstrate cover crops and promote soil health.	$60,000		
			Partner with Howard County to host demonstration days to demonstrate installation of two-stage ditch no less than once every 10 years.	$15,000		

Public Awareness: Targeted Education Programs	Strengthen liaison with local area planning commissions to support water quality related policies.	Local elected officials	Present Watershed Management Plan and Cost Share Program to local area planning commissions once in 2016.	$2,000	Counties, ACPs, SWCDs	University of Purdue, SWCDs, NRCS, ISDA
			Annually, or as needed, provide assistance and feedback to area plan commissions when water quality related policies are examined and updated.	$3,000		
Public Awareness: Targeted Education Programs	Continue quarterly Hoosier Riverwatch-based volunteer monitoring through 2025.	Community volunteers, Businesses, Charter schools, Youth and Scout groups	Continue annual training and consider retraining volunteers as needed.	$2500	Purdue University, City of Delphi, Town of Flora, Town of Camden, Town of Galveston, FFA, Community Organizations	Hoosier Riverwatch-certified trainer, IDNR Hoosier Riverwatch program staff
			Continue recruiting volunteer monitors.	$3,000		
			Annually, profile volunteers and their monitoring efforts on partner websites and through marketing effort.	$2,500		
			Complete quarterly sampling through 2045.	$40,000		
Public Awareness: Protect Natural Areas/Public Impacts to Water Quality	Develop a partner and volunteer tracking list by 2015.	Community members targeted by each identified strategy	Develop a list of potential partner groups and identify a contact within each group by 2017.	$3,000	Cities, counties, community groups	Cities, counties, community groups
			Identify a method of contacting partner groups and approach each potential partner no less than annually to explore opportunities.	$5,000		
			Develop a volunteer tracking database and utilize this to track volunteer involvement by 2017.	$3,000		

Public Awareness: Protect Natural Areas/Public Impacts to Water Quality	Share and communicate past, current, and future activities on a regular basis through 2025.	Community members targeted by each identified strategy	Complete updates to the DCSC website quarterly and provide that information to partners for update to their websites as well.	$5,000	Purdue University, City of Delphi, Town of Camden, Town of Flora, Town of Galveston, Counties, County SWCDs, Community organizations, Chambers, Festival Planning Committees	Purdue University, City of Delphi, Town of Camden, Town of Flora, Town of Galveston, Counties, County SWCDs
			Host annual public meetings or events at which the public can comment on watershed efforts.	$10,000		
			Develop a message for county fairs annually and attend county fairs for Cass, Carroll, Howard, Miami, and, Tippecanoe counties on an annual basis. Attend additional county fairs as appropriate.	$25,000		
			Create pamphlets, brochures, and marketing materials as needed and distribute through partner organizations, on websites, and via direct mailings and meetings.	$10,000		
			Create press releases quarterly or as needed.	$1,000		
			Annually attend local events and festivals in Delphi, Flora, Camden, and Galveston to promote efforts and events.	$10,000		
			Provide information to existing newsletter publishers such as SWCDs and others as identified no less than annually.	$5,000		
			Explore the potential and need for a semi-annual or quarterly newsletter in paper and electronic format and produce as determined through 2025.	$5,000		
			Explore ways in which the website, webinars, phone apps, and social media can most effectively target and assist in educating various communities in the watershed. Implement social media strategy.	$5,000		
			Annually host awards for water quality and land stewardship.	$5,000		
			Partner with the Carroll SWCD to host a booth at Ag Days annually.	$5,000		

Public Awareness: Protect Natural Areas/Public Impacts to Water Quality	Build on existing youth education programs.	School groups, youth-targeted groups	Partner with the Carroll SWCD to host a booth at Ag Days annually.	$5,000	SWCDs, local schools, FFA, other youth organizations as appropriate	Local SWCDs, NRCS, ISDA, CCSI, CTIC
			Increase FFA involvement in field days, sampling, and other activities as needed.	$5,000		
			Investigate the potential for a youth-based Deer Creek float trip (ala Arrowhead Country RC&D) and implement annually as possible.	$10,000		
			Coordinate with local schools to incorporate water quality issues into High School curriculums.	$5,000		
			Organize High School field trips to examine demonstration sites and problem areas, developing problem-solving activities and competitions. Host high school field trips no less than once every four years.	$15,000		
Public Awareness: Protect Natural Areas/Public Impacts to Water Quality	Work with local groups and partners to highlight local streams and the Wabash River and natural aspects of the watershed.	Community members targeted by each identified strategy	Annually, create one walking tour, one Google Earth tour, and quarterly podcasts highlighting unique features, green practices, unique features (natural areas, parks), and activities in the watershed from 2015-2025.	$60,000	Purdue University, City of Delphi, Town of Flora, Town of Camden, Town of Galveston SWCDs, Consultants, Web developers, School groups, Community groups organizing local festivals, video developers, marketers	Purdue University, City of Delphi, Town of Flora, Town of Camden, Town of Galveston SWCDs, Consultants, Web developers, School groups, Community groups organizing local festivals, video developers, marketers
			Increase awareness of natural areas with annual photo and art competitions.	$10,000		
			Explore opportunities to partner with local community events and festivals to highlight the streams in the watershed. Attend no less than one festival annually.	$2,000		
			Develop videos targeted at adult community groups (20 minutes) and kids groups (10 minutes) and create list of potential partner groups at which presentation could occur. Present to 5 partner groups annually.	$20,000		

Public Awareness: Protect Natural Areas/Public Impacts to Water Quality	Promote hands-on opportunities to improve natural areas and the streams in the watershed.	Nature enthusiast, Children	In 2017, identify partner organizations which host field days, work days, and clean-up events.	$2,000	NICHES, DNR, SWCDs,	NICHES, DNR, SWCDs,
			Annually, identify partner opportunities to promote field days throughout the watershed and post to a central website or calendar.	$5,000		
			Annually, identify partner work days for river clean-up, exotic species control, or habitat restoration opportunities.	$5,000		
Public Awareness: Protect Natural Areas/Public Impacts to Water Quality	Increase natural areas information flow to service organizations.	Service organizations	In 2017, create a list of service organizations throughout the watershed.	$3,000	DNR, NICHES, SWCD	DNR, NICHES, SWCD
			Annually, meet with two service organizations to present information on water quality, agricultural practices, natural land preservation, or the Deer Creek-Sugar Creek Watershed	$5,000		
			Annually, request assistance from service organizations on natural areas maintenance, clean-up events, Sampling Blitz, or other volunteer opportunities.	$1,000		
			Annually recognize service groups for their participation by honoring the most active group relative to natural areas conservation and improvement and/or volunteerism.	$2,000		
Public Awareness: Protect Natural Areas/Public Impacts to Water Quality	Place high quality photographs in 20 professional offices by 2025.	People using professional services	In 2017, identify and hire a photographer to develop a natural areas and DCSC watershed-based portfolio.	$5,000	WREC, NICHES, local Arts Foundations	photographers
			In 2017, identify 10 professional offices for photograph placement and complete placement in 2018.	$2,000		
			By 2025, identify a total of 20 professional offices for photograph placement and complete placement.	$2,000		
			Annually, rotate photographs to maintain fresh views of natural resources.	$3,000		

Public Awareness: Protect Natural Areas/Public Impacts to Water Quality	By 2015, become a supporter of WBAA to promote water quality.	WBAA listening audience	In 2017, identify a funding mechanism to purchase weekly spots on WBAA.	$2,200	Identified partners	WBAA staff
			In 2017, develop a calendar of weekly water quality messages.	$5,000		
			In 2017, identify partners to assist with message development and delivery.	$2,000		
			Complete weekly water quality message for WBAA through 2025.	$5,000		

*One cost-share program and one education plan will be developed covering all strategies identified. Development costs of each plan are for one-half of the Watershed Coordinator's time for two quarters plus meeting materials.

**Implementation of the education plan includes salary for the Watershed Coordinator to implement education and outreach over five years.

12.0 TRACKING EFFECTIVENESS

The overall success of a watershed management plan depends upon the implementation of action items as outlined by the plan's goals. Below are measurable success indicators or milestones which will help stakeholders in the Deer Creek-Sugar Creek track their progress and aid in updating and revising the watershed management plan as goals, objectives, and strategies are met. Strategies to achieve scaled goals are designed a 5-year implementation schedule. Regular water quality monitoring, social indicator surveys, and tracking of administrative successes associated with objectives and strategies is necessary to help realize actual water quality targets. Indicators identified below will be tracked and reported on a quarterly basis.

12.1 Indicator Tracking

Measuring stakeholder successes towards goals and assessing progress toward the vision of Deer Creek, Sugar Creek and their tributaries is vital. Stakeholders will complete the following concrete milestones as they work towards each goal. Interim measures or indicators will help stakeholders evaluate their progress towards chosen goals. For each goal, a series of indicators are detailed below. Indicator tracking will be completed by the Wabash River Enhancement Corporation. To request information on the status of progress towards goals, contact the Wabash River Enhancement Corporation at 200 North 2nd St, Lafayette, Indiana, 47901, or via phone at (765) 520-8505.

12.1.1 Water Quality Indicators

Water quality indicators are measurements of water chemistry, instream biota, or instream and riparian habitats. As part of our effort to show a measureable change in water quality, volunteer water quality monitoring will continue within the Deer Creek-Sugar Creek watershed throughout the implementation period. Water quality indicators will be measured as detailed below through 2045. After the first five years of implementation, indicators will be used to track implementation progress as follows:

- Nitrate-nitrogen and total phosphorus will be measured quarterly during the growing season at the twelve Hoosier Riverwatch monitoring stations (see Section 3.3.1 for details on station locations). After five years of implementation, water quality samples will indicate a statistically significant improvement in water quality when compared with pre-implementation samples and will show a decreasing trend, with more samples annually meeting the target level for nitrate-nitrogen of 1 mg/L and for total phosphorus of 0.3 mg/L.
- Total suspended solids will be measured quarterly during the growing season at the twelve Hoosier Riverwatch monitoring stations (see Section 3.3.1 for details on station locations). After five years of implementation, water quality samples will indicate a statistically significant improvement in water quality when compared with pre-implementation samples and will show a decreasing trend, with more samples annually meeting the target level for total suspended solids of 15 mg/L.
- *E. coli* will be measured monthly during the growing season at twelve Hoosier Riverwatch monitoring stations (see Section 3.3.1 for details on station locations). After five years of implementation, water quality samples will show a decreasing trend, with more samples annually meeting the state standard.

- Macroinvertebrate communities (mIBI), fish communities (IBI) and in-stream habitat (QHEI) will be monitored annually at the twelve Hoosier Riverwatch stations (see Section 3.3.1 for details on station locations). After five years of implementation, mIBI and IBI scores and instream cover and riparian habitat QHEI metric scores will show an increasing trend with each year's score measuring higher than scores recorded during the previous year.

Water quality indicators will be tracked using the Hoosier Riverwatch water quality database. These data will be considered along with the historic data and data collected during the planning phase of this project. Data will be updated quarterly and reported to the steering and monitoring committees on an annual basis. Additional monitoring will supplement the volunteer monitoring as additional funding allows.

12.1.2 Social Indicators

Social indicators provide information about stakeholder awareness, attitudes, capacity, and behaviors that directly affect water quality improvement and protection. Social indicators will be used as follows:

- Changes in knowledge about Deer Creek, Sugar Creek, and their tributaries.
- Changes in knowledge about and attitudes towards practices to improve water quality.
- Changes in knowledge about conservation and land practices.
- Changes in awareness about watershed activities, concerns, and accomplishments.
- Changes in participation in watershed, creek and tributary activities.
- Participation in cost-share and education programs.

Social indicator data will be tracked in both the planning phase and the post-implementation survey. If possible, comparisons between these data will be generated. Surveys will be completed by Purdue University five years after implementation begins and will cost $20,000. Results will be reported to the steering committee when data are available.

12.1.3 Administrative indicators

Administrative indicators provide information that water quality and social indicator data cannot. These indicators are used to track program participation, strategy completion, and goal attainment. Administrative indicators will be used to track the following:

- Attendance at workshops and field days.
- Emails sent, read, and responses received.
- Conservation practice installation including anticipated load reduction, size, and timing.
- Photo monitoring of installed practices.
- Media hits (newspaper stories, radio stories, website hits).
- Number of educational materials distributed.

Administrative indicators will be tracked using a database in which date of activity, number of attendees or participants, and an activity description will be recorded. Installed practices will be tracked in a project database using Geographic Information Systems. Administrative indicator tracking will occur as part of the cost-share and education programs and will be completed by the WREC Watershed Coordinator. Data will be reported to the steering committee no less than annually with updates to the database occurring quarterly.

12.2 Future Considerations

There are several considerations stakeholders should keep in mind as they implement the Deer Creek-Sugar Creek Watershed Management Plan. Many of these considerations are noted in the proceeding sections of this text, but due to their importance, they warrant reiteration.

12.2.1 Water Quality Monitoring

An active water quality monitoring program will continue within the Deer Creek-Sugar Creek watershed. Water chemistry, habitat, and biological monitoring will continue as part of the Hoosier Riverwatch volunteer monitoring program in an effort to show changes in water quality.

A monitoring committee will be convened annually to discuss results of water quality monitoring and to provide recommendations to the steering committee for watershed management plan refinements. The following will be considered at annual monitoring committee meetings:

- Have implemented best management practices been effective in improving water quality?
- Should a different suite of best management practices be used?
- Have water quality goals been achieved?
- Have water quality goals changed?
- Has the density of exotic species changed?

12.2.2 Social Indicator Monitoring

As detailed above, monitoring of social indicators will occur five years after implementation begins and no less than every 10 years after that. Additional social indicator surveys will be scheduled during each phase of implementation. The education committee will be convened following each survey (2020, 2030, 2040) to review results and identify changes in social indicator data. After each social indicator assessment, the following will be considered at annual education committee meetings:

- Are watershed stakeholders more informed about water quality concerns and watershed issues?
- Have methods for distributing information to stakeholders been effective?
- Have the desired uses of the Wabash River tributaries in the Deer Creek-Sugar Creek watershed changed?

12.2.3 Permits, Easements, and Agreements

Permission to implement any on-the-ground implementation project must be obtained from property owners prior to installation occurring. Likewise, any instream or near-stream restoration activities will likely require permits. All permits will be obtained by the Wabash River Enhancement Corporation prior to any work beginning.

12.2.4 Installed Practice Monitoring

Annually, a practice technical committee will be convened to review installed best management practices and successes or failures of installed practices. Members from the following organizations will be contacted and asked to serve on this committee: Soil and Water Conservation District personnel, Natural Resource Conservation Service personnel, The Nature Conservancy staff, County surveyors, IDEM representatives, IDNR representatives, County Health Department staff, engineering, stormwater and sewer staff from Delphi, Flora, Camden and Galveston, Purdue University Physical Facilities staff, and NICHES Land Trust staff. Other members will be invited as identified. The board will meet annually to review the following:

- Location and number of best management practices installed.
- Annual plans for best management practice installation.
- Potential areas for collaboration on best management practice installation.
- Grant funding opportunities and potential project targets.

12.2.5 Plan Tracking

Each strategy will be tracked on a quarterly basis. Work completed towards each strategy will be documented in a tracking database which will include scheduled and completed activities, numbers of individuals attending or efforts completed toward each objective, and load calculations or monitoring results for each goal, objective, and strategy. Overall project progress will be tracked by measureable items such as workshops held, BMPs installed, meetings held, etc. Load reductions will be calculated for each BMP installed. These values and associated project details including BMP type, location, length of conservation commitment, easement, size, cost, installer, and more will be tracked over time in a single database. Individual landowner contacts and information will be tracked for both identified and installed projects.

Information about the project and updates on implementation can be found on the project website:

12.2.6 Plan Revision

The steering committee of the Deer Creek-Sugar Creek watershed will continue to meet on a regular basis for the purpose of plan implementation. Annually, this committee will review findings of the education, monitoring, and implementation committees. The steering committee will review project efforts according to the management plan's goals, objectives, and strategies no less than every five years.

This watershed management plan is meant to be a living document. Revisions and updates to the plan will be necessary as stakeholders begin to implement the plan and as stakeholders become more active in implementing the plan and as subsequent water quality monitoring may warrant adjustments to initial load conditions. The Wabash River Enhancement Corporation and the Carroll County Soil and Water Conservation District will be jointly responsible for holding and revising the Deer Creek-Sugar Creek Watershed Management Plan as appropriate based on stakeholder feedback.

This plan may be adapted or blended with other watershed management plans to effectively create living documents which cover larger-scale projects and capitalize on potential shared resources.

Updated project information can be found at http://www.wabashriver.net/deer-creek-sugar-creek/ or by contacting:

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Appendix A: Geographic Information Systems Metadata

GIS data sources.

The following geographic information systems (GIS) data sources were used to create one or more of the maps in the Deer Creek-Sugar Creek Watershed Management Plan as listed below:

(IGS, 1998) LANDSURVEY_COUNTY_POLY_IN: County boundaries in polygon format. Derived from the U.S. Geological Survey's 1:24,000 digital raster graphic (DRG) series. (no scale) Polygon shapefile.

(INDOT, 2001). INCORPORATED_AREAS_INDOT_IN: Incorporated Boundaries in Indiana, INDOT, Graphics and Engineering. (no scale) Polygon Shapefile.

(USCB, 2005) ROADS_2005_INDOT_IN: Indiana Roads from INDOT and TIGER Files, 2005. (1:100,000) Line Shapefile.

(USGS, 1991) WATERSHEDS_HUC08_CATALOG_UNITS_USGS_IN: 8-digit hydrologic accounting units. Derived from the 14-digit hydrologic units in Indiana created by U.S. Geological Survey and National Resources Conservation Service. (1:24,000) Polygon shapefile.

(USGS, 2008a) HYDROGRAPHY_HIGHRES_FLOWLINE_NHD_USGS: Streams, Rivers, Canals, Ditches, Artificial Paths, Coastlines, Connectors, and Pipelines. Derived from National Hydrography Dataset which was originally developed at 1:100,000 scale to be developed at 1:24,000-1:12,000 scale. (1:24,000) Linear shapefile.

(IDEM, 2002) NPDES_FACILITY_IDEM_IN: Facilities in the National Pollutant Discharge Elimination System with assigned UTM Coordinates in Indiana. IDEM, Office of Water Quality, Data Management Section. (no scale) Point Shapefile.

(IDEM, 2003) RECREATIONAL_FACILITIES_IDNR_IN: Outdoor recreational facilities in Indiana. IDNR, Department of Outdoor Recreation (1:24,000) Point shapefile.

(IDNR, 2004) FLOODPLAINS_DFIRM_IDNR_IN: Floodplain locations. Derived from FEMA Flood Rate Insurance Maps (FIRM), Digital Flood Insurance Rate Map (DFIRM), and Flood Insurance Studies (FIS). (1:12,000) Polygon shapefile.

(IDEM, 2012) IMPAIRED_STREAMS_IDEM_IN: Impaired Streams in Indiana on the 303(d) List of 2006. Indiana Department of Environmental Management, Office of Water Quality. Line Shapefile.

(IDEM, 2007a). CONFINED_FEEDING_OPERATIONS_IDEM_IN: Confined Feeding Operation Facilities in Indiana, IDEM, Office of Land Quality, Compliance and Response Branch, Solid Waste Compliance Section. (no scale) Point Shapefile.

2010 CONFINED_FEEDING_OPERATIONS_IDEM_IN: Confined Feeding Operation Facilities in Indiana (Indiana Department of Environmental Management, Point Shapefile)

(IDEM, 2007b) OPEN_DUMPS_IDEM_IN: Open Dump Sites in Indiana, IDEM, Office of Land Quality, Compliance and Response Branch, Solid Waste Compliance Section. (no scale) Point Shapefile.

(IDEM, 2007c) WASTE_INDUSTRIAL_IDEM_IN: Industrial Waste Sites in Indiana, IDEM, Office of Land Quality, Compliance and Response Branch, Industrial Waste Section. (no scale) Point Shapefile.

(IDEM, 2009a) BROWNFIELDS_IDEM_IN: Defined as a parcel of real estate that is abandoned or inactive, or may not be operated at its appropriate use, and on which expansion, redevelopment, or reuse is complicated because of the presence or potential presence of a hazardous substance, a contaminant, petroleum, or a petroleum product that poses a risk to human health and the environment. IDEM, Office of Land Quality. (unknown scale) Point shapefile.

(IDEM, 2009b) CONFINED_FEEDING_OPERATIONS_IDEM_IN: Shows swine, chicken, turkey, beef or dairy agribusinesses that have large enough numbers of animals that IDEM regulates for environmental concerns, as defined by IC 13-18-10 of the Indiana Code. IDEM, Office of Land Quality. (unknown scale) Point shapefile.

(IDEM, 2009c) LUST_IDEM_IN: Leaking Underground Storage Tanks in Indiana, IDEM, Office of Land Quality, Remediation Service Branch, Leaking Underground Storage Tank Section. (no scale) Point Shapefile.

(IDEM, 2009d) OPEN_DUMPS_IDEM_IN: unregulated, illegal dump sites of solid waste as defined by IAC 10-2-28 329 and IAC 10-2-128 of the Indiana Administrative Code. IDEM, Office of Land Quality. (unknown scale) Point shapefile.

(IDNR, 2009b) RECREATIONAL_FACILITIES_IDNR_IN: Outdoor recreation facilities, including facilities managed by federal, state, and local governments, as well as non-government organizations, private and commercial entities, and schools. It does not include sites that are private and not open to the public. (1:24,000) Point shapefile.

(IGS, 2001a). IS2001USGS_IN: Estimated Percentages of Impervious Surfaces in Indiana in 2001. Derived from the National Land Cover Database (NLCD 2001, United States Geological Survey, 30-Meter Grid), digital representation by Chris Dintaman, 2007.

2011IMPERVIOUS_SURFACE_2006_USGS_IN: Estimated Percentage of Impervious Surface in Indiana in 2006, Derived from the 2006 National Land Cover Database (United States Geological Survey, 30-Meter TIFF Image)

(IGS, 2001b) LC2001USGS_IN: 2001 Land Cover in Indiana, Derived from the National Land Cover Database (NLCD 2001, United States Geological Survey, 30-Meter Grid), digital representation by Chris Dintaman.

2011LAND_COVER_2006_USGS_IN: Land Cover in Indiana, Derived from the 2006 National Land Cover Database (United States Geological Survey, 30-Meter TIFF Image)

(IGS, 2003) ECOREGIONS_USGS_IN: Ecoregions, Levels III and IV, Indiana. Derived from U.S. Geological Survey. (1:250,000) Polygon Shapefile.

(IGS, 2004) CENSUS_MCD_POPCHANGE_IN: Population Densities and Changes of Densities of Minor Civil Divisions in Indiana from 1890 to 2000. Derived from United States Census Bureau. (1:500,000) Polygon Shapefile, digital representation by Denver Harper, 2004.

(IGS, 2007) TC2001USGS_IN: Estimated Percentage of Tree Canopy in Indiana in 2001, Derived from the National Land Cover Database (NLCD 2001, United States Geological Survey, 30-Meter Grid), digital representation by Chris Dintaman.

(INDOT, 2004) HIGHWAYS_INDOTMODEL_IN: Highways in Indiana, INDOT, Graphics and Engineering. (1:24,000) Line Shapefile.

(NRC, 1997) RIVERS_OUTSTANDING_NRC_IN: Outstanding Rivers in Indiana, as listed by the Natural Resource Commission which identifies rivers and streams which have particular environmental or aesthetic interest. (1:100,000) Linear shapefile.

(NRCS, 2009) WBDHU_12_L_IN: 12-digit and 10-digit hydrologic accounting units. (1:24,000) Polygon shapefile.

(TCPWQ, 2005) MS4_BOUNDARY: Boundary for the municipal separate storm sewer system for the Tippecanoe Partnership for Water Quality. (unknown scale) Linear shapefile.

(USCB, 2000b) URBAN_AREAS_TIGER00_IN: major urban areas identified by the U.S. Bureau of the Census. Derived from U.S. Department of Commerce, U.S. Census Bureau, Census 2000 Tiger Line Files. (1:100,000) Polygon Shapefile.

(USDA, 1994) SOILS_STATSGO_IN: Soil Associations in Indiana. U. S. Department of Agriculture, Natural Resources Conservation Service. 1994. (1:250,000) Polygon Shapefile.

2002SOILS_STATSGO_IN: Soil Associations in Indiana (U.S. Dept. of Agriculture, 1:250,000, Polygon Shapefile)

(USDA, 2004) CULTIVATED_AREAS_USDA_IN: Percentage of cultivated land in homogeneous land-use areas. Derived from the National Agricultural Statistics Survey, U.S. Department of Agriculture. Ground resolution is approximately 56 meters by 56 meters. (1:100,000) Grid file.

(USDA, 2008) CROPS_2008_USDA_IN: Shows categorized land-cover data produced using satellite imagery for the purpose of providing supplemental acreage estimates for the state's major commodities. The imagery was collected between the dates of April 1, 2008 and September 30, 2008. Derived from National Agricultural Statistics Service, U.S. Department of Agriculture. Ground resolution is approximately 56 meters by 56 meters. (1:100,000) Grid file.

(USFWS, 2009) ALL_IN_NWI_CURRENT_DRAFT_09212009: Updated National Wetland Inventory dataset which was originally developed in 1979. Latest version updates 1979 dataset through the use of aerial photographs. (1:24,000) Polygon shapefile.

(USGS, 1996) PLACES_POINTS_USGS_IN: Shows the locations of populated places, extracted from the Geographic Names Information System (GNIS) developed by the U.S. Geological Survey. Elevations (feet above sea level) are also provided. (1:24,000) Point shapefile.

(USGS, 1987) BEDROCK_GEOL_MM48_IN: Bedrock Geology of Indiana (Indiana Geological Survey, 1:500,000, Polygon Shapefile)

CROPS_2008_USDA_IN: Crops in Indiana for 2008, Derived from National Agricultural Statistics Service (United States Department of Agriculture, 1:100,000, 56-Meter TIFF Image)

2008 RECREATIONAL_FACILITIES_IDNR_IN: Outdoor Recreational Facilities in Indiana (Indiana Department of Natural Resources, 1:24,000, Point Shapefile)

(USGS, 2008a) HYDROGRAPHY_HIGHRES_FLOWLINE_NHD_USGS: Streams, Rivers, Canals, Ditches, Artificial Paths, Coastlines, Connectors, and Pipelines. Derived from National Hydrography Dataset which was originally developed at 1:100,000 scale to be developed at 1:24,000-1:12,000 scale. (1:24,000) Linear shapefile.

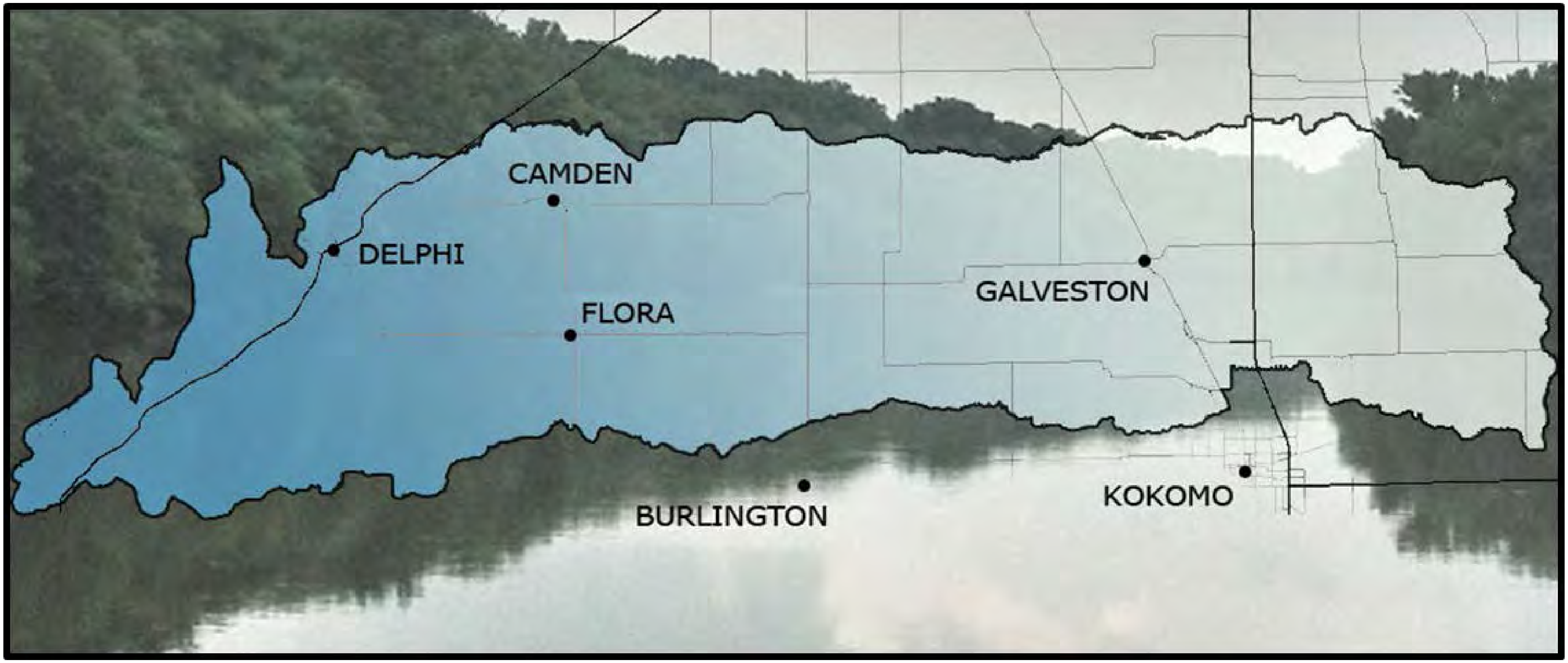
(USGS, 2008b) HYDROGRAPHY_HIGHRES_WATERBODYLINEAR_NHD_USGS: Rivers, Inundation Areas, Canals, Submerged Streams, and Other Linear Waterbodies. Derived from National Hydrography Dataset which was originally developed at 1:100,000 scale to be developed at 1:24,000-1:12,000 scale. (1:24,000) Linear shapefile.

(WREC, 2009a) CURRENT_SAMPLE_SITES: Locations of stream-road crossings where water quality samples are being collected as digitized by WREC staff based on latitude/longitude collected from field locations. (no scale) Point shapefile.

(WREC, 2009b) HISTORIC_SAMPLE_SITES: Locations of stream-road crossings where water quality samples have been previously collected as digitized by WREC staff based on stream name and road crossing name and/or latitude/longitude as provided. (no scale) Point shapefile.

2010 CROPS_2008_USDA_IN: Crops in Indiana for 2008, Derived from National Agricultural Statistics Service (United States Department of Agriculture, 1:100,000, 56-Meter TIFF Image)

Appendix B: Social Indicator Survey Full Report



Human Dimensions of Water Quality in the Deer Creek-Sugar Creek Watersheds

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I. Methods

Mail Survey

612 Surveys distributed

43 Bad addresses

269 Completed (47% response rate after accounting for bad addresses)

II. Your Water Resources

1. Of these activities, which is the most important to you? (select one) (n=219)
7.3% Canoeing / kayaking / other boating
20.1% Fishing
1.4% Swimming
16.0% Picnicking and family activities
55.3% Enjoying scenic beauty

2. Do you know where the rain water goes when it runs off of your property? (Yes or No) (n=244)
89.3% Yes
10.7% No

3. If you answered 'Yes' above, where does your rain water drain to?
See Appendix B-1

III. Your Opinions

Please indicate your level of agreement or disagreement with the statements below.

		Strongly Disagree (1)	Disagree (2)	Neither Agree nor Disagree (3)	Agree (4)	Strongly Agree (5)	Mean (n)
a.	The way that I care for my lawn and yard can influence water quality in local streams.	4.0%	8.5%	18.8%	54.5%	14.3%	3.67 (224)
b.	Using recommended management practices on farms improves water quality.	0.4%	0.8%	6.8%	69.7%	22.3%	4.13 (251)
c.	It is my personal responsibility to help protect water quality.	0.4%	0.8%	6.4%	69.5%	22.9%	4.14 (249)
d.	It is important to protect water quality even if it slows economic development.	0.8%	3.2%	23.0%	57.3%	15.7%	3.84 (248)
e.	My actions have an impact on water quality.	1.2%	4.8%	13.3%	65.1%	15.7%	3.89 (249)
f.	I would be willing to pay more to improve water quality (for example: through local taxes or fees).	15.4%	24.3%	38.5%	20.2%	1.6%	2.68 (247)
g.	I would be willing to change the way I care for my lawn and yard to improve water quality.	5.7%	10.2%	35.2%	42.6%	6.1%	3.33 (244)
h.	I would be willing to change management practices to improve water quality.	3.7%	9.4%	31.1%	50.4%	5.3%	3.44 (244)
i.	The quality of life in my community depends on good water quality in local rivers and streams.	1.6%	5.2%	18.1%	62.7%	12.4%	3.79 (249)

IV. Water Impairments

Below is a list of water pollutants and conditions that are generally present in water bodies to some extent. The pollutants and conditions become a problem when present in excessive amounts. In your opinion, how much of a problem are the following water impairments in your area?

	Not a Problem (1)	Slight Problem (2)	Moderate Problem (3)	Severe Problem (4)	Don't Know	Mean (n)
a. Sedimentation (dirt and soil) in the water	15.7%	30.2%	32.3%	6.9%	14.9%	2.36 (211)
b. Nitrogen	23.9%	23.9%	17.5%	4.8%	29.9%	2.05 (176)
c. Phosphorus	23.9%	24.3%	17.9%	3.2%	30.7%	2.01 (174)
d. Bacteria and viruses in the water (such as E. coli / coliform)	21.6%	22.0%	17.6%	6.0%	32.8%	2.12 (168)
e. Trash or debris in the water	16.0%	31.6%	31.2%	9.6%	11.6%	2.39 (221)
f. Pesticides	22.4%	26.4%	15.6%	6.0%	29.6%	2.07 (176)

V. Consequences of Poor Water Quality

Poor water quality can lead to a variety of consequences for communities. In your opinion, how much of a problem are the following issues in your area?

	Not a Problem (1)	Slight Problem (2)	Moderate Problem (3)	Severe Problem (4)	Don't Know	Mean (n)
a. Contaminated fish	29.9%	24.7%	15.9%	6.8%	22.7%	1.99 (194)
b. Reduced beauty of streams	33.5%	30.7%	19.9%	5.6%	10.4%	1.97 (225)
c. Reduced opportunities for water recreation	40.6%	25.3%	12.0%	5.2%	16.9%	1.78 (207)
d. Reduced quality of water recreation activities	38.2%	27.3%	13.7%	4.4%	16.5%	1.81 (208)
e. Excessive aquatic plants or algae	29.8%	29.4%	12.1%	5.2%	23.4%	1.91 (190)
f. Fish kills	47.6%	20.4%	8.4%	3.2%	20.4%	1.59 (199)
g. Lower property values	53.0%	15.1%	6.4%	3.2%	22.3%	1.48 (195)

VI. Sources of Water Pollution

The items listed below are sources of water quality pollution across the country. In your opinion, how much of a problem are the following sources in your area?

		Not a Problem (1)	Slight Problem (2)	Moderate Problem (3)	Severe Problem (4)	Don't Know (3)	Mean (n)
a.	Discharges from industry into streams	32.2%	28.6%	14.5%	4.3%	20.4%	1.89 (203)
b.	Discharges from sewage treatment plants	29.3%	21.9%	19.5%	7.0%	22.3%	2.06 (199)
c.	Soil erosion from farm fields	14.6%	44.7%	25.7%	5.9%	9.1%	2.25 (230)
d.	Soil erosion from streambanks	15.4%	38.2%	25.6%	8.7%	12.2%	2.31 (223)
e.	Improperly maintained septic systems	24.3%	29.8%	14.9%	4.7%	26.3%	2.00 (188)
f.	Manure from farm animals	42.9%	27.0%	13.5%	4.4%	12.3%	1.76 (221)
g.	Littering/illegal dumping of trash	15.2%	37.9%	30.1%	5.1%	11.7%	2.28 (226)
h.	Excessive use of fertilizers for crop production	38.8%	26.7%	13.3%	3.9%	17.3%	1.79 (211)
i.	Pasture grazing	64.6%	15.4%	4.7%	1.2%	14.2%	1.33 (218)
j.	Animal feeding operations	45.1%	23.5%	10.6%	3.5%	17.3%	1.67 (211)
k.	Construction of highways, roads, and bridges	35.0%	27.6%	14.2%	7.5%	15.7%	1.93 (214)
l.	Urban stormwater runoff	27.8%	23.8%	20.6%	9.5%	18.3%	2.15 (206)

VII. Practices to Improve Water Quality

Please indicate which statement most accurately describes your level of experience with each practice listed below.

		Not relevant for my property	Never Heard of It (0)	Somewhat familiar with it (1)	Know how to use it; not using it (2)	Currently Use It (3)	Mean (n)
a.	Regular servicing of septic system	16.3%	9.5%	20.6%	6.3%	47.2%	3.09 (211)
b.	Using regular soil tests for pH, phosphorous, nitrogen, and potassium to determine nutrient application rates	10.0%	2.8%	8.0%	6.0%	73.1%	3.66 (224)
c.	Using manure in accordance with its nutrient content	48.0%	1.2%	8.4%	4.4%	38.0%	3.52 (130)
d.	Following university recommendations for fertilization rates	13.8%	4.9%	14.6%	5.7%	61.1%	3.43 (213)
e.	Using variable rate application technology for more precise crop production	16.2%	3.2%	8.1%	10.1%	62.3%	3.57 (207)
f.	Considering location and soil characteristics to minimize leaching or runoff	14.7%	2.4%	18.4%	4.9%	59.6%	3.43 (209)
g.	Constructing a facility for composting dead animals	71.6%	2.4%	5.2%	8.8%	12.0%	3.07 (71)
h.	Retaining crop residue on soil surface to reduce erosion	12.4%	1.2%	10.4%	5.6%	70.3%	3.66 (218)
i.	Following an approved grazing plan to maintain grass quality and reduce erosion	68.1%	2.4%	5.9%	7.9%	15.7%	3.16 (81)
j.	Using a grassed waterway to reduce erosion and soil loss	19.3%	1.2%	7.5%	4.3%	67.7%	3.72 (205)
k.	Using fences to exclude livestock from streams and ditches	73.6%	0.8%	2.8%	7.9%	15.0%	3.40 (67)
l.	Using conservation tillage, including no-till, strip-till and ridge till	21.5%	0.8%	11.6%	18.7%	47.4%	3.44 (197)

VIII. Constraints for Specific Practices

A. Feedlot Runoff Diversion

Use of a built diversion structure, filter strips, or grassed waterways to prevent surface water from flowing through feedlots.

1. How familiar are you with this practice? (n=241)
72.6% Not relevant for my operation
2.5% Never heard of it
8.3% Somewhat familiar with it
3.7% Know how to use it; not using it
12.9% Currently use it

2. If the practice is not relevant, please explain why.
See Appendix B-2

3. Are you willing to try this practice? (n=109)
32.1% Yes or already do
27.5% Maybe
40.4% No

How much do the following factors limit your ability to implement this practice?	**Not at all (1)**	**A little (2)**	**Some (3)**	**A lot (4)**	**Don't Know**	**Mean (n)**
a. Don't know how to do it	39.7%	14.0%	12.4%	2.5%	31.4%	1.67 (83)
b. Time required	26.7%	15.8%	17.5%	6.7%	33.3%	2.06 (80)
c. Cost	21.7%	12.5%	23.3%	9.2%	33.3%	2.30 (80)
d. The features of my property make it difficult	32.8%	13.4%	11.8%	8.4%	33.6%	1.94 (79)
e. Insufficient proof of water quality benefit	28.6%	19.3%	11.8%	4.2%	36.1%	1.87 (76)
f. Desire to keep things the way they are	33.1%	15.3%	12.9%	9.7%	29.0%	1.99 (88)
g. Hard to use with my farming system	36.7%	11.7%	13.3%	5.8%	32.5%	1.83 (81)
h. Lack of equipment	34.5%	16.0%	12.6%	5.9%	31.1%	1.85 (82)

B. Cover Crops

Planting cover crops for erosion protection and soil improvement.

1. How familiar are you with this practice? (n=243)

15.2% Not relevant for my operation
1.6% Never heard of it
25.9% Somewhat familiar with it
26.7% Know how to use it; not using it
30.5% Currently use it

2. If the practice is not relevant, please explain why.

See Appendix B-3

3. Are you willing to try this practice? (n=190)

31.1% Yes or already do
50.5% Maybe
18.4% No

How much do the following factors limit your ability to implement this practice?	**Not at all (1)**	**A little (2)**	**Some (3)**	**A lot (4)**	**Don't Know**	**Mean (n)**
a. Don't know how to do it	48.6%	13.7%	19.1%	1.1%	17.5%	1.67 (151)
b. Time required	22.8%	17.9%	30.4%	10.9%	17.9%	2.36 (151)
c. Cost	20.5%	13.5%	28.6%	16.8%	20.5%	2.52 (147)
d. The features of my property make it difficult	44.6%	15.1%	15.6%	3.8%	21.0%	1.73 (147)
e. Insufficient proof of water quality benefit	35.2%	15.9%	20.3%	3.3%	25.3%	1.89 (136)
f. Desire to keep things the way they are	37.6%	17.2%	14.5%	14.0%	16.7%	2.06 (155)
g. Hard to use with my farming system	29.9%	16.3%	20.1%	13.6%	20.1%	2.22 (147)
h. Lack of equipment	29.7%	19.2%	22.0%	11.0%	18.1%	2.17 (149)

C. Two Stage Ditch
A small main channel with vegetated benches that utilize the stream flow process to create a stable ditch, which requires less maintenance.

1. How familiar are you with this practice? (n=242)
23.1% Not relevant for my operation
38.0% Never heard of it
20.2% Somewhat familiar with it
10.7% Know how to use it; not using it
7.9% Currently use it

2. If the practice is not relevant, please explain why.
See Appendix B-4

3. Are you willing to try this practice? (n=172)
12.2% Yes or already do
58.7% Maybe
29.1% No

How much do the following factors limit your ability to implement this practice?	**Not at all (1)**	**A little (2)**	**Some (3)**	**A lot (4)**	**Don't Know**	**Mean (n)**
a. Don't know how to do it	24.6%	8.8%	22.8%	11.1%	32.7%	2.30 (115)
b. Time required	18.2%	10.6%	22.4%	13.5%	35.3%	2.48 (110)
c. Cost	12.8%	9.3%	19.8%	24.4%	33.7%	2.84 (114)
d. The features of my property make it difficult	20.8%	12.5%	17.3%	10.1%	39.3%	2.27 (102)
e. Insufficient proof of water quality benefit	26.3%	14.4%	18.6%	5.4%	35.3%	2.05 (108)
f. Desire to keep things the way they are	32.6%	13.1%	14.9%	10.3%	29.1%	2.04 (124)
g. Hard to use with my farming system	27.4%	13.1%	13.7%	8.9%	36.9%	2.07 (106)
h. Lack of equipment	22.5%	8.9%	17.2%	13.0%	38.5%	2.34 (104)

D. Vegetated Riparian Buffer

Establishing vegetation to function as a buffer to ponds, wetlands, rivers, streams, and creeks.

1. How familiar are you with this practice? (n=242)
21.5% Not relevant for my operation
18.6% Never heard of it
20.2% Somewhat familiar with it
5.0% Know how to use it; not using it
34.7% Currently use it

2. If the practice is not relevant, please explain why.
See Appendix B-5

3. Are you willing to try this practice? (n=163)
39.9% Yes or already do
35.6% Maybe
24.5% No

How much do the following factors limit your ability to implement this practice?	**Not at all (1)**	**A little (2)**	**Some (3)**	**A lot (4)**	**Don't Know**	**Mean (n)**
a. Don't know how to do it	40.5%	10.1%	14.6%	5.1%	29.7%	1.77 (111)
b. Time required	31.2%	17.2%	14.6%	9.6%	27.4%	2.04 (114)
c. Cost	27.0%	13.2%	16.4%	15.1%	28.3%	2.27 (114)
d. The features of my property make it difficult	39.9%	11.4%	14.6%	4.4%	29.7%	1.77 (111)
e. Insufficient proof of water quality benefit	41.4%	10.8%	15.3%	2.5%	29.9%	1.70 (110)
f. Desire to keep things the way they are	40.6%	15.0%	13.8%	6.3%	24.4%	1.81 (121)
g. Hard to use with my farming system	40.8%	10.2%	13.4%	7.6%	28.0%	1.83 (113)
h. Lack of equipment	37.6%	10.8%	16.6%	6.4%	28.7%	1.88 (112)

IX. Making Decisions for My Property

In general, how much does each issue limit your ability to change your management practices?

	Not at All (1)	A little (2)	Some (3)	A lot (4)	Don't Know	Mean (n)
a. Personal out-of-pocket expense	11.2%	13.8%	33.2%	31.0%	10.8%	2.94 (207)
b. Lack of government funds for cost share	15.7%	14.0%	33.2%	21.4%	15.7%	2.72 (193)
c. My own physical abilities	32.9%	17.3%	26.8%	13.4%	9.5%	2.23 (209)
d. Not having access to the equipment I need	21.7%	18.6%	27.9%	19.9%	11.9%	2.52 (199)
e. Lack of available information about a practice	23.5%	22.6%	25.2%	11.9%	16.8%	2.31 (188)
f. No one else I know is implementing the practice	31.1%	19.7%	15.8%	7.9%	25.4%	2.01 (170)
g. Concerns about reduced yields	26.3%	21.5%	20.2%	18.9%	13.2%	2.36 (198)
h. Approval of my neighbors	51.5%	14.1%	14.5%	5.3%	14.5%	1.69 (194)
i. Don't want to participate in government programs	40.0%	13.5%	20.4%	12.2%	13.9%	2.06 (198)
j. Requirements or restrictions of government programs	20.2%	17.1%	21.1%	24.6%	17.1%	2.60 (189)
k. Possible interference with my flexibility to change land use practices as conditions warrant	17.5%	14.0%	31.1%	18.9%	18.4%	2.63 (186)
l. Don't know where to get information and/or assistance for new practices	42.9%	22.3%	13.4%	4.5%	17.0%	1.75 (186)
m. Environmental damage caused by practice	41.2%	17.5%	13.2%	5.7%	22.4%	1.79 (177)

n.	Legal restrictions on my property	34.8%	16.3%	16.3%	10.6%	22.0%	2.03 (177)
o.	I do not own the property	63.9%	5.1%	12.5%	8.8%	9.7%	1.63 (195)
p.	Concerns about resale value	50.9%	13.2%	14.0%	6.6%	15.4%	1.72 (193)
q.	Not being able to see a demonstration of the practice before I decide	34.8%	19.8%	17.2%	9.7%	18.5%	2.02 (185)
r.	The need to learn new skills or techniques	35.0%	20.4%	20.8%	6.2%	17.7%	1.98 (186)

X. About Your Farm Operation

1. Please select the option that best describes who generally makes management decisions for your operation. (n=248)

31.9% Me alone or with my spouse
35.5% Me with my family partners (siblings, parents, children)
3.6% Me with the landowner
16.5% Me with my tenant
5.6% Me and my business partners
4.8% Someone else makes the decisions for the operation
2.0% Other: ____________________________

- "All the answers but the last one"
- "me and my son"
- "N/A"
- "Tenants"

2. Please estimate the total crop and pasture acreage (owned and/or rented) of your farming operation this year. (n=242)

Range: 0 – 6500
Mean: 571

3. This year, how many acres of pasture do you manage? If none, please enter a zero. (n=250)

Range: 0 - 3000
Mean: 25

4. How many years have you been farming? (n=235)

Range: 0 – 80
Mean: 33

5. Did any family member own and operate this farm before you did? (n=245)

28.2% No
71.8% Yes

6. If you answered 'yes' to the previous question, how many years has the farm been in the family? (n=180)

Range: 15 – 180
Mean: 77

7. How likely is it that any family member will continue farm operations when you retire or quit farming? (n=247)

9.3% Definitely will not happen
19.0% Probably will not happen
43.3% Probably will happen
28.3% Definitely will happen

8. Does the property you manage touch a stream, river, or wetland? (n=250)

62.0% Yes
38.0% No

9. Do you have a nutrient management plan for your farm operation? (n=237)

67.9% Yes
32.1% No

10. If you do have a nutrient management plan, does your nutrient management plan meet the NRCS technical standard 590? (n=157)

70.7% I don't know
0.0% No
29.3% Yes

11. Who developed your current nutrient management plan? (n=156)

10.9% My soil and water conservation district, University Extension, or NRCS office
61.5% A private-sector agronomist or crop consultant
13.5% I created my own plan
9.0% I don't know
5.1% Other: ________________________

- "Cash Renter"
- "Co-op"
- "My tenant"
- "Tenant"
- "Tenant"
- "Tenant"
- "Tenant manages"

XI. About You

1. Do you make the home and lawn care decisions in your household? (n=248)

92.3% Yes
7.7% No

2. What is your gender? (n=250)

86.8% Male
13.2% Female

3. What is your age? (n=241)

Range: 24 -101
Mean: 64

4. What is the highest grade in school you have completed? (n=248)

6.9% Some formal schooling
39.1% High school diploma / GED
21.4% Some college
8.1% 2 year college degree
16.9% 4 year college degree
7.7% Post-graduate degree

5. What is the approximate size of your residential lot? (n=244)

3.3% ¼ acre or less
13.5% More than ¼ acre but less than 1 acre
67.6% 1 acre to less than 5 acres
15.6% 5 acres or more

6. Do you own or rent your home? (n=249)

96.0% Own
4.0% Rent

7. How long have you lived at your current residence (years)? (n=246)

Range: 1 - 90
Mean: 32

8. Which of the following best describes where you live? (n=251)

3.6% In a town, village, or city
82.5% On a farm
8.0% In an isolated, rural, non-farm residence
6.0% Rural subdivision or development

9. Do you use a professional lawn care service? (n=251)

0.4% Yes, just for mowing
0.8% Yes, for mowing and fertilizing
6.4% Yes, just for fertilizing and pest control
0.4% Yes, for mowing, fertilizing, and pest control
92.0% No

10. Where are you likely to seek information about soil and water conservation issues? (check all that apply) (n=267)

46.1% Newsletters / brochures / fact sheets
24.7% Internet
3.7% Radio
28.8% Workshops / demonstrations / meetings
37.1% Conversations with others
27.7% Trade publications / magazines
15.4% None of the above

11. Where are you likely to seek information about water quality issues? (check all that apply) (n=267)

44.9% Newsletters / brochures / fact sheets
26.6% Internet
4.1% Radio
28.1% Newspapers / magazines
26.2% Workshops / demonstrations / meetings
33.7% Conversations with others
12.4% None of the above

XII. Information Sources

People get information about water quality from a number of different sources. To what extent do you trust those listed below as a source of information about soil and water?

		Not at all (1)	Slightly (2)	Moderately (3)	Very much (4)	Am not familiar	Mean (n)
a.	Soil and Water Conservation District	2.9%	4.9%	29.2%	58.8%	4.1%	3.50 (233)
b.	Natural Resources Conservation Service	3.8%	10.0%	30.8%	47.1%	8.3%	3.32 (220)
c.	Purdue Extension	2.9%	11.3%	29.2%	52.5%	4.2%	3.37 (230)
d.	Indiana State Department of Agriculture	6.6%	15.4%	34.9%	36.1%	7.1%	3.08 (224)
e.	Indiana Department of Environmental Management	14.6%	21.3%	32.1%	22.9%	9.2%	2.70 (218)
f.	Indiana Department of Natural Resources	7.1%	18.4%	35.6%	31.4%	7.5%	2.99 (221)
g.	Fertilizer representatives	13.0%	20.2%	34.9%	26.1%	5.9%	2.79 (224)
h.	Crop consultants	8.8%	16.4%	35.7%	31.5%	7.6%	2.97 (220)
i.	Wabash River Enhancement Corporation	15.9%	13.8%	17.2%	10.9%	42.3%	2.40 (138)
j.	NICHES Land Trust	18.8%	9.2%	9.6%	4.2%	58.2%	1.98 (100)
k.	Other landowners / friends	8.0%	24.4%	44.5%	18.1%	5.0%	2.77 (226)
l.	Hoosier Environmental Council	19.8%	15.2%	5.5%	5.5%	54.0%	1.93

							(109)
m.	U.S. Environmental Protection Agency	30.8%	24.9%	16.0%	8.4%	19.8%	2.03 (190)
n.	Local government	18.1%	34.9%	28.2%	8.8%	10.1%	2.31 (214)
o.	Farm Bureau	11.2%	23.2%	36.9%	18.7%	10.0%	2.70 (217)
p.	Farm Service Agency	5.4%	14.5%	38.6%	36.1%	5.4%	3.11 (228)

XIII. Your Septic System

1. Do you have a septic system? (n=257)

7.0% No – **(Thank you, survey complete. Please enter any comments below.)**
1.6% Don't know
91.4% Yes

2. If you answered 'yes' to the previous question, in what year was it installed? (n=156)

Range: 1910 - 2013
Mean: 1982

3. Within the last five years, have you had any of the following problems? (check all that apply) (n=235)

6.8% Slow drains
1.7% Sewage backup in house
0.4% Bad smells near tank or drain field
0.9% Sewage on the surface
0.0% Sewage flowing to ditch
0.0% Frozen septic
1.3% Other:______________________________

- "It's alright"
- "None"
- "Septic tank full"

84.7% None
3.0% Don't know

4. Does your septic system have an absorption field (finger system)? (n=229)

76.0% Yes
12.2% No
11.8% Don't know

5. How would you know if your septic system was NOT working properly? (check all that apply) (n=235)

67.2% Slow drains
58.7% Sewage backup in house
43.8% Bad smells
66.0% Toilet backs up
46.8% Wet spots in lawn
29.4% Pumping tank monthly or more

7.7% Straight pipe to ditch
8.9% Frozen septic
7.7% Don’t know
5.5% Other:________________________________

- “Alert system”
- “All”
- “Any of the above. We have no problem!”
- “Color of grass over fingers”
- “Don’t have problems”
- “Have not had a problem”
- “I have it checked and maintained every other year”
- “If it don’t work”
- “Inspections every 3-5 years + pumping tank”
- “Never had a problem”
- “No problem”
- “None”

Appendix B-1

3. If you answered 'Yes" above, where does your rain water drain to?

		Frequency
Valid		50
	Most of are water goes to the Dehaven ditch then goes N to the Deer Creek	1
	A Branch of the Bachelor Run Ditch, eventually drains to Deer Creek & Wabash River	1
	A COUNTY DRAIN LINE AND IT EMPTIES INTO DEER CREEK	1
	an open ditch	1
	Bachelor River	1
	Bachelor Run	3
	BACHELOR RUN	1
	bachelor run creek	1
	Bachelor Run Ditch	1
	Bachelor Run then Big Deer Creek	1
	Bachelor Run to Deer Creek	1
	BACHLOR RUN C	1
	Back ditch that flows into Deer Creek	1
	Batchlor Run Creek	1
	Bear Creek, Pipe Creek & Wabash River	1
	BECHELOR RUN	1
	Bracher Run	1
	BRIDGE CREEK	1
	BRIDGE CREEK, DEER CREEK, ROBINSON RUN	1
	Brown's Ditch	1

Deer Creek-Sugar Creek Watershed

Buck Creek	1
Buck Creek Ditch then to the Wabash River	1
COUNTY DITCH	2
county drainage ditch	1
COUNTY DRAINS	1
creek	2
Creek	2
CREEK	4
CREEKS AND RIVERS	1
Creeks and streams	1
Deer	1
deer creek	1
Deer creek	1
Deer Creek	18
DEER CREEK	21
Deer Creek and Paint Creek	1
DEER CREEK WATERSHED	1
DEER CREEK-SUGAR CREEK WATERSHED	1
deer creek-wabash	1
Deer Creek-Wild Cat	1
Deer creek, big and little	1
derr creek	1
DIRECTLY TO WABASH RIVER VIA BRIDGE CREEK	1
ditch	4
DITCH	1

ditch just north of our property	1
DITCHES AND THEN ?	1
down hill or street sewer	1
DOWN IN THE GROUND	1
drainage ditch	1
Drainage ditch	1
Drainage ditch south 3/4 mile	1
DRAINAGE TILE	1
Drains in the ground and out in towel	1
drains into ditches then into rivers	1
FIELD	1
field tile	1
Field tile	1
FIELD TILE	1
field tile and open ditch	1
field tile to Deer Creek	1
Fields	1
FIELDS AND DITCH-THOMPSON DRAIN	1
Filter Strips to Open ditch	1
Finger System/Field	1
Gilbert Ditch	1
GROUND	1
Gulf of Mexico	1
Hyman ditch through drain tile	1
If not absorbed, it goes to tile ditches which drain into Deer Creek or Bachelor Run (depending on the direction)	1

IN AN OPEN DITCH	1
In little Deer Creek	1
in the bachelor run	1
IN THE SOIL OR IN THE DITCH	1
INTO A FIELD TILE AND INTO AN OPEN DITCH	1
into an open ditch	1
into deer creek	1
Into Deer Creek	1
INTO DEER CREEK	1
into deer creek then into the wabash	1
Into drainage tile, tile empties into open ditches, open ditches empties into creeks and streams, then to rivers, and into the gulf of Mexico	1
Into our local creeks , then to our rivers then to the Gulf of Mexico	1
Into the groud	1
IT DRAINS INTO CREEKS AND OPEN DITCHES	1
Johns Ditch	1
KOKOMO RESORVOIR	1
Little Deer Creek	1
LITTLE DEER CREEK	1
LITTLE DEER CREEK OR IN THE GROUND	1
McKay dredge and eventually the Wabash	1
McKay Dredge Ditch	1
MISSISNAWA RESIVOIR	1
Mississippi River	1
MOST OF IT DRAINS INTO THE MCKAY DITCH	1
Munson ditch-Deer Creek-Wabash	1

NEAR BY STREAM	1
NORTH TO MIAMI COUNTY, THEN WEST TO THE WABASH RIVER. INTO OUR CREEK THEN	1
Oceans	1
Open ditch	1
OPEN DITCH	1
OPEN DITCH THAT FEEDS INTO DEER CREEK	1
open ditch then to bachelor run to deer creek-etc	1
open ditches field tile then to small rivers	1
OPEN DITCHES, THEN CREEK, POINT CREEK OR DEER CREEK	1
Paint Creek	2
Paint Creek to Deer Creek	1
Paint Creek/Deer Creek	1
Pond on property and the WIldcat Creek	1
Ponds-creek	1
Really two places, down into the earth and to a drainage ditch on west side of property...	1
Rice Bell Drain	1
Ridenour Ditch & Deer Creek	1
Ridenour Ditch & to Little Deer Creek & then to Big Deer Creek	1
rivers	1
Rock Creek	1
ROCK CREEK	2
Si FK Deer Creek	1
SMALL CREEK ON FARM	1
Small ditches that end up in time in the Wildcat creek	1
small streams that eventually drains into Deer Creek	1

soil, field tile, creek.	1
SOME IN SUGAR CREEK, OTHER IN OTHER OPEN DITCHES	1
STORM SEWER	1
Sugar Creek	2
SUGAR CREEK	2
Sugar Creek + Wabash River	1
SUGAR CREEK AND OPEN DITCH THAT RUNS TO SUGAR CREEK	1
Sugar Creek and to the Wildcat Creek	1
SUGAR CREEK DEER CREEK	1
SUGAR CREEK THEN TO WABASH RIVER	1
suger creek	1
THE CREEK!	1
the Gulf of Mexico	1
THE OPEN DITCH THAT RUNS THROUGH THE FARM	1
the Wabash	1
the Wabash River	1
THE WATER DRAINS INTO A NEARBY DITCH	1
Tiles-open ditches-wildcat-wabash	1
tiles, creeks, rivers	1
Tippecanoe, Wabash, Deer Creek	1
TO BATCHELOR RUN THEN TO LITTLE DEER CREEK	1
to deer creek	1
TO DEER CREEK	1
to open ditch	1
TO THE CREEK	1

TO THE DEER CREEK WATERSHED BY OPEN DITCH AND SUBSTRATE TILE	1
to the ditch, Deer Creek, Wildcat, Wabash, Miss, Cal	1
to the river	1
turley ditch on state road 18	1
underground ditches	1
Wabash	1
WABASH	1
Wabash River	1
WABASH RIVER	2
walbash river	1
water runs toward the creek within one mile of property	1
WATERWAY	1
WE HAVE INVESTED IN WATERWAYS THRU SOIL CONSERVATION SERVICES	1
Wild Cat Creek	1
wildcat	1
Wildcat + Rockcreek	1
WILDCAT CREEK	2
WILDCAT CREEK, WABASH RIVER GULF OF MEXICO	1
Total	267

Appendix B-2

2. If the practice is not relevant, please explain why:

		Frequency
Valid		111
	no livestock	1
	4 acre pasture with 2 horses	1
	ANIMALS ARE ALL IN A BUILDING	1
	another person does my farming for me	1
	CAFO	1
	confined buildings around us	1
	DO NOT FEED CATTLE OR HOSS	1
	do not have a feedlot	1
	do not have a food operation	1
	Do not have any animals.	1
	do not have feed lot	1
	DO NOT HAVE FEED LOTS	1
	DO NOT HAVE FEEDLOT	1
	DO NOT HAVE FEEDLOTS	1
	Do not have feedlots, all water off of buildings flow thru filter strip	1
	DO NOT HAVE LIVESTOCK	1
	do not raise livestock	1
	DO NOT RAISE LIVESTOCK	1
	does not apply to my situation	1
	don't have	1
	don't have a feed lot	1

Don't have a feed lot	1
DON'T HAVE A FEEDLOT	1
Don't have a feelot	1
don't have any feedlots close	1
DON'T HAVE ANY LIVESTOCK OR FARMLAND	1
Don't have cattle or feedlot	1
DON'T HAVE FEED LOTS	1
Don't have feedlots	1
don't have livestock	1
DON'T HAVE LIVESTOCK STRUCTURES	1
don't have that much livestock	1
DON'T HAVE THAT MUCH LIVESTOCK	1
Don't know	1
Don't raise livestock	1
DON'T RAISE LIVESTOCK	1
dont have feed lot	1
FEED LOTS UNDER ROOF	1
half acre, homeowner	1
have ditch area, etc	1
have no cattle	1
HAVE NO FEED LOTS	1
have no feedlots	1
HAVE NO FEEDLOTS	1
have no livestock	1
HAVE NO LIVESTOCK	1

I do not have a feedlot	1
I DO NOT HAVE LIVESTOCK	1
I DON'T HAVE A FEEDLOT	1
I don't have any livestock	1
I don't own farmland in Carroll County	1
I have no animals on my ground except for wild animals	1
I HAVE NO LIVESTOCK	1
I live in a rural residential home, no livestock	1
JUST GRAIN FARM NOT LIVESTOCK	1
maybe	1
MY WATER DOESN'T GO IN A STREAM	1
no animals	3
No animals	1
No Animals	1
NO ANIMALS	2
NO CATTLE, NO FEEDLOT!!	1
no feed lot	1
NO FEED LOT	2
NO FEED LOT OR ANIMALS	1
NO FEED LOT, NO ANIMALS	1
no feed lots	2
No feed lots	1
No Feed lots	1
NO FEED LOTS	3
no feedlot	3

No Feedlot	2
NO Feedlot	1
NO FEEDLOT	5
no feedlot on property	1
No feedlot present	1
no feedlots	3
No feedlots	1
No Feedlots	2
NO FEEDLOTS	5
no feedlots have or running of [illegible]	1
NO FEEDLOTS ON PROPERTY	1
NO FEEDLOTS OR LIVESTOCK	1
No feedlots.	1
no livestock	9
No livestock	3
No Livestock	2
NO LIVESTOCK	12
No livestock - no feelots	1
No livestock and tillable acreage is fallow	1
NO LIVESTOCK ON LAND	1
NO LIVESTOCK ON PROPERTY	1
NO LIVESTOCK ON PROPERTY; NOT RELEVANT	1
NO LIVESTOCK OR LIVESTOCK FACILITIES	1
No livestock outside	1
No open feedlot on my property	1

	no outside feed lots	1
	NO STEILSE	1
	not a farmer	1
	NOT FEEDING ANYTHING IN A FEDLOT	1
	OUR CATTLE DO NOT HAVE ACCESS TO A STREAM	1
	PROPERTY 1 ACRE LOT	1
	property planted CRP program	1
	RAISE CORN AND SOYBEANS ONLY	1
	Surface water does not flow through feedlot	1
	THERE ARE NO ANIMALS ON PROPERTY	1
	THERE ARE NO FEEDLOTS IN THIS AREA	1
	WE DO NOT HAVE FEEDLOTS	1
	we don't have any cattle and we don't have a feed lot	1
	WE DON'T HAVE LIVESTOCK	1
	WE HAVE FLAT SOIL	1
	we have no feed lot	1
	WE HAVE NO FEEDLOTS	1
	Total	267

Appendix B-3

2. If the practice is not relevant, please explain why:

		Frequency
		228
	0-2% SCOPES	1
	0-2% SLOPE/	1
	1 ACRE LOT	1
	All tillable acreage is fallow/CRP	1
	already using minimum tillage	1
	another person does my farming for me	1
	CRP program field planted w/ cold weather grasses	1
	Don't know	1
	DON'T NEED	1
Valid	Don't own farmland in Carroll County	1
	dont farm with cover crop	1
	flat ground	1
	FLAT LAND	1
	half acre homeowner	1
	I DO NOT FARM	1
	I DO NOT FARM MY GROUND	1
	I do not farm our land but the tenant does rotate and does nice job of workong the land and plants winter wheat	1
	I do not farm.	1
	I DON'T HAVE ANY EROSION PROBLEMS	1
	I live in a rural residential home, Only have a garden	1

I LIVE IN TOWN	1
I rent out fhe farm ground	1
I rent out the farm land. He uses rotation.	1
JUST NOT USING IT RIGHT NOW	1
NO ALL TILLAGE	1
NO COVER CROPS	1
No crop land	1
NO EROSION	1
NO EROSION!!	1
No Farm land, 3 acre of CRP	1
no flat land	1
no till	1
not farming	1
NOT NEEDED	1
NOT RB0PANG	1
rotation	1
tenant does not practise it	1
time and cost	1
USED WHERE NEEDED	1
Total	267

Appendix B-4

2. If the practice is not relevant, please explain why:

		Frequency
Valid		228
	?	1
	all field tile	1
	CATTLE DO NOT HAVE ACCESS TO A STREAM	1
	CRP Program	1
	DO NOT NEED	1
	DON'T HAVE	1
	don't have any open ditching	1
	DON'T KNOW	1
	Don't own farmland in Carroll County	1
	FLAT GROUND	1
	half acre homeowner	1
	HAS FLAT SOIL	1
	I do not farm the land but we have very few ditches	1
	I GUESS OUR COUNTY ELECTED NOT TO USE IT WHEN CLEANING OUR DITCH THIS SUMMER	1
	I have no ditches	1
	I live in a rural residential home, not farming	1
	IN SIRTURUT	1
	Just have the main ditch running through the property.	1
	LIVE IN TOWN	1
	NEVER TRIED IT	1

	no ditch	1
	no ditching	1
	NO OPEN DITCH	1
	NO OPEN DITCHES	1
	no small main channel	1
	NO SMALL MAIN CHANNEL	1
	no stream	1
	NO STREAMS AROUND PROPERTY	1
	No two stage ditch	1
	takes more space	1
	that is a county practice. they maintain regulated drains	1
	The land is not that steep	1
	The Land is not that steep	1
	THERE IS NO DITCH ON THIS PROPERTY	1
	THIS WAS VOTED AGAINST, IF I REMEMBER	1
	Too small operation	1
	water drains through woods and CRP ground	1
	we don't have an open ditch on our property	1
	we have no open ditches going thru any ground we farms	1
	Total	267

Appendix B-5

2. If the practice is not relevant, please explain why:

		Frequency
		240
	95% OF MY DITCH BANK SLOPE TOWARD THE FIELD	1
	am not located near any of the above	1
	DO NOT FARM NEAR MAJOR STREAMS-CREEKS	1
	DON'T KNOW ABOUT IT	1
	Don't own farmland in Carroll County	1
	FLAT GROUND	1
	half acre homeowner	1
	have woods for buffers	1
	i do not farm the land we do have a wet land that we do not farm	1
Valid	I live in a rural residential home, I don't have property on a water body in this watershed	1
	LIVE IN TOWN	1
	no ditch or streams run by farms we farms	1
	NO PONDS	1
	no ponds on property	1
	no ponds R.S.C.	1
	No ponds, streams, etc.	1
	no water	1
	none of above	1
	Not a farmer	1
	not close to any	1

	not farming	1
	NOT NEEDED	1
	security in case of accident	1
	SEE ABOVE	1
	water runs in tiles	1
	we don't have any ponds and streams on our property	1
	WE HAVE FLAT GROUND	1
	Total	267

Appendix C: Endangered, Threatened, and Rare Species List

Indiana County Endangered, Threatened and Rare Species List

County: Carroll

Species Name	Common Name	FED	STATE	GRANK	SRANK
Mollusk: Bivalvia (Mussels)					
Cyprogenia stegaria	Eastern Fanshell Pearlymussel	LE	SE	G1Q	S1
Epioblasma torulosa rangiana	Northern Riffleshell	LE	SE	G2T2	SX
Epioblasma torulosa torulosa	Tubercled Blossom	LE	SE	G2TX	SX
Epioblasma triquetra	Snuffbox		SE	G3	S1
Fusconaia subrotunda	Longsolid		SE	G3	SX
Lampsilis fasciola	Wavyrayed Lampmussel		SSC	G5	S3
Obovaria subrotunda	Round Hickorynut		SSC	G4	S1
Plethobasus cyphyus	Sheepnose	C	SE	G3	S1
Pleurobema clava	Clubshell	LE	SE	G2	S1
Pleurobema cordatum	Ohio Pigtoe		SSC	G4	S2
Pleurobema plenum	Rough Pigtoe	LE	SE	G1	S1
Pleurobema rubrum	Pyramid Pigtoe		SE	G2G3	SX
Potamilus capax	Fat Pocketbook	LE	SE	G1G2	S1
Ptychobranchus fasciolaris	Kidneyshell		SSC	G4G5	S2
Quadrula cylindrica cylindrica	Rabbitsfoot	C	SE	G3G4T3	S1
Toxolasma lividus	Purple Lilliput		SSC	G3	S2
Villosa fabalis	Rayed Bean	C	SSC	G2	S1
Insect: Coleoptera (Beetles)					
Dryobius sexnotatus	Six-banded Longhorn Beetle		ST	GNR	SNR
Insect: Odonata (Dragonflies & Damselflies)					
Enallagma divagans	Turquoise Bluet		SR	G5	S3
Ophiogomphus rupinsulensis	Rusty Snaketail		SR	G5	S2S3
Fish					
Etheostoma maculatum	Spotted Darter		SSC	G2	S2S3
Etheostoma tippecanoe	Tippecanoe Darter		SSC	G3G4	S3
Percina copelandi	Channel Darter		SE	G4	S2
Percina evides	Gilt Darter		SE	G4	S1
Reptile					
Clemmys guttata	Spotted Turtle		SE	G5	S2
Clonophis kirtlandii	Kirtland's Snake		SE	G2	S2
Sistrurus catenatus catenatus	Eastern Massasauga	C	SE	G3G4T3T4Q	S2
Bird					
Haliaeetus leucocephalus	Bald Eagle	LT,PDL	SE	G5	S2
Mammal					
Lutra canadensis	Northern River Otter		SSC	G5	S2
Lynx rufus	Bobcat	No Status	SSC	G5	S1
Mustela nivalis	Least Weasel		SSC	G5	S2?
Taxidea taxus	American Badger		SSC	G5	S2

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Indiana County Endangered, Threatened and Rare Species List

County: Carroll

Species Name	Common Name	FED	STATE	GRANK	SRANK
Vascular Plant					
Aster furcatus	Forked Aster		SR	G3	S2
Berberis canadensis	American Barberry		SE	G3	S1
Carex eburnea	Ebony Sedge		SR	G5	S2
Cypripedium calceolus var. parviflorum	Small Yellow Lady's-slipper		SR	G5	S2
Erysimum capitatum	Prairie-rocket Wallflower		ST	G5	S2
Napaea dioica	Glade Mallow		SR	G4	S2
Oryzopsis racemosa	Black-fruit Mountain-ricegrass		SR	G5	S2
Panax trifolius	Dwarf Ginseng		WL	G5	S2
Rudbeckia fulgida var. fulgida	Orange Coneflower		WL	G5T4?	S2
Satureja glabella var. angustifolia	Calamint		SE	G5	S1
Spiranthes lucida	Shining Ladies'-tresses		SR	G5	S2
Viburnum molle	Softleaf Arrow-wood		SR	G5	S2
High Quality Natural Community					
Wetland - fen	Fen		SG	G3	S3
Wetland - seep circumneutral	Circumneutral Seep		SG	GU	S1
Other					
Geomorphic - Nonglacial Erosional Feature - Water Fall and Cascade	Water Fall and Cascade			GNR	SNR

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Indiana County Endangered, Threatened and Rare Species List

County: Cass

Species Name	Common Name	FED	STATE	GRANK	SRANK
Mollusk: Bivalvia (Mussels)					
Cyprogenia stegaria	Eastern Fanshell Pearlymussel	LE	SE	G1Q	S1
Epioblasma torulosa rangiana	Northern Riffleshell	LE	SE	G2T2	SX
Epioblasma triquetra	Snuffbox		SE	G3	S1
Lampsilis fasciola	Wavyrayed Lampmussel		SSC	G5	S3
Obovaria subrotunda	Round Hickorynut		SSC	G4	S1
Plethobasus cyphyus	Sheepnose	C	SE	G3	S1
Pleurobema clava	Clubshell	LE	SE	G2	S1
Pleurobema cordatum	Ohio Pigtoe		SSC	G4	S2
Ptychobranchus fasciolaris	Kidneyshell		SSC	G4G5	S2
Quadrula cylindrica cylindrica	Rabbitsfoot	C	SE	G3G4T3	S1
Toxolasma lividus	Purple Lilliput		SSC	G3	S2
Villosa fabalis	Rayed Bean	C	SSC	G2	S1
Villosa lienosa	Little Spectaclecase		SSC	G5	S3
Fish					
Etheostoma tippecanoe	Tippecanoe Darter		SSC	G3G4	S3
Moxostoma valenciennesi	Greater Redhorse		SE	G4	S2
Percina evides	Gilt Darter		SE	G4	S1
Amphibian					
Hemidactylium scutatum	Four-toed Salamander		SE	G5	S2
Reptile					
Clemmys guttata	Spotted Turtle		SE	G5	S2
Sistrurus catenatus catenatus	Eastern Massasauga	C	SE	G3G4T3T4Q	S2
Bird					
Haliaeetus leucocephalus	Bald Eagle	LT,PDL	SE	G5	S2
Tyto alba	Barn Owl		SE	G5	S2
Mammal					
Lutra canadensis	Northern River Otter		SSC	G5	S2
Lynx rufus	Bobcat	No Status	SSC	G5	S1
Taxidea taxus	American Badger		SSC	G5	S2
Vascular Plant					
Arenaria stricta	Michaux's Stitchwort		SR	G5	S2
Armoracia aquatica	Lake Cress		SE	G4?	S1
Aster furcatus	Forked Aster		SR	G3	S2
Carex sparganioides var. cephaloidea	Thinleaf Sedge		SE	G5	S2
Carex straminea	Straw Sedge		ST	G5	S2
Coeloglossum viride var. virescens	Long-bract Green Orchis		ST	G5T5	S2
Cypripedium calceolus var. parviflorum	Small Yellow Lady's-slipper		SR	G5	S2
Deschampsia cespitosa	Tufted Hairgrass		SR	G5	S2

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Indiana County Endangered, Threatened and Rare Species List

County: Cass

Species Name	Common Name	FED	STATE	GRANK	SRANK
Eriophorum angustifolium	Narrow-leaved Cotton-grass		SR	G5	S2
Erysimum capitatum	Prairie-rocket Wallflower		ST	G5	S2
Festuca paradoxa	Cluster Fescue		ST	G5	S1
Juglans cinerea	Butternut		WL	G4	S3
Lemna minima	Least Duckweed		SE	GNR	S1
Matteuccia struthiopteris	Ostrich Fern		SR	G5	S2
Melanthium virginicum	Virginia Bunchflower		SE	G5	S1
Milium effusum	Tall Millet-grass		SR	G5	S2
Myriophyllum verticillatum	Whorled Water-milfoil		SR	G5	S2
Napaea dioica	Glade Mallow		SR	G4	S2
Oryzopsis racemosa	Black-fruit Mountain-ricegrass		SR	G5	S2
Panicum boreale	Northern Witchgrass		SR	G5	S2
Passiflora incarnata	Purple Passion-flower		SR	G5	S2
Rhynchospora macrostachya	Tall Beaked-rush		SR	G4	S2
Sanguisorba canadensis	Canada Burnet		SE	G5	S1
Satureja glabella var. angustifolia	Calamint		SE	G5	S1
Schizachne purpurascens	Purple Oat		SE	G5	S1
Scirpus purshianus	Weakstalk Bulrush		SR	G4G5	S1
Scutellaria parvula var. parvula	Small Skullcap		SX	G4T4	SX
Stenanthium gramineum	Eastern Featherbells		ST	G4G5	S1
Tofieldia glutinosa	False Asphodel		SR	G4G5	S2
Utricularia purpurea	Purple Bladderwort		SR	G5	S2
Valeriana edulis	Hairy Valerian		SE	G5	S1
Zigadenus elegans var. glaucus	White Camas		SR	G5T4T5	S2
High Quality Natural Community					
Forest - floodplain mesic	Mesic Floodplain Forest		SG	G3?	S1
Primary - cliff limestone	Limestone Cliff		SG	GU	S1
Other					
Geomorphic - Nonglacial Erosional Feature - Water Fall and Cascade	Water Fall and Cascade			GNR	SNR

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Indiana County Endangered, Threatened and Rare Species List

County: Howard

Species Name	Common Name	FED	STATE	GRANK	SRANK
Mollusk: Bivalvia (Mussels)					
Epioblasma torulosa rangiana	Northern Riffleshell	LE	SE	G2T2	SX
Lampsilis fasciola	Wavyrayed Lampmussel		SSC	G5	S3
Pleurobema clava	Clubshell	LE	SE	G2	S1
Ptychobranchus fasciolaris	Kidneyshell		SSC	G4G5	S2
Toxolasma lividus	Purple Lilliput		SSC	G3	S2
Reptile					
Thamnophis butleri	Butler's Garter Snake		SE	G4	S1
Bird					
Falco peregrinus	Peregrine Falcon	No Status	SE	G4	S2B
Mammal					
Lynx rufus	Bobcat	No Status	SSC	G5	S1
Myotis sodalis	Indiana Bat or Social Myotis	LE	SE	G2	S1
Taxidea taxus	American Badger		SSC	G5	S2
Vascular Plant					
Crataegus pedicellata	Scarlet Hawthorn		ST	G5	S2
Crataegus prona	Illinois Hawthorn		SE	G4G5	S1
Crataegus succulenta	Fleshy Hawthorn		SR	G5	S2
Glyceria grandis	American Manna-grass		SX	G5	SH
Linum sulcatum	Grooved Yellow Flax		SR	G5	S2
High Quality Natural Community					
Forest - flatwoods central till plain	Central Till Plain Flatwoods		SG	G3	S2

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Indiana County Endangered, Threatened and Rare Species List

County: Miami

Species Name	Common Name	FED	STATE	GRANK	SRANK
Mollusk: Bivalvia (Mussels)					
Epioblasma triquetra	Snuffbox		SE	G3	S1
Lampsilis fasciola	Wavyrayed Lampmussel		SSC	G5	S3
Obovaria subrotunda	Round Hickorynut		SSC	G4	S1
Plethobasus cyphyus	Sheepnose	C	SE	G3	S1
Pleurobema clava	Clubshell	LE	SE	G2	S1
Ptychobranchus fasciolaris	Kidneyshell		SSC	G4G5	S2
Quadrula cylindrica cylindrica	Rabbitsfoot	C	SE	G3G4T3	S1
Toxolasma lividus	Purple Lilliput		SSC	G3	S2
Venustaconcha ellipsiformis	Ellipse		SSC	G4	S2
Villosa fabalis	Rayed Bean	C	SSC	G2	S1
Fish					
Moxostoma valenciennesi	Greater Redhorse		SE	G4	S2
Reptile					
Emydoidea blandingii	Blanding's Turtle		SE	G4	S2
Thamnophis proximus proximus	Western Ribbon Snake		SSC	G5T5	S3
Bird					
Circus cyaneus	Northern Harrier		SE	G5	S2
Haliaeetus leucocephalus	Bald Eagle	LT,PDL	SE	G5	S2
Mammal					
Lynx rufus	Bobcat	No Status	SSC	G5	S1
Taxidea taxus	American Badger		SSC	G5	S2
Vascular Plant					
Crataegus succulenta	Fleshy Hawthorn		SR	G5	S2
Hypericum pyramidatum	Great St. John's-wort		ST	G4	S1
Napaea dioica	Glade Mallow		SR	G4	S2
High Quality Natural Community					
Forest - upland dry-mesic	Dry-mesic Upland Forest		SG	G4	S4
Forest - upland mesic	Mesic Upland Forest		SG	G3?	S3
Other					
Geomorphic - Nonglacial Erosional Feature - Water Fall and Cascade	Water Fall and Cascade			GNR	SNR

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Indiana County Endangered, Threatened and Rare Species List

County: Tippecanoe

Species Name	Common Name	FED	STATE	GRANK	SRANK
Mollusk: Bivalvia (Mussels)					
Cyprogenia stegaria	Eastern Fanshell Pearlymussel	LE	SE	G1Q	S1
Epioblasma torulosa rangiana	Northern Riffleshell	LE	SE	G2T2	SX
Epioblasma torulosa torulosa	Tubercled Blossom	LE	SE	G2TX	SX
Epioblasma triquetra	Snuffbox		SE	G3	S1
Fusconaia subrotunda	Longsolid		SE	G3	SX
Lampsilis fasciola	Wavyrayed Lampmussel		SSC	G5	S3
Obovaria subrotunda	Round Hickorynut		SSC	G4	S1
Plethobasus cicatricosus	White Wartyback	LE	SE	G1	SX
Plethobasus cyphyus	Sheepnose	C	SE	G3	S1
Pleurobema clava	Clubshell	LE	SE	G2	S1
Pleurobema cordatum	Ohio Pigtoe		SSC	G4	S2
Pleurobema plenum	Rough Pigtoe	LE	SE	G1	S1
Pleurobema rubrum	Pyramid Pigtoe		SE	G2G3	SX
Potamilus capax	Fat Pocketbook	LE	SE	G1G2	S1
Ptychobranchus fasciolaris	Kidneyshell		SSC	G4G5	S2
Quadrula cylindrica cylindrica	Rabbitsfoot	C	SE	G3G4T3	S1
Simpsonaias ambigua	Salamander Mussel		SSC	G3	S2
Toxolasma lividus	Purple Lilliput		SSC	G3	S2
Villosa fabalis	Rayed Bean	C	SSC	G2	S1
Insect: Coleoptera (Beetles)					
Lissobiops serpentinus	A Rove Beetle		SE	GNR	S1
Insect: Ephemeroptera (Mayflies)					
Paracloeodes minutus	A Small Minnow Mayfly		SR	G5	S2
Insect: Lepidoptera (Butterflies & Moths)					
Speyeria idalia	Regal Fritillary		SE	G3	S1
Insect: Mecoptera					
Merope tuber	Earwig Scorpionfly		SE	G3G5	S1
Insect: Odonata (Dragonflies & Damselflies)					
Erpetogomphus designatus	Eastern Ringtail		ST	G5	S2
Somatochlora tenebrosa	Clamp-tipped Emerald		SR	G5	S2S3
Fish					
Etheostoma tippecanoe	Tippecanoe Darter		SSC	G3G4	S3
Amphibian					
Hemidactylium scutatum	Four-toed Salamander		SE	G5	S2
Reptile					
Clemmys guttata	Spotted Turtle		SE	G5	S2
Emydoidea blandingii	Blanding's Turtle		SE	G4	S2
Bird					

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Indiana County Endangered, Threatened and Rare Species List

County: Tippecanoe

Species Name	Common Name	FED	STATE	GRANK	SRANK
Ammodramus henslowii	Henslow's Sparrow		SE	G4	S3B
Asio flammeus	Short-eared Owl		SE	G5	S2
Bartramia longicauda	Upland Sandpiper		SE	G5	S3B
Botaurus lentiginosus	American Bittern		SE	G4	S2B
Buteo platypterus	Broad-winged Hawk	No Status	SSC	G5	S3B
Cistothorus platensis	Sedge Wren		SE	G5	S3B
Dendroica cerulea	Cerulean Warbler		SE	G4	S3B
Falco peregrinus	Peregrine Falcon	No Status	SE	G4	S2B
Grus canadensis	Sandhill Crane	No Status	SSC	G5	S2B,S1N
Haliaeetus leucocephalus	Bald Eagle	LT,PDL	SE	G5	S2
Ixobrychus exilis	Least Bittern		SE	G5	S3B
Lanius ludovicianus	Loggerhead Shrike	No Status	SE	G4	S3B
Nycticorax nycticorax	Black-crowned Night-heron		SE	G5	S1B
Rallus elegans	King Rail		SE	G4	S1B
Sturnella neglecta	Western Meadowlark		SSC	G5	S2B
Mammal					
Corynorhinus rafinesquii	Rafinesque's Big-eared Bat		SSC	G3G4	SH
Geomys bursarius	Plains Pocket Gopher		SSC	G5	S2
Lasiurus borealis	Eastern Red Bat		SSC	G5	S4
Lynx rufus	Bobcat	No Status	SSC	G5	S1
Mustela nivalis	Least Weasel		SSC	G5	S2?
Myotis septentrionalis	Northern Myotis		SSC	G4	S3
Myotis sodalis	Indiana Bat or Social Myotis	LE	SE	G2	S1
Nycticeius humeralis	Evening Bat		SE	G5	S1
Spermophilus franklinii	Franklin's Ground Squirrel		SE	G5	S2
Taxidea taxus	American Badger		SSC	G5	S2
Vascular Plant					
Androsace occidentalis	Western Rockjasmine		ST	G5	S2
Arenaria patula	Pitcher's Stitchwort		SE	G4	S1
Aster oblongifolius	Aromatic Aster		SR	G5	S2
Astragalus tennesseensis	Tennessee Milk-vetch		SRE	G3	SX
Bacopa rotundifolia	Roundleaf Water-hyssop		ST	G5	S1
Besseya bullii	Kitten Tails		SE	G3	S1
Botrychium matricariifolium	Chamomile Grape-fern		SR	G5	S2
Botrychium simplex	Least Grape-fern		SE	G5	S1
Camassia angusta	Wild Hyacinth		SE	G5?Q	S1
Carex flava	Yellow Sedge		ST	G5	S2
Carex gravida	Heavy Sedge		SE	G5	S1
Chelone obliqua var. speciosa	Rose Turtlehead		WL	G4T3	S3
Chrysopsis villosa	Hairy Golden-aster		ST	G5	S2

Fed: LE = Endangered; LT = Threatened; C = candidate; PDL = proposed for delisting

State: SE = state endangered; ST = state threatened; SR = state rare; SSC = state species of special concern; SX = state extirpated; SG = state significant; WL = watch list

GRANK: Global Heritage Rank: G1 = critically imperiled globally; G2 = imperiled globally; G3 = rare or uncommon globally; G4 = widespread and abundant globally but with long term concerns; G5 = widespread and abundant globally; G? = unranked; GX = extinct; Q = uncertain rank; T = taxonomic subunit rank

SRANK: State Heritage Rank: S1 = critically imperiled in state; S2 = imperiled in state; S3 = rare or uncommon in state; G4 = widespread and abundant in state but with long term concern; SG = state significant; SH = historical in state; SX = state extirpated; B = breeding status; S? = unranked; SNR = unranked; SNA = nonbreeding status unranked

Indiana County Endangered, Threatened and Rare Species List

County: Tippecanoe

Species Name	Common Name	FED	STATE	GRANK	SRANK
Circaea alpina	Small Enchanter's Nightshade		SX	G5	SX
Cirsium hillii	Hill's Thistle		SE	G3	S1
Coeloglossum viride var. virescens	Long-bract Green Orchis		ST	G5T5	S2
Crataegus pedicellata	Scarlet Hawthorn		ST	G5	S2
Cypripedium candidum	Small White Lady's-slipper		WL	G4	S2
Eriophorum angustifolium	Narrow-leaved Cotton-grass		SR	G5	S2
Erysimum capitatum	Prairie-rocket Wallflower		ST	G5	S2
Euphorbia obtusata	Bluntleaf Spurge		SE	G5	S1
Gentiana alba	Yellow Gentian		SR	G4	S2
Houstonia nigricans	Narrowleaf Summer Bluets		SR	G5	S2
Linum sulcatum	Grooved Yellow Flax		SR	G5	S2
Lithospermum incisum	Narrow-leaved Puccoon		SE	G5	S1
Melampyrum lineare	American Cow-wheat		SR	G5	S2
Muhlenbergia cuspidata	Plains Muhlenbergia		SE	G4	S1
Napaea dioica	Glade Mallow		SR	G4	S2
Onosmodium hispidissimum	Shaggy False-gromwell		SE	G4	S1
Orobanche riparia	Bottomland Broomrape		SE	G5	S2
Oryzopsis racemosa	Black-fruit Mountain-ricegrass		SR	G5	S2
Panicum rigidulum var. pubescens	Long-leaved Panic-grass		SX	G5T5?	SX
Plantago cordata	Heart-leaved Plantain		SE	G4	S1
Poa paludigena	Bog Bluegrass		WL	G3	S3
Psoralea tenuiflora	Few-flowered Scurf-pea		SX	G5	SX
Sanguisorba canadensis	Canada Burnet		SE	G5	S1
Selaginella apoda	Meadow Spike-moss		WL	G5	S1
Silene regia	Royal Catchfly		ST	G3	S2
Trichostema dichotomum	Forked Bluecurl		SR	G5	S2
Viola pedatifida	Prairie Violet		ST	G5	S2
High Quality Natural Community					
Barrens - gravel	Gravel Slope Barrens		SG	G3	S1
Barrens - sand	Sand Barrens		SG	G3	S2
Forest - upland dry-mesic	Dry-mesic Upland Forest		SG	G4	S4
Forest - upland mesic	Mesic Upland Forest		SG	G3?	S3
Lake - lake	Lake		SG	GNR	S2
Prairie - dry-mesic	Dry-mesic Prairie		SG	G3	S2
Wetland - fen	Fen		SG	G3	S3
Wetland - marsh	Marsh		SG	GU	S4
Wetland - seep circumneutral	Circumneutral Seep		SG	GU	S1
Other					
Geomorphic - Nonglacial Erosional Feature - Water Fall and Cascade	Water Fall and Cascade			GNR	SNR

Indiana Natural Heritage Data Center
Division of Nature Preserves
Indiana Department of Natural Resources
This data is not the result of comprehensive county surveys.

Fed: LE = Endangered; LT = Threatened; C = candidate; PDL = proposed for delisting

State: SE = state endangered; ST = state threatened; SR = state rare; SSC = state species of special concern; SX = state extirpated; SG = state significant; WL = watch list

GRANK: Global Heritage Rank: G1 = critically imperiled globally; G2 = imperiled globally; G3 = rare or uncommon globally; G4 = widespread and abundant globally but with long term concerns; G5 = widespread and abundant globally; G? = unranked; GX = extinct; Q = uncertain rank; T = taxonomic subunit rank

SRANK: State Heritage Rank: S1 = critically imperiled in state; S2 = imperiled in state; S3 = rare or uncommon in state; G4 = widespread and abundant in state but with long term concern; SG = state significant; SH = historical in state; SX = state extirpated; B = breeding status; S? = unranked; SNR = unranked; SNA = nonbreeding status unranked

Appendix D: Land Cover Definitions

2006 Land Cover Definitions

- Open Water - All areas of open water, generally with less than 25% cover of vegetation or soil.
- Developed, Open Space - Areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
- Developed, Low Intensity - Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover. These areas most commonly include single-family housing units.
- Developed, Medium Intensity - Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.
- Developed, High Intensity - Highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.
- Barren Land (Rock/Sand/Clay) - Areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
- Deciduous Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.
- Evergreen Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.
- Mixed Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.
- Shrub/Scrub - Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.
- Grassland/Herbaceous - Areas dominated by gramanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.
- Pasture/Hay - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.
- Cultivated Crops - Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled
- Woody Wetlands - Areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
- Emergent Herbaceous Wetlands - Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Appendix E: Water Quality Sampling Data

Water Chemistry

Site Name: BC #1 - Buck Creek at Stair Road
Site Number: 1

Exceedance Key

target	N/A	N/A	>4	6-9	9.89	N/A	235	15	1	0.08	0.3
number of samples	17	17	17	17	17	25	26	26	23	26	26
samples in exceedance (bolded)	N/A	N/A	0	0	10	N/A	15	6	21	15	7

Sonde Data

Date/Time (EST)	Temp C	SpC mS/cm	DO mG/L	pH	Turbidity NTU	Guage Based Flow cfs	E. coli cfu/100 mL	TSS mg/L	NO3+NO2 mg-N/L	TP mg-N/L2	TP mg-N/L22
8/28/12 11:10	19.13	0.595	8.06	8.45	8.9	1.5	**2149.6**	6.8	0.0419	0.0599	0.0599
9/11/12 13:59	17.29	0.709	9.37	7.7	7.6	0.0	**517.2**	1.5	**2.8555**	0.035	0.035
9/25/12 12:30	12.96	0.704	9.43	7.54	0		**410.6**	0.9	**3.2706**	0.0227	0.0227
10/11/12 14:04	11.23	0.711	9.7	7.71	0.5	0.0	172.3	1	**3.3038**	**0.089**	0.089
10/23/12 11:34	14.83	0.445	7.62	7.91	9.4	4.1	**727**	**35.7**	**1.5893**	**0.2489**	0.2489
11/6/12 13:51						0.4	47.1	5.6	**2.8386**	0.0434	0.0434
11/19/12 13:48						0.2	27.9	1.1		**0.5074**	**0.5074**
12/4/12 12:45						0.2	**461.1**	0.7	**2.7549**	**0.1483**	0.1483
12/18/2012 1:18	6.58	0.718	10.85	9.13	6.7	0.1	82	0.3	**3.0639**	0.0427	0.0427
1/3/2013 11:14						0.5	17.3	**32.4**		**0.6871**	**0.6871**
1/15/2013 11:16						23.2	**1299.7**	8.1		**0.4314**	**0.4314**
1/31/2013 11:34	2.33	0.614	11.89	8.2	66.9	43.3	**579.4**	**36.6**	**21.5838**	**1.0443**	**1.0443**
2/12/2013 13:53	4.3	0.727	10.5	8.33	**23.8**	12.9	42	4	**16.9725**	0.0626	0.0626
2/27/2013 11:16	2.23	0.558	12.77	8.34	**117**	63.9	**1046.2**	**74**	**26.187**	**0.128**	0.128
3/12/2013 10:15	3.93	0.687	10.13	8.59	55.5	25.8	114.5	9.6	**22.089**	**0.107**	0.107
3/26/13 10:37						4.2	42	4.7	**10.714**	0.009	0.009
4/9/2013 13:02	19.29	0.673	10.73	9.59	**16.8**	4.8	63.1	3	**10.225**	0.018	0.018
4/24/2013 10:36	7.46	0.355	8.91	6.74	**361**	133.4	**3255.4**	**226**	**12.0610**	**0.31**	**0.31**
5/7/2013 13:18	17.98	0.629	6.73	7.28	13.1	9.3	161.6	2.8	**11.661**	0.005	0.005
5/22/2013 14:02	18.74	0.663	4.39	7	12.5	6.2	193.5	3.6	**5.1680**	0.0530	0.0530
6/4/2013 11:28						22.7	**461.1**	5.3	**22.7010**	**0.1000**	0.1000
6/18/2013 11:18	19.59	0.711	8.09	7.34	**70.4**	7.2	**1986.3**	3.5	**15.4680**	**0.9130**	**0.9130**
7/2/2013 12:52	17.38	0.693	8.88	7.55	**19.4**	14.4	**866.4**	2.7	**8.172**	**0.0960**	0.0960
7/17/2013 12:33	21.69	0.693	8.23	7.49	6.4	1.8	**344.8**	8.1	0.082	0.042	0.042
7/30/2013 12:28						0.4	**866.4**	2.8	**4.125**	**0.365**	**0.365**
8/13/2013 11:11						0.2	**1986.3**	**59.5**	**3.03**	**0.254**	0.254

Site Name: SC #2 Sugar Creek at SR 25/Stair Road
Site Number: 2

Exceedance Key

target	N/A	N/A	>4	6-9	9.89	N/A	235	15	1	0.08	0.3
number of samples	18	18	18	18	18	25	26	26	23	26	26
samples in exceedance (bolded)	N/A	N/A	0	2	9	N/A	14	8	21	9	4

Sonde Data

Date/Time (EST)	Temp C	SpC mS/cm	DO mG/L	pH	Turbidity NTU	Guage Based Flow cfs	E. coli cfu/100 mL	TSS mg/L	NO3+NO2 mg-N/L	TP mg-N/L	TP mg-N/L2
8/28/12 11:20	20.43	0.514	8.01	8.31	**22**	3.9	**435.2**	5	0.0277	0.0258	0.0258
9/11/12 13:28	18.27	0.645	8.89	7.8	7.2	0.2	**325.5**	1.8	**1.4757**	0.0233	0.0233
9/25/12 12:16	13.28	0.555	9.2	7.61	0		**298.7**	1.2	**1.8577**	0.0143	0.0143
10/11/12 13:40	11.48	0.662	10.03	7.82	0.4	0.0	45.7	0.9	**2.061**	0.074	0.074
10/23/12 11:22	14.49	0.625	7.82	7.99	8.3	10.4	**547.5**	**27.3**	0.8524	**0.0815**	0.0815
11/6/12 13:29						1.1	67	0.4	**1.726**	**0.0872**	0.0872
11/19/12 13:29	7.97	0.687	12.9	8.62	4.1	0.5	13.1	1		**0.1479**	0.1479
12/4/12 12:24						0.6	62.4	1.6	**1.6129**	**0.0822**	0.0822
12/18/2012 13:01	6.58	0.698	11.14	**9.2**	2.8	0.1	84.2	0.6	**1.9244**	**0.8304**	**0.8304**
1/3/2013 11:05						1.3	25.6	1.1		0.0478	0.0478
1/15/2013 11:05						59.2	**344.8**	**23.4**		**0.4025**	**0.4025**
1/31/2013 11:24	2.45	0.476	11.12	8.11	**154**	109.2	**461.1**	**59.5**	**16.0346**	**0.3428**	**0.3428**
2/12/2013 13:25	4.46	0.698	10.13	8.29	**31.1**	32.9	38.8	**28**	**14.41**	0.0599	0.0599
2/27/2013 11:10	3.24	0.452	13.73	8.14	**147**	163.2	**435.2**	**96**	**18.933**	**0.585**	**0.585**
3/12/2013 10:10	4.4	0.614	10.65	8.5	**58.5**	65.8	**344.8**	11.5	**16.555**	0.062	0.062
3/26/2013 10:29						10.8	24.3	1.3	**7.091**	0.007	0.007
4/9/2013 13:36	21.74	0.647	9.39	**9.56**	**26.1**	12.2	37.9	3.3	**6.527**	0.029	0.029
4/24/2013 10:28	7.3	0.252	9.45	6.74	**711**	340.9	**1299.7**	**364**	**6.881**	**0.284**	0.284
5/7/2013 12:55	17.97	0.609	6.96	7.34	**13.9**	23.7	129.6	14.2	**7.532**	0.056	0.056
5/22/2013 13:36	20.54	0.649	4.38	7.02	6.2	15.8	133.4	6.1	**3.8070**	0.0240	0.0240
6/4/13 10:18						56.6	**461.1**	11.3	**16.7710**	0.0540	0.0540
6/18/2013 11:06	20.89	0.648	7.41	7.28	**51.4**	18.4	**575.4**	**22.5**	**12.5820**	0.0590	0.0590
7/2/2013 12:30	18.06	0.692	8.09	7.63	2.9	36.9	**387.3**	6.1	**6.344**	0.0180	0.0180
7/17/2013 12:09	24.59	0.682	8.07	7.65	8.3	4.6	**579.4**	3.3	**3.236**	0.053	0.053
7/30/2013 12:06						0.9	228.2	1.7	**2.304**	0.031	0.031
8/13/2013 10:59						0.7	**1413.6**	**21.6**	**1.512**	0.043	0.043

Site Name: DCD #3 - Deer Creek - downstream at Trail Head Park
Site Number: 3

Exceedance Key

target	N/A	N/A	>4	6-9	9.89	N/A	235	15	1	0.08	0.3
number of samples	18	18	18	18	18	26	26	26	24	26	26
samples in exceedance (bolded)	N/A	N/A	0	2	12	N/A	11	9	20	12	2

Sonde Data

Date/Time (EST)	Temp C	SpC mS/cm	DO mG/L	pH	Turbidity NTU	Discharge cfs	E. coli cfu/100 mL	TSS mg/L	NO3+NO2 mg-N/L	TP mg-N/L	TP mg-N/L2
8/28/12 10:33	22.34	0.621	7.82	8.16	3.4	46	62.7	6.4	**1.101**	0.0309	0.0309
9/11/12 12:49	19.73	0.615	8.68	7.84	**11.1**	71	**387.3**	10.4	0.8651	0.0471	0.0471
9/25/12 11:52	13.61	0.658	9.27	7.73	0	26	51.2	2.1	**1.1328**	0.0384	0.0384
10/11/12 13:18	10.18	0.702	12.21	8.14	0	38	21.6	0.8	**1.0383**	0.0717	0.0717
10/23/12 10:56	14.28	0.661	7.44	8.09	**217**	115	**456.9**	**139.2**	0.6835	**0.1188**	0.1188
11/6/12 13:02						79	13.2	1.7	0.987	0.0293	0.0293
11/19/12 12:58	5.87	0.688	13.7	8.71	2.5	69	9.6	1.8		**0.3243**	**0.3243**
12/4/12 11:52						64	12.1	1.4	0.8806	**0.1518**	0.1518
12/18/2012 12:30	5.16	0.744	11.52	**9.28**	2.9	50	14.6	1.1	**1.2075**	**0.1289**	0.1289
1/3/2013 10:50						136	13.4	1.7		**0.3082**	**0.3082**
1/15/2013 10:47						1140	**517.2**	**102.5**	**8.7697**	**0.2772**	0.2772
1/31/2013 11:04	3.3	0.512	10.04	8.07	**200**	1460	**1299.7**	**134.1**	**11.1161**	**0.2748**	0.2748
2/12/2013 12:54	3.22	0.697	11.71	8.38	**24.7**	328	37.3	7	**8.8325**	0.045	0.045
2/27/2013 10:48	2.64	0.583	12.2	8.39	**111**	927	**648.8**	**80**	**10.835**	**0.266**	0.266
3/12/2013 9:41	4.47	0.39	10.94	8.47	**89.4**	776	209.8	**45.7**	**12.321**	**0.117**	0.117
3/26/2013 10:09						157	14.8	2	**5.456**	0.065	0.065
4/9/2013 12:05	16.65	0.648	8.75	**9.85**	**29.5**	195	77.6	8.4	**4.749**	0.035	0.035
4/24/2013 9:59	8.43	0.357	8.68	6.77	**534**	3170	**1986.3**	**329**	**6.18**	**0.151**	0.151
5/7/2013 12:16	17.03	0.631	7.27	7.14	**16.2**	268	73.3	4.3	**5.886**	0.044	0.044
5/22/2013 12:50	21.99	0.634	4.21	7.06	**23.9**	157	63.1	13.2	**5.7380**	0.0120	0.0120
6/4/2013 9:46						536	**365.4**	**30.8**	**12.6210**	**0.0910**	0.0910
6/18/2013 10:10	20.83	0.573	7.79	7.06	**70.6**	479	**325.5**	**35**	**8.2810**	**0.1730**	0.1730
7/2/2013 11:29	19.13	0.617	7.66	7.51	**27.5**	205	**547.5**	**19.3**	**5.597**	0.0790	0.0790
7/17/2013 11:37	25.97	0.669	7.71	7.52	7.7	100	**235.9**	9.3	**3.901**	0.062	0.062
7/30/2013 11:30						45	93.4	3.1	**1.845**	0.045	0.045
8/13/2013 10:24						60	**365.4**	7.3	**1.564**	0.08	0.08

Site Name: BR #4 - Bachelor Run at 350N
Site Number: 4

Exceedance Key

target	N/A	N/A	>4	6-9	9.89	N/A	235	15	1	0.08	0.3
number of samples	18	18	18	18	18	26	26	26	24	25	25
samples in exceedance (bolded)	N/A	N/A	18	2	11	N/A	9	7	22	10	5

Sonde Data

Date/Time (EST)	Temp C	SpC mS/cm	DO mG/L	pH	Turbidity NTU	Guage Based Flow cfs	E. coli cfu/100 mL	TSS mg/L	NO3+NO2 mg-N/L	TP mg-N/L	TP mg-N/L2
3/26/2013 9:50						19.9	157.6	7.3	**6.772**	0	0
4/9/2013 11:35	17.85	0.735	**10**	**9.19**	**37.4**	23.4	69.1	5.3	**6.167**	0.021	0.021
9/25/12 11:00	14.04	0.816	**9.92**	7.67	1.5	3.1	18.3	1.1	**1.3757**	0.0253	0.0253
9/11/12 12:01	22.11	0.76	**9.71**	7.87	4.1	8.5	18.5	4.1	0.4858	0.0295	0.0295
5/7/2013 11:37	17.29	0.686	**6.85**	7.09	**38.7**	33.9	128.3	12.2	**6.417**	0.032	0.032
8/28/12 10:03	21.92	0.708	**9.7**	8.26	4	5.5	19.9	7.3	**1.0945**	0.0406	0.0406
1/3/2013 10:30						16.3	80.9	1.5		0.0425	0.0425
10/11/12 12:35	12.49	0.782	**12.49**	8.06	3.1	4.6	6.3	**59.3**	**1.0821**	0.0463	0.0463
7/2/2013 10:53	18.02	0.786	**8.93**	7.49	**9.9**	25.1	**325.5**	4.1	**5.48**	0.0470	0.0470
7/30/2013 10:55						6.7	95.9	1.9	**1.93**	0.049	0.049
11/6/12 12:32						9.5	14.5	1.3	**1.2083**	0.0506	0.0506
2/12/2013 12:17	3.96	0.691	**11.02**	8.36	**23**	37.0	60.2	4.8	**11.2843**	0.052	0.052
7/17/2013 11:07	26.57	0.749	**9.4**	7.41	**13**	14.2	156.5	3.1	0.087	0.054	0.054
8/13/2013 10:03						7.2	218.7	4.7	**1.783**	0.058	0.058
5/22/2013 12:17	20.67	0.761	**4.46**	6.99	**12.8**	20.7	104.3	6.6	**4.0930**	0.0650	0.0650
10/23/12 10:21	15.32	0.631	**7.68**	7.88	1.4	13.5	**248.1**	5.8	**1.0255**	**0.094**	0.094
6/4/2013 9:27						64.4	**410.6**	**17.4**	**14.7890**	**0.0960**	0.0960
12/4/12 11:25						7.7	43.2	1.7	**1.3113**	**0.1572**	0.1572
6/18/2013 9:49	19.99	0.671	**7.98**	6.99	**64.7**	57.6	**410.6**	**23.5**	**10.2290**	**0.2040**	0.2040
1/15/2013 10:31						138.2	**387.3**	**36.5**	**14.8697**	**0.2105**	0.2105
4/24/2013 9:38	7.78	0.368	**8.78**	6.54	**526**	379.9	**2187.2**	**276**	**6.566**	**0.307**	**0.307**
1/31/2013 10:46	2.75	0.571	**10.44**	8	**150**	176.7	**1413.6**	**75.5**	**15.8638**	**0.3674**	**0.3674**
11/19/12 12:27	7.52	0.82	**13.19**	8.5	3.5	8.3	5.2	1.4		**0.4223**	**0.4223**
12/18/2012 12:03	6.26	0.86	**10.84**	**9.39**	3.9	5.8	8.5	1.6	**1.7114**	**0.505**	**0.505**
3/12/2013 9:26	3.97	0.683	**11.19**	8.5	**60.9**	93.3	**435.2**	13.4	**15.054**	**0.589**	**0.589**
2/27/2013 10:32	3.4	0.118	**11.2**	8.18	**109**	108.4	**1046.2**	**56.7**	**15.997**		

Site Name: PC #5 - Paint Creek at 450 N
Site Number: 5

Exceedance Key

target	N/A	N/A	>4	6-9	9.89	N/A	235	15	1	0.08	0.3
number of samples	18	18	18	18	18	26	25	25	23	25	25
samples in exceedance (bolded)	N/A	N/A	1	1	12	N/A	19	4	15	11	5

Sonde Data

Date/Time (EST)	Temp C	SpC mS/cm	DO mG/L	pH	Turbidity NTU	Guage Based Flow cfs	E. coli cfu/100 mL	TSS mg/L	NO3+NO2 mg-N/L	TP mg-N/L	TP mg-N/L2
2/27/2013 10:16	3.52	0.624	11.56	7.75	**67.1**	41.1	**325.5**	**30.2**	**15.968**	0.008	0.008
5/7/2013 11:06	15.01	0.698	6.87	6.64	**52.2**	13.0	56.5	2.3	**11.017**	0.011	0.011
3/26/2013 9:32						7.3	25.3	1.3	**8.071**	0.018	0.018
9/25/2012 10:28	12.18	0.692	7.02	7.33	6.8	1.2	**290.9**	3.9	0.8653	0.0195	0.0195
4/9/2013 11:03	15.14	0.672	9	8.84	**25.2**	9.0	**238.2**	4.8	**8.545**	0.02	0.02
7/30/2013 10:26						2.6	**1203.3**	0.5	**1.992**	0.026	0.026
7/2/2013 10:23	17.4	0.711	8.08	7.04	5.4	9.7	**866.4**	2	**11.329**	0.0280	0.0280
9/11/2012 11:15	17.25	0.681	6.04	7.34	**14.1**	3.3	**387.3**	3.2	0.2492	0.0297	0.0297
8/28/2012 9:44	20.4	0.556	**3.74**	7.69	**20.5**	2.1	**290.9**	**504**	0.0386	0.034	0.034
11/6/2012 12:03						3.7	**2149.6**	1.5	0.6164	0.0356	0.0356
5/22/2013 11:44	11.07	0.7	4.18	6.78	**10.9**	8.0	**387.3**	3.8	**6.1760**	0.0410	0.0410
6/4/2013 9:09						25.0	**344.1**	3	**17.9010**	0.0490	0.0490
6/18/2013 9:28	18.38	0.693	7.17	6.55	**39.4**	22.3	**770.1**	4.4	**17.0680**	0.0530	0.0530
7/17/2013 10:39	21.91	0.718	7.88	7.02	4.5	5.5	**980.4**	3.5	**8.129**	**0.086**	0.086
10/11/2012 12:01	8.92	0.697	7.91	7.52	**29**	1.8	**261.3**	2	1.0185	**0.1086**	0.1086
10/23/2012 9:47	14.66	0.668	4.58	7.56	3.6	5.2	**313**	6	1.0648	**0.1123**	0.1123
4/24/2013 9:18	7.01	0.313	8.23	6.2	**252**	144.2	**1119.9**	**96**	**10.1880**	**0.179**	0.179
12/4/2012 10:56						3.0	125.9	3.9	0.2525	**0.185**	0.185
3/12/2013 9:10	3.55	0.67	9.44	8.05	**49.1**	35.9	204.6	5.7	**14.13**	**0.195**	0.195
12/18/2012 11:39	5.18	0.739	9.18	**9.01**	5.9	2.2	**1046.2**	2	0.779	**0.3691**	**0.3691**
1/15/2013 10:17						53.6	**240.0**	8.3		**0.5716**	**0.5716**
2/12/2013 11:57	3.07	0.695	10.79	8.13	**17.8**	14.2	**275.5**	2.1	**12.048**	**0.7507**	**0.7507**
11/19/2012 11:55	5.66	0.732	10.43	8.12	7.8	3.2	79.8	1.8		**1.1769**	**1.1769**
1/31/2013 10:30	2.38	0.569	9.72	7.66	**50.1**	68.4	185.0	**17.2**	**15.4215**	**1.6923**	**1.6923**
1/3/2013 10:18						6.2					
8/13/2013 9:46						2.8	**1299.7**	2.7	**1.35**		0.18

Site Name: LDU #6 - Little Deer Creek - upstream at SR 29
Site Number: 6

Exceedance Key

	Temp	SpC	DO	pH	Turbidity	Flow	E. coli	TSS	NO3+NO2	TP	TP
target	N/A	N/A	>4	6-9	9.89	N/A	235	15	1	0.08	0.3
number of samples	18	17	17	17	17		23	22	21	22	22
samples in exceedance (bolded)	N/A	N/A	0	1	11	N/A	14	5	13	11	3

Sonde Data

Date/Time (EST)	Temp C	SpC mS/cm	DO mG/L	pH	Turbidity NTU	Guage Based Flow cfs	E. coli cfu/100 mL	TSS mg/L	NO3+NO2 mg-N/L	TP mg-N/L	TP mg-N/L2
5/7/2013 9:45	15.26	0.634	6.19	6.81	**71.5**	34.0	**290.9**	6.3	**7.532**	0.022	0.022
2/12/2013 10:47	1.9	0.729	10.6	8.34	**20.7**	37.6	167.4	3.3	**9.8291**	0.0409	0.0409
5/22/2013 11:06	20.36	0.637	4.27	6.74	**12.9**	20.7	**290.9**	4.5	**5.3820**	0.0410	0.0410
7/30/13 9:21						6.7	**365.4**	2.1	**1.696**	0.045	0.045
7/17/2013 9:25	24.71	0.615	6.38	7.21	2.3	14.2	**816.4**	3.6	0.097	0.051	0.051
8/28/2012 8:57	20.64	0.516	5.44	7.73	9.6	5.5	**648.8**	10	0.0581	0.0541	0.0541
9/11/2012 9:32	17.49	0.611	6.35	7.5	**17.4**	8.6	**410.6**	11.2	0.3583	0.0569	0.0569
11/6/2012 10:41						9.5	59.1	2.2	0.8561	0.0584	0.0584
6/4/2013 8:39						65.2	**365.4**	9.3	**14.2950**	0.0630	0.0630
4/9/2013 9:41	13.42	0.636	6.99	8.61	**30.7**	23.5	**727**	5.3	**6.016**	0.067	0.067
8/13/2013 9:13						7.0	**547.5**	4.4	**1.641**	0.074	0.074
2/27/2013 9:46	2.89	0.589	11.94	8.14	**101**	103.5	**613.1**	**68.3**	**13.645**	**0.097**	0.097
9/25/2012 9:20	12.52	0.625	7.79	7.65	**13.5**	3.0	178.2	9.6	0.5431	**0.0974**	0.0974
3/12/2013 8:36	3.77	0.633	9.84	8.35	**49.4**	94.5	98.8	10.2	**13.983**	**0.115**	0.115
6/18/2013 8:50	19.42	0.541	6.94	6.78	**57.6**	58.2	**488.4**	**24.5**	**9.4990**	**0.1420**	0.1420
10/11/2012 10:28	8.97	0.687	6.44	7.46	4.9	4.6	85.7	3.3	0.886	**0.1671**	0.1671
1/15/2013 9:44						142.1	151.5	**31.3**	**11.9633**	**0.207**	0.207
10/23/2012 9:12	13.95	0.657	6.9	7.77	3	13.2	**280.9**	5.7	0.4018	**0.2266**	0.2266
4/24/2013 8:44	7.42	0.324	8.89	6.54	**309**	368.6	**1732.9**	**159**	**6.8340**	**0.228**	0.228
12/4/2012 10:10	11.1					7.7	142.1	7.1	0.4927	**0.3494**	**0.3494**
11/19/2012 10:36	5.25	0.723	9.48	8.16	5.7	8.3	54.8	3.6		**0.354**	**0.354**
1/31/2013 9:46	2.79	0.584	11.59	8.1	**54.7**	180.7	**307.6**	**26.5**	**13.5842**	**1.4174**	**1.4174**
12/18/2012 10:29	4.16	0.733	8.57	**9.04**	4.4	5.8	70.6				
1/3/2013 9:54						15.8					
3/26/2013 9:00											
7/2/2013 9:20						25.5					

Site Name: LDD #7 - Little Deer Creek - downstream at 300 N
Site Number: 7

Exceedance Key

target	N/A	N/A	>4	6-9	9.89	N/A	235	15	1	0.08	0.3
number of samples	18	18	18	18	18	26	24	24	23	24	24
samples in exceedance (bolded)	N/A	N/A	0	1	12	N/A	13	10	16	11	2

Sonde Data

Date/Time (EST)	Temp C	SpC mS/cm	DO mG/L	pH	Turbidity NTU	Guage Based Flow cfs	E. coli cfu/100 mL	TSS mg/L	NO3+NO2 mg-N/L	TP mg-N/L	TP mg-N/L2
3/26/2013 9:23						27.8	14.5	5.3	**6.017**	0.002	0.002
5/7/2013 10:39	17.59	0.611	5.8	6.89	**61.8**	50.0	148.3	5.5	**6.711**	0.015	0.015
4/9/2013 10:36	16.6	0.639	7.94	8.88	**35.1**	34.5	**248.1**	7.9	**5.724**	0.019	0.019
5/22/2013 11:15	20.87	0.632	4.1	7.05	**11.4**	30.5	231.0	5	**4.8500**	0.0210	0.0210
7/2/2013 9:53	18.73	0.612	7.44	7.34	**10.8**	37.0	**648.8**	7.5	**7.636**	0.0450	0.0450
7/17/2013 10:32	24.32	0.649	6.71	7.23	4.5	20.9	**686.7**	6.4	**3.235**	0.047	0.047
8/28/2012 9:30	20.51	0.539	6.62	7.89	3.5	8.1	157.8	7.7	0.0522	0.0475	0.0475
2/12/2013 11:26	2.96	0.717	10.41	8.24	**22.2**	55.3	66.3	5.7	**8.9914**	0.052	0.052
7/30/2013 11:05						9.9	**365.4**	1.8	**1.585**	0.055	0.055
11/6/2012 11:39						14.0	135.4	**32**	0.5137	0.0586	0.0586
9/25/2012 10:20	13.47	0.666	8.77	7.67	2.3	4.4	**365.4**	2.9	0.3811	0.0704	0.0704
6/4/2013 9:01						95.8	**387.3**	**18.5**	**13.8430**	0.0740	0.0740
8/13/2013 9:37						10.6	**920.8**	6.3	**1.371**	0.075	0.075
9/11/2012 10:45	17.92	0.694	8.71	7.83	**10.9**	12.6	**517.2**	7.1	0.2627	**0.0827**	0.0827
3/12/2013 9:01	3.89	0.623	10.27	8.4	**64.8**	138.5	145.0	**16.9**	**13.5335**	**0.087**	0.087
10/23/2012 9:35	14.27	0.731	6.59	7.83	4.2	19.8	**360.9**	14.8	0.8028	**0.1157**	0.1157
10/11/2012 11:32	10.2	0.737	9.62	7.87	2.2	6.7	214.3	1.5	0.7352	**0.1274**	0.1274
6/18/2013 9:22	20.35	0.53	6.92	6.72	**79.4**	85.6	**410.6**	**34.3**	**9.1040**	**0.1320**	0.1320
2/27/2013 10:08	2.45	0.551	10.74	8.18	**142**	154.5	**435.2**	**111**	**8.69**	**0.18**	0.18
1/15/2013 10:08						207.3	214.3	**58**	**11.2502**	**0.1994**	0.1994
1/31/2013 10:19	2.93	0.548	10.22	7.97	**104**	264.0	**648.8**	**62**	**12.7755**	**0.2214**	0.2214
4/24/2013 9:08	8.07	0.304	8.65	6.61	**413**	552.7	**1986.3**	**238**	**5.0940**	**0.228**	0.228
11/19/2012 11:31	6.43	0.724	12.38	8.5	**24.3**	12.2	107.1	**442**		**0.4204**	**0.4204**
12/18/2012 11:17	5.46	0.764	9.71	**9.1**	5.2	8.5	161.6	**52.3**	0.7532	**1.4561**	**1.4561**
12/4/2012 10:45						11.3					
1/3/2013 10:12						23.7					

Site Name: MD #8 McCloskey Ditch
Site Number: 8

Exceedance Key

target	N/A	N/A	>4	6-9	9.89	N/A	235	15	1	0.08	0.3
number of samples	18	18	18	18	18	26	25	25	24	25	25
samples in exceedance (bolded)	N/A	N/A	1	0	9	N/A	16	4	18	11	2

Sonde Data

Date/Time (EST)	Temp C	SpC mS/cm	DO mG/L	pH	Turbidity NTU	Guage Based Flow cfs	E. coli cfu/100 mL	TSS mg/L	NO3+NO2 mg-N/L	TP mg-N/L	TP mg-N/L2
3/26/2013 9:13						8.4	48.0	1.6	**5.539**	0	0
5/22/2013 10:48	20.13	0.682	**3.68**	6.62	**11.5**	9.2	**461.1**	3.3	**4.0060**	0.0050	0.0050
5/7/2013 10:17	15.46	0.673	6.4	6.66	**62.8**	15.0	206.4	4.7	**6.277**	0.011	0.011
4/9/2013 10:10	16.68	0.669	7.73	8.61	**49**	10.4	**290.9**	8.3	**5.248**	0.018	0.018
9/25/2012 9:50	12.98	0.77	7.63	7.32	4.1	1.3	**290.9**	6.4	0.3683	0.0331	0.0331
7/30/2013 9:51						3.0	**435.2**	2.6	**1.685**	0.035	0.035
6/4/2013 8:50						28.8	**2419.6**	8.5	**12.4110**	0.0440	0.0440
9/11/2012 10:10	18.57	0.796	6.93	7.35	7.7	3.8	114.5	3.9	**1.9206**	0.0452	0.0452
2/27/2013 9:55	2.57	0.564	11.14	8.1	**140**	46.5	**1203.3**	**76**	**11.269**	0.046	0.046
8/28/2012 9:16	19.96	0.612	6.31	7.81	0	2.5	228.2	2.9	0.0459	0.0508	0.0508
7/2/2013 9:55	17.71	0.661	7.14	7.11	6.8	11.1	**727.0**	5.6	**4.989**	0.0530	0.0530
6/18/13 9:07	18.82	0.675	6.99	6.88	**42.5**	25.7	**1203.3**	12.2	**9.3250**	0.0630	0.0630
7/17/2013 10:02	23.01	0.7	6.86	7.12	4.8	6.3	**1046.2**	5.1	**2.89**	0.068	0.068
2/12/2013 11:03	3.4	0.733	10.04	8.07	**21.1**	16.6	**547.5**	3.9	**9.9278**	0.0735	0.0735
8/13/2013 9:26						3.2	**410.6**	4.4	**1.253**	**0.094**	0.094
11/6/2012 11:14						4.2	47.9	1.7	**1.4455**	**0.0941**	0.0941
10/23/2012 9:27	13.93	0.799	8.68	7.8	0	6.0	**579.4**	3.4	1.0855	**0.1162**	0.1162
1/15/2013 9:56						62.4	**980.4**	**20**	**10.8065**	**0.1283**	0.1283
10/11/2012 11:03	9.57	0.851	8.6	7.52	3.3	2.0	75.4	1.6	0.5969	**0.1345**	0.1345
4/24/2013 8:57	7.18	0.256	8.91	6.48	**427**	164.7	**1413.6**	**260**	**5.5520**	**0.209**	0.209
1/31/2013 10:00	2.67	0.568	10.46	7.83	**79.5**	79.9	**579.4**	**40.8**	**12.5231**	**0.2213**	0.2213
11/19/2012 11:07	6.9	0.78	12.42	8.33	4.8	3.7	38.4	2.6		**0.2342**	0.2342
3/12/2013 8:48	3.73	0.65	9.5	8.18	**56.1**	41.7	**410.6**	9.6	**12.812**	**0.288**	0.288
12/18/2012 10:56	5.46	0.789	9.94	9	5.3	2.6	37.9	1.3	0.5258	**0.3685**	**0.3685**
12/4/2012 10:30						3.4	48	1.4	0.2392	**0.7698**	**0.7698**
1/3/2013 10:04						7.0					

Site Name: SFD #9 - South Fork Deer Creek - downstream at 1125 S
Site Number 9

Exceedance Key

target	N/A	N/A	>4	6-9	9.89	N/A	235	15	1	0.08	0.3
number of samples	19	19	19	19	19	26	25	25	24	25	25
samples in exceedance (bolded)	N/A	N/A	1	1	13	N/A	17	9	20	16	2

Sonde Data

Date/Time (EST)	Temp C	SpC mS/cm	DO mG/L	pH	Turbidity NTU	Guage Based Flow cfs	E. coli cfu/100 mL	TSS mg/L	NO3+NO2 mg-N/L	TP mg-N/L	TP mg-N/L2
3/12/2013 8:17	4.29	0.598	10.04	8.25	**76.1**	102.2	**613.1**	**15.2**	**10.522**	0.014	0.014
5/7/2013 9:04	15.98	0.675	5.59	6.6	**82.1**	36.6	75.4	**17**	**4.255**	0.016	0.016
3/26/2013 8:45						20.4	**517.2**	4	**5.521**	0.026	0.026
4/9/2013 9:06	13.51	0.667	6.86	8.64	**13.2**	24.9	146.7	4.9	**4.652**	0.037	0.037
6/4/2013 8:22						70.8	**261.3**	**24.5**	**9.4100**	0.0430	0.0430
2/12/2013 10:08	2.5	0.669	10.01	8.23	**29.1**	40.5	151.5	7.8	**8.2371**	0.0598	0.0598
9/11/2012 9:19	18.86	0.507	7.42	7.32	**12.5**	9.5	**387.3**	6.4	0.2378	0.0694	0.0694
6/18/2013 8:30	20.63	0.507	6.37	6.62	**87.4**	63.3	**365.4**	**44**	**5.9710**	0.0710	0.0710
7/2/2013 9:00	18.79	0.644	6.54	7.22	**23.4**	27.5	**387.3**	13.2	**3.414**	0.0800	0.0800
8/28/2012 8:35	21.03	0.505	6.03	**5.97**	**21**	6.0	**1046.2**	**16**	0.0341	**0.0995**	0.0995
7/30/2013 8:50						7.3	**275.5**	3.6	**1.185**	**0.124**	0.124
12/18/2012 9:53	5.17	0.78	8.11	8.95	6.3	6.2	125.9	3	**1.8076**	**0.1241**	0.1241
9/25/2012 8:48	12.14	0.705	6.66	7.21	**12**	3.2	**488.4**	2.3	**1.3162**	**0.1262**	0.1262
4/24/2013 8:27	8.9	0.314	7.71	6.5	**354**	394.3	**1732.9**	**151**	**3.7670**	**0.13**	0.13
8/13/2013 8:37						7.5	**816.4**	6	**1.09**	**0.149**	0.149
11/6/2012 10:05						10.2	66.3	14.7	**1.5664**	**0.1888**	0.1888
5/22/2013 9:30	19.91	0.621	**3.68**	6.58	**26.5**	22.3	**461.1**	13.7	**6.5760**	**0.1910**	0.1910
11/19/12 10:11	5.18	0.732	9.35	8.09	3.7	8.9	77.1	1.3		**0.1944**	0.1944
7/17/2013 9:55	24.67	0.683	5.98	7.03	6.6	15.3	**435.2**	5.3	**1.7**	**0.196**	0.196
1/31/2013 9:25	3.17	0.492	9.92	7.83	**119**	197.1	**866.4**	**56**	**9.5078**	**0.2334**	0.2334
10/11/2012 11:42	8.25	0.738	6.79	7.39	2	4.9	103.9	1.2	**1.6393**	**0.2409**	0.2409
1/15/2013 9:25						155.6	**648.8**	**63.5**	**7.3972**	**0.2542**	0.2542
10/23/2012 8:50	13.93	0.696	5.92	7.74	1.8	13.9	**416**	3.8	0.5942	**0.2924**	0.2924
2/27/2013 9:24	2.57	0.598	10.87	8.19	**137**	109.8	**1119.9**	**79**	**6.82**	**0.308**	**0.308**
12/4/2012 9:48	10.8	0.748	6.17	8.91	2.1	8.3	104.6	3.7	0.6687	**0.3124**	**0.3124**
1/3/2013 9:38						17.0					

Site Name: DCM #10 - Deer Creek - midstream at SR 35
Site Number: 10

Exceedance Key

target	N/A	N/A	>4	6-9	9.89	N/A	235	15	1	0.08	0.3
number of samples	19	19	19	19	19	26	25	25	23	25	25
samples in exceedance (bolded)	N/A	N/A	0	0	12	N/A	19	8	13	16	4

	Sonde Data										
Date/Time (EST)	Temp C	SpC mS/cm	DO mG/L	pH	Turbidity NTU	Guage Based Flow cfs	E. coli cfu/100 mL	TSS mg/L	NO3+NO2 mg-N/L	TP mg-N/L	TP mg-N/L2
8/28/12 8:22	19.3	0.582	5.46	7.65	9.8	8.7	**686.7**	11	0.045	0.0568	0.0568
9/11/12 8:39	16.15	0.315	6.38	7.27	**12.1**	13.8	**248.9**	8.8	0.0281	**0.1024**	0.1024
9/25/12 8:19	12.08	0.685	7.9	7.49	7.1	4.7	178.2	5.4	0.0928	0.0424	0.0424
10/11/12 9:07	8.2	0.719	6.51	7.4	4.4	7.2	70.8	4	0.3537	**0.1606**	0.1606
10/23/12 8:42	14.27	0.654	6.89	7.79	**29.2**	20.2	**1011.2**	**26.7**	0.3196	**0.2267**	0.2267
11/6/12 9:37						14.9	141.4	2.5	0.842	0.0708	0.0708
11/19/12 9:41	4.8	0.731	9.47	8.15	5.9	13.0	48.7	3.5		**0.6394**	**0.6394**
12/4/12 9:36	11.46	0.73	6	8.5	2.7	12.1	91	4.4	-0.0198	**0.166**	0.166
12/18/2012 9:26	5.01	0.754	8.09	8.99	6.3	9.1	93.3	2.1	0.4871	**1.0107**	**1.0107**
1/3/2013 9:28						24.1					
1/15/2013 9:16						230.1	**517.2**	**61**		**0.2424**	0.2424
1/31/2013 9:14	3.45	0.485	10.26	7.83	**111**	286.6	**1299.7**	**59**	**9.8961**	**0.1965**	0.1965
2/12/2013 9:56	3.01	0.641	10.71	8.12	**27.6**	58.8	**517.2**	6.9	**9.4822**	0.0711	0.0711
2/27/13 9:15	2.9	0.467	10.54	7.94	**209**	157.5	**2419.6**	**141**	**9.488**	**0.261**	0.261
3/12/2013 8:07	3.93	0.555	9.48	8.08	**80.6**	149.7	**365.4**	**17.3**	**11.018**	**0.353**	**0.353**
3/26/2013 8:35						30.2	**260.3**	2.1	**5.742**	**0.461**	**0.461**
4/9/2013 8:46	11.48	0.549	6.72	8.36	**186**	36.2	**1413.6**	**82**	**7.215**	**0.125**	0.125
4/24/2013 8:18	7.66	0.203	8.2	6.36	**718**	567.6	**2909.3**	**365**	**4.1320**	**0.257**	0.257
5/7/13 8:40	15.81	0.595	5.62	6.48	**78.5**	53.2	**325.5**	4.7	**6.388**	0.026	0.026
5/22/2013 9:18	18.6	0.625	4.02	6.64	**12.6**	33.0	**325.5**	5.6	**6.9410**	0.0550	0.0550
6/4/2013 8:14						103.0	**461.1**	14.8	**11.4570**	0.0620	0.0620
6/18/2013 8:26	18.94	0.568	7.02	6.53	**68.2**	92.0	**727.0**	**22.5**	**7.6910**	**0.1330**	0.1330
7/2/2013 8:48	17.58	0.626	7.29	7.24	**24.6**	40.0	**770.1**	13	**8.243**	**0.0830**	0.0830
7/17/2013 8:41	22.44	0.671	6.45	7.09	0.9	22.3	**387.3**	3.6	**2.981**	0.051	0.051
7/30/2013 8:41						10.6	**275.5**	2.6	0.795	0.052	0.052
8/13/13 8:27						10.9	**727**	5.7	0.777	**0.095**	0.095

Site Name: SFU #11 - South Fork Deer Creek - upstream at Touby Road
Site Number: 11

Exceedance Key

target	N/A	N/A	>4	6-9	9.89	N/A	235	15	1	0.08	0.3
number of samples	19	19	19	19	19	26	26	26	23	26	26
samples in exceedance (bolded)	N/A	N/A	2	0	9	N/A	14	5	16	18	3

Sonde Data

Date/Time (EST)	Temp C	SpC mS/cm	DO mG/L	pH	Turbidity NTU	Guage Based Flow cfs	E. coli cfu/100 mL	TSS mg/L	NO3+NO2 mg-N/L	TP mg-N/L	TP mg-N/L2
5/22/2013 7:51	18.12	0.604	**3.35**	6.72	**18**	8.0	**1203.3**	6	**7.8350**	0.0510	0.0510
6/4/2013 7:41						25.3	**344.8**	11.8	**10.5350**	0.0550	0.0550
9/25/2012 7:28	13.28	0.534	6.63	7.35	3	1.1	58.1	1.9	0.0844	0.0564	0.0564
3/26/2013 8:03						7.4	231	2.1	**6.467**	0.057	0.057
4/9/2013 7:43	11.88	0.622	6.13	8.31	**27.3**	8.6	166.4	3.3	**6.149**	0.06	0.06
8/28/2012 8:40	19.09	0.393	**3.93**	6.79	0	2.1	228.2	2.6	0.0504	0.0678	0.0678
2/12/2013 8:54	4.03	0.626	9.47	7.75	**33.8**	14.5	186	3.6	**8.7111**	0.0771	0.0771
11/6/2012 8:35						3.6	47.1	3.6	**2.9367**	0.0784	0.0784
9/11/2012 7:36	15.69	0.506	4.92	6.96	3.2	3.4	**272.3**	3	0.7655	**0.0834**	0.0834
7/2/2013 7:55	18.17	0.614	5.58	6.94	**11.2**	9.9	**613.1**	3	**3.809**	**0.0870**	0.0870
3/12/2013 7:32	3.79	0.038	8.88	7.7	6.4	36.8	**579.4**	7.8	**10.644**	**0.099**	0.099
7/17/2013 7:41	23.72	0.643	5.24	6.57	0.9	5.4	**488.4**	2.7	**1.481**	**0.101**	0.101
6/18/2013 7:46	20.05	0.425	5.54	6.04	**74**	22.4	**410.6**	**28.7**	**5.5680**	**0.1050**	0.1050
10/23/2012 7:57	14.48	0.678	6.22	7.79	4.2	4.7	**290.9**	6.2	**1.4728**	**0.1103**	0.1103
7/30/2013 7:48						2.6	**435.2**	5.3	0.174	**0.132**	0.132
12/18/2012 8:32	5.21	0.734	9.54	8.95	4.7	2.2	95.9	1.3	**2.1665**	**0.1548**	0.1548
8/13/2013 7:39						2.7	127.4	6.2	0.321	**0.173**	0.173
10/11/2012 7:54	6.71	0.568	6.83	7.38	7.6	1.7	**1986.3**	5.5	0.2348	**0.1948**	0.1948
5/7/2013 7:44	14.66	0.504	4.74	6	**106**	13.0	125.9	11.3	**5.47**	**0.208**	0.208
11/19/2012 8:40	4.77	0.719	11.06	8.14	3.9	3.2	62	2		**0.2123**	0.2123
4/24/2013 7:45	7.77	0.186	7.11	6.13	**502**	135.2	**5794.3**	**202**	**3.4650**	**0.248**	0.248
1/31/2013 8:38	4.63	0.356	9.75	7.62	**99.1**	70.8	**920.8**	**37**	**9.6995**	**0.2578**	0.2578
1/15/2013 8:45						57.0	**547.5**	**46.7**		**0.2607**	0.2607
1/3/2013 8:46						5.9	214.3	1.6		**0.3655**	**0.3655**
2/27/2013 8:41	3.14	0.435	**8.06**	7.45	**122**	37.1	**686.7**	**47.5**	**9.375**	**0.389**	**0.389**
12/4/2012 8:36	12.26	0.678	**7.32**	8.57	3.5	2.9	137.6	3.8	0.5191	**0.3947**	**0.3947**

Site Name: DCU #12 - Deer Creek - upstream at Elm St.
Site Number: 12

Exceedance Key

target	N/A	N/A	>4	6-9	9.89	N/A	235	15	1	0.08	0.3
number of samples	19	19	19	19	19		26	26	23	25	25
samples in exceedance (bolded)	N/A	N/A	1	0	13	N/A	22	11	13	13	4

Sonde Data

Date/Time (EST)	Temp C	SpC mS/cm	DO mG/L	pH	Turbidity NTU	Guage Based Flow cfs	E. coli cfu/100 mL	TSS mg/L	NO3+NO2 mg-N/L	TP mg-N/L	TP mg-N/L2
8/28/2012 8:01	18.87	0.699	5.08	6.99	**13.1**	5.5	**579.4**	**48.3**	0.0372	0.0532	0.0532
9/11/2012 8:09	15.86	0.622	5.59	7.12	**12.8**	8.7	**1553.1**	8.7	0.0927	0.0614	0.0614
9/25/2012 7:52	12.02	0.705	7.04	7.2	8	3.0	**1203.3**	3.7	0.1848	0.0354	0.0354
10/11/2012 8:31	6.86	0.723	6.61	7.32	5.3	4.3	**1046.2**	3.2			
10/23/2012 8:18	14.13	0.647	6.31	7.87	2.5	12.6	214.2	5.4	0.2245	**0.1634**	0.1634
11/6/2012 9:09						9.5	186	2.6	0.6881	**0.089**	0.089
11/19/12 9:11	4.23	0.719	9.71	8.12	**11.1**	8.3	**727**	2.4	0.0865	**0.6975**	**0.6975**
12/4/2012 9:04	11.99	0.729	5.64	8.42	6.1	7.7	**816.4**	5.2	-0.0485	**0.1229**	0.1229
12/18/2012 9:00	4.67	0.733	8.37	8.99	6.1	5.7	214.2	1.4	0.6435	**2.5953**	**2.5953**
1/3/2013 9:11						15.3	**387.3**	2.1		**0.1854**	0.1854
1/15/2013 9:00						146.1	**770.1**	**64**		**0.2399**	0.2399
1/31/2013 8:56	3.64	0.492	10.26	7.8	**101**	184.4	**2419.6**	**47.7**	**10.5161**	**0.7911**	**0.7911**
2/12/2013 9:24	2.46	0.652	10.05	8.08	**31.8**	37.8	**1732.9**	7.7	**10.2306**	**2.4033**	**2.4033**
2/27/2013 8:58	2.99	0.477	9.82	7.79	**202**	97.8	**1553.1**	**118**	**9.931**	**0.182**	0.182
3/12/2013 7:49	3.65	0.571	9.81	8.05	**82.3**	95.1	**461.1**	**17**	**11.522**	0.04	0.04
3/26/2013 8:19						19.2	167	3.4	**6.387**	**0.249**	0.249
4/9/2013 8:15	11.35	0.532	6.62	8.24	**149**	22.5	**1299.7**	**67**	**7.392**	**0.186**	0.186
4/24/2013 8:02	7.48	0.209	7.45	6.27	**642**	356.8	**3075.9**	**306**	**4.2120**	**0.233**	0.233
5/7/2013 8:11	14.52	0.581	5.59	6.47	**77.2**	33.8	**648.8**	5.5	**6.179**	0.016	0.016
5/22/2013 8:23	18.41	0.628	**3.61**	6.5	**12.9**	21.0	**517.2**	11	**6.7110**	0.0520	0.0520
6/4/2013 7:58						65.4	**579.4**	**18.2**	**11.6680**	0.0620	0.0620
6/18/2013 8:02	19.45	0.552	6.56	6.64	**66.5**	58.4	**1119.9**	**29.3**	**8.3000**	0.0770	0.0770
7/2/2013 8:28	17.63	0.643	6.96	7.15	**25.2**	25.4	**1299.7**	**16.6**	**7.972**	0.0690	0.0690
7/17/2013 8:09	22.53	0.682	6.09	6.96	8.3	14.1	**920.8**	9.3	**2.872**	0.06	0.06
7/30/2013 8:13						6.7	**980.4**	6.3	0.292	0.062	0.062
8/13/2013 8:07						6.9	**1413.6**	**87.7**	0.806	0.058	0.058

Fish

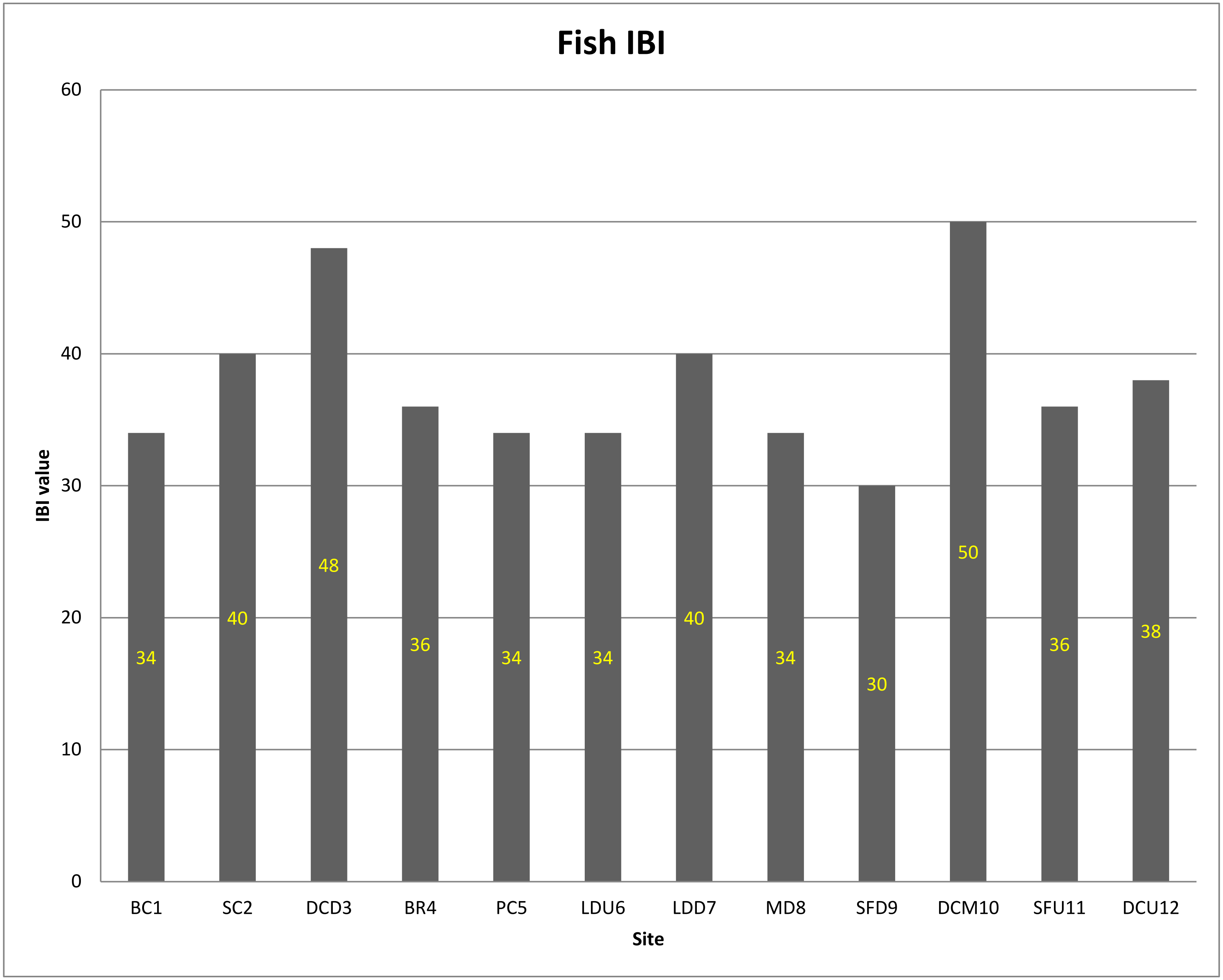
SITE	BC1	SC2	DCD3	BR4	PC5	LDU6	LDD7	MD8	SFD9	DCM10	SFU11	DCU12
Bigeye Chub		3	107	2			29			1	2	7
Black Bullhead												
Blacknose Dace	8	10			24	1	1					6
Blackside darter		1	5				5				2	1
Blackstriped Topminnow		1	3			1	2	5	14	13	16	
Bluegill	13	55	30	1	36	64	58	74	88	58	124	32
Bluntnose Minnow	16	94	28	38	14	3	80	191		42	128	14
Quillback									2			
Brook Stickleback												
Brown Bullhead												
Central Mud Minnow												
Central Stoneroller	73	22	5	37	92	10	44	115		7	156	3
Common Carp										1		4
Creek Chub	127	131		1	29	42	19	128		4	33	22
Creek Chubsucker					21			14				
Emerald Shiner								1				
Fantail Darter				9	1	9	1			2		1
Fathead Minnow												
mimic shiner										2		
Gizzard Shad												
Goldfish												
Golden Redhorse			8				2	3	7	31		
Grass Pickerel								2				
Green Sunfish	5		7		29		4	15	31	5	2	3
Greenside Darter			5	3	1	5	14	4		11	6	7
Horneyhead Chub		2	4	28		18	11	1		5	2	14
Johnny Darter						2	5	8	5	10	35	17
Largemouth Bass										1		
logperch												
Longear Sunfish	4	13	67	8	1		3	21	7	9	10	12
Mississippi Silvery Minnow		37	78	1			62	46		16		34
Mottled Sculpin	131	15		29	18							
Northern Hog Sucker		1	9	4		1	10	2		1		5
Orangespot sunfish			2				3		18		11	7
Orangethroat Darter	3				16	2	4	10			9	1
Pumpkinseed	1	1	1				4	19		22		
Rainbow Darter	5		7	36		4	5	12		5	7	2

SITE	BC1	SC2	DCD3	BR4	PC5	LDU6	LDD7	MD8	SFD9	DCM10	SFU11	DCU12
Redear Sunfish		2	5			1	5					
Redfin Shiner		2	1	1	33			6		7	2	
River Chub												
River Shiner		2	29									
Rock Bass			28	2		5	5	13	6	62		
Rosyface shiner		6	4	2		3	12			18	1	1
Sand Shiner		734	143	1			50	7		5	52	1
Silverjaw Minnow	1	21	2		11	2	11	1		2	36	
Smallmouth Bass	3	3	13	2			8	2		7		
steel color shiner											1	
Spotfin Shiner	42	76	3	15		5	5	1				1
Spotted Bass	1	1	4					5		5		1
Southern Redbellied Dace					16							
Spotted Sucker										1		
Stonecat Madtom		1	3	4		2						2
Striped Shiner	2	1	6		1	4	1	135		69	38	22
Suckermouth Minnow												
White Sucker	70	1			12		1	33	2	48	22	60
Yellow Bullhead	1				2		4		1		1	
Bluegill/Green Sunfish Hybrid												
Pumpkinseed/Green Sunfish Hybrid												
Bluegill/Pumpkinseed Hybrid									5			
Bluegill/Longear Sunfish Hybrid												
Longear/Green Hybrid												
white crappie									1			
Warmouth										1	3	10
Total Species	18	26	28	20	18	20	31	28	13	31	24	27
Number of individuals	506	1,236	607	224	357	184	468	874	187	471	699	290
time in seconds	3,460	2,016	2,433	2,082	2,771	2,413	3,387	4,281	3,845	4,309	2,031	2,815
Drainage area	11.18	28.56	298.77	35.91	13.81	35.43	52.93	15.92	38.75	56.34	13.74	35.77

SITE	BC1	SC2	DCD3	BR4	PC5	LDU6	LDD7	MD8	SFD9	DCM10	SFU11	DCU12
Total species	18	26	28	20	18	20	31	28	13	31	24	27
#of Darters Madtoms Sculpin	4	FALSE	FALSE	FALSE	5	FALSE	FALSE	5	FALSE	FALSE	6	FALSE
# of darters	2	1	3	3	3	5	6	4	1	4	5	6
% Headwater species	27	2	0	17	17	5	0	0	0	0	0	2
# of sunfish	4	4	7	3	3	3	7	5	6	6	5	5
# of minnows sp								12	1	11	9	10
# of suckers	1	2	2	1	2	1	3	4	3	4	1	2
# if sensitive species	3	8	12	11	2	7	11	9	3	12	7	9
% of tolerant species	45	19	6	17	31	25	23	42	18	21	27	38
% omnivores	17	11	17	17	7	2	31	31	1	23	21	39
%insectivorus	41	75	72	50	48	55	46	39	84	54	49	39
% Pioneer								55	19	15	57	21
% Carnivores	1	0	7	2	0	3	3	3	3	16	0	4
CPUE	146	613	249	108	129	76	138	204	49	109	344	103
% Simple Lithophilic	17	4	40	19	15	7	25	28	5	37	11	47
%DELTS	0											

SITE	BC1	SC2	DCD3	BR4	PC5	LDU6	LDD7	MD8	SFD9	DCM10	SFU11	DCU12
Ibi												
Total species scoring classification	5	5	5	3	5	3	5	5	1	5	5	5
#of Darters Madtoms Sculpin scoring classification	3	3	3	5	5	5	5	5	1	5	5	5
# of darters scoring classification	3	1	3	5	5	5	5	5	1	5	5	5
% Headwater species	0.27	2.02	0.00	16.96	16.53	5.43	0.43	0.00	0.00	0.42	0.00	2.41
# of sunfish scoring classification	5	5	5	3	3	3	5	5	5	5	3	3
score for % headwater	3	5	1	5	5	5	5	1	1	5	1	5
# of minnows sp scoring classification	5	5	5	5	5	5	5	5	1	5	5	5
# of suckers scoring classification	1	3	3	1	1	1	3	3	3	5	1	3
# of sensitive species scoring classification	3	3	5	5	1	3	5	5	1	5	5	3
% of tolerant individuals	45	19	6	17	31	25	23	42	18	21	27	38
% of tolerant scoring classifacation	3	1	1	1	1	1	1	1	1	1	1	1
% omnivores	5	5	5	5	5	5	3	3	5	5	5	3
%insectivorus	3	5	5	5	3	5	3	3	5	5	3	3
% Pioneer	3	5	5	3	1	3	3	1	5	5	1	5
% Carnivores	1	1	3	1	5	1	1	1	1	5	3	1
CPUE	146.24	613.1	249.49	107.6	128.8	76.25	138.2	204.2	48.63	109.31	344.2	103.02
CPUE scoring classification	3	5	3	1	3	1	1	3	1	1	5	1
% Simple Lithophilic	17.391	4.4498	40.198	19.2	14.85	6.522	24.57	27.57	4.813	36.518	11.16	47.2414
% Simple Lithophilic scoring classification	1	1	5	1	1	1	3	3	1	3	1	5
%DELTS	5	5	5	5	5	5	5	5	5	5	5	5
IBI Score	**34**	**40**	**48**	**36**	**34**	**34**	**40**	**34**	**30**	**50**	**36**	**38**

SITE	BC1	SC2	DCD3	BR4	PC5	LDU6	LDD7	MD8	SFD9	DCM10	SFU11	DCU12



Macroinvertebrates

	SITES		BC1	SC2	DCD3	BR4	PC5	LDU6	LDD7	MD8	SFD9	DCM10	SFU11	DCU12
Order	***Family***	***Genus***												
Acariformes	Hydrachnidia	Unknown		1			2						10	1
Amphipoda	Talitridae	Hyalella			10	3					8			
Amphipoda	Talitridae	Unknown						3						
Amphipoda	Unknown	Unknown						1	1	85	2		20	
Bivalvia	Unknown (larval)	Unknown				1		21						
Coleoptera	Dytiscidae	Matus	1											
Coleoptera	Elmidae	Dubiraphia- larvae			1		26	22	2	2	43	2	14	24
Coleoptera	Elmidae	Dubiraphia- adult											1	
Coleoptera	Elmidae	Macronychus						9						1
Coleoptera	Elmidae	Microcylloepus		2	1			9						
Coleoptera	Elmidae	Optioservus		2		1	1	136	2	1				1
Coleoptera	Elmidae	Stenelmis	2	12	2	21		187	2					3
Coleoptera	Haliplidae	Peltodytes		9			1	2		1			4	
Coleoptera	Haliplidae	Peltodytes-adult			1							1		
Coleoptera	Hydrophilidae	Berosus		10	1	1						1	5	
Coleoptera	Hydrophilidae	Hydrocus						2			2			
Coleoptera	Hydrophilidae	Hydrophilus	1					1						
Coleoptera	Lutrochidae	Lutrochus	1											
Coleoptera	Psephenidae	Psepherus						28						
Coleoptera	Scirtidae	Scirtes						1			6			2
Coleoptera	Scirtidae	Prionocyphon							2					
Diptera	Ceratopogonidae	Culicoides												
Diptera	Ceratopogonidae	Probezzia		1										
Diptera	Ceratopogonidae	Serromyia									2			
Diptera	Chironomidae	Ablabesmyia			7									
Diptera	Chironomidae	Chironominae					26					46		
Diptera	Chironomidae	Chironomini	113	23				67			2			1
Diptera	Chironomidae	Chironomus			3						9			1
Diptera	Chironomidae	Diamesinae	1	3				23			67			
Diptera	Chironomidae	Orthocladiinae	37	25				30						
Diptera	Chironomidae	Podonominae	5	2			17	25			11	26		
Diptera	Chironomidae	Prodiamesinae	4					20			3			
Diptera	Chironomidae	Tanypodinae	14	14			7	90			2	3		1
Diptera	Chironomidae	Tanytarsini	13	6				27				1		4
Diptera	Chironomidae	Unknown			81	40	1	14	52	155	8		46	168
Diptera	Culicidae	Anopheles									1			
Diptera	Dixidae	Dixa	1	1										

	SITES		BC1	SC2	DCD3	BR4	PC5	LDU6	LDD7	MD8	SFD9	DCM10	SFU11	DCU12
Diptera	Empididae	Hemerodromia	11	5							1			
Diptera	Simulidae	Simulium						2	1					
Diptera	Syrphidae	Unknown	2											
Diptera	Tabanidae	Chrysops	4				1	6	1					1
Diptera	Tabanidae	Merycomyia	1											
Diptera	Tabanidae	Tabanus						5						2
Diptera	Tipulidae	Antocha	6	2		1			1					1
Diptera	Tipulidae	Dicranota		2										
Diptera	Tipulidae	Hexatoma						2						
Diptera	Tipulidae	Paradelphomyia	1					1						
Diptera	Tipulidae	Pedicia						1						
Diptera	Tipulidae	Tipula		2				1						
Ephemeroptera	Ameletidae	Ameletus		2				19						
Ephemeroptera	Baetidae	Acentrella						3						
Ephemeroptera	Baetidae	Acerpenna		1	3									2
Ephemeroptera	Baetidae	Baetis				19		13						1
Ephemeroptera	Baetidae	Callibaetis				1			7			2	11	
Ephemeroptera	Baetidae	Centroptilum							13	1			7	
Ephemeroptera	Baetidae	Diphetor hagen		1				1						
Ephemeroptera	Baetidae	Fallceon		2				5						
Ephemeroptera	Baetidae	Paracloeodes		1				13						
Ephemeroptera	Baetidae	Plauditis						1						
Ephemeroptera	Baetidae	Pseudocleon						1						
Ephemeroptera	Baetidae	Unknown	1	2			1	20			2			1
Ephemeroptera	Baetiscidae	Baetisca	1					1						
Ephemeroptera	Caeniidae	Caenis		11	20	1	37	337	40	25	18	12	93	26
Ephemeroptera	Ephemeridae	Ephemera						2						
Ephemeroptera	Heptageniidae	Epeorus						2						
Ephemeroptera	Heptageniidae	Heptagenia		5	4			14						
Ephemeroptera	Heptageniidae	Leucrocuta		1				3						
Ephemeroptera	Heptageniidae	Maccaffertium		9		3		251	18					1
Ephemeroptera	Heptageniidae	Nixe						4						1
Ephemeroptera	Heptageniidae	Stenacron						21						
Ephemeroptera	Heptageniidae	Stenonema femoratum		10	2	8		97						1
Ephemeroptera	Heptageniidae	Unknown	3	7			1	41						1
Ephemeroptera	Isonychiidae	Isonychia		4		1		31						
Ephemeroptera	Leptohyphidae	Tricorythodes		10	174	108		6	14					
Ephemeroptera	Leptophlebiidae	Paraleptophlebia			1			1	1					
Ephemeroptera	Polymitarcyidae	Ephoron						1						

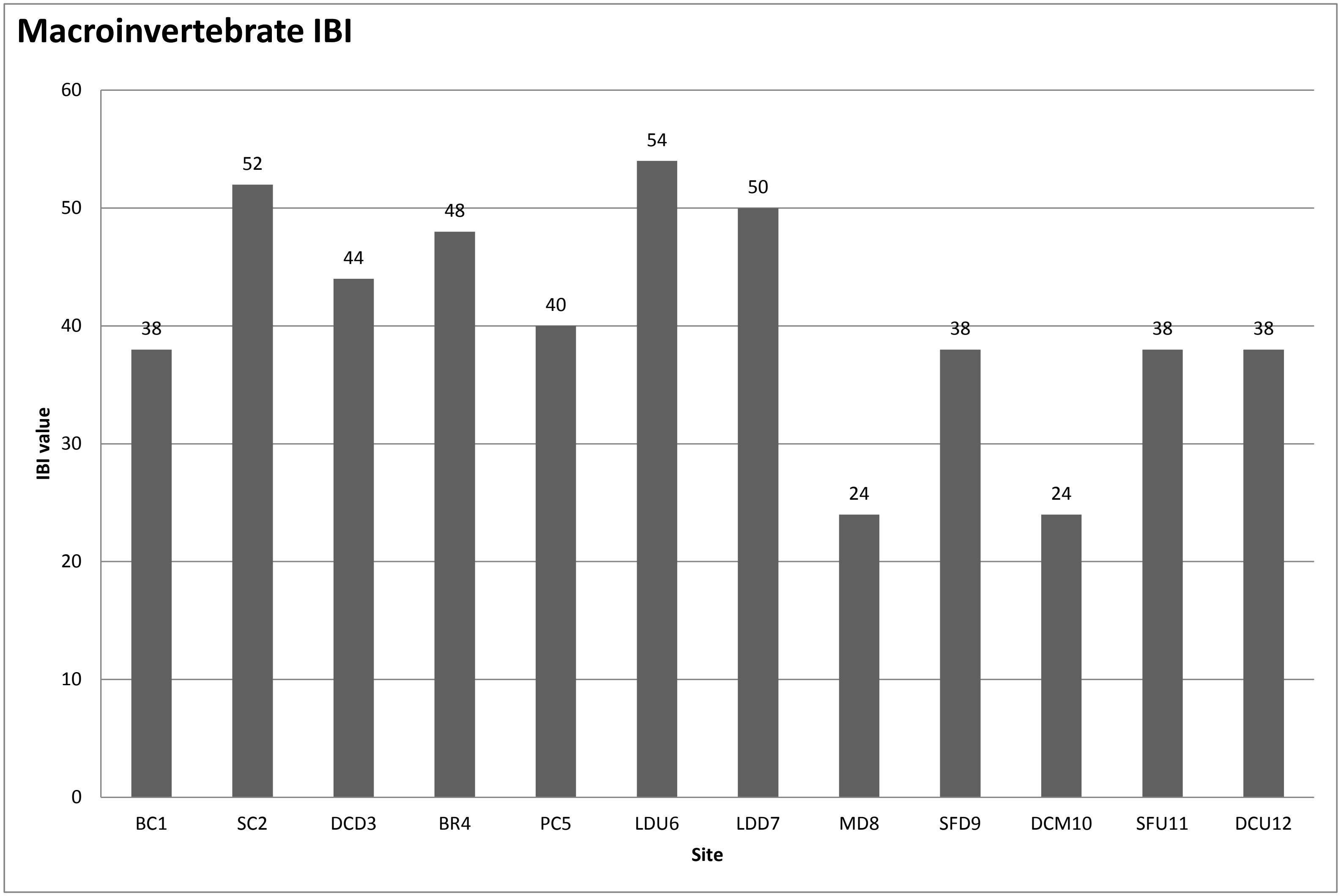
	SITES		BC1	SC2	DCD3	BR4	PC5	LDU6	LDD7	MD8	SFD9	DCM10	SFU11	DCU12
Gastropoda	Ancylidae	Unknown		1			1		2				1	1
Gastropoda	Physa	Unknown	4	3	1	6	10	11	5				1	2
Gastropoda	Planorbidae	Unknown			3		4		1					2
Gastropoda	Sphaeriidae	Unknown					4					5	1	
Gastropoda	Valvatidae	Valvata									1			
Hemiptera	Corixidae	Corixinae						4			7			
Hemiptera	Corixidae	Trichocorixa						3						
Hemiptera	Corixidae	Unknown			1		91	1						
Hemiptera	Gerridae	Aquarius												1
Hemiptera	Gerridae	Limnoporus									1			
Hemiptera	Gerridae	Rheumatobates									1			
Hemiptera	Gerridae	Trepobates		1							14			
Hemiptera	Naucoridae	Pelocoris	1											
Hemiptera	Ochteridae	Ochterus						1						
Hemiptera	Saldidae	Unknown		1										
Hemiptera	Veliidae	Steinovelia								1				
Isopoda	Asellidae	Asellus	3	15		17								
Lepidoptera	Crambidae	Petrophila				1								
Lepidoptera	Neargyractis	Unknown		1										
Odonata	Calopterygidae	Calopteryx						1						
Odonata	Calopterygidae	Hetaerina				1								
Odonata	Coenagrionidae	Amphiagrion						10	3					
Odonata	Coenagrionidae	Argia		1				2			2		1	
Odonata	Coenagrionidae	Chromagrion			3	1								2
Odonata	Coenagrionidae	Coenagrion								5			24	
Odonata	Coenagrionidae	Enallagma								1	3			
Odonata	Coenagrionidae	Unknown					1	1			3			
Odonata	Libellulidae	Libellula								2				
Oligochaeta	Stylaria	Unknown			3									
Oligochaeta	Unknown	Unknown			18		7		8	35	1	45	12	48
Orthoptera	Acrididae	Eotettix	1											
Plecoptera	Capniidae	Allocapnia		5	8									
Plecoptera	Capniidae	Capnura		1										
Plecoptera	Capniidae	Unknown	2	93				5						
Plecoptera	Chloroperlidae	Alloperla		11										
Plecoptera	Chloroperlidae	Unknown						1						
Plecoptera	Leuctidae	Leuctra		20										
Plecoptera	Nemouridae	Nemoura			13									
Plecoptera	Nemouridae	Shipsa		1				2						

	SITES		BC1	SC2	DCD3	BR4	PC5	LDU6	LDD7	MD8	SFD9	DCM10	SFU11	DCU12
Plecoptera	Nemouridae	Unknown		1				5						
Plecoptera	Perlodidae	Isoperla												
Plecoptera	Perlodidae	Unknown		2										
Plecoptera	Taeniopterygidae	Oemopteryx		5				2						
Plecoptera	Taeniopterygidae	Strophopteryx		8		2			21					
Plecoptera	Taeniopterygidae	Taeniopteryx						32						
Plecoptera	Taeniopterygidae	Unknown		8				7						
Plecoptera	Unknown	Unknown		4				11						
Trichoptera	Brachycentridae	Brachycentrus									1			
Trichoptera	Brachycentridae	Micrasema						1						
Trichoptera	Glossosomatidae	Agapetus	1											1
Trichoptera	Glossosomatidae	Protoptila							2					
Trichoptera	Helicopsychidae	Helicopsyche		1		11		48	20			3		
Trichoptera	Hydropsychidae	Ceratopsyche		3		1		13			1			
Trichoptera	Hydropsychidae	Cheumatopsyche	28	16		8		90	1					5
Trichoptera	Hydropsychidae	Hydropsyche	12	8	1			20	6					
Trichoptera	Hydropsychidae	Potamyia			1				2					
Trichoptera	Hydropsychidae	Unknown		1				2	1					
Trichoptera	Hydroptilidae	Hydroptila			1			1						
Trichoptera	Hydroptilidae	Mayatrichia						3						
Trichoptera	Hydroptilidae	Unknown						1						
Trichoptera	Leptoceridae	Mystacious						3						
Trichoptera	Leptoceridae	Oecetis						7						
Trichoptera	Leptoceridae	Setodes	1			1								
Trichoptera	Leptoceridae	Trianodes						1						
Trichoptera	Limnephilidae	Hydatophylax	3					5						
Trichoptera	Odontoceridae	Psilotreta						2						
Trichoptera	Philopotamidae	Chimarra	11	4		6		83	1					
Trichoptera	Philopotamidae	Dolophilodes		1										
Trichoptera	Phryganeidae	Agrypnia	1											
Trichoptera	Polycentropodidae	Cyrnellus		3					1					
Trichoptera	Polycentropodidae	Neureclipsis	1	1				10						
Trichoptera	Polycentropodidae	Polycentropus						4						
Trichoptera	Polycentropodidae	Unknown						2						
Turbellaria	Planariidae	Unknown			6	2			2					

SITES	BC1	SC2	DCD3	BR4	PC5	LDU6	LDD7	MD8	SFD9	DCM10	SFU11	DCU12
Total	292	408	370	266	239	2019	233	314	222	147	251	307
Drainage Area	11.18	28.56	298.77	35.91	13.81	35.43	52.93	15.92	38.75	56.34	13.74	35.77
Total # Taxa	33	59	25	24	17	82	28	10	25	11	12	27
Total # *Indiv*	292	408	370	266	239	2019	233	314	222	147	251	307
Total EPT	12	35	11	13	3	50	15	2	4	3	3	10
Total Dipter Taxa	14	12	3	2	5	15	4	1	10	4	1	8
%Chiro	0.64	0.18	0.25	0.15	0.21	0.15	0.22	0.49	0.46	0.52	0.18	0.57
%NonInsect	0.02	0.05	0.11	0.11	0.12	0.02	0.08	0.38	0.05	0.34	0.18	0.18
%Intolerant	0.15	0.58	0.61	0.62	0.15	0.52	0.56	0.08	0.09	0.10	0.40	0.12
%Tolerant	0.03	0.05	0.10	0.10	0.08	0.01	0.07	0.41	0.14	0.31	0.23	0.17
%Predators	0.10	0.09	0.01	0.01	0.41	0.06	0.01	0.03	0.16	0.03	0.12	0.02
%Shred/Scraper	0.04	0.49	0.10	0.20	0.07	0.44	0.32	0.01	0.03	0.03	0.02	0.06
%C-F	0.23	0.12	0.01	0.06	0.02	0.14	0.06	0.00	0.01	0.04	0.00	0.03
% Sprawlers	0.24	0.50	0.59	0.52	0.15	0.34	0.47	0.09	0.09	0.10	0.37	0.10
# of Taxa	3	5	3	3	1	5	3	1	3	1	1	3
# Indiv	5	5	5	5	5	5	5	5	5	3	5	5
#EPT	5	5	3	5	1	5	5	1	3	1	1	5
%Chiro	1	5	3	5	5	5	5	1	3	1	5	1
%NonInsect	5	5	5	5	5	5	5	1	5	3	5	5
Total Dipter Taxa	5	3	1	1	1	5	1	1	3	1	1	3
%Intolerant	1	5	5	5	1	5	5	1	1	1	5	1
%Tolerant	5	5	5	5	5	5	5	1	3	1	3	3
%Predators	1	1	1	1	5	1	1	1	1	1	1	1
%Shred/Scraper	1	5	3	3	1	5	5	1	1	1	1	1
%C-F	1	3	5	5	5	3	5	5	5	5	5	5
% Sprawlers	5	5	5	5	5	5	5	5	5	5	5	5
Total Score	38	52	44	48	40	54	50	24	38	24	38	38

Unimpaired (green)
Impaired (red)

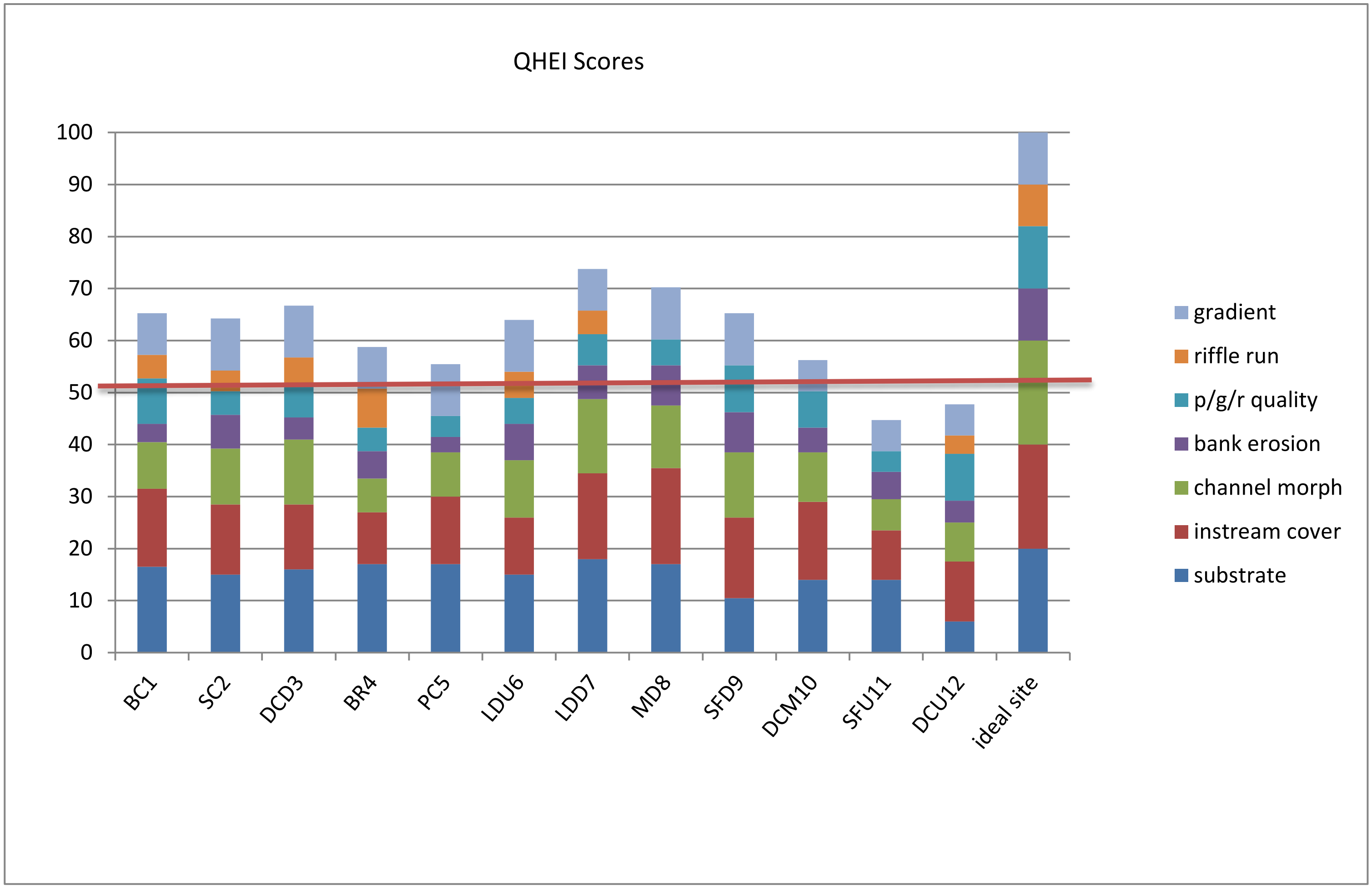
SITES	BC1	SC2	DCD3	BR4	PC5	LDU6	LDD7	MD8	SFD9	DCM10	SFU11	DCU12



Habitat

SITES	BC1	SC2	DCD3	BR4	PC5	LDU6	LDD7	MD8	SFD9	DCM10	SFU11	DCU12	ideal site
substrate	16.5	15	16	17	17	15	18	17	10.5	14	14	6	20
instream cover	15	13.5	12.5	10	13	11	16.5	18.5	15.5	15	9.5	11.5	20
channel morph	9	10.75	12.5	6.5	8.5	11	14.25	12	12.5	9.5	6	7.5	20
bank erosion	3.5	6.5	4.25	5.25	3	7	6.5	7.75	7.75	4.75	5.25	4.25	10
p/g/r quality	8.75	4.5	6.5	4.5	4	5	6	5	9	7	4	9	12
riffle run	4.5	4	5	7.5	0	5	4.5	0	0	0	0	3.5	8
gradient	8	10	10	8	10	10	8	10	10	6	6	6	10
total	65.25	64.25	66.75	58.75	55.5	64	73.75	70.25	65.25	56.25	44.75	47.75	

data is averaged from two scorers



IDEM

INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

We Protect Hoosiers and Our Environment.

Mitchell E. Daniels Jr.
Governor

Thomas W. Easterly
Commissioner

100 North Senate Avenue
Indianapolis, Indiana 46204
(317) 232-8603
Toll Free (800) 451-6027
www.idem.IN.gov

July 18, 2012

Sara Peel, Director, Watershed Projects
Wabash River Enhancement Corporation
200 North 2nd Street
Lafayette, IN 47901

Dear Ms. Peel:

Re: QAPP Approval
FFY 2011 Section 319 Project
EDS# A305-2-22

This letter is to inform you that the Quality Assurance Project Plan (QAPP) for the *Deer Creek-Sugar Creek Watershed Project* has been approved by our office. The signature page is enclosed for your records.

Thank you for your interest in furthering Indiana's nonpoint source pollution goals by facilitating water quality monitoring efforts in your watershed. We appreciate your work and anticipate that much good will come from your efforts. Please remember to address quality assurance (QA) activities as required by the QAPP in the Quarterly Progress Reports for your project. If you have any questions or if we can be of further assistance, do not hesitate to contact your Watershed Specialist, Leanne Whitesell, at (317) 308-3119 or our QA Manager, Betty Ratcliff, at 317/308-3135.

Sincerely,

Bonny F. Elifritz

Bonny F. Elifritz, Chief
Watershed Planning and Restoration Section
Office of Water Quality

Enclosure

Cc: Jessica Fulgoni, Watershed Resource Specialist
Wabash River Enhancement Corporation

1.0 Title Page

Quality Assurance Project Plan

for

Deer Creek – Sugar Creek Watershed

ARN # 305-2-22

Prepared by:

Jessica Fulgoni, Watershed Resource Specialist
Sara Peel, Director of Watershed Projects
Wabash River Enhancement Corporation

Prepared for:

Indiana Department of Environmental Management
Office of Water Quality
Watershed Planning & Restoration Section
Final Draft
July 2012

Approved By:

Project Manager:	Sara Peel (signed)	7/10/12 Date
TLS QA Manager:	Betty Ratcliff (signed)	7/16/12 Date
WPR Section Chief:	Bonny Elifritz (signed)	7/18/12 Date

2.0 **Table of Contents**

3.0 List of Appendices & Tables

3.1 List of Appendices & Tables

3.2 List of Tables

3.3 Distribution List

Betty Ratcliff, IDEM NPS Quality Assurance Manager
Technical and Logistical Services Section
Indiana Department of Environmental Management
100 North Senate Avenue
MC 65-44 IGCN 1255
Indianapolis, IN 46204-2251

Leanne Whitesell, IDEM NPS Project Manager
Watershed Planning & Restoration Section
Indiana Department of Environmental Management
100 North Senate Avenue
MC 65-44 IGCN 1255
Indianapolis, IN 46204-2251

Sara Peel, Director of Watershed Projects
Wabash River Enhancement Corporation
200 North 2nd Street
Lafayette, IN 47901

Jessica Fulgoni, Watershed Resource Specialist
Wabash River Enhancement Corporation
200 North 2nd Street
Lafayette, IN 47901

Rhonda Hicks, Carroll County SWCD

1523 North Highway 421, Ste #2
Delphi, IN 46923

Ron Turco, Project Director for Water Sampling
915 West State Street
West Lafayette, IN 47906

Megan Haas, Water Chemistry and Bacteria Technician
915 West State Street
West Lafayette, IN 47906

Reuben Goforth, Project Director for Biological Sampling
196 Marstellar Street
West Lafayette, IN 47907

Beth Bailey, Project Technician for Biological Sampling
196 Marstellar Street
West Lafayette, IN 47907

4.0 Project Task/or Organization

In general, the Director of Watershed Projects is responsible for overall implementation of the project. The Water Chemistry and Bacteria Technician reports to the Project Director for Water Sampling. The Project Technician for Biological Sampling reports to the Project Director for Biological Sampling who in turn coordinates with the Project Director for Water Sampling. The Project Director for Water Sampling coordinates with the Director of Watershed Projects, who shares data with the IDEM Quality Assurance Manager, IDEM Project Manager, and the project steering committee.

4.1 Key Personnel

Sara Peel, Director of Watershed Projects
Phone: 765-337-9100 Address: 200 N. 2nd Street Lafayette
E-mail: speel@lafayette.in.gov
Oversees the project and development of the watershed management plan

Rhonda Hicks, Sponsoring SWCD
Phone: 765-564-4480 x3 Address: 1523 North Highway 421, Ste #2, Delphi, IN 46923
E-mail: swcdcc@ffni.com
Coordinates with local volunteers and reviews collected data

Ron Turco, Project Director for Water Sampling, Water Chemistry and Bacteria QC Director
Phone: 765-494-8077 Address: 915 W. State St. West Lafayette, IN 47907
E-mail: rturco@purdue.edu
QC director for water chemistry, oversees project finances and water quality sampling, operates Purdue University's Soil Microbiology Lab

Megan Haas, Water Chemistry and Bacteria Technician

Phone: 765-494-8098 Address: 915 W. State St. West Lafayette, IN 47907
E-mail: mheller@purdue.edu
Will sample and analyze for water chemistry and bacteria parameters, technician at Purdue University's Soil Microbiology Lab

Reuben Goforth, Project Director for Biological Sampling and Habitat Evaluation
Phone: 765-494-0009 Address: 195 Marstellar Street West Lafayette
E-mail: rgoforth@purdue.edu
QC director for biological sampling, responsible for biological and habitat sampling implementation

Beth Bailey, Technician for Biological Sampling and Habitat Evaluation
Phone: 765-494-0009 Address: 195 Marstellar Street West Lafayette. Email: baileyej@purdue.edu.
Will sample and analyze all fish, macroinvertebrate, mussels, and habitat data

4.2 Project Organization Chart

The Project Director for Water Sampling is responsible for:
Oversight of the WCB Technician
Implementation of the QAPP
Water chemistry sampling
Review of water chemistry data entry to completeness and accuracy
Analysis of collected information

The Water Chemistry and Bacteria Technician is responsible for:
Water chemistry QAPP development
Collection of general watershed parameters
Geolocation of sampling sites
Water chemistry sampling
Data entry for water chemistry samples
Analysis of collected information

The Project Director for Biological Sampling is responsible for:
Oversight of field and laboratory technicians (to be identified at a later date)
Implementation of the QAPP
Biological community and physical habitat sampling
Review of biological and physical habitat data entry for completeness and accuracy
Analysis of collected information

The Director of Watershed Projects is responsible for:
QAPP development
Analysis of collected information
Volunteer monitor coordination

5.0 Special Training Needs/Certification & Qualifications

Special training is required to collect and analyze water chemistry and biological/habitat samples. All training will be provided for these activities by the Project

Directors for Water Sampling and Biological Sampling, respectively. Volunteer monitors will be trained in the Hoosier Riverwatch sample collection, analysis and reporting method prior to participating in Hoosier Riverwatch-based volunteer monitoring. Wabash Sampling Blitz volunteers will be instructed in sample collection and analysis procedures at the time of sampling.

6.0 Problem Definition/Background

6.1 Problem Statement

Water quality throughout the Deer Creek – Sugar Creek watershed is relatively poor.

6.2 Historical & Background Information

The area under study encompasses 240,203 acres or 345 square miles. This watershed includes all areas that drain into Deer Creek and Sugar Creek prior to joining the Wabash River in the southwest portion of the watershed. This area includes three 10-digit watersheds: Sugar Creek – Wabash River (HUC 0512010504; 62,978 acres), Deer Creek (HUC 0512010505; 131,140 acres), and South Fork Deer Creek (HUC 0512010506; 46,085 acres). The Deer Creek – Sugar Creek watershed is part of a larger, 8-digit Middle Wabash – Deer Watershed.

Impaired biotic communities, *E. coli*, PCBs, and mercury have been persistent problems in this portion of the Wabash River watershed. In 2008 and on the draft 2010, the IDEM 303(d) list included the following identified impairments for this watershed: Deer Creek, Paint Creek, Plank Ditch, Guckien Cohee Ditch, Buck Creek, Bachelor Run-Kuns Ditch, Sugar Creek, Little Sugar Creek, and unnamed tributaries for *E. coli*; Buck Creek and its tributaries for impaired biotic communities; Deer Creek and the Wabash River for PCBs in fish tissue; Wabash River for mercury in fish tissue. Because of these impairments, a water management plan is needed to get the levels of these four parameters within their Total Maximum Daily Load ranges

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7.0 Process Design

7.1 Study Site Description

The study area encompasses 240,203 acres or 345 square miles of land including portions of Carroll, Cass, Howard, Miami, and Tippecanoe counties.

8.0 Quality Objectives & Criteria for Measurement Data

8. 1 Goal Statements & Objective Statements

The objective of this study is to determine what water quality levels are currently normal for these watersheds throughout the year as well as identify sources of pollution that may be reduced through implementation of a watershed management plan. Chemical, biological, and physical conditions on the selected streams will be documented. The collection of this data will allow for the identification of problem areas, characterization of the watershed, implementation of the watershed management plan, and assessment of implementation success for tributaries to the Wabash River. Ultimately, this monitoring program is designed to show changes in water quality from the watershed management planning phase to the implementation phase. Collected data will be compared with data collected during development of the watershed management plan.

In summary, the goal of the water quality collection portion of this project is to determine the quality of water within the Deer Creek – Sugar Creek watershed and to establish whether a change in water quality can be displayed during the implementation phase(s) of this program. These goals will be achieved through the following actions:

Action 1: Field and laboratory water chemistry data collection at each site will include monitoring for nutrients (nitrogen, phosphorous), *E. coli*, total suspended solids, dissolved oxygen, conductivity, turbidity, temperature, and pH at all sites monitored. Nutrients, *E. coli* and total suspended solids will be determined in the laboratory using approved methods. Dissolved oxygen, conductivity, turbidity, temperature, and pH will be determined on site using either handheld or in-situ probes.

Action 2: Flow will be measured at each of the 12 sample sites using US Forest Service methods. Personnel will complete cross section measurements of velocity and depth.

Action 3: Fish communities will be sampled using an ETS backpack electroshocker at (12) twelve biological monitoring stations. Fish will be identified in the field. Fish will be measured for total length in millimeters (mm). Fish will be released following each sampling event. Fish will be reported by species and fish Index of Biotic Integrity (IBI) will be calculated according to the protocol developed for use by the Indiana Department of Natural Resources and Indiana Department of Environmental Management.

Action 4: Benthic macroinvertebrates (primarily aquatic insect larvae and nymphs) will be sampled at each site using a frame kick net (500 µm mesh) at the same (12) twelve biological monitoring stations. Macroinvertebrate samples will be preserved in the field using 90% ethanol. Preserved samples will be processed and individuals identified to the lowest practicable taxonomic level (i.e., Genus for most groups; Family for Chironomidae). Purdue staff will report macroinvertebrate data according to identifications to the lowest practicable taxonomic level, and we will also calculate a macroinvertebrate IBI (mIBI) using protocols developed for use by the Indiana Department of Environmental Management.

Action 5: Mussels will be sampled at each of the (12) twelve biological monitoring stations. Mussel communities will be analyzed using the mussel methodology used by the Indiana Department of Natural Resources.

Action 6: Stream habitat at each site will be evaluated using the Qualitative Habitat Evaluation Index (QHEI, Ohio Environmental Protection Agency, 2006).

Action 7: Volunteer monitors will collect standard Hoosier Riverwatch parameters at the (12) twelve biological monitoring sites. Volunteers will be trained prior to sampling and will submit quarterly collected data to the Watershed Coordinator and the Hoosier Riverwatch database.

Action 8: Volunteer monitors will collect field samples and conduct in-situ and field station monitoring at approximately 200 stream sites as part of the Wabash Sampling Blitz. Volunteers will be instructed in sample collection and analysis at the time of sampling.

Action 9: Current water quality data will be analyzed to allow for comparison with historical and previously collected data to provide baseline and post-implementation water quality condition information.

To achieve the goal of evaluating a change in water quality, standardized data collection methodology and analysis will be used at each of the sampling stations. Consistencies in methodology will ensure that sampling stations will be comparable to one another and between sampling periods allowing for the watershed group to determine which sites are degraded relative to one another and determine if a measurable change in water quality is present. Methodologies will follow those established and accepted by the scientific community and regulatory agencies (IDEM, Ohio EPA, and USEPA).

8.2 Study Site

Water samples will be collected at the sites detailed in Table 1 and displayed in Figure 1.

Table 1: Sampling Program (PC=Professional Chemistry; B=Biology)

Site Number	Stream Site	Latitude/Longitude	Parameters Sampled
1	Buck Creek at Stair Road, Tippecanoe County	40.4966, -86.8084	PC, B
2	Sugar Creek at SR 25/Stair Road, Tippecanoe County	40.5123, -86.7861	PC, B
3	Deer Creek at Trail Head Park, Carroll County	40.5871, -86.6659	PC, B
4	Bachelor Run at CR 350 N, Carroll County	40.5979, -86.5741	PC, B
5	Paint Creek at CR 450 N, Carroll County	40.6126, -86.4823	PC, B
6	Little Deer Creek at SR 29, Carroll County	40.5573, -86.3954	PC, B
7	Little Deer Creek at CR 300 N, Carroll County	40.5903, -86.4670	PC, B
8	McCloskey Ditch at CR 600 E, Carroll County	40.5972, -86.4112	PC, B
9	South Fork Deer Creek at CR 1225 S, Cass County	40.5882, -86.2142	PC, B
10	Deer Creek at SR 35, Cass County	40.6025, -86.2020	PC, B
11	South Fork Deer Creek at Touby Road, Howard County	40.5429, -86.0931	PC, B
12	Deer Creek at CR 300 E, Miami County	40.6023, -86.0134	PC, B

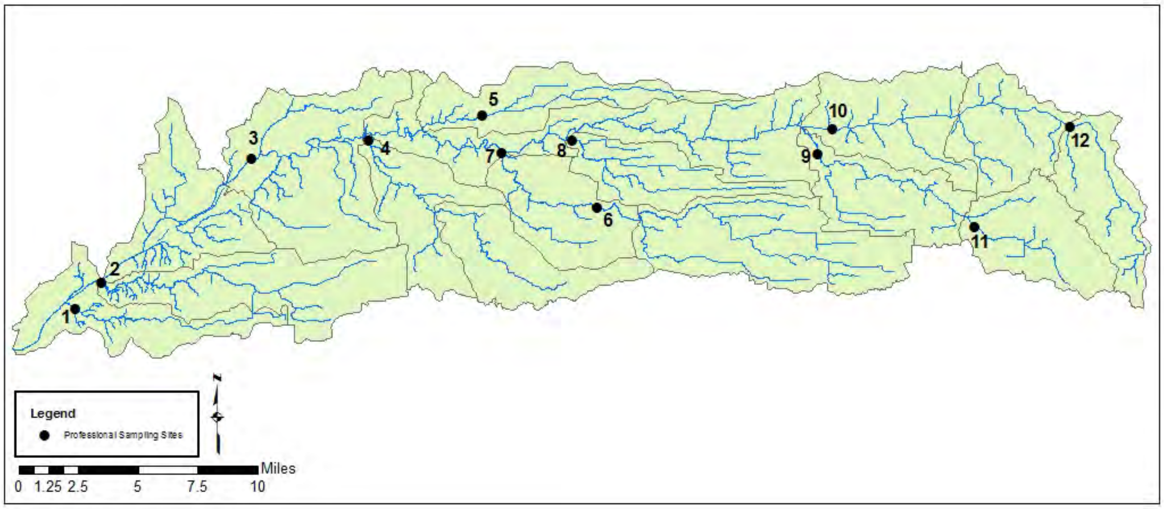


Figure 1: Map of water sampling sites located in the Deer Creek – Sugar Creek Watershed. (Numbers correspond to site numbers in Table 1)

8.3 Sampling Design

The sampling program includes professional water chemistry, volunteer water quality, and professional biological monitoring.

Professional Water Chemistry

A multi-tiered water chemistry monitoring plan will be implemented to establish a baseline for Deer Creek, Sugar Creek and their tributaries within the watershed. Water chemistry monitoring sites will be located on the Monitoring sites will be established throughout the watershed. Sites will be located on Bachelor Run, Buck Creek, Deer Creek, Little Deer Creek, McCloskey Ditch, Paint Creek, South Fork Deer Creek, and Sugar Creek. All sites are shown in Figure1.

Each site will be sampled on a biweekly basis for nutrients (nitrogen, phosphorous), *E. coli*, total suspended solids, flow, dissolved oxygen, conductivity, turbidity, temperature, and pH. Dissolved oxygen, conductivity, turbidity, temperature, and pH will be analyzed *in situ* with field equipment. Sampling will commence upon approval of the QAPP and continue for a period of one year. The minimum number of sampling events for the twelve sites will be 26 per year. Discharge will be calculated from velocity measurements one time at each sample site using approved USFS methods. The water chemistry sampling schedule is flexible enough to prevent sampling during inappropriate weather or when equipment is not working. Following each sampling event, all water chemistry samples will be transported to Purdue University's Soil Microbiology Lab for analysis.

Stream Flow

Stream flow will be monitored once at all of the water chemistry sites. Stream flow monitoring will follow USFS protocols. Discharge will be calculated based on velocity and depth measurements Drainage areas will be taken from Hoggatt (1975) and confirmed using the watershed delineation tools in ArcInfo Geographic Information System (GIS).

Volunteer Monitoring
Volunteer monitoring will occur quarterly throughout the sampling period as detailed in Appendix A. Sampling will commence upon approval of QAPP through January 2016. Volunteer monitoring sites will correspond with sites shown in Figure 1. In total, twelve sites will be sampled by volunteer monitors using the Hoosier Riverwatch monitoring protocol.

Biological Monitoring
Biological samples will be collected annually from the water chemistry sites described above. Sample site locations are provided in Figure 1. Fish and macroinvertebrate samples will be collected annually in the first and last year of the agreement and mussels will be sampled once during the first year of the agreement. Physical habitat will be evaluated annually using the QHEI during the first and last year of the agreement. Biological samples will be taken on comparable dates each project year as possible given potential weather constraints. Fish and mussels will be identified on-site. Benthic macroinvertebrate samples will be preserved in 90% ethanol on-site, and the samples will be transported to Purdue University's Aquatic Ecology Lab (Department of Forestry and Natural Resources, Forestry Building Rm. 114) for processing and identification.

8.4 Study Timetable

Water chemistry and bacterial monitoring will commence upon approval of QAPP and will continue for one year. All sites will be sampled in the morning on the same day. At the field, metered measurements will be taken at that time. Samples will be transported immediately back to the lab and stored. E. coli will be set up that day and results will be read 24 hours later. Nutrients will be prepped for analysis and will be stored at 4^{o}C for 28 days or frozen for up to 6 months. Batch samples stored at 4^{o}Cwill be analyzed for nutrients 1-2 times per month. Frozen batch samples will be analyzed within a 6 month period Total suspended solids will be analyzed the same day.

Table 2: Study Schedule

Activity	Sample Schedule	Start Date	End Date
Water chemistry monitoring	Biweekly	Upon approval of QAPP	1 year from start date
Volunteer water quality monitoring	Quarterly	Upon approval of QAPP	February 13, 2015
Biological monitoring (fish and macroinvertebrates)	1st and last year of grant agreement	Upon approval of QAPP	January 31, 2016
Mussel monitoring	Once	Upon approval of QAPP	1 year from start date
Habitat assessment	1st and last year of grant agreement	Upon approval of QAPP	January 31, 2016
Flow	Once	Upon approval of QAPP	1 year from water chemistry start date

There are several potential constraints that may affect sampling and analysis. The first is weather. Should weather conditions make it dangerous for the technician to sample on the planned date,sampling will occur on the next available date after weather conditions have improved. Sampling will then continue as normal. Weather may also affect the ability of the technician to obtain water samples. In winter the streams and rivers may freeze over. Should this occur, an attempt to break the ice will be made. If the ice cannot be broken, or if it is too dangerous to do so, then sampling will not be done at that site for that sampling period. During the summer, there may be no-flow conditions in which an insufficient amount of water is not present for sampling. In this case sampling may be skipped. All conditions will be noted on field sheets. Other constraints that may occur include equiment unavailability or malfunction. If this occurs it will be dealt with in a timely manner and noted with the data.

Reports to IDEM will be made on a quarterly basis. A final report will be submitted at project's end.

9.0 Data Quality Indicators (*for Measurement Data)*

The project goals are to establish a baseline of water quality data by which change can be shown during the implementation phase and to obtain an overview of water quality in Deer Creek, Sugar Creek and their tributaries from which a watershed management plan can be developed. Like many projects, this project has financial, temporal, and other constraints. For example, water chemistry data will be collected from only six tributaries with the goal of establishing a baseline by which a change in water quality can be shown during the implementation phase(s). Biological and physical habitat data will be collected at twelve total sites; these twelve sites are the same as the ones to be sampled for water quality data. The sampling design will not provide data for every tributary within the watershed; rather the data will be representative of an agricultural and urban watershed. This will allow for the collection of more data per level of effort. Based on this, the general data quality objectives are to gather representative information on the ecosystem's health at the watershed scale, collect broad watershed scale data to make broad conclusions, and perform collection by accepted protocols to ensure the effort can be repeated in the future. The data quality objectives for measurement of data are precision, accuracy, representativeness, comparability, and completeness.

9.1 Precision

Field Water Chemistry Parameters

Field equipment and instruments will be calibrated following manufacturer's guidelines before each sampling event. Field equipment will follow recommended usage by the equipment manufacturer. This will allow for high precision. Precision will be measured by calculating the Relative Percent Difference as follows:

$$RPD = \frac{(C - C') \times 100\%}{(C + C') / 2}$$

Where: C=the larger of the two values and C'=the smaller of the two values. An acceptable RPD value is 5%.

Laboratory Water Chemistry Parameters

One duplicate will be taken for every 20 samples taken. One duplicate will be taken in a sterilized plastic amber bottle while the second will be taken in a nutrient free glass amber bottle. Each sample will be taken back to the lab and analyzed for each appropriate parameter (plastic: E. coli, glass: nutrients and total suspended solids). For every 20 samples, one split sample will be analyzed for each parameter. In the event that more than 20 samples need to be taken during a sampling event, an appropriate number of duplicates and split samples will be analyzed so that 5% of samples are duplicates. Should lab data not meet the DQOs in this QAPP, the data will be reviewed by the Water Chemistry and Bacteria Technician and/or the Project Director for Water Quality Sampling and proper action taken.

For nutrients (nitrogen, phosphorus) and total suspended solids, RPD will be calculated as show above using both duplicates and split samples. RPD values should be less than 10%. For E. coli, a 95% confidence interval will be calculated for each site.

Blanks results should fall within 10% of the detection limit for each method.

Field Biological and Physical Habitat Parameters

No calibration is required for biological field sampling equipment and the QHEI is a metric-based protocol. Precision will be assurred by taking replicate samples at each site in time and space. Three replicate 100-m fish samples will be collected at each site on a quarterly basis. Six macroinvertebrate samples will be collected from riffle habitats using a D-net. Physical habitats will be evaluated on one occasion at each site, and the Project Director for Biological Sampling will conduct all of these evaluations for consistency.

Laboratory Biological Parameters

Precision in laboratory-processed macroinvertebrate samples will be assured by processing all six samples collected at each site on each sampling date.

Global Positioning System Parameters

Location coordinate data precision is expected to be high (Table 4).

9.2 Accuracy and or Bias

Field Water Chemistry Parameters

Accuracy for in-situ parameters (dissolved oxygen, conductivity, turbidty, temperature, and pH) will be maintained through proper calibration techniques as provided by the manufacturers of the sonde. These calibrations will take place as needed. Accuracy levels for each parameter measured can be found in Table 3.

Laboratory Water Chemistry Parameters

Accuracy will be maintained through adherance to the following protocols. Accuracy for analyical instruments will be maintained by proper instrument maintenance and following manufacturer's protocal. For each sampling trip, a field blank, trip blank, and lab blank will be analyzed for each parameter (E. coli, nutrients, total suspended solids). A field blank will ensure no contamination during sampling events in the field. A trip blank will ensure proper transportation techniques. A lab blank will ensure proper handling techniques in the lab. These blanks will be analyzed for all laboratory parameters: *E. coli*, total suspended solids, and nutrients (nitrate+nitrite-N, ammonia-N, and total phosphate). The day of sampling, a stock control will be made containing a known amount of nutrients. All samples to be analyzed for nutrients and the stock control will be stored in glass containers at 4^{o}C. Samples will not be preserved with sulfuric acid because it causes interference with the analytical instruments. Any nutrient losses over the storage period will be accounted for with the stock control. At time of nutrient analysis, a matrix spike will be created from a sample chosen at random from the batches to be analyzed. A known amount of each nutrient will be added. Percent recovery will be calculated as follows:

%R= [(A-B)x100]/C

Where A = the concentration of the spiked sample,
B = the concentration of the unspiked sample, and
C = the actual concentration of the spike added.

For each nutrient analysis, equipment blanks will be run. Check standards of high and low concentrations will be run A set of standards of known concentration for each nutrient will also be run during each analysis event. These standards will also be used to determine the percent bias. Percent bias will be calculated as follows:

%B = [(x-T)x100]/T
Where x = the mean of the results of duplicate analyses of the standard and
T = the concentration of the standard.

Accuracy for all analysis will be maintained through use of blanks. Should a blank result be outside of the ±10% detection limit range, the sample will be considered contaminated for that parameter and appropriate corrective actions will be taken.

Field Biological and Physical Habitat Parameters

Accuracy in fish and mussel identification and enumeration will be assured through collection and maintenance of voucher specimens for each species collected at each sampling site on each sampling date. Accuracy in habitat evaluations will be assured through consisent evaluations by the Project Directory for Biological Sampling.

Laboratory Biological Parameters
Accuracy in benthic macroinvertebrate identification and enumeration will be assured based on R. Merrit & K. Cummins. 1996. AQUATIC INSECTS OF NORTH AMERICA, 3rd Ed.)

Global Positioning System Parameters
Table 3 details accuracy for site geolocation.

9.3 Completeness

In the event that some catastrophic event (i.e. weather anomaly, chemical spill, etc) were to occur, the first action take would be to delay the sampling to a later time of the week in hopes that sampling could occur under more representative conditions. There is flexibility built into the project's schedule to allow sampling to occur during favorable conditions to preserve data quality.

Field and Laborary Water Chemistry Parameters
One hundred percent collection of field laboratory samples is expected. Sampling locations were field checked to ensure sampling access and proper hydrology is present at each site. However, climatic (frozen streams) or other changes may alter conditions in the watershed. Equipment malfunction or problems during sample collection and analysis could limit the amount of water chemistry data over the term of the project. 85% is an acceptable number because there will likely be events that will prevent sampling for a period of time such as frozen streams.
Valid data will be required from 85% of the scheduled sampling events per site. Completeness will be calculated as follows:

% Completeness = (number of valid measurements obtained) x 100
(number of measurements expected)

85% Completeness = <u>(22 valid sampling events)</u> x 100
(26 expected sampling events)

Biological and Habitat Parameters
One hundred percent collection of biological samples and physical habitat parameters is expected. Unpredictable and/or extended weather constraints may necessitate delayed sampling events on occasion. However, no issues with achieving 100% sampling for this portion of the project are anticipated.

Global Positioning System Parameters
The geolocation of sample sites is not dependent upon weather or other climatic situations (barring the loss of satellites). Since GPS data can be collected over the length of the project, 100% completeness should be achieved.

9.4 Representativeness

The project monitoring committee met prior to sample site selection to identify a representative agricultural and urban watershed along with a control for both. The selected water chemistry sites are considered representative of typical agricultural and urban conditions within the Deer Creek – Sugar Creek watershed. For biological sampling, sites are representative of the overall watershed and will provide information for prioritization purposes based on both small and large watershed drainage areas.

9.5 Comparability

Comparability will be maintained by adhering to the methods stated in this document at all times. These methods were developed from published sources, or from methods developed by USEPA, IDEM, USDA, or Ohio EPA.

9.6 Sensitivity

Methods for bacteria and water chemistry parameters are highly sensitive. Table 3 summarizes the sensitivites and detection limits for each parameter.

Table 3: Data Quality Objectives

Parameter	Precision	Accuracy	Completeness	Sensitivity	Detection Limit
Nitrate+Nitrite-N	RPD ≤ 10%	Maintained through use of blanks	C ≥ 85%	Measures out to 1/100th of mg	0.25mg-N/L
Total Phosphorus	RPD ≤ 10%	Maintained through use of blanks	C ≥ 85%	Measures out to 1/1000th of mg	0.0.01mg-P/L
E. coli	95% Confidence Interval	Maintained through use of blanks	C ≥ 85%	Measures out to 1/10th of cfu/mL	1 cfu/100mL
Total Suspended Solids	RPD ≤ 10%	Maintained through use of blanks	C ≥ 85%	Measures out to 1/10th of mg (as determined by analytical scale)	4mg/L
pH	RPD ≤ 5%	± 0.2 units	C ≥ 85%	Measures out to 1/100th of unit	0-14 units (detection range)
Turbidity	RPD ≤ 5%	± 2% of reading or ± 1 least significant digit; ± 3% of reading at 500 to 1000NTU	C ≥ 85%	Measures out to 1/10th of NTU	0-1000NTU (detection range)
Dissolved Oxygen	RPD ≤ 5%	% = 0 to 200% ± 2% of reading or 2% air saturation, whichever is greater. 200%-500% ±6% of reading	C ≥ 85%	Measures out to 1/100th of mg	0-50mg/L (detection range)
Temperature	RPD ≤ 5%	± 0.2°C	C ≥ 85%	Measures out to 1/100th of °C	-5-+50°C (detection range)
Conductivity	RPD ≤ 5%	± 0.5% of reading or 0.001mS/cm, whichever is greater	C ≥ 85%	Measures out to 1/1000th to 1/10th of mS (dependent on range)	0-100mS/cm (detection range)
Blanks-chemistry and bacteria	±10% of Detection Limit of method	If blanks are positive, the sample will be considered contaminated and corrective actions will be taken	C ≥ 85%	N/A	N/A
Split Samples-E. coli	95% Confidence Interval	Maintained through use of blanks	C ≥ 85%	N/A	N/A
Split Samples Nutrients and TSS	RPD ≤ 10%	Maintained through use of blanks	C ≥ 85%	N/A	N/A

Matrix Spike-Nutrients	N/A-used to calculate accuracy	% Recovery ≥ 90%	C ≥ 85%	N/A	N/A
Fish	N/A	N/A	C=100%	N/A	N/A
Mussel	N/A	N/A	C=100%	N/A	N/A
Macroinvertebrates	N/A	N/A	C=100%	N/A	N/A
Habitat	N/A	N/A	C=100%	N/A	N/A
Volunteer Monitoring	See Appendix A	See Appendix A	See Appendix A		
Geolocation	N/A	<7 meters, 95% 2D RMS w/WAAS/EGNOS <3 meters, 95% 2d RMS	N/A	N/A	N/A

10.0 Non Direct (Secondary Data)

11.0 Monitoring Requirements

11.1 Monitoring Process Design

Identify parameters or indicators and link monitoring design to goals and objectives. Clearly describe if sample will be analyzed by volunteer method analysis or analytical laboratory analysis

11.2 Monitoring Methods

Water Chemistry Sampling

Measurements made in the field will be made using manufacturer's guidelines and procedures, and as detailed in Table 4. Measurements made in the field include temperature, dissolved oxygen, pH, turbidity, and conductivity. Field data will be recorded on the field sheet. See Appendix B.

Samples for nitrogen, phosphorus, E. coli, and total suspended solids will be obtained by grab sampling. At each site, each bottle will be given a unique identification number from a label list. This label will be placed on the bottle and recorded on the field sheet prior to sampling. At this time, weather conditions and any other items of interest will be recorded on the field sheet. Bottles obtained through grab samples will be securely attached to a swing sampler (Nasco). A swing sampler allows a bottle to be attached to a pole and swing so that collection of samples may be taken at any angle. In the tributaries, samples will be taken in the thalweg from below the water surface using the hand-dip method, as summarized by Myers and Wilde (2003). Lids will be taken off just before lowering the jar into the water and will be placed face up on the ground where they will not be contaminated. Upon jar retrieval, lids will immediately be placed back on the jar. Once all jars are filled for that site, they will be placed in a cooler with ice packs until arrival back at the lab. At this time, jars will be stored at 4^{o}C until analysis can be performed.

Two 1-L bottles of water will be filled at each site. One sample container is a sterilized amber polypropylene bottle, the other is a nutrient-free glass amber bottle. The polypropylene bottle sample will be used for *E. coli* analysis while the glass bottle will be used for total suspended solids and nutrient analysis. All relevant equipment, preparation, collection, holding times, and analysis can be found in Appendices B-I for each given analysis.

Equipment used for *E. coli* analysis will be washed with soapy water, triple rinsed with tap water, triple rinsed with distilled deionized water (DDW) and allowed to dry. Once dry, equipment will be sterilized. Equipment for total suspended solids will be washed in the same manner as *E. coli* equipment, but will not be sterilized. Equipment for nutrient analysis will be rinsed with tap water, placed in a 50% hydrochloric acid bath, soaked overnight, triple rinsed with DDW, and allowed to dry. This glassware will be kept separate from other glassware in the lab to minimize nutrient exposure between uses.

Table 4: Sampling Procedures

Parameter	Sample Matrix	Sampling Frequency	Sampling Method	Sample Container	Sample Volume	Holding Time
E. coli	Collected Water Sample	Biweekly	Surface water grab sample-Colilert analysis as used by IDEM	Sterile amber polypropylene	100mL	6 hours
Total Suspended Solids	Collected Water Sample	Biweekly	Surface water grab sample-ASTM analysis method	Nutrient-free amber glass	100mL-1000mL	24 hours
Nitrate+Nitrite-N	Collected Water Sample	Biweekly	Surface water grab sample-SEAL Analytical EPA-114-A analysis method	Nutrient-free amber glass	20mL	28 days if stored at $4^{o}C$, 6 months if frozen
Total Phosphorus	Collected Water Sample	Biweekly	Surface water grab sample-SEAL Analytical EPA-119-A analysis method	Nutrient-free amber glass	20mL	28 days if stored at $4^{o}C$, 6 months if frozen
Dissolved Oxygen	Field Water Sample	Biweekly	Hach Hydrolab Quanta Sonde	N/A	N/A	N/A
Conductivity	Field Water Sample	Biweekly	Hach Hydrolab Quanta Sonde	N/A	N/A	N/A
Turbidity	Field Water Sample	Biweekly	Hach Hydrolab Quanta Sonde	N/A	N/A	N/A
pH	Field Water Sample	Biweekly	Hach Hydrolab Quanta Sonde	N/A	N/A	N/A
Temperature	Field Water Sample	Biweekly	Hach Hydrolab Quanta Sonde	N/A	N/A	N/A
Fish	Stream Reach	2 times (1^{st} and last year)	Backpack Electroshocker	N/A	N/A	<1hr
Macroinvertebrates	Stream Reach	2 times (1^{st} and last year)	Surber Sampler	500mL Nalgene	100-500mL	Up to 90 days
Mussel	Stream Reach	1 time	Buckets and rakes	N/A	N/A	N/A

Habitat	Stream Reach	1 time	QHEI Published Protocol	N/A	N/A	N/A
Stream flow	Field Sample	1 time	Sounding weights, type AA current meter and digitizer	N/A	N/A	N/A
Geolocation	Field sampling	1 time	Magellan Explorist 300	N/A	N/A	N/A

Biological and Physical Habitat Sampling

Fish, mussels and benthic macroinvertebrate samples will be collected. Specifically, a backpack electroshocker (ETS) will be used to sample fish from three replicate 100-m reaches within each sample site. Fish will be identified, measured, and released following processing, and the fish data will be used to calculate fish-based biological integrity measures (e.g., species richness, % intolerant species, and fish IBI). Macroinvertebrate samples will be collected using a D-frame benthic net (Wildco) scooped through submerged vegetation, riffles and other cover. Macroinvertebrate samples will be placed in 90% ethanol (EtOH) in the field and then later picked and sorted in the laboratory. Individual macroinvertebrates will be identified to the lowest practicable taxonomic level under magnification (primarily to Genus; Chironomidae (midges) will be identified to sub-family only). Biological integrity measures will be calculated based on the macroinvertebrate samples (e.g., taxa richness, % intolerant taxa, Family Biotic Index (Hilsenhoff 1988), mIBI). Physical habitat will be evaluated by the Project Director for Biological Sampling using the QHEI (Ohio Environmental Protection Agency 2006). Fish IBI and mIBI will be calculated using established IDEM procedures by ecoregion.

Stream Flow

Stream flow will be calculated one time using methods based on USFS methodology (Appendix J).

11.3 Site Description

A map is included as Figure 2.

11.4 Field QC Activities

Calibration of field equipment will be performed in the lab before each samlping event. Should the equipment be out of range, it will be recalibrated according to the manufacturer's procedure. Standard calibration solutions will be used to calibrate field meters. Calibration checks of lab analytical equipment will be performed before each sample analysis according to methods found in Appendices B-I.

12.0 Analytical Requirements

12.1 Analytical Methods

See Table 5 for a summary of the analysis procedures. Appendices B-I detail analysis methods to be used in Purdue's Soil Microbiology Laboratory.

Table 5: Analytical Procedures

Parameter	Analytical Method	Performance Range	Units
E. coli	IDEXX Colilert test method-SM 9223B, APHA:Section 9223	1-2,419.2	MPN/100mL
Total Suspended Solids	ASTM D5907-03	4-20,000	mg/L
Nitrate+Nitrite-N	SEAL Analytical AQ2 Discrete Analyzer-EPA method 353.2	0.25-15	mg-N/L
Total Phosphorus	SEAL Analytical AQ2 Discrete Analyzer-EPA method 365.1	0.005-1.0	mg-P/L
Dissolved Oxygen	Hach Hydrolab Quanta; SM 4500 O G	0-500 (as a percent) or 0-50	% or mg/L
Conductivity	Hach Hydrolab Quanta;; SM 2510A	1-200	mS/cm
pH	Hach Hydrolab Quanta;; SM 4500 H+	0-14	Units
Temperature	Hach Hydrolab Quanta;; SM 2550 B (2)	-5 to 70	^{o}C
Turbidity	Hach Hydrolab Quanta;; SM 2540 B	0-1000	NTU

12.2 Analytical QC Activities

Quality control will be achieved by strict adherence to written protocol. Quality control procedures are stated in more detail in Section 9 and in each individual analysis method in Appendices B-I. Lab blanks, field blanks, trip blanks, stock controls, matrix spikes and standard solutions will all be used to ensure high quality data (Table 6). The Water Chemistry and Bacteria Technician will be trained in proper sample handling techniques and how to perform *E. coli* and nutrient analysis on analytical equipment. Any other persons who work for the WCM Technician for this project will be trained and made aware of the requirements of this QAPP.

All field biological sample labels and field data sheets will be initialed by Project Director for Biological Sampling or a qualified designee following his/her approval of the sampling and preservation methods used. In the field, the numbers of samples and measures collected for each sampling site will be recorded on the field form. The Project Director for Biological Sampling or qualified designee will initial the field form to confirm the number of samples collected.

Field form and laboratory form data will be digitized by the Project Director for Biological Sampling or a qualified designee. Project personnel will initial each data sheet after the data have been digitized. After all data have been digitized, project personnel will check all digitized data against the original data sheets. Project personnel will initial data sheets to indicate that the digitized data and data sheets are in agreement. Any errors will be recorded and corrected. The Project Director for Biological Sampling or designee will verify data quality by checking digitized data against original data sheets for every third data sheet.

Table 6: Quality Control Procedures

Quality Control Procedure	Field	Laboratory	Frequency

Field Blank	Yes	Yes	Once per 20 samples collected
Lab Blank	No	Yes	Once per 20 samples collected
Trip Blank	Yes	Yes	Once per 20 samples collected
Stock Control	No	Yes	Once per sampling event
Matrix Spike	No	Yes	Once per analysis event
Standards	No	Yes	Once per analysis event

DATA GENERATION & ACQUISITION

13.0 Sample Handling and Custody Requirements

Field water chemistry samples will be labeled with a unique identification code and logged into a field data sheet (see Appendix B). Field data sheets will include site identification, sampling date and time, sampler name, sample parameters, and field meter results. Samples will be directly taken to the lab and analyzed, or stored properly for later analysis. Before leaving the field, field sheets will be checked to make sure everything is complete, properly filled out, and legible. Samples will be logged into a laboratory log sheet (Appendix B) as they are analyzed by the sampler. It will also be noted on the sheet when samples are discarded. Both paper and electronic versions of these completed forms will be stored in the Purdue University Soil Microbiology Laboratory. Because all samples will remain in custody of the organization performing the sampling, no chain of custody documentation will be needed. Biological and physical habitat field data sheets will be checked over and then maintained in the Purdue University Aquatic Ecology Laboratory. Macroinvertebrate samples will be signed in when brought in from the field, and resulting data sheets will be signed upon completion of processinng for each field sample. Physical data sheets (fish, macroinvertebrate, mussel, and physical habitat) will also be signed once they have been entered into Excel spreadsheets.

14.0 Testing, Inspection Maintenance and Calibration

Calibration of field equipment will be performed in the lab before each samlping event. Should the equipment be out of range, it will be recalibrated according to the manufacturer's procedure. Standard calibration solutions will be used to calibrate field meters. Calibration checks of lab analytical equipment will be performed before each sample analysis according to methods found in Appendices B-I.

ASSESSMENTS/OVERSIGHT

15.0 Assessment/Oversight/Data Quality Assessment & Decision Rules

15.1 Data Quality Indicators

Precision and Accuracy/Bias

Precision and accuracy will be maintained by adherence to protocol as stated in Section 3. Data quality controls outlined in the sections above will be sufficient to meet the objectives of the study. Data quality assessments conducted by Purdue University's Soil Microbiology Lab will be sufficient to meet the objectives of the project. Laboratory analysis of precision and accuracy checks, including control levels for duplicate and replicate samples and field and laboratory blanks, will be kept on file in the laboratory. All laboratory data will be assessed by Purdue University's Soil Microbiology Lab to determine if data quality falls within the required precision levels. The lab will follow established protocols to determine if data is valid. Any data that is determined to not meet laboratory quality control guidelines will not be reported or used for prioritization of implementation activities. All QA/QC measure for each run of samples will be included in the lab's final data analysis and will be included in IDEM reports.

Field measurements and biological and habitat data will be accepted as valid provided no significant problems occur during calibration and sampling. Field water chemistry measurements will be repeated if precision failures are observed (RPD>5%). Data that does not meet precision goals will not be included in sample analysis and subwatershed prioritization. The accuracy of field measurements and biological and habitat data will not be quantified. However, the data will be acceptable provided that no significant problems occurred during equipment calibration or sampling. Sampling will be rescheduled if problems occur during equipment calibration. Field measurements will be repeated if difficulties occur during sampling.

Completeness

Completeness will be determined as stated in Section 3. Should completeness goals not be met, data collected will still be considered valid. If completeness goals are not met, the watershed coordinator will inform the IDEM Project Manager. At the end of the study, it will be determined whether data collected is representative of the watersheds under investigation.

15.2 Corrective Action

Should problems be revealed, corrective actions will be taken based on the problem that occurs. Some actions that may be taken include the following: resterilizing bottles, acid washing bottles or glassware and baking at 400C to remove all nutrients, checking chemials for proper storage and expiration dates, checking incubators for temperature control, checking equipment for malfunction and calibration.

18.2 Validation & Qualifiers

Results that do not meet DQI limits as defined in Section 9 will be flagged by the Technician at time of data entry and analysis.

18.3 Reconciliation with User Requirements

For Data Qualifiers and Flags where estimations are required, the raw result will be used as an estimation of the true result. The reported result will be marked as estimated (J). If no estimations are needed and the data meets all DQIs, the data will be marked as accepted (A).

Data Qualifiers and Flags

R: Rejected
J: Estimated.
Q: One or more of the QC checks or criteria was out of control.
H: The analysis for this parameter was performed out of the holding time. The results will be estimated or rejected on the basis listed below:
  1) If the analysis was performed between the holding time and 1½ times the holding time the result will be estimated.
  2) If the analysis was performed outside the 1½ times the holding time window the result will be rejected.

D: The Relative Percent Difference (RPD) for this parameter was above the acceptable control limits. The parameter will be considered estimated or rejected on the basis listed below:
  1) If the RPD is between the established control limits and two times the established control limits then the sample will be estimated.
  2) If the RPD is twice the established control limits then the sample will be rejected.

B: This parameter was found in field or lab blank. Whether the result is accepted, estimated, or rejected will be based upon the level of contamination listed below.
  1) If the Sample result is greater than the reporting limit but less than five times the blank contamination the result will be rejected.
  2) If the Sample result is between five and ten times the blank contamination the result will be estimated.
  3) If the Sample result is less than the Reporting limit or greater than ten times the Blank contamination the result will be accepted.
  4) If the Sample result is < 10 times the Reporting limit then the result will be flagged (J+) as estimated high. In other words it is usable but the result is probably biased high.

U: The result of the parameter is above the Method Detection Limit (MDL) but below the reporting limit and will be estimated.
L: The result of the parameter is below the detection limit and will be rejected. Any RPD calculated using this result will not be valid
A: Accepted

18.4 Modeling or Statistical Methods Used

Calculations and statistics required to measure these results against previously collected data in a paired watershed analysis will also be utilized.

19.0 Reports to Management, Documentation, Records

Field sheets will be inspected before leaving each sample site. RPD will be calculated once back in the lab and all data analyzed for that site. Calibration logs will be kept in a notebook in the lab.

Data review will be done by the WCM Technician. Raw data sheets will be reviewed prior to leaving sample site. Data will be entered into a spreadsheet or other similar program and reviewed at that time. The WCM Technician will review all data collected in the field. It will be reviewed for completeness. The Project Director for Water Sampling will also review field sheets and check data sheets for completeness against the field sheets.

19.1 Data Reporting

Data will be transmitted in a suitable format such as Microsoft Excel, Access or other compatable software. All raw data and data analysis results generated as part of this grant project will be submitted in an electronic format with the Final Report to the IDEM Project Manager or Quality Assurance Manager. The format will be compatible with the software currently used by IDEM. At a minimum, the file will contain the project name, sample name, site number, site description, date, time, sample matrix, results, units, detection limits, latitude, longitude, and quality control comments in addition to analytical results.

19.2 Data Management

Include databases, models, format (date, time, staff, parameters, units, methods, results), data qualifyers, QC samples, unique group number, sample numbers, site number, locational information, results, and data quality assessment level (shown below). Provide hard copy and electronic copy of QAPP to IDEM. The documentation should include: sample number, site number, latitude, logitude, medium, purpose for collection, method used to obtain latitude & logitude, date, time, parameter, units, results, analytical method, detection limit, data quality assessment level, qualifiers.

19.3 Quality Assurance Reports

Quality Assurance (QA) reports will be submitted to IDEM's Watershed Management Section every three months as part of the Quarterly Progress Report and/or Final Report. Any problems that are found with the data will be documented in the quarterly reports. Quality assurance reports will include any quality control problems encountered, the actions taken, and any effect these problems had on data.

20.0 References

Harrelson, Cheryl C; Rawlins, C. L.; Potyondy, John P. 1994. Stream channel reference sites: an illustrated guide to field technique. Chapter 10: Measuring Discharges. Gen. Tech. Rep. RM-245. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.

Hoggatt, R.E. 1975. Drainage areas of Indiana streams. Report prepared by the U.S. Geological Survey, in cooperation with the State of Indiana Department of Natural Resources.

IDEM. 2008. Indiana's 2008 303(d) List of Impaired Waters. Available at: http://www.in.gov/idem/4680.htm. Last accessed October 27, 2008.

Myers, D., and F. Wilde. 2003. Chapter A7 Biological Indicators, Techniques of Water-Resource Investigation Report No. 09-A7, 3rd edition, U.S. Geological Survey.

Runkel, R.L., Crawford, C.G., and Cohn, T.A., 2004, Load Estimator (LOADEST): A FORTRAN Program for Estimating Constituent Loads in Streams and Rivers**:** U.S. Geological Survey Techniques and Methods Book 4, Chapter A5, 69 p.

21.0 Appendices

Appendix A: Volunteer Monitoring QAPP

1. Hoosier Riverwatch Program

Hoosier Riverwatch is a program sponsored by the Indiana Department of Natural Resources (DNR). Participants are trained in workshops and provided basic chemical analysis kits and data forms. Hoosier Riverwatch sampling will be conducted as part of the education and outreach and monitoring portions of the current watershed management planning effort. Sampling will be completed only by trained volunteer monitors and will be coordinated by the volunteer coordinator. Sampling is planned to occur at the 12 biological monitoring sites throughout the target watershed no less than quarterly. Sampling is scheduled to begin upon approval of the QAPP and will continue on a quarterly basis through January 2016. Sampling at additional sites or more often than quarterly may occur depending upon requests and interest from the public.

Each sampling event will include all four Hoosier Riverwatch monitoring areas including: habitat evaluation, chemical monitoring, biological monitoring, and stream flow calculation. Sampling will follow the Hoosier Riverwatch sampling protocols and procedures as found in the handbook *Volunteer Stream Monitoring training Manual* (Hoosier Riverwatch, 2012). Chemical parameters will include: dissolved oxygen, pH, temperature, temperature change, orthophosphate, nitrate, nitrite, and turbidity. Biological oxygen demand and *E. coli* bacteria may be included as well.

Sampling will occur quarterly as possible by volunteer monitors and will be coordinated between sites as possible. Sampling will not occur on the same date and time as professional monitoring. Additionally, sampling will be independent of rain events with sampling to be rescheduled if unsafe, high flow conditions occur. All samples will be collected and analyzed by Hoosier Riverwatch volunteers at the site where collected using Hoosier Riverwatch methods. If biological oxygen demand and *E. coli* bacteria are collected, they will be analyzed on the date samples are collected by one volunteer monitor. Macroinvertebrate sampling will be randomly scheduled and should occur no less than once in the fall and once in the spring with the anticipation that monitoring will occur quarterly. All data will be entered into the Hoosier Riverwatch electronic database within one week of the monitoring session.

Volunteer Study Schedule

Summer 2012	Riverwatch volunteer coordination begins
Summer 2012	Sample sites and volunteers identified
Summer 2012	Hoosier Riverwatch volunteer training, if needed
QAPP Approval – Jan. 2016	Quarterly sampling occurs
QAPP Approval – Jan. 2016	Volunteer coordination continues

2. Hoosier Riverwatch Organization and Personnel

Personnel

Jessica Fulgoni, Wabash River Enhancement Corporation
200 N. 2nd Street
Lafayette, Indiana 47906
Phone: 269-377-5418 email: jfulgoni@lafayette.in.gov

Hoosier Riverwatch Project Organization

The volunteer coordinator is responsible for coordinating volunteer monitoring efforts within the Deer Creek – Sugar Creek watershed.

- The volunteer coordinator will lead implementation of the Hoosier Riverwatch volunteer monitoring program.
- The volunteer coordinator will rely on local Hoosier Riverwatch trainers, as possible, and/or will become trained to conduct Hoosier Riverwatch training.
- The volunteer coordinator and all volunteers will follow Hoosier Riverwatch procedures including entering data directly into the Hoosier Riverwatch database. The coordinator will include volunteer data in the final watershed management plan.
- Volunteers will be identified to conduct monitoring at primary sites which are anticipated to correspond with professional biological monitoring program sites. Volunteers may choose to monitor other sites and will provide copies of datasheets to the volunteer coordinator for record-keeping purposes.

3. Data Quality Objectives

Precision, Accuracy, and Completeness

Hoosier Riverwatch standards for quality assurance and quality control will be in effect for this monitoring program. Only data collected by trained Hoosier Riverwatch volunteers will be accepted. Data quality objectives are listed in Table 1. Precision, accuracy, and completeness goals will be met when volunteers do as follows:

- Collect the water samples as directed
- Rinse bottles and tubes with sample water before collecting the water sample and with distilled water after completing the test.
- Perform tests immediately after collecting the water sample unless directed otherwise.
- Calibrate, use, and maintain the testing equipment according to guidelines provided.
- Follow the specific directions of a testing protocol exactly as described.
- Repeat measurements to check for accuracy.
- Analyze duplicates for quality control.
- Minimize contamination of stock chemicals and testing equipment.
- Store kits away from heat and sunlight.
- Check expiration dates on chemicals and replace supplies as needed.
- Check to be sure results submitted via the Hoosier Riverwatch database are the same as those recorded on the data sheets.

Table 1. Date quality objectives.

Parameter	Precision	Accuracy	Completeness
Dissolved oxygen	1 duplicate sample per quarter	Test distilled water as a blank; add oxygen by blowing into water through a straw and check again	All sites sampled quarterly June 2009 through December 2010
Biological oxygen demand	1 duplicate sample per quarter	1 blank (distilled water)	All sites sampled quarterly June 2009 through December 2010
E. coli bacteria	3 samples (each 3-5 ml or less if after rainfall) One duplicate sample per quarter	1 blank (distilled water)	All sites sampled quarterly June 2009 through December 2010
pH	1 duplicate sample per quarter	1 neutral solution test	All sites sampled quarterly June 2009 through December 2010
Water temperature/ temperature change	2 readings averaged at testing sites; 2 readings averaged one mile upstream	Temperature will be taken at both sites not more than 2 hours apart.	All sites sampled quarterly June 2009 through December 2010
Orthophosphate	1 duplicate sample per quarter	1 blank (distilled water)	All sites sampled quarterly June 2009 through December 2010
Nitrate/nitrite	1 duplicate sample per quarter	1 blank (distilled water)	All sites sampled quarterly June 2009 through December 2010
Turbidity	3 readings at one testing site averaged. One duplicate sample per quarter	Samples must be taken in representative stream flow	All sites sampled quarterly June 2009 through December 2010
Benthic macroinvertebrates	3 samples from different locations in a 200 ft stream reach in a variety of habitats. One duplicate sample per quarter	3 minute kick seine technique or 20 dip net jabs at each location	Minimum of 2 monitoring events at each site (30 minutes collecting and identifying macroinvertebrates during each event)

Representativeness

Sampling is planned to occur at the biological monitoring sites to capture indicators from each of these subwatersheds. Results of these sites will be representative of general water quality within each subwatershed and will help to identify areas of concern.

Comparability

Results from this monitoring program will be comparable with results obtained by other Hoosier Riverwatch volunteers across the state. Some of the volunteer sites may correspond with professional monitoring sites as well and will be compared with results from these sites for accuracy.

Sensitivity

Sensitivity of field measurements will be the detection limits listed in Table 3.

4. Hoosier Riverwatch Sampling Procedures

Sampling procedures are described in the Hoosier Riverwatch program manual *Volunteer Stream Monitoring Training Manual* (Hoosier Riverwatch, 2012). Chemical parameters will be tested using the equipment provided by Hoosier Riverwatch. Although training of all volunteers is not yet complete, it is assumed that volunteers will utilize the following methodologies. Methods include: CHEMetrics phosphate and dissolved oxygen test kits, WaterWorks test strips for nitrate and pH, Coliscan Easygel by Microbiology Laboratories, Inc. for *E. coli* sampling, and a turbidity tube for turbidity measurements. Sampling procedures are detailed in Table 2. Habitat quality will be quantified using the Citizens Qualitative Habitat Evaluation Index (CQHEI). The macroinvertebrate community will be sampled using a kick seine or dip net technique as detailed in the Hoosier Riverwatch manual.

Table 2. Sampling procedures.

Parameter	Sample Matrix	Sampling Frequency	Sampling Method	Sample Container	Sample Volume	Holding Time
Dissolved oxygen	Rinse 25 ml collection container 3 times; collect sample water 3-5 inches below surface in thalweg	Quarterly 6/09-3/11	CHEMetrics Dissolved Oxygen kit K-7512	CHEMet ampoule	25 ml	N/A
Biological oxygen demand	Rinse black bottle collection container three times; collect water and cap bottle 3-5 inches below water surface in thalweg	Quarterly 6/09-3/11	CHEMetrics Dissolved Oxygen Kit K-7512	Black bottle and CHEMet ampoule	25 ml	N/A
E. coli bacteria	Use sterile pipettes to collect samples from main stream flow; put 3-5 ml of sample water in Easygel bottle immediately	Quarterly 6/09-3/11	Coliscan Easygel solution bottles from Micrology Labs.	Petri dishes from incubated at 35C for 24 hours	3-5 ml placed in each Petri dish	Samples will be plated within 8 hours
pH	Rinse collection container 3 times; collect sample water 3-5 inches below surface in thalweg	Quarterly 6/09-3/11	WaterWorks pH TestStrips #481104	Plastic cup	3 ounces	N/A ; Complete test within 2 minutes
Water temperature/ change	Take water temperature in thalweg at each site	Quarterly 6/09-3/11	Thermometer	N/A	N/A	N/A
Orthophosphate	Rinse 25 ml collection container three times; collect sample water 3-5 inches below surface in thalweg	Quarterly 6/09-3/11	CHEMetrics Phosphate Kit K-8510	CHEMet ampoules	25 ml	N/A ; Complete test within 5 minutes
Nitrate/nitrite	Rinse collection container three times; collect sample water 3-5 inches below surface in thalweg	Quarterly 6/09-3/11	WaterWorks Nitrate/Nitrite Test Strips #480009	Plastic cup	3 ounces	N/A ; Complete test within 2 minutes
Turbidity	Rinse tube with sample water. Collect	Quarterly 6/09-3/11	Riverwatch turbidity tube	Bucket and	Varies	N/A

	samle in bucket and pour into tube until the bottom symbol is not visible then release water until symbol appears. Convert to NTU using manual pg 52.		method (pg 51-52 Hoosier Riverwatch manual)	turbidity tube		
Flow	Single cross stream measurement	Quarterly 6/09-3/11	Riverwatch flow method	N/A	N/A	N/A
Benthic macroinvertebrates	3 samples collected at 3 sites in 200 ft reach	Quarterly 6/09-3/11	3 minute kick seine technique or 20 dip net jabs at each location in a variety of habitats	Minimum of 30 minutes spent collecting and identifying	N/A	N/A

5. Hoosier Riverwatch Custody Procedure

Most samples will not be transported to other locations, rather sampling will occur immediately followed by analysis by the sample collector. If biological oxygen demand and/or *E. coli* sample analyses are included as part of the sampling program, these analyses will be completed off-site by the volunteer coordinator. In this case, volunteers will deliver samples to the volunteer coordinator on ice and with collection times recorded on the sample containers. Chain of custody forms will be signed by the volunteer coordinator prior to accepting the *E. coli* or BOD sample(s). The volunteer coordinator will store the samples on ice until analysis can occur. All analyses will occur within the holding time.

6. Hoosier Riverwatch Calibration Procedures and Frequency

No equipment requires calibration.

7. Hoosier Riverwatch Sample Analysis Procedures

Water quality monitoring will follow the sample analysis procedures defined in the Hoosier Riverwater monitoring manual. Analytical procedures for the specific tests are noted in Table 3.

Table 3: Analytical procedures

Parameter	Analytical Method	Performance Range	Units
Dissolved oxygen	CHEMetrics DO Kit K-7512	Range: 5.4-14.2 mg/L; IN avg: 9.8 mg/L	mg/L
Biological Oxygen Demand	CHEMetrics DO Kit K-7512	Range: 0-6.3 mg/L; IN avg: 1.5 mg/L	mg/L
E. coli	Coliscan easygel solution bottles and Petri dishes	Range: 1-1157 col/100 mL; IN avg: 645 col/100 mL	Colonies/100 mL
pH	WaterWorks pH test strips #481104	Range: 7.2-8.8; IN avg: 8.0	pH units
Water temperature change	Thermometer	State standard: < 5 degrees change	Degrees
Orthophosphate	CHEMetrics phosphate kit K-8510	None	mg/L
Nitrate	WaterWorks nitrate/nitrite test strips #480009	Range: 0-36.08 mg/L; IN avg: 12.32 mg/L	mg/L
Turbidity	Turbidity tube	Range: 0-173 NTU; IN avg: 36 NTU	NTU
Macroinvertebrates	3 samples at 3 locations in 200 ft; 3 minute kick seine or 20 dip net jabs	Pollution Tolerance Index range: 0-23	PTI

8. Hoosier Riverwatch Quality Control Procedures

Volunteers will be trained and instructed to follow Hoosier Riverwatch procedures as defined in the monitoring manual. All but two of these tests are done in thefield (Table 4). The volunteer coordinator will assist volunteers with all test procedures and questions as they arise.

Table 4: Quality Control Procedures

Quality Control Procedure	Field (Yes/No)	Off Site (yes/no)	Frequency (minimum)
Dissolved oxygen	Yes	No	12 sites quarterly
Biological Oxygen Demand	No	Yes	12 sites quarterly
E. coli	No	Yes	12 sites quarterly
pH	Yes	No	12 sites quarterly
Water temperature change	Yes	No	12 sites quarterly
Orthophosphate	Yes	No	12 sites quarterly
Nitrate	Yes	No	12 sites quarterly
Turbidity	Yes	No	12 sites quarterly
Macroinvertebrates	Yes	No	12 sites quarterly

9. Hoosier Riverwatch Data Reduction, Analysis, Review, and Reporting

Results will be entered into the Hoosier Riverwatch database by the volunteer coordinator and trained Riverwatch volunteers. Sampling results will be submitted to IDEM 319 grant managers in access or excel including sample number, project name, site number, date, sample matrix, method, results, units, detection limit, latitude, longitude, and quality control comments. The volunteer coordinator will review and analyze the results and prepare a final report on monitoring activities as part of the grant project. This report will include complete results for each parameter tested.

10. Hoosier Riverwatch Performance and System Audits

All data worksheets will be kept on file by the volunteer coordinator and available for review by IDEM staff. All data will be reported online to the Hoosier Riverwatch database which is open for public access. The volunteer coordinator will contact each volunteer during the monitoring timeframe to discuss any questions or problems. IDEM reserves the right to conduct external performance and/or system audits of any component of this study.

11. Hoosier Riverwatch Preventative Maintenance

After each use, the volunteer coordinator will check the equipment. Any missing or expired chemicals or damaged equipment will be replaced prior to the equipment's next use.

12. Hoosier Riverwatch Data Quality Assessment

The volunteer coordinator and volunteers together will review all data sheets before submitting results to Hoosier Riverwatch. Precision, accuracy, and completeness will be covered in this review process. If data is not within typical ranges or is incomplete, it will not be entered into the Hoosier Riverwatch database.

13. Hoosier Riverwatch Corrective Action

The volunteer coordinator will determine if corrections are needed to ensure the success of the monitoring program. If the coordinator feels that changes are needed to meet the program objectives, proposed changes will be submitted first to the IDEM project manager for approval prior to implementation. The coordinator will also be in contact with volunteers at least once quarterly. Additionally, all volunteers will be part of the monitoring subcommittee to ensure that the volunteers get the feedback necessary to make the monitoring program successful.

14. Hoosier Riverwatch Quality Assurance Reports

Quality Assurance reports will be submitted to IDEM's watershed management section as part of the quarterly progress reports and/or final report.

The QA report will include:

- Assessment of the data in terms of accuracy, precision, and completeness;
- Results of any performance audits performed during the quarter;
- Any significant quality control problems encountered and the recommended solutions;
- Discussion of whether the QA objectives are being met and the resulting impacts on decision-making; and
- Any limitations on the use of the data.

15. Hoosier Riverwatch References

Hoosier Riverwatch. 2012. Volunteer Stream Monitoring Training Manual. Indiana Department of Natural Resources, Indianapolis, Indiana.

Appendix B: Sample Log Sheets

Water Chemistry and Bacteria Monitoring of the Lafayette-West Lafayette Reach of the Wabash River Watershed

Purdue University Soil Microbiology Laboratory

Field Data sheet

Date/Time: ______ Site ID: ______

Collection made by: ______

Weather Conditions, Notes and Other Observations: ______

Field Blank Collected: ______ Trip Blank Collected: ______

Sample ID	**Notes**

Meter Results:

Dissolved Oxygen (mg/L)	
Conductivity (mS/cm)	
pH (units)	
Temperature (ºC)	
Turbidity (NTU)	

Initials of person filling out form: ______

Water Chemistry and Bacteria Monitoring of the Lafayette-West Lafayette Reach of the Wabash River Watershed

Purdue University Soil Microbiology Laboratory

Lab Bench Sheet

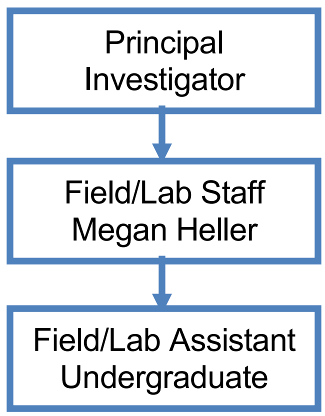
Date / Time In	Sample ID	Analysis Performed	Date / Time Out	Notes	Initials

Appendix C: Colilert Test Method Standard Operating Procedure

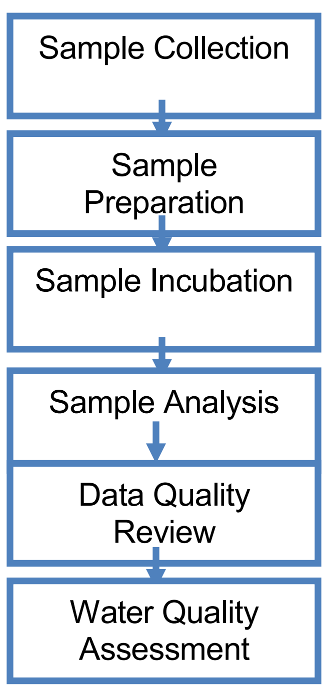
This method is modified from the Colilert Test Method provided by IDEM.

1. Scope and Application, Matrix
    a. Colilert is used for the simultaneous detection, specific identification, confirmation and quantification of total coliforms and *E. coli* in water.
    b. Colilert may be used for drinking water, pool water, surface water and bottled water, and it can be used as a pass or fail (presence/absence) test without Quanti-Trays or a quantification test using Quanti-Trays.
    c. Colilert may be performed in a fixed or mobile laboratory setting. The mobile laboratory setting requires a standard outside AC electrical outlet and/or and AC/DC power inverter powered by a DC battery or DC battery pack.
2. Summary of Method, Detection Limit
    a. Total coliforms and *E. coli* are specifically and simultaneously detected and identified at 1 MPN (Most Probable Number)/100mL (1 MPN/100mL is equivalent to 1 CFU/100mL) of sample in 24 hours or less by inoculating the reagent with the water sample and incubating it. Samples may be quantified using Quanti-Trays with a range of 1 MPN/100mL to 2419.2 MPN/100mL or 10 MPN/100mL to 24192 MPN/100mL if a 1:10 dilution is performed. No further sample manipulation or testing is necessary.
3. Comments
    a. Avoid prolonged exposure of Colilert to sunlight because it may cause a false positive in the sample.
    b. Shake sample thoroughly before inoculation with reagents
    c. Do not transfer colonies or cultures pre-grown in any enrichment media to Colilert, suppressant reagents may be overloaded by transferring heavy inocula of certain non-coliforms. This does not apply to dilute pure cultures used in controls.
    d. Do not pre-filter sample and place the membrane in Colilert.
    e. Do not dilute sample in buffered water for addition to Colilert; samples may be diluted with sterile laboratory pure water.
    f. Colilert training will be provided by the United States Geological Survey Ohio Water Microbiology Laboratory to the laboratory technician. Any other persons requiring training in the future will be taught by the laboratory technician. Training will consist of reading this document and field and laboratory demonstrations of the proper Colilert methods. The training is finalized by the trainee’s demonstration of proficiency in the field and in a fixed and/or mobile laboratory by actual successful water sample collection and analysis under direct supervision of the trainer.

g. Water sample are collected according to a suitable method capable of meeting or exceeding the performance requirements of this test method. A log will be maintained in the laboratory to keep track of all samples.
h. Both electronic data if applicable and hardcopy data are accurately and continuously maintained, so all data fields are occupied. All data are readily available and saved for a minimum of 2 years. Electronic data are stored on a secure Purdue University hard drive. Hardcopy data are stored in the Purdue Agronomy Soil Microbiology Laboratory.
i. Any disposable material coming into contact with culture media is discarded in a special biohazard trash receptacle. These special biohazard trash receptacles are routinely picked up by Purdue Radiological and Environmental Management and are properly disposed of in accordance with applicable local, state and federal laws.
j. Roles and Personnel



k. Process



4. Equipment and Materials
    a. Incubator set at 35.0°C +/- 0.5°C
    b. Long wavelength ultraviolet lamp (365nm)
    c. Sterile, non-fluorescent container
    d. Thermometer
    e. IDEXX sealer with rubber template
    f. Sanitizer
    g. Paper towels
    h. Biohazard trash receptacle
    i. Sterile 10mL pipet with pipet pump or bulb
    j. Sterile deionized water
    k. Laboratory bench sheets and/or electronic equivalent
    l. Sterile gloves
5. Reagents, Cultures and Culture Media
    a. Colilert reagent packet (Snap Pack) for 100mL sample
    b. Procedural controls if applicable
6. Procedure
    a. Before starting any laboratory work, put on gloves and then sanitize self and all laboratory bench tops. For a mobile laboratory setting, plug in vehicle to an electrical outlet if at a hotel or similar location or turn on AC/DC power inverter if an electrical outlet is unavailable. Turn on incubator if not already on.
    b. Remove samples from cooler, place on bench and allow to warm
    c. Log samples into laboratory bench sheets and/or electronic equivalent using sample identification.
    d. If using sample container as culture flask for the presence/absence test, shake sample container approximately 20 times or about 30 seconds and adjust sample volume to 100mL if needed. If a separate container is required, then number container with lab number.
    e. Separate one Colilert Snap Pack from the strip taking care not to accidentally open the pack, or the adjacent one.
    f. Tap the Colilert reagent snap pack to ensure that all the powder is in the bottom of the pack.
    g. Snap open the pack at the score line at the top of the pack. Do not touch the top of the pack.
    h. Aseptically add the contents of the Colilert Snap Pack to the culture container (sample bottle), cap and seal; shake the container approximately 20 times or about 30 seconds to thoroughly mix the sample and reagent. Further dissolution will occur with incubation.
        i. If performing an MPN by Quanti-Tray:
        ii. Turn on the Quanti-Tray Sealer to preheat. Green light indicates ready status.

iii. Prepare a dilution if sample is excessively turbid (>50 NTU) or known to have high *E. coli* counts based on recent collection efforts. .
iv. Label all Quanti-Trays with the lab number and dilution if applicable.
v. Pour the sample or diluted sample containing the Colilert into the properly labeled Quanti-Tray.
vi. Press the Run button to seal the Quanti-Tray.

i. Incubate sample/reagent mixture at 35.0^{o}C +/- 0.5^{o}C for 24 hours.
j. Read the reaction at 24 hours. If yellow color is seen, check for fluorescence. Samples, which are indeterminate, may be incubated for an additional 4 hours for a total of 28 hours of incubation. Color should be uniform throughout the container. If not, mix by inversion before reading.

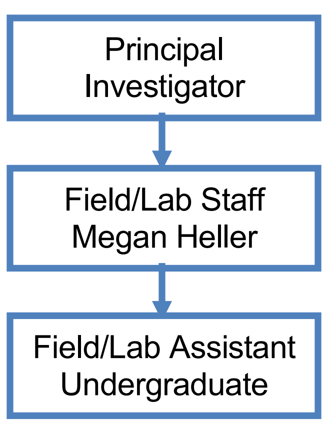
7. Interpretation
   a. Check yellow tests for fluorescence, which would indicate the presence of *E. coli.*
   b. For quantification, count the number of large yellow wells and small yellow wells that fluoresce for *E. coli.*
   c. Use the chart accompanying the Quanti-Tray containers or an approved adaptation of this chart to determine the results of MPN/100mL for *E. coli*. Record these values on laboratory bench sheet, lab notebook and/or electronic equivalent.
   d. If there is ever a question about this test method, then consults IDEXX.
8. Quality Control
   a. Procedural controls consist of:
      i. Blanks consisting of DDW will be run with each set of samples
9. References

   a. “Colilert Product Brochure,” IDEXX Laboratories, One IDEXX Drive, Westbrook Maine, 04092, 2002.
   b. “Colilert Test Method”, Indiana Department of Environmental Management, 100 N. Senate Ave, Indianapolis, Indiana, 46204, 2008.
   c. Standard Methods for the Examination of Water and Wastewater, 20th Edition, Natural Bathing Beaches, Method 9213 D., 1998.
   d. Standard Methods for the Examination of Water and Wastewater, 20th Edition, Enzyme Substrate Test, Method 9223 B., 1998.

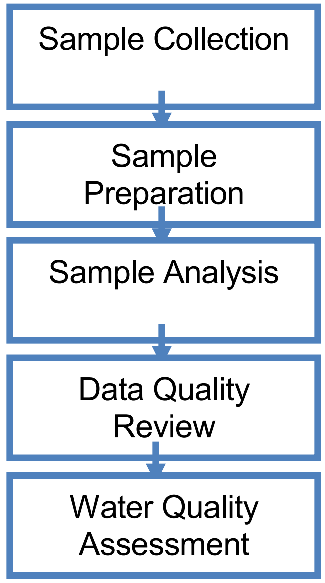
Appendix D: Total Suspended Solids Standard Operating Procedure

This method is modified from ASTM D5907 Standard Test Method for Filterable and Nonfilterable Matter in Water.

1. Scope and Application, Matrix
    a. This method may be used to determine the amount of non-filterable (total suspended solids – TSS) in water.
    b. This method may be used for drinking, surface and saline waters, domestic and industrial waste waters.
    c. This method may be performed in a laboratory setting.
2. Summary of Method, Detection Limit
    a. Suspended solids in a water sample of known volume are retained on a 1.5um filter of known weight. This filter is dried at $105^{o}C$ and weighed. The difference in weight is equal to the amount of TSS. The range of detection for TSS is between 4 and 20,000 mg/L.
3. Comments
    a. This method is only meant to include particulates. Leaves, sticks, insects, fish, etc should be removed before analysis.
    b. Due to the nature of some materials, they may not be measured correctly. Such substances include glycerin and sulfuric acid which remain liquid at room temperature.
    c. Algae or very fine particles may increase the filter time by plugging the filter. This may affect the results.
    d. Water sample are collected according to a suitable method capable of meeting or exceeding the performance requirements of this test method. A log will be maintained in the laboratory to keep track of all samples.
    e. Both electronic data if applicable and hardcopy data are accurately and continuously maintained, so all data fields are occupied. All data are readily available and saved for a minimum of 2 years. Electronic data are stored on a secure Purdue University hard drive. Hardcopy data are stored in the Purdue Agronomy Soil Microbiology Laboratory.
    f. Roles and Personnel



g. Process



4. Equipment and Materials
    a. Laboratory bench sheets and/or electronic equivalent
    b. Glass fiber filters-binder free-Whatman 934-AH 1.5um or equivalent
    c. Membrane filter assembly
    d. Aluminum pan
    e. Drying oven set at 105°C
    f. Analytical balance capable of measuring to the nearest 0.1mg
5. Reagents, Cultures and Culture Media
    a. Distilled Deionized Water (DDW)
6. Procedure
    a. Prepare the glass fiber filters
        i. Place the filter on the assembly.
        ii. With the vacuum applied, rinse filter with three successive rinses. Each rinse should be equal to 3mL DDW per square centimeter of filterable surface area. For 35mm filterable area filters, use 30mL per wash.
        iii. Do not combine total volume into a single rinse. This is not as effective as three separate rinses.
        iv. Throw out the rinses once all water has been removed from the filter
        v. Carefully remove the filter with forceps and place in labeled aluminum pan
        vi. Place pan and filter in 105°C oven for one hour.
        vii. Once dry, pan and filter should only be handled with forceps, tongs, or lint-free gloves.
        viii. Remove from oven and place in a desiccator until completely cool.

ix. When cool, weigh pan and filter to the nearest 0.1mg just before use.

b. Determine proper sample volume
   i. For standard filters with 35mm filterable area, begin with 100mL of sample. If 2.5mg of dry solids is not caught by the filter, increase the volume until you get 2.5 – 200mg of dry matter. Do not exceed 200mg.
      1. If other size area filters or filter apparatus' are used, use a volume of sample equal to $10mL/cm^2$ of filterable area.
   ii. If filtering time exceeds 5 minutes, follow Break-Point Determination steps below.
      1. Place filter on apparatus. Filter and time a known volume of sample.
      2. Repeat the above step with increasing volumes of sample until filtration rate rapidly drops off.
      3. Plot time on x-axis and volume on the y-axis. Choose the volume to filter based off of the time. This should be the time just before the rate drops off.
      4. If less than 2.5mg of is retained by the filter, a larger diameter filter may need to be used.
      5. If 20mL or less of sample is to be filtered, dilute sample in 100 – 1000mL of water. Do not pipet as the tip can act as a filter.
c. Assemble filter apparatus
d. Mix the sample well and pour into a graduated cylinder. Measure the volume. Pour this known volume into the filter assembly with suction applied until all liquid has passed through.
e. Wash the graduated cylinder, filter apparatus, and filter with three separate rinses of water. For 35mm filterable area filters, use about 20mL per wash. For other filters, use $2mL/cm^2$ filterable area. Discard washed water when done.
f. Once the filter is dry, remove it using forceps and place in original pan.
g. Dry for at least 1 hour at 105^oC or until constant weight is achieved.
   i. Constant weight is achieved when there is a 0.5mg difference or less between weight checks. A 4% difference may also be used, whichever is greater.
h. Once dry, place in a desiccator until cool. Weigh to the nearest 0.1mg.

7. Interpretation
   a. Calculate Total Suspended Solids as follows in mg/L:

$$= \frac{(\text{mg of residue + filter}) - \text{mg of filter}}{\text{mL of sample filtered}} \text{ X } 1000$$

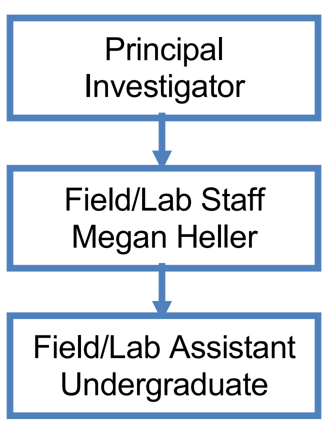
   b. Report values to the nearest milligram.

8. Quality Control
   a. Procedural controls consist of running one blank with each batch of samples.
   b. Each DDW blank will be taken through the same procedure stated above.
   c. Blanks may decrease in mass by about 0.2mg. If a weight increase or mass loss greater than 0.4mg occurs, samples in the batch will be rerun.
9. References
   a. ASTM International, Standard Test Method for Filterable and Nonfilterable Matter in Water, Method D5907 – 03, 2003.

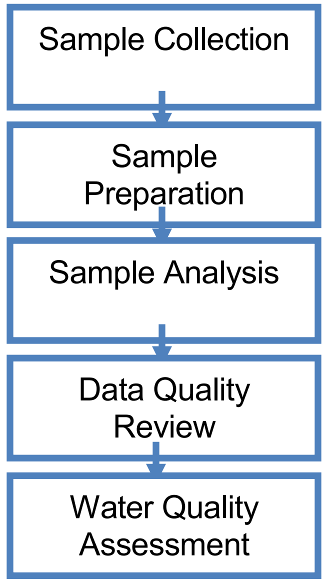
Appendix E: Nitrate-N + Nitrite-N Standard Operating Procedure

This method is modified from SEAL Analytical, Nitrate-N + Nitrite-N in Drinking and Surface Waters, and Domestic and Industrial Wastes.

1. Scope and Application, Matrix
    a. This method may be used to determine the amount of nitrate and nitrite ions in samples.
    b. This method may be used for drinking and surface water, and industrial and domestic wastes.
    c. This method may be performed in a laboratory setting.
2. Summary of Method, Detection Limit
    a. Copperized cadmium reduces nitrate to nitrite. Nitrite reacts with sulfanilamide, which, in the presence of a dilute phosphoric acid, combines with N-(1-naphthyl)-ethylenediamine dihydrochloride to form a reddish purplish azo dye. This is measured spectrophotometrically. Detection limit for this method is 0.03mg N/L.
3. Comments
    a. Training will be provided by a technician experienced with using the SEAL Analytical machine.
    b. Samples should be filtered before analysis to remove turbidity.
    c. Samples should be analyzed as soon as possible after collection.
    d. If it is not possible to run samples after collection samples should be kept at 4^{o}C for up to 28 days or frozen for up to 6 months.
    e. Water sample are collected according to a suitable method capable of meeting or exceeding the performance requirements of this test method. A log will be maintained in the laboratory to keep track of all samples.
    f. Both electronic data if applicable and hardcopy data are accurately and continuously maintained, so all data fields are occupied. All data are readily available and saved for a minimum of 2 years. Electronic data are stored on a secure Purdue University hard drive. Hardcopy data are stored in the Purdue Agronomy Soil Microbiology Laboratory.
    g. Roles and Personnel



h. Process



4. Equipment and Materials
   a. Laboratory bench sheets and/or electronic equivalent
   b. Analytical balance
   c. Properly prepared glassware
   d. SEAL Analytical machine
   e. Filters
5. Reagents
   a. Deionized Distilled Water (DDW)
   b. Dilute hydrochloric acid solution: 90 parts water with 10 parts HCl.
   c. Copper (II) Sulfate: Dissolve either 20g of copper (II) sulfate anhydrous or 31.3g copper (II) sulfate pentahydrate in about 800mL of DDW. Bring to 1L volume
   d. Triton X-100: First weigh 25g Triton X-100 (neat liquid) into a separate weigh boat. In a 250mL container, add about 200mL DDW and stir while slowly adding the Triton X-100. Dilute to 250mL volume once dissolved.
   e. Ammonium chloride buffer stock pH 8.5: Under a fume hood, dissolve 134.2g ammonium chloride and 1.2g ethylenediaminetetraacetic acid, disodium salt hydrate in about 800mL of DDW. Using a concentrated ammonium hydroxide solution (or 10% w/v sodium hydroxide), adjust pH to 8.5. Dilute to 1L with DDW.
      i. Because ACS grade ammonium chloride may contain nitrate contamination, an alternative to the buffer stock is as follows: Under a fume hood, carefully add 210mL concentrated hydrochloric acid, 164mL concentrated ammonium hydroxide and 1.2g ethylenediaminetetraacetic acid to about 500mL DDW. Adjust pH to 8.5 with concentrated ammonium hydroxide. Dilute to 1L with DDW.

f. Working buffer: Add 0.25mL of Triton X-100 solution to 100mL of ammonium chloride buffer and mix.
g. Sulfanilamide-NEDD reagent: To about 300mL of DDW, carefully add 10mL of concentrated phosphoric acid. To that add 7.5g sulfanilamide and 0.375g N-(1-naphthyl)-ethylenediamine dihydrochloride and dissolve. Before adding ammonium chloride buffer, test a small volume to make sure the solution does not turn pink. Add 156mL of buffer if test batch does not turn pink. Fill volume to 500mL with DDW. Store for 1 month at $4^{o}C$ unless a pink color develops. Filter the reagent at time of use for best results.

6. Procedure
    a. Preparation of Glassware
        i. All glassware should first be rinsed in the dilute HCl solution, and then rinsed with DDW. Glassware may be soaked overnight in a 50% HCl bath
        ii. Prepped equipment will be stored in an area where it will not be contaminated and should only be used for nutrient analysis
    b. Standard Preparation
        i. To prepare standard stock solutions:
            1. NITRATE-Stock Nitrate-N standard solution: Dry a sample of sodium nitrate at 105oC for at least 2 hours. Cool in desiccator. In about 350mL of DDW, dissolve 1.517g sodium nitrate. Bring to 500mL volume with DDW. This will yield 500mg NO_3-N/L.
            2. NITRITE-Stock Nitrite-N standard solution: Dry a sample of sodium nitrite in a desiccator for at least 4 hours. In about 800mL DDW dissolve 2.463g sodium nitrite. Bring to 1L volume. This solution can be stored in a dark bottle at $4^{o}C$. This will yield 500mg NO_2-N/L.
        ii. Intermediate standard solutions (ISS):
            1. NITRATE-Intermediate Nitrate-N stock standard solution: Dilute 3mL of Nitrate-N stock solution to 100mL volume with DDW. Store at $4^{o}C$ and remake solution every 2 weeks. This will yield 15mg NO_3-N/L.
            2. NITRITE-Intermediate Nitrite-N stock standard solution: Dilute 3mL of Nitrite-N stock solution to 100mL volume with DDW. Remake this solution twice per week if needed that often. Otherwise, make fresh solution each time samples are run. This will yield 15mg NO_2-N/L.
        iii. Working standard solutions:
            1. The SEAL machine will dilute the ISSs to the appropriate concentrations to create a standard curve.
    c. Sample Preparation

i. If frozen, allow samples to completely thaw and gently invert to mix
ii. Samples will be filtered through a glass fiber syringe filter
iii. Place an amount of sample into a labeled reaction cup

d. Analysis
    i. Place standards and samples in the autosampler tray
    ii. Set up the machine to run according to training.

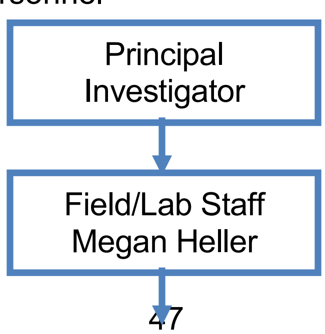
7. Interpretation
    a. Data generated by the machine is in the format of mg N/L based on the standard curve.
8. Quality Control
    a. Blanks containing DDW will be run with every set of samples run on the machine.
9. References

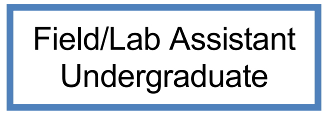
    a. SEAL Analytical, Nitrate-N + Nitrite-N in Drinking and Surface Waters, and Domestic and Industrial Wastes, 2006.

Appendix F: Total Phosphorus Standard Operating Procedure

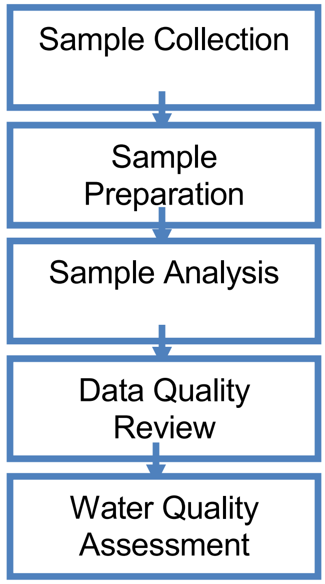
This method is modified from SEAL Analytical, Phosphorus-P, Total, in Drinking, Saline and Surface Waters, and Domestic and Industrial Wastes.

1. Scope and Application, Matrix
    b. This method may be used to determine the amount of total phosphorus in samples.
    c. This method may be used for drinking, surface and saline water, and industrial and domestic wastes
    d. This method may be performed in a laboratory setting.
2. Summary of Method, Detection Limit
    a. Forms of phosphorus are converted to orthophosphate by acid-persulfate digestion. Ammonium molybdate and antimony potassium tartrate react with orthophosphate to form an antimony phopho-molybdate complex. Ascorbic acid reduces this complex from which absorbance at 880nm is read. Detection limit for this method is 0.002mg P/L.
3. Comments
    a. Training will be provided by a technician experienced with using the SEAL Analytical machine.
    b. Samples should be filtered before analysis to remove turbidity.
    c. Samples should be run as soon as possible after collection.
    d. If it is not possible to run samples after collection samples should be kept at $4^{o}C$ for up to 28 days or frozen for up to 6 months.
    e. Water sample are collected according to a suitable method capable of meeting or exceeding the performance requirements of this test method. A log will be maintained in the laboratory to keep track of all samples.
    f. Both electronic data if applicable and hardcopy data are accurately and continuously maintained, so all data fields are occupied. All data are readily available and saved for a minimum of 2 years. Electronic data are stored on a secure Purdue University hard drive. Hardcopy data are stored in the Purdue Agronomy Soil Microbiology Laboratory.
    g. Roles and Personnel





h. Process



4. Equipment and Materials
    a. Laboratory bench sheets and/or electronic equivalent
    b. Analytical balance
    c. Properly prepared glassware
    d. SEAL Analytical machine
    e. Filters
5. Reagents
    a. Deionized Distilled Water (DDW)
    b. Potassium dihydrogen orthophosphate (KH_2PO_4)
    c. Dilute hydrochloric acid solution: 90 parts water with 10 parts HCl
    d. Stock molybdate reagent-ammonium molybdate 4%: Dissolve 4g ammonium molybdate tetrahydrate in 100mL DDW by stirring at least 2 hours. Store solution in a plastic bottle at 4^{o}C. If solution turns turbid or blue then throw out.
    e. Sulfuric acid 5N: Slowly add 70mL sulfuric acid to 400mL of DDW. Let cool and bring to 500mL volume
    f. Antimony potassium tartrate (Sb-K-tartrate): Dissolve 1.5g antimony potassium tartrate in 400mL DDW. Dilute to 500mL volume once dissolved. Store in an amber bottle at 4^{o}C. Solution will keep for 1 month.
    g. Ascorbic acid: Dissolve 4g ascorbic acid in 100mL of DDW. Will keep for 1 week at 4^{o}C. If the solution turns yellow, throw out.
    h. Working phosphate color reagent: In the orders given, add 40mL of 5N sulfuric acid, 20mL of 4% ammonium molybdate and swirl to

mix. Add 6mL of antimony potassium tartrate stock and swirl to mix. Fill to 100mL volume with DDW and mix. This solution can be stored for 2-3 weeks in a plastic bottle. If solution turns blue or turbid, discard.

i. Alkaline EDTA rinse: Dissolve 5g disodium EDTA dihydrate (Na_2EDTA) and 10g sodium hydroxide in 500mL DDW.

j. 11N sulfuric acid solution: Slowly add 155mL concentrated sulfuric acid to 300mL DDW. Once cool, dilute to 500mL.

k. Ammonia persulfate

6. Procedure
    a. Preparation of Glassware
        i. All glassware should first be rinsed in the dilute HCl solution, and then rinsed with DDW. Glassware may be soaked overnight in a 50% HCl bath.
        ii. Prepped equipment will be stored in an area where it will not be contaminated and should only be used for nutrient analysis
    b. Standard Preparation
        i. To prepare standard stock solution:
            1. Dry an amount of KH_2PO_4 at 105°C and cool in a desiccator.
            2. Weigh 2.197g of KH_2PO_4 into a 500mL volumetric flask. Bring to volume with DDW. This will give the solution 1000 mg/L Phosphorous.
            3. This solution may be stored at 4°C.
        ii. To prepare Intermediate Standard Solution (ISS):
            1. Add 1mL of standard stock solution to a 1L flask and bring to volume with DDW. This will yield 1.0mg P/L.
            2. Digest this standard as stated below
        iii. The SEAL will dilute the ISS to appropriate concentrations to make the standard curve.
    c. Sample Preparation
        i. Samples will be filtered through a glass fiber syringe filter
        ii. For Phosphorus
            1. Add 0.2mL of sulfuric acid solution to a 10mL sample
            2. Add 0.08g ammonia persulfate to each sample
            3. Steam autoclave samples for 30 minutes at 15psi.
            4. Filter if sample is not clean
            7. Run sample on SEAL
        i. For Orthophosphate
            1. Place an amount of sample into a labeled reaction cup
            2. Run on seal

b. Analysis
    i. Place standards and samples in the autosampler tray
    ii. Set up the machine to run according to training.

8. Interpretation
    a. Data generated by the machine is in the format of mg P/L based on the standard curve.
9. Quality Control
    a. Blanks containing DDW will be run with every set of samples run on the machine.
10. References

    a. SEAL Analytical, Phosphorus-P, Total, in Drinking, Saline and Surface Waters, and Domestic and Industrial Wastes, 2005.
    b. O'Dell, J.W., 1993. "Determination of phosphorus by semi-automated colorimetry". EPA Method 365.1.

Appendix G: Hach Hydrolab Quanta Sonde Manual

Y S I *incorporated*

6-Series
Multiparameter Water Quality Sondes

User Manual

6-Series:
6600 V2
6600EDS V2
6920 V2
6820 V2
600 OMS V2
600XL
600XLM
600LS
600R
600QS

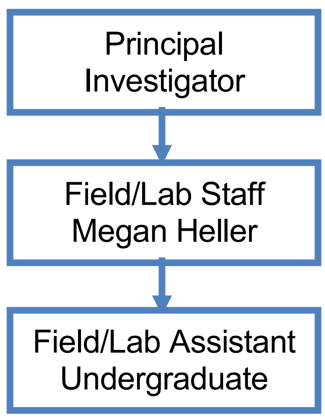
Appendix H: USFS Flow Monitoring Protocol

This method is modified from US Forest Service RM-242 Chapter 10.

1. Scope and Application, Matrix
    - e. This method may be used to determine the discharge of a stream
    - f. This method may be used for streams and rivers with a bridge
    - g. This method may be performed in the field

11. Summary of Method, Detection Limit
    - a. The stream cross section is divided up into verticals. Water velocity and depth is measured at each vertical. Measurements are used to calculate discharge

12. Comments
    - a. Training will be provided by a technician experienced with this method
    - b. Both electronic data if applicable and hardcopy data are accurately and continuously maintained, so all data fields are occupied. All data are readily available and saved for a minimum of 2 years. Electronic data are stored on a secure Purdue University hard drive. Hardcopy data are stored in the Purdue Agronomy Soil Microbiology Laboratory.
    - c. Roles and Personnel



13. Equipment and Materials
    - a. Sounding weights and reels
    - b. Type AA current meter
    - c. Digitizer
    - d. Bridge board (if measuring from a bridge)

14. Reagents
    - a. None needed

15. Procedure
    - a. Equipment Assembly
        - i. Place the adjustable foot on the bridge and extend out past the bridge rail. (You may use the roller that attaches to the

bottom of the bridge board so that it can be easily rolled along the bridge railing).

ii. Attach the removable handle to the sounding reel. Place the sounding reel on the mounting plate of bridge board. The suspension cable can be stretched out over the sheave at the end of 4 foot long boom. (Note: don't lower the cable before attaching the current meter and sounding weight. Caution: Sounding Reel Drag Brake should be locked at this moment.

iii. Attach the digitizer by using a rod mount on the side of adjustable foot (Figure 1E). A two-wire electrical cord with standard connector socket is used to connect the digitizer and sounding reel.

iv. Assembly type AA Current Meter (Figure 1C):

v. Assemble the tail piece: Slide the horizontal fin into vertical fin flanges until the curved locking recess aligns beneath the tab curve.

vi. Insert the fin assembly fully into the AA Current Meter and tighten the fin set screw. Move the balance weight as needed to balance the current meter.

vii. Insert stainless steel hanger bars into the hole of the sounding weight and use pin to thread into the bar through the hole in the weight.

viii. Insert the other side of stainless steel hanger bar to the hanger screw hole and use pin to thread into bar through the middle hole in the current meter.

ix. Insert the end of the sounding reel cable to the end of stainless steel hanger's hole. The electrical connection of the sounding reel is connected to the contact chamber cap of the current meter.

x. Gently lift the current meter and sounding weight and place over the bridge. The current meter and sounding weight are then suspended from the cable and are in position to be lowered into water below. Unlock the sounding reel drag brake and lower them into water.

b. Discharge Measurements

i. Stretch the tape measure across the channel width. Anchor it in place using cable ties, as necessary. Determine the approximate spacing of the verticals to provide about 20 subsections. The verticals should be spaced so that no subsection has more than 10 percent (ideally 5 percent) of the total discharge. The do not need to be evenly spaced.

ii. Move the bridge board to the first section. Record the horizontal distance (x) from the right bank for each place where you measure velocity on Table 1.

iii. Measure the water depth, $\boldsymbol{d_i}$, at this point:

iv. Lower the sounding reel until the weight is just touching the surface of the water. Record the last three digits of the counter in Table 1 (surface reading D1); this gives distance in 100ths of meters (i.e. 746 indicates 7.46 m).
v. Continue to lower the sounding weight until you can feel it hit the bottom of the river. Record the last three digits of the counter on Table 1 (bottom reading D2).
vi. The total depth d_i (meters) is (bottom reading (D2) – surface reading (D1))/100.
vii. Measure velocity at 0.2* d_i and 0.8* d_i and record on Table 2 the velocity reported by the current meter, v_i. Follow the instruction for using the digitizer to measure velocity.
viii. Multiply the depth (d_i)*.2 and subtract this from the bottom reading. This is the location of the first velocity reading ($v_{i,0.8}$).
ix. Take the upper velocity reading. Multiply the depth (d_i)*.6 and subtract this from the current reading $d_{i,.8}$. This is the location of the second velocity reading ($v_{i,0.2}$).

c. How to use the digitizer
   i. Press the ON/SELECT button to turn on.
   ii. Press ON/SELECT button to cycle through the type of meter used; choose "1-2: AA current meter/metric measurement"
   iii. Press COUNT/STOP button to confirm your selection. From here, the selection will focus on the time settings.
   iv. Press ON/SELECT button to cycle through the amount of time desired for counting. Use 40 seconds.
   v. Press the COUNT/STOP to begin the counting process.
   vi. When the timer has reached the timer limit, it will continue timing until the final signal is received.
   vii. Press COUNT/STOP button to calculate and display VELOCITY.

16. Interpretation
   a. Calculate the width of each section: $w_i = \left(x_{i+1} - x_{i-1}\right)/2$
   b. Section average velocity: $v_i = \left(v_{i,0.2} + v_{i,0.8}\right)/2$
   c. Calculate the discharge through section i: $q_i = \overline{v}_i \cdot d_i \cdot w_i$
   d. Calculate stream discharge: $Q = \sum_{i=1}^{10} q_i$

17. Quality Control
18. References

   a. Bowling, L. 2012. Environmental Hydrology Laboratory Manual. Purdue University.
   b. Harrelson, Cheryl C; Rawlins, C. L.; Potyondy, John P. 1994. Stream channel reference sites: an illustrated guide to field

echnique. Chapter 10: Measuring Discharges. Gen. Tech. Rep. RM-245. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.

Appendix F: Best Management Practices Installed in Carroll, Cass, Howard, Miami, and Tippecanoe Counties, 2009-2013

Installed BMPs By County

FOTG Code	Conservation Practice	Metric	IDEM	NRCS Technical Team Top Pick	Carroll County 2008	2009	2010	2011	2012	2013	County-wide Annual Average Installation	In DCSC*
472	Access Control	ac	Eligible	x					281	50	166	41
560	Access Road	ft	Eligible		2,000	80	240	1,310	3,578	1,706	1,486	371
316	Animal Mortality Facility	no	Eligible	x	4	2	4	1		1	2.4	0.6
575	Animal Trails and Walkways	ft	Eligible						1,100	850	975	244
317	Composting Facility	no	Eligible	x								
100	Comprehensive Nutrient Management Plan	no	Eligible									
103	Comprehensive Nutrient Management Plan - Applied	no	Eligible									
102	Comprehensive Nutrient Management Plan - Written	no	Eligible			1	3	1		4	2.3	0.6
327	Conservation Cover	ac	Eligible									
340	Cover Crop	ac	Eligible	x	257	102	5,590	5,538	4,773	1,318	2,930	732
342	Critical Area Planting	ac	Eligible		2	2	3	2	2	4	2.4	0.6
747	Denitrifying Bioreactor	ac	Eligible									
554	Drainage Water Management	ac	Eligible									
382	Fence	ft	Eligible	x	8,900	4,150	800	860	2,434	2,317	3,244	811
386	Field Border	ac	Eligible	x								
393	Filter Strip	no	Eligible	x								
393	Filter Strip	ac	Eligible	x								
512	Forage and Biomass Planting	ac	Eligible	x	72	6	119	121	87	113	86	22
410	Grade Stabilization Structure	no	Eligible	x	2	2	3	1		2	2.0	0.5
412	Grassed Waterway	ac	Eligible	x	2	1	1	2	2		1.7	0.4
561	Heavy Use Area Protection	ac	Eligible	x	3	1	1	2	2	3	2.0	0.5
468	Lined Waterway or Outlet	ft	Eligible	x	210	20	15	10	50		61	15
516	Livestock Pipeline	ft	Eligible	x			1,010		1,400		1,205	301
484	Mulching	ac	Eligible	x	0	1	0	2	2		1.0	0.2
590	Nutrient Management	ac	Eligible	x	7,287	4,132	2,721	4,656	2,968	3,506	4,212	1,053
595	Pest Management	ac	Eligible	x	1,780	1,580	6,807	12,964	16,621	10,487	8,373	2,093
338	Prescribed Burning	ac	Eligible									
528	Prescribed Grazing	ac	Eligible		8				12	7	8.8	2.2
533	Pumping Plant	no	Eligible					1	1		1.0	0.3
345	Residue and Tillage Management, Mulch Till	ac	Eligible					902	902	902	902	225
329	Residue and Tillage Management, No till/Strip till/Direct Seed	ac	Eligible	x	935	478	2,558	3,345	3,198	875	1,898	475
391	Riparian Forest Buffer	ac	Eligible					0			0.1	0.0
390	Riparian Herbaceous Cover	ac	Eligible							1	1.0	0.3
558	Roof Runoff Structure	no	Eligible		1		2				1.5	0.4

Installed BMPs By County

					Carroll County							
FOTG Code	***Conservation Practice***	***Metric***	***IDEM***	***NRCS Technical Team Top Pick***	***2008***	***2009***	***2010***	***2011***	***2012***	***2013***	***County-wide Annual Average Installation***	**In DCSC***
367	Roofs and Covers	no	Eligible									
574	Spring Development	no	Eligible									
578	Stream Crossing	no	Eligible				2		2	1	*1.7*	**0.4**
580	Streambank and Shoreline Protection	ft	Eligible			100					*100*	**25**
606	Subsurface Drain	ft	Eligible	x	1,090	907	1,210	1,633	2,000		*1,368*	**342**
612	Tree/Shrub Establishment	ac	Eligible	x	16	2	2	3			*5.7*	**1.4**
620	Underground Outlet	ft	Eligible		40						*40*	**10**
633	Waste Recycling	ac	Eligible									
313	Waste Storage Facility	no	Eligible	x	2		1	2		4	*2.3*	**0.6**
633	Waste Utilization	ac	Eligible	x	6,247	8,082	10,278	13,102	7,718	2,862	*8,048*	**2,012**
636	Water and Sediment Control Basin	no	Eligible	x	4						*4.0*	**1.0**
642	Water Well	no	Eligible		2			1	2		*1.7*	**0.4**
614	Watering Facility	no	Eligible				4		1		*2.5*	**0.6**
658	Wetland Creation	ac	Eligible	x								
659	Wetland Enhancement	ac	Eligible	x								
657	Wetland Restoration	ac	Eligible	x			1				*1.0*	**0.3**

*Installed practices within the boundary of the Deer Creek-Sugar Creek watershed estimated at 1/4 the total county-wide practices.

Installed BMPs By County

					Cass County						
FOTG Code	***Conservation Practice***	***Metric***	***IDEM***	***NRCS Technical Team Top Pick***	***2009***	***2010***	***2011***	***2012***	***2013***	***County-wide Annual Average Installation***	**In DCSC***
472	Access Control	ac	Eligible	x							
560	Access Road	ft	Eligible								
316	Animal Mortality Facility	no	Eligible	x							
575	Animal Trails and Walkways	ft	Eligible								
317	Composting Facility	no	Eligible	x							
100	Comprehensive Nutrient Management Plan	no	Eligible								
103	Comprehensive Nutrient Management Plan - Applied	no	Eligible								
102	Comprehensive Nutrient Management Plan - Written	no	Eligible		1	1	1			*1*	**0.13**
327	Conservation Cover	ac	Eligible								
340	Cover Crop	ac	Eligible	x	849	1,103	4,311	4,491	4,172	*2,985*	**373**
342	Critical Area Planting	ac	Eligible								
747	Denitrifying Bioreactor	ac	Eligible								
554	Drainage Water Management	ac	Eligible								
382	Fence	ft	Eligible	x							
386	Field Border	ac	Eligible	x	102	49	116	20	8		
393	Filter Strip	no	Eligible	x	25	45	70	63	16	*44*	**5.48**
393	Filter Strip	ac	Eligible	x	45	81	126	113	29	*79*	**9.86**
512	Forage and Biomass Planting	ac	Eligible	x	130	86	22	10		*62*	**7.75**
410	Grade Stabilization Structure	no	Eligible	x	1	1	1			*1*	**0.13**
412	Grassed Waterway	ac	Eligible	x	23	40	20	67	46		
561	Heavy Use Area Protection	ac	Eligible	x							
468	Lined Waterway or Outlet	ft	Eligible	x							
516	Livestock Pipeline	ft	Eligible	x							
484	Mulching	ac	Eligible	x							
590	Nutrient Management	ac	Eligible	x	1,494	804	505	505	360	*734*	**92**
595	Pest Management	ac	Eligible	x							
338	Prescribed Burning	ac	Eligible								
528	Prescribed Grazing	ac	Eligible								
533	Pumping Plant	no	Eligible								
345	Residue and Tillage Management, Mulch Till	ac	Eligible								
329	Residue and Tillage Management, No till/Strip till/Direct Seed	ac	Eligible	x	1,494	804	505	505	360	*734*	**92**
391	Riparian Forest Buffer	ac	Eligible								
390	Riparian Herbaceous Cover	ac	Eligible								
558	Roof Runoff Structure	no	Eligible								
367	Roofs and Covers	no	Eligible								

Installed BMPs By County

					Cass County						
FOTG Code	***Conservation Practice***	***Metric***	***IDEM***	***NRCS Technical Team Top Pick***	***2009***	***2010***	***2011***	***2012***	***2013***	***County-wide Annual Average Installation***	**In DCSC***
574	Spring Development	no	Eligible								
578	Stream Crossing	no	Eligible								
580	Streambank and Shoreline Protection	ft	Eligible								
606	Subsurface Drain	ft	Eligible	x							
612	Tree/Shrub Establishment	ac	Eligible	x		13	5				
620	Underground Outlet	ft	Eligible								
633	Waste Recycling	ac	Eligible								
313	Waste Storage Facility	no	Eligible	x							
633	Waste Utilization	ac	Eligible	x							
636	Water and Sediment Control Basin	no	Eligible	x							
642	Water Well	no	Eligible								
614	Watering Facility	no	Eligible								
658	Wetland Creation	ac	Eligible	x							
659	Wetland Enhancement	ac	Eligible	x							
657	Wetland Restoration	ac	Eligible	x	3	23	2		25		

*Installed practices within the boundary of the Deer Creek-Sugar Creek watershed estimated at 1/8 the total county-wide practices.

Installed BMPs By County

					Howard County						
FOTG Code	Conservation Practice	Metric	IDEM	NRCS Technical Team Top Pick	2009	2010	2011	2012	2013	County-wide Annual Average Installation	In DCSC*
472	Access Control	ac	Eligible	x							
560	Access Road	ft	Eligible								
316	Animal Mortality Facility	no	Eligible	x				1		1.0	0.1
575	Animal Trails and Walkways	ft	Eligible								
317	Composting Facility	no	Eligible	x							
100	Comprehensive Nutrient Management Plan	no	Eligible		2					2.0	0.3
103	Comprehensive Nutrient Management Plan - Applied	no	Eligible			5	1			3.0	0.4
102	Comprehensive Nutrient Management Plan - Written	no	Eligible		1					1.0	0.1
327	Conservation Cover	ac	Eligible		1	29	30	41	33	27	3.4
340	Cover Crop	ac	Eligible	x		70	503	1,251	954	695	87
342	Critical Area Planting	ac	Eligible								
747	Denitrifying Bioreactor	ac	Eligible								
554	Drainage Water Management	ac	Eligible								
382	Fence	ft	Eligible	x	5,100	3,700	3,728	2,365	2,580	3,495	437
386	Field Border	ac	Eligible	x							
393	Filter Strip	no	Eligible	x							
393	Filter Strip	ac	Eligible	x	23					23	2.9
512	Forage and Biomass Planting	ac	Eligible	x	26	17	5	12	28	18	2.2
410	Grade Stabilization Structure	no	Eligible	x	13	1			3	5.7	0.7
412	Grassed Waterway	ac	Eligible	x	27	28	20	29	10	23	2.9
561	Heavy Use Area Protection	ac	Eligible	x	0				0	0.0	0.0
468	Lined Waterway or Outlet	ft	Eligible	x		10				10	1.3
516	Livestock Pipeline	ft	Eligible	x	650	3,171				1,911	239
484	Mulching	ac	Eligible	x	11	0	73			28	3.5
590	Nutrient Management	ac	Eligible	x	4,709	2,767	1,231	92	2,499	2,260	282
595	Pest Management	ac	Eligible	x	4,394	2,308	401	95	2,015	1,843	230
338	Prescribed Burning	ac	Eligible						7	7.0	0.9
528	Prescribed Grazing	ac	Eligible			82	67	109	13	68	8.5
533	Pumping Plant	no	Eligible								
345	Residue and Tillage Management, Mulch Till	ac	Eligible		5,057	2,869	3,516	3,649	1,418	3,302	413
329	Residue and Tillage Management, No till/Strip till/Direct Seed	ac	Eligible	x	2,572	2,839	1,367	5,324	1,859	2,792	349
391	Riparian Forest Buffer	ac	Eligible								
390	Riparian Herbaceous Cover	ac	Eligible						1	1.0	0.1
558	Roof Runoff Structure	no	Eligible								
367	Roofs and Covers	no	Eligible								

Installed BMPs By County

FOTG Code	Conservation Practice	Metric	IDEM	NRCS Technical Team Top Pick	Howard County 2009	2010	2011	2012	2013	County-wide Annual Average Installation	In DCSC*
574	Spring Development	no	Eligible								
578	Stream Crossing	no	Eligible						1	*1.0*	**0.1**
580	Streambank and Shoreline Protection	ft	Eligible								
606	Subsurface Drain	ft	Eligible	x	10,834	450	1,180			*4,155*	**519**
612	Tree/Shrub Establishment	ac	Eligible	x		22		4	11	*12*	**1.5**
620	Underground Outlet	ft	Eligible		20					*20*	**2.5**
633	Waste Recycling	ac	Eligible				73	307		*190*	**24**
313	Waste Storage Facility	no	Eligible	x		1				*1.0*	**0.1**
633	Waste Utilization	ac	Eligible	x	1,974	712				*1,343*	**168**
636	Water and Sediment Control Basin	no	Eligible	x	2					*2.0*	**0.3**
642	Water Well	no	Eligible								
614	Watering Facility	no	Eligible		1	4			1	*2.0*	**0.3**
658	Wetland Creation	ac	Eligible	x							
659	Wetland Enhancement	ac	Eligible	x							
657	Wetland Restoration	ac	Eligible	x							

*Installed practices within the boundary of the Deer Creek-Sugar Creek watershed estimated at 1/8 the total county-wide practices.

Installed BMPs By County

FOTG Code	Conservation Practice	Metric	IDEM	NRCS Technical Team Top Pick	Miami County						
					2009	2010	2011	2012	2013	County-wide Annual Average Installation	In DCSC*
472	Access Control	ac	Eligible	x							
560	Access Road	ft	Eligible					700		700	88
316	Animal Mortality Facility	no	Eligible	x	1					1	0.1
575	Animal Trails and Walkways	ft	Eligible								
317	Composting Facility	no	Eligible	x	1			1		1	0.1
100	Comprehensive Nutrient Management Plan	no	Eligible		1					1	0.1
103	Comprehensive Nutrient Management Plan - Applied	no	Eligible			1				1	0.1
102	Comprehensive Nutrient Management Plan - Written	no	Eligible								
327	Conservation Cover	ac	Eligible		4	71	110	159	6	70	8.8
340	Cover Crop	ac	Eligible	x	609	136	1,114	299	1,359	703	88
342	Critical Area Planting	ac	Eligible								
747	Denitrifying Bioreactor	ac	Eligible								
554	Drainage Water Management	ac	Eligible								
382	Fence	ft	Eligible	x	8,310	13,055	20,220			13,862	1,733
386	Field Border	ac	Eligible	x	10	73	24	8		29	3.6
393	Filter Strip	no	Eligible	x							
393	Filter Strip	ac	Eligible	x	22	51	8			27	3.4
512	Forage and Biomass Planting	ac	Eligible	x	75	43	38	6		41	5.1
410	Grade Stabilization Structure	no	Eligible	x	3	8	14	3		7	0.9
412	Grassed Waterway	ac	Eligible	x	34	52	216	62	11	75	9.4
561	Heavy Use Area Protection	ac	Eligible	x	1					1	0.1
468	Lined Waterway or Outlet	ft	Eligible	x	20	90	120	60		73	9.1
516	Livestock Pipeline	ft	Eligible	x	700					700	88
484	Mulching	ac	Eligible	x		4	1			3	0.3
590	Nutrient Management	ac	Eligible	x	2,890	884	2,181		65	1,505	188
595	Pest Management	ac	Eligible	x	2,244	450	1,011		65	943	118
338	Prescribed Burning	ac	Eligible								
528	Prescribed Grazing	ac	Eligible			54	39	25		39	4.9
533	Pumping Plant	no	Eligible								
345	Residue and Tillage Management, Mulch Till	ac	Eligible		3,235	5,184	3,831	3,927	328	3,301	413
329	Residue and Tillage Management, No till/Strip till/Direct Seed	ac	Eligible	x	1,756	935	758	2,676	355	1,296	162
391	Riparian Forest Buffer	ac	Eligible			10	2			6	0.8
390	Riparian Herbaceous Cover	ac	Eligible		9					9	1.1
558	Roof Runoff Structure	no	Eligible					1		1	0.1

Installed BMPs By County

FOTG Code	Conservation Practice	Metric	IDEM	NRCS Technical Team Top Pick	Miami County 2009	2010	2011	2012	2013	County-wide Annual Average Installation	In DCSC*
367	Roofs and Covers	no	Eligible								
574	Spring Development	no	Eligible								
578	Stream Crossing	no	Eligible				1			*1*	**0.1**
580	Streambank and Shoreline Protection	ft	Eligible								
606	Subsurface Drain	ft	Eligible	x	3,490	11,705	10,407	838		*6,610*	**826**
612	Tree/Shrub Establishment	ac	Eligible	x	26	37	5	5		*18*	**2.3**
620	Underground Outlet	ft	Eligible			1,515		427		*971*	**121**
633	Waste Recycling	ac	Eligible								
313	Waste Storage Facility	no	Eligible	x							
633	Waste Utilization	ac	Eligible	x	506	367				*437*	**55**
636	Water and Sediment Control Basin	no	Eligible	x		3	2			*3*	**0.3**
642	Water Well	no	Eligible								
614	Watering Facility	no	Eligible		4			1		*3*	**0.3**
658	Wetland Creation	ac	Eligible	x							
659	Wetland Enhancement	ac	Eligible	x							
657	Wetland Restoration	ac	Eligible	x			5			*5*	**0.6**

*Installed practices within the boundary of the Deer Creek-Sugar Creek watershed estimated at 1/8 the total county-wide practices.

Installed BMPs By County

FOTG Code	Conservation Practice	Metric	IDEM	NRCS Technical Team Top Pick	Tippecanoe County 2008	2009	2010	2011	2012	2013	County-wide Annual Average Installation	In DCSC*
472	Access Control	ac	Eligible	x					50	35	43	5.3
560	Access Road	ft	Eligible					0	0		0	0.0
316	Animal Mortality Facility	no	Eligible	x		1		1			1	0.1
575	Animal Trails and Walkways	ft	Eligible									
317	Composting Facility	no	Eligible	x								
100	Comprehensive Nutrient Management Plan	no	Eligible		1		1				1	0.1
103	Comprehensive Nutrient Management Plan - Applied	no	Eligible					1			1	0.1
102	Comprehensive Nutrient Management Plan - Written	no	Eligible							1	1	0.1
327	Conservation Cover	ac	Eligible				28	87	2		39	4.9
340	Cover Crop	ac	Eligible	x	136	449	223	1,456	4,716	3,702	1,780	223
342	Critical Area Planting	ac	Eligible					10	0		5	0.6
747	Denitrifying Bioreactor	ac	Eligible					0	1	0	0	0.0
554	Drainage Water Management	ac	Eligible						0		0	
382	Fence	ft	Eligible	x	4,100	3,900		2,275	0		2,569	321
386	Field Border	ac	Eligible	x	0.45	4	8	2	5		4	0.5
393	Filter Strip	no	Eligible	x								
393	Filter Strip	ac	Eligible	x	45	15		2			21	2.6
512	Forage and Biomass Planting	ac	Eligible	x		38	106	71	183	70	94	12
410	Grade Stabilization Structure	no	Eligible	x	3	5	1	5	10		5	0.6
412	Grassed Waterway	ac	Eligible	x	14	3	7	53	34		22	2.8
561	Heavy Use Area Protection	ac	Eligible	x	1		1	1	0		1	0.1
468	Lined Waterway or Outlet	ft	Eligible	x	20	60	40	120	202		88	11
516	Livestock Pipeline	ft	Eligible	x	650	140		203			331	41
484	Mulching	ac	Eligible	x	7	5	4	6	1,923		389	49
590	Nutrient Management	ac	Eligible	x	2,322	1,032	1,028	702	267	70	904	113
595	Pest Management	ac	Eligible	x	1,609	437	517	757	749	114	697	87
338	Prescribed Burning	ac	Eligible									
528	Prescribed Grazing	ac	Eligible		30	111		25	32		50	6.2
533	Pumping Plant	no	Eligible		2						2	0.3
345	Residue and Tillage Management, Mulch Till	ac	Eligible		957	765	455	1,711	237	290	736	92
329	Residue and Tillage Management, No till/Strip till/Direct Seed	ac	Eligible	x	1,039	1,963	2,112	2,282	1,956	301	1,609	201
391	Riparian Forest Buffer	ac	Eligible									
390	Riparian Herbaceous Cover	ac	Eligible									
558	Roof Runoff Structure	no	Eligible									

Installed BMPs By County

FOTG Code	Conservation Practice	Metric	IDEM	NRCS Technical Team Top Pick	Tippecanoe County 2008	2009	2010	2011	2012	2013	County-wide Annual Average Installation	In DCSC*
367	Roofs and Covers	no	Eligible									
574	Spring Development	no	Eligible		2						*2*	**0.3**
578	Stream Crossing	no	Eligible									
580	Streambank and Shoreline Protection	ft	Eligible									
606	Subsurface Drain	ft	Eligible	x	8,660	6,095	4,410	7,695	25,839		*10,540*	**1,317**
612	Tree/Shrub Establishment	ac	Eligible	x	6		103	5	47	1	*32*	**4.1**
620	Underground Outlet	ft	Eligible					45			*45*	**5.6**
633	Waste Recycling	ac	Eligible					224	295	224	*248*	**31**
313	Waste Storage Facility	no	Eligible	x								
633	Waste Utilization	ac	Eligible	x	80	390	327				*266*	**33**
636	Water and Sediment Control Basin	no	Eligible	x								
642	Water Well	no	Eligible		2						*2*	**0.3**
614	Watering Facility	no	Eligible		4		2				*3*	**0.4**
658	Wetland Creation	ac	Eligible	x		1					*1*	**0.1**
659	Wetland Enhancement	ac	Eligible	x				2	26		*14*	**1.8**
657	Wetland Restoration	ac	Eligible	x	39	63	86	143	153	24	*85*	**11**

*Installed practices within the boundary of the Deer Creek-Sugar Creek watershed estimated at 1/8 the total county-wide practices.

Summary of IDEM Eligible, NRCS Selected BMPS
(estimated count in Deer Creek-Sugar Creek watershed)

FOTG Code	Conservation Practice	Metric	Miami	Tippecanoe	Cass	Howard	Carroll	Total Estimated Feasible Installations in Watershed	
			Current estimated annual installation in watershed						
			(1/8 of county-wide practice counts*)				(1/4 of county-wide practice		
472	Access Control	ac		5.3			41	**47**	acres
316	Animal Mortality Facility	no	0.1	0.1		0.1	0.6	**1**	facilities
317	Composting Facility	no	0.1					**0.1**	facilities
340	Cover Crop	ac	88	223	373	87	732	**1,503**	acres
382	Fence	ft	1,733	321		437	811	**3,302**	feet
386	Field Border	ac	3.6	0.5				**4**	acres
393	Filter Strip	ac	3.4	2.6	9.9	2.9		**19**	acres
512	Forage and Biomass Planting	ac	5.1	12	7.8	2.2	22	**48**	acres
410	Grade Stabilization Structure	no	0.9	0.6	0.1	0.7	0.5	**3**	structures
412	Grassed Waterway	ac	9.4	2.8		2.9	0.4	**15**	acres
561	Heavy Use Area Protection	ac	0.1	0.1		0.0	0.5	**1**	acres
468	Lined Waterway or Outlet	ft	9.1	11		1.3	15.3	**37**	feet
516	Livestock Pipeline	ft	88	41		239	301	**669**	feet
484	Mulching	ac	0.3	48.6		3.5	0.2	**53**	acres
590	Nutrient Management	ac	188	113	92	282	1,053	**1,728**	acres
595	Pest Management	ac	118	87		230	2,093	**2,529**	acres
329	Residue and Tillage Management, No till/Strip till/Direct Seed	ac	162	201	92	349	475	**1,278**	acres
606	Subsurface Drain	ft	826	1,317		519	342	**3,005**	feet
612	Tree/Shrub Establishment	ac	2.3	4.1		1.5	1.4	**9**	acres
313	Waste Storage Facility	no				0.1	0.6	**1**	facilities
633	Waste Utilization	ac	55	33		168	2,012	**2,268**	acres
636	Water and Sediment Control Basin	no	0.3			0.3	1.0	**2**	basins
658	Wetland Creation	ac		0.1				**0.1**	acres
659	Wetland Enhancement	ac		1.8				**2**	acres
657	Wetland Restoration	ac	0.6	11			0.3	**11**	acres

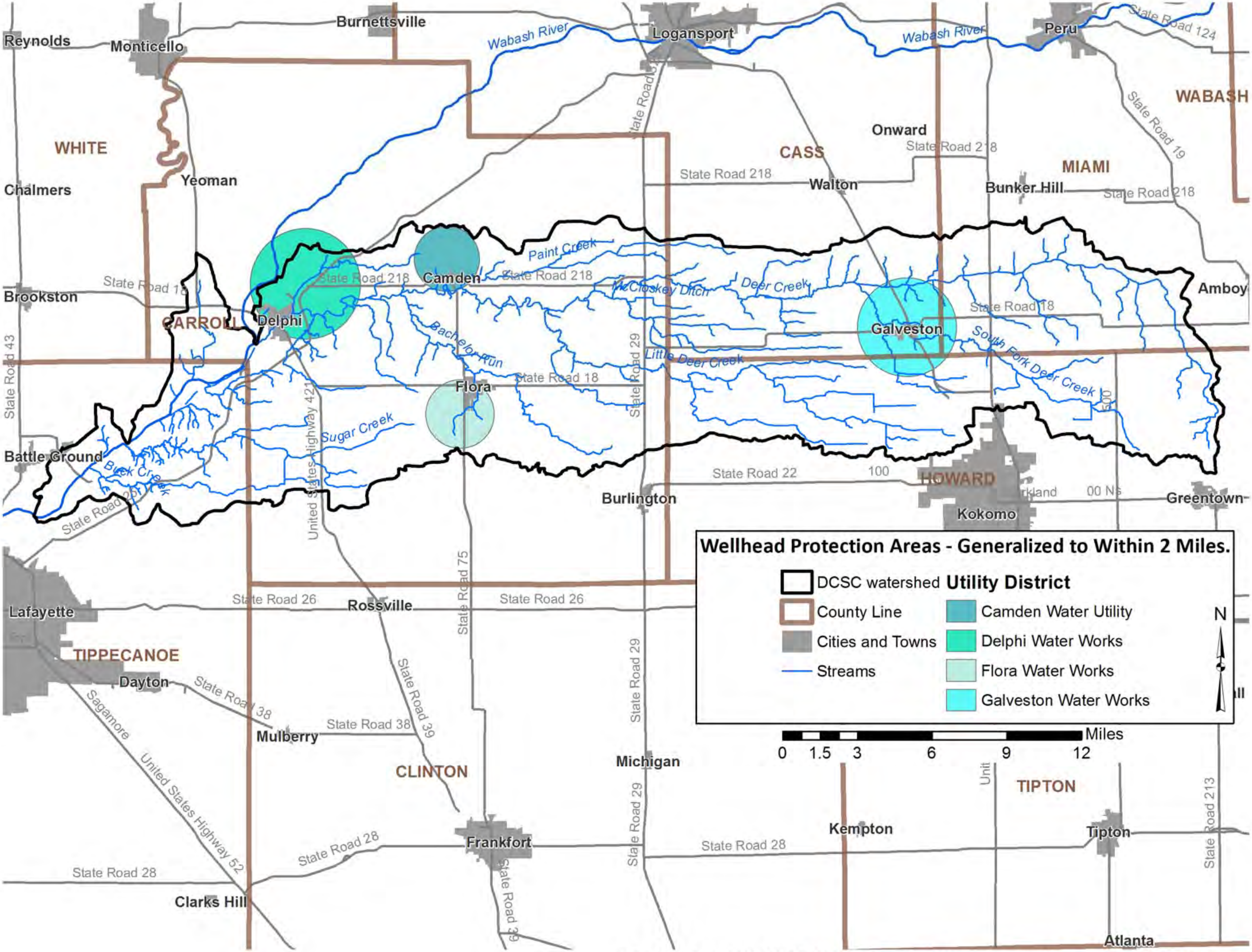
*average county-wide practice counts from 2009-2013

All BMPs considered by NRCS Technical Team,
Public Meeting Participants, and Survey Respondents

Conservation Practice	***NRCS top pick***	***IDEM Eligible***	***Public Meeting "votes"***	***SIS % currently use***	***SIS % willing to try (yes + maybe)***	**Estimated Current Annual Installations in Watershed**	
Access Control	x	x		na	na	**47**	acres
Animal Mortality Facility	x	x		na	na	**1**	facilities
Composting Facility	x	x	2	12%	na	**0.1**	facilities
Cover Crop	x	x	8	30%	80%	**1,503**	acres
Fence	x	x	0	15%	na	**3,302**	feet
Field Border	x	x		na	na	**4**	acres
Filter Strip	x	x	9	34%	76%	**19**	acres
Forage and Biomass Planting	x	x		na	na	**48**	acres
Grade Stabilization Structure	x	x		na	na	**3**	structures
Grassed Waterway	x	x	4	67%	na	**15**	acres
Heavy Use Area Protection	x	x		na	na	**1**	acres
Lined Waterway or Outlet	x	x		na	na	**37**	feet
Livestock Pipeline	x	x		na	na	**669**	feet
Mulching	x	x		na	na	**53**	acres
Nutrient Management	x	x	5	38%	na	**1,728**	acres
Pest Management	x	x	4	na	na	**2,529**	acres
Residue and Tillage Management, No till/Strip till/Direct Seed	x	x	3	48-70%	na	**1,278**	acres
Subsurface Drain	x	x		na	na	**3,005**	feet
Tree/Shrub Establishment	x	x		na	na	**9**	acres
Waste Storage Facility	x	x		na	na	**1**	facilities
Waste Utilization	x	x		na	na	**2,268**	acres
Water and Sediment Control Basin	x	x		na	na	**2**	basins
Wetland Creation	x	x		na	na	**0.1**	acres
Wetland Enhancement	x	x		na	na	**2**	acres
Wetland Restoration	x	x		na	na	**11**	acres
Two Stage Ditch		x	3	8%	71%	**0**	ditches
Clearing Ditches			9		na	unknown	
Service Septic Systems			7	47%	na	unknown	
Diversion structures		x	3	12%	60%	unknown	
Field ditch			2		na	unknown	
Variable rate application		?	2	62%	na	unknown	
Prescribed Grazing		x	1	16%	na	22	acres
Bioreactor		x	na		na	< 1	unit
Regular soil tests		?	2	73%	na	unknown	
Drainage water management		x	na		na	0	acres
University fertilization recommendations		?		61%	na	unknown	
Consider soil characteristics to minimize runoff		?	3	60%	na	unknown	

Appendix G: Other Planning Efforts, Maps and Figures

Well fields & Groundwater Maps



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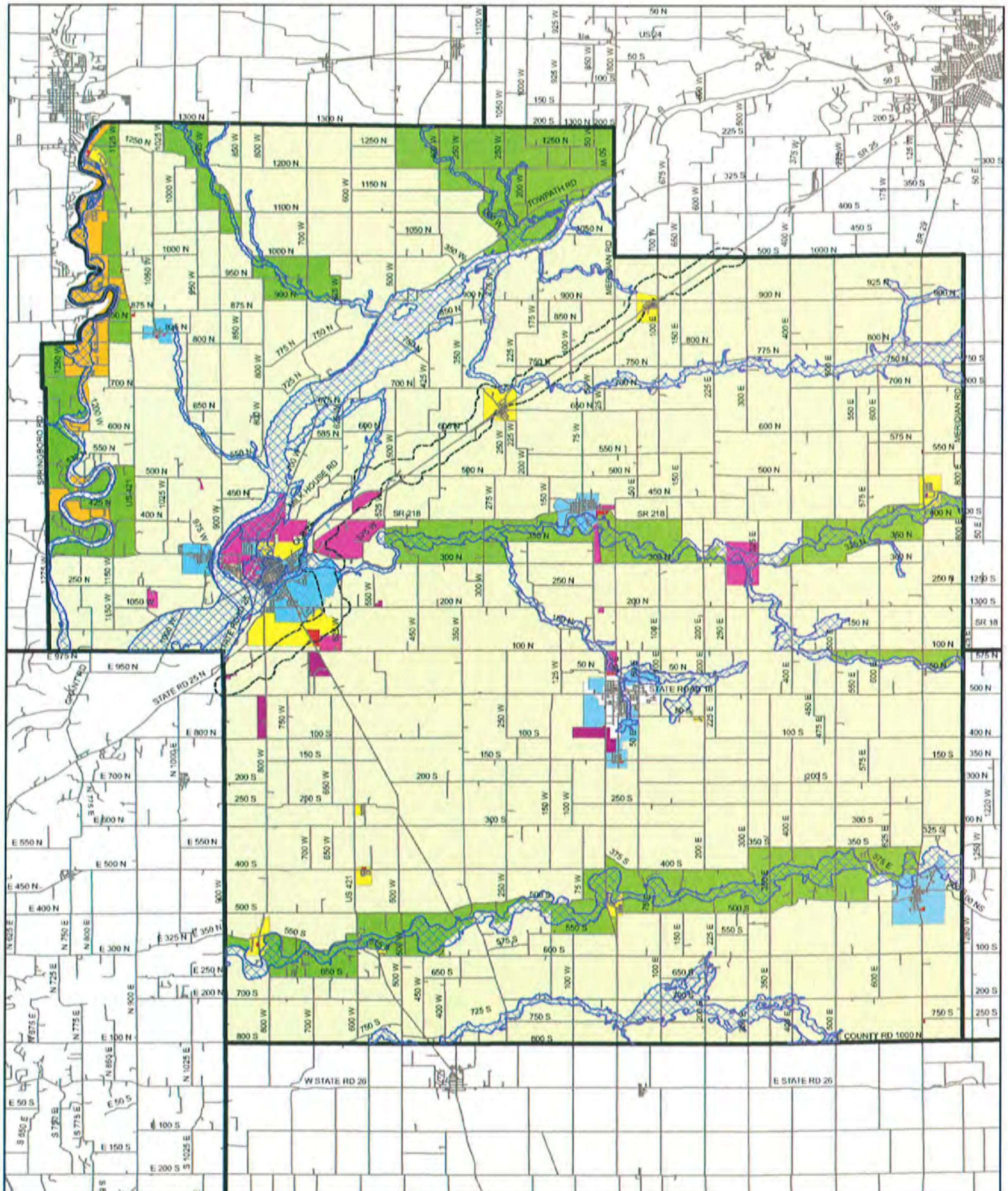
Carroll County Maps



Zoning Legend

- A
- B-1
- B-2
- B-3
- I-1
- I-2
- L-1
- S-1
- U-1
- U-2
- R-R

Carroll County, Indiana Zoning Map

Engineers · Architects · Planners
GRW Engineers, Inc.
7112 Waldemar Drive
Indianapolis, IN 46268
Voice 317.347.3650
Fax 317.347.3656

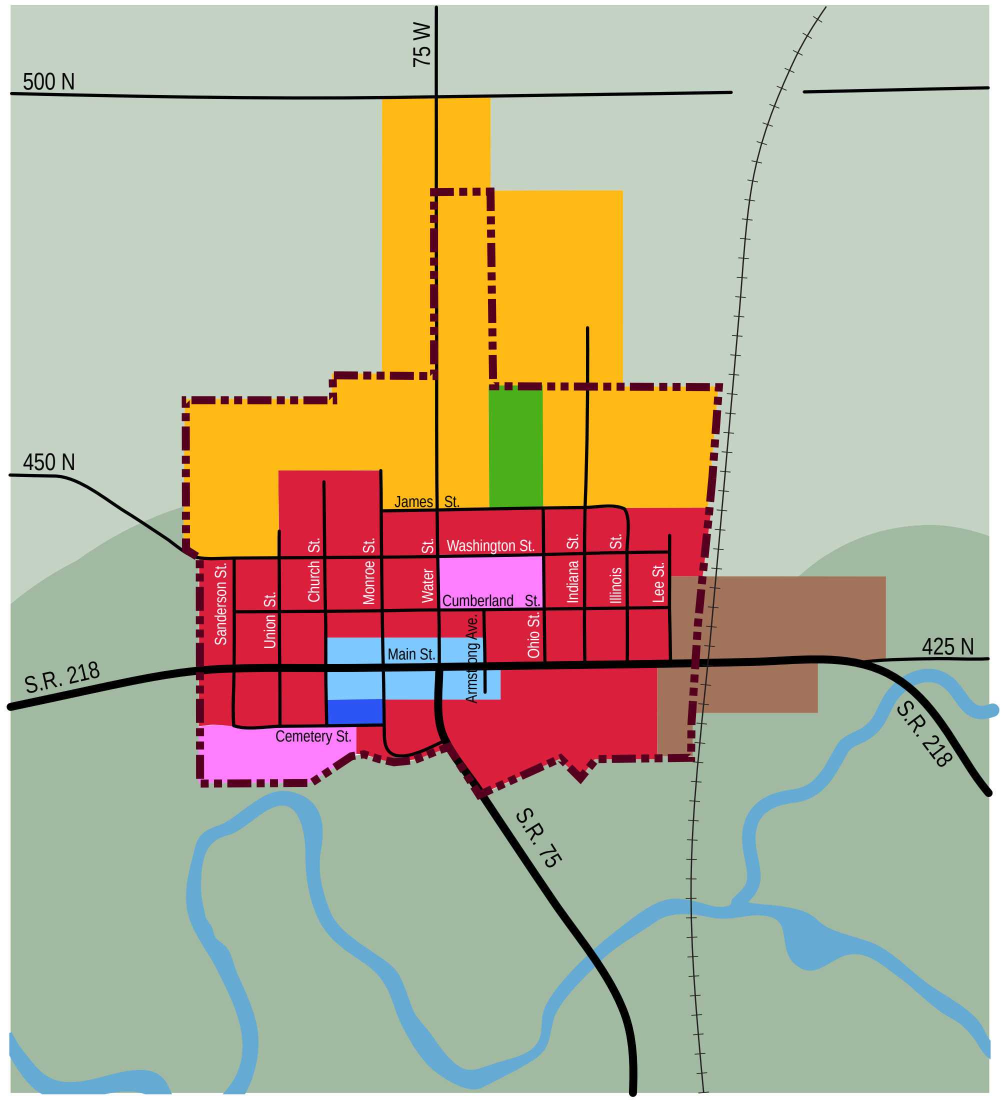
Base Map Legend

- FEMA Floodplain
- County Boundary
- Hoosier Heartland Highway ROW
- Road Centerline

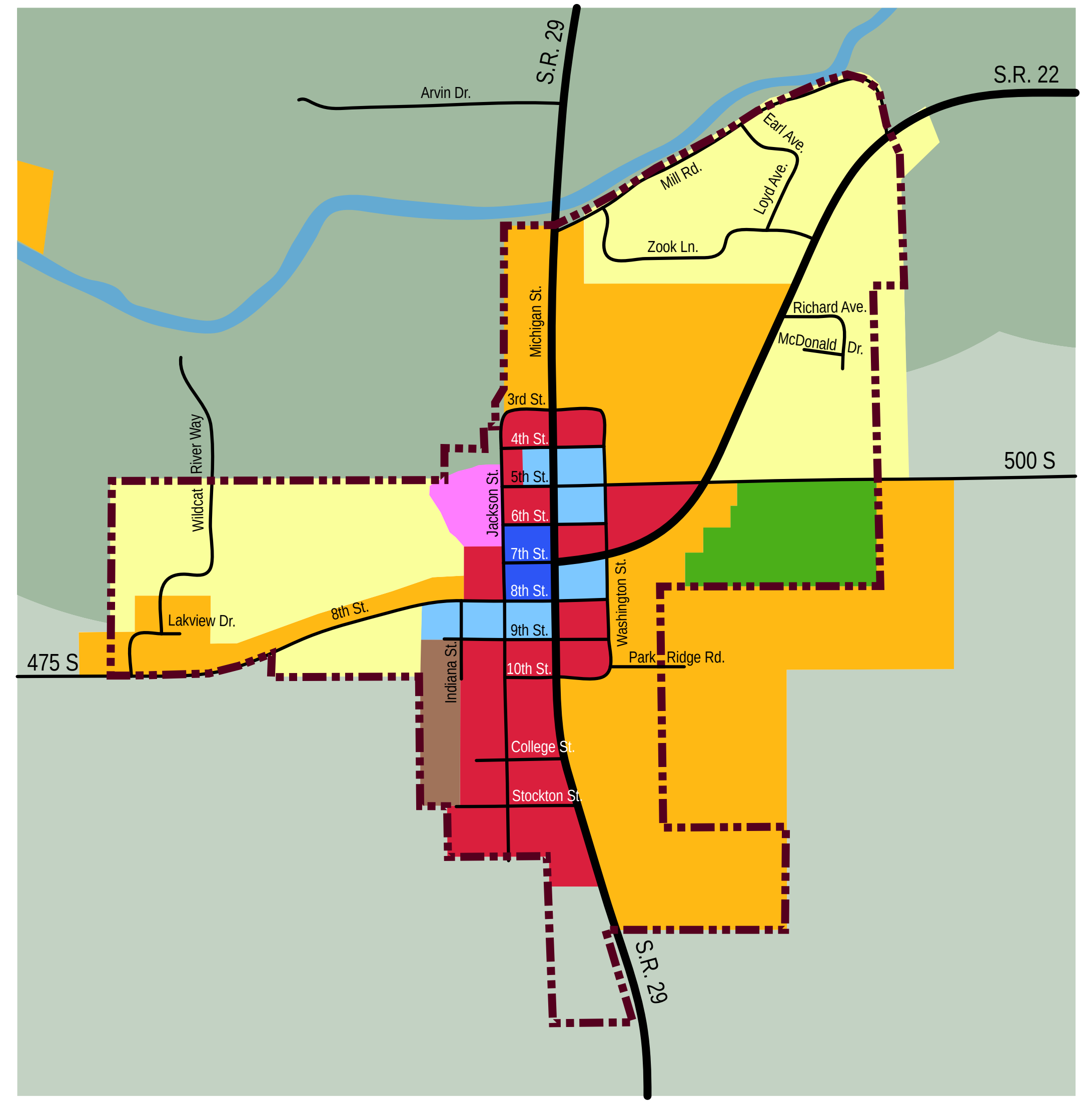
0 6,000 12,000 24,000
Scale In Feet

Printed: September 19, 2013

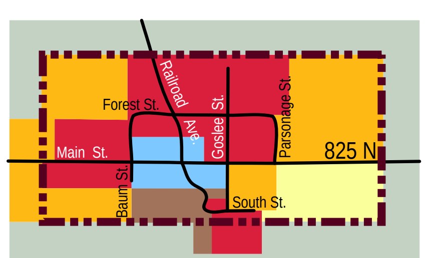
Future Land Use Map
Burlington, Camden and Yeoman, Indiana



Camden



Burlington



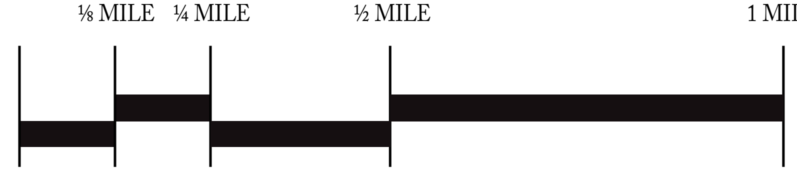
Yeoman

MAP LEGEND

- Environmentally Managed Land
- General Agriculture
- Parks and Recreation
- Low Density Residential
- Medium Density Residential
- Lake Residential
- High Density Residential
- Institutional
- Downtown Mixed
- General Commercial
- Highway Commercial
- Business Park
- Industrial
- Proposed Industrial/Flex Option
- Mineral Resources
- Corporate Limits
- River/Stream
- Railroad

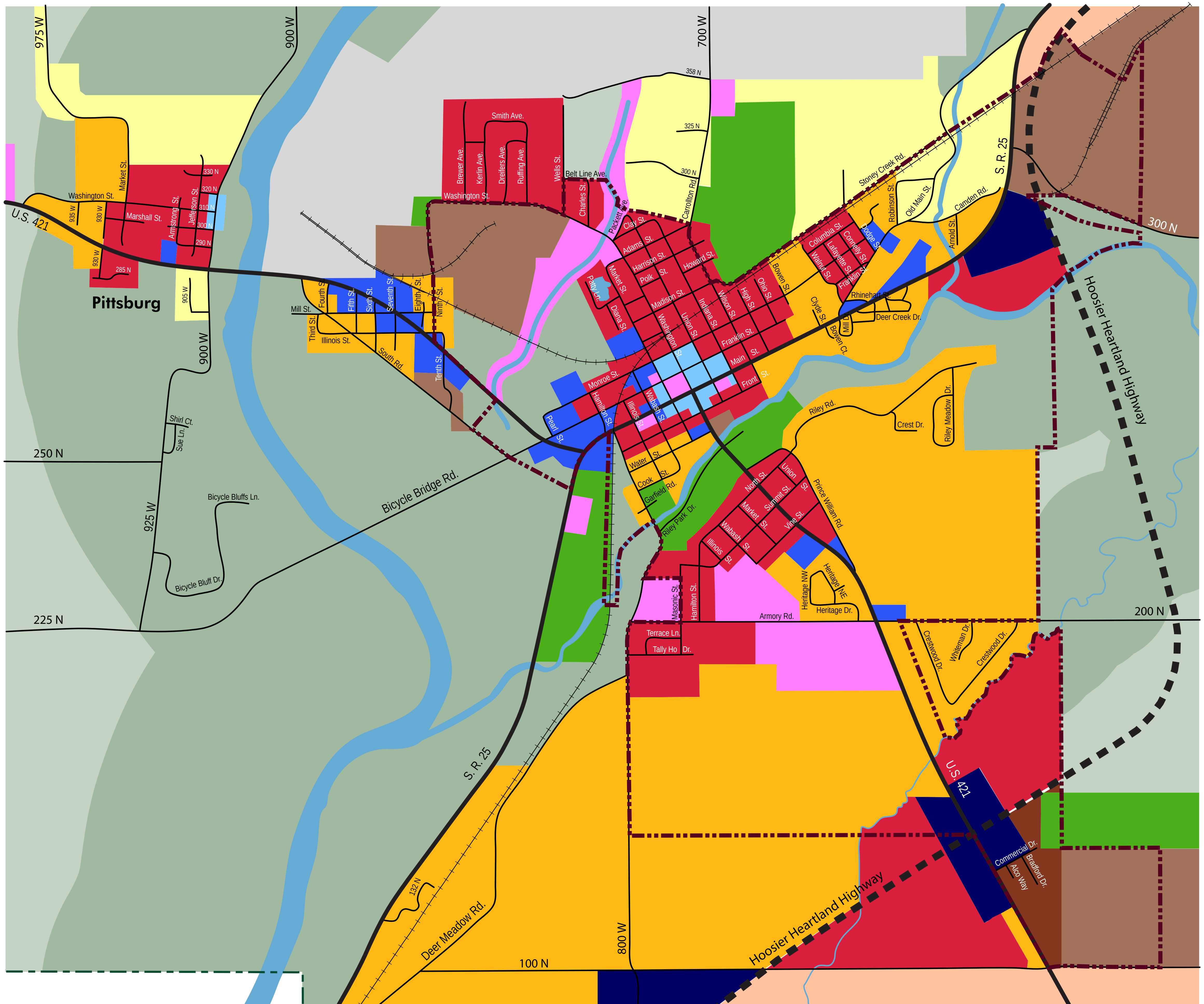
N

This Future Land Use Map is to be considered a guide for future development. However, each proposed development should be judged upon its merit and compatibility with surrounding land uses as well as the goals and objectives set by the governing body.



GroundRules
website www.groundrulesinc.com

Future Land Use Map
Delphi, Indiana



MAP LEGEND

- Environmentally Managed Land
- General Agriculture
- Parks and Recreation
- Low Density Residential
- Medium Density Residential
- Lake Residential
- High Density Residential
- Institutional
- Downtown Mixed
- General Commercial
- Highway Commercial
- Business Park
- Industrial
- Proposed Industrial/Flex Option
- Mineral Resources
- Corporate Limits
- River/Stream
- Railroad
- County Line

N

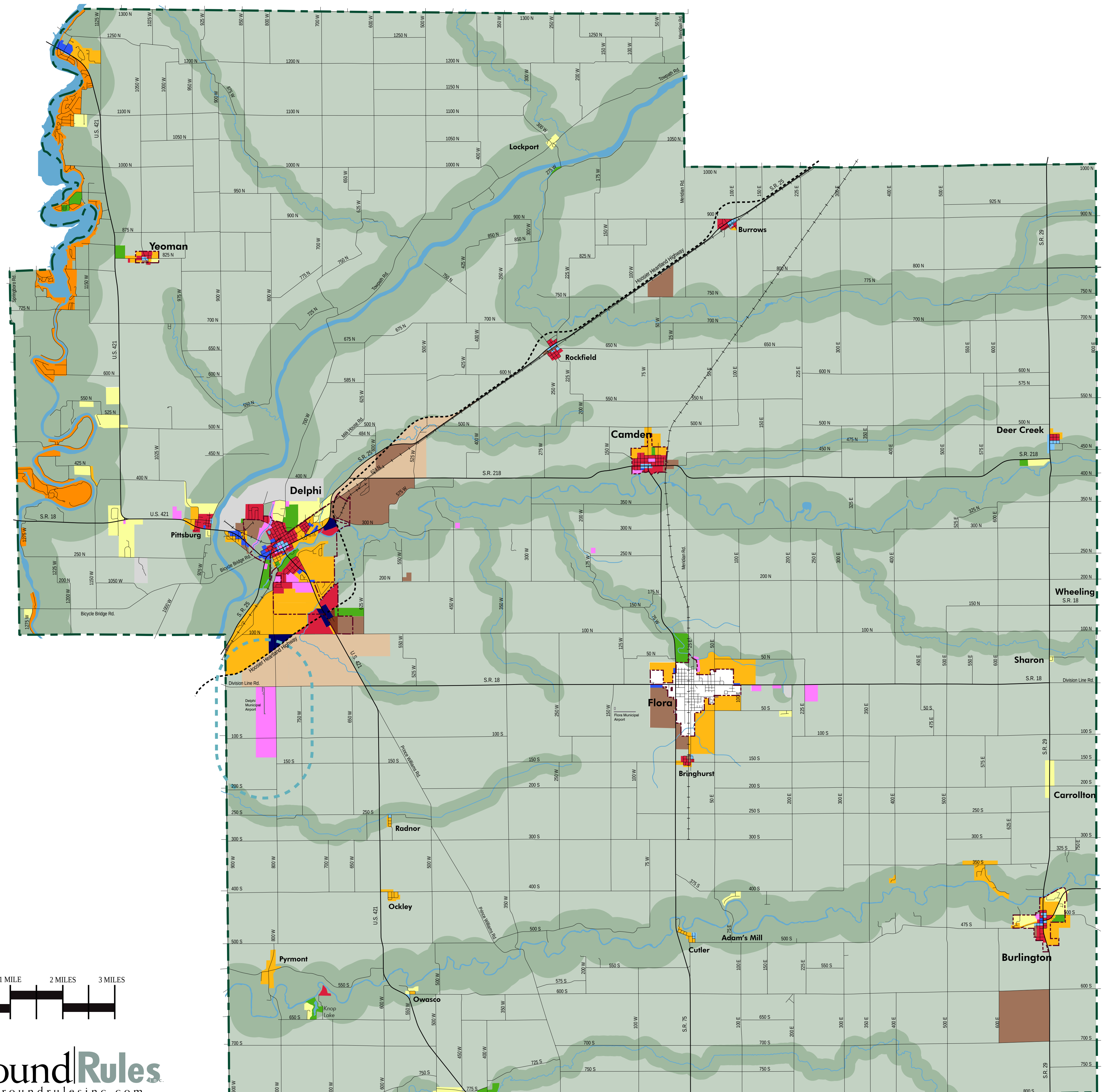
This Future Land Use Map is to be considered a guide for future development. However, each proposed development should be judged upon its merit and compatibility with surrounding land uses as well as the goals and objectives set by the governing body.

⅛ MILE ¼ MILE ½ MILE 1 MILE

GroundRules
website www.groundrulesinc.com

This map is not a certified survey and no reliance may be placed in its accuracy. Users of this map are hereby notified that primary sources of information (deeds, surveys, rights-of-way, legal drains, etc.) should be consulted to verify this and additional information contained on this map.

Future Land Use Map
Carroll County, Indiana



MAP LEGEND

- Environmentally Managed Land
- General Agriculture
- Parks and Recreation
- Low Density Residential
- Medium Density Residential
- Lake Residential
- High Density Residential
- Institutional
- Downtown Mixed
- General Commercial
- Highway Commercial
- Business Park
- Industrial
- Proposed Industrial/Flex Option
- Mineral Resources
- Corporate Limits
- Airport Hazard Area
- Lake
- River/Stream
- Railroad
- County Line

This Future Land Use Map is to be considered a guide for future development. However, each proposed development should be judged upon its merit and compatibility with surrounding land uses as well as the goals and objectives set by the governing body.

This map is not a certified survey and no reliance may be placed in its accuracy. Users of this map are hereby notified that primary sources of information (deeds, surveys, rights-of-way, legal drains, etc.) should be consulted to verify this and additional information contained on this map.

GroundRules
website www.groundrulesinc.com

Cass County Maps

Figure 6-2: Park and Recreation/Connectivity Opportunities map.

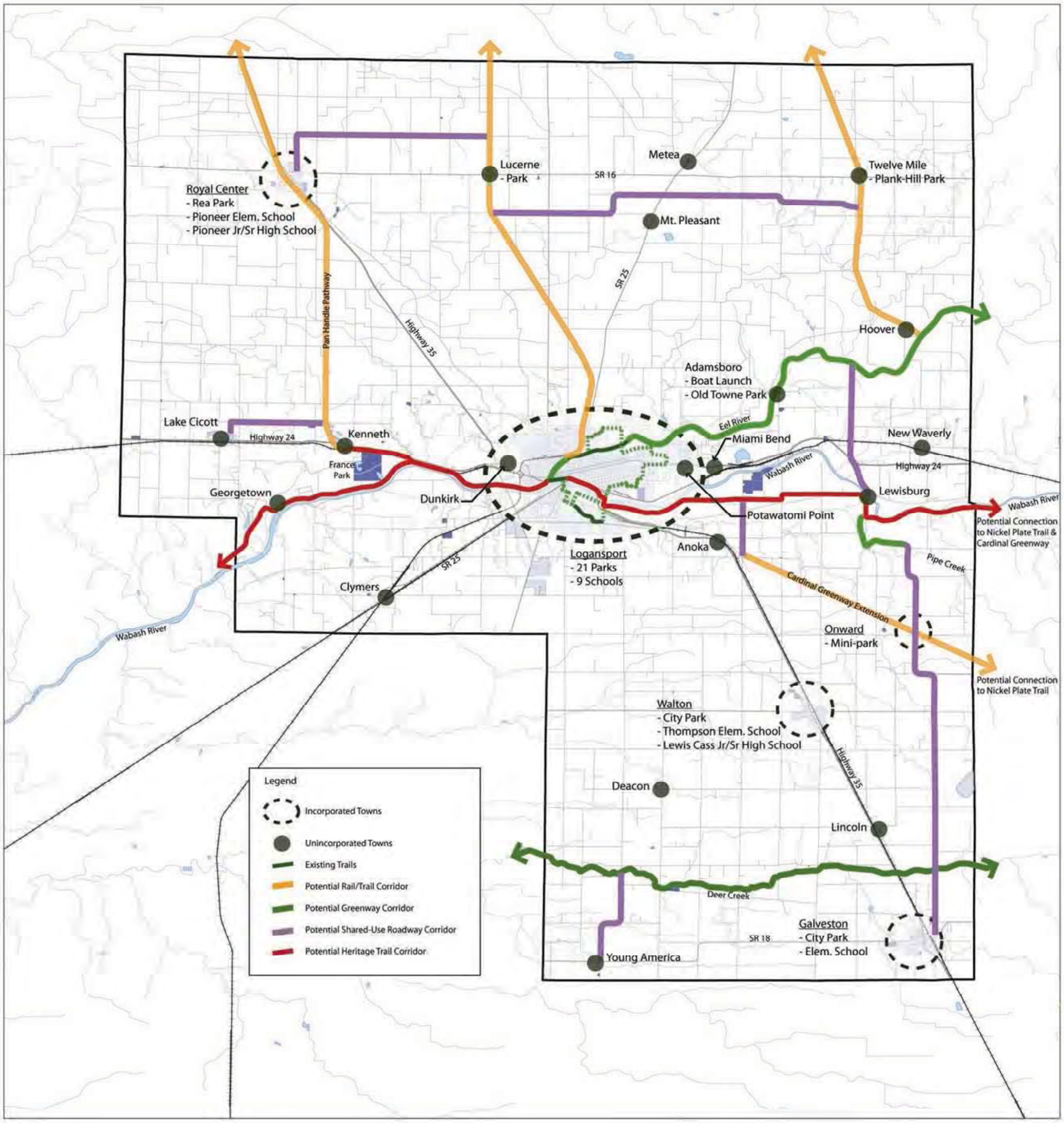


Figure 4-2: Future Land Use

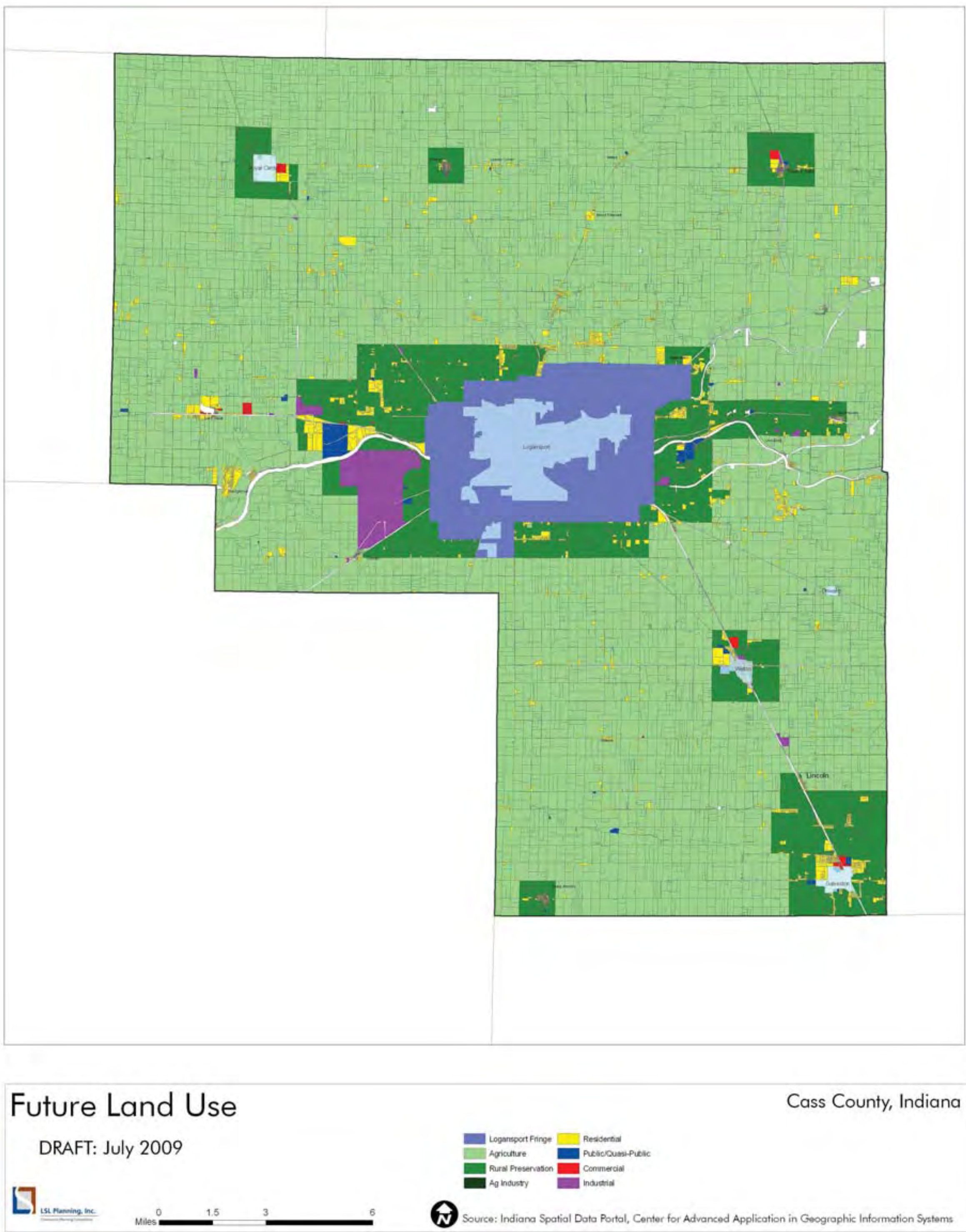
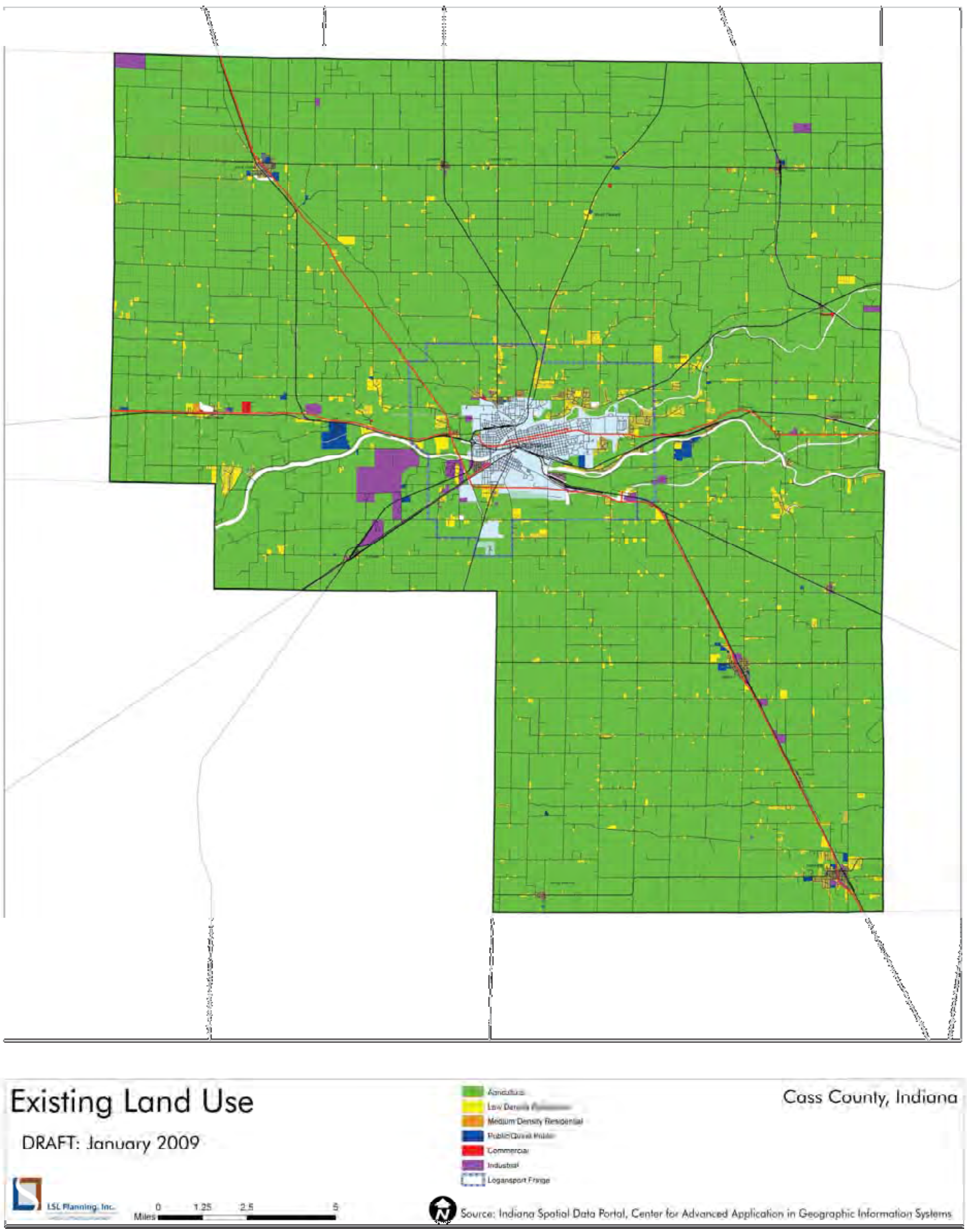
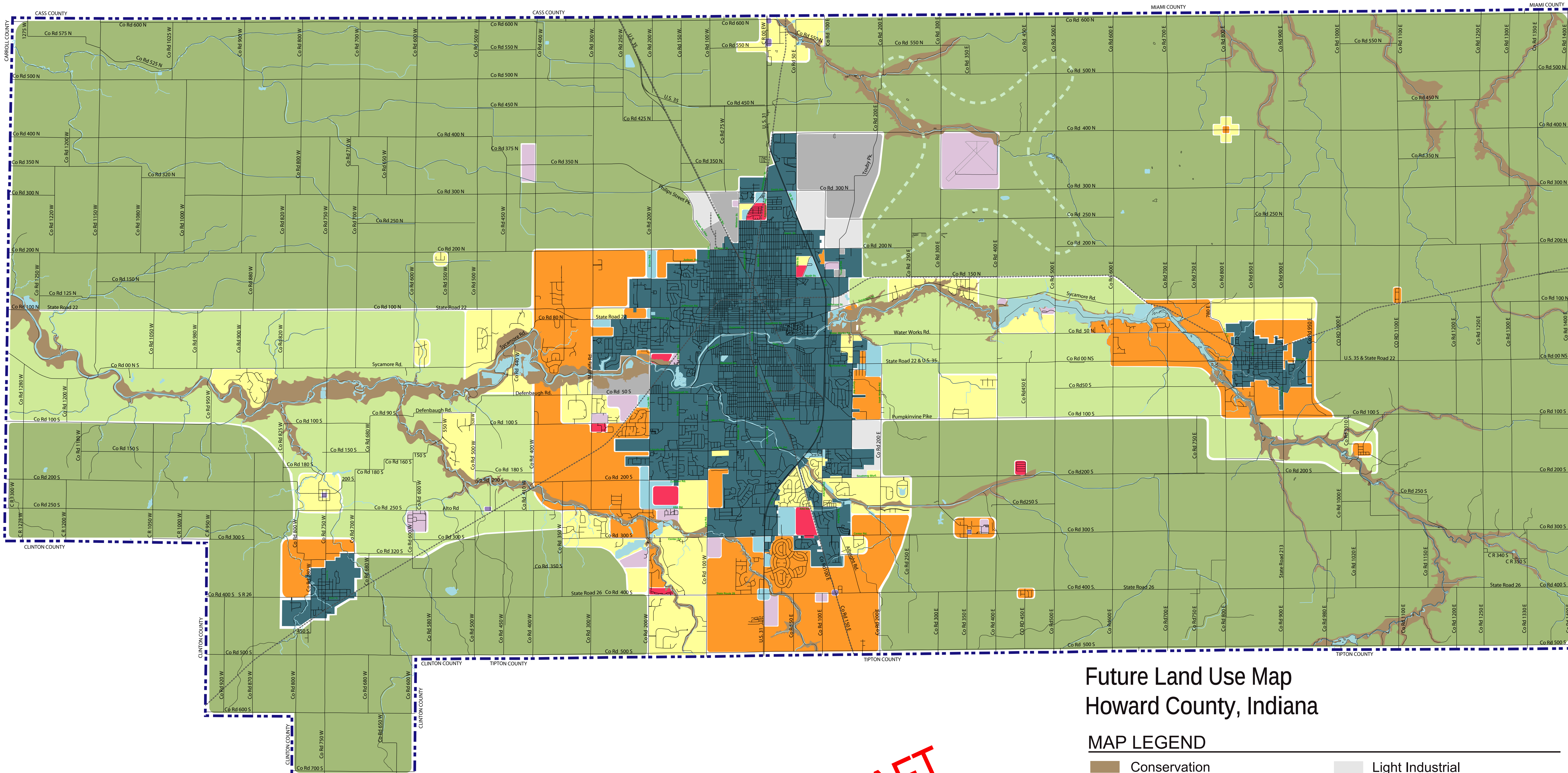


Figure 4-1: Existing Land Use



Howard County Maps



Future Land Use Map
Howard County, Indiana

MAP LEGEND

- Conservation
- Agricultural
- Rural Residential
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Government/Institutional
- Village Commercial
- General Commercial
- Light Industrial
- Heavy Industrial
- Streets
- Railroad
- Creek/Stream
- Municipal Jurisdiction
- Currently Not Used
- Airport Hazard Zone

DRAFT

GroundRules
website w w w . g r o u n d r u l e s i n c . c o m

1 MILE 2 MILES 3 MILES

North

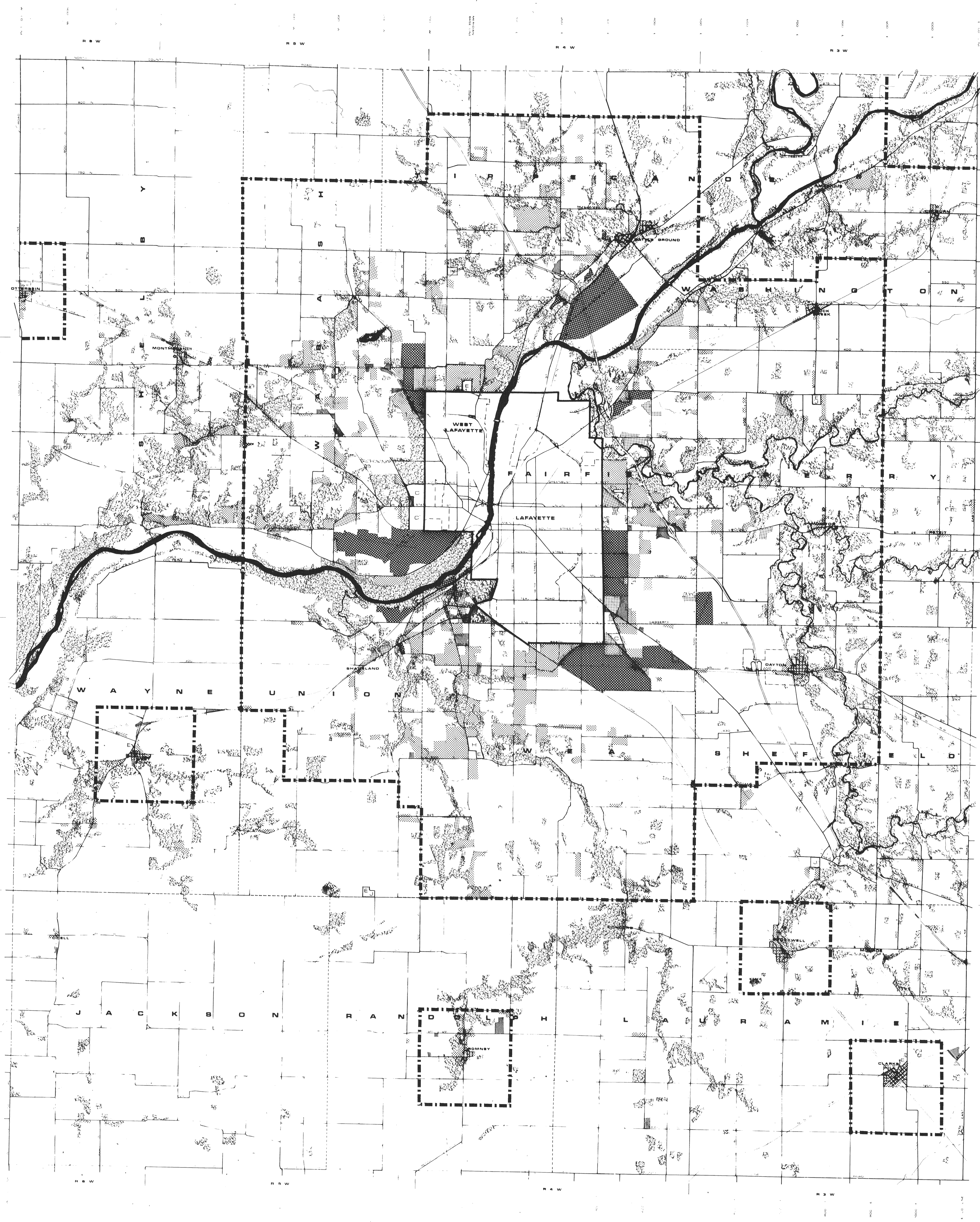
Last Revised: May 5, 2005

Miami County Maps


MIAMI COUNTY
Future Land Use Policy
ASSUMED NORTH
SCALE 1" = 5000'
PLANNING JURISDICTION
AG - AGRICULTURE
PB - PUBLIC SEMI PUBLIC
LR - LOW DENSITY RESIDENTIAL
MD - MEDIUM DENSITY RESIDENTIAL
CR - COMMERCIAL/RESIDENTIAL MIXED USE
C - COMMERCIAL
CI - COMMERCIAL/INDUSTRIAL MIXED USE
I - INDUSTRIAL
MACY
GILEAD
BIRMINGHAM
STOCKDALE
DEEDSVILLE
PERRYSBURG
DENVER
CHILI
MEXICO
ERIE
PERU
FRANCES SLOCUM STATE FOREST
PEORIA
MISSISSINEWA RESERVOIR
NEAD
LEONDA
GRISSOM AEROPLEX
BUNKER HILL
SANTA FE
LOREE
MIAMI
NORTH GROVE
AMBOY
BENNETTS SWITCH
WAUPECONG
CONVERSE

Tippecanoe County Maps

CURRENT AND EXPECTED LAND USE



LEGEND

- RESIDENTIAL
- AGRICULTURAL
- INDUSTRIAL
- COMMERCIAL
- OPEN SPACE
- E J H C SCHOOLS
- URBAN BOUNDARY
- URBANIZING BOUNDARY

N

0 6000

DRAWN BY R A DAVIS

TIPPECANOE COUNTY

AREA PLAN COMMISSION

SUMMER 1980

REVISED AUGUST 1981

Howard County Little Deer Watershed Management Plan Maps

Critical Areas for Land Treatment

Critical areas for implementing water quality protection practices were identified by comparing pollutant loads and yields from individual sub-watersheds. The project area was divided into has five sub-watersheds (Figure 4) defined by the location of water sampling sites (Table 5). The size of each sub-watershed was estimated from 1:20,000 scale soil maps using an acreage measuring grid.

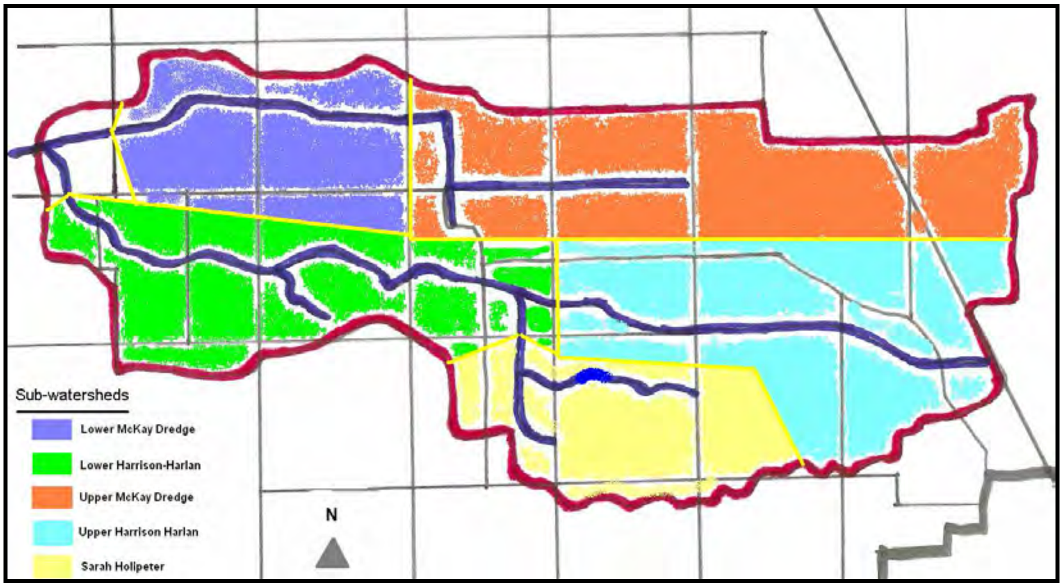


Figure 4. Estimated Sub-watersheds of Little Deer Creek Headwaters 205j Project.

Table 5. Estimated acreages of sub-watersheds in the Little Deer Creek Headwaters 205j project area.

Sub-watershed Name	Estimated Acres	Sub-watershed Outlet Water Sampling Site
Lower McKay Dredge[1]	1,100	MD 1 (MD 3)
Lower Harrison Harlan Ditch[1]	2,250	MD 2 (MD 4 & 5)
Upper McKay Dredge Ditch	2,525	MD 3
Sarah Holipeter Ditch	1,400	MD 4
Upper Harrison Harlan Ditch	1,950	MD 5

[1] These locations also include inputs from upstream sub-watersheds named in parentheses.

Pollutant Loads

The quantity of pollutant leaving a watershed over time is called a load. Comparison of pollutant loads is useful for identifying problem areas (critical areas) within a watershed. Pollutant loads were calculated for each sub-watershed using test results for spring and fall water samples plus stream discharge measurements (Table 6). Although this is a rough analysis and there are only two water samples to compare at each site, this approach helps in locating needs for certain conservation practices.

Table 6. Pollutant Loads Leaving Little Deer Creek Headwaters Watershed During High and Low Stream Flow.

Pollutant	Spring (high flow) Total Load	Fall (low flow) Total Load
Ammonia	119 (lbs/day)	3 (lbs/day)
Total Kjeldahl Nitrogen	1,523 (lbs/day)	23 (lbs/day)
Nitrite+Nitrate	9,109 (lbs/day)	354 (lbs/day)
Total Phosphorus	338 (lbs/day)	2 (lbs/day)
Atrazine	1850 (g/day)	7 (g/day)
E. Coliform bacteria	8.E + 12 (cfu/day)	2.E +10 (cfu/day)

Pollutant loads in spring runoff are much higher than in fall stream flow as shown in Figures 5-10. The three most upstream sub-watersheds (Upper McKay Dredge, Sarah Holipeter and Upper Harrison Harlan) carry significant loads of nitrogen and phosphorus when stream discharge is high, such as after a rain event of at least 0.5" as was measured in this project. Pollutant loading drops to low levels when discharge falls. High loads are usually associated with agricultural activities that take place during spring when vegetative cover to protect soils from rains is at a minimum and the application of manure and chemicals (pesticides and fertilizers) is taking place. Failing or incomplete septic systems are also a source of nutrient loading.

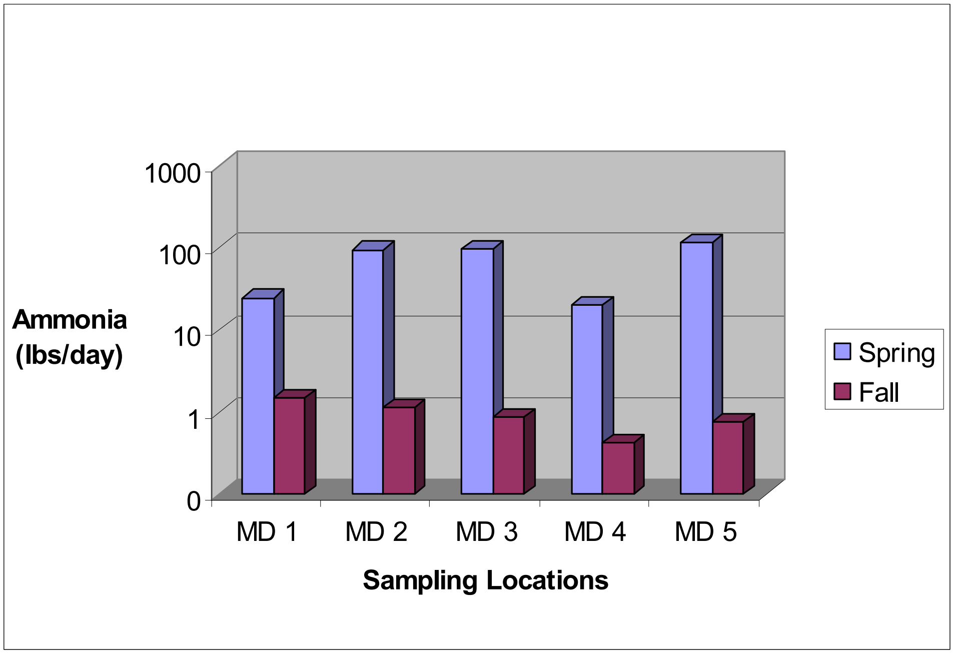


Figure 5. Ammonia Load: Spring vs. Fall (2003)

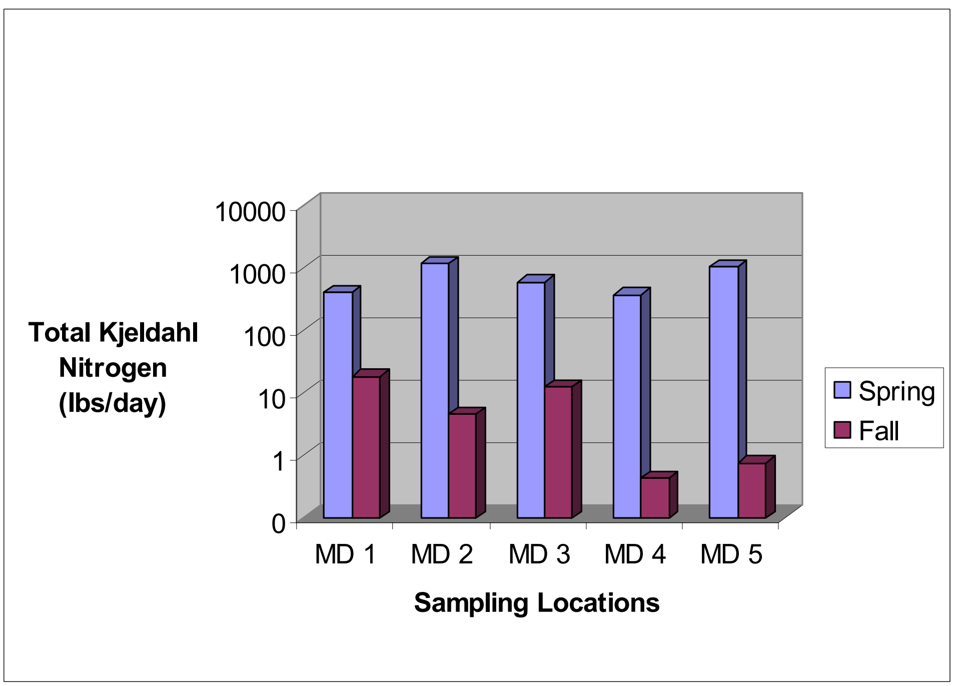


Figure 6. Total Kjeldahl Nitrogen Load: Spring vs. Fall (2003)

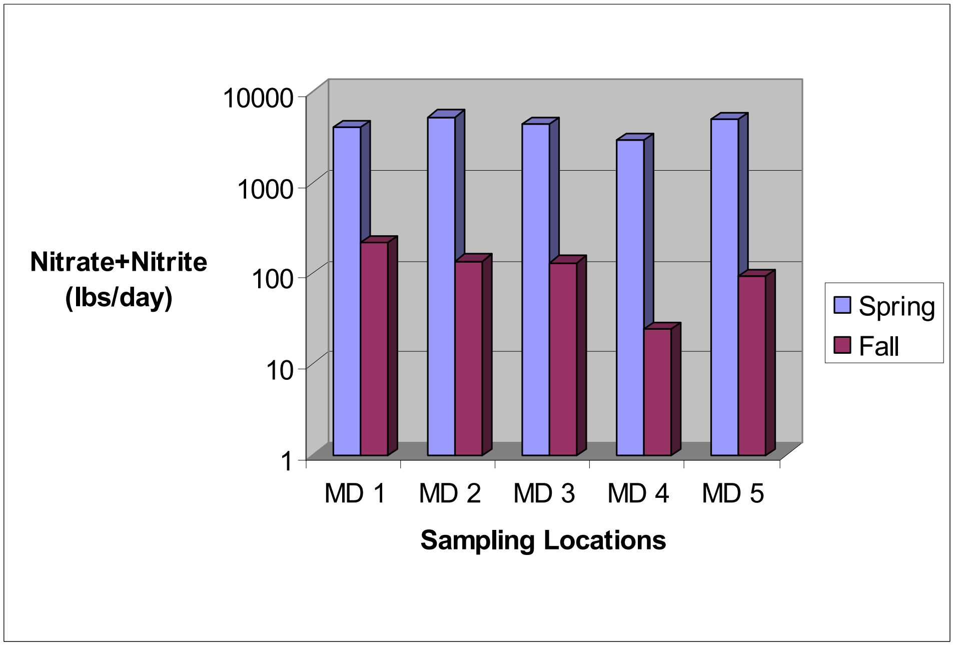


Figure 7. Nitrate + Nitrite Load: Spring vs. Fall (2003)

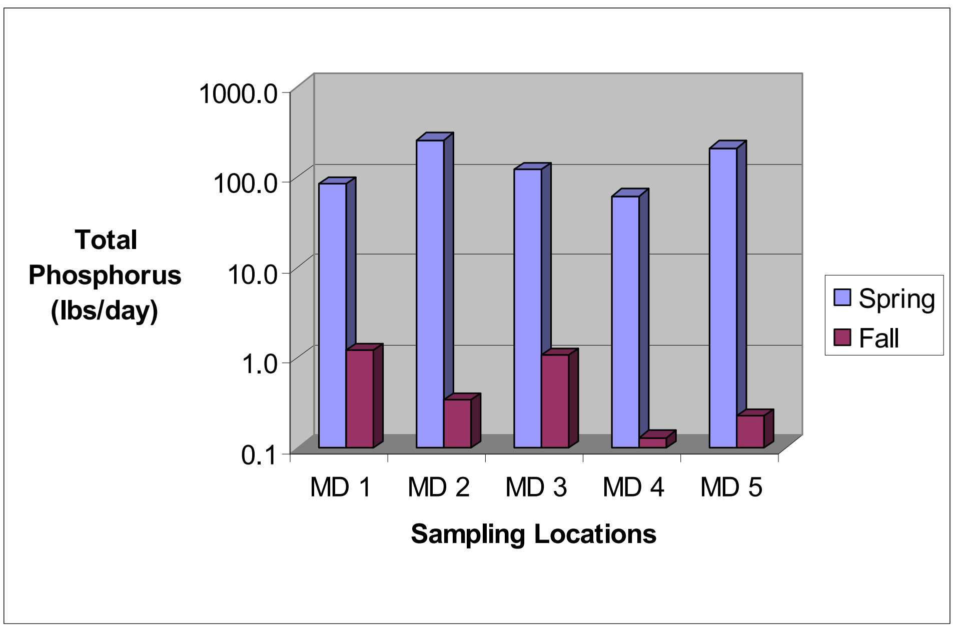


Figure 8. Total Phosphorus Load: Spring vs. Fall (2003)

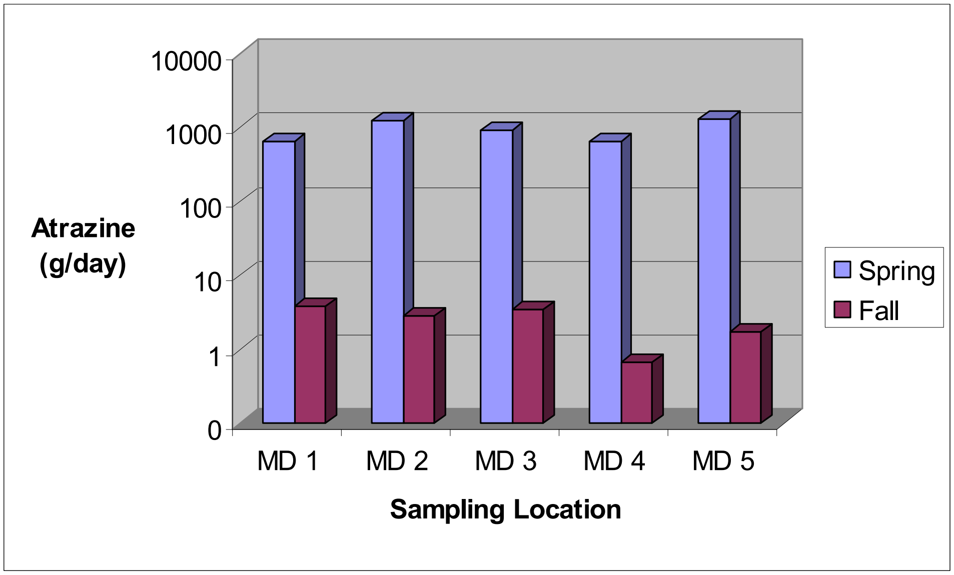


Figure 9. Atrazine Load: Spring vs. Fall (2003)

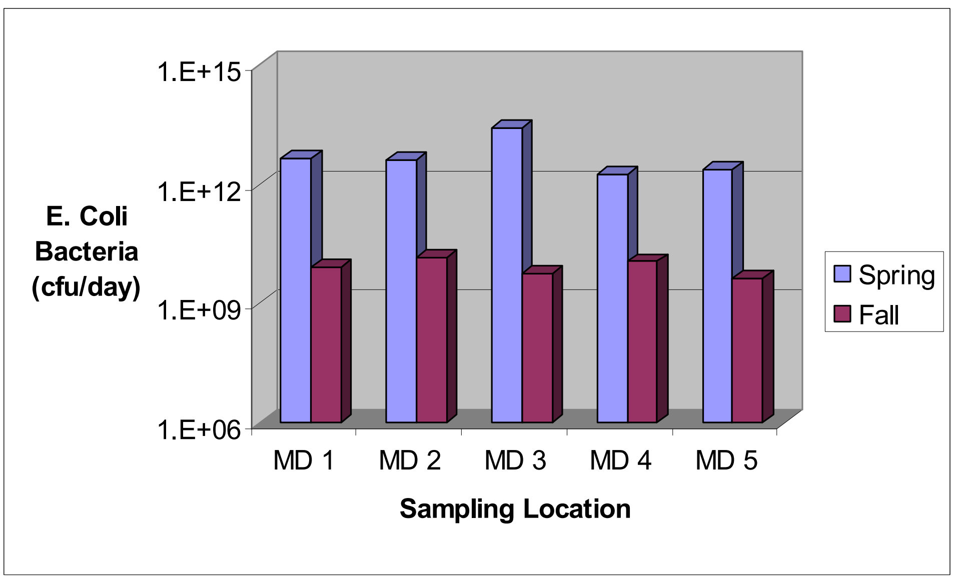


Figure 10. E. Coli Bacteria Load: Spring vs. Fall (2003)

Pollutant Yields

Another method of comparing the amount of pollutants contributed from different sub-watersheds is to calculate the yield (load divided by drainage area), or the amount of pollutant generated per acre in each sub-watershed. Figures 11 and 12 show that all three headwaters watersheds are fairly close in nutrient and Atrazine yield, but the Upper Harrison Harlan (above MD 5) sub-watershed has slightly greater pollutant yields.

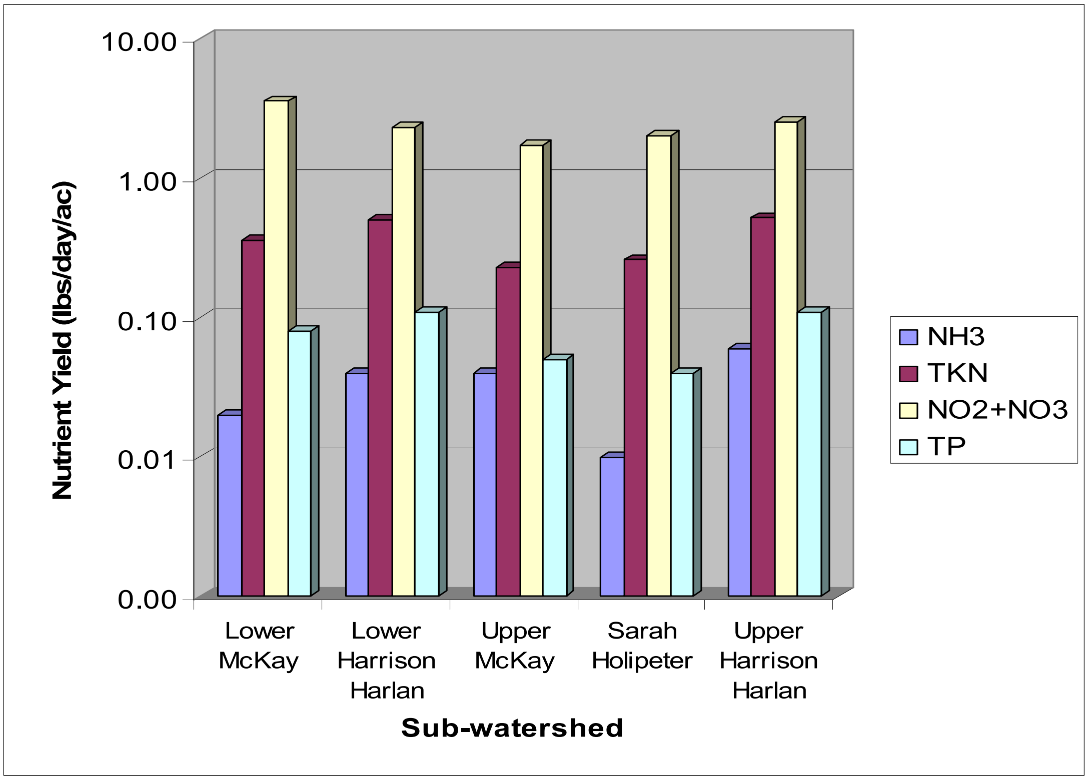


Figure 11. Nutrient Yield From Sub-watersheds: Spring (2003)

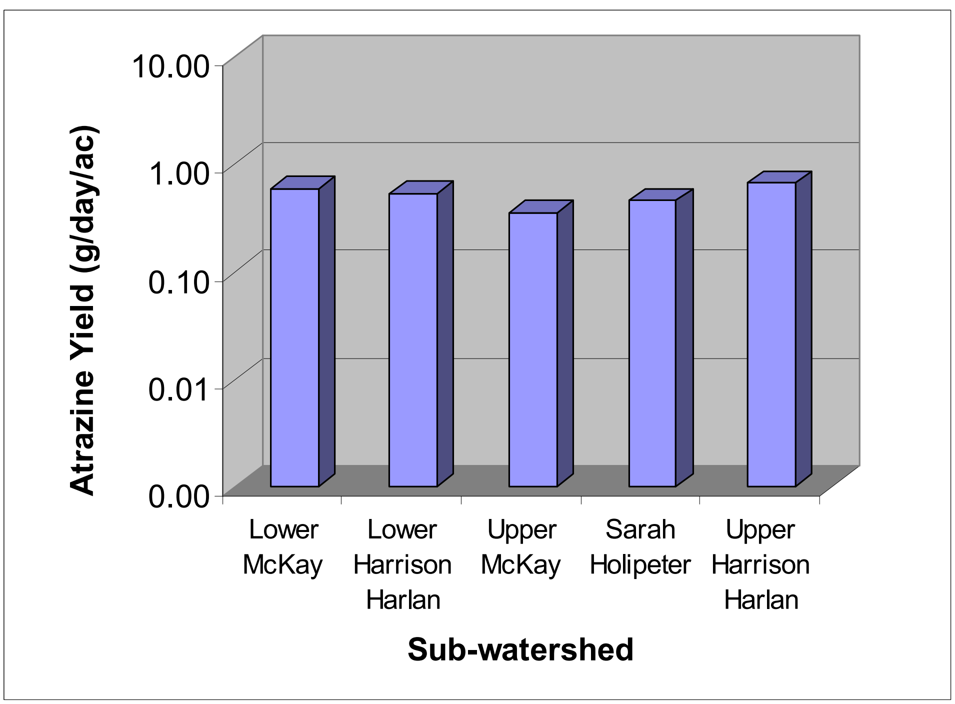


Figure 12. Atrazine Yields From Sub-watersheds: Spring (2003)

Wabash River Total Maximum Daily Load Report Maps

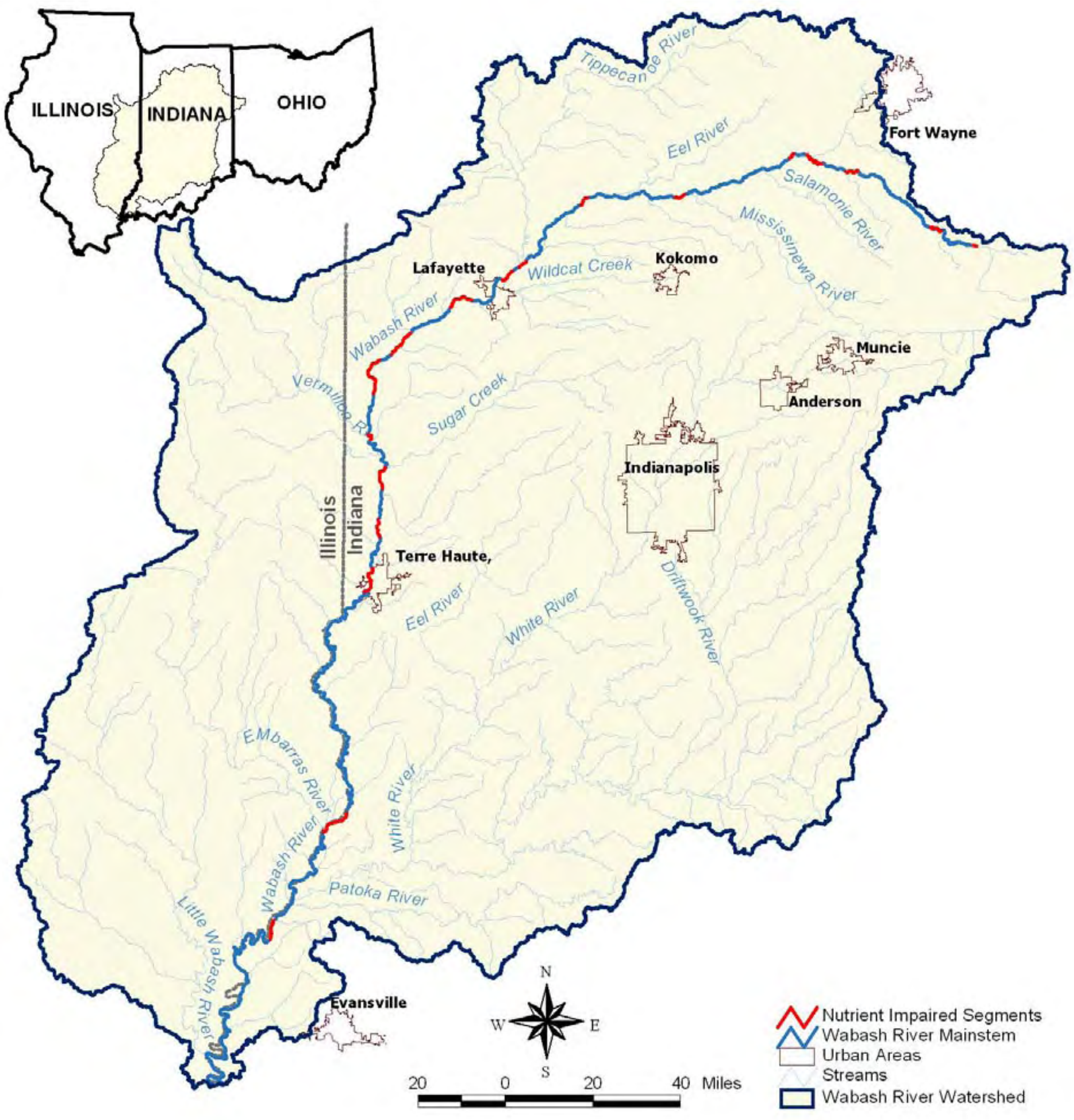


Figure 2-3. Verified nutrient impaired segments.

2.4 Sources

A variety of different types of sources contribute pollutants to the Wabash River. Due to the extremely large size of the watershed it was beyond the scope of this study to evaluate each of these sources individually. Instead, existing loads and load allocations were made to the following three source categories:

1) National Pollutant Discharge Elimination System (NPDES) facilities that discharge directly to the Wabash River
2) Subwatersheds draining directly to the Wabash River

Figure 2-2. Water quality sampling stations along the Wabash River.

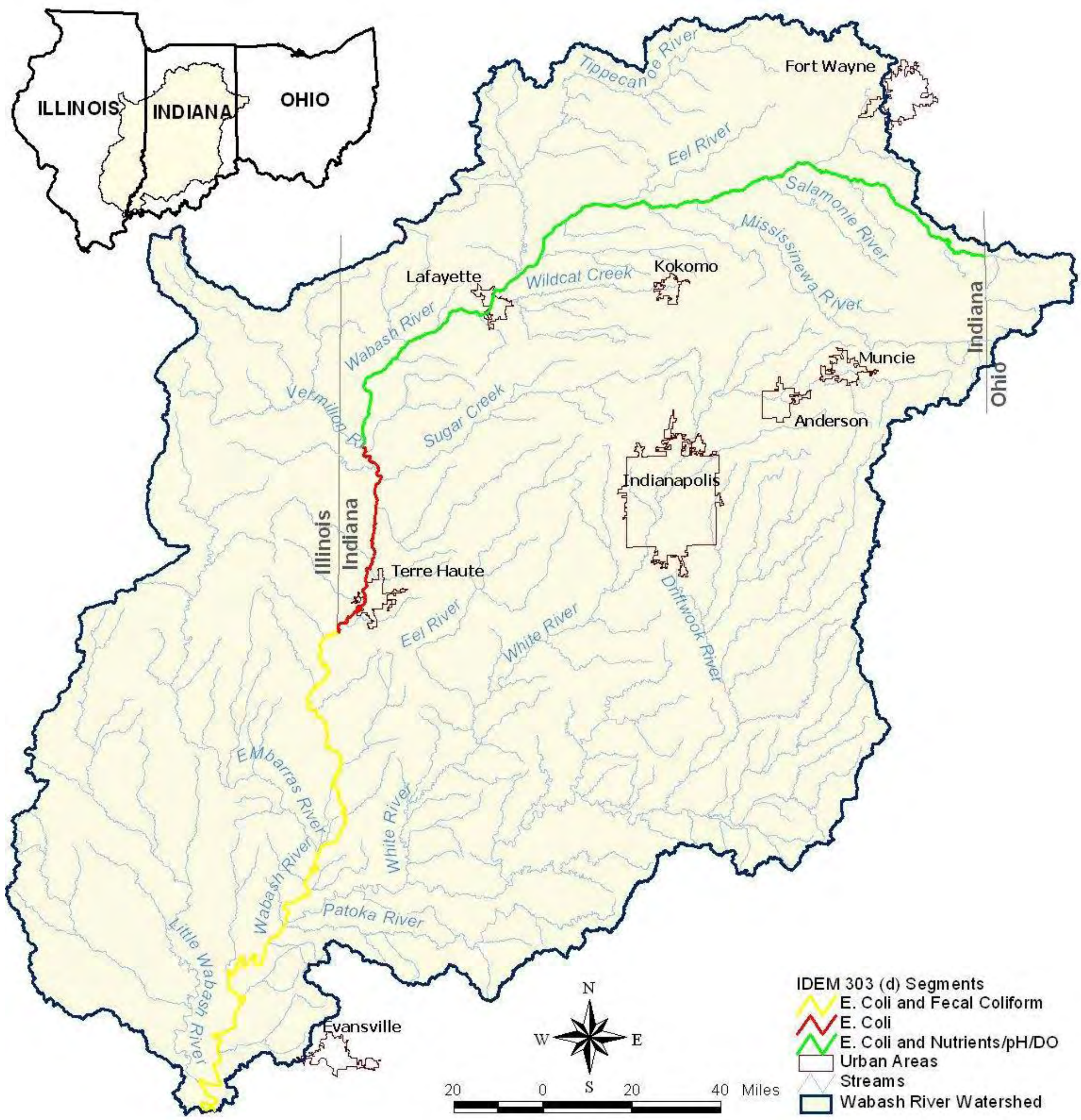


Figure 2-1. Location of impaired Wabash River segments addressed by the TMDLs presented in this report.