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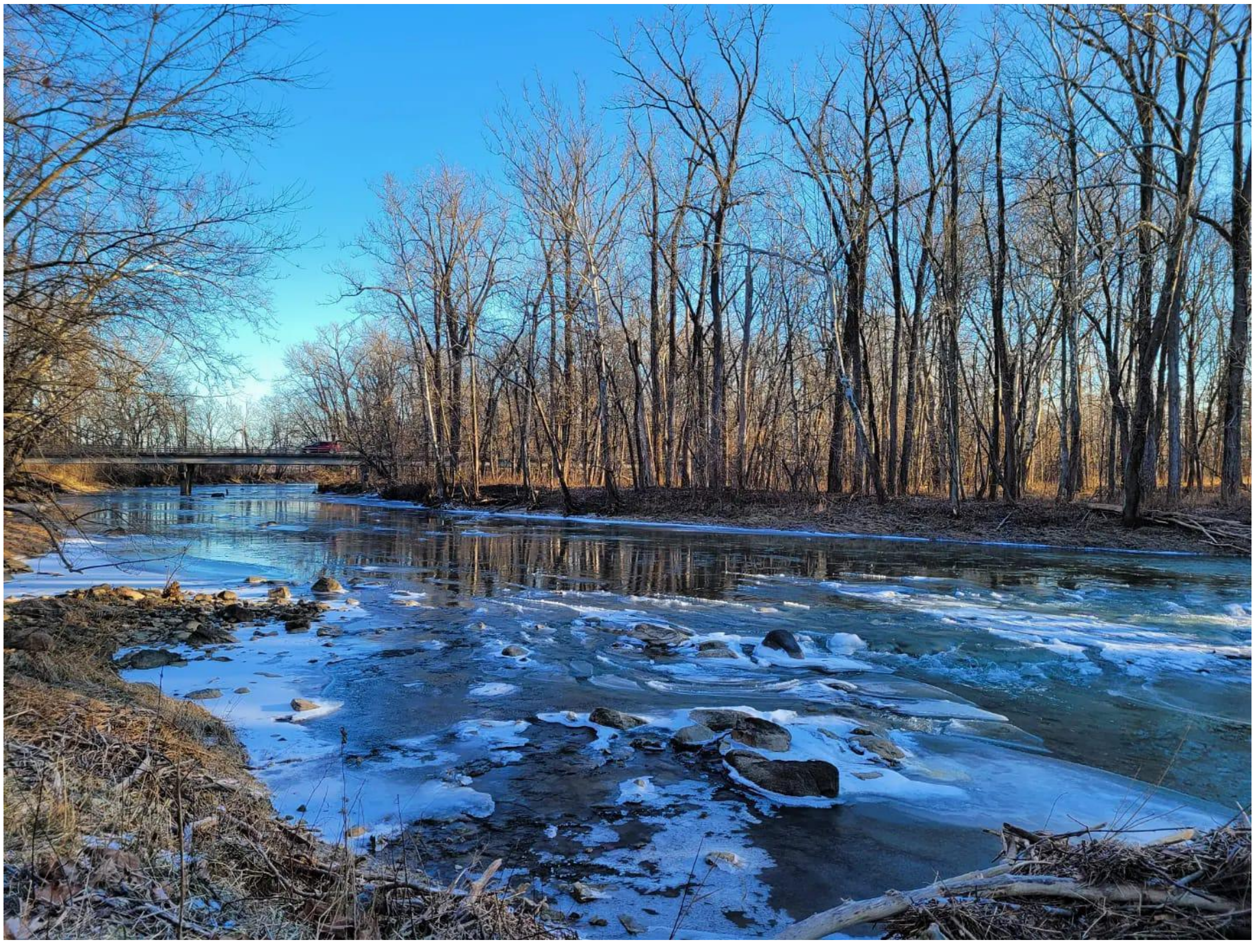
UPPER SUGAR CREEK WATERSHED MANAGEMENT PLAN
BOONE, CLINTON, MONTGOMERY AND TIPPECANOE COUNTIES, INDIANA



A PROJECT OF THE
MONTGOMERY COUNTY SOIL AND WATER CONSERVATION DISTRICT
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1.0 WATERSHED INTRODUCTION

1.1 Watershed Community Initiative

A watershed is the land area that drains to a common point, such as a location on a river. In this case, the Upper Sugar Creek Watershed is of interest (Figure 1). All of the water that falls on a watershed will move across the landscape collecting in low spots and drainageways 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.

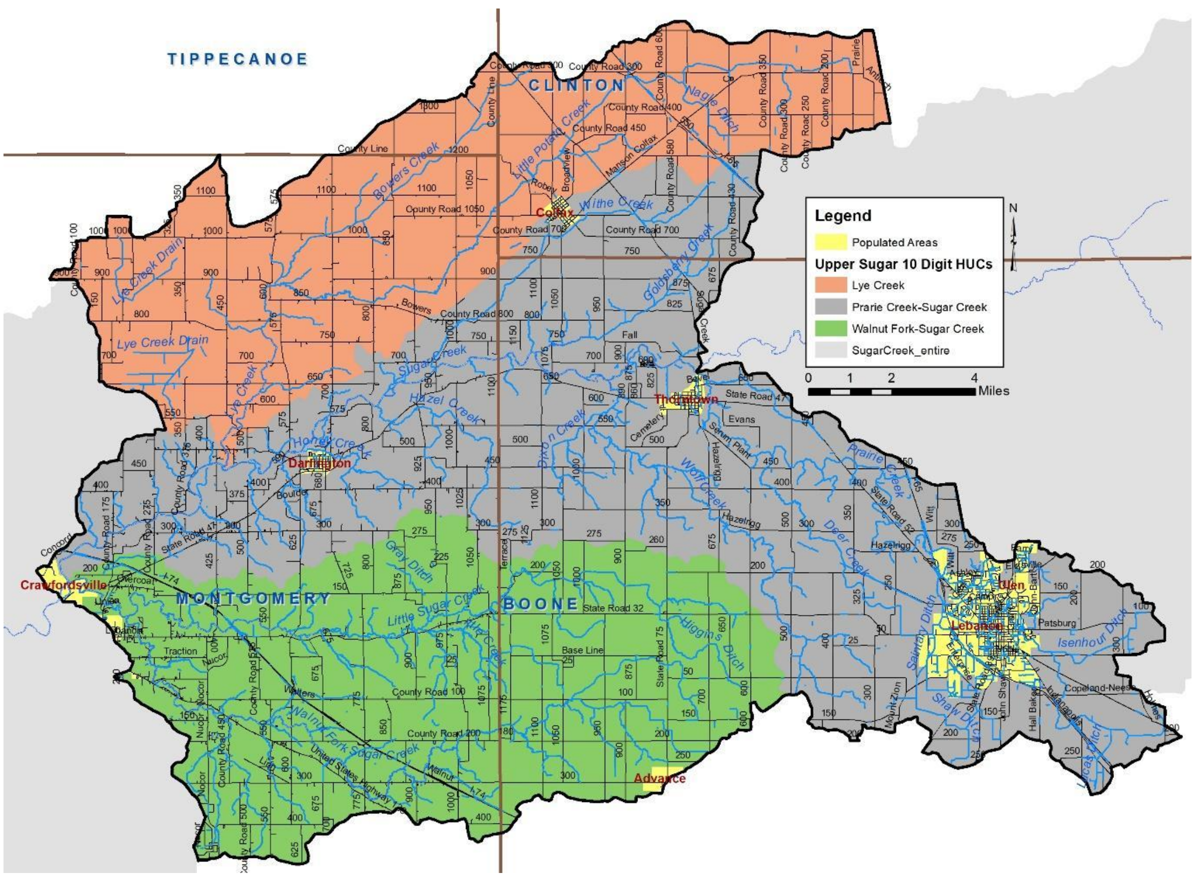


Figure 1. Upper Sugar Creek Watershed including the three-10 digit hydrologic unit code drainages and populous areas.

The Upper Sugar Creek Watershed starts downstream of the Browns Wonder-Sugar Creek Watershed receiving water from Prairie Creek, Walnut Fork-Sugar Creek and Lye Creek in addition to drainage from the Browns Wonder-Sugar Creek Watershed. In total, the Upper Sugar Creek Watershed drains 508 square miles of which 319 square miles will be addressed in this watershed management plan. The watershed includes drainage from Lebanon, Darlington, Colfax and Thorntown (Figure 1). The watershed includes three 10-digit hydrologic unit codes (HUCs): 0512011002 (Lye Creek), 0512011003 (Walnut Fork-Sugar Creek) and 0512011004 (Prairie Creek-Sugar Creek). The Upper Sugar Creek Watershed is comprised of three major basins: Prairie Creek draining north and west from the City of Lebanon, Walnut Fork-Sugar Creek draining west along the southern portion of the watershed and Lye Creek draining the north and eastern portion of the watershed. Lye Creek, Prairie Creek and Walnut Fork-Sugar Creek and other tributaries join Sugar Creek upstream of Crawfordsville. Sugar Creek continues south and west through Montgomery, Fountain and Parke Counties where it meets the Wabash River north of Montezuma. The Wabash River flows south to join with the Ohio River (Figure 2).

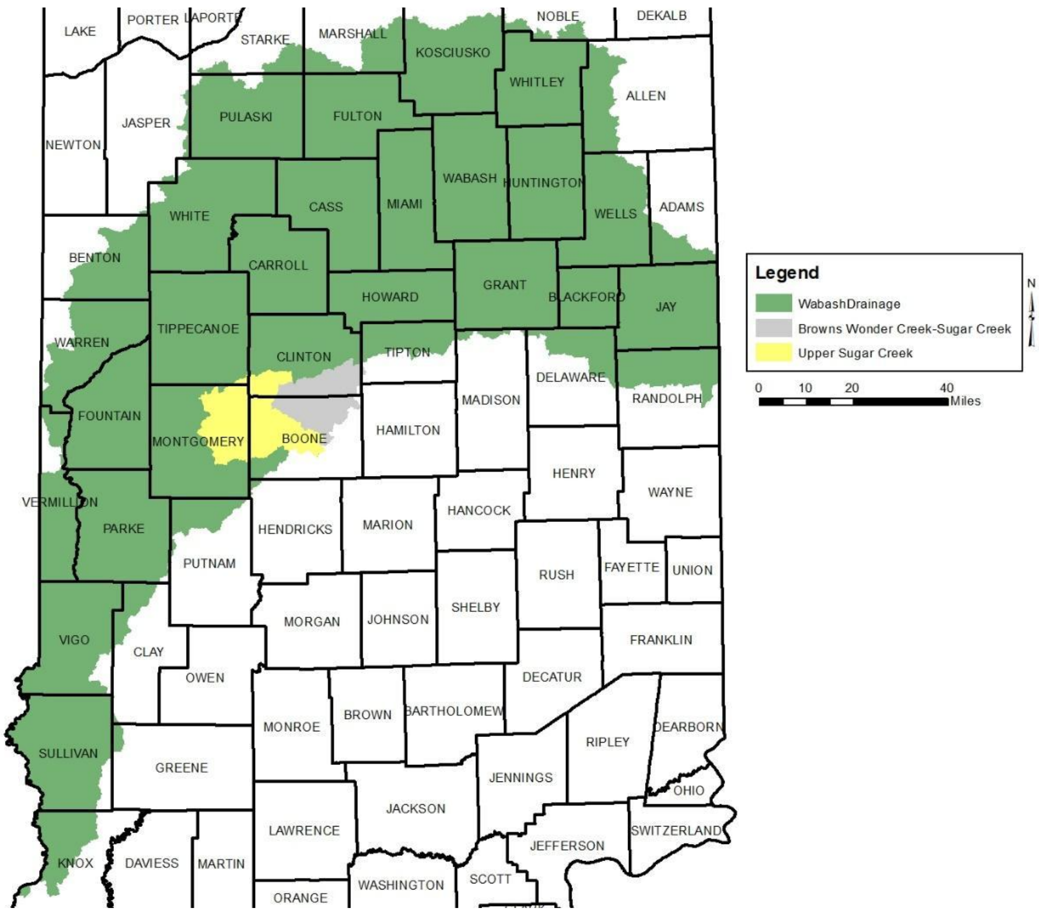


Figure 2. The Wabash River Basin highlighting the Upper Sugar Creek Watershed.

1.2 Project History

The Upper Sugar Creek Project launched in late 2021 as a result of a Section 319 grant awarded to develop the Upper Sugar Creek Watershed Management Plan. The Upper Sugar Creek Watershed includes all of the City of Lebanon and Towns of Colfax, Thorntown and Darlington. The watershed includes a variety of land uses including agricultural, forest and natural areas, including nature preserves, as well as urban and urbanizing land uses. Much of the watershed is dominated by agricultural land use with intact forested riparian areas especially adjacent to the mainstem of Sugar Creek. One exception is the predominantly urban and urbanizing drainages in the Prairie Creek headwaters (Sanitary Ditch-Prairie Creek and Deer Creek-Prairie Creek). The mix of land uses generate nutrient, sediment and pathogen runoff concerns. Stakeholders also identified the need to maintain high-quality habitat and aesthetic conditions that leads Sugar Creek to be a recreation destination.

Based on these concerns, the Montgomery County SWCD approached community groups and individuals throughout the watershed that might be interested in working with them to assess and improve water quality within Upper Sugar Creek and its tributaries. Identified potential stakeholders include: Boone, Clinton and Tippecanoe County SWCD and NRCS staff; City of Lebanon MS4s; Indiana DNR; Indiana State Department of Agriculture; Boone, Clinton, Montgomery and Tippecanoe County surveyors, parks departments, health departments and Purdue Extension; The Nature Conservancy; Wabash College faculty, students and staff; Friends of Sugar Creek, NICHES Land Trust; local landowners, educators and more. This group formed a Steering Committee (Table 1), conducted windshield surveys of the watershed, and held several meetings open to the public in order to generate input in the development of a watershed management plan for the Upper Sugar Creek Watershed.

1.3 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. The Upper Sugar Creek Project involved stakeholders in the watershed management planning process through a series of public meetings and education and outreach events including windshield surveys, workshops, field days and education events.

1.3.1 Steering Committee

Individuals representing the towns and counties within the watershed, environmental groups, natural resource professionals, agricultural and commercial representatives, and private citizens comprised the steering committee. The steering committee has met quarterly to develop the WMP starting in January 2022. Table 1 identifies the steering committee members and their affiliation.

Table 1. Upper Creek Watershed steering committee members and their affiliation.

Individual	Organization(s) Represented
Brian Daggy and Sheryl Vaughn	Boone SWCD
Sina Parks	Ceres
Scott Calvert	City of Lebanon MS4
Daniel Sheets	Clinton Surveyor
Olivia Wenger, Stephen Miller	Clinton SWCD
David Hadley, Cindy Woodall, Mark Elrod	Friends of Sugar Creek
Lindsay Hylton Adams	Indiana Dept of Environmental Management
Sarah Gordon	Indiana American Water
George Reger, Matt Williams	Indiana State Department of Agriculture
John Frey	Montgomery County
Amber Reed	Montgomery Health Department
Monica Wilhoit, Tricia Herr	Montgomery Purdue Extension
Tom Cummins	Montgomery surveyor
Kristen Latzke and Megan Sweeney	Montgomery SWCD

Individual	Organization(s) Represented
Angie Garrison	NRCS
Chris Torp and Kenny Cain	Pheasants Forever
Adam Shanks	Purdue Extension - Clinton
Raoul Moore	Sugar Creek Advisory Board
Spencer Willem	Tippecanoe Surveyors office
Michelle Gilbert	Tippecanoe SWCD
Seth Harden	The Nature Conservancy
Chris Anderson	Wabash College

1.3.2 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 and listening sessions. The purpose of the public meetings was to provide information on the overall planning effort and its progress; solicit stakeholder input, opinions, and participation; create opportunities for the public to recommend programs, policies, and projects to improve water quality; and build support for future phases of the project. The public meeting occurred in March 2022, with the agricultural listening session occurring in August 2022. They were used to introduce the project, develop a concerns list and allow individuals to provide their thoughts on potential projects that will be targeted in future implementation efforts.

The public meetings/listening sessions were advertised through press releases distributed to local newspapers in the watershed and via the project website and emails sent to local landowners and conservation partners. The meetings/listening sessions were also advertised through word of mouth as staff from the Soil and Water Conservation District put together mailings that advertised the events.

The first public meeting occurred on March 16, 2022 and was hosted in part by the Wabash College Discourse and Diversity. The farmer listening session occurred on August 15, 2022 and the recreation listening session occurred on January 24, 2023. Concerns and other input gathered as part of the three events are included in the subsequent sections.

The second public meeting occurred July 31, 2023 and was hosted in part by the Friends of Sugar Creek. The meeting included an overview of the project and included an update on the status of the project and focused on gathering feedback on critical areas, practices selected for implementation and the likelihood of meeting project goals gathered.

1.4 Public Input

Throughout the planning process, project stakeholders, the steering committee, and the general public listed concerns for the Upper Sugar Creek Watershed including Sugar Creek, its tributaries, and its watershed. Public and committee meetings were the primary mechanism of soliciting individual concerns. All comments were recorded and included as part of the concern documentation and prioritization process. Concerns voiced throughout the process are listed in Table 2. Similar stakeholder concerns were grouped roughly by topic and condensed by the committee. The order of concern listing does not reflect any prioritization by watershed stakeholders.

Table 2. Stakeholder concerns identified during public input sessions, steering committee meetings and via the watershed inventory process. Note: The order of concern listing does not reflect any prioritization by watershed stakeholders.

Stakeholder Concerns
Additional water inputs are changing sugar creek – getting straighter
Beaver impacts
Bridges are not replaced in Lye Creek Basin due to high flow – options to study flow through these systems
Change is hard – fear reduced yields (other impacts should be included here)
Climate change
Concerns about how this information will be used
Confined feeding operations, manure volume
County roads –build right up to them
Cover crop information is lacking
Cover crop profitability must be emphasized/detailed for farmer adoption
Cover crops - climate barrier
Dam removal at Crawfordsville opens the Upper Sugar Creek to recreation
Deer death in small streams/deer over population
Drinking water protection (Indiana American Water)/source water
E. coli levels are elevated
Economic development – Lebanon (water pollution, water usage, trash)
Education for controlled drainage – drainage water management and others that target water quantity are needed
Elevated sediment and nutrient levels
Encourage landowners to practice stewardship at their residence
Encourage local farmers to practice a good land ethic
Engaging/leveraging resources for industrial developers
Erosion – farmers are farming into ditches
Farmers are blamed even if it isn’t their fault
Farmers are resistant to change
Farmland conservation and preservation needed
Fertilizer use optimization (4Rs)
Fish community is declining
Fish seining and netting
Flooding: too much water entering stream too quickly
Funding constraints
Industrial and residential development along I65/within city of Lebanon
Invasive species threats to biodiversity of both flora and fauna with an untold economic cost to forestry and tourism
Is new development in Boone County following requirements or best practices?
Issues with cover crop planting, harvest, timing
Keeping the creek healthy/ maintain quality fish community

Lack of awareness
Lebanon is growing, lack of land for agriculture, increased traffic, no room for ag equipment on roads
Livestock access
Logjams
Maintenance of regulated drains needed
Municipal sludge is applied to farm ground
Need to build a sense of community between agriculture and recreation
Need to engage agricultural landowners
On farm issue: time and interest in cover crops, but time constraint for fall harvest
Ponding sometimes occurs when farmers farm into (road) ditches
Protect and improve (terrestrial) habitat
Provide opportunities to access Sugar Creek
Recreational vehicles must be excluded from streams
River otter population impacting fish communities in farm ponds and Sugar Creek
Runoff from pesticides and soil
Septic soil limitations, straight pipes, lack of maintenance
Soil erosion and nutrient loss
Some farmers don't want to be told what they can/cannot do
Spray, drift, and volatilization issues/concerns – herbicides, others
Stream flow issues
Stream widening through erosion – shallow water
Streambank erosion
Sugar Creek provides good habitat and aesthetics – it should be protected
Threats from industry, residential development
Towns are an issue but don't get blamed
Traditional farming and traditional tillage leads to silt runoff, wind erosion, soil loss
Trash accumulation
Tree line removal impacts
Urban areas and their water quality impacts – City of Lebanon
Washouts in large rain events
Water quality is poor
Wetland loss/wetland restoration in marginal land targeting Lye/Potatoe Creek areas
What is the source of E. coli (human, animal, etc)
Wildlife corridors should connect watershed headwaters

1.5 Social Indicator Survey

The ability of Montgomery 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.
- Determine what practices they adopt on the land they manage.
- Determine what factors affect their land management decisions.

Social indicator surveys provide one way to analyze these attitudes, 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. The Upper Sugar Creek project tailored an existing survey system that was originally developed for use in nonpoint source pollution projects by a regional team of researchers.

1.5.1 Survey Methods

Because the Upper Sugar Creek watershed is almost entirely agricultural, recipients for the survey were purchased from DTN which maintains a database of agricultural producers. The 13-page survey was sent to 472 addresses in the watershed. Of these, 39 addresses were removed from the pool as they were deceased or undeliverable. In total, 193 responses were returned to the project garnering a response rate of 44%.

A standardized delivery and collection method was used. In February 2023, 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 two weeks following the postcard. After two more weeks, a final letter was sent to all non-respondents with instructions on how to complete the survey online.

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. A copy of the mailed survey as well as detailed tables, including raw statistical data, are included in Appendix A.

1.5.2 Survey Results

As detailed above, the agricultural survey was sent to 472 producers and resulted in a 44% return rate.

Rating of Water Quality

Respondents were asked to rank the importance of several water-related activities. "Scenic beauty/enjoyment" and "fish habitat" were the highest ranked response categories, while "swimming" in the water received the lowest rating. "Picnicking" and "Canoeing, kayaking, and other boating" and "eating locally caught fish" activities ranked in the middle. This suggests a prevalent "look but don't touch" attitude toward recreational use of the water in the Sugar Creek Watershed. However, respondents clearly seem comfortable with activities which bring them onto or in close proximity to the water.

Septic Systems

Respondents were asked several questions related to septic systems. A majority of respondents (over 80%) indicated that they have a septic system. Most respondents knew when, or roughly when, their system was installed, with the average septic installation occurring around 1993, resulting in most systems in the watershed being 30 years old or older. Most respondents with septic systems reported that they did not experience any problems with them in the last five years. Slow drains, bad smells near tank or drain field and sewage backups in the house were the three most common problems reported if a system did malfunction. Most respondents (86%) said that they have a finger system, while 14% said they did not. When asked how their septic system was designed, 41% responded that their septic was designed to treat sewage and get rid of waste. In total, 11% of Upper Sugar Creek septics were designed only to treat sewage, while 29% were designed only to remove waste.

When asked if they would like a reminder from the local health department regarding inspection/maintenance of the system, a majority (over 90%) of respondents indicated a reminder was not necessary. Further, when asked if they thought a local government agency should handle inspection and maintenance, over 85% of respondents also indicated that government involvement with inspections and maintenance was not preferred.

Water Quality Attitudes

Respondents were asked to rank their level of agreement with several 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 and education and outreach efforts have been implemented. A one to five “strongly disagree” to “strongly agree” scale was used. In general, respondents believe that recommended agricultural practices can improve water quality in the Upper Sugar Creek Watershed and that they are willing to accept responsibility for improving water quality. Respondents also lean favorably towards the ideas that personal actions can impact water quality in the Upper Sugar Creek Watershed, 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. However, Upper Sugar Creek respondents 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 in the Upper Sugar Creek Watershed. 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 of each of 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, excessive aquatic plants or algae and polluted swimming areas were seen as the most serious issues. All of these consequences ranked as “slight problems.” Respondents were less aware of less visible issues, such as contaminated drinking water, fish kills, and reduced quality of water for recreation activities. However, those who were aware of these issues also ranked contaminated fish and excessive aquatic plants or algae as slight problems. These responses suggest that respondents are most aware of visible and recreational-related issues, and for those that are aware of other issues, fish and algae blooms are the most serious issues. 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. Responses also indicated that land development or redevelopment was seen as a problem, ranking at nearly 27% seeing it as a moderate problem. Respondents were also aware of additional agricultural sources of pollution, such as manure from farm animals and excessive use of fertilizers but ranked these of lower concern. Each of these sources rated as not a problem or a slight problem. Respondents were less aware of sources including septic systems, discharge from sewage treatment plants, industrial discharges and urban stormwater runoff. Those that were aware of these sources of water pollution considered stormwater runoff to be the biggest concern, ranking it a slight to moderate contributor of water pollution in the Upper Sugar Creek Watershed. 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 3**Error! Reference source not found.** through Figure 5). Of all listed practices to improve water quality, respondents are most familiar with or were currently using soil testing. Of these, 86.8% reported they were currently using soil testing, and 3.5% reported they knew how to use it, but were not. (Figure 4).The practice participants were next most familiar with or were currently rotating crops to control soil erosion, with 81.2% reporting they were currently using this practice, and 2.8% reporting they knew how to use it, but were not using it. Of the practices, participants were least familiar with heavy use area protection for waste management, with 15% reporting they had never heard of the practice.

An average of 99 respondents felt that questions related to livestock were relevant to their property. Of these, 14% currently use approved grazing plans and fences to exclude livestock from streams (Figure 3), while 28% of respondents currently use manure in accordance with its nutrient content (Figure 4). An average of 132 respondents felt that questions related to crop agriculture were relevant to their property. Of these, 72% of respondents currently use grassed waterways to reduce erosion (Figure 3) and 81% of respondents rotate crops to control soil erosion (Figure 4). About 60% of respondents currently use field records of crops, pests and pesticide use to help develop pest control strategies (Figure 3). Additionally, 63% of respondents use conservation tillage (Figure 3), however, 13% of respondents said they know how to use conservation tillage but are not currently using it. Respondents were the least familiar with heavy use area protection for waste management, with only 13% of respondents currently use this practice (Figure 4), while 68% of respondents were only slightly familiar with it or had never heard of it.

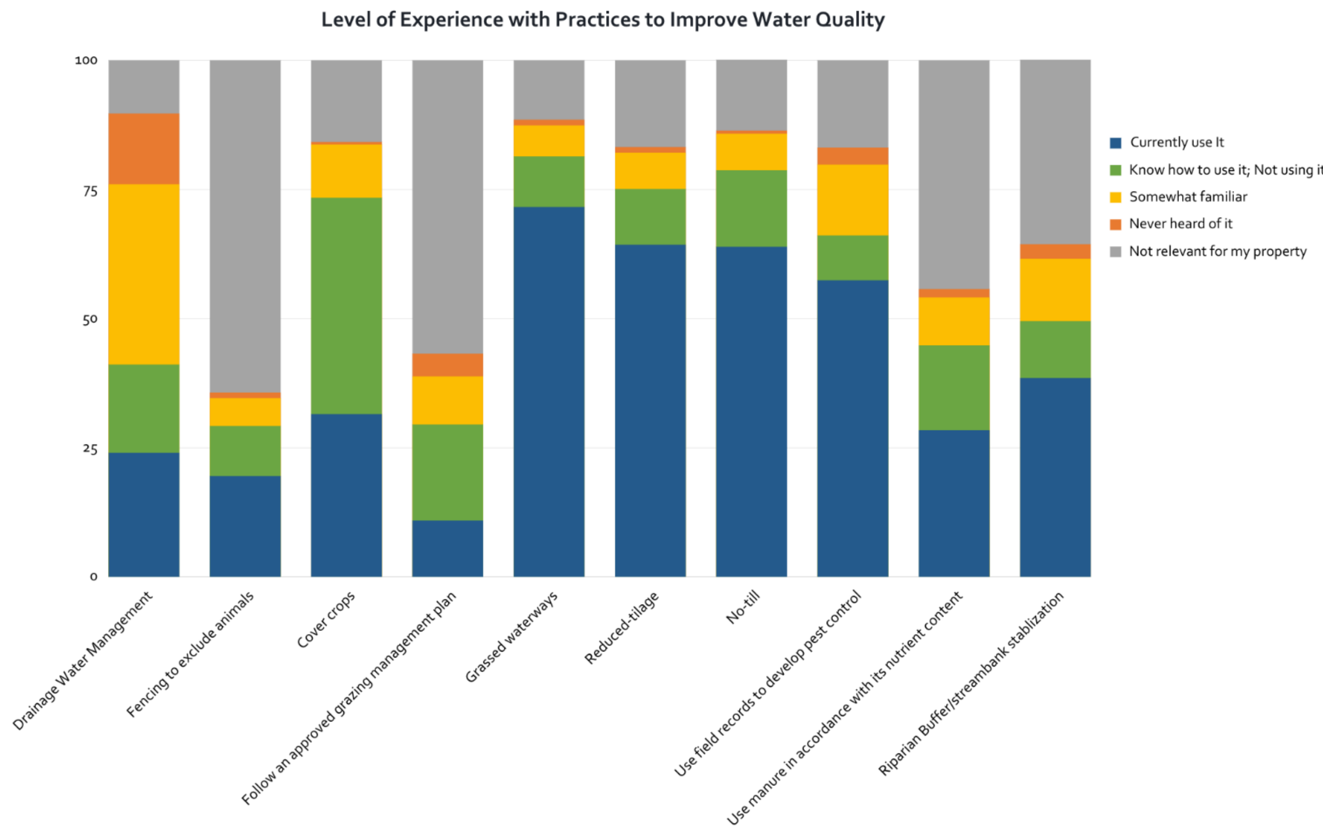


Figure 3. Level of experience with practices to improve water quality.

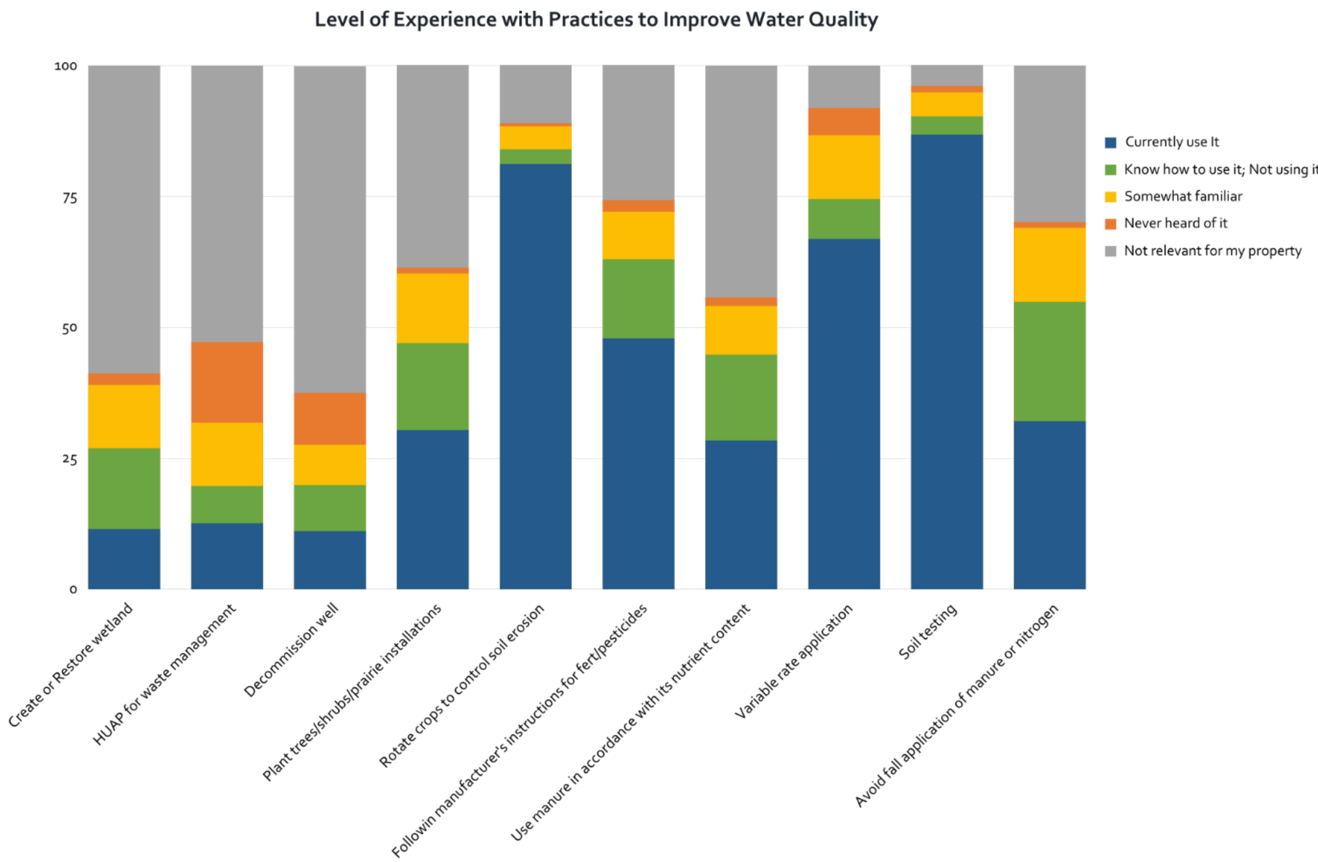


Figure 4. Level of experience with practices to improve water quality.

Constraints for Specific Practices

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

Cover Crops

Around 30% of respondents currently use cover crops (Figure 3). Additionally, 16% are somewhat familiar with this practice. Very few indicate they had never heard of cover crops. Nearly half of respondents either said they know how to use cover crops but choose not to use them or feel that cover crops are not relevant for their operation. Responses given for why the practice might not be relevant include "flat ground" and "not needed for erosion control" demonstrating that many respondents who are not using the practice feel the primary purpose of a cover crop is to prevent erosion on sloped fields. Nearly 80% indicated they might be willing to try this practice ("yes" or "maybe") (Figure 5). Cost, difficulty of using existing farming equipment and time required ranked the highest as constraints preventing adoption of cover crops in the Upper Sugar Creek Watershed.

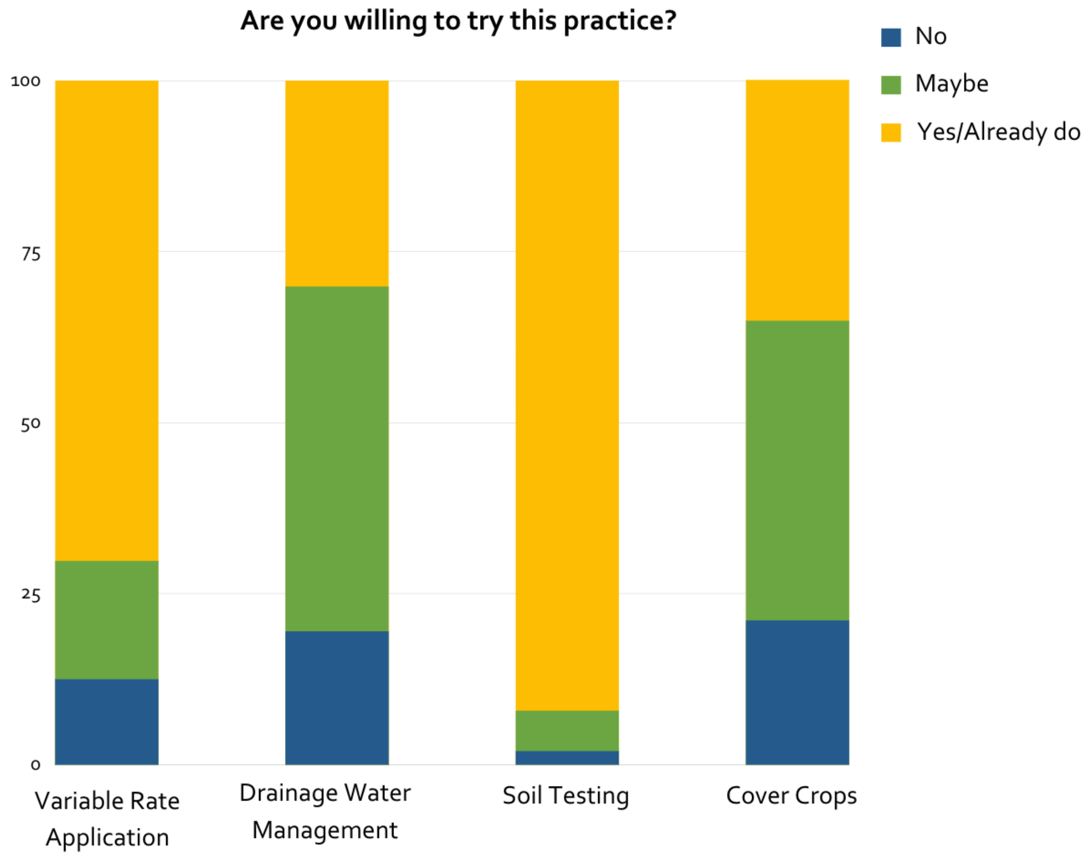


Figure 5. Respondents' willingness to try practices.

Variable Rate Application (use variable rate application technology for fertilizer to reduce environmental losses)
A majority (66%) of respondents indicate they currently use variable rate application of fertilizer (Figure 4). Around 18% state they have either never heard of this practice or were somewhat familiar with it. Additionally, 8% indicated variable rate application was not relevant for their property. Nearly 90% state they might be willing to try variable rate application ("yes" or "maybe") (Figure 5). Desire to "keep things the way they are," lack of equipment and cost ranked the highest constraints preventing adoption of this practice.

Drainage Water Management (Manage the water level in tile lines/drainage water management utilizing blind inlets, boxes, inline structures)
Nearly a quarter of respondents (24%) currently use drainage water management (Figure 3). Over 27% know how to use drainage water management tools but choose not to or do not feel they would be relevant for their operation. Almost 50% of respondents are only somewhat familiar with this practice or had never heard of drainage water management. Around 80% of respondents indicate they might be willing to try drainage water management ("yes" or "maybe") Figure 5). Cost, features of their property and lack of equipment rated the highest constraints preventing adoption of this practice.

Soil Testing
Nearly 87% of respondents currently use soil testing (Figure 4). Around 8% of respondents know how to use soil testing but choose not to or do not feel they would be relevant for their operation. Nearly 5% of

respondents are only somewhat familiar with this practice or had never heard of it. In total, 98% of respondents indicated they might be willing to try soil testing ("yes" or "maybe") (Figure 5). Cost was the highest rated constraint preventing adoption of soil testing, though only 7% of respondents rated this as "a lot" and 14% rated this as "some" when asked how this limits their ability to implement soil testing.

Socio-Demographics

The majority of respondents (over 90%) are male with a mean age of 64. A majority of respondents (35%) also stated they have a 4-year college degree with 27% obtaining their high school degree or GED. Nearly 100% of respondents own their homes with the average duration of living in that home being 28 years. A majority (78%) also live on a farm. Nearly 75% of respondents run their operation alone, with a spouse or with family partners. Respondents have been farming for several decades (mean = 38 years), have had the farm in the family for generations (mean = 81 years) and a majority think it likely that family will continue the farming operations after they retire with over 65% indicating this will probably happen or will definitely happen. Nearly 75% of respondents also believe that in 5 years their farming operation will be about the same size that it is today with nearly 24% indicating they feel their operation will be larger. Average tillable acreage per respondent averaged 1,215 acres. A majority of property managed (66%) touches a stream, river or wetland. Additionally, a majority of operations (over 70%) say they have a nutrient management plan. Nearly 50% of respondents worked with private sector agronomists or crop consultants to develop these plans. In total, 90% of respondents conduct soil testing in some form with 24% of respondents reporting that they soil test annually and an additional 23% indicate they soil text every two years (22.8%). In total, 93% of respondents indicate their nutrient application recommendations are based on current soil testing data.

Information Sources

Respondents were asked if they regularly read a local newspaper. The answer was fairly split with 46% answering yes and 54% answering no. Respondents were also asked to select all the sources where they are likely to seek information about soil and water conservation issues. Newsletters, brochures, and fact sheets (25%); conversations with others (25%) and the internet (17%) rated highest sources of information.

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) the Soil and Water Conservation District, Natural Resource Conservation Service and Purdue Extension with all rated between "moderately" and "very much." These sources would thus be the best options for promotional and outreach materials. IDEM, local fertilizer representatives, local government and local community leaders garnered the least amount of trust with all four scoring near the "slightly" trusted mark. Respondents indicated that they "slightly" to "moderately" trust the local watershed project, though over 7% reported that they were not familiar with the organization.

1.5.3 Survey Summary

Most Upper Sugar Creek Watershed 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 is clear that Upper Sugar Creek Watershed producers 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, garnered 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 3 through Figure 5). Respondents frequently identified financial factors as the primary constraint to adopting conservation practices.

2.0 WATERSHED INVENTORY I: WATERSHED DESCRIPTION

2.1 Watershed Location

The Upper Sugar Creek Watershed (HUC 0512011002, 0512011003, 0512011004) is part of the Sugar Creek Watershed and covers portions of Boone, Clinton, Montgomery, and Tippecanoe counties (Figure 2). The Upper Sugar Creek Watershed includes all the land that enters Sugar Creek, Prairie Creek, Lye Creek, Walnut Fork Sugar Creek, Little Sugar Creek, Little Potatoe Creek and their 204,370 acre drainage downstream of the Browns Wonder-Sugar Creek Watershed. This management plan focuses solely on the Upper Sugar Creek portion located immediately upstream of Thorntown, Indiana starting at the confluence of Prairie Creek and Sugar Creek. The headwaters of Sugar Creek, also known as the Browns Wonder-Sugar Creek Watershed, is not included in this project as this watershed already has a complete watershed management plan and is in its first phase of implementation (2022).

2.2 Subwatersheds

In total, fourteen 12-digit Hydrologic Unit Codes are contained within the Upper Sugar Creek Watershed (Figure 6,Table 3). Each of these drainages will be discussed in further detail under *Watershed Inventory II*.

Table 3. 12-digit Hydrologic Unit Code (HUC) watersheds in the Upper Sugar Creek Watershed.

Subwatershed Name	Hydrologic Unit Code	Area (acres)	Percent of Watershed
Headwaters Little Potatoe Creek	051201100201	11,674	5.71%
Bowers Creek	051201100202	11,927	5.83%
Lye Creek Drain	051201100203	10,910	5.33%
Little Potatoe Creek-Lye Creek	051201100204	16,114	7.88%
Little Creek-Little Sugar Creek	051201100301	16,181	7.91%
Little Sugar Creek	051201100302	12,917	6.32%
Town of Linnsburg-Walnut Fork Sugar Creek	051201100303	30,600	14.96%
Sanitary Ditch-Prairie Creek	051201100401	14,226	7.00%
Deer Creek-Prairie Creek	051201100402	17,381	8.50%
Wolf Creek	051201100403	16,258	7.95%
Goldsberry Creek-Sugar Creek	051201100404	11,307	5.50%
Withe Creek-Sugar Creek	051201100405	10,902	5.33%
Hazel Creek-Sugar Creek	051201100406	16,166	7.90%
Town of Garfield-Sugar Creek	051201100407	7,973	3.90%
	Entire Watershed	**204,536**	100%

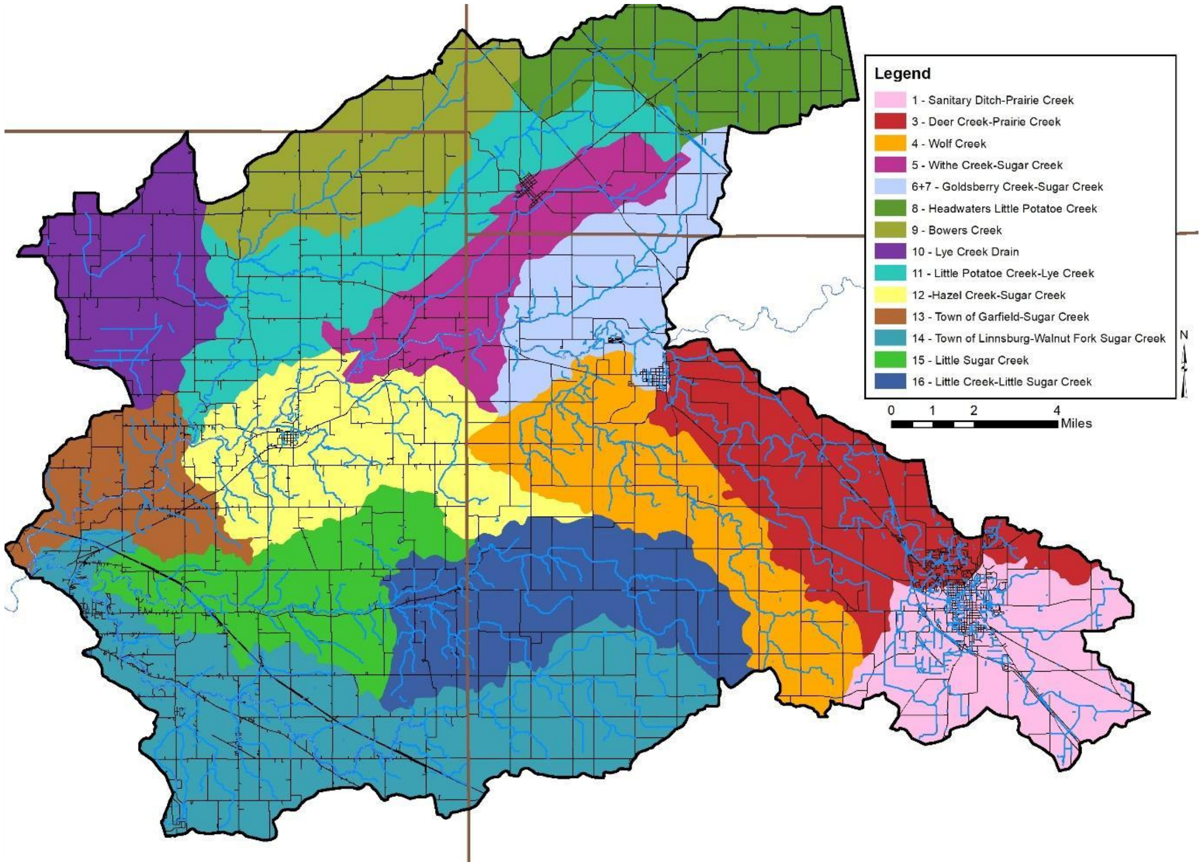


Figure 6. 12-digit subwatersheds in the Upper Sugar Creek Watershed.

2.3 Climate

In general, Indiana has a temperate climate with warm summers and cool or cold winters. Climate in the Upper 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 (23°F) in the winter. The growing season typically extends from April through September. On average, 40 inches of precipitation occurs within the watershed per year; approximately 62% of this precipitation falls during the 205-day growing season. Rainfall intensity and timing affect watershed response to precipitation. This information is important in evaluating the effects of stormwater on the Upper Sugar Creek watershed.

2.4 Geology and Topography

Borden Group bedrock deposits cover much of the Upper Sugar Creek Watershed and are from the Pennsylvanian age. The extreme eastern edge of the watershed is covered by Mississippian age rocks (New Albany Shale and Muscatatuck Group). Pennsylvanian bedrock generally consists of sandstone and shale, while Mississippian bedrock is typically siltstone and shale (Hill et al., 1982). New Albany shale covers some of the eastern portion of the Upper Sugar Creek Watershed. Minor areas of Muscatatuck Group and Wabash formation also lie along the eastern edge of the watershed (Figure 7). The Borden Group is dominated by siltstones, sandstones and shale, while the Muscatatuck group consists of several kinds of carbonate and evaporite lithologies (Droste and Shaver, 1986). Till covers much of the Upper Sugar Creek Watershed (Figure 8). Sand and gravel deposits found along all major and many minor streams originate from the Wisconsinan outwash. Lacustrine deposits found near Lebanon originate from the Illinoian till and represent historic lake beds. Sand and gravel are readily available resources along watershed stream floodplains as evidenced by the complex drift formations present.

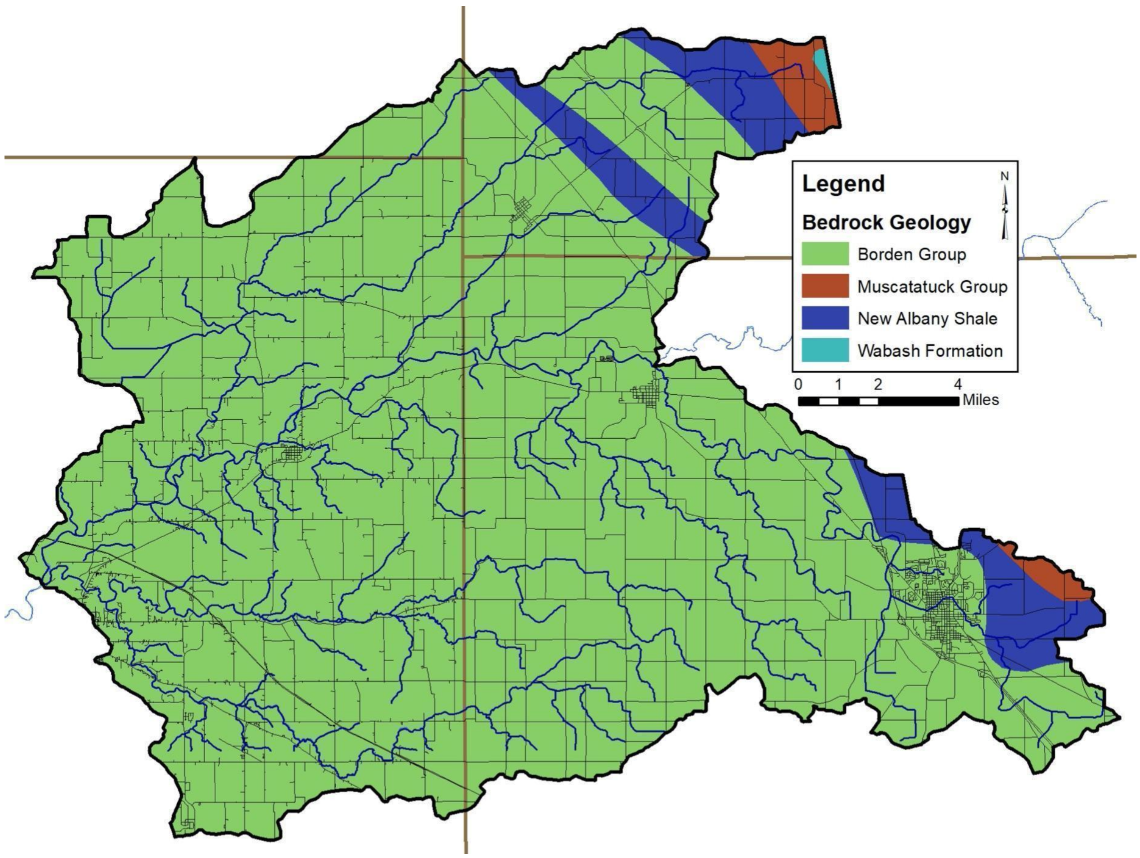


Figure 7. Bedrock in the Upper Sugar Creek Watershed.

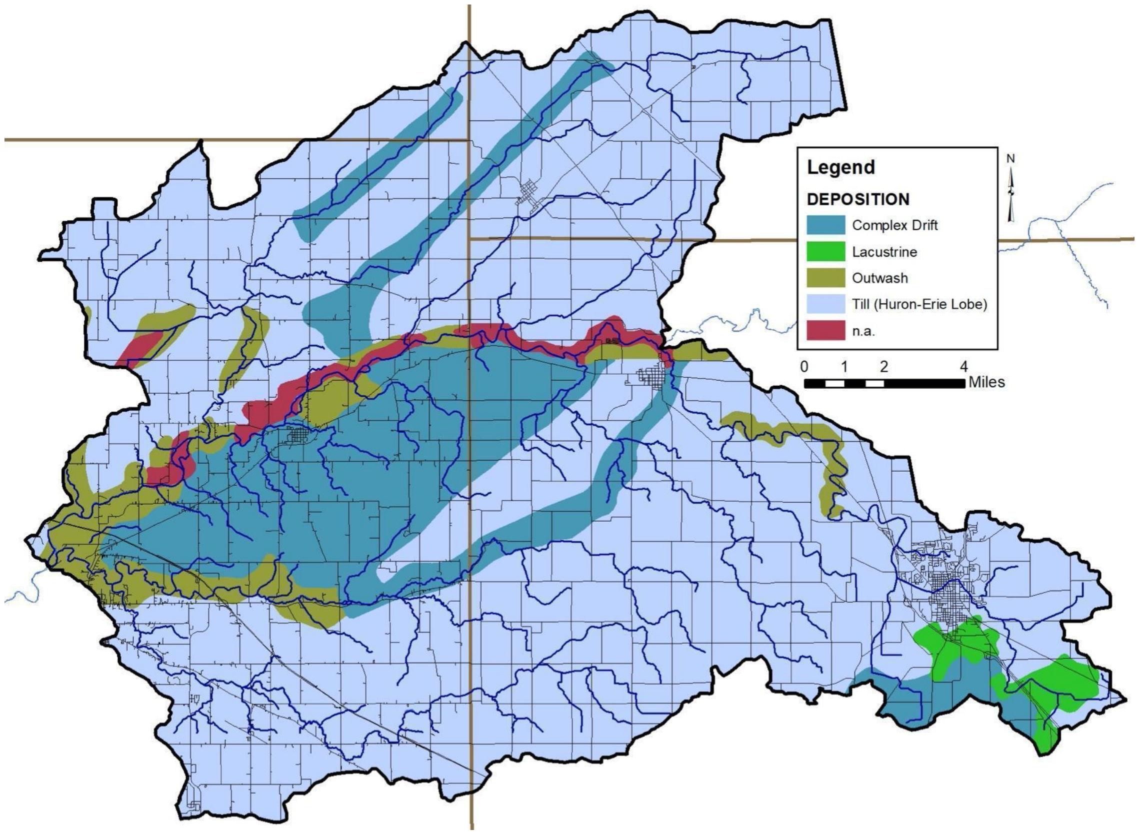


Figure 8. Surficial geology throughout the Upper Sugar Creek Watershed.

The topography of the Upper Sugar Creek Watershed generally slopes from west to east with the highest elevations occurring near Lebanon with lower elevations along the mainstem of Sugar Creek. As a whole, this watershed is flat, making it ideal for agricultural crop production (Figure 9). The Upper Sugar Creek Watershed elevation is highest measuring 915 feet mean sea level (msl) in the southeast part of the watershed near Lebanon. The lowest point of elevation (661 feet msl) occurs at the confluence of the Sugar Creek and the Walnut Fork-Sugar Creek/Little Sugar Creek near Crawfordsville. The watershed also has relatively narrow channels that follow the floodplains with eskers creating a dramatic shift in elevation.

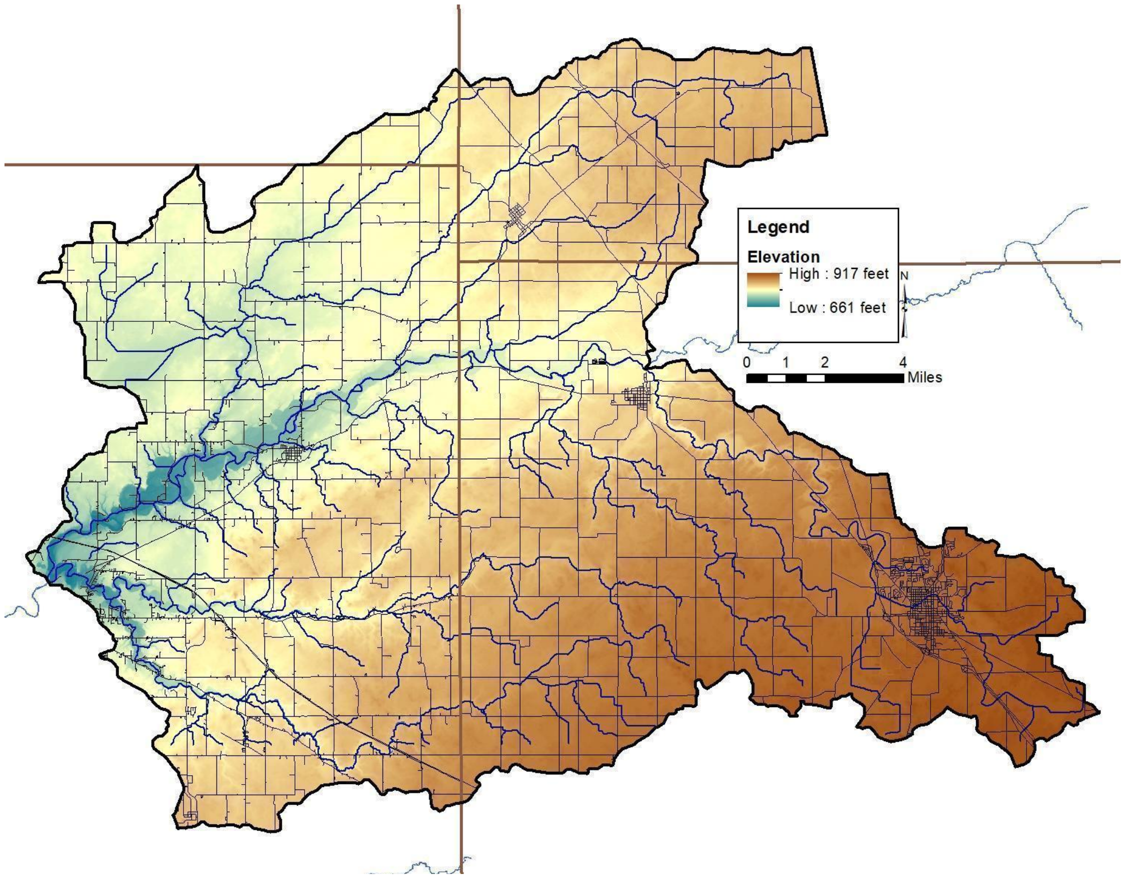


Figure 9. Surface elevation in the Upper Sugar Creek Watershed.

2.5 Soil Characteristics

There are many different soil types located within the Upper Sugar Creek Watershed. These soil types are delineated by their unique characteristics. The types are then arranged by relief, soil type, drainage pattern, and position within the landscape into soil associations. These associations provide the overall characteristics across the landscape. Soil associations are not used at the individual field level for decision-making. Rather, the individual soil types are used for field-by-field management decisions. Some specific soil characteristics of interest, including septic limitations and soil erodibility, for watershed and water quality management are detailed below.

2.5.1 Hydrologic Soil Group

The hydrologic soil group classification is a means for categorizing soils by similar infiltration and runoff characteristics during periods of prolonged wetting. The vast majority of the Upper Sugar Creek Watershed is covered by well-drained soils from materials weathered from shale, siltstone and sandstone. These moderately deep soils are found on moderately sloping to steeply sloping land. Within floodplains, somewhat poorly drained to well-drained soils are located within historic river deposits on nearly level land. Soils are classified by the NRCS into four hydrologic soil groups based on the soil's runoff potential (Table 4). The majority of the watershed is covered by category B soils (77.5%) followed by category C soils (19%), category A soils (3.4%), and category D soils (0.14%). Category B soils cover over three-quarters of the watershed (Figure 10). Category B soils are moderately deep and well-drained, while Category C soils are finer and allow for slower infiltration. In these areas, D soils are slow infiltration soils where flooding can regularly occur. B and C soil types are predominant along the main stem of Sugar Creek, Little Sugar Creek, and Walnut Fork of Sugar Creek. B and C soil types make up 96.5% of the soil types for this watershed. This means that regular flooding occurs throughout much of the watershed's riparian areas. Further, this is a concern for stakeholders.

Table 4. Hydrologic soil group summary.

Hydrologic Soil Group	Description
A	Soils with high infiltration rates. Usually deep, well-drained sands or gravels. Little runoff.
B	Soils with moderate infiltration rates. Usually moderately deep, moderately well-drained soils.
C	Soils with slow infiltration rates. Soils with finer textures and slow water movement.
D	Soils with very slow infiltration rates. Soils with high clay content and poor drainage. High amounts of runoff.

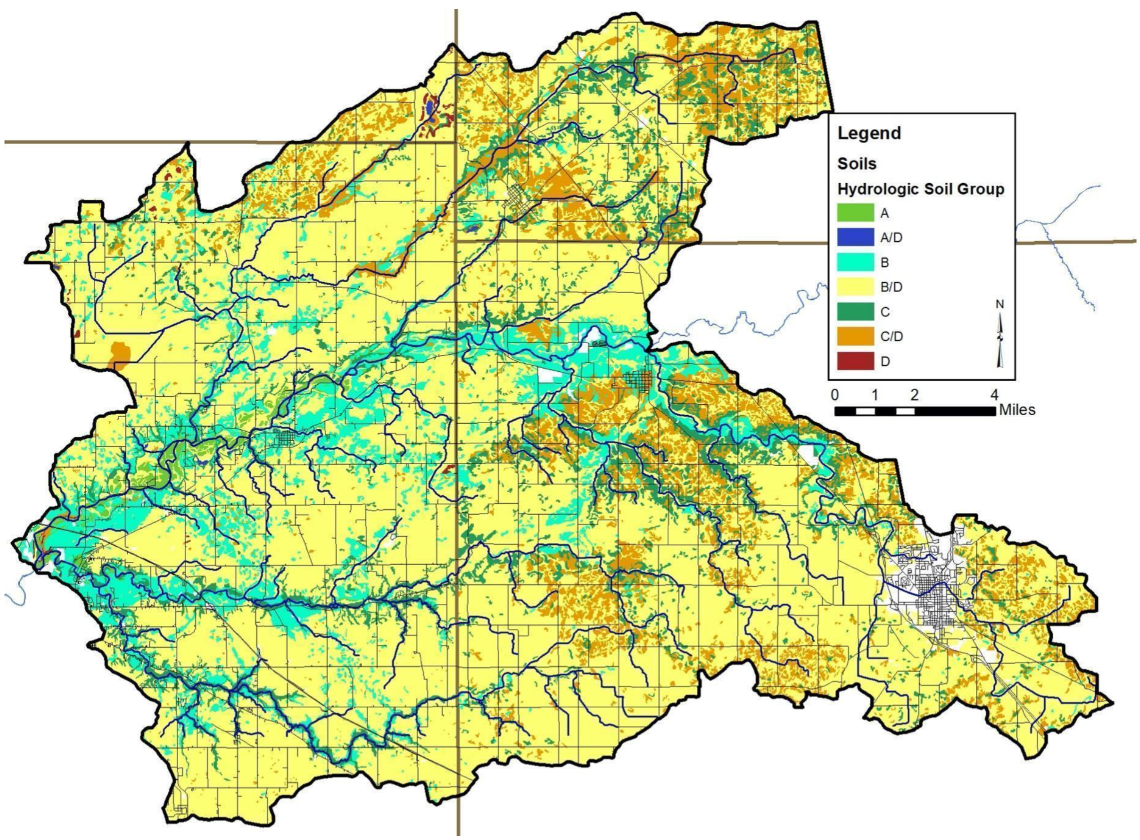


Figure 10. Hydrologic Soil Groups in the Upper Sugar Creek Watershed.

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 and pesticides, which can result in impaired water quality by increasing plant and algae growth or even killing aquatic life. The ability and/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. 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 value or 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.

Watershed stakeholders are concerned about soil erosion. As detailed above, soils which have high erodibility index values are those that are located on steep slopes and are easily moved by wind, water, or land uses. Figure 11 details locations of highly erodible soils within the Upper Sugar Creek Watershed. Highly erodible soils cover 58.7% of the watershed or 119,1712 acres. Highly erodible soils are found throughout the watershed with generally lower density in northwest Montgomery County, southeast Tippecanoe County and along the main stem of Sugar Creek.

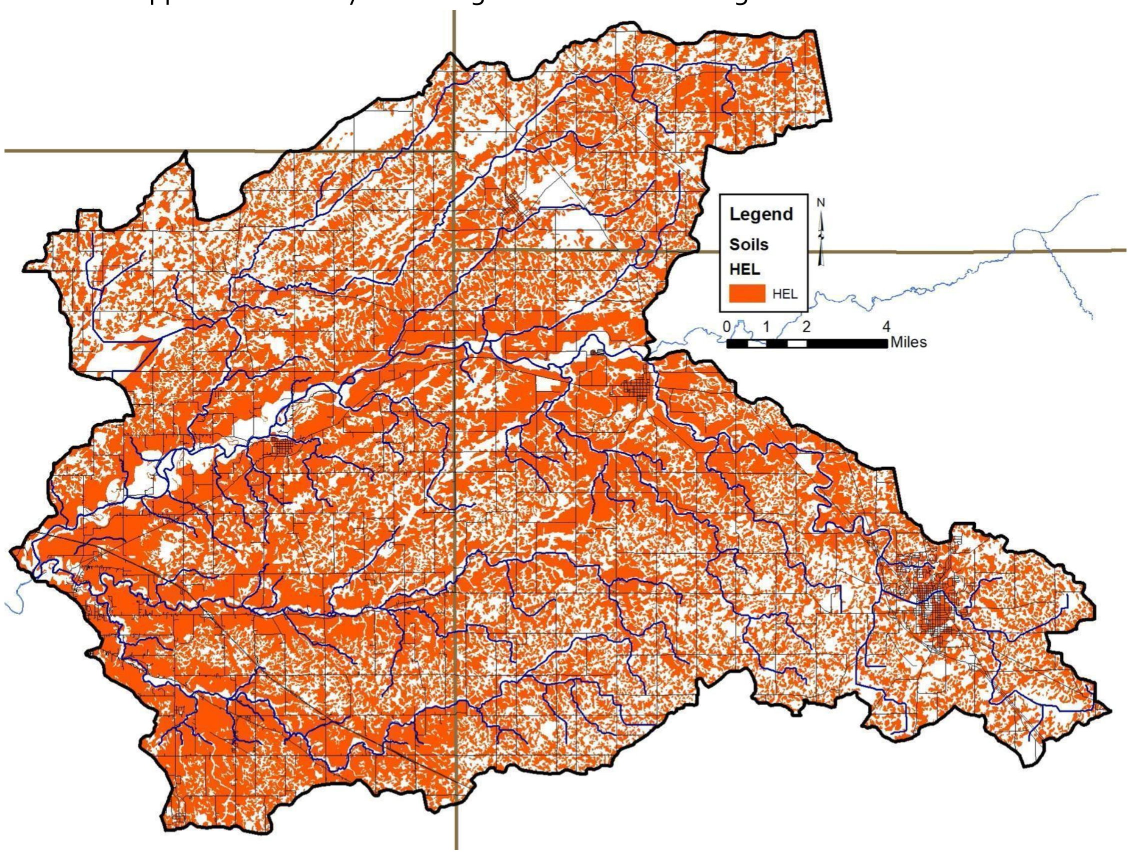


Figure 11. Highly erodible land in the Upper Sugar Creek Watershed.

2.5.3 Hydric Soils

Hydric soils are those which remain saturated for a sufficient period of time to generate a series of chemical, biological, and physical processes. The oxidation and reduction of iron in the soil, or "redox", causes color changes characteristic of prolonged fluctuations in the water table. After undergoing these processes, the soils maintain the resultant characteristics even after draining or use modification occurs. Watershed stakeholders are concerned about the conversion of wetlands into agricultural and urban land uses. Approximately 73,151 acres (35.7%) of the watershed was covered by hydric soils (Figure 12). Hydric soils are limited to agricultural flatland located away from streams. 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.

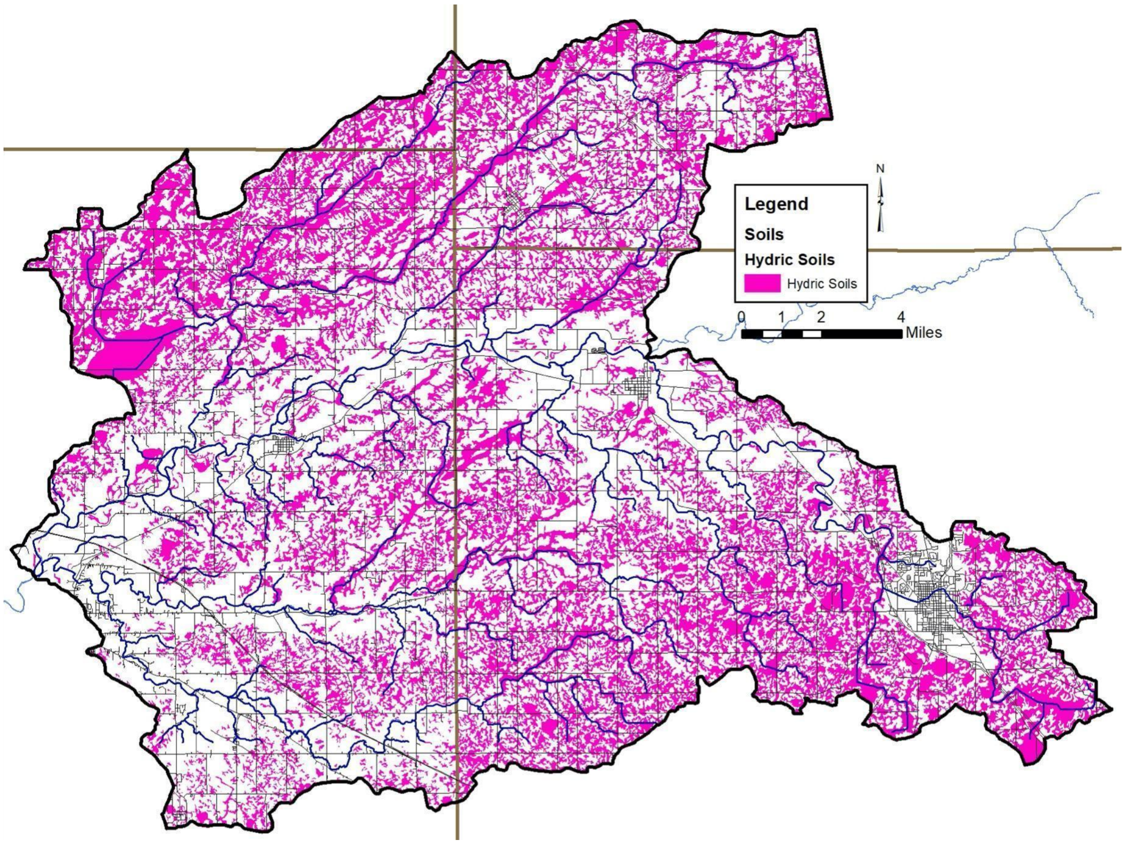


Figure 12. Hydric soils in the Upper Sugar Creek Watershed.

2.5.4 Tile-Drained Soils

Soils drained by tile drains cover 155,499 acres or 76% of the Upper Sugar Creek Watershed as estimated utilizing methods detailed in Sugg (2007). This method of drainage is widely used in row crop agricultural settings within the watershed and has become even more intensively used within the last ten years. This results in altered hydrology, allowing the water to drain from the landscape more quickly to improve conditions for farming, but also potentially exacerbating downstream flooding and incising streams which cuts them off from their natural floodplains. In these areas, materials such as nutrients applied to agricultural soils are directly transported downstream, bypassing natural features such as filter strips that might otherwise filter out or assimilate nutrients. As the demands of production on each acre of land increases, more tile is put in, typically in a network or series as extensive as 30 to 50 foot spacing between tiles. Impacts on stream water quality can be reduced by the use of tile control structures and drainage water management. Based on our analysis, tile-drained soils are found throughout the watershed with the exception of the mainstem of the Sugar Creek, along the lower portions of Little Sugar Creek and Walnut Fork-Sugar Creek and throughout the Town of Lebanon (Figure 13). Most of these areas are relatively flat where drainage augmentation is required to move water from agricultural fields in order to produce row crops. In these areas, materials applied to agricultural soils are directly transported to downstream waterbodies.

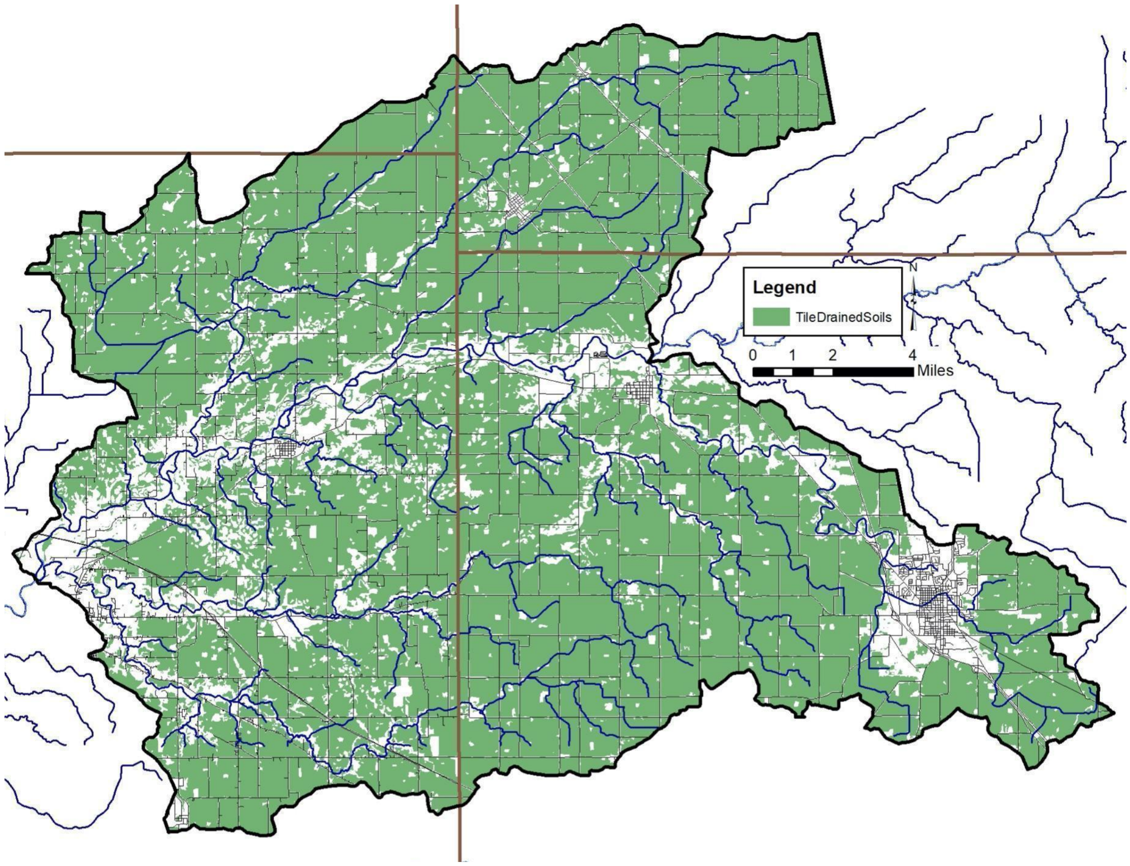


Figure 13. Tile-drained soils in the Upper Sugar Creek Watershed.

2.6 Wastewater Treatment

2.6.1 Soil Septic Tank Suitability

Throughout Indiana, households depend upon septic tank absorption fields in order to treat wastewater. Seven soil characteristics, including position in the landscape, soil texture, slope, soil structure, soil consistency, depth to limiting layers, and depth to seasonal high water table, are utilized to determine suitability for on-site septic treatment. Septic tanks require soil characteristics that allow for gradual movement of wastewater from the surface into the groundwater. A variety of characteristics limit the ability for soils to adequately treat wastewater. High water tables, shallow soils, compact till, and coarse soils all limit soils abilities in their use as septic tank absorption fields. Specific system modifications are necessary to adequately address soil limitation; however, in some cases, soils are too poor for treatment and therefore prove inadequate for use in septic tank absorption fields.

Until 1990, residential homes located on 10 acres or more and occurring at least 1,000 feet from a neighboring residence were not required to comply with any septic system regulations. In 1990, a new septic code corrected this loophole. Current regulations address these issues and require that individual septic systems be examined for functionality. Additionally, newly constructed systems cannot be placed within the 100-year floodplain and systems installed at existing homes must be placed above the 100-year flood elevation. However, many residences grandfathered into this code throughout the state have not upgraded or installed fully functioning systems (Krenz and Lee, 2005). In these cases, septic effluent discharges into field tiles or open ditches and waterways and will likely continue to do so due to the high cost of repairing or modernizing systems ($4,000 to $15,000; ISDH, 2001). Lee et al. (2005)

estimates that 76,650 gallons of untreated wastewater per system is expelled in the state of Indiana annually. The true impact of these systems on the water quality in the watershed cannot be determined without a complete survey of systems.

The 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 or very limited 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 or somewhat limited 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. Use of soils that are rated moderately or severely limited generally require special design, planning, and/or maintenance to overcome limitations and ensure proper function.

Watershed stakeholders are concerned about the lack of maintenance associated with septic tanks, the use of soils that are not suited for septic treatment, and the presence of straight pipe systems within the watershed. These concerns are exacerbated by the fact that severely limited soils cover essentially the entire watershed (Figure 14). Nearly 202,334 acres or 98.9% of the watershed is covered by soils that are considered very limited for use in septic tank absorption fields. Approximately 425 (0.2%) acres are somewhat limited meaning that these soils are generally suitable for septic systems. The remaining 1,623 acres (0.7%) not rated for septic usage as it is not generally industry standard to install a septic system in these geographic locations.

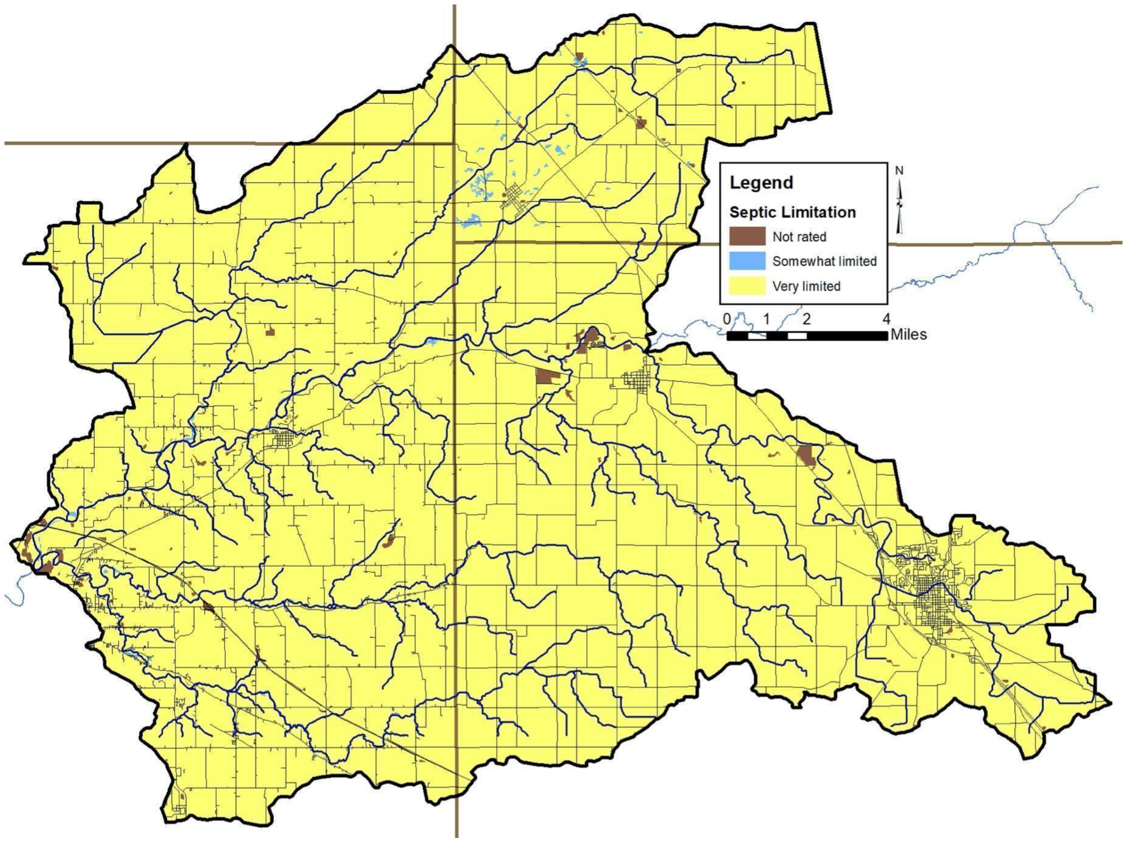


Figure 14. Suitability of soils for septic tank usage in the Upper Sugar Creek Watershed.

Septic systems that are properly designed and maintained should not serve as a source of contamination to surface waters. However, septic systems do fail for a variety of reasons. Common soil-type limitations which contribute to failure are seasonal high-water tables, compact glacial till, bedrock, coarse sand and gravel outwash and fragipan. When these septic systems fail via surface breakouts or due to inadequate soil filtration there can be adverse effects to surface waters due to E. coli, nitrate and total phosphorus (Horsely and Witten, 1996). Septic systems contain all the water discharged from homes and businesses and can be significant sources of pathogens and nutrients.

2.6.2 Wastewater Treatment

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 larger, publicly-owned facilities, and school facilities. In total, six NPDES-regulated facilities are located within the watershed (Figure 15). Wastewater treatment plant septage sludge is applied to approximately 5,397.6 acres of the Upper Sugar Creek Watershed. Table 5 details the NPDES facility name, activity, and permit number. More detailed information for each wastewater facility is discussed below.

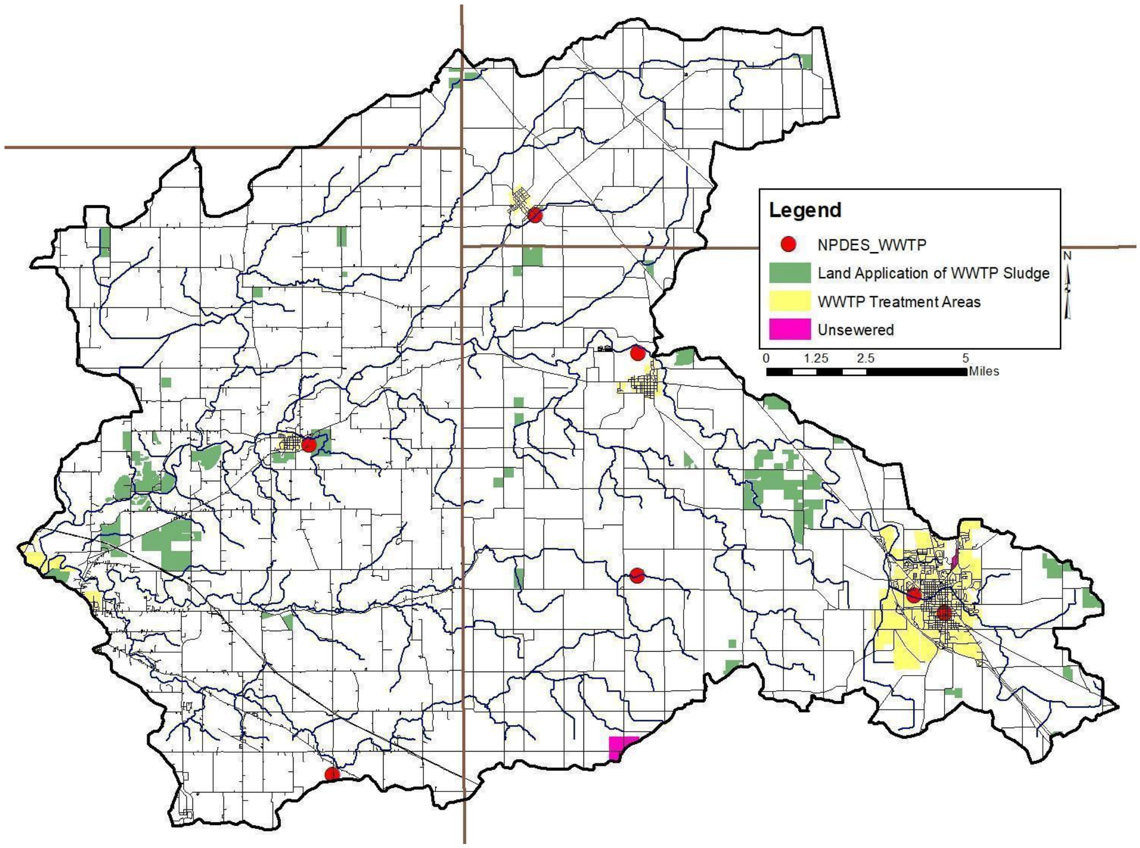


Figure 15. NPDES-regulated facilities, wastewater treatment plant service areas, land application of sludge and dense unsewered, dense housing locations within the Upper Sugar Creek Watershed.

Table 5. NPDES-regulated facility information.

NPDES ID	Facility Name	Volume (MGD)
IN0020443	COLFAX WWTP, TOWN OF	0.11
IN0020818	LEBANON WWTP	3.4
IN0022721	DARLINGTON MUNICIPAL WWTP	0.13
IN0024589	THORNTOWN WWTP	0.16
IN0041157	WESTERN BOONE JR/SR HIGH SCHOOL	0.04
IN0054682	NUCOR STEEL CORP	1.17

2.6.3 Municipal Wastewater Treatment

In the relatively rural Upper Sugar Creek Watershed, there are six wastewater treatment facilities located within and discharging to Sugar Creek or a tributary including the Town of Colfax Wastewater Treatment Plant (WWTP), Lebanon WWTP, Darlington Municipal WWTP and Thorntown WWTP. This list also includes the Western Boone Jr/Sr High School and one corporate discharger (Figure 15). None of these facilities possess combined sewer overflows.

The Town of Colfax currently operates a Class I, 0.110 MGD extended aeration treatment facility consisting of a gravity system to the plant lift station, an influent flow meter, a flow distribution box, a comminutor with bar screens, a 200,000-gallon equalization tank with blowers, dual 61,800-gallon aeration tanks, dual 16,050-gallon clarifiers, dual sludge holding tanks, a 2,690-gallon chlorine tank, chlorination by chlorine gas, dechlorination by sulfur dioxide and a final flow meter. Final solids are hauled by a licensed contractor. In the last quarter of 2021, the Town of Colfax received a grant from OCRA to study wastewater and storm drains after receiving multiple effluent limit violations as a direct result of the facility being hydraulically overloaded. The collection system evaluation generated an unsatisfactory rating. A records review indicates that two Sanitary Sewer Overflow (SSO) events occurred during 2019. , Numerous unreported overflow events also occurred at three different locations at the WWTP. Additionally, the collection system area was rated as unsatisfactory due to the facility experiencing excessive inflow and infiltration (I/I) in the collection system which continues to hydraulically overload the wastewater treatment plant. The Town of Colfax is working on upgrades to the facility to remedy additional issues such as no alternative power source, lack of any alarm system for the facility and flow measurement issues.

The City of Lebanon WWTP currently operates a Class III, 3.4 MGD activated sludge treatment facility with a peak design capacity of 8.6 MGD. Treatment consists of an influent flow meter, headworks with a mechanical fine screen and manual bypass bar screen, a head tank, an aerated grit tank, four oxidation ditches, two secondary clarifiers, chlorination/dechlorination facilities, chemical phosphorus removal facilities and an effluent flow meter. Sludge treatment consists of three aerobic digesters and a centrifuge for dewatering. Dewatered and/or liquid sludge is hauled offsite. Excessive wastewater flows greater than the 8.6 MGD peak design capacity are directed to a flow equalization basin (0.75 MG capacity), where it is held prior to being reintroduced to the influent for full treatment. If peak flows exceed the 8.6 MGD peak design capacity and the storage capacity of the equalization basin is exceeded, the equalization basin overflows into the chlorine contact tank via bypass Outfall 101. Outfall 101 is located at Latitude: 40° 3' 3" N, Longitude: 86° 28' 59" W, which is located on Prairie Creek. Due to regular sanitary sewer overflows during heavy rain events, The City of Lebanon is currently (2022) working on a forced main reroute to alleviate this issue. The additional external outfall will take the facility from a 3.5 MGD to 5.0 MGD upon completion.

The Town of Darlington operates the Town of Darlington Wastewater Treatment Plant, a minor municipal wastewater treatment plant located on State Road 47. The permittee is authorized to discharge to Honey Creek then into Sugar Creek in accordance with the effluent limitations, monitoring requirements and other conditions set forth in their permit. In September of 2021, the operation was rated as unsatisfactory. At the time of the inspection there were excessive solids in the form of sludge and thick algae that was holding onto sludge being discharged from the final clarifier and into the disinfection chamber as well as the final effluent channel. Maintenance was rated as unsatisfactory due to an inadequate preventative maintenance program. Sludge disposal was rated as unsatisfactory due to a high solids inventory throughout the facility. The Darlington WWTP is applying more liquid chlorine and chlorine tablets to mitigate the algae levels, as well as power washing the clarifiers and skimming debris as needed.

The Town of Thorntown currently operates a Class I, 0.16 Million Gallons per Day (MGD) continuous flow-through lagoon facility consisting of an influent flow meter, a 16.1-acre lagoon which has been divided into two cells with floating curtains, two solar-powered floating mixers, chlorination/dechlorination facilities and an effluent flow meter. Plant design peak flow is 0.16 MGD. As of July of 2021, IDEM found that the Thorntown WWTP is in significant noncompliance due to continuing ammonia-nitrogen effluent violations. As of May 2022, the Town of Lebanon is in the process of designing and building a new WWTP.

The Western Boone School Corporation operates the Western Boone Junior-Senior High School Wastewater Treatment Plant, a minor semi-public wastewater treatment plant. The permittee is authorized to discharge to Riggins Ditch in accordance with the effluent limitations, monitoring requirements, and other conditions set forth in the permit. In a November 2016 inspection, IDEM noted that the operation was rated as unsatisfactory due to their current flow meter not reading properly. IDEM also noted that Western Boone Junior High School self-reported violations of the effluent limits for pH and BOD. Western Boone Junior High has since worked to mitigate these issues and in October of 2021 received a Satisfactory Compliance evaluation.

Nucor Steel Corp operates a privately owned facility that manufactures steel. At this facility, plant operations result in an average discharge of 0.147 million gallons per day of noncontact cooling water in Walnut Fork via Eperson Ditch in Montgomery County. In a December 2021 inspection, IDEM noted that the operation was rated as unsatisfactory and noted that receiving waters appearance was rated as unsatisfactory due to excessive solids noted in the receiving stream and turbidity at the outfall.

2.6.4 Unsewered Areas

Approximately 224 acres of unsewered, dense housing were identified within the watershed (Figure 15). This area includes the towns of Advance and Ulen, which are unsewered. Areas that have at least 25 houses within a square mile outside of the sanitary district boundaries were classified as dense, unsewered areas.

2.7 <u>Hydrology</u>

Watershed streams, reservoirs, 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 detail in subsequent sections.

2.7.1 Watershed Streams

The Upper Sugar Creek Watershed contains approximately 604.2 miles of perennial streams and regulated drains with an additional 199.6 miles of tile drains, underground pipes and artificial channels (Figure 16). Of these, approximately 167.8 miles are regulated drains, 436.4 miles are streams and 199.6 miles are tile drains. The majority of streams in the Upper Sugar Creek Watershed are not regulated. It should be noted that regulated drains are maintained by the county surveyor's office and all of the regulated drains within the watershed have both a regular maintenance fund and a regular maintenance schedule. 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. Each time a ditch is cleaned out or maintained, this action increases the amount of sediment going downstream towards the mainstem of Upper Sugar Creek. The unnamed streams consist of drains, and private pipes and tiles.

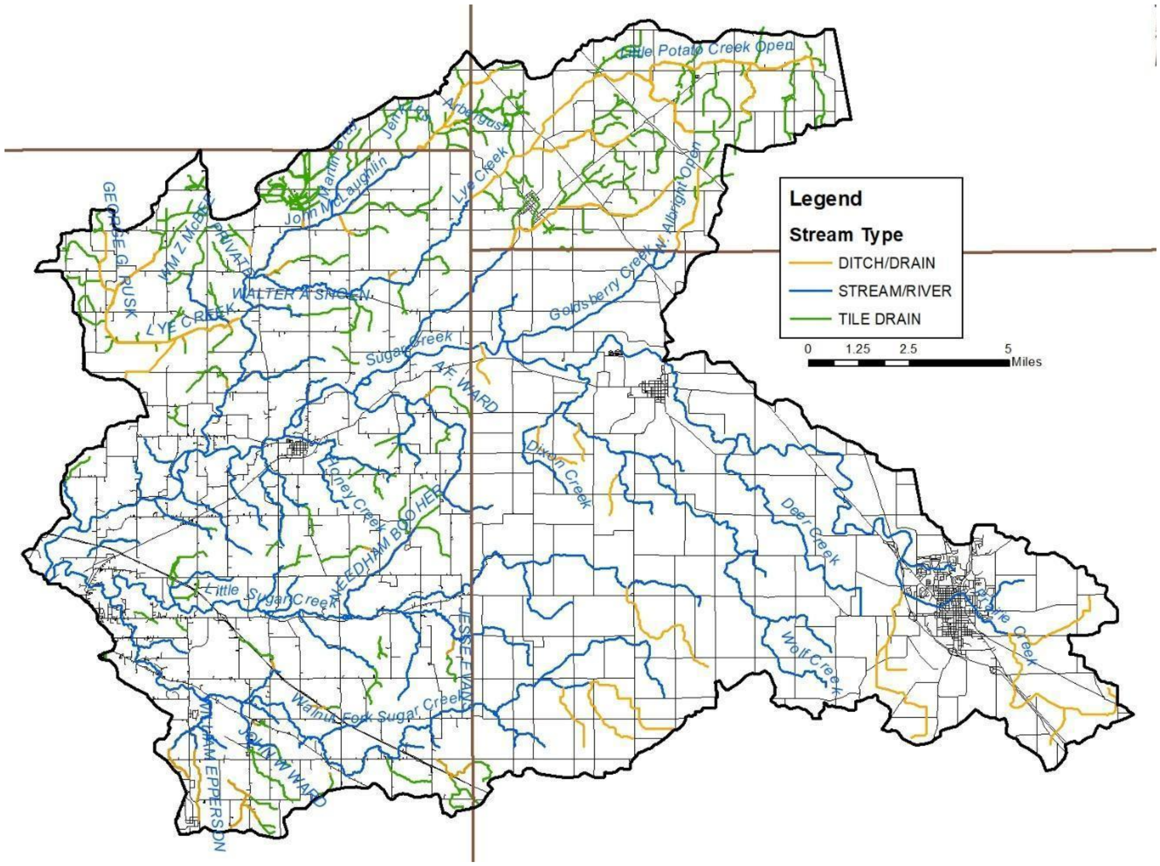


Figure 16. Waterbodies by type in the Upper Sugar Creek Watershed. Note legal drains from Boone County are not included in this map (10 May 2022).

Sugar Creek flows 22.6 miles from the confluence with Prairie Creek to the mouth of the Upper Sugar Creek Watershed. The major tributaries to Upper Sugar Creek include Walnut Fork-Sugar Creek, Prairie Creek, Little Sugar Creek, Little Potatoe Creek, Wolf Creek, With Creek, Bowers Creek, Deer Creek and Goldsberry Creek (Table 6). Many additional named streams, creeks and legal drains are present in the Upper Sugar Creek Watershed. Upper Sugar Creek from the tailwaters to the mouth is used for recreational kayaking and canoeing as well as fishing, swimming, and aesthetic enjoyment. Several tributaries to Upper Sugar Creek are also used for canoeing, kayaking, fishing and aesthetic enjoyment. Stakeholders are concerned with maintaining the recreational value of the creeks and have some concerns because portions of the watershed have been designated as impaired by IDEM for *E. coli*, nutrients, impaired biotic communities and mercury and PCBs in fish tissue.

Table 6. Named streams in the Upper Sugar Creek watershed.

Stream Name	Length (mi)	Stream Name	Length (mi)
Bowers Creek	8.8204	Lucas Ditch	1.5643
Cross Ditch	2.3426	Lye Creek	7.3932
Deer Creek	8.36	Lye Creek Drain	3.3244
Dixon Creek	4.2774	Mann Ditch	1.8982
Edlin Ditch	0.1145	Nagle Ditch	2.2796
Goldsberry Creek	8.0447	Needham Booher Ditch	0.8494
Gray Ditch	0.9058	Prairie Creek	24.8382
Hazel Creek	7.7174	Sanitary Ditch	1.5883
Higgins Ditch	4.2787	Shaw Ditch	3.817
Honey Creek	4.6885	Sugar Creek	22.6237
Isenhour Ditch	2.9247	Walnut Fork Sugar Creek	28.0139
Little Creek	4.1574	Withe Creek	10.2797
Little Potatoe Creek	20.6866	Wolf Creek	16.0815
Little Sugar Creek	22.3315		

2.7.2 Lakes, Ponds and Impoundments

There are 252 lakes and ponds in the Upper Sugar Creek Watershed. Most of these are likely farm ponds used for aesthetics, flood control, fishing and limited recreation. All of the lakes are under 10 acres and only two of which are named: Pennington & Norman lakes. These provide local swimming holes, recreational boating options and localized fishing as well as providing water storage and retention to assist with flooding. There are currently no dams (lowhead or otherwise) in the Upper Sugar Creek Watershed. Of note, the Sugar Creek lowhead dam that was recently removed is located on Sugar Creek immediately downstream of this watershed.

2.7.3 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. Local stakeholders are concerned about impacts to floodplains from development, lack of landowner maintenance, and soil erosion and deposition within the floodplain.

Figure 17 details the locations of floodplains within the Upper Sugar Creek Watershed. Floodplain remains among the mainstem of Sugar Creek. There are also narrow floodplains that lie adjacent to Little Sugar Creek, Walnut Fork-Sugar Creek and Prairie Creek. Approximately 5% (9,178.0 acres) of the Upper Sugar Creek Watershed lies within the 100-year floodplain (Figure 17). 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. The Upper Sugar Creek Watershed has very little floodplain; Of the land within Zone A, floodplain constitutes nearly 7,251 acres (3.5% of the watershed).
- 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. Nearly 2,349 acres (1.14%) of the Upper Sugar Creek Watershed floodplain is in Zone AE.
- 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.

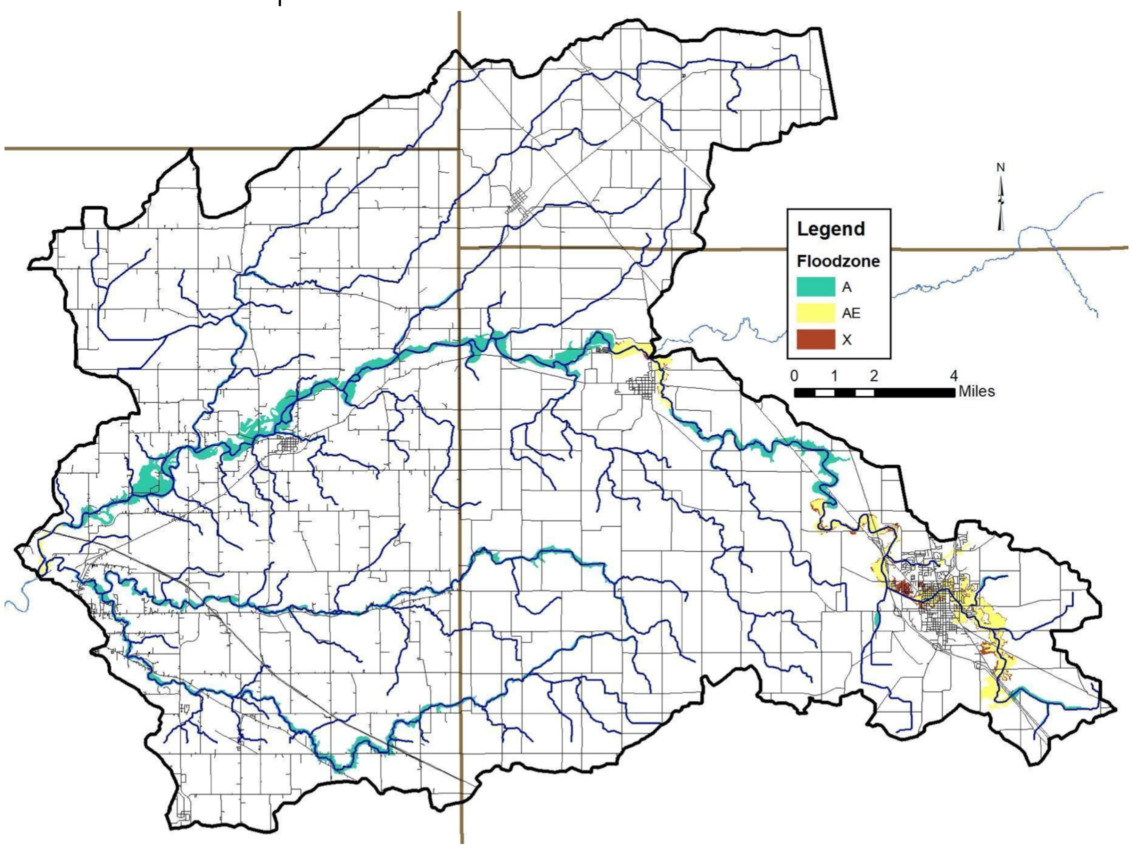


Figure 17. Floodplain locations within the Upper Sugar Creek Watershed.

2.7.4 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 natural wetlands are regulated through the IDEM and the U.S. Army Corps of Engineers while USDA has jurisdiction over wetlands on agricultural fields. Any modification to wetlands requires permits from these agencies.

Wetlands cover 5,612.7 acres, or 7.7%, of the watershed. When hydric soil coverage (67,938 acres) is used as an estimate of historic wetland coverage, it becomes apparent that more than 93% of wetlands have been modified or lost over time. This represents more than 62,325 acres of wetland loss within the Upper Sugar Creek Watershed. As commodity prices continue to go up and down, area land values remain high and as a result, individuals are spending a great deal of money to drain small natural wetlands in their fields in order to be able to farm that additional couple acres of land as it is cheaper to tile it than to buy ground already in production.

Figure 18 shows the current extent of wetlands within the Upper Sugar Creek Watershed. Wetlands displayed in Figure 18 results 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. Using this map will help us to identify which portions of the watershed would make ideal candidates for wetland restoration efforts which would reduce the amount of sediment and nutrients reaching the creek, as well as helping to restore the natural hydrology of the area which could help to reduce flooding impacts locally.

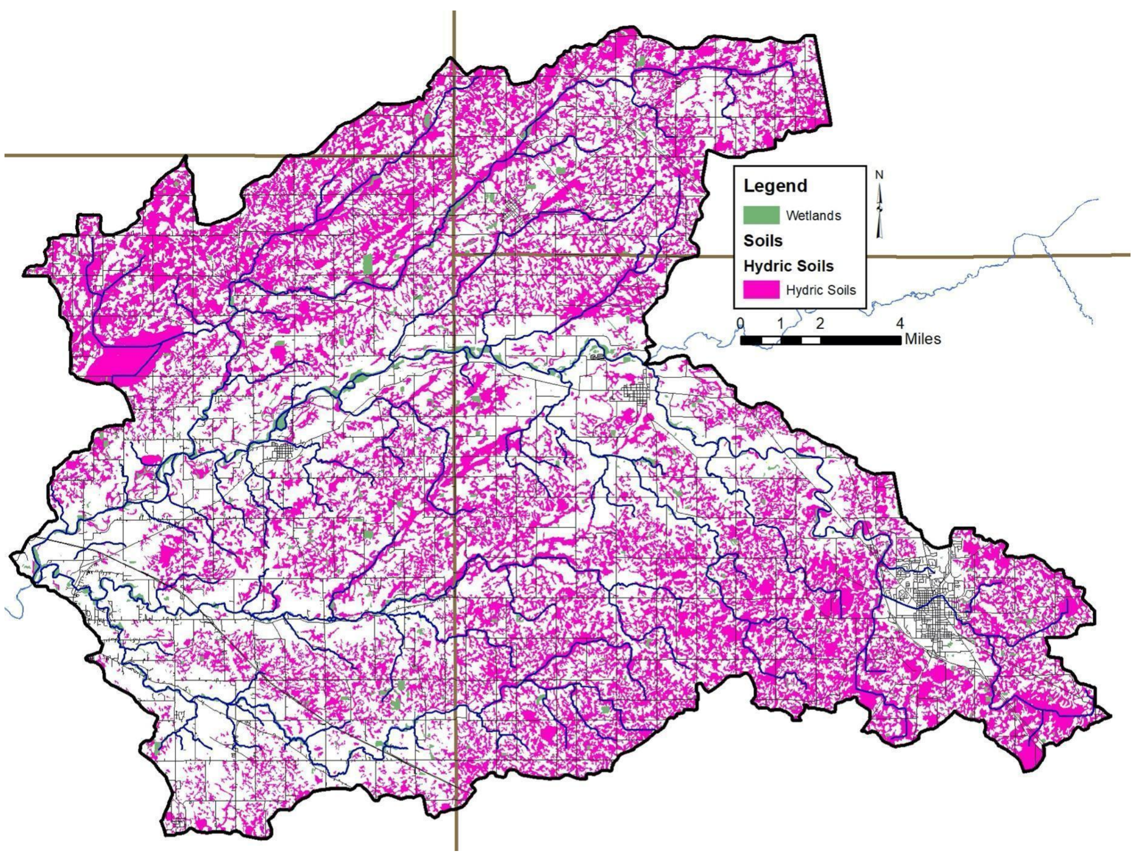


Figure 18. Wetland and hydric soils (historic wetland) locations within the Upper Sugar Creek Watershed. Source: USFWS, 2017.

2.7.5 Stormwater and Storm Drains

Under natural conditions, the majority of precipitation is allowed to infiltrate the soil and recharge groundwater resources. The volume of infiltration and groundwater recharge diminishes as development increases. To handle the large volume of precipitation falling in urban areas, stormwater systems have been constructed. Storm drain systems are present in most urban areas throughout the watershed. There is one municipal separate storm sewer system (MS4) in the Upper Sugar Creek Watershed. MS4s are defined as a conveyance or system of conveyances owned by a state, city, town or other public entity that discharges to waters of the United States and is designed or used for collecting or conveying storm water. Regulated conveyance systems include roads with drains, municipal streets, catch basins, curbs, gutters, storm drains, piping, channels, ditches, tunnels and conduits. It does not include combined sewer overflows (CSOs) and publicly owned treatment works. Figure 19 details the MS4 boundaries for the City of Lebanon (17.3 square miles). It should be noted that the only MS4 in this watershed resides in Lebanon which is located in the Sanitary Creek-Prairie Creek Subwatershed. Its permit ID is #INR040113. More than 17 square miles of the Upper Sugar Creek Watershed are located in one of the one designated MS4 community. Rule 5 plan review and monthly inspections are handled by City of Lebanon MS4 staff and contractors. Any inspections and enforcement are handled on a case-by-case basis.

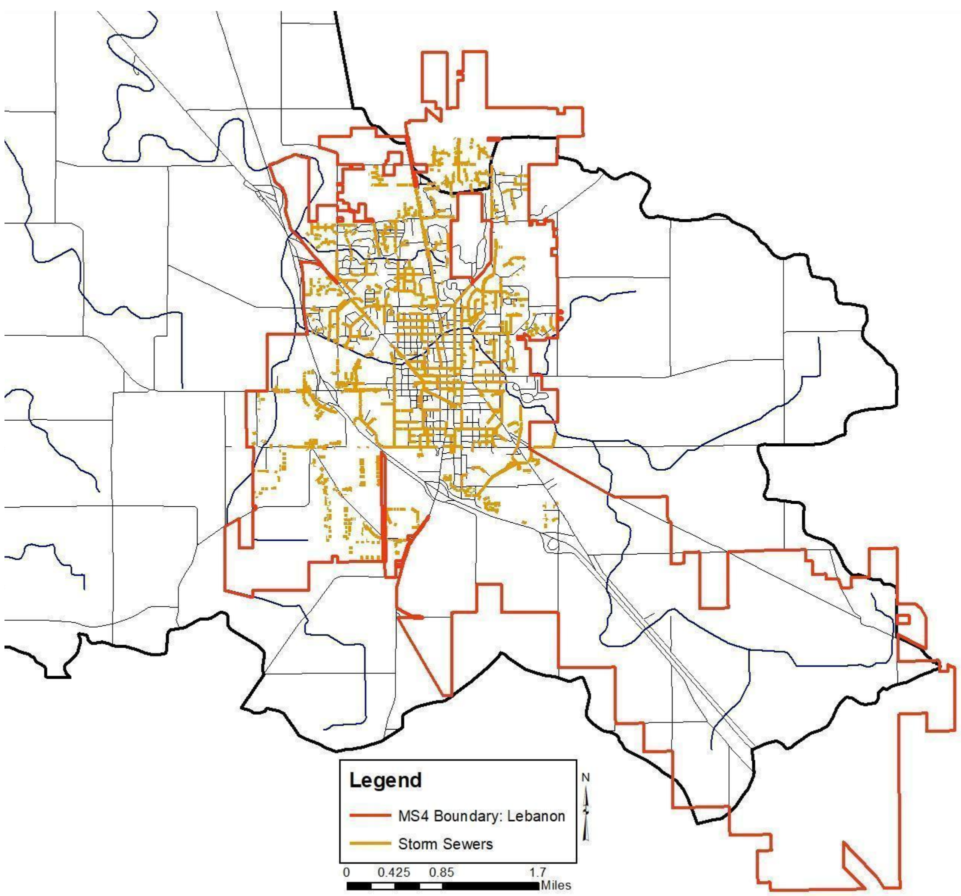


Figure 19. MS4 boundaries for the city of Lebanon, located within the Upper Sugar Creek Watershed.

2.7.6 Wellfields/Groundwater Sensitivity

Recharge to the bedrock aquifer occurs at bedrock outcrops where precipitation enters the aquifer directly or indirectly via unconsolidated deposits. Table 7 lists wellhead protection areas within and adjacent to the Upper Sugar Creek Watershed. Potential pollution from construction, sewage outfalls or overflows, illegal dumping, agriculture, and stormwater runoff must be avoided or controlled due to the recharge of these aquifers from runoff and river water.

Table 7. Wellhead protection areas in and adjacent to the Upper Sugar Creek Watershed.

County	PWSID	System name	Population
Boone	5206001	Advance Water Works	500
Boone	5206003	Lebanon Utilities	16098
Boone	5206005	Thorntown Utilities	1600
Clinton	5212001	Colfax Water Company	690
Clinton	5212002	Country Estate Mobile Home Park	90
Montgomery	5254003	Darlington Water	850
Montgomery	5254005	Indiana American Water - Crawfordsville	15,093
Montgomery	5254007	Linden Water Department	759
Montgomery	5254015	Indian Forb Mobile Estates	60
Montgomery	5254019	Country View Estates	30

2.8 <u>Natural History</u>

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 Ecoregion Description

According to Homoya et al.'s (1985) classification of natural regions in Indiana, the Upper Sugar Creek Watershed lies within the Central Till Plain Natural Region. The Central Till Plain natural region is the largest natural region in the state and is home to several glacial features and moraines. It is characterized by moderately thick loess over Wisconsinan till. This region is also what Homoya refers to as a "concentrated melting pot of species with northern, southern, eastern and western affinities." This region could be further classified into two sub-regions. The first is the Tipton Till Plain, which consists of nearly flat to gently rolling glacial plain traversed by several low terminal moraines. Mainly ground-moraine deposits with some end-moraine, valley-train, and outwash-plain deposits cover much of the Tipton Till Plain. Sand and gravel deposits are found along all major and many minor streams within the Tipton Till Plain and originate from the Wisconsinan outwash. Some areas of the watershed have significant topographic relief due to postglacial stream erosion. These areas comprise the second sub-region: the Entrenched Valley Section. The Entrenched Valley covers the confluence and mainstem of the lower portion of Sugar Creek, Walnut Fork-Sugar Creek and Little Sugar Creek. This sub-region is covered by Pennsylvanian, Devonian, Silurian and Mississippian bedrock outcrops which form cliffs and valleys along the riverine systems. This sub-region is fairly diverse as it is also covered with prairie, gravel-hill prairie, fen, marsh, savannas, cliff, seep springs and ponds. Streams of this sub-region are typically medium-gradient, relatively clear, and rocky. The Upper Sugar Creek Watershed also lies in the Eastern Corn Belt Plains (Loamy, High Lime Till Pains) Ecoregion as defined by Omernik and Gallant (1988).

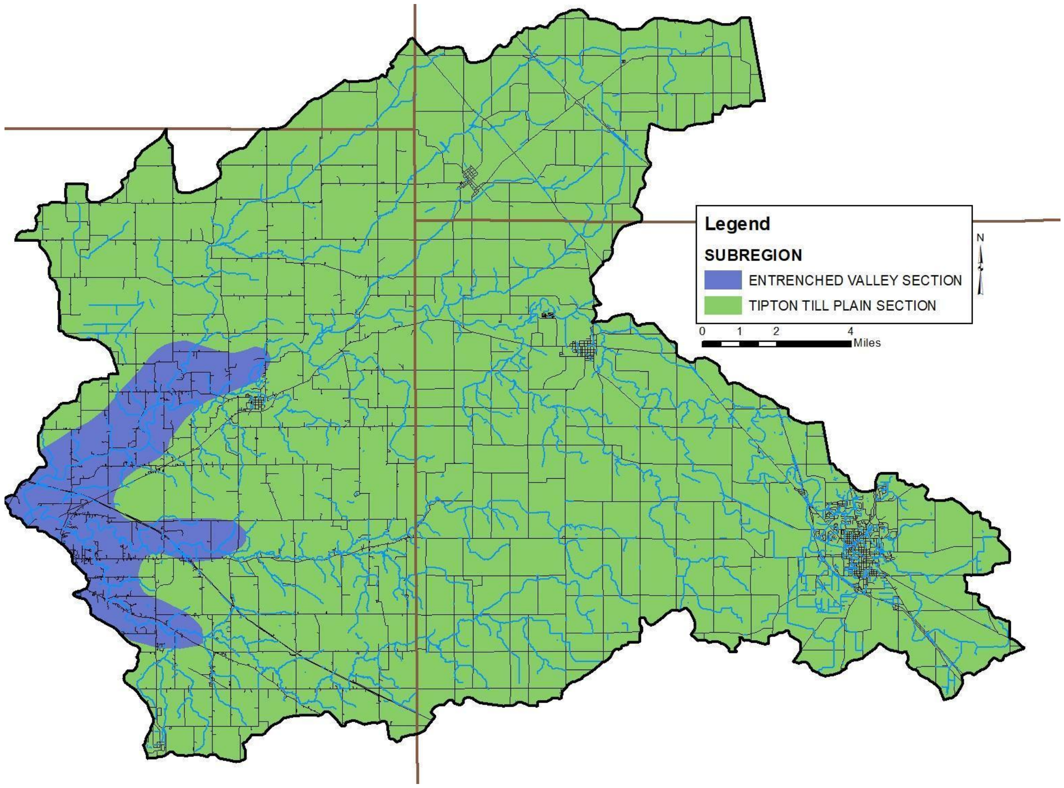


Figure 20. Level 5 natural region in the Upper Sugar Creek Watershed.

2.8.2 Wildlife Populations and Pets

The Indiana Department of Natural Resources (IDNR) is tasked with managing wildlife populations throughout the state. In order to complete this task, the IDNR must have an idea of the population density within specific areas, counties, or regions. The most recent survey of wildlife populations for which data are publicly available occurred in 2005. Those densities are shown in Table 8 with deer, squirrels and turkey being the most common wildlife present within the region. It should be noted that these numbers could both underestimate and overestimate populations within the watershed. Densities are recorded based on animal observations per 1000 hours of overall observation. If observations areas are not equally spread throughout the region, over or underestimates of the populations could occur. Likewise, animals are not likely equally distributed throughout the region; therefore, the regional density may again over or underestimate the true density of the animal in question. Nonetheless, these estimates provide the best guess at wildlife densities. Wildlife waste will be an issue in the more natural, forested or wetland portions of the watershed.

Table 8. Surrogate estimates of wildlife density in the IDNR north central region, which includes the Upper Sugar Creek Watershed.

Animal	2005 Population Observation (per 1000 hours of observation)
Beaver	0.4
Bobcat	1.2
Bobwhite	38.6
Coyote	43.4
Deer	806.3
Fox squirrel	572
Gray fox	1.2
Gray squirrel	156.3
Grouse	4
Domestic cat	12.3
Muskrat	0.8
Opossum	14.7
Rabbit	19.9
Raccoon	41.8
Red fox	3.6
Skunk	7.6
Turkey	255.8

Source: Plowman, 2006.

Pet populations can affect pathogen levels similarly to the impacts provided by wildlife. While a count of pets for the Upper Sugar Creek Watershed was not completed, numbers can be estimated using statistics reported in the 2012 U.S. Pet Ownership & Demographics Sourcebook. Specifically, the Sourcebook reports that on average 36.5 percent of households own dogs and 30.4 percent of households own cats. Typically, the average number of pets per household is 1.6 dogs and 2.1 cats. However, pets are likely only a significant source of E. coli in population centers including Lebanon, Darlington, Colfax, and Thorntown. The estimated number of domestic pets in the Upper Sugar Creek Watershed is based on the average number of pets per household multiplied by the population of the watershed resulting in a suggested population of 14,577 cats and 12,805 dogs. Pet waste issues are more predominant in the urban areas noted above but are also present in any residential parcel.

2.8.3 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 total, 53 observations of listed species and/or high-quality natural communities occurred within the Upper Sugar Creek Watershed (Figure 21; Davis, personal communication). These observations include 11 invertebrates including five mollusk species, four vascular plants, 30 vertebrate animals, including one bat species, 20 birds, two badgers, one snake and one turtle as well as seven terrestrial high-quality natural communities. State endangered species include the Upland Sandpiper, Marsh Wren, Sedge Wren, Least Bittern, Loggerhead Shrike, Black-crowned Night Heron, Virginia Rail, Cerulean Warbler, Indiana Bat and Kirtland's Snake. State threatened species include the Butternut and Bog Bluegrass. The Central Till Plain Flatwoods, Wet-mesic Floodplain forest, mesic prairie and Circumneutral Seep rate as high-quality natural communities. Appendix B includes the database results for the Upper Sugar Creek Watershed, as well as county-wide listings for Tippecanoe, Boone, Montgomery, and Clinton Counties.

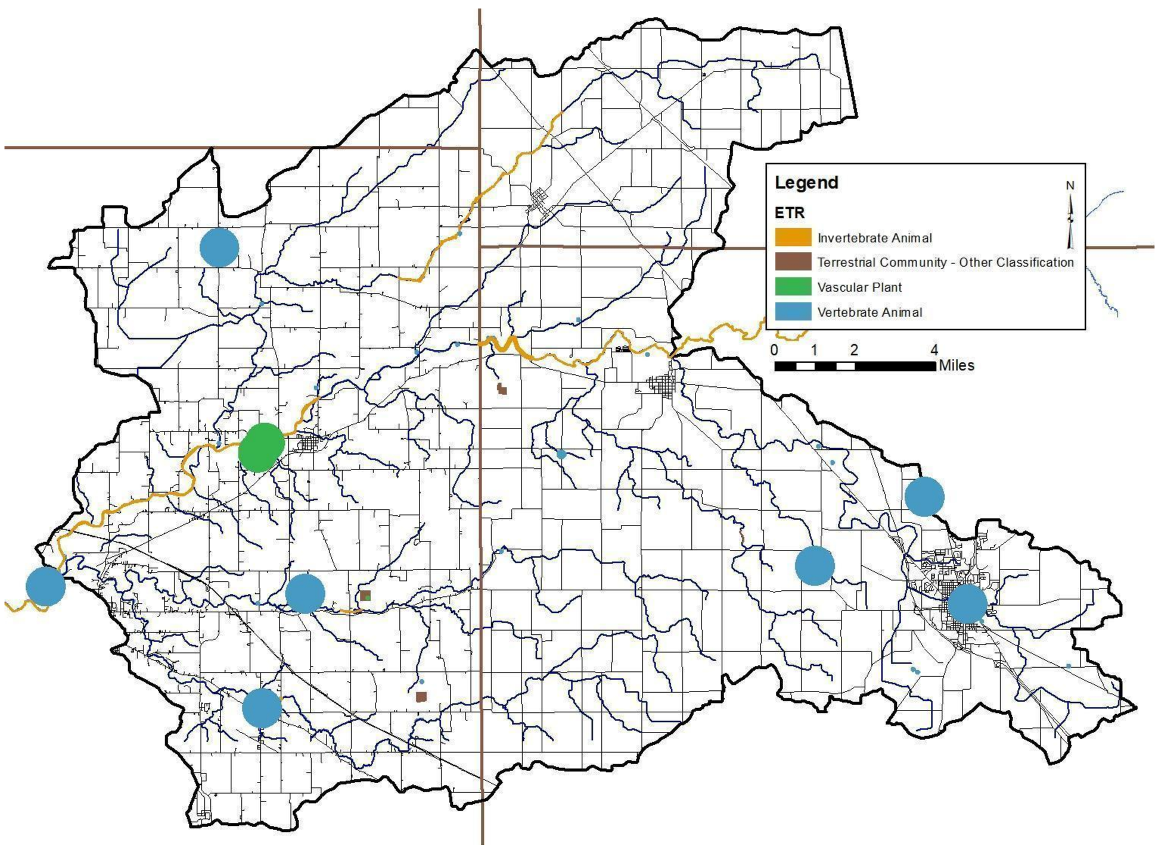


Figure 21. Locations of special species and high-quality natural areas observed in the Upper Sugar Creek Watershed. Source: Davis, 2022.

2.8.4 Recreational Resources and Significant Natural Areas

A variety of recreational opportunities and natural areas exist within the Upper Sugar Creek Watershed. Recreational opportunities include parks, fish and wildlife areas, nature preserves, fairgrounds, golf courses, racetracks, and school grounds (Table 9, Figure 22). There are several significant natural areas located within the Upper Sugar Creek Watershed. The Indiana DNR and Darlington Park Board maintain, preserve and protect these properties. The IDNR provides access to Hazel Creek, Sugar Creek and other streams. Additional recreational opportunities exist at various schools, golf complexes and recreational facilities.

Table 9. Natural areas in the Upper Sugar Creek Watershed.

Natural Area	County	Organization	Access
Calvert and Porter Woods Nature Preserve	Montgomery	IDNR	Restricted
Calvert and Porter Woods Managed Area	Montgomery	IDNR	Restricted
Old School Park	Montgomery	Darlington Park Board	Restricted

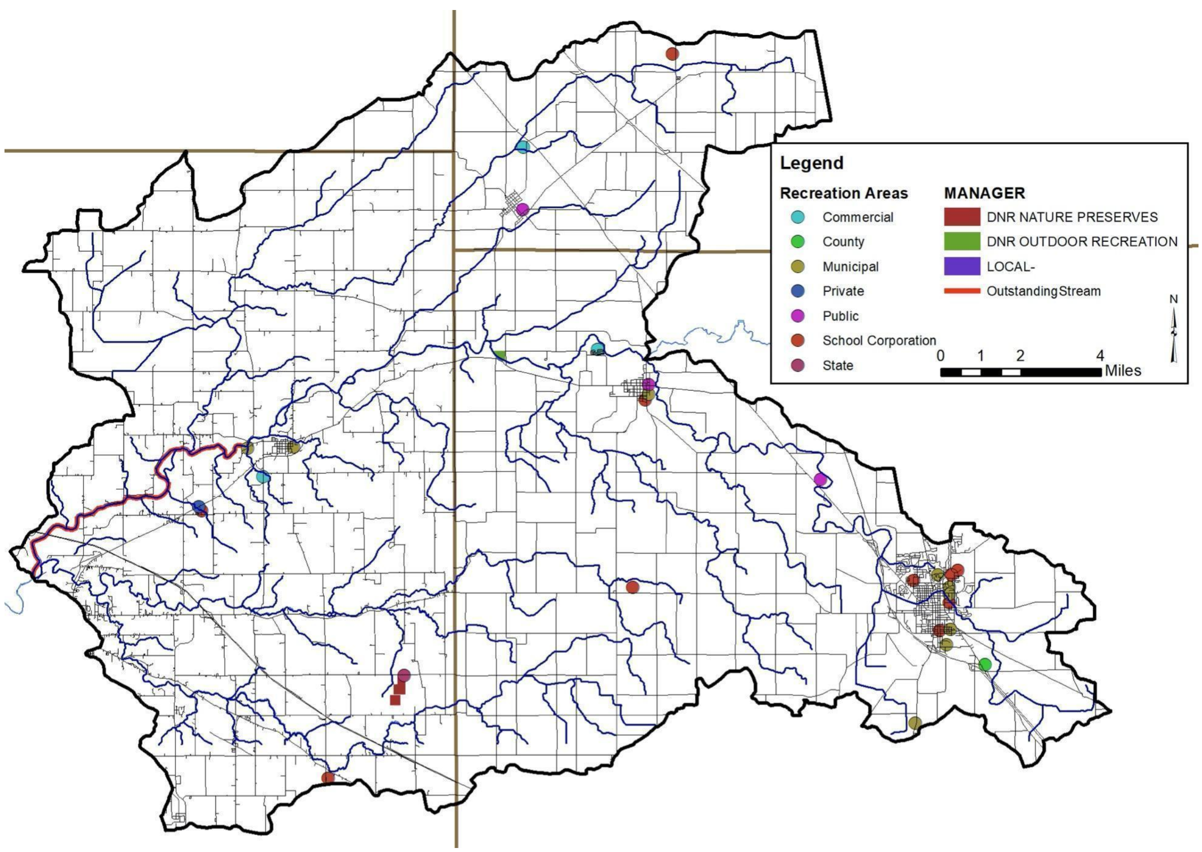


Figure 22. Recreational opportunities and natural areas in the Upper Sugar Creek Watershed.

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, and manure, to name a few. However, when water flows across parking lots or from rooftops 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.

2.9.1 Current Land Use

Today, the majority of the Upper Sugar Creek Watershed is covered by cultivated crop (86%; Table 10, Figure 23). Developed open space and low, medium and high density developed land covers 8% of the watershed. Forested land use covers 5% of the watershed. Grassland, open water, and wetlands cover the remaining 1% of the watershed.

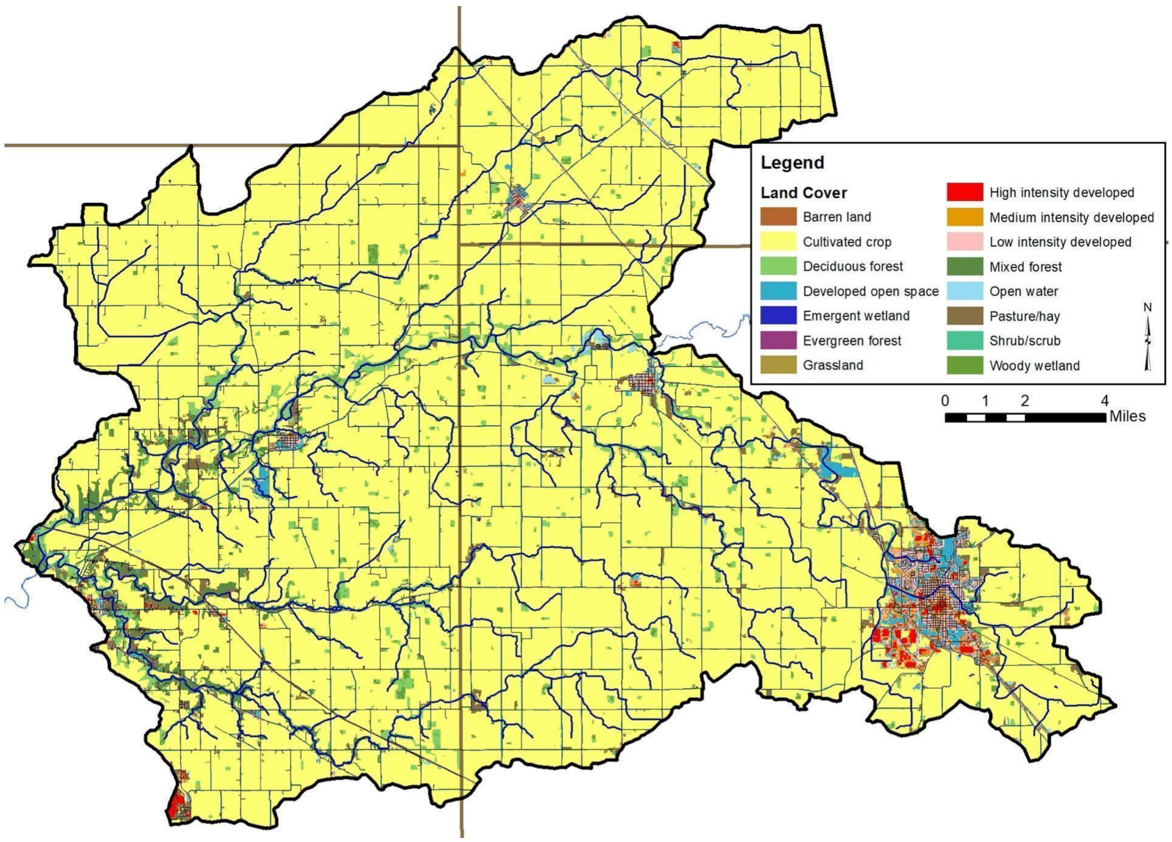


Figure 23. Land use in the Upper Sugar Creek Watershed. Source: NLCD, 2016.

Table 10. Detailed land use in the Upper Sugar Creek Watershed.

Classification	Area (acres)	Percent of Watershed
Cultivated crop	172,219.5	84.2%
Developed open space	9,624.8	4.7%
Deciduous forest	7,142.4	3.5%
Low intensity developed	3,918.7	1.9%
Mixed forest	3,593.3	1.8%
Pasture/hay	3,041.7	1.5%
Woody wetland	1,488.4	0.7%
Medium intensity developed	1,318.6	0.6%
High intensity developed	744.4	0.4%
Grassland	671.4	0.3%
Open water	426.4	0.2%
Emergent wetland	258.5	0.1%
Barren land	41.6	<0.1%
Evergreen forest	33.9	<0.1%
Shrub/scrub	17.6	<0.1%
Entire Watershed	204,541.8	100.0%

Source: USGS, 2016

2.9.2 Agricultural Land Use

Individuals are concerned about the impact of agricultural practices on water quality. Specifically, the volume of exposed soil entering adjacent waterbodies, the prevalence of tiled fields and thus the transport of chemicals into waterbodies, the use of agricultural chemicals and the volume of manure applied via small animal farms and through confined animal feeding operations are concerning to local residents. Each of these issues will be discussed in further detail below.

Tillage Transect

Tillage transect information data for Boone, Clinton, Montgomery and Tippecanoe Counties were compiled for 2021 (Table 11; ISDA, 2021A-D). As reported by ISDA, members of Indiana's Conservation Partnership (ICP) conduct a field survey of tillage methods. A tillage transect is an on-the-ground survey that identifies the types of tillage systems farmers are using and long-term trends of conservation tillage adoption using GPS technology, plus a statistically reliable model for estimating farm management and related annual trends. It is however, likely an underestimate of the actual use of tillage due to the early spring nature of the transect occurring. Table 11 provides the number of acres and percent of acres on which conservation tillage was utilized for each county by corn and soybeans.

Table 11. Conservation tillage data as identified by county tillage transect data for corn and soybeans (ISDA, 2021).

County	Corn (acres)	Corn (%)	Soybeans (acres)	Soybeans (%)
Boone	3,663	4%	8,868	9%
Clinton	7,313	7%	6,388	6%
Montgomery	6,424	5%	4,866	4%
Tippecanoe	8,256	8%	12.150	13%

Agricultural Input Usage

Agricultural pesticides and 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 are not currently collected. Rather, data is 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. These data were last collected in 2006 (NASS, 2006). Additionally, NASS collects farmland data for the number of acres in agricultural production by type (i.e. corn, soybeans, grains) by county (NASS, 2021). These data indicate that corn (427,726 acres planted in Tippecanoe, Montgomery, Boone and Clinton counties) and soybeans (420,111 acres planted in Tippecanoe, Montgomery, Boone and Clinton counties) are the two primary crops grown in the watershed.

Nitrogen is more typically applied to corn than to soybeans. Soybeans have symbiotic bacteria on their roots that act as nitrogen fixers, which means that they pull the nitrogen that they need from the atmosphere 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). Fall application of nitrogen also occurs and is particularly problematic. Agricultural data indicate that corn receives 93% of the nitrogen applied in the state and 87% of the phosphorus. For these reasons, nutrient calculations were only completed for corn as applications to soybeans are likely negligible. Based on these data, it is estimated that 31,523 tons of nitrogen and 15,593 tons of phosphorus are applied annually within the counties in which the Upper Sugar Creek Watershed is located (Table 12).

Table 12. Agricultural nutrient usage for corn in the Upper Sugar Creek Watershed counties.

Nutrient	Acres of Corn	% of Area Applied	Applications (#/year)	Rate/Application (lb/acre)	Total Applied/Year (tons)
Nitrogen	427,726	100	2.2	67	31,523
Phosphorus	427,726	93	1.4	56	15,593

Source: NASS, 2007; NASS, 2021

Pesticides are also used on crops grown in Indiana. The Office of the Indiana State Chemist indicates that the two predominant herbicide active ingredients applied are atrazine and glyphosate. Atrazine is most commonly applied as a corn herbicide, while glyphosate is used on both corn and soybean fields as an herbicide. NASS indicates that in 2005, an average of 1.24 pounds of atrazine and 0.6 pounds of glyphosate were applied per acre of corn, and 0.73 pounds of glyphosate were applied per acre of soybeans (NASS, 2006). Using these rates, we estimated that a little over 265 tons of atrazine and approximately 281 tons of glyphosate are applied to cropland in the Upper Sugar Creek Watershed counties annually (Table 13).

Table 13. Agricultural herbicide usage in the Upper Sugar Creek Watershed counties.

Crop	Acres	Application Rate (lb/acre)	Total Applied (lbs)	Total Applied/Year (tons)
Corn (Atrazine)	427,726	1.24	530,381	265
Corn (Glyphosate)	427,726	0.6	256,636	128
Soybeans (Glyphosate)	420,111	0.73	306,681	153

Source: NASS, 2006; NASS, 2021

Confined Feeding Operations and Hobby Farms

A mixture of small, unregulated and larger, regulated livestock operations are found within the Upper Sugar Creek Watershed. Small farms are those which house less than 300 animals, while larger farms that house large numbers of animals for longer than 45 days per year are regulated by IDEM as confined feeding operations (CFO) or concentration animal feeding operations (CAFO). 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 (CFO). There are 15 active confined feeding operations located in the watershed (Figure 24). In total, the facilities are permitted to house up to 575 finish steers, 71,470 pigs and 53,800 turkeys. In total, 202 small, unregulated animal farms containing more than 2,500 animals were identified during the windshield survey, which is most likely an underestimate of the actual number. These small "mini farms" contain small numbers of cattle, horses, pigs, sheep or goats, which could be sources of nutrients and *E. coli* as these animals exist on small acreage lots with limited ground cover. In total, approximately 128,400 animals per year are housed in CFOs and on unregulated farms in the watershed, generating approximately 353,554 tons of manure per year spread over the watershed. This volume of manure contains approximately 2,420,504 pounds of nitrogen, 1,995,198 pounds of phosphorus and 1.35E+16 col of E. coli.

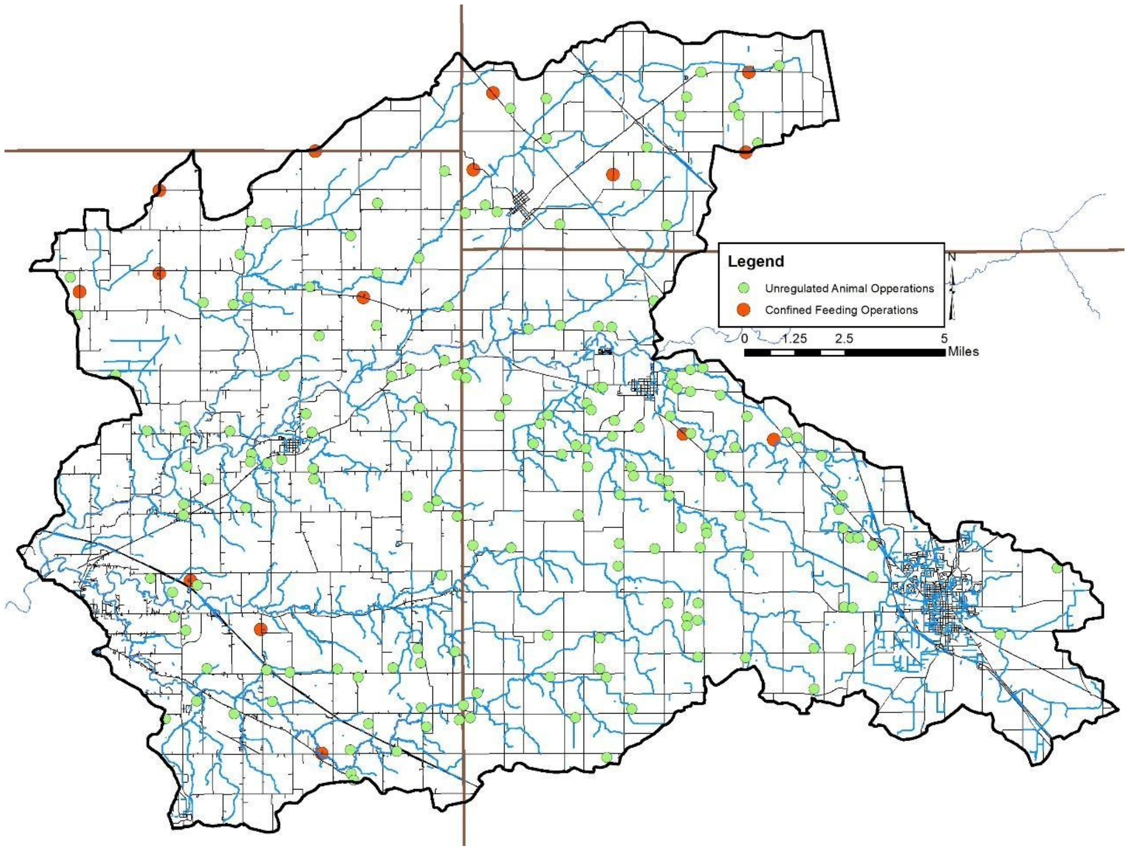


Figure 24. Confined feeding operation and unregulated animal farm locations within the Upper Sugar Creek Watershed.

2.9.3 Natural Land Use

Natural land uses including forest, wetlands, and open water cover approximately 6% of the watershed. Approximately 9,210.0 acres or 5% of the watershed is covered by trees. Forest cover occurs adjacent to waterbodies throughout the watershed.

2.9.4 Urban Land Use

Urban land uses cover approximately 14,188.7 acres or nearly 8% of the watershed (Table 15). Most developed areas are associated with the City of Lebanon, the edge of the City of Crawfordsville, as well as the towns of Darlington, Colfax and Thorntown. Although this is only a small portion of the watershed, there are some significant issues related to the developed areas. Especially troublesome are issues related to failing septic systems, impervious surfaces, flooding and stormwater runoff that allow untreated sewage and stormwater to flow into the watershed during heavy rain events.

2.9.5 Impervious Surfaces

Impervious surfaces are hard surfaces that limit surface water from infiltrating into the land surface to become groundwater thereby creating high overland flow rates. Hard surfaces include concrete, asphalt, compacted soils, rooftops, and buildings or structures. In developed areas, land which was once permeable has been covered by hard, impervious surfaces. This results in rain which once absorbed into the soil running off of rooftops and over pavement to enter the stream with not only higher velocity but also higher quantities of pollutants.

Overall, the watershed is covered by low levels of impervious surfaces. However, high impervious densities are present in the City of Lebanon and along roads throughout the watershed. In some areas of the watershed, including the City of Lebanon, individual drainages have much higher impervious coverage. 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. Higher impervious surface coverage results in further impairments including water quality problems, increased bacteria concentrations, higher levels of toxic chemicals, high temperatures, and lower dissolved oxygen concentrations (CWP, 2003).

Urban Chemical Use

At least three golf courses including the Lebanon Trophy Club, Ulen Country Club, and Rocky Ridge Golf Club in Linnsburg are located in the Upper Sugar Creek Watershed. Regularly applied fertilizer is likely common on these golf courses as well as lawns in the MS4 community of Lebanon. Urban pesticide and herbicide use has not been quantified for the Upper Sugar Creek Watershed. However, studies of nitrogen sources in urban landscapes throughout the United States have found that nitrogen-based fertilizer typically represents the dominant nitrogen source in urban areas. A large proportion of the fertilizer nitrogen is incorporated into plant biomass or soil organic matter pools, with the latter accumulating in the system for years to decades (Raciti et al. 2011).

2.9.6 Legacy Pollutant Remediation Sites

Remediation sites including leaking underground storage tanks (LUST) and brownfields are present throughout the Upper Sugar Creek Watershed (Figure 25). Most of these sites are located within the developed areas of the watershed including the City of Lebanon and Towns of Thornton, Darlington and Colfax as well as along State Road 32 and 47 and Interstate 65. In total, 126 underground storage tanks of which 48 are considered LUST facilities and four brownfields are present within the watershed.

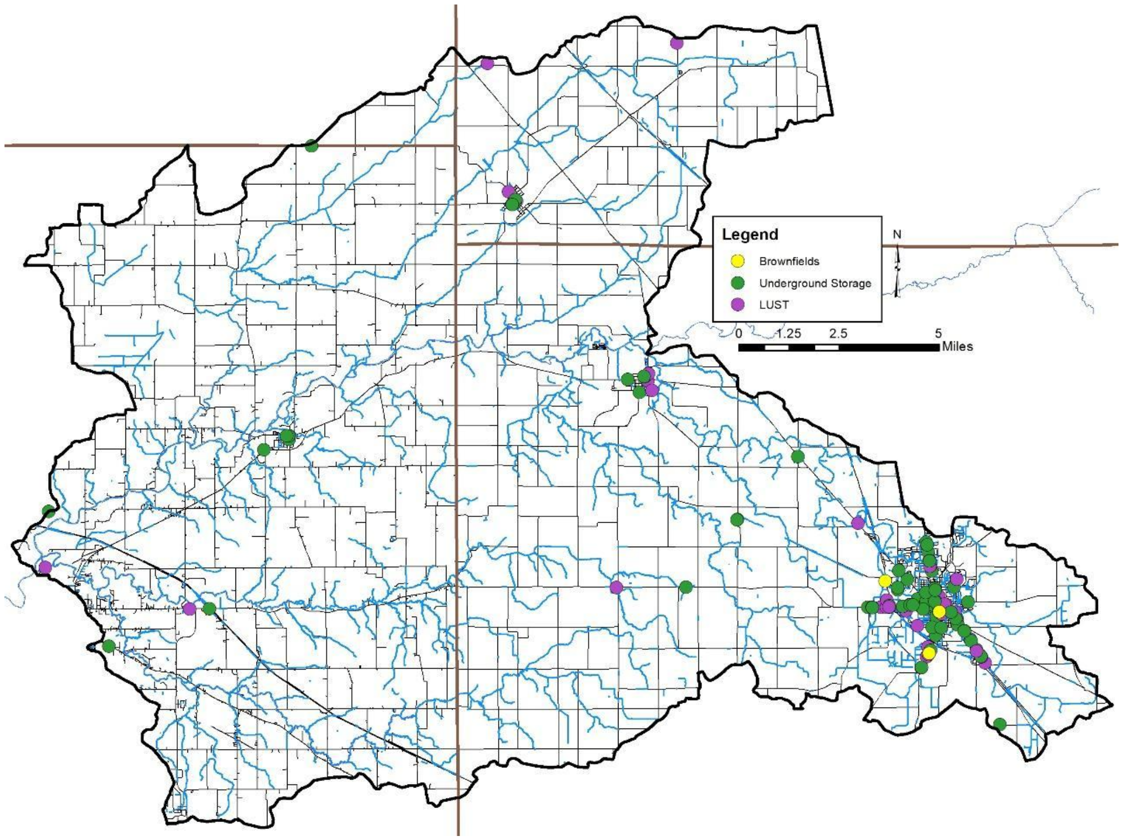


Figure 25. Industrial remediation and waste sites within the Upper Sugar Creek Watershed.

2.10 Population Trends

The Upper Sugar Creek Watershed is a mix of relatively sparsely populated areas and urban centers in general. Lebanon, Darlington, Colfax and Thorntown house the highest density populations. Table 14 details the population of each county in the Upper Sugar Creek Watershed. These data indicate that all four counties are growing – this is especially true for Boone County where the City of Lebanon continues to grow.

Table 14. Population data for counties in the Upper Sugar Creek Watershed.

County	2000	2010	2020
Boone	46,415	56,914	66,875
Clinton	33,958	33,221	32,186
Montgomery	37,567	38,097	38,295
Tippecanoe	149,313	173,102	193,302

Tracking population changes within a watershed is challenging as data is published by counties and townships rather than watershed boundaries. Estimated populations in the Upper Sugar Creek Watershed indicate that 64% of the population is rural residents while 36% of the population reside in urban locations. Table 15 displays estimated populations for the portion of each county located within the watershed (US Census data, 2010).

Table 15. Estimated watershed demographics for the Upper Sugar Creek Watershed.

County	2020 Population	Total Estimated Watershed Population	Total Estimated Watershed Urban Population	Total Estimated Watershed Rural Population	Percent of Total Watershed Population
Boone	66,875	27,420	17,163	10,257	41%
Clinton	32,186	3,934	787	3,147	12.2%
Montgomery	38,295	17,392	857	16,535	1.4%
Tippecanoe	193,302	2,630	0	2,630	45.4%
Total	**330,658**	**51,376**	**18,807**	**33,044**	**100%**

2.11 Planning Efforts in the Watershed

Multiple plans have encompassed portions of the Upper Sugar Creek Watershed or areas which it drains or outlets into. Planning efforts include Upper Sugar Creek and Walnut Fork-Sugar Creek LARE Diagnostic studies, Lebanon Storm Drainage ordinance, the Lebanon Thoroughfare plan and more. Plans are listed in chronological order.

Lye Creek Work Plan (1975)

The Lye Creek Work Plan was produced by the Montgomery County SWCD and Montgomery County Drainage board in 1975 with assistance from what was at the time the U.S. Soil Conservation Service (now NRCS). Some of the key topics of the work plane:

- Identified and analyzed the existing soil use, water and land quality and biological resources present throughout the watershed.
- Described the Lye Creek watershed, which is about 20 square miles within Montgomery County.
- Included recommendations on how to remediate issues present in the watershed, including listing state and federal technical assistance programs to remedy these issues.

Recommendations in this plan included:

- Installing appropriate land treatment measures on about 4,850 acres
- Implementing proper land use
- Eliminating illegal trash and garbage dumping
- Eliminating feedlot discharge
- Restricting land use for a distance of 50 feet from stream banks
- Installing stream improvements for fish and wildlife habitats
- Converting the upwards of 1,800 acres of cropland to wetlands, forest and upland wildlife areas.

Little Sugar Creek WMP (2002)

The Little Sugar Creek WMP is a strategic land-use management document that guides the comprehensive management, development and use for recreation, natural resources and cultural resources that are efficient and cost-effective throughout the life of the Little Sugar Creek Project. This Watershed Management Plan was created as a result of the committee's efforts to reduce pollution as much as possible from nonpoint sources in the watershed. In order to accomplish this, the committee focused its attention on four main areas in the watershed:

- Agricultural nonpoint source pollution from cropland activities
- Agricultural nonpoint source pollution from livestock farming
- Lack of vegetated riparian buffers near Little Sugar Creek and its tributaries

- Education for landowners in the watershed and community members on nonpoint source pollution problems and solutions

As a result of these concerns, the steering committee developed goals and objectives to address each of the four topics. The environmental goals of this plan include:

- Reduce manure application of fertilizer by educating about soil testing and optimum usage for certain soil types.
- By November 2007, see no-till on 50% of corn after soybeans and 90% of beans after corn.
- Increase awareness on how cropping practices can impact water quality and about cost-share available through other programs such as the Farm Bill.
- Promote use of alternative water and manure management systems in the Little Creek Subwatershed.
- Fence livestock from waterways where applicable.

Riparian goals include:

- Install buffer strips in the Little Creek subwatershed.
- Connect buffers along waterways to create a corridor in Needam-Booher subwatershed.
- Educate the public on the importance of habitat.
- Start Hoosier Riverwatch program in Montgomery County and Boone County schools.
- Get into Montgomery County and Boone County schools to provide education on watersheds, nonpoint source pollution, 319 Grant, and the importance of conservation.

Browns Wonder-Sugar Creek Watershed LARE Diagnostic Study (2013)

The LARE Diagnostic study was conducted when the Boone and Clinton County Soil and Water Conservation Districts received a grant from the Indiana Department of Natural Resources, Division of Fish and Wildlife, through the Indiana Lake and River Enhancement Program (LARE). The purpose of the grant was to assist the districts in making a diagnosis of water quality problems within the Browns Wonder-Sugar Creek watershed and to propose solutions to address any water quality issues found. Some of the conclusions the study drew included:

- Aquatic habitat was generally good at most sites and only a few of the streams sampled had been artificially straightened or channelized.
- Nitrate values at most sites were low in comparison to many other Indiana streams in agricultural areas.
- In contrast, phosphorus concentrations were elevated at some sites and E. coli concentrations often exceeded Indiana water quality standards for recreational use, especially during wet weather.
- Aquatic communities (macroinvertebrates) were negatively impacted by excessive sediment inputs in some tributaries of Sugar Creek.
- Three tributary sub-watersheds (Browns Wonder Creek, Mallot Ditch, and Scott Wincoop Ditch) were identified as the areas where water quality improvements could have the biggest positive impacts within the watershed.
- Some goals of this plan include implementing land and field treatments. A breakdown of their goals are as follows:

  Land Treatments:

  Filter Strips (150 acres)
  Grasses Waterways (10,000 feet)
  10 WASCOB's

Field Practices:
Conservation Tillage (1000 acres)
Nutrient Mgmt. (1000 acres)
Streambank Vegetation (1000 feet)
Cover Crops (1000 acres)

Lebanon Storm Drainage Ordinance (2015)

Lebanon City Government recognized the need to develop a city-wide comprehensive stormwater improvement plan to provide an accounting of known stormwater drainage issues, along with a plan for identifying, prioritizing and implementing sustainable solutions and providing a guideline for future improvements. The purpose of this ordinance is to provide for the health, safety and general welfare of the citizens of City of Lebanon through the regulation of stormwater and non-stormwater discharges to the storm drainage system; to enhance economic objectives; and to protect, conserve and promote the orderly development of land and water resources within the City of Lebanon. This ordinance includes the following guidance:

- To reduce the hazard to public health and safety caused by excessive stormwater runoff.
- To regulate the contribution of pollutants to the storm drain system from active construction site runoff.
- To regulate the contribution of pollutants to the storm drain system from runoff from new development and re-development.
- To prohibit discharges of non-stormwater flow into the storm drain system.
- To establish legal authority to carry out all inspection, monitoring, and enforcement procedures necessary to ensure compliance with this ordinance.

Sugar Creek Flood Inundation report (2016)

This Flood Inundation report was created by the Indiana Office of Community and Rural Affairs for USGS stream gage 03339500, which is on Sugar Creek at Crawfordsville. The maps cover a reach about 6.5 miles long from U.S. Interstate 74 to approximately 0.5 mi downstream of County Road N225W near Crawfordsville. ages. The HEC–RAS hydraulic model was calibrated to the current stage-discharge relation at USGS stream gage 0333950 and to the flood of April 19, 2013. The below map, Figure 26, details the flood inundation as calculated by the USGS at stream gage 03339500.

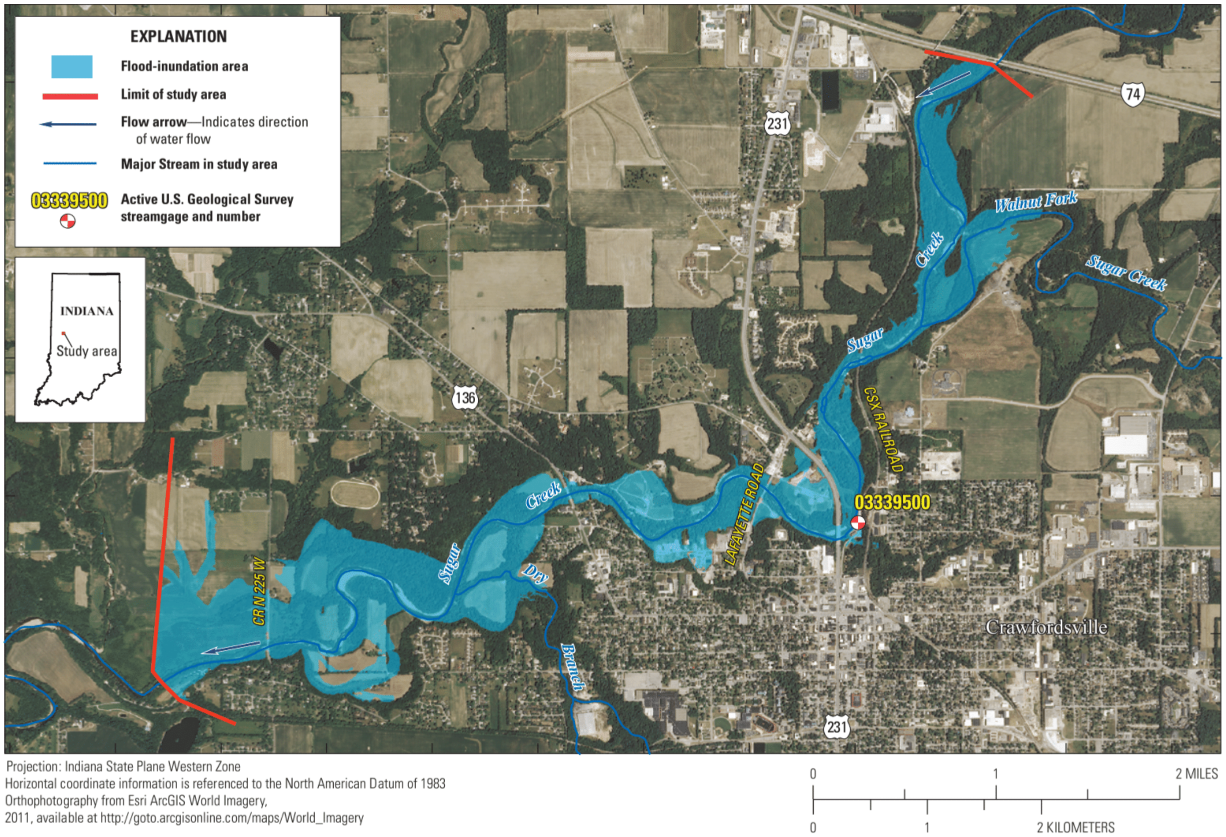


Figure 26. Flood-inundation map for Sugar Creek at Crawfordsville, Indiana, corresponding to a stage of 16.0 feet at the U.S. Geological Survey stream gage 03339500.

Browns Wonder Creek-Sugar Creek Watershed Management Plan (2017)
This watershed management plan is a comprehensive assessment of all natural aspects of the Browns Wonder Creek-Sugar Creek Watershed by assessing water quality and overall condition of the watershed. The watershed plan created the following goals:

- Reduce sediment runoff after large rain events and reduce TSS loads by 25% over 5 years.
- Reduce E. coli levels in water by 37% to 235 cfu/100 ml, which is the maximum level allowed for swimmable water according to the EPA.
- Reduce total phosphorus concentrations by 76% and reduce nitrate-nitrite levels by 75%.
- Increase IDEM QHEI and IBI scores by 50%.
- Establish Critical Land Areas and Priority Protection Areas. The objective identified:
  - Implement at least 8,500 cubic yards (approximately 4 acres) of bank stabilization practices such as a 2-stage ditch, streambank protection, or grassed waterways.
  - Implement 500 acres of No-till each year so that at least 1% of agricultural cropland has year-round vegetation coverage.
  - Implementat at least three urban practices that address sedimentation and drainage such as rain gardens, permeable pavement or bioswales.

Lebanon Thoroughfare plan (2017)
The City of Lebanon began the process of updating the Lebanon Thoroughfare Plan in 2016 to develop a transportation planning tool that provides guidance on the future needs for the transportation system as the community grows. This process engaged a steering committee of both city and county officials,

as well as the general public, to create roadway standards based on proposed land uses and population growth. Goals for this plan include:

- The transportation system should support a complete streets philosophy and interconnectivity for all users.
- The transportation system should guide and support economic development initiatives in the city.
- The transportation system should provide adequate capacity to meet the travel demand within the city.
- The transportation system should provide excellent access for all citizens to the employment, residential, commercial, institutional, and recreational opportunities in the city.
- The transportation system should support a high-quality of life for residents and visitors to Lebanon.

City of Lebanon Comprehensive Plan (2018)

The comprehensive plan for Lebanon directs the future physical development of the community. It addresses the use of land to accommodate future activities, the improvement of the infrastructure (roads and utilities) to sustain development, the provision of community and recreation facilities to meet the needs of its residents and the preservation of natural and historic amenities to protect the heritage of the community. Environmental-related goals in the plan include the need to:

- Ensure the zoning map and unified development ordinance support development in accordance with the future land use plan and other recommendations of this plan.
- Explore expanding the City's planning and zoning jurisdiction to be able to more pro-actively plan for new development within Center Township.
- Protect flood hazard areas and wetlands from future development and promote removal of existing structures within these areas.
- Incentivize green infrastructure and stormwater best management practices to reduce stormwater volumes and the subsequent risk of flooding.
- Coordinate utility, transportation, stormwater, and other infrastructure improvements to combine construction projects and reduce costs where possible.

McLaughlin Drain Hydraulic Analysis (2018)

The analysis of the McLaughlin Drain was completed to show the impacts of proposed maintenance along upper portions of the drain and potential alternatives to offset the impacts or improve conditions downstream. Maintenance and creation of 2-stage ditches can create more flow area and reduce flood elevations in the vicinity of McLaughlin Drain but the increase incapacity of the stream also increases downstream flow rates.

Stone Eater Park Development plan (2020)

Stone Eater Bike Park is a rough terrain bike park designed in partnership of City of Lebanon and with the National Interscholastic Cycling Association (NICA). It would include a bike park, destination trail system and professional mountain bike racing, competition and special event venue. As of April 2022, the project was still working to remove trees and create an artificial geology enclosure. This portion will be updated as information becomes available.

Walnut Fork-Sugar Creek Watershed Diagnostic Study (2021)

The Walnut Fork-Sugar Creek Watershed Diagnostic Study is a comprehensive examination of Little Sugar Creek and Walnut Fork-Sugar Creek and their surrounding watershed. In 2020, with funding from the Indiana Department of Natural Resources Lake and River Enhancement (LARE) Program, the

Montgomery County SWCD hired Arion Consultants to conduct the study. The scope of the study included the following:

- Data review and mapping current conditions: Collection and review of historic studies, water quality and fisheries reports, and base mapping of watershed conditions.
- Public engagement and outreach: Completion of a watershed tour and landowner and public meetings.
- Watershed assessment: Complete tributary water quality Sampling and water quality modeling.
- Analysis and data interpretation: Review of Historic and Current Conditions, assessment collected water quality data, and compilation of results recommendation.
- The study recommended various ways to improve the watershed. These include:
    - Reduce total suspended solids concentrations in streams throughout the watershed.
    - Reduce E.coli concentrations in streams throughout the watershed.
    - Reduce soluble and total phosphorus concentrations in streams throughout the watershed.
    - Apply for Lake and River Enhancement (LARE) funds to best management practices.
    - Target best management practice implementation on non-protected parcels mapped as highly erodible land.
    - Extend Management at the watershed level.
    - Provide information about streams within the Walnut Fork-Sugar Creek Watershed to local landowners.
    - Reach out to a school or other volunteer group to begin volunteer monitoring at additional sites within the watershed through the Hoosier Riverwatch Program.
    - Invite producers and other landowners to visit successful project sites.

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 relationships within specific subwatersheds are discussed in more detail in subsequent sections.

2.12.1 Topography, Soils and Nutrient and Sediment Loss

Much of the topography and terrain characteristics within the Upper Sugar Creek Watershed have a direct correlation to water quality. Approximately 91% of the Upper Sugar Creek Watershed is mapped in highly erodible lands. Highly erodible lands are very susceptible to erosion. Nutrients, such as phosphorus, and sediment erode easily when these soils are not covered. Sediments and nutrients that reach Upper Sugar Creek waterbodies are likely to degrade water quality. Highly erodible lands that are used for animal production or are located on cropland are more susceptible to soil erosion. Topography within the watershed is relatively flat with the exception of the City of Lebanon.

2.12.2 Wetland Loss, Hydromodification and Flooding

Wetlands cover 5,613 acres, or 8%, of the watershed. When hydric soil coverage (67,539 acres) is used as an estimate of historic wetland coverage, it becomes apparent that more than 93% of wetlands have been modified or lost over time. Additionally, it is estimated that more than 200 miles of surface tile drains have been constructed in the watershed to move water more rapidly from land to adjacent waterbodies. In total, nearly 76% of the watershed is estimated to be covered by tile-drained soils. As commodity prices continue to go up and down, area land values remain high and as a result, individuals are spending a great deal of money to drain small natural wetlands in their fields in order to be able to farm that additional couple acres of land as it is cheaper to tile it than to buy ground already in production.

The modification of the Upper Sugar Creek Watershed directly impacts its ability to retain and store water. Additionally, these efforts push water from one area to another resulting in flooding in portions of the watershed.

2.12.3 Topography, Population Centers and Septic Soil Suitability

Much of the watershed's population is located within unincorporated areas outside of the City of Lebanon and Towns of Darlington, Colfax and Thorntown. Unsewered, dense housing areas are located throughout the watershed with small subdivisions and roadside housing developments occurring throughout the watershed. This is a concern because adequate filtration may not occur and this water may easily reach water sources and groundwater. With a lack of natural filtration of septic fields to groundwater, degradation of water quality is likely if septic systems are not maintained. Septic maintenance is a concern of Upper Sugar Creek Watershed stakeholders.

2.12.4 High-quality Habitat and ETR Species

Many high-quality communities occur throughout the Upper Sugar Creek Watershed. Several of these are preserved for future generations. The high-quality natural areas including, heavily forested riparian areas associated with the mainstem of Sugar Creek provide unique habitats which house several endangered, threatened or rare communities and species. The topography, bedrock and soils in this area support ravines and mature forest habitats that provide rare habitat that is home to many species of wildlife, fish, and plants. The topography here made this area less suitable for farming and so more of the natural community and habitat has been preserved here. Many of the endangered, threatened and rare species and high-quality natural communities in the watershed are found along this stretch of the stream corridor, making this an important area to focus habitat preservation and restoration efforts.

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 was available or if additional data needed to be collected in order to characterize water quality problems. Once the water quality data assessment occurred, the watershed was then characterized to determine potential sources of any water quality issues identified by the data review. Subsequently, pollutant sources could then be tied to stakeholder concerns and collected data could be used to estimate pollutant loads from each identified source location. 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 Upper 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. Monitoring 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	>4 mg/L or <12 mg/L	Indiana Administrative Code
pH	>6 or <9	Indiana Administrative Code
Temperature	Monthly standard	Indiana Administrative Code
Conductivity	<1050 mmhos/cm	Indiana Administrative Code
E. coli	<235 colonies/100 mL	Indiana Administrative Code
Nitrate-nitrogen	<1 mg/L	Dodds et al. (1998)
Ammonia-nitrogen	Varies by pH/temp	Indiana Administrative Code
Total Kjeldahl nitrogen	2.18 mg/L	USEAP (2000)
Total phosphorus	<0.08 mg/L	Dodds et al. (1998)
Orthophosphorus	<0.005 mg/L	Dunne and Leopold (1978)
Total suspended solids	<15 mg/L	Waters (1995)
Turbidity	<6.36 NTU	USEPA (2000)
Qualitative Habitat Evaluation Index	>51 points	IDEM (2008)
Index of Biotic Integrity	>36 points	IDEM (2008)
Macroinvertebrate Index of Biotic Integrity	>2.2 points (old) >36 points (new)	IDEM (2008)

3.2 Historic Water Quality Sampling Efforts

A variety of water quality assessment projects have been completed within the Upper Sugar Creek Watershed (Figure 27). Statewide assessments and listings include the impaired waterbodies assessment and fish consumption advisories. Additionally, Indiana Department of Environmental Management (IDEM), Indiana Department of Natural Resources (IDNR), developers of the Little Sugar Creek Watershed Management Plan and Walnut Fork-Sugar Creek LARE diagnostic study and Hoosier Riverwatch volunteers have all completed assessments within the watershed. A summary of each assessment methodology and general results are discussed below. Specific data results are detailed within subwatershed discussions in the subsequent section.

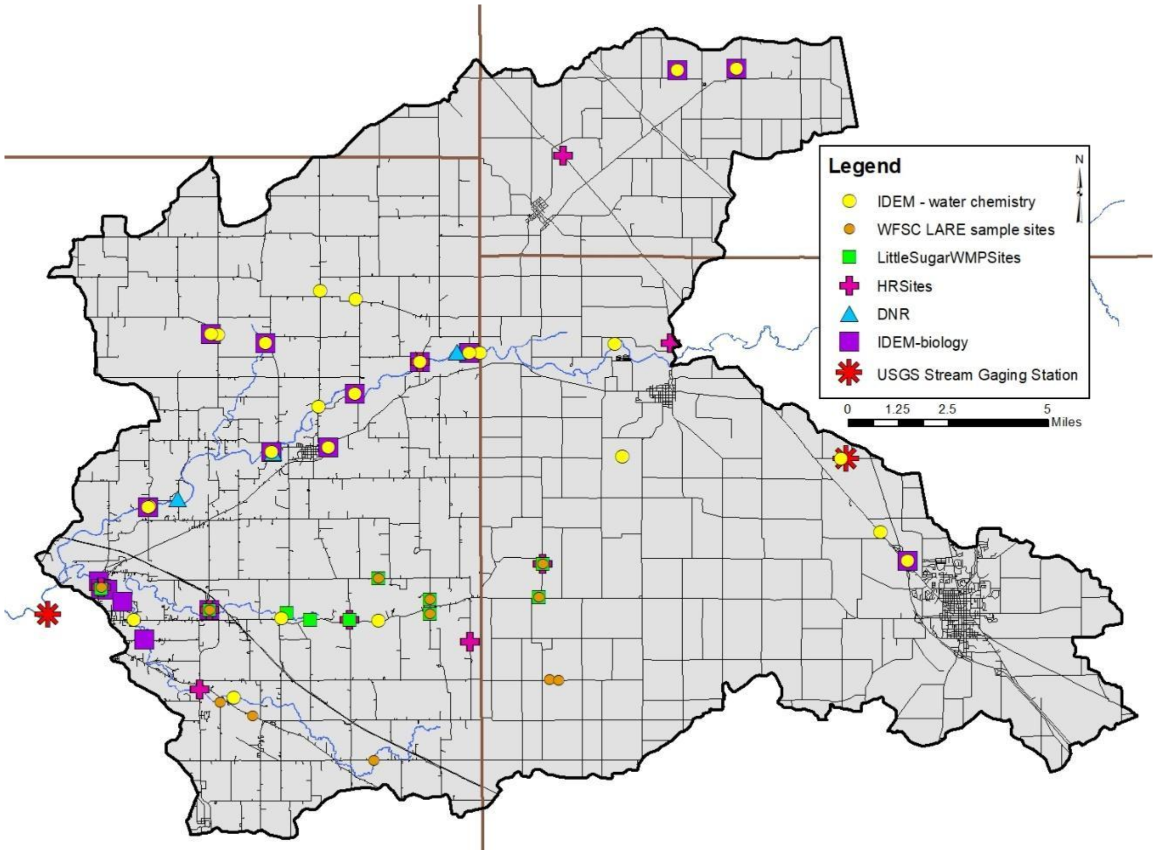


Figure 27. Historic water quality assessment locations.

3.2.1 **Impaired Waterbodies (303(d) List)**

The impaired waterbodies, or 303(d) List, is prepared biannually by the Indiana Department of Environmental Management. Waterbodies are included on the list if water quality assessments indicate that they do not meet their designated use. More information on the listing process is included in section 3.2.1. In total, 26 stream segments within the Upper Sugar Creek Watershed are included on the list of impaired waterbodies (IDEM, 2022). Figure 21 details the listings in the watershed, while Figure 28 maps the segments and their locations within the watershed. Waterbodies are listed as impaired for *E. coli* (119 miles), nutrients (21 miles), impaired biotic communities (21 miles), pH (11 miles) and PCBs in fish tissue (92 miles).

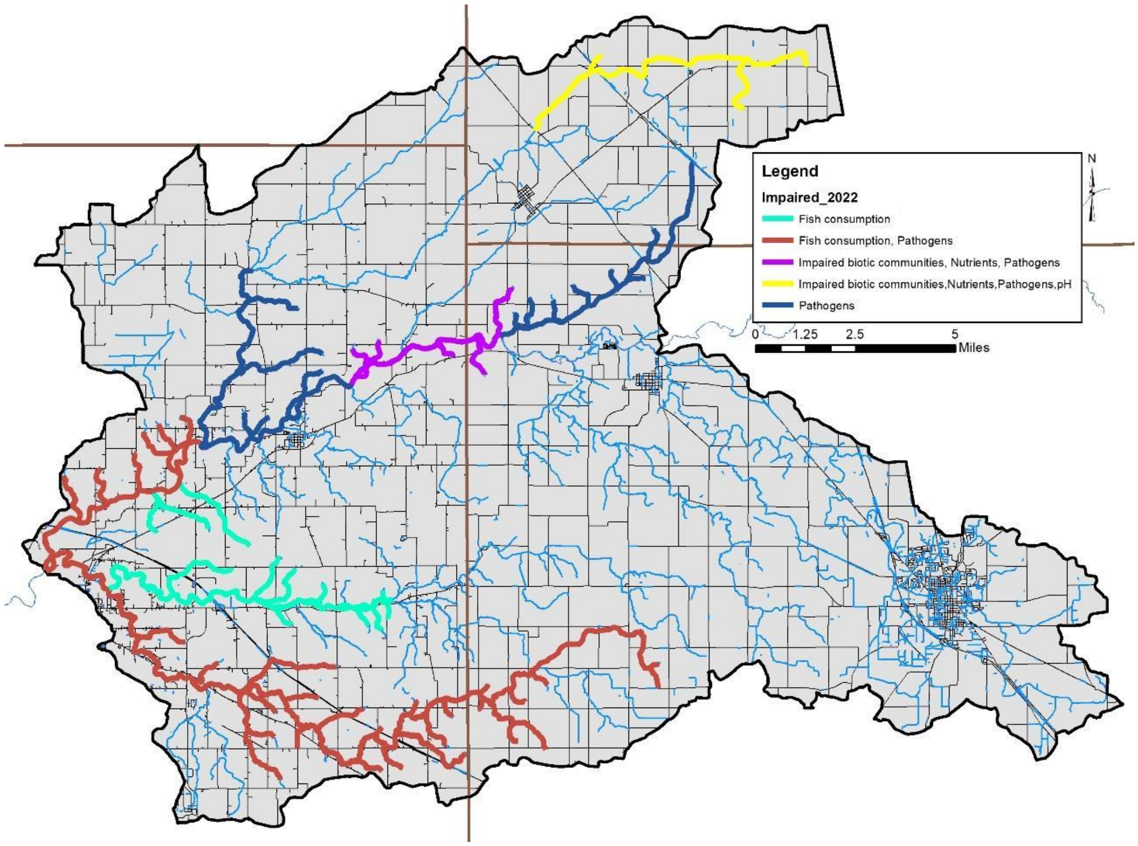


Figure 28. Impaired waterbody locations in the Upper Sugar Creek Watershed. Source: IDEM, 2022.

Table 17. Impaired waterbodies on the Upper Sugar Creek Watershed 2022 IDEM 303(d) list.

Stream Name	Assessment Unit	Impairment
Goldsberry Creek	INB1044_T1003	Pathogens
Goldsberry Creek	INB1044_T1004	Pathogens
Little Potatoe Creek	INB1021_01	Impaired biotic communities, Nutrients, Pathogens, pH
Little Sugar Creek	INB1032_02	Fish consumption
Little Sugar Creek	INB1032_03	Fish consumption
Little Sugar Creek	INB1032_05	Fish consumption
Little Sugar Creek	INB1032_04	Fish consumption
Little Sugar Creek-Unnamed tributary	INB1032_T1003	Fish consumption
Lye Creek	INB1024_02	Pathogens
Lye Creek	INB1024_03	Pathogens
Lye Creek-Unnamed tributary	INB1024_T1002	Pathogens
Sugar Creek	INB1045_03	Impaired biotic communities, Nutrients, Pathogens
Sugar Creek	INB1046_03	Pathogens
Sugar Creek	INB1046_02	Pathogens
Sugar Creek	INB1045_02	Impaired biotic communities, Nutrients, Pathogens

Stream Name	Assessment Unit	Impairment
Sugar Creek	INB1047_03	Fish consumption, Pathogens
Sugar Creek	INB1047_02	Fish consumption, Pathogens
Sugar Creek-Unnamed tributary	INB1047_T1003	Fish consumption
Sugar Creek-Unnamed tributary	INB1047_T1004	Fish consumption
Walnut Fork Sugar Creek	INB1033_02	Fish consumption, Pathogens
Walnut Fork Sugar Creek	INB1033_05	Fish consumption, Pathogens
Walnut Fork Sugar Creek	INB1033_06	Fish consumption, Pathogens
Walnut Fork Sugar Creek	INB1033_04	Fish consumption, Pathogens
Walnut Fork Sugar Creek	INB1033_03	Fish consumption, Pathogens
Walnut Fork Sugar Creek - Unnamed tributary	INB1033_T1003	Fish consumption, Pathogens
Walnut Fork Sugar Creek - Unnamed tributary	INB1033_T1004	Fish consumption, Pathogens

3.2.2 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. Advisories listings by the ISDH are as follows:

- Level 3 – limit consumption to one meal per month for adults with pregnant or breastfeeding women, women who plan to have children, and children under 15 consuming zero volume of these fish.
- Level 4 – limit consumption to one meal every 2 months for adults with women and children detailed above having zero consumption.
- Level 5 – zero consumption or do not eat.

Further, sensitive populations are defined as females under 50 except those no longer able to become pregnant, males under 15 or people with compromised immune systems, while general populations are defined as males over the age of 15 and women over the age of 50 or who are no longer capable of becoming pregnant.

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

- All fish upstream of I-74 in Sugar Creek are located well above the known PCB contamination sources. However, fish have been found to be much lower in PCBs. Consumers should follow the Safe Eating Guidelines as follows: consume carp up to 23 inches no more than one meal per week and carp larger than 23 inches one meal per month; redhorse species no more than one meal per week; rock bass species, smallmouth bass and sunfish species nor more than one meal per week.
- Fish from Little Sugar Creek should not be consumed by those in the sensitive or general populations.
- Fish from Walnut Fork Sugar Creek should be limited by sensitive populations as follows: consume carp up to 14 inches no more than one meal per week and carp larger than 14 inches one meal per month; redhorse species no more than one meal per week; rock bass species and

smallmouth bass species nor more than one meal per week. For the general population, consume carp up to 14 inches no more than one meal per week and carp larger than 14 inches one meal per month; redhorse species no more than one meal per month and smallmouth bass nor more than one meal per week.

3.2.3 **IDEM Rotational Basin Assessments (1991-2021)**

IDEM sampled water chemistry, macroinvertebrates, fish and habitat at several locations in the Upper Sugar Watershed via their rotational basin, watershed assessment, and source ID assessment programs between 1991 and 2020. A few of the assessments which occurred via various IDEM assessment programs included a single sample event with most assessments including five sample events and a few assessments including up to 12 events. Based on the water chemistry assessments, the following conclusions can be drawn:

- *E. coli* concentrations exceeded the state standard in 80% of samples collected in the Upper Sugar Creek Watershed.
- Nitrate-nitrogen concentrations exceeded target concentrations in 69% of samples collected in the Upper Sugar Creek Watershed.
- Total phosphorus concentrations exceeded the recommended criteria in 74% of samples collected in the Upper Sugar Creek Watershed.
- Turbidity levels routinely exceed the recommended standard in 69% of samples collected in the Upper Sugar Creek Watershed.

Based on the fish and macroinvertebrate community and habitat assessments, the following conclusions can be drawn:

- Macroinvertebrate community assessments indicate that Upper Sugar Creek and its tributaries rate as moderately impaired to not impaired using the kick net sampling procedure. All of the sites sampled using the multi-meric habitat approach rate as fully supporting scoring 36 points or more.
- Fish community assessments indicate that Upper Sugar Creek and its tributaries rate as poor (34) to excellent (54). Only 6% of samples did not meet their aquatic life use designation scoring less than 36.
- Habitat assessments completed along Upper Sugar Creek and its tributaries indicate that habitat is generally fully supported for aquatic life uses with QHEI scores ranging from 23 to 89 during fish and macroinvertebrate community assessments. Approximately 15% of assessments indicate habitat that does meet its aquatic life use designation.

3.2.4 **Indiana Department of Natural Resources Assessments (1973-2003)**

The DNR assessed the fish communities within the Walnut Fork-Sugar Creek Watershed in 1973 (Huffaker, 1973), 1998 (Keller, 1998), and 2003 (Keller, 2004). Based on these assessments, the following conclusions can be drawn:

- Huffaker sampled three stream sites, two on Walnut Fork and one on Little Sugar Creek in 1973. Between 18 and 20 species were identified at the Walnut Fork sites, while 16 species were identified at the Little Sugar Creek site. Huffaker suggested that a confined feeding operation established in the Little Sugar Creek drainage in 1973 which had a history of manure spills may have impacted the fish community present.
- Keller sampled multiple locations along both Walnut Fork and Little Sugar Creek in 1998. The study aimed at determining fish distribution, game and non-game fish species abundance, assess aquatic habitat and determine recovery of the Little Sugar Creek fishery following fish

kills. In total, 6,969 fish representing 42 species and families were collected. Keller noted that the community indicated good rebound capabilities following manure spills and fish kills.

- Keller sampled Little Sugar Creek and Walnut Fork again in 2003. Keller noted that the previously abundant darter species had been mostly eliminated as were the intolerant redhorse and hogsucker communities, intolerant minnow species and rock bass. The fish community in Little Sugar Creek was only one-fifth as abundant as the community present in Walnut Fork.

3.2.5 **Gammon Assessments (1973-2003)**

James Gammon of DePauw university assessed the fish communities within the Upper Sugar Creek Watershed regularly from 199 to 2002. In total, 22 sites were assessed. Based on these assessments, the following conclusions can be drawn:

- Little Sugar Creek's fish community on average rated as fair using the Index of Biotic Integrity developed by Karr (1981).
- Walnut Fork's fish community on average rated as good using the IBI.

3.2.6 **Little Sugar Creek Watershed Management Plan (2001-2004)**

The Little Sugar Creek watershed coordinator assessed water chemistry at 10 sites twice monthly for 22 months as part of the Little Sugar Creek watershed management plan development process. Average concentrations by site are provided in the plan. Based on these assessments, the following conclusions can be drawn:

- On average, nitrate-nitrogen concentrations were elevated throughout the Little Sugar Creek drainage with 96% of samples exceeding target concentrations. Average concentrations ranged from 2.6 to 13.1 mg/L with all sites averaging concentrations which exceed target concentrations (1.5 mg/L). Site 7, the tributary which drained hog CFO barns present at the time of the assessment possessed the highest average nitrate-nitrogen concentration.
- Average total phosphorus concentrations ranged from 0.025 to 0.068 mg/L. All average concentrations measured below target concentration; however, individual grab samples exceeded target concentrations (0.08 mg/L) in 22% of collected samples.
- E. coli concentration averages measured below the state standard (235 col/100 mL) with site 1 recording the highest average concentration (100 col/100 mL). E. coli concentrations exceeded state standards in only 3% (8 of 285) samples.
- Dissolved oxygen concentrations exceeded the higher state standards (12 mg/L) in 43% of collected samples.
- Summer temperatures measured at Sites 1-3 measured higher than levels suitable for smallmouth bass, a popular game fish in the Sugar Creek drainage.
- Macroinvertebrate and fish communities as well as available habitat rated low at sites 2, 6 and 10 with those sites with the poorest habitat registering the lowest community scores.

3.2.7 **Walnut Fork-Sugar Creek Diagnostic Study (2020-2021)**

Arion Consultants assessed water chemistry at 13 sites twice – once during base flow and once during storm flow, macroinvertebrate community and habitat in 2020 as part of the Walnut Fork Sugar Creek diagnostic study development process. Average concentrations by site are provided in the plan. Based on these assessments, the following conclusions can be drawn:

- On average, nitrate-nitrogen concentrations were elevated throughout the Walnut Fork Sugar Creek drainage with 85% of samples exceeding target concentrations. Concentrations ranged from 0.81 mg/L to 2.66 mg/L during base flow, while storm flow nitrate- nitrogen concentrations ranged from 1.16 mg/L to 1.88 mg/L.

- Total phosphorus concentrations ranged from 0.07 mg/L to 0.24 mg/L with 54% of samples exceeding the target concentration.
- E. coli concentration ranged from 435 col/100 ml to 2420 col/100 ml with 77% of samples exceeding state standards.
- The overall evaluation of biotic health and habitat quality in the Walnut Fork-Sugar Creek Watershed indicates that headwaters and tributary sites are slightly to moderately degraded while mainstem and outlet sites possess higher quality habitat. Many of the headwaters and tributary sites lacked at least one of the key elements of natural, healthy stream habitats. These missing key elements limit the functionality of these systems. The QHEI evaluations from each of the headwaters site describe moderate substrate quality throughout streams in the Walnut Fork-Sugar Creek Watershed.

3.2.8 **Hoosier Riverwatch Sampling (2002-2022)**

From 2001 to present, volunteers trained through the Hoosier Riverwatch program assessed nine sites in the Upper Sugar Creek Watershed. Volunteers monitored stream stage, flow rate, and discharge; collected water chemistry samples for analysis using HACH test kits; assessed instream habitat using the Citizen's QHEI; and surveyed the stream's macroinvertebrate community. Using the chemical data, the Water Quality Index (WQI) was calculated. Volunteers calculated a Pollution Tolerance Index (PTI) using the biological data. Based on these data, the following conclusions can be drawn:

- Dissolved oxygen concentrations typically measured within the state standard with concentrations ranging from 0.1 to 14 mg/L. None of the samples collected exceeded state standards.
- When measured, E. coli concentrations were relatively low with only one of six samples measuring above the state standard.
- Nitrate concentrations ranged from 0 to 22 mg/L with 38% of samples exceeding the water quality target.
- Orthophosphorus concentrations were elevated in 76% of samples. There is no pattern to sites with elevated orthophosphorus concentrations.
- Turbidity levels were elevated across all sample sites with 26% of samples exceeding the transparency which indicates poor water quality (29 cm).

3.3 Current Water Quality Assessment

3.3.1 Water Quality Sampling Methodologies

As part of the current project, the Upper Sugar Creek Watershed Project implemented a one-year water quality monitoring program. The program included monthly water chemistry sample collection and one fish community, macroinvertebrate community and habitat assessment. The program is detailed below and in the Quality Assurance Project Plan for the Upper Sugar Creek Watershed Management Plan approved on January 7, 2022. Sites sampled through this program are displayed in Figure 29. Sample sites were selected based on watershed drainage and correspond with sites sampled by IDEM in the past. In total, 16 sample sites were selected. Sites represent the outlets of 14 12-digit HUCs, a side tributary (Site 7) to allow the drainage for that basin to be cumulative, and the outlet of the Browns Wonder-Sugar Creek Watershed (Site 2). The monthly sampling regimen was enacted to create a baseline of water quality data.

Stream Flow

Stream flow was calculated by scaling stream flow measured at the U.S. Geological Survey (USGS) stream gages to subwatershed drainage area during high flow events. The Sugar Creek USGS gage at

Crawfordsville (USGS 03339500) was used for tributary stream sites, while the Prairie Creek at Lebanon (USGS 03339280) was used to scale flow for the outlet of Sugar Creek.

Field and Laboratory Chemistry Parameters

The Upper Sugar Creek Watershed Project established sixteen chemistry monitoring stations as part of the monitoring program. Dissolved oxygen, temperature, pH, turbidity, conductivity, nitrate-nitrogen, total phosphorus, E. coli and total suspended solids were measured monthly at the sampling stations. Sampling occurred from January 2022 through December 2022. Appendix C details the parameters measured. Site 10 was either dry or frozen from August to December 2022.

Biological Community and Habitat

The physical habitat at each of the 16 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. Macroinvertebrate and fish communities were assessed using the Index of Biotic Integrity (IBI) with all 16 sites assessed from July to August 2022.

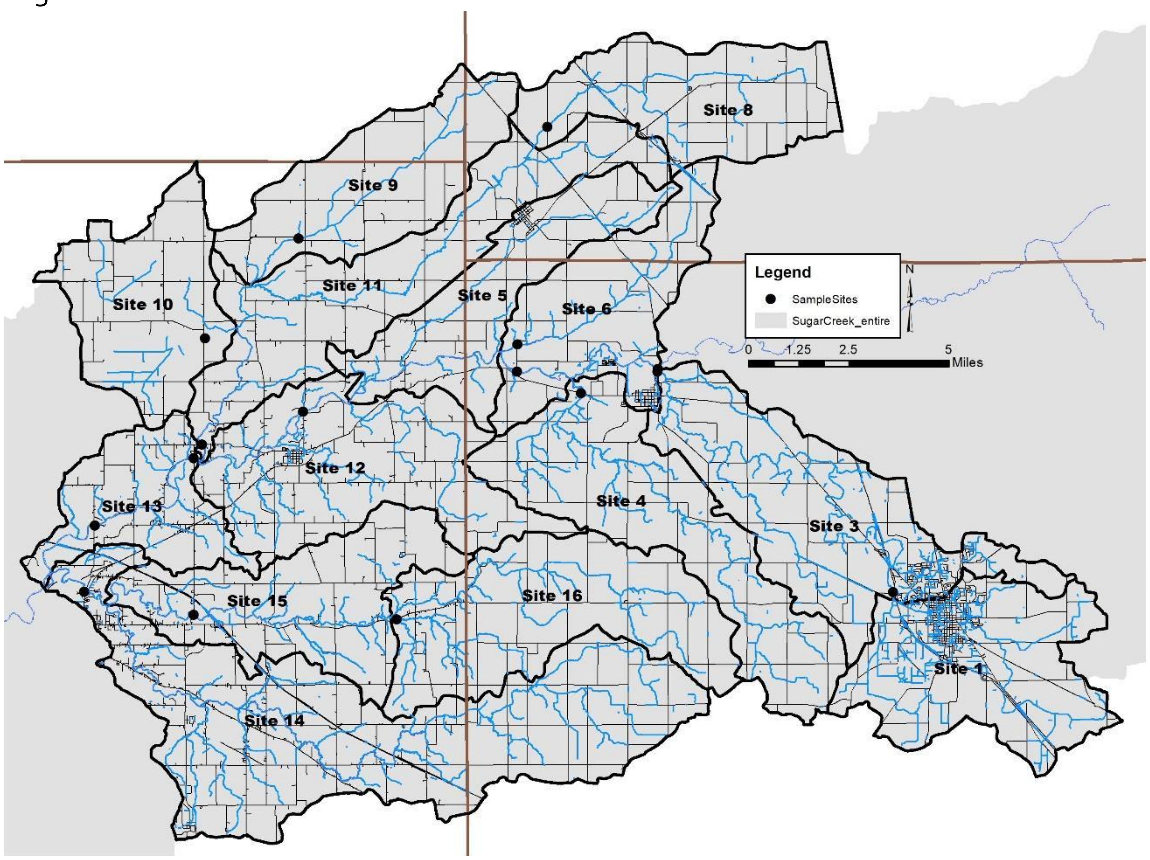


Figure 29. Sites sampled as part of the Upper Sugar Creek Watershed Management Plan.

3.3.2 Field Chemistry Results

Figure 2 through Figure 35 display results for non-nutrient field chemistry data collected monthly at the sixteen sample sites. At each of the stream sites, a multi parameter probe was deployed during each sampling event. The probe collects data for temperature, dissolved oxygen, specific conductivity, and pH. All field chemistry results are contained in Appendix C.

Temperature

Figure 2 illustrates the monthly temperature measurements in the watershed streams. 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 between -2.7 to 26.4 °C in all streams. The highest temperatures occurred during the June, July and August assessments depending on riparian cover and stream depth present at each location.

Dissolved Oxygen

Dissolved oxygen concentrations also display seasonal changes like those observed for temperature. However, as shown in Figure 31 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 lower in summer. All streams display variation in dissolved oxygen concentration due to individual conditions present within each system. The lowest dissolved oxygen concentration occurred at Site 14 during July 2022, with a concentration level of 3.9. The highest dissolved oxygen concentration occurred at Site 16 during March 2022, with a concentration level of 18. In total, 1.1% of samples (2 of 184 samples) measured above or below the lower and higher dissolved oxygen state standard (4 m/g/L and 12 m/g/L).

pH

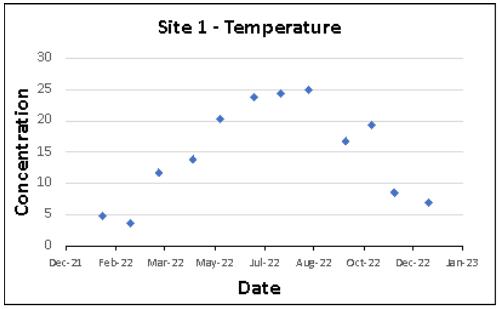
Throughout the sampling period, pH generally remained in an acceptable range in all watershed streams. No discernible pattern can be found in pH levels in any of the monitored streams and all samples measured with state standards (**Figure 32**).

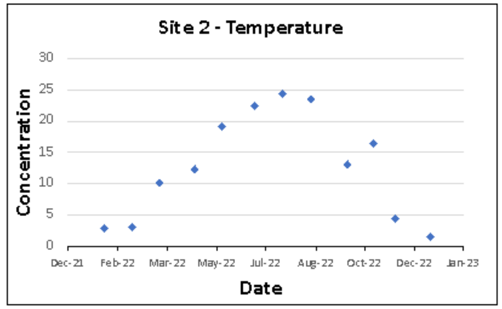
Specific Conductivity

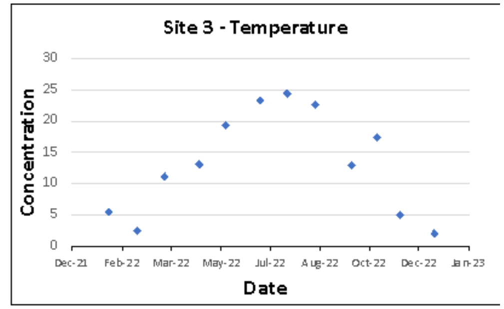
Figure 33 displays conductivity measurements in the watershed streams. Conductivity measurements varied greatly over the sampling period. Conductivity exceeded state standard (1050 mg/L) during several sampling events. In total, 11 out 184 samples (6%) exceeded the conductivity target. Exceedances occurred at Site 1 (six events), Site 3 (three events), Site 7 (one event) and Site 14 (one event) Conductivity did not exceed state standards at any other sites. Sites that exceed state standards peak between fall and early winter.

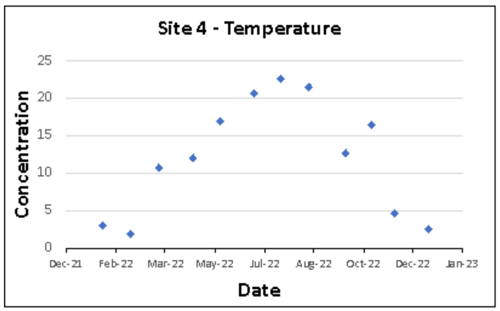
Turbidity

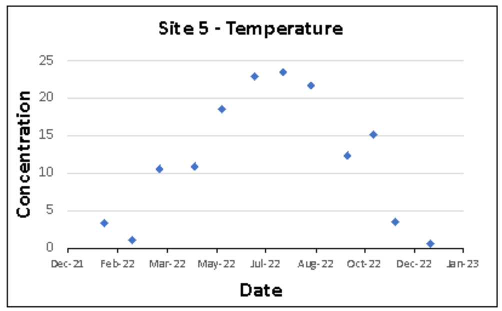
Figure 34 displays conductivity measurements in the watershed streams. Turbidity measurements varied greatly over the sampling period. Turbidity exceeded target levels at all sites during the February and March 2022 sampling event. In total, 55 of 184 samples (30%) exceeded turbidity targets of 5.7 NTU during the sampling period. Most exceedances occurred during the spring storm events with nearly all sites exceeded water quality targets in April and May 2022.

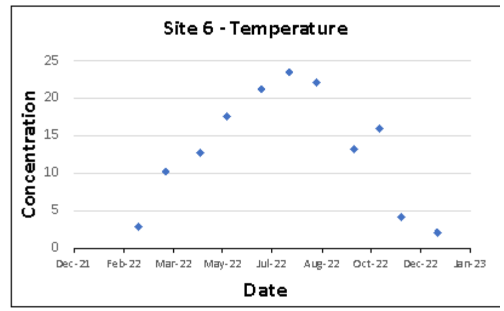

Site 1 - Temperature
Concentration
0 5 10 15 20 25 30
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date

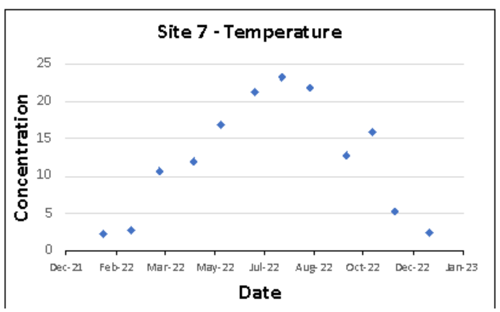

Site 2 - Temperature
Concentration
0 5 10 15 20 25 30
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date

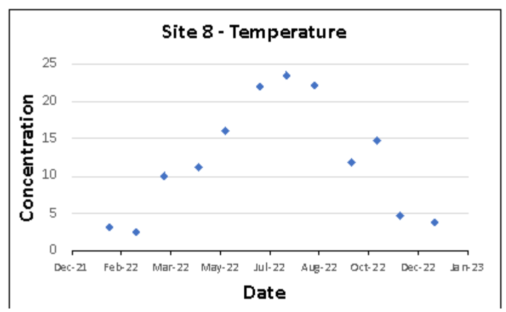

Site 3 - Temperature
Concentration
0 5 10 15 20 25 30
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date


Site 4 - Temperature
Concentration
0 5 10 15 20 25
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date


Site 5 - Temperature
Concentration
0 5 10 15 20 25
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date


Site 6 - Temperature
Concentration
0 5 10 15 20 25
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date


Site 7 - Temperature
Concentration
0 5 10 15 20 25
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date


Site 8 - Temperature
Concentration
0 5 10 15 20 25
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date

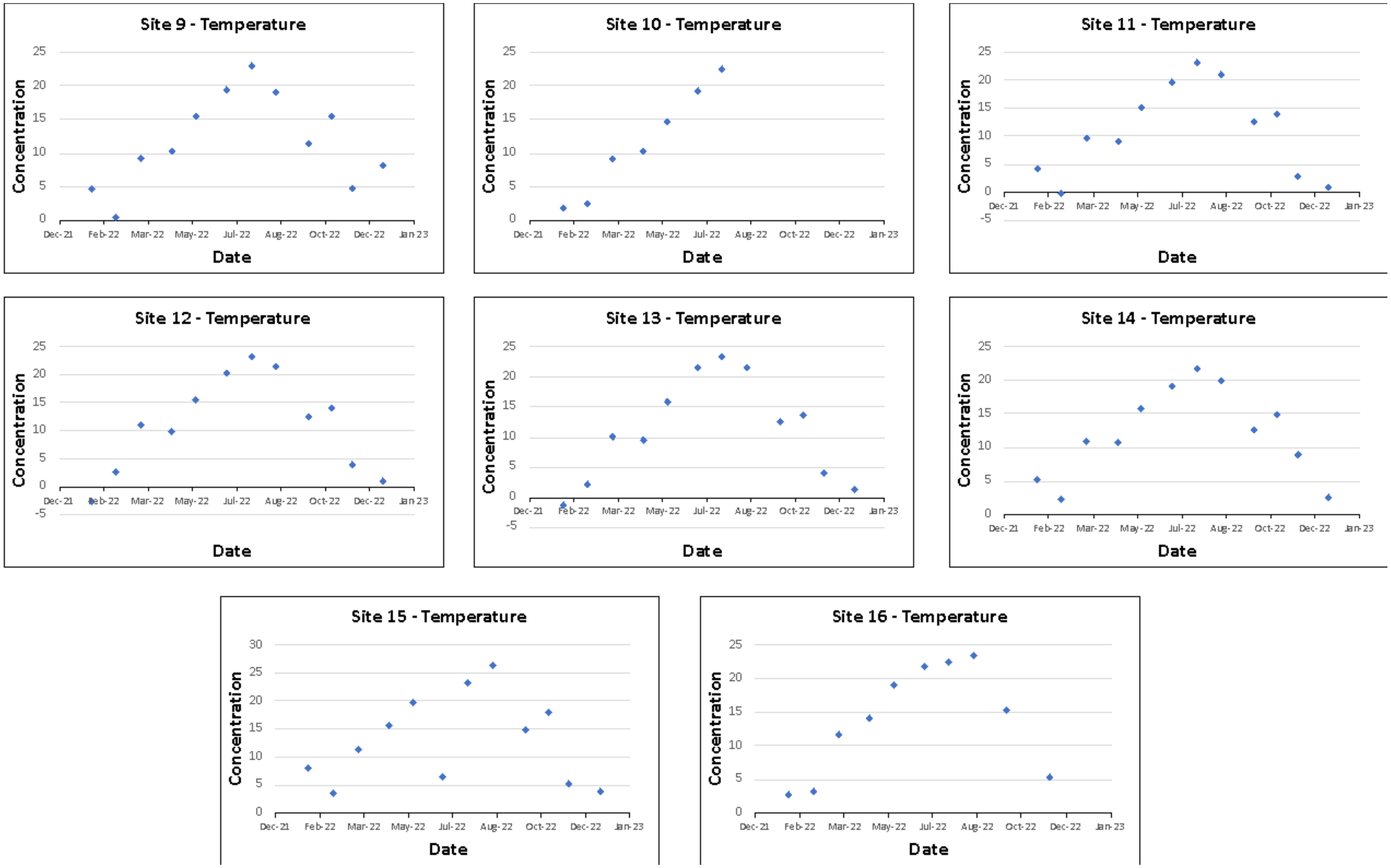
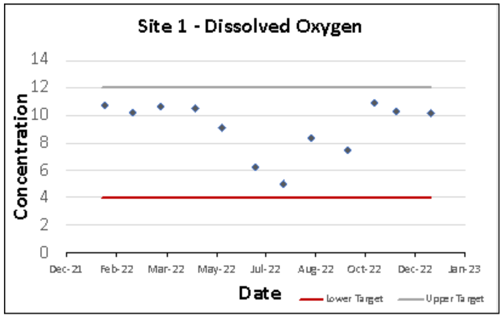
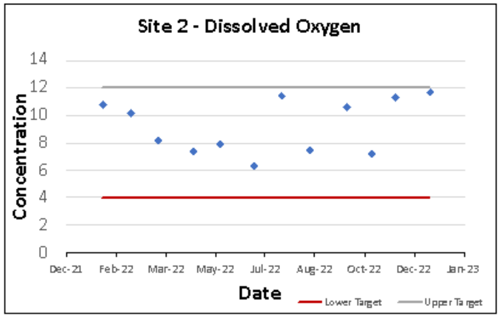
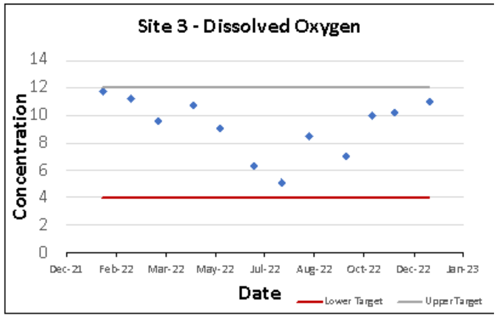
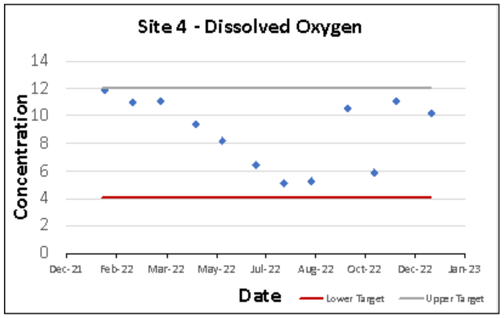


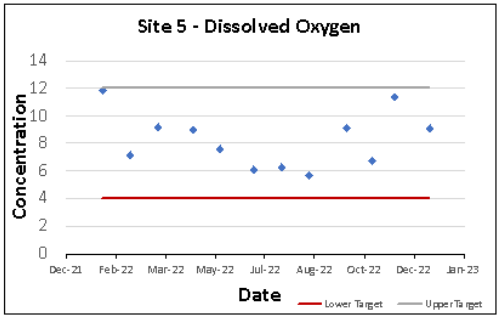
Figure 30. Temperature measurements in Upper Sugar Creek Watershed samples sites from January 2022-December 2022. Note differences in scale along the concentration (y) axis.

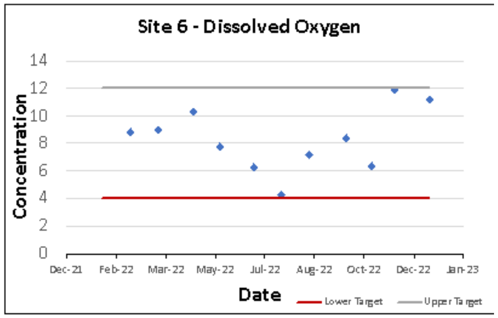

Site 1 - Dissolved Oxygen
Concentration
Date
Lower Target
Upper Target

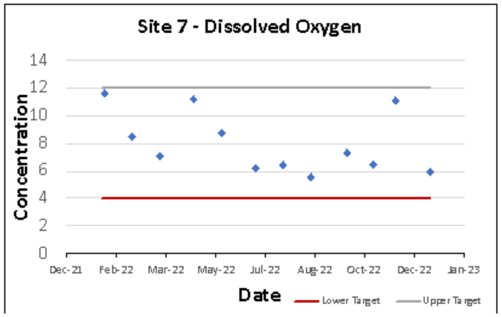

Site 2 - Dissolved Oxygen
Concentration
Date
Lower Target
Upper Target

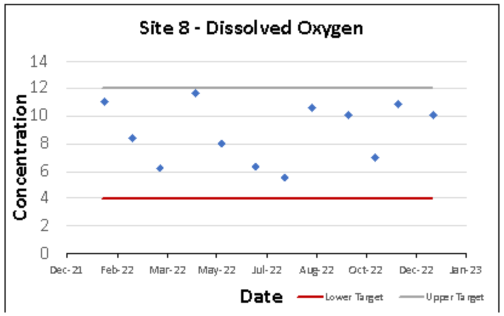

Site 3 - Dissolved Oxygen
Concentration
Date
Lower Target
Upper Target


Site 4 - Dissolved Oxygen
Concentration
Date
Lower Target
Upper Target


Site 5 - Dissolved Oxygen
Concentration
Date
Lower Target
Upper Target


Site 6 - Dissolved Oxygen
Concentration
Date
Lower Target
Upper Target


Site 7 - Dissolved Oxygen
Concentration
Date
Lower Target
Upper Target


Site 8 - Dissolved Oxygen
Concentration
Date
Lower Target
Upper Target

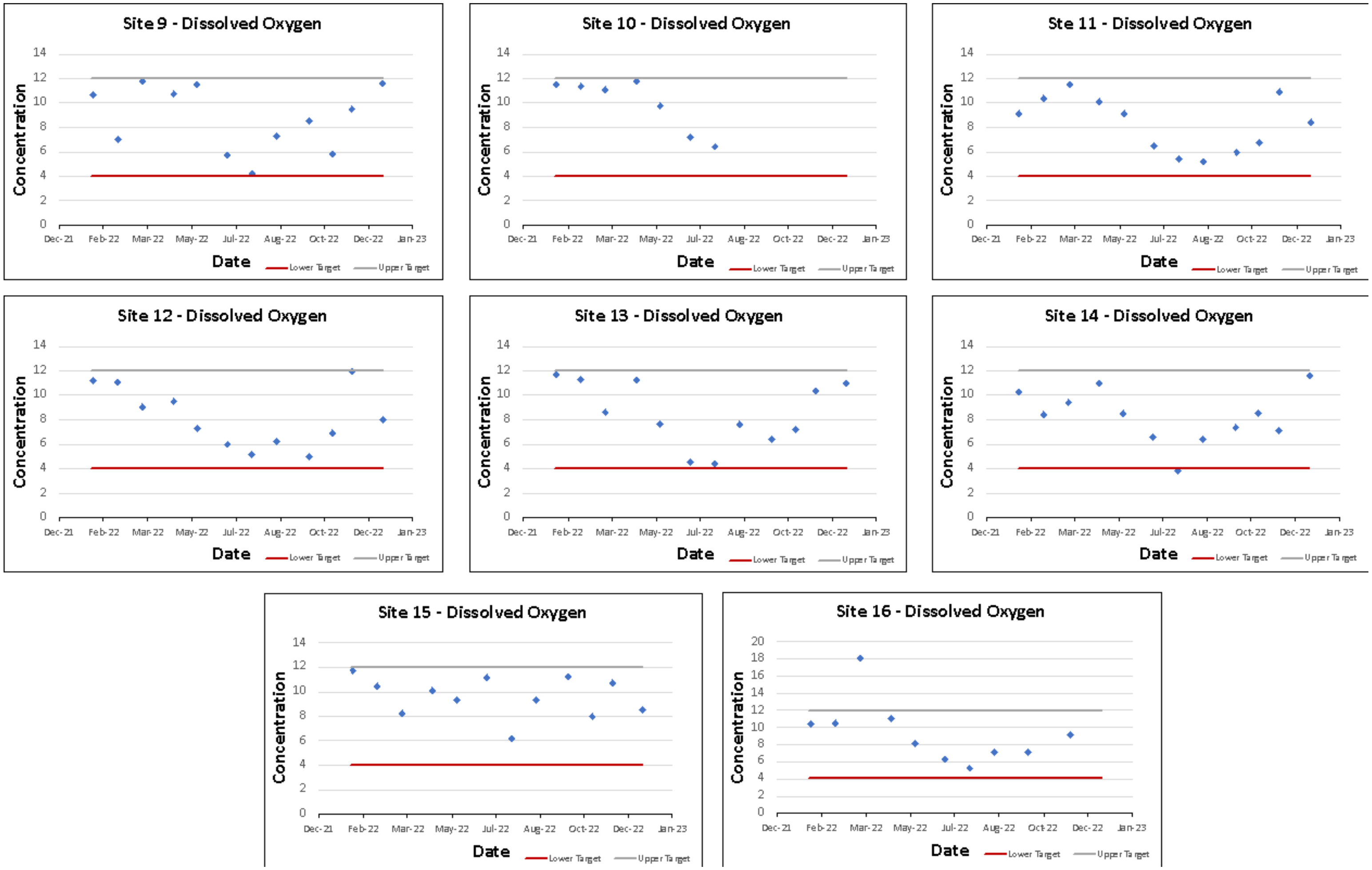
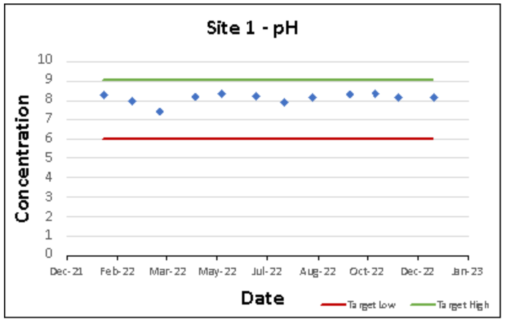
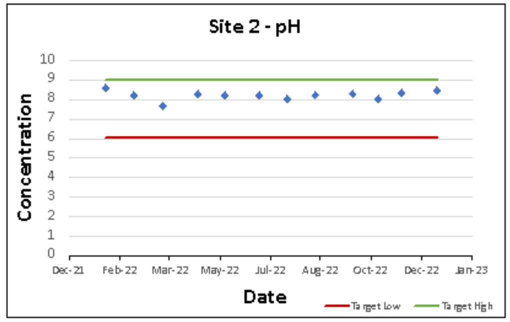
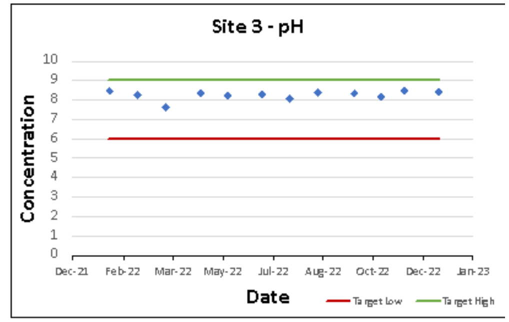
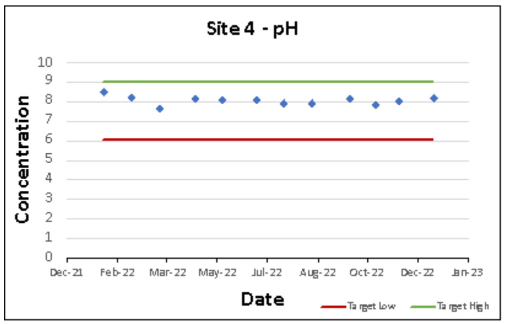


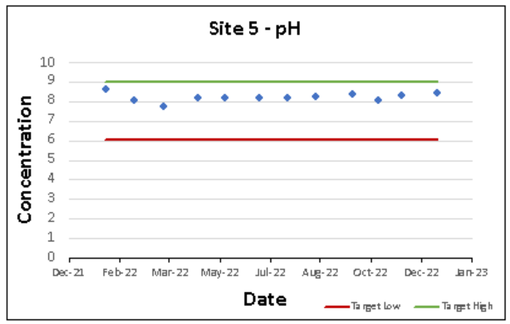
Figure 31. Dissolved oxygen measurements in Upper Sugar Creek Watershed samples sites from January 2022-December 2022. Note differences in scale along the concentration (y) axis.

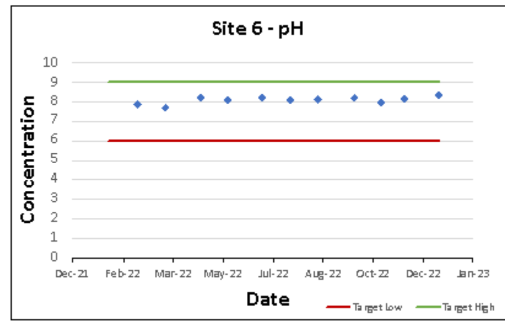

Site 1 - pH
Concentration
Date
Target low
Target High

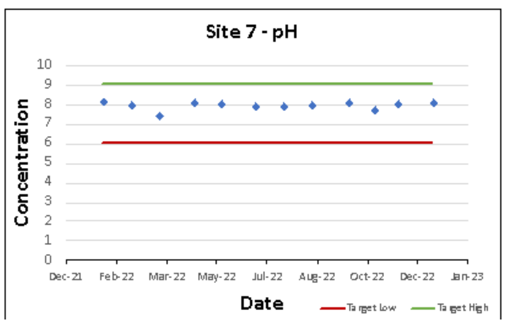

Site 2 - pH
Concentration
Date
Target low
Target High

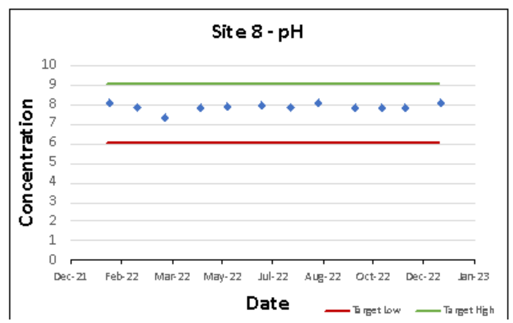

Site 3 - pH
Concentration
Date
Target low
Target High


Site 4 - pH
Concentration
Date
Target low
Target High


Site 5 - pH
Concentration
Date
Target low
Target High


Site 6 - pH
Concentration
Date
Target low
Target High


Site 7 - pH
Concentration
Date
Target low
Target High


Site 8 - pH
Concentration
Date
Target low
Target High

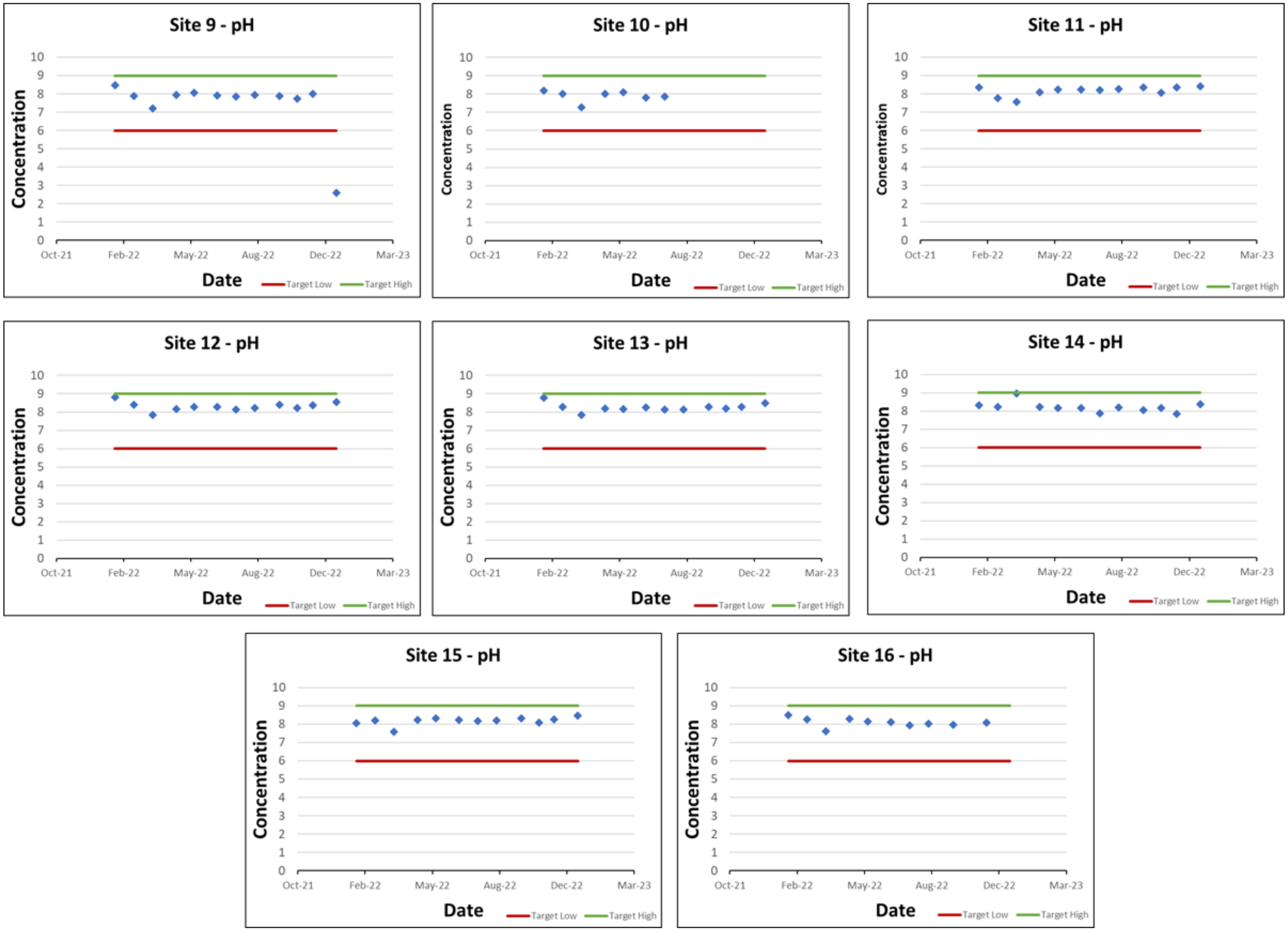
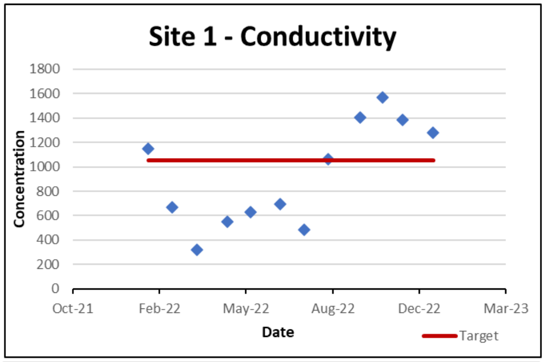
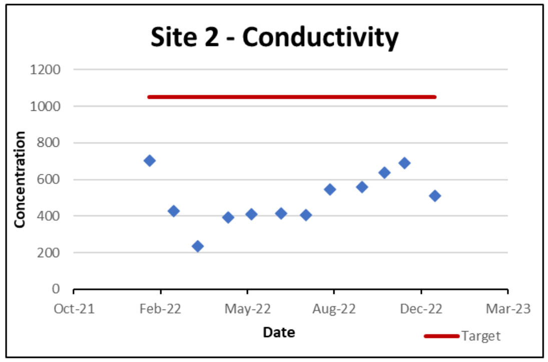
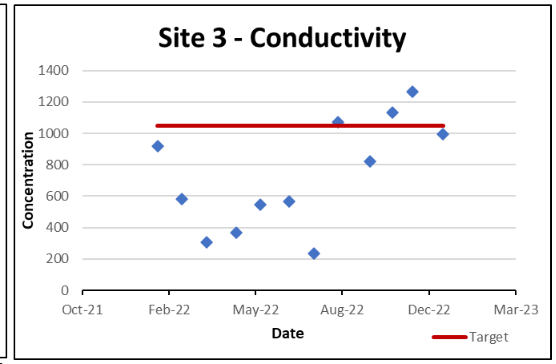
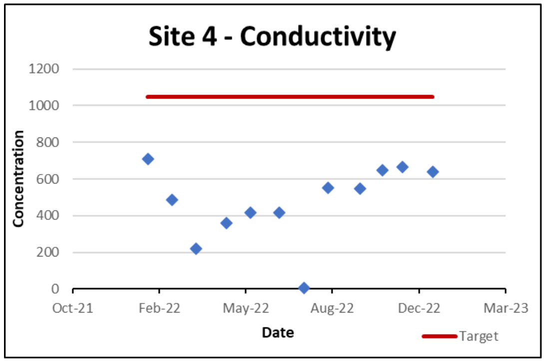


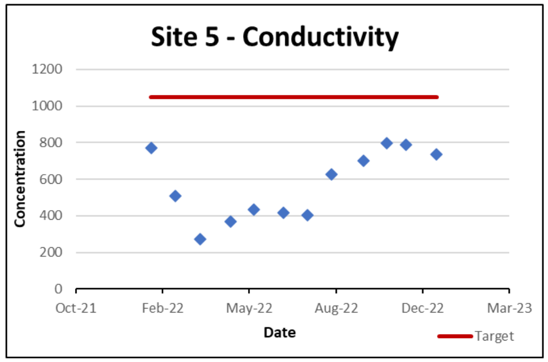
Figure 32. pH measurements in Upper Sugar Creek Watershed samples sites from January 2022-December 2022. Note differences in scale along the concentration (y) axis.

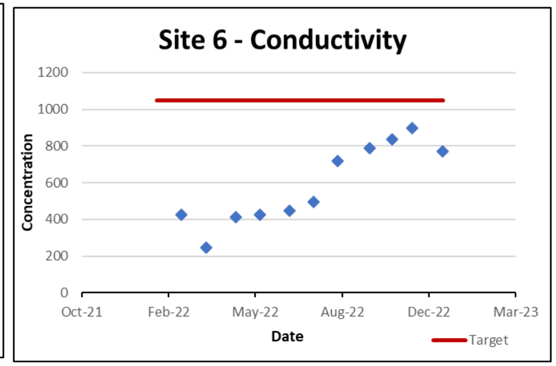

Site 1 - Conductivity
Concentration
Date
Target

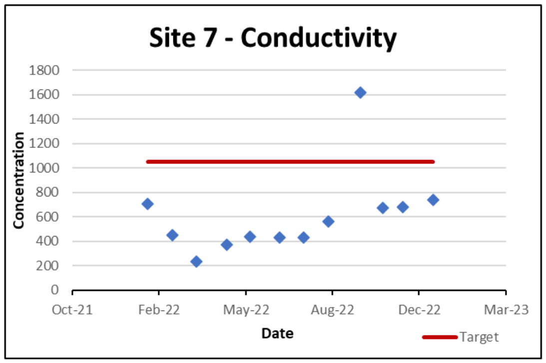

Site 2 - Conductivity
Concentration
Date
Target

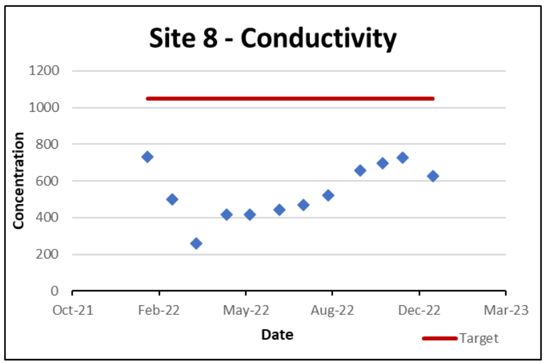

Site 3 - Conductivity
Concentration
Date
Target


Site 4 - Conductivity
Concentration
Date
Target


Site 5 - Conductivity
Concentration
Date
Target


Site 6 - Conductivity
Concentration
Date
Target


Site 7 - Conductivity
Concentration
Date
Target


Site 8 - Conductivity
Concentration
Date
Target

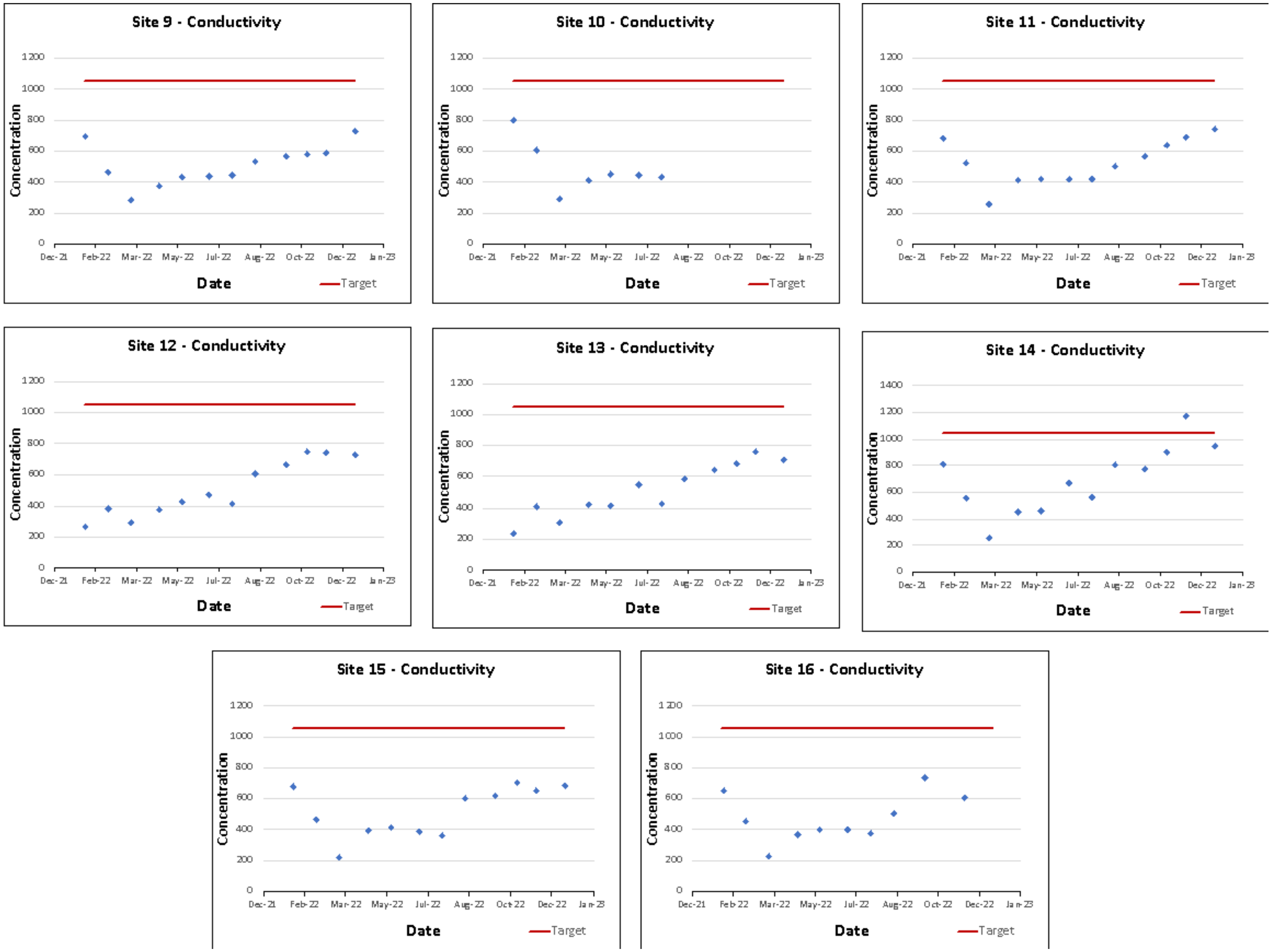
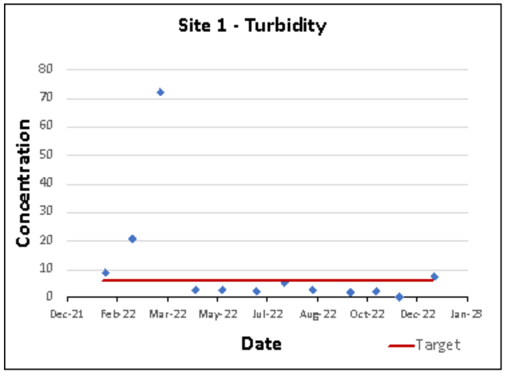
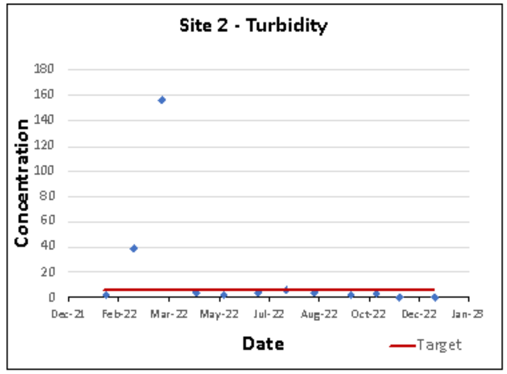
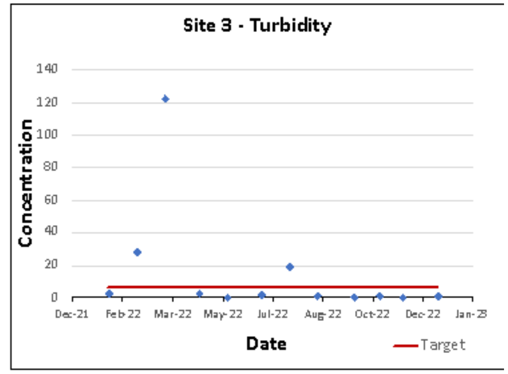
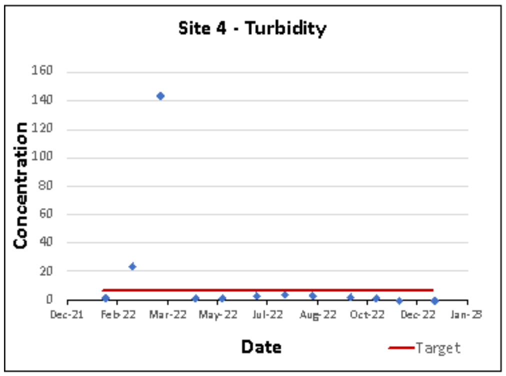


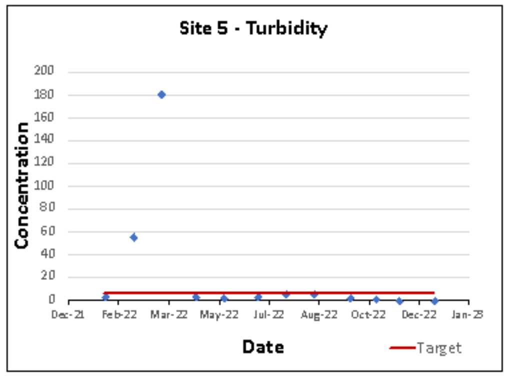
Figure 33. Conductivity measurements in Upper Sugar Creek Watershed samples sites from January 2022-December 2022. Note differences in scale along the concentration (y) axis.

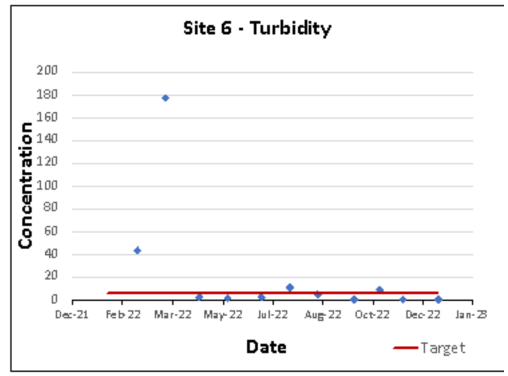

Site 1 - Turbidity
0 10 20 30 40 50 60 70 80
Concentration
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date
Target

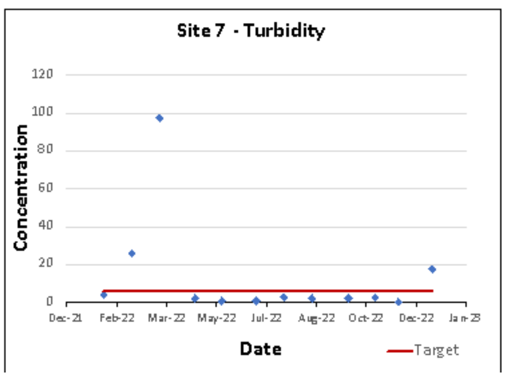

Site 2 - Turbidity
0 20 40 60 80 100 120 140 160 180
Concentration
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date
Target

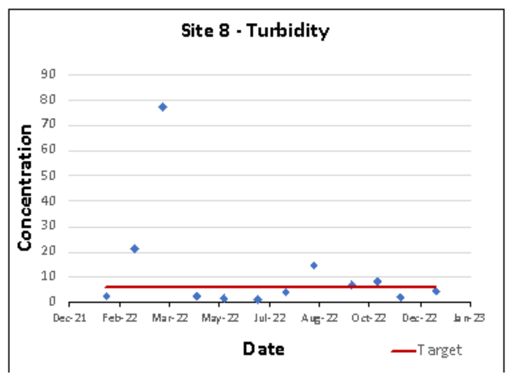

Site 3 - Turbidity
0 20 40 60 80 100 120 140
Concentration
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date
Target


Site 4 - Turbidity
0 20 40 60 80 100 120 140 160
Concentration
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date
Target


Site 5 - Turbidity
0 20 40 60 80 100 120 140 160 180 200
Concentration
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date
Target


Site 6 - Turbidity
0 20 40 60 80 100 120 140 160 180 200
Concentration
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date
Target


Site 7 - Turbidity
0 20 40 60 80 100 120
Concentration
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date
Target


Site 8 - Turbidity
0 10 20 30 40 50 60 70 80 90
Concentration
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date
Target

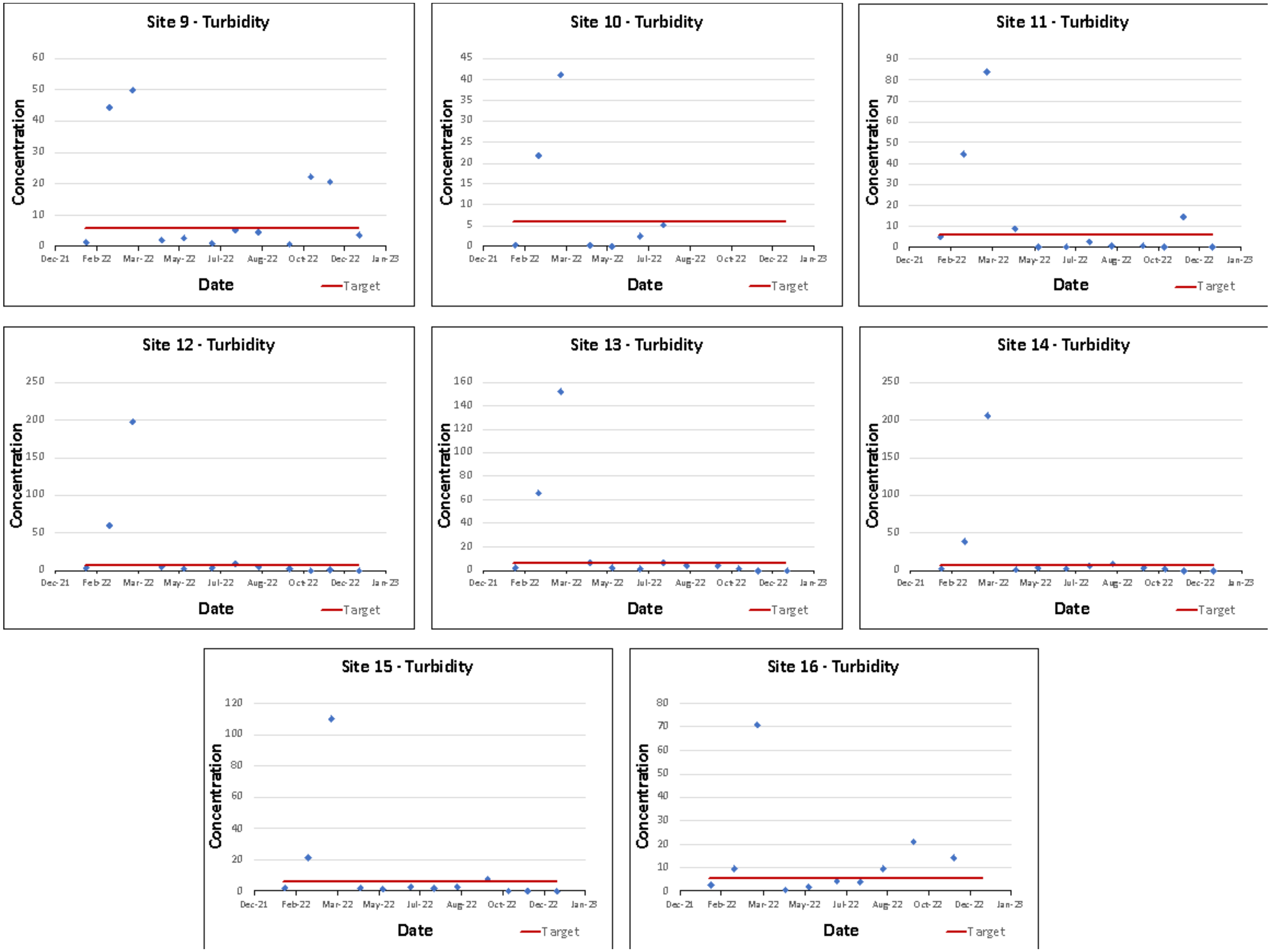


Figure 34. Turbidity measurements in Upper Sugar Creek Watershed samples sites from January 2022-December 2022. Note differences in scale along the concentration (y) axis.

3.3.3 Water Chemistry Results

Figure 35 to Figure 38 display results for nitrate-nitrogen, total phosphorus, total suspended solids, and *E. coli* collected monthly from sixteen locations in the Upper Sugar Creek Watershed. Data are displayed in comparison to target concentration and on load duration curves during the sample period. Appendix C details individual measurements collected throughout the sampling period.

Nitrate-nitrogen

Figure 35 displays nitrate-nitrogen concentrations compared to target levels (1 mg/L). As shown below, nitrate-nitrogen concentrations exceeded target levels in more than 68% of collected samples (126 of 184). Sites 1, 3, 6 and 15 always measured above the nitrate-nitrogen target level. Most nitrate-nitrogen concentrations measured the highest during late winter and early spring, decreasing throughout the summer and increasing again in the fall. Every site except Site 8 averaged nitrate-nitrogen concentrations higher than the median concentration at which biological communities are impaired (1.0 mg/L).

Total Phosphorus

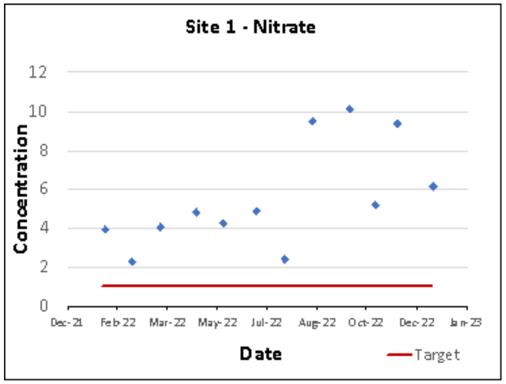
Total phosphorus concentrations exceed target concentrations in 70% of samples (128 of 184 samples; Figure 36**Error! Reference source not found.**). Site 7 had the highest total phosphorus average (0.90 mg/L) while Site 16 had the lowest with an average of 0.23 mg/L. Concentrations measured throughout the watershed measured in excess of the level at which total phosphorus concentrations impair biological communities (0.08 mg/L) with exceedances under all flow conditions. In total, 13 out of 16 sites peaked in the month of March with the remaining sites peaking in a summer month.

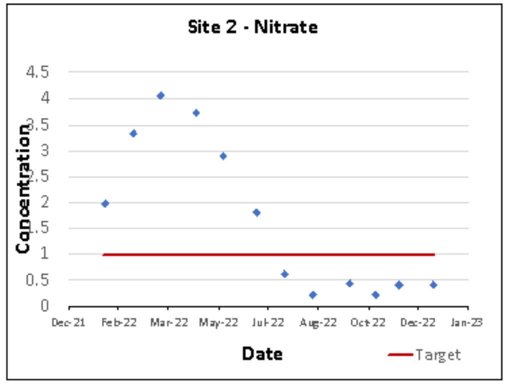
Total Suspended Solids

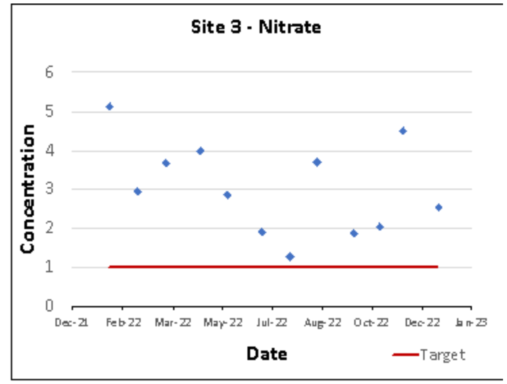
Total suspended solids (TSS) levels measured above target levels (15 mg/L) during high flow events (Figure 37) with 20% of samples exceeding target concentrations (36 of 184 samples). Most sites (15 of 16 sites) possessed the highest TSS concentrations in February or March. Site 8's highest TSS measurement occurred in August. Site 13 contained the highest average concentrations measuring 30.0 mg/L.

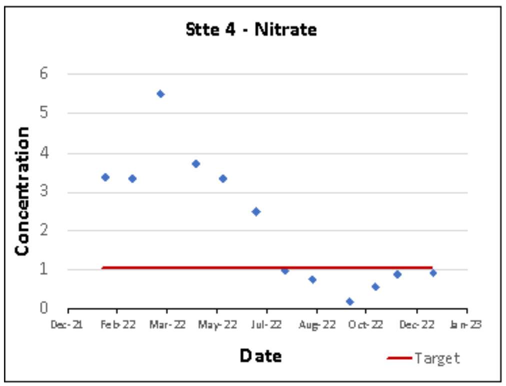
E. coli

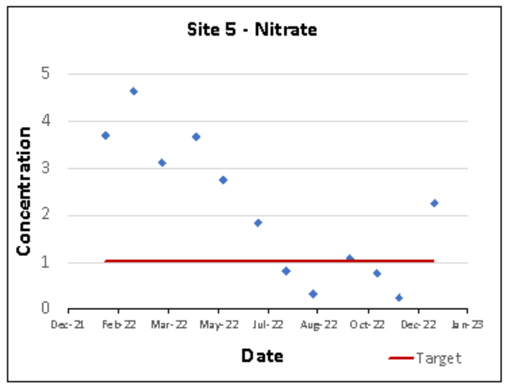
E. coli concentrations observed at Upper Sugar Creek Watershed sites are shown in Figure 38. *E. coli* concentrations exceed state standards in 36% of collected samples (66 of 184 samples). All sites except Site 9 and Site 11 possessed average *E. coli* concentrations in excess of state standards (235 col/100 mL). *E. coli* exceedances at several sites appear to coincide with both high and low flow conditions. Site 1, Site 3 and Site 16 exceeded state standards almost half (43%) of the time samples were collected. Most exceedances occurred between late spring and fall.

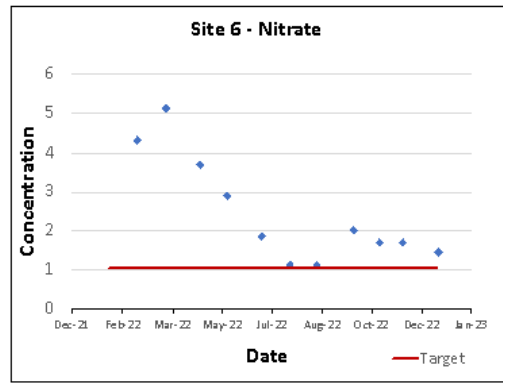

Site 1 - Nitrate
Concentration
Date
Target

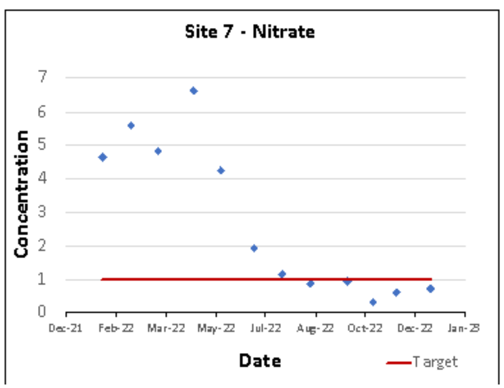

Site 2 - Nitrate
Concentration
Date
Target

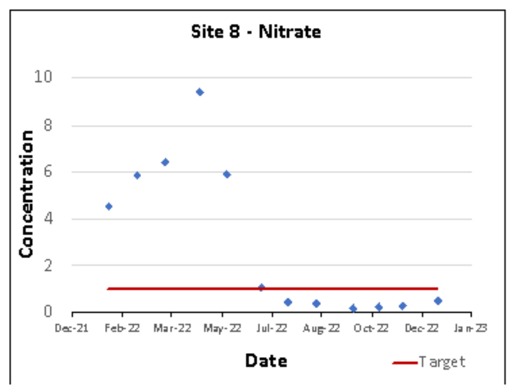

Site 3 - Nitrate
Concentration
Date
Target


Stte 4 - Nitrate
Concentration
Date
Target


Site 5 - Nitrate
Concentration
Date
Target


Site 6 - Nitrate
Concentration
Date
Target


Site 7 - Nitrate
Concentration
Date
Target


Site 8 - Nitrate
Concentration
Date
Target

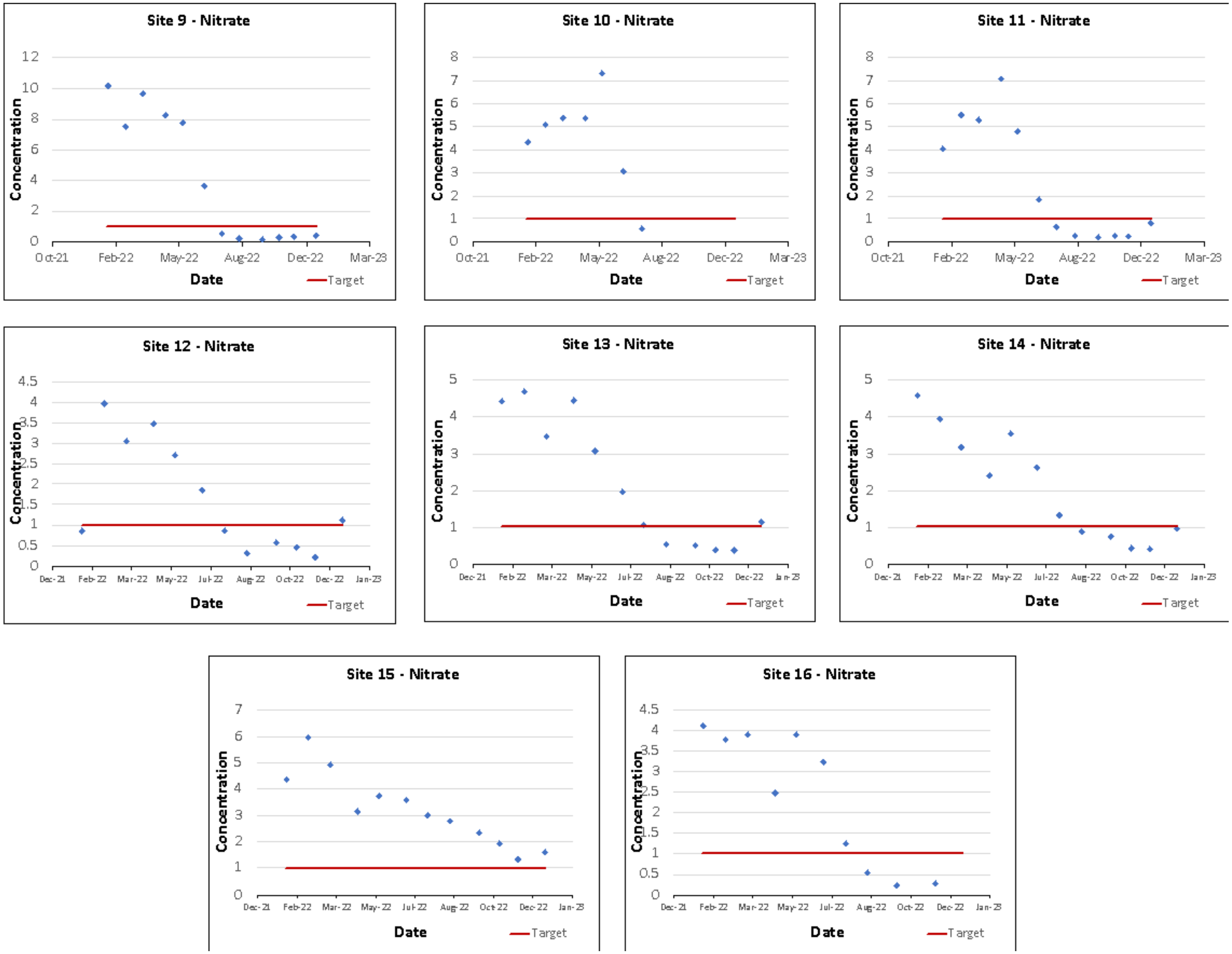
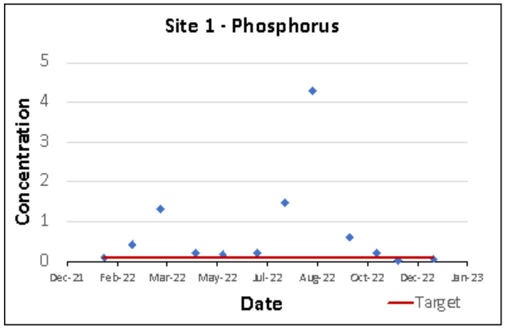
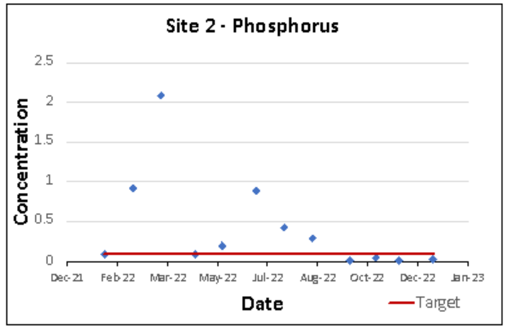
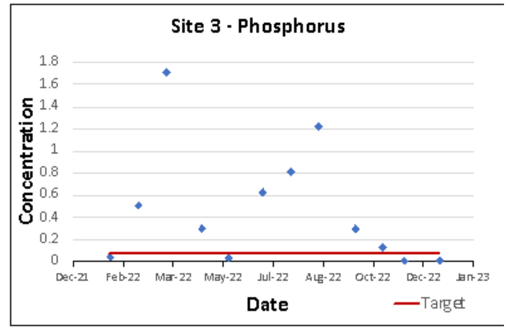
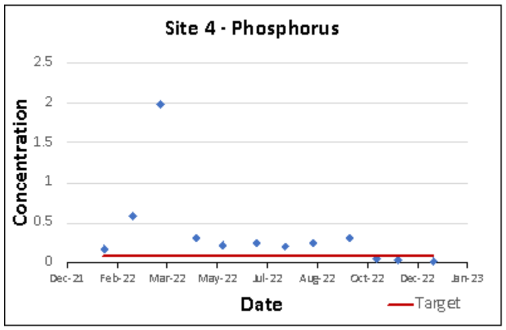


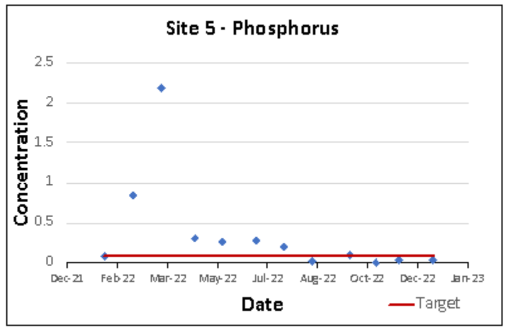
Figure 35. Nitrate-nitrogen concentrations measured in Upper Sugar Creek Watershed samples sites from January 2022-December 2022. Note differences in scale along the concentration (y) axis.

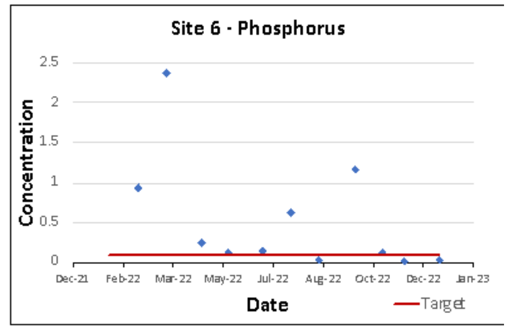

Site 1 - Phosphorus
Concentration
0 1 2 3 4 5
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date
Target

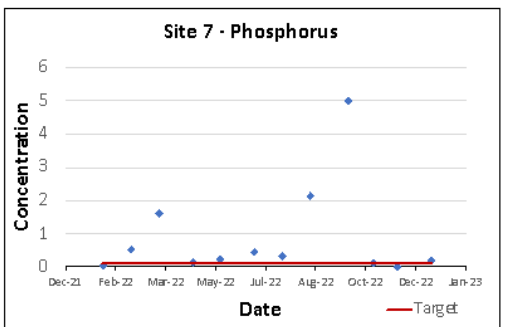

Site 2 - Phosphorus
Concentration
0 0.5 1 1.5 2 2.5
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date
Target

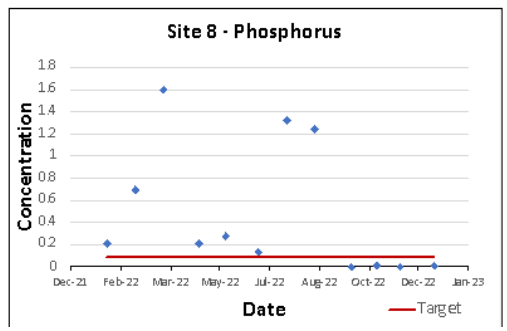

Site 3 - Phosphorus
Concentration
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date
Target


Site 4 - Phosphorus
Concentration
0 0.5 1 1.5 2 2.5
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date
Target


Site 5 - Phosphorus
Concentration
0 0.5 1 1.5 2 2.5
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date
Target


Site 6 - Phosphorus
Concentration
0 0.5 1 1.5 2 2.5
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date
Target


Site 7 - Phosphorus
Concentration
0 1 2 3 4 5 6
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date
Target


Site 8 - Phosphorus
Concentration
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date
Target

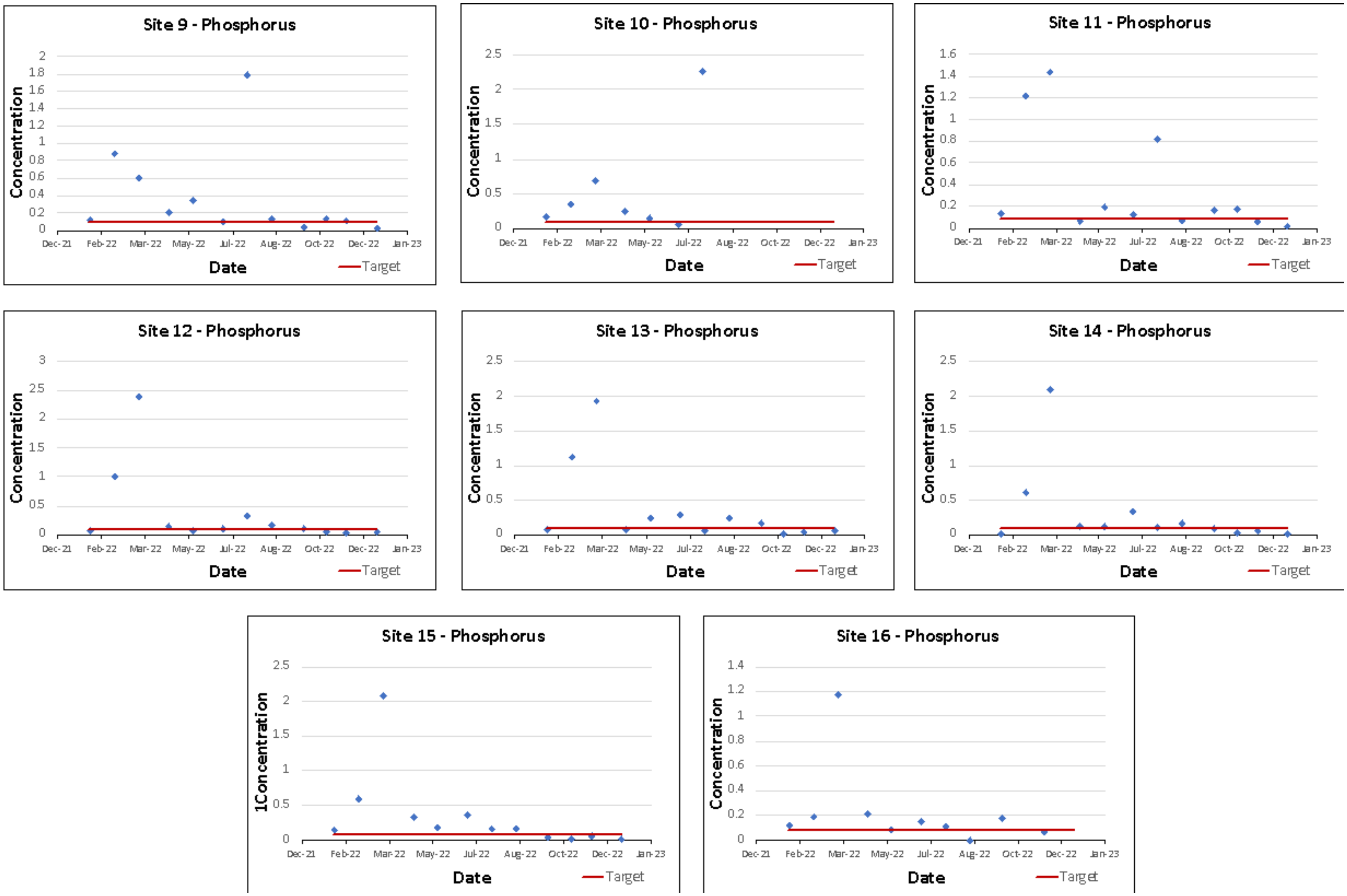
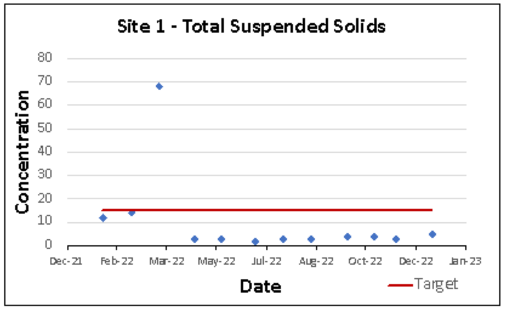
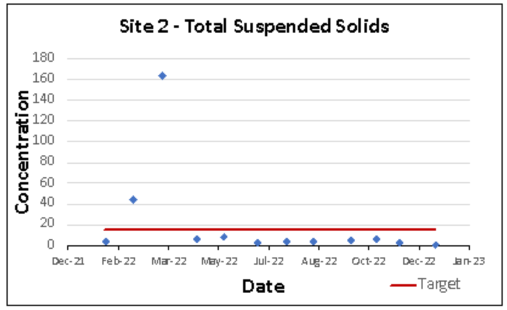
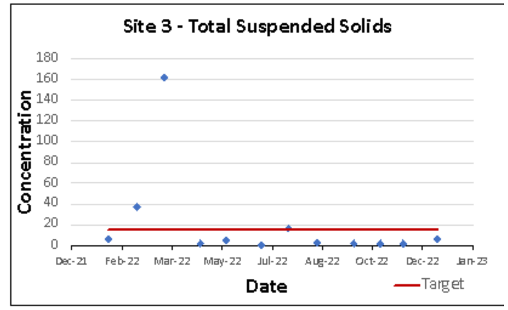
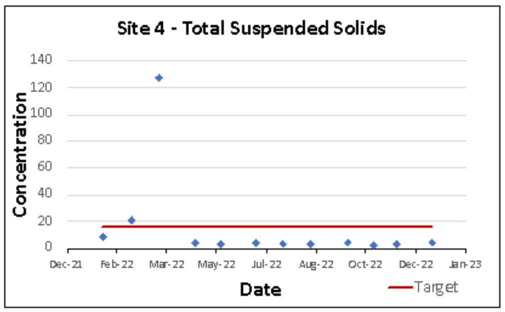


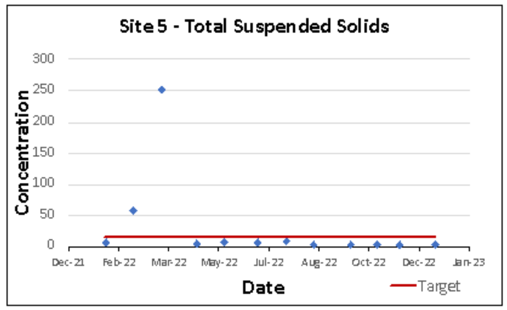
Figure 36. Total phosphorus concentrations measured in Upper Sugar Creek Watershed samples sites from January 2022-December 2022. Note differences in scale along the concentration (y) axis.

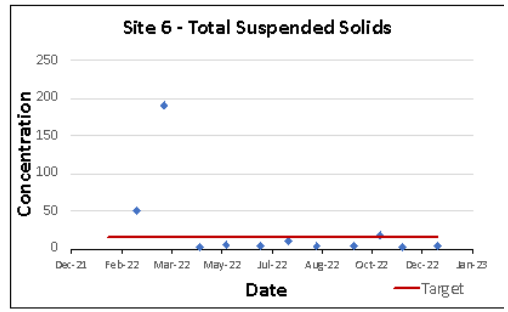

Site 1 - Total Suspended Solids
Concentration
Date
Target

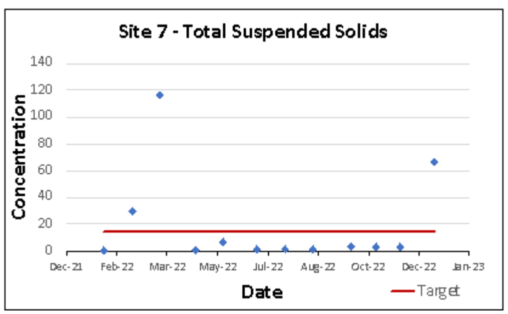

Site 2 - Total Suspended Solids
Concentration
Date
Target

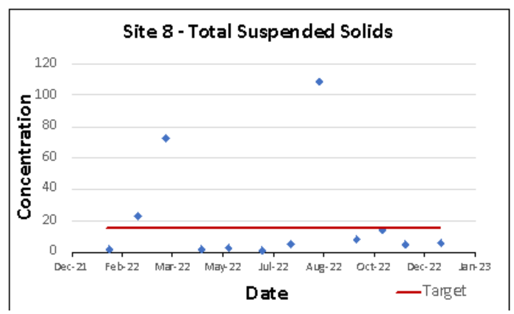

Site 3 - Total Suspended Solids
Concentration
Date
Target


Site 4 - Total Suspended Solids
Concentration
Date
Target


Site 5 - Total Suspended Solids
Concentration
Date
Target


Site 6 - Total Suspended Solids
Concentration
Date
Target


Site 7 - Total Suspended Solids
Concentration
Date
Target


Site 8 - Total Suspended Solids
Concentration
Date
Target

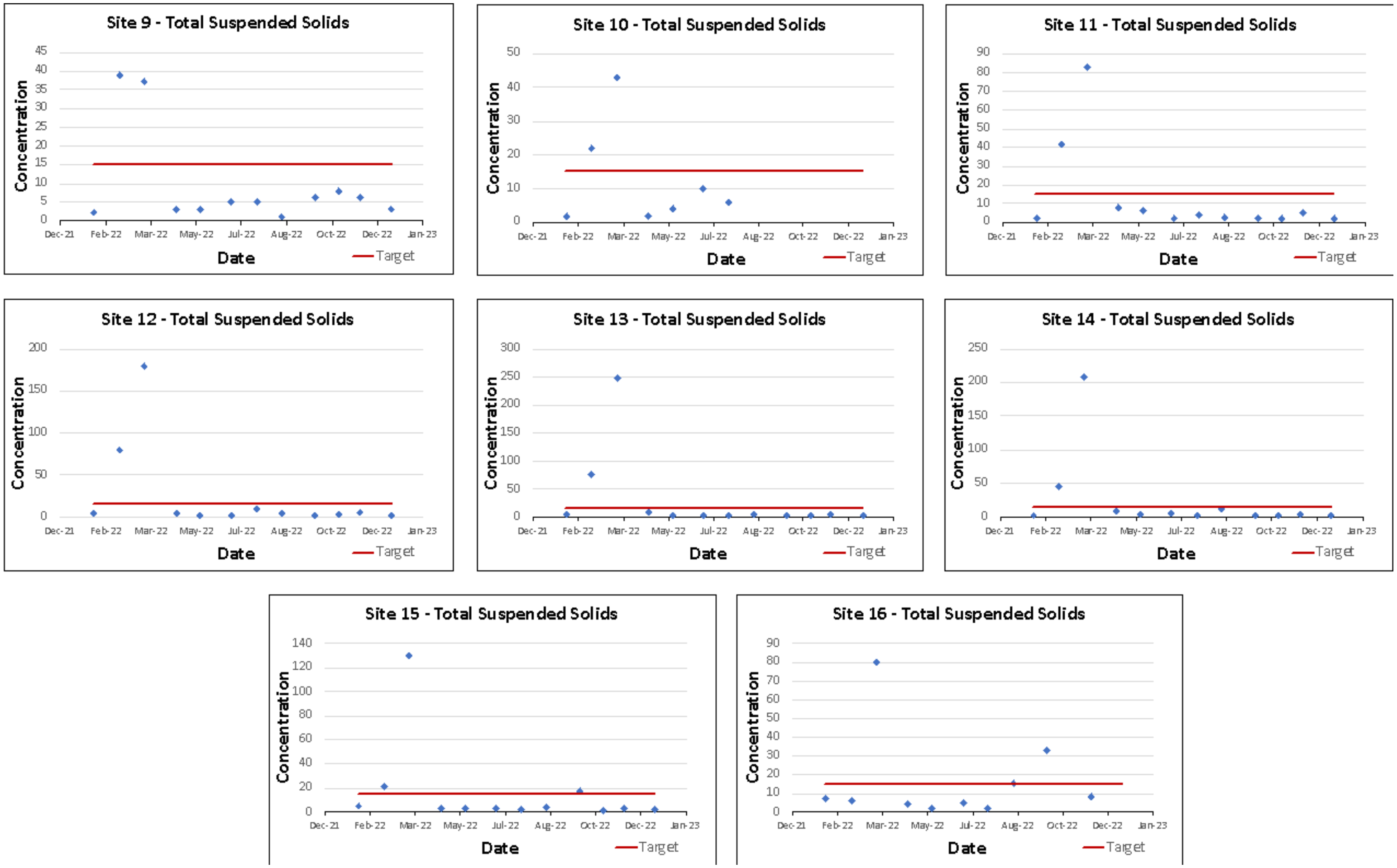
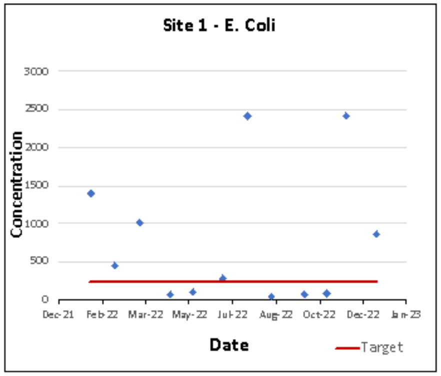
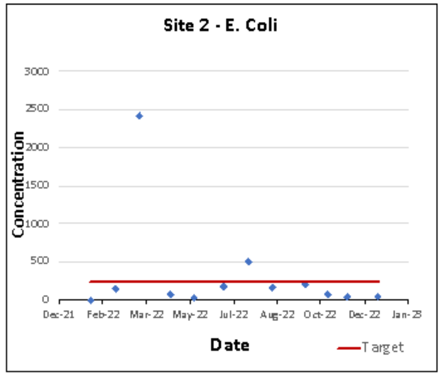
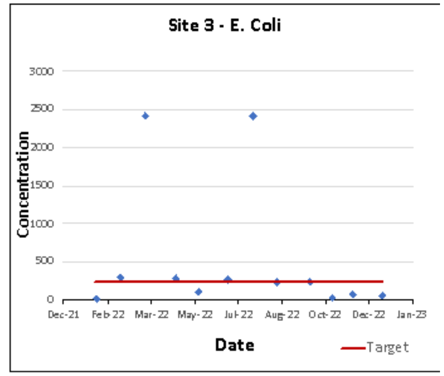
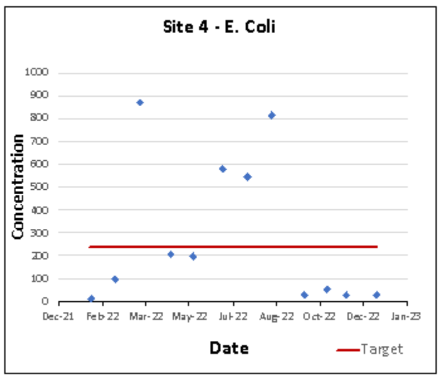


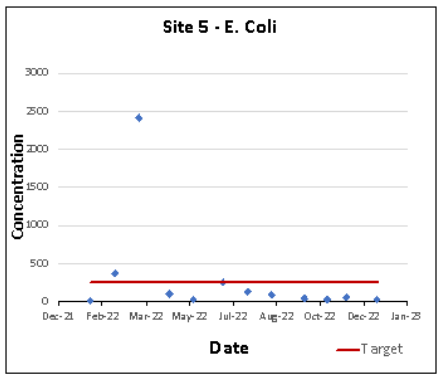
Figure 37. Total suspended solids concentrations measured in Upper Sugar Creek Watershed samples sites from January 2022-December 2022. Note differences in scale along the concentration (y) axis.

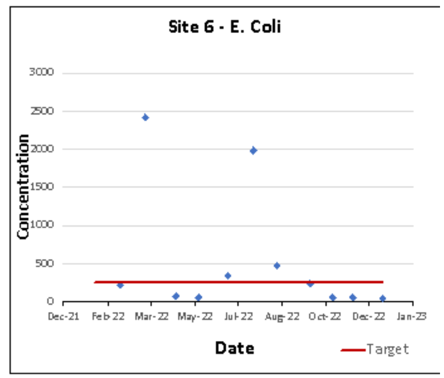

Site 1 - E. Coli
Concentration
3000
2500
2000
1500
1000
500
0
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date
Target

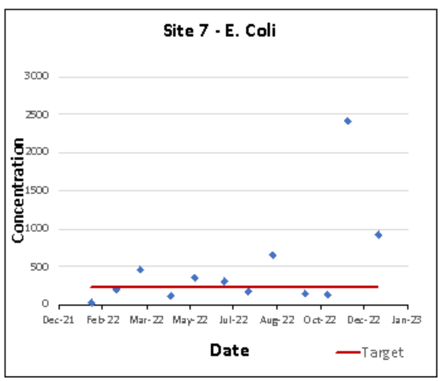

Site 2 - E. Coli
Concentration
3000
2500
2000
1500
1000
500
0
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date
Target

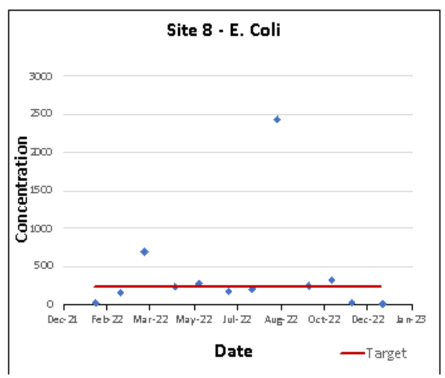

Site 3 - E. Coli
Concentration
3000
2500
2000
1500
1000
500
0
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date
Target


Site 4 - E. Coli
Concentration
1000
900
800
700
600
500
400
300
200
100
0
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date
Target


Site 5 - E. Coli
Concentration
3000
2500
2000
1500
1000
500
0
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date
Target


Site 6 - E. Coli
Concentration
3000
2500
2000
1500
1000
500
0
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date
Target


Site 7 - E. Coli
Concentration
3000
2500
2000
1500
1000
500
0
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date
Target


Site 8 - E. Coli
Concentration
3000
2500
2000
1500
1000
500
0
Dec-21 Feb-22 Mar-22 May-22 Jul-22 Aug-22 Oct-22 Dec-22 Jan-23
Date
Target

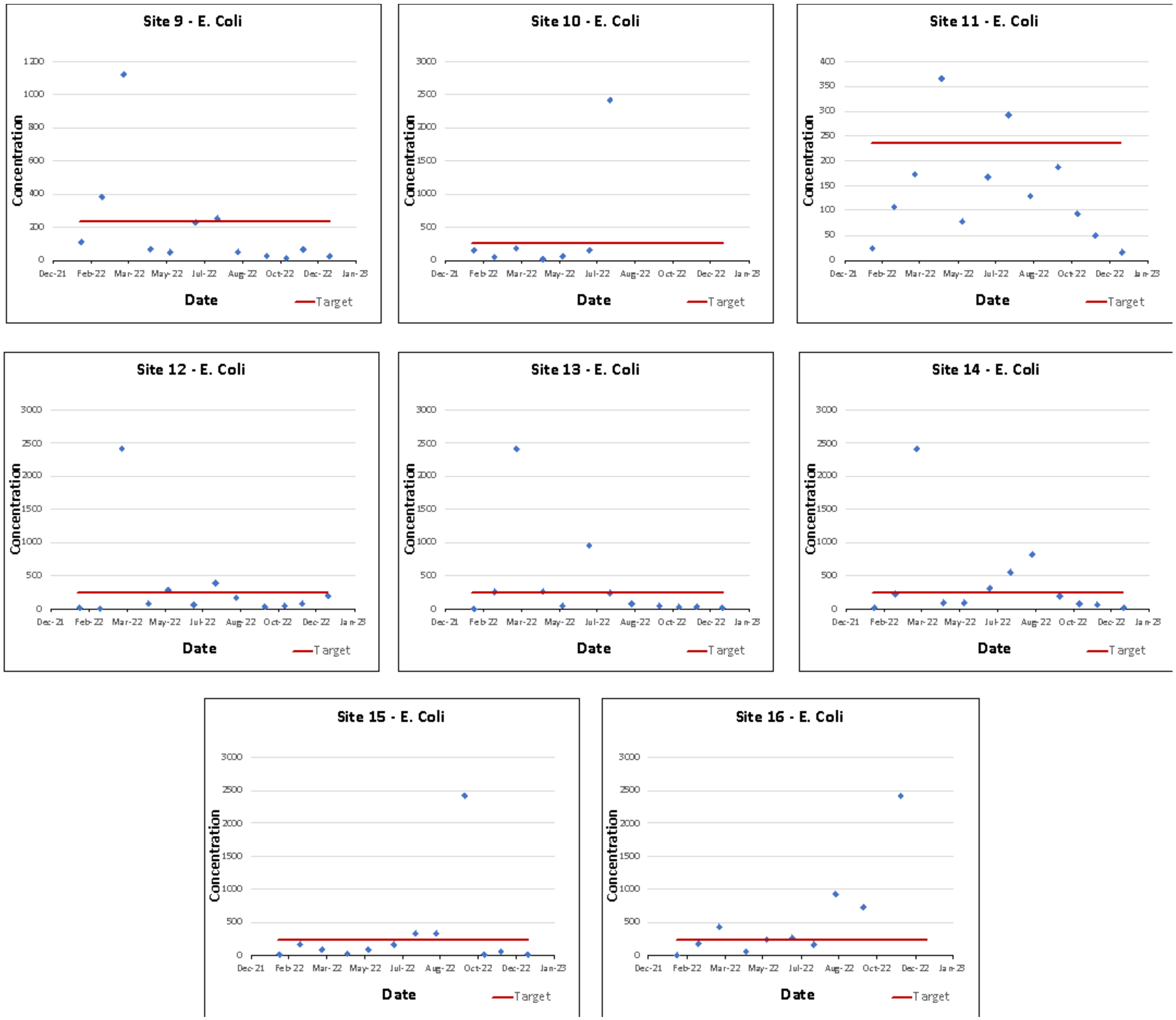


Figure 38. *E. coli* concentrations measured in Upper Sugar Creek Watershed samples sites from January 2022-December 2022. Note differences in scale along the concentration (y) axis.

3.3.4 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 sixteen sample sites during the time of study from January 2022 to December 2022. Data used for the curves were calculated by scaling flow measured at Sugar Creek near Crawfordsville and Prairie Creek near Lebanon. Stream flow measured at the U.S. Geological Survey gauge was scaled to watershed size for each of the sixteen monitoring stations as follow:

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 39 to Figure 42). 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). The time exceeded refers to instream flow conditions. 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), Dry (60-90), and Low (90-100). Exceedances falling in the moist range (10-40) are typically associated with 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-nitrogen Load Duration Curves

Nitrate-nitrogen loads measure higher than target loads at most sites during all conditions. A majority (14 sites) exceeded target load levels half or more than half the time. Sites 1, 3, 6, 10 and 15 nitrate-nitrogen loading rates measured above target levels around 90% of the time. This suggests that a steady stream of nitrate-nitrogen is available within these subwatersheds. Further, nitrate-nitrogen concentrations at all sites are highest during high flow conditions (0% of the time) and lower during low flow conditions (100% of the time). Sites 1, 3, 6, 10 and 15 indicate sources of nitrate-nitrogen to these streams under all flow conditions suggesting that nitrate-nitrogen loads into the streams during both high flow, high runoff conditions and low flow, low runoff conditions. This could mean that there are continuous sources of nitrate-nitrogen at these sites including septic system inputs or nitrogen from manure or other dissolved sources as well as nitrate-nitrogen available under runoff conditions.

Total Phosphorus Load Duration Curves

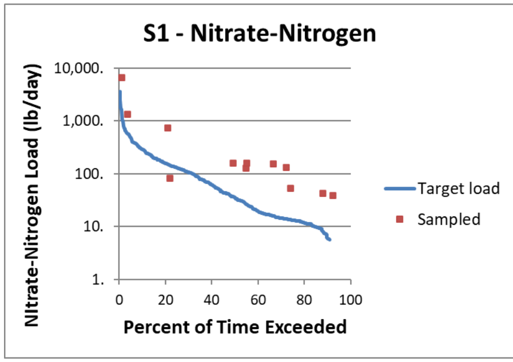
Total phosphorus (TP) levels generally measured above target levels under all flow conditions (Figure 40). All sites exceeded target levels either half or more than half of the time. This is somewhat surprising considering that most total phosphorus enters streams attached to suspended solids. Exceedances of the target levels occurred under storm flow conditions at most sites suggesting erosion or runoff is the cause of these values. All sites exceeded target levels under high flow conditions while about half exceeded under low flow conditions. This suggests that a steady stream of total phosphorus is present in much of the Upper Sugar Creek Watershed and that total phosphorus enters Sugar Creek sites under high flow conditions at all sites.

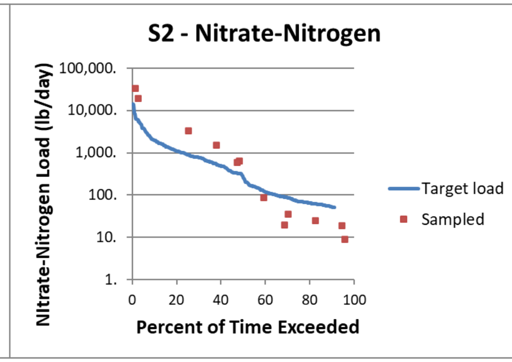
Total Suspended Solids Load Duration Curves

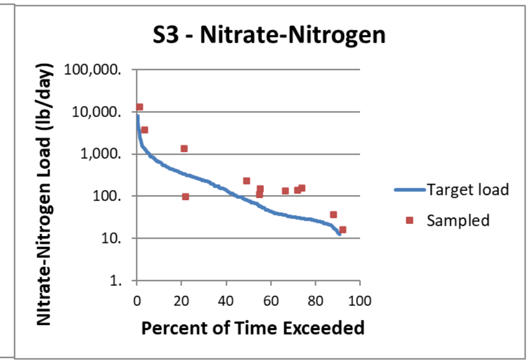
Total suspended solids (TSS) levels generally measured below target levels during most flow events at most stream sites (Figure 41). Most exceedances occurred in the Upper Sugar Creek Watershed during high flow. However, two sites' exceedances (Sites 7and 16) occurred during mid-range or dry conditions. Possible sources of total suspended solids include livestock access or streambank and bed erosion, both of which can provide a continuous source of total suspended solids.

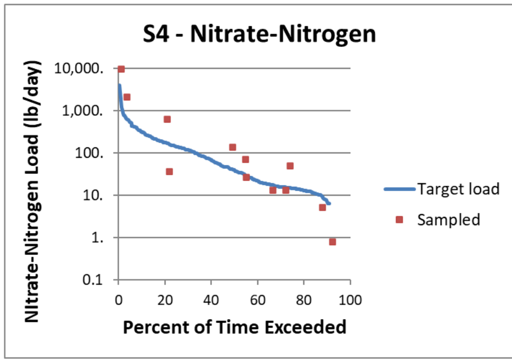
***E. coli* Load Duration Curves**

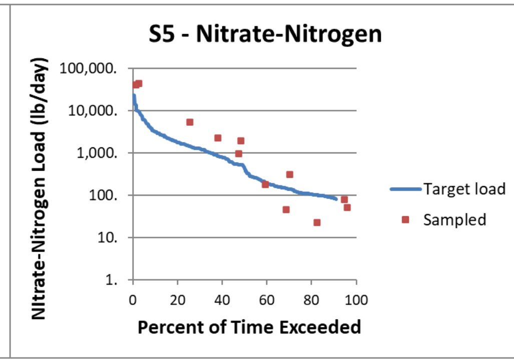
E. coli curves indicate that *E. coli* levels exceed targets during all flow conditions. While more than half of the sites measured at or below target levels, when targets were exceeded, they varied during flow conditions. These data suggest a nearly continuous source of *E. coli* within these streams. More than half of the sites had *E. coli* concentrations measure above target levels during high (0-10) and dry or low conditions (60-100), suggesting there are sources of *E. coli* within these streams under most flow conditions.

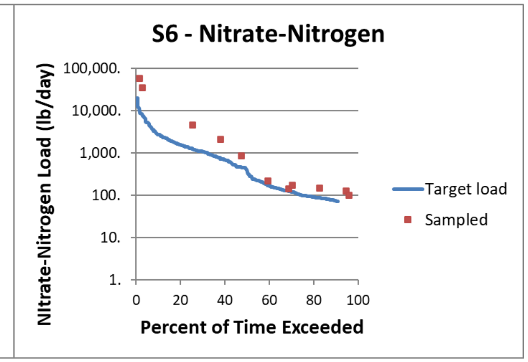

S1 - Nitrate-Nitrogen
Nitrate-Nitrogen Load (lb/day)
10,000.
1,000.
100.
10.
1.
0 20 40 60 80 100
Percent of Time Exceeded
Target load
Sampled

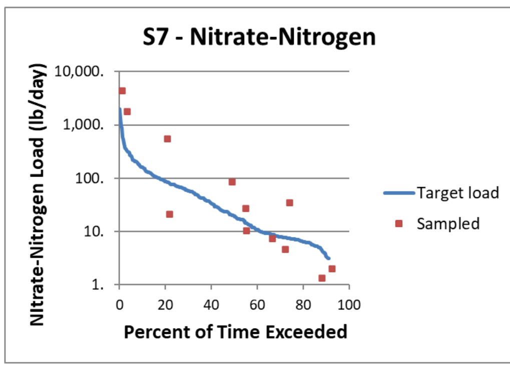

S2 - Nitrate-Nitrogen
Nitrate-Nitrogen Load (lb/day)
100,000.
10,000.
1,000.
100.
10.
1.
0 20 40 60 80 100
Percent of Time Exceeded
Target load
Sampled

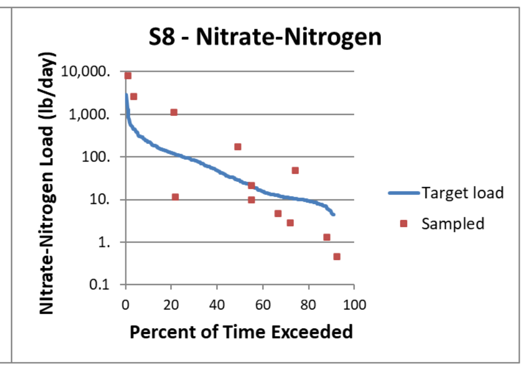

S3 - Nitrate-Nitrogen
Nitrate-Nitrogen Load (lb/day)
100,000.
10,000.
1,000.
100.
10.
1.
0 20 40 60 80 100
Percent of Time Exceeded
Target load
Sampled


S4 - Nitrate-Nitrogen
Nitrate-Nitrogen Load (lb/day)
10,000.
1,000.
100.
10.
1.
0.1
0 20 40 60 80 100
Percent of Time Exceeded
Target load
Sampled


S5 - Nitrate-Nitrogen
Nitrate-Nitrogen Load (lb/day)
100,000.
10,000.
1,000.
100.
10.
1.
0 20 40 60 80 100
Percent of Time Exceeded
Target load
Sampled


S6 - Nitrate-Nitrogen
Nitrate-Nitrogen Load (lb/day)
100,000.
10,000.
1,000.
100.
10.
1.
0 20 40 60 80 100
Percent of Time Exceeded
Target load
Sampled


S7 - Nitrate-Nitrogen
Nitrate-Nitrogen Load (lb/day)
10,000.
1,000.
100.
10.
1.
0 20 40 60 80 100
Percent of Time Exceeded
Target load
Sampled


S8 - Nitrate-Nitrogen
Nitrate-Nitrogen Load (lb/day)
10,000.
1,000.
100.
10.
1.
0.1
0 20 40 60 80 100
Percent of Time Exceeded
Target load
Sampled

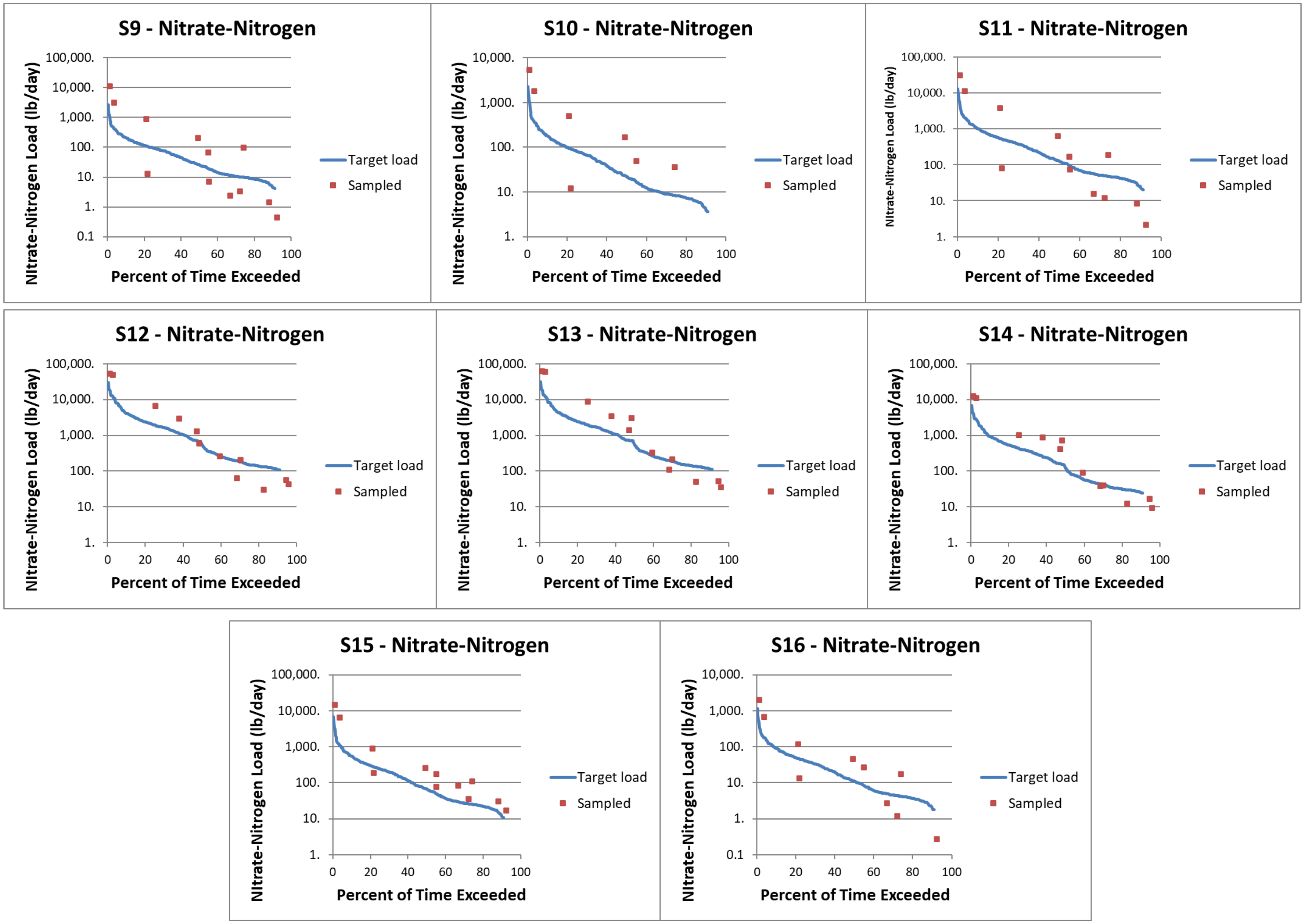
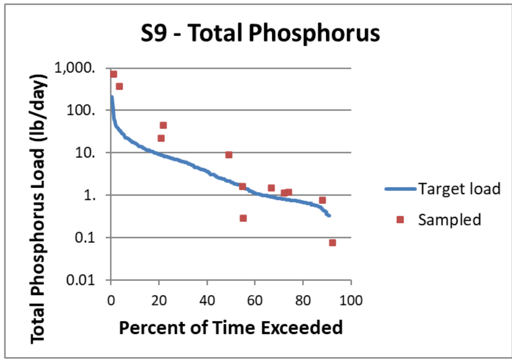
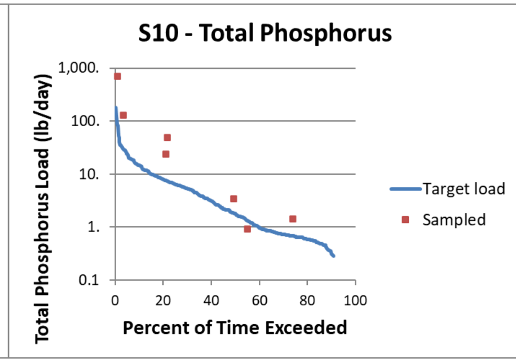
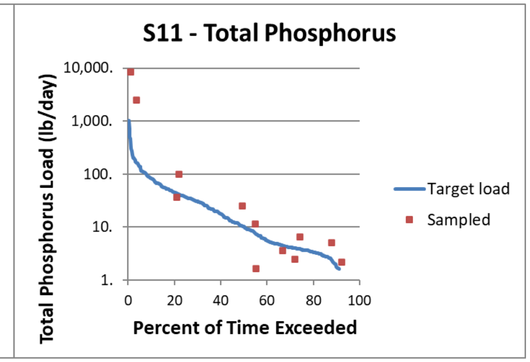
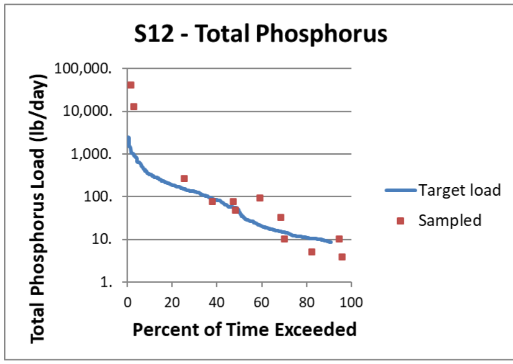


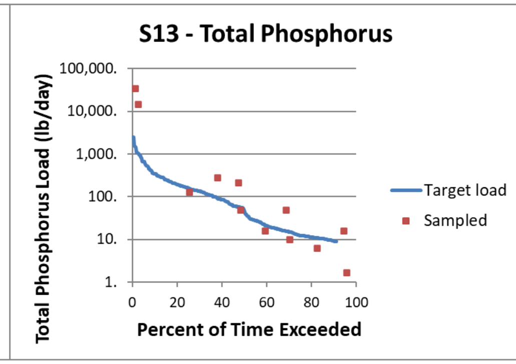
Figure 39. Nitrate-nitrogen load duration curves for Upper Sugar Creek Watershed samples sites from January 2022-December 2022.

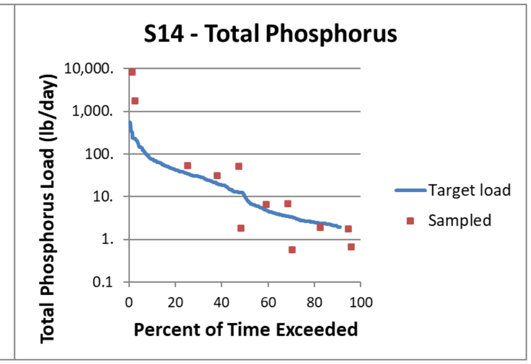

S9 - Total Phosphorus
Total Phosphorus Load (lb/day)
1,000.
100.
10.
1.
0.1
0.01
0
20
40
60
80
100
Percent of Time Exceeded
Target load
Sampled

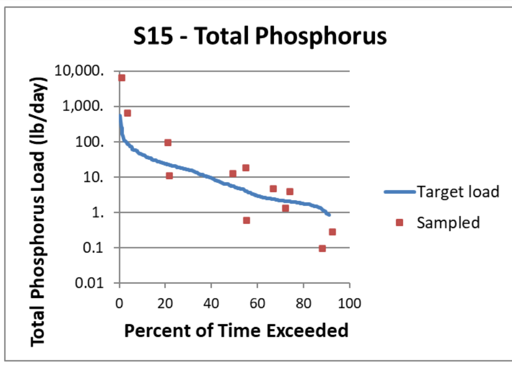

S10 - Total Phosphorus
Total Phosphorus Load (lb/day)
1,000.
100.
10.
1.
0.1
0
20
40
60
80
100
Percent of Time Exceeded
Target load
Sampled

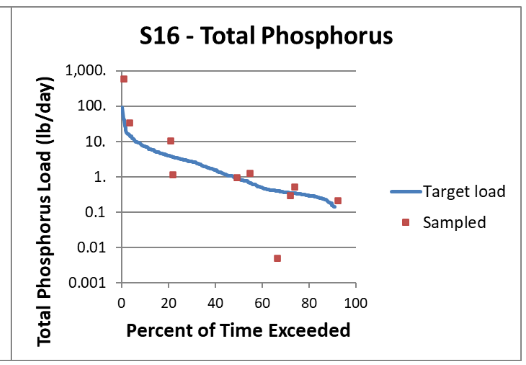

S11 - Total Phosphorus
Total Phosphorus Load (lb/day)
10,000.
1,000.
100.
10.
1.
0
20
40
60
80
100
Percent of Time Exceeded
Target load
Sampled


S12 - Total Phosphorus
Total Phosphorus Load (lb/day)
100,000.
10,000.
1,000.
100.
10.
1.
0
20
40
60
80
100
Percent of Time Exceeded
Target load
Sampled


S13 - Total Phosphorus
Total Phosphorus Load (lb/day)
100,000.
10,000.
1,000.
100.
10.
1.
0
20
40
60
80
100
Percent of Time Exceeded
Target load
Sampled


S14 - Total Phosphorus
Total Phosphorus Load (lb/day)
10,000.
1,000.
100.
10.
1.
0.1
0
20
40
60
80
100
Percent of Time Exceeded
Target load
Sampled


S15 - Total Phosphorus
Total Phosphorus Load (lb/day)
10,000.
1,000.
100.
10.
1.
0.1
0.01
0
20
40
60
80
100
Percent of Time Exceeded
Target load
Sampled


S16 - Total Phosphorus
Total Phosphorus Load (lb/day)
1,000.
100.
10.
1.
0.1
0.01
0.001
0
20
40
60
80
100
Percent of Time Exceeded
Target load
Sampled

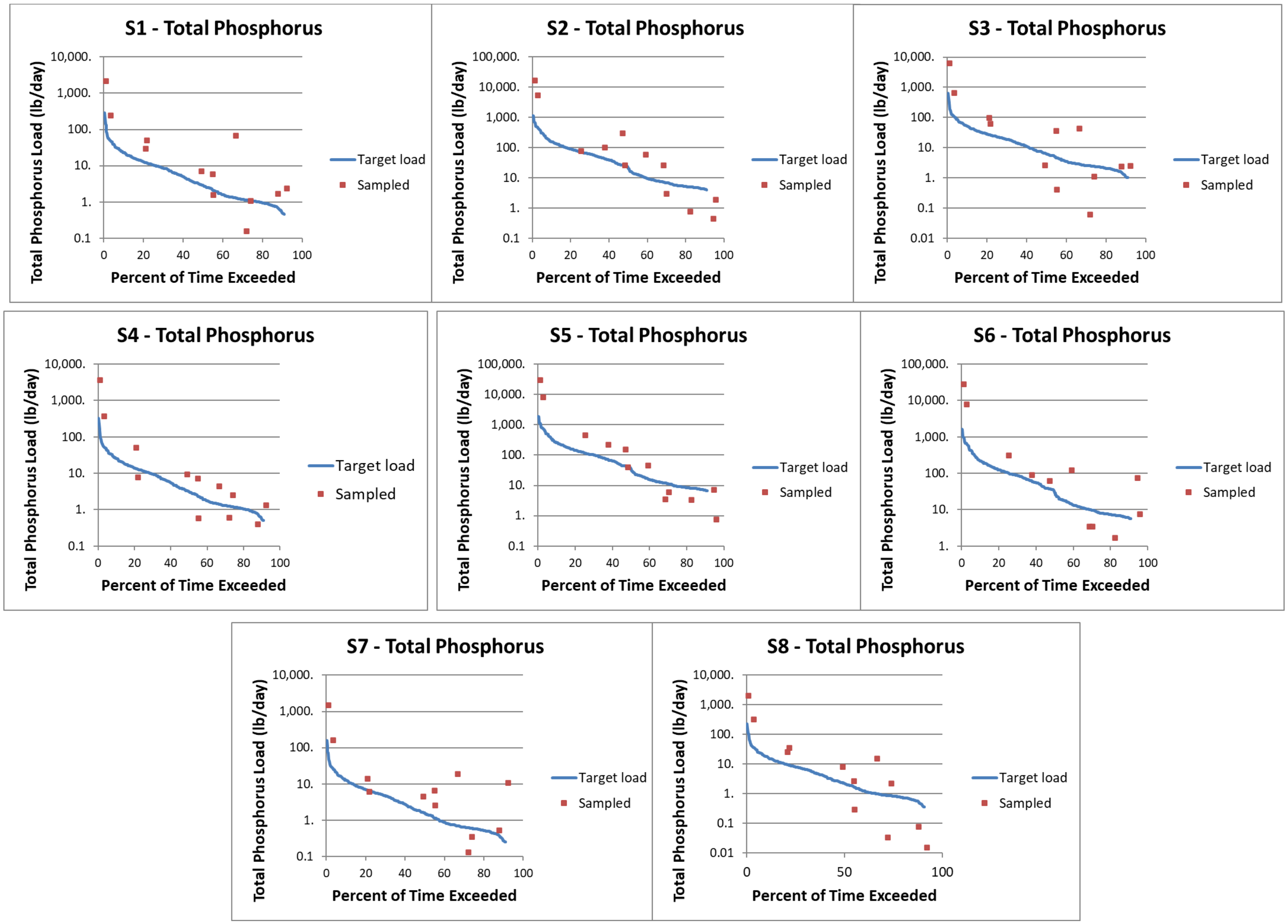
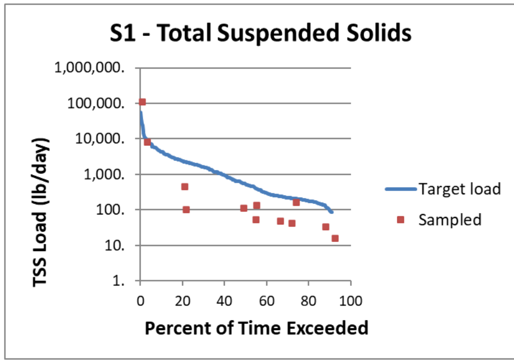
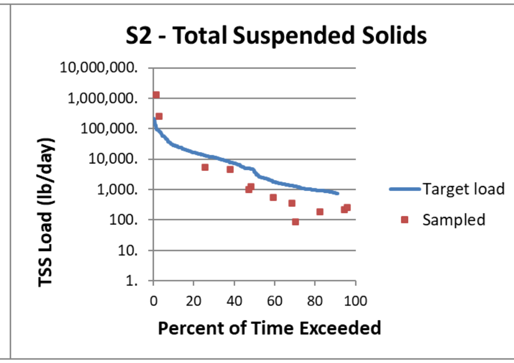
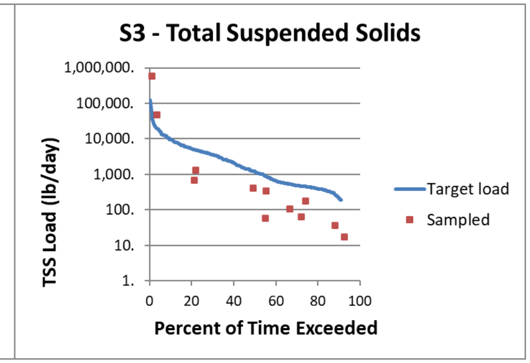
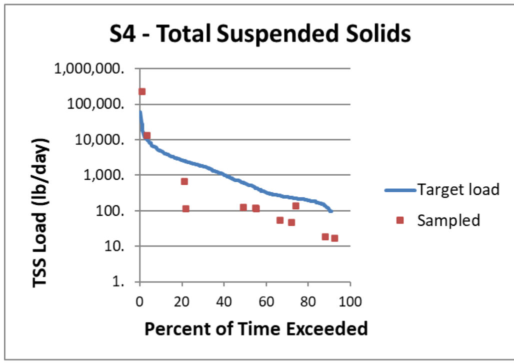


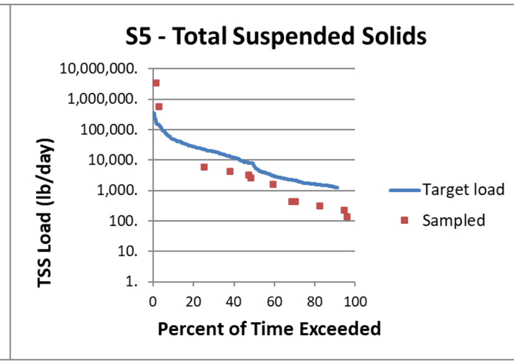
Figure 40. Total phosphorus load duration curves for Upper Sugar Creek Watershed samples sites from January 2022-December 2022.

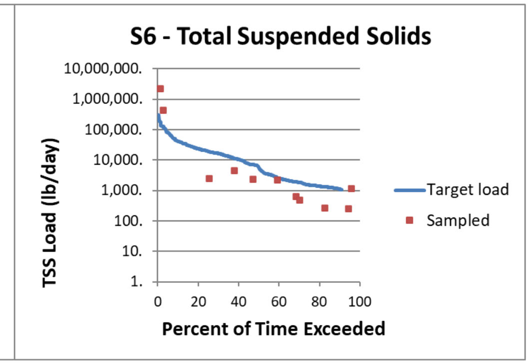

S1 - Total Suspended Solids
TSS Load (lb/day)
1,000,000.
100,000.
10,000.
1,000.
100.
10.
1.
0 20 40 60 80 100
Percent of Time Exceeded
Target load
Sampled

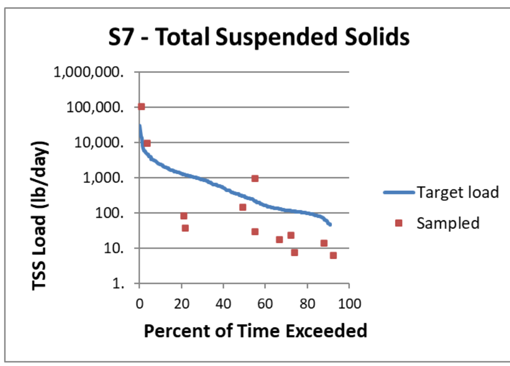

S2 - Total Suspended Solids
TSS Load (lb/day)
10,000,000.
1,000,000.
100,000.
10,000.
1,000.
100.
10.
1.
0 20 40 60 80 100
Percent of Time Exceeded
Target load
Sampled

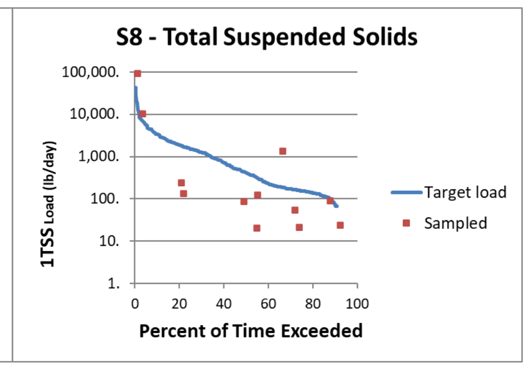

S3 - Total Suspended Solids
TSS Load (lb/day)
1,000,000.
100,000.
10,000.
1,000.
100.
10.
1.
0 20 40 60 80 100
Percent of Time Exceeded
Target load
Sampled


S4 - Total Suspended Solids
TSS Load (lb/day)
1,000,000.
100,000.
10,000.
1,000.
100.
10.
1.
0 20 40 60 80 100
Percent of Time Exceeded
Target load
Sampled


S5 - Total Suspended Solids
TSS Load (lb/day)
10,000,000.
1,000,000.
100,000.
10,000.
1,000.
100.
10.
1.
0 20 40 60 80 100
Percent of Time Exceeded
Target load
Sampled


S6 - Total Suspended Solids
TSS Load (lb/day)
10,000,000.
1,000,000.
100,000.
10,000.
1,000.
100.
10.
1.
0 20 40 60 80 100
Percent of Time Exceeded
Target load
Sampled


S7 - Total Suspended Solids
TSS Load (lb/day)
1,000,000.
100,000.
10,000.
1,000.
100.
10.
1.
0 20 40 60 80 100
Percent of Time Exceeded
Target load
Sampled


S8 - Total Suspended Solids
1TSS Load (lb/day)
100,000.
10,000.
1,000.
100.
10.
1.
0 20 40 60 80 100
Percent of Time Exceeded
Target load
Sampled

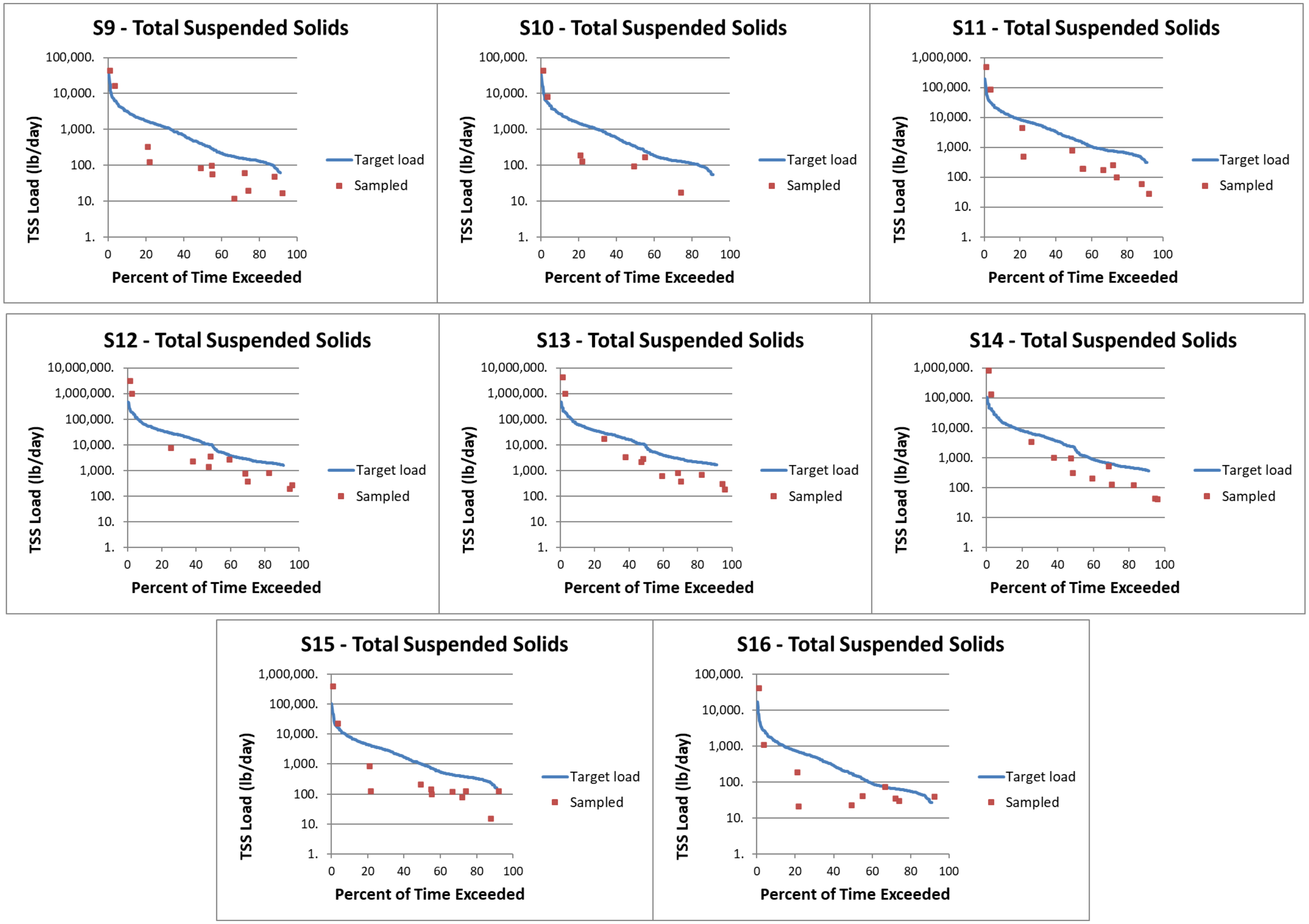
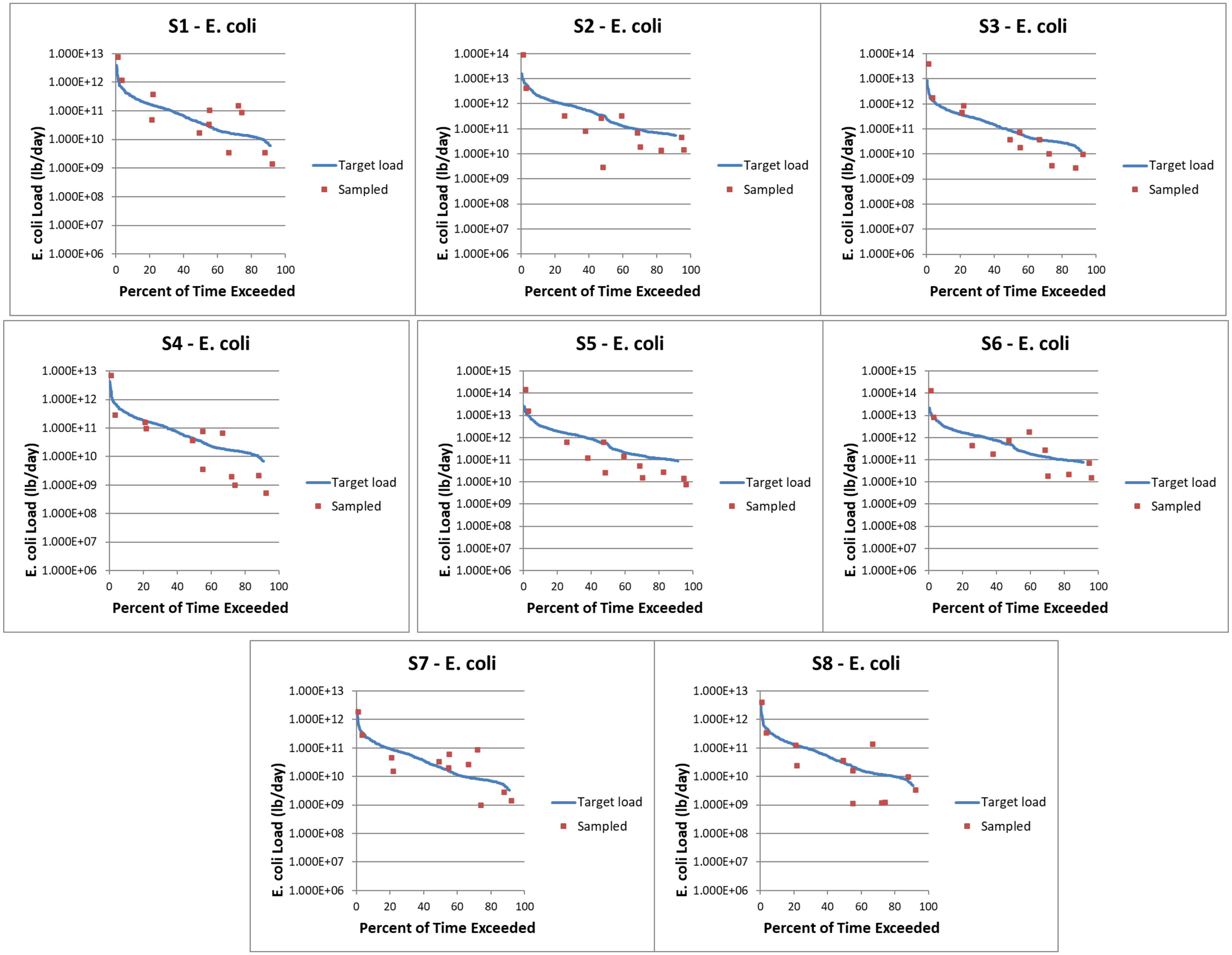


Figure 41. Total suspended solids load curves for Upper Sugar Creek Watershed samples sites from January 2022-December 2022.


S1 - E. coli
S2 - E. coli
S3 - E. coli
S4 - E. coli
S5 - E. coli
S6 - E. coli
S7 - E. coli
S8 - E. coli
E. coli Load (lb/day)
Percent of Time Exceeded
Target load
Sampled
1.000E+15
1.000E+14
1.000E+13
1.000E+12
1.000E+11
1.000E+10
1.000E+09
1.000E+08
1.000E+07
1.000E+06
0
20
40
60
80
100

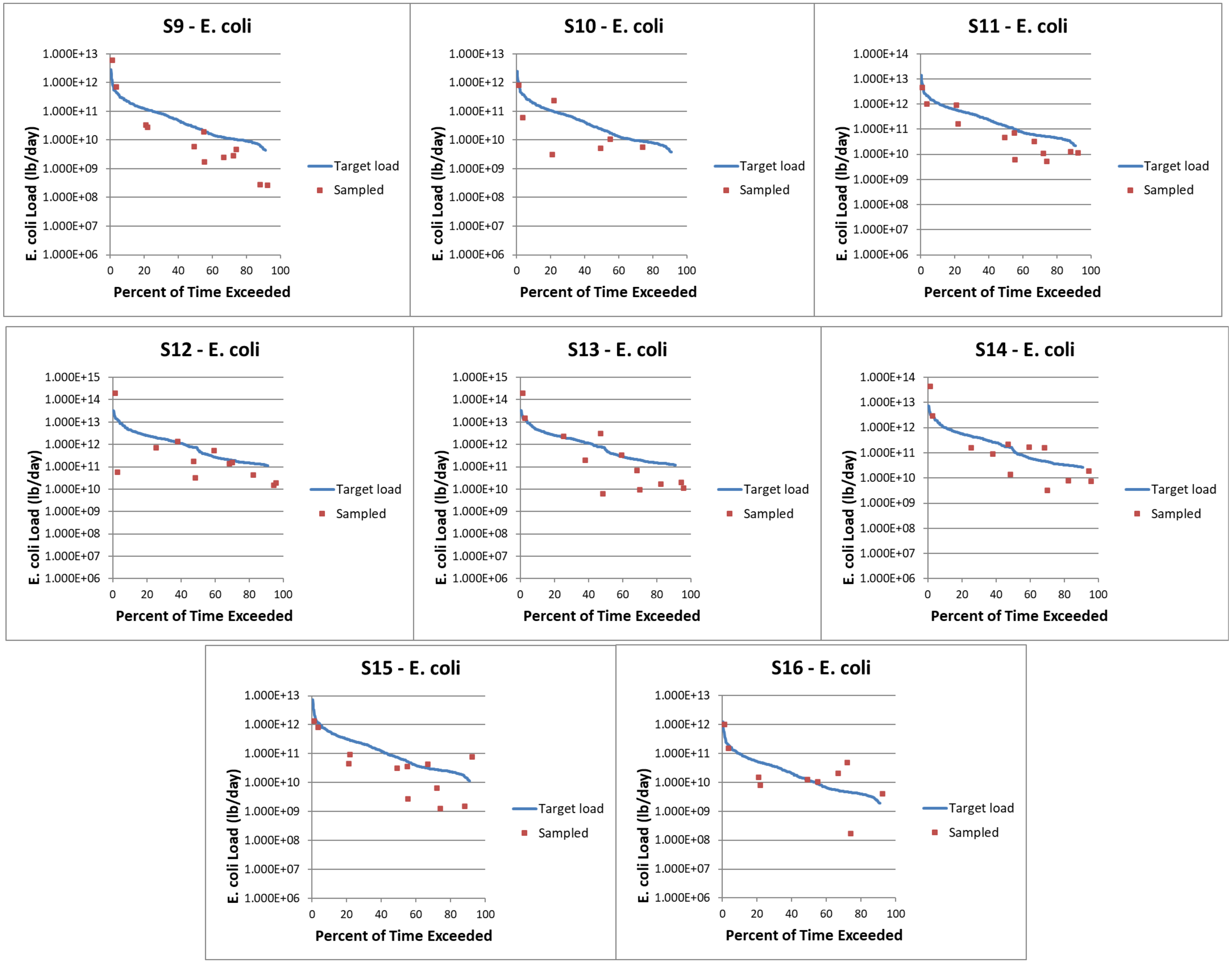


Figure 42. *E. coli* concentrations load duration curves for Upper Sugar Creek Watershed samples sites from January 2022-December 2022.

3.3.5 Fish Community Assessment

Methods

Data from fish community sampling at each of the 16 sites in the Upper Sugar Creek Watershed were used to calculate the index of biotic integrity (IBI). Owen and Karr (1978) found that natural streams support fish communities of high species diversity. Fish communities in natural streams are seasonally more stable than the fish communities of modified streams. "Structurally diverse natural streams typically have a great deal of buffering capacity: meanders tend to moderate the effect of floods, pools offer excellent refuges for fishes during dry periods, and tree shade decreases heat loads and minimizes the oxygen-robbing effect of decomposing and extensive algal blooms" (Karr and Schlosser, 1977). Many endangered species are restricted to specific habitat complexes within streams and have become endangered as a result of habitat loss, fragmentation, or pollution.

Fish were collected during base flow conditions on July 18, 19,20 and August 2, 2022. Each sampling reach measured 15 times the streams' wetted width with sampling occurring over no less than 50 m (164 ft.). Fish were collected using backpack electrofishing equipment. All fish encountered were collected, identified to species, measured, and returned to the water. Fish species and abundance information was recorded at each site. Length and width measurements were recorded for game fish species.

The IBI is a multi-metric (12 metrics) index designed to provide a complete assessment of a stream's biological integrity. Metrics include number of native species; number of darters, madtoms, and sculpins; percent headwater species; percent sensitive and intolerant species; percent tolerant species; percent detritivores; percent invertivores; person pioneers; catch per unit effort; percent simple lithophils; and percent DELT anomalies. IDEM uses two versions of the IBI for streams with drainages smaller than 20 square miles and a second for those with drainages larger than 20 square miles. Each metric is scored as detailed in Table 18. Appendix C details the fish species collected at each sample site.

Table 18. IDEM IBI metric scoring criteria.

Metric	1	3	5
Total number of species	Varies with drainage area		
Number of darters, madtoms, sculpin (DMS; <20 square miles)	Varies with drainage area		
Number of darters (>20 square miles)	Varies with drainage area		
Percent headwaters species (<20 square miles)	Varies with drainage area		
Number of sunfish (> 20 square miles)	Varies with drainage area		
Number of minnow species (<20 square miles)	Varies with drainage area		
Number of sucker species (>20 square miles)	Varies with drainage area		
Percent pioneer species	Varies with drainage area		
Number of sensitive species	<25%	25-50%	>50%
Percent tolerant species	<25%	25-50%	>50%
Percent omnivores	<25%	25-50%	>50%
Percent insectivores	<25%	25-50%	>50%
Percent carnivores (>20 square miles)	>50%	25-50%	<25%
Catch per unit effort	Varies with drainage area		
Percent simple lithophils	>40%	20-40%	<20%
Percent DELT (lesions, tumors)	<0.1%	0.1-1.3%	>1.3%

Results

Mainstem Sugar Creek sites possess better fish communities than many of the Upper Sugar Creek tributaries (Figure 43, Figure 44,**Table 19**). Site 2 (Browns Wonder-Sugar Creek), Site 4 (Wolf Creek) and Site 14 (Town of Linnsburg-Walnut Fork Sugar Creek) supported more diverse communities than other sites in the Upper Sugar Creek Watershed. All sites contained at least 25 fish species. Additionally, Site 2 (Browns Wonder-Sugar Creek) and Site 14 (Town of Linnsburg-Walnut Fork Sugar Creek), along with Site 5 (Withe Creek-Sugar Creek), had the greatest IBI scores of 54. The greatest number of sensitive species were collected at Site 12 (Hazel Creek-Sugar Creek) with 13 sensitive species observed. Twelve sensitive species were observed at both Site 2 (Browns Wonder-Sugar Creek) and Site 5 (Withe Creek-Sugar Creek). Site 10 (Lye Creek Drain) and Site 16 (Little Creek-Little Sugar Creek) contained the least number of sensitive species collected with zero to one species observed, respectively. Additionally, Site 10 (Lye Creek Drain) had the lowest IBI score of 32 rating this site as poor. Site 16 (Little Creek-Little Sugar Creek) displayed the greatest percentage of tolerant species collected with 48% of species observed identified as tolerant. Site 6 (Goldsberry Creek-Sugar Creek) had the lowest percentage (1.9%) of tolerant species collected.

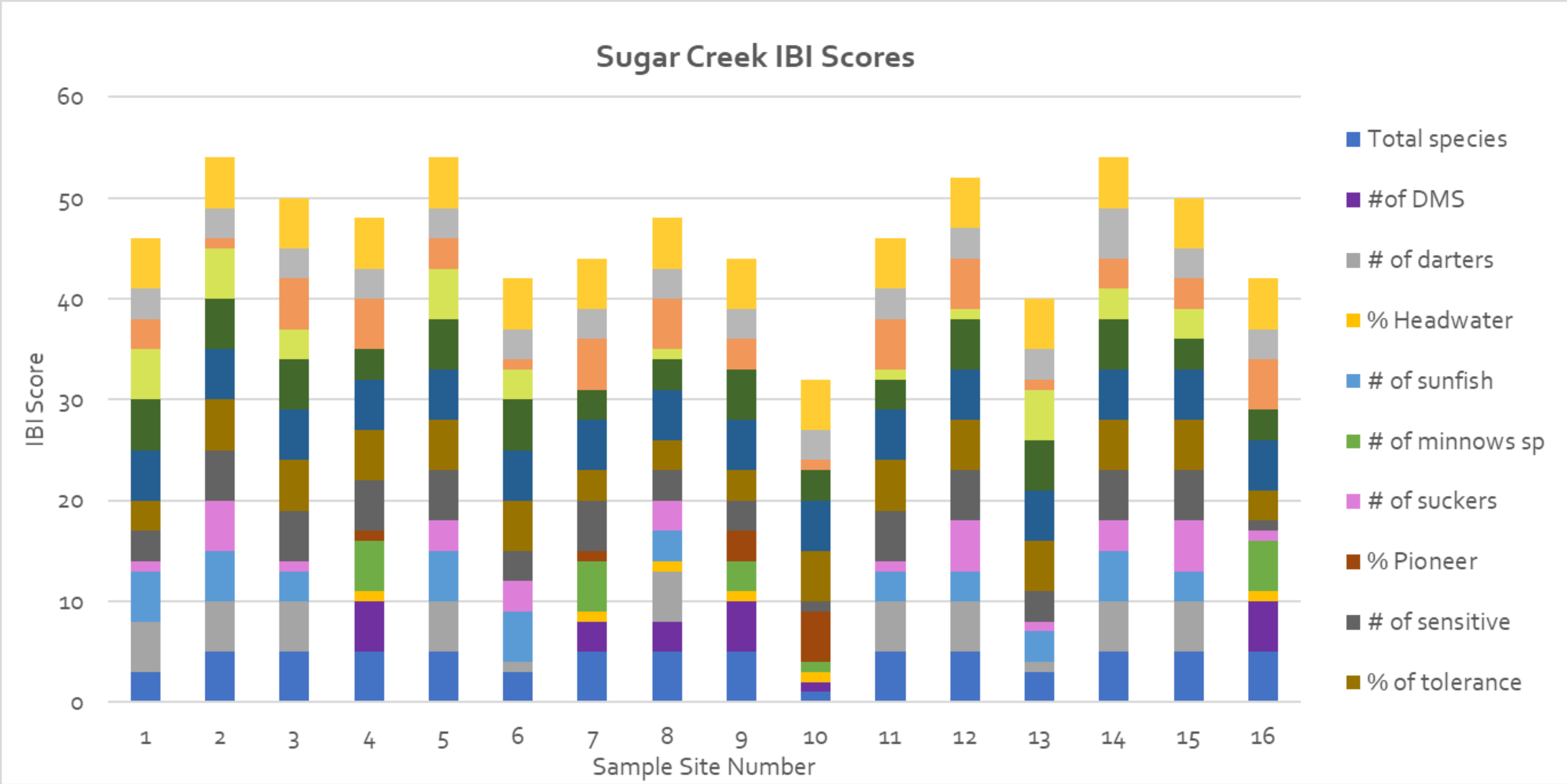


Figure 43. Cumulative metrics used to calculate IBI scores for Upper Sugar Creek Watershed streams in 2022.

Table 19. Metric classification scores and IBI score for the Upper Sugar Creek Watershed sample sites as sampled in 2022.

IBI Metric Scores	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**	**S14**	**S15**	**Site 16**
Total species score	3	5	5	5	5	3	5	5	5	1	5	5	3	5	5	5
#of DMS score				5			3	3	5	1						5
# of darters score	5	5	5		5	1		5			5	5	1	5	5	
% Headwater score				1			1	1	1	1						1
# of sunfish score	5	5	3		5	5		3			3	3	3	5	3	
# of minnows sp score				5			5		3	1						5
# of suckers score	1	5	1		3	3		3			1	5	1	3	5	1
% Pioneer score				1			1		3	5						
# of sensitive score	3	5	5	5	5	3	5	3	3	1	5	5	3	5	5	1
% of tolerance score	3	5	5	5	5	5	3	3	3	5	5	5	5	5	5	3
% omnivores score	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
% insectivores score	5	5	5	3	5	5	3	3	5	3	3	5	5	5	3	3
% Carnivores score	5	5	3		5	3		1			1	1	5	3	3	
CPUE score*	3	1	5	5	3	1	5	5	3	1	5	5	1	3	3	5
% Simple Lithophil score	3	3	3	3	3	3	3	3	3	3	3	3	3	5	3	3
%DELTS score	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Total IBI (site <= 20 sq. mi)	**0**	**0**	**0**	**48**	**0**	**0**	**44**	**0**	**44**	**32**	**0**	**0**	**0**	**0**	**0**	**42**
Total IBI (site > 20 sq. mi)	**46**	**54**	**50**	**0**	**54**	**42**	**0**	**44**	**0**	**0**	**46**	**52**	**40**	**54**	**50**	**0**

*CPUE=Catch per unit effort.

Figure 44 details IBI scores and ratings for the Upper Sugar Creek Watershed. Site 2 (Browns Wonder), Site 5 (Withe Creek-Sugar Creek) and Site 14 (Town of Linnsburg-Walnut Fork Sugar Creek) had IBI scores rated as excellent. Site 1 (Sanitary Ditch-Prairie Creek), Site 3 (Deer Creek-Prairie Creek), Site 4 (Wolf Creek), Site 11 (Little Potatoe Creek-Lye Creek), Site 12 (Hazel Creek-Sugar Creek) and Site 15 (Little Sugar Creek) had IBI scores rated as good. Site 6 (Goldsberry Creek-Sugar Creek), Site 7 (Goldsberry Creek-Sugar Creek), Site 8 (Headwaters Little Potato), Site 9 (Bowers Creek), Site 13 (Town of Garfield-Sugar Creek) and Site 16 (Little Creek-Little Sugar Creek) had IBI scores rated as good. Site 10 (Lye Creek Drain) had an IBI score rated as poor.

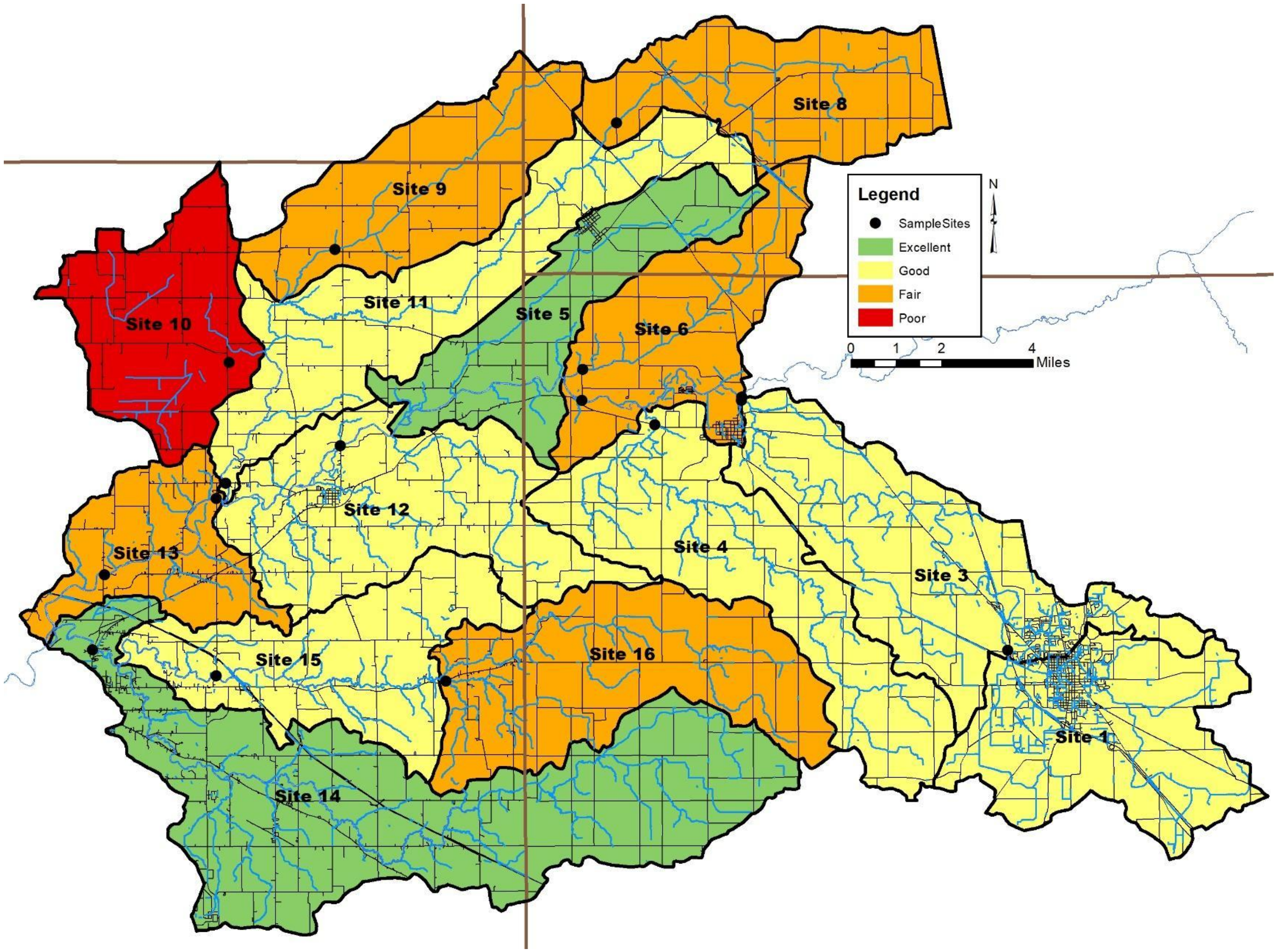


Figure 44. IBI ratings for Upper Sugar Creek Watershed stream sites. Black dots denote the sample site within the subwatershed.

3.3.6 Macroinvertebrate Community Assessment

Methods

Data from macroinvertebrate sampling at Upper Sugar Creek Watershed streams were used to calculate a macroinvertebrate index of biotic integrity. Aquatic macroinvertebrates are important indicators of environmental change. The macroinvertebrate community composition reflects water quality. Research shows that different macroinvertebrate orders and families react differently to pollution sources. Thus, indices of biotic integrity are valuable because aquatic biota integrate cumulative effects of sediment and nutrient pollution (Ohio EPA, 1995).

Macroinvertebrates were collected during base flow conditions on July 15 to 16, 2022 using the multihabitat approach detailed in the USEPA Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, 2nd ed. (Barbour et al. 1999). The macroinvertebrate samples were processed using the laboratory processing protocols detailed in the IDEM macroinvertebrate index of biotic integrity (mIBI). Organisms were identified to the genus level.

IDEM's mIBI is a multi-metric (12 metrics) index designed to provide a complete assessment of a stream's biological integrity. Karr and Dudley (1981) define biological integrity as "the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization compared to the best natural habitats within the region". Metrics include number of taxa; species richness, number of *Ephemeroptera*, *Plecoptera* and *Trichoptera* (EPT) tax, percent of orhoclads/tanyrsids, percent non-insect, number of dipteran taxa, and percent tolerant, intolerant, predators, shredders/scrapers, collectors-filterers and sprawlers. Each metric is scored as detailed in Table 20. Cumulative mIBI scores for each site are then compared with IDEM's mIBI target score (36). Sites which score lower than 36 are considered impaired, while sites score more than 36 are considered non-impaired.

Table 20. mIBI metric scoring criteria for genus level identification.

Metric	1	3	5
Taxa Richness	<21	<21 and >41	>41
Species Richness	<129	<129 and <258	>258
Number of EPT Taxa	Varies by drainage area		
Percent Orthoclads/Tanyarsids	>47	>24 and <47	<24
Percent non-insect	>35	>18 and <35	<18
Number of Dipteran Taxa	<7	>7 and <14	>14
Percent Intolerant	<15.9	>15.9 and <31.8	>31.8
Percent Tolerant	>25.3	>12.6 and <25.3	<12.6
Percent Predators	<18	>18 and <36	>36
Percent Shredders/Scrapers	<10	>10 and <20	>20
Percent Collectors-Filterers	>20	>10 and <10	<10

Percent Sprawlers	<3	>3 and <6	>6

Results

Overall, macroinvertebrate community quality was good in the Upper Sugar Creek Watershed with 13 of 16 sites rating as not impaired (Table 21, Figure 45). Sanitary Ditch-Prairie Creek (Site 1) and Browns Wonder-Sugar Creek (Site 2) supported the most diverse community with 28 and 32 taxa observed, respectively. Browns Wonder-Sugar Creek (Site 2) possessed the greatest mIBI score (44), while Sanitary Ditch-Prairie Creek (Site 1) and Little Sugar Creek (Site 15) possessed the second highest scores (42). It is important to note, however, that Sites 1 and 2 contained more tolerant species than intolerant species. Sanitary Ditch-Prairie Creek (Site 1) had only 2% of taxa identified as intolerant species, while 22% were tolerant species. Similarly, Browns Wonder-Sugar Creek (Site 2) had 6% of taxa identifies as intolerant species with 40% identified as tolerant species. Site 5 (Withe Creek-Sugar Creek) contained the highest percentage of intolerant species (14%) with only 1% of tolerant species observed. However, Site 5 had the second lowest mIBI rating with a score of 34 suggesting it is an impaired stream. Site 9 (Bowers Creek) had the worst mIBI score of the sixteen sites sampled, with a score of 28. Bowers Creek supported the least diverse communities with 14 taxa observed. Further, Bowers Creek had the highest percent tolerant species (87%) present and the lowest percent of observed intolerant species (0%). It also had one of the lowest numbers of the sensitive EPT taxa observed with only two individuals collected. Site 10 (Lye Creek Drain) also only had two individuals of the EPT taxa collected. Appendix C details the macroinvertebrate species collected at each sample site.

Table 21. Metric classification scores and mIBI score for the Upper Sugar Creek Watershed sample sites as sampled in 2022.

mIBI Metric Scores	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**	**S14**	**S15**	**S16**
Total Taxa score	3	3	3	3	1	3	3	3	1	1	1	1	1	1	3	3
Total # Individuals score	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
#EPT Taxa score	5	3	3	5	3	3	3	3	1	1	3	3	3	5	5	3
% Orthoclads &Tanytarsids score	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
% Non-Insects (minus crayfish) score	5	5	5	5	5	5	5	3	1	3	5	5	5	5	5	5
# Dipteran Taxa score	3	3	3	1	1	1	1	1	1	1	3	1	1	1	3	3
% Intolerant score	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
% Tolerant score	3	1	5	1	5	3	3	1	1	1	5	5	3	5	5	3
% Predators score	1	3	1	1	1	1	1	1	1	5	1	1	3	1	1	1
% Shredders & Scrapers score	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
% Collector-Filterers score	1	5	1	1	1	1	3	3	5	5	1	1	3	1	1	1
% Sprawlers score	5	5	3	5	1	5	5	5	1	3	1	1	5	1	3	5
Total Score	**42**	**44**	**40**	**38**	**34**	**38**	**40**	**36**	**28**	**36**	**36**	**34**	**40**	**36**	**42**	**40**

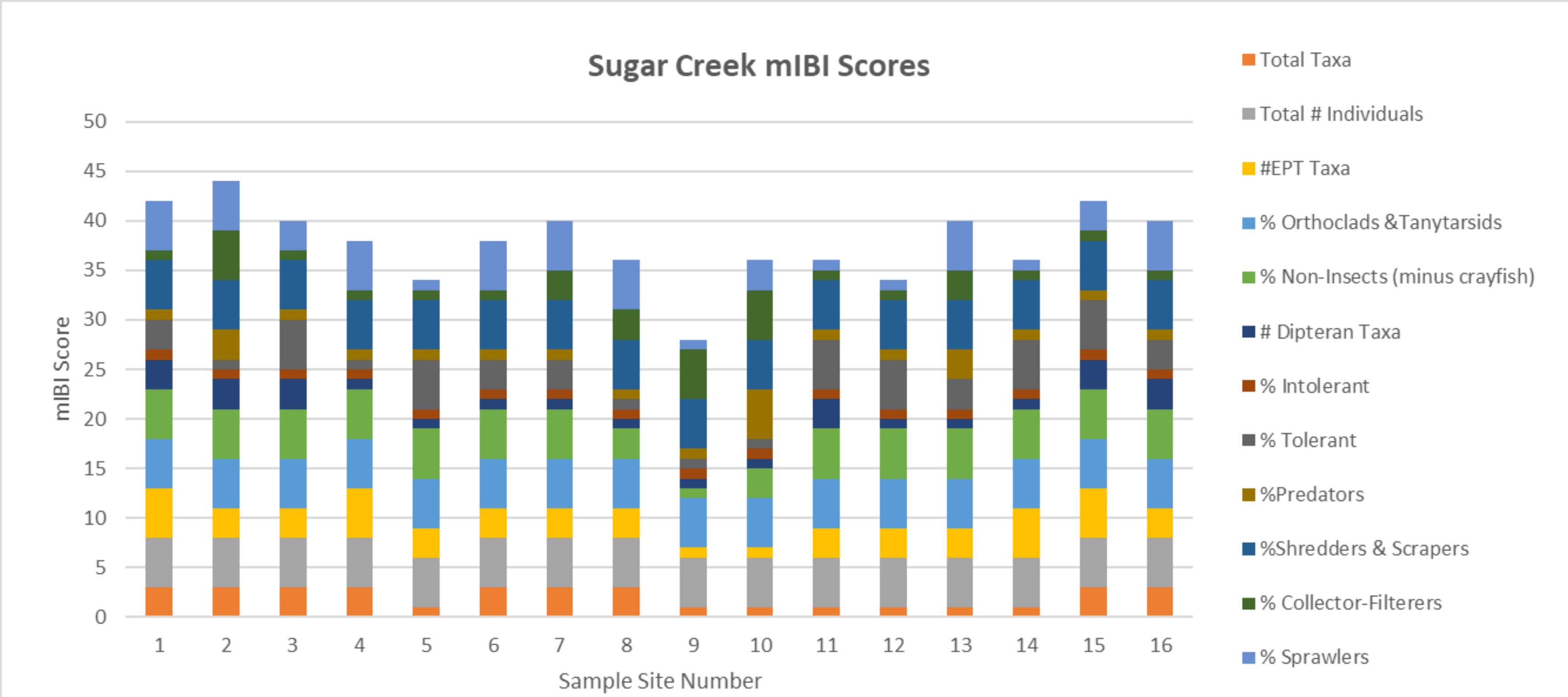


Figure 45. Cumulative metrics used to calculate mIBI scores for Upper Sugar Creek Watershed streams in 2022.

Figure 46 details mIBI scores and ratings for the Upper Sugar Creek Watershed. Site 1 (Sanitary Ditch-Prairie Creek), Site 2 (Browns Wonder), Site 3 (Deer Creek-Prairie Creek), Site 4 (Wolf Creek), Site 6 and 7 (Goldsberry Creek-Sugar Creek), Site 8 (Headwaters Little Potato), Site 10 (Lye Creek Drain), Site 11 (Little Potatoe Creek-Lye Creek), Site 13 (Town of Garfield-Sugar Creek), Site 14 (Town of Linnsburg-Walnut Fork Sugar), Site 15 (Little Sugar Creek) and Site 16 (Little Creek-Little Sugar Creek) had mIBI scores rated as fair. Site 5 (With Creek-Sugar Creek), Site 9 (Bowers Creek) and Site 12 (Hazel Creek-Sugar Creek) had mIBI scores rated as poor (Figure 46).

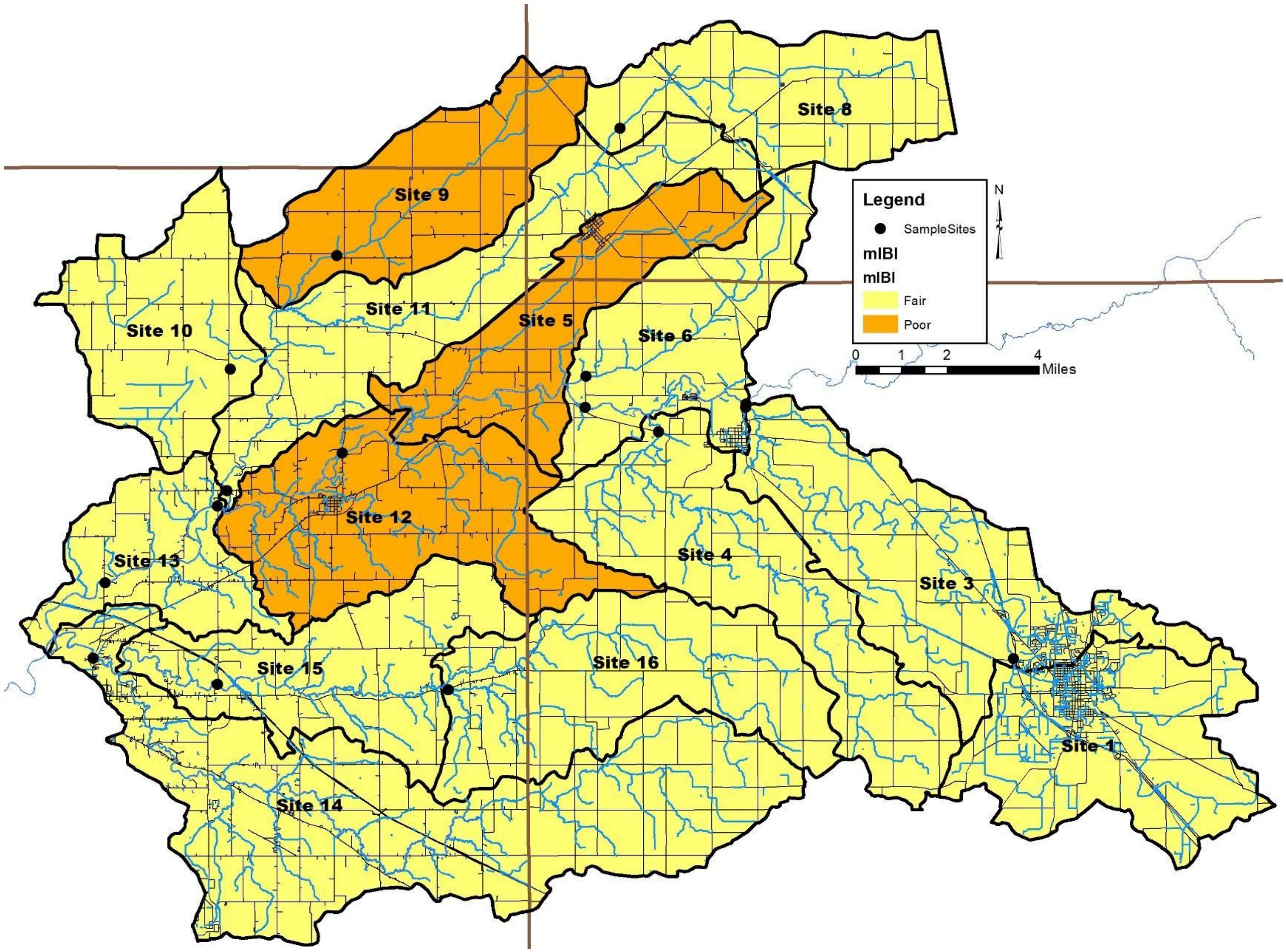


Figure 46. mIBI ratings for Upper Sugar Creek Watershed stream sites. Black dots denote the sample site within the subwatershed.

3.3.7 Habitat Assessment

Methods

Physical habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989, 1995). Various attributes of the stream and riparian zone habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional aquatic faunas. The type(s) and quality of substrates; amount and quality of instream cover; channel morphology; extent and quality of riparian vegetation; pool, run, and riffle development and quality; and gradient are some of the metrics used to determine the QHEI score. The QHEI score ranges from 20 to 100.

Substrate type(s) and quality are important factors of habitat quality and the QHEI score is partially based on these characteristics. Sites that have greater substrate diversity receive higher scores as they can provide greater habitat diversity for benthic organisms. The quality of substrate refers to the embeddedness of the benthic zone. Small particles of soil and organic matter will settle into small pores and crevices in the stream bottom. Many organisms can colonize these microhabitats, but high levels of silt in a streambed can result in the loss of habitat within the substrate. Thus, sites with heavy embeddedness and siltation receive lower QHEI scores for the substrate metric.

Instream cover, another metric of the QHEI, represents the type(s) and quantity of habitat provided within the stream itself. Examples of instream cover include woody logs and debris, aquatic and overhanging vegetation and root wads extending from the stream banks. The channel morphology metric evaluates the stream's physical development with respect to habitat diversity. Pool and riffle development within the stream reach, the channel sinuosity and other factors that represent the stability and direct modification of the site are evaluated to comprise this metric score.

A wooded riparian buffer is a vital functional component of riverine ecosystems. It is instrumental in the detention, removal, and assimilation of nutrients. According to the Ohio EPA (1999), riparian zones govern the quality of goods and services provided by riverine ecosystems. Riparian zone and bank erosion were examined at each site to evaluate the quality of the buffer zone of a stream, the land use within the floodplain that affects inputs to the waterway, and the extent of bank erosion, which can reflect insufficient vegetative stabilization of the stream banks. For the purposes of the QHEI, a riparian buffer is a zone that is forest, shrub, swamp, or woody old field vegetation. Typically, weedy, herbaceous vegetation does not offer as much infiltration potential as woody components and does not represent an acceptable riparian zone type for the QHEI (Ohio EPA, 1989).

The fifth QHEI metric evaluates the quality of pool/glide and riffle/run habitats in the stream. These zones in a stream, when present, provide diverse habitat and in turn can increase habitat quality and availability. The depth of pools within a reach and the stability of riffle substrate are some factors that affect the QHEI score in this metric.

The final QHEI metric evaluates the topographic gradient in a stream reach. This is calculated using topographic data. The score for this metric is based on the premise that both very low and very high gradients will have negative effects on habitat quality and the biota in the stream.

Moderate gradients receive the highest score, 10, for this metric. The QHEI is used to evaluate the characteristics of a stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar.

QHEI scores from hundreds of stream segments in Ohio have indicated that values greater than 60 are *generally* conducive to the existence of warmwater faunas. Scores greater than 75 typify habitat conditions that have the ability to support exceptional warmwater faunas (Ohio EPA, 1999). IDEM indicates that QHEI scores above 64 suggest the habitat is capable of supporting a balanced warmwater community; scores between 51 and 64 are only partially supportive of a stream's aquatic life use designation, while scores less than 51 are deemed non-supporting the stream's aquatic life use designation (IDEM, 2000).

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 22 and Figure 46 presents the results of QHEI assessments at each of the 16 stream sites sampled in the Upper Sugar Creek Watershed during the summer of 2022. Site 5 (Withe Creek-Sugar Creek), Site 7 (Goldsberry Creek-Sugar Creek) and Site 14 (Town of Linnsburg-Walnut Fork Sugar Creek) rated as excellent, while Site 11 (Little Potatoe Creek-Lye Creek), Site 12 (Hazel Creek-Sugar Creek) and Site 15 (Little Sugar Creek) rated as good. For these sites, pool/riffle development scores, stream substrate, instream cover, and gradient were relatively good for Indiana streams contributing to overall high quality QHEI scores. Site 2 (Browns Wonder), Site 3 (Deer Creek-Prairie Creek), Site 4 (Wolf Creek), Site 6 (Goldsberry Creek-Sugar Creek), Site 13 (Town of Garfield-Sugar Creek) and Site 16 (Little Creek-Little Sugar Creek) rated as fair. Site 1 (Sanitary Ditch-Prairie Creek), Site 8 (Headwaters Little Potato) and Site 10 (Lye Creek Drain) rated poor while Site 9 (Bowers Creek) rated very poor. The lowest scores occurred at sites which possessed poor substrate, poor instream cover, limited riparian quality and lacked pool/riffle complexes. Appendix C details the habitat assessment at each sample site.

Table 22. Qualitative Habitat Evaluation Index (QHEI) scores measured in the Upper Sugar Creek Watershed.

Site	Substrate	Cover	Channel	Riparian	Pool/Current	Riffle/Run	Gradient	QHEI Score
1	10	8	7	3.5	8	3	4	**43.5**
2	12	11	12	6	7	3	4	**55**
3	14	8	10	4	8	5	4	**53**
4	12	8	11	6	7	1	4	**49**
5	20	15	18	5.5	11	7	4	**80.5**
6	11	10	11	7.75	9	1	4	**53.75**
7	14	16	16	10	11	4.5	4	**75.5**
8	12	5	9	2	9	3	4	**44**
9	5	6	6	2	3	0	4	**26**
10	1	11	4	4.25	7	0	4	**31.25**
11	16	11	12	7	5	5	4	**60**
12	10	9	17	8	10	4	4	**62**
13	12.5	13	13	8.25	8	0	4	**58.75**
14	16	16	18.5	7.25	12	7	4	**80.75**
15	13	11	17	5	9	6	4	**65**
16	12	6	12	6.5	4	0	4	**44.5**

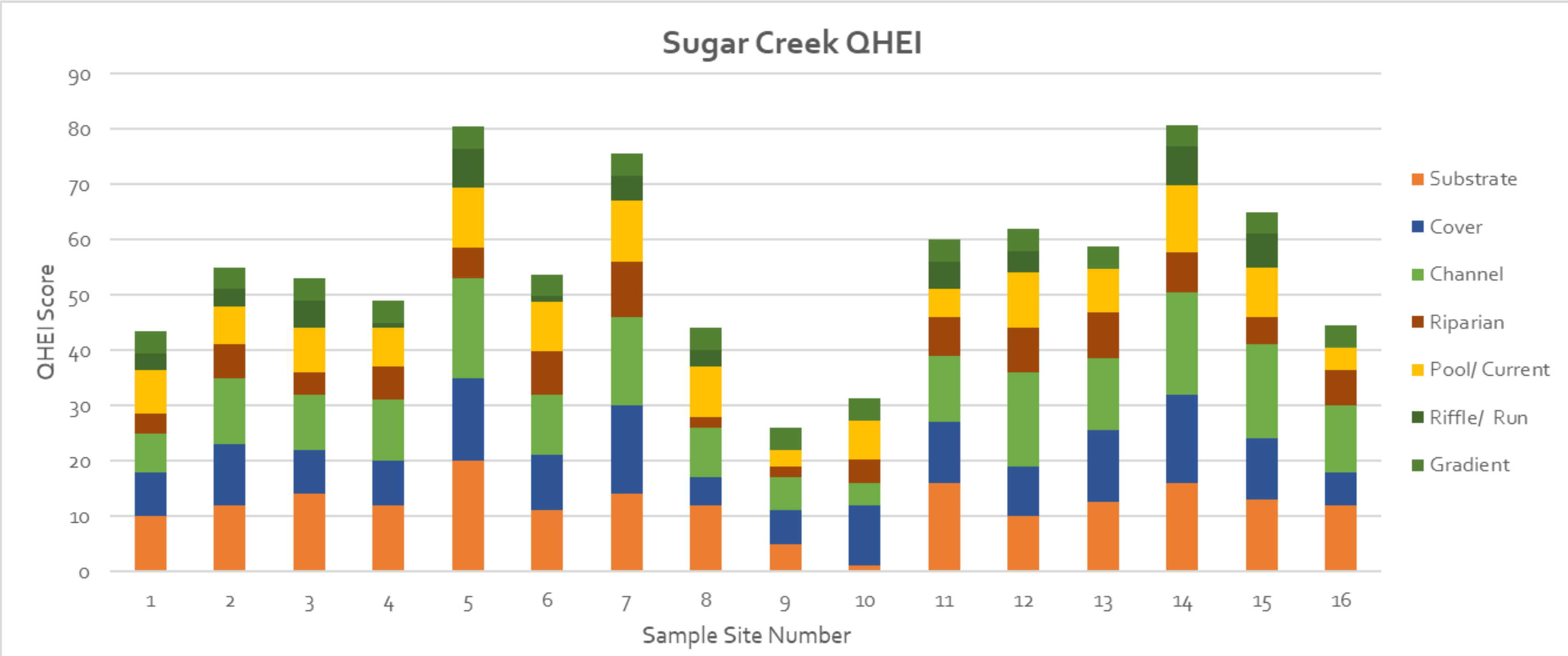


Figure 17. Qualitative Habitat Evaluation Index (QHEI) total and component scores measured for stream sites in the Upper Sugar Creek Watershed.

Figure 47 details metric and total scores for all sites. Site 5 (With Creek-Sugar Creek), Site 7 (Goldsberry Creek-Sugar Creek) and Site 14 (Town of Linnsburg-Walnut Fork Sugar Creek) rated as excellent. Site 11 (Little Potatoe Creek-Lye Creek), Site 12 (Hazel Creek-Sugar Creek) and Site 15 (Little Sugar Creek) rated as good. Site 2 (Browns Wonder), Site 3 (Deer Creek-Prairie Creek), Site 4 (Wolf Creek), Site 6 (Goldsberry Creek-Sugar Creek), Site 13 (Town of Garfield-Sugar Creek) and Site 16 (Little Creek-Little Sugar Creek) rated as fair. Site 1 (Sanitary Ditch-Prairie Creek), Site 8 (Headwaters Little Potato) and Site 10 (Lye Creek Drain) rated poor while Site 9 (Bowers Creek) rated very poor.

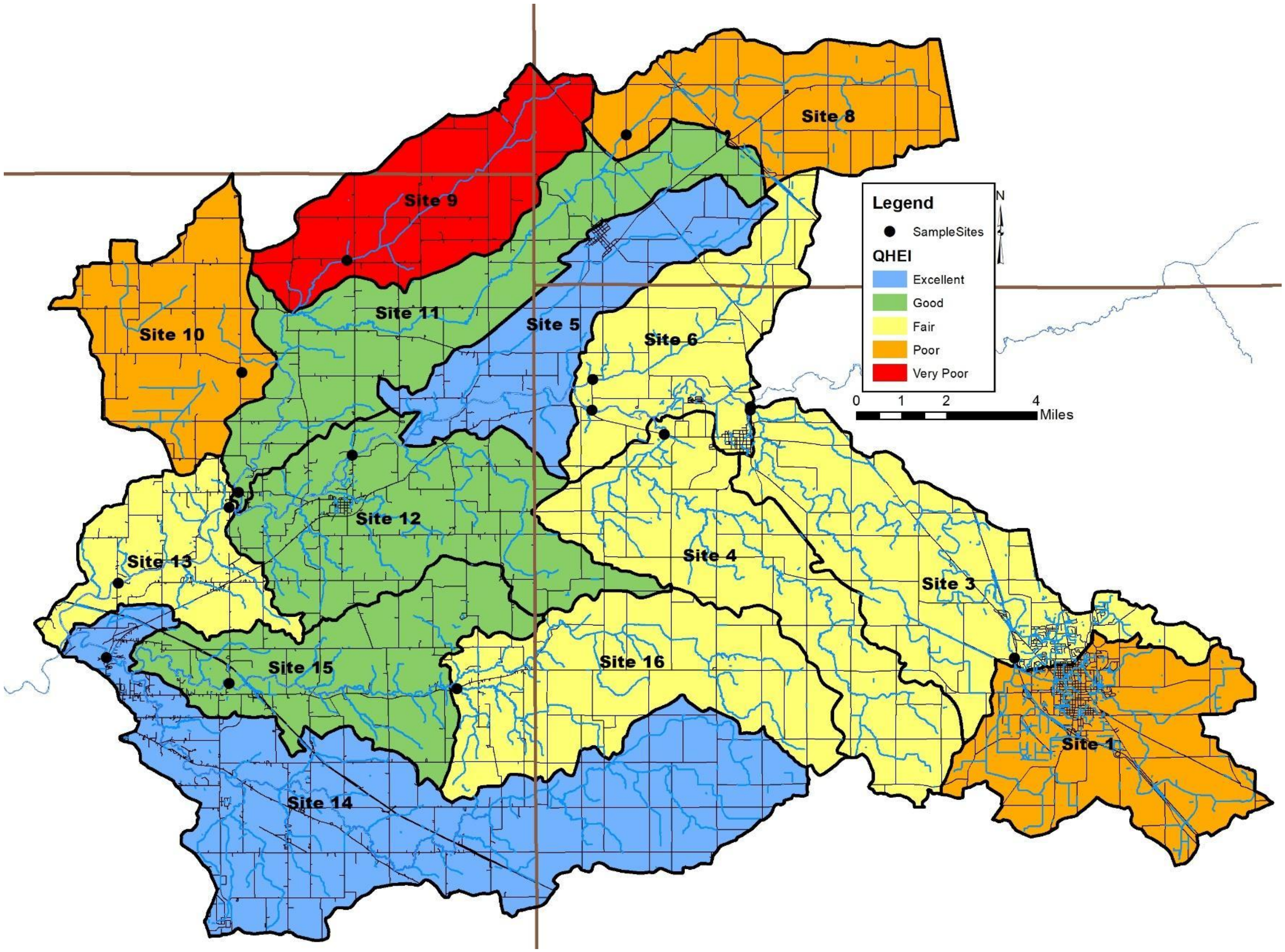


Figure 47. QHEI ratings for Upper Sugar Creek Watershed stream sites. Black dots denote the sample site within the subwatershed.

3.4 Watershed Inventory Assessment

3.4.1 Watershed Inventory Methodologies

Volunteers completed windshield surveys throughout the Upper Sugar Creek Watershed in spring 2022. Volunteers 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 Project Coordinator 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
- Logjams located within the stream
- Dumping areas or areas where trash or debris accumulate
- Small, unregulated farms
- Environmental site confirmation (NPDES, CFO, open dump, Superfund, etc.)

3.4.2 Watershed Inventory Results

All accessible road-stream crossings were inventoried. A majority of issues identified fall into five categories: stream buffers limited in width or lacking altogether, areas of livestock access, streambank erosion, dumping areas, and unregulated farms. l details locations throughout the Upper Sugar Creek Watershed where problems were riparian area problems identified. Much of the watershed is not visible from the road and additional assessments will be on-going; therefore, those identified in Figure 48 should not be considered exhaustive. Nearly 22.3 miles of streams possessed limited buffers, nearly 84.8 miles of streambank were eroded, and livestock had access to nearly 15.8 miles of streams. Note that these data are preliminary and additional inventory efforts will augment this map as the project moves forward.

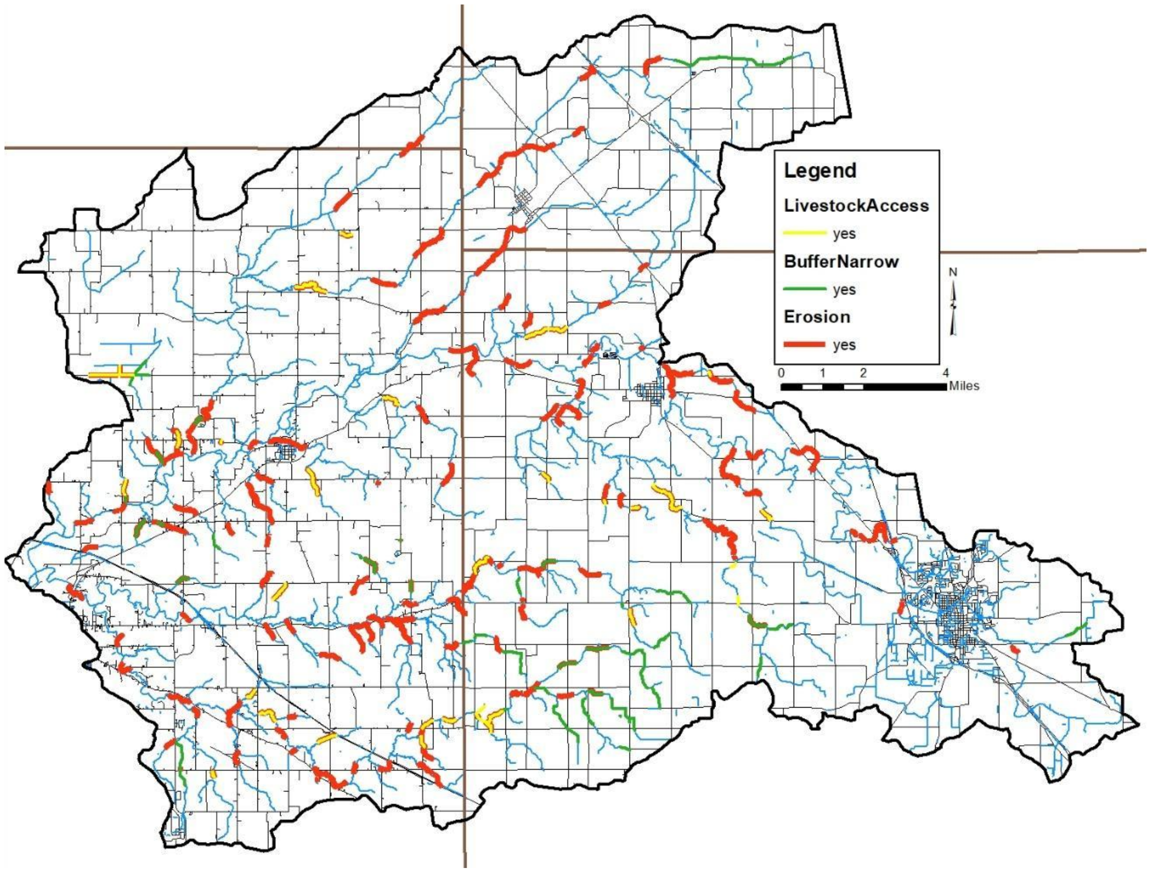


Figure 48. Stream-related watershed concerns identified during watershed inventory efforts.

4.0 WATERSHED INVENTORY II-B: SUBWATERSHED DISCUSSIONS

To gather more specific, localized data, the Upper Sugar Creek Watershed was divided into fourteen (14) subwatersheds with each subwatershed reflecting one 12-digit Hydrologic Unit Code (HUC; Figure 49.) These subwatersheds reflect specific tributary drainages and similar land uses and hydrology. Land uses, point and non-point watershed concern areas, and historic water quality sampling locations and results are discussed in detail below for each subwatershed.

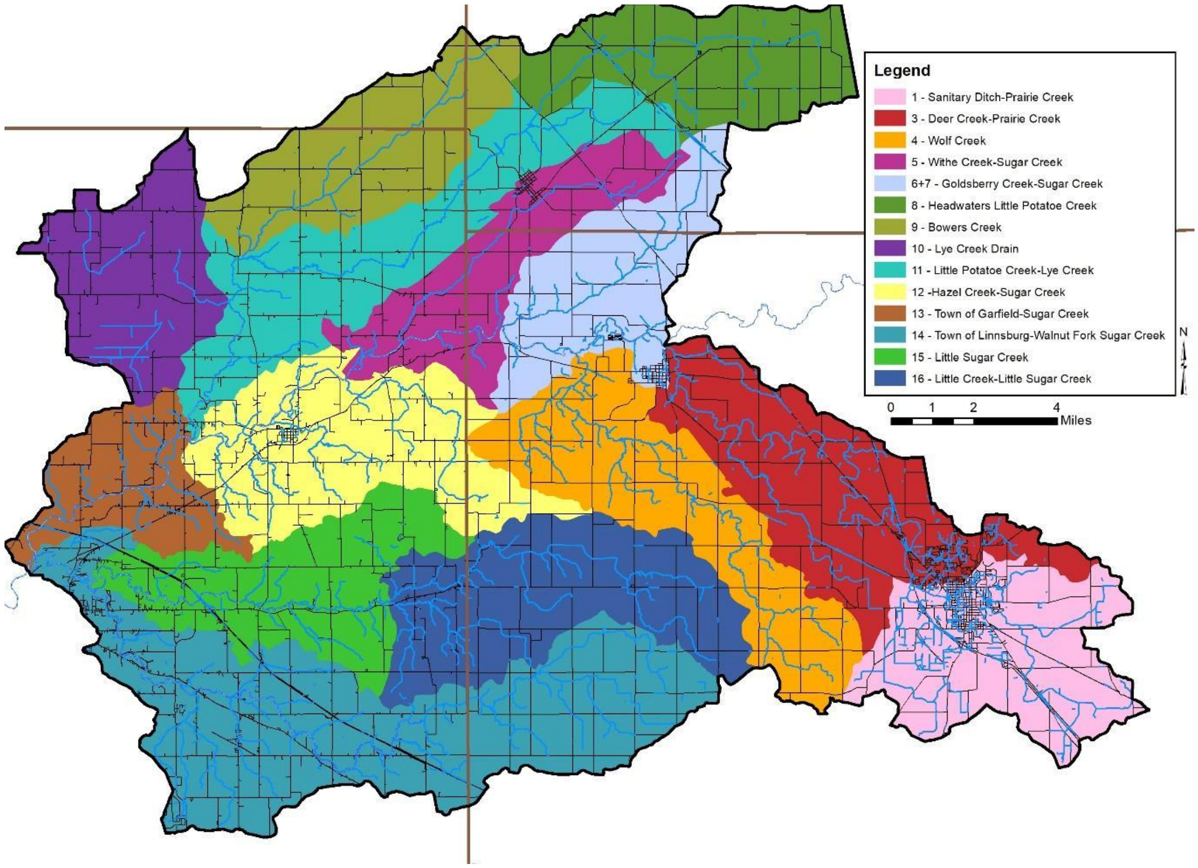


Figure 49. 12-digit Hydrologic Unit Codes subwatersheds in the Upper Sugar Creek Watershed.

4.1 Headwaters Little Potatoe Creek subwatershed

The Headwaters Little Potatoe Creek subwatershed is the northernmost subwatershed of the Upper Sugar Creek Watershed and forms the northern edge of the Upper Sugar Creek Watershed. The Headwaters Little Potatoe Creek subwatershed lies entirely within Clinton County (Figure 50). It encompasses one 12-digit HUC watershed: 051201100201. This subwatershed drains 11,674 acres or 18.2 square miles and accounts for 7% of the total watershed area. There are 17.3 miles of stream. IDEM has classified 10.8 miles of stream as impaired for *E. coli*, nutrients, pH and impaired biotic communities.

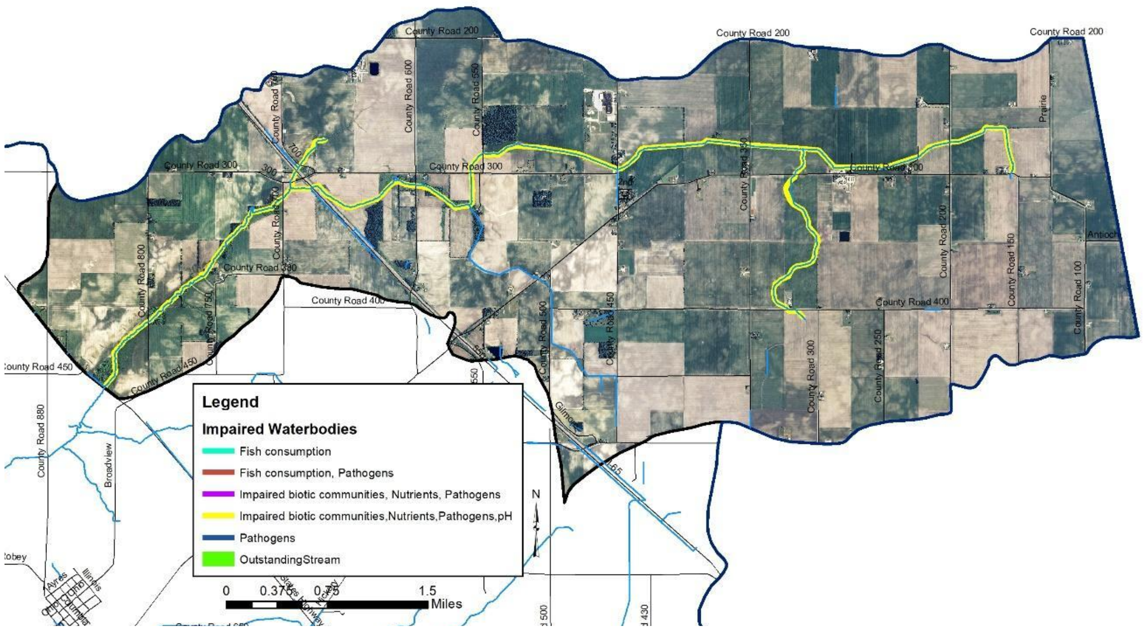


Figure 50. Headwaters Little Potatoe Creek subwatershed.

4.1.1 Soils

Hydric soils cover 5,212.7 acres or 44.7% of the subwatershed; wetlands currently cover 0.6% (66.1 acres) of the subwatershed. Highly erodible soils are prevalent throughout the subwatershed covering 6,329.3 acres or 54.2% of the subwatershed. Nearly all of the subwatershed, 99.1% (11,573.3 acres), has soils which are very limited for septic use.

4.1.2 Land Use

Agricultural land use dominates the Headwaters Little Potatoe Creek subwatershed at 92.9% (10,850.1 acres), with row crops and pastureland accounting for the majority of agricultural land uses. Urban land use is the next largest use of the subwatershed, but only accounts for 5.5% (637.4 acres) of use. Forest land makes up just 1.0% (111.2 acres) of the subwatershed. Wetlands, open water, and grassland cover just 66.1 acres, or 0.6%, of the subwatershed.

4.1.3 Point Source Water Quality Issues

There is one potential point source of water pollution in the subwatershed, an underground storage tank. No open dumps, NPDES-permitted locations, superfund sites, corrective action sites, or voluntary remediation sites are located within the Headwaters Little Potatoe Creek subwatershed.

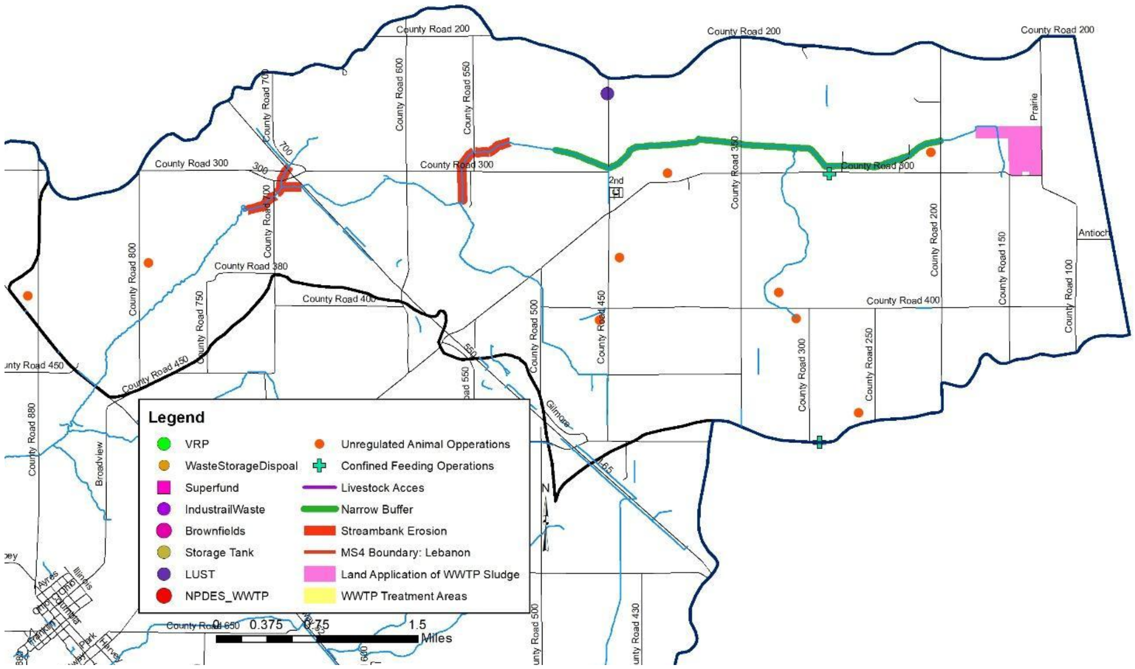


Figure 51. Potential point and non-point sources of pollution and suggested solutions in the Headwaters Little Potatoe Creek subwatershed.

4.1.4 Non-Point Source Water Quality Issues

Agricultural land uses are the predominant land use in the Headwaters Little Potatoe Creek subwatershed. As a result, various small animal operations and pastures are also present (Figure 51). Nine unregulated animal operations housing more than 50 cows and horses were identified during the windshield survey. Livestock do not have access to the Headwaters Little Potatoe Creek subwatershed streams based on observations during the windshield survey. Two active CFOs were also identified, housing up to 6,725 dairy cattle. In total, manure from small animal operations and the two CFOs total over 148,348 tons per year, which contains almost 70,477 pounds of nitrogen, 34,565 pounds of phosphorus and 4.21E+15 col of *E. coli*. Streambank erosion and lack of buffers are a concern in the subwatershed. Approximately 3.1 miles (18%) of insufficient stream buffers and 1.3 miles (7.7%) of streambank erosion were identified within the subwatershed.

4.1.5 Water Quality Assessment

Waterbodies within the Headwaters Little Potatoe Creek subwatershed have been sampled historically at three locations (Figure 52). One site in the Headwaters Little Potatoe Creek subwatershed is being sampled as part of the current project. Historic assessments include collection of water chemistry (3 sites) and fish data by IDEM (1 site) and Hoosier Riverwatch Volunteers (1 site). No stream gages are in the Headwaters Little Potatoe Creek subwatershed.

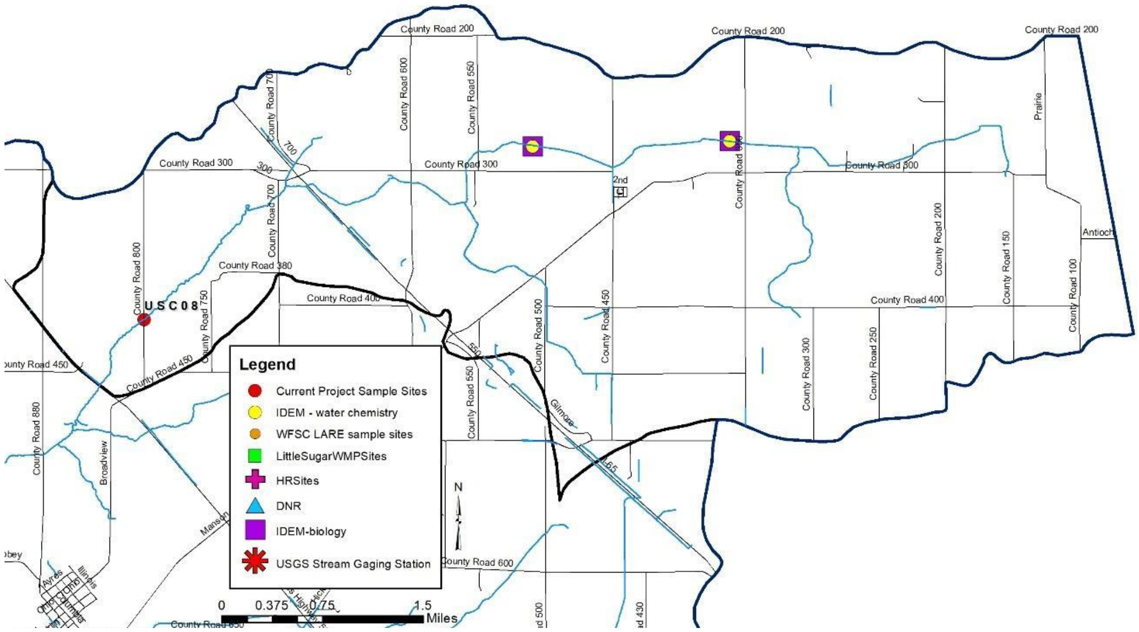


Figure 52. Locations of historic and current water quality data collection in the Headwaters Little Potatoe Creek subwatershed.

Table 23 details historic water quality sampled collected in the Headwaters Little Potatoe Creek subwatershed. As shown in the table, E. coli samples exceed state grab sample standards (235 col/100 ml) in 60% of samples collected. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 67% of samples, while total Kjeldahl nitrogen concentrations exceed water quality targets (0.50 mg/L) in 33% of samples. Total phosphorus concentrations exceed water quality targets (0.08 mg/L) in 100% of samples. Turbidity levels exceed water quality targets (5.7NTU) in 57% of samples. Additionally, dissolved oxygen concentrations exceeded the upper state standard (12 mg/L) in 44% of samples collected.

Table 23. Headwaters Little Potatoe Creek subwatershed historic water quality data summary.

Parameter	Minimum	Maximum	Number Exceeding Target	Number of Samples	Percent Exceeding
Dissolved oxygen (mg/L)	3.4	14.4	4	9	44%
E. coli (col/100 mL)	61.6	1299.7	3	5	60%
Total Kjeldahl nitrogen (mg/L)	0.2	0.588	1	3	33%
Nitrate (mg/L)	0.2	24.2	2	3	67%
pH	7.25	10.12	1	9	11%
Total Phosphorus (mg/L)	0.083	0.417	3	3	100%
Specific conductance (µmhos/cm)	569	657	0	9	0%
Turbidity (NTU)	2.5	87	4	7	57%

Table 24 details water quality data collected in the Headwaters Little Potatoe Creek Subwatershed (Site 8). As shown in the table, *E. coli* samples exceed state standards (235 col/100 ml) in 42% of samples collected. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 50% of samples. Total phosphorus concentrations exceed water quality targets (0.08 mg/L) in 67% of samples. Total suspended solids concentrations exceed water quality targets (15 mg/L) in 25% of samples, while turbidity levels exceed water quality targets (5.7 NTU) in 42% of samples. Dissolved oxygen, pH and conductivity concentrations did not exceed water quality standards in samples collected from this site.

Table 24. Headwaters Little Potatoe Creek subwatershed water quality data summary.

Site		Temp (deg C)	DO (mg/L)	pH	Cond (µmhos/cm)	Turb (NTU)	Nitrate (mg/L)	TP (mg/L)	TSS (mg/L)	*E. coli* (col/100 ml)
8	Median	11.45	9.25	7.89	510.0	4.28	0.78	0.21	5.5	214.8
	Max	23.40	11.70	8.12	730.0	77.00	9.38	1.60	109.0	2419.6
	Min	2.40	5.50	7.35	260.0	1.29	0.15	0.00	1.0	12.2
	#Samples	12	12	12	12	12	12	12	12	12
	#Exceed		0	0	0	5	6	8	3	5
	% Exceed	0%	0%	0%	0%	42%	50%	67%	25%	42%

IDEM conducted fish community assessments at two sites with habitat assessed a second time at one site (three total assessments) and one site was assessed as part of the current project. Habitat scores ranged from 28 to 51 with 25% of sites scoring below the state target (51). Fish community assessments rated poor to fair with 50% of assessments not meeting the state's aquatic life use designation (Table 25). Macroinvertebrate assessments scored 36 with 100% of multihabitat samples meeting their aquatic life use designation.

Table 25. Headwaters Little Potatoe Creek subwatershed biological assessment data summary.

Parameter	Minimum	Maximum	Number Exceeding Target	Number of Samples	Percent Exceeding
Habitat (QHEI)	38	51	1	4	25%
Fish (IBI)	34	44	2	4	50%
Macroinvertebrates (mIBI, Kick)	--	--	--	--	--
Macroinvertebrates (mIBI, Multi Habitat)	36	36	0	1	0%

4.2 Bowers Creek subwatershed

The Bowers Creek subwatershed forms the northwestern boundary of the Upper Sugar Creek Watershed and sits in three counties, Tippecanoe, Clinton, and Montgomery (Figure 53). It encompasses one 12-digit HUC watershed: 051201100202. This subwatershed drains 11,927 acres and has a total drainage of 18.6 square miles. The Bowers Creek subwatershed accounts for 7% of the total watershed area. There are 13.9 miles of stream. IDEM has not classified any portions of this subwatershed as impaired.

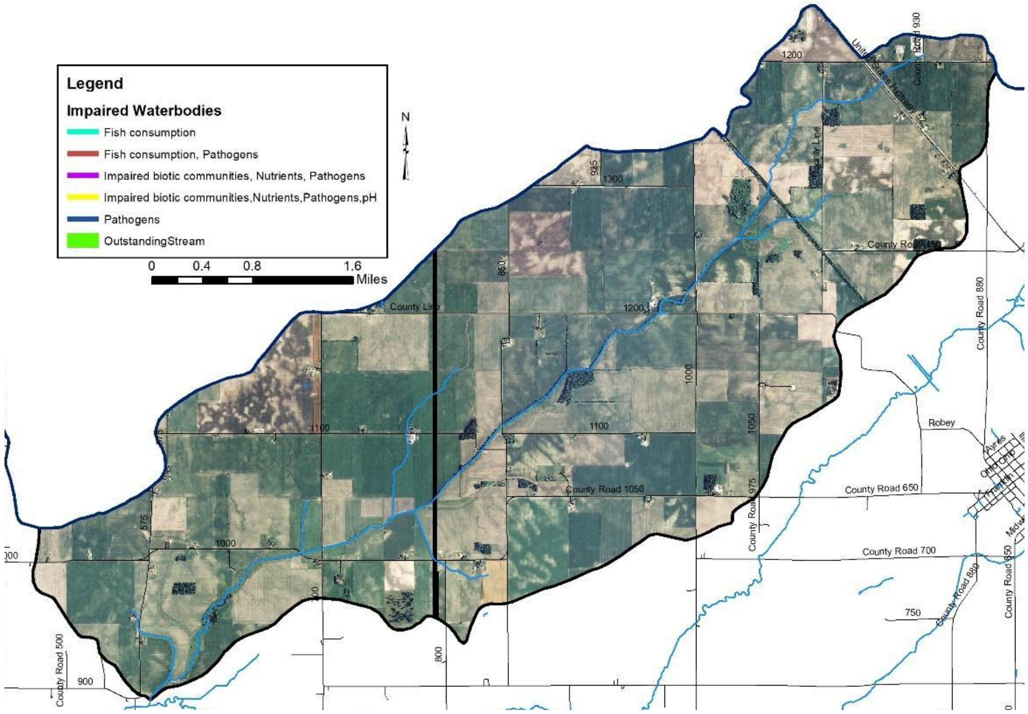


Figure 53. Bowers Creek subwatershed.

4.2.1 Soils

Hydric soils cover 6,416.4 acres or 53.8% of the subwatershed. Wetlands currently cover 0.6% (75.7 acres) of the subwatershed. Highly erodible soils nearly cover just under half of the subwatershed (41.2%) or 4,917.2 acres. In total, 11,915.0 acres or 99.9% of the subwatershed is identified as very limited for septic use. The majority of the Bowers Creek subwatershed is rural indicating many homes utilize on-site septic systems. Based on the soil septic suitability, maintenance and inspection of septic systems is important to ensure proper function and capacity.

4.2.2 Land Use

Agricultural land use dominates the Bowers Creek subwatershed at 94.7% (11,292.0 acres), with row crops and pasture land accounting for the majority of agricultural land uses. Urban land use is the next largest use of the subwatershed, but only accounts for 4.1% (494.6 acres) of the subwatershed land use. Forest land makes up just 0.5% (55.9 acres) of the subwatershed. Wetlands, open water, and grassland cover just 75.7 acres, or 0.6%, of the subwatershed.

4.2.3 Point Source Water Quality Issues

There are two potential sources of water pollution in the subwatershed: two underground storage tanks. No open dumps, NPDES-permitted locations, superfund sites, corrective action sites, or voluntary remediation sites are located within the Bowers Creek subwatershed.

4.2.4 Non-Point Source Water Quality Issues

Agricultural land uses are the predominant land use in the Bowers Creek subwatershed. Additionally, a number of small animal operations and pastures are also present. In total, 32 unregulated animal operations housing more than 67 cows were identified during the windshield survey (Figure 54). Based on windshield survey observations, livestock appear to have access to 0.3 miles of the Bowers Creek subwatershed streams. There are two confined feeding operations housing up to 2,978 cows and pigs in the subwatershed. These animal operations produce more than 40,377 tons of manure annually which contains more than 34,476 pounds of nitrogen, 21,737 pounds of phosphorus and more than 9.75E+14 colonies of *E. coli*. Streambank erosion is also a concern in the subwatershed. Approximately 1.7 miles (12.5%) of streambank erosion were identified within the subwatershed.

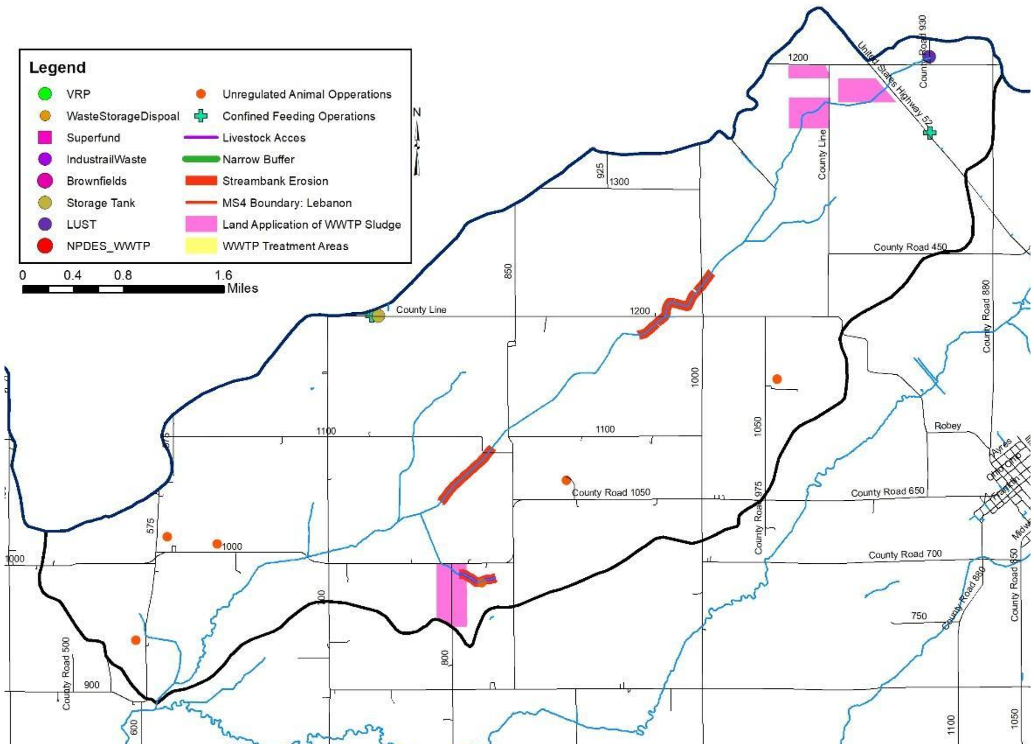


Figure 54. Potential point and non-point sources of pollution and suggested solutions in the Bowers Creek subwatershed.

4.2.5 Water Quality Assessment

Waterbodies within the Bowers Creek subwatershed have not been sampled historically. One site in the Bowers Creek subwatershed is being sampled as part of the current project (Figure 55). Table 26 details water quality data collected in the Bowers Creek Subwatershed (Site 9). As shown in the table, *E. coli* samples exceed state grab sample standards (235 col/100 ml) in 25% of samples collected. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 58% of samples. Total phosphorus concentrations exceed water quality targets (0.08 mg/L) in 83% of samples. Total suspended solids concentrations exceed water quality targets (15 mg/L) in 17% of samples, while turbidity levels exceed water quality targets (5.7 NTU) in 33% of samples. Dissolved oxygen, pH and conductivity concentrations did not exceed water quality standards in samples collected from this site.

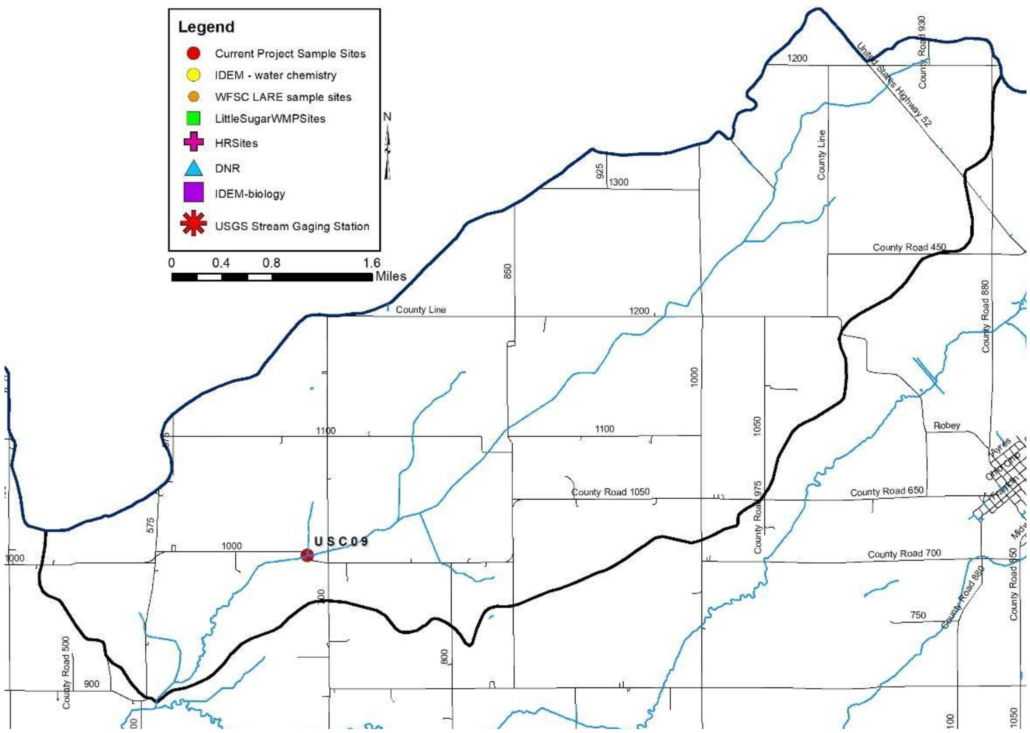


Figure 55. Locations of historic and current water quality data collection in the Bowers Creek subwatershed.

Table 26. Bowers Creek subwatershed water quality data summary.

Site		Temp (deg C)	DO (mg/L)	pH	Cond (µmhos/cm)	Turb (NTU)	Nitrate (mg/L)	TP (mg/L)	TSS (mg/L)	*E. coli* (col/100 ml)
9	Median	10.85	9.00	7.91	499.5	4.16	2.06	0.13	5.0	64.2
	Max	23.00	11.80	8.48	732.0	50.00	10.10	1.79	39.0	1119.7
	Min	0.50	4.20	7.22	287.0	0.77	0.16	0.02	1.0	10.2
	#Samples	12	12	12	12	12	12	12	12	12
	#Exceed		0	0	0	4	7	10	2	3
	% Exceed	0%	0%	0%	0%	33%	58%	83%	17%	25%

During the current project, habitat scored 26 with 100% of sites scoring below the state target (51). The fish community rated fair with 100% of assessments meeting the state's aquatic life use designation. The macroinvertebrate assessment scored 44 with 100% of multihabitat samples meeting their aquatic life use designation.

4.3 Lye Creek Drain subwatershed

The Lye Creek Drain subwatershed forms the northwestern border of the Upper Sugar Creek Watershed and lies entirely in Montgomery County (Figure 56). It encompasses one 12-digit HUC watershed: 051201100203. There are 14.9 miles of stream. There are no recorded impairments in the Lye Creek Drain subwatershed.

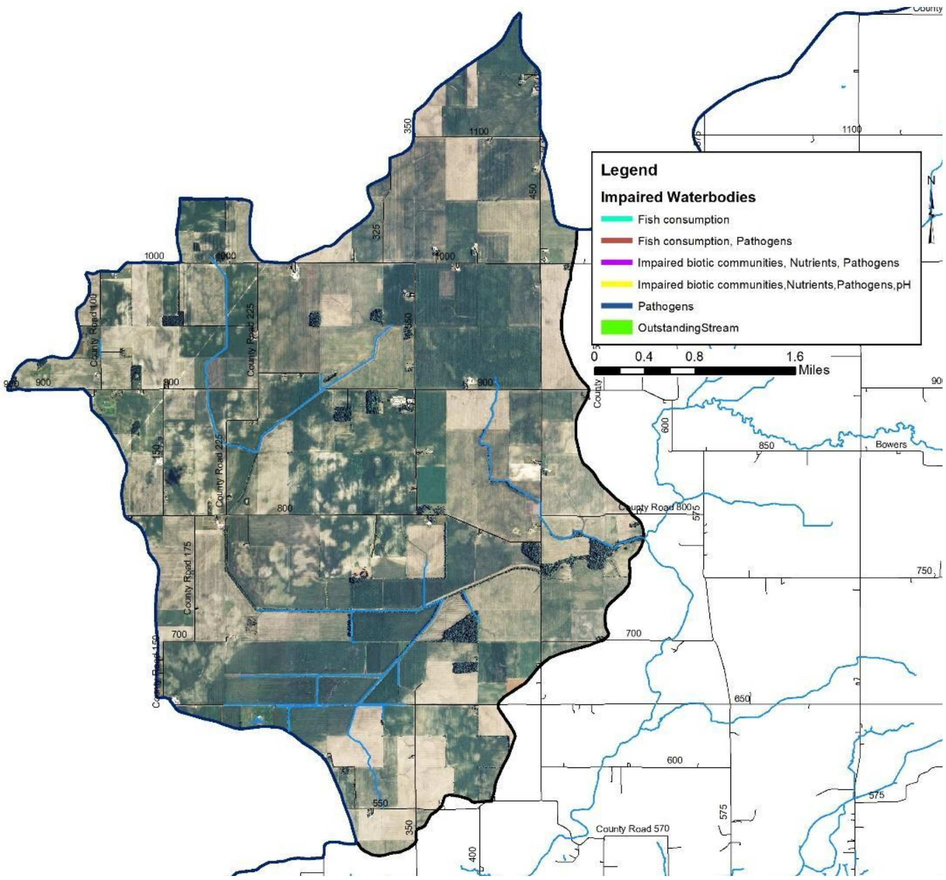


Figure 56. Lye Creek Drain subwatershed.

4.3.1 Soils

Hydric soils cover 6,248.2 acres (57.3%) of the subwatershed indicating that over half of the subwatershed was historically wetlands. Currently, wetlands currently cover 0.4% (47.0 acres) of the subwatershed. Highly erodible soils cover 45.8% of the subwatershed (5,011.0 acres). Nearly the entire subwatershed, 10,887.1 acres (99.8%) are identified as very limited for septic use. The majority of the Lye Creek Drain subwatershed is rural indicating homes pump to an on-site wastewater system. Maintenance and inspection of these septic systems are important to ensure proper function and capacity.

4.3.2 Land Use

Agricultural land use dominates the Lye Creek Drain subwatershed with 94.8% (10,346.2 acres) in agricultural land uses, including row crop and pasture. Nearly 4% (415.0 acres) of the Lye Creek Drain subwatershed is in urban land use. Wetlands and forested land use cover less than 2% of the subwatershed.

4.3.3 Point Source Water Quality Issues

There are no point sources of water pollution in the subwatershed (Figure 57).

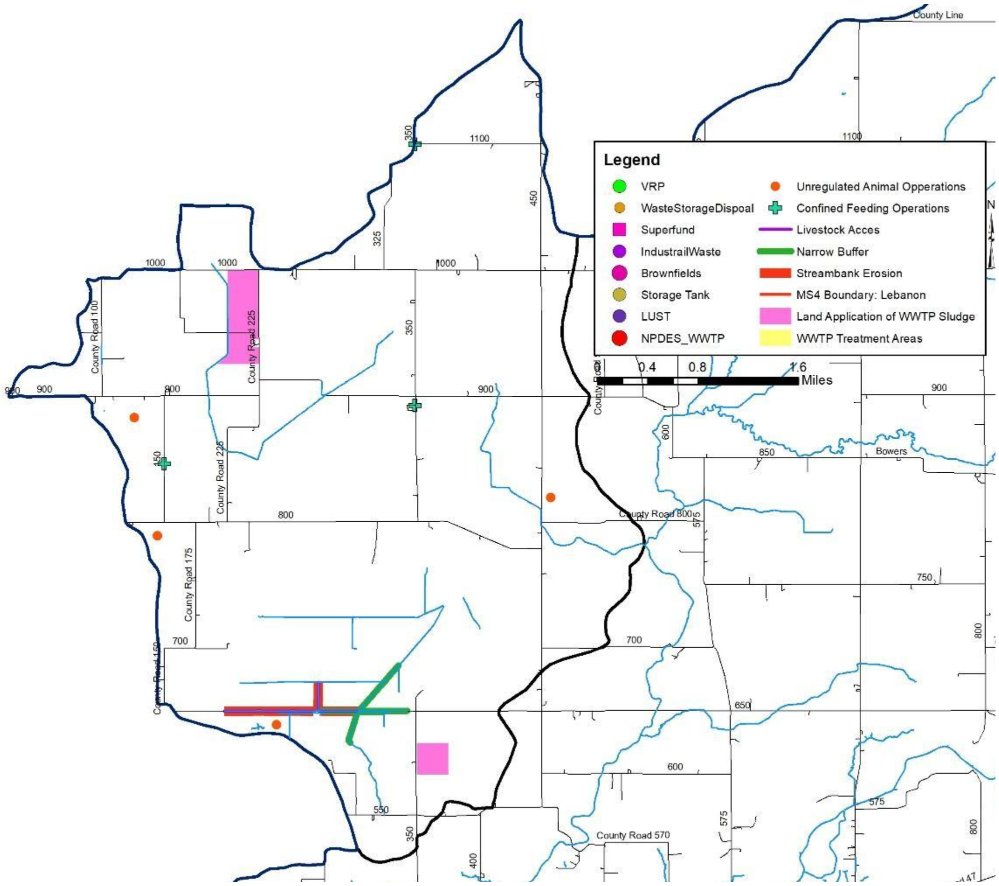


Figure 57. Potential point and non-point sources of pollution and suggested solutions in the Lye Creek Drain subwatershed.

4.3.4 Non-Point Source Water Quality Issues

Agricultural land uses are the predominant land use in the Lye Creek Drain subwatershed. Additionally, four unregulated animal operations housing more than 76 horses and cows were identified during the windshield survey. Based on windshield survey observations, livestock have access to 1.2 miles (8.3%) of Lye Creek Drain subwatershed streams. There are three active CFOs housing up to 21,164 pigs and cows in the subwatershed. In total, manure from these animal operations total over 432,320 tons per year, which contains almost 224,408 pounds of nitrogen, 116,075 pounds of phosphorus and 1.21E+16 colonies of *E. coli*. Streambank erosion and lack of buffers are a concern in the subwatershed. Approximately 1.6 miles (10.9%) of insufficient stream buffers and 1.2 miles (8.3%) of streambank erosion were identified within the subwatershed.

4.3.5 Water Quality Assessment

Waterbodies within the Lye Creek Drain subwatershed have been sampled at two locations (Figure 58). One site in the Lye Creek Drain subwatershed is being sampled as part of the current project. Historic assessments include collection of water chemistry (2 sites) and biology data by IDEM (1 site). No stream gages are in the Lye Creek Drain subwatershed.

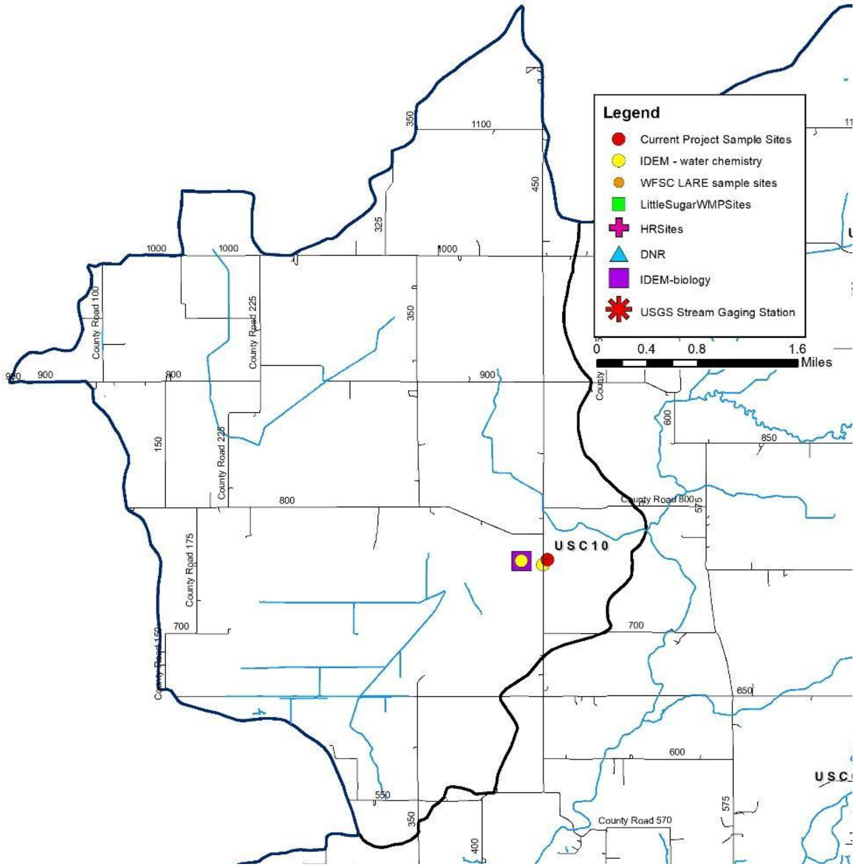


Figure 58. Locations of historic and current water quality data collection in the Lye Creek Drain subwatershed.

Table 27 details historic water chemistry data. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 33% of samples, while total Kjeldahl nitrogen concentrations exceed water quality targets (0.5 mg/L) in 67% of samples. Total phosphorus concentrations exceed water quality targets (0.08 mg/L) in 100% of samples. Turbidity levels exceed water quality targets (5.7 NTU) in 100% of samples.

Table 27. Lye Creek Drain subwatershed historic water quality data summary.

Parameter	Minimum	Maximum	Number Exceeding Target	Number of Samples	Percent Exceeding
Dissolved oxygen (mg/L)	7.64	11.15	0	3	0%
Total Kjeldahl nitrogen (mg/L)	0.17	0.73	2	3	67%
Nitrate (mg/L)	0.2	6	1	3	33%
pH	7.8	8.17	0	3	0%
Total Phosphorus (mg/L)	0.11	0.26	3	3	100%
Specific conductance (μmhos/cm)	694	725	0	3	0%
Turbidity (NTU)	13	56.9	2	2	100%

Table 28 details water quality data collected in the Lye Creek Drain Subwatershed (Site 10). As shown in the table, *E. coli* samples exceed state grab sample standards (235 col/100 ml) in 86% of samples collected. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 100% of samples. Total phosphorus concentrations exceed water quality targets (0.08 mg/L) in 86% of samples. Total suspended solids concentrations exceed water quality targets (15 mg/L) in 29% of samples, while turbidity levels exceed water quality targets (5.7 NTU) in 29% of samples. Dissolved oxygen, pH and conductivity concentrations did not exceed water quality standards in samples collected from this site.

Table 28. Lye Creek Drain subwatershed water quality data summary.

Site		Temp (deg C)	DO (mg/L)	pH	Cond (µmhos/cm)	Turb (NTU)	Nitrate (mg/L)	TP (mg/L)	TSS (mg/L)	*E. coli* (col/100 ml)
10	Median	10.20	11.10	8.01	444.0	2.55	5.07	0.25	6.0	143.9
	Max	22.60	11.80	8.18	802.0	41.08	7.30	2.26	43.0	2419.6
	Min	1.80	6.40	7.27	290.0	0.07	0.56	0.06	2.0	7.3
	#Samples	7	7	7	7	7	7	7	7	7
	#Exceed		0	0	0	2	7	6	2	6
	% Exceed	0%	0%	0%	0%	29%	100%	86%	29%	86%

Fish community assessments were conducted by IDEM at one site with habitat scored concurrent with fish community analysis and one site was assessed as part of the current project. The habitat scores were low (23 and 31) scoring below the state target (51). Fish community assessments rated as fair to poor and 50% rated below IDEM's target for their aquatic life use designation (Table 29). The macroinvertebrate assessment scored 36 with 100% of multihabitat samples meeting their aquatic life use designation.

Table 29. Lye Creek Drain subwatershed biological assessment data summary.

Parameter	Minimum	Maximum	Number Exceeding Target	Number of Samples	Percent Exceeding
Habitat (QHEI)	23	31	0	2	100%
Fish (IBI)	32	40	1	2	50%
Macroinvertebrates (mIBI, Kick)	--	--	--	--	--
Macroinvertebrates (mIBI, Multi Habitat)	36	36	0	1	0%

4.4 <u>Little Potatoe Creek-Lye Creek subwatershed</u>

The Little Potatoe Creek-Lye Creek subwatershed is in the northern portion of the Upper Sugar Creek Watershed and lies within Clinton, Montgomery and Boone Counties (Figure 59). It encompasses one 12-digit HUC watershed: 051201100204. This subwatershed drains 16,114 acres and accounts for 9% of the total watershed area. The Little Potatoe Creek-Lye Creek subwatershed receives water from the

Bowers Creek and Headwaters Potato Creek subwatersheds. The Little Potatoe Creek-Lye Creek subwatershed drains 25.2 square miles. In total, the Little Potatoe Creek-Lye Creek subwatershed, Bowers Creek subwatershed, and Headwaters Potato Creek subwatersheds drain 62 square miles. There are 30.5 miles of stream in the Little Potatoe Creek-Lye Creek subwatershed. IDEM has classified 10.2 miles of stream as impaired for *E. coli* and 0.02 miles of stream as impaired for nutrients, pH and fish consumption.

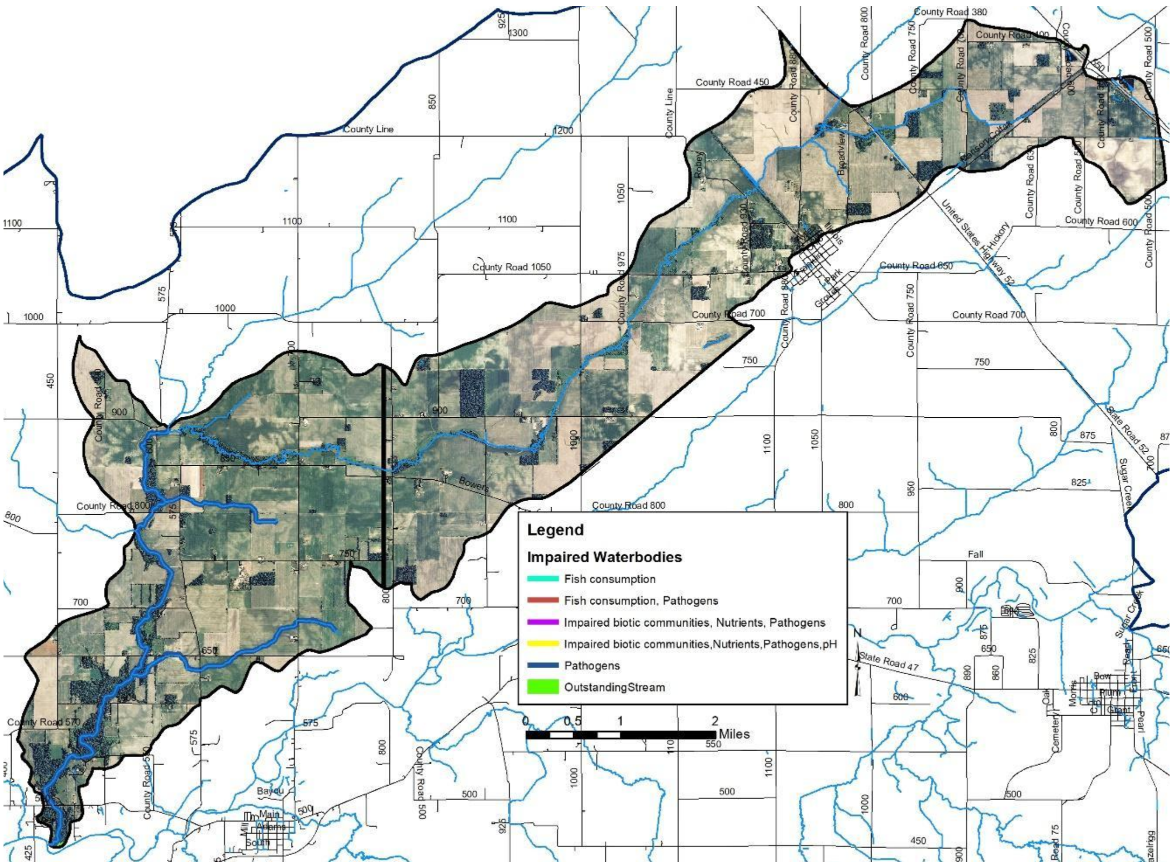


Figure 59. Little Potatoe Creek-Lye Creek subwatershed.

4.4.1 Soils

Hydric soils cover 29.5 acres or 23.6% of the subwatershed. Wetlands currently cover 0.8% (102.2 acres) of the subwatershed. Highly erodible soils nearly cover 57.8% of the subwatershed or 9,321.1 acres. In total, 15,764.7 acres or 97.8% of the subwatershed is identified as very limited for septic use. Maintenance and inspections of septic systems in the Little Potatoe Creek-Lye Creek subwatershed is important to ensure proper function and capacity.

4.4.2 Land Use

Agricultural land use dominates the Little Potatoe Creek-Lye Creek subwatershed at 87.8% (14,145.1 acres) with row crops and pasture land accounting for the majority of agricultural land uses. Forested and urban land uses are the next largest use of the subwatershed, with forested land use only accounting for 4.8% (776.4 acres) of use and urban accounting for 4.7% (762.2 acres). Wetlands, open water, and grassland cover just 417.6 acres, or 2.6%, of the subwatershed.

4.4.3 Point Source Water Quality Issues

There are no point sources of water pollution in the subwatershed (Figure 60).

4.4.4 Non-Point Source Water Quality Issues

Agricultural land uses are the predominant land uses in the Little Potatoe Creek-Lye Creek subwatershed. Additionally, a number of small animal operations, pastures, and confined feeding operations are also present. Surveyors observed 11 unregulated animal operations housing more than 161 cows, horses and sheep during the windshield survey (Figure 60). There are two active CFOs housing up to 6,274 cows and pigs in the subwatershed. Based on windshield survey observations, livestock have access to 1.2 miles of the Little Potatoe Creek-Lye Creek subwatershed streams. Animals produce more than 43,507 tons of manure annually which contains more than 77,350 pounds nitrogen, 55,812 pounds of phosphorus and more than 6.04E+14 colonies of *E. coli*. Streambank erosion and lack of buffers are a concern in the subwatershed. Approximately 1.5 miles (5%) of insufficient stream buffers and 7.9 miles (25.8%) of streambank erosion were identified within the Little Potatoe Creek-Lye Creek subwatershed.

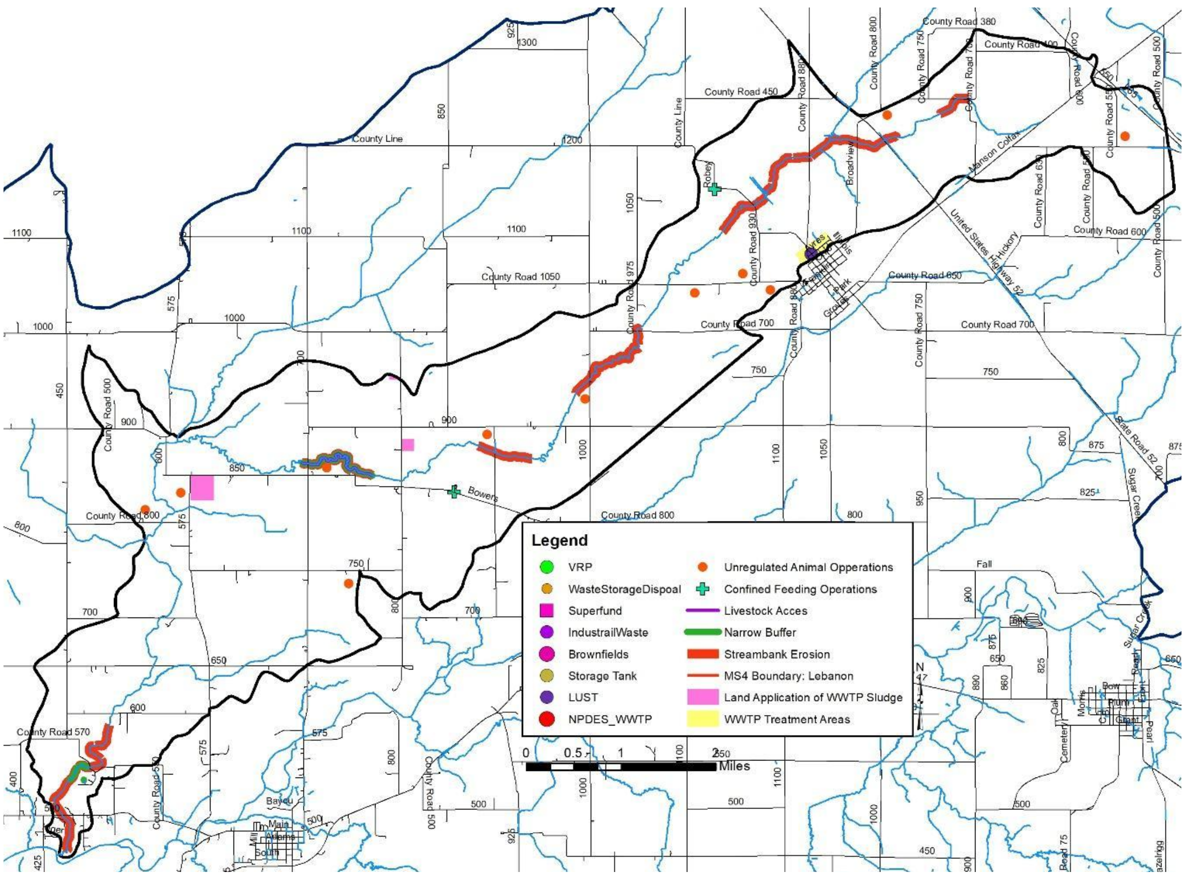


Figure 60. Potential point and non-point sources of pollution and suggested solutions in the Little Potatoe Creek-Lye Creek subwatershed.

4.4.5 Water Quality Assessment

Waterbodies within the Little Potatoe Creek-Lye Creek subwatershed have been sampled at four locations historically (Figure 61). One site in the Little Potatoe Creek-Lye Creek subwatershed is being sampled as part of the current project. Historic assessments include collection of water chemistry (3 sites) and biology data by IDEM (1 site) and Hoosier Riverwatch Volunteers (1 site). No stream gages are in the Little Potatoe Creek-Lye Creek subwatershed.

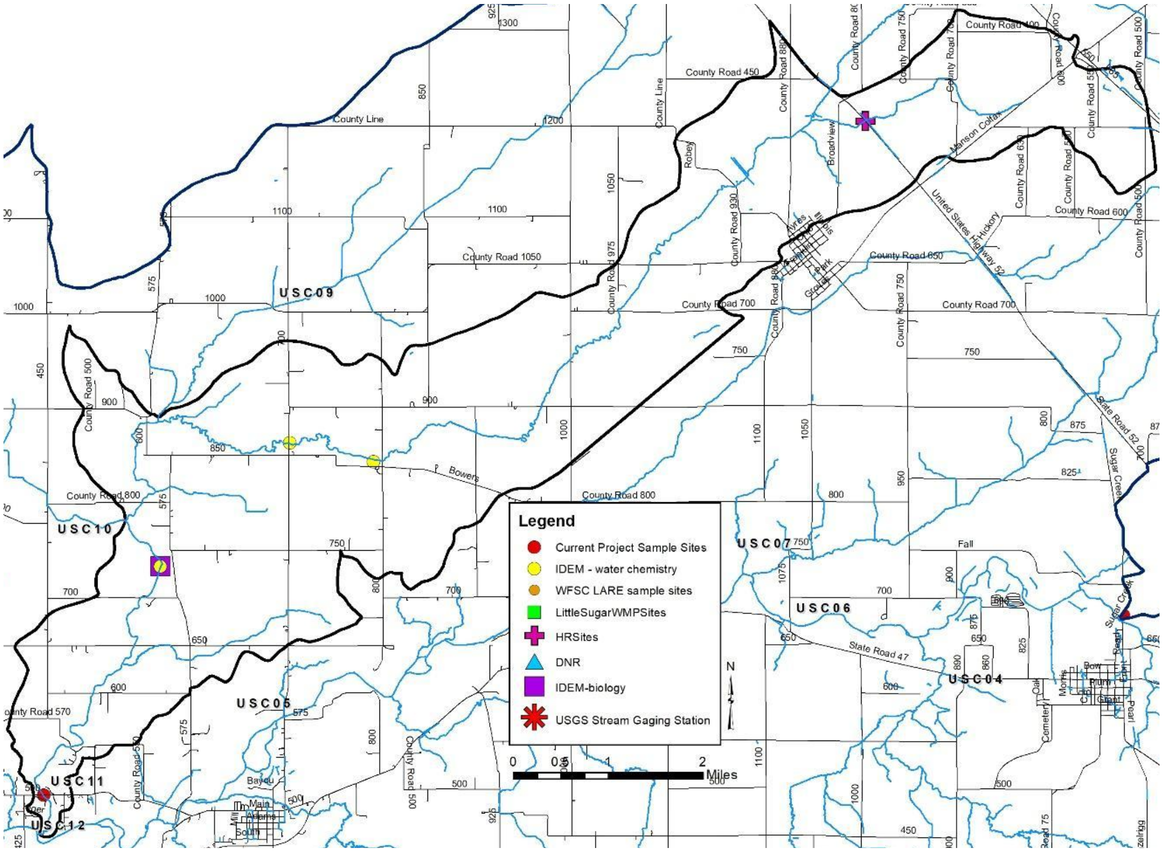


Figure 61. Locations of historic and current water quality data collection in the Little Potatoe Creek-Lye Creek subwatershed.

Table 30 details historic water chemistry data collected in the Little Potatoe Creek-Lye Creek subwatershed. As shown in the table, none of the dissolved oxygen, conductivity or pH samples exceeded state standards or target concentrations. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 25% of samples, while total Kjeldahl nitrogen concentrations exceed water quality targets (0.5 mg/L) in 75% of samples. Total phosphorus concentrations exceed water quality targets (0.08 mg/L) in 100% of samples. Turbidity levels exceed water quality targets (5.7 NTU) in 25% of samples.

Table 30. Little Potatoe Creek-Lye Creek subwatershed historic water quality data summary.

Parameter	Minimum	Maximum	Number Exceeding Target	Number of Samples	Percent Exceeding
Dissolved oxygen (mg/L)	4.92	11.45	0	4	0%
E. coli (col/100 ml)	--	--	--	--	--
Total Kjeldahl nitrogen (mg/L)	0.38	1.8	3	4	75%
Nitrate (mg/L)	0.07	9.3	1	4	25%

pH	7.82	8.35	0	4	0%
Total Phosphorus (mg/L)	0.13	0.3	4	4	100%
Specific conductance (μmhos/cm)	545	621	0	4	0%
Turbidity (NTU)	55.79	55.79	1	4	25%

Table 31 details water quality data collected in the Little Potatoe Creek-Lye Creek Subwatershed (Site 11). As shown in the table, *E. coli* samples exceed state grab sample standards (235 col/100 ml) in 17% of samples collected. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 67% of samples. Total phosphorus concentrations exceed water quality targets (0.08 mg/L) in 67% of samples. Total suspended solids concentrations exceed water quality targets (15 mg/L) in 17% of samples, while turbidity levels exceed water quality targets (5.7 NTU) in 33% of samples. Dissolved oxygen, pH and conductivity concentrations did not exceed water quality standards in samples collected from this site.

Table 31. Little Potatoe Creek- Lye Creek subwatershed water quality data summary.

Site		Temp (deg C)	DO (mg/L)	pH	Cond (μmhos/cm)	Turb (NTU)	Nitrate (mg/L)	TP (mg/L)	TSS (mg/L)	*E. coli* (col/100 ml)
11	Median	11.15	8.75	8.24	515.5	1.62	1.31	0.15	3.50	117.8
	Max	23.20	11.50	8.42	740.0	84.00	7.02	1.44	83.00	365.4
	Min	-0.10	5.20	7.57	262.0	0.02	0.16	0.02	2.00	14.5
	#Samples	12	12	12	12	12	12	12	12	12
	#Exceed		0	0	0	4	8	8	2	2
	% Exceed	0%	0%	0%	0%	33%	67%	67%	17%	17%

IDEM conducted a fish community assessment at one site and one site was assessed as part of the current project. Habitat was assessed concurrently with the fish community assessment (Table 32). Habitat scored well rating 60 to 67 of 100 points scoring above the state target (51). The fish community assessment rated poor to good scoring 40 and 46 and meeting the state's aquatic life use designation. The macroinvertebrate assessment scored 36 with 100% of multihabitat samples meeting their aquatic life use designation (Table 32).

Table 32. Little Potatoe Creek-Lye Creek subwatershed biological assessment data summary.

Parameter	Minimum	Maximum	Number Exceeding Target	Number of Samples	Percent Exceeding
Habitat (QHEI)	60	67	0	2	0%
Fish (IBI)	40	46	0	2	0%
Macroinvertebrates (mIBI, Kick)	--	--	--	--	--
Macroinvertebrates	36	36	0	1	0%

(mIBI, Multi Habitat)					

4.5 Little Creek-Little Sugar Creek subwatershed

The Little Creek-Little Sugar Creek subwatershed lies fully within Montgomery County (Figure 62). It encompasses one 12-digit HUC watershed: 051201100301. This subwatershed drains 16,181 acres and accounts for 9% of the total watershed area. In total, the Little Creek-Little Sugar Creek subwatershed drains 25.3 square miles. There are 43.7 miles of stream. There are no recorded impairments to the Little Creek-Little Sugar Creek subwatershed.

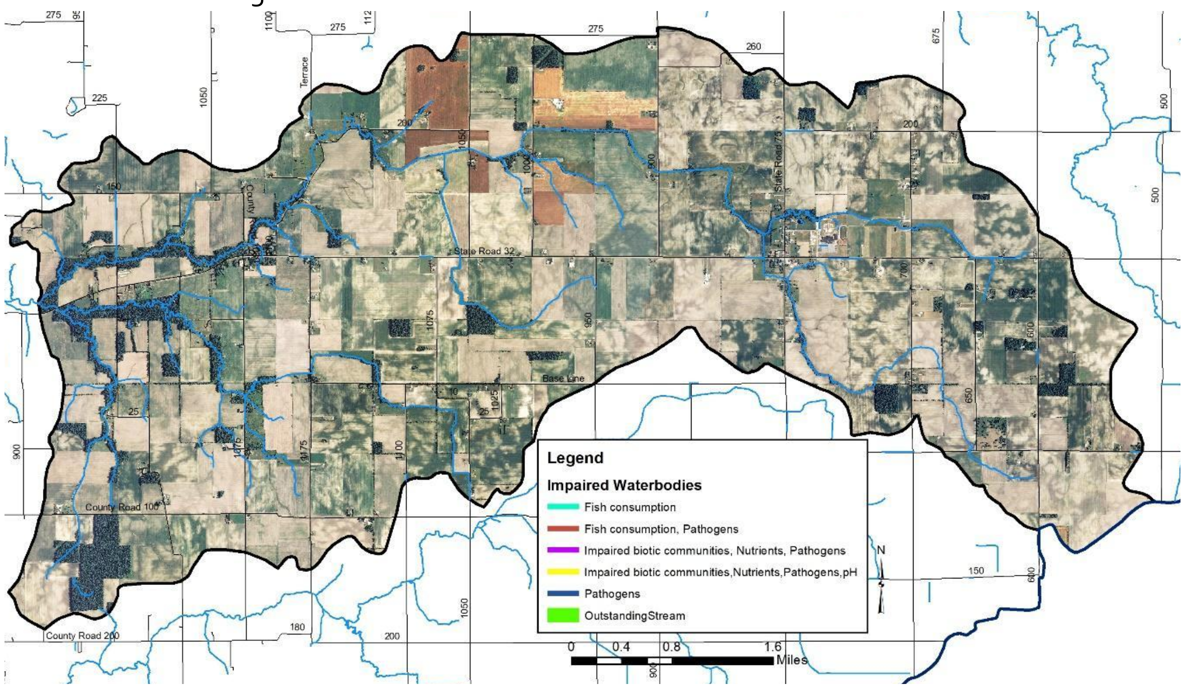


Figure 62. Little Creek-Little Sugar Creek subwatershed.

4.5.1 Soils

Hydric soils cover 6,452.9 acres (39.9%) of the subwatershed. Wetlands currently cover 1.2% (191.2 acres) of the subwatershed. Highly erodible soils cover over half of the subwatershed (58.1%). In total, 16,169.2 miles (99.9%) of the subwatershed are identified as very limited for septic use. The majority of the subwatershed is rural indicating homes pump to on-site septic systems. Based on the septic suitability of the soil, the majority of the subwatershed is very limited. Therefore, maintenance and inspections of septic systems in the area are important to ensure proper function and capacity.

4.5.2 Land Use

Agricultural land use makes up the majority of the Little Creek-Little Sugar Creek subwatershed with 90.8% (16,169.2 acres) in agricultural land uses, including row crop and pasture. The remaining three uses account for less than 10% of the overall land use for the subwatershed. Urban land use accounts for 4.3% (703.2 acres). Forested land use accounts for 3.6% (582.1 acres). Wetlands, open water, and grassland cover 191.2 acres, or 1.2%, of the subwatershed.

4.5.3 Land Use

Point Source Water Quality Issues

There are few potential point sources of water pollution in the subwatershed. There are two underground storage tank sites (Figure 63) in the subwatershed. There are no NPDES-permitted facilities, open dumps, brownfields, corrective action sites, voluntary remediation sites, or industrial waste facilities located within the Little Creek-Little Sugar Creek subwatershed.

4.5.4 Non-Point Source Water Quality Issues

Agricultural land use is the predominant land use in the Little Creek-Little Sugar Creek subwatershed. During the windshield survey, 17 unregulated animal operations housing more than 150 cows, horses, and sheep were identified. Livestock have access to 1.7 miles (3.9%) of Little Creek-Little Sugar Creek streams. There are no active CFOs located within the Little Creek-Little Sugar Creek subwatershed. In total, manure from small animal operations total over 1,855 tons per year, which contains almost 2,279 pounds of nitrogen, 1,090 pounds of phosphorus and 5.80E+14 colonies of *E. coli*. Streambank erosion and lack of buffers are a concern in the subwatershed. Approximately 4.3 miles (9.9%) of insufficient stream buffers and 9.8 miles (22.5%) of streambank erosion were identified within the subwatershed.

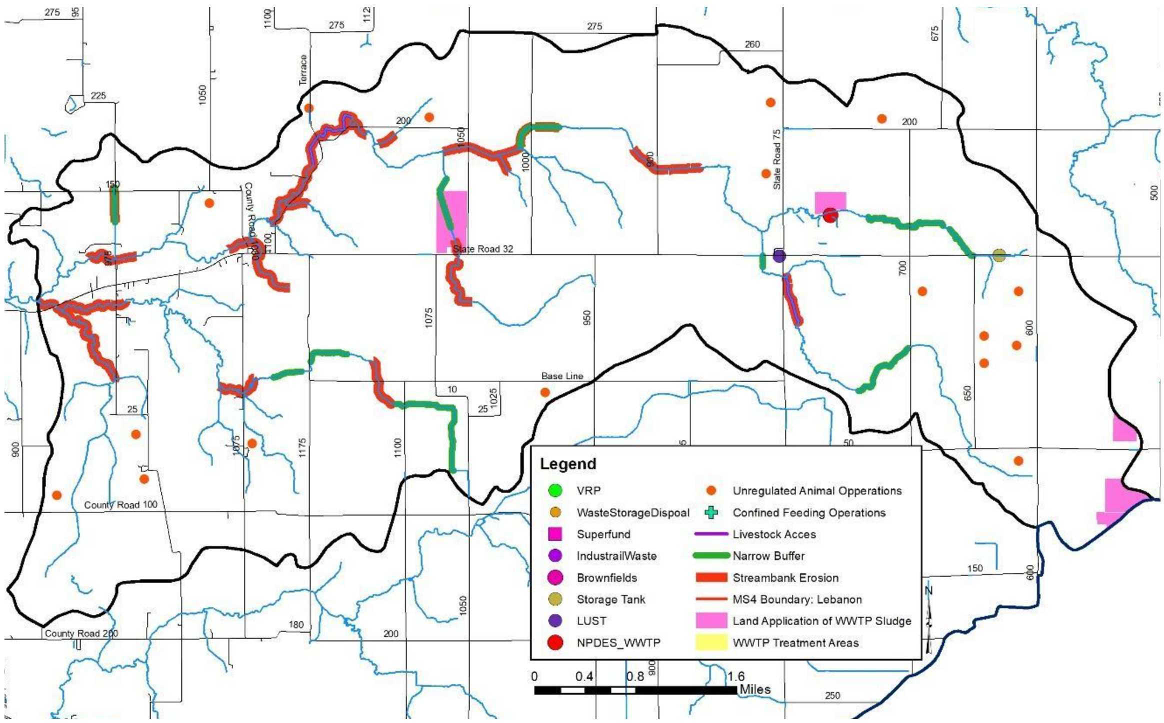


Figure 63. Potential point and non-point sources of pollution and suggested solutions in the Little Creek-Little Sugar Creek subwatershed.

4.5.5 Water Quality Assessment

Waterbodies within the Little Creek-Little Sugar Creek subwatershed have been sampled historically at 11 sites (Figure 64). One site in the Little Creek-Little Sugar Creek subwatershed is being sampled as part of the current project. Assessments include collection of water chemistry through development of the Little Sugar Creek Watershed Management Plan (4 sites), development of the Walnut Fork-Sugar Creek LARE study (5 sites) and by Hoosier Riverwatch volunteers (2 sites). No stream gages are in the Little Creek-Little Sugar Creek subwatershed.

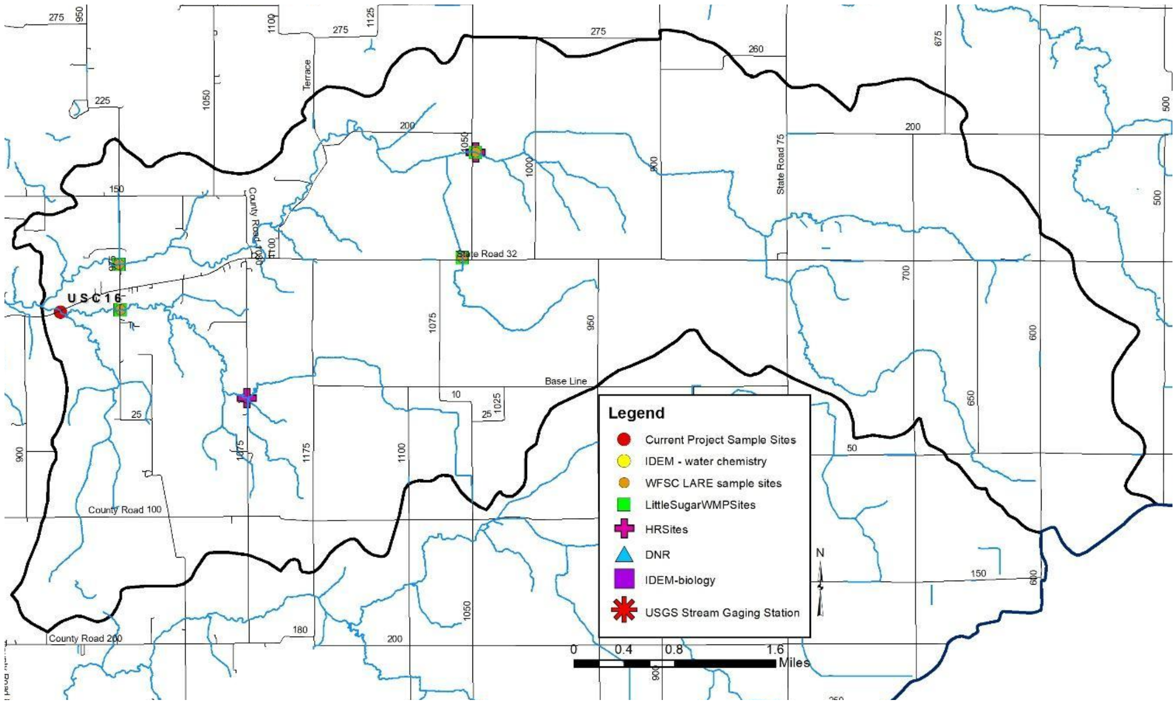


Figure 64. Locations of historic and current water quality data collection in the Little Creek-Little Sugar Creek subwatershed.

Table 33 details historic water chemistry data collected in the Little Creek-Little Sugar Creek subwatershed As shown in the table, conductivity samples exceed state standards (1050 µmhos/cm) in 2% of samples collected. E. coli samples exceed state grab sample standards (235 col/100 ml) in 6% of samples collected. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 70% of samples, while total Kjeldahl nitrogen concentrations exceed water quality targets (0.5 mg/L) in 4% of 67% of samples. Total phosphorus concentrations exceed water quality targets (0.08 mg/L) in 71% of samples. Turbidity levels exceed water quality targets (5.7NTU) in 90% of samples.

Table 33. Little Creek-Little Sugar Creek subwatershed historic water quality data summary.

Parameter	Minimum	Maximum	Number Exceeding Target	Number of Samples	Percent Exceeding
Dissolved oxygen (mg/L)	2.97	19.5	66	179	37%
E. coli (col/100 ml)	0	2420	11	178	6%
Total Kjeldahl nitrogen (mg/L)	0.11	29	120	178	67%
Nitrate(mg/L)	0.12	31	124	178	70%
pH	7.7	8.8	0	164	0%
Total Phosphorus (mg/L)	0.07	31	126	178	71%
Specific conductance (µmhos/cm)	271.1	1711	2	178	1%
Turbidity (NTU)	3.89	740	9	10	90%

Table 34 documents Hoosier Riverwatch volunteer data. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 83% of samples. Orthophosphorus concentrations exceed water quality targets (0.03 mg/L) in 25% of samples. Turbidity levels exceed water quality targets (5.7NTU) in 100% of samples.

Table 34. Little Creek-Little Sugar Creek subwatershed Hoosier Riverwatch historic water quality data summary.

Parameter	Minimum	Maximum	Number Exceeding Target	Number of Samples	Percent Exceeding
Dissolved Oxygen (mg/L)	6	11	0	6	0%
Nitrate (mg/L)	0	22	5	6	83%
Ortho P (mg/L)	0	0	1	4	25%
pH	7	8	0	6	0%
Turbidity (NTU)	15	18	6	6	100%

Table 35 details water quality data collected in the Little Creek-Little Sugar Creek Subwatershed (Site 16). As shown in the table, *E. coli* samples exceed state grab sample standards (235 col/100 ml) in 60% of samples collected. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 80% of samples. Total phosphorus concentrations exceed water quality targets (0.08 mg/L) in 80% of samples. Total suspended solids concentrations exceed water quality targets (15 mg/L) in 20% of samples, while turbidity levels exceed water quality targets (5.7 NTU) in 50% of samples. Dissolved oxygen, pH and conductivity concentrations did not exceed water quality standards in samples collected from this site.

Table 35. Little Creek-Little Sugar Creek Subwatershed water quality data summary.

Site		Temp (deg C)	DO (mg/L)	pH	Cond (µmhos/cm)	Turb (NTU)	Nitrate (mg/L)	TP (mg/L)	TSS (mg/L)	*E. coli* (col/100 ml)
16	Median	14.65	8.60	8.11	427.5	6.86	2.86	0.14	6.50	255.7
	Max	23.40	18.00	8.50	732.0	71.00	4.12	1.17	80.00	2419.6
	Min	2.70	5.30	7.61	228.0	0.44	0.23	0.00	2.00	9.0
	#Samples	10	10	10	10	10	10	10	10	10
	#Exceed		0	0	0	5	8	8	2	6
	% Exceed	0%	0%	0%	0%	50%	80%	80%	20%	60%

Macroinvertebrate community assessments were conducted by Arion Consultants as part of the Walnut Fork-Sugar Creek diagnostic study at five sites and one site was assessed as part of the current project. Habitat was scored concurrently with biological monitoring. Habitat scores ranged from 17 to 62 with 83% of sites scoring below the state target (51). Fish assessments scored 42 rating fair with 100% of samples meeting their aquatic life use designation Macroinvertebrate assessments scored from 24 to 42 with 83% of multihabitat samples not meeting their aquatic life use designation (Table 36).

Table 36. Little Creek-Little Sugar Creek subwatershed biological assessment data summary.

Parameter	Minimum	Maximum	Number Exceeding Target	Number of Samples	Percent Exceeding
Habitat (QHEI)	17	62	5	6	83%
Fish (IBI)	42	42	0	1	0%
Macroinvertebrates (mIBI, Kick)	--	--	--	--	--
Macroinvertebrates (mIBI, Multi Habitat)	24	42	5	6	83%

4.6 Little Sugar Creek subwatershed

The Little Sugar Creek subwatershed is lies within Montgomery and Boone Counties (Figure 65). It encompasses one 12-digit HUC watershed: 051201100302. This subwatershed drains 12,917 acres and accounts for 7% of the total watershed area. In total, the Little Sugar Creek subwatershed drains 20.2 square miles. There are 31.9 miles of stream. IDEM has classified 19.9 miles of stream as impaired for fish consumption.

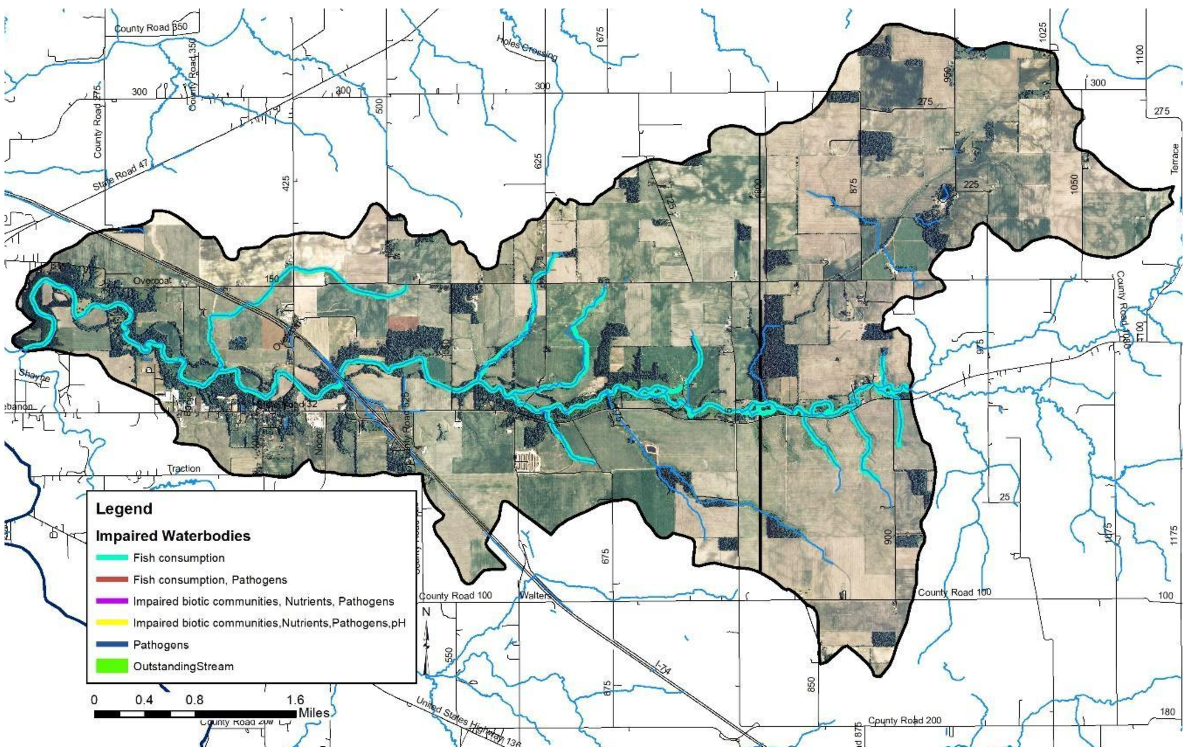


Figure 65. Little Sugar Creek subwatershed.

4.6.1 Soils

Hydric soils cover 3,052.0 acres (23.6%) of the subwatershed. Wetlands currently cover 0.8% (102.2 acres) of the subwatershed. Highly erodible soils cover over half of the subwatershed (69.3%). In total, 12,741.7 acres (98.6%) of the subwatershed are identified as very limited for septic use. The majority of the subwatershed is rural, indicating homes pump to on-site septic systems. Based on the septic suitability of the soil, the majority of the subwatershed is very limited. Therefore, maintenance and inspections of septic systems in the area are important to ensure proper function and capacity.

4.6.2 Land Use

Agricultural land uses are the major land use of the Little Sugar Creek subwatershed (85.5%) (11,038.1 acres) including row crop and pasture. Nearly 8.5% (1,096.8 acres) of the subwatershed is in forested land use. Urban land use accounts for 5.2% (669.6 acres) of the subwatershed with portions of unincorporated Crawfordsville within this subwatershed. Wetlands, open water, and grassland cover 102.2 acres, or 0.8%, of the subwatershed.

4.6.3 Point Source Water Quality Issues

There are no point sources of water pollution in the subwatershed (Figure 66).

4.6.4 Non-Point Source Water Quality Issues

Agricultural land uses are the predominant land uses in the Little Sugar Creek subwatershed. Seven unregulated animal operations housing more than 113 cows and horses were identified during the windshield survey. Livestock have access to 0.5 miles (1.7%) of Little Sugar Creek streams. There are two active CFOs which house 16,643 pigs and cows located within the Little Sugar Creek subwatershed. In total, manure from small animal operations and the CFOs total over 161,910 tons per year, which contains almost 194,714 pounds of nitrogen, 132,679 pounds of phosphorus and 3.27E+15 colonies of *E. coli*. Streambank erosion and lack of buffers are a concern in the subwatershed. Approximately 1.0 mile (3.2%) of insufficient stream buffers and 6.7 miles (21.1%) of streambank erosion were identified within the subwatershed.

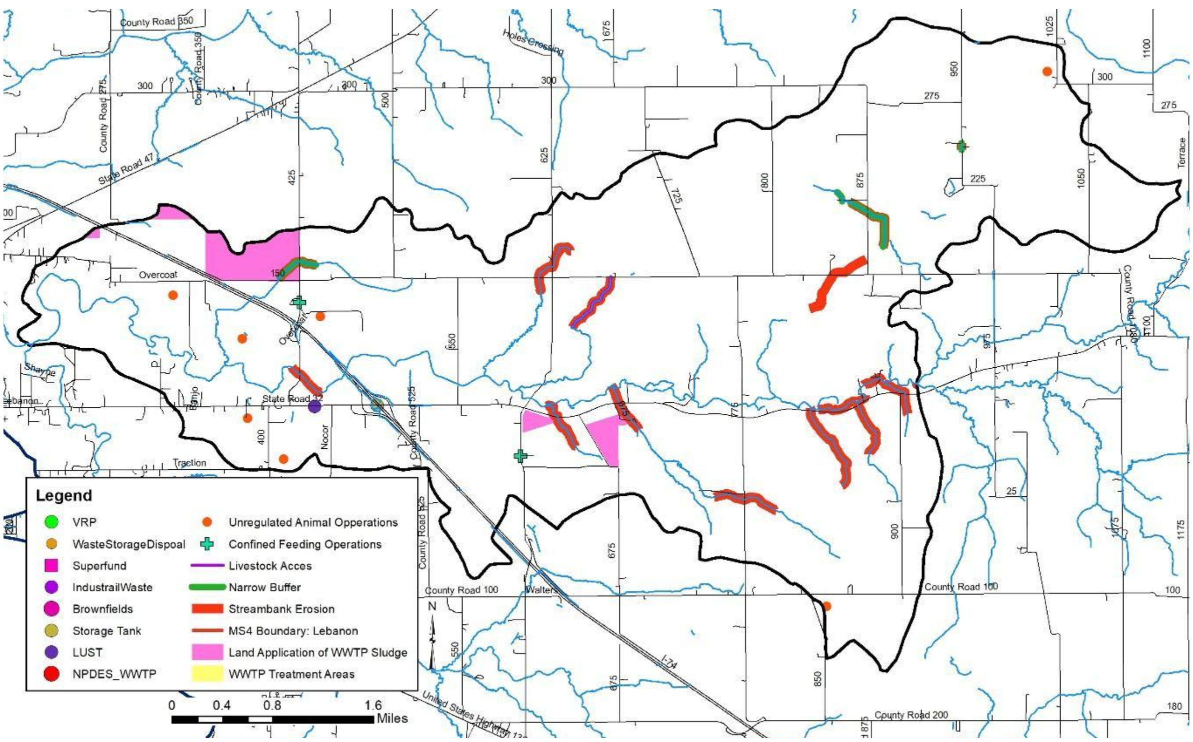


Figure 66. Potential point and non-point sources of pollution and suggested solutions in the Little Sugar Creek subwatershed.

4.6.5 Water Quality Assessment

Waterbodies within the Little Sugar Creek subwatershed have been sampled historically at 12 locations (Figure 67). One site in the Little Sugar Creek subwatershed is being sampled as part of the current project (insert data when available). Historic assessments include collection of water chemistry (3 sites), as part of development of the Little Sugar Creek watershed management plan and via Hoosier Riverwatch Volunteers (2 sites). No stream gages are in the Little Sugar Creek subwatershed.

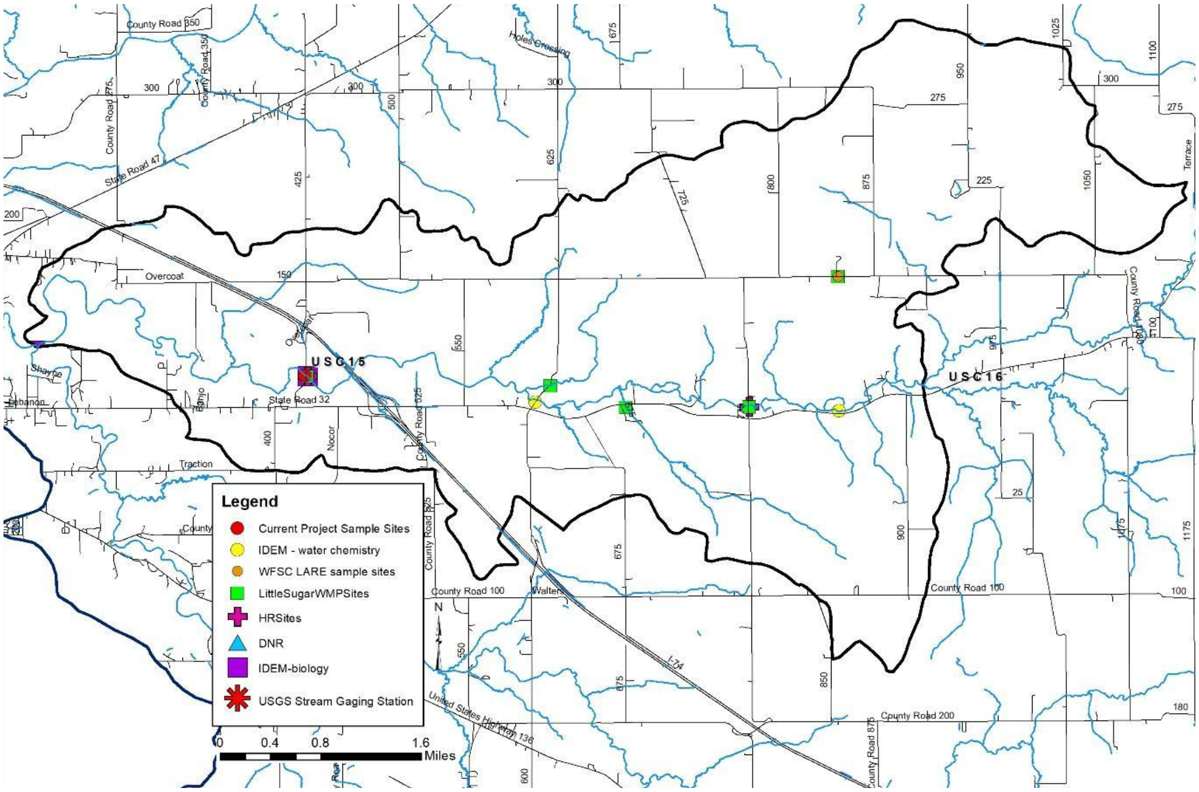


Figure 67. Locations of historic and current water quality data collection in the Little Sugar Creek subwatershed.

Table 37 details historic water chemistry data collected in the Little Sugar Creek subwatershed. As shown in the table, conductivity samples exceed state standards (1050 µmhos/cm) in 3% of samples collected. E. coli samples exceed state grab sample standards (235 col/100 ml) in 2% of samples collected. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 71% of samples, while total Kjeldahl nitrogen concentrations exceed water quality targets (0.5 mg/L) in 53% of samples. Total phosphorus concentrations exceed water quality targets (0.08 mg/L) in 71% of samples. Turbidity levels exceed water quality targets (5.7 NTU) in 50% of samples.

Table 37. Little Sugar Creek subwatershed historic water quality data summary.

Parameter	Minimum	Maximum	Number Exceeding Target	Number of Samples	Percent Exceeding
Dissolved oxygen (mg/L)	6.92	16.69	62	252	25%
E. coli (col/100 ml)	1	2420	5	252	2%
Total Kjeldahl nitrogen (mg/L)	0.02	48.6	136	258	53%
Nitrate (mg/L)	0.02	79	189	268	71%
pH	0.02	79	160	263	61%
Total Phosphorus (mg/L)	0.02	30	184	258	71%
Specific conductance (µmhos/cm)	211	1808	7	270	3%
Turbidity (NTU)	4.66	8.09	1	2	50%

Table 38 documents Hoosier Riverwatch volunteer data. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 100% of samples. Orthophosphorus concentrations exceed water quality targets (0.03 mg/L) in 33% of samples. Turbidity levels exceed water quality targets (5.7NTU) in 100% of samples.

Table 38. Little Sugar Creek subwatershed Hoosier Riverwatch historic water quality data summary.

Parameter	Minimum	Maximum	Number Exceeding Target	Number of Samples	Percent Exceeding
Dissolved Oxygen (mg/L)	6	12	0	8	0%
E. coli (col/100 ml)	67	67	0	2	0%
Nitrate (mg/L)	2	22	8	8	100%
Ortho P (mg/L)	0	0	2	6	33%
pH	7	8	0	8	0%
Turbidity (NTU)	15	15	7	7	100%

Table 39 details water quality data collected in the Little Sugar Creek Subwatershed (Site 15). As shown in the table, *E. coli* samples exceed state grab sample standards (235 col/100 ml) in 25% of samples collected. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 100% of samples. Total phosphorus concentrations exceed water quality targets (0.08 mg/L) in 67% of samples. Total suspended solids concentrations exceed water quality targets (15 mg/L) in 25% of samples. Turbidity levels exceed water quality targets (5.7 NTU) in 25% of samples. Dissolved oxygen, pH and conductivity concentrations did not exceed water quality standards in samples collected from this site.

Table 39. Little Sugar Creek Subwatershed water quality data summary.

Site		Temp (deg C)	DO (mg/L)	pH	Cond (µmhos/cm)	Turb (NTU)	Nitrate (mg/L)	TP (mg/L)	TSS (mg/L)	*E. coli* (col/100 ml)
15	Median	12.95	9.70	8.23	533.0	2.15	3.09	0.16	3.00	98.5
	Max	26.40	11.70	8.46	703.0	110.00	5.94	2.08	130.00	2419.6
	Min	3.50	6.10	7.60	219.0	0.00	1.35	0.01	1.00	11.1
	#Samples	12	12	12	12	12	12	12	12	12
	#Exceed		0	0	0	3	12	8	3	3
	% Exceed	0%	0%	0%	0%	25%	100%	67%	25%	25%

IDEM assessed the macroinvertebrate community at one site in the Little Sugar Creek subwatershed and one site was assessed as part of the current project (Table 40). Habitat scored 65 to 69 which is above the state target (51). The fish community scored 50 which rates as good with 100% of multihabitat samples meeting their aquatic life use designation Macroinvertebrate assessments indicated the community scored 40 to 42 using the multihabitat assessment which meets the state's aquatic life use designation (Table 40).

Table 40. Little Sugar Creek subwatershed biological assessment data summary.

Parameter	Minimum	Maximum	Number Exceeding Target	Number of Samples	Percent Exceeding
Habitat (QHEI)	65	69	0	2	0%
Fish (IBI)	50	50	0	1	0%
Macroinvertebrates (mIBI, Kick)	--	--	--	--	--
Macroinvertebrates (mIBI, Multi Habitat)	40	42	0	2	0%

4.7 Town of Linnsburg-Walnut Fork Sugar Creek subwatershed

The Town of Linnsburg-Walnut Fork Sugar Creek subwatershed forms much of the southern boundary of the Upper Sugar Creek Watershed (Figure 68). It encompasses one 12-digit HUC watershed: 051201100303 and is the largest subwatershed draining 30,600 acres and accounting for 17% of the total watershed area. In total, the Town of Linnsburg-Walnut Fork Sugar Creek subwatershed drains 47.8 square miles. There are 88.6 miles of stream. IDEM has classified 51.9 miles of stream as impaired for fish consumption and *E. coli*.

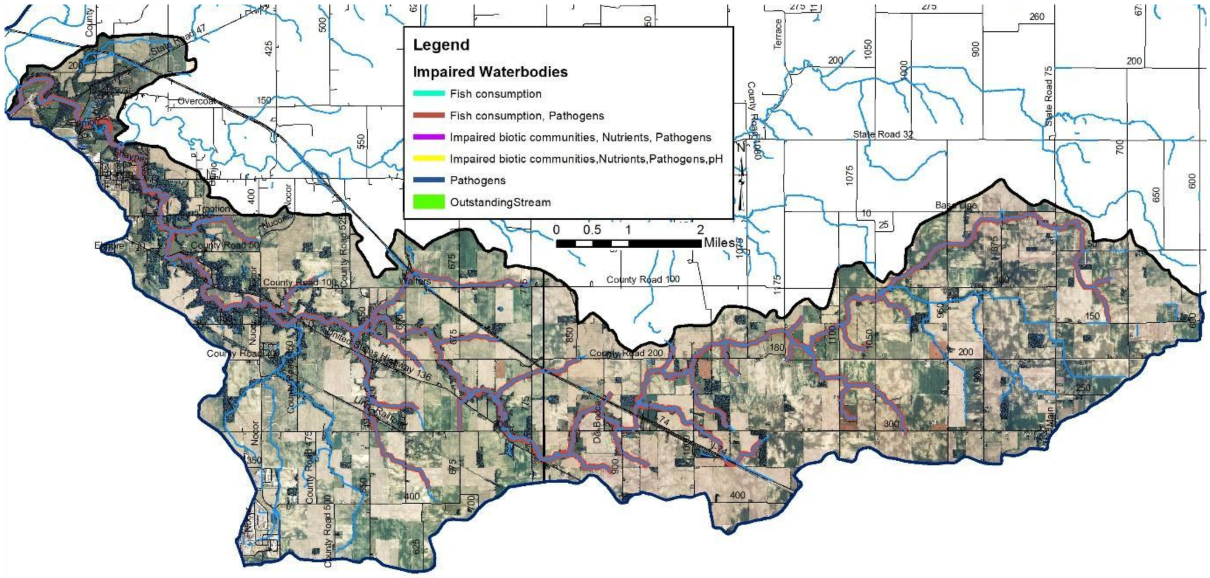


Figure 68. Town of Linnsburg-Walnut Fork Sugar Creek subwatershed.

4.7.1 Soils

Hydric soils cover 8,281.4 acres (27.1%) of the subwatershed. Wetlands currently cover 0.9% (270.5 acres) of the subwatershed. Highly erodible soils cover over half of the subwatershed (66.2%). In total, 30,285.9 miles (99%) of the subwatershed are identified as very limited for septic use. The majority of the subwatershed is rural, indicating homes pump to on-site septic systems. Based on the septic suitability of the soil, the majority of the subwatershed is very limited. Therefore, maintenance and inspections of septic systems in the area are important to ensure proper function and capacity.

4.7.2 Land Use

Agricultural land use dominates the Town of Linnsburg-Walnut Fork Sugar Creek subwatershed with 84.5% (25,850.7 acres) in agricultural land uses, including row crop and pasture. Forested land use is the second largest uses of the subwatershed accounting for 7.4% (2,258.4 acres) of the subwatershed. Additionally, urban land use accounts for 7.2% (2,197.0 acres) of the subwatershed. Wetlands, open water and grassland cover 270.5 acres, or 0.9%, of the subwatershed.

4.7.3 Point Source Water Quality Issues

There are few potential point sources of water pollution in the subwatershed. There are two underground storage tank sites (Figure 69) in the subwatershed. There is one NPDES-permitted facility - the Nucor Steel Corporation. There are no open dumps, brownfields, corrective action sites, voluntary remediation sites, or industrial waste facilities located within the Town of Linnsburg-Walnut Fork subwatershed.

4.7.4 Non-Point Source Water Quality Issues

Agricultural land use is the predominant land use in the Town of Linnsburg-Walnut Fork subwatershed. During the windshield survey, 26 unregulated animal operations housing more than 379 cows, horses and sheep were identified. Livestock have access to 4.5 miles (5.1%) of Town of Linnsburg-Walnut Fork subwatershed streams. There is one active CFO which houses up to 7,800 cows located within the Town of Linnsburg-Walnut Fork subwatershed. In total, manure from small animal operations and the CFO total over 178,356 tons per year, which contains almost 85,450 pounds of nitrogen, 41,893 pounds of phosphorus and 5.34E+15 colonies of *E. coli*. Streambank erosion and lack of buffers are a concern in the subwatershed. Approximately 9.7 miles (11%) of insufficient stream buffers and 17.1 miles (19.2%) of streambank erosion were identified within the subwatershed.

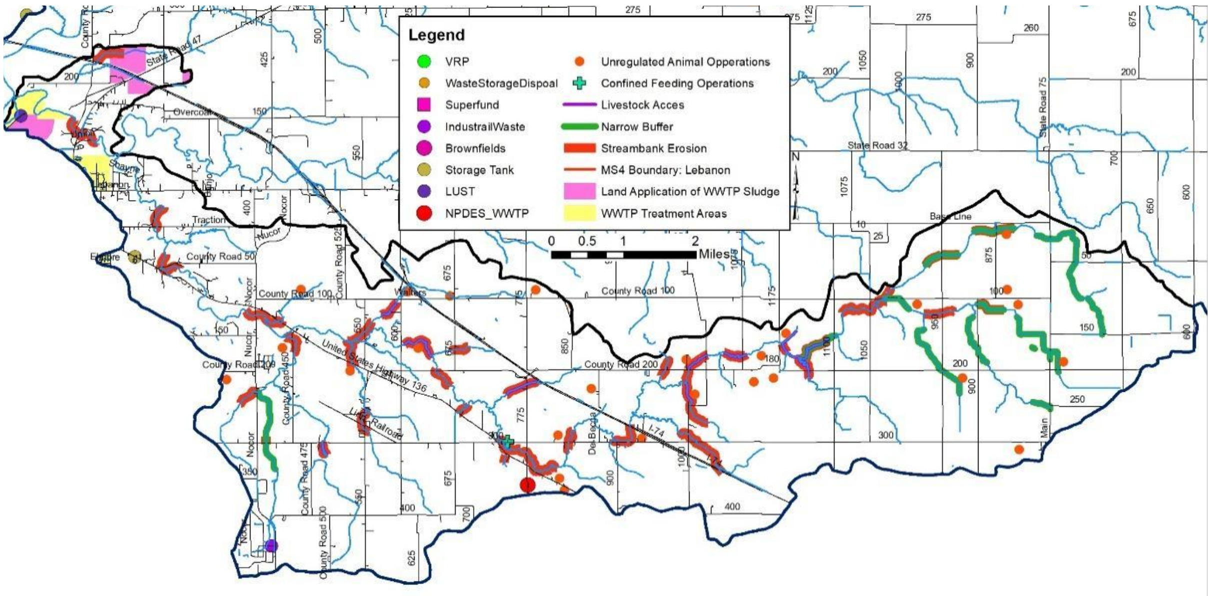


Figure 69. Potential point and non-point sources of pollution and suggested solutions in the Town of Linnsburg-Walnut Fork Sugar Creek subwatershed.

4.7.5 Water Quality Assessment

Waterbodies within the Town of Linnsburg-Walnut Fork Sugar Creek subwatershed have been sampled historically at 13 locations (Figure 70). One site in the Town of Linnsburg-Walnut Fork Sugar Creek subwatershed is being sampled as part of the current project. Historic assessments include collection of water chemistry (3 sites) and biology data by IDEM (4 sites), as part of the Walnut Fork-Sugar Creek LARE study (8 sites for water chemistry and biology) and Hoosier Riverwatch Volunteers (2 sites). No stream gages are in the Town of Linnsburg-Walnut Fork Sugar Creek subwatershed.

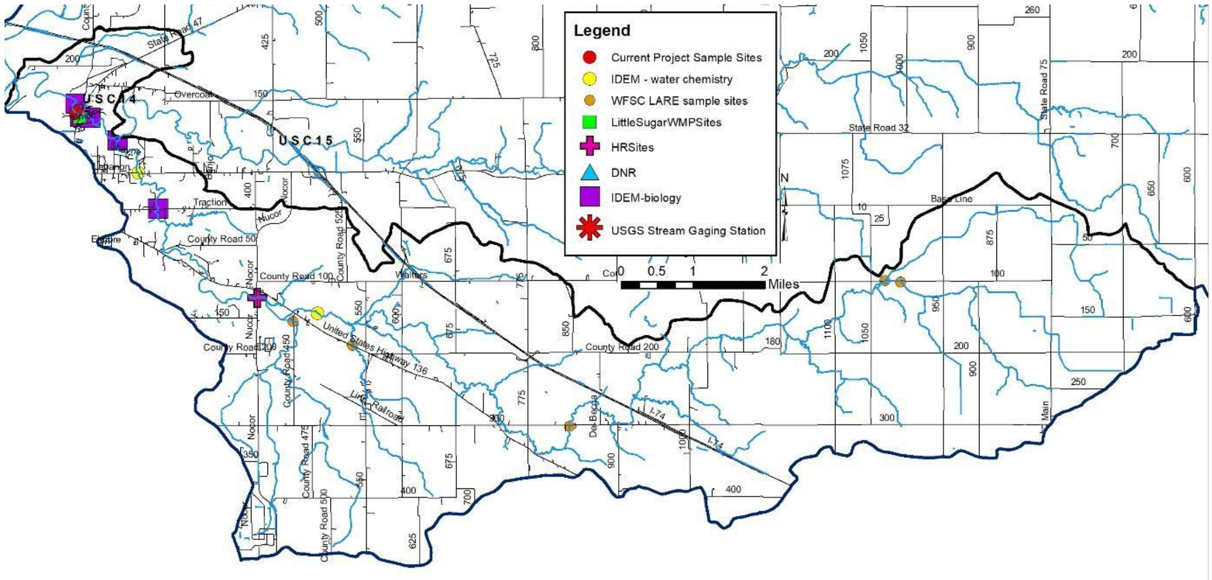


Figure 70. Locations of historic and current water quality data collection in the Town of Linnsburg-Walnut Fork Sugar Creek subwatershed.

Table 41Table 41 details historic water chemistry data collected in the Town of Linnsburg-Walnut Fork Sugar Creek subwatershed. As shown in the table, conductivity samples exceed state standards (1050 µmhos/cm) in 5% of samples collected. E. coli samples exceed state grab sample standards (235 col/100 ml) in 79% of samples collected. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 93% of samples, while total Kjeldahl nitrogen concentrations exceed water quality targets (0.5 mg/L) in 100% of samples. Total phosphorus concentrations exceed water quality targets (0.08 mg/L) in 59% of samples. Turbidity levels exceed water quality targets (5.7 NTU) in 68% of samples.

Table 41. Town of Linnsburg-Walnut Fork Sugar Creek subwatershed historic water quality data summary.

Parameter	Minimum	Maximum	Number Exceeding Target	Number of Samples	Percent Exceeding
Dissolved oxygen (mg/L)	3.67	137.6	10	29	34%
E. coli (col/100 ml)	36	2420	15	19	79%
Total Kjeldahl nitrogen (mg/L)	0.874	2.51	17	17	100%
Nitrate (mg/L)	0.93	2.66	13	14	93%
pH	8.15	8.43	0	8	0%
Total Phosphorus (mg/L)	0.07	0.441	10	17	59%
Specific conductance (µmhjos/cm)	244.1	1570	1	22	5%
Turbidity (NTU)	2.77	74.3	15	22	68%

Table 42 documents Hoosier Riverwatch volunteer data. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 88% of samples. Orthophosphorus concentrations exceed water quality targets (0.03 mg/L) in 67% of samples. Turbidity levels exceed water quality targets (5.7NTU) in 100% of samples. E. coli samples exceed state grab sample standards (235 col/100 ml) in 20% of samples collected.

Table 42. Town of Linnsburg-Walnut Fork Sugar Creek subwatershed Hoosier Riverwatch historic water quality data summary.

Parameter	Minimum	Maximum	Number Exceeding Target	Number of Samples	Percent Exceeding
Dissolved Oxygen (mg/L)	6	12	0	8	0%
E. coli (col/100 ml)	33	300	1	5	20%
Nitrate (mg/L)	1	22	7	8	88%
Ortho P (mg/L)	0	0	2	3	67%
pH	7	9	0	8	0%
Turbidity (NTU)	15	18	7	7	100%

Table 43details water quality data collected in the Town of Linnsburg-Walnut Fork Sugar Creek Subwatershed (Site 13). As shown in the table, *E. coli* samples exceed state grab sample standards (235 col/100 ml) in 33% of samples collected. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 83% of samples. Total phosphorus concentrations exceed water quality targets (0.08 mg/L) in 67% of samples. Total suspended solids concentrations exceed water quality targets (15 mg/L) in 17% of samples, while turbidity levels exceed water quality targets (5.7 NTU) in 33% of samples. Dissolved oxygen concentrations measured both below the lower water quality standard in 8% of samples collected. Conductivity measured above the water quality target (1050 mmhos/cm) in 8% of samples collected.

Table 43. Town of Linnsburg-Walnut Fork Sugar Creek Subwatershed water quality data summary.

Site		Temp (deg C)	DO (mg/L)	pH	Cond (µmhos/cm)	Turb (NTU)	Nitrate (mg/L)	TP (mg/L)	TSS (mg/L)	*E. coli* (col/100 ml)
14	Median	11.80	8.45	8.20	718.0	2.87	1.88	0.11	4.00	139.3
	Max	21.80	11.60	8.95	1170.0	206.00	4.58	2.10	208.00	2419.6
	Min	2.40	3.90	7.85	257.0	0.00	0.40	0.01	2.00	17.3
	#Samples	12	12	12	12	12	12	12	12	12
	#Exceed		1	0	1	4	10	8	2	4
	% Exceed	0%	8%	0%	8%	33%	83%	67%	17%	33%

Biological monitoring was conducted by IDEM and Arion Consultants as part of the development of the Walnut Fork-Sugar Creek diagnostic study and one site was assessed as part of the current project (Table 44).. In total, IDEM assessed the fish community three times at two sites and the macroinvertebrate community eight times at four sites. Arion Consultants assessed the macroinvertebrate community at seven sites. Habitat assessment occurred concurrently with fish and macroinvertebrate community assessments. Habitat scores ranged from 23 to 89 with 26% of sites (5 of 18) scoring below the state target (51). Fish community assessments rated fair with all assessments meeting the state's aquatic life use designation. Macroinvertebrate assessments rated moderately impaired to slightly impaired using the kick sampling method with all sites meeting their aquatic life use designation and from 16 to 46 with 55% of multihabitat samples not meeting their aquatic life use designation (Table 44).

Table 44. Town of Linnsburg-Walnut Fork-Sugar Creek subwatershed biological assessment data summary.

Parameter	Minimum	Maximum	Number Exceeding Target	Number of Samples	Percent Exceeding
Habitat (QHEI)	23	89	5	19	26%
Fish (IBI)	40	54	0	5	0%
Macroinvertebrates (mIBI, Kick)	3.2	5	0	8	0%
Macroinvertebrates (mIBI, Multi Habitat)	16	46	5	9	55%

4.8 Sanitary Ditch-Prairie Creek subwatershed

The Sanitary Ditch-Prairie Creek subwatershed forms the southeastern corner of the Upper Sugar Creek Watershed and sits in Boone County (Figure 71). It encompasses one 12-digit HUC watershed: 051201100401. This subwatershed drains 14,226 acres and accounts for 8% of the total watershed area. In total, the Sanitary Ditch-Prairie Creek subwatershed drains 22.2 square miles. There are 62.3 miles of stream. There are no recorded impairments in the Sanitary Ditch-Prairie Creek subwatershed.

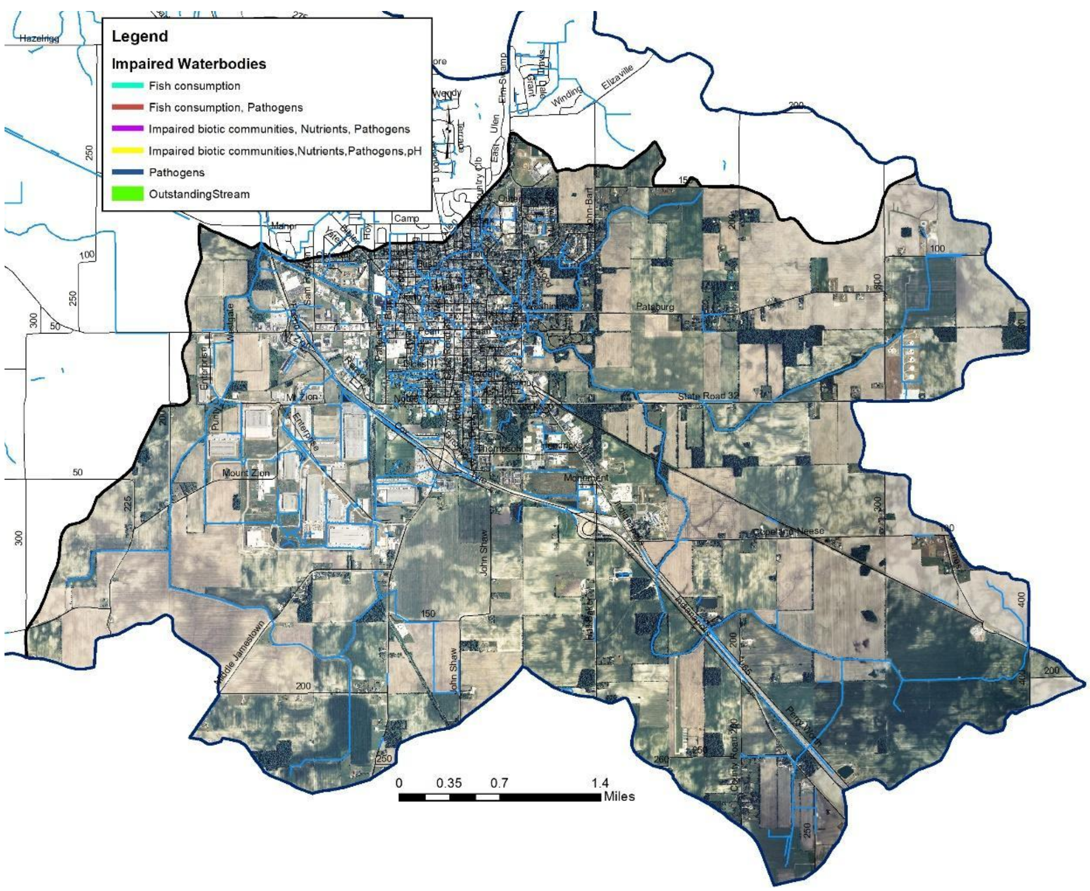


Figure 71. Sanitary Ditch-Prairie Creek subwatershed.

4.8.1 Soils

Hydric soils cover 6,656.6 acres (46.8%) of the subwatershed. Wetlands currently cover 1.8% (254.2 acres) of the subwatershed. Highly erodible soils cover over half of the subwatershed (46%). In total, 14,166.9 acres (99.6%) of the subwatershed are identified as very limited for septic use. The majority of the subwatershed is rural, indicating homes pump to on-site septic systems. Based on the septic suitability of the soil, the majority of the subwatershed is very limited. Therefore, maintenance and inspections of septic systems in the area are important to ensure proper function and capacity.

4.8.2 Land Use

Agricultural land use dominates the Sanitary Ditch-Prairie Creek subwatershed with 71.5% (10,172.3 acres) in agricultural land uses, including row crop and pasture. An additional24.8% (3,530.6 acres) of the subwatershed is in urban land use-with a majority of the City of Lebanon sitting in this subwatershed. The Sanitary Ditch-Prairie Creek subwatershed contains the highest urban land use density of all Upper Sugar Creek subwatersheds. Wetlands, open water and grassland cover 254.2 acres, or 1.8%, of the subwatershed. Forested land use accounts for 1.8% of the subwatershed as well (259.0 acres).

4.8.3 Point Source Water Quality Issues

There are many potential point sources of water pollution in the subwatershed. There are 78 underground storage tank sites (Figure 72) and one NPDES-permitted facility in the subwatershed, the City of Lebanon WWTP. The City of Lebanon is a regulated MS4 community. Of note, this subwatershed also has four brownfields, which are the only brownfields in the watershed. There are no open dumps, corrective action sites, voluntary remediation sites, or industrial waste facilities located within the Sanitary Ditch-Prairie Creek subwatershed.

4.8.4 Non-Point Source Water Quality Issues

Agricultural and urban land uses are the predominant land uses in the Sanitary Ditch-Prairie Creek subwatershed. Additionally, a number of small animal operations and pastures are also present (Figure 72). In total, one unregulated animal operation housing more than 10 cows were identified during the windshield survey. No active confined feeding operations are located within the Sanitary Ditch-Prairie Creek subwatershed. In total, manure from small animal operations total over 219 tons per year, which contains almost 104 pounds of nitrogen, almost 51 pounds of phosphorus and 6.22E+12 colonies of *E. coli*. Livestock appear to have no access to the subwatershed streams based on windshield survey observations. Streambank erosion and lack of buffer is a concern in the subwatershed. Approximately 0.5 miles (0.9%) of streambank erosion and 0.6 miles (0.9%) of narrow buffer were identified within the subwatershed.

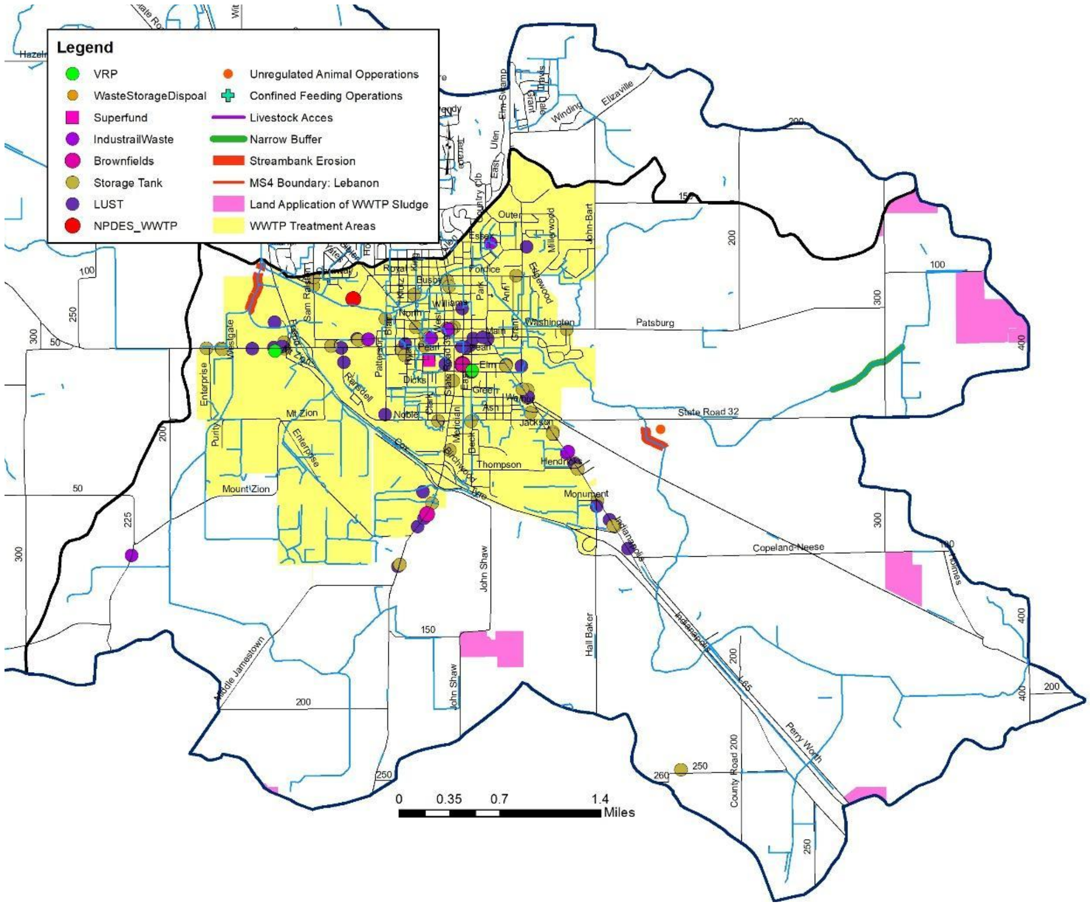


Figure 72. Potential point and non-point sources of pollution and suggested solutions in the Sanitary Ditch-Prairie Creek subwatershed.

4.8.5 Water Quality Assessment

Waterbodies within the Sanitary Ditch-Prairie Creek subwatershed have not been sampled historically. One site in the Sanitary Ditch-Prairie Creek subwatershed is being sampled as part of the current project (Figure 73). No stream gages are in the Sanitary Ditch-Prairie Creek subwatershed.

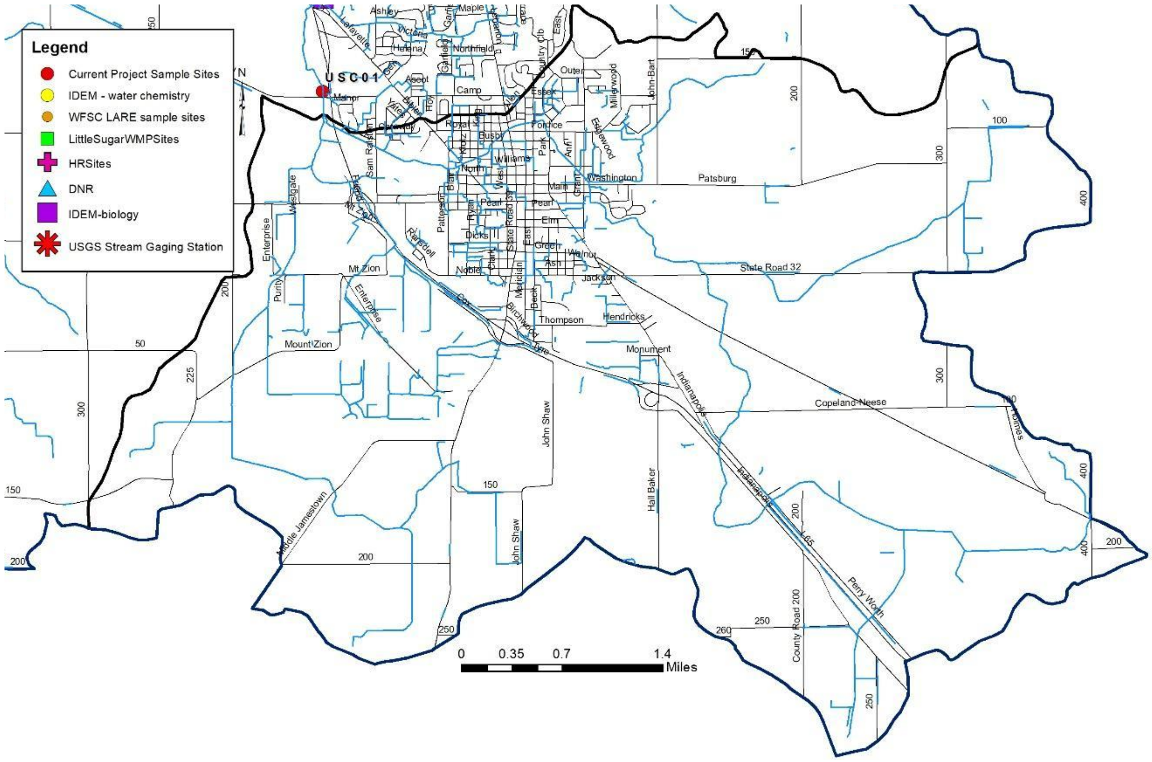


Figure 73. Locations of historic and current water quality data collection in the Sanitary Ditch-Prairie Creek subwatershed.

Table 45 details water quality data collected in Sanitary Ditch-Prairie Creek Subwatershed (Site 1). As shown in the table, *E. coli* samples exceed state standards (235 col/100 ml) in 58% of samples collected. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 100% of samples. Total phosphorus concentrations exceed water quality targets (0.08 mg/L) in 75% of samples. Total suspended solids concentrations exceed water quality targets (15 mg/L) in 8% of samples, while turbidity levels exceed water quality targets (5.7 NTU) in 33% of samples. Dissolved oxygen concentrations did not exceed water quality standards in samples collected from this site. Conductivity measured above the water quality target (1050 µmhos/cm) in 50% of samples collected. This suggests there may be a source of dissolved salts within the Sanitary Ditch-Prairie Creek Subwatershed.

Table 45. Sanitary Ditch-Prairie Creek Subwatershed water quality data summary.

Site		Temp (deg C)	DO (mg/L)	pH	Cond (µmhos/cm)	Turb (NTU)	Nitrate (mg/L)	TP (mg/L)	TSS (mg/L)	*E. coli* (col/100 ml)
1	Median	15.35	10.20	8.17	878.5	2.65	4.85	0.21	3.50	364.6
	Max	25.00	10.90	8.36	1568.0	72.00	10.10	4.29	68.00	2419.6
	Min	3.80	5.00	7.41	321.0	0.00	2.29	0.01	2.00	48.0

	#Samples	12	12	12	12	12	12	12	12	12
	#Exceed		0	0	6	4	12	9	1	7
	% Exceed	0%	0%	0%	50%	33%	100%	75%	8%	58%

Habitat and biological communities were assessed at one site as part of the current project. Habitat scored 44 which is below the state target (51). The fish community scored 46 which rates as good with 100% of samples meeting their aquatic life use designation Macroinvertebrate assessments indicated the community scored 42using the multihabitat assessment which meets the state's aquatic life use designation.

4.9 Deer Creek-Prairie Creek subwatershed

The Deer Creek-Prairie Creek subwatershed forms a majority of the eastern boundary of the Upper Sugar Creek Watershed and is entirely within Boone County (Figure 74). It encompasses one 12-digit HUC watershed: 051201100402 and receives drainage from the Sanitary Ditch-Prairie Creek subwatershed. This subwatershed drains 17,381 acres and accounts for 10% of the total watershed area. In total, the Deer Creek-Prairie Creek subwatershed drains 27.2 square miles. There are 62.9 miles of stream. There are no recorded impairments in the Deer Creek-Prairie Creek subwatershed.

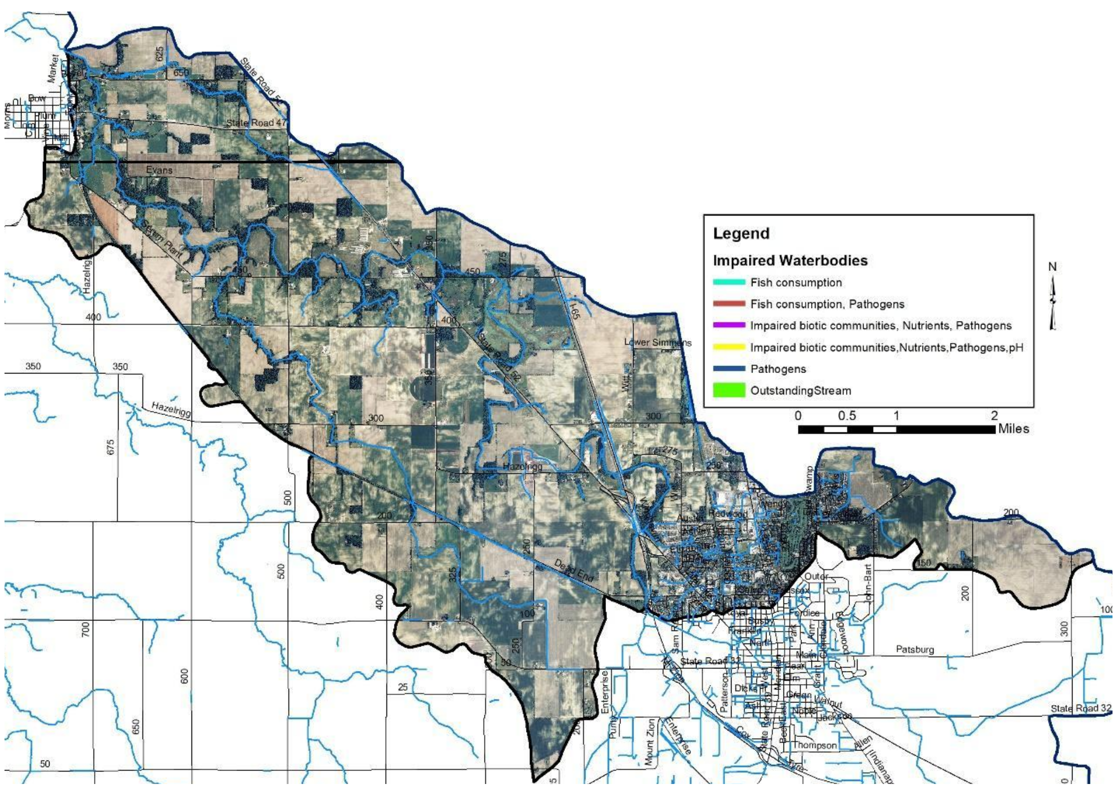


Figure 74. Deer Creek-Prairie Creek subwatershed.

4.9.1 Soils

Hydric soils cover 5,609.1 acres (32.3%) of the subwatershed. Wetlands currently cover 1.4% (237.7 acres) of the subwatershed. Highly erodible soils cover over half of the subwatershed (58.4%). In total, 17,182.4 acres (98.9%) of the subwatershed are identified as very limited for septic use. The majority of the subwatershed is rural, indicating homes pump to on-site septic systems. Based on the septic suitability of the soil, the majority of the subwatershed is very limited. Therefore, maintenance and inspections of septic systems in the area are important to ensure proper function and capacity.

4.9.2 Land Use

Agricultural land use dominates the Deer Creek-Prairie Creek subwatershed with 79.7% (13,860.6 acres) in agricultural land uses, including row crop and pasture. Deer Creek-Prairie Creek has the second highest urban land use percentage in the watershed, behind the Sanitary Ditch-Prairie Creek subwatershed. This is due to the City of Lebanon lying partially within the subwatershed. Urban land use accounts for 14.1% (2,456.0 acres) of the Deer Creek-Prairie Creek subwatershed. Forested land use covers 4.7% (814.0 acres). Wetlands, open water, and grassland cover just 1.4% (237.7 acres) of this subwatershed.

4.9.3 Point Source Water Quality Issues

There are few potential point sources of water pollution in the subwatershed. There are 18 underground storage tank sites (Figure 75) in the subwatershed. There are no NPDES-permitted facilities, open dumps, brownfields, corrective action sites, voluntary remediation sites, or industrial waste facilities located within the Deer Creek-Prairie Creek subwatershed.

4.9.4 Non-Point Source Water Quality Issues

Agricultural land use is the predominant land use in the Deer Creek-Prairie Creek subwatershed. Additionally, a number of small animal operations and pastures are also present (Figure 75). In total, 29 unregulated animal operations housing more than 404 cows and horses were identified during the windshield survey. No active confined feeding operations are located within the Deer Creek-Prairie Creek subwatershed. In total, manure from small animal operations total over 8,718 tons per year, which contains almost 4,290 pounds of nitrogen, 2,123 pounds of phosphorus and 2.34E+14 colonies of *E. coli*. Livestock appear to have access to 0.5 miles (0.8%) the subwatershed streams based on windshield survey observations. Streambank erosion is a concern in the subwatershed. Approximately 9.9 miles (15.8%) of streambank erosion were identified within the subwatershed.

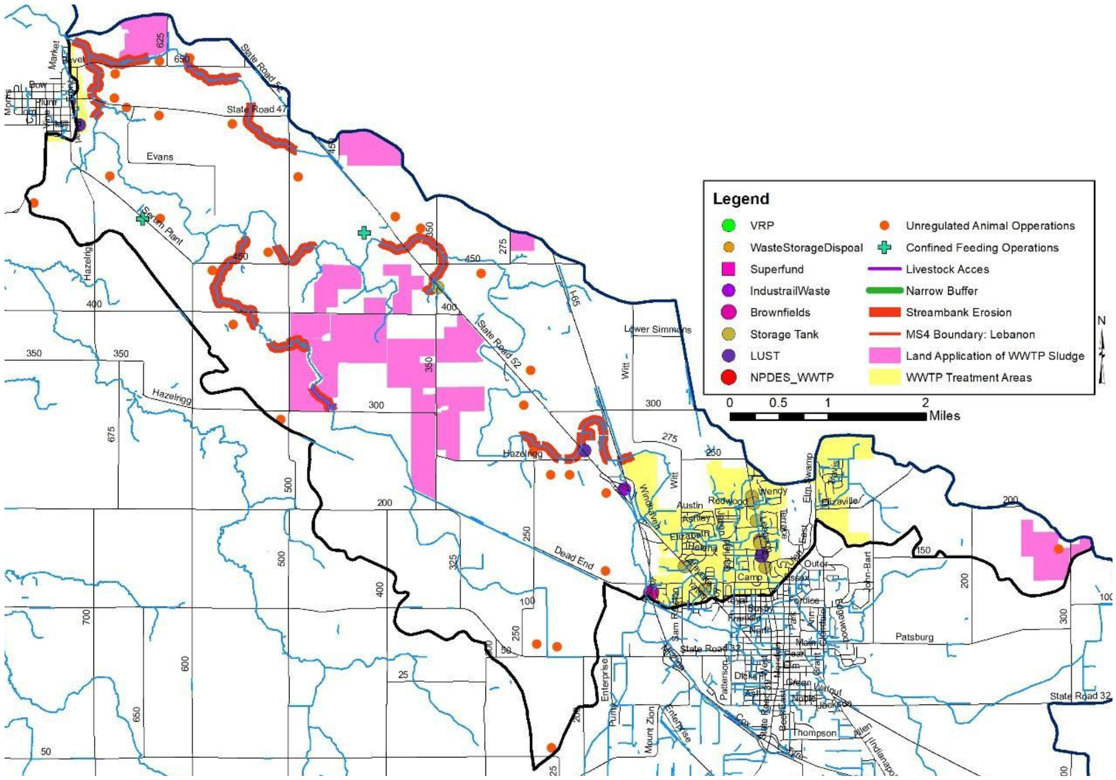


Figure 75. Potential point and non-point sources of pollution and suggested solutions in the Deer Creek-Prairie Creek subwatershed.

4.9.5 Water Quality Assessment

Waterbodies within the Deer Creek-Prairie Creek subwatershed have been sampled historically at three locations (Figure 76). One site in the Deer Creek-Prairie Creek subwatershed is being sampled as part of the current project. Historic assessments include collection of water chemistry (3 sites) and biology data by IDEM (1 site). One stream gage located on Prairie Creek is located in the Deer Creek-Prairie Creek subwatershed. Table 46 details historic water chemistry data collected in the Deer Creek-Prairie Creek subwatershed. Turbidity levels exceed water quality targets (5.7 NTU) in 93% of samples.

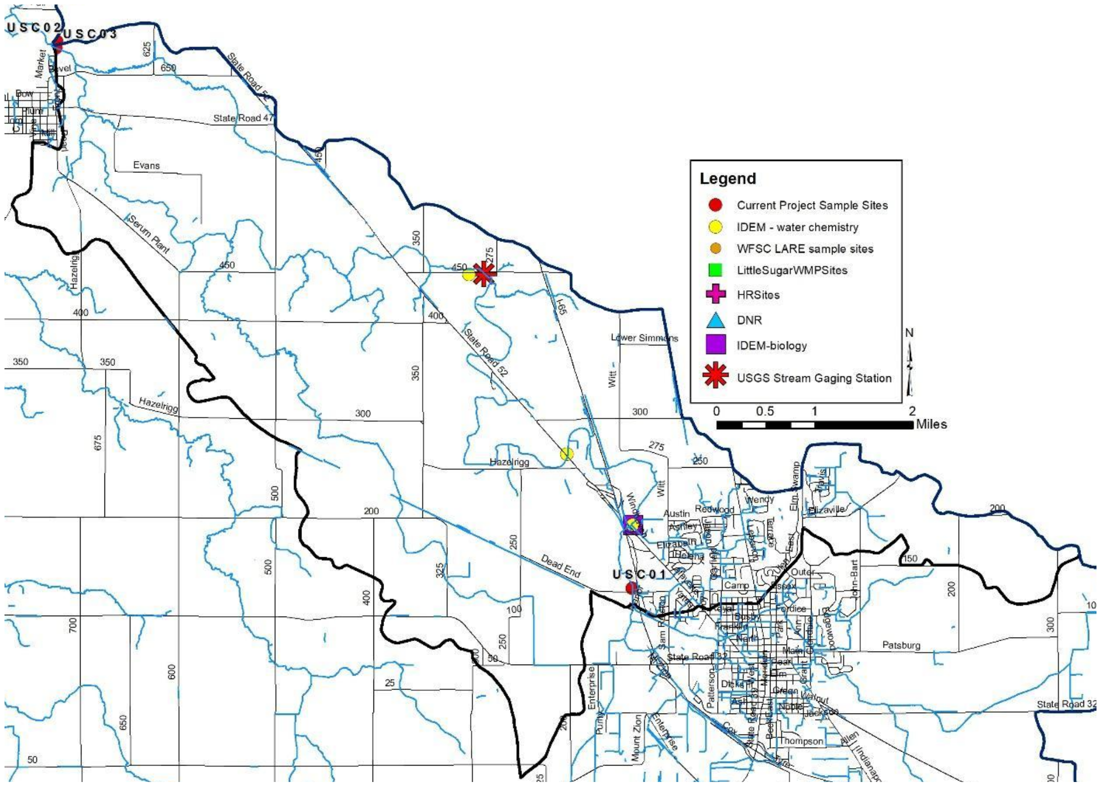


Figure 76. Locations of historic and current water quality data collection in the Deer Creek-Prairie Creek subwatershed.

Table 46. Deer Creek-Prairie Creek subwatershed historic water quality data summary.

Parameter	Minimum	Maximum	Number Exceeding Target	Number of Samples	Percent Exceeding
Dissolved oxygen (mg/L)	7.28	11.3	0	14	0%
pH	7.65	8.89	0	15	0%
Specific conductance (μmhos/cm)	569	998	0	15	0%
Turbidity (NTU)	4.5	95.5	14	15	93%

Table 47 details water quality data collected in the Deer Creek-Prairie Creek Subwatershed (Site 3). As shown in the table, *E. coli* samples exceed state standards (235 col/100 ml) in 58% of samples collected. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 100% of samples. Total phosphorus concentrations exceed water quality targets (0.08 mg/L) in 67% of samples. Total suspended solids concentrations exceed water quality targets (15 mg/L) in 25% of samples, while turbidity levels exceed water quality targets (5.7 NTU) in 25% of samples. Dissolved oxygen concentrations did not exceed water quality standards in samples collected from this site. Conductivity measured above the water quality target (1050 μmhos/cm) in 25% of samples collected. This suggests there may be a source of dissolved salts within the Deer Creek-Prairie Creek Subwatershed or that this site is influenced by conductivity levels from the upstream Sanitary Ditch-Prairie Creek Subwatershed.

Table 47. Deer Creek-Prairie Creek Subwatershed water quality data summary.

Site		Temp (deg C)	DO (mg/L)	pH	Cond (µmhos/cm)	Turb (NTU)	Nitrate (mg/L)	TP (mg/L)	TSS (mg/L)	*E. coli* (col/100 ml)
3	Median	13.05	9.80	8.31	701.0	1.42	2.90	0.29	4.00	242.4
	Max	24.50	11.80	8.45	1267.0	122.00	5.14	1.70	161.00	2419.6
	Min	2.10	5.10	7.66	233.0	0.00	1.28	0.00	1.00	24.4
	#Samples	12	12	12	12	12	12	12	12	12
	#Exceed		0	0	3	3	12	8	3	7
	% Exceed	0%	0%	0%	25%	25%	100%	67%	25%	58%

Biological monitoring was conducted by IDEM at one site twice for macroinvertebrate community assessments and one time for fish community assessments and one site was assessed as part of the current project. Habitat assessment occurred concurrently with biological community assessments. Habitat scores ranged from 53 to 67 with all sites scoring above the state target (51). Fish community assessment rated fair to good with all assessments meeting their aquatic life use designation. Macroinvertebrate assessments rated moderately impaired to slightly impaired using the kick sampling method with 50% of sites not meeting their aquatic life use designation. During the current assessment, the macroinvertebrate community meets its aquatic life use designation (**Table 48**).

Table 48. Deer Creek-Prairie Creek subwatershed biological assessment data summary.

Parameter	Minimum	Maximum	Number Exceeding Target	Number of Samples	Percent Exceeding
Habitat (QHEI)	53	67	0	4	0%
Fish (IBI)	44	54	0	2	0%
Macroinvertebrates (mIBI, Kick)	2.6	3.4	1	2	50%
Macroinvertebrates (mIBI, Multi Habitat)	40	40	0	1	0%

4.10 Wolf Creek subwatershed

The Wolf Creek subwatershed is very centrally located within the watershed, with a small portion forming some of the southern boundary of the Upper Sugar Creek Watershed (Figure 77). The Wolf Creek subwatershed is within Boone County. It encompasses one 12-digit HUC watershed: 051201100403. This subwatershed drains 16,258 acres and accounts for 9% of the total watershed area. In total, the Wolf Creek subwatershed drains 25.4 square miles. There are 42.4 miles of stream. There are no recorded impairments in the Wolf Creek subwatershed.

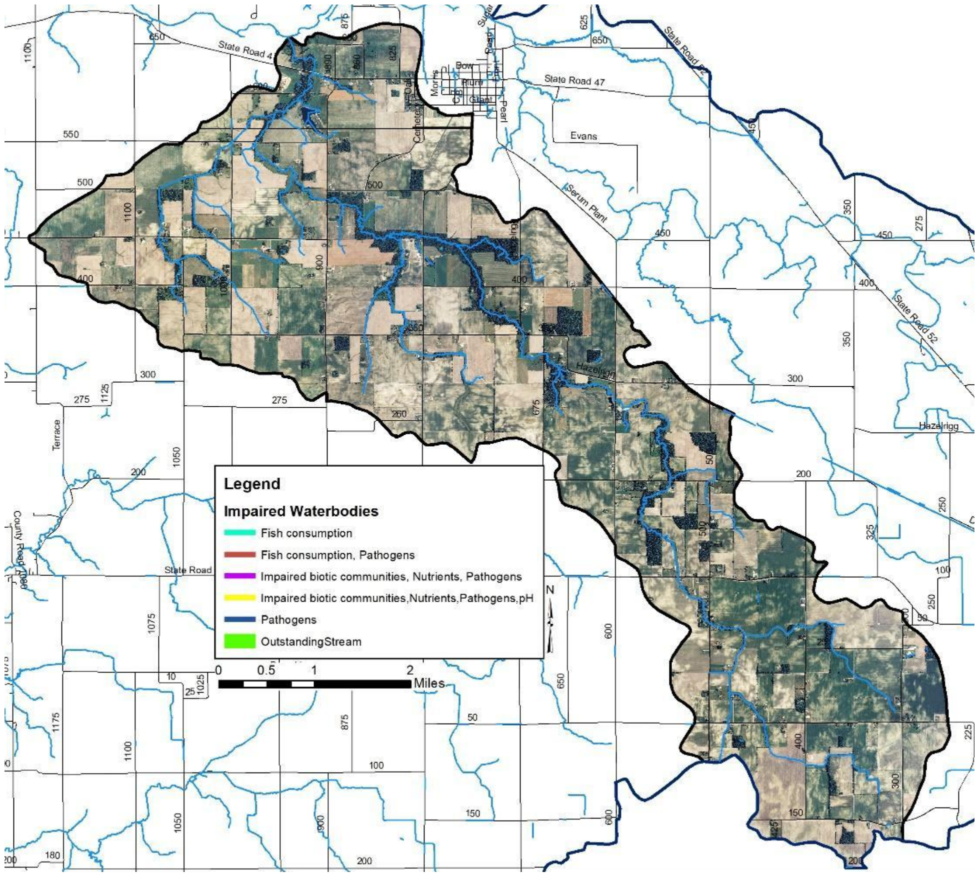


Figure 77. Wolf Creek subwatershed.

4.10.1 Soils

Hydric soils cover 5,898.4 acres (36.3%) of the subwatershed. Wetlands currently cover 1% (169.7 acres) of the subwatershed. Highly erodible soils cover more than half of the subwatershed (59.1%). In total, 16,182.6 acres (99.5%) of the subwatershed are identified as very limited for septic use. The majority of the subwatershed is rural, indicating homes pump to on-site septic systems. Based on the septic suitability of the soil, the majority of the subwatershed is very limited. Therefore, maintenance and inspections of septic systems in the area are important to ensure proper function and capacity.

4.10.2 Land Use

Agricultural land use dominates the Wolf Creek subwatershed with 89.7% (14,575.9 acres) in agricultural land uses, including row crop and pasture. Forested land use cover 4.7% (758.8 acres) of the subwatershed. In total, 741.5 acres or 4.6% of the subwatershed are in urban land uses. Wetlands, open water, and grassland cover 169.7 acres, or 1%, of the subwatershed.

4.10.3 Point Source Water Quality Issues

There are few potential point sources of water pollution in the subwatershed. There is one underground storage tank site. (Figure 78). There are no open dumps, NPDES sites, brownfields, corrective action sites, voluntary remediation sites, or industrial waste facilities located within the Wolf Creek subwatershed.

4.10.4 Non-Point Source Water Quality Issues

Agricultural land use is the predominant land use in the Wolf Creek subwatershed. Nearly 28 unregulated animal operations housing more than 319 cows, horses, goats, and sheep were identified during the windshield survey. Livestock have access to 2.3 (5.4%) miles of Wolf Creek streams. There are two active CFOs which houses 54,694 turkeys and cows located within the Wolf Creek subwatershed. In total, manure from small animal operations and the CFOs total over 13,939 tons per year, which contains almost 1,518,400 pounds of nitrogen, 1,319,218 pounds of phosphorus and 1.15E+16 colonies of *E. coli*. Streambank erosion and lack of buffers are a concern in the subwatershed. Approximately 1.7 miles (3.9%) of insufficient stream buffers and 7.8 miles (18.4%) of streambank erosion were identified within the subwatershed.

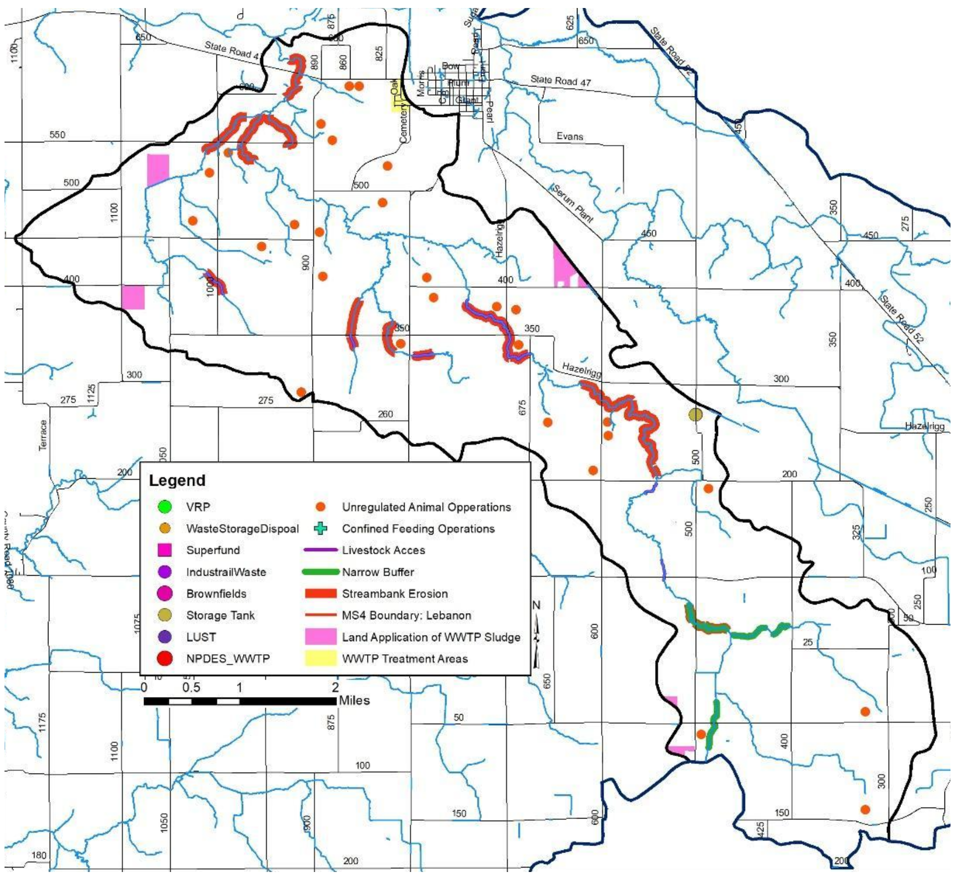


Figure 78. Potential point and non-point sources of pollution and suggested solutions in the Wolf Creek subwatershed.

4.10.5 Water Quality Assessment

While an IDEM water chemistry sample point is shown in the Wolf Creek subwatershed, no data is available for this sample point (Figure 79). One site in the Wolf Creek subwatershed is being sampled as part of the current project (Table 49). No stream gages are in the Wolf Creek subwatershed. Table 10 details water quality data collected in the Wolf Creek Subwatershed (Site 4). As shown in the table, *E. coli* samples exceed state standards (235 col/100 ml) in 33% of samples collected. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 92% of samples. Total phosphorus concentrations exceed water quality targets (0.08 mg/L) in 75% of samples. Total suspended solids concentrations exceed water quality targets (15 mg/L) in 17% of samples, while turbidity levels exceed water quality targets (5.7 NTU) in 17% of samples. Dissolved oxygen, pH and conductivity concentrations did not exceed water quality standards in samples collected from this site.

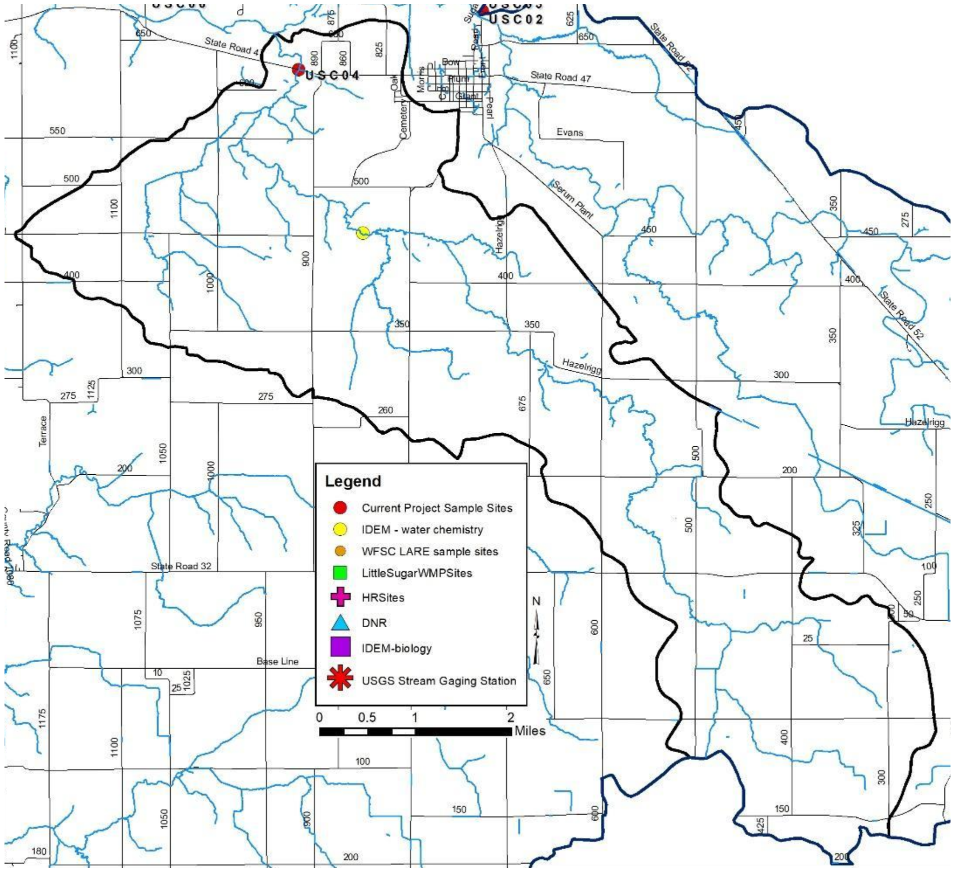


Figure 79. Locations of historic and current water quality data collection in the Wolf Creek subwatershed.

Table 49. Wolf Creek Subwatershed water quality data summary.

Site		Temp (deg C)	DO (mg/L)	pH	Cond (µmhos/cm)	Turb (NTU)	Nitrate (mg/L)	TP (mg/L)	TSS (mg/L)	*E. coli* (col/100 ml)
4	Median	12.45	9.80	8.09	517.0	1.84	1.72	0.24	4.00	147.6
	Max	22.80	11.90	8.51	711.0	144.00	5.51	1.99	127.00	870.4
	Min	2.00	5.10	7.61	220.0	0.00	0.19	0.02	2.00	14.3
	#Samples	12	12	12	12	12	12	12	12	12
	#Exceed		0	0	0	2	11	9	2	4
	% Exceed	0%	0%	0%	0%	17%	92%	75%	17%	33%

Habitat and biological communities were assessed at one site as part of the current project. Habitat scored 49 which is below the state target (51). The fish community scored 48 which rates as good with 100% of samples meeting their aquatic life use designation. Macroinvertebrate assessments indicated the community scored 38 using the multihabitat assessment which does not meet the state's aquatic life use designation.

4.11 Goldsberry Creek-Sugar Creek subwatershed

The Goldsberry Creek-Sugar subwatershed forms much of the eastern boundary of the Upper Sugar Creek Watershed and drains portions of Clinton and Boone Counties (Figure 80). It encompasses one 12-digit HUC watershed: 051201100404. This subwatershed drains 11,307 acres and accounts for 6% of the total watershed area. The Goldsberry Creek-Sugar Creek subwatershed drains 17.7 square miles. The Goldsberry Creek-Sugar Creek subwatershed receives the drainage from the Browns Wonder-Sugar Creek watershed. There are 30.1 miles of stream. IDEM has classified 12.4 miles of stream as impaired for E. coli.

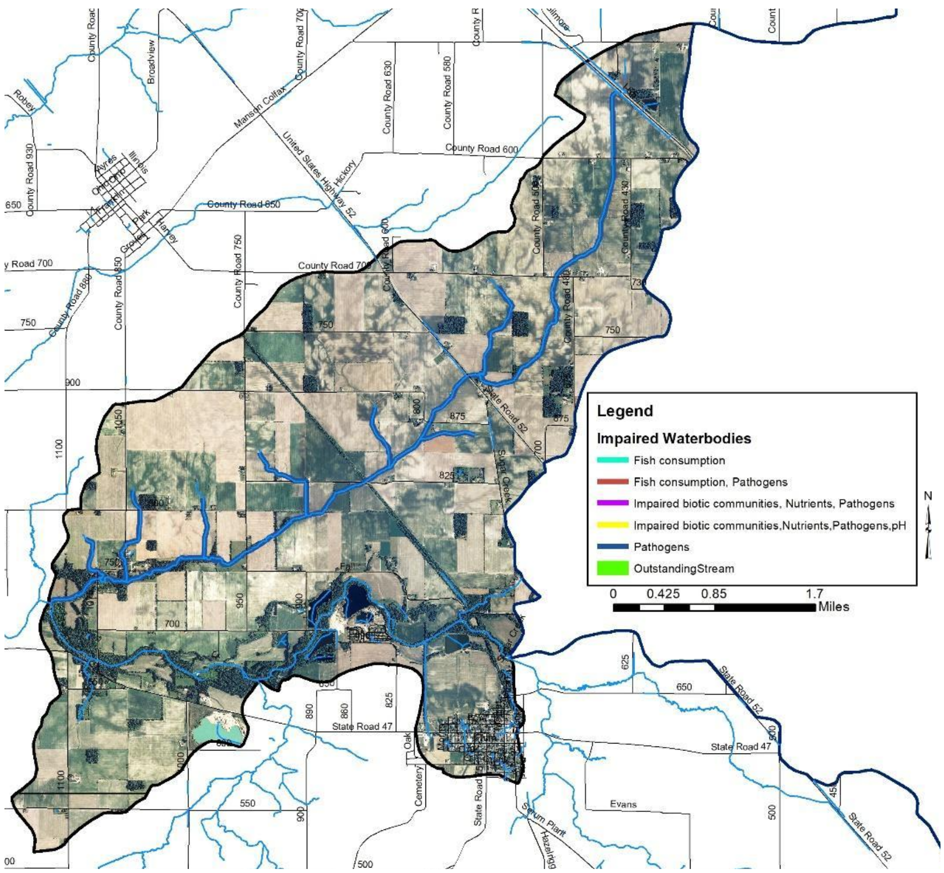


Figure 80. Goldsberry Creek-Sugar Creek subwatershed.

4.11.1 Soils

Hydric soils cover 3,459.3 acres (30.6%) of the subwatershed. Wetlands currently cover 2.5% (278.9 acres) of the subwatershed. Highly erodible soils nearly 57.8% the subwatershed with 6,532.3 acres. In total, 10,978.7 acres (97.1%) of the subwatershed are identified as very limited for septic use.

Maintenance and inspections of septic systems in the area is important to ensure proper function and capacity.

4.11.2 Land Use

Agricultural land use dominates the Goldsberry Creek-Sugar Creek subwatershed covering 85% (9,614.7 acres) with row crops and pastureland accounting for the majority of agricultural land uses. Urban land use constitutes the next largest use of the subwatershed with the Towns of Thorntown and Colfax residing in this subwatershed. Urban land use makes up 7.1% or 807.2 acres of this subwatershed. Forested land use covers 5.3% (597.2 acres). Wetlands, open water, and grassland cover just 278.9 acres, or 2.5%, of the subwatershed.

4.11.3 Point Source Water Quality Issues

There are a few potential sources of Point Source water quality issues in the subwatershed. There are two NPDES-permitted facilities in this watershed - the Thorntown WWTP and the Western Boone School Corporation WWTP. While a small portion of the town of Colfax resides in this subwatershed, it will be discussed later as its WWTP & outfall resides in the Withe Creek subwatershed. There are eight underground storage tanks located in this subwatershed. There are no open dumps, brownfields, corrective action sites, voluntary remediation sites or industrial waste facilities located within the Goldsberry Creek-Sugar Creek subwatershed (Figure 81).

4.11.4 Non-Point Source Water Quality Issues

Agricultural land use is the predominant land use in the Goldsberry Creek-Sugar Creek subwatershed. Additionally, a number of small animal operations and pastures are also present (Figure 81). In total, eight unregulated animal operations housing more than 120 cows and horses were identified during the windshield survey. No active confined feeding operations are located within the Goldsberry Creek-Sugar Creek subwatershed. Manure from small animal operations total over 2,611 tons per year, which contains almost 1,260 pounds of nitrogen, 620 pounds of phosphorus and 7.23E+13 colonies of *E. coli*. Livestock appear to have access to 1.2 miles (3.9%) of the subwatershed streams based on windshield survey observations. Streambank erosion is a concern in the subwatershed. Approximately 3 miles (10.1%) of streambank erosion were identified within the subwatershed.

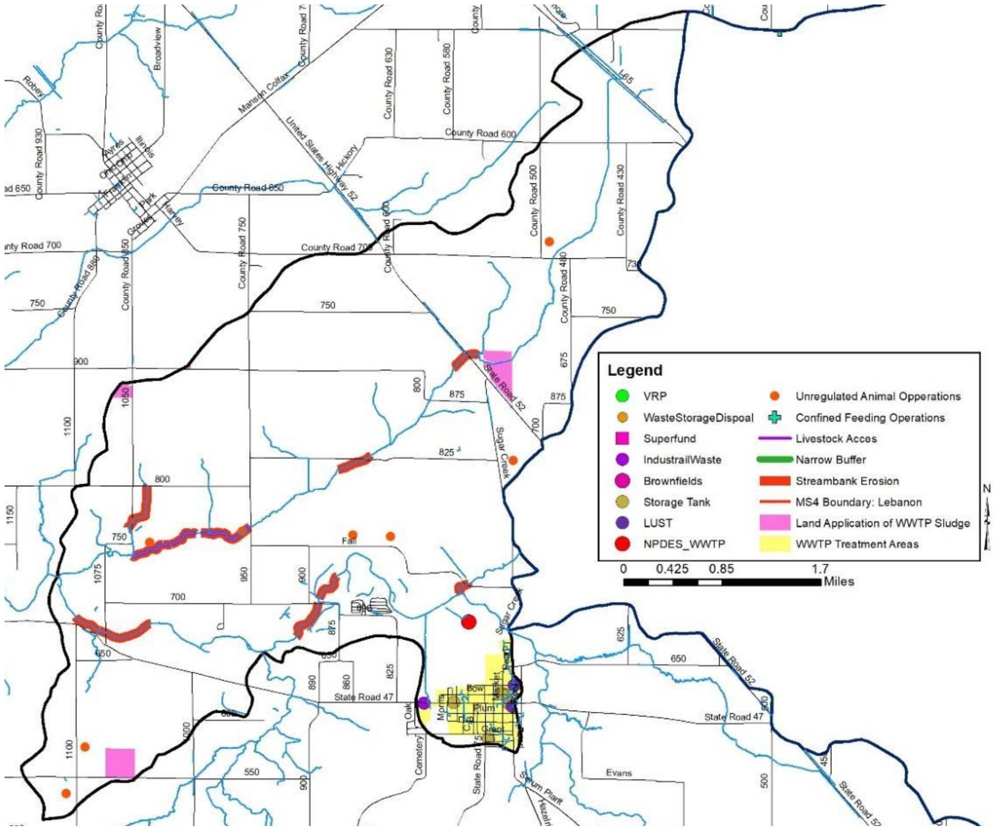


Figure 81. Potential point and non-point sources of pollution and suggested solutions in the Goldsberry Creek-Sugar Creek subwatershed.

4.11.5 Water Quality Assessment

Waterbodies within the Goldsberry Creek-Sugar Creek subwatershed have been sampled at one location by Hoosier Riverwatch volunteers (Figure 82). Two sites in the Goldsberry Creek-Sugar Creek subwatershed are being sampled as part of the current project. No stream gages are in the Goldsberry Creek-Sugar Creek subwatershed.

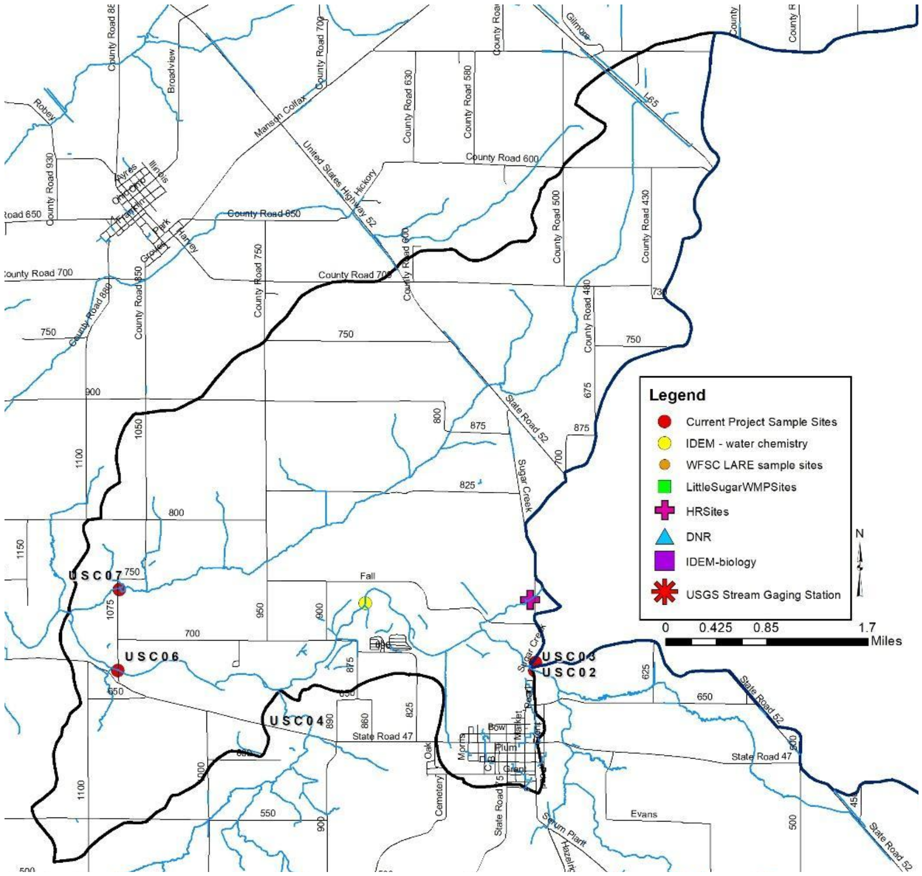


Figure 82. Locations of historic and current water quality data collection in the Goldsberry Creek-Sugar Creek subwatershed.

Table 50 documents Hoosier Riverwatch volunteer data. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 75% of samples. Orthophosphorus concentrations exceed water quality targets (0.03 mg/L) in 100% of samples. Turbidity levels exceed water quality targets (5.7NTU) in 100% of samples. E. coli samples did not exceed state grab sample standards (235 col/100 ml).

Table 50. Goldsberry Creek-Sugar Creek subwatershed historic Hoosier Riverwatch water quality data summary.

Parameter	Minimum	Maximum	Number Exceeding Target	Number of Samples	Percent Exceeding
Dissolved Oxygen (mg/L)	5	10	0	4	0%
E. coli (col/100 ml)	100	100	0	1	0%
Nitrate (mg/L)	0	22	3	4	75%
Ortho P (mg/L)	0	1	3	3	100%
pH	7	8	0	4	0%
Turbidity (NTU)	15	70	4	4	100%

Table 51 details water quality data collected in the Goldsberry Creek-Sugar Creek Subwatershed (Sites 6 and 7). Site 6 is located on the mainstem of Sugar Creek while Site 7 is located on Goldsberry Creek. As shown in the table, *E. coli* samples exceed state standards (235 col/100 ml) in 45% of samples collected in Site 6 and in 50% of samples collected in Site 7. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 100% of samples collected in Site 6 and in 92% of samples collected in Site 7. Total phosphorus concentrations exceed water quality targets (0.08 mg/L) in 73% of samples collected in Site 6 and 83% of samples collected in Site 7. Total suspended solids concentrations exceed water quality targets (15 mg/L) in 27% of samples collected in Site 6 and 25% of samples collected in Site 7. Turbidity levels exceed water quality targets (5.7 NTU) in 36% of samples collected in Site 6 and 25% of samples collected in Site 7. Dissolved oxygen concentrations did not exceed water quality standards in samples collected from Site 6 and 7. Conductivity measured above the water quality target (1050 µmhos/cm) in 8% of samples collected from Site 7.

Table 51. Goldsberry Creek-Sugar Creek Subwatershed water quality data summary.

Site		Temp (deg C)	DO (mg/L)	pH	Cond (µmhos/cm)	Turb (NTU)	Nitrate (mg/L)	TP (mg/L)	TSS (mg/L)	*E. coli* (col/100 ml)
6	Median	13.20	8.40	8.11	494.0	3.22	1.84	0.13	5.00	218.7
	Max	23.60	11.90	8.30	897.0	177.00	5.12	2.38	192.00	2419.6
	Min	2.10	4.30	7.69	248.0	0.26	1.14	0.02	2.00	34.1
	#Samples	11	11	11	11	11	11	11	11	11
	#Exceed		0	0	0	4	11	8	3	5
	% Exceed	0%	0%	0%	0%	36%	100%	73%	27%	45%
7	Median	12.35	7.15	8.02	506.0	2.36	1.52	0.27	3.00	251.5
	Max	23.30	11.60	8.17	1619.0	97.00	6.63	5.00	117.00	2419.6

	Min	2.30	5.50	7.45	234.0	0.22	0.30	0.02	1.00	29.3
	#Samples	12	12	12	12	12	12	12	12	12
	#Exceed		0	0	1	3	11	10	3	6
	% Exceed	0%	0%	0%	8%	25%	92%	83%	25%	50%

Biological monitoring occurred at two sites as part of the current project. Habitat assessment occurred concurrently with biological community assessments. Habitat scores ranged from 54 to 75 with all sites scoring above the state target (51). Fish community assessment rated fair with all assessments meeting their aquatic life use designation. Macroinvertebrate assessments rated as not impaired using the mulithabitat sampling method with all sites meeting their aquatic life use designation (Table 52).

Table 52. Goldsberry Creek subwatershed biological assessment data summary.

Parameter	Minimum	Maximum	Number Exceeding Target	Number of Samples	Percent Exceeding
Habitat (QHEI)	54	75	0	2	0%
Fish (IBI)	42	44	0	2	0%
Macroinvertebrates (mIBI, Kick)	--	--	--	--	--
Macroinvertebrates (mIBI, Multi Habitat)	38	40	0	2	0%

4.12 Withe Creek-Sugar Creek subwatershed

The Withe Creek-Sugar Creek subwatershed is in the northern half of the Upper Sugar Creek Watershed and lies within Boone, Clinton, and Montgomery Counties (Figure 83). It encompasses one 12-digit HUC watershed: 051201100405. This subwatershed drains 10,902 acres or 17 square miles, and accounts for 6% of the total watershed area. The Withe Creek-Sugar Creek subwatershed receives water from the Goldsberry Creek-Sugar Creek subwatershed. There are 24.4 miles of stream in the Withe Creek-Sugar Creek subwatershed. IDEM has classified 10.6 miles of stream as impaired for *E. coli*, nutrients and fish consumption.

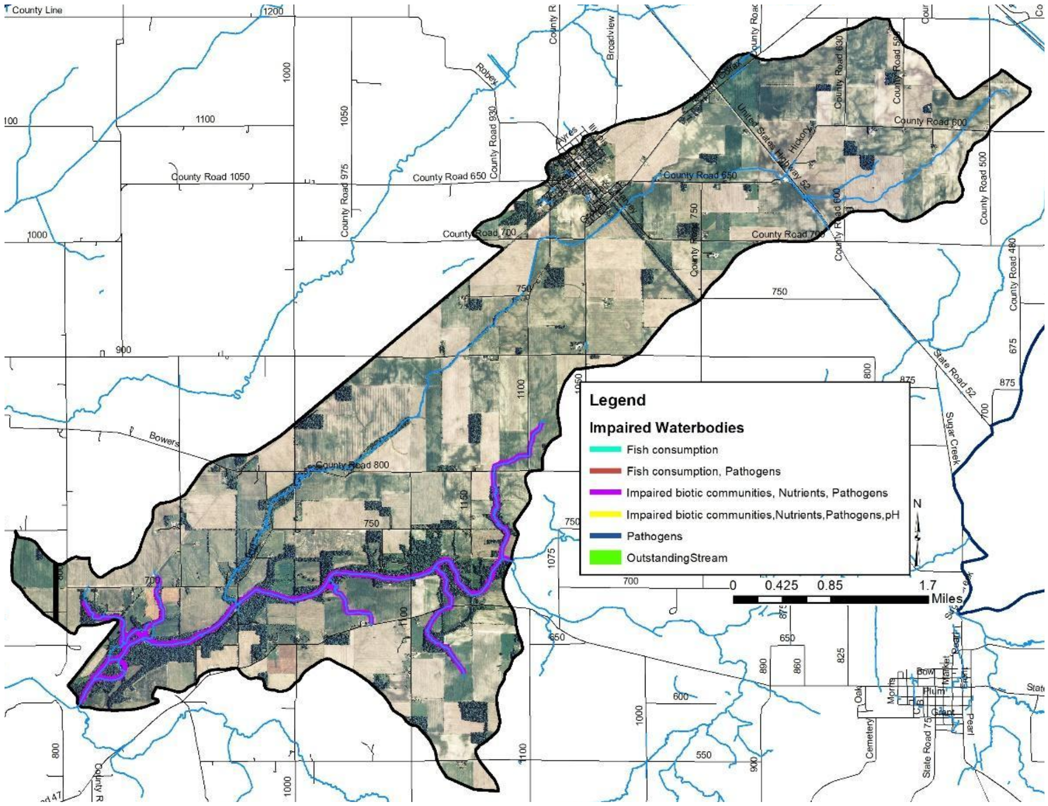


Figure 83. Withe Creek-Sugar Creek subwatershed.

4.12.1 Soils

Hydric Soils cover 30.9% or 3,373.1 acres of the subwatershed. Wetlands currently cover 2.1% (225.6 acres) of the subwatershed. Highly erodible soils cover more than half of the subwatershed with 6,269.4 acres or 57.5%. More than 10,765.0 miles (98.7%) of the subwatershed are identified as very limited for septic use. Homes in the Withe Creek-Sugar Creek subwatershed are mostly rural using on-site septic systems. Maintenance and inspection of septic systems in this area are important to ensure proper function and capacity.

4.12.2 Land Use

Agricultural land use dominates the Withe Creek-Sugar Creek subwatershed at 84.1% (9,170.1 acres), with row crops and pastureland accounting for the majority of agricultural land uses. Forested and urban land uses are the next largest use of the subwatershed, with forested land use only accounting for 7.7% (834.2 acres) of use and urban land use accounting for 6.1% (663.8 acres). The town of Colfax, which had a population of 813 in 2020, resides in this subwatershed. Wetlands, open water, and grassland cover just 225.6 acres, or 2.1%, of the subwatershed.

4.12.3 Point Source Water Quality Issues

There are seven potential point sources of water pollution in the subwatershed (Figure 84). This subwatershed has six underground storage tanks and one NPDES-permitted location, the town of Colfax WWTP. No open dumps, superfund sites, corrective action sites or voluntary remediation sites are located within the Withe Creek-Sugar Creek subwatershed.

4.12.4 Non-Point Source Water Quality Issues

Agricultural land uses are the predominant land use in the Withe Creek-Sugar Creek subwatershed. Additionally, a number of small animal operations, pastures and one confined feeding operation are also present. In total, 10 unregulated animal operations housing more than 141 cows and horses were identified during the windshield survey. There is one active CFO housing 10,000 cows in the subwatershed. Based on windshield survey observations, livestock do not appear to have access to the subwatershed streams. In total, manure from animal operations total over 222,073 tons per year, which contains almost 105,477 pounds of nitrogen, 51,726 pounds of phosphorus and 6.31E+15 colonies of *E. coli*. Streambank erosion is a concern in the subwatershed. Approximately 5.2 miles (21.2%) of streambank erosion were identified within the subwatershed.

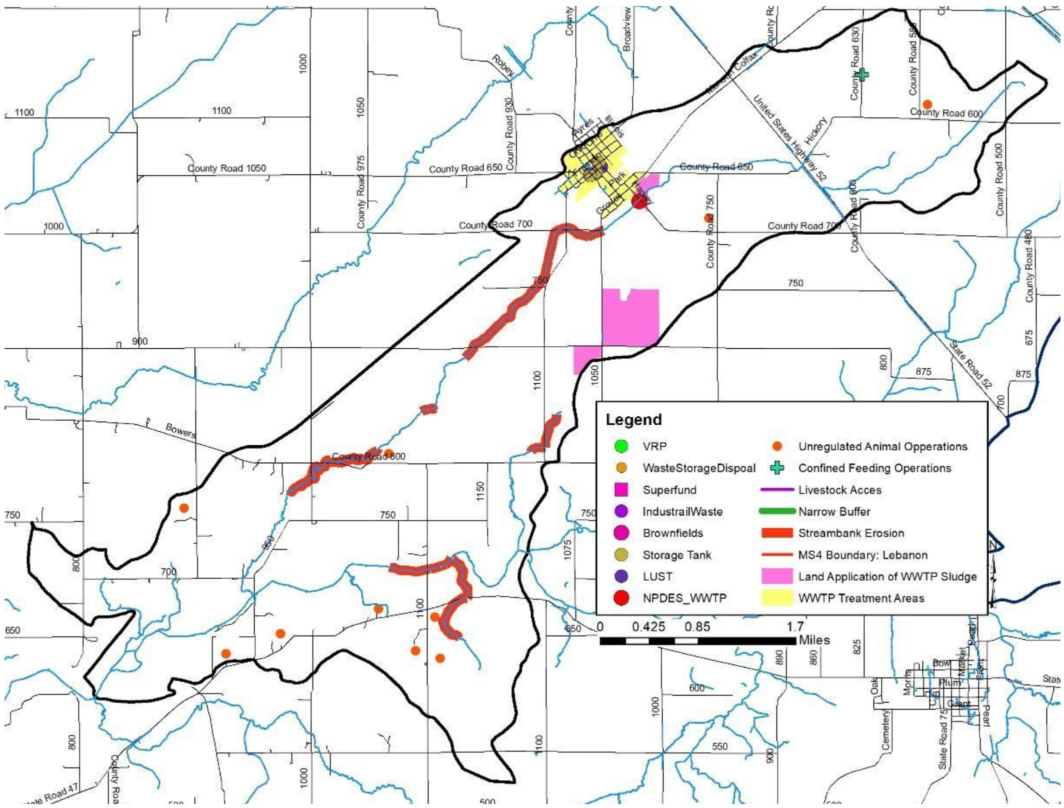


Figure 84. Potential point and non-point sources of pollution and suggested solutions in the Withe Creek-Sugar Creek subwatershed.

4.12.5 Water Quality Assessment

Waterbodies within the Withe Creek-Sugar Creek subwatershed have been sampled historically at five locations (Figure 85). One site in the Withe Creek-Sugar Creek subwatershed is being sampled as part of the current project. Historic assessments include collection of water chemistry (4 sites) and biology data by IDEM (1 site) and Hoosier Riverwatch Volunteers (1 site). No stream gages are in the Withe Creek-Sugar Creek subwatershed.

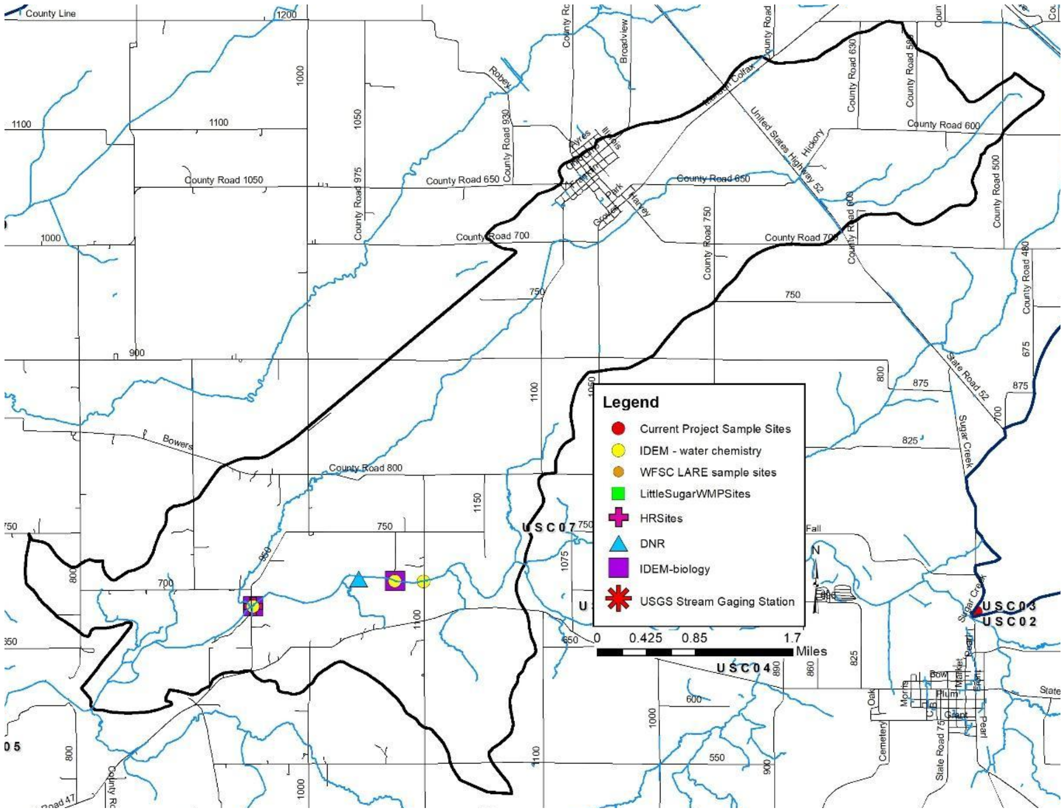


Figure 85. Locations of historic and current water quality data collection in the Withe Creek-Sugar Creek subwatershed.

Table 53 details historic water chemistry data collected in the Withe Creek-Sugar Creek subwatershed. E. coli samples exceed state grab sample standards (235 col/100 ml) in 100% of samples collected. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 100% of samples, while total Kjeldahl nitrogen concentrations exceed water quality targets (0.5 mg/L) in 100% of samples. Total phosphorus concentrations exceed water quality targets (0.08 mg/L) in 100% of samples. Turbidity levels exceed water quality targets (5.7 NTU) in 100% of samples.

Table 53. Withe Creek-Sugar Creek subwatershed historic water quality data summary.

Parameter	Minimum	Maximum	Number Exceeding Target	Number of Samples	Percent Exceeding
Dissolved oxygen (mg/L)	8.19	9.64	0	10	0%
E. coli (col/100 ml)	387.3	3873	5	5	100%
Total Kjeldahl nitrogen (mg/L)	0.697	2.26	2	2	100%
Nitrate (mg/L)	1.37	7.91	3	3	100%
pH	7.91	8.56	0	10	0%
Total Phosphorus (mg/L)	0.15	0.365	3	3	100%
Specific conductance (μmhos/cm)	403	614	0	10	0%
Turbidity	8.3	644.1	9	9	100%

Table 54 details water quality data collected in the Withe Creek-Sugar Creek Subwatershed (Site 5). As shown in the table, *E. coli* samples exceed state standards (235 col/100 ml) in 25% of samples collected. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 83% of samples. Total phosphorus concentrations exceed water quality targets (0.08 mg/L) in 58% of samples. Total suspended solids concentrations exceed water quality targets (15 mg/L) in 17% of samples, while turbidity levels exceed water quality targets (5.7 NTU) in 17% of samples. Dissolved oxygen, pH and conductivity concentrations did not exceed water quality standards in samples collected from this site.

Table 54. Withe Creek-Sugar Creek Subwatershed water quality data summary.

Site		Temp (deg C)	DO (mg/L)	pH	Cond (µmhos/cm)	Turb (NTU)	Nitrate (mg/L)	TP (mg/L)	TSS (mg/L)	*E. coli* (col/100 ml)
5	Median	11.75	8.30	8.22	567.5	2.38	2.03	0.15	4.50	68.4
	Max	23.60	11.90	8.61	796.0	181.00	4.64	2.19	250.00	2419.6
	Min	0.70	5.70	7.76	272.0	0.00	0.22	0.01	2.00	11.0
	#Samples	12	12	12	12	12	12	12	12	12
	#Exceed		0	0	0	2	10	7	2	3
	% Exceed	0%	0%	0%	0%	17%	83%	58%	17%	25%

Biological monitoring was conducted by IDEM at three sites with macroinvertebrate community assessments occurring once or twice at each site and fish community assessment occurring twice at one site and one site was assessed as part of the current project. Habitat assessment occurred concurrently with biological monitoring. Habitat scores ranged from 47 to 81 with 17% of sites scoring below the state target (51). Fish community assessments rated very poor to excellent with all assessments meeting their aquatic life use designation. Macroinvertebrate assessments rated moderately impaired to not impaired using the kick sampling method with 0% of sites not meeting their aquatic life use designation and scored 34 to 42 with all multihabitat samples meeting their aquatic life use designation (Table 55).

Table 55. Withe Creek-Sugar Creek subwatershed biological assessment data summary.

Parameter	Minimum	Maximum	Number Exceeding Target	Number of Samples	Percent Exceeding
Habitat (QHEI)	47	81	1	6	17%
Fish (IBI)	54	54	0	3	0%
Macroinvertebrates (mIBI, Kick)	2.6	6.2	0	2	0%
Macroinvertebrates (mIBI, Multi Habitat)	34	42	0	2	50%

4.13 Hazel Creek-Sugar Creek subwatershed

The Hazel Creek-Sugar Creek subwatershed sits near the center of the Upper Sugar Creek Watershed and within Montgomery and Boone counties (Figure 86). It encompasses one 12-digit HUC watershed: 051201100406. This subwatershed drains 16,166 acres and accounts for 9% of the total watershed area. In total, the Hazel Creek-Sugar Creek subwatershed drains 25.25 square miles. There are 42.2 miles of stream. IDEM has classified 8.6 miles of stream impaired for *E. coli*.

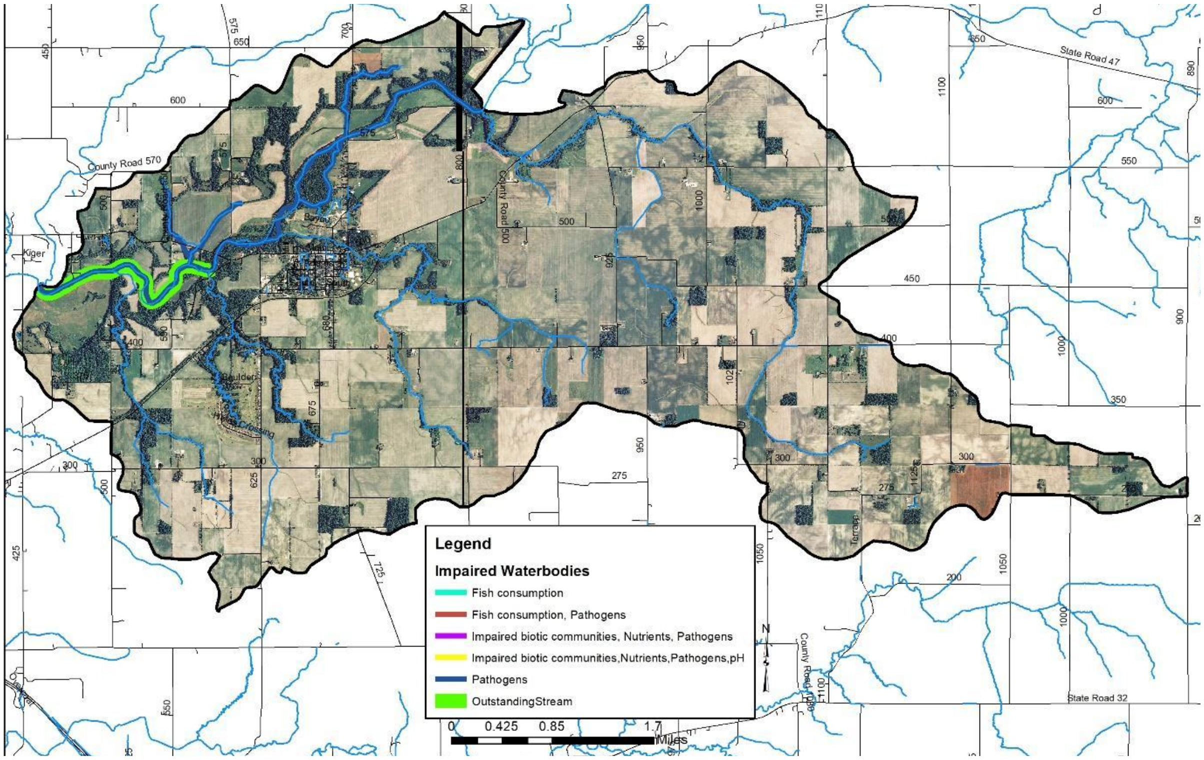


Figure 86. Hazel Creek-Sugar Creek subwatershed.

4.13.1 Soils

Hydric soils cover 4,610.2 acres (28.5%) of the subwatershed. Wetlands currently cover 2.1% (336.5 acres) of the subwatershed. Highly erodible soils cover over half of the subwatershed (63.1%). In total, 16,028.8 acres (99.2%) of the subwatershed are identified as very limited for septic use. The majority of the subwatershed is rural, indicating homes pump to on-site septic systems. Based on the septic suitability of the soil, the majority of the subwatershed is very limited. Therefore, maintenance and inspections of septic systems in the area are important to ensure proper function and capacity.

4.13.2 Land Use

Agricultural land uses dominate the Hazel Creek-Sugar Creek subwatershed with 83.7% (13,524.5 acres) in agricultural land uses, including row crop and pasture. Forested land use cover the next largest portion of the subwatershed with 7.4% (1,197.7 acres) in forested land use. Wetlands, open water, and grassland cover 336.5 acres, or 2.1%, of the subwatershed. The Montgomery County seat of Crawfordsville and the town of Darlington reside in the Hazel Creek-Sugar Creek subwatershed. In total, 1,094.9 acres or 6.8% of the subwatershed are in urban land uses.

4.13.3 Point Source Water Quality Issues

There are few potential point sources of water pollution in the subwatershed. There are seven underground storage tank sites (Figure 87) and one NPDES-permitted facilities in the subwatershed:

the Town of Darlington WWTP. There are no open dumps, brownfields, corrective action sites, voluntary remediation sites, or industrial waste facilities located within the Hazel Creek-Sugar Creek subwatershed.

4.13.4 Non-Point Source Water Quality Issues

Agricultural land use is the predominant land use in the Hazel Creek-Sugar Creek subwatershed. Additionally, a number of small animal operations and pastures are also present (Figure 87). In total, 16 unregulated animal operations housing more than 280 cows, horses and pigs were identified during the windshield survey. No active confined feeding operations are located within the Hazel Creek-Sugar Creek subwatershed. In total, manure from small animal operations total over 5,259 tons per year, which contains almost 3,047 pounds of nitrogen, almost 1,652 pounds of phosphorus and 1.37E+14 colonies of *E. coli*. Livestock appear to have access to 1.5 miles (3.5%) of the subwatershed streams based on windshield survey observations. Streambank erosion is a concern in the subwatershed. Approximately 7.2 miles (17%) of streambank erosion were identified within the subwatershed.

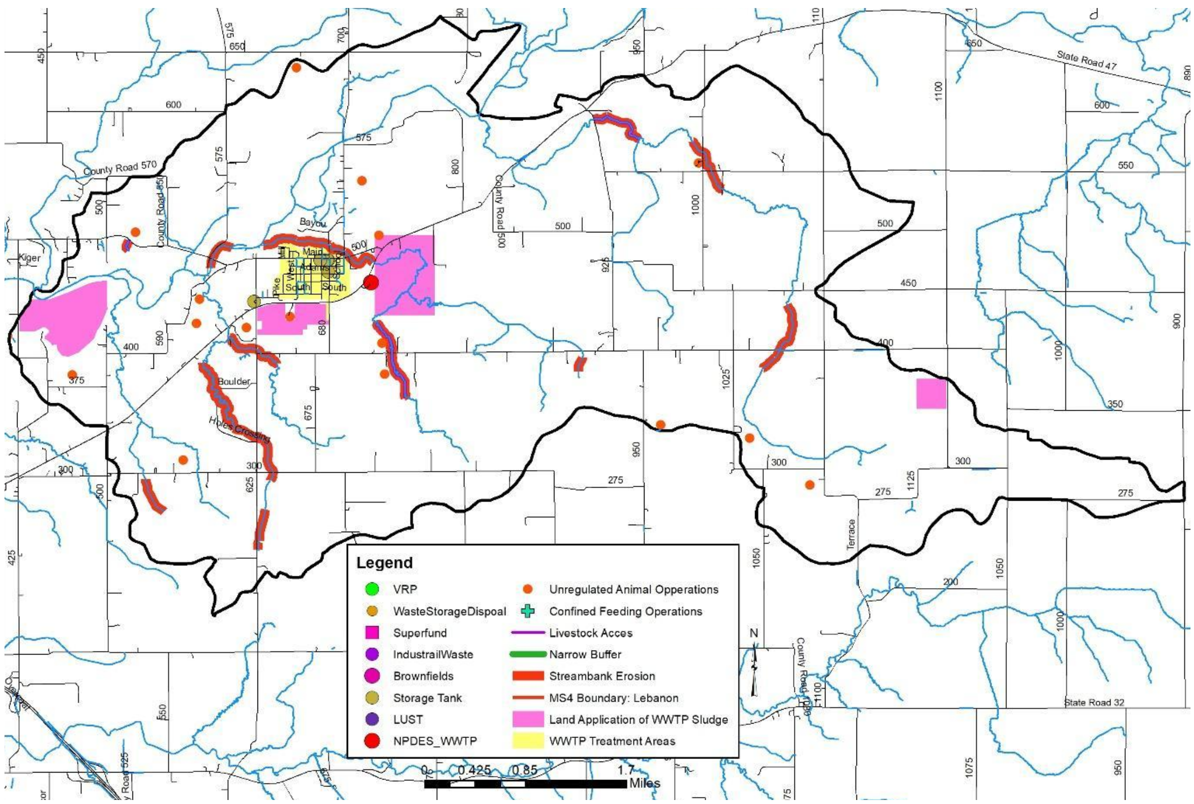


Figure 87. Potential point and non-point sources of pollution and suggested solutions in the Hazel Creek-Sugar Creek subwatershed.

4.13.5 Water Quality Assessment

Waterbodies within the Hazel Creek-Sugar Creek subwatershed have been sampled historically at two locations (Figure 88). One site in the Hazel Creek-Sugar Creek subwatershed is being sampled as part of the current project. Historic assessments include collection of water chemistry (2 sites) and biology data by IDEM (2 sites). No stream gages are in the Hazel Creek-Sugar Creek subwatershed.

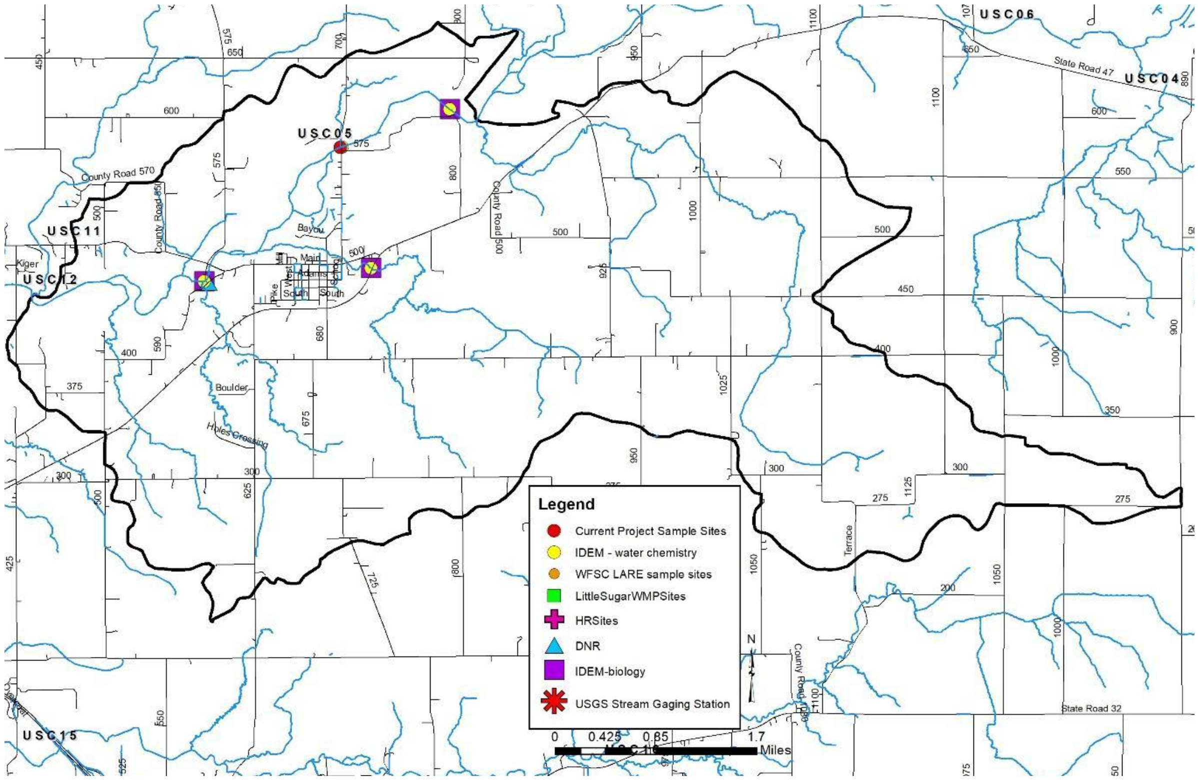


Figure 88. Locations of historic and current water quality data collection in the Hazel Creek-Sugar Creek subwatershed.

Table 56 details historic water chemistry data collected in the Hazel Creek-Sugar Creek subwatershed. E. coli samples exceed state grab sample standards (235 col/100 ml) in 80% of samples collected. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 100% of samples, while total Kjeldahl nitrogen concentrations exceed water quality targets (0.5 mg/L) in 100% of samples. Total phosphorus concentrations exceed water quality targets (0.08 mg/L) in 100% of samples. Turbidity levels exceed water quality targets (5.7 NTU) in 42% of samples.

Table 56. Hazel Creek-Sugar Creek subwatershed historic water quality data summary.

Parameter	Minimum	Maximum	Number Exceeding Target	Number of Samples	Percent Exceeding
Dissolved oxygen (mg/L)	6.7	12.37	4	14	29%
E. coli (col/100 ml)	139.6	1986.3	4	5	80%
Total Kjeldahl nitrogen (mg/L)	0.63	0.84	3	3	100%
Nitrate (mg/L)	3.4	6.7	3	3	100%
pH	7.35	8.58	4	14	29%
Total Phosphorus (mg/L)	0.2	0.62	3	3	100%
Specific conductance (μmhos/cm)	457.9	822.1	0	12	0%
Turbidity (NTU)	1.99	27	5	12	42%

Table 57 details water quality data collected in the Hazel Creek-Sugar Creek Subwatershed (Site 12). As shown in the table, *E. coli* samples exceed state standards (235 col/100 ml) in 25% of samples collected. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 75% of samples. Total phosphorus concentrations exceed water quality targets (0.08 mg/L) in 58% of samples. Total suspended solids concentrations exceed water quality targets (15 mg/L) in 17% of samples, while turbidity levels exceed water quality targets (5.7 NTU) in 25% of samples. Dissolved oxygen, pH and conductivity concentrations did not exceed water quality standards in samples collected from this site.

Table 57. Hazel Creek-Sugar Creek Subwatershed water quality data summary.

Site		Temp (deg C)	DO (mg/L)	pH	Cond (µmhos/cm)	Turb (NTU)	Nitrate (mg/L)	TP (mg/L)	TSS (mg/L)	*E. coli* (col/100 ml)
12	Median	11.75	7.65	8.27	449.0	3.27	1.01	0.11	4.00	75.6
	Max	23.30	11.90	8.81	752.0	197.00	3.98	2.39	179.00	2419.6
	Min	-2.70	5.00	7.85	270.0	0.00	0.23	0.04	2.00	1.0
	#Samples	12	12	12	12	12	12	12	12	12
	#Exceed		0	0	0	3	9	7	2	3
	% Exceed	0%	0%	0%	0%	25%	75%	58%	17%	25%

Biological monitoring was conducted by IDEM at six sites with two sites assessed for macroinvertebrates and two sites assessed for fish and one site was assessed as part of the current project. Habitat assessment occurred eight times in total and scores ranged from 49 to 82. Only 12% of sites scored below the state target (51). Fish community assessments rated good and meets the state's aquatic life use designation in 67% of samples collected. Macroinvertebrate assessments rated moderately impaired to not impaired using the kick sampling method with all sites meeting their aquatic life use designation and from 34 to 48 with 33% of multihabitat samples not meeting their aquatic life use designation (Table 58).

Table 58. Hazel Creek-Sugar Creek subwatershed biological assessment data summary.

Parameter	Minimum	Maximum	Number Exceeding Target	Number of Samples	Percent Exceeding
Habitat (QHEI)	49	82	1	8	12%
Fish (IBI)	34	48	1	3	33%
Macroinvertebrates (mIBI, Kick)	3.6	6.2	0	2	0%
Macroinvertebrates (mIBI, Multi Habitat)	34	48	1	3	33%

4.14 Town of Garfield-Sugar Creek subwatershed

The Town of Garfield-Sugar Creek subwatershed forms the western boundary of the Upper Sugar Creek Watershed and is the most downstream subwatershed receiving water from all basins in the Upper Sugar Creek Watershed (Figure 89). It encompasses one 12-digit HUC watershed: 051201100407. This subwatershed drains 7,973 acres and accounts for 4% of the total watershed area. In total, the Town of Garfield-Sugar Creek subwatershed drains 12.4 square miles. There are 25.2 miles of stream. IDEM has classified 20.3 miles of stream as impaired for fish consumption and 14.6 miles of stream impaired for *E. coli*.

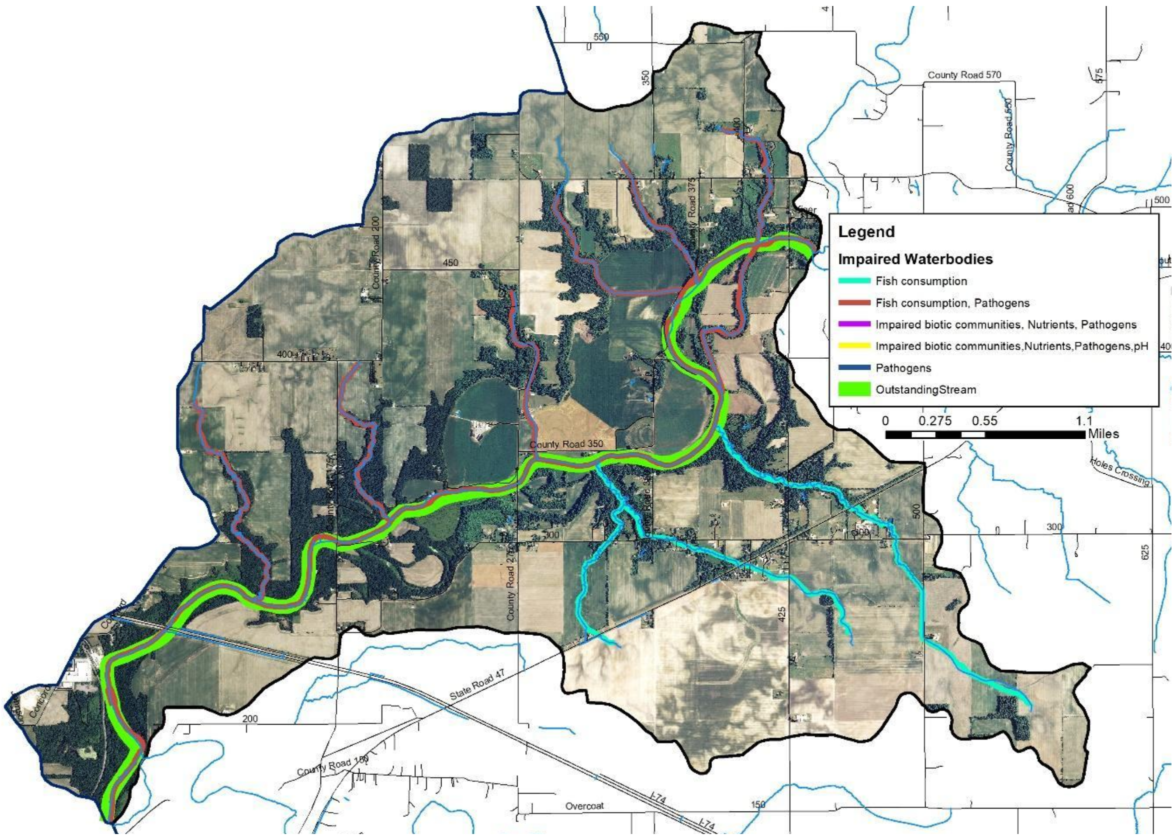


Figure 89. Town of Garfield-Sugar Creek subwatershed.

4.14.1 Soils

Hydric soils cover 1,599.0 acres (20.1%) of the subwatershed. Wetlands currently cover 2.3% (186.8 acres) of the subwatershed. Highly erodible soils cover over half of the subwatershed (64.3%). In total, 7,693.2 acres (96.5%) of the subwatershed are identified as very limited for septic use. The majority of the subwatershed is rural, indicating homes pump to on-site septic systems. Based on the septic suitability of the soil, the majority of the subwatershed is very limited. Therefore, maintenance and inspections of septic systems in the area are important to ensure proper function and capacity.

4.14.2 Land Use

Agricultural land use dominates the Town of Garfield-Sugar Creek subwatershed with 75.2% (5,991.8 acres) in agricultural land uses, including row crop and pasture. An additional17.1% (1,367.3 acres) is in forested land use. Wetlands, open water, and grassland cover 186.8 acres, or 2.3%, of the subwatershed. In total, 421.2 acres or 5.3% of the subwatershed are in urban land uses.

4.14.3 Point Source Water Quality Issues

There are few potential point sources of water pollution in the subwatershed. There is one underground storage tank site in the Town of Garfield-Sugar Creek subwatershed (Figure 90). There are no open dumps, brownfields, corrective action sites, voluntary remediation sites, NPDES sites, or industrial waste facilities located within the Town of Garfield-Sugar Creek subwatershed.

4.14.4 Non-Point Source Water Quality Issues

Agricultural land use is the predominant land use in the Town of Garfield-Sugar Creek subwatershed. Additionally, a number of small animal operations and pastures are also present (Figure 90). In total, six unregulated animal operations housing more than 182 cows and horses were identified during the windshield survey. No active confined feeding operations are located within the Town of Garfield-Sugar Creek subwatershed. In total, manure from small animal operations total over 3,731 tons per year, which contains almost 2,066 pounds of nitrogen, 1,051 pounds of phosphorus and 7.92E+13 colonies of *E. coli*. Livestock have access to 0.9 miles (3.4%) of the subwatershed streams based on windshield survey observations. Streambank erosion and lack of buffers are a concern in the subwatershed. Approximately 0.5 miles (0.9%) of insufficient stream buffers and 0.6 miles (0.9%) of streambank erosion were identified within the subwatershed.

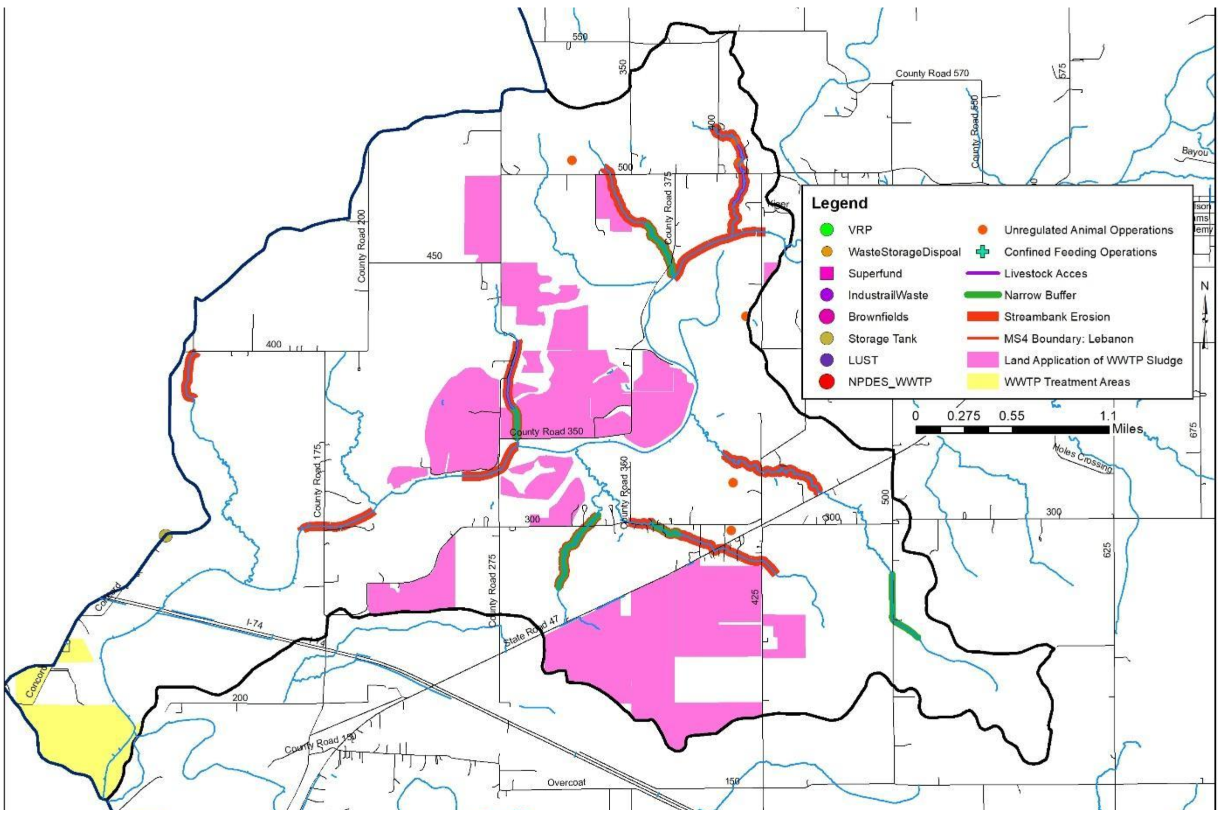


Figure 90. Potential point and non-point sources of pollution and suggested solutions in the Town of Garfield-Sugar Creek subwatershed.

4.14.5 Water Quality Assessment

Waterbodies within the Town of Garfield-Sugar Creek subwatershed have been sampled historically at two locations (Figure 91). One site in the Town of Garfield-Sugar Creek subwatershed is being sampled as part of the current project. Historic assessments include collection of water chemistry (2 sites) and biology data by IDEM (2 sites). No stream gages are in the Town of Garfield-Sugar Creek subwatershed.

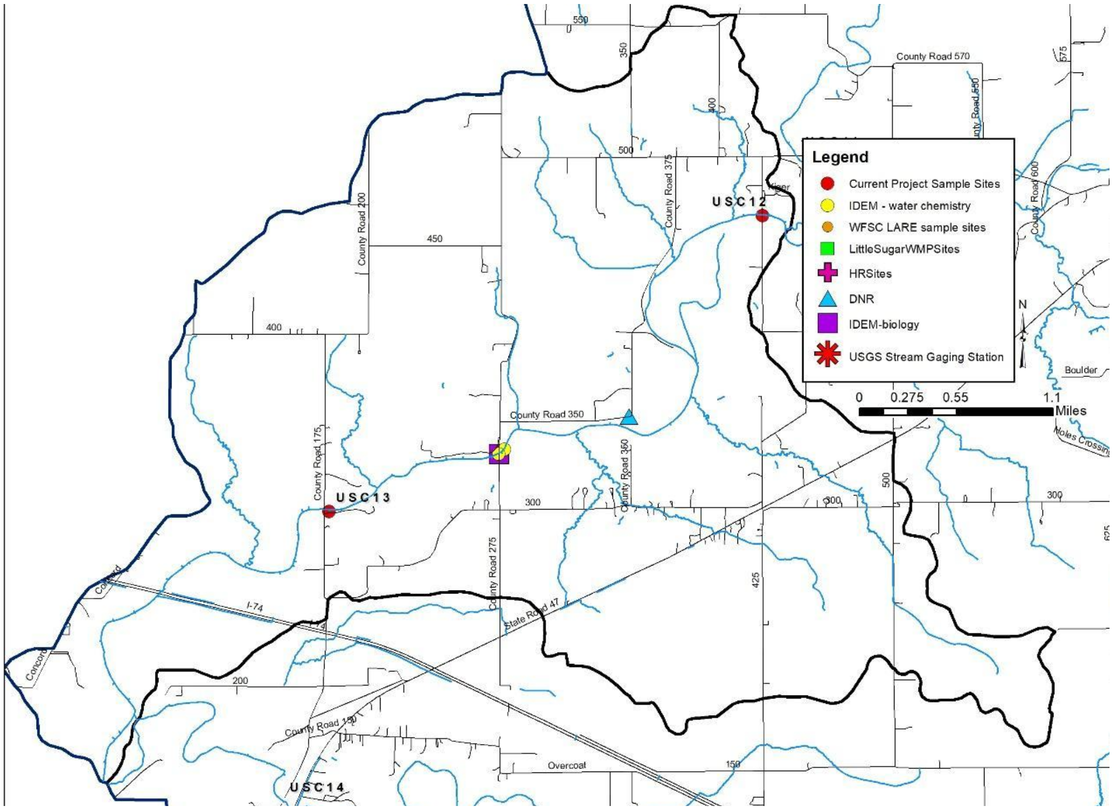


Figure 91. Locations of historic and current water quality data collection in the Town of Garfield-Sugar Creek subwatershed.

Table 59 details historic water chemistry data collected in the Town of Garfield-Sugar Creek subwatershed. E. coli samples exceed state grab sample standards (235 col/100 ml) in 60% of samples collected. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 50% of samples, while total Kjeldahl nitrogen concentrations exceed water quality targets (0.5 mg/L) in 60% of samples. Total phosphorus concentrations exceed water quality targets (0.08 mg/L) in 50% of samples. Turbidity levels exceed water quality targets (5.7 NTU) in 78% of samples.

Table 59. Town of Garfield-Sugar Creek subwatershed historic water quality data summary.

Parameter	Minimum	Maximum	Number Exceeding Target	Number of Samples	Percent Exceeding
Dissolved oxygen (mg/L)	7.35	11.18	0	18	0%
E. coli (col/100 ml)	206.4	2,755	3	5	60%
Total Kjeldahl nitrogen (mg/L)	0.2	1.68	3	5	60%
Nitrate (mg/L)	0.739	6.64	3	6	50%
pH	7.63	8.37	0	18	0%
Total Phosphorus (mg/L)	0.034	0.174	3	6	50%
Specific conductance (μmhos/cm)	513	700	0	18	0%
Turbidity (NTU)	3.39	79.5	14	18	78%

Table 60 details water quality data collected in the Town of Garfield-Sugar Creek Subwatershed (Site 13). As shown in the table, *E. coli* samples exceed state standards (235 col/100 ml) in 42% of samples collected. Nitrate-nitrogen concentrations exceed water quality targets (1 mg/L) in 83% of samples. Total phosphorus concentrations exceed water quality targets (0.08 mg/L) in 50% of samples. Total suspended solids concentrations exceed water quality targets (15 mg/L) in 17% of samples, while turbidity levels exceed water quality targets (5.7 NTU) in 33% of samples. Dissolved oxygen concentrations did not exceed water quality standards in samples collected from this site.

Table 60. Town of Garfield-Sugar Creek Subwatershed water quality data summary.

Site		Temp (deg C)	DO (mg/L)	pH	Cond (µmhos/cm)	Turb (NTU)	Nitrate (mg/L)	TP (mg/L)	TSS (mg/L)	*E. coli* (col/100 ml)
13	Median	11.40	8.10	8.22	491.5	2.93	1.56	0.12	3.50	60.6
	Max	23.30	11.70	8.79	765.0	152.00	4.68	1.93	248.00	2419.6
	Min	-1.10	4.40	7.83	235.0	0.00	0.38	0.02	2.00	2.0
	#Samples	12	12	12	12	12	12	12	12	12
	#Exceed		0	0	0	4	10	6	2	5
	% Exceed	0%	0%	0%	0%	33%	83%	50%	17%	42%

Biological monitoring was conducted by IDEM at two sites with both sites assessed for macroinvertebrates and for fish and habitat assessed a total of five times and one site was assessed as part of the current project. Habitat scores ranged from 54 to 88 with all sites scoring above the state target (51). Fish community assessments are good with all assessments meeting their aquatic life use designation. Macroinvertebrate assessment sites meet their aquatic life use designation using the multihabitat assessment (Table 61).

Table 61. Town of Garfield-Sugar Creek subwatershed biological assessment data summary.

Parameter	Minimum	Maximum	Number Exceeding Target	Number of Samples	Percent Exceeding
Habitat (QHEI)	54	88	0	6	0%
Fish (IBI)	40	50	0	3	0%
Macroinvertebrates (mIBI, Kick)	--	--	--	--	--
Macroinvertebrates (mIBI, Multi Habitat)	40	42	0	3	0%

5.0 WATERSHED INVENTORY III: WATERSHED INVENTORY SUMMARY

Several important factors and relationships become apparent when the Upper Sugar Creek Watershed is observed both as a whole and in part. Many of these were discussed in the individual subwatershed discussions above. An overall summary of water quality impairments and a review of stakeholder concerns and any data which support these concerns are included below.

5.1 Water Quality Summary

Several water quality impairments were identified during the watershed inventory process, based on historic data collected from Indiana Department of Environmental Management, Indiana Department of Natural Resources, developers of the Little Sugar Creek Watershed Management Plan and Walnut Fork-Sugar Creek LARE diagnostic study and Hoosier Riverwatch volunteers as well as current water quality assessments conducted during the current project. These impairments include elevated nutrient, sediment and *E. coli* concentrations. Based on historic data, Table 62 highlights those locations within the Upper Sugar Creek Watershed where concentrations of these parameters measured higher than the target concentrations by subwatershed. Data used in this table are detailed in Section 3 and were collected between 1991 and 2020. Figure 92 shows the locations of historical sites that that exceeded target values. Sample sites are mapped only if 50% or more of samples collected at those sites were outside the target values.

Table 62. Percent of samples historically collected in Upper Sugar Creek subwatersheds which measured outside target values.

Subwatershed	DO	Cond	Turb	pH	Nitrate	TKN	TP	Ecoli
Headwaters Little Potatoe Creek	44%	0%	57%	11%	67%	33%	100%	60%
Bowers Creek	--	--	--	--	--	--	--	--
Lye Creek Drain	0%	0%	67%	0%	33%	67%	100%	--
Little Potatoe Creek-Lye Creek	23%	2%	71%	0%	70%	54%	20%	4%
Little Creek-Little Sugar Creek	37%	1%	90%	0%	70%	67%	71%	6%
Little Sugar Creek	25%	3%	50%	0%	71%	53%	71%	2%
Town of Linnsburg-Walnut Fork Sugar Creek	34%	5%	68%	0%	93%	100%	59%	79%
Sanitary Ditch-Prairie Creek	--	--	--	--	--	--	--	--
Deer Creek-Prairie Creek	0%	0%	93%	0%	--	--	--	--
Wolf Creek	--	--	--	--	--	--	--	--
Goldsberry Creek-Sugar Creek	0%	--	100%	0%	75%	--	--	0%
Withe Creek-Sugar Creek	0%	0%	90%	0%	100%	100%	100%	100%
Hazel Creek-Sugar Creek	29%	0%	42%	0%	100%	100%	100%	80%
Town of Garfield-Sugar Creek	0%	0%	78%	0%	50%	60%	50%	60%

Historic nitrate-nitrogen concentrations sampled in the Headwaters Little Potatoe Creek, Little Potatoe Creek-Lye Creek, Little Creek-Little Sugar Creek, Little Sugar Creek and Town of Linnsburg-Walnut Fork Sugar Creek subwatersheds exceeded targets in more than 50% of samples collected. Total phosphorus concentrations in the Headwaters Little Potatoe Creek, Lye Creek Drain, Little Creek-Little Sugar Creek, Little Sugar Creek, Withe Creek-Sugar Creek and Hazel Creek-Sugar Creek exceeded water quality targets in more than 50% of samples collected. Total Kjeldahl nitrogen concentrations in Lye Creek Drain, Little Creek-little Sugar Creek, Little Sugar Creek, Town of Linnsburg-Walnut Fork Sugar Creek, Withe Creek-Sugar Creek, Hazel Creek-Sugar Creek and Town of Garfield-Sugar Creek exceeded water quality targets in more than 50% of samples collected. E. coli concentrations measured in Headwaters Little Potatoe Creek, Town of Linnsburg-Walnut Fork-Sugar Creek, Withe Creek-Sugar Cree, Hazel Creek-Sugar Creek and Town of Garfield-Sugar Creek exceeded state standards in more than 50% of samples collected. A limited number of pH exceedances occurred in the Headwaters Little Potatoe Creek subwatershed all of which measured above the upper level and suggest an algal bloom occurred at the time of sample collection. Dissolved oxygen exceedances occurred in the Headwaters Little Potatoe Creek, Little Potatoe Creek-Lye Creek, Little Creek-Sugar Creek, Little Sugar Creek, Town of Linnsburg-Walnut Fork Sugar Creek and Hazel Creek-Sugar Creek subwatersheds with all exceedances measuring higher than the upper dissolved oxygen state standard at the time of sampling. Conductivity exceedances occurred a limited number of times in the Little Potatoe Creek-Lye Creek, Little Sugar Creek and Town of Linnsburg-Walnut Fork Sugar Creek subwatersheds.

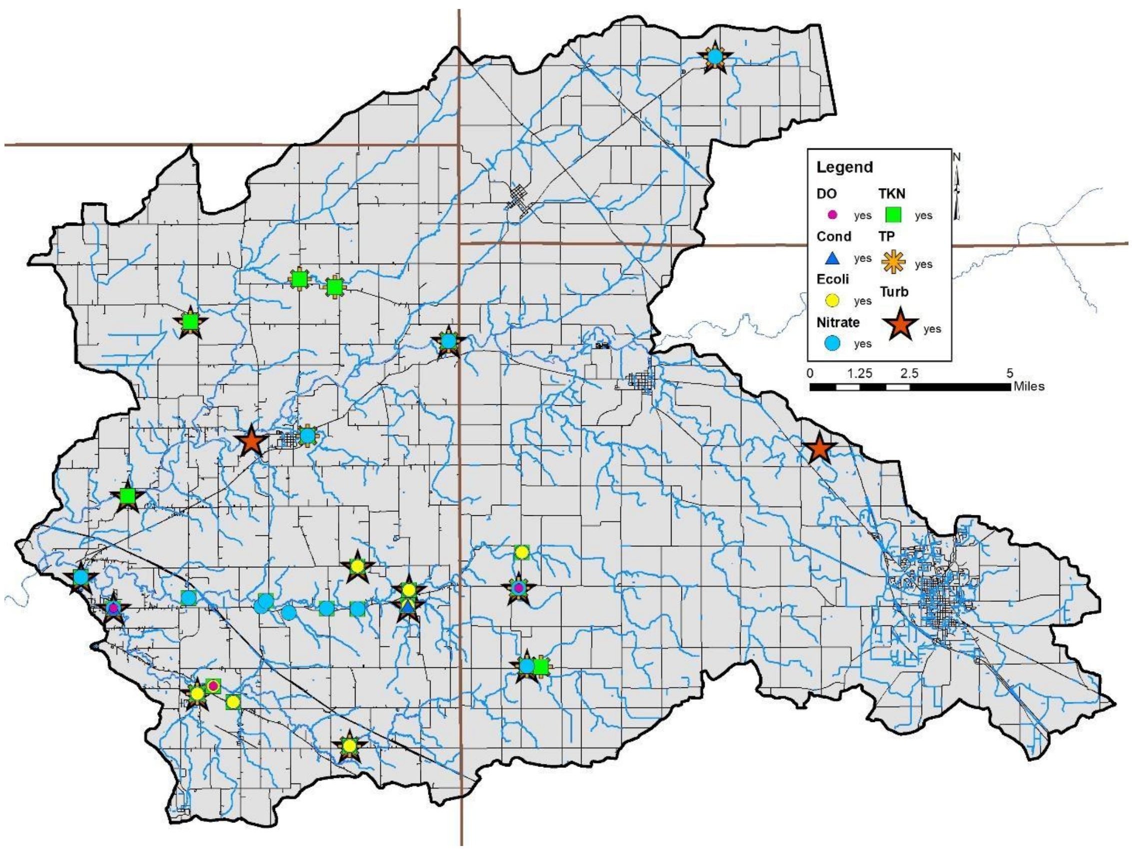


Figure 92. Upper Sugar Creek Watershed historical sampling sites that exceed target values.

Table 63 summarizes current samples which measured outside the target values during the current assessment. Figure 93 provides a map of current sampling sites that exceed target values. Elevated nitrate-nitrogen concentrations were observed at all sample sites with Lye Creek Drain, Little Sugar Creek, Sanitary Ditch-Prairie Creek and Deer Creek-Prairie Creek samples exceeding nitrate-nitrogen target concentrations during all sampling events. In total, 69% of collected samples throughout the watershed exceeded nitrate-nitrogen target concentrations. Elevated total phosphorus concentrations were observed at all sample sites with concentrations exceeding total phosphorus targets in 70% of collected samples. Bowers Creek, Lye Creek Drain and Little Creek-Little Sugar Creek samples exceeded target total phosphorus concentrations in 80% or more of collected samples. Elevated total suspended solids concentrations were observed at all sites with 20% of all samples exceeding targets. However, no site exceeded target TSS concentrations in more than half of collected samples. Rather, TSS concentrations generally measured low then increased to concentrations higher than targets during storm flow events. *E. coli* concentrations that exceeded the state grab sample standard were measured at all sites. Exceedances were most common at Lye Creek Drain, Little Creek-Little Sugar Creek, Sanitary Ditch-Prairie Creek and Deer Creek-Prairie Creek sites. In total, 36% of samples exceeding state standards.

Table 63. Percent of samples collected in the Upper Sugar Creek Watershed during the 2022 sample collection which measured outside target values.

Subwatershed	DO	pH	Turb	Cond	TP	Nitrate	TSS	Ecoli
Headwaters Little Potatoe	0%	0%	42%	0%	67%	50%	25%	42%
Bowers Creek	0%	8%	33%	0%	83%	58%	17%	25%
Lye Creek Drain	0%	0%	29%	0%	86%	100%	29%	86%
Little Potatoe Creek-Lye Creek	0%	0%	33%	0%	67%	67%	17%	17%
Little Creek-Little Sugar Creek	0%	0%	50%	0%	80%	80%	20%	60%
Little Sugar Creek	0%	0%	25%	0%	67%	100%	25%	25%
Town of Linnsburg-Walnut Fork Sugar Creek	8%	0%	33%	8%	67%	83%	17%	33%
Sanitary Ditch-Prairie Creek	0%	0%	33%	50%	75%	100%	8%	58%
Deer Creek-Prairie Creek	0%	0%	25%	25%	67%	100%	25%	58%
Wolf Creek	0%	0%	17%	0%	75%	92%	17%	33%
Goldsberry Creek-Sugar Creek	0%	0%	31%	4%	78%	96%	26%	48%
Withe Creek-Sugar Creek	0%	0%	17%	0%	58%	83%	17%	25%
Hazel Creek-Sugar Creek	0%	0%	25%	0%	58%	75%	17%	25%
Town of Garfield-Sugar Creek	0%	0%	33%	0%	50%	83%	17%	42%

Only two samples exceeded dissolved oxygen state standards – both were measured in the Town of Linnsburg-Walnut Fork Sugar Creek subwatershed and measured above the high state standard. Specific conductivity exceeded targets at four sites – Town of Linnsburg-Walnut Fork Sugar Creek, Deer Creek-Prairie Creek, Goldsberry Creek-Sugar Creek and Sanitary Ditch-Prairie Creek, the latter of which exceeded conductivity targets in 50% of collected samples. pH concentrations exceeded targets at a single site (Bowers Creek) during one sampling event.

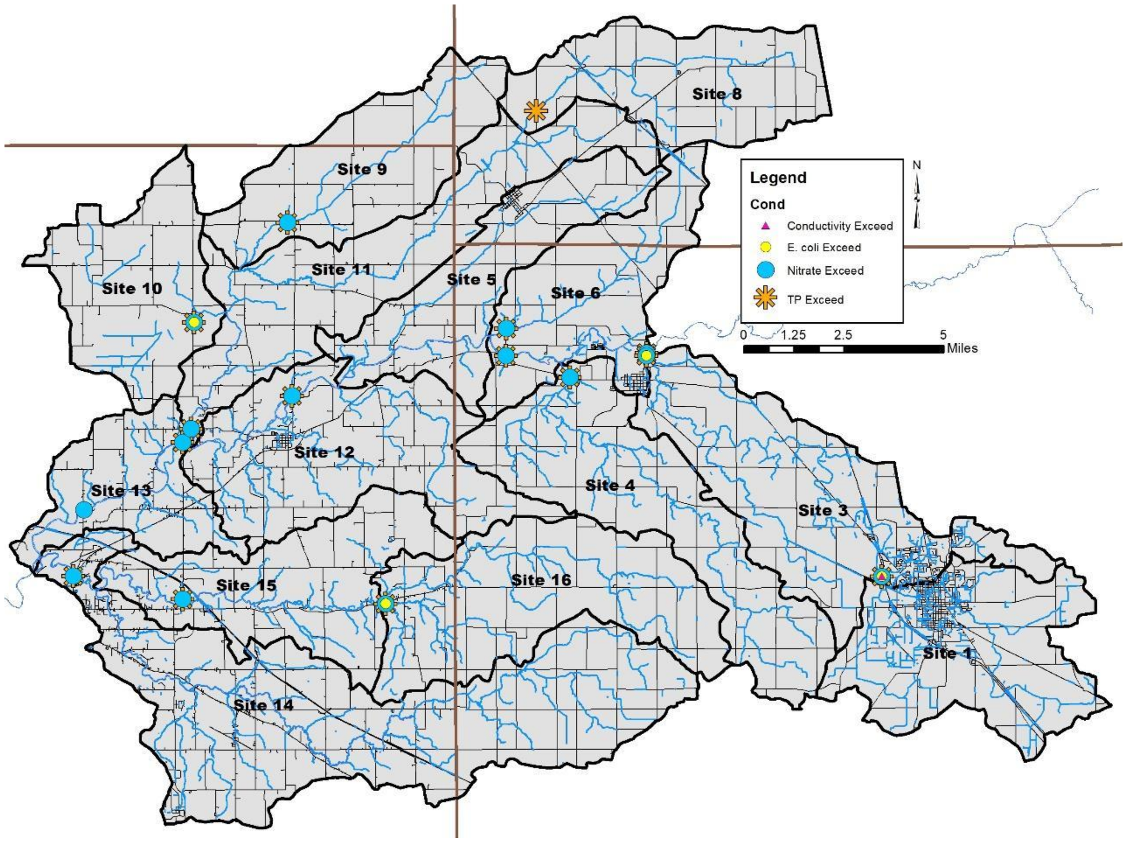


Figure 93. Upper Sugar Creek Watershed sampling sites that exceed target values during the current sampling period.

Biological assessments of the fish and macroinvertebrate community and an associated habitat assessment occurred once during the project. There is no pattern between habitat, macroinvertebrate community and fish community ratings (Table 64). All sites except Site 10 (Lye Creek Drain) possessed an IBI score which meets the streams' aquatic life use designation. Only Site 10 rated poorer than targets for the fish community in the Upper Sugar Creek assessment. Conversely, three sites - Site 5 (With Creek-Sugar Creek), Site 9 (Bowers Creek) and Site 12 (Hazel Creek-Sugar Creek) – possessed mIBI scores which rated as impaired. In total, six stream sites' habitat scored below the QHEI target (51). Site 4 (Wolf Creek), and Site 16 (Little Creek-Little Sugar Creek) rated as fair, while Site 1 (Sanitary Ditch-Prairie Creek), Site 8 (Headwaters Little Potato) and Site 10 (Lye Creek Drain) rated poor and Site 9 (Bowers Creek) rated very poor.

Table 64. Biological and habitat assessment summary for Upper Sugar Creek Watershed streams. Green shading indicates the highest rated stream reaches, while red indicates the poorest rated reaches.

Site	IBI	QHEI	mIBI
1	Good	Poor	Fair
2	Excellent	Fair	Fair
3	Good	Fair	Fair
4	Good	Fair	Fair
5	Excellent	Excellent	Poor
6	Fair	Fair	Fair
7	Fair	Excellent	Fair
8	Fair	Poor	Fair
9	Fair	Very Poor	Poor
10	Poor	Poor	Fair
11	Good	Good	Fair
12	Good	Good	Poor
13	Fair	Fair	Fair
14	Excellent	Excellent	Fair
15	Good	Good	Fair
16	Fair	Fair	Fair

5.2 Agricultural Conservation Planning Framework (ACPF) Summary

The Agricultural Conservation Planning Framework (ACPF) was developed by the USDA's Agricultural Research Service in partnership with the USDA Natural Resources Conservation Service. ACPF supports agricultural watershed management by using high-resolution elevation data and an ArcGIS toolbox to identify site-specific opportunities for installing conservation practices across watersheds. This non-prescriptive approach provides a menu of conservation options to facilitate conservation discussions. The framework is used in conjunction with local knowledge of water and soil resource concerns, landscape features, and producer conservation preferences. Together, these provide a better understanding of the options available to develop and implement a watershed management plan.

Sediment delivered from watershed erosion can cause substantial damage and degradation to waterways and water quality. Controlling sediment loading requires knowledge about soil erosion and sedimentation. Drainage area, basin slope, climate, land use and land cover affect the sediment delivery process. Problems caused by soil erosion and sediments include losses of soil productivity, water quality degradation, and less capacity to prevent natural disasters such as floods. Sediments may carry pollutants into water systems and cause significant water quality problems. Sediment yields are also associated with waterway damages. Sediment deposition in streams reduces channel capacity and result in flooding damages. The water storage capacity of a reservoirs can be depleted by accumulated sediment deposition. Sediment yield is a critical factor in identifying non-point source pollution as well as in the design of the construction such as dams and reservoirs. However, sediment yield is usually not available as a direct measurement but estimated by using a sediment delivery ratio (SDR). Figure 94 details the sediment delivery ratio for each agricultural field in the Upper Sugar Creek Watershed. Sediment delivery ratio utilizes both the distance from the stream and the field's steepness to calculate the rating. Coarser texture sediment and sediment from sheet and rill erosion have more chances to be deposited or to be trapped, compared to fine sediment and sediment from channel erosion. Therefore, the delivery ratio of sediment with coarser texture or from sheet and rill erosion are relatively lower than the fine sediment or sediment from channel erosion. A small watershed with a higher channel density has a higher sediment delivery ratio compared to a large watershed with a low channel density. Conversely, a watershed with steep slopes has a higher sediment delivery ratio than a watershed with flat and wide valleys.

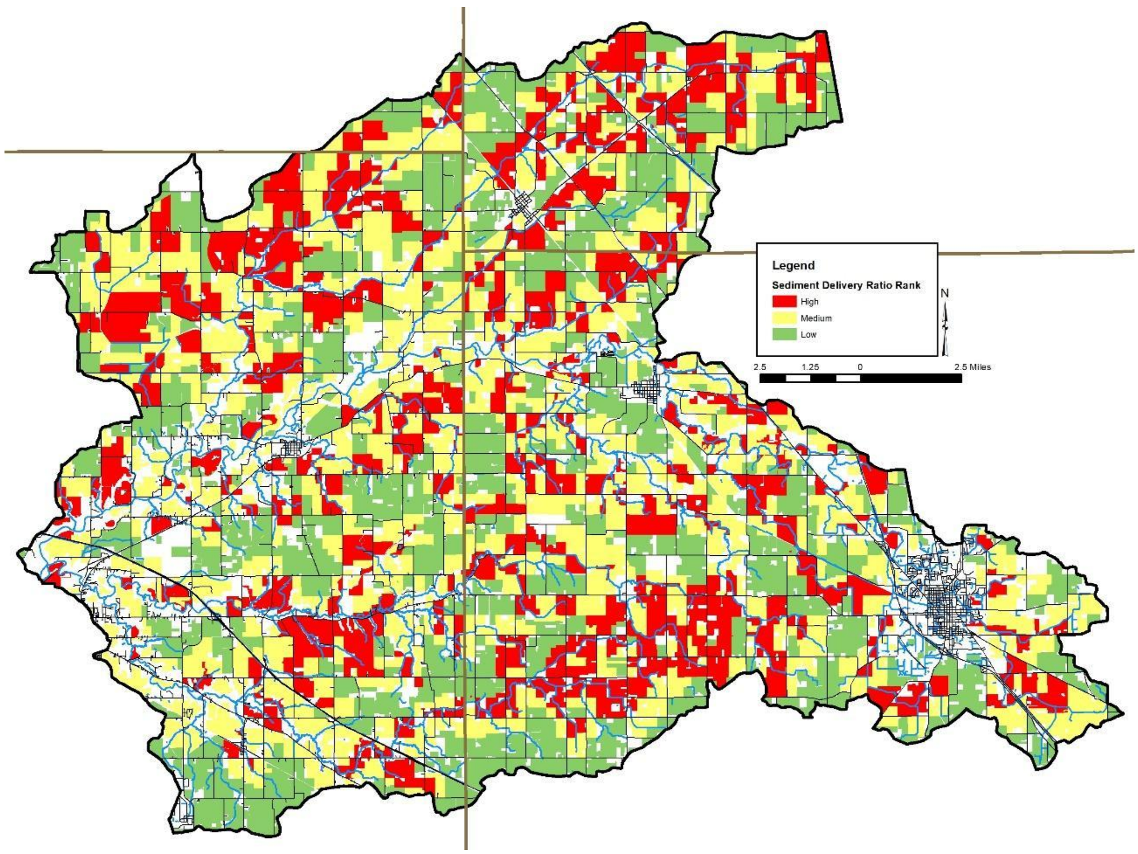


Figure 94. Sediment delivery ratio developed using ACPF for the Upper Sugar Creek Watershed.

Similarly, runoff risk calculates the direct runoff contribution to stream channels in the watershed. Runoff risk prioritize fields where multiple erosion control practices are most needed. Fields that are closer in proximity to a stream and are steeper in slope have a higher runoff risk. Those that are further away, or flatter, have a lower runoff risk. Because sediment and phosphorus are not lost evenly from all parts of a fields but rather are lost from a few critical source areas these are the most limiting areas of significant extent, or are generally those areas of the field that have the steepest slope. Figure 95 details the runoff risk for farm fields in the Upper Sugar Creek Watershed. Runoff risk is categorized into low, moderate, high and very high. It should be noted that even fields rated as low will benefit from runoff control-based conservation practices; however, fields which rank moderate, high or very high will likely benefit more.

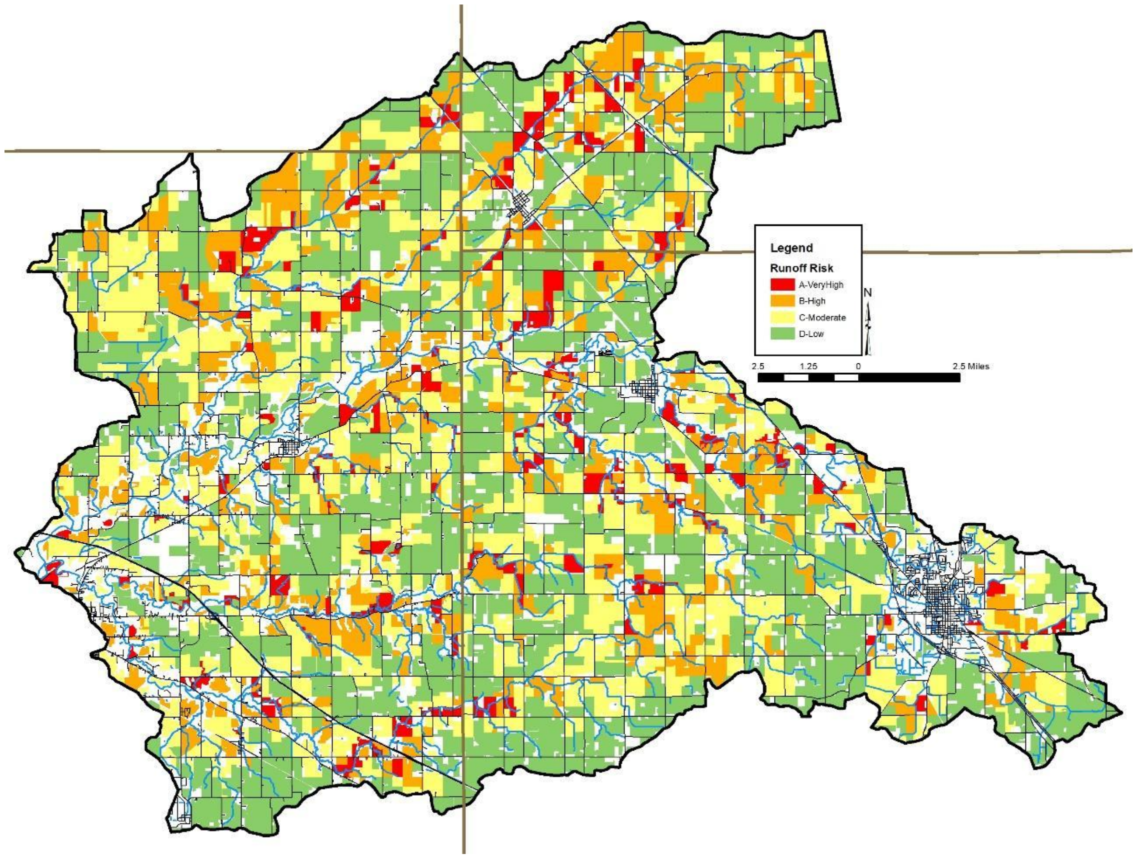


Figure 95. Runoff risk ratio developed using ACPF for the Upper Sugar Creek Watershed.

5.3 Stakeholder Concern Analysis

All identified concerns generated both from stakeholder input and through water quality and watershed inventory efforts are detailed in Table 65. This list represents a work in progress and additional concerns may be added as the steering and monitoring committees work through data analysis. The steering committee rated each concern as to whether it is supported by watershed-based data, what evidence does or does not support the concern, 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.

Table 65. Analysis of stakeholder concerns identified in the Upper Sugar Creek Watershed.

Concern	Supported by our data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
Streambank erosion Soil erosion and nutrient loss	Yes	86.1 miles of streambank were identified as eroding during the windshield survey. 85% of the watershed is covered by row crop or pastureland. Between 4 and 8% of corn and 4 and 13% of soybean fields use conservation tillage per the tillage transect. 58% of the watershed is covered by highly erodible lands. 30% of turbidity and 20% of TSS samples exceed targets.	Yes	No	Yes
Elevated sediment and nutrient levels Water quality is poor	Yes	20% of TSS samples, 70% of TP samples, 69% of nitrate samples, 36% of E. coli samples collected during current monitoring exceed water quality targets. 11% of E. coli samples, 71% of turbidity samples, 25% of TP samples, 76% of nitrate samples collected historically exceed water quality targets. 10.6 miles of streams are listed as impaired for nutrients and 115.2 miles of streams are listed as impaired for E. coli.	Yes	No	Yes
Septic soil limitations, straight pipes, lack of maintenance	No data available	99% of the watershed is covered by soils which rate as very limited for septic use. Anecdotal information suggests that straight pipes	Not really	Yes – education	Yes - education

Concern	Supported by our data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
		and facility maintenance is an issue in the watershed.			
E. coli levels are elevated	Yes	36% of E. coli samples collected during current monitoring exceed water quality targets. 11% of E. coli samples collected historically exceed water quality targets. 115.2 miles of stream area listed as impaired for E. coli	Yes	No	Yes
What is the source of E. coli (human, animal, etc)	No	Source water assessment has not been completed for Upper Sugar Creek.	Consider source typing once full data set is collected	Possibly	No
Stream widening through erosion – shallow water	No	86.1 miles of streambank were identified as eroding during the windshield survey. Data on stream widening or shallowness created by widening has not been collected.	No	No	No
Fertilizer use optimization (4Rs)	yes	NASS estimates (2005) indicates that approximately 265 tons of atrazine and 281 tons of glyphosate are applied to cropland in the Upper Sugar Creek Watershed counties annually. IN State Chemist data indicates 148,810 tons of fertilizer were applied in 2015 (most recent data).	yes	No	Yes
Runoff from pesticides and soil	No		No	Yes	No
Spray, drift, and volatilization issues/concerns – herbicides, others	No		No	Yes	No

Concern	Supported by our data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
Flooding: too much water entering stream too quickly Ponding sometimes occurs when farmers farm into (road) ditches Washouts in large rain events Erosion – farmers are farming into ditches Climate change impacts Additional water inputs are changing sugar creek – getting straighter County roads –build right up to them Stream flow issues Maintenance of regulated drains needed	Yes	Floodplain covers 9,992 acres of the watershed (5%). Tile drainage occurs on an estimated 76% of the watershed. 93% of historic wetlands in Upper Sugar Creek have been modified or lost. 25.4 miles or narrow buffer were observed during the windshield survey. CBBEL estimated a peak 100 year discharge for Lye Creek Drain of 1790 to 13600 cfs, 0.4 increase in flood elevation, 6% increase in flooded acres (CBBEL, 2017). There is anecdotal evidence of historic flooding in the Lye Creek, Potatoe Creek basins No data have been collected with regards to ponding of watershed streams. Anecdotal evidence based on communication with stakeholders. . The watershed approximately 200 miles of tile drains, underground pipes and artificial channels. Maintenance data have not been collected by the group. Surveyors have data and are constantly completing maintenance.	Yes	No	Yes Consult with surveyors office to coordinate maintenanc e and associated projects Also, consider climate change impacts in long term impacts

Concern	Supported by our data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
Bridges are not replaced in Lye Creek Basin due to high flow – options to study flow through these systems		Anecdotal evidence based on communication with stakeholders.			
Protect and improve (terrestrial) habitat	Yes	Central Till Plain Flatwoods, Wet-mesic Floodplain forest, mesic prairie and Circumneutral Seep rate as high-quality natural communities. Cool Creek PF 3000 acres of habitat restoration.	Yes	No	Yes
Sugar Creek provides good habitat and aesthetics – it should be protected	Yes	Stream health assessments (QHEI) occurred 37 times historically. 86% of assessments indicate stream reaches meet their aquatic life use designation. Fish communities assessed at all but one site during the current project meet their aquatic life use designation. QHEI assessments should be used to assess individual sites and rate potential for improving instream habitat.	Yes	No	Yes
Keeping the creek healthy/ maintain quality fish community	Yes	The fish community was assessed by IDEM, DNR 15 times historically. 93% of assessments indicate that the fish community meets their aquatic life use designation. 38% of sites assessed do not meet state habitat quality targets. Fish communities assessed at all but one site during the current project meet their aquatic life use designation.	Yes	No	Yes
Fish community is declining	No	Historic and current Sugar Creek fish community assessments do not document a decline in fish community quality.	Not at this time	yes	No

Concern	Supported by our data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
Drinking water protection (Indiana American Water)/source water	Yes	10 wellhead protection areas are present in the watershed, protecting drinking water for 35,770 people.	Yes	No	Yes
Recreational vehicles must be excluded from streams	No	While the impacts of recreational vehicles is well documented, areas of access and watershed impacts from rec vehicles has not been documented.	No	Yes	No
Provide opportunities to access Sugar Creek	Yes	The DNR & Darlington Parks (public), Sugar Creek campground (CR 175, private) provide access.	Yes	No	No – access is adequate; Yes- education
Urban areas and their water quality impacts – City of Lebanon Towns are an issue but don't get blamed Economic development – Lebanon (water pollution, water usage, trash) Lebanon is growing, lack of land for agriculture, increased traffic, no room for ag equipment on roads Threats from industry, residential development Engaging/leveraging resources for industrial developers Industrial and residential development along I65/within city of Lebanon Is new development in Boone County following requirements or best practices?	Yes	Urban land uses cover approximately 14,188.7 acres or nearly 8% of the watershed. A majority of the urban land is located in the City of Lebanon. Lebanon adopted a comprehensive plan and addended it to include a thoroughfare plan in 2017. These plans guide development along the interstate. Stormwater impacts in Lebanon are governed by the Lebanon MS4 which requires documented stormwater improvements for development impacts. Developments are required to follow the Lebanon stormwater technical standards.	Yes	No	Yes
Need to engage agricultural landowners	Yes	85% of the watershed is covered by row crop or pastureland. To positively impact the watershed, agricultural producer and landowner engagement is necessary.	Yes	No	Yes

Concern	Supported by our data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
Some farmers don't want to be told what they can/cannot do	Yes	Anecdotal evidence based on communication with stakeholders.	Yes	No	Yes
Farmers are resistant to change	Yes		Yes	No	Yes
Change is hard – fear reduced yields (other impacts should be included here)	Not at this time	Anecdotal evidence based on communication with stakeholders.	No, survey may provide data	No	Yes
Traditional farming and traditional tillage leads to silt runoff, wind erosion, soil loss	Yes	85% of the watershed is covered by row crop or pastureland. Tillage transect data indicates 4-8% of corn and 4-13% of soybean fields utilize conservation tillage in Upper Sugar Creek counties. Traditional farming tends to leech the land of its nutrition over time resulting in soil that is undernourished and eroded.	Yes	No	Yes
Farmers are blamed even if it isn't their fault	No	Anecdotal evidence based on communication with stakeholders.	No	Yes	No
Farmland conservation and preservation needed	Yes	The most recently available NASS data (2017) notes a 2% loss of land in farms in Montgomery County, a 4%, 1% and 11% increase in Boone, Tippecanoe and Clinton Counties respectively from 2012 to 2017.	Yes	Yes	No
On farm issue: time and interest in cover crops, but time constraint for fall harvest	Yes	Research documents the top barriers to cover crop use: establishment; time and labor required to manage cover crops and seeding the right species for my operation. Farmers' motivations to plant cover crops are directly related to their perceived benefits of increased soil health,	Yes	No	Yes
Cover crop profitability must be emphasized/detailed for farmer adoption					
Cover crops - climate barrier					
Cover crop information is lacking					
Issues with cover crop planting, harvest, timing					

Concern	Supported by our data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
		increased organic matter and reduced soil erosion			
Need to build a sense of community between agriculture and recreation	No	Magical unicorn	No	No	Yes
Wetland loss/wetland restoration in marginal land targeting Lye/Potatoe Creek areas	Yes	Wetlands cover 5,613 acres (8%) of the watershed. It is estimated that 93% of wetlands have been modified or lost over time.	Yes	No	Yes
Trash accumulation	No	Individual observations during the watershed inventory indicate trash accumulation is a problem.	No	No	Yes – education
Logjams	No	Logjams were identified during the windshield inventory. Anecdotal information documents the presence of logjams.	No	No	Yes
Beaver impacts	No	Anecdotal information documents the impacts of beavers in the watershed. No data have been collected on their impacts.	No	No	No
Encourage local residents to have a good land ethic	No	Anecdotal evidence based on communication with stakeholders.	No	No	Yes - education
Tree line removal impacts	No	6% of the watershed is forested. Historically 42% of the watershed was mapped in forest land.	No	No	Yes
Wildlife corridors should connect watershed headwaters					
Lack of awareness	Yes	Anecdotal evidence based on communication with stakeholders.	No	No	Yes
Education for controlled drainage/drainage water management that target water quantity are needed	Yes		No	No	Yes
Dam removal at Crawfordsville opens the Upper Sugar Creek to recreation	Yes	Dam removal occurred downstream of the Upper Sugar Creek Watershed. It's removal is likely to impact recreation on Sugar Creek but it is likely too soon to know what those impacts will be.	Yes	Yes	No
Funding constraints	Yes	Anecdotal evidence based on communication with stakeholders.	Yes	No	Yes

Concern	Supported by our data?	Evidence	Able to Quantify?	Outside Scope?	Group wants to focus on?
Concerns about how this information will be used	Yes	Anecdotal evidence based on communication with stakeholders.	Not really	No	Yes - education
Livestock access	Yes	Livestock have access to approximately 16 miles of watershed streams. Additional access is likely present but was not observed during the windshield survey.	Yes	No	Yes
Confined feeding operations, manure volume	Yes	119,000 animals are permitted on CFOs in the watershed producing more than 45,200 tons of manure annually.	Yes	No	Yes
Municipal sludge is applied to farm ground	Yes	Municipal sludge is applied to 5325 acres of row crop agriculture in the watershed.	Yes	No	Yes
Invasive species threats to biodiversity of both flora and fauna with an untold economic cost to forestry and tourism	Yes	Several invasive species were observed in riparian areas during the windshield survey; however, specific species list and presence/absence surveys have not been complete.	Yes	No	Yes- education
River otter populations negatively impact farm pond and Sugar Creek fish populations	Yes, anecdotal	River otter reintroduction occurred 1995-1999 and otters were removed from the state endangered species list in 2005. DNR notes that damage to farm ponds is common and suggestions using a licensed trapper to relocate nuisance otters.	Not really	Yes	No

Following a review of the stakeholder concerns, the steering committee determined the following concerns identified by the public to be outside of this project's approach:

- What is the source of E. coli (human, animal, etc). The committee noted that watershed inventory efforts should provide sufficient information to identify potential sources without using lab testing.
- Stream widening through erosion, shallow water. The committee noted this concern will likely be covered by addressing flow and that the creation or mitigation of shallow water issues falls outside of their sphere of influence.
- Runoff from pesticides and spray, drift, and volatilization issues/concerns, herbicides, others. The committee noted several programs focus on pesticide impacts and that spreading

educational materials from these programs likely meet this concern without focusing on it as part of the planning process.

- Fish community is declining. The committee noted an interest in including if data supports this concern; however, as data does not support a change in fish community quality, this concern will not be a focus of the watershed plan.
- Recreational vehicles must be excluded from streams. The committee agrees but feels this is a conservation officer issue rather than a watershed planning issue.
- Provide opportunities to access Sugar Creek. The committee deemed access to be adequate and will consider for education about and promotion of access locations.
- Farmers are blamed even if it isn't their fault. The committee agrees but could not identify a viable watershed planning option to mitigate this issue.
- Farmland conservation and preservation needed. The committee agrees and reworked this to focus on both agricultural and urban preservation, land ethic, sustainability and more.
- Beaver and otter impacts. These have been observed throughout the watershed; however, the committee indicates that the DNR's recommended actions are sufficient and watershed planning will neither negatively nor positively impact either species.
- Dam removal at Crawfordsville opens the Upper Sugar Creek to recreation. The committee agrees; however, this project is not located in our planning area.

6.0 PROBLEM AND CAUSE IDENTIFICATION

After evaluation of stakeholder concerns and completion of the watershed inventory, watershed problems can be summarized as shown in Table 66. Problems represent the condition that exists due to a particular concern or group of concerns, then details potential causes of problems identified.

Table 66. Problems and causes identified for the Upper Sugar Creek watershed based on stakeholder and inventory concerns.

Concern(s)	Problems/Causes
● Drinking water protection (Indiana American Water)/source water ● Elevated sediment and nutrient levels ● Erosion – farmers are farming into ditches ● Flooding: too much water entering stream too quickly ● Is new development in Boone County following requirements or best practices? ● Lebanon is growing; industrial and residential development along I65 corridor near Lebanon ● Soil erosion and nutrient loss ● Stream flow issues ● Streambank erosion ● Threats from industry, residential development ● Towns are an issue but don't get blamed ● Traditional farming and traditional tillage leads to silt runoff, wind erosion, soil loss ● Urban areas and their water quality impacts ● Washouts in large rain events ● Water quality is poor ● Wetland loss/wetland restoration in marginal land targeting Lye/Potato Creek areas	**Problem:** Sediment: area streams are cloudy/turbid **Cause(s)**: Suspended Sediment concentration levels exceed the target set by this project

Concern(s)	Problems/Causes
• Livestock access • Flooding: too much water entering stream too quickly • Ponding sometimes occurs when farmers farm into (road) ditches • Washouts in large rain events • Erosion – farmers are farming into ditches • Additional water inputs are changing sugar creek – getting straighter • County roads –build right up to them • Stream flow issues • Maintenance of regulated drains needed • Bridges are not replaced in Lye Creek Basin due to high flow – options to study flow through these systems • Climate change impacts • Log jams • Urban areas and their water quality impacts • Economic development – Lebanon (water pollution, water usage, trash) • Threats from industry, residential development • Engaging/leveraging resources for industrial developers • Is new development in Boone County following requirements or best practices? • Encourage local residents to have a good land ethic • Concerns about how this information will be used • Funding constraints	
• Drinking water protection (Indiana American Water)/source water • Economic development – Lebanon (water pollution, water usage, trash) • Elevated sediment and nutrient levels • Is new development in Boone County following requirements or best practices? • Lebanon is growing; industrial and residential development along I65 • Soil erosion and nutrient loss • Threats from industry, residential development • Towns are an issue but don't get blamed • Traditional farming and traditional tillage leads to silt runoff, wind erosion, soil loss • Urban areas and their water quality impacts • Water quality is poor • Wetland loss/wetland restoration in marginal land targeting Lye/Potato Creek areas • Fertilizer use optimization (4Rs) • Erosion – farmers are farming into ditches • Flooding: too much water entering stream too quickly	**Problem:** Nutrients: Area streams have nutrient levels exceeding the target set by this project **Cause(s)**: Nutrient levels exceed the target set by this project Targeted nutrient reduction education does not exist

Concern(s)	Problems/Causes
• Septic soil limitations, straight pipes, lack of maintenance • Stream flow issues • Streambank erosion • Washouts in large rain events • Livestock access • Confined feeding operations, manure volume • Municipal sludge is applied to farm ground • Flooding: too much water entering stream too quickly • Ponding sometimes occurs when farmers farm into (road) ditches • Washouts in large rain events • Erosion – farmers are farming into ditches • Additional water inputs are changing sugar creek – getting straighter • County roads –build right up to them • Stream flow issues • Maintenance of regulated drains needed • Bridges are not replaced in Lye Creek Basin due to high flow – options to study flow through these systems • Climate change impacts • Deer death in small streams/deer over population • Urban areas and their water quality impacts • Economic development – Lebanon (water pollution, water usage, trash) • Threats from industry, residential development • Engaging/leveraging resources for industrial developers • Is new development in Boone County following requirements or best practices? • Encourage local residents to have a good land ethic • Concerns about how this information will be used • Funding constraints	
• Drinking water protection (Indiana American Water)/source water • Economic development – Lebanon (water pollution, water usage, trash) • Is new development in Boone County following requirements or best practices? • Lebanon is growing; industrial and residential development along I65 • Threats from industry, residential development • Towns are an issue but don't get blamed • Urban areas and their water quality impacts • Water quality is poor • Septic soil limitations, straight pipes, lack of maintenance • E. coli levels are elevated	**Problem**: E. coli: Area streams are impaired for recreational contact by IDEM's 303(d) list **Cause(s)**: E.coli levels exceed the water quality standard

Concern(s)	Problems/Causes
● Erosion – farmers are farming into ditches ● Flooding: too much water entering stream too quickly ● Stream flow issues ● Streambank erosion ● Livestock access ● Confined feeding operations, manure volume ● Municipal sludge is applied to farm ground	
● Flooding: too much water entering stream too quickly ● Ponding sometimes occurs when farmers farm into (road) ditches ● Washouts in large rain events ● Erosion – farmers are farming into ditches ● Additional water inputs are changing sugar creek – getting straighter ● County roads –build right up to them ● Stream flow issues ● Maintenance of regulated drains needed ● Bridges are not replaced in Lye Creek Basin due to high flow – options to study flow through these systems ● Climate change impacts Maintenance of regulated drains needed	**Problem:** Drainage patterns impact water quantity **Cause(s)**: Humans altered the natural drainage pattern. Balance should be restored.
● Keeping the creek healthy/ maintain quality fish community ● Log jams ● Maintenance of regulated drains needed ● Protect and improve habitat ● Sugar Creek provides good habitat and aesthetics – it should be protected ● Trash accumulation ● Tree line removal impacts ● Invasive species threats to biodiversity of both flora and fauna with an untold economic cost to forestry and tourism ● River otter population impacting fish communities in farm ponds and Sugar Creek ● Fish seining and netting ● Wildlife corridors should connect watershed headwaters	**Problem:** Habitat in the Upper Sugar Creek Watershed is impacted by terrestrial and riparian alterations. **Cause(s)**: Habitat modification both historic and present day altered the watershed use and impacted biological communities
● Urban areas and their water quality impacts ● Economic development – Lebanon (water pollution, water usage, trash) ● Lebanon is growing; Industrial and residential development along I65 ● Threats from industry, residential development ● Engaging/leveraging resources for industrial developers ● Is new development in Boone County following requirements or best practices?	**Problem**: Education and cohesion is lacking

Concern(s)	Problems/Causes
• Encourage local residents to practices a good land ethic • Encourage landowners to practice stewardship at their residence • Concerns about how this information will be used • Funding constraints • Change is hard/farmers are resistant to change	**Cause(s)**: Local regulations are key to minimizing impacts from development in the watershed. Lack of focused education programming focused on agricultural/rural area and agricultural area highlighting their common ground and differences.
• Lack of awareness • On farm issue: time and interest in cover crops, but time constraint for fall harvest • Cover crop profitability must be emphasized/detailed for farmer adoption • Cover crops - climate barrier • Cover crop information is lacking • Issues with cover crop planting, harvest, timing • Education for controlled drainage – drainage water management and others that target water quantity are needed • Encourage local farmers to practice a good land ethic • Farmland conservation/preservation needed • Need to build a sense of community between agriculture and recreation • Need to engage agricultural landowners • Some farmers don't want to be told what they can/cannot do • Encourage landowners to practice stewardship at their residence • Concerns about how this information will be used Funding constraints	**Problem:** -A unified group for the entire watershed does not exist - Watershed restoration is underfunded - Education of the public, both adults and children, is needed to increase awareness of water quality protection needs and solutions. **Cause(s)**: Lack of education and awareness limits ability of general public to appreciate the importance of good water quality.

7.0 SOURCE IDENTIFICATION AND LOAD CALCULATION

7.1 Source Identification: Key Pollutants of Concern

Nonpoint pollution sources are varied, yet common throughout almost any watershed. Several earlier sections of this document identify potential sources of the pollutants of concern in the Upper Sugar Creek Watershed. These and other potential sources of these causes are discussed in further detail in subsequent sections. A summary of potential sources identified in the Upper Sugar Creek Watershed for each of our concerns is listed below:

Sediment:

- Conventional tillage cropping practices
- Streambank and bed erosion
- Poor riparian buffers
- Poor forest management
- Gully or ephemeral erosion
- Cropped floodplains
- Livestock access to streams
- Altered hydrology (ditching and draining, altered stream courses)
- Urban land use and development impacts (diffuse, disorganized, lack of proper stabilization technique use)
- Invasive species impacts to land cover/soil stability
- Stormwater from municipal sources (MS4s)

Nutrients (Nitrogen and Phosphorus):

- Conventional tillage cropping practices
- Wastewater treatment discharges
- Agricultural fertilizer
- Poor riparian buffers
- Poor forest management
- Streambank and bed erosion
- Animal waste (livestock in streams, poor manure management, domestic and wildlife runoff)
- Confined feeding operations
- Human waste (failing septic systems, sanitary sewer overflows, inadequately treated wastewater)
- Development impacts (diffuse, disorganized, lack of proper stabilization technique use)
- Invasive species impacts to land cover/soil stability
- Stormwater from municipal sources (MS4s)

E. coli:

- Human waste (failing septic systems, sanitary sewer overflows, inadequately treated wastewater)
- Animal waste (livestock in streams, poor manure management, domestic and wildlife runoff)

7.1.1 Potential Sources of Pollution

The steering committee used GIS data, water quality data, watershed inventory observations and anecdotal information as available to evaluate the potential sources of nonpoint pollution in the Upper Sugar Creek Watershed. Appendix D contains tables detailing each potential source within each subwatershed. Table 67 through Table 73 summarizes the magnitude of potential sources of pollution for each problem identified in the Upper Sugar Creek Watershed. Several sources listed above are not included below as specific data for each concern is not available: conventional tillage by subwatershed; gully or ephemeral erosion (none identified during the watershed inventory but likely present); poor forest management (not assessed); animal waste (domestic and wildlife runoff numbers not identified on the subwatershed level); cropped floodplains (they occur but density and distribution was not mapped); development impacts; invasive species (a list was developed but the volume was not assessed).

Table 67. Potential sources causing sediment problems.

Problems:	Area streams are cloudy and turbid.
Potential Causes:	Suspended sediments and/or turbidity exceed target values set by this project.
Potential Sources:	● 85 miles of stream lack adequate stabilization, with the highest percent of stream miles lacking stabilization found Little Potatoe Creek-Lye Creek (26%), Town of Garfield-Sugar Creek (26%), Little Creek-Little Sugar Creek (23%) and Withe Creek-Sugar Creek (21%) subwatersheds. ● Livestock access (15.8 miles of streams) was observed in the Bowers Creek, Lye Creek Drain, Little Potatoe Creek-Lye Creek, Little Creek-Little Sugar Creek, Deer Creek-Prairie Creek, Wolf Creek, Goldsberry Creek, Hazel Creek-Sugar Creek Subwatershed. This does not mean livestock do not have access at other locations, but rather they were not observed during the windshield survey. ● 22.3 miles of stream lack adequate buffers with observations occurring in the Headwaters Little Potatoe Creek, Lye Creek Drain, Little Potatoe Creek-Lye Creek, Little Creek-Sugar Creek, Little Sugar Creek, Town of Linnsburg-Walnut Fork Sugar Creek, Sanitary Ditch-Prairie Creek, Wolf Creek, and Town of Garfield-Sugar Creek subwatersheds. ● 4-13% of soybean fields and 4-8% of corn fields are under conservation tillage. ● Nearly 2,400 animals were observed on unregulated animal operations throughout the watershed. The highest density of animals was identified in the Town of Linnsburg-Walnut Fork Sugar Creek, Deer Creek-Prairie Creek, Wolf Creek and Hazel Creek-Sugar Creek subwatersheds. These operations can be sources due to livestock defecating in or near streams, soil compaction, streambank erosion, and improper manure storage and spreading. ● 112,286 acres of highly erodible land occur within the watershed. The highest density of HES occurs in Little Sugar Creek (69%), Town of Linnsburg-Walnut Fork Sugar Creek (66%),Town of Garfield-Sugar Creek (64%), Hazel Creek-Sugar Creek (63%), Deer Creek-Prairie Creek (59%), Wolf Creek (59%), subwatersheds. ● The City of Lebanon MS4 lies partially within the Upper Sugar Creek Watershed.

Table 68. Potential sources causing nutrient problems.

Problems:	Nutrient concentrations threaten the health of Upper Sugar Creek and its tributaries.
Potential Causes:	Nutrient concentrations exceed target values set by this project.
Potential Sources:	● 85 miles of stream lack adequate stabilization, with the highest percent of stream miles lacking stabilization found Little Potatoe Creek-Lye Creek (26%), Town of Garfield-Sugar Creek (26%), Little Creek-Little Sugar Creek (23%) and Withe Creek-Sugar Creek (21%) subwatersheds. ● Livestock access (15.8 miles of streams) was observed in the Bowers Creek, Lye Creek Drain, Little Potatoe Creek-Lye Creek, Little Creek-Little Sugar Creek, Deer Creek-Prairie Creek, Wolf Creek, Goldsberry Creek, Hazel Creek-Sugar Creek Subwatershed. This does not mean livestock do not have

	access at other locations, but rather they were not observed during the windshield survey. ● 22.3 miles of stream lack adequate buffers with observations occurring in the Headwaters Little Potatoe Creek, Lye Creek Drain, Little Potatoe Creek-Lye Creek, Little Creek-Sugar Creek, Little Sugar Creek, Town of Linnsburg-Walnut Fork Sugar Creek, Sanitary Ditch-Prairie Creek, Wolf Creek, and Town of Garfield-Sugar Creek subwatersheds. ● 4-13% of soybean fields and 4-8% of corn fields are under conservation tillage. ● Nearly 2,400 animals were observed on unregulated animal operations throughout the watershed. The highest density of animals was identified in the Town of Linnsburg-Walnut Fork Sugar Creek, Deer Creek-Prairie Creek, Wolf Creek and Hazel Creek-Sugar Creek subwatersheds. These operations can be sources due to livestock defecating in or near streams, soil compaction, streambank erosion, and improper manure storage and spreading. ● More than 119,000 animals are permitted on confined feeding operations in the watershed. Animals are most dense in the Wolf Creek, Lye Creek Drain, Little Sugar Creek and Withe Creek-Sugar Creek subwatersheds. ● Animals in the watershed produce more than 45,200 tons of manure annually which produces 45,200 tons of phosphorus, 27,500 tons of phosphorus and 2.2xE15 colonies of E. coli annually. ● 112,286 acres of highly erodible land occur within the watershed. The highest density of HES occurs in Little Sugar Creek (69%), Town of Linnsburg-Walnut Fork Sugar Creek (66%),Town of Garfield-Sugar Creek (64%), Hazel Creek-Sugar Creek (63%), Deer Creek-Prairie Creek (59%), Wolf Creek (59%), subwatersheds. ● The City of Lebanon MS4 lies partially within the Upper Sugar Creek Watershed.

Table 69. 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:	● 85 miles of stream lack adequate stabilization, with the highest percent of stream miles lacking stabilization found Little Potatoe Creek-Lye Creek (26%), Town of Garfield-Sugar Creek (26%), Little Creek-Little Sugar Creek (23%) and Withe Creek-Sugar Creek (21%) subwatersheds. ● Livestock access (15.8 miles of streams) was observed in the Bowers Creek, Lye Creek Drain, Little Potatoe Creek-Lye Creek, Little Creek-Little Sugar Creek, Deer Creek-Prairie Creek, Wolf Creek, Goldsberry Creek, Hazel Creek-Sugar Creek Subwatershed. This does not mean livestock do not have access at other locations, but rather they were not observed during the windshield survey. ● 22.3 miles of stream lack adequate buffers with observations occurring in the Headwaters Little Potatoe Creek, Lye Creek Drain, Little Potatoe Creek-Lye Creek, Little Creek-Sugar Creek, Little Sugar Creek, Town of

	Linnsburg-Walnut Fork Sugar Creek, Sanitary Ditch-Prairie Creek, Wolf Creek, and Town of Garfield-Sugar Creek subwatersheds. ● Nearly 2,400 animals were observed on unregulated animal operations throughout the watershed. The highest density of animals was identified in the Town of Linnsburg-Walnut Fork Sugar Creek, Deer Creek-Prairie Creek, Wolf Creek and Hazel Creek-Sugar Creek subwatersheds. These operations can be sources due to livestock defecating in or near streams, soil compaction, streambank erosion, and improper manure storage and spreading. ● More than 119,000 animals are permitted on confined feeding operations in the watershed. Animals are most dense in the Wolf Creek, Lye Creek Drain, Little Sugar Creek and Withe Creek-Sugar Creek subwatersheds. ● Animals in the watershed produce more than 45,200 tons of manure annually which produces 45,200 tons of phosphorus, 27,500 tons of phosphorus and 2.2xE15 colonies of E. coli annually. ● Soils which are severely limited for septic use cover 190,761 aces or 99% of the Upper Sugar Creek Watershed. Failing septic systems could contribute *E. coli* to the system within the rural portion of the.

Table 70. Potential sources causing flooding problems.

Problems:	Flooding, loss of natural floodplain/natural habitat in urban settings
Potential Causes:	Periodic flooding of streams causes property damage, increased stream bank erosion and lateral stream movement. Modification of stream channels, especially in urban environments, limits the connectivity between streams and floodplains.
Potential Sources:	Riparian habitat alterations; disconnection and development of the floodplain; ditching, draining and tiling; stormwater runoff

Table 71. Potential sources causing instream and terrestrial habitat problems.

Problems:	Habitat in the Upper Sugar Creek Watershed is impacted by terrestrial and riparian alterations.
Potential Causes:	Habitat modification both historic and present day altered the watershed use and impacted biological communities
Potential Sources:	N/A

Table 72. Potential sources causing education and cohesion problems.

Problems:	Focused cohesive education and outreach activities and promotion of activities is needed to build public awareness and cohesion.
Potential Causes:	Interest and benefits are lacking.
Potential Sources:	N/A

Table 73. Potential sources causing watershed funding and unified group problems.

Problems:	• Watershed restoration is underfunded • A unified group for the entire watershed does not exist • Lack of cohesive regulations and governance makes implementation challenging.
Potential Causes:	Unified approach, time and interest are lacking; limited perceived benefit
Potential Sources:	N/A

7.2 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 stormwater runoff, construction activities, solid waste disposal, atmospheric deposition, streambank erosion, and more. Inventory data in Table 67 to Table 73 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 could be used to understand the loading of nutrients, sediment, and pathogens in waterbodies in the Upper Sugar Creek Watershed: 1) measured results from the monitoring regime completed as part of the current watershed planning project and 2) 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 monitoring data to draft long term goals and critical areas. The fixed station data were used to calculate potential draft goals and then after discussion, set long term and interim term goals as well as determine critical areas.

As discussed in Section 3.4, sixteen monitoring sites were sampled monthly from January to December 2022. There is clear value in using these measurements from the Upper 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. As discussed in Section 3.1, the steering committee selected water quality benchmarks that will significantly improve water quality in Upper Sugar Creek (Table 16). Target loads needed to meet these benchmarks were calculated for each subwatershed for each parameter. Sample site data from the subwatersheds pour point sampling site was used to calculate annual loading rates and load reductions. The load reduction needed was then calculated for each subwatershed, which corresponds to each sample site, in lb/year or col/year and as a percent of the current load (Table 34 to Table 37). It should be noted that sample sites and subwatershed names shown represent the loading rate to that point inclusive of drainage upstream of the subwatershed. As there was no single outlet stream monitored, the most downstream stream site monitored on the Sugar Creek mainstem (Site 13) for the Town of Garfield-Sugar Creek Subwatershed and the most downstream stream site monitored on Walnut Fork-Sugar Creek (Site 14) for the Town of Linnsburg-Walnut Fork Sugar Creek subwatershed were added together. Subsequently, the loading rates calculated for the Browns Wonder-Sugar Creek Subwatershed located upstream, were subtracted from the cumulate loading rates for Sugar Creek plus Walnut Fork-Sugar Creek to generate the Upper Sugar Creek loading rate.

Table 74. Estimated nitrogen load reduction by subwatershed needed to meet water quality target concentrations in the Upper Sugar Creek Watershed.

Subwatershed Name	Site(s)	Current Loading Rate (lb/year)	Target Loading Rate (lb/year)	Load Reduction (lb/year)	% Reductio n
Headwaters Little Potatoe Creek	S8	397,163	35,358	361,806	91%
Bowers Creek	S9	522,110	32,821	489,288	94%
Lye Creek Drain	S10	264,738	28,285	236,453	89%
Little Potatoe Creek-Lye Creek	S11	1,529,035	161,060	1,367,975	89%
Little Creek-Little Sugar Creek	S16	94,356	14,075	80,282	85%
Little Sugar Creek	S15	756,107	84,358	671,750	89%
Town of Linnsburg-Walnut Fork Sugar Creek	S14	848,526	149,001	699,525	82%
Sanitary Ditch-Prairie Creek	S1	320,330	45,471	274,860	86%
Deer Creek-Prairie Creek	S3	641,258	100,721	540,538	84%
Wolf Creek	S4	435,739	50,158	385,582	88%
Goldsberry Creek-Sugar Creek	S6, S7	3,546,829	461,499	3,085,330	87%
Withe Creek-Sugar Creek	S5	3,049,798	506,578	2,543,220	83%
Hazel Creek-Sugar Creek	S12	3,612,051	657,482	2,954,569	82%
Town of Garfield-Sugar Creek	S13	4,356,853	673,956	3,682,897	85%
Watershed Total	S13+S1 4	**5,205,378**	**822,957**	**4,382,421**	**84%**
Browns Wonder-Sugar Creek	S2	1,891,187	308,377	1,582,810	
Upper Sugar Creek Watershed Total		**3,314,191**	**514,580**	**2,799,611**	**84%**

Table 75. Estimated phosphorus load reduction by subwatershed needed to meet water quality target concentrations in the Upper Sugar Creek Watershed.

Subwatershed Name	Site(s)	Current Loading Rate (lb/year)	Target Loading Rate (lb/year)	Load Reduction (lb/year)	% Reduction
Headwaters Little Potatoe Creek	S8	82,757	2,829	79,928	97%
Bowers Creek	S9	37,365	2,626	34,739	93%
Lye Creek Drain	S10	30,157	2,263	27,894	92%
Little Potatoe Creek-Lye Creek	S11	367,294	12,885	354,409	96%
Little Creek-Little Sugar Creek	S16	22,075	1,126	20,949	95%
Little Sugar Creek	S15	243,109	6,749	236,361	97%
Town of Linnsburg-Walnut Fork Sugar Creek	S14	343,380	11,920	331,460	97%
Sanitary Ditch-Prairie Creek	S1	87,724	3,638	84,087	96%
Deer Creek-Prairie Creek	S3	241,031	8,058	232,973	97%
Wolf Creek	S4	138,562	4,013	134,549	97%
Goldsberry Creek-Sugar Creek	S6, S7	1,258,182	36,920	1,221,262	97%
Withe Creek-Sugar Creek	S5	1,285,472	40,526	1,244,946	97%
Hazel Creek-Sugar Creek	S12	1,829,689	52,599	1,777,091	97%
Town of Garfield-Sugar Creek	S13	1,632,607	53,916	1,578,691	97%
Watershed Total	**S13+S14**	**1,975,987**	**65,837**	**1,910,151**	**97%**
Browns Wonder-Sugar Creek	S2	761,635	24,670	736,965	
Upper Sugar Creek Watershed Total		**1,214,352**	**41,166**	**1,173,186**	**97%**

Table 76. Estimated total suspended solids load reduction by subwatershed needed to meet water quality target concentrations in the Upper Sugar Creek Watershed.

Subwatershed Name	Site(s)	Current Loading Rate (lb/year)	Target Loading Rate (lb/year)	Load Reduction (lb/year)	% Reduction
Headwaters Little Potatoe Creek	S8	3,614,599	530,365	3,084,234	85%
Bowers Creek	S9	2,011,085	492,319	1,518,766	76%
Lye Creek Drain	S10	1,770,977	424,277	1,346,700	76%
Little Potatoe Creek-Lye Creek	S11	19,441,378	2,415,899	17,025,479	88%
Little Creek-Little Sugar Creek	S16	1,462,880	211,121	1,251,760	86%
Little Sugar Creek	S15	14,499,607	1,265,363	13,234,244	91%
Town of Linnsburg-Walnut Fork Sugar Creek	S14	32,508,873	2,235,017	30,273,855	93%
Sanitary Ditch-Prairie Creek	S1	4,155,655	682,060	3,473,594	84%
Deer Creek-Prairie Creek	S3	21,849,070	1,510,811	20,338,259	93%
Wolf Creek	S4	8,439,933	752,367	7,687,566	91%
Goldsberry Creek-Sugar Creek	S6, S7	94,246,713	6,922,489	87,324,224	93%
Withe Creek-Sugar Creek	S5	133,657,514	7,598,666	126,058,849	94%
Hazel Creek-Sugar Creek	S12	137,783,267	9,862,224	127,921,042	93%
Town of Garfield-Sugar Creek	S13	182,771,809	10,109,336	172,662,473	94%
Watershed Total	**S13+S14**	**215,280,682**	**12,344,353**	**202,936,329**	**94%**
Browns Wonder-Sugar Creek	S2	54,547,188	4,625,659		
Upper Sugar Creek Watershed Total		**160,733,493**	**7,718,695**	**153,014,799**	**95%**

Table 77. Estimated E. coli load reduction by subwatershed needed to meet water quality target concentrations in the Upper Sugar Creek Watershed.

Subwatershed Name	Site(s)	Current Loading Rate (col/year)	Target Loading Rate (col/year)	Load Reduction (col/year)	% Reduction
Headwaters Little Potatoe Creek	S8	1.59E+14	3.77E+13	1.22E+14	76%
Bowers Creek	S9	2.33E+14	3.50E+13	1.98E+14	85%
Lye Creek Drain	S10	3.69E+13	3.02E+13	6.69E+12	18%
Little Potatoe Creek-Lye Creek	S11	2.21E+14	1.72E+14	4.95E+13	22%
Little Creek-Little Sugar Creek	S16	4.37E+13	1.50E+13	2.87E+13	66%
Little Sugar Creek	S15	8.03E+13	9.00E+13	-9.64E+12	-12%
Town of Linnsburg-Walnut Fork Sugar Creek	S14	1.62E+15	1.59E+14	1.46E+15	90%
Sanitary Ditch-Prairie Creek	S1	3.21E+14	4.85E+13	2.73E+14	85%
Deer Creek-Prairie Creek	S3	1.48E+15	1.07E+14	1.38E+15	93%
Wolf Creek	S4	2.71E+14	5.35E+13	2.17E+14	80%
Goldsberry Creek-Sugar Creek	S6, S7	4.86E+15	4.92E+14	4.37E+15	90%
Withe Creek-Sugar Creek	S5	5.65E+15	5.40E+14	5.11E+15	90%
Hazel Creek-Sugar Creek	S12	6.79E+15	7.01E+14	6.09E+15	90%
Town of Garfield-Sugar Creek	S13	7.45E+15	7.19E+14	6.74E+15	90%
Watershed Total	S13+S14	**9.08E+15**	**8.78E+14**	**8.20E+15**	**90%**
Browns Wonder-Sugar Creek	S2	3.29E+15	3.29E+14	2.96E+15	
Upper Sugar Creek Watershed Total		**5.79E+15**	**5.49E+14**	**5.24E+15**	**91%**

8.0 CRITICAL AND PRIORITY AREA DETERMINATION

Critical areas are defined as the areas where sources of water quality problems occur in the highest densities and where restoration measures can improve water quality. These areas indicate locations where best management practices should be targeted to address nonpoint sources of pollution. Priority areas are those areas of the watershed where high quality habitat is found, and the aquatic biological community is classified as good or excellent. Best management practices to protect the higher quality conditions should be targeted to these areas.

Using the list of potential sources developed for each parameter of concern as a base, the steering committee developed a mechanism for determining critical areas for each parameter. GIS-based mapping data from desktop and windshield survey efforts, loading calculations, and current and historic water quality data were used as a basis for decision-making. The steering committee divided into teams to review subwatershed data and develop a criteria list for each parameter. For each parameter, each subwatershed was evaluated to determine whether it met each criterion developed by each steering committee team. Teams presented their suggested criteria for each parameter to the entire steering committee and the steering committee reviewed, modified, if needed, and finalized criteria for each parameter. Each parameter team reviewed available data and selected a suite of data they considered most useful for their parameter. Once selected, data for each criterion were normalized by watershed size, then ranked based on each subwatersheds available data. Rankings occurred as follows:

- Water quality data: The highest percent exceedance for water quality data ranked as 1, while the lowest percent exceedance ranked as 14. Subwatersheds without water quality data were not ranked.
- Land cover: The highest percent land cover ranked as 1, while the lowest percent land cover ranked as 14.
- Stream impairments and observed water quality problems: The highest percent stream length rated as impaired ranked as 1, while the lowest percent impaired ranked as 14. Subwatersheds without impairments were not ranked. Likewise, the highest percent observed water quality ranked as 1, while the lowest percent ranked as 14.

Data and rankings for each subwatershed are detailed in Appendix E.

8.1 Critical Areas for Nitrate-Nitrogen and Total Phosphorus

Nitrate-nitrogen and total Kjeldahl nitrogen were the nitrogen form used to determine our critical areas. Total phosphorus was the form of phosphorus used to determine phosphorus critical areas. Nitrate-nitrogen and total phosphorus are readily available in watershed, entering surface water via human and animal waste, fertilizer use, and tile drains on agricultural lands. Phosphorus enters the watershed through streambank and bed erosion, unfiltered runoff, agricultural land use in floodplains, stormwater runoff, and livestock access. Based on the data reviewed by the steering committee (Table 78), the following datasets were priorities for nutrients critical areas:

- Nitrogen exceedance – historic and current
- Phosphorus exceedance – historic and current
- Livestock access
- Agricultural land use
- Impaired waterbodies – nutrients

Critical subwatersheds for nutrients are those that scored 6.3 or less and include the following: Bowers Creek (202), Goldsberry Creek-Sugar Creek (404), Headwaters Little Potatoe Creek (201), Little Creek-Little Sugar Creek (301), Little Potatoe Creek-Lye Creek (204), Little Sugar Creek (302), Lye Creek Drain (203), Town of Linnsburg-Walnut Fork Sugar Creek (303) and Wolf Creek (Figure 96).

Table 78. Nutrient critical area criterion ranking based on source evaluation and average rating.

HUC	Nitrate: Hist	TKN: Hist	Nitrate: Current	TP: Hist	TP: Current	Livestock Access	Ag Land Cover	Impaired Nutrients	Avg
201	4	1	14	5	7	14	3	1	6.13
202	ND	ND	13		2	9	1	ND	6.25
203	2	4	1	5	1	1	1	ND	2.14
204	1	6	12	5	7	4	6	ND	5.86
301	5	5	10	3	3	5	4	ND	5.00
302	6	2	1	3	7	10	7	ND	7.14
303	8	7	7	2	7	3	9	ND	6.14
401	ND	ND	1	ND	5	14	14	ND	8.50
402	ND	ND	1	ND	7	11	12	ND	7.75
403	ND	ND	6	ND	5	2	5	ND	4.50
404	7	ND	ND	ND	4	6	7	ND	5.80
405	9	7	7	5	12	14	9	2	8.13
406	9	7	11	5	12	7	9	ND	8.57
407	3	3	7	1	14	8	13	ND	7.00

ND=No data

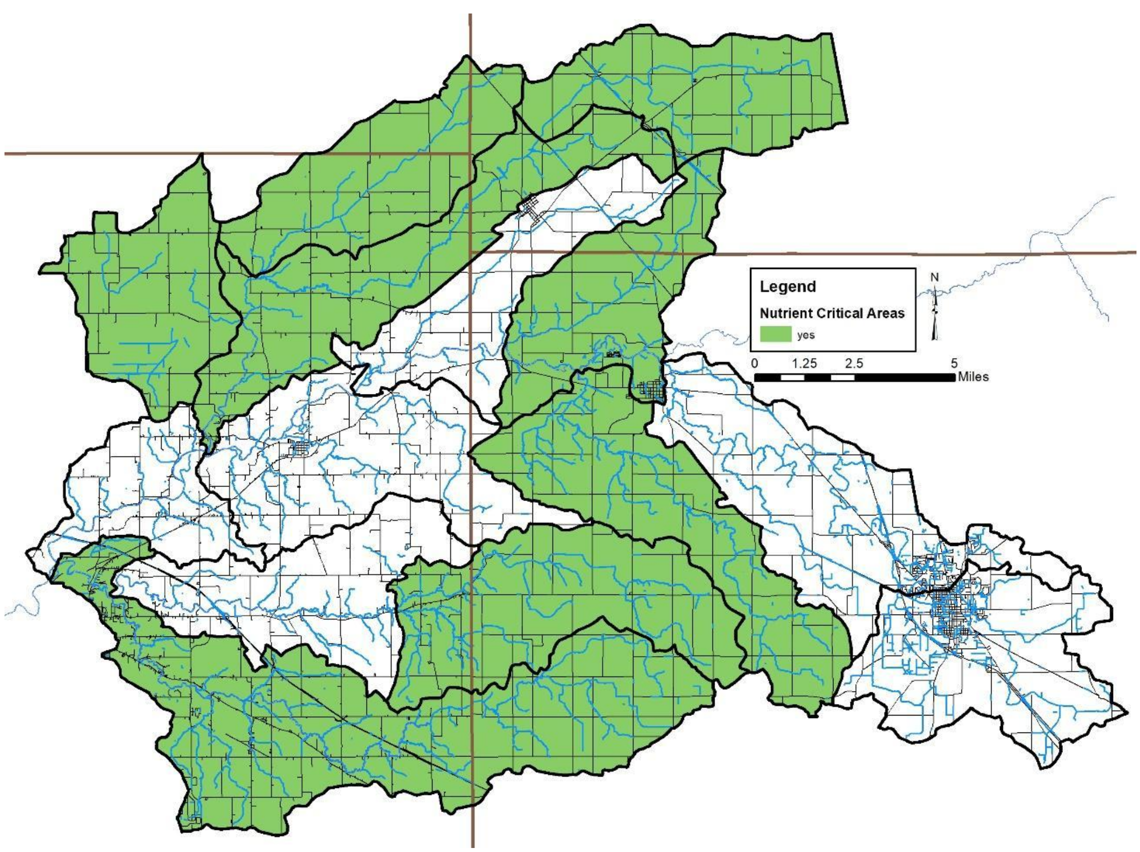


Figure 96. Critical areas for nutrients in the Upper Sugar Creek Watershed.

8.2 Critical Areas for Sediment

Total suspended solids concentrations were used to determine sediment-based critical areas (Figure 97). Total suspended solids enter streams in the watershed through streambank and bed erosion, unfiltered runoff, agricultural land use in floodplains, stormwater runoff, and livestock access. Based on the data reviewed by the steering committee (Table 79), the following datasets were priorities for sediment critical areas:

- Conventional tillage cropping practices by subwatershed is the preferred dataset; however, these data were not available when the committee met. The Montgomery County SWCD is working with the Indiana State Department of Agriculture to develop this dataset. In the interim, agricultural dominance was utilized.
- Narrow buffer coverage
- Streambank erosion
- Livestock access
- Agricultural land in the floodplain
- Urban land use/stormwater
- Turbidity exceedance – historic and current
- TSS exceedance – historic and current

Critical subwatersheds for sediment are those that scored 7.3 or less and including the following: Town of Garfield-Sugar Creek (407), Goldsberry Creek-Sugar Creek (404), Lye Creek Drain (203), Little Potatoe Creek-Lye Creek (204), Headwaters Little Potatoe Creek (201), Bowers Creek (202), Little Creek-Little Sugar Creek (301), Town of Linnsburg-Walnut Fork Sugar Creek (303, Figure 97).

Table 79. Sediment critical area criterion ranking based on source evaluation and average rating.

HUC	Ag Land	Narrow Buffer	Streambank Erosion	Livestock Access	Ag in Floodplain	Urban	Turb: hist	Turb: current	TSS: current	Avg
201	3	1	13	14	14	7	9	2	3	7.33
202	1	14	10	9	1	13	ND	3	7	7.25
203	1	2	12	1	10	14	8	9	1	6.44
204	6	6	1	4	13	10	6	3	7	6.22
301	4	4	3	5	2	12	3	1	6	4.44
302	7	8	4	10	12	9	10	10	3	8.11
303	9	2	6	3	9	3	7	3	7	5.44
401	14	9	14	14	3	1	ND	3	14	9.00
402	12	14	9	11	6	2	2	10	3	7.67
403	5	7	7	2	5	11	ND	13	7	7.13
404	7	14	11	6	7	4	1	8	2	6.67
405	9	14	4	14	11	6	3	14	7	9.11
406	9	14	8	7	4	5	11	12	7	8.56
407	13	5	1	8	8	8	5	3	7	6.44

ND=No data

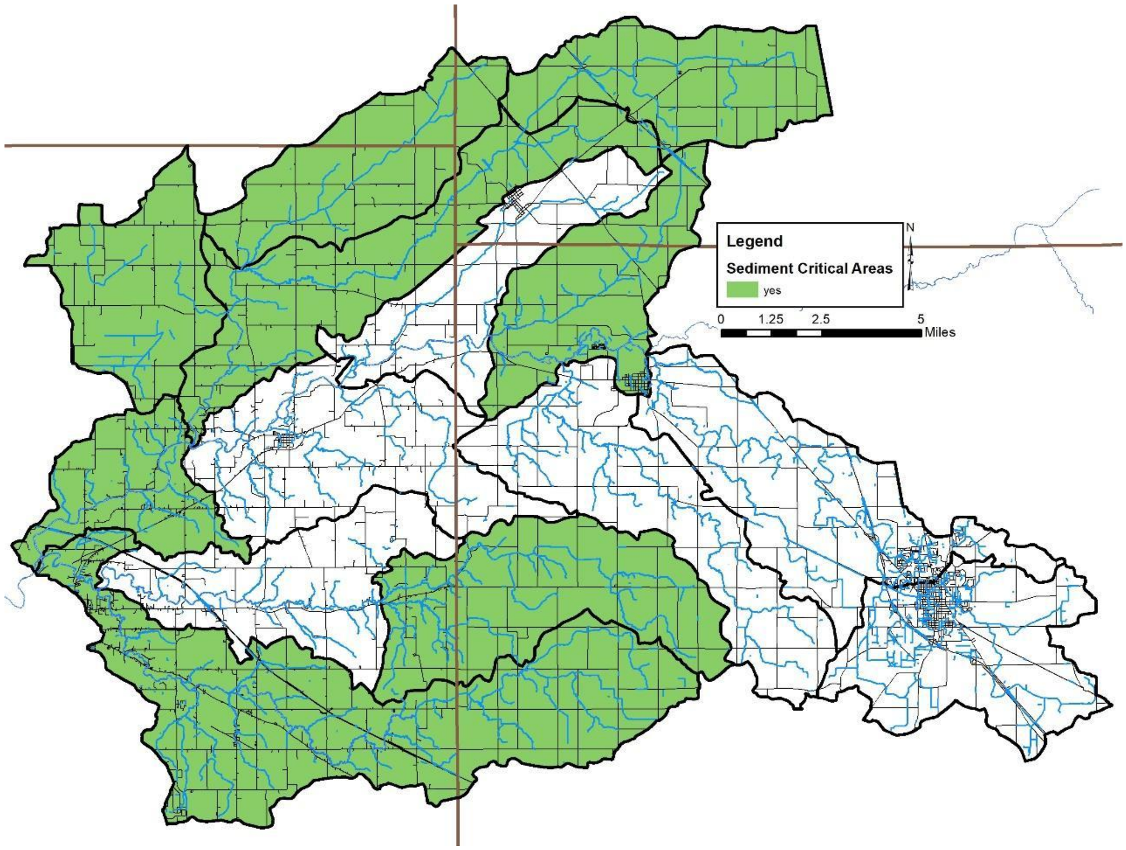


Figure 97. Critical areas for sediment in the Upper Sugar Creek Watershed.

8.3 Critical Areas for *E. coli*

E. coli concentrations were used to determine *E. coli*-based critical areas (Figure 98). *E. coli* enters streams in the watershed through human and animal waste, livestock access, and infrastructure issues. Additional areas of concern, such as areas with manure management issues or failing septic systems, may also be included. While those areas have not been quantified, dense unsewered areas were included as a method for identifying these areas. Based on the data reviewed by the steering committee (Table 80), the following datasets were priorities for sediment critical areas:

- E. coli exceedance – historic and current
- E. coli impaired waterbodies – percent of subwatershed waterbodies
- Septic soils – rejected as there is little variation in the data
- Manure volumes and presence/absence of CFO/CAFOs considered but as manure does not necessarily get spread within the subwatershed of its mailing address, rejected as a data point

Critical subwatersheds for E. coli are those that scored 6.3 or less and include the following: Deer Creek-Prairie Creek (402), Goldsberry Creek-Sugar Creek (404), Hazel Creek-Sugar Creek (406), Headwaters Little Potatoe Creek (201), Little Creek-Little Sugar Creek (301), Lye Creek Drain (203), Sanitary Ditch-Prairie Creek (401), Town of Garfield-Sugar Creek (407), Town of Linnsburg-Walnut Fork Sugar Creek (303), Withe Creek-Sugar Creek (405, Figure 98).

Table 80. E. coli critical area criterion ranking based on source evaluation and average rating.

HUC	E. coli: Hist	E. coli: Current	Impaired E. coli	Average
201	4	6	1	3.7
202	ND	10	ND	10.0
203	ND	1	ND	1.0
204	ND	14	6	10.0
301	3	2	ND	2.5
302	2	10	ND	6.0
303	6	8	2	5.3
401	ND	3	ND	3.0
402	ND	3	ND	3.0
403	ND	8	ND	8.0
404	1	5	5	3.7
405	8	10	4	7.3
406	7	10	7	8.0
407	5	6	3	4.7

ND=No data

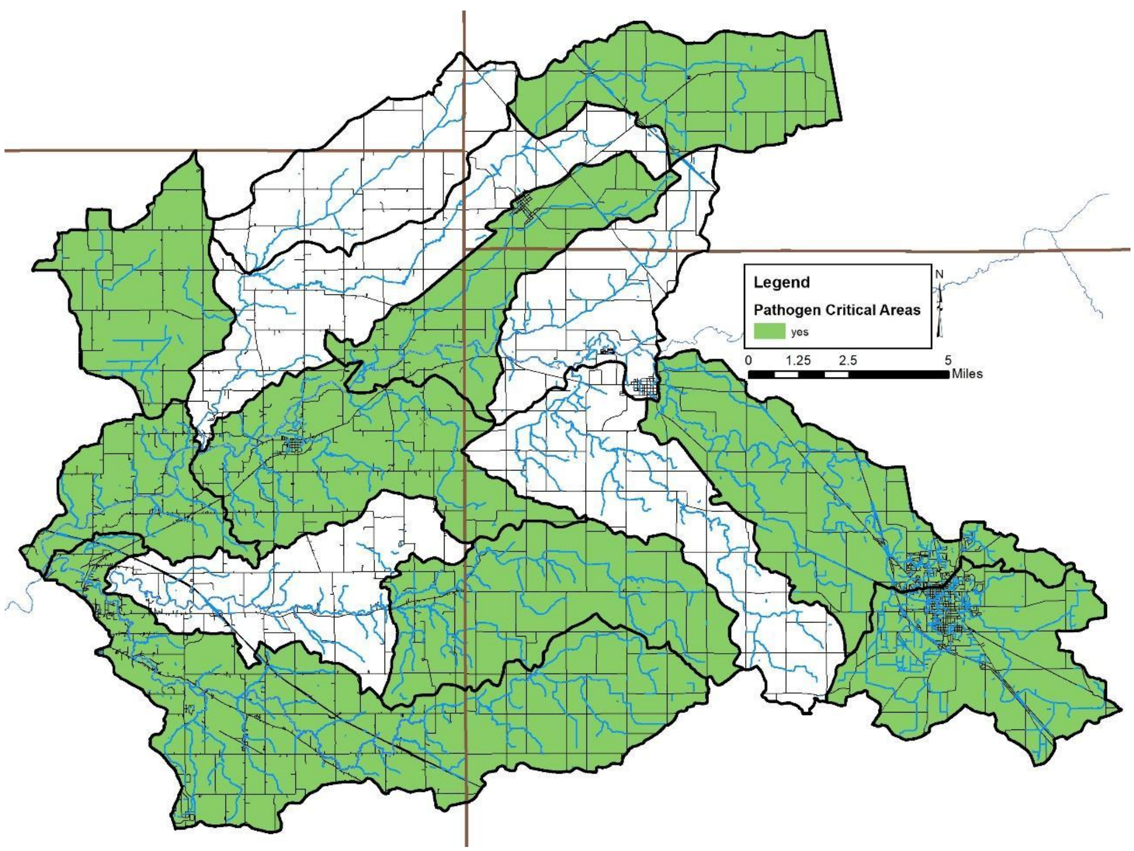


Figure 98. Critical areas for *E. coli* in the Upper Sugar Creek Watershed.

8.4 Flooding Critical Areas

The Upper Sugar Creek steering committee identified flooding as a problem. With this in mind, criterion for defining each of these critical areas were reviewed and the following datasets prioritized for flooding (Table 81).

Flooding:

- Wetland loss
- Floodplain percent area
- Poorly drained and very poorly drained soils

Table 81. Flooding critical area criterion ranking based on source evaluation and average rating.

HUC	Wetland Loss	Poorly drained	Very poorly drained	Floodplain	Average
201	4	2	5	14	6.25
202	2	5	2	14	5.75
203	1	3	1	14	4.75
204	6	1	9	10	6.5
301	5	8	4	9	6.5
302	13	12	13	7	11.25
303	12	13	10	8	10.75
401	3	14	3	2	5.5
402	8	10	7	3	7
403	7	11	6	14	9.5
404	10	9	8	4	7.75
405	9	4	12	5	7.5
406	11	7	11	6	8.75
407	14	6	14	1	8.75

ND=No data

Critical subwatersheds for flooding are those that scored 7.8 or less and include the following: Goldsberry Creek-Sugar Creek (404), Withe Creek-Sugar Creek (403), Deer Creek-Prairie Creek (402), Little Potatoe Creek-Lye Creek (204), Little Creek-Little Sugar Creek (301), Headwaters Little Potatoe Creek (201), Bowers Creek (202), Sanitary Ditch-Prairie Creek (401), Lye Creek Drain (203, Figure 99).

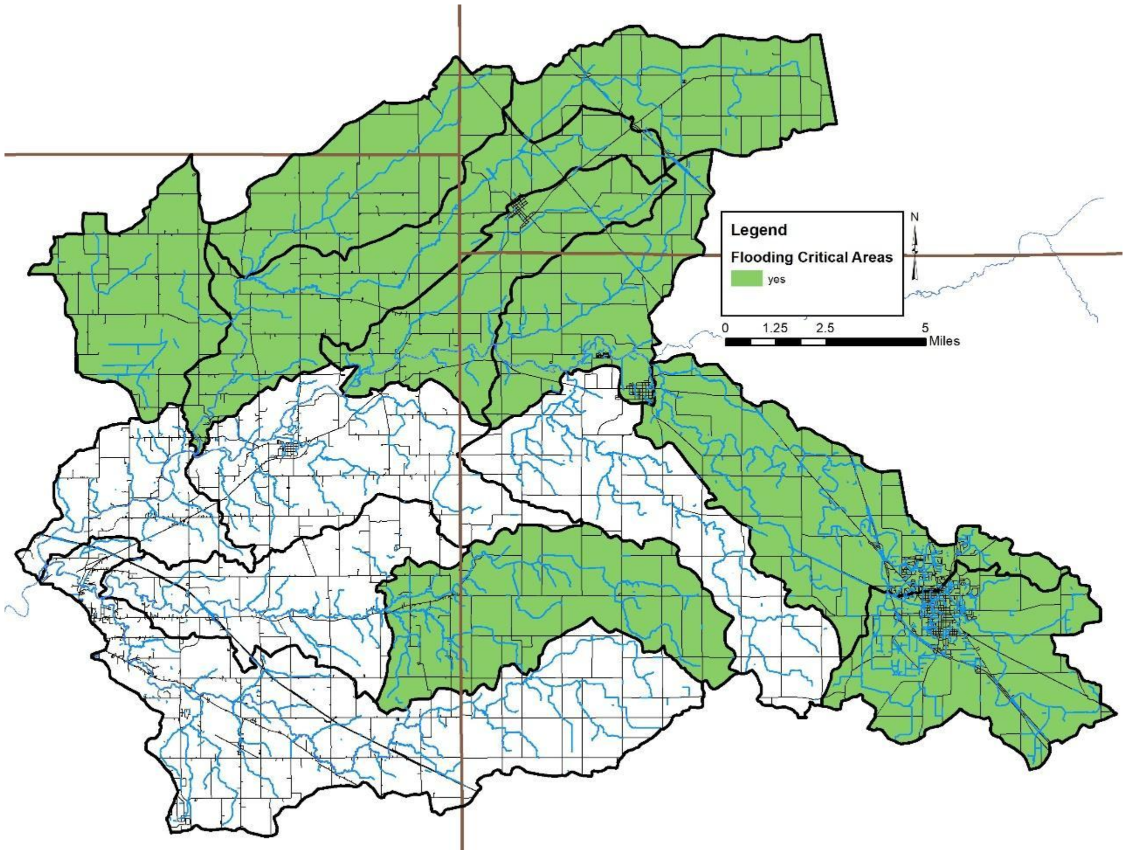


Figure 99. Critical areas for flooding in the Upper Sugar Creek Watershed.

8.5 Habitat Critical Areas

The steering committee's habitat concerns are focused on connectivity of natural areas. With this in mind, connectivity issues will be addressed on an as needed basis wherever restoration of historic wetland, forests, grasslands or prairies can occur. Therefore, habitat is not tied to a specific mapped critical area.

8.6 Critical Areas Summary

The subwatersheds identified as critical areas for each parameter are summarized in Figure 96 to Figure 99. To identify the highest priority subwatersheds, the steering committee decided to divide them into three tiers (high, medium and low priority), based on the number of parameters that were determined to be critical. The highest priority subwatersheds are those that were determined to be critical for three or more parameters of the four potential parameters (nutrients, sediment, *E. coli*, flooding). The medium priority subwatersheds are those that were determined to be critical for two of four potential parameters. The lowest priority subwatersheds were critical for one of four potential parameters (Figure 100). Subwatersheds were prioritized as follows:

- High priority: Bowers Creek, Headwaters Little Potatoe Creek, Goldsberry Creek-Sugar Creek, Little Creek-Little Sugar Creek, Little Potatoe Creek-Lye Creek, Lye Creek Drain, Town of Linnsburg-Walnut Fork Sugar Creek
- Medium priority: Sanitary Ditch-Prairie Creek, Deer Creek-Prairie Creek, Withe Creek-Sugar Creek, Town of Garfield-Sugar Creek
- Low priority: Hazel Creek-Sugar Creek, Wolf Creek

One subwatershed, Little Sugar Creek was not prioritized as critical meaning it was not identified as an area of highest concern for any of the four parameters (nutrients, sediment, pathogen, flooding). Implementation efforts will target high priority critical areas first, followed by medium priority then low priority areas. It is anticipated that implementation efforts will be targeted in medium and low priority subwatersheds as part of EPA-funded implementation efforts only after implementation efforts are exhausted in higher priority areas. Implementation via other funding sources, via landowner interest in NRCS-based federal funding programs will occur as landowners are interested. The Upper Sugar Creek stakeholder group will continue volunteer monitoring efforts to continue to assess the quality of these subwatersheds and identify any changes in water quality as they occur.

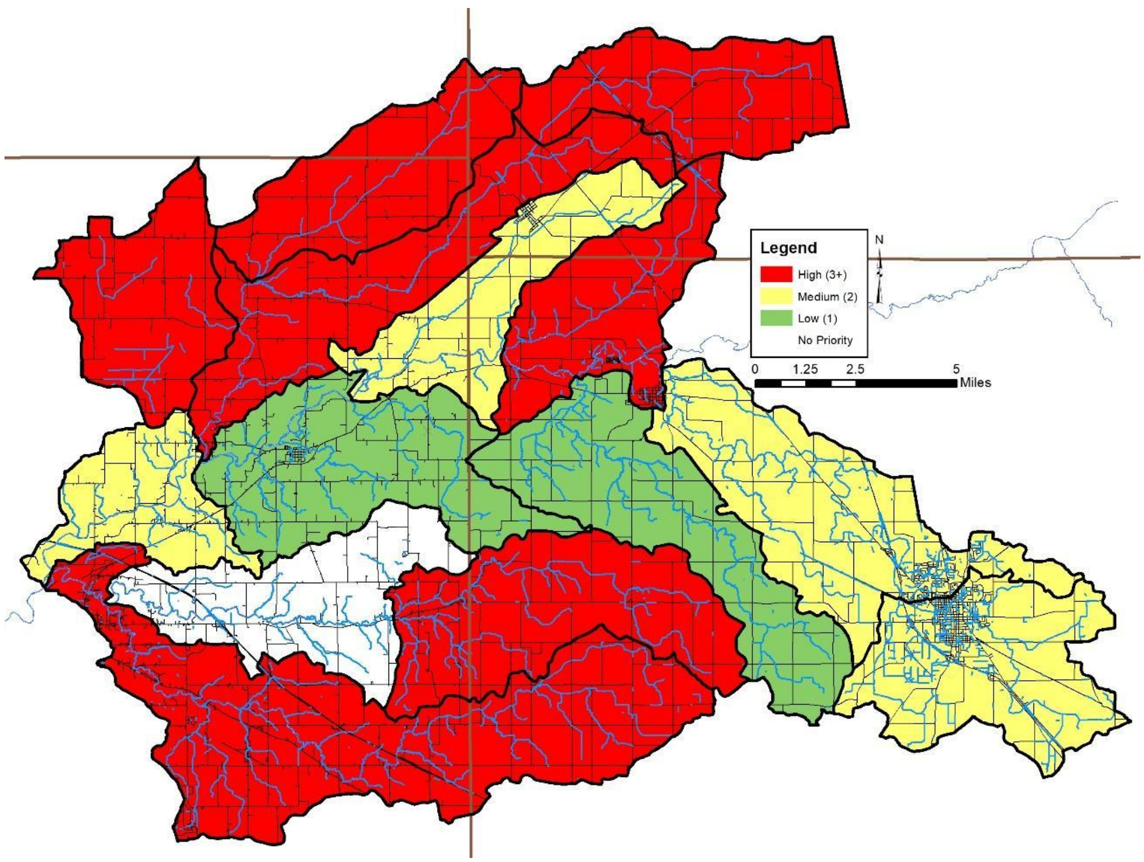


Figure 100. Prioritized critical areas in the Upper Sugar Creek Watershed.

8.7 Critical Acre Determination

To be eligible for Mississippi River Basin Initiative (MRBI) Funding, the Upper Sugar Creek Watershed steering committee considered options for targeting all agricultural acreage within the watershed rather than limiting implementation efforts to specific 12-digit HUC subwatersheds. Table 82details critical acres by subwatershed based on the criteria selected for nutrient, sediment and *E. coli* critical areas. The steering committee will target hot spots or problem areas identified within each subwatershed including but not limit to 1) ensuring that all highly erodible soils are protected or covered; 2) targeting livestock restriction, streambank erosion and buffer strip installation in areas where erosion, livestock access and/or narrow buffers were identified; and 3) working with producers to reduce the impacts from manure production within the Upper Sugar Creek Watershed (Figure 101). Upper Sugar Creek Watershed stakeholders identified the need for soils with septic limitation to be targeted for septic treatment; however, this is not an MRBI targeted practice and is therefore not included in Table 82. Note that manure application acres have not been mapped as these application areas are only identified as potential areas for manure application for each permitted confined feeding operation.

Table 82. Critical acres by subwatershed in the Upper Sugar Creek Watershed.

Subwatershed Name	HUC	Ag Land (acres)	HEL (acres)	Manure Estimate (tons)	Municipal Sludge App (acres)	Livestock Access (miles)	Streambank Erosion (miles)	Narrow Buffer (miles)
Headwaters Little Potatoe Creek	051201100201	10,850	6,329	6,725	72.6	0.0	1.3	3.1
Bowers Creek	051201100202	11,292	4,917	1,467	192.1	0.3	1.7	0.0
Lye Creek Drain	051201100203	10,346	5,011	1,652	155.0	1.2	1.2	1.6
Little Potatoe Creek-Lye Creek	051201100204	14,145	9,321	3,472	53.2	1.2	7.9	1.5
Little Creek-Little Sugar Creek	051201100301	14,693	9,403	1,855	168.9	1.7	9.8	4.3
Little Sugar Creek	051201100302	11,038	8,954	2,467	246.1	0.5	6.7	1.0
Town of Linnsburg-Walnut Fork Sugar Creek	051201100303	25,851	20,251	7,536	302.1	4.5	17.1	9.7
Sanitary Ditch-Prairie Creek	051201100401	10,172	6,545	219	258.1	0.0	0.5	0.6
Deer Creek-Prairie Creek	051201100402	13,861	10,144	8,718	1,609.1	0.5	9.9	0.0
Wolf Creek	051201100403	14,576	9,609	3,141	150.1	2.3	7.8	1.7
Goldsberry Creek-Sugar Creek	051201100404	9,615	6,532	2,611	97.5	1.2	3.0	0.0
Withe Creek-Sugar Creek	051201100405	9,170	6,269	3,073	200.9	0.0	5.2	0.0
Hazel Creek-Sugar Creek	051201100406	13,524	10,205	5,259	520.2	1.5	7.2	0.0
Town of Garfield-Sugar Creek	051201100407	5,992	5,126	3,731	1371.4	0.9	6.7	1.8

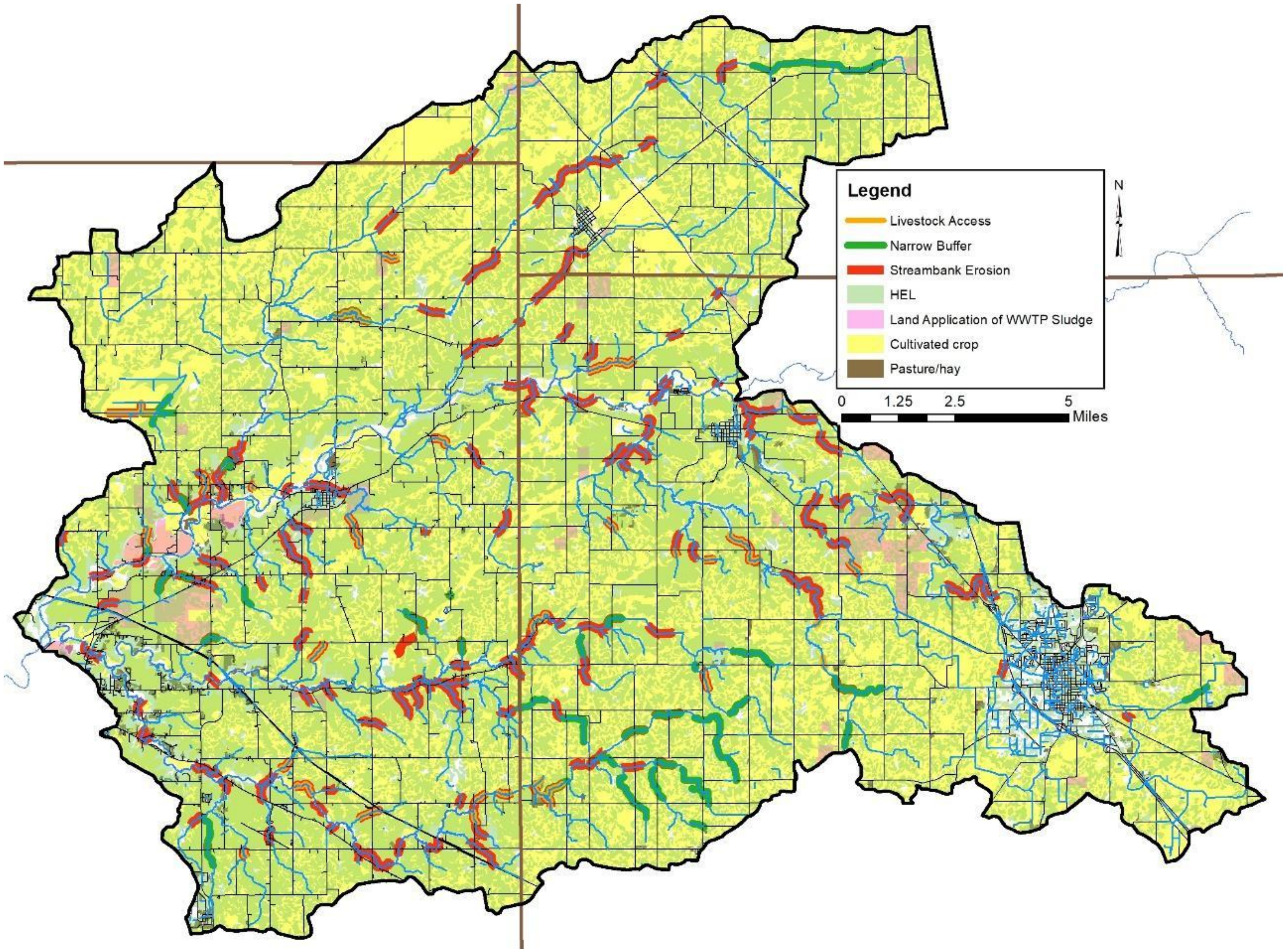


Figure 101. Critical acres in the Upper Sugar Creek Watershed.

8.8 Current Level of Treatment

Based on data from the Indiana Conservation Partnership, more than 5,816 acres of best management practices including but not limited to cover crops, conservation cover, fencing, firebreak installation, forage and biomass planting, residue tillage, water facility and heavy use protection area construction and more have been implemented over the last 5 years in the Upper Sugar Creek Watershed. Table 83 details practices by acre.

Table 83. Practices installed from 2018-2022 in the Upper Sugar Creek Watershed by 12-digit HUC based on Indiana Conservation Partner data in acres.

Practice	201	202	203	204	301	302	303	401	402	403	404	405	406	407	Total
Conservation Cover	0.5	--	--	--	446.9	--	--	--	--	--	--	--	--	--	475.5
Cover Crop	79.9	--	--	1,131.3	--	200.2	967.1	--	322.9	108.7	655.4	--	573.5	415.3	4,454.3
Pollinator Habitat	-- 3.9	--	--	--	--	--	--	--	--	--	--	--	--	--	3.9
Upland Wildlife Habitat Management	--	--	--	--	--	--	--	--	--	1.5	--	--	--	--	25
Wetland Restoration	--	--	--	--	--	--	--	--	--	--	--	--	--	--	19.2
Forage and Biomass Planting	--	--	--	--	--	--	--	--	--	--	--	--	71.3	--	131.1
Heavy Use Area Protection	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.14
Fence	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.02
Grassed Waterway	--	--	--	--	--	--	--	--	--	--	--	--	--	--	10.93
Pollinator Habitat	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.3
Residue and Tillage Mgmt/Reduced Till	--	--	--	--	--	--	--	--	--	--	--	--	--	--	52.6
Wildlife Habitat Planting	--	--	--	--	1.7	--	--	0.5	--	--	--	--	--	--	2.2
Early Successional Habitat Development	--	--	--	--	--	--	--	--	--	1.6	--	--	--	--	1.6
Firebreak	--	--	--	--	--	--	--	--	--	0.54	--	--	--	--	0.54
Tree/Shrub Establishment	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2.3
Critical Area Planting	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2

Watering Facility	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1

9.0 GOAL SETTING

Based on watershed inventory efforts; stakeholder input for concerns, problems, and sources; and watershed loading information, the following goals and strategies were developed.

9.1 Goal Statements

The steering committee wrote goals for each parameter or area of concern based on a goal of meeting the target concentrations identified by the committee. The current loading rate was calculated using water chemistry data collected monthly at each of the sixteen sample sites and flow data from the USGS stream gages at Sugar Creek at Crawfordsville (USGS 03339500) and Prairie Creek at Lebanon (USGS 03339280). Flow data from both gages were scaled to the drainage area for Upper Sugar Creek sample sites with the Prairie Creek gage used to calculate loading rates for tributary sites (Sites 1, 3, 4, 7, 8, 9, 10, 11, 15 and 16) and the Sugar Creek gage used to calculate loading rates at Sugar Creek mainstem sites (Sites 2, 5, 6, 12, 13 and 14). In an effort to scale goals to manageable levels, short term (10 year), medium term (20 year), and long term (30 year) goals were generated. The calculation process is described below:

1. Current and target loading rates were determined for the Upper Sugar Creek sample sites. Loading rates and target reductions for the entire watershed were calculated using data generated for the most downstream Sugar Creek mainstem site (Site 13) and the most downstream site on Walnut Fork Sugar Creek (Site 14). These were added together to calculate the loading rate for the Sugar Creek Watershed at the watershed outlet. The loading rate for the Browns Wonder-Sugar Creek outlet (Site2) was subtracted from this to generate the loading rate from within the Upper Sugar Creek Watershed as this is the area which can be directly impacted by on-the-ground implementation efforts within the Upper Sugar Creek basin.
2. Drainage basin outlet loading rates were calculated for each of the other 12-digit HUC watershed outlets. This allows for calculation of loading rates within each 12-digit HUC. While the steering committee determined this was useful information and will allow for tracking of local impacts, the overall impact of their efforts was deemed the most impactful. The individual subwatershed loading rates may be utilized in the future when efforts focus on localized impacts.
3. The steering committee selected a generational timeframe of 30 years. Once set, the ability to reach long term goals which will result in water quality (nutrient, sediment and E. coli) targets being met throughout the watershed in 30 years will be reviewed and adjusted as needed.
4. The steering committee set short term and medium term goals for one-third of that timeframe or 10 years for each phased goal. With this in mind, short term goals will be met in 10 years (2033) and medium term goals will be met in 20 years (2043).

Reduce Nutrient Loading

Based on collected water quality data for the Upper Sugar Creek Watershed, the committee set the following long-term goals: Reduce nitrate-nitrogen loading from 3,314,191 lb/year to 514,580 lb/year (84%) by 2053 and reduce total phosphorus loading from 1,214,352 lb/year to 41,166 lb/ year (97%) by 2053.

High priority goal: Reduce total phosphorus inputs from 1,214,352 pounds per year to 823,291 pounds per year (32% reduction) and nitrate-nitrogen from 3,314,191 pounds per year to 2,380,988 pounds per year (28% reduction) in Upper Sugar Creek in 10 years (2033).

Medium priority goal: Reduce total phosphorus inputs from 823,291 pounds per year to 432,228 pounds per year (47% reduction) and nitrate-nitrogen from 2,380,988pounds per year to 1,447,783 pounds per year (39% reduction) in Upper Sugar Creek in 10 years (2043).

Low priority goal: Reduce total phosphorus inputs from 432,228 pounds per year to 41,166 pounds per year (90% reduction) and nitrate-nitrogen from 1,447,783 pounds per year to 514,580 pounds per year (64% reduction) in Upper Sugar Creek in 10 years (2053).

Table 84. Nitrate-nitrogen short, medium, and long-term goal calculations for prioritized critical areas in Upper Sugar Creek.

Goal Timeframe	Current Load (lb/yr)	Load Reduction (lb/yr)	Target Load (lb/yr)	Percent Reduction
High Priority (10 years)	3,314,190.9	933,203.8	2,380,987.2	28%
Medium Priority (20 years)	2,380,987.2	933,203.8	1,447,783.4	39%
Low Priority (30 years)	1,447,783.4	933,203.8	514,579.6	64%

Table 85. Total phosphorus short, medium, and long-term goal calculations for prioritized critical areas in Upper Sugar Creek.

Goal Timeframe	Current Load (lb/yr)	Load Reduction (lb/yr)	Target Load (lb/yr)	Percent Reduction
High Priority (10 years)	1,214,352.5	391,062.0	823,290.5	32%
Medium Priority (20 years)	823,290.5	391,062.0	432,228.4	47%
Low Priority (30 years)	432,228.4	391,062.0	41,166.4	90%

Reduce Sediment Loading

Based on collected water quality data for the Upper Sugar Creek Watershed, the committee set the following long-term goal: reduce total suspended solids loading from 160,733,493 lb/year to 7,718,695 lb/year (95%) by 2053.

High priority goal: Reduce total suspended solids inputs from 160,733,493 pounds per year to 109,728,561 pounds per year (32% reduction) in Upper Sugar Creek in 10 years (2033).

Medium priority goal: Reduce total suspended solids inputs from 109,728,561 pounds per year to 58,723,628 pounds per year (46% reduction) in Upper Sugar Creek in 10 years (2043).

Low priority goal: Reduce total suspended solids inputs from 58,723,628 pounds per year to 7,718,695 pounds per year (87% reduction) in Upper Sugar Creek in 10 years (2053).

Table 86. Total suspended solids short, medium, and long-term goal calculations for prioritized critical areas in Upper Sugar Creek.

Goal Timeframe	Current Load (lb/yr)	Load Reduction (lb/yr)	Target Load (lb/yr)	Percent Reduction
High Priority (10 years)	160,733,493.5	51,004,932.9	109,728,560.6	32%
Medium Priority (20 years)	109,728,560.6	51,004,932.9	58,723,627.6	46%
Low Priority (30 years)	58,723,627.6	51,004,932.9	7,718,694.7	87%

Reduce *E. coli* Loading
Based on collected water quality data for the Upper Sugar Creek Watershed, the committee set the following long-term goal: reduce E. coli loading from 5.79E+15 to 5.49E+14 (55%) by 2053.

High priority goal: Reduce total suspended solids inputs from 5.79E+15 colonies per year to 4.04E+15 colonies per year (30% reduction) in Upper Sugar Creek in 10 years (2033).

Medium priority goal: Reduce total suspended solids inputs from 5.79E+15 colonies per year to 2.30+15 colonies per year (43% reduction) in Upper Sugar Creek in 10 years (2043).

Low priority goal: Reduce total suspended solids inputs from 2.30+15 colonies per year to 5.49+14 colonies per year (76% reduction) in Upper Sugar Creek in 10 years (2053).

Table 87. E. coli short, medium, and long-term goal calculations for prioritized critical areas in Upper Sugar Creek.

Goal Timeframe	Current Load (lb/yr)	Load Reduction (lb/yr)	Target Load (lb/yr)	Percent Reduction
High Priority (10 years)	5.79E+15	1.75E+15	4.04E+15	30%
Medium Priority (20 years)	4.04E+15	1.75E+15	2.30E+15	43%
Low Priority (30 years)	2.30E+15	1.75E+15	5.49E+14	76%

Reduce Flooding Impacts
Long term: Reduce flooding impacts by increasing storage and infiltration across the watershed by 2053.

Habitat Impacts
Long term: Natural habitat (grasslands, forest, wetlands) will increase by a total of 5% with a focus on improving habitat connectivity across the Upper Sugar Creek watershed by 2053.

Increase Public Awareness and Education
Long term: By 2053, 50% of property owners and producers will be informed about practices that can be implemented to positively impact Upper Sugar Creek and no less than 30% of individuals living and farming in the watershed will be engaged in the project within 30 years.

Baseline in 2023 - Property owners: 13,600 parcel addresses; Producers: 460 based on DTN contact list and producers who identified as such at a public event for the Upper Sugar Creek Watershed.

10.0 IMPROVEMENT MEASURE SELECTION

A wide variety of practices are available for on-the-ground implementation to reduce sediment, nutrient, and *E. coli* loading within the Upper Sugar Creek Watershed. A list of potential best management practices was reviewed by the project steering committee. From this list, the practices which were deemed most appropriate to remediate the sources of pollution in the watershed 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 Descriptions

A list of potential BMPs were reviewed by the Upper Sugar Creek steering committee. Committee members reviewed potential practices taking into account the identified resource concerns, watershed land uses, and Upper Sugar Creek Watershed Project goals. From the potential practice list, the most appropriate BMPs to remediate sources of pollution and address resource concerns in the Upper Sugar Creek Watershed was developed. This practice list is not exhaustive and new and emerging technologies and techniques should be considered as possible and necessary options to meet water quality targets within the Upper Sugar Creek Watershed. A combination of practices detailed below aimed at avoiding, controlling and trapping nutrients and sediment and the implementation of a conservation system could be necessary to make lasting, measurable changes in Upper Sugar Creek water quality. Selected practices are appropriate for all critical areas since they predominantly contain agriculture land use and pasture, and crop resource concerns were identified in all subwatersheds. Several urban practices were also identified. These should be targeted at residential and commercial areas throughout the watershed including Crawfordsville, Lebanon, and small towns and reservoirs present throughout the watershed. Selected practices with descriptions are listed below.

Potential best management practices include the following:

- Access Control
- Alternate Watering System
- Animal Mortality Facility
- Bioreactor
- Bioretention – Rain Garden, Bioswale
- Composting Facility
- Conservation Tillage: Residue and Tillage Management, No till/Strip till/Direct Seed
- Consider soil characteristics to minimize runoff
- Cover Crop
- Diversion structures
- Drainage Water Management
- Fencing
- Field Border or Filter Strip
- Flow Splitter
- Forage and Biomass Planting
- Grade Stabilization Structure
- Grassed Waterway
- Green Roof
- Greenways and Trails
- Habitat Corridor Identification and Improvement
- Livestock Restriction/Prescribed Grazing
- Manure Management Planning
- Mulching
- Nutrient and/or Pest Management
- Pervious Pavement
- Phosphorus Free Fertilizer Usage
- Point Source Discharge Reduction
- Pollinator Planting
- Septic System Care and Maintenance
- Streambank Stabilization
- Subsurface Drain (Agricultural)
- Subsurface Infiltration (urban)
- Threatened and Endangered Species Protection
- Tree Box Filter
- Tree/Shrub Establishment
- Two Stage Ditch
- University fertilization recommendations
- Variable rate application
- Vegetated Swale
- Waste Storage Facility
- Waste Utilization

Heavy Use Area Protection
Infrastructure Retrofits
Lined Waterway or Outlet
Livestock Pipeline
Water and Sediment Control Basin
Wetland Creation, Wetland Enhancement, Wetland Restoration

Access Control
Access control involves the temporary or permanent exclusion of animals, people, vehicles, and/or equipment from an area. Access control is used to achieve and maintain desired resource conditions by monitoring and managing the intensity of use by animals, people, vehicles, and/or equipment in coordination with the application schedule of practices, measures and activities specified in the conservation plan.

Animal Morality Facility
An animal mortality facility is an on-farm facility for the treatment or disposal of animal carcasses due to routine mortality. This standard applies to livestock and poultry operations where routine animal carcass storage, treatment, or disposal is needed. This standard does not apply to catastrophic animal mortality.

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.

Bioretention
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 not be used in highly urbanized areas rather, it should be used in areas where on-site storage space is available.

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 (No-till)
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, and 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).

Cover Crops/Critical Area Planting/Conservation Cover

Cover crops include legumes, such as clover, hairy vetch, field peas, alfalfa, and soybean, 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. Runoff water can wash soluble phosphorus from the surface soil and crop residue and carry it off the field. The cover crop vegetation recovers plant-available nutrients in the soil and recycles them through the plant biomass for succeeding crops.

Diversion Structures

A diversion structure is a channel generally constructed across the slope with a supporting ridge on the lower side. This practice may be applied to support various purposes including breaking up concentrations of water on long slopes, on undulating land surfaces, and on land that is generally considered too flat or irregular for terracing. Diverting water away from farmsteads, agricultural waste systems, and other improvements. Collecting or directing water for storage, water- spreading or water-harvesting systems. Protecting terrace systems by diverting water from the top terrace where topography, land use, or land ownership prevents terracing the land above. Intercept surface and shallow subsurface flow. Reducing runoff damages from upland runoff. Reducing erosion and runoff on urban or developing areas and at construction or mining sites. Diverting water away from active gullies or critically eroding areas. Supplementing water management on conservation cropping or strip cropping systems. Diversion structures can be applied to all land uses where surface runoff water control and/or management are needed and where soils and topography are such that the diversion can be constructed, and a suitable outlet is available or can be provided.

Drainage Water Management/Subirrigation

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 subirrigation, cover crops and conservation tillage to promote a systems approach and be better stewards of water quantity.

Fencing/Alternate Watering Systems
Fencing livestock out of stream systems allows for the restoration of the stream channel. 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. Alternative watering systems may include pump systems or gravity systems connected to a well, or running pipe from a pond or spring.

Field Border/Buffer Strip/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. Buffers provide many benefits including restoring hydrologic connectivity, reducing 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., 1996; 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 buffer. 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.

Filter strips 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.

Flow Splitter
A flow splitter is an engineered structure used to divide flow into two or more parts and divert these parts to different places. The design of a flow splitter uses specifically designed structures, pipes, orifices, and weirs set at specific elevations to control the direction of flow. An illustration of a simple type of flow splitter is provided in the accompanying figure. Typically, when managing storm water flows, a flow splitter is used to direct initial storm water flows to an off-line BMP. The splitter is placed at

an elevation coordinated with the elevation of the treatment BMP, so that the elevation of water in the BMP governs the elevation in the flow splitter. As shown in the example illustration, storm water flows to the BMP until it reaches a pre-determined elevation. Once storm water reaches that elevation, a weir (or other hydraulic feature) directs additional flow to an alternative outlet. This simple type of flow splitter works on hydraulic principles and requires no mechanical components or instrumentation.

Forage and Biomass Planting
Forage and biomass plantings establish adapted and/or compatible species, varieties, or cultivars of herbaceous species suitable for pasture, hay or biomass production. Purposes include: Improve or maintain livestock nutrition and/or health; provide or increase forage supply during periods of low forage production; reduce soil erosion; improve soil and water quality; produce feedstock for biofuel or energy production.

Grade Stabilization
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.

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. The amount of precipitation that runs off the soil surface rather than infiltrating down into the soil profile is increased by tillage and other farming activities that increase soil compaction and decrease soil organic matter and macro-pore content. For these reasons, the establishment or refurbishing of a grassed waterway should, when possible, be coupled with other practices that aim to increase the rate of water infiltration into the soil. 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.

Green Roof
A green roof system is an extension of the existing roof which involves, at a minimum, high quality waterproofing, root repellent system, drainage system, filter cloth, a lightweight growing medium, and plants.

Green roof systems may be modular, with drainage layers, filter cloth, growing media, and plants already prepared in movable, often interlocking grids, or loose laid/built-up whereby each component of the system may be installed separately. Green roof development involves the creation of "contained" green space on top of a human-made structure. This green space could be below, at, or above grade, but in all cases, it exists separate from the ground.

Green roofs can provide a wide range of public and private benefits and have been successfully installed in countries around the world. Green roofs provide a variety of environmental benefits

to aesthetic improvements, waste diversion, moderation of the heat island effect, improved air quality, and stormwater benefits. Some of the water benefits include; water is stored by the substrate and then taken up by the plants from where it is returned to the atmosphere through transpiration and
evaporation, in summer, green roofs can retain 70-90% of the precipitation that falls on them, in winter, green roofs can retain between 25-40% of the precipitation that falls on them, green roofs not only retain rainwater, but also moderate the temperature of the water and act as natural filters for any of the water that happens to run off, and green roofs reduce the amount of stormwater runoff and also delay the time at which runoff occurs, resulting in decreased stress on sewer systems at peak flow periods.

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. Maintaining a good riparian buffer can mitigate the negative impacts of approximately 5% additional impervious surface in the watershed.

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 fee simple land purchase. Donations can be solicited and encouraged through incentive programs. Outright purchase of property offers a secondary option and is frequently the least complicated and most permanent protection technique but is also the most costly. A conservation easement is a less expensive technique than outright purchase 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 in the process 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.

Heavy Use Area Protection
HUAP is used to stabilize a ground surface that is frequently used by people, animals, or vehicles and to protect water quality.

Infrastructure Retrofits
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.

Livestock Restriction/Prescribed (Rotational) Grazing/Lined Waterway or Outlet
Livestock that have unrestricted access to a stream or wetland have the potential to degrade the waterbody's water quality and biotic integrity. 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 impacted 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. Landowners can additionally section off the pastureland and move the animals from one paddock to the next, ensuring adequate vegetation growth for nutrient removal. Using this system of rotational grazing no one piece of land gets overgrazed and ensures a high-quality food for the livestock and adequate ground cover for nutrient and sediment retention. 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 Big Pine 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.

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/Pest Management Planning including Variable Rate Application and Waste Storage Facility
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 and can be in commercial/non-manure fertilizer or manure-based fertilizers. 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.

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 Fertilizer Usage
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 program estimates that a one acre lawn fertilized with traditional fertilizer supplies 7.8 pounds of phosphorus to local waterbodies annually. Given that 75% of urban residents within the Region of the Great Bend of the Wabash River Watershed indicate either limited knowledge or that they don't use phosphorus free fertilizers, there is great potential for reducing urban sources of phosphorus by targeting this practice. 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.

Prescribed Grazing
This practice where grazing and/or browsing animals are managed on a prescribed schedule. Removal of herbage by the grazing animals is in accordance with production limitations, plant sensitivities and management goals. Frequency of defoliations and season of grazing is based on the rate of growth and physiological condition of the plants. Duration and intensity of grazing is based on desired plant health and expected productivity of the forage species to meet management objectives. In all cases enough vegetation is left to prevent accelerated soil erosion. Application of this practice will manipulate the intensity, frequency, duration, and season of grazing to: Improve water infiltration, maintain or improve riparian and upland area vegetation, protect stream banks from erosion, manage for deposition of fecal material way from water bodies and promote ecological and economically stable plant communities which meet landowner objectives. (FOTG Code 528, NRCS, 2010)

Rain Barrel
A rain barrel is a container that collects and stores rainwater from your rooftop (via your home's disconnected downspouts) for later use on your lawn, garden, or other outdoor uses. Rainwater stored in rain barrels can be useful for watering landscapes, gardens, lawns, and trees. Rain is a naturally soft water and devoid of minerals, chlorine, fluoride, and other chemicals. In addition, rain barrels help to reduce peak volume and velocity of stormwater runoff to streams and storm sewer systems. Although rain barrels don't specifically reduce nutrient or sediment loading to waterbodies, their presence can reduce the first flush of water reaching storm drains. This impact is great especially in portions of the watershed where combined sewers are still in operation. Although a high percentage of urban residents indicated a general knowledge of rain barrels, only 3% of survey respondents indicate that they have installed a rain barrel. Furthermore, 75% of respondents indicate a willingness to consider installing a rain barrel.

Septic System Care, Maintenance, and Upgrades
Septic, or on-site waste disposal systems, are the primary means of sanitary flow treatment outside of incorporated areas including most of the small towns and unincorporated areas in the Upper Sugar Creek 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. Our efforts will include developing an education plan for homeowners in the watershed, and hosting a series of septic system care and maintenance workshops.

Soil testing - Consider soil characteristics to minimize runoff
Soil testing can be used to determine Determines nutrient levels in the soil, determine pH levels and thus, lime needs; provides a decision-making tool to determine what nutrients to apply, how much, and when. Regular soil testing and the application of fertilizers at or below university fertilizer recommendations provides the potential for higher yielding, high quality crops with more targeted fertilizer use.

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 many of the stream's natural functions (flood storage, nutrient removal, etc.) without restoring the stream completely to its original condition. However, even a partial restoration of this type is extremely expensive, takes quite a bit of land to accomplish, and is likely unrealistic as a large scale strategy in this watershed. Our efforts will focus primarily on two-stage ditch construction, which is a cheaper way to incorporate a small floodplain into the ditch itself in the form of benches on either side of the main channel that allow for increased capacity in the ditch resulting in slower moving water along the banks resulting in reduced bank slumping and failure. 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.

T&E Species Protection (Habitat Improvement)
Threatened and endangered species are those plant and animal species whose survival is in peril. Federally and state listed species identified within the Upper 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.

Tree Box Filters
Tree box filters are a proprietary biotreatment device that is designed to mimic natural systems such as bioretention areas by incorporating plants, soil, and microbes. Tree box filters are installed at curb level and consist of an open bottom concrete barrel filled with a porous soil media, an underdrain in crushed gravel, and a tree. Tree box filters are highly adaptable solutions that can be used in all types of development and in all types of soils but are especially applicable to ultra-urban areas.

Tree/Shrub Establishment
Reforestation is the establishment of forests, usually accomplished through the planting of tree seedlings. It is important to match the species being planted to the site chosen for reforestation. Control of competing vegetation and invasive plants is often necessary to ensure establishment and survival of planted trees. This is usually done through mowing and/or herbicide application. Reforestation can provide many benefits to the landscape. Increasing the amount of forest through tree planting provides more habitat for forest dependent species, improves water quality by reducing erosion, decreases nutrient loading and lowers floodwater velocity.

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 depending on the size of the channel. 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 aquatic 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. A recent study by the University of Notre Dame found that the average two-stage ditch reduces the amount of sediment transported annually by over 100,000 pounds per half mile of two-stage (Tank, unpublished data).

University fertilization recommendations/Soil testing
Soil Testing can be used to determine Determines nutrient levels in the soil, determine pH levels and thus, lime needs; provides a decision-making tool to determine what nutrients to apply, how much, and when. Regular soil testing and the application of fertilizers at or below university fertilizer recommendations provides the potential for higher yielding, high quality crops with more targeted fertilizer use.

Variable Rate Application/Technologies
Precision agriculture is defined as a management system that uses information, technology, and site-specific data to manage variability within fields for optimum profitability, sustainability, and environmental protection. This method also includes guidance systems for agricultural equipment. The

purposes of using precision agriculture are: To improve water quality by targeting pesticide or soil amendment applications to meet field-specific cropland yield capabilities; reduce the potential off-site impacts of fertilizer and pesticide applications; improve water quality by reducing pesticide and fertilizer inputs through avoidance of overlapping and end row/turn row applications; reduce surface runoff and
through precisely controlled cropping equipment, resulting in less fuel being used; reduce compaction by limiting traffic to specified travel lane; and increase opportunity to operate equipment after dark.

Vegetated Swale
Vegetated swales are used in agricultural areas and are often considered landscape features. Swales are graded to be linear with a shallow, open channel of a trapezoidal or parabolic shape. Vegetation which is water tolerant is planted within the channel which promotes the slowing of water flow through the system. Swales reduce sediment and nutrients as water moves through the swale and water infiltrates into the groundwater.

Waste Utilization
Large volumes of manure are generated by small, unregulated animal operations located throughout the Lower Salt 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.

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 Construction or Restoration
Visual observation and historical records indicate at least a portion of the Upper 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.

10.2 Best Management Practice Selection and Load Reduction Calculations

Table 88 details selected agricultural and urban best management practices and reflect those parameters which NRCS eFOTG, if appropriate, indicate can be utilized to impact each parameter. The critical area and the selected best management practices are based on subwatershed characteristics and available water quality data. Table 89 outlines suggested BMPs, estimated load reduction for nutrients and sediment (if available), and the target volume (area, length) of each practice, while Table 90 details estimated costs for implementing each practice based on the target volume. The steering committee identified BMPs that would be of interest to local producers, while the project coordinator calculated volume of BMPs necessary to meet project goals.

Table 88. Suggested Best Management Practices to address Upper Sugar Creek critical areas. Note: BMPs were selected by the steering committee.

Practice	Nutrients	Sediment	Pathogens
Access Control/Fencing	X	X	X
Alternative Watering System	X		X
Animal Mortality Facility			X
Bioreactor	X		
Bioretention	X	X	X
Composting Facility			
Conservation Tillage	X	X	X
Cover Crop/Critical Area Planting/Conservation Cover	X	X	X
Diversion Structures	X	X	
Drainage Water Management	X	X	
Fencing	X	X	X
Field Border/Buffer Strip	X	X	X
Flow Splitter	X	X	X
Forage/Biomass Planting	X	X	X
Grade Stabilization Structure	X	X	
Grassed Waterway/Mulching/Subsurface Drain	X	X	X
Green Roof	X		
Greenways and Trails	X	X	

Practice	Nutrients	Sediment	Pathogens
Habitat Corridor Identification and Improvement	X	X	
Heavy Use Area Protection	X	X	X
Lined Waterway or Outlet	X	X	X
Livestock Restriction/Pipeline; Prescribed Grazing	X	X	X
Manure Management Planning	X		X
Mulching	X	X	X
Nutrient/Pest Management	X		
Pervious Pavement	X	X	
Phosphorus Free Fertilizer	X		
Point Source Discharge Reduction			
Rain Barrel	X	X	
Septic System Care/Maintenance	X		X
Soil Testing	X	X	X
Streambank Stabilization	X	X	
Subsurface Drain (agricultural)			
Subsurface Infiltration (Urban)			
Tree Box Filter	X	X	
T&E Species Protection (Habitat Improvement)	X	X	
Tree/Shrub Establishment	X	X	
Two Stage Ditch	X	X	X
University Fertilization Recommendations/Soil Testing	X		
Variable Rate Application	X		
Vegetated Swale	X	X	
Waste Storage Facility	X		X
Waste Utilization	X		X
Water and Sediment Control Basin	X	X	
Wetland Creation/Enhancement/Restoration	X	X	X

The Region V model was used to estimate the approximate load reductions for BMPs unless otherwise noted. BMPs with dashes (-) do not have load reductions available using the Region V Model or other identifiable source. The target volumes of BMPs proposed to be installed are not required to be implemented as the quantities suggest. These targets are simply guidelines for achieving goals. Load reductions solely using this model meet the project targets for nitrogen, phosphorus and sediment goals for short, medium, and long-term goals. If the volume of practices specific in Table 89 is met, then the target loading rates detailed in Table 84 through Table 87 will be achieved for high priority critical areas (Bowers Creek, Headwaters Little Potatoe Creek, Goldsberry Creek-Sugar Creek, Little Creek-Little Sugar Creek, Little Potatoe Creek-Lye Creek, Lye Creek Drain, Town of Linnsburg-Walnut Fork Sugar Creek); medium priority critical areas (Sanitary Ditch-Prairie Creek, Deer Creek-Prairie Creek, Withe Creek-Sugar Creek, Town of Garfield-Sugar Creek); and low priority critical areas (Hazel Creek-Sugar Creek, Wolf Creek). The steering committee realizes that the model's calculations are only an estimate, and actual reductions could be beyond the model's estimation. The Region V model does not provide estimated reductions for all suggested BMPs; these load reductions cannot be included in the calculations. The steering committee acknowledges that they have set the bar high by establishing ambitious water quality targets that may be difficult to obtain. The group is committed to improve water quality the best that they can, even in the event that the original load reduction goals are not met.

Table 89. Suggested Best Management Practices, target volumes, and their estimated load reduction per practice to meet high priority, medium priority and low priority goals for each 10 year implementation phase.

Suggested BMPs:	High priority BMP Targets	Medium priority BMP Targets	Low priority BMP Targets	Unit	Nitrogen (lb/year)	Phosphorus (lb/year)	Sediment (t/year)
Conservation Cover (327)	2,000	2,000	2,000	acre	46,000	22,000	72,020
Cover Crop (340)	40,000	40,000	40,000	acre	375,000	175,000	5,000,000
Fence (382)	5,000	5,000	5,000	feet	400	400	400
Filter Strip (393)	1,000	1,000	1,000	acre	24,000	12,000	58,510
Forage and Biomass Planting (512)	1,500	1,500	1,500	acre	115,000	55,000	50,000
Grassed Waterway (412)	500	500	500	acre	116,450	58,200	50,650
Livestock Restriction (Alt Watering System, Access Control)	1,000	1,000	1,000	Feet; units	2,800	830	67,520
Nutrient/Pest Management (590)^	25,000	25,000	25,000	Acre	104,000	156,000	--
Pollinator planting (CP42)	750	750	750	acres	46,000	22,000	72,020
Prescribed Grazing (528)	5,000	5,000	5,000	acre	85,000	45,000	114,050
Residue and Tillage Management (329)	25,000	25,000	25,000	acres	483,000	230,000	46,000,000
Streambank Stabilization**	100	100	100	feet	0	830	67,520
Tree/shrub Establishment (612)	1,500	1,500	1,500	acre	20,000	10,000	90,020
Wetland Creation/Restoration	100	100	100	acre	820	290	6,977

^Assumes all nutrient management is non-manure based. Increase to 6.24 lb/ac/yr for N and 8.77 lb/ac/yr P for manure-based nutrient management.
*Assumes average width of 5 feet.

Table 90. Estimated cost for selected Best Management Practices to meet high priority, medium priority and low priority goals.

Suggested BMPs:	**Estimated Cost per Unit**	**Short-term Estimated Cost**	**Medium-term Estimated Cost**	**Long-term Estimated Cost**
Conservation Cover (327)	$75-$300	$150,000	$150,000	$150,000
Cover Crop (340)	$25-$40	$1,000,000	$1,000,000	$1,000,000
Fence (382)	$1.00 temp./ $3.00 perm.	$5,000	$5,000	$5,000
Filter Strip (393)	$75-$300	$75,000	$75,000	$75,000
Forage and Biomass Planting (512)	$75-$300	$112,500	$112,500	$112,500
Grassed Waterway (412)	$5,000	$2,500,000	$2,500,000	$2,500,000
Livestock Restriction (Alt Watering System, Access Control)	$1,000	$1,000,000	$1,000,000	$1,000,000
Nutrient/Pest Management (590)	$4	$100,000	$100,000	$100,000
Pollinator planting (CP42)	$175	$56,250	$56,250	$56,250
Prescribed Grazing (528)	$15	$75,000	$75,000	$75,000
Residue and Tillage Management (329)	$15	$375,000	$375,000	$375,000
Streambank Stabilization**	$1,000	$100,000	$100,000	$100,000
Tree/shrub Establishment (612)	$450	$900,000	$900,000	$900,000
Wetland Creation/Restoration	$1,000	$100,000	$100,000	$100,000
Total Cost		**$6,548,750.00**	**$6,548,750.00**	**$6,548,750.00**

10.3 Action Register

All activities to be completed as part of the Upper Sugar Creek Watershed management plan are identified in Table 91. The goals set by the steering committee are listed below. Each objective in the action register corresponds to one or more goals and reflects the estimated amount of each BMP that will be needed in order to achieve the target load reductions. Nutrient and sediment removal efficiencies were not available for all BMPs, so the estimated number of BMPs needed was calculated based only on those BMPs that had load reduction estimates. For those BMPs that did not have associated load reduction estimates, the objective was developed with an amount of each BMP that the steering committee determined to be reasonably achievable. Therefore, if all the BMPs listed in all objectives are implemented, the total load reductions achieved will far exceed the load reductions needed to meet the water quality benchmarks.

Table 91. Action Register.

Education and Outreach Goals	Objective	Target Audience	Milestone	Cost	Possible Partners (PP) & Technical Assistance (TA)
Nutrients, Sediment, *E. coli*	Coordinate on-the-ground cost-share program starting in 2024.	Farmers, homeowners, urban residents	Develop a cost-share program (2024).	$25,000 annually staffing	PP & TA: NRCS, SWCD, Health department, Purdue extension, surveyors office, ISDA, CCA, retail agronomists
			Implement cost-share program (2024-2053).		
			Identify and apply for potential funding sources to augment cost-share program including MRBI, RCPP, LARE, CWA and others. Once received, implement cost-share program per program guidance.		
Nutrients, Sediment, *E. coli*	Promote and fund conservation practices which emphasize, soil health, livestock and manure management, natural resources restoration and management and target urban BMP implementation (Table 88).	Farmers, homeowners, urban residents	Meet BMP annual targets for short, medium and long term goals (Table 88).	$900,000 annually BMP implementation	PP & TA: NRCS, SWCD, Health department, Purdue extension, surveyors office, ISDA, CCA, retail agronomists, MS4
			Increase adoption of conservation plans and nutrient (including manure management) plans.		
			Work with Lebanon and any future MS4 communities to ensure that urban BMPs are implemented on new construction and retrofits are included as possible on lands already developed.		
			Achieve short-term load reductions: 28% reduction in nitrate loading, 32% reduction in total phosphorus loading, 32% reduction in total suspended solids loading and 30% reduction in E. coli loading.		
			Achieve medium-term load reductions: 39% reduction in nitrate loading, 47% reduction in total phosphorus loading, 46% reduction in total suspended solids loading and 43% reduction in E. coli loading.		
			Achieve long-term load reductions: 64% reduction in nitrate loading, 90% reduction in total phosphorus loading, 80% reduction in total suspended solids loading and 76% reduction in E. coli loading.		

Education and Outreach Goals	Objective	Target Audience	Milestone	Cost	Possible Partners (PP) & Technical Assistance (TA)
Education; E. coli; nutrients	Work with Health Depts to increase septic system maintenance and installation awareness	Home owners, urban residents, contractors, Health dept.	Produce and distribute septic maintenance brochure at local events, field days, city festivals and county fairs.	$5,000 annually	PP: Health department, contractors TA: contractors
			Offer cost-share incentives to producers proving voluntary septic maintenance.		
			Explore options for future septic system maintenance or upgrade assistance funding.		
Education	Work with local entities to establish an inorganic pollution education program	Home owners, residents	Continue to promote trash pick up, annual clean up events and identify new opportunities (adopt a road, community corrections clean up events, student engagement) to reduce trash pollution.	$5,000 annually	PP/TA: MS4, master gardeners, solid waste management district, FOSC
			Establish an annual reporting mechanism to determine how much trash was saved from entering and removed from Lower Salt Creek streams.		
Flooding, habitat impacts	Protect and restore floodplains and stream buffers	Landowners, farmers	Develop and implement a floodplain maintenance and reforestation program targeting urban residential and commercial and row crop agricultural areas.	$50,000 annually	PP/TA: NRCS, Pheasants Forever, Ducks Unlimited, Purdue extension, ISDA, SWCDs
			Identify high quality riparian lands and their owners.		
			Work with riparian landowners to protect high quality riparian lands via conservation easements, reforestation and/or restoration.		
			Conserve and protect open space networks and implement stormwater management and low impact development.		
Flooding; Nutrients, Sediment, *E. coli*	Increase storage and filtration	Landowners, farmers	Increase tree canopy cover across the watershed.	$150,000 annually	PP/TA: Crop advisors, retail agronomist, MS4, NRCS, SWCD, Health department, Purdue extension, surveyors office, ISDA,
			Increase stormwater storage capacity through agricultural storage, wetland restoration and reforestation efforts.		
			Consider two-stage ditch design, saturated buffers, drainage water management, bioreactors, WASCOBs and other alternatives to address flooding issues and related resource concerns.		
			Explore wetland creation and mitigation efforts including IDNR's in lieu fee program		
			Increase systematic conservation drainage management using "Batch-and-Build" program design/ implementation.		

Education and Outreach Goals	Objective	Target Audience	Milestone	Cost	Possible Partners (PP) & Technical Assistance (TA)
Education	Educate Upper Sugar Creek Project stakeholders about soil erosion, increase awareness about applicable BMPs, inorganic pollution and cost share opportunities	Home and landowners, farmers, urban residents	Develop an education plan targeting each practice identified above by 2024 (Page 3).	$5,000 annually	PP/TA: Indiana Conservation Partnership, Pheasants Forever
			Create mechanism to promote each practice using methods including but not limited to press releases; workshops; field days; stream clean up; float trip; stream, field or pasture walk; website creation; local events; county fair booth; educational booth; and public meetings.		
			Develop funding mechanism for education efforts.		
			The education program should include educational efforts which includes but is not limited to the following: all practices identified by the steering committee and noted in tables above; septic system use, maintenance and care; high quality natural areas; wetland protection and preservation and general stream processes.		
			Continue to maintain a project-based website and social media to promote events, cost share fund availability and build project awareness.		
Education	Create a cohesive education and outreach program focused on increasing public awareness and building a sense of place and watershed connectivity.	Home and landowners, farmers, urban residents	Identify opportunities to highlight where you live, where your water flows, connection from Lebanon to Crawfordsville and all areas in between.	$5,000 annually	PP/TA: Indiana Conservation Partnership, Pheasants Forever
			Implement sense of place and watershed connectivity education programming.		
			Promote local natural areas which provide access to Upper Sugar Creek and its tributaries. Highlight options to engage with or get out onto water.		
Education; habitat impacts; Flooding	Work with partners to identify and promote hands-on opportunities to improve natural areas and habitat in the watershed.	Home and landowners, farmers, urban residents	Identify partner organizations which host field days, work days, and clean-up events.	$5,000 annually	PP/TA: Indiana Conservation Partnership, Pheasants Forever
			Annually, identify partners for river clean-ups, float trips, invasive species control, trash removal, illegal dumping or habitat restoration opportunities and promote throughout the watershed.		

Education and Outreach Goals	Objective	Target Audience	Milestone	Cost	Possible Partners (PP) & Technical Assistance (TA)
Education	Educate local stakeholders and elected officials about the state of Sugar Creek, resources needs and resource availability	Watershed stakeholders, elected officials	Host legislative tour no less than every three years to highlight agricultural and urban BMPs and project successes. Tour will target local, state and regional officials.	$5,000 annually	PP/TA: ICP, MS4, local nonprofit groups
			Host a biological monitoring demonstration no less than every three years to highlight what lives in Sugar Creek.		
			Annually provide updates to county commissioners, county council, city and town councils, chamber of commerce and other groups with the goal of building excitement around Sugar Creek.		
			Annually calculate the economic impact of the Upper Sugar Creek project.		
Nutrients, Sediment, *E. coli*	Monitor annual loading rates using IDEM fixed station data and consider options for delisting streams currently on IDEM's 303(d) list for E. coli and nutrients	Watershed stakeholders, IDEM	Establish an annual volunteer monitoring program to assess nutrient and sediment impacts to the Upper Sugar Creek Watershed. Monitoring will occur quarterly.	$1,000 annually	PP/TA: ICP, MS4, local nonprofit groups
			Collect E. coli samples no less than every 5 years with the goal of calculating the geometric mean (5 samples over 30 days).		
Flooding, Nutrients, Sediment	Improve water quality and habitat to obtain passing mIBI, IBI, and QHEI scores and delist streams currently on IDEM's 303(d) list for IBC	Watershed stakeholders, IDEM	Implement BMPs noted above targeting sediment, nutrients and E. coli reductions, flood mitigation and riparian habitat improvement.	$20,000	PP/TA: ICP, MS4, local nonprofit groups
			Monitor fish and macroinvertebrate populations every five years and habitat annually.		

11.0 FUTURE ACTIVITIES

The next steps for the project include starting implementation of the Upper Sugar Creek Watershed Management Plan. The Montgomery County SWCD in partnership with the project steering committee and other regional partners will consider options for submitting implementation-focused grant applications for IDEM Section 319 funds, Mississippi River Basin Initiative Funds, DNR LARE, Clean Water Indiana and other funds. If funded, this grant would provide funds for a cost-share program to install BMPs, promotion of the cost-share program, and an education and outreach program. If the grant is awarded, the steering committee will develop a cost-share program that will include steps to meeting the goals and management strategies of this plan. The anticipated cost-share program will use a ranking system to fund applications that will have the most impact in improving water quality. Factors such as location within watershed (priority areas), distance from streams, number of resource concerns addressed, and number of practices planned will be considered as part of the ranking process to further prioritize BMPs. It is anticipated that implementation efforts will target high priority critical areas and focus on the implementation of short-term goals.

1.1 Tracking Effectiveness

Implementation of policies, programs, and practices will improve water quality and watershed conditions within the Upper Sugar Creek Watershed, helping reach goal statements by 2053 (Table 92). For each practice identified which the committee deemed familiar and routinely utilized in the Upper Sugar Creek Watershed and for which a load reduction calculation is readily available, an annual target for the acres or number of each BMP implemented is included in Table 93. Measurement of the success of implementation is a necessary part of any watershed project (Table 92). Both social indicator and water quality data will be used to measure observable changes following implementation. In order to track the project's progress of reaching goals and improving water quality, information and data will need to be continually collected during implementation.

The tracking strategies illustrated in Table 92 will be used to document changes and aid in the plan re-evaluation. The steering committee listed potential partners and technical assistance provides as both unless otherwise noted. Activities to be completed as part of this watershed management plan are identified in the action register Table 91). Table 93 identifies the annual target for the number or acres of BMPs to be installed during each implementation phase. Work completed towards each goal/objective documented will include scheduled and completed activities, numbers of individuals attending or efforts completed toward each objective, and load calculations for each goal, objective, and strategy. Overall, project progress will be tracked by measurable items such as workshops held, BMPs installed, meetings held, number of attendees, etc. Load reductions will be calculated for each BMP installed. These values and associated project details including BMP type, location, dimensions, load reductions, and more will be tracked over time and documented on the Indiana State Department of Agriculture Conservation Tracking sheet. Individual landowner contacts and information will be tracked for both identified and installed BMPs. The Montgomery County SWCD will be responsible for keeping the mentioned records.

Table 92. Strategies for and indicators of tracking goals and effectiveness of implementation.

Tracking Strategy	Frequency	Total Estimated Cost (Staff Time Included)	Partners/Technical Assistance
BMP Count	Continuous	$5,000	SWCDs, NRCS, ISDA, MS4
BMP Load Reductions	Continuous	$5,000	SWCDs, NRCS, ISDA, MS4
Attendance at Workshops/Field Days	Yearly	$500/workshop	N/A
Post Workshop Surveys for Effectiveness	Yearly	$250/workshop	SWCD, NRCS, Purdue Extension
Number of Educational Programs/students reached	Yearly	$250/program	N/A
Windshield Surveys	Every 4-5 years	$2,500 annually	SWCDs, Committee, ISDA
Tillage/Cover Crop Transects	Yearly	$20,000 in SWCD and ISDA staff time	SWCDs, NRCS, ISDA Staff
Number of educational publications/press releases	Yearly	$500/release	SWCD
IDEM Probabilistic Monitoring	Every 9 years	N/A (IDEM provides staff and funding)	IDEM

Table 93. Annual targets for best management practices.

Suggested BMPs:	Annual BMP Targets	Units
Conservation Cover (327)	200	acre
Cover Crop (340)	2,500	acre
Fence (382)	100	Feet
Filter Strip (393)	100	Acre
Forage and Biomass Planting (512)	500	Acre
Grassed Waterway (412)	50	Feet
Livestock Restriction (Alt Watering System, Access Control)	100	Feet, unit
Nutrient/Pest Management (590)	2,500	acres
Pollinator planting (CP42)	200	acres
Prescribed Grazing (528)	500	acres
Residue and Tillage Management (329)	2,300	acres
Streambank Stabilization	10	Feet
Tree/shrub Establishment (612)	200	acres
Wetland Creation/Restoration	10	Acres

1.2 Indicators of Success

Water quality, social, and administrative indicators will be used to monitor progress towards successful achievement of the goals for the high and medium priority critical areas. Water quality indicators will include monitoring total phosphorus, nitrate-nitrogen, total suspended solids and *E. coli*. Monitoring will occur as part of the Hoosier Riverwatch volunteer program, at a minimum. If local laboratory partners will continue to analyze collected samples as an in-kind service, laboratory data will be utilized as an indicator for each parameter. Administrative indicators will be listed with each strategy included in the action register.

Reduce Nutrient Loading

- Water Quality Indicator: Nitrate-nitrogen and total phosphorus will be measured monthly at the IDEM fixed station monitoring sites. After five years of implementation, water quality samples will show a decreasing trend, with more samples annually meeting the target level for nitrate-nitrogen of 1.0 mg/L and for total phosphorus of 0.08 mg/L.
- Administrative Indicator: The number of BMPs that can reduce nitrate-nitrogen and total phosphorus will be tracked annually. The total number of acreage will be compared against annual targets identified in Table 93. Individual load reductions calculated for each BMP will be reviewed to determine if cumulative loading rates for nitrate-nitrogen and phosphorus are sufficient to meet the target reductions.

Reduce Sediment Loading

- Water Quality Indicator: Total suspended solids will be measured monthly at the IDEM fixed station monitoring sites. After five years of implementation, water quality samples will show a decreasing trend, with more samples annually meeting the target level for total suspended solids of 15 mg/L.
- Administrative Indicator: The number of BMPs that can reduce total suspended solids will be tracked annually. The total number of acreage will be compared against annual targets identified in Table 93 Individual load reductions calculated for each BMP will be reviewed to determine if the cumulative loading rate for total suspended solids is sufficient to meet the target reduction.

Reduce *E. coli* Loading

- Water Quality Indicator: *E. coli* will be measured by volunteers annually following geometric mean sampling methods. After ten years of implementation, water quality samples will show a decreasing trend, with more samples annually meeting the state standard.
- Administrative Indicator: The number of BMPs that can reduce *E. coli* will be tracked annually. The total number of acres will be compared against annual targets identified in Table 93.

Reduce Flooding Impacts

- Administrative Indicator: Wetland acreage, floodplain land cover acreage and coverage of poorly drained and very poorly drained soils will be calculated using each new National Land Cover Dataset, which is released approximately every six years. After six years of implementation, wetland, floodplain land cover and poorly drained/very poorly drained cover acreage will measure higher than the measurement which occurred during the previous assessment. Total acreage of wetland, floodplain land cover and poorly drained/very poorly drained cover will be compared with previous total. If LIDAR data is available, this calculation will occur using these data.

Habitat Impacts

- Administrative Indicator: Natural habitats (grassland, forest, wetland) acreage will be calculated using each new National Land Cover Dataset, which is released approximately every six years. After six years of implementation, natural lands will measure greater than the measurement which occurred during the previous assessment. Total acreage of natural lands will be compared with previous total. If LIDAR data is available, this calculation will occur using these data.

Increase Public Awareness and Participation

- Administrative Indicator: The number of people who attend education and outreach events will be tracked. The percent of targeted households reached will increase annually.
- Social Indicator: Pre and post surveys of attendees will be conducted at workshops to determine changes in individuals' knowledge of the topic as a result of attending the workshop. It would be expected that 75% of workshop attendees would have a better understanding of the topic after the workshop.

1.3 NEPA Concerns and Compliance

The National Environmental Policy Act (NEPA) was signed into law in 1970. The law requires federal agencies to assess the environmental impacts of their proposed actions prior to making decisions. This law also applies to watershed planning activities. As part of the planning process the NRCS is required to evaluate the individual and cumulative effects of proposed actions. Any project that has significant environmental impacts must be evaluated with an Environmental Assessment (EA) or Environmental Impact Statement (EIS) unless the activities are eligible under a categorical exclusion or already covered by an existing EA or EIS. The NRCS utilizes a planning process that incorporates an evaluation of potential environmental impacts using an Environmental Evaluation Worksheet. There are several NRCS conservation practices and activities that fall under a categorical exclusion. A categorical exclusion is a category of actions that do not normally create a significant individual or cumulative effects on the human environment. There are 21 NRCS approved conservation or restoration categorical exclusions identified in GM190 §410.6. These categorical exemptions include practices that reduce soil erosion, involve planting vegetation and restoring areas to natural ecological systems.

This watershed plan calls for conservation practices that control soil erosion and runoff from agricultural fields and structural practices to address runoff and waste management issues. Many of these practices are covered by either a categorical exclusion or may be included in an existing environmental assessment. A list of practices likely to be used to implement the plan is listed in Table 88.

Prior to practice implementation with USDA NRCS assistance, an NRCS CPA 52 Environmental Evaluation form will be completed for each practice. Using this form, each planned practice and practices system will be evaluated to determine if it meets the criteria of categorical exclusions and any existing Environmental assessments. Any adverse impacts from practices will first try to be avoided then minimized or mitigated as necessary. If resource concerns are found, NRCS will contact the agency with responsibility for the resource. Agencies will include but are not limited to US Fish and Wildlife Service and the State Historic Preservation Office. It is not anticipated that the practices planned for the

Upper Sugar Creek Watershed will require an Environmental Assessment or an Environmental Impact Statement.

2.0 OUTREACH PLAN

Based on steering committee knowledge, a multi-tiered strategy will be required to fully implement the Upper Sugar Creek Watershed Management Plan. The plan will use targeted outreach to agricultural producers which will encourage the adoption of conservation practices to avoid, control and trap nutrients and sediment. Additional associated landowners will receive information about the project with the goal of raising awareness and informing the local community. For the targeted producers, outreach methods will include but not be limited to the following:

- Targeted landowner and producer mailings to announce the program and encourage the adoption of conservation practices. Mailings will occur no less than once but may occur annually, as needed.
- Practice specific field days and workshops. No less than 2 workshops or field days will occur annually.
- Newsletters. The Upper Sugar Creek steering committee will work with partners to distribute information on a quarterly basis within partner newsletters including SWCD, county extension, FSA, and others.
- Post information at public locations such as farm and garden centers.
- Work with regional CCAs to provide information about the program.
- Maintain a project website which will be used to promote project events, announce fund availability and detail funding deadlines. Updates will be made to the project website no less than monthly or when education and engagement events occur, cost share funds are available or project-based meetings or other activities can be highlighted.
- Social media posts will occur on project social media no less than monthly and will be shared across partner social media as well.
- Radio announcements (PSAs) and news releases will occur no less than quarterly to local media.
- Additional options such as billboards, videos, tabling at community events, and others will be considered by the technical committee.

The following partners will be engaged as part of the outreach efforts:

- Natural resources conservation service (NRCS) conservationists provide technical assistance and expertise, coordinate conservation planning and distribute financial assistance for local producers. The Montgomery, Clinton, Boone and Tippecanoe County service centers provide assistance for Upper Sugar Creek Watershed.
- Montgomery, Clinton, Boone and Tippecanoe County SWCD offices assist producers with conservation choices via farm planning assistance as well as targeted education and outreach.
- Indiana State Department of Agricultural staff provides technical assistance and expertise with conservation practice design and assessment.
- The Upper Sugar Creek Watershed Project will provide education and outreach assistance and assist with program promotion.

2.1 Adapting Strategies in the Future

Due to the uncertainty of the watershed management planning, an adaptive management strategy will be implemented to improve the project's success. While much thought and expertise has been put into the planning process, not all scenarios can be foreseen. Oftentimes there are changes such as a shift in community attitude/behavior, changes in resource concerns, development of new information or accomplishing a goal sooner or later than expected. By implementing an adaptive management strategy, the Upper Sugar Creek Project Steering Committee can adjust the watershed management plan to ensure project success. A four-step adaptive management strategy has been outlined for the Upper Sugar Creek Watershed Project and can be found below.

Step 1: Planning The planning process used to develop the Upper Sugar Creek WMP follows the IDEM 2009 Watershed Management Checklist. The project coordinator worked in concert with and was guided by the Upper Sugar Creek Project Steering Committee to develop the WMP using knowledge of the watershed, inputs from stakeholders, new data from water monitoring and windshield surveys, and historical data. This plan includes goals, action register, and schedule outlining how and when to achieve the defined goals.

Step 2: Implementation The action register and schedule will be implemented to achieve the goals of the Upper Sugar Creek Watershed Project objectives and goals. Partnering agencies such as NRCS, SWCD, ISDA, and IDEM will carry out the implementation. Implementation will include a cost-share program and education events targeting both youth and adults. Practices implemented through the cost-share program will follow the NRCS Field Office Technical Guide (FOTG) Practice Standards or other technical standards as detailed in the cost-share program, once developed. The cost-share program will include but will not be limited to practices such as cover crops, watering facilities, fencing, conservation buffers, grassed waterways, and nutrient and pest management plans. Cost-share funding will be implemented in priority areas. A ranking system will be used to prioritize applications that will have the greatest impact on water quality improvement.

Step 3: Evaluate & Learn Evaluations of indicators identified above and in Table 92 will occur often to check the progress being made toward the project goals. The steering committee will annually review progress and determine if the project is on track to meet interim and project end goals outlined in the Action Plan (Table 91) and goals. Factors evaluated will include but will not be limited to numbers of BMPs installed, calculated/estimated load reductions of installed BMPs, number of individuals reach through outreach, etc. The evaluations will be conducted by the Upper Sugar Creek Project Steering Committee. The group will then provide recommendations that will improve project success. Progress against the watershed management plan will be reviewed no less than every two years (i.e. 2024, 2026, etc).

Step 4: Alter Strategy The project's implementation and management strategy will be adjusted to improve the project's success. If progress is not made proportionate to the time into the project (i.e. at the end of year 3, approximately 30% (3/10) of 10 year goals should be met), the steering committee will have the opportunity to alter their strategy in order to meet the goals of the project. Adjustments will be based off of recommendations from the Evaluate and Learn step. Once the adjustments are agreed upon by the steering committee, the project will revert back to Implementation (Step 2) to continue with the Adaptive Management strategy (steps 2-4) until all goals have been met or all conservation opportunities have been exhausted.

The Upper Sugar Creek Project coordinated by the Montgomery County SWCD, are responsible for maintaining records for the project including tracking plan successes and failures and any necessary watershed management plan revisions. The plan will be re-evaluated at the end of Year 5 and every 5 years after that.

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