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UPPER MISSISSINEWA RIVER WATERSHED
WATERSHED MANAGEMENT PLAN
March 13, 2018

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WATERSHED MANAGEMENT PLAN

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FlatLand Resources, a planning and design-build civil engineering firm based out of Muncie, Indiana, conducted fieldwork, data collection, report writing and mapping, facilitated public meetings and outreach, and provided project oversight. The FlatLand Resources team consisted of Phil Tevis, Colby Gray, Clair Burt, Barb Frost, Candace Kindt, David Heilman, Kristin Riga, Chris Tomsic, Jacob Riddle, Luke Waltz, Paige Story, and Amanda Arnold.

Special thanks to Mississinewa River landowners who participated in our public concerns and implementation drive, public input meetings, and social indicators survey, and to individuals who provided project support/consultation or contributed data to this report.

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Water Quality Indiana (BSU Geology)
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EXECUTIVE SUMMARY

“One of the ground-breaking legislative efforts to clean up pollution in the country’s rivers and lakes was the 1972 Federal Clean Water Act. The initial focus of this legislation was on establishing and enforcing standards for “point source” dischargers (municipalities and industries that used water and put it back into a stream or lake through a system of pipes). In the first decade of its existence, the Clean Water Act resulted in large improvements in water quality. During the 1980’s there was an increasing awareness by scientists that water quality was also impacted greatly by “nonpoint sources” of pollution. These were pollutants dispersed through atmospheric deposition or by diffuse sources of wet weather runoff. An important assessment of environmental conditions in the early 1990’s determined that nearly half of the nation’s rivers and streams did not fully support their beneficial uses. The pollutants identified as most often contributing to water quality problems were sediments, nutrients, pathogens, and pesticides. It was determined in this report that agricultural activities were the primary source of these pollutants in 72% of the impaired rivers and streams.

“In recent years, there have been many new federal, state, and local programs directed toward addressing these nonpoint sources of pollution and the general understanding of sources has changed and evolved. The emphasis in many of these programs has been a “watershed approach,” which encourages managers to examine all factors contributing to water quality problems within the entire land area from which a stream receives its flow. By addressing how land is used within a watershed, and making and implementing plans for improvements in land use (“best management practices,” or BMPs), wet weather runoff into streams and rivers will be less polluted.”[1] The United States Environmental Protection Agency administers funding provided through The Federal Clean Water Act (Section 319(h)) initiated to provide funding for various projects that work to reduce nonpoint source water pollution. The Indiana Department of Environmental Management (IDEM) Nonpoint Source (NPS) Section in the Office of Water Quality manages this federal funding through federal pass-through grant programs aimed at improving water quality in the state. Section 319(h) and Section 205(j); each named after the portion of the Clean Water Act that authorizes the programs.[2]

PROJECT OVERVIEW AND PROCESS

This project was funded by a 205(j) grant awarded by IDEM. The main objective of this project is to make recommendations, based on scientific data and community concerns, for reducing non-point sources of pollution within the Upper Mississinewa River Watershed (UMRW). FlatLand Resources, LLC was the Project Manager for this project. Support and guidance was provided throughout the project by a Steering Committee consisting of stakeholders and community members, many of whom hold environmental and conservation positions. Certain leaders involved with this project formed the Upper Mississinewa River Watershed Partnership (UMRW-P), which will collaborate to address action items set forth in this watershed management plan. The UMRW-P has been especially important in the initial steps of this project by helping to identify priorities and guide the approach for various components of the project, such as involving additional stakeholders. The UMRW-P will continue to be instrumental in the implementation phase of this project, as actions recommended in this plan are implemented.

This report contains an analysis of community concerns gathered at the beginning of this project, a Watershed Inventory (which provides data and analysis from various sources regarding the Upper Mississinewa River Watershed’s physical features and land use) and a Water Quality Inventory (which provides historical water quality, biological, and habitat data as well as results and analysis from chemical and biological water quality monitoring that were conducted as part of this study). Results from these inventories are used to identify subwatersheds within the Upper Mississinewa River Watershed that have the most impaired water quality (referred to from herein as “critical areas”). The final portion of the plan determines possible sources of pollution in these critical areas and recommends a plan of action to mitigate them.

THE UPPER MISSISSINEWA RIVER WATERSHED

The Upper Mississinewa River Watershed (UMRW) is approximately 415,000 acres encompassing 650 square miles and portions of six Indiana counties (Grant, Blackford, Madison, Delaware, Jay, and Randolph) as well as a portion of Darke County, Ohio. Within the watershed, approximately 78% of the land is cropland, 9.7% is urban, 7.4% is forest, and 3.6% is pasture/grasslands. Only 0.5% are wetlands. Fifty-five miles of the Mississinewa River flow through the watershed. Within the watershed, there are approximately 924 miles of streams and ditches flowing into the Mississinewa River along its 55 mile reach. Three hundred (300) miles of streams are listed on the 2014 303(d) list of impaired waterbodies. Reasons for impairments included E. coli, biotic communities, and PCBs. Of the 300 miles of streams listed on the 2014 303(d) list, 135 were added to the list since 2008.[3]

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1 Commonwealth Biomonitoring. Mississinewa River (Phase II) Watershed Diagnostic Study. 2005. http://www.in.gov/dnr/fishwild/files/Mississinewa_River_Watershed_DiagII-Delaware-Randolph-Jay-June04.pdf

2 Indiana Department of Environmental Management. Clean Water Act Section 319(H) Grants. http://www.in.gov/idem/nps/2524.htm

3 According to the Clean Water Act, states must develop a Total Maximum Daily Load (TMDL) for any waterbody listed on the 303(d) list. Pollutant loads are generated from data to create the TMDL; this allows required pollutant reductions to be calculated, aiding in the development of appropriate projects needed to meet target loads. IDEM is developing a TMDL for the Upper Mississinewa River Watershed with data IDEM collected for this study.

PUBLIC INPUT PROCESS

Public input was solicited as part of this study in order to identify public concerns regarding water quality and to generate public interest in cost-share opportunities. Because not all of the 87,000 individuals living in the watershed region could be contacted, the Project Manager contacted individuals identified as owning >40 acres adjacent to the Mississinewa River.

Four thousand (4,000) individuals own parcels that are greater than 40 acres in size. This group of individuals control 66% or more of the total acres in the region and is the project's target audience. One thousand (1,000) individuals from the target audience (selected if parcels are adjacent to a waterway) were invited (through direct mail) to attend one of seven public input meetings. One hundred eighty-two (182) individuals either attended public meetings or provided comment through a response card system.

Results of these interactions indicated that residents understand that the mainstem Mississinewa River is not meeting IAC 14-25-7-2 standards (Table 12.1, p.198). The subwatershed areas with the most vocal stakeholders were Fetid Creek-Mississinewa River, Platt Nibarger Ditch-Mississinewa River and Branch Creek-Mississinewa River. Overall, the project had 150 concerns (some of which were generated by the Steering Committee) broadly categorized into (a) fish and wildlife concerns, (b) health (drinking water/recreation) concerns, and (c) socioeconomic concerns. Many of these concerns were quantifiable and confirmed as problems caused by excess nutrients, sediment, E. coli or logjams.

Logjams were the greatest concern expressed on comment cards and/or at public meetings. Landowners noted specific impacts of logjams to recreational safety, adjacent agricultural flooding, impaired tile drainage, and exacerbated streambank erosion. The greatest concentration of concerns were on Fetid Creek-Mississinewa River subwatershed; a 2014 canoe survey found seven Condition 3 and three Condition 4 logjams in this reach.

Interest in cost-share programs was also measured. One hundred (100) participants were interested in participating in cost-share programs. Covercrops, grassed waterway, no-till equipment modifications, and vegetated streambank stabilization were the items in which participants were most interested.

Many valid concerns were also identified by the Steering Committee (through the watershed inventory and water quality monitoring results) that were seldom mentioned by the public in comment cards and/or at public meetings. A listing of all concerns are found in Tables 12.3-12.5 on pp. 199-207. Concerns discussed by the steering committee were typically related to the actual causes of impaired water quality (i.e. excess nitrogen, phosphorus, sediment, and E. coli). There may be limited awareness of these causes by general public survey respondents or they simply may have not been reported. Either way, the Steering Committee has identified potential barriers to awareness, as well as strategies to develop educational initiatives. Action items specifically tailored to increasing awareness of these causes of impaired water quality include (1) a Hoosier River Watch sampling demonstration, (2), the promotion of Best Management Practices, (3) the development of supplemental educational research agendas, and (4) the identification of future strategic partners to assist with education. A complete list of action items can be found in Tables 16.6 through 16.17 on pp. 259-281.

PAST WATER QUALITY STUDIES

Many of the concerns regarding the water quality of the UMRW had already been validated by past studies. Past data and studies reviewed within this plan include (a) STORET (EPA Storage and Retreival Database), IDEM, HRW (Hoosier Riverwatch) & DNR water quality data, (b) eight relevant scientific studies performed in the region, (c) four HUC10 LARE Diagnostic Studies 2000-2012, (d) a 2013 Indiana Canoeing Trail study, and (e) a 2010 Ecoregion water quality comparative study. However, performing a comparative analysis of twenty-eight watersheds using historic data is challenging due to variations in datasets. Due to these limitations, an independent contemporary water quality assessment was conducted.

WATER QUALITY AND LAND USE ASSESSMENT

To assess contemporary water quality, sampling for E. coli, TSS, nitrogen, phosphorus, flow, turbidity, dissolved oxygen, pH, and temperature was conducted monthly from in 2014 and 2015 at twenty-eight sites representing twenty-eight HUC 12 subwatersheds within the UMRW. Twelve of these sites were located on the mainstem of the Mississinewa River, while the remaining 16 were located on tributary subwatersheds. Using flow data, samples were categorized into either high flow or low flow events. Target concentrations for each parameter were selected by the Project Manager. In accordance with watershed planning guidelines, the targets were "as stringent as the NPS TMDL target."[4] These targets came from a variety of sources and both can be found in Table 6.1 on p. 98. Water quality was also assessed through biological and habitat assessments (IBI, mIBI, and QHEI). A set of targets for these can be found in Section 9, Biological Assessments, p. 148.

Available data regarding items such as land use, physical characteristics, soils, and hydrology were also collected and analyzed. This data, along with water quality data, allowed for the identification of possible sources of pollution.

Twelve primary 12-digit HUC critical areas were determined based on estimated pollutant load reductions needed to reach target pollutant loads (Gray Branch, Halfway Creek, Little Mississinewa, Lugar Creek, Walnut Creek, Campbell Creek, Barren Creek, Little Deer Creek, Deer Creek, Upper Big Lick Creek, Big Lick Creek, and Little Walnut Creek). Critical areas, sources of pollution within these areas, and reasons for being critical can be found in Section 14, Critical Areas, p. 221. A table of watershed critical areas is found on p. 16. The following narratives synthesize water quality results and UMRW land-use and physical characteristics results.

4 IDEM. Watershed Management Plan Checklist and Instructions (2009). http://www.in.gov/idem/nps/3429.htm

Total Suspended Solids
Mainstem average TSS was 6.7 times greater than target levels, and requires an 86% load reduction in order to reach these target levels. Levels at tributary subwatershed sites were generally lower than those at mainstem sites; however, most were still exceeding targets during high flow. In general, sites that had a combination of factors that contribute to surface erosion (highly erodible soils, high sediment transport prediction due to topography, and high levels of conventional tillage) had higher average TSS levels. These subwatersheds were concentrated in the western part of the watershed. Sites that had lower levels of these factors were concentrated in the eastern part of the subwatershed and generally had lower average TSS. However, sites in the very easternmost part of the watershed did not follow this pattern; they had high average TSS but fewer factors contributing to surface erosion, suggesting that streambank erosion or other sources of suspended solids may also be influencing results. Streambanks are predicted to be a significant sediment source on Lugar Creek and Walnut Creek based on comments from landowners as well as desktop survey and windshield survey results. Stakeholder "fish and wildlife" concerns are related to the impact of turbidity/sediment on aquatic ecosystems. The loss of agricultural land (bank and surface erosion) was also a socioeconomic concern frequently cited by stakeholders.

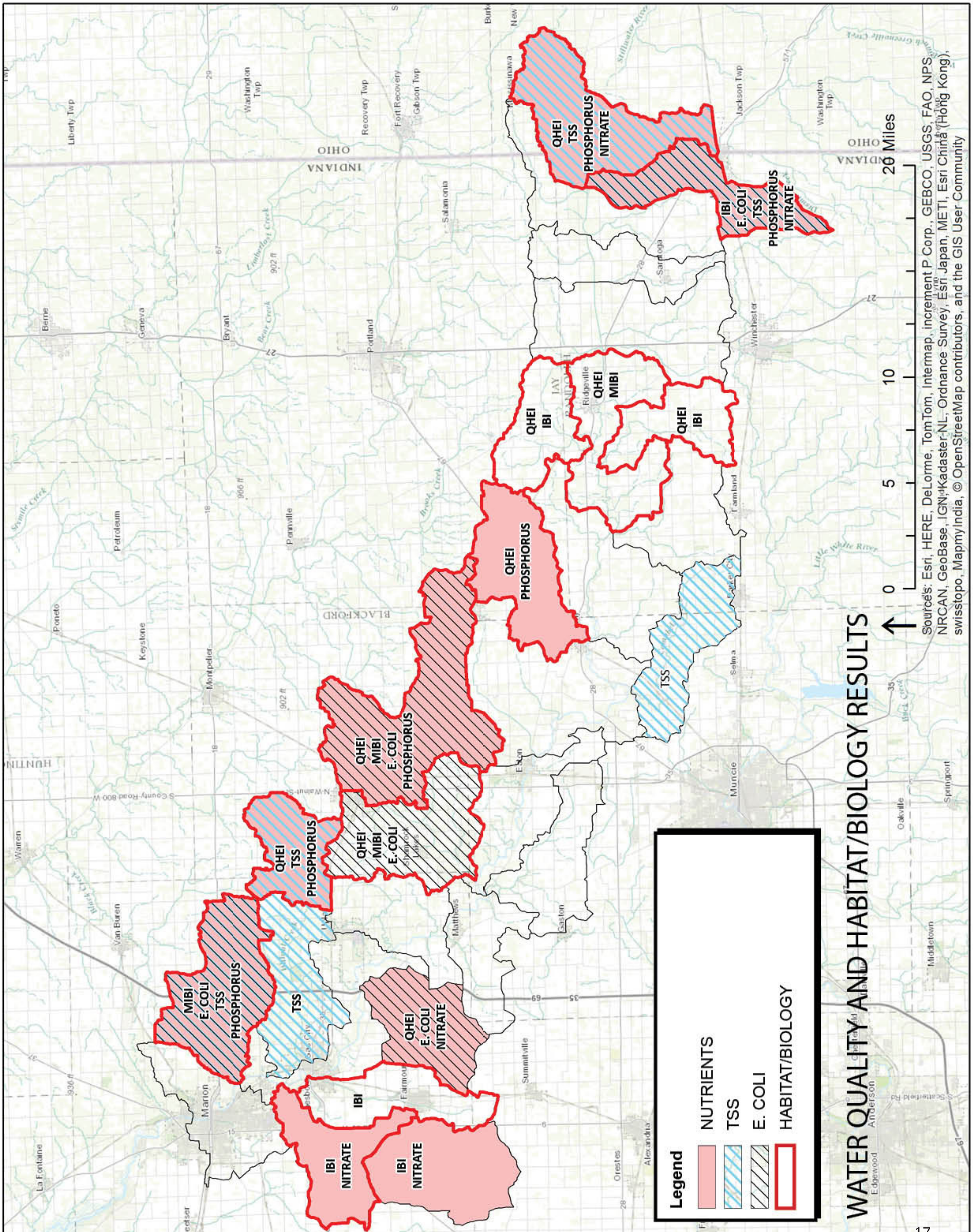
TABLE 0.1 | Critical HUC 12 Tributary Subwatersheds

Critical Tributary Subwatershed	Sources of Pollution	Reason for Being Critical
Bush Creek	cropland; CFO's	nitrogen
Gray Branch	cropland	nitrogen, phosphorus, TSS
Barren Creek	areas where livestock have access to streams	nitrogen, E. coli
Little Mississinewa River	cropland; CFO's	nitrogen, phosphorus, E. coli, TSS
Little Deer Creek	cropland	nitrogen
Deer Creek	cropland	nitrogen
Lugar Creek	eroding streambanks	phosphorus, E. coli, TSS
Little Walnut	cropland; eroding streambanks	phosphorus, TSS
Halfway Creek	cropland	phosphorus
Upper Big Lick Creek	areas where livestock have access to streams	phosphorus, E. coli
Big Lick Creek	areas where livestock have access to streams	E. coli
Walnut Creek	eroding streambanks; cropland	TSS
Campbell Creek	septic systems; eroding streambanks; cropland	TSS

Nutrients
Mainstem nitrogen averaged 7.21 mg/L, 8.4 times target, requiring an 88% load reduction. Nitrogen was highest in subwatersheds with the largest percentage of agricultural land-use; this is consistent with pre-sampling modeling (Simple Coefficient Model). Seasonal nitrogen levels showed a clear connection to agricultural land application patterns (pre-season application, side dressing). Subwatersheds with the highest concentration of lawns, sports fields, and/or golf courses had lower nitrogen levels compared to predominantly agricultural subwatersheds. Local On-Farm Network®/ Infield Advantage data demonstrates that 85% of participating producers are applying optimal levels of nitrogen; excess nitrogen in waterways is likely driven by solubility, not over application. Based on survey data from landowners, covercrop usage is uncommon, but in demand. Stakeholders were concerned that excess nutrients/algae is causing stress to fish and other aquatic wildlife. However, biological data did not indicate that nitrogen levels influenced biological score. Stakeholders were also concerned about the financial loss associated with nitrogen leaching.

E. coli
Mainstem E. coli data was 8.2 times above the target (84% reduction needed) and the subwatershed average was 9.6 times above the target (89% reduction needed). In general, stakeholders were concerned about pathogen impact to recreation and drinking water quality. Sample sites with the highest E. coli averages were located in areas with high population densities, where higher concentrations of CSOs and septic tanks are present, and in areas with high concentrations of CFOs. Expansion/sprawl resulting in an increase in septic tanks is a concern to stakeholders. Although there is an overall population decrease in the watershed, some rural census tracts adjacent to these urban areas are growing in population.

Improper field application of CFO waste was a stakeholder concern. The eastern portion of the watershed has the highest concentration of CFOs in the watershed. High flow averages were consistently high in this area. Land application of manure from these CFOs is likely a source. While septic tanks may also be a source, this area has some of the lowest estimated concentrations of septic systems within the watershed. Desktop surveys also indicated that livestock are given access to streams at specific locations throughout the watershed; this is another source of E. coli.



MAP 0.1 | Water Quality and Habitat/Biology Results

Biological Results
Biological scores were higher (better) at mainstem sites than at tributary subwatershed sites. Five tributary subwatersheds had poor IBI scores and three had poor mIBI scores. Only one mainstem site had a poor mIBI score and none had poor IBI scores. Higher quality habitat may explain these differences; mainstem sites had higher QHEI scores than tributary subwatershed sites in general. Forty-one percent (41%) of tributary sites had poor average QHEI scores, while only 9% of mainstem sites had poor average QHEI scores. Pollutants causing poor water quality may be another cause of biological impairment; four sites had lower IBI scores than were expected based on QHEI scores.

PROJECT APPROACHES TO SOLVING WATER QUALITY PROBLEMS
The mission of the Upper Mississinewa River Watershed Partnership (UMRW-P) is to advocate and ensure the beneficial uses of water outlined by IAC 14-25-7-2 and summarized by this plan as fish and wildlife, health (recreation and drinking) and socioeconomic uses. The UMRW-P will address the problems identified in this watershed management plan and will collaboratively enhance marketing, education, and promotional efforts. Partnership efforts from 2014-2016 leveraged $230,000 implementation dollars through the DNR LARE Program (logjam removal on Mississinewa River and streambank stabilization on Deer Creek); a $5,000 covercrop cost-share through The Ball Brothers Foundation (serving 250 acres); and approximately $50,000 of in-kind educational contribution from students and faculty at Ball State University. Seeking similar sources of funding, the UMRW-P strives to reduce key water quality impairments (sediment, phosphorus, nitrogen, and TSS) using Best Management Practices (BMPs) and measures outlined in the watershed management plan in critical areas.

Cost-share Promotion
The UMRW-P will promote state and federal cost-share programs and advocate for the implementation of these programs in critical areas. The UMRW-P will assist landowners in the development of cost-share applications when feasible.

Cost-share Programs
The UMRW-P will develop a cost-share program that will fund BMPs that (a) target sources specifically identified through windshield and desktop surveys, (b) are prioritized based on critical area ranking criteria outlined in the watershed management plan, and (c) will maximize pollutant load reductions based on quantifiable calculations. The UMRW-P will also be mindful of BMPs demanded by landowners in a 2014 social survey and/or at public meetings held throughout the watershed planning process. The primary focus will be on a “system approach,” advocating the adoption of covercrops, grassed waterways, filterstrips, no-till practices, and the creation of manure/nutrient management plans.

TABLE 0.2 | Landowner Interest in Best Management Practices (750 people surveyed)

Best Management Practice	Number of Respondents Interested	Percentage of Respondents Interested (90 total respondents)
Drainage Water Management	28	19%
Cover Crops	24	17%
Grassed Waterway	20	14%
Streambank Protection	18	12%
Residue and Tillage Management	17	12%
Filter Strips	13	9%
Stormwater Runoff Control	13	9%
Tree and Shrub establishment	12	8%

The UMRW-P will also consider funding any BMP in the NRCS FOTG field guide that meets the above rationale and UMRW-P cost-share program plan guidelines. The UMRW-P will select BMP projects what will maximize load reduction.

Additionally, the UMRW-P suspects that Little Mississinewa, Lugar Creek and Walnut Creek’s elevated sediment levels during high flow events are driven by instream sources (based on land-use considerations, geomorphological characteristics, and professional judgement). Cost-share on 2-stage ditches & vegetated stream bank stabilization practices will be considered only for these three critical areas as outlined in this document.

Educational Objectives

A. The UMRW-P will continue to develop a relationship with our target audiences. Purdue Extension estimates that 50% of landowners in the region are non-producer/renters while 50% are producer/landowners. The UMRW-P will seek to differentiate between these two audiences and tailor its education and outreach efforts to these specific subgroups. The over-arching goal will be to build social networks within each subgroup and develop educational resources based on the needs and interests of each unique subgroup.

B. The UMRW-P will seek to better understand local policy and ordinances related to water quality, drainage, land management, and conservation. The UMRW-P will work with landowners and representatives to explore opportunities for local policy proposals and/or changes.

C. The UMRW-P will build relationships with regional Health Departments and Sanitary Districts, sharing water quality results, and partnering where possible to reduce E. coli from septic and CSO sources.

D. The UMRW-P will focus on "unseen" impairments such as pathogens, nutrients, and sediment. These were concerns rarely mentioned on comment cards and/or at public meetings, yet these concerns are the primary causes of water quality problems in the watershed. Educating landowners about these pollutants and how they relate to their (i) health (recreation and drinking water), (ii) fish and widlife, and (iii) socioeconomic concerns are a goal of the project. In response, UMRW-P will develop education initiatives that:

1. Explain the health risks associated with drinking or having full body contact with polluted waters (pathogens & nutrients/algae).
2. Emphasize the connection between rainfall, land-use, and aquifers (wells/drinking water).
3. Use Hoosier Riverwatch (CHEMetrics and ColiScan) methods/testing kits as a means of educating and training the public in how to "see" the unseen water quality impairments affecting the region's water quality. Demonstrate these methods through interactive exhibits at tradeshows/festivals. Document sampling events and chemical testing procedures in a video format to use on website/social media.
4. Collaborate with Water Quality IN (A Portal for Trans-Disciplinary Pedagogy and Research Linking Water Resources) and/or Delaware County Department of GIS to develop innovative education and cost-share promotion media including videos, interactive web resources, mobile GeoForm data collection applications, and ArcGIS Online maps and ArcGIS "story maps".
5. Continue to host events at the Davis Purdue Agricultural Center (DPAC) and begin hosting events at the Ball State University Hults Environmental Learning Center.

E. The UMRW-P will work with local conservation organizations to increase awareness of recreational opportunities along the Mississinewa River and at Mississinewa Lake Reservoir.

1. Guide local groups in the application and removal of canoeing impairments such as logjams and dams.
2. Educate about health and safety issues relating to full body contact.
3. Assist local conservation groups in creating additional canoe access sites.
4. Host a clean-up/canoe run or clean up.

Monitoring Program/Tracking Effectiveness

The Project Manager will collaborate with Water Quality IN (WQI) and/or Delaware County GIS in developing methods for grass-root data collection and promoting supplemental water quality data collection/analysis. This collaborative partnership will equip students and community members in the watershed to use a variation of Hoosier Riverwatch level water quality methods/assessment. The development of a capable volunteer base will allow for cost-effective monitoring of installed BMPs (i.e. BMPs installed with or without 319 cost-share funding) at either the site where the BMPs have been applied or at the subwatershed scale.

FUTURE ACTIVITIES

This watershed management plan will position the group for future 319 funding, and also will make the project more competitive for LARE implementation grants and funding through local/regional foundations. The UMRW-P manager, in partnership with private funders in Delaware County (2008, 2012-2015), have demonstrated the capacity to sustain watershed groups beyond the 319 funding mechanism. Contingent on success and delivery of high quality services to our sponsors, we expect the UMRW-P to continue beyond the 319 funded grant period utilizing these same partners. In the absence of 319 cost-share dollars, the group will continue to promote existing state and federal conservation programs/easements.

1. WATERSHED COMMUNITY INITIATIVE

1.1 INTRODUCTION

Funding for the development of this watershed management plan (WMP) for the Upper Mississinewa River Watershed (UMRW) was received from the Indiana Department of Environmental Management (Office of Water Quality, Watershed Planning and Restoration Section), the Ball Brothers Foundation, and the George and Frances Ball Foundation. Funds were obtained by the Delaware County Soil and Water Conservation District (SWCD).

The UMRW is approximately 415,000 acres encompassing 650 square miles and portions of six Indiana counties (Grant, Blackford, Madison, Delaware, Jay, and Randolph) as well as a portion of Darke County, Ohio (Map 1.1, p. 21). It is comprised of 28 HUC 12 subwatersheds. Fifty-five miles of the Mississinewa River flow through it, with approximately 924 miles of streams and ditches flowing into the river throughout this reach. Within the UMRW, approximately 78% of the land is cropland, 9.7% is urban, 7.4% is forest, and 3.6% is pasture/grasslands. Only 0.5% are wetlands.

Three hundred miles of the waterways within the UMRW are listed on the 2014 Section 303(d) List of Impaired Waters. Impairments for assessment units were for one or more of the following: E. coli, impaired biotic communities, and PCBs. A fish consumption advisory is issued for streams with PCB impairments. There has been an increase in the amount of waterways in the UMRW appearing on the Section 303(d) List of Impaired Waters, with 135 of the 300 miles being added since 2008. It is likely that even more miles will be added to the 2016 303(d) List; a TMDL report under development has identified additional impairments and impaired stretches of stream through recent water quality testing conducted in a portion UMRW.

This watershed management plan (WMP) is intended to provide guidance for the improvement of water quality within the UMRW. It will serve as a basis for watershed-related actions. The WMP will address items such as:

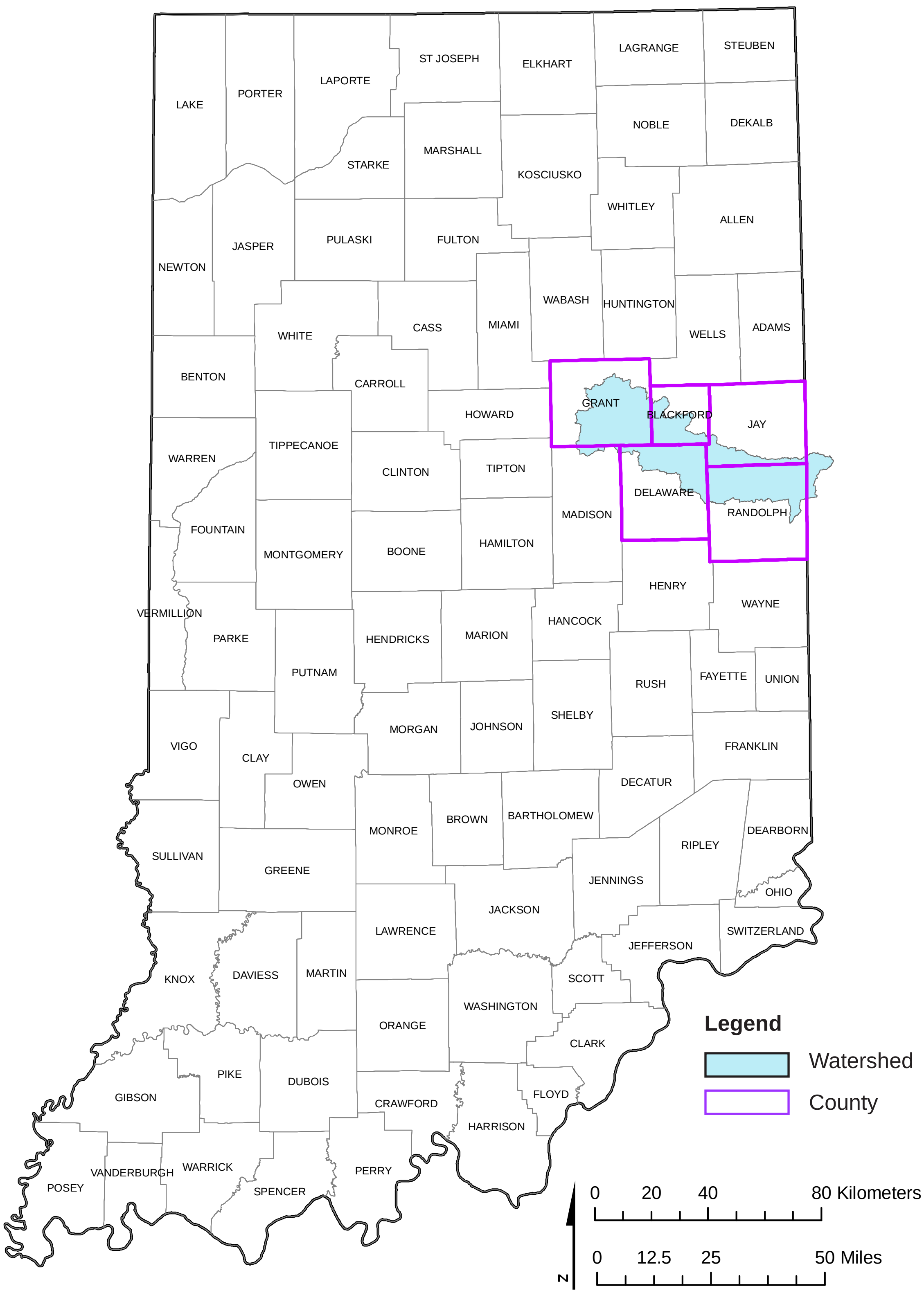
- Identifying water quality concerns through stakeholder input and through the analysis of a watershed inventory and water quality monitoring data
- Identifying nonpoint sources of pollution
- Choosing measures/BMPs to apply
- Providing education and outreach
- Increasing preservation, restoration, and protection of terrestrial and aquatic environments through the use of BMPs
- Increasing cooperation, coordination, and collaboration with stakeholders
- Maintaining a solid organization to implement the plan's action register.

This WMP follows the Indiana Department of Environmental Management (IDEM) requirements for watershed management plans, including these sections:

- Watershed Inventory
- Problems and Causes
- Sources and Loads
- Setting Goals and Identifying Critical Areas
- Action Register and Schedule
- Tracking Effectiveness

This WMP is intended to be comprehensive, identifying problem areas and outlining action items that will address water quality concerns. The subwatersheds in the UMRW have various concerns and problems that need to be addressed. In order to comprehensively address some of these problems, the group will work with local stakeholders, organized as a steering committee, to promote and fund Best Management Practices (BMPs) and other measures (from the action register) that will result in the improvement of water quality within the subwatersheds. Because of the size of the task at hand, this WMP will also be used as a platform to pursue additional grants and funding for implementation of the many different measures recommended in the plan.

The 28 HUC 12 subwatersheds within the UMRW comprise five larger HUC 10 subwatersheds (Map 3.1, p. 40): Headwaters Mississinewa River (HUC_1 0 0512010301), Halfway Creek (HUC_10 0512010302), Pike Creek (HUC_10 0512010304), Big Lick Creek (HUC_10 0512010303), and Massey Creek (HUC_1 00512010305). Four of these HUC 10 subwatersheds (Headwaters Mississinewa River, Halfway Creek, Pike Creek, and Massey Creek) have had LARE diagnostic studies completed in the past 10 years. Only one HUC 10 subwatershed (Big Lick Creek) has not had a LARE diagnostic study completed to date. Individual HUC 10 discussions are presented later in this plan (Section 10, Subwatershed Discussions, p.159). Because HUC 10 boundaries roughly align with county boundaries, these HUC 10 discussions will be presented to each county upon approval of this WMP so that recommended actions can be considered and implemented at the county level.



MAP 1.1 | Watershed boundary

1.2 PROJECT INITIATION RATIONALE

The Delaware County SWCD initiated development of this Watershed Management Plan (WMP) with support from regional partners in the area. In 2013, the Upper Mississinewa River Watershed Partnership (UMRW-P) was established. The establishment of the UMRW-P and the initiation of the WMP was due to the following factors.

Recognition of Water as a Shared Multicounty Resource
Counties in the UMRW-P have been engaged in watershed planning initiatives for the river independently since 2001. Lake and River Enhancement (LARE) program grants funded four HUC 10 studies (Headwaters Mississinewa River, Halfway Creek, Pike Creek, and Massey Creek) completed in the past 15 years. SWCD activities related to these initiatives have taken place within the limits of each respective county. Steering committee members for these projects have long recognized that watershed and water quality resources seldom operate within political boundaries; concerns, problems, and sources often cross county and even state lines. As a result, working together to address water quality issues can be in everyone's best interest.

Desire to Address Resource Concerns Collectively
The UMRW-P seeks to address resource concerns identified through the LARE Diagnostic Studies. These resource concerns include nutrients, sediment, flooding, and logjams.

Need to Secure a Funding Source for Promotion of Project
Securing funding to supplement education and outreach activities and promote water quality discoveries was also a rationale for undertaking the 205(j) grant. Despite the completion of the previous studies, minimal implementation has occurred in this region (associated with LARE implementation dollars). Some of the factors causing this breakdown in implementation include: (a) Community "outsiders" were contracted to do many of the studies and lack the long-term commitment required to follow through on action recommendations. (b) University personnel (i.e. students) turn over on a semester basis and move on to other communities. (c) Limited funding to market programs and study findings to land owners. (d) Historical cuts to LARE funding have prohibited some implementation opportunities through the LARE program.

Advantage of Bringing Existing LARE Studies into Compliance with 319/EPA Standards
Bringing existing LARE plans into compliance with the Clean Water Act Section 319 program will diversify funding opportunities and enable future 319 implementation phases.

Economic Impact of Improving State-Wide Water Quality Rankings
In 2013 the Delaware County SWCD compared streams (of similar stream volume/scale) listed as canoe trails on the Indiana DNR website and concluded that the Mississinewa River was the second worst polluted DNR canoeing river in the State of Indiana (through an aggregate ranking of all water quality impairments) using the last 30 years of IDEM data. However, because of many favorable structural and habitat characteristics, there is great opportunity for the Mississinewa River's recovery.

Desire for Updated Water Quality Data
The UMRW-P wanted a mechanism for guiding implementation dollars to the most impaired areas of the region (from a water quality perspective). Water quality monitoring results from this study will supplement existing studies and be used in the comprehensive planning process to determine geographic regions with the most impaired water quality. Stream samples collected by the Delaware County Soil and Water Conservation District (DCSWCD) will be analyzed by the Muncie Bureau of Water Quality.

Desire for Updated Social Information
The UMRW-P also wanted to reassess and update the understanding of public input concerns in the region. The WMP effort will investigate identified stakeholder concerns. Landowner feedback will guide education and outreach activities and will also be a factor in directing future funding and technical assistance towards the implementation of specific BMPs. Districts within the UMRW-P benefit from parcel data analysis as it can provide long-term guidance for targeted mailings.

1.3 LOCAL LEADERSHIP

Because the grant funding awarded to complete the plan was initiated, secured, and managed by the Delaware County SWCD (DCSWCD), board members of the DCSWCD provide primary oversight to the Project Manager. However, the UMRW-P, the Project Manager, and the planning process are guided by five components: (1) Regional Soil and Water Conservation District Boards and Natural Resources and Conservation Service District Coordinators (2) Stakeholders/Landowners represented by aggregate feedback from ongoing public meetings and surveys, (3) Representatives of the Indiana Department of Environmental Management TMDL Section and (4) A steering committee (Table 1.1) consisting of technical contributors to the project. A diagram of these contributors is shown in Fig. 1.1.

Soil and Water Conservation District Boards
The role of each SWCD board is to function as the point of contact for landowners in their respective county. Because of their long-lasting relationship with landowners in the region, and as engaged citizens in their respective counties, SWCD Board members facilitate support of the project and help select specific education and outreach activities to undertake. Once the WMP is complete, the SWCD Boards will be primarily responsible for guiding the allocation of cost-share funds in the region.

NRCS District Coordinators
NRCS district coordinators in each county function in a similar capacity as SWCD Boards – their frequent dealings with conservation issues and landowners in implementing their own cost-share programs make them invaluable at gauging landowner interest in cost-share programs and practices. District coordinators communicate (1) FOTG practices that are in high demand and (2) which programs are underfunded in their respective counties. In addition, NRCS District Coordinators can also help promote other Upper Mississinewa River Watershed Project cost-share programs to landowners that do not qualify for NRCS programs.

Technical Working Group
The technical working group consists of collaborators in the watershed planning process. This group provides greater breadth of technical assistance for WMP components including geographic information, water quality monitoring tasks, and landowner surveys. The group provides guidance to the Project Manager in coordinating those efforts. Many ad-hoc groups are formed within the Technical Working Group specific to projects including but not limited to the Logjam Removal Working Group, Headwaters Monitoring Group, Emerging Media Group, Demographic Analysis Group, and the Stakeholder Mailings Group.

TMDL Partnership
Concurrent with the watershed planning process, IDEM developed a TMDL for three of the five HUC 10s in the watershed area. A Total Maximum Daily Load, or TMDL, is the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. A TMDL is the sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources. IDEM is developing TMDLs for impaired waters in Indiana to characterize the causes of the impairments, identify potential sources of pollution, calculate pollutant reductions needed to meet water quality standards and recommend practices that can be implemented to reduce the pollutants. Project managers of the TMDL program have been in collaboration with UMWM-P and have helped coordinate development efforts and initial public meeting and outreach efforts as well as sharing water quality data and geographic information to assist with WMP development.

IDEM sample sites were located in the central portion of the Mississinewa River, in Pike Creek, Halfway Creek, and Big Lick Creek HUC 10 subwatersheds. Sample sites were selected using a modified geometric site selection and targeted site selection. In all, thirty-five sites were selected for analysis by the TMDL program. The objective of the TMDL was to perform baseline monitoring, which is "an intensive targeted watershed design that characterizes the current condition of an individual watershed [...] Selecting a spatial monitoring design with sufficient sampling density to accurately characterize water quality conditions is a critical step in the process of developing an adequate local scale watershed study."[1] Sample sites were selected "based on a geometric progression of drainage areas starting with the areas at the mouth of the main stem stream and working upstream through the tributaries to the headwaters."[2] Of these 35 sites sampled by IDEM, data collected at eight sites located on tributaries and at five sites located on the mainstem of the Mississinewa have been extracted and used along with UMRW-P data for comprehensive analysis.

Stakeholders
Stakeholder engagement was orchestrated through a geographic information systems (GIS) process that sought to identify all landowners in the watershed. This process specifically targeted landowners of 40 acres or more adjacent to waterways in the region. These landowners were targeted with a direct mailing response card and an invitation to attend public meetings, which occurred in the first two quarters of the project. The stakeholder group is comprised of citizens active in public meetings as well as those completing comment cards. Both of these methods of engaging stakeholders were sustained throughout the project and helped guide the Project Manager and local leadership in understanding landowners' concerns and desire for the project in the region. Throughout the project, education events were held on topics related to the project. The Project Manager gave a brief overview of the project at these meetings and additional watershed concerns were generated at these events.

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1 Fields, Timothy. IDEM. 2014 Sampling an Analysis Workplan for Baseline Monitoring of the Upper Mississinewa River Watershed. www.in.gov/idem/nps/files/tmdl_mississinewa-upper_sampling_workplan.pdf.

2 Ibid.

1.4 PROJECT ORGANIZATION

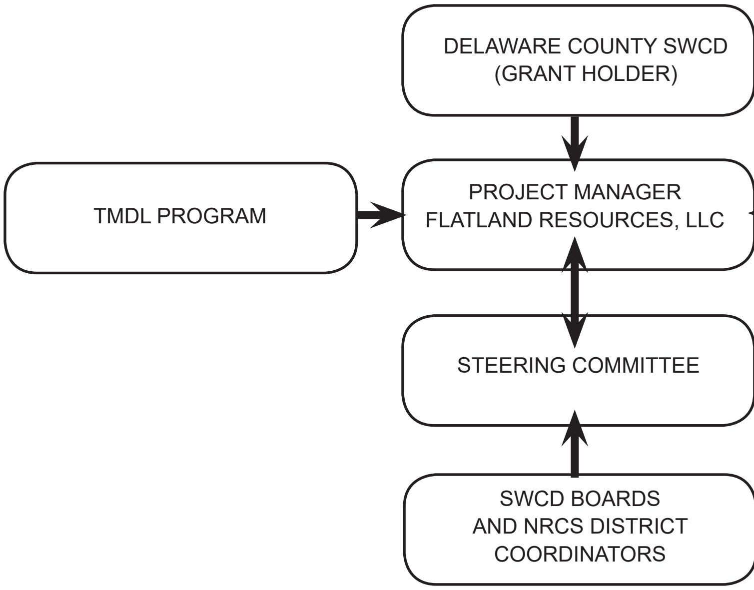


FIG. 1.1 | Project organization

1.5 STEERING COMMITTEE

TABLE 1.1 | Steering Committee	
Rhonda Fowler	Grant County SWCD
Becky Daugherty	Delaware County SWCD
Stacy White	Randolph County SWCD
Karen Kitterman	Blackford County SWCD
Bettie Jacobs	Jay County SWCD
Jared Coppess	Darke County SWCD
Josh Gruver	Ball State University Department of Natural Resources and Environmental Science
Lee Florea	Ball State University Department of Geology
Adam Kuban	Ball State University Department of Journalism
Wesley Slain	Natural Resources Conservation Service
Rob Santoni	Citizen
Kyle Johnson	Delaware County Department of GIS
Lory Stinton	Delaware Muncie Metropolitan Planning Commission
Michael O’Donnel	Purdue Extension
Drew Holloway	Muncie Bureau of Water Quality
Laura Bowley	Muncie Bureau of Water Quality
Mike Guebert	Taylor University

2. PUBLIC INPUT

DEVELOPING A TARGET AUDIENCE

The Upper Mississinewa River Watershed Partnership (UMRW-P) created a methodology for identifying key agricultural landowners using geographic information systems (GIS): (a) A ranking system was developed to quantify quarter acre land parcels on a spectrum classifying the land as prime farmland or problematic farmland. (b) In addition, parcels greater than 40 acres in size were identified. These two factors helped narrow the 87,000 people who live in the Upper Mississinewa River Watershed (UMRW) to a target audience of approximately 4,000 landowners. Conveniently, these 4,000 landowners control approximately 66% of the land in the 55 mile watershed area due to trends in land centralization.

PUBLIC MEETINGS AND PUBLIC COMMENT

Working with this target audience the UMRW-P began promoting seven public meetings that were held in the spring and summer of 2014. The purpose of the public meeting was to introduce the project, gather stakeholder water quality concerns, develop potential steering committee volunteers, determine which type of rural land use residents need cost-share support, and determine which specific practices can meet the areas of concern or need. A direct mail campaign was used to promote the event, and also solicit public comment through a return mail system. One thousand (1,000) individuals from the target audience (selected if parcels are adjacent to a waterway) were invited (through direct mail) to attend one of seven public input meetings or provide comment through a response card system. The locations of properties belonging to members of the target audience can be seen in Map 2.1 on p. 26.

Public Meeting Locations

Delaware County: Knights of Columbus Hall – March 12, 2014 - 6:30pm.
Randolph County: Davis Purdue Research Center, Farmland, IN – March 13, 2014 – 2:30pm.
Blackford County: Blackford County Annex, Hartford City, IN – March 13, 2014 – 6:30pm.
Darke County: Arts Depot, Union City – April 24, 2014 – 9:30am.
Grant County: Grant County Government Center, Marion, IN – April 24, 2014 – 2:30pm.
Delaware County: Eaton Community Center, Eaton, IN – May 31, 2014 - 6:30pm.
Randolph County: Davis Purdue Research Center, Farmland, IN – July 17, 2014 – 9:30am.
Grant County: Upland Community Building, Upland, IN – July 17, 2014 – 2:30pm.
Delaware County: Eaton Community Center, Eaton, IN – July 17, 2014 – 6:30pm.

Mainstem Mississinewa - TMDL Cohort

The first mailing occurred on February 27, 2014. It targeted 119 landowners in Delaware County, 26 landowners in Jay County, 62 landowners in Randolph County, and 65 landowners in Blackford County. This group consisted of landowners adjacent to the mainstem of the Mississinewa River with land holdings greater than 40 acres. The group was targeted based on its overlap with the TMDL study region. Landowners were provided a response card in the mail and were invited to attend the following public meetings:

Randolph County: Davis Purdue Research Center, Farmland, IN – March 13, 2014 – 2:30pm.
Blackford County: Blackford County Annex, Hartford City, IN – March 13, 2014 – 6:30pm.

Mainstem Mississinewa

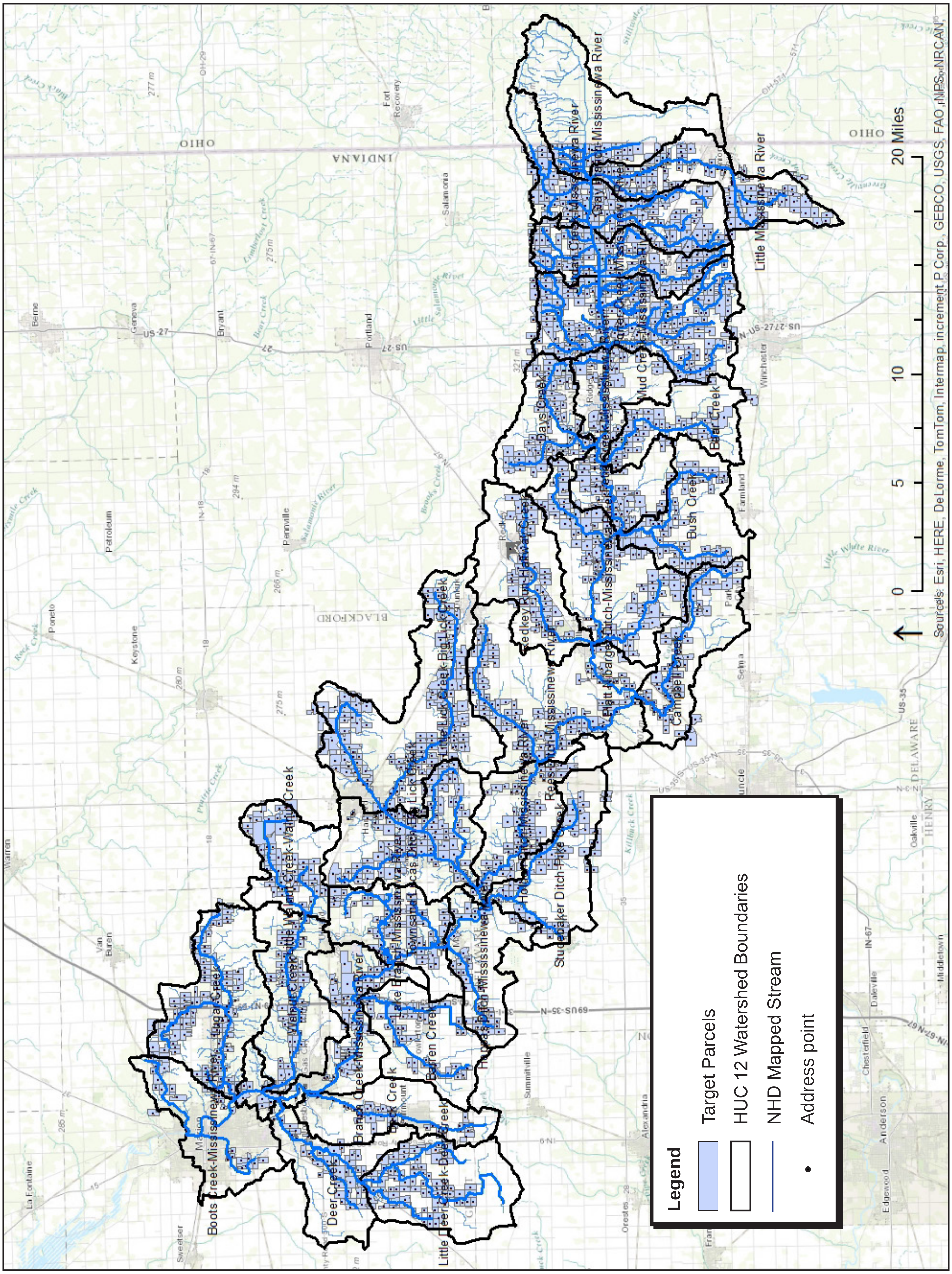
The second mailing occurred on April 10, 2014. It targeted 200 landowners in Grant County, 131 landowners in Randolph County, and 138 landowners in Darke County. This group consisted of landowners adjacent to the mainstem of the Mississinewa River with land holdings greater than 40 acres. Landowners were provided a response card in the mail and were invited to attend the following public meetings:

Darke County: Arts Depot, Union City – April 24, 2014 – 9:30am.
Grant County: Grant County Government Center, Marion, IN – April 24, 2014 – 2:30pm.

Watershed Tributaries

The third mailing occurred on July 3, 2014. It targeted 142 landowners in Randolph County, 48 landowners in Jay County, 99 landowners in Grant County, 34 landowners in Delaware County, and 55 landowners in Blackford County. This group consisted of landowners adjacent to tributaries of the Mississinewa River with land holdings greater than 40 acres. They were provided a response card in the mail and were invited to attend the following public meetings:

Randolph County: Davis Purdue Research Center, Farmland, IN – July 17, 2014 – 9:30am.
Grant County: Upland Community Building, Upland, IN – July 17, 2014 – 2:30pm.
Delaware County: Eaton Community Center, Eaton, IN – July 17, 2014 – 6:30pm.



MAP 2.1 | Target landowners (Darke County not shown due to lack of parcel data)

2.1 WATERSHED CONCERNS / RESULTS

PUBLIC MEETINGS
The targeted 1,000 landowners represent decision making for about 175,151 acres of the watershed area, or 40% (total acres 435,806). There was a 18% engagement rate for the public meetings and response card system. The 180 people who attended public meetings or indicated a desire for receiving cost-share funding for practices represent approximately 22,000 acres or 5% percent of the landmass. One hundred and ten people (11% of mailing) attended the public meetings, averaging approximately 12 people per meeting. Meetings consisted of an overview of the project, scope, and timeline as well as included a period of open conversation about concerns in the watershed.

The Project Manager encouraged participants to fill out formal comment cards (discussed in the next section) but characterized public meeting discussion in the following trends:

Drainage
Initial feedback suggests landowners are most concerned with drainage issues in the Mississinewa River, noting an increase in flooding resulting from ongoing stream channel modification in the headwaters and the existence of debris and blockages in the channel. The existence of logjams and bank erosion was a persistent discussion topic at all of the public meetings.

E. coli Regulation
Concerns were expressed about stricter regulations for septic and potential increased costs associated with maintenance and inspection fees. Interestingly, despite the high levels of E. coli in the Mississinewa River, no public comment or concerns were expressed on this issue by landowners adjacent to streams in the watershed.

Economic Impacts
Many of the concerns discussed were about the economic impacts of regulations and also that practices being advocated are economically unfeasible. There was also great concern expressed about the loss of soil on land and banks and the connection to agricultural economic loss.

SURVEY/COMMENT CARD
Included in the campaigns and at the public meetings was a return mailing survey card designed to solicit concerns, gauge stakeholder interest in NRCS/319 Conservation Programs, determine land use types in need of cost-share assistance, and determine practices to be promoted as educational and technical assistance programs.

Concerns
Seventy-six individuals utilized the comment card system to express their concerns (Tables 2.1-2.6). Only four individuals utilized the card system and also attended the public meetings (making the total contacts in the area 182 individuals). This made the engagement rate at approximately 18%.

Of the 76 card-specific respondents, approximately 55 concerns were identified in the comment section. An overview of comments is included in Tables 2.1 through 2.6. Some comments were paraphrased or simplified for clarity and site-specific references were excluded (but will be discussed in further sections). Similar to comments expressed in the public meeting, a major concern for landowners in the region were logjams, flooding, and erosion. The word cloud in Fig. 2.1 on p. 28 illustrates the concerns gathered from stakeholders. Font size corresponds to the number of stakeholders who have a particular concern. Larger fonts indicate a higher number of concerned stakeholders, smaller fonts indicate a lower number of concerned stakeholders.

TABLE 2.1 | Blackford County concerns	
Hartford City, IN	Surface erosion occurring on farm fields.
Hartford City, IN	Concerned about covercrop usage.
Hartford City, IN	Concerned about the application of animal waste on farm fields.
Hartford City, IN	Erosion of waterways.
Hartford City, IN	Headcuts in streams and rivers.

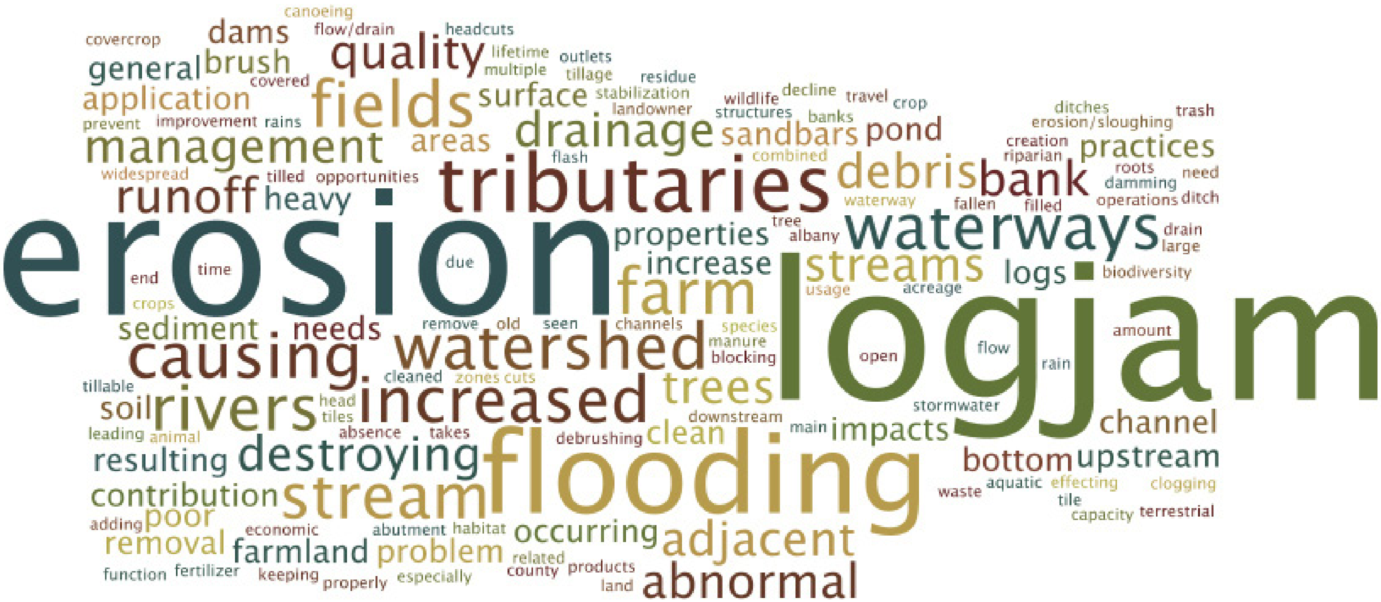


FIG. 2.1 | Landowner feedback

TABLE 2.2 | Grant County concerns	
Marion, IN	Increased upstream water contribution and flash flooding impacts to properties.
Gas City, IN	Sandbars and logjams forming in the channel.
Upland, IN	Logs, brush, and trash clogging waterways.
Upland, IN	Habitat Quality of riparian zones and stream channels.
Gas City, IN	Trees damming the waterway causing bank erosion.
Jonesboro, IN	River bank erosion.
Jonesboro, IN	Logjams causing increased flooding and destroying crops.
Upland, IN	Increased upstream water contribution flooding landowner properties.
Upland, IN	Concerned about residue and tillage management.

TABLE 2.3 | Delaware County concerns	
Redkey, IN	Concerned about poor pond management practices.
Albany, IN	Concerned about the biodiversity of aquatic and terrestrial species.
Albany, IN	Tributaries in the watershed that are filled with logjams and sandbars resulting in abnormal flooding of farm fields.
Muncie, IN	Erosion of tributaries and adjacent farmland.
Muncie, IN	Debris in stream and adjacent channels.
Albany, IN	Concerned about ditch reconstruction practices.
Eaton, IN	Abnormal river erosion and impacts to farmland.

TABLE 2.4 | Jay County concerns	
Fort Recovery, OH	Heavy rains flooding pond and structures.
Portland, IN	Keeping open ditches clean from debris and logjams.
Portland, IN	Clean brush from rivers and waterways.
Redkey, IN	Concerned that the removal of wetlands is leading to increased flooding.

TABLE 2.5 | Darke County concerns	
Fort Recovery, OH	Concerned about the amount of logs/debris in streams.
Ansonia, OH	Sediment runoff from tilled fields.
Ansonia, OH	The over application of crop protection products and fertilizer.
Union City, OH	Erosion occurring on sloped land and waterways.

TABLE 2.6 | Randolph County concerns	
Union City, IN	Fallen trees in the Mississinewa River and its tributaries.
Union City, IN	Beaver dams in watershed tributaries are affecting capacity of farm tiles to function.
Ridgeville, IN	The Mississinewa needs drastic improvement. “It is the worst I have seen in my lifetime.”
Union City, IN	Heavy rain resulting in abnormal erosion.
Union City, IN	Bank erosion/sloughing is causing an increase in logjams.
Union City, IN	Remove log jams and sediment dams that don’t allow water to drain.
Portland, IN	The Mississinewa River needs to be cleaned of logjams.
Hingham, MA	Concerned about general water quality decline.
Redkey, IN	Concerned about a widespread increase in soil erosion.
Redkey, IN	The flooding is destroying stream banks of streams and rivers in the watershed.
Redkey, IN	There is a need for debrushing and the removal of logjams in the Mississinewa River and it’s tributaries
Redkey, IN	An abutment from an Old Covered bridge is causing logjams in the mainstem of the Mississinewa River.
Redkey, IN	Stormwater runoff is destroying large trees that end up in the river blocking more water and adding to the problem.
Redkey, IN	Logjams are a problem in the Mississinewa River.
Redkey, IN	Concerned about the surface erosion and runoff.
Ridgeville, IN	The Mississinewa river does not flow/drain properly due to multiple log jams. (Especially from Highway 27 to Albany, IN). This causes very poor drainage for all farms in the watershed because of the time it takes for the water to travel downstream.
Redkey, IN	Streambank and adjacent property erosion.
Redkey, IN	Concerned about general water quality.
Redkey, IN	Concerned about debris and tree roots impeding flow and drainage of tillable acreage.
Ridgeville, IN	Concerned about log jams and how to prevent them.
Ridgeville, IN	Drainage issues related to logs in streams and rivers.
Ridgeville, IN	The creation of headcuts at County tile outlets.
Ridgeville, IN	Soil stabilization in River bottom areas.
Ridgeville, IN	Concerned about missed economic opportunities with recreational canoeing.
Ridgeville, IN	Concerned about Combined Feeding Operations and their manure management.
Ridgeville, IN	The absence of wildlife in river bottom areas.

2.2 LAND-USE CONCERNS

The survey asked respondents to indicate their interest in cost-share practices organized into the following land-use classifications:

1. Stormwater
2. Farming
3. Streams
4. Forest / Prairie
5. Livestock
6. Wetlands

Despite the written and verbal concerns for flooding, erosion, and logjams–a high percentage of interest in cost-share practices were in the category of agricultural land uses (Fig. 2.2). This was expected due to the fact that approximately 83% of the land mass is used for agricultural purposes. Researchers aimed to interpret interest in specific cost-share programs as an indicator of desire to address concerns associated with the management of a particular land use. Therefore, although agricultural concerns were not heavily expressed on the comment cards formally, the desire for funding implies some level of concern for the land use and need for improvement in the short-term.

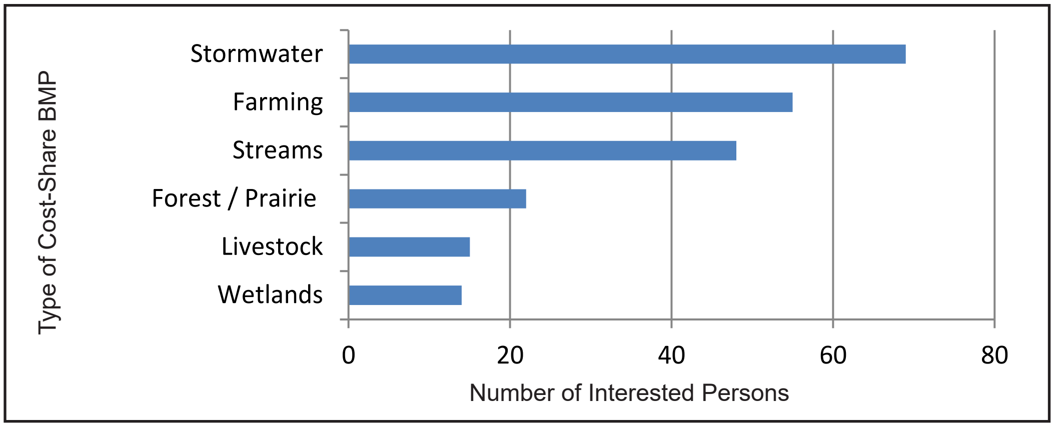


FIG. 2.2 | Feedback on land management types

This data also helped the Project Manager determine and tailor education and outreach programs to specific land-use types and landowners. Future planning/action items will be developed based on priority land uses like streams/stormwater conveyance systems and agricultural row cropping. Furthermore, within each of these categories, specific best management practices were ranked based on their rate of selection (Table 2.7). Out of the 750 surveys sent out, 90 landowners responded.

TABLE 2.7 | Interest in Best Management Practices

Stormwater	Interested Persons
Drainage Water Management	28
Grassed Waterway	20
Stormwater Runoff Control	13
Roof Runoff Structure (Cistern)	4

Farming	Interested Persons
Cover Crops	24
Residue and Tillage Management	17
Field Border	10
Contour Farming	4

Livestock	Interested Persons
Livestock Access Control/Fence	5
Livestock Watering	4
Prescribed Grazing	3
Animal Trails and Walkways	2
Animal Mortality Facility	1
Manure Storage	1

Streams	Interested Persons
Streambank Protection	18
Filterstrip	13
Riparian Forest Buffer	8
Stream Habitat Improvement	6
2-Stage Ditch	4
Riparian Herbaceous Cover	3

Wetlands	Interested Persons
Wetland Enhancement	4
Wetland Restoration	3
Constructed Wetland	3
Wetland Creation	4

Forest / Prairie	Interested Persons
Tree and Shrub Establishment	12
Prescribed Burning	6
Critical Area Planting	3
Forest and Biomass Planting	1

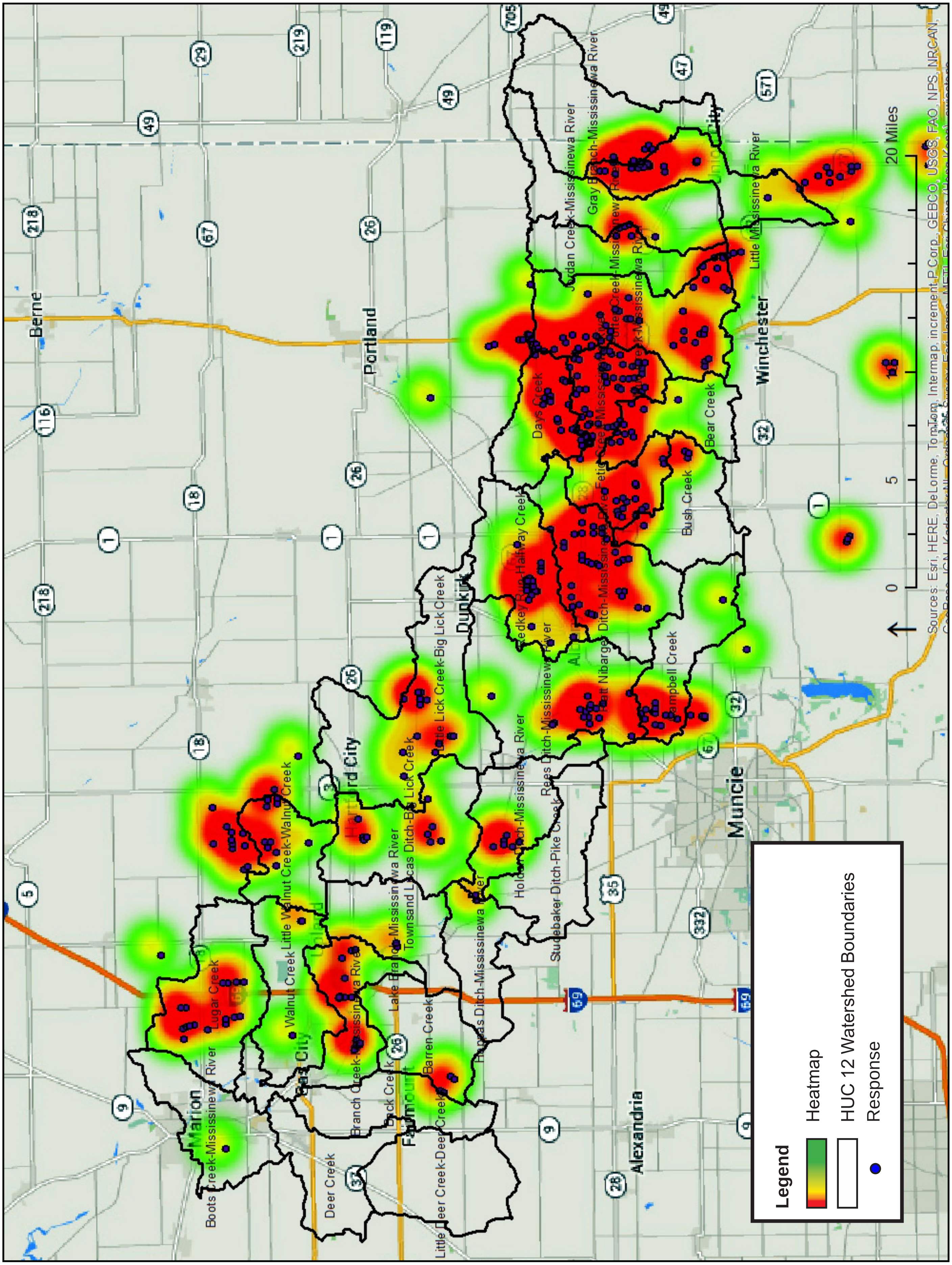
2.3 GEOGRAPHIC RESULTS

The Project Manager used Geographic Information Systems (GIS) to identify public comment concentration geographically based on both rate of return and a percentage of response rate. Project coordinators analyzed outreach and response on a HUC12 level basis (Table 2.8). Figures A.1-A.3 in Appendix A represent HU12 concentrations by original target audience, total respondents, and percentage of respondents based on the amount of targeted landowners. The subwatershed areas with most vocal stakeholders are Fetid Creek-Mississinewa River, Platt Nibarger Ditch-Mississinewa River, and Branch Creek-Mississinewa River. These subwatersheds are generally located between Ridgeville, Indiana and the intersection of State Road 1 and the Mississinewa River. Higher concentrations of concern through portions of Randolph County suggest need for further investigation.

TABLE 2.8 | Response rate by subwatershed

HU_10_NAME	HU_12_NAME	percentage of response rate
Halfway Creek-Mississinewa River	Fetid Creek-Mississinewa River	49.78%
Halfway Creek-Mississinewa River	Platt Nibarger Ditch-Mississinewa River	22.27%
Massey Creek-Mississinewa River	Branch Creek-Mississinewa River	20.82%
Halfway Creek-Mississinewa River	Bear Creek	17.13%
Halfway Creek-Mississinewa River	Days Creek	17.08%
Headwaters Mississinewa River	Mud Creek-Mississinewa River	16.76%
Massey Creek-Mississinewa River	Little Walnut Creek-Walnut Creek	16.12%
Halfway Creek-Mississinewa River	Redkey Run-Halfway Creek	15.48%
Massey Creek-Mississinewa River	Lugar Creek	12.31%
Pike Creek-Mississinewa River	Campbell Creek	11.84%
Headwaters Mississinewa River	Gray Branch-Mississinewa River	10.97%
Pike Creek-Mississinewa River	Rees Ditch-Mississinewa River	10.70%
Headwaters Mississinewa River	Little Mississinewa River	8.32%
Pike Creek-Mississinewa River	Holden Ditch-Mississinewa River	7.07%
Headwaters Mississinewa River	Porter Creek-Mississinewa River	7.04%
Big Lick Creek	Townsand Lucas Ditch-Big Lick Creek	5.98%
Halfway Creek-Mississinewa River	Bush Creek	5.93%
Big Lick Creek	Little Lick Creek-Big Lick Creek	4.95%
Massey Creek-Mississinewa River	Barren Creek	3.78%
Massey Creek-Mississinewa River	Walnut Creek	3.02%
Massey Creek-Mississinewa River	Lake Branch-Mississinewa River	2.30%
Massey Creek-Mississinewa River	Boots Creek-Mississinewa River	1.41%
Headwaters Mississinewa River	Jordan Creek-Mississinewa River	1.12%
Massey Creek-Mississinewa River	Hoppas Ditch-Mississinewa River	0.47%
Massey Creek-Mississinewa River	Back Creek	0.00%
Pike Creek-Mississinewa River	Studebaker Ditch-Pike Creek	0.00%
Massey Creek-Mississinewa River	Deer Creek	0.00%
Massey Creek-Mississinewa River	Little Deer Creek-Deer Creek	0.00%

An additional layer of data generated by the survey cards was also represented geographically. Map 2.2 shows point layers of respondents/public meeting participants overlaid against a heat map created to show high concentration areas of stakeholder engagement/response. The heat map's color gradient mimics the visible spectrum: reds to oranges to yellows to greens. Areas with the highest concentration of responses are represented by red and areas with the lowest concentration of response are represented by green. Areas of high demand, interest, and participation suggest areas of high BMP adoption. Irrespective of water quality data, these hot spot areas are suggestive of areas with a critical mass of interest required to impact water quality improvement at a level detectable by HUC 12 level monitoring points.



MAP 2.2 | Response rate concentrations : Areas in red have the highest concentrations of response rates, areas in green have the lowest concentrations of response rates.

2.4 BEST-MANAGEMENT PRACTICES

Surveys also allowed respondents to identify specific BMPs that they might be interested in using (Figure 2.2 and Table 2.7). This data helped researchers determine/tailor the education and outreach program to specific Best Management Practices (BMPs). Future planning action items will be developed based on implementing these BMPs. Respondents indicated a desire for continued funding of conservation practices like conservation tillage, cover crops, filter strips, and grassed waterways; especially near floodplain areas. The interest in these practices will be analyzed based on their relationship to water quality data results at a HUC12 delineation.

TABLE 2.9 | Best Management Practices with Most Stakeholder Interest

BMP	Number of Intested Persons
Drainage Water Management	28
Cover Crops	24
Grassed Waterway	20
Streambank Protection	18
Residue and Tillage Management	17
Filter Strips	13
Stormwater Runoff Control	13
Tree and Shrub establishment	12

2.5 SOCIAL SURVEY DISCUSSION

Although a return rate of 12% seems low, this is above direct mailing response standards (3-4%) and it generated 182 new contacts in the region. Developing these types of contacts is key to the success of future and contemporary watershed planning initiatives. Additionally, the direct mail marketing campaign was a success because it put program information directly into the hands of 1,000 key landowners/decision-makers and solicited multiple methods for public input. Complete documentation of contact methodology helps justify the decision making process for outreach selection.

Geospatial direct mail campaigns are the most effective means of targeting the diminishing amount of landowners in the UMRW. This method is especially strong compared to other outreach initiatives that are more diffuse (newspaper, billboard, etc.) or dependent on audience attendance such as the Agricultural Days, 4-H Fairs and other tradeshows.

The targeting method gave the Project Manager specific insight into attitudes/concerns of large landowners adjacent to waterways in the UMRW. The UMRW-P is confident that the 182 respondents are representative of the other 3,000 major landowners in the watershed.

The areas with the most vocal stakeholders are Fetid Creek-Mississinewa River, Platt Nibarger Ditch-Mississinewa River and Branch Creek-Mississinewa River. Concerns are mostly about drainage issues, the abundance of logjams, and erosion from in-stream sources and agricultural farm fields. The land uses of farming, drainageways, and rivers are a greater concern than wetlands, forests, and livestock infrastructure. Drainage water management, covercrops, grassed waterways, and residue and tillage management are the BMPs most likely to be implemented.

2.6 PUBLIC INPUT CONCLUSIONS

The goal of the initial planning and public input phase was to create a baseline assessment of landowner concerns and establish a mechanism for organizing a steering committee. This information has helped facilitate a course of action for the following two years of activity in the region. These activities included:

A. Working with landowners to understand results of the water quality monitoring program.
B. Utilizing watershed planning data to assist landowners in applying for cost-share programs.
C. Educating landowners about best management practices for primary land uses.
D. Targeting additional public input in areas where there is a high stakeholder engagement or interest in watershed protection and management.

The UMRW-P also made the following observations from the research.

Public Meeting Turnout
The overall turnout of targeted landowners was relatively low compared to the amount of direct mail promotional activities. This causes the UMRW-P to make the following assumptions:
A. Landowners have no concerns about water quality.
B. Landowners have water quality concerns but are apathetic towards communicating them.
C. Landowners are unaware of water quality issues.

Lack of Water Quality Concerns
When analyzing response card and public input meeting discussion, there was little concern about water quality:
This causes the UMRW-P to make the following assumptions:
A. Vocal stakeholders have no concerns about water quality.
B. Vocal stakeholders have water quality concerns but are apathetic towards communicating them.
C. Vocal stakeholders are unaware of water quality issues.

Theory: Logjam Concerns as Priority
The overwhelming concern for logjams may have trumped all other landowners concerns. Logjams have a persistent impact on bank erosion, cause land/surface erosion, are visually identifiable, and have direct resulting impact to agricultural production via flooding. The Project Manager believes that logjam concerns will distract from other concerns so long as they persist. Logjams were documented as part of this initial public input phase for confirmation; there were 10 major logjams in the region identified in the summer of 2014.

These unanswered questions further underscore the need to better understand why there is limited water quality concerns in the region. To address these issues the UMRW-P will:
A. Analyze water quality and report monitoring results to landowners
B. Educate landowners about state and federal water quality standards
C. Develop a social indicator survey to better understand landowner attitudes towards water quality. The intention of the study will be to:
1. Understand attitudes towards state standards
2. Gauge the degree that those state standards are understood
3. Assess the attitude towards water quality once state/federal standards are communicated.

The social survey research will be a final and supplemental piece in understating how to craft education and outreach in the watershed. It will help craft an action register and result in community-driven improvements to water quality.

2.7 CRITICAL AREA PUBLIC INPUT

Following the determination of critical areas (described in Section 14, Critical Area, p. 221), the UMRW-P hosted secondary public input efforts in these critical areas. Similar to the primary public input approach, the Project Manager mailed six hundred (600) notices to landowners with properties adjacent to waterways (greater than 40 acres in size) in the critical areas. The mailings included information about the identified water resource concern, an invitation to attend a public input meeting hosted in the subwatershed area, and a return mailing survey card designed to solicit concerns and gauge stakeholder interest in NRCS/319 Conservation Programs.

GRANT COUNTY–CRITICAL AREAS

The first secondary input campaign was in Grant County, targeting Walnut Creek and Lugar Creek critical areas. These subwatersheds were identified as having high sediment levels during both high flow and low flow sampling events. Public concerns submitted through the comment cards are included in Table 2.10. The public meeting discussion centered around two primary themes: (a) Hydromodification of Lugar Creek and development of impervious surface areas near I-69. A major concern expressed by landowners was an increase in flooding and flow regimes that have occurred as a result of these recent changes. (b) The second major series of concerns was regarding Walnut Creek. Of the tributary subwatersheds, Walnut Creek had the highest rate of concern expressed through our public survey (a combination of public meeting and comment card). Concerns specifically noted sediment erosion, logjam presence, and lack of maintenance. Walnut Creek is also challenged by the fact much of the drainage area is in a glacial moraine (unconsolidated surface materials and bedrock) which is contributing to instability. Stakeholder “fish and wildlife” concerns are related to the impact of turbidity/sediment on aquatic ecosystems. The loss of agricultural land (bank and surface erosion) was also a socioeconomic concern frequently cited by landowners. Walnut Creek is 15 miles long. Approximately 8 miles of the tributary is managed by a private drainage board in Blackford County (3 of the miles of their jurisdiction is actually in Grant County). The remaining 7 miles is managed by the Grant County Surveyor and 5 of those miles require a SEA 368 Review. Unfortunately, stream segments that require a SEA 368 Review are oftentimes neglected. The Project Manager met with the Blackford Private Drain Board for Walnut Creek, toured the project area, and performed a windshield survey of many of the erosion sites in Grant County. The Project Manager also identified many of the erosion sites in the headwaters region through aerial photography. The Blackford Private Drainage Board has requested guidance on how to address erosion sites using Natural Channel Design.

Public Meeting Location
Grant County: Ivy Tech Community College Marion, IN – October 15, 2015 – 5:00pm.

TABLE 2.10 | Grant County focus concerns	
Gas City, IN	Much debris is jammed in both creeks on my property (Walnut Creek, Long Branch) causing erosion on the banks.
Defiance, OH	Flooding of open ditches causing crop loss.
Defiance, OH	Trees have grown up in ditches which were cleared out 25 or so years ago, I have paid maintenance fee ever since - do not know what Grant County is doing with the money.
Marion, IN	I have had a bank eroding that I put broken bricks/blocks on so it would slow the erosion. Also, the creek topped the road last spring to wash out the bank beside the road in a spot.
Hartford City, IN	Ditch banks caved in from spring rains. Headwalls collapsed and erosion upstream. Waterways needing to be rebuilt but not eligible for CRP.
Marion, IN	Excessive rain water run off from recent development with no regard for surface water
Marion, IN	Lugar Creek runs through our property, which is mostly wooded. The County dredged it several years ago and screwed it up. It is slow to recover. Please do not dredge this area again.
Upland, IN	I am somewhat concerned about surface and wastewater from properties located “above” mine. I live near Walnut Creek.
Gas City, IN	Since 1982 the flood zone has increased by several hundred feet this years. I was to build a garage and now cannot because my property is completely flood zoned. The city diverted water to this creek and since they have we have seen an increase in flooding-nearly entering our house on three occasions in past three years. The water is not flowing like it should. There is a S-curve in the creek that is also slowing the flow.
Hartford City, IN	In 2015, the Walnut Creek main was cleaned on our property. Now some banks have fell in. Need to clean the main ditch over in Grant County before working on more prongs. Get the main cleared and flowing first.
Marion, IN	You should check out the two foot wide hole in front of the property by the road. Eroding fast and is going to cave the road in. We have had significant damage to our basement and the whole yard.
Marion, IN	Lots of bank erosion. If bank was tampered and seeded with grass I feel that would help. Trees are falling in due to bank erosion.
Gas City, IN	It seems to wash out bad during floods. Every year the creek bank erodes.

RANDOLPH COUNTY–CRITICAL AREAS

An additional secondary public input meeting was targeted for critical areas in Randolph, Darke, and Delaware County. These critical areas were selected primarily for nitrogen reduction BMPs. The meeting included a report on Upper Mississinewa River Watershed Project activities and current and future cost-share opportunities in the region. The UMRW-P also hosted a Natural Resource Conservation Service representative to discuss the EQIP program and the various nutrient reduction BMPs available. Public concerns submitted through the comment cards are included in Table 2.11. Despite the meeting being advertised as a nutrient critical area information session, and the topic of discussion primarily geared toward nutrient reduction BMPs, the public meeting discussion revolved primarily around logjams, erosion, and flooding issues throughout the watershed.

Public Meeting Locations

Grant County: Davis Purdue Research Center, Farmland, IN – January 4, 2016 – 10:00pm.

TABLE 2.11 | Randolph County and Delaware County focus concerns	
Ridgeville, IN	Logjams on river. Backing water over the fields. Tile cannot work they are full when drainage is needed killing crops in growing fields (need river cleaned) main problem.
Albany, IN	Water from higher ground that doesn't belong comes down through my farms and through ditches and pipes.
Albany, IN	Logjams, sand bars, junk on banks
Eaton, IN	Open ditch maintenance
Eaton, IN	Erosion
Ridgeville, IN	I currently farm land in the watershed near the river. The obstructed river channel does not allow us to take advantage of the funding sources listed above. We many times loose our crop due to flooding. If the funding could assist removing obstructions in the river, this would be a big help to the entire watershed.
Winchester, IN	Federal usurpation of local property owners rights
Winchester, IN	Logjam removal
Muncie, IN	Programs

3. WATERSHED INVENTORY

3.1 GATHERING WATERSHED DATA

Surface water quality is influenced by multiple factors related to the setting and characteristics of its watershed. Therefore understanding these settings and characteristics is essential to understanding water quality. To this end, a watershed inventory containing a comprehensive assessment of geography and topography, hydrology, soils, and land use was completed. Data from multiple secondary sources were gathered and analyzed to provide an understanding of these components.

The Project Manager also developed a series of desktop surveys using aerial imagery provided by the geobrowser, Google Earth. This inventory section concludes with a summary of observations and concerns that were either (a) developed through the inventory process and/or (b) through discussion of the assessment at monthly steering committee meetings and quarterly stakeholder meetings held throughout the project. Data was collected by the Project Manager from February 2014 - September 2015 using the various assessment processes described below:

1. Inventory of Previous Land Use Planning Reports
There have been five water quality and comprehensive planning reports developed in this region since 2001. The land use and geographical assessments included in the existing plans provided an effective starting point for development of relevant information to be included in this WMP. The plans have helped guide the Project Manager and aided in the understanding of many geographical features and land use concerns. There are many additional ongoing comprehensive planning efforts within the watershed (not necessarily water quality related) which are also briefly summarized. Summaries of additional reports and studies conducted in the watershed is included in Appendix G (A28).

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2. Publicly Available Geospatial Data
Supplemental land use observations and resources (i.e. cartography, diagrams, tables, figures, and symbols) were generated through an analysis of land use data in ArcMAP by the Project Manager. Data sources were obtained predominantly from Indianamap.org, the NRCS Geospatial Gateway, the USGS, and the Indiana Spatial Data Portal. Basemaps were also obtained from data sources native to ESRI Infrastructure. Land use data tables were analyzed in both ArcMap and Excel in conjunction with IDEM land use modeling equations and formulas. References for other data obtained and discussed are included in the narrative or with tables (in the document or in appendices) and are referenced comprehensively in the bibliography found at the end of this report.

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3. Desktop Aerial Assessment of Landuse Features
The Project Manager performed a visual assessment of the watershed (using aerial imagery) and identified features (relevant to the watershed management planning process) that had not been previously documented through public resources available at Indianamap.org. The Project Manager used the virtual globe software Google Earth, which displays the most recent aerial imagery available for the study. The aerial imagery used for the assessment was predominantly from 2012-2014 depending on its location in the watershed. Features included, but are not limited to: quarry sites, greyfields, rill/gully formation, urban junk storage sites, stream erosion, livestock access sites, and auto tracks. Observations are reported in the inventory and incorporated in the conclusions when relevant. Additional heat map diagrams and subwatershed based high-low gradient diagrams are located in Appendix E. The dataset generated for this assessment process is available upon request. Results and conclusions of the desktop survey can be found in Section 3.8.

3.8 DESKTOP SURVEY	75
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4. Aerial Assessment of National Land Cover Database (NHD) Mapped Streams
The Project Manager performed a desktop survey of major NHD mapped streams. The primary objective of the analysis was to assess the presence of vegetation on stream banks and/or the presence of substantial buffering from the adjacent land use.

3.4 CURRENT AND HISTORIC HYDROLOGY 42
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5. Windshield Survey
A windshield survey was completed as a supplement to the aerial assessment of land use features. The Project Manager collected water quality data from 2014-2015 and made ongoing observations of the landscape while driving to stream sampling locations. Formal documentation of sites was conducted from 2015 to 2016 by the Project Manager. Critical subwatersheds were targeted on the windshield survey completed on April 20 and April 29, 2016, with the exception of those subwatersheds that were critical for nitrate *only*. The Project Manager was confident, based on water quality and land use analysis, that cropland is the source of high nitrate levels in these subwatersheds; further investigation did not seem warranted. Results and discussion of the windshield survey can be found in Section 3.9.

3.9 WINDSHIELD SURVEY 75

6. Logjam Assessment and Inventory
The Project Manager canoed portions of the Mississinewa River in Randolph, Delaware, and Grant counties. These sections of the river were reported by landowners to have an exceptional amount of debris and/or morphological concerns. The assessments identified seven Condition 3 and three Condition 4 logjams located in Randolph County. A comprehensive report on these logjams, their history, and their potential sources in Randolph County is included in Section 3.7.

3.7 FUNCTIONAL USES OF THE RIVER 69

7. Desktop Inventory of NPDES data
The Project Manager performed a desktop inventory of available data from NPDES sites. EPA's ECHO database was used to gather data regarding wastewater quality violations. The site also provided data regarding the location of sludge disposal. Results are of this inventory are found in the subwatershed discussions in Section 10.

10.0 SUBWATERSHED DISCUSSIONS 159

3.2 BASIC GEOLOGY AND TOPOGRAPHY OF THE REGION

Geology and topography influence how water moves across the landscape in a watershed. Geology and topography also influence how water interacts with the landscape and how it collects and carries pollutants from non-point sources to waterbodies. The Upper Mississinewa River Watershed (UMRW), like all geographic regions on the globe, has went through a tremendous amount of change during the Earth's ~4.5 billion year history. The different geologic processes that have shaped it have created an area with subtly variable topography. Understanding the subtly variability of the topography is important in order to understand how it differentially influences water quality as well as how it differentially influences the extent to which land uses impact water quality (i.e. surface runoff from cropland is generally greater on sloped land than on flat land).

BEDROCK FORMATION

Significant deposits in the UMRW bedrock date from the Devonian and Carboniferous periods. It was during the Devonian period (often called the "Age of the Fish") that the continental United States was submerged under water. Millions of years of marine fossils (consisting of calcium carbonate) decomposed at the bottom of the shallow "midwestern sea," forming bedrock generally consisting of shale, siltstone, limestone, dolostones, and abundant fossils.[1]

CINCINNATI ARCH AND MAHOMET-TEAS RIVER VALLEY

Tectonic shifts following the Devonian period resulted in a broad structural "uplift" through Tennessee, Kentucky, Indiana, and Ohio called the Cincinnati Arch. This phenomenon exposed some of the oldest bedrock in the state of Indiana (consisting of the limestone, dolomite, and shale of the early and middle Silurian Period). The arch was the most dominant topological feature in the region, and shaped the pre-glacial Mahomet-Teays River Valley. The Mahomet-Teays River was thought to originate in the States of Virginia and West Virginia and to have flowed northwesterly through Indiana into Illinois (as opposed to the southwesterly drainage of the Ohio River today). This major bedrock valley still exists far below the surface; portions of it lay under the northwest part of the watershed.

GLACIER ACTIVITY

The contemporary landscape of the UMRW (and the northern two-thirds of Indiana) is the product of the Wisconsin Stage glacial advances/retreats which ended approximately 10,000 years ago. Sediments borne by the ice sheets were deposited as till (an unsorted mixture of sand, silt, clay and boulders) when the glaciers advanced and as outwash (sand and gravel) when the ice melted. Although the Mississinewa River valley may have once shared a similar landscape as Southern Indiana, or even parts of Tennessee and Kentucky, the fill of unconsolidated glacial till deposits into the ancient bedrock valleys have resulted in the contemporary flat to gently rolling terrain.

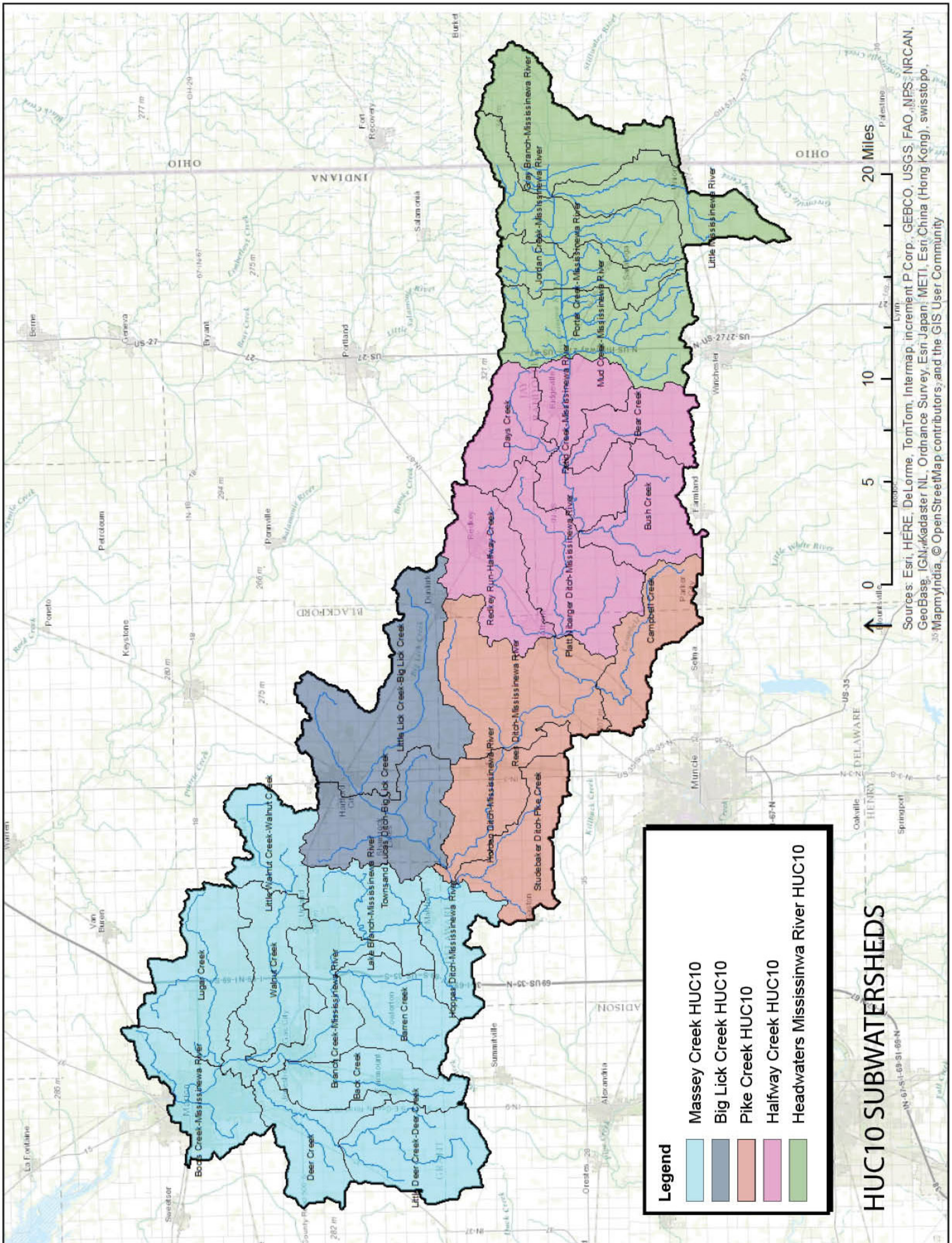
AQUIFER SYSTEMS

The bedrock Mahomet-Teays River Valley, once the primary drainageway for the region, now serves as a foundation for an expansive unconsolidated aquifer network. Not only did the glaciers create the aquifers during glacial advance, but they also filled these unconsolidated sand and gravel deposits with meltwater during glacial retreat periods, resulting in easily accessible groundwater. The aquifers are the most significant groundwater resource for residents and commercial/industrial entities in the region. These aquifers also contribute baseflow to streams, which function as an important source of water to rivers between rainstorms. Figure 3.6 on p. 47 shows depth to consolidated bedrock throughout the watershed region, and Figure 3.5 on p 47 shows subwatersheds ranked on a gradient (red-high and green-low) based on gross aquifer holding capacity.

GLACIER RETREAT AND WASHOUT

The last major glacial recession (associated with the Erie Lobe of the Wisconsin Ice sheet) left pronounced swaths of unconsolidated debris (soil and rock) throughout north-central Indiana. These glacially formed accumulations are called moraines. Four major moraines, the Mississinewa, Salamonie, Wabash, and Fort Wayne moraines, form the north ridge of the four major rivers in region (Mississinewa, Salamonie, Wabash and St. Mary's, respectively). The Mississinewa River Valley sits (along with the Upper White River Watershed) between the Mississinewa Moraine to the immediate north and the Knightstown Ridge Moriane to the south. Major glacial outwashes were also formed during the Erie Lobe retreat, further establishing the Wabash river (the northwestern discharge of the Mississinewa River) as the dominant waterway in northern Indiana. In addition, an eastern outwash of the Erie Lobe (through the Knightstown Moraine) formed the Blue River Valley to the south. These geological features are observable through aerial imagery and quaternary geologic maps.

1 Rosenshein, J.S., 1958, Ground-water resources of Tippecanoe County, Indiana: Indiana Department of Conservation, Division of Water Resources Bulletin 8, 37 p.



MAP 3.1 | HUC10 watersheds

TOPOGRAPHY

Unlike parts of southern Indiana, there is no karst topography present in the watershed. Because of the scouring of the glaciers and the deposits of unconsolidated materials into the ancient bedrock valleys, the surface topography of the Mississinewa River valley appears moderately flat, resulting in a fairly even drainage pattern across the 415,000 acre region. There is a 380 feet change in elevation over the course of the watershed. This change in elevation is represented in Figure B.3 (Appendix B) in 100 foot intervals. The topographic interval map depicts the high points (1170 feet above sea level) of the watershed (red) in Darke County, Ohio and near Union City in Randolph County. These high points drain into a headwater "valley" accumulating near the City of Ridgeville (blue). Passing through Ridgeville, the Mississinewa River takes a long meandering run through the remainder of Randolph, Jay, and Delaware counties, receiving Blackford County's Big Lick Creek (green), and reaching its lowest elevation (790 feet above sea level) through the City of Marion in Grant County (orange). The flattest area of the watershed is located in southwestern Grant County. The Mississinewa River has an overall grade of 3 feet/mile during its run through the watershed area. These observational topological patterns loosely relate to the categorization of 10-digit subwatershed boundaries in the UMRW (Map 3.1 on the previous page).

3.3 SUBWATERSHEDS AND THEIR GEOMORPHOLOGICAL ANALYSIS

HYDROLOGIC UNIT CODES

Watersheds in the United States are identified using a hierarchical system of categorization referred to as Hydrologic Unit Codes (HUC). The greater the number of digits within the HUC code, the smaller the size of the watershed (or subwatershed) it identifies. There are five 10-digit watersheds (i.e. HUC10) in the project area: (1) Headwaters Mississinewa River Watershed (0512010301) is comprised of 83,635 acres, (2) Halfway Creek-Mississinewa River Watershed (0512010302) is comprised of 87,128 acres, (3) Pike Creek-Mississinewa River Watershed (0512010304) is comprised of 66,086 acres, (4) Big Lick Creek Watershed (0512010303) is comprised of 48,813 acres and (5) Massey Creek-Mississinewa River Watershed (0512010305) is comprised of 150,256 acres. There are twenty-eight 12-digit HUC (i.e. HUC 12) subwatersheds contained within these HUC 10 watershed delineations. They are listed in Table 3.1 below, along with their respective acreages. Map 3.1 on the previous page depicts the watershed and subwatershed boundaries.

TABLE 3.1 | HUC delineations

Big Lick Creek	**512010303**
Townsand Lucas Ditch-Big Lick Creek	51201030302
Little Lick Creek-Big Lick Creek	51201030301
Halfway Creek-Mississinewa River	**512010302**
Redkey Run-Halfway Creek	51201030205
Platt Nibarger Ditch-Mississinewa River	51201030206
Bush Creek	51201030204
Bear Creek	51201030202
Fetid Creek-Mississinewa River	51201030203
Days Creek	51201030201
Headwaters Mississinewa River	**512010301**
Little Mississinewa River	51201030101
Gray Branch-Mississinewa River	51201030102
Mud Creek-Mississinewa River	51201030105
Porter Creek-Mississinewa River	51201030104
Jordan Creek-Mississinewa River	51201030103
Massey Creek-Mississinewa River	**512010305**
Hoppas Ditch-Mississinewa River	51201030501
Lugar Creek	51201030509
Branch Creek-Mississinewa River	51201030510
Deer Creek	51201030508
Walnut Creek	51201030506
Little Walnut Creek-Walnut Creek	51201030505
Back Creek	51201030504
Little Deer Creek-Deer Creek	51201030507
Barren Creek	51201030503
Lake Branch-Mississinewa River	51201030502
Boots Creek-Mississinewa River	51201030511
Pike Creek-Mississinewa River	**512010304**
Rees Ditch-Mississinewa River	51201030402
Holden Ditch-Mississinewa River	51201030404
Studebaker Ditch-Pike Creek	51201030403
Campbell Creek	51201030401

GEOMORPHOLOGICAL STUDIES

To quantify topographical differences between subwatersheds in the project area, the Project Manager performed a series of geomorphological studies. The intent of the research was to be able to compare subwatersheds (and water quality data in these subwatersheds) based on geomorphological similarities rather than geographic proximity. Geomorphological characteristics measured included average bifurication ratio, drainage density, stream frequency, and relief ratio (definitions below Table B.1 in Appendix B). In order to perform these analyses, LIDAR data was acquired through OpenTopography and used in conjunction with ArcMap to generate high resolution flow lines throughout the entire watershed area. Over 9,200 miles of ‘flow lines’ were generated using this method, creating a more detailed understanding of drainage patterns throughout the watershed. ‘Flow line segments’ were classified using a variant of the Strahler stream ordering methodology which was necessary to perform the bifurication ratio analysis. Watersheds were assigned a comparative ranking for each study. Rankings for drainage density (Dd), stream frequency (Fu), and relief ratio (Rr) were averaged and subsequently ranked to prioritize subwatersheds with the greatest sediment transport potential. The final column in Table B.1 in Appendix B lists the average of Dd, Fu, and Rr for each subwatershed. Figure B.6 in Appendix B, entitled “Sediment Transport Prediction,” uses a gradient to represent these averages (of Dd, Fu, and Rr); subwatersheds with the lowest predicted sediment transport potential are represented in green and those with the highest predicted sediment transport potential represented in red. Each individual geomorphological characteristic measured can also be found in Table B.1; gradient maps for some of these geomorphologic characteristics are found in Figures B.7 through B.10 (Appendix B). There are approximately 435 miles of United States Geological Survey (USGS) National Hydrography Dataset (NHD) mapped streams in the UMRW. Approximately 73 miles of NHD mapped streams are considered artificial paths/ditches. An additional 543 miles of streams/ditches in the watershed have been digitally mapped as part of the USGS High Resolution Flowline shapefile.

3.4 CURRENT AND HISTORIC HYDROLOGY

WATER SOURCE CONTRIBUTION TO RIVERS

While much of the Mississinewa River baseflow is fed through groundwater aquifers, changes in flow regime is largely driven by storms and climate conditions. “While Indiana has warm summers and cold winters, temperatures fluctuate both daily and seasonally as surges of polar air move southward or tropical air masses move northward. Temperature fluctuations are more common in winter than in summer....The Upper Mississinewa River watershed experiences some of the moderating effect of Lake Michigan on Indiana’s climate, including lake-effect precipitation during the winter months.”[2] The watershed receives about 40 inches of annual rainfall and average annual snowfall of approximately 26.7 inches. The region has average temperatures ranging from 34°F to 72°F, with an average temperature of 51.4°F. High temperatures measure approximately 85°F in July and August, while low temperatures measure near freezing (31°F) in January. This averaging is a result of the climatic forces that result in the distinct seasons of spring, summer, fall and winter.

While average annual rainfall for the area was typical during this study, rainfall patterns in the region appear to be changing. The number of very heavy rainfall events increased by 30% in the 20th century, with much of the increase occurring in the last three decades of that century.[3] In Indiana, only one year from 2001 to 2011 did not see severe flooding due to heavy precipitation.[4] Most scientists agree that these changes in climate are due to global warming. One researcher has predicted that by the end of this century, precipitation within a 24-hour period could increase by 30 percent in parts of Indiana.[5] Flooding was one of the three most commonly expressed stakeholder concerns; based on these climatic trends, it appears that flooding problems could continue to worsen in the UMRW. Increased flooding will also likely result in increased erosion and logjams, which are the other two most commonly expressed stakeholder concerns.

GAUGE DATA

There are two USGS stream gauges on the Mississinewa River that measure streamflow. One is in Marion, IN (USGS 03326500) and the second is near Ridgeville, IN (USGS 03325500). Flow data information for 2014 is displayed in Tables 3.2 and 3.3 for Marion and Ridgeville, respectively.

TABLE 3.2 | USGS discharge data Marion

Site	Marion
Date	11/14 - 12/15
Average	1020 cfs
Standard Deviation	2238 cfs
Minimum	59 cfs
Maximum	17800

TABLE 3.3 | USGS discharge data Ridgeville

Site	Ridgeville
Date	11/14 - 12/15
Average	194 cfs
Standard Deviation	566 cfs
Minimum	2.5 cfs
Maximum	5440

2 HARZA Engineering Company. Upper Mississinewa River Watershed Diagnostic Study. 2001. http://in.gov/dnr/fishwild/files/Upper_Mississinewa_River_Watershed_DiagI-Delaware.pdf

3 Ekwurzel, B. et al. 2011. [web page] Climate Hop Map: Global Warming Effects Around the World. Indianapolis, IN, USA. http://www.climatehotmap.org/global-warming-locations/indianapolis-in-usa.html.

4 Ibid.

5 Ibid.

HISTORIC NATURAL REGIONS: FOREST-WETLAND SYSTEM

The Natural Region classification system was developed by Homoya et al. in 1985. Under this framework, the Mississinewa River Watershed is located in the 'Central Till Plain Natural Region.' The classification is delineated by the southernmost extent of the Wisconsinan ice sheet and identifies the entire section of Indiana as "flattened" by glacial infill.

This relatively flat, low-grade, diffuse landscape, with high annual rainfall makes for ideal conditions for the extensive forest-wetland system that once dominated the region (historic records indicate that a high percentage of the region was characterized by wetlands prior to settlement). Flatwoods (forests occurring on relatively level and often poorly drained soils) were the most common forest type present, with mesic upland forest and ephemeral swamps well represented (beech forests and oak-sugar maple forests being the major type on the drier areas and beech and elm-ash swamp forests dominating the wetter areas).[6,7] There were also various wetland communities (forested swamps) along river valleys. Species composition varies with the extent and duration of flooding, but red maple, sycamore, buttonbush, and willow represent some of the more prevalent species in these river valley areas.

Evidence for the extensive wetland geography that once dominated the UMRW can be found in the soil profile as hydric soils. Hydric soil series are soils that formed under conditions of saturation, flooding, or ponding for a duration long enough to develop anaerobic conditions in the upper part of the soil column during the growing season.[8] Hydric soils make up a significant portion of the watershed, consisting of roughly 38% of all soils. Figure B.4 in Appendix B uses a color gradient to represent the relative concentrations of hydric soils in the watershed.

HYDROLOGIC SOIL GROUPS

Soil types play an important role in the hydrology of the UMRW. There are four hydrologic soil groups (HSG) that are defined by the Natural Resources Conservation Service (NRCS); all four are found within the UMRW. Map 3.3 on p. 45 delineates the locations of these soils groups in the watershed. These hydrologic soil groups are based on the soil's runoff potential and are grouped as A, B, C or D. Group A soils generally have the smallest runoff potential and Group D soils the greatest. The following HSG definitions were taken from Purdue University's LTHIA website:

"Group A is sand, loamy sand or sandy loam types of soils. It has low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission. Group B is silt loam or loam. It has a moderate infiltration rate when thoroughly wetted and consists chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. Group C soils are sandy clay loam. They have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine structure. Group D soils are clay loam, silty clay loam, sandy clay, silty clay or clay. This HSG has the highest runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material."[9]

Overall, there are 9% of group A and B soils, 77% of group D soils, and 27% of group C soils in the UMRW. The high presence of poorly draining soils additionally suggests a poorly drained landscape, enhancing the conditions for the once-dominant forest-wetland system. Today, this poorly drained landscape can be a problem in agricultural areas. Surface runoff on conventionally tilled fields can cause erosion; this can result in a loss of soil from agricultural land and an increase in turbidity in streams and rivers. Surface erosion on agricultural fields was a concern expressed by stakeholders. Figures B.1 and B.2 in Appendix B use a color gradient to represent the relative concentrations of Group C and D soils in the watershed.

NORMATIVELY POOR INFILTRATION INTO AQUIFER

The highest concentration of poorly drained soils (Group D soils) is located in the northwestern section of the watershed. The northwestern region has the largest groundwater reserve as observed though depth to bedrock data analysis (part of the Teays River Valley aquifer, shown as gradient figures on Fig. 3.5 and 3.6 on p. 47). Aquifer recharge rates throughout the watershed area are negatively impacted by (a) contemporary agricultural drainage infrastructure moving water off the landscape, (b) a high concentration of wells (due to the elevated population density), and (c) the region's naturally poorly infiltrating soils. According to Marion Utilities 2016 Annual Water Quality Report, the city's wells pump water from the Teays River Valley aquifer. About 4 million gallons of water per day is pumped from this aquifer (which was formed during glacial periods, when glaciers filled in the ancient valley with glacial till).[10] Landowners are concerned that aquifers are being depleted a rate faster than they are being replenished.

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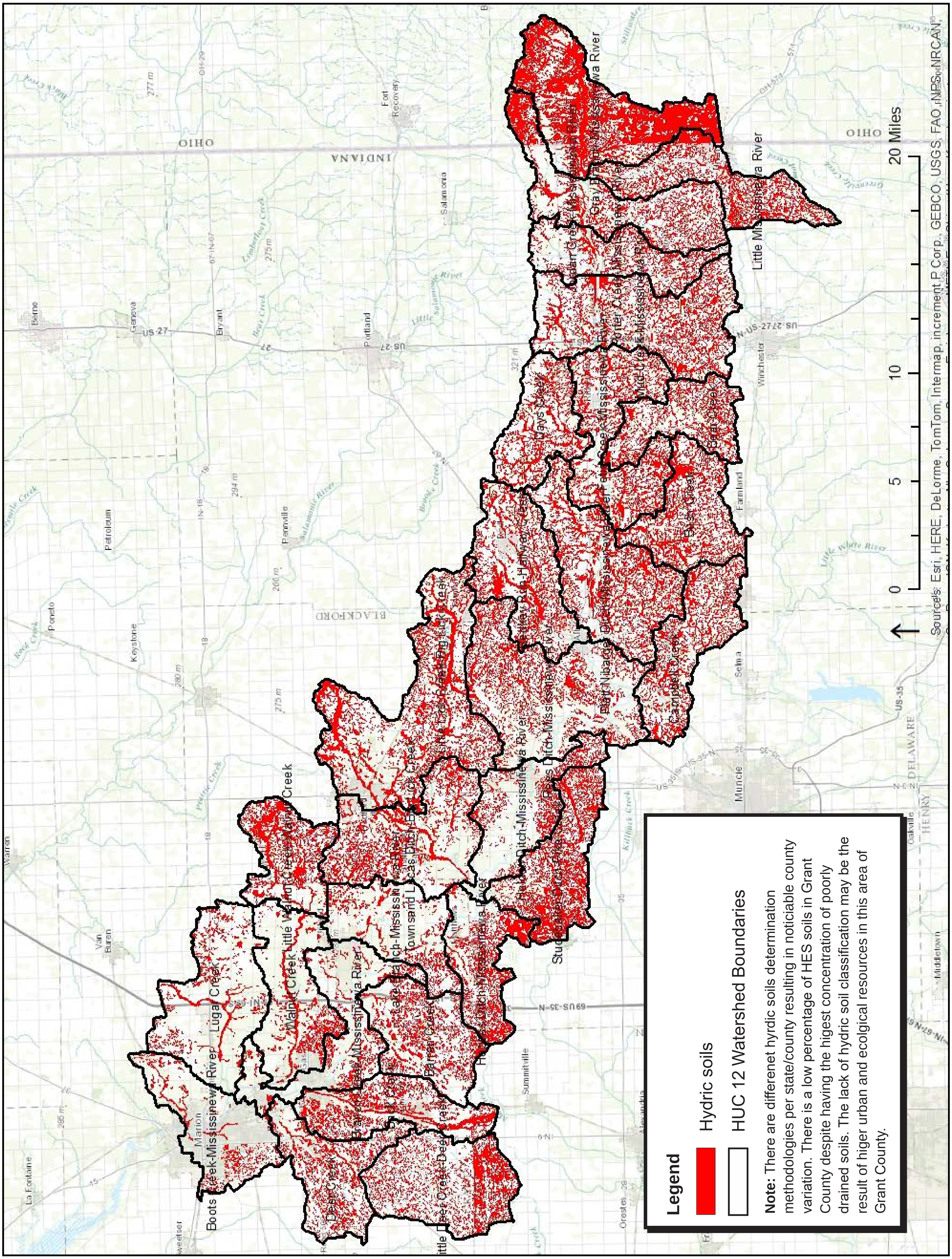
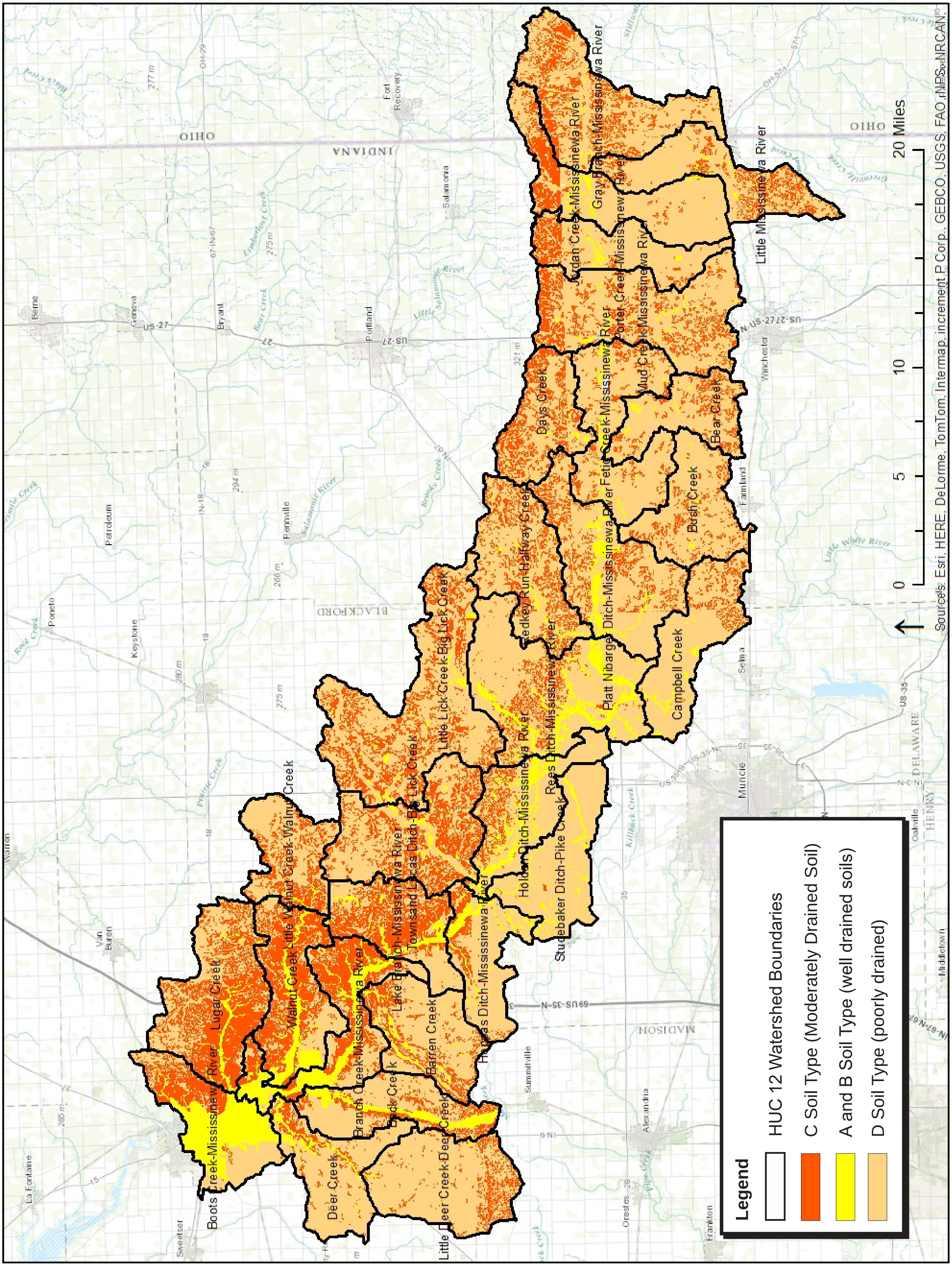
6 Homoya, Michael A. et al. 1985. The Natural Regions of Indiana. Indiana Academy of Science. Vol. 94. p 245-268.
7 Griffith, Glen. 2010. [web page] Level III North American Terrestrial Ecoregions: United States Descriptions. [Accessed 20 July 2016].
8 Environmental Laboratory. 1987. Corps of Engineers wetlands delineation manual. Tech. Rep. Y-87-1. U.S. Army Corps of Engineers Waterways Exp. Stn., Vicksburg, MS. <http://el.erdc.usace.army.mil/wetlands/>
9 Purdue University. 2011. [web page] LTHIA. [Accessed 19 July 2016].
10 Marion Utilities Water Department. Marion Utilities 2016 Annual Water Quality Report. http://www.marionutilities.com/wp-content/uploads/2016/05/2016-Annual-CCR-Report.pdf.



MAP 3.2 | Hydric soils



MAP 3.3 | NRCS Soil type classifications

EARLY HUMAN HABITATION

The pre-European geographic conditions were problematic for human habitation. Decentralized waterways made navigation of the Mississinewa River and its tributaries (especially in the upper most regions) by canoe, flatboat, etc. a challenge. Densely forested and wet terrestrial conditions also made hunting and surface transportation difficult. The Mississinewa River Valley was part of Miami Indian territory (named by the Miami and meaning "laughing waters"). However, there is limited evidence of any Native American settlements along the Mississinewa River prior to European arrival to the Americas. Some of the first residents were actually Delaware Indians permitted by the Miami to reside in the region in response to European settlements on the East Coast. The Shawnees (originating from southern Indiana) were later permitted to live along the Mississinewa River in 1798 (through an agreement with the Miami and the Delaware). In later years, concurrent with ongoing state-wide conflicts with the Europeans, the Miami moved the centroid of the Miami Nation along the Mississinewa River, setting up camps there. These camps were destroyed during some of the last major Native American resistance efforts against European expansion within Indiana, most notably the Battle of the Mississinewa in 1812. After a series of subsequent treaties with the United States, virtually no Native Americans lived in Indiana by 1840.[11]

EUROPEAN LAND TRANSFORMATION

The first era of European settlement in the Mississinewa River Valley initially followed Native American migration and trade routes. European towns were established along major rivers in the region (the primary mode of transportation at the time). Early water/surface transportation networks likely connected southern Indiana through the Whitewater River system to Greenville, Ohio and from Greenville through the Mississinewa Watershed west to the Wabash River. Hartford City, an early settlement in the region, is thought to be an evolution of "Harts Ford"; it was a key location for accessing and traversing Big Lick Creek.[12]

As trading posts were established and as farmstead establishment(s) became more feasible, more settlement occurred in the region. U.S. federal laws, like the Swamp Land Act of 1850, essentially provided a mechanism for transferring title of federally owned swampland to private parties agreeing to drain the land and turn it to productive/agricultural land uses. Cheap land was a major motivation for early Indiana settlers and resulted in an unprecedented transformation of the forest-wetland ecosystem into agricultural uses. Approximately 17 million acres of wetlands/forests were eliminated statewide as part of this effort. In the UMRW an estimated 316,000 acres of forest was converted to agricultural land. In addition, early settlers established a network of drainage tile, ditches, and canals to drain agricultural fields. There are approximately 600 miles of modified streams/ditches and approximately 65,300 miles of artificial drainage tile in the watershed.[13]

HYDROMODIFICATION

The early settlers' modifications to the landscape had major impacts to the Mississinewa River and its natural tributaries. Removal of the forest canopy (which once absorbed 10% of rainfall) and the destruction of historic wetlands resulted in additional water volume entering the waterways during storm events. In conjunction with the deployment of the expansive network of ditches and field tiles, these changes increased the speed that both groundwater and rainfall enters channels during storm events, resulting in higher peak flow events and frequencies (hydrograph). To accommodate the increased flows, land managers dredged channels and widened their cross-sectional area. In some cases channels were straightened to increase drainage velocity. This has resulted in unstable streams throughout the watershed. These streams are consistently seeking new equilibriums and attempting to return to natural meander wavelengths through the process of aggradation and degradation (erosion). While sediment transport is a natural function of streams, elevated levels of sediment may be a result of incised or over-widened channels in the watershed. Undercutting caused by erosion has also resulted in trees falling into channels and creating logjams (seven Category 3 and three Category 4 logjams were identified on the Mississinewa River; see Section 3.7, Functional Uses of the River, p. 69).

Because of these changes, many of the floodplains on smaller Mississinewa River tributaries no longer function at 2-year flood intervals. These floodplains are more prone to flooding due to these hydromodifications. This can be especially troublesome for human land uses within the floodplain. The floodplains in the UMRW that are mapped by FEMA include 23,840 acres that are categorized according to specific land use classifications (see Table 3.4).

TABLE 3.4 | Watershed land use within floodplain

Misc	Wetlands	Urban	Forest	Crops	Pasture/Grass
521 ac.	1,455 ac.	2,047 ac.	4,330 ac.	14,448 ac.	1,036 ac.

Erosion, flooding and logjams were the top three concerns expressed by stakeholders (Tables 2.1-2.6, pp. 27-29 and Tabels 2.10-2.11, pp. 35-36). Erosion from both streambanks and overland flow from fields were concerns. All of these concerns are tied to these hydromodifications.

11 Vanderstel, David G. [web page]. Native Americans in Indiana. http://www.connerprairie.org/Learn-And-Do/Indiana-History/America-1800-1860/Native-Americans-In-America.aspx [Accessed 10 August 2015].

12 Hartford City, Indiana. [webpage] https://en.wikipedia.org/wiki/Hartford_City,_Indiana. [Accessed 20 July 2016].

13 and at 40 foot spacing, there is 1090 feet of drainage tile per acre resulting

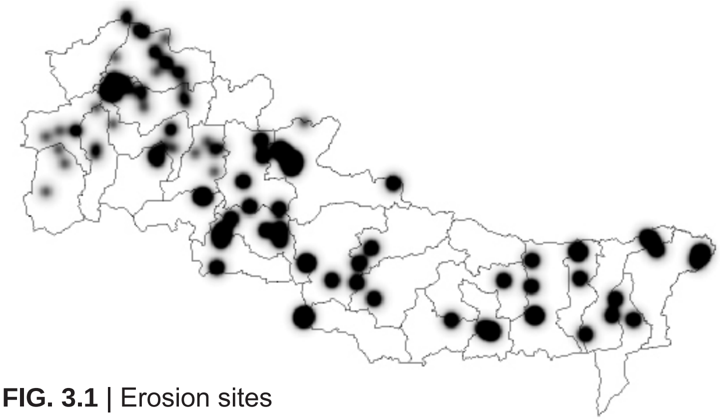


FIG. 3.1 | Erosion sites

Heatmap diagram indicates the presence of erosion locations in streams. These are sites where lake edges or large sections of river are sluffing off. Sites were identified by the Project Manager through an aerial desktop survey in 2014-2015.

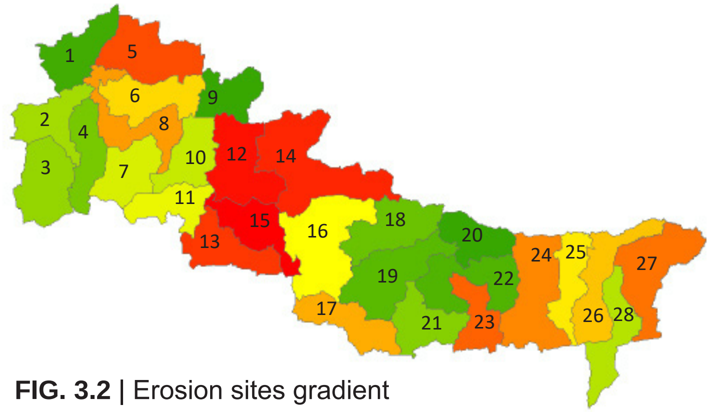


FIG. 3.2 | Erosion sites gradient

Subwatersheds are ranked on a gradient (red high and green low) based on erosion site presence. Highest presence of erosion sites are in Blackford and Delaware County. (See numeric Key below)

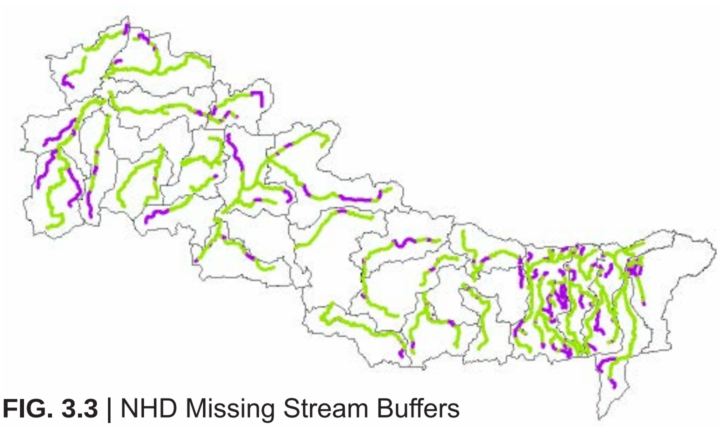


FIG. 3.3 | NHD Missing Stream Buffers

Tributaries in the watershed were analyzed for the presence of vegetated buffers. Tributary stretches that do not have a buffer are represented with purple. Tributary stretches that do have buffers are represented with green.

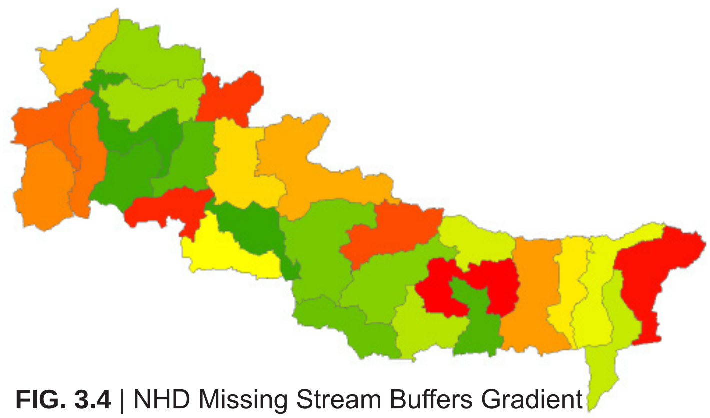


FIG. 3.4 | NHD Missing Stream Buffers Gradient

Subwatersheds are ranked on a gradient (red high and green low) based on percentage of missing buffer presence. Each county has subwatersheds that need buffering.

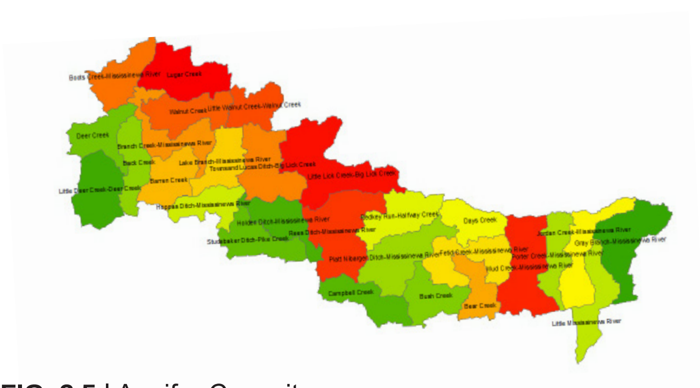


FIG. 3.5 | Aquifer Capacity

Subwatersheds are ranked on a gradient (red high and green low) based on aquifer capacity (cubic feet). The Subwatersheds with the largest aquifer capacity is in northern Grant County and Blackford County. Mud Creek Subwatershed also has a high aquifer capacity.

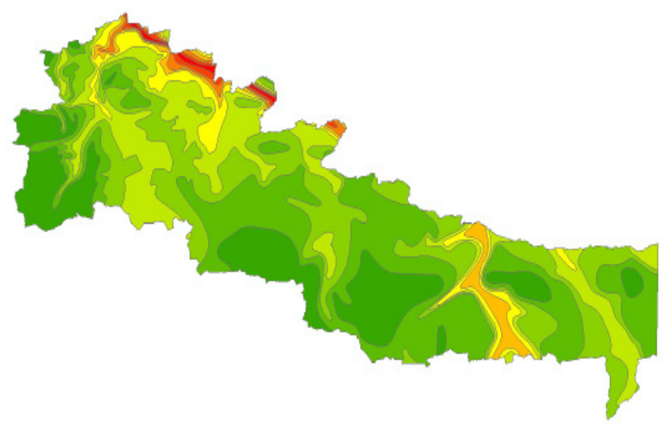


FIG. 3.6 | Unconsolidated aquifer depth

Depth to consolidated bedrock is represented on a gradient (red high and green low). This correlated to the presence of the glacier moraine that impacted the region. Unconsolidated aquifers are one of the most significant ecological features in the region.

KEY | 1-Boots Creek-Mississinewa River, 2-Deer Creek, 3-Little Deer Creek-Deer Creek, 4-Back Creek, 5-Lugar Creek, 6-Walnut Creek, 7-Barren Creek, 8-Branch Creek-Mississinewa River, 9-Little Walnut Creek-Walnut Creek, 10-Lake Branch-Mississinewa River, 11-Hoppas Ditch-Mississinewa River, 12-Townsand Lucas Ditch-Big Lick Creek, 13-Studebaker Ditch-Pike Creek, 14-Little Lick Creek-Big Lick Creek, 15-Holden Ditch-Mississinewa River, 16-Rees Ditch-Mississinewa River, 17-Campbell Creek, 18-Redkey Run-Halfway Creek, 19-Platt Nibarger Ditch-Mississinewa River, 20-Days Creek, 21-Bush Creek, 22-Fetid Creek-Mississinewa River, 23-Bear Creek, 24-Mud Creek-Mississinewa River, 25-Porter Creek-Mississinewa River, 26-Jordan Creek-Mississinewa River, 27-Gray Branch-Mississinewa River, 28-Little Mississinewa River.

The presence of vegetation on streambanks may help stabilize sediments on unstable streams or drainageways without typical floodplain access. Watershed planners performed a desktop survey of bank vegetation and grass buffers on major NHD mapped streams. Figure 3.3 on p. 47 shows both streams with adequate buffers and streams without adequate buffers. Bank erosion potential can also be predicted using Near Bank Stress analysis and the Bank Erosion Hazard Index. While a comprehensive assessment of streams using these assessment tools is beyond the scope of this WMP, future analysis may be completed in subwatersheds suspected of having high levels of bank erosion based on water quality results.

LEGAL DRAINS
The Indiana statute IC 36-9-27 contains the County Drainage Code. This law authorizes county drainage boards to regulate certain drains. The intent of this law is to increase the hydraulic efficiency of waterways and control upstream ponding and flooding. The county surveyor is the technical authority on the construction, reconstruction, and maintenance of all regulated drains or proposed regulated drains in the county. Both open ditches and tile drain can be legal drains. The County drainage code requires the county surveyor to classify regulated drains in the county as:

1. Drains in need of reconstruction
2. Drains in need of periodic maintenance; or
3. Drains that should be vacated.

The county drainage boards across the state fund reconstruction and maintenance of regulated drains. Among the board's duties, as defined in the statute, is the reconstruction of regulated drains that do not properly function and may require erosion control or grade stabilization structures. This is an avenue for implementing watershed management projects that may be under utilized in the state. Watershed management projects affecting legal drains will require the approval of the county drainage board. Stakeholders raised concerns regarding legal drains. Drainage problems, including brush and downed trees blocking the flow of water in legal drains, were concerns that were voiced.

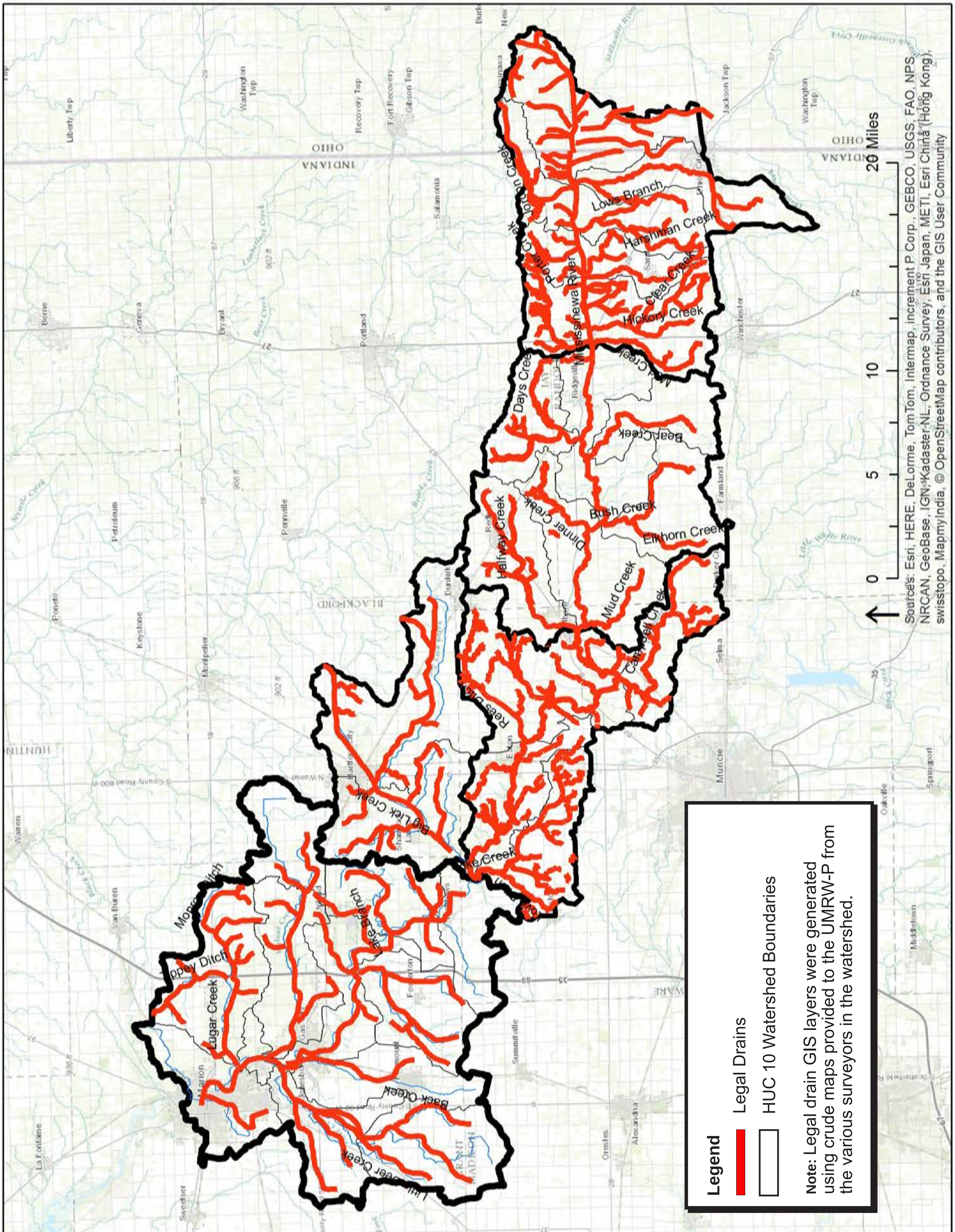
Legal drain GIS layers were generated using crude maps provided to the UMRW-P from the various surveyors in the watershed. There were 950 miles of legal drains documented and/or estimated (Map 3.4). Many county surveyors or their representatives expressed concern over historical record keeping and in some instances precise locations of underground legal drains were unknown. The combination of the crude maps and questionable record keeping makes accurate reporting of legal drain mileage and location difficult. A secondary estimate of 1,150 miles was generated using a stream ordering system developed in conjunction with the geomorphological study conducted for this project.

TABLE 3.5 | Documented/Estimated Legal Drain Miles in Watershed

Grant	Blackford	Delaware	Randolph/Jay	Darke
224 miles	89 miles	172 miles	443 miles	20 miles

NATIVE VEGETATION ALONG LEGAL DRAINS
Removing overstory, shrub, and herbaceous vegetation and replacing it with cool season grasses is a commonly accepted management practice for legal drains in the UMRW. However, the presence of trees and shrubs that shade the water aids in keeping water temperatures low, allowing for higher levels of dissolved oxygen. The removal of the native herbaceous layer and the subsequent replacement with cool season grass also reduces the biodiversity of the riparian area. Of the tributaries mapped by the National Land Cover Database (NLCD), roughly 30% (100 miles) need buffers. The only water body that has relatively good shading and a riparian corridor lush with habitat is the Mississinewa River. Concern from the steering committee was raised over the lack of vegetation on banks leading to erosion and poor quality of habitat. Streams needing buffers were relatively evenly distributed throughout the watershed. Figure 3.3 was generated using NLCD data; tributaries needing buffers appear in purple, and those with adequate buffers in green. Figure 3.4 depicts the relative percentages of the NLCD mapped tributaries needing buffers. In this figure, percentages have been converted to a gradient, with subwatersheds in red having the highest percentage of tributaries needing buffers, and those in green having the least. As part of this watershed project, landowners will have the option to enroll in programs to reestablish buffers along streams.

HYDROMODIFICATIONS TO THE MISSISSINEWA RIVER
While many subwatershed streams have been straightened and given a trapezoidal design, the Mississinewa River has remained mostly untouched. For the majority of the river's length, it has access to the floodplain and its channel meanders have expected wavelengths. Only one section of the river has been straightened. This straightened section begins near the river's origin and ends near the town of Ridgeville. Other modifications include the installation of low height dams.



MAP 3.4 | Open Legal Drain Map

EFFECTS OF HYDROMODIFICATION: RIVERBANK AND STREAMBANK EROSION

Excessive bank erosion is expected to be a major source of sediment pollution throughout the watershed. Moderate erosion of ditches is characterized by bare banks, with slight overhang from vegetation on the top of bank. Severe erosion is characterized by the presence of massive failures, gullies, and bare rills. A desktop survey identified erosion sites throughout the watershed. Using Google Earth's aerial imagery, the Project Manager documented 222 erosion sites within the watershed (see Section 3.8, *Desktop Survey*). These sites were directly adjacent to streams, lakes, or the river, and are suspected to be eroding directly into the water. The severity of erosion could not be assessed using this method. Fig. 3.9 and 3.10 on p. 54 show the locations of the sites and the relative concentration of the sites by subwatershed, respectively. During a windshield survey performed by the Project Manager in April, 2016, twenty sites with varying degrees of bank erosion were identified (six with slight erosion, five with moderate erosion, and nine with high erosion; see Section 3.9, *Windshield Survey*). Specific locations with erosion include Walnut Creek and Lugar Creek, as reported at public input meetings (see Section 2.7, p. 35, for a complete list of concerns from the Nov. 18, 2015 meeting).

Channelization of the Mississinewa from its headwaters to Ridgeville has increased the velocity of the river, causing the following chain of events downstream of Ridgeville: increased undercutting of banks, increased logjams, and increased bank erosion due to logjams (see Section 3.7, *Functional Uses of the River* on p. 69 for more information about logjams on the river.). According to the EPA Region 5 model for estimating load reductions for agricultural and urban BMPs, an eroded 500 foot section of bank that is 10 feet high, with silt loam soils, would contribute over 4500 tons of sediment for every three inches of erosion. Assuming a concentration of nitrogen in the soil of 0.1% and phosphorus of 0.05%, this is equivalent to over two tons of phosphorus and almost 5 tons of nitrogen that would also be polluting the waterway with the sediment.

WETLANDS

While it is difficult to predict the total amount of wetlands that existed prior to European settlement, hydric soils map (Map 3.2) indicates wetland presence as a part of the historically vast forest wetland system. Today there are 1,455 acres of wetlands throughout the watershed (Table 3.4; for higher resolution maps see Maps 10.1 through 10.5, pp. 165-189). These wetlands are regulated by IDEM. Wetlands are important to the watershed because of their capacity to mitigate rain events, contain flood flows, and remove pollutants prior to their entrance to waterways.

Most wetlands within the watershed are privately owned; private uses of these wetlands are unknown. Federal law prohibits the disturbance of over one-tenth of an acre of a wetland area. To disturb more than this, an individual must receive a permit from the appropriate agency. Off-site or on-site mitigation at the landowner's expense is required if a permit is issued.

A few wetlands in the watershed are owned by universities, land trust organizations, or the State of Indiana; these are also mentioned within the appropriate subwatershed discussions (Section 10, *Subwatershed Discussions,* p. 159). These properties provide opportunities for hiking, nature viewing, hunting, and outdoor education. They include:

1) Botany Glen, 7300 Wheeling Pike, Jonesboro, IN. Access is permitted to Indiana Wesleyan faculty and students only or by consent of property manager. This forty-five acre property is adjacent to the Mississinewa River. The site has been studied by Master's students and university faculty.
2) Mike J. Kiley Forest Preserve, 13800 E Edgewater Rd, Albany, IN. A mowed trail is open to the public. The site includes thirty-five acres, including riparian forest along the Mississinewa River. It is owned by Red-tail Land Conservancy.
3) McVey Memorial Forest, IN-1 Farmland, IN. This site is 249 acres and includes riparian forest along the Mississinewa River as well as wetlands. Trails on the property are open to the public. It is owned by Redtail Conservancy.
4) Randolph County Wildlife, IN-1 Farmland, IN. The site is managed by Wilbur Wright Fish and Wildlife Area. It is a 519 acre public property that offers waterfowl hunting.

PONDS AND LAKES

Ponds and lakes are also known as open-water features. There are 1,555 acres of open-water in the watershed region. All are relatively small-sized. Because no official difference exists between the term "pond" and "lake," the names will be used interchangeably here. Most ponds in the watershed are assumed to be man-made. However, it is possible that a few natural ox-bow lakes may exist along the Mississinewa River. Man-made ponds sometimes exist for agricultural reasons, such as providing a water source for livestock; recreational reasons, such as providing a place to fish; or ecological/ aesthetic purposes, such as creating a natural, attractive setting.

There are no known publicly-owned ponds in the watershed; all ponds are assumed to be privately owned. One stakeholder was concerned about poor pond management practices; we assume the concern was regarding a private pond. Two pond management workshops were held in Delaware County as part of the 319 grant requirements for this project. The dates of the workshops were 7/2/2014 and 7/7/2015. The Project Manager found that pond owners are increasingly realizing that mimicking natural features like lakes and wetlands is an effective long-term strategy for maintaining proper nutrient balance and a healthy aquatic ecosystem.

One lake community exists in the watershed. The town of Shamrock Lakes is situated on seven lakes. According to Wikipedia, the first lake was created to be a water supply for livestock.[14] This small "town" is more aptly described as a lake subdivision; the residents of the town all own property along the lakes. The town has its own wastewater treatment plant.

Although there are no known public ponds in the watershed, some privately-owned ponds may be accessible to the public. According to www.takemefishing.org/, a website of the Recreational Boating & Fishing Foundation,[15] there are four pond/lakes that are available for fishing within the watershed. While the extent that the public can (or cannot) use these lakes is not clear for all of these lakes, we have still chosen to list them.

1) Sports Lake, located in Walnut Creek subwatershed at the Sports Lake Campground, is located at the headwaters of Sports Run, a tributary of Walnut Creek. The Sports Lake Campground appears to serve mostly RVs (based on the Project Manager's inspection of the site using Google Earth).
2) Taylor Lake is located in Branch Creek subwatershed on the campus of Taylor University near Upland. It is used for swimming but it is not clear if it is open to the public. It does not drain into the Mississinewa or any of its tributaries.
3) Lake Mohee is located in Big Lick Creek subwatershed, along Fiddler Ditch, a tributary of Big Lick Creek. Using Google Earth's aerial imagery, the Project Manager determined that the lake is roughly 15.75 acres in size. Fifteen or more homes are situated on the lake.
4) Lake Placid is located in Little Lick Creek at the Lake Placid Conference Center. It is at the headwaters of a tributary of Little Lick Creek. Lake Placid Conference Center is served by a WWTP.

The Indiana Department of Natural Resources's "Where to Fish in Indiana" app was also inspected by the Project Manager; no fishing lakes were identified within the watershed using this resource.

THE MISSISSINEWA RIVER: FUNCTIONAL USES

The Mississinewa River is used for fishing and other recreational uses, such as canoeing and kayaking. It is also a water source for various cities and towns found along it. Section 3.7, *Functional Uses of the River*, on p. 69 contains an in-depth discussion of various uses and stakeholder concerns regarding the Mississinewa River. This section contains the results of a canoe survey along the Mississinewa; several logjams were identified on the survey.

3.5 HISTORIC AND CURRENT LAND USE

EARLY INDUSTRIAL HISTORY

The invention and deployment of the railroad system revolutionized travel and accelerated the settlement of the Mississinewa River Valley. The railroad linked towns with early agricultural manufacturing elements and drove their growth and development. In 1876, natural gas was discovered near the town of Eaton in Delaware County and would become known as the Trenton Oil Field. The discovery of natural gas also accelerated railroad connections in the region and led to the establishment of speculative towns. The town of Matthews, thought to be located at the centroid of the Trenton Oil Field, was platted to be a gas boom town and was once idealistically envisioned as the future capital of Indiana. The early river town of Harrisburg was expanded/plotted and renamed Gas City in anticipation of the gas boom. Upland was intentionally created as a speculative town located on an anticipated route of a major rail line connecting Cincinnati to Chicago. The establishment of the railroad infrastructure also led to new towns along railroad corridors; these "second wave" towns are unique due to their isolation from major river systems. Map D.1 in Appendix D shows the relationship between "River Communities," i.e. early settlements in the region, the rail lines that connected these early settlements, and the second wave of cities and towns located along railroad lines.

MARION, INDIANA

The history of Marion is representative of the many other smaller towns in the region. Located along the Mississinewa River, Marion grew slowly for more than 50 years as an agricultural trading center supported by small farm and forest-related industries. With the formation of Grant County in 1831, Marion, the largest city in the watershed, was established as the county seat. The availability of natural gas attracted many businessmen to the city/region. From 1870 to 1900, the city of Marion grew 120% annually, from 1,658 to 17,337. Unfortunately, by 1910, 90% of the natural gas had been used due to wastefulness and unregulated drilling practices. Marion's prosperity plateaued just prior to World War I, when the gas boom officially ended. The end of the gas boom meant widespread stabilization or decline in the population of nearly all towns in the region.

Following World War II, General Motors located a stamping and tool plant in Marion and a new era launched overnight, raising the sights of local residents who migrated to the city in unprecedented numbers with thoughts of a vastly expanded employment potential. The surge in industrial development following World War II was largely catalyzed by the automobile revolution and the establishment of the state highway systems. These "revolutions" impacted the growth of Marion, Hartford City, Upland, and Gas City, likely due to their proximity to the enhanced auto transit systems and already existing population base for labor. Except for bedroom communities near metropolitan centers, Marion's growth during the 1950s exceeded all but one Indiana city with populations of 10,000-100,000. Population growth increased by 4% through the 1960s. Due to globalization trends and competition with other regional cities and towns (described in subsequent sections), Marion's population has declined since the 1960s by 26%.

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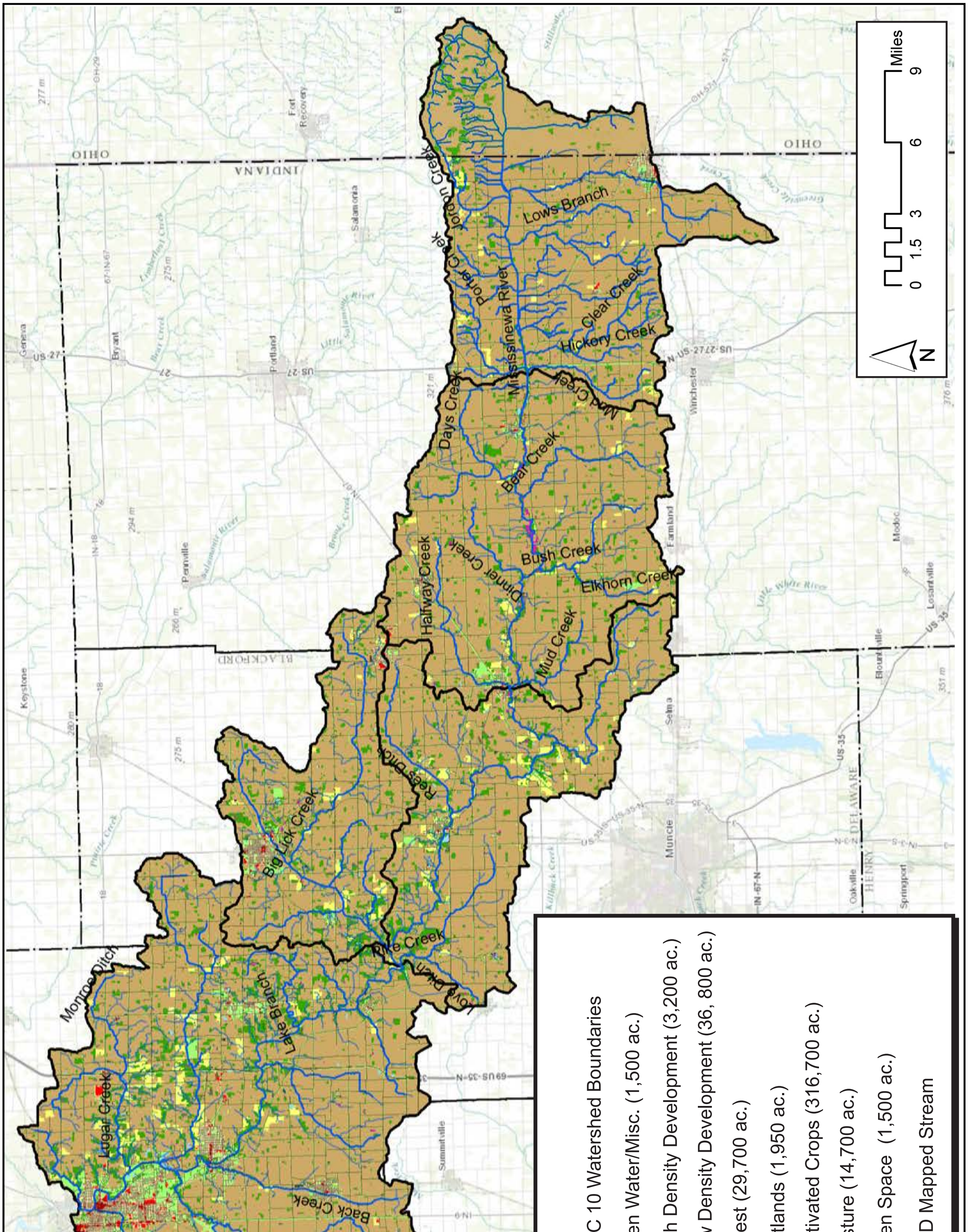
14 Shamrock Lakes, Indiana [web page]. https://en.wikipedia.org/wiki/Shamrock_Lakes,_Indiana [Accessed 10 June 2016].

15 The RBFF is a national, non-profit organization "that is leading the drive...to increase participation in recreational boating and fishing, thereby helping to conserve and restore our country's aquatic natural resources."



MAP 3.5 | Land use map

EMERGENCE OF INDUSTRIAL AGRICULTURE

Following World War II, (through a mix of policy decisions and advances in technology) agriculture practices in the UMRW (and the rest of the United States) shifted towards an industrial farming system. In industrial agriculture, the farm is modeled after a factory system, with “inputs” (pesticides, fertilizers) and “outputs” (crops). Characteristics of this type of farm operation are ever-increasing yields, controlled costs, monocropping, and the replacement of manual labor with machines and petro-chemicals like pesticides and fertilizers. This change eventually led to the centralization of lands into larger farms. Four thousand landowners control approximately 66% of the land in the UMRW due to these trends in land centralization.

CURRENT LAND USE

To understand current land use, land use data was obtained from the 2011 National Land Cover Database (NLCD) available from IndianaMap. Map 3.5 on p. 52 depicts the distribution of land use types throughout the watershed. Cultivated cropland is the predominant land use type, comprising 78.3% of the total watershed area. Urban areas (considered as residential, commercial and industrial landscapes) account for 10% and forest/wetland account for 8%. An additional 3.6% of the watershed is pasture or hay fields. Each of these land uses and their associated concerns will be discussed subsequently and in subwatershed analyses.

TABLE 3.6 | Land use in watershed		
Open Water/Misc	1,500	0.4%
Wetlands	1,950	0.5%
Urban	40,000	9.9%
Forest	29,700	7.3%
Crops	316,700	78.3%
Pasture/Grass	14,700	3.6%
Total	404,550	100.0%

TABLE 3.7 | Simplified land use categorization		
Ecological	47,850	12%
Crops	316,700	78%
Urban	40,000	10%
Total	404,550	

AGRICULTURE

The largest land use in the watershed is agriculture (78.3%); it is the most important economic resource in the region. There is much homogeny in regional farm operations and nearly all producers follow conventional practices, standards, and application rates. Most farms identified follow a corn and soybean rotation. Industrial agricultural practices significantly influence water quality and externalities include the presence of elevated levels of nutrient and sediments found in waterways. Factors such as the timing, quantities, and methods of fertilizer application on cropland influence nutrient loading in streams (Figure C.5 in Appendix C). Density of cropland also influences nutrient loading in streams (Figure C.1 in Appendix C). Tillage practices expose soils and make them susceptible to transport in surface runoff, effecting the amount of sediment in rivers and streams. Additionally, animal waste used as fertilizer has the potential to harbor bacteria and other pathogens, as well as nutrients, that may also enter waterways through surface runoff. Understanding the seasonal rhythms of both fertilizer application and tillage practices helps watershed planners interpret seasonal water quality variability.

CHEMICAL FERTILIZER PROJECTIONS

Annual contributions of chemical fertilizers (used on agricultural land) to the aquatic environment were estimated using the Export Coefficient Model. This model provides generic yearly projections; it was chosen for its simplicity. The Export Coefficient Model was developed by Reckhow et al in 1982.[16] “The Export Coefficient Model relies heavily on land use data without direct consideration of soil type and slope, riparian cover, site-specific chemical usage, and tillage practices.”[17] Maps of projected fertilizer contribution by subwatershed are found in Appendix C, Figures C.6 and C.7. Because the projections are driven by land use data, there is a relationship between the subwatersheds with the largest percentage of farmland and the highest projected contribution. The outcomes of this comparison are discussed in the following paragraphs. Table 3.8 includes the subwatersheds that contribute the largest amounts of fertilizer runoff to streams.

16 Reckhow, K. H:, Beaulac, M. N., and Simpson, J. T. (1980). “Modeling phosphorus loading and lake response under uncertainty: A manual and compilation of export coefficients,” U.S. EPA Report No. EPA-440/5-80-011, Office ofWater Regulations, Criteria and Standards Division, U.S. Environmental Protection Agency, Washington, DC.

17 Taylor University. Earth and Environmental Sciences Department. 2012. Middle Mississinewa River Watershed Diagnostic Study.

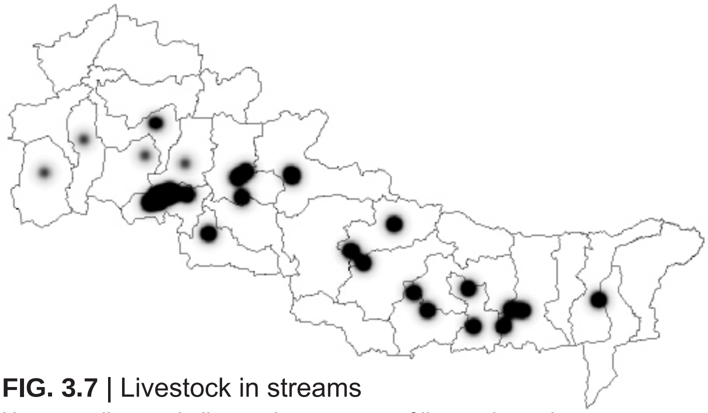


FIG. 3.7 | Livestock in streams

Heatmap diagram indicates the presence of livestock grazing in streams. Sites were identify through aerial desktop survey.

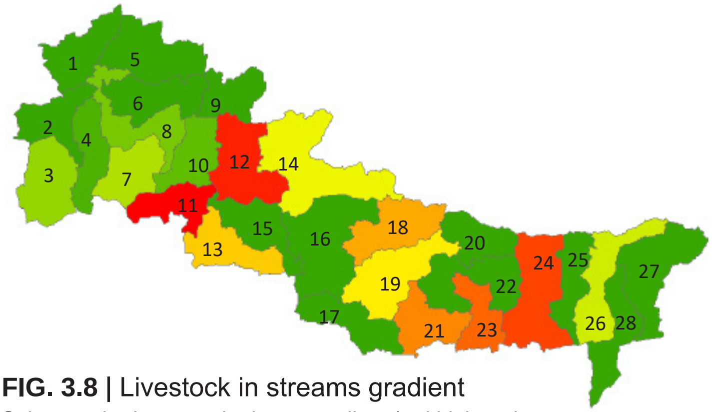


FIG. 3.8 | Livestock in streams gradient

Subwatersheds are ranked on a gradient (red high and green low) based on the presence of livestock in stream. Highest presence of highly erodible soils in the watershed are in Blackford and Randolph Counties. (See numeric Key below)

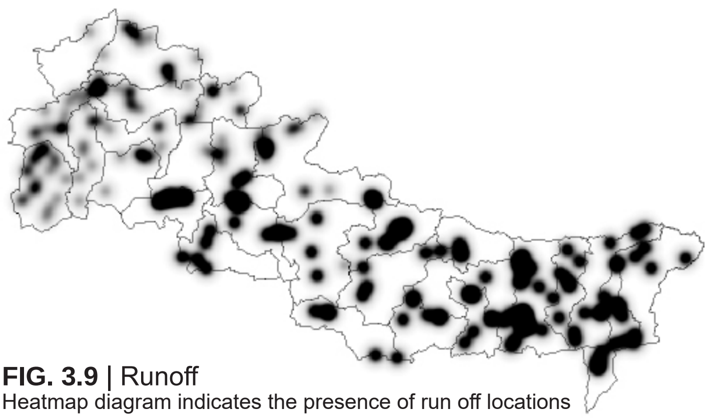


FIG. 3.9 | Runoff

Heatmap diagram indicates the presence of run off locations in streams. Runoff sites are areas where rill/gullies or swales have direct access to a water body or where vehicular access sites were identified. Sites were identified through aerial desktop survey.

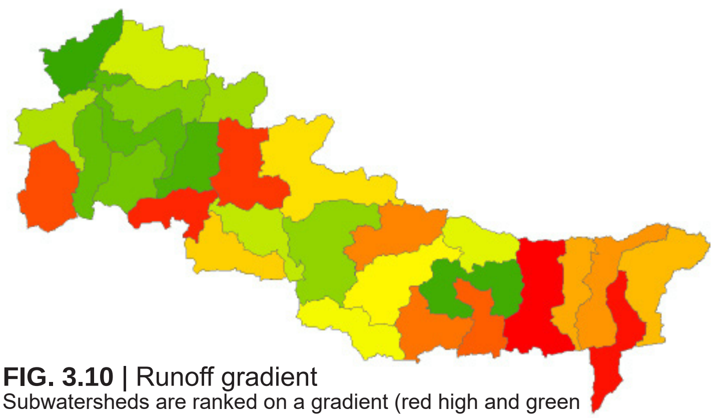


FIG. 3.10 | Runoff gradient

Subwatersheds are ranked on a gradient (red high and green low) based on identified runoff sites. Spread throughout the watershed highest concentrations are in predominantly agricultural landuses.

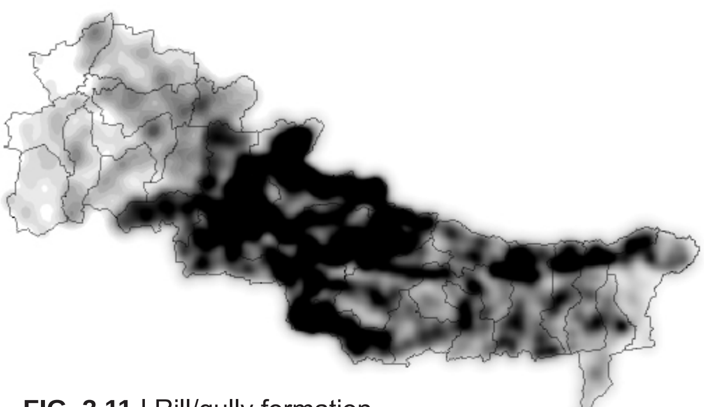


FIG. 3.11 | Rill/gully formation

Heatmap diagram indicates the presence of rill and gully formations on the landscape. Sites were identified through aerial desktop survey.

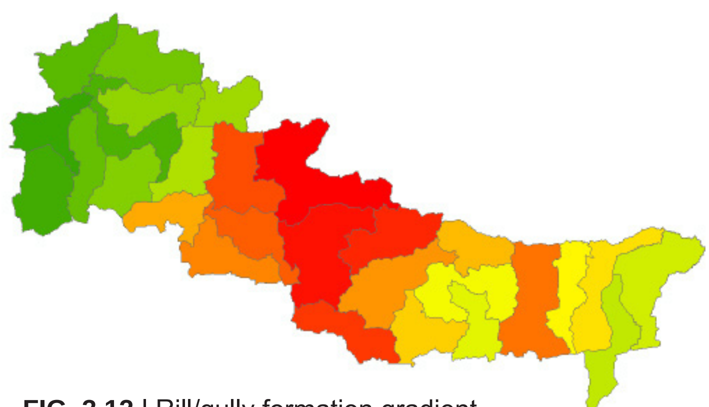


FIG. 3.12 | Rill/gully formation gradient

Subwatersheds are ranked on a gradient (red high and green low) based on the presence of rill and gully formations. The highest concentration of rill and gully formation is in Blackford and Delaware County.

KEY | 1-Boots Creek-Mississinewa River, 2-Deer Creek, 3-Little Deer Creek-Deer Creek, 4-Back Creek, 5-Lugar Creek, 6-Walnut Creek, 7-Barren Creek, 8-Branch Creek-Mississinewa River, 9-Little Walnut Creek-Walnut Creek, 10-Lake Branch-Mississinewa River, 11-Hoppas Ditch-Mississinewa River, 12-Townsand Lucas Ditch-Big Lick Creek, 13-Studebaker Ditch-Pike Creek, 14-Little Lick Creek-Big Lick Creek, 15-Holden Ditch-Mississinewa River, 16-Rees Ditch-Mississinewa River, 17-Campbell Creek, 18-Redkey Run-Halfway Creek, 19-Platt Nibarger Ditch-Mississinewa River, 20-Days Creek, 21-Bush Creek, 22-Fetid Creek-Mississinewa River, 23-Bear Creek, 24-Mud Creek-Mississinewa River, 25-Porter Creek-Mississinewa River, 26-Jordan Creek-Mississinewa River, 27-Gray Branch-Mississinewa River, 28-Little Mississinewa River.

RELATIONSHIP BETWEEN POUNDS OF NITRATE/TOTAL PHOSPHORUS AND CROPLAND PERCENTAGE

Because the Export Coefficient Model is a simple model and has only one input (agricultural land), rankings for subwatershed nutrient loading are consistent with rankings for each subwatershed's percentage of agricultural lands. In other words, watersheds with the highest percentages of agricultural lands have the highest nitrate loading estimates. Based on preliminary research from the On-farm Network/Infield Advantage (which includes farms in Delaware and Randolph Counties) 80% of producers are applying nitrogen rates on corn cycles at "optimal" levels. This data came from guided stalk sampling (GSS), an assessment method that measures nitrogen content in cornstalks that have reached black layer (i.e. maturity). Results tell producers if their nitrogen inputs were low (<250 ppm), marginal (250-1,000 ppm), optimal (1,000-2,000 ppm), borderline (2,000-4,000 ppm), or excessive (>4,000 ppm). Due to widespread adoption of industry standards and application rates provided by agricultural research institutions like Purdue University, it is likely that On-farm Network/Infield Advantage producers are representative of the region as a whole. Water quality results (discussed further in Section 8, *Current Water Quality*) showed elevated levels of nitrate in subwatersheds with higher percentages of agricultural lands (Figures C.6 and C.7 in Appendix C). This does not suggest that producers in these subwatersheds are deviating from the industry standards and applying "excessive" rates of nitrogen; rather, it simply reflects the higher percentage of cropland in these subwatersheds. The use of a subwatershed sampling program to identify "outliers," or farms contributing "excessive" nitrogen, would be difficult due to the low percentage of acres estimated to be in this range ("excessive") relative to the whole of the watershed.

TABLE 3.8 | Nitrate contribution by watershed

Subwatershed	Urban (ton/yr)	Forest (ton/yr)	Crops (tons/yr)	Pasture/ Grass (ton/yr)	Total Tons/ Yr	Ton/Yr/Ac
Little Deer - N	4.32	0.32	109.33	0.42	114.41	0.0069
Porter - N	2.61	0.47	70.57	0.74	74.41	0.0067
Bear - N	1.90	0.55	65.15	1.23	68.84	0.0067
Gray - N	0.77	0.25	21.94	0.06	23.03	0.0066
Barren - N	4.56	0.55	82.67	0.77	88.56	0.0067
Days - N	2.23	0.88	69.19	0.34	72.65	0.0066

TILLAGE TRANSECT DATA

Another agricultural concern is the increase of sediments to waterways. Sediment causes an increase in levels of TSS. TSS levels above 25 mg/L can harm aquatic life. A previous study from the White River Watershed Project, conducted on Buck Creek in 2011, suggested that instream sources of sediment as a result of unstable stream channels are the highest source of sediment to rivers (other than construction). This study was conducted in Delaware County; it is located near the UMRW. However, another major source of sediment to waterways is surface erosion from farm fields. This is especially true for farm fields that have more sloping terrain (as identified in Section 3.3, *Subwatersheds and their geomorphological analysis*, on p. 41); farm fields adjacent to waterways that do not have filterstrips, buffers, vegetation and other types of stabilization/filtration practices (Figures 3.3-3.4 on p. 47 and Appendix B, Figure B.6); and farm fields on which conventional tillage rather than conservation tillage is used. It is believed that conservation tillage has more potential than any other agricultural BMP to reduce soil erosion, improve water quality, and promote long-term productivity of soils in intensive cropping systems.[18] Table 3.10 below depicts the correlation between percent residue cover and soil loss. County transect data was collected in 2014 by the NRCS in partnership with local SWCDs; Table 3.9 below shows how counties within the UMRW rank among other counties in the state for no-till.

TABLE 3.9 | No-till by county

County	Corn No-till State Rank (out of 92 counties)	Percentage of Corn Acres in No-till	Bean No-till State Rank (out of 92 counties)	Percentage of Soybean Acres in No-till
Grant	73	8%	79	36%
Blackford	83	6%	52	55%
Delaware	49	20%	35	63%
Jay	53	17%	60	49%
Randolph	24	35%	17	71%
Darke	NA	NA	NA	NA

TABLE 3.10 | Conventional tillage loss

Percent Residue Cover	Soil Loss (tons/ac)
0	12.4
41	3.2
71	1.4
93	0.3

Generally, cultivated fields are separated into four major categories: conventional tillage, reduced tillage, mulch tillage, and no-till (strip-till/ridge-till). When 0-15% residue cover exists after planting it is considered conventional tillage. Reduced tillage systems provide 16-30%. Mulch and no-till systems leave 30% or greater residue cover. Agricultural BMP's that reduce soil erosion, improve water quality, and increase long-term productivity are most beneficial to be used with conventional tillage. Tillage transect data was obtained at the county and state level from the Indiana State Department of Agriculture (ISDA) for 2013. Figures C.8 through C.11 in Appendix C use a color gradient to show the relative percentages of conventional tillage among HUC 12 subwatersheds.

18 Hill, P. R., & Mannering, J. V. (n.d.). Conservation Tillage and Water Quality. Retrieved from Cooperative Extension Service, Purdue University: http://www.extension.purdue.edu/extmedia/WQ/WQ-20.html.

In 2013, the state average for no-till was 52% for beans and 23% for corn. Randolph County was the only county in the UMRW that exceeded state averages in 2013 for corn no-till, while Blackford, Delaware and Randolph exceed state averages for bean no-till in 2013.[19]

TABLE 3.11 | Cover crops per county, based on 2015 Tillage Transect Data for Indiana Counties and Darke County SWCD data for Darke County

County	Living Covers Planted in Corn (%)	Living Covers Planted in Soybeans (%)	Living Cover Planted (%), Previous Crop Not Specified
Blackford	1	8	NA
Delaware	3	3	NA
Grant	1	4	NA
Jay	10	12	NA
Randolph	3	6	NA
Darke	NA	NA	0.74

The Project Manager estimated sediment loss due to conventional tillage for each subwatershed by using the following equation: Acres cropland x Percentage of conventional tillage (from Tillage Transect Data) x Estimated soil loss per acre per year due to conventional tillage[20] = Estimated soil loss (from surficial runoff) for each subwatershed in ton/ac/yr. The highest estimated surficial discharge based on conventional tillage is shared by Grant, Blackford, and Jay Counties (Figure C.12, Appendix C). While Grant County has the highest percentage of conventional farming, it also has a lower amount of cropland compared to other subwatersheds due to an increase in urban areas and ecological areas relative to the rest of the watershed; this lowered the estimated sediment loss for this area. Due to the higher presence of hydric soils, and poorly drained soils, in these regions, it is likely that producers use conventional tillage practices as a means to dry soil. Regardless, while growers in these areas might not see the benefit in conservation tillage from a water management perspective, soil stabilizing practices like cover crops may benefit the region as a whole. Because of the more varied terrain identified in geomorphological studies (Section 3.3, p. 41), and the higher concentration of streams, there is greater risk for surficial runoff in these areas. Therefore, it is important that there is an increase in the use of best management practices like filter strips and grassed waterways are used to filter out the sediment in runoff.

COVER CROPS

Cover crop data is also collected during tillage transect surveys. According to the results for 2015, Jay County has the highest percentage of cropland planted in cover crops (10% in corn and 12% in soybeans) of all the counties within the UMRW. Blackford County ranks next (1% in corn and 8% in soybeans), followed by Randolph County (3% in corn and 6% in soybeans) and Delaware County (3% in corn and 3% in soybeans). Grant County ranks second to last (1% in corn and 4% in soybeans). Darke County ranks last. However, it should be noted that cover crop acres are not collected during tillage transect surveys in Ohio. The percentage of farmland planted in cover crops was based on acres planted through the EQIP program. Therefore, the percentage of cover crops reported here for Darke County is likely lower than actual.

SEDIMENT TRANSPORT AND PHOSPHORUS

Water quality results for total suspended solids (discussed further in Section 8.4, p. 127) show elevated levels of sediment in subwatersheds with higher percentage of conventional tillage and sediment transport potential. Phosphorus, which is a nonsoluable fertilizer which attaches to sediment for transport is also elevated in these same regions. Because major phosphorus sources also include septic systems and municipal overflows (also highest in this region) it is difficult to determine if elevated phosphorus is linked to sediment transporting fertilizer. If so, sediment transport potential, not included in the Simple Coefficient Model, would suggest that although producers are also likely applying phosphorus at standard rates, their phosphorus contribution to streams are higher due to their elevated contribution of sediment. Because of the more varied terrain identified in geomorphological studies (Section 3.3, p. 41) and the higher concentration of streams, there is greater risk for surficial runoff in these areas. Therefore, it is important that there is an increase in the use of best management practices like filter strips and grassed waterways; these practices are used to filter out the sediment-bound phosphorus in runoff.

HIGHLY ERODIBLE SOILS

Stakeholder's expressed concern for the lack of conservation tillage on watershed soils that are considered highly erodible. Highly Erodible Soils (HES) are highly susceptible to erosion based on multiple factors including, soil texture, slope gradient and length, and force of rainfall hitting the soil. They are characterized by the USDA with a tolerance and index value (the higher the value the more erodible the soil type). Special caution should be taken to minimize disturbance to highly erodible soils as these soils have a higher probability of being washed into streams and other waterbodies. Both crop production and construction can cause a high amount of disturbance of these soils. Highly erodible soils in the watershed comprise roughly 42% of the watershed. Map 3.6 shows the distribution of highly erodible soils in the watershed. Fig. 3.13 represents the relative concentrations of HES in each subwatershed. Methodology for determining HES can vary which may account for why Darke County has significantly less HES identified. Unfortunately, many subwatersheds with high concentrations of HES are also subwatersheds with poorly draining soils, increased terrain/sediment transport potential, and lower rates of conservation tillage. The presence of highly erodible soils accelerates the erosion potential in these subwatershed areas.

19 Indiana State Department of Agriculture. Cover Crop and Tillage Transect Data. http://www.in.gov/isda/2383.htm

20 Estimated at 10 tons/ac, based on results of RWEQ modeling (Revised Wind Erosion Equation) by Merrill et al., 1999.

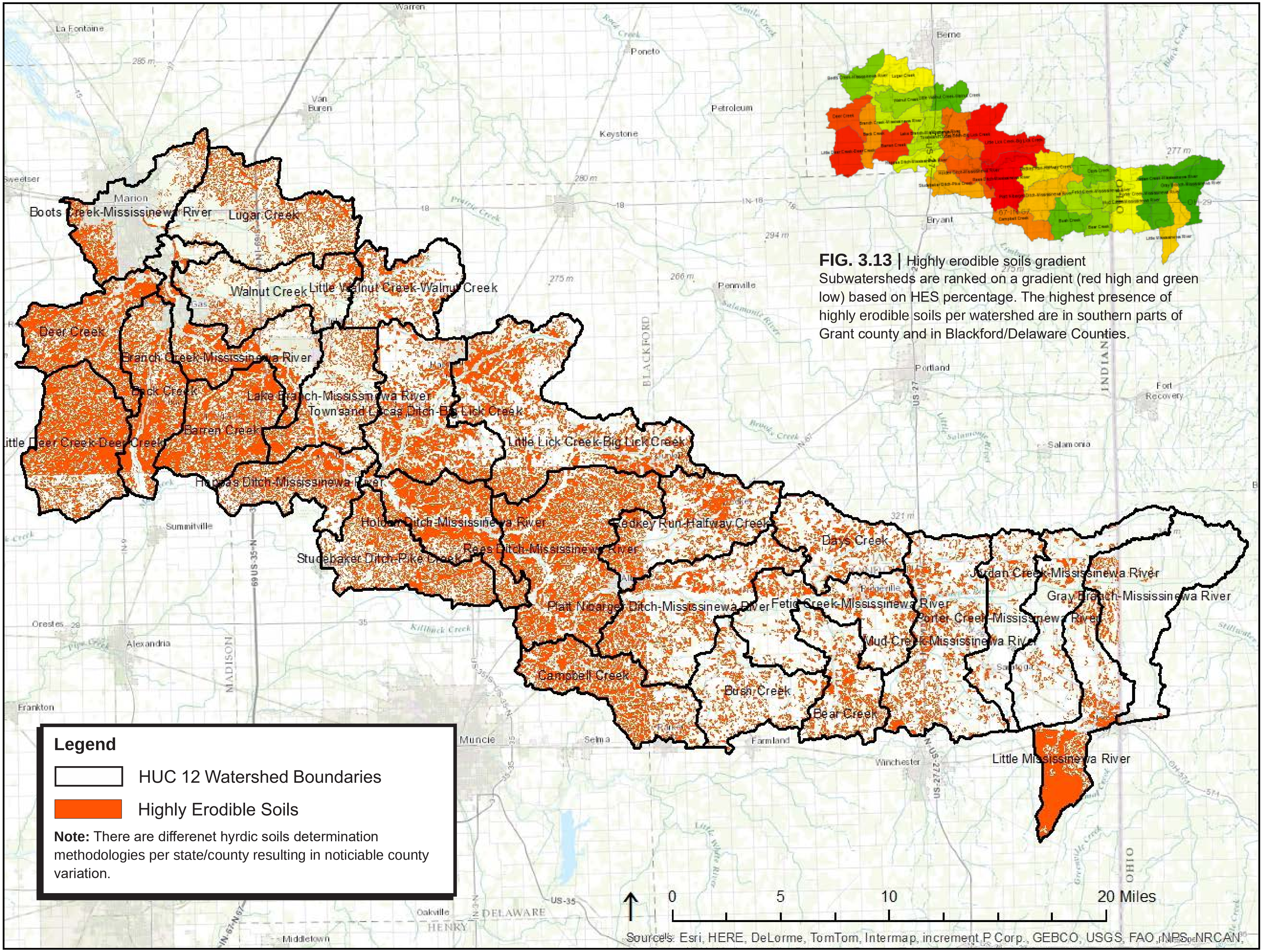


FIG. 3.13 | Highly erodible soils gradient
Subwatersheds are ranked on a gradient (red high and green low) based on HES percentage. The highest presence of highly erodible soils per watershed are in southern parts of Grant county and in Blackford/Delaware Counties.

MAP 3.6 | Highly erodible soils map

GROUND SURFACE EROSION

Areas that show the tendency to have repeated rill and gully formation were inventoried using the information gathered through a desktop survey completed by the Project Manager in 2015 using Google Earth. The process of uncovering this information included examining the oblique images from Google Earth (for areas that show rill and gully formation). As these images range from 2010 to 2014, they provide an extended time frame to observe areas with repeated erosion. The highest concentration of identified rill/gully locations (Figure 3.12) were in Blackford County (Little Lick Creek-Big Lick Creek and Townsand Lucas Ditch-Big Lick Creek) and Delaware County (Campbell Creek, Holden Ditch-Mississinewa River, Rees Ditch-Mississinewa River, and Studebaker Ditch-Pike Creek). Grant County had the lowest concentrations of rills and gullies, with the exception of Hoppas Ditch-Mississinewa River, which has concentrations similar to those found in Blackford and Delaware County (Figure 3.12). In the eastern part of the watershed, northern Randolph and southern Jay County also have high concentration of rills/gullies, as shown in Figure 3.11. This area of high concentration contains the subwatersheds of Halfway Creek and the very northern parts of Mud Creek, Porter Creek, and Jordan Creek.

Subwatersheds with high rill/gully erosion had higher rates of conventional tillage, higher percentage of agricultural lands, and higher amounts of HES. Lack of agricultural no-till practices BMPs and the erosion of agriculture fields and ditches in the watersheds cause excessive sediment and nutrient pollution that is degrading habitat and limiting use of the waterways for recreation, drainage, and aesthetic purposes. According to the 2015 Indiana tillage transect survey, many subwatersheds in the region have substantial amount of conservation tillage.

Sites having rill/gully erosion or other soil runoff draining directly into streams were also identified in the desktop aerial survey (Fig. 3.9 and 3.10). Higher relative concentrations of these sites in certain watersheds may be due to a large number of factors, including buffer presence and width, cropland percentages, rill/gully concentration, sloping terrain, conventional tillage, and HES soils. These sites were also identified on the windshield survey conducted by the Project Manager in April, 2016, which found that the inlets of many culverts crossing beneath roadways are lacking buffers. The Project Manager asserts that inlets of culverts leading directly to streams should be regarded as a streambank edge in cases in which sediment reaching these inlets is transported directly to streams. Grassed waterways or buffers could be beneficial in these areas.

LIVESTOCK

Livestock can also be a source of sediment in streams, as well as nutrients and pathogens. Livestock accessing streams can erode streambanks and stream bottoms. The Project Manager used Google Earth to identify sites where livestock are directly accessing streams in the watershed (Fig. 3.7 and 3.8). Hoppas Ditch and Big Lick Creek subwatersheds had the highest number of these sites.

Livestock manure that is spread on agricultural fields can also be a source of nutrients and pathogens to streams. The centralization of livestock into “combined feeding operations” (CFO) is another trend associated with the industrialization of agriculture; manure byproduct from these facilities is spread on fields to provide fertilization and to dispose of the manure. Although CFO waste-management systems are regulated by IDEM, stakeholders have persistent concerns regarding the distribution of manure through land application. Stakeholders are concerned that applicators are not following setbacks and other such requirements.

CFOs are found throughout the watershed, but are more highly concentrated in its eastern part. Fig. C.4 in Appendix C shows relative CFO concentrations throughout the watershed. Gray Branch and Jordan Creek have the highest concentration of CFOs in the watershed.

Smaller livestock producers that are not considered CFOs are also present in the watershed. However, there has been a reduction of pasture grazing in the watershed; few livestock grazing sites have been identified in the region through aerial imagery. There is a however a higher concentration of range livestock in Grant County and Northern Delaware County.

To further demonstrate the magnitude of CFO livestock production in the eastern part of the watershed, statistics from the United States Department of Agriculture were examined. We found that some of the most concentrated livestock production in the states of Indiana and Ohio is found in counties that portions of the UMRW are located within. According the the United States Department of Agriculture’s 2012 Census of Agriculture, Darke County, Ohio ranks 1st and 2nd in the nation for the number of pullets for laying stock replacement and layers, respectively. It also ranks 68th and 72nd in the nation for hogs and pigs and turkeys, respectively, and 2nd for both in the state.[21] Figure C.1 (Appendix C) is a heat density map showing the concentrations of CFOs in the state of Ohio. In Indiana, Jay County ranks 5th and 28th in the nation for the number of pullets for laying flock replacement and layers, respectively, and 1st and 4th in the state. Jay County also ranks fifth, fifth, and sixth in the state for turkeys, hogs and pigs, and duck production, respectively. Although only portions of these counties lie within the UMRW, these statistics demonstrate the intensity of livestock production in the general area.

21 https://www.agcensus.usda.gov/Publications/2012/Online_Resources/County_Profiles/Ohio/cp39037.pdf

AGGRESSIVE FARMING/LIVESTOCK LANDUSES
As demand, yield, and crop prices continue to rise, landowners have greater incentive to maximize farmable land. Crop insurance might be reducing the risk associated with attempting to farm marginal ground. In many cases marginal ground may be considered areas with poor drainage, high terrain, and highly erodible soils. According to the NRCS, promoting incentive programs that transition marginal farmground into conservation lands may help further reduce misallocation of land use. A framework developed for classifying land within the UMRW into a spectrum of farmable-nonfarmable is described in Section 3.6, *Wildlife and Ecology* on p. 66.

RESIDENTIAL, COMMERCIAL, AND INDUSTRIAL CONCERNS
A total of 9.7% of the watershed is developed, including commercial, industrial, and residential areas as well as developed open space. The projected population of the watershed area in 2014 was 84,947. The population has decreased by 6,300 residents since 2000. One major influence of the population decline is a decrease of jobs in the area; there were 3,000 jobs lost from 2000-2010. There is currently a Employee/Residential Population Ratio: 0.43:1. Factors driving the loss of population/jobs is the continued automation and centralization of farming operations and national trends influencing the globalization/automation of industry. In 2002, the manufacturing sector made up 28% of total primary jobs in the region; in 2011 it was down to 16.5%. Many of the industrial establishments and employment opportunities are located in the larger population centers (Marion, Hartford City, Upland). A general overview of trends that lead to the establishment and growth of these cities is included in Appendix D, Table D.2 and Figure D.7; a summary of ESRI LifeMode Groups is included in Table D.1

TABLE 3.12 | Employment in the watershed

Health Care and Social Assistance	18.60%
Manufacturing	16.50%
Educational Services	16.00%
Retail Trade	11.70%
Accommodation and Food Services	7.00%
Administration & Support	4.90%
Wholesale Trade	4.60%
Public Administration	4.30%
Construction	2.90%
Other	13.50%

TABLE 3.13 | 2010 populations

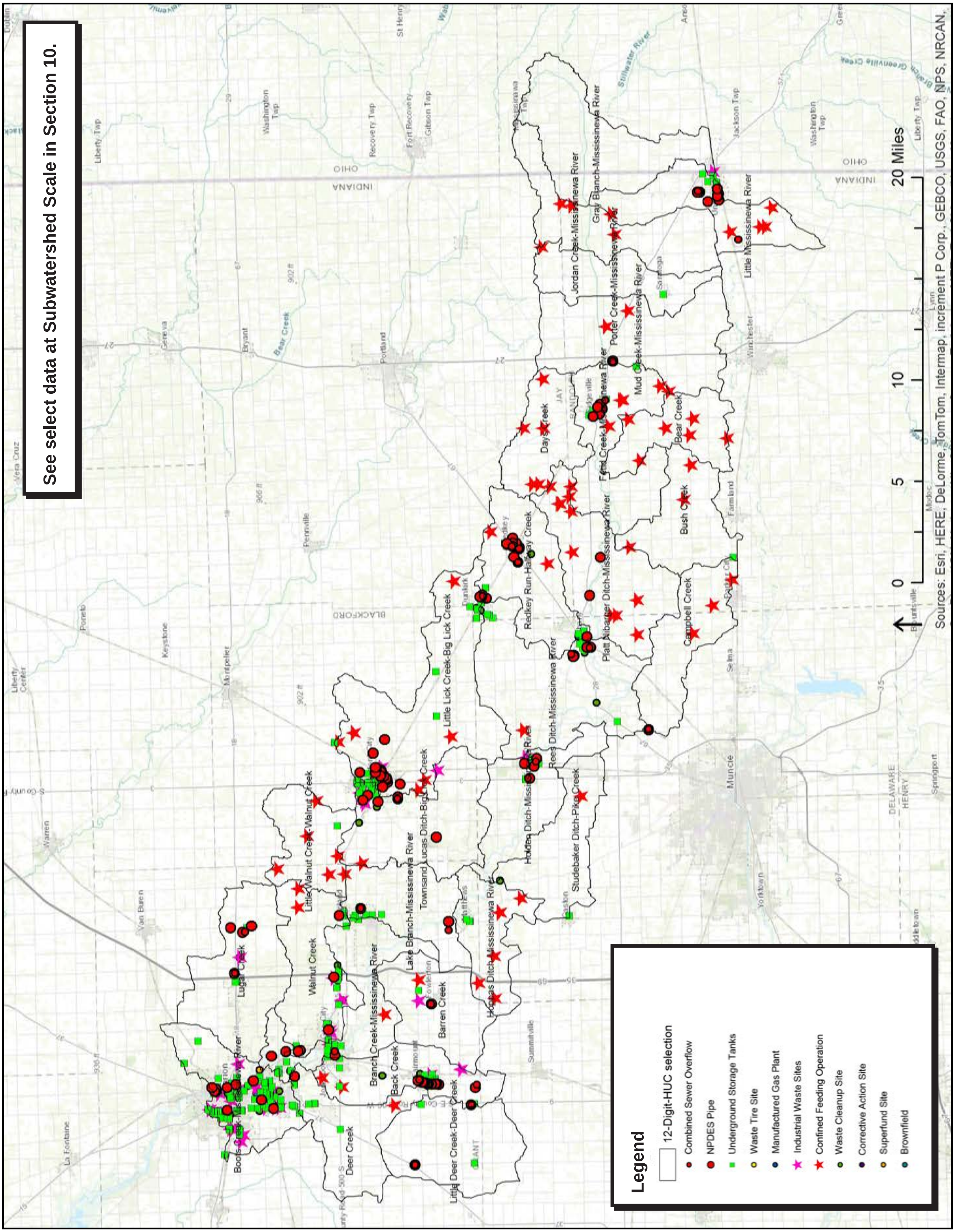
Town or City	Number of Persons
Marion	29,948
Hartford City	6,220
Gas City (Harrisburg)	5,965
Upland	3,845
Union City	3,584
Fairmount	2,954
Dunkirk	2,362
Albany	2,165
Ridgeville	803

POTENTIAL SOURCES OF POINT SOURCE CONTAMINATION
Stakeholder concerns in urban and other populated areas include industrial sources of pollutants, illegal dumping, and existing remediation sites. A number of potential point sources of contamination were identified within the Mississinewa watershed study area using Indianamap.org. Point source pollution is contamination that enters the environment through any discernible, confined, and discrete conveyance such as a smokestack, pipe, ditch, tunnel, or conduit. Point source pollution remains a major cause of pollution to both air and water. Point sources are differentiated from non-point sources, which are those that spread out over a large area and have no specific outlet or discharge point.[1] Point source pollution in the United States is regulated by the Environmental Protection Agency (EPA).

Map 3.7 on the following page shows the location of industrial sites in this region, including brownfields, cleanup sites, corrective action sites, institutional control sites, superfund sites, and underground storage tank sites. There are 129 leaking underground storage tanks, two brownfields, 35 institutional control landfills, seven voluntary remediation sites, three industrial parks, and 30 sites with NPDES wastewater permits located the UMRW. Blackford and Grant Counties have higher concentrations of these point sources. Stakeholder concerns associated with point source pollutants were found throughout the watershed but an especially high number were found in urban areas such Hartford City, Ridgeville, Albany, and Union City.

NATURAL RESOURCE EXTRACTION SITES
There are four active sand and gravel pits in the Mississinewa watershed: Fowler Sand & Gravel located on 500 East Road east of Granville, Shideler Pit located on 800 North Road south of Granville in the main river drainage, Jack Himelick Gravel Company located on 700 S near Upland, and Gas City Pit on Garthwaite Rd. There are also two active crushed stone pits: Meshberger Brothers Stone Corporation located on St Rd 28 near Ridgeville and US Aggregates Inc. located south of St Rd 28 and west of St Rd 1 on 1000 W (near Fairview). There are 77 abandoned sand and gravel pits in the watershed and there are 10 abandoned quarries in the watershed. There are also several petroleum sites in the Mississinewa watershed, including 25 active gas well and 43 active oil wells. There is also 1,631 abandoned gas and oil wells and 257 dry holes. There are an additional 1,666 speculative abandoned wells based on old maps.

1 United States EPA. [web page] What is Nonpoint Source? https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/what-nonpoint-source [Accessed 1 June 2016].



MAP 3.7 | Regulated point sources in watershed

CSOs
National Pollution Discharge Elimination System (NPDES) sites located in urban areas, especially combined sewer overflows (CSOs), are of concern by stakeholders for their impact on water quality. Sometimes, during heavy rain and snow storms, combined sewers receive higher than normal flows. Treatment plants are unable to handle flows that exceed design capacity and when this occurs, a mix of excess stormwater and untreated wastewater discharges directly into the waterways at certain outfalls. This is called a combined sewer overflow (CSO). Stakeholders are concerned about CSOs because of their effect on water quality and recreational uses. CSOs are also a source of phosphorus and nutrients (found in human waste). The most CSOs are located in Fairmount and Hartford City. Table 3.14 below shows subwatersheds containing CSOs and the number of CSOs per subwatershed is represented in a gradient figure in Appendix D, D.14.

TABLE 3.14 | CSOs located in watershed

Subwatershed, City	# of CSOs
Back Creek, Fairmount	16
Little Lick Creek-Big Lick Creek, Hartford City	12
Redkey Run-Halfway Creek, Redkey	4
Townsand Lucas Ditch-Big Lick Creek, Hartford City	3
Fetid Creek-Mississinewa River, Ridgeville	3
Boots Creek-Mississinewa River, Marion	3
Holden Ditch-Mississinewa River, Eaton	2

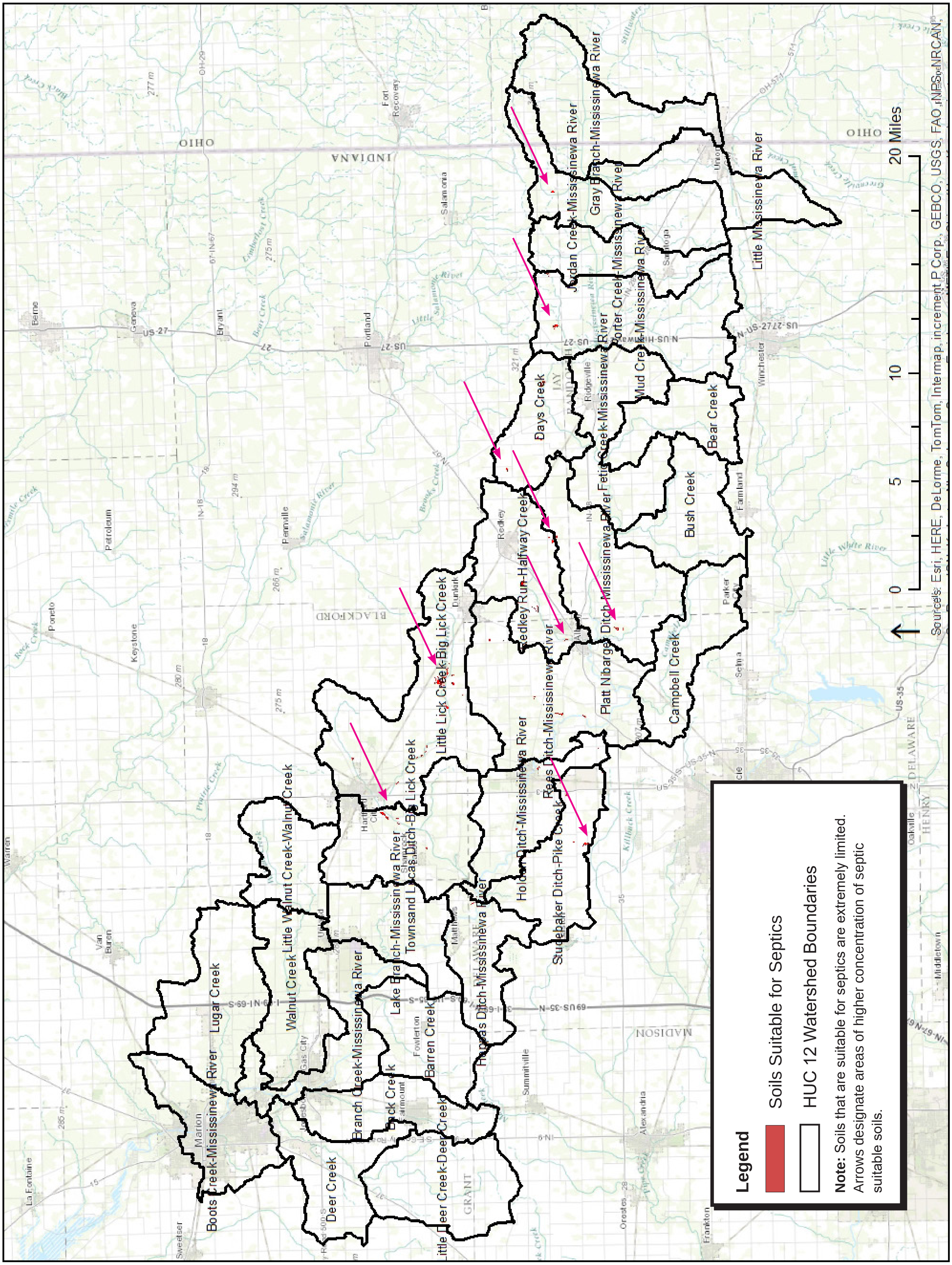
SEPTIC SYSTEM SUITABILITY
Septic systems are another source of E. coli and nutrients to waterways. Septic systems provide on-site sewage treatment for individual properties in the watershed. They are comprised of a septic tank that settles solids and a leach field that filters and treats effluent. As water released from leach lines percolates through the soil, pathogens and nutrients are removed. However, soils differ in their ability to effectively filter and treat effluent. Based on soil properties, soils are rated on their suitability for on-site septic systems. The majority of soils in the UMRW has poor septic tank suitability; less than 0.1% of the land is suitable for septic systems (Map 3.8, p. 63). Therefore, it is predicted that there are numerous rural and suburban houses with failing septic systems throughout the UMRW. Unfortunately, this leads to the release of hundreds of gallons of untreated wastewater from failing on-site septic systems annually. Prior to the early 1980's, soil suitability was not considered prior to the installation of on-site septic systems.[1] Soils that are unsuitable for traditional septic systems require alternative septic systems (such as mound septic systems) which are usually expensive and may require that appropriate soils be brought from off-site for their construction. Additional steps and procedures, such as regular pumping of septic tanks, must occur on poor soils in order to ensure that septic systems function at the optimal level the soil allows.

SEPTIC SYSTEMS WITHIN THE WATERSHED
Residences and businesses in non-incorporated areas of the watershed use septic systems to treat wastewater. There are multiple areas in the watershed where failing septic systems are suspected. There are many unsewered communities in the watershed with over 100 residences in close proximity. These suburban landscapes/concentration areas are 41,036 acres in total (roughly 10% of the watershed) and in many cases are located in proximity to incorporated areas (Map 3.9, p. 65). Some of these high density unsewered areas are mobile home sites (these sites were identified through a desktop aerial survey). The Project Manager identified high concentrations of households outside of incorporated areas and represented them in a heat map (Appendix D, Figure D.10). An estimated number of septic systems was also generated for each subwatershed using population numbers in unincorporated areas and the average household size for the area (Appendix D, Figure D.15).

WELLHEAD PROTECTION
"The IDEM Ground Water Section administers the Wellhead Protection Program, which is a strategy to protect ground water drinking supplies from pollution. The Safe Drinking Water Act (42 U.S.C. §300f et seq. (1974)) and the Indiana Wellhead Protection Rule (327 IAC 8.4-1) mandates a wellhead program for all Community Public Water Systems. The Wellhead Protection Programs consist of two phases. Phase I involves the delineation of a Wellhead Protection Area (WHPA), identifying potential sources of contamination, and creating management and contingency plans for the WHPA. Phase II involves the implementation of the plan created in Phase I, and communities are required to report to IDEM how they have protected ground water resources."[2] There are 17 wellhead protection areas in the UMRW. Thirteen of these are for municipal water supplies. The remaining four are for mobile home communities. A list of these 17 wellhead protection plans can be found in Section 4.2, *Local Government Planning Efforts*, on p. 82. A gradient map of well locations throughout the watershed is located in Appendix D (D.13).

1 Lee, Brad and Don Jones. 2004. Grandfathered Septic Systems: Location and Replacement/Repair. Purdue Extension. HENV-6-W.
2 Indiana Department of Environmental Management. Water Quality in Indiana: Wellhead Protection Program. http://www.in.gov/idem/cleanwater/2456.htm

TABLE 3.15 | Estimated number of septic systems in watershed, organized by HUC12		
Subwatershed	HUC	Estimated Septic Systems
Big Lick Creek	512010303	
Townsand Lucas Ditch-Big Lick Creek	51201030302	83
Little Lick Creek-Big Lick Creek	51201030301	771
Halfway Creek-Mississinewa River	512010302	
Redkey Run-Halfway Creek	51201030205	36
Platt Nibarger Ditch-Mississinewa River	51201030206	390
Bush Creek	51201030204	247
Bear Creek	51201030202	117
Fetid Creek-Mississinewa River	51201030203	267
Days Creek	51201030201	106
Headwaters Mississinewa River	512010301	
Little Mississinewa River	51201030101	60
Gray Branch-Mississinewa River	51201030102	753
Mud Creek-Mississinewa River	51201030105	438
Porter Creek-Mississinewa River	51201030104	279
Jordan Creek-Mississinewa River	51201030103	229
Massey Creek-Mississinewa River	512010305	
Hoppas Ditch-Mississinewa River	51201030501	167
Lugar Creek	51201030509	901
Branch Creek-Mississinewa River	51201030510	2007
Deer Creek	51201030508	287
Walnut Creek	51201030506	614
Little Walnut Creek-Walnut Creek	51201030505	145
Back Creek	51201030504	868
Little Deer Creek-Deer Creek	51201030507	283
Barren Creek	51201030503	237
Lake Branch-Mississinewa River	51201030502	442
Boots Creek-Mississinewa River	51201030511	4880
Pike Creek-Mississinewa River	512010304	
Rees Ditch-Mississinewa River	51201030402	1191
Holden Ditch-Mississinewa River	51201030404	363
Studebaker Ditch-Pike Creek	51201030403	131
Campbell Creek	51201030401	391



MAP 3.8 | Septic suitability map

URBAN SOURCES OF NUTRIENT POLLUTANTS IN URBAN AREAS

Urban and suburban fertilizer application poses another threat to water quality. Public perception of the beauty of green, well-manicured lawns frequently results in significant quantities of fertilizer being applied by homeowners and managers of recreational facilities such as golf courses and athletic fields. These fertilizers often contain nitrogen and phosphorus and are likely applied by homeowners adjacent to stormwater retention ponds as well as recreational facilities directly adjacent to the Mississinewa River and its tributaries. Pet waste is also a concern in populated urban areas because waste from animals can contain pathogens that pollute water. Areas of high population density are suspected to have the highest source potential.

SPRAWL / POPULATION CHANGE

A watershed-wide analysis of population trends shows slight overall decline in population. However, areas of eastern Grant County near Upland and Gas/City, as well as stretches of land adjacent to the Mississinewa river, are showing population increases (see Appendix D, Figure D.17). The phenomenon of sprawl, in which urban footprint growth exceeds population growth, is a concern of landowners. Sprawl threatens agricultural land and the limited ecological resources that remain in the area. In addition, unnecessary development also increases impermeable surface in the watershed, consequently resulting in greater runoff volumes and higher pollutant concentrations. Research has found that when 12% of the watershed consists of impervious surfaces, stream quality impairments are seen; severe impairments are seen when 30% of the watershed consists of impervious surfaces.[1] There is a total of 8,237 acres of impervious surface classified in the watershed. Stakeholders are concerned that continued development (especially along the Mississinewa River) will increase septic systems in the area, increase impervious surface, and compromise floodplain agricultural/ecological resources. As roads continue to be a significant backbone of industrial connectivity in post-WWII America, contemporary road infrastructure/improvement projects continue to impact East Central Indiana. A new manufacturing corridor is emerging along State Road 24 and may lead to growth of industrial communities like Marion and Hartford City. Sprawl should be avoided if possible due to its detrimental impacts to water quality.

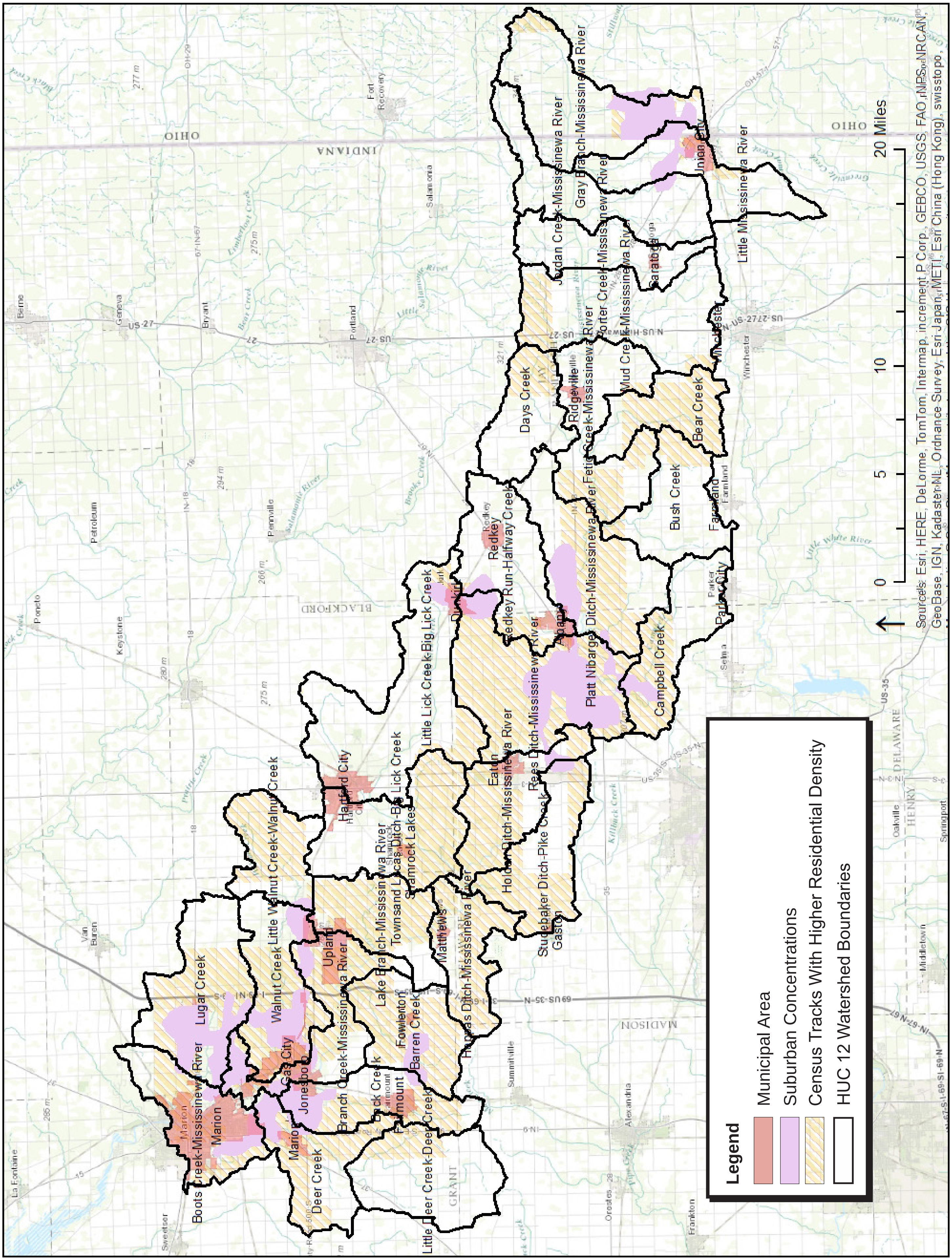
OTHER SUBURBAN POINT SOURCES

The Project Manager identified sites throughout the watershed that were characteristic of rural/sprawling areas. This includes junk storage sites, vehicular storage sites, construction waste storage sites, and sites where these land-use activities were near a waterway (direct access sites). These sites may not be considered landfill or waste sites, as defined and regulated by IDEM, but they are point sources that are potential sources of pollution to waterways. The Project Manager will report findings to Health Departments and Regional Waste Districts with the highest concentrations of these sites that are near small towns and areas of higher population density (Dunkirk, Albany, Ridgeville).

DEMOGRAPHICS

Population growth is most significant in areas east of Marion/Gas City and south of Upland. Additional growth is occurring in unincorporated sprawling areas identified in Figure D.17 (Appendix D) near Albany, Eaton, Desoto, and Redkey (specifically in areas northwest and west of Albany). These two areas of growth also tie to the two highest ranked SuperZips in the watershed (Upland, 67 and Albany, 45). SuperZips are trending areas in the country that are experiencing a trend toward enclaves/conglomerations of residents with higher income and education. The SuperZip classifications also loosely correlates to ESRI's tapestry segmentation. ESRI classifies the greater Upland region residents as "Upscale" with the highest concentration of residents with upper middle class incomes and higher education. Higher income earners are more likely to build new homes. There are a few factors that may be leading to development in these areas: (a) the tendency for new homeowners to desire to build rural homes next to ecological features such as the Mississinewa River, (b) the growth area east of Marion and west of Upland has the highest concentration of cultural amenities outside of Marion, (c) residents with higher education desire to live in proximity to college institutions (at Taylor University) and engage in high intensity leisure activities like sport biking (on the Cardinal Greenway bike trail) and/or long-distance canoeing (on the Mississinewa River), and (d) there is a tendency for new construction to occur in proximity to other new construction. Table D.1 (Appendix D) compares major ESRI LifeMode Groups and gives a generic categorization of them and Figure D.2 (Appendix D) shows the distribution of these LifeMode Groups throughout the watershed.

1 Klein, Richard D. 1979. Urbanization and Stream Quality Impairment. Water Resources Bulletin. American Water Resources Association. Vol. 15, No. 4.



MAP 3.9 | Residential areas and density concentration map

3.6 WILDLIFE AND ECOLOGY

REMAINING ECOLOGICAL LANDS

Human habitation and agricultural development has had significant impact on the natural ecology of the Upper Mississinewa River Watershed (UMRW). The forest-wetland ecosystem which dominated the Central Till Plain Natural region (described in Section 3.4, *Current and Historic Hydrology*) has been all but eliminated. Despite the widespread transformation of the landscape for urban and agricultural resources, ecological lands do remain. Ecological lands refer to lands that are part of the native ecology of the region, such as forests, wetlands, and grasslands/pasture. According to NLCD data, approximately 1,942 acres of wetlands occur in the watershed (once estimated to be as great as 37 percent).[1] Remaining wetlands may be used for wildlife viewing as well as hunting. Forest resources make up approximately 29,702 acres. Individuals are concerned that too much forested land is being lost within the watershed and would like to see reforestation prioritized. Forest cover occurs adjacent to waterbodies throughout the watershed in non-contiguous tracts. Large lengths of the watershed streams no longer contain intact riparian cover.

CONSERVATION APPROACH

Despite the negative impacts of European culture on pre-existing natural resources, the region's agricultural resources and heritage are important to celebrate, protect, and enhance. There is very limited arable farmland that exists in the world, and as the global population continues to grow, it is important to maximize the potential of this important economic and life-sustaining resource. Therefore, the UMRW-P believes that any efforts to restore ecological lands in the region must be concurrent with an effort to preserve agricultural resources. In order to achieve this balance, the UMRW-P evaluates the restoration potential of farmland using the simplistic assumption that there are two primary types of land, (a) productive farmland (high productivity) and (b) marginal farmland (low productivity). Our objective is to preserve highly productive agricultural land for generations to come, and facilitate incentives to ensure that marginal farmground stays out of production (and in ecological uses). The Project Manager identified and ranked ¼ acre land parcels in the watershed for their production potential. By assigning a numeric ranking to these land parcels, using indicators such as soil type, hydrology, erodibility, wetlands, floodplain, and slope, the Project Manager was able to assess the degree of productivity and/or the suitability for conservation on a scale. This ranking helped the Project Manager to prioritize and target landowners and tailor education and outreach programs based on this land ranking system.

NON-FARMABLE LANDS | GREATEST ECOLOGICAL POTENTIAL

Using the productive/marginal ranking, watershed planners have identified the greatest potential for long-term conservation in Reese Ditch, Holden Ditch, and Little Lick Creek subwatersheds (Figure 3.14). A large factor driving the Big Lick Creek region are the high concentration of D, C, and hydric soils, while Reese Ditch and Holden Ditch were predominantly driven by bottomland/floodplain areas. The already existing elevated levels of ecological lands in Lugar Creek, Lake Branch, and Branch Creek mean the potential for an enhanced ecological corridor in that region. Stakeholders desired to see long-term conservation tied with enhanced recreational opportunities.

HUB AND CORRIDOR CONSERVATION

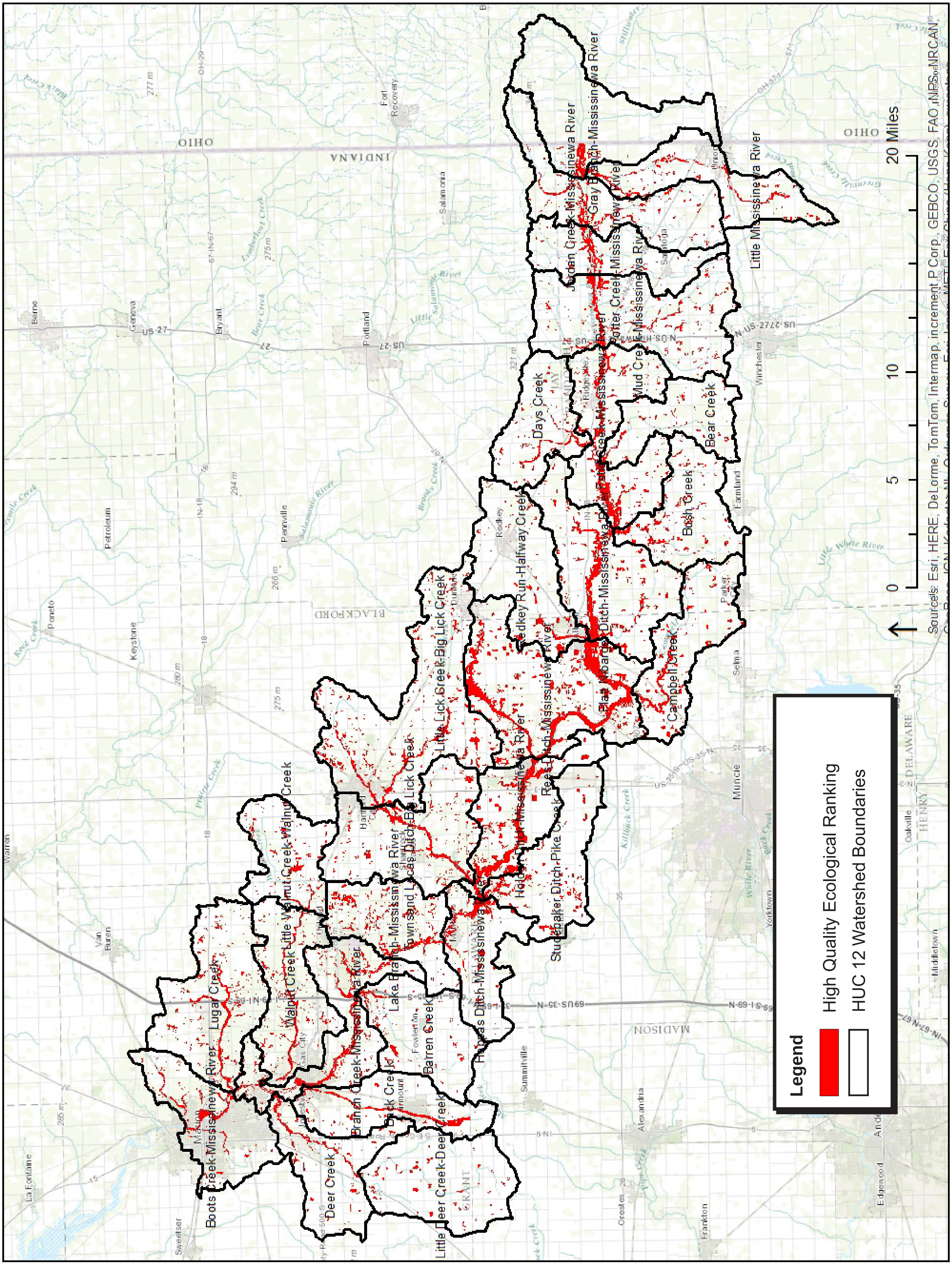
Ecological lands that do remain are typically found along streams and stream collection zones. Not only do these corridors have an important wildlife function, but they are the best BMPs for filtration and buffering against non-point source pollutants. Expanding/enhancing existing ecological lands along floodplains/corridors will establish an important backbone for an effective "hub and corridor" conservation strategy. Map 3.10 shows were ecological lands currently exist in the watershed. Figure 3.15 on p. 69 shows the concentration of ecological lands at a subwatershed level.

REMAINING WILDLIFE

The reduction of ecological habitat has a concurrent effect on wildlife. Many aquatic and terrestrial species of have gone extinct from the region due to human impacts. Species that do remain span the gamut of native, non-native, invasive, or noxious. Changes in the landscape has resulted in increased habitat for invasive urban waterfowl using retention ponds and other developed areas adjacent to streams. Stakeholders are concerns about contribution of animal waste (and bacteria impairments from these sources. The Indiana Natural Heritage Data Center database, maintained by the Indiana Department of Natural Resource Division of Nature Preserves, maintains a list of endangered, threatened, and rare species by county[2] (Tables F.1 through F.7 in Appendix F). The state of Indiana uses the following definitions for classification of species:[3]

> "*State-Endangered:* Any species whose prospects for survival or recruitment within 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."
>
> "*State-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. Species currently known to have six to twenty occurrences in the state are considered threatened.
>
> *State-Rare:* Any species that is rare or uncommon but not immediately threatened. Species currently known to have from 21 to 100 occurrences in the state.

1 37% of the watershed has soils that are identified as hydric. We are assuming that wetlands were responsible for the development of these soils.
2 Indiana Department of Natural Resources. Endangered Plant and Wildlife Species. http://www.in.gov/dnr/naturepreserve/4725.htm
3 Indiana Department of Natural Resources. Indiana Endangered Species. http://www.in.gov/dnr/fishwild/7662.htm



MAP 3.10 | Projected long-term ecological areas

Species falling into these categories with the UMRW include 9 species of mollusks, 5 reptiles, 6 birds, 3 mammals, and 8 plants. Of these, four are federally listed as endangered: the Indiana Bat (Myotis sodalist), the Northern Riffleshell Rangiana (Epioblasma torulosa), the Clubshell (Pleurobema clava), and the Running Buffalo Clover (Trifolium stoloniferum).

FEDERALLY ENDANGERED SPECIES

Identifying, protecting, and restoring endangered and threatened species is the primary objective of the U.S. Fish and Wildlife Service's endangered species program. Four species found within the Upper Mississinewa River Watershed are federally endangered species. A description of each is included below for educational purposes (while there are two endangered mollusks in the watershed, only a general description of mollusks is included). For a comprehensive list of State and Federally endangered species found in the entire watershed, see Appendix F, Table F.1. All state and federal listings by county can also be found in Appendix F (Table F.2-F.7). We belive that the five federally endangered species are the most important species of concern.

INDIANA BAT

"The Mississinewa River watershed is within the range of the federally endangered Indiana bat (Myotis sodalis). Indiana bats are found in the cavernous limestone areas of the Midwestern, southern, and eastern United States. This range extends from the Ozarks of Oklahoma in the west, north to southern Wisconsin, as far east as Vermont, and as far south as northern Florida. During their winter hibernation, they are found throughout the Ohio Valley but are absent from southern Michigan, northern Indiana, and south of Tennessee (Thomson, 1982). In winters, Indiana bats live in caves and mines that are appropriate for hibernation, with a cool, stable temperature. In spring, females migrate north from their hibernacula and form maternity colonies in predominantly agricultural areas of Missouri, Iowa, Illinois, Indiana, and Michigan. These colonies, consisting of 50 to 150 adults and their young, normally roost under the loose bark of dead, large-diameter trees throughout summer; however, living shagbark hickories (Carya ovata) and tree cavities are also used occasionally (Humphrey et al. 1977; Gardner et al. 1991; Callahan 1993; Kurta et al. 1993). Normally, Indiana bats leave the hibernation sites from April to June (Thomson, 1982). In the summer, males and females live apart from each other, with the females forming nursery colonies in hollow trees or under bark. Indiana bats leave their roosts about a half an hour after sunset to forage. They prefer to forage near the canopy in dense forests. (Kurta, 1995). Karst topography in Indiana is located in the lower third of the state; therefore it is not believed that there are any over-wintering sites within the Mississinewa River watershed. Indiana bats may forage and breed within the watershed, however."[4]

MOLLUSK - BIVALVIA (MUSSELS)

"Ninety-nine percent of the documented extinctions in mollusks are of non-marine (terrestrial and freshwater) species. Although much more research has to be carried out to document population declines and identify with certainty their definitive causes, there is increasing evidence suggesting that human activities are directly related to the declines [....] Scientists are pointing to two main, but not exclusive, potential culprits: (1) direct habitat destruction by human activities, such as forest clearing, dam construction, and pollution (2) introduction of non-native or exotic species, intentional or not."

"Mollusk species have their own habitat preferences. Some are restricted to certain types of woodland and forests; others live in grasslands, wetlands, certain types of rivers and lakes [....] Direct destruction of some of these habitats—because of agricultural and urban development and habitat transformation resulting from dam construction and water pollution—are important causes of mollusk population declines. Most freshwater mollusks species are highly sensitive to water quality partly because of their permeable skins and because they need a good oxygen supply. There are reported cases of species disappearing in association with the acidification of water. Among the species most vulnerable to pollution are the freshwater mussels (unionids), because their parasitic larval stage is dependent on fish hosts. This group of species reaches its peak of diversity in North America. At present, only about a quarter of the host fish for the mussels in the USA have been properly identified. Therefore it is difficult to predict the impact that pollution and habitat transformation due to damming and pollution might have on these freshwater bivalve populations."[5]

TRIFLOIUM STOLONIFERUM - RUNNING BUFFALO CLOVER

"Running buffalo clover is a federally endangered species [....] Running buffalo clover is a perennial species with leaves divided into three leaflets. It is called running buffalo clover because it produces runners (i.e., stolons) that extend from the base of erect stems and run along the surface of the ground. These runners are capable of rooting at nodes and expanding the size of small clumps of clover into larger ones. The flower heads are about 1-inch wide, white, and grow on stems that are 2 to 8 inches long. Each flower head has two large opposite leaves below it on the flowering stem. Running buffalo clover flowers from late spring to early summer [....] Running buffalo clover may have depended on bison to periodically disturb areas and create habitat, as well as to disperse its seeds. As bison were eliminated, vital habitat and a means of seed dispersal were lost. [....] Clearing land for agriculture and development has led to elimination of populations, loss of habitat, and fragmentation of the clover populations that remain. Small, isolated populations of running buffalo clover are prone to extinction from herbivory, disease, and inbreeding [....] Invasive non-native species, such as white clover, garlic mustard, and Japanese honeysuckle out-compete running buffalo clover for moisture, nutrients, space, and sunlight. Non-native clovers are believed to have introduced diseases and insect predators [....] Natural succession has resulted in a loss of open woodlands and a reduction in running buffalo clover habitat. Excessive grazing directly kills plants through herbivory or trampling and can indirectly kill plants by degrading the habitat. Mowing may remove seed heads before seeds are mature but may help the clover by controlling competing vegetation."[6]

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4 Cedar Eden Environmental. 2009. Watershed Diagnostic Study of the Upper Mississinewa River Watershed, Phase III.

5 Parent, Christine E. [web page] The Global Decline of Mollusks. http://www.actionbioscience.org/biodiversity/parent.html. [Accessed 19 July 2016]

6 U.S. Fish and Wildlife Service. [web page] Running Buffalo Clover Fact Sheet. http://www.fws.gov/midwest/endangered/plants/runningb.html [Accessed 19 July 2016]

3.7 FUNCTIONAL USES OF THE RIVER

Although the primary function of the river may be an ecological function, the waters in the Upper Mississinewa River Watershed (UMRW) serve many other functions for both urban and agricultural areas. Many Mississinewa River subwatersheds receive water from wastewater treatment plants and storm sewer systems (Table 3.14, p. 61). Numerous streams in the UMRW function as a legal drain (a stream, ditch, or tile under the maintenance authority of a County Drainage Board) and have at some point been dredged and channelized, including portions of the Mississinewa River from the headwater to Ridgeville, Indiana. This channelization ensures drainage capacity of adjacent fields and ensure agricultural capabilities in the region. There are five dams in the watershed used for either discharging industrial by-products, municipal water intake, or sanitary waste assimilation. The Mississinewa River and its tributaries pass through some livestock pastures and these streams are used as water sources. Recreational fishing is a reported use by watershed residents. The Mississinewa is listed on the Indiana DNR canoeable streams list and is advocated by public recreational resources. Fishing and canoeing occur on the Mississinewa River and canoeing is common. Stretches of the river from Ridgeville, IN to State Road 1 are considered high quality fishing reaches by local enthusiasts. Healthy fish populations and the safeness for full-body water contact recreation are concerns expressed by watershed stakeholders. Rivers function naturally to process water and excess nutrients from natural features and land uses. Other uses may include: (1) Domestic (2) Agricultural irrigation (3) Industrial (4) Commercial (5) Power generation (6) Energy conversion (7) Public water supply (8) Waste assimilation (9) Navigation (10) Fish and wildlife (11) Recreational.

The main recreational use of the Mississinewa River in the sections of the river that the Project Manager surveyed by canoe appears to be fishing, canoeing, and kayaking. The 1998 DNR fisheries survey (Appendix G, p. A30) showed fishable populations of smallmouth and rock bass, suggesting that this recreational resource could provide further economic value to the communities in Delaware or Randolph counties if public access to the river with parking facilities were provided. The DNR public access program could provide assistance in acquiring and construction of more DNR boat ramp sites with support from local residents.

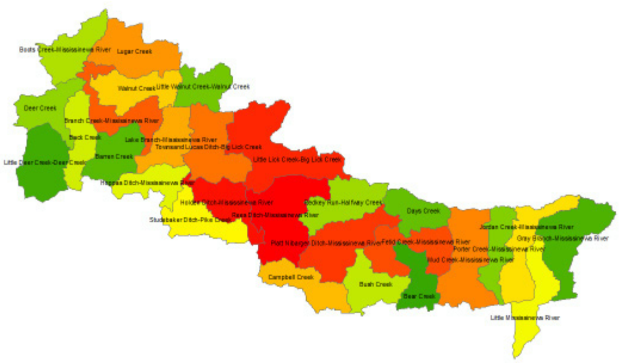


FIG. 3.14 | Ecological potential gradient

Subwatersheds are ranked on a gradient (red high and green low) based on % of ecological potential. Ecological potential refers to the amount of marginal farmland present. Marginal farmland is considered less productive due to a number of factors, including poor drainage and frequent flooding. Marginal farmland is prioritized over highly productive farmland for ecological restoration efforts.

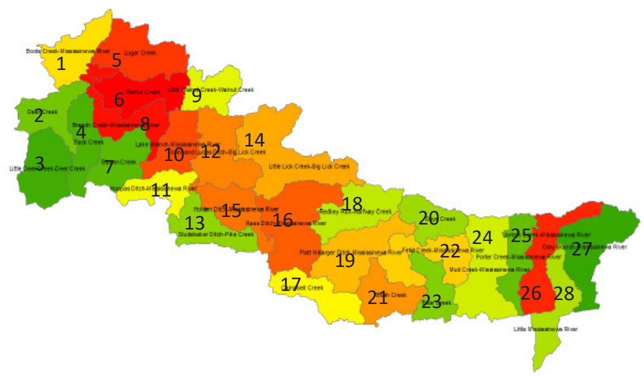


FIG. 3.15 | Ecological % gradient

Subwatersheds are ranked on a gradient (red with the highest percent and green with the lowest percent) based on the percent of existing ecological areas within them. Ecological areas are those containing forests, wetlands, or grasslands/ pastures. (See numeric Key below)

KEY | 1-Boots Creek-Mississinewa River, 2-Deer Creek, 3-Little Deer Creek-Deer Creek, 4-Back Creek, 5-Lugar Creek, 6-Walnut Creek, 7-Barren Creek, 8-Branch Creek-Mississinewa River, 9-Little Walnut Creek-Walnut Creek, 10-Lake Branch-Mississinewa River, 11-Hoppas Ditch-Mississinewa River, 12-Townsand Lucas Ditch-Big Lick Creek, 13-Studebaker Ditch-Pike Creek, 14-Little Lick Creek-Big Lick Creek, 15-Holden Ditch-Mississinewa River, 16-Rees Ditch-Mississinewa River, 17-Campbell Creek, 18-Redkey Run-Halfway Creek, 19-Platt Nibarger Ditch-Mississinewa River, 20-Days Creek, 21-Bush Creek, 22-Fetid Creek-Mississinewa River, 23-Bear Creek, 24-Mud Creek-Mississinewa River, 25-Porter Creek-Mississinewa River, 26-Jordan Creek-Mississinewa River, 27-Gray Branch-Mississinewa River, 28-Little Mississinewa River.

LOGJAM RESEARCH

The overwhelming concern expressed (on the comment cards and/or at public meetings) was about debris and logjams on the Mississinewa (and the subsequent flooding and erosion). The presence of logjams is a major factor limiting the functional usage of the river. Fetid Creek and Platt Nibarger Ditch had the highest response rate in the entire UMRW (49.78% and 22.27% response rate, respectively).

The Indiana General Assembly enacted legislation (IC 2-5-25-5) which directs a “Water Resources Study Committee (WRSC)” to study and make recommendations concerning all matters relating to the surface and groundwater resources of Indiana. In 2009 a major concern for the committee was logjams. The Committee heard testimony from government agencies, including the Indiana Department of Natural Resources and Indiana Department of Environmental Management and specifically Randolph County representatives including then Randolph County Commissioners Troy Prescott and Noel Carpenter, Randolph County Surveyor Ed Thornburg and local farmer Tim Acton. Each of these Randolph County representatives were vocal about the problem of logjams and described how they have been affected by the problem.

According to a 2009 press-release from the Indiana General Assembly, it was acknowledged that “for years, erosion has been a problem along the Mississinewa River in Randolph County, washing away the banks. For years, trees have toppled into the river, blocking the river’s flow and forcing the Mississinewa to change course. These course changes have led to flooded farm fields, yards and other property [...] the logjams continue to get worse and, because of government bureaucracy, no one will take responsibility or advise property owners about how to get theses messes cleaned up. This is not fair to residents whose property is being damaged....There are too many hands and too much confusion involved.”[1]

From 2009-2014, no action has been taken. The Randolph County SWCD, in collaboration with the LARE program, seeks to provide leadership and guidance for logjam removal in the area. The SWCD has identified the following factors leading to logjam issues on the Mississinewa River:

Geomorphology impacts to Logjams

Upstream of the project reach, the Mississinewa River (from the State Line to Ridgeville) has seen significant channel modification. In the 1950s, eight miles of this headwater reach were dredged and straightened. This has resulted in an increase in gradient, a higher velocity of stream flow, and both man-made and natural channel incision. Concurrent artificial drainage networks installed on adjacent farm fields (tiles, ditches etc.) has lead to an increase in peak discharge during storm events. Conversely, the stream reach from Ridgeville to Albany is relatively unaltered. Much of the pre-European/natural channel form and sinuosity is intact. The increased flows and velocity into this reach from upstream sources (150 sq mi, and adjacent watershed) is causing elevated bank stress and channel erosion during high-flow events. Persistent erosion/falling trees during these high-flow events have resulted in an increase of blockages/logjams, pooling backwaters, which has subsequently lead to sediment deposition (during low-flow events), and, in some instances, the formation of new channels. While sediment transport is a natural function of streams, the natural tendency towards equilibrium has been impacted by human activity/anthropomorphic hydromodifications (perhaps more so on this reach that other sections of the Mississinewa River).

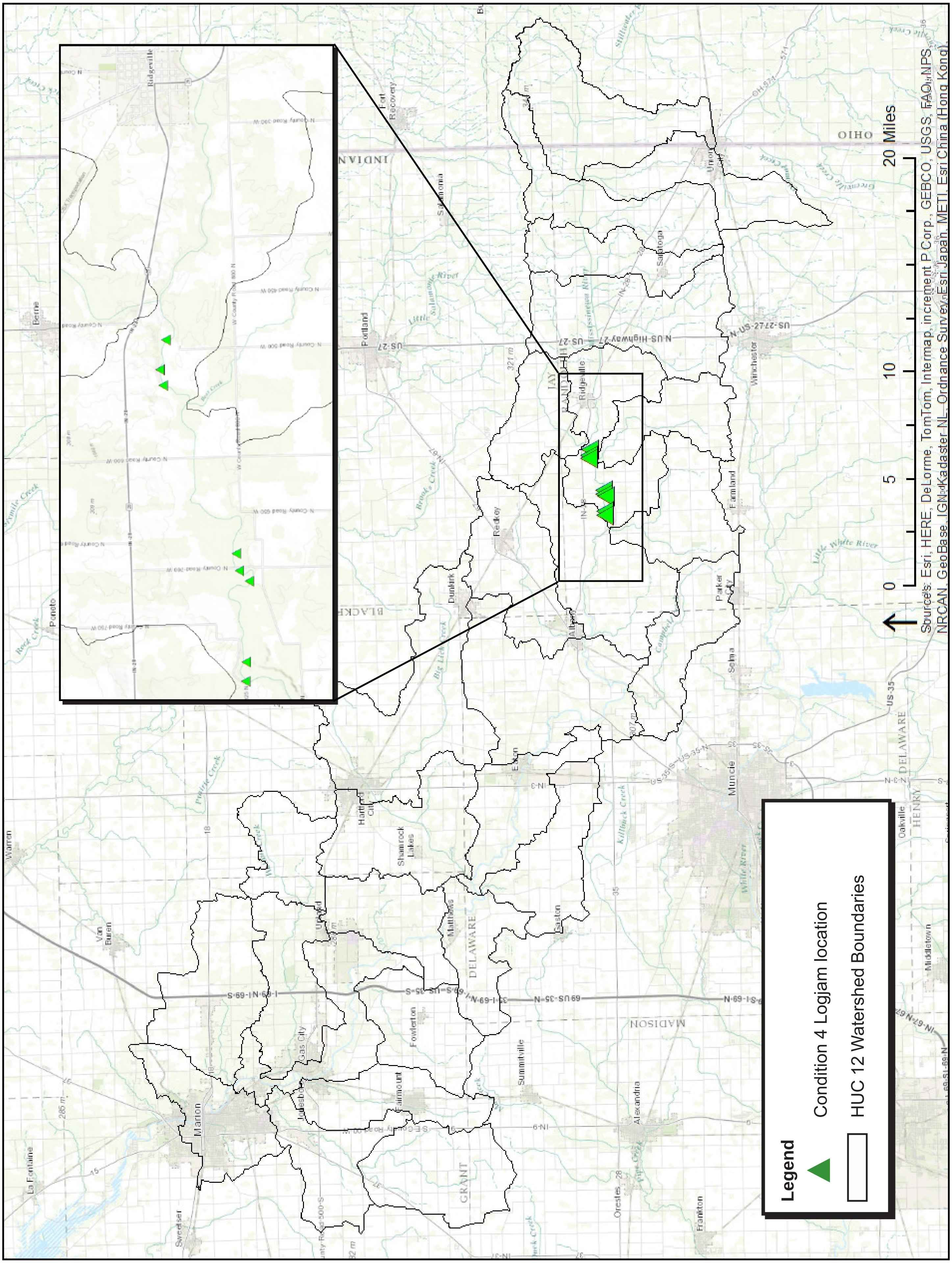
Also, the Mississinewa River, from the state line to the Reservoir, can be classified into regions based on topological characteristics. A 100 foot contour interval profile of the stream indicates that the project reach is in the flattest runs of the entire Mississinewa River. This would suggest a tendency for trees and debris to be more stagnant in this stream reach (relative to the rest of the Mississinewa River) and experience more limited debris transport during baseflow conditions. Many of the logjams have been present for 15 years or more.

Site Analysis

In the Summer of 2014, the UMRW Project Manager surveyed via canoe the LARE project reach (Ridgeville to Albany), and discovered 10 cross-channel logjams meeting at least Condition 3 classification (see Map 3.11 for locations of Condition 4 logjams and see Table 3.16 (p. 72)[2] for a general overview of the classification system). A number of Condition 1 and Condition 2 logjams were observed but funding was not sought for their removal in the LARE grant application (beaver dams were also not included in the application). There is no sediment buildup or debris collection behind Condition 1 and 2 logjams, indicating that their presence is not impeding water flow to the degree that other debris will drop out or catch on them and cause the logjam to increase in size. These Condition 1 and Condition 2 logjams may be naturally broken up and moved downstream during high flow events. Therefore, their mechanical removal may be a waste of funding. Condition 4 logjams are larger in size, and continue to catch debris. They are less likely to be broken up naturally by the force of the water, making mechanical removal necessary. In the fall of 2014, faculty and students in a BSU immersive learning class assisted the Project Manager in the further classification of logjams. Two of these logjams were classified as Condition 3 logjams and eight were classified as Condition 4 logjams. Students documented the Condition 4 logjams in the Mississinewa River with various media deliverables (video, photography etc.) and collected/analyzed upstream and downstream water quality data (found at http://waterqualityin.com/).

1 Stock, Tyler. 2009. [web page] Answer Needed: Who Fixes Log Jams? http://www.in.gov/portal/news_events/43581.htm [Accessed 19 July 2016].

2 Indiana Department of Natural Resources. [web page] Frequently Asked Questions. http://www.in.gov/dnr/water/files/wa-LogjamDebrisRemovalFAQs.pdf [Accessed 19 July 19].



MAP 3.11 | Locations of logjams identifed through surveys

TABLE 3.16 | Descriptions of the five logjam conditions, from the *Indiana Drainage Handbook*[1]	
Condition	Description
1	A single log located either in or across the waterway channel.
2	Two or more logs in or across the channel. The accumulated logs are interlocked, but there is no sediment build-up or debris collecting on in the channel at site.
3	Two or more logs in or across the channel. The accumulated logs are interlocked and sediment and debris have begun to collect on the jam. There is still water movement through the logjam.
4	Two or more logs in or across the channel. The accumulated logs are interlocked and sediment and debris have compacted into the logjam. There is no water movement through the logjam. The logjam acts as dam, holding back water within the channel; water movement is now through the overbank areas rather than the channel.
5	Logjam is located on a waterway within an area providing significant environmental benefit or within a critical area for fish spawning.

Logjam Impacts
At each of the Condition 4 logjam sites, there was evidence of backwater, flooding of adjacent fields, and/or the evidence of new channel formations. The widespread amount of debris and the 10 cross-channel logjams require excessive portage and compromise the stream's capacity to accommodate an adequate canoeing and fishing experience.

Biological Impacts
The elevated/unnatural levels of sediment are thought to be providing an adverse effect to aquatic life in the project reach. The increase sediment/erosion associated with the Condition 4 logjams likely offset any benefits from logjam habitat. Furthermore, (a) the presence of many Condition 2 logjams throughout the region, (b) the limited amount of floodplain development, and (c) the strong canopy/understory throughout the reach all are reasons to suggest logjam removal will not have an adverse effect on comprehensive QHEI/habitat scores/resources.

2005 Ice Storm
The Project Manager suspects that the 2005 icestorm may still be a contributing factor towards the large amount of debris in the Mississinewa River. Branch failure due to ice loading as well as complete failure of trees (i.e. ice loading impact to already eroding/leaning trees in the bankful region) likely have contributed or even established many of the older logjams in the reach (15 years old or greater).

Improper Maintenance
Some of the trees embedded in Mississinewa River logjams show signs of mechanical clearing. This suggests that landowners are attempting to deal with eroding trees themselves, but might not always be effective in getting the cut trees out of the floodplain. This further suggests a need for collaboration and funding to supplement landowner efforts to eliminate blockages.

Jurisdictional Issues
As mentioned by the Indiana General Assembly, there is confusion about whose responsibility the logjams are. Randolph County Surveyor Ed Thornburg has attended Randolph County/Upper Mississinewa River Watershed Project meetings and has helped the Project Manager understand the legal limits for surveyor involvement.

Action
A DNR LARE grant was awarded in 2014. The grant award was used to hire a contractor to remove eight Condition 4 logjams on the Mississinewa between Ridgeville and Albany. Removal of logjams started in July 2016 and was completed by August 2016. Removal equipment was run only on the banks of the river and did not enter the river. There were 106 dump truck loads of small debris and 30 semi loads of logs removed from the site. Disturbed areas of the banks were seeded with grass. The location of the eight Condition 4 logjams that were removed are shown in Map 3.11 on the previous page.

1 Christopher B. Burke Engineering, LTD. Indiana Drainage Handbook: An Administrative and Technical Guide for Activities within Indiana Streams and Ditches.

3.8 DESKTOP SURVEY

Additional desktop surveys were performed from December 2014 to February 2015 by the Project Manager using Google Earth. The following sites were identified, pinned on the map, and tallied in a spreadsheet: points where livestock are accessing streams, vehicular tracks, vehicular storage, construction storage, quarries, golf courses, sports facilities, derelict properties, rills/gullies, lawns, bank erosion, runoff sites, mobile home parks, miles of streams needing buffers, and junk storage. Tables 3.17-3.18 show the number of these sites identified in each subwatershed. Figures in Appendix E show the locations of these sites as well as the relative concentrations of them throughout the watershed. Figures 3.9 through 3.12 on p. 54 in Section 3.5 also show the locations and relative concentrations of rill/gully erosion sites and runoff sites.

TABLE 3.17 | Sites identified through desktop survey

HU_12_NAME	Rills/ Gullies	Rills/ Gullies per acre	Lawns	Sport Fields	Bank Erosion sites	Runoff sites	Junk storage sites	Livestock accessing stream sites
Back Creek	164	0.01	14	2	3	8	2	1
Barren Creek	179	0.01	1	0	5	7	1	1
Bear Creek	3234	0.29	6	0	9	21	0	6
Boots Creek-Mississinewa River	132	0.01	17	11	2	1	1	0
Branch Creek-Mississinewa River	206	0.01	43	7	15	10	1	2
Bush Creek	4074	0.29	30	3	3	21	0	6
Campbell Creek	8904	0.61	61	6	9	12	3	0
Days Creek	3618	0.30	9	0	0	9	9	0
Deer Creek	79	0.01	9	2	4	11	0	0
Fetid Creek-Mississinewa River	5596	0.30	24	3	3	3	6	0
Gray Branch-Mississinewa River	4076	0.18	18	6	12	21	0	0
Holden Ditch-Mississinewa River	8388	0.59	69	6	15	12	15	0
Hoppas Ditch-Mississinewa River	4524	0.39	24	6	6	24	15	27
Jordan Creek-Mississinewa River	5952	0.33	9	0	12	24	9	3
Lake Branch-Mississinewa River	473	0.03	19	2	5	3	1	1
Little Deer Creek-Deer Creek	77	0.00	2	1	3	19	2	1
Little Lick Creek-Big Lick Creek	18592	0.57	103	18	22	25	25	4
Little Mississinewa River	3144	0.22	48	6	6	33	15	0
Little Walnut Creek-Walnut Creek	431	0.04	7	0	0	8	0	0
Lugar Creek	209	0.01	21	1	12	12	3	0
Mud Creek-Mississinewa River	9084	0.37	21	3	12	69	12	9
Platt Nibarger Ditch-Mississinewa River	6404	0.30	37	0	3	15	6	3
Porter Creek-Mississinewa River	4206	0.35	21	3	9	18	12	0
Redkey Run-Halfway Creek	9806	0.56	30	6	3	24	18	6
Rees Ditch-Mississinewa River	13126	0.47	84	4	12	13	19	0
Studebaker Ditch-Pike Creek	5742	0.38	72	9	12	15	9	3
Townsand Lucas Ditch-Big Lick Creek	9256	0.44	47	1	15	27	10	9
Walnut Creek	416	0.03	31	6	10	10	3	0
Total	130,092	-----	877	112	222	475	197	82

Definitions | Rill/Gully Formation -The action of flowing water can be erosive as it cuts into the soil. Similar but smaller incised channels are known as microrills; larger incised channels are known as gullies. **Bank and Lake Erosion Sites** – Erosion sites on lake edges or large sections of river (where entire stretches are being sluffed off) are also significant sources of erosion. **Runoff** – Runoff sites are areas where rill/gullies or swales have direct access to a water body without a buffer or other form of BMP. This category also includes locations that appear to function as a river crossings (where machinery may have access to the stream).

Based on the desktop survey, subwatersheds with the highest number of rills/gullies per acre are located in the central part of the watershed. They include Big Lick Creek HUC 10, Pike Creek HUC 10, Halfway Creek HUC 12, and Hoppas Ditch HUC 12. A program promoting soil conservation BMPs would be appropriate in these areas. Subwatersheds with the highest number of livestock accessing streams were Hoppas Ditch HUC 12, Big Lick Creek HUC 12, and Mud Creek HUC 12. A program promoting livestock BMPs would be appropriate for the Blackford, Delaware, and Grant tri-county area. Subwatersheds with the highest number of lawns were in Big Lick Creek HUC 10 and Pike Creek HUC 10. We are making the assumption that at least some of these lawns are fertilized, and that the areas with the highest concentrations of lawns are more likely to have the highest occurrence of lawn fertilization. A program promoting lawn BMPs would be appropriate in these areas. These areas also have some of the highest numbers of sport fields and golf course.

TABLE 3.18 | Sites identified through desktop survey

HU_12_NAME	Mobile home sites	Tracks from recreational vehicles	Vehicle storage sites	Miles of tributaries needing buffers	Construction sites	Quarry sites	Golf Courses	Derelict properties
Back Creek	5	0	2	4	0	1	0	1
Barren Creek	1	0	1	0	0	0	0	0
Bear Creek	3	9	6	1	0	0	0	0
Boots Creek-Mississinewa River	0	1	0	3	0	2	1	8
Branch Creek-Mississinewa River	3	0	2	0	0	9	0	2
Bush Creek	0	3	0	2	0	0	3	0
Campbell Creek	0	0	0	2	0	3	0	0
Days Creek	0	0	0	2	0	0	0	0
Deer Creek	1	1	2	5	0	1	0	0
Fetid Creek-Mississinewa River	6	3	0	2	0	3	0	0
Gray Branch-Mississinewa River	0	3	0	4	0	0	0	0
Holden Ditch-Mississinewa River	12	6	21	0	0	3	3	0
Hoppas Ditch-Mississinewa River	0	0	9	3	0	0	0	3
Jordan Creek-Mississinewa River	3	0	9	6	0	0	0	0
Lake Branch-Mississinewa River	0	1	0	1	0	0	0	0
Little Deer Creek-Deer Creek	1	0	1	8	0	0	0	1
Little Lick Creek-Big Lick Creek	21	3	11	6	5	0	0	3
Little Mississinewa River	0	0	0	3	0	3	0	0
Little Walnut Creek-Walnut Creek	0	1	1	4	0	0	0	0
Lugar Creek	2	1	0	3	0	1	0	1
Mud Creek-Mississinewa River	3	3	9	20	0	0	0	0
Platt Nibarger Ditch-Mississinewa River	3	0	6	1	3	3	0	0
Porter Creek-Mississinewa River	0	3	6	6	0	0	0	6
Redkey Run-Halfway Creek	9	3	9	4	3	0	3	0
Rees Ditch-Mississinewa River	4	1	16	1	0	0	0	3
Studebaker Ditch-Pike Creek	3	0	6	3	3	0	0	0
Townsand Lucas Ditch-Big Lick Creek	7	0	8	6	3	0	3	3
Walnut Creek	1	2	2	2	1	7	1	3
Total	88	44	127	101	18	36	14	34

Definitions | Material storage sites – These sites many include the storage of vehicles, trailers, construction waste, wood, gravel, and other such materials. These sites are a potential source of pollutants to rivers. **Auto Tracks** – Dirt bikes, ATV, and literal automobile tracks can be sources of pollution to streams due to the high concentration of engine based fuels, coolants, and lubricants. **Derelict properties** – These are properties that once had a development (house, industry etc.) that has since been abandoned or demolished. Some of these sites are neglected and overgrown with invasive species.

3.9 WINDSHIELD SURVEY

A windshield survey was conducted on April 20th and 29th, 2016. The purpose of the windshield survey was to ground truth the findings of the desktop surveys performed by the Project Manager. Because of the large size of the Upper Mississinewa, it was not feasible to survey the entire watershed. Instead, the Project Manager decided to survey only critical areas for two strategic reasons: (1) these areas are likely to have a greater number of pollution sources, and (2) cost-share funds will be directed to these areas, so the identification of additional sources of pollution will be helpful for generating additional projects to be funded. Two critical subwatersheds, Deer Creek and Little Deer Creek, were excluded from the survey. These two subwatersheds are critical for nitrogen only. Because the Project Manager is confident that high percentages of farmland in these areas are the cause of high nitrate levels (which are likely entering waterways via tile drains), it was unnecessary to survey the area for additional pollution sources. Five subwatersheds that are not critical areas were included in the survey because they were on the survey's route.

METHODS

Routes with a high number of stream crossings along them were selected in order to maximize the number of streams surveyed and to increase the probability of identifying sites with erosion problems. Roughly 80 miles were surveyed on April 20, 2016, starting near Fowlerton in Grant County and moving in an easterly direction through Blackford, Jay, and Randolph counties, and ending in Union City in Randolph County. Darke County was not entered but traveling the state line road made visual surveying possible. Roughly 12 miles were surveyed on April 29, 2016 in Campbell Creek watershed in Delaware and Randolph counties.

A camera and smartphone with geotagging capabilities were used to take pictures of many of the sites. Photos were uploaded to Google Earth. The following attributes were recorded: buffer width, bank erosion, rills/gullies, livestock accessing streams, livestock adjacent to streams but fenced out, and goose populations. Conventional tillage was tallied in Grant County but due to time constraints, the Project Manager did not continue it throughout the rest of the survey. Furthermore, this data had already been generated by county agencies and would have been redundant. Sampling was refined in the field to account for differences observed in rill/gully formations. It was observed that some rills were the result of water exiting culvert outlets, some were the result of a headcut formed because culvert inlets were below the level of the field, and some had no associations with culverts. Additionally, if it appeared that the rill/gully was washing directly into a waterway, this was also noted. These differences may affect prioritization of remediation actions for these rills/gullies. Size of rills/gullies was not measured and they are referred to collectively as rill/gully because no differentiation was made between the two.

LIMITATIONS

Certain aspects of the survey design and differences in methods between surveys likely skewed results. The following are reasons that results lack statistical significance: (1) Miles traveled in each subwatershed ranged from 2.11 to 11.83. Results from subwatersheds with fewest miles surveyed likely had skewed results due to low numbers of attributes observed. (2) The Campbell Creek route was selected using different methods, which resulted in a higher number of stream crossings being surveyed. Campbell Creek was also surveyed nine days after the other sites, and rills/gullies may have been filled in during this time (a great deal of tilling and planting took place during this time). (3) Only a small percentage of each subwatershed was surveyed. More extensive sampling was not feasible. (4) Windshield surveys are also limited because only roughly less than half of the geographic area can be observed from the road.

RESULTS

Despite these limitations, results were still analyzed. Windshield survey results were also compared to both desktop survey results and water quality results. From analysis, broad generalizations can be made concerning attributes that are influencing water quality. A total of 49 rills were identified on the windshield survey. A correlation was found between the number of rills per mile identified in the windshield survey and the number of rills identified in the desktop survey. Grant County had the lowest number of rills/gullies in both (0.19 per mile, windshield). Blackford County had the highest number of rills/gullies in the windshield survey (0.84 per mile) and one of the highest concentrations of rills/gullies identified in the desktop survey. This suggests that rill/gully formations may have less of an influence on TSS in the critical subwatersheds surveyed in Grant County than in those surveyed in other counties. Since three of the four critical subwatersheds surveyed within Grant County are critical for TSS, it suggests that instream sources of sediment may be a contributor to TSS loads.

Bank erosion is likely contributing sediment in all subwatersheds. Bank erosion was found in all but three subwatersheds surveyed (Table 3.17). The lack of bank erosion in these subwatersheds is likely due to a either a low number of miles surveyed, a low number of stream crossings surveyed, or both. Sites with no moderate or high erosion observed at streambanks (Barren, Branch, Halfway, Creek, Jordan, and Mud) also had the least numbers of streamcrossings sampled out of all subwatersheds, suggesting that moderate or high erosion is more likely to be found when assessing a greater number of streambank buffers. Grant County and Delaware County had the highest number of sites with high levels of streambank erosion (both had 3).

A total of 34 inadequate buffers were identified during the windshield survey. Inadequate buffers are also likely influencing water quality in all subwatersheds. Buffers less than 10 ft in width were found in all subwatersheds except for Branch Creek (Table 3.17). This was likely because only two buffers were assessed in Branch Creek and they were along the Mississinewa River. Inspection of the watershed using Google Earth shows that buffers along the river are usually adequate, whereas tributaries lack buffers more often.

While livestock entering waterways and goose populations may be sources of E. coli in waterways, a low number of these sites were observed on the windshield survey. Livestock entering waterways may also be a source of sediment in waterways. In all, two sites with livestock entering waterways and two sites with goose populations were observed (Table 3.21). While several sites with cattle entering waterways were identified on the desktop survey, they were not commonly observed during the windshield survey. This can be attributed to the fact that the windshield survey only covered a very small area of the watershed, while the entire watershed was observed through the desktop survey.

The three attributes from the windshield survey that likely are sources of sediment entering waterways were combined for each site and compared to water quality data for TSS. Correlation was weak. Correlation between other parameters (E. coli and livestock in or adjacent to streams, goose populations; phosphorus and bank erosion, rill/gully formations, buffer width) were also weak. Lack of correlation illustrates (1) the need to collect more data, (2) the pervasive nature of nonpoint source pollution and (3) the importance of water quality monitoring for helping to determine critical areas.

Although the results of analysis is limited, the survey was useful for numerous other reasons: (1) It allowed the identification of streambank erosion sites that had not been identified before. These new streambank erosion sites are possible new cost-share opportunities. (2) Desktop survey results and water quality results are further validated. (3) The experience gained and photos taken on this windshield survey can be used to improve future windshield surveys and to tailor a program for utilizing volunteers to conduct windshield surveys in the future. Creating a standardized volunteer windshield survey procedure and utilizing volunteers can allow for the collection of a larger set of data in the future. (4) Gravel roads are a potential nonpoint source of pollution that was identified and their prevalence may be able to be calculated from county data.

Conducting this windshield survey illustrated the necessity for water quality monitoring in addition to a watershed inventory (which includes the windshield survey). It also suggested that the desktop survey may be more comprehensive for surveying rill/gully formation and in some instances, measuring buffer width (along lengths that have herbaceous or shrub buffers). A windshield survey may be most useful for identifying streambank erosion, for determining buffer width at sites that have large canopy trees in the buffer (which can obscure true buffer width in satellite images), and for identifying rills that are eroding directly into streams.

TABLE 3.19 | Count of sites with inadequate stream buffers and with streambank erosion observed on windshield survey

HUC 12 Name	miles driven	Buffer < 10 ft	Number of Buffers Assessed	Bank Erosion Slight	Bank Erosion Moderate	Bank Erosion High
Barren Creek	6.06	1	2	0	0	0
Big Lick Creek	8.97	2	6	1	1	0
Branch Creek	1.39	0	2	0	0	0
Campbell Creek	11.83	5	17	1	1	3
Days Creek	8.31	2	5	1	1	0
Gray Branch	5.15	1	3	0	0	1
Halfway Creek	7.35	1	1	1	0	0
Jordan Creek	2.59	0	0	0	0	0
Little Lick Creek	8.29	3	9	0	0	1
Little Mississinewa	5.12	1	4	0	1	0
Little Walnut Creek	5	5	6	0	0	2
Lugar Creek	8.85	7	14	1	0	1
Mud Creek	4.52	1	1	1	0	0
Porter Creek	2.11	2	3	0	1	0
Walnut Creek	7.06	3	9	0	0	1
Total	92.6	34	82	6	5	9

TABLE 3.20 | Count of sites with rills observed on windshield survey						
HUC 12 Name	miles driven	Total rills	Rill, no additional info about it	Rill due to culvert outfall	rill due to headcut formed by culvert	rill entering waterway
Barren Creek	6.06	0	0	0	0	0
Big Lick Creek	8.97	7	5	2	0	0
Branch Creek	1.39	0	0	0	0	0
Campbell Creek	11.83	2	1	0	1	0
Days Creek	8.31	6	3	0	1	2
Gray Branch	5.15	7	3	0	4	0
Halfway Creek	7.35	2	0	0	2	0
Jordan Creek	2.59	1	1	0	0	0
Little Lick Creek	8.29	9	8	0	0	1
Little Mississinewa	5.12	1	1	0	0	0
Little Walnut Creek	5	1	1	0	0	0
Lugar Creek	8.85	2	0	2	0	0
Mud Creek	4.52	5	4	0	1	0
Porter Creek	2.11	3	3	0	0	0
Walnut Creek	7.06	3	2	1	0	0
Total	92.6	49	32	5	9	3

TABLE 3.21 | Count of sites with possible E. coli sources observed on windshield survey				
HUC 12 Name	miles driven	Livestock accessing stream	Livestock adjacent to stream	Goose population
Barren Creek	6.06	0	2	0
Big Lick Creek	8.97	1	1	0
Branch Creek	1.39	0	1	0
Campbell Creek	11.83	0	0	0
Days Creek	8.31	0	0	0
Gray Branch	5.15	0	0	0
Halfway Creek	7.35	0	1	0
Jordan Creek	2.59	0	0	0
Little Lick Creek	8.29	0	0	0
Little Mississinewa	5.12	1	0	1
Little Walnut Creek	5	0	0	0
Lugar Creek	8.85	0	1	0
Mud Creek	4.52	0	1	0
Porter Creek	2.11	0	0	0
Walnut Creek	7.06	0	0	1
Total	92.6	2	7	2

4. OTHER PLANNING EFFORTS

4.1 EXISTING WATERSHED PLANNING EFFORTS

While no IDEM-approved comprehensive watershed management plans exist within the watershed, watershed planning efforts have taken place within the Upper Mississinewa River Watershed. This subsection contains summaries of (1) four recent HUC 10 LARE (Lake and River Enhancement) studies, (2) a 319 study, and (3) the recent TMDL report generated by IDEM (the data from which was used in this study). The first three summaries, which cover HUC 10 LARE phases I, II, and III, are excerpts from a literature review of existing water quality studies completed by Taylor University (additional excerpts from this review can be found in Appendix G). The summary of the LARE phase IV study is an original summary generated by the Project Manager. The final part of this section contains summaries of local comprehensive plans generated by municipalities or counties. These plans are land use and development plans created to guide growth in urban, suburban, and rural areas. Since land use is important to watershed and water quality, understanding them is important to watershed planning efforts.

UPPER MISSISSINEWA RIVER WATERSHED DIAGNOSTIC STUDY (LARE, PHASE I)
This study was authorized by the Randolph County SWCD on December 3, 1999. Water quality sampling and biological assessments were performed during May, 2000. "The [Headwaters Mississinewa River] watershed (HUC 5120103010) is located predominantly in Randolph County, Indiana with smaller portions of the watershed in Jay County, Indiana and Darke County, Ohio. This study assessed nine sub-watersheds within a 51,207-acre (80 sq mi or 207 sq km) portion located from the Indiana border east to nearby Ridgeville. "Based on historical data of the study watershed, there is some evidence of improving water quality conditions. Declines in concentrations of biochemical oxygen demand (BOD) and ammonia nitrogen may be linked to dramatic adoption of conservation tillage between 1989 and 1999. However, the link between the two cannot be validated and may also be due to improvements in point source control in Union City. "Ecological integrity was assessed for six of the nine sub-watersheds with physical, biological and chemical data. Very high dissolved oxygen (DO) was detected in all six streams (as high as 274 percent of saturation), and is attributed to abundant filamentous algae on the sand and gravel stream beds. The study also suggests the streams are subject to very high diurnal fluctuations in DO due to high nutrient concentration, which can be a stressor for aquatic animals. The level of impact by non-point source pollution was evaluated for the six monitored sub-watersheds based on key indicators of stream integrity: coliform bacteria, nutrient concentrations, turbidity, habitat (QHEI scores) and biology (Family Biotic Index, FBI scores). Additionally, all nine subwatersheds were modeled for sediment and phosphorus loading. All nine sub-watersheds were assigned high, moderate and low priority for investment in nonpoint source pollution (NPS) controls. Best management practices (BMPs) were recommended, specifically conservation tillage, buffers, nutrient management planning, and constructed wetlands. "Finally, the study recommends two major institutional initiatives to maintain and improve the health of the Headwaters Mississinewa River watershed: (1) formation of a stakeholder group for implementation recommendations and (2) development of a conscious planning process with education as a priority. The SWCD must take responsibility to identify, develop and complete education activities directed toward the land user."[1]

UPPER MISSISSINEWA RIVER WATERSHED DIAGNOSTIC STUDY (LARE, PHASE II)
"This LARE-funded watershed diagnostic study was conducted from 2002 to 2003 on the Upper Mississinewa watershed (HUC 5120103020) primarily in Randolph County including portions in Jay and Delaware counties. The study area includes the [Halfway Creek] watershed from Ridgeville to Albany with an area of approximately 85,760 acres (134 sq mi or 340 sq km). The land use is 92 percent agriculture, and based on IDEM's 2001 Unified Watershed Assessment there is low concern for septic system density and moderately high concern for livestock density and cropland pressure. Fourteen sites were monitored: three on the Mississinewa River, ten sites among six tributary sub-watersheds, and one reference site: Stoney Creek near Windsor Pike (Commonwealth Biomonitoring, 2005)."The sites were monitored for water quality, macroinvertebrates and habitat. Nutrient and suspended sediment values were elevated at most sites compared to many other Indiana streams in agricultural areas, especially during wet weather. Other water quality measurements fell within ranges suitable for most forms of freshwater aquatic life. E. coli bacteria, were present at concentrations exceeding Indiana water quality standards for five of thirteen sites during dry weather and at all thirteen sites during wet weather. The source of bacterial contamination is unknown. Pollution intolerant groups of macroinvertebrates were abundant at most sites but noticeably absent at one site, Fetid Creek. The sub-watersheds in this study having sediment tolerant macroinvertibrates compared almost identically with the areas predicted to yield high sediment loads watersheds by the 2005 Taylor University study. Aquatic habitat was generally good at most sites, especially within the Mississinewa River itself, which was comparable to the high quality reference site, Stoney Creek. Habitat at some sites was impaired by channelization and lack of stream bank vegetation. "Four tributaries were identified as areas where water quality could be significantly improved. Best management practices were recommended to address E. coli reduction, sediment reduction and erosion on steep slopes, nutrient reduction, and aquatic habitat restoration."[2]

1 Taylor University. Earth and Environmental Sciences Department. 2012. Middle Mississinewa River Watershed Diagnostic Study.

2 Taylor University. Earth and Environmental Sciences Department. 2012. Middle Mississinewa River Watershed Diagnostic Study..

WATERSHED DIAGNOSTIC STUDY OF THE UPPER MISSISSINEWA RIVER WATERSHED (LARE, PHASE III)

"This portion of the Upper Mississinewa River watershed between Albany and 21.5 miles downstream to near Wheeling (HUC 5120103030) lies predominantly in northeast Delaware County, with very minor portions in Jay and Randolph counties. The study area is 66,088 acres (103 sq mi; 267 sq km) and includes five sub-watersheds ranging from 1,675 to 15,566 acres contributing to the Mississinewa (Cedar Eden, 2009). "The study assessed water quality, macroinvertibrates and habitat at twenty monitoring sites including three on the Mississinewa River and seventeen distributed among the five subwatersheds. Water quality within the watershed was characterized by high concentration of nutrients (phosphorus and nitrogen) and high counts of E. coli bacteria."[3] Water quality sampling was conducted April 13 and August 11, 2004. Additional sampling was conducted on September 16, 2005. Macroinvertebrate sampling and habitat assessment was done on August 11, 2004. Fish communities were not assessed. "Based on macroinvertebrates (modified Index of Biotic Integrity) measurements, seventeen of the twenty sites were moderately impaired and two were slightly impaired and one was not impaired. Based on habitat scores (QHEI), three sites were severely impaired, six were moderately impaired, five were slightly impaired, and one was unimpaired. "Each monitoring site and the associated subwatersheds were ranked based on the data from water quality, biological integrity, and habitat impairment—along with modeling results for sediment and nutrients. The rankings from all four data sets were combined to identify two subwatersheds with the highest priority for implementation of best management practices, especially with regard to management of E. coli, nutrients and sediment."[4]

MIDDLE MISSISSINEWA RIVER WATERSHED DIAGNOSTIC STUDY (LARE, PHASE IV)

This study was conducted by Taylor University faculty and students and funded by a grant obtained through the LARE program of the IDNR and a match from the Grant County SWCD. Objectives of the study were to "diagnose the ecological health of the middle Mississinewa River watershed in order to make suggestions for maintaining or enhancing its aquatic resources." Water chemistry, stream biology and physical quality were monitored and watershed geomorphology was assessed. Models were created for both nutrient and sediment loading. Researchers also reviewed geologic data, land use data, and historic river data as well as past studies of the Mississinewa River watershed. The study area consisted of eleven subwatersheds. Samples were taken at one site in each subwatershed located near the stream's confluence with the Mississinewa River. Samples were also taken to analyze water chemistry at four points along the Mississinewa River mainstem. Water samples were collected four times from 2007-2011 to determine chemical and physical water quality. Flow conditions at the different sampling times were baseflow (July), low flow (October and November), and moderate flow (April), the last being measured over a period of four days. Samples were measured for discharge, temperature, pH, dissolved oxygen, conductivity, turbidity, total nitrogen, nitrates, ammonia, total phosphorus, and orthophosphate. E. coli was sampled for separately, weekly over a period of five weeks. Biological sampling was conducted once in each subwatershed and evaluated using a combined modified ICI and EPT/C ratio. Stream physical quality was assessed through a QHEI survey conducted on 3 occasions from 2005 to 2010. Nutrient loading was modeled using the Export Coeffficient Method. Sediment loading was modeled using the RUSLE. Chemical and physical testing of water showed that while measured values were sometimes above the state's standards, none were consistently so. However, some sites stood out when compared with each other. It was also found that higher turbidity correlated positively with higher topographic relief. The geometric mean for E. coli was above the Indiana water quality standard for 10 of the 12 sites. All sites had increased E. coli concentrations following rain events. Because CSOs are not located in each subwatershed, this suggests that other sources besides CSOs are contributing to E. coli concentration in streams. There are several CFOs in the study area, which are likely contributing to E. coli concentrations in streams. Results of biological sampling showed Massey Creek to be the most impaired subwatershed, followed by Hummel and Boots Creek. Massey and Boots Creek also had the lowest QHEI scores which rated their habitat as impaired. According to the model, predicted nutrient loads were generally higher in areas with more land in agriculture. Southern subwatersheds have a higher percentage of land in agriculture. In contrast, predicted sediment loading was generally higher for northern subwatersheds due to higher slopes in these subwatersheds created by the glacial moraine. This is also consistent with the results of the geomorphological analysis. To further synthesize monitoring and modeling results and information collected from past studies, the 11 subwatersheds were ranked on 7 different parameters, except for the Mississinewa mainstem, which was only ranked on 3. Rankings for each subwatershed were totaled and an overall priority rank for remediation was assigned to each. The report ranks subwatersheds according to the seven parameters as well as a summary of impairments and recommended treatments for each subwatershed. The two most impaired subwatersheds, Massey and Boots Creek, have the lowest percentages of agricultural land and the highest percentages of developed land. Although subwatersheds were ranked by priority, impairments and critical concerns were found in all subwatersheds and recommendations for BMPs were made.

"LAND USE AND SEDIMENT LOADING IN THE MISSISSINEWA WATERSHED"

This study was funded by a 319 fund and conducted by faculty and students at Taylor University. Sampling for began in June of 2002 and ended in August on 2003. The final report was submitted in April, 2005. The following summary of this study was taken from the Watershed Diagnostic Study of the Upper Mississinewa River Watershed, Phase III. "The Taylor University Environmental Research Group conducted a land use and sediment loading study of the Mississinewa River Watershed, and their final report entitled "Land Use and Sediment Loading in the Mississinewa Watershed" was completed in April 2005. The purpose of their study was to create a field-validated model of sediment loading in two selected subwatersheds in the Mississinewa watershed that could be used to evaluate and prioritize all 48 HUC-14 subwatersheds. The Revised Universal Soil Loss Equation (RUSLE) was used with a GIS interface to calculate sediment loadings in all subwatersheds. The model was calibrated using water quality data that was collected in the Walnut Creek and the Barren Creek subwatersheds. Once the model was calibrated, it was used to evaluate sediment loadings from other subwatershed in the Mississinewa River watershed.

3 Taylor University. Earth and Environmental Sciences Department. 2012. Middle Mississinewa River Watershed Diagnostic Study.

4 Taylor University. Earth and Environmental Sciences Department. 2012. Middle Mississinewa River Watershed Diagnostic Study.

The Taylor study also conducted QHEI evaluations at five stations in the two study subwatersheds and evaluated numerous best management practices for sediment reduction.“Based on the Taylor study, the Rees Ditch subwatershed had the lowest sediment load ranking.

The Campbell Creek subwatershed had a moderate sediment load ranking. The eastern portion of the Phase III Mississinewa River watershed, including that portion of the direct drainage of the Mississinewa River and the Boseman Ditch subwatershed had a moderately high sediment load ranking. The western portion of the Phase III watershed, downstream of Rees Ditch, including the subwatersheds of Pike Creek, Holden Ditch, Unnamed Ditch, and that portion of the Mississinewa River direct drainage had the highest sediment load ranking.”[5]

“TOTAL MAXIMUM DAILY LOAD REPORT FOR THE UPPER MISSISSINEWA RIVER WATERSHED”

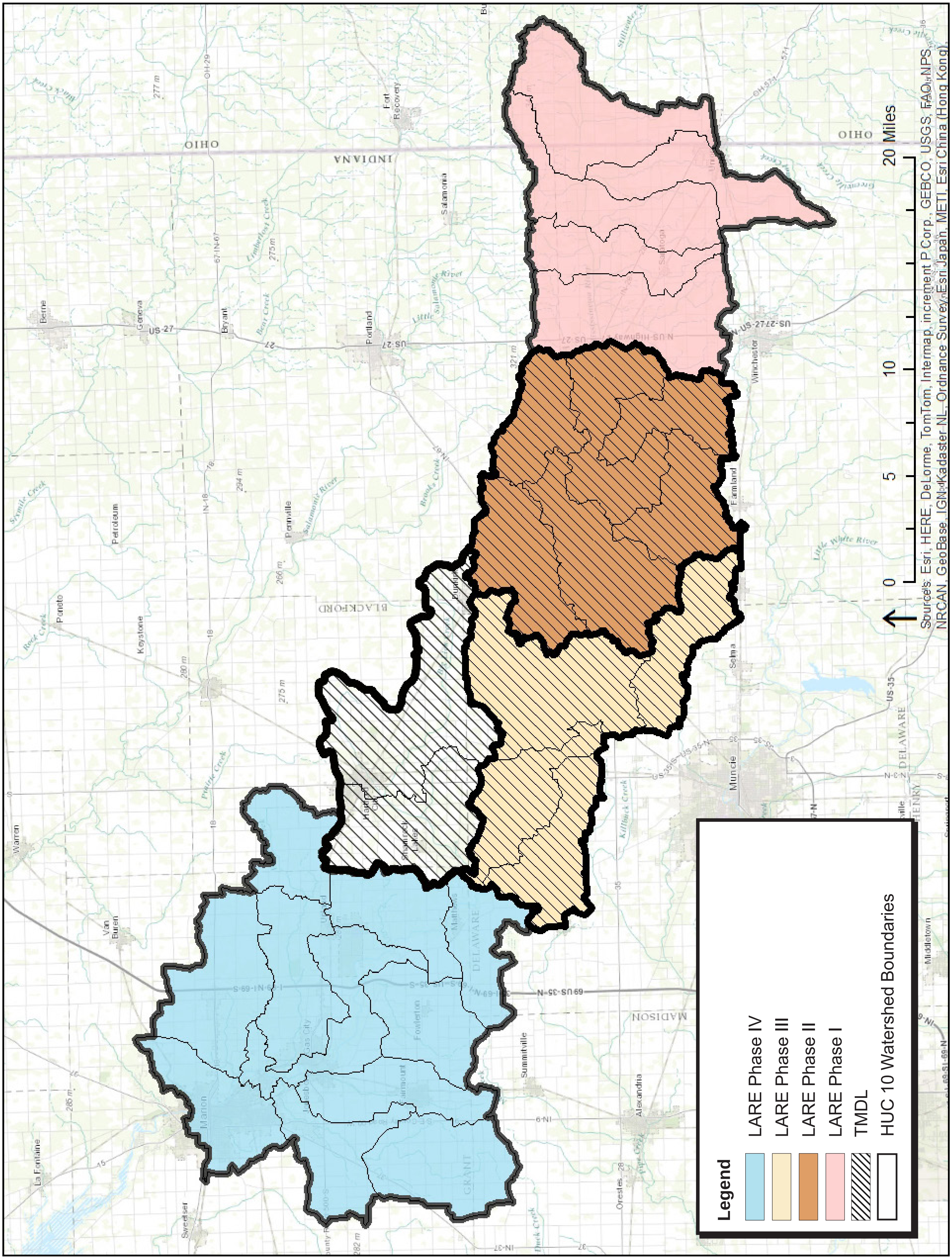
A TMDL study for a portion of the Upper Mississinewa River was initiated in conjunction with the initiation of the development of this WMP. The UMRW-P and the Project Manager teamed up with the IDEM TMDL group to hold kickoff meetings, with the first on March 13, 2014. Water quality data collected by IDEM for the TMDL was presented in this WMP and used for the development of critical areas. Three HUC 10 watersheds are part of the TMDL study. They are Big Lick Creek HUC 10, Halfway Creek HUC 10, and Pike Creek HUC 10. Thirty-five sample sites were monitored as part of a probabilistic sampling program. Tributaries sampled included Big Lick Creek, Little Lick Creek, Townsand Lucas Ditch, Bush Creek, Bear Creek, Halfway Creek, Redkey Run, Flesher Creek, Moore Prong, Rees Ditch, Bosman Ditch, Studebaker Ditch, and Campbell Creek. The Mississinewa River was also sampled. Parameters assessed included habitat, biological communities (both fish and macroinvertebrate), nutrients, TSS, toxins, stream flow, and physical parameters such as dissolved oxygen, pH, temperature and turbidity.[6] A draft version of the TMDL report (total maximum daily load) was made available to the Project Manager near the end of this WMP’s completion. IDEM’s draft version of the TMDL was received by the Project Manager on May 24, 2016. Data and analysis from the TMDL will be discussed in this WMP. Within the TMDL report, percent reductions needed for parameters exceeding water quality targets or applicable water quality standards were calculated for each site based on the observed maximum concentration recorded at the site. These data and results are analyzed and summarized in the subwatershed discussions in Section 10, *Subwatershed Discussions*, on p. 159. Biological results from the TMDL report are also discussed in Section 9, *Biological Assessments*, on p. 148. Raw data from TMDL sites near pour points was also used by the Project Manager to create an independent analysis and comparison of all sites near pour points within the UMRW. Finally, the Potential Priority Implementation Area (PPIA) rankings presented in the draft TMDL are listed in Table 4.1 below. These PPIA rankings were generated using the Recovery Potential Screening Tool (RPST) found on the US EPA’s website. The RPST ranks PPIAs based on the likelihood that the streams in these areas will recover beneficial uses with a minimal amount of BMP implementation. Watershed characteristics that can favor a top PPIA ranking include: relatively high percentages of forest cover, streams with relatively high quality habitat and biological communities, relatively high income levels, relatively high percentages of reduced tillage, and relatively low quantities of stressors such as CSOs, CFOs, percentage of agricultural lands, and percentage of stream miles impaired.

TABLE 4.1 | Potential Priority Implementation Area (PPIA) Rankings and Recommended Implementation Actions from the Draft TMDL Report for the Upper Mississinewa River Watershed

Subwatershed	PPIA Rank	Implementation Action
Campbell Creek	1	Outreach and education and training Stormwater Planning and Management Conservation tillage/residue management Cover crops Two Stage Ditch Conservation easements Grazing land management Comprehensive Nutrient Management Plan Drainage Water Management Stream fencing (animal exclusion) Manure handling, storage, treatment, and disposal Riparian buffers Filter strips Rain gardens Green roof Constructed Wetlands
Studebaker Ditch	2	
Bear Creek	3	
Rees Ditch	4	
Days Creek	5	
Bush Creek	6	
Townsand Lucas Ditch	7	
Fetid Creek	8	
Holden Ditch	9	
Redkey Run	10	
Platt Nibarger Ditch	11	
Little Lick Creek	12	

5 Cedar Eden Environmental LLC. 2009. Watershed Diagnostic Study of the Upper Mississinewa River Watershed, Phase III.

6 Indiana Department of Environmental Management. 2016. Upper Mississinewa River Watershed TMDL. http://www.in.gov/idem/nps/3918.htm



MAP 4.1 | Locations of previous watershed planning efforts

4.2 LOCAL GOVERNMENT PLANNING EFFORTS

The following are planning efforts currently underway within the Upper Mississinewa River Watershed. They are taking place at the local government level. While this may not be an exhaustive list, it includes plans relevant to the watershed planning process. There is two regional sewer district in the watershed; one stormwater plan; and seven master plans, either at the county level, city level, or city and county level combined. All plans and planning efforts outlined in this section take place at the county scale (i.e. within county boundaries) unless otherwise indicated on MAP 4.2. The following is a discussion of each.

BLACKFORD COUNTY COMPREHENSIVE PLAN, BLACKFORD COUNTY

This county wide plan was created in 2011. It recognizes a need to protect and improve its greenspace. Greenway projects are one of the community's highest parks and recreation priorities. A proposed trail will run from Blackford High School to the north side of the town. Only a very small portion of the trail will be within the UMRW. They would like to seek additional trail opportunities within the county. Connecting to Cardinal Greenway is mentioned as a possibility. Additionally, the plan emphasizes the need to update floodplain ordinances to prohibit occupied structures in floodplains. Protecting floodplains is important for water quality. While this plan does not propose a future date for a complete update of the plan, it does state that "every year or so the planning commission and other should review the plan to make sure it is current."[7]

Three actions suggested by this plan could help to reduce flooding, which is a major stakeholder concern. These actions are: "reduce residential zones to areas already served by existing utilities, revitalize existing neighborhoods over building new ones, and actively enforce codes regarding neglected or abandoned housing." These actions are important because they could help to reduce the amount of impervious surfaces in the city, thereby helping to reduce flooding downstream.

MAP, DELAWARE COUNTY

The Muncie Action Plan (MAP) 2010 outlines progressive community based goals and objectives for the future development of Muncie. The plan was created in 2010. It provides five initiatives with 47 corresponding actions to aid in implementation. Numerous action points focus on environmental restoration and sustainable development evolving around Prairie Creek Reservoir's enhancement and protection, enhancing the White River corridor for recreation, improving blighted or vacant industrial areas (brownfields), improving corridors with green infrastructure, and supporting sustainable growth and development. These actions formed by citizen support will subsequently place focus on environmental developments and provide involvement and action from local government and the community to improve the water resources of Muncie and Delaware County. Improving blighted or vacant industrial areas can help to reduce the amount of impervious surfaces and thereby help to reduce flooding, a major stakeholder concern. In 2013, public forums were held to re-evaluate the plan and an updated plan called MAP 2.0 was created. The plan is scheduled to be updated every 5 years, with the next update occurring in 2018.

MDCCP, DELAWARE COUNTY

Muncie and Delaware County officials, along with the community, have outlined a plan (created in 2000 and most recently updated in 2010) that focuses on seven key elements forming the Muncie-Delaware County Comprehensive Plan (MDCCP). These goals include preserving, restoring, and expanding or improving valuable assets within the community. This plan focuses on preserving and maintaining the health of agricultural land, the natural environment, greenways, and open space areas. Stakeholders are concerned about the lack of wildlife in riparian areas; a commitment to protect the natural environment will help to address this concern. Another main focus is regionalism and how growth in the future will affect Muncie and Delaware County as well as the surrounding areas. This is a key focus in watershed management and development which can work hand-in-hand with community regional initiatives.

This plan suggests pursuing the creation of recreational activities to generate revenue. Creating recreational activities would address stakeholder concerns about missed recreational opportunities due to water quality/conditions. One stakeholder was concerned about missed economic opportunities with recreational canoeing. Another expressed the concern that fish populations were of poor quality for fishing.

This plan also suggests that new development, including infill development, should be focused around service area villages like Eaton and Albany. Infill development, rather than new development, can help reduce flooding by reducing the amount of runoff during storm events. Flooding is one of the biggest concerns expressed by stakeholders. Flooding can also cause another big stakeholder concern: erosion. We suggest that measures to encourage infill development should be strengthened to help reduce the amount of impervious surfaces in the watershed.[8]

The plan document specifies that the plan should be updated every 5 years and that the plan should be reviewed annually to determine progress.

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7 Strategic Development Group, Inc. and Hannum, Wagle & Cline Engineering. 2011.

8 Investors are in the process of creating a large infill development in Muncie at the site of the former Indiana Steel and Wire Co. Although this development is outside of the watershed, it can serve as a local example of how municipalities can work with investors to create infill developments. It can also be used to help encourage the creation of measures that would help promote similar developments at other sites in the future.

DELAWARE COUNTY MS4 PARTNERSHIP, DELAWARE COUNTY
This MS4 area is regulated through the NPDES Phase II Program. Phase II Rules are found in 327 IAC 15-13 (Rule 13). Under these rules, a Storm Water Quality Management Plan (SWQMP) has been developed for this area.
SWQMP, CITY OF MARION
The Stormwater Quality Management Plan for the City of Marion in Grant County provides management and regulation for Marion and Indiana Wesleyan University. It provides data for 6 watersheds, identifying areas of concern and developing objectives and BMP implementation to increase the viability and health of the waterways. This data also aids in establishing continual monitoring efforts in the most threatened areas, which include the Mississinewa River and Boots and Massey creeks.

MARION 2030, GRANT COUNTY
A joint effort between community leaders and the Plan Commission have developed a long-range plan entitled "Marion 2030." The planning process was initiated in 2008. It was adopted by the Marion Common Council. This plan outlines improvements for the Historic Downtown of Marion, and other natural, social, and economic developments. Several elements were outlined with concurrent objectives and actions to help achieve this vision for 2030. The plan suggests incorporating LID stormwater practices such as bioswales and landscaped parking lots. Preserving open spaces and preventing development in the floodplain are also goals of the plan. The Marion 2030 plan suggests branding Marion as a "green city." To do this, it suggests retrofitting city-owned properties with green roofs. Increasing the number of green roofs in the watershed can help reduce flooding by reducing runoff. Flooding was one of the biggest concerns expressed by stakeholders. Increasing the tree canopy within the city is another suggestion made by the Marion 2030 plan. A tree replacement program was suggested. Tree canopies can absorb up to 10% of the water during a rain event. Therefore, an increase in trees in the watershed could help to further reduce flooding. This plan also suggests retrofitting the current dam or creating a new dam which would generate power, as part of their initiative to develop alternative energies. The continued existence of the dam could impede recreational opportunities like canoeing. One stakeholder was concerned about missed economic opportunities with recreational canoeing. Although the plan does not give a time frame for updates, it is noted that each section of the plan can be updated independently of other sections. The plan was intentionally created this way to encourage the frequent update of different sections of the plan.

JAY COUNTY 20/20, JAY COUNTY
This countywide strategic plan was developed by the community in 2010 and outlines four main focus areas: economic development; education; health, wellness and recreation; and quality of life. These focus areas provide three to four basic goals that provide vision for actions to create progress. Business and agricultural development will go hand in hand with monitoring and protecting water resources as outlined in stated strategies. The plan was reviewed and updated in 2012. It has continued to function on a two-year action plan cycle, in which action goals are set for a two year period and then evaluated and updated at the end of the two-year period.

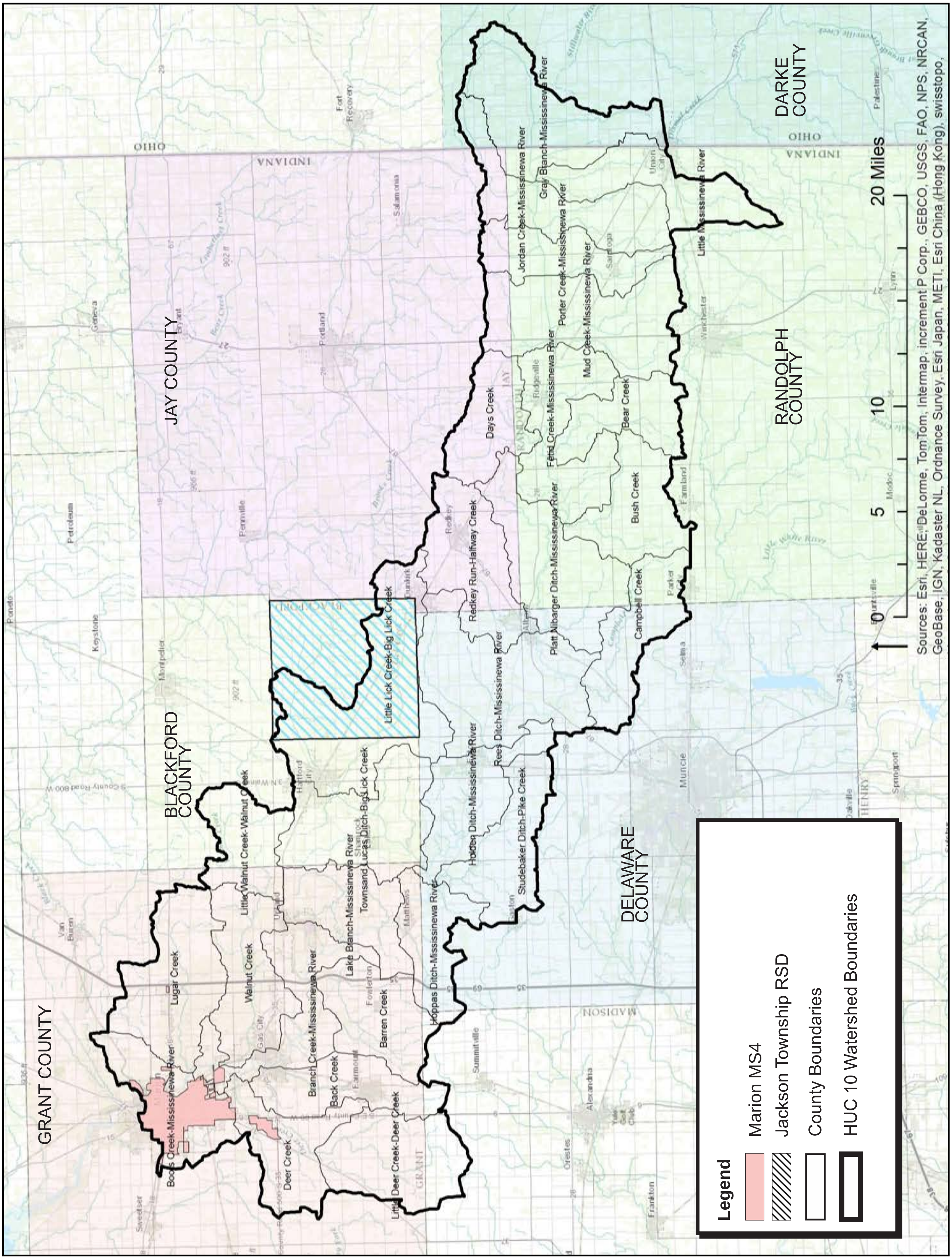
REDC, RANDOLPH COUNTY
In 2014, the Randolph Economic Development Board of Directors created an Economic Strategic Plan for the community. This plan focuses on encouraging, expanding, and improving local business and development. Maintaining clean water sources, quality of life, natural resources, and energy developments were all areas for which members of task forces will help identify directions, formulate goals, and implement solutions for future development. Stakeholders are concerned with water quality and the lack of wildlife. The goals listed above can help to address these. This plan is for 2015-2019.

GREENVILLE PLAN, DARKE COUNTY
The Comprehensive Plan for the city of Greenville, created in 1992 and updated in 2004, supports long-term efforts for redevelopment and new development. The four areas of focus include: land use, economic and industrial development, transportation and transit services, and community image and infrastructure. It provides land use analysis to better understand and protect land use and water infrastructure.

REGIONAL SEWER DISTRICTS
Two regional sewer districts exist in the watershed. They are Jackson Township Regional Sewer District, located in Blackford County, and Jay County Regional Sewer District (county-wide). These regional sewer districts are located in rural and suburban areas. Because sanitary sewers are even more costly in rural and suburban areas than in cities, regional sewer districts are uncommon. However, they play an important role in the areas they serve by helping to decrease pollution. As discussed on p. 61, septic systems have limited suitability in the watershed. Therefore, sanitary sewers should be more effective at treating human waste.

WELLHEAD PROTECTION AREAS
Several wellhead protection ares exist throughout the watershed. They are listed below by county:

Blackford County: Hartford City Water Works
Delaware County: Albany Water Department; Eaton Water Works; Gaston Water Works
Grant County: County Line Mobile Home Park (Back Creek), Fairmount Water Works, Gas City Water Department, Liberty Mobile Home Park (Little Deer Creek), Deerwood Mobile Home Park (Deer Creek), Jonesboro Water Department, Marion City Water Works, Upland Water Department
Jay County: Dunkirk Water Department, Redkey Water Plant
Randolph County: Ridgeville Water Department, Union City Water Works, Riverside Community



MAP 4.2 | Location of governmental planning efforts

5. WATERSHED INVENTORY SUMMARY

The Delaware County Soil and Water Conservation District obtained funding for this watershed management plan (WMP) from EPA/IDEM, the Ball Brothers Foundation, and the George and Francis Ball Foundation. Data and analysis from this study will identify the most impaired areas of the watershed and direct funding toward them. Other objectives of this WMP include public education and outreach and the involvement of local stakeholders.

The Upper Mississinewa River Watershed (UMRW) is approximately 415,000 acres encompassing 650 square miles and portions of six Indiana counties (Grant, Blackford, Madison, Delaware, Jay, and Randolph) as well as a portion of Darke County, Ohio. Fifty-five miles of the Mississinewa River run through the watershed, with approximately 924 miles of streams and ditches flowing into it. Within the watershed, approximately 78% of the land is cropland, 9.7% is urban, 7.4% is forest, and 3.6% is pasture/grasslands. Only 0.5% are wetlands.

ADDRESSING WATERSHED CONCERNS THROUGH A MULTI-COUNTY PARTNERSHIP INVOLVING LOCAL STAKEHOLDERS

Past watershed planning efforts, mainly through LARE studies conducted within single counties, had low success during implementation phases. Community leaders recognized that a limiting factor in implementing LARE recommendations was funding. In addition, counties in the Mississinewa region recognized opportunities existed for greater collaboration in the management of the this common resource. Such factors resulted in a shift to a multicounty approach and the forming of the Upper Mississinewa River Watershed Partnership. The partnership was formed with the primary task to update existing management plans and seek implementation dollars. The Project Manager, FlatLand Resources, is guided by five entities: SWCD boards from each county, NRCS district coordinators, a technical working group, TMDL partners from IDEM, and stakeholders.

Despite 87,000 individuals living in the watershed region, only 4,000 individuals own parcels greater than 40 acres in size. This group of individuals control 66% or more of the total acres in the region and is the project's target audience. One thousand stakeholders (those identified as owning >40 acres adjacent to river or tributaries) were invited to share concerns and attend one of seven public input meetings. One hundred eighty-two (182) individuals either attended public meetings or provided comment on survey cards mailed directly to them. The subwatershed areas with most vocal stakeholders were Fetid Creek-Mississinewa River, Platt Nibarger Ditch-Mississinewa River and Branch Creek-Mississinewa River. The project had 150 concerns broadly categorized into (a) fish and wildlife, (b) health (drinking water/recreation), and (c) socioeconomic. The major water quality concerns that landowners expressed were logjams, flooding, and erosion. A list of these concerns can be found in Tables 5.1 to 5.4 on pp. 89-90. Out of 28 cost-share practices presented stakeholders, drainage water management, cover crops, and grassed waterways were the top three in which they expressed interest.

During these meetings, steering committee members and stakeholders discussed results and information from the study as it evolved. A second set of concerns, different from the stakeholder's concerns, began to emerge. These concerns included the safety of waterways for recreation and the need for educating the public about the "unseen" water quality impairments, such as E. coli and nutrients. Most stakeholder concerns gathered through the direct mail surveys were tied to the stakeholders' own personal property, rather than the quality of the water in streams. The main concerns identified in the first set of concerns were the erosion and flooding of personal property, as well as the logjams that were sometimes the cause of this erosion and flooding. The Project Manager recognized that the second set of concerns, centered around pollutants in streams, such as E. coli and nutrients, are also necessary to address in order to ensure that the rivers and waterbodies are safe for human contact and human consumption as well as for fish and aquatic organisms. Although these concerns were not the primary ones expressed by landowners, the Project Manager, and steering committee feel they are public concerns that may be expressed once other more pressing concerns are addressed. This justifies the further exploration of chemical and bacterial water quality impairments.

There were also many additional events in which stakeholders were engaged. The Project Manager presented information about the watershed project at annual SWCD meetings in Randolph (7/30/2015), Delaware (3/26/2015), and Grant (2/18/2015) counties; hosted educational events including On-Farm Network (1/22/2015), Conservation Cropping Systems Initiative (8/22/2014), and a cover crop field day (9/4/2014); engaged additional groups/boards in the community, such as a local chapter of the Robert Cooper Audubon Society, the Blackford County Drainage Board, a private drainage board serving a portion of Blackford and Grant counties, Muncie Kiwanis Club, and the Upland Area Greenways Association. Furthermore, students from Ball State University were engaged in the project. Participating departments included GIS, Natural Resources and Environmental Management, Geology, and Journalism. The Project Manager worked with two Ball State faculty members and helped contribute to their immersive learning course by sharing information about the watershed and the watershed project. Additional information regarding stakeholder engagement can be found in the UMRWP's 205(j) grant final report.

A WATERSHED INVENTORY: USING EXISTING DATA AND INFORMATION TO UNDERSTAND FACTORS AFFECTING WATERSHED HEALTH

One of the initial steps in this study was the creation of a watershed inventory using data from multiple secondary sources. This inventory involved analysis of the many facets of the watershed that may affect water quality, including geological and geographical characteristics of the landscape as well as the historical and current environments and land uses. The Project Manager also developed a series of primary geographic studies. A summary of existing planning efforts in the watershed was also included as a source of further insight into the current understanding and involvement of local communities regarding the health of their subwatersheds.

STRENGTHS OF THE WATERSHED

A strong agricultural economy exists within the watershed. The geography of the region, formed by glaciation, is ideal for agriculture and supports a high percentage of prime agricultural farmland. Glacial activity also deposited unconsolidated materials in pre-glacial bedrock valleys, allowing the formation of aquifers that provide a groundwater supply for drinking water and irrigation. The same unconsolidated materials provide the basis for a gravel extraction industry. Bedrock limestone outcroppings that form the substrate in some channels and valley confinements generally helps regulate pH, protecting the environment against acid rain.

The Mississinewa River is a recreational destination which can continue to be improved. It's beauty, highly intact stretches, and structure make recovery/enhancement for recreation a realistic, attainable goal.

WEAKNESSES OF THE WATERSHED

While agriculture is important and should be preserved, its negative effects are widespread. The hydrology of the watershed tributaries has been altered greatly since European settlement for the purpose of creating agriculturally suitable land. Conversion of wetlands into farmland has compromised the land's ability to capture and delay the release of nutrients, sediment and water as they move towards waterways. Nutrients, mainly nitrogen applied for fertilizer on fields, are also transported to streams through tile drainage systems installed early in the region's history. These tile drainage systems likely also decrease aquifer recharge, which could compromise future supplies of water for drinking and irrigation.

In addition to tile drainage networks, drainage of agricultural land has been augmented by the channelization and widening of streams. While the resulting increase in velocity increases drainage, it also leads to a lack of streambank stability, causing increased bank erosion. This makes ongoing maintenance, like dredging, necessary and is estimated to be a major source of sedimentation.

Conventional tillage of farmland is another cause of sedimentation. Hydric soils in the watershed encourage conventional tillage, as it helps speed the drying of soils in the spring for timelier planting of crops. Analysis of floodplain maps in conjunction with soil and land use maps shows that most soils in the Mississinewa River floodplain are hydric and that a significant portion of the floodplain is cultivated cropland.

Further sediment loss is due to the widespread presence of highly erodible soils (HES) in the watershed, a substantial portion of which are cultivated cropland. These comprise approximately 42% of watershed soils. A significant portion of these highly erodible soils are adjacent to Mississinewa River tributaries. Continual disturbance of highly erodible soils near watershed tributaries increases the probability of high sediment and nutrient loads entering surface waters. Sediment and nutrient loss can be decreased by buffers along streams; however, in many areas buffers are minimal. Incentives could increase buffer restoration.

Highly rural cropland is ideal for concentrated feeding operations (CFO's), which are highly concentrated in the eastern end of the watershed. Wastes from these facilities are disposed through application to cropland. Due to low nutrient/volume ratio, shipping is expensive and much of it is applied to nearby land. Small livestock operations were also identified through desktop surveys. Some of these small farms allowed livestock access to adjacent streams and ditches for drinking water, which exposes these waterways to animal wastes as well as bank degradation through erosion.

Human waste is also a contributor of nutrients and pathogens to waterways. Soils data also indicate that nearly all of the watershed soils are limited for septic system suitability. Sanitary sewer service is limited to eleven municipalities. Three schools, a conference center, and a mobile home park that are all outside of municipal sanitary sewer services also have waste treatment facilities. Local planning efforts to increase sewer service in the watershed will benefit water quality in the future. However, failing septic systems will continually contaminate surface waters in the watershed until sewer service availability substantially increases. Additionally, sanitary sewers are failing or outdated in some cities within the watershed.

The loss of industry in the watershed has caused a decline in jobs and population. However, some urban areas have continued to grow. This urban growth, in conjunction with population decline, is a major threat/stressor to communities within the watershed. In most parts of the world, population decline translates to a shrinking foot print. However, in communities within the watershed, growth (development) continues around the fringes of urban areas. This results in a “donut hole” in urban centers. This “fringe expansion” results in the need for additional roads and infrastructure, but the declining population doesn't provide the increased tax revenue needed to pay for these amenities. This phenomenon prevents a community from building assets needed to attract and retain recent graduates and other members of the workforce.

The resulting “brain drain” hurts the local economy. Based on demographic analysis, a high percentage of money earned in the watershed does not remain in the watershed. A focus on inner city renewal by limiting/prohibiting this fringe expansion would be beneficial. Additionally, sprawl has the potential to threaten ecological areas and prime farm ground. The loss of industry has also left many abandoned industrial areas that contain impervious surfaces. It is important to have strategies to transition these areas into new uses and remove unnecessary impervious surfaces.

Aerial surveys indicated that a high percentage of subwatershed tributary streams are devoid of any vegetative habitat. Furthermore, it can be concluded from the analysis that these tributaries are extremely impaired due to channelization. Data from this study confirmed that there is a strong need for the restoration of riparian vegetation along stream banks, as it is the best strategy for addressing the overall water quality issues related to impaired biotic communities. Roots from riparian vegetation would increase bank stabilization and decrease sedimentation. The plants themselves would slow/stop surface runoff containing sediment and phosphorus from washing into waterways. Additionally, shade provided by riparian vegetation would help keep water temperatures lower, thereby increasing dissolved oxygen.

Logjams were the greatest concern expressed on comment cards and/or at public meetings. Specific impacts of logjams noted by landowners were threats to recreational safety and to the drainage of adjacent agricultural land, impairment of tile drainage, and exacerbation streambank erosion. The greatest concentration of concerns were on Fetid Creek-Mississinewa River Subwatershed; a 2014 canoe survey found eight Category 4 logjams in this reach. It is also interesting to note that many of the logjams in the watershed are located in the lower gradient areas of the watershed where there is slower velocity, less volume, and compared to other areas is less meandering as a result of less grade. The Project Manager has confirmed that these logjams are, in fact, a threat to safety, farming, flooding and recreation.

There were many valid concerns identified by the Steering Committee (through the watershed inventory and water quality monitoring results) that were seldom mentioned by the public in comment cards and/or at public meetings (a complete listing of all concerns is found in Section 12, p. 198). These concerns discussed by the steering committee were typically related to the actual causes of impaired water quality (i.e. excess nitrogen, phosphorus, sediment, and E. coli). There may be limited awareness of these causes by general public survey respondents or they simply may have not been reported. Either way, the steering committee has identified potential barriers to awareness, as well as strategies to develop educational initiatives.

OPPORTUNITIES FOR IMPROVING WATER QUALITY AND THE WATERSHED

It is known that many people enjoy engaging in recreational activities on the river. One hopes of this plan is to enhance and promote recreational opportunities along the Mississinewa. We believe that by increasing the understanding of the interrelationships within the natural world and by promoting the river as a recreational amenity, it will help people to take ownership of the resource and make them proud to live within this watershed. This can help garner support for not only its protection, but also for the thoughtful development of a tourist economy centered around the river.

Low tech and low cost natural BMPs such as filter strip and covercrop planting an help improve water quality. They have the ability to be implemented in a very short time frame by willing landowners. Another aim of the watershed plan is to preserve high quality farmground and keep marginal farmground out of production and into conservation. Protecting and enhancing natural systems through conservation has the opportunity to enhance our strengths. Recognizing the economic incentives that exist to take marginal farmground out of production, researchers have developed a system for classifying ground into farmable-nonfarmable ground to help guide conservation efforts to appropriate lands. This addresses weaknesses such as the improper use of floodplains for agriculture/development. This intentional conservation approach can also help in the creation of wildlife corridors and the strategic placement of wetlands. The development of additional high-quality recreational opportunities can also be strategically placed to enhance/conserve/recreate natural systems.

The Project Manager has observed that are many opportunities to provide education, specifically health risks associated with water quality pollution. Many causes of impaired water quality (i.e. excess nitrogen, phosphorus, sediment, and E. coli) were seldom reported by the public as concerns on either comment cards and/or at public meetings. The Steering Committee assumes that there is limited awareness of these causes. The group has identified barriers and strategies to develop educational initiatives, as well as action items specifically tailored to increasing awareness of these causes which are outlined in subsequent sections. Land surveys will also be incorporated into the action register for further exploration and assessment.

SUMMARY

The specific concerns and objectives that the Project Manager has identified through the watershed inventory analysis are briefly summarized below. The over arching goals are to (a) value and preserve the soil and water natural features throughout the watershed region and (b) understand the risks and threats to those natural features. These two goals will assist with in the identification of methodologies to mitigate water quality problems.

1.) Advocate the protection of the region's valuable farmground.
  - Encourage BMP's like cover crops, conservation tillage, and precision farming.
  - Highlight the economic gains possible with BMP implementation.
  - Highlight the larger environmental gains of reducing fertilizer, such as reducing hypoxia in the Gulf of Mexico.
  - Target high concentrations of farmland to diffuse high concentration of nutrients.

2.) Advocate protection of the region's aquifers through the protection/enhancement of the region's forest-wetlands.
  - Provide education about the importance of recharging aquifers.
  - Provide education about nature's role in this process and about how environmental changes have altered it.
  - Target Lugar and Walnut creeks, where hydric soils and D drainage types are ideal for aquifer recharge.

3.) Advocate protection of the region's ecological features.
  - Work with planning commissions in those Grant County and Upland, where sprawl is occurring
  - Ensure preservation of ecological areas along river.
  - Protect all remaining non-farmable habitat.

4.) Form a comprehensive E. coli reduction strategy.
  - Alert landowners of potential well contamination.
  - Promote stream exclusion and manure application BMPs.

5.) Encourage sediment reduction.
  - Provide education in Blackford and Grant County about the benefits of conventional tillage.
  - Target areas where geomorphology, HES, and high rates of conventional tillage high contribute to sediment loss.
  - Promote natural channel design.
  - Prioritize streambank stabilization in subwatersheds with areas of high instream erosion.

6.) Promote recreational uses of the river and clear impediments to recreation.
  - Continue to pursue grants for logjam removal.
  - Provide education through the creation of a recreational guide.

TABLES 5.1–5.4: Concerns voiced by stakeholders who attended various public progress meetings during the watershed planning process, obtained from 2014–2016.

TABLE 5.1 | Recreational/Human Health Concerns
E. coli Concerns
Concern
Some farms lack manure management BMPs
Drinking well and river water is unhealthy
E. coli from animal waste
Public knowledge of High E. coli from TMDL studies
Livestock have access to streams at multiple points
Reduced recreation opportunities do to fear of contaminates
Geese – potential relationship between ammonia and E. coli
Water contact is unhealthy
failing septics, lack of septic system maintenance
Sediment Concerns
Concern
Destabilization of soil do to ground cover removal
Lack of BMP on tile intake points
Shrink swell
Poorly managed HES
Poor fish population for recreation such as fishing
Nutrient Concerns
Concern
Non filtering drainage tiles
direct runoff from areas managed for recreation
direct access to the stream for nutrients applied to turfgrass
Public Education Concerns
Concern
Lack of education regarding non-structural BMPs
Dumping areas
Various illicit dumping areas
Former buried landfill
The public doesn't know who to contact about concerns
Lack of Aesthetics

TABLE 5.2 | Socioeconomic Concerns
Sediment Concerns
Concern
Drainage laws
Poorly designed field ditches
potential loss of fertile soils
Lack of no-till/grassed waterways throughout both watersheds
Erosion control practices don't appear to be used properly
Sprawl
Nutrient Concerns
Concern
The public lacks education about fertilizer use
Increasing discharge rates collecting more surface pollutants
Under appreciation of ecosystem services
Public Education Concerns
Concern
Watershed restoration is underfunded
Homogenized watershed planning
Limited BMP Concerns
Concern
Lack of low impact storm water planning
Lack of smaller scale planning efforts
BMPs not considered in new developments
Over engineered water management solutions

TABLE 5.3 | Fish and Aquatic Wildlife Concerns
Sediment (Streambank Sources) Concerns
Concern
Streambank sediment loss
High near bank stress on channelized streams
Lack of riparian habitat on stream segments
Removal of gravel from riffles
Disregard for the headwaters of stream systems
Altered floodplain with more hydromodifcation
Destabilized stream bank with removal of vegetation
Abutments and impoundments
Erosion of banks
Channelized ditches throughout watersheds
Lack of vegetation/habitat along river systems
Sediment (Sheetflow Sources) Concerns
Concern
Poor sediment management strategies
Destabilization of soil do to ground cover removal
Lack of BMP on tile intake points
Shrink/swell characteristics
Poorly managed HES
Increase in impervious land cover
Runoff from Urban Areas
storm water system to outfalls in the river
Runoff from various parking lots adjacent to waterways
General storm water issues
Auto salvage yards
Increased water discharge

TABLE 5.4 | Fish and Aquatic Wildlife Concerns Continued
Nutrients (Sheetflow Sources) Concerns
Concern
Lack of wetlands for chemical processing
Lack of on site infiltration on farmland
Chemicals from fertilizers and agricultural practices
Lack of agricultural BMPs
Fear of the ignorance of underground drainage tiles.
Chemical Usage on Genetically Engineered Agriculture crops
Runoff from former factories
Nutrient rich runoff from fertilizers from recreational sources
Removal of forests and wetland systems
Miscellaneous Fish and Aquatic Wildlife Concerns
Concern
larger rain events with climate change
High stream temperatures
Riparian Zones neglected
Disregard for historic natural systems
Lack of Wildlife Diversity (threatened/endangered species, and invasive/exotic species)

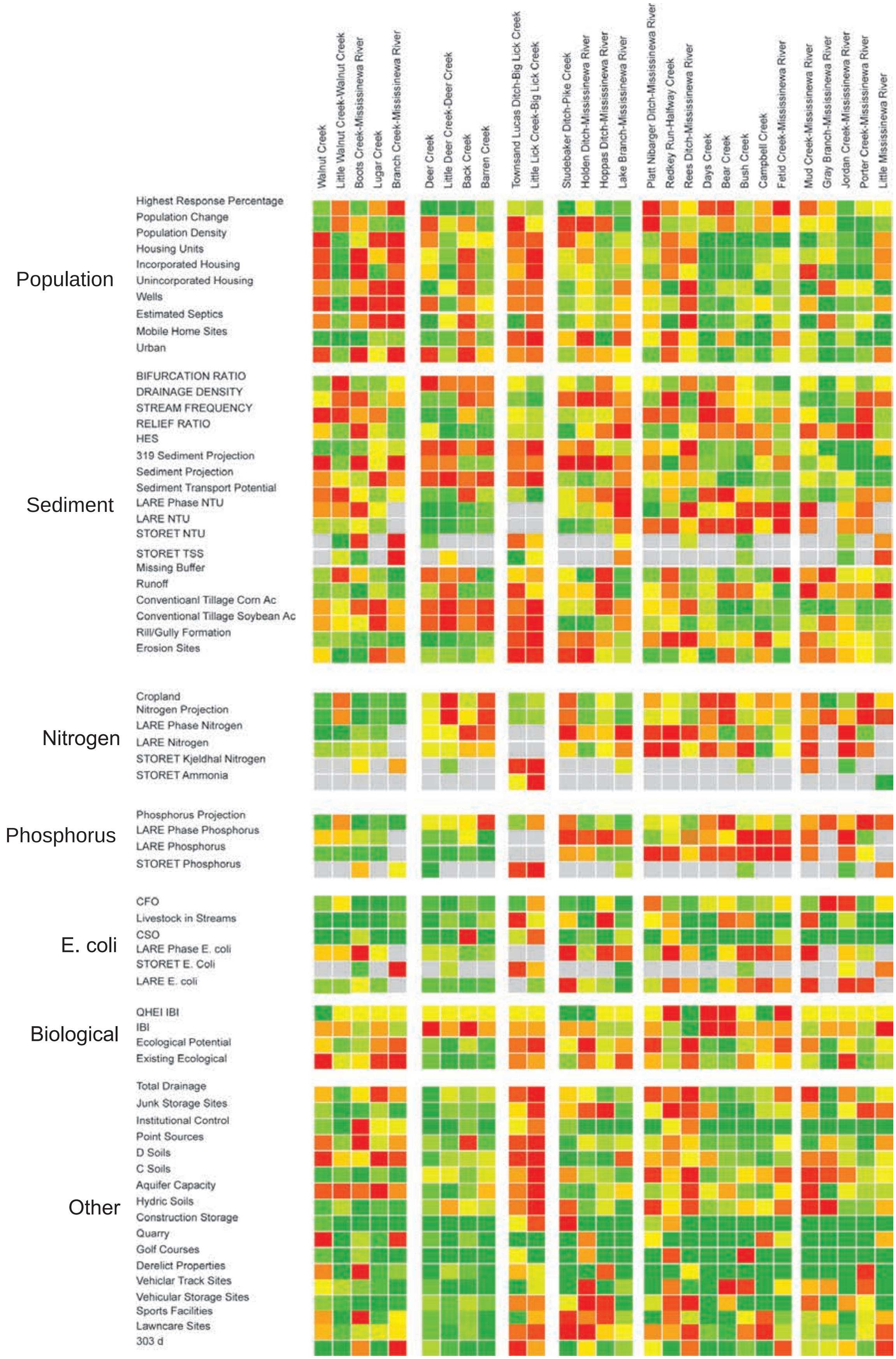


FIG. 5.1 | Color Chart
Comprehensive representation of data gathered during the watershed and water quality inventories. Only lacks results of water quality monitoring conducted for this plan. Left column lists specific analyses performed, organized into groups based on similarities. Top row lists subwatersheds, roughly organized from west to east. The color gradient follows the visible spectrum: reds to oranges to yellows to greens. Highest values are represented by red and lowest values by green.

6. UNDERSTANDING WATER QUALITY

In order to understand the effects of land-use and physical characteristics on water quality within the Upper Mississinewa River Watershed (UMRW), it is necessary to look at past and current water quality data. This section will include a discussion of the factors effecting water quality and an introduction to the various water quality parameters used to assess water quality. The underlying reasons for water quality monitoring conducted by the state of Indiana is also discussed.

6.1 UNDERLYING REASON FOR WATER QUALITY MONITORING

According to the laws of the State of Indiana, waterways are a public resource that are owned and used collectively by the citizenry. In order to protect functional uses that waterways provide to citizens, the Indiana General Assembly has established baseline mandated requirements. These functional uses are referred to as “beneficial uses” and are defined in Indiana Code 14-25-7-2 as “the use of water for any useful and productive purpose.” There are eleven beneficial uses: (1) Domestic, (2) Agricultural, including irrigation, (3) Industrial, (4) Commercial, (5) Power generation, (6) Energy conversion, (7) Public water supply, (8) Waste assimilation, (9) Navigation, (10) Fish and wildlife, and (11) Recreational. The protection of these beneficial uses is important to the health of Indiana’s citizens, economy, environment, and wildlife. The Indiana Department of Environmental Management (IDEM) is the primary agency that protects the beneficial uses of waterways in Indiana. In order to determine if beneficial uses are being met, IDEM uses a water quality monitoring and assessment strategy. Every two years, IDEM develops and submits to the United States Environmental Protection Agency (EPA) a report called the Integrated Monitoring and Assessment Report 305(b). The most recent report was delivered to the EPA in 2014. This report determines where “beneficial uses” are adversely affected. Map 6.1 on p. 94 was included in the 2014 report. It shows the monitoring locations for all of IDEM’s surface water sampling programs and illustrates the sampling density achieved through IDEM’s water quality monitoring strategy over a five year period (2009-2013). There are three general approaches to water quality monitoring used by IDEM: probabilistic, fixed, and targeted. Probabilistic monitoring was not conducted in the Upper Wabash River Basin (which contains the UMRW) during this five year period (2009-2013). It was performed in the Upper Wabash in 2008 and most recently in 2015. Probabilistic monitoring performed at the basin level serves the purpose of assessing all waters of the state. Results show overall trends in water quality and allows comparison of basins. However, it does not indicate the sources of specific impairments. As part of the probabilistic approach, the state has been divided into nine watershed basins which have been monitored on a rotating basis since 2011, with one basin being monitored each year. In another monitoring approach, fixed station monitoring, water quality data is collected at a fixed station monthly, giving long-term data for the site. The final monitoring approach, targeted monitoring, can employ a probabilistic design but is done on a much smaller scale than the basin level monitoring. Water quality testing performed by IDEM in the UMRW in 2014 was done by the Targeted Studies Section and is an example of targeted monitoring. Sites shown within the UMRW in Map 6.1 include two fixed stations, and may include State Revolving Fund Clean Water Projects and targeted sites. This ongoing collection and analysis of water quality data using these monitoring approaches is a crucial strategy to ensure that beneficial uses of the river are being met.

6.2 WATER QUALITY PARAMETERS FOR MONITORING BENEFICIAL USES

Water quality monitoring is not used to assess whether *all* of the beneficial uses are being met, as the chemical and physical water quality parameters analyzed do not indicate the sustainability of all beneficial uses. However, the beneficial uses that chemical and physical water quality parameters primarily assess are (a) Fish and wildlife, (b) Recreational, and (c) Public water quality. Therefore, these are the beneficial uses with which the UMRW-P are the most concerned. The public water supply and recreational uses are affected mainly by pathogens, nutrients and suspended solids. Fish and other aquatic wildlife are directly and indirectly affected by a wider range physical and chemical factors. The following sections will look at the parameters used to assess water quality for these three beneficial uses.

FOUR BASIC INDICATORS OF AQUATIC ECOSYSTEM HEALTH

To determine if waterways support aquatic life, four basic parameters are measured. If any of these parameters are not within the optimum ranges necessary to support life, it could lead to the loss or impairment of aquatic life. The basic parameters used to assess the water quality for aquatic organisms in Indiana streams are (1) dissolved oxygen, (2) pH, (3) temperature, and (4) clarity (turbidity or transparency). Besides indicating the health of an aquatic ecosystem, these parameters can also serve as indicators of environmental pollutants within the water. The following descriptions of these core chemical and physical indicators of water quality contain excerpts from the publication, “Monitoring Water in Indiana,” by Jane Frankenberger and Laura Esman of Purdue University.

1.) Dissolved Oxygen
"Dissolved oxygen (DO) concentration represents the amount of oxygen that is dissolved in a waterbody. The solubility of oxygen varies with temperature, and DO levels fluctuate regularly, particularly between day and night. Percent saturation is the level of DO in the water compared to the total amount of DO that the water has the ability to hold at a given temperature and pressure. Dissolved oxygen levels indicate whether the water can support aquatic life. Causes of insufficient DO include:

- Rapid decomposition of organic materials, including dead algae, shoreline vegetation, manure or wastewater.
- High ammonia concentrations use up oxygen in the process of oxidizing ammonia (NH4+) to nitrate (NO3 -).
- Higher temperatures, which allow less oxygen to dissolve in water.
- Lack of turbulence or mixing to expose water to atmospheric oxygen.
- Low flow or water level

While an aquatic system cannot have "too much" oxygen, high levels of dissolved oxygen (12-18 ppm), known as "super-saturation," often occur in stagnant waters when nutrient pollution has stimulated an algal bloom. Plants or algae produce large amounts of oxygen during the day through the process of photosynthesis, resulting in a high dissolved oxygen level. When photosynthesis stops for the evening, those same plants and algae will consume oxygen from the water for respiration, causing a dip in dissolved oxygen levels."[1]

2.) PH
"pH is the concentration of hydrogen ions in a solution on a scale of 0 to 14 (<7 is acidic, 7=neutral, >7 is basic). A change of 1 unit on a pH scale represents a 10 fold change in the pH, for example, water with a pH of 6 is 10 times more acidic than water with a pH of 7. pH levels indicate whether the water can support aquatic life. Most aquatic animals and plants have adapted to life in water with a specific pH and even slight changes can reduce hatching success of fish eggs, irritate fish and aquatic insect gills and damage membranes, and affect amphibian populations."[2] Due to the state's limestone geology, Indiana surface waters will typically have a pH that is relatively basic (>7). According to Hoosier Riverwatch's Volunteer Stream Monitoring Training Manual, pH typically ranges from 7.2 to 8.8 and the Indiana average is 8.0.

3.) Temperature
"Water temperature is a critical water quality and environmental parameter because it governs the kinds and types of aquatic life, regulates the maximum dissolved oxygen concentration of the water, and influences the rate of chemical and biological reactions. The organisms within the ecosystem have preferred temperature regimes that change as a function of season, organism age or life stage, and other environmental factors. Most aquatic organisms are poikilothermic ("cold-blooded"), which means they are unable to internally regulate their core body temperature. Therefore, temperature exerts a major influence on the biological activity and growth of aquatic organisms; the higher the water temperature, the higher the rate of metabolic reactions. The rate of photosynthesis is also affected by temperature resulting in increased plant and algal growth with increased temperatures.

"Temperature is also an important influence on water chemistry. The rate of chemical reactions generally increases at higher temperature, which in turn affects biological activity. Warmer temperatures increase the solubility of salts in water but decrease the solubility of gasses in water. Another important example of the effects of temperature on water chemistry is its impact on oxygen. Warm water holds less oxygen than cool water, so it may be saturated with oxygen but still not contain enough for survival of aquatic life."[3]

4.) Clarity
"Turbidity and transparency are both measures of water clarity. Turbidity and transparency are not measures of the concentration of suspended materials in water, but rather their scattering and shadowing effect on light shining through the water. Suspended materials include soil particles (clay, silt, and sand), algae, plankton, microbes, and other substances, which are typically in the size range of 0.004 mm (clay) to 1.0 mm (sand). Turbidity is a measure of how much the material suspended in water decreases the passage of light through the water, and is generally measured using a turbidity meter. Transparency measures how far light can penetrate a body of water and can be measured using a secchi disk or transparency tube.

"Turbidity and transparency indicate the visibility distance in water, which directly affects aquatic organisms....Turbidity and transparency are dependent upon the amount of suspended materials (algae and sediments) that are present in the water. Excessive amounts of these materials can be an indication of eutrophication"[4] Suspended sediments can be detrimental to fish and aquatic life by "[absorbing] heat from sunlight, which increases water temperature and subsequently decreases levels of dissolved oxygen (warmer water holds less oxygen than cooler water). Photosynthesis also decreases, since less light penetrates the water. Suspended solids can also destroy fish habitat because they settle to the bottom and can eventually blanket the riverbed, smothering the eggs of fish and aquatic insects, and suffocating newly-hatched insect larvae. Suspended materials can also harm fish directly by clogging gills, reducing growth rates, and lowering resistance to disease. Changes to the aquatic environment may result in diminished food sources, and increased difficulties in finding food. Natural movements and migrations of aquatic populations may also be disrupted."[5]

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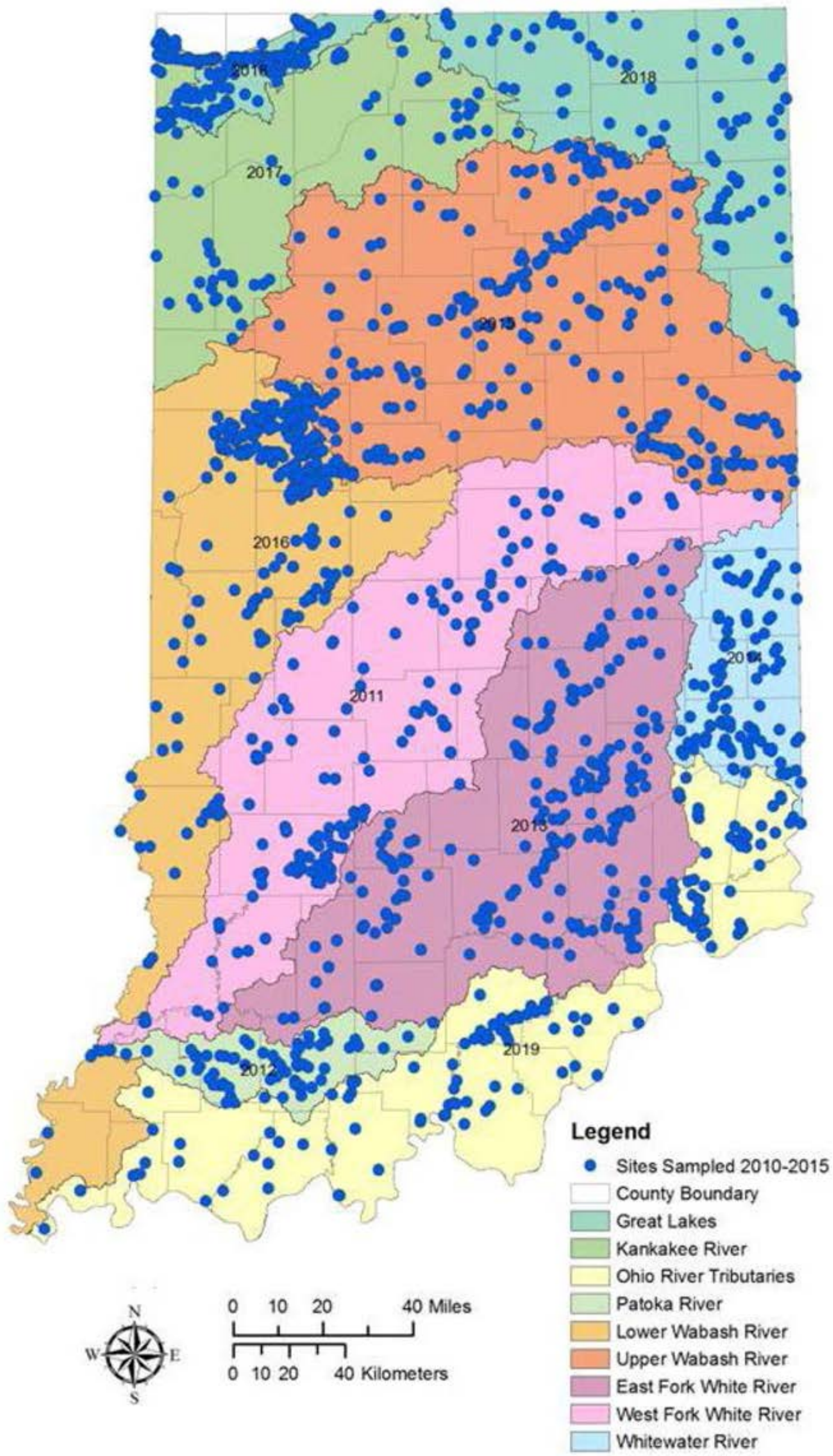
1 Frankenberger J, Esman L. *Monitoring Water in Indiana: Choices for Nonpoint Source and Other Watershed Projects.* Department of Agricultural and Biological Engineering, Purdue University. 2012.
2 Frankenberger, *Monitoring Water in Indiana*, 88.
3 Ibid.
4 Ibid.
5 Ibid.



MAP 6.1 | IDEM sample sites

SPECIFIC POLLUTANT PARAMETERS AFFECTING AQUATIC LIFE

As indicated in the previous narrative, certain parameters are interrelated, with imbalances in one resulting in imbalances in another (for example, a decrease in clarity can cause an increase in temperature, which then causes a decrease in dissolved oxygen). In turn, these imbalances are often driven by excessive levels of nutrients and sediments. When nutrients and sediments exceed naturally occurring targets, they function as pollutants. Pollution is a broad descriptor that is loosely defined as elements in the natural environment that cause adverse change, and includes many types of chemical substances often classified as either foreign or naturally occurring. While nutrients and sediments are found naturally in streams, excessive levels are often a result of human influences in the watershed and are considered pollutants. "Nutrient pollution" is furthermore broken down into subcategories based of the type of nutrient (i.e. nitrogen and phosphorus) and its source. Other types of pollutants (with the exception of pathogens, described in the next section) are beyond the scope of this watershed plan. Figure 6.1 on the following page illustrates the relationships between several water quality parameters. The following description of the different types of nutrient pollutants commonly found in Indiana water contains excerpts from "Monitoring Water in Indiana," by Jane Frankenberger and Laura Esman of Purdue University.

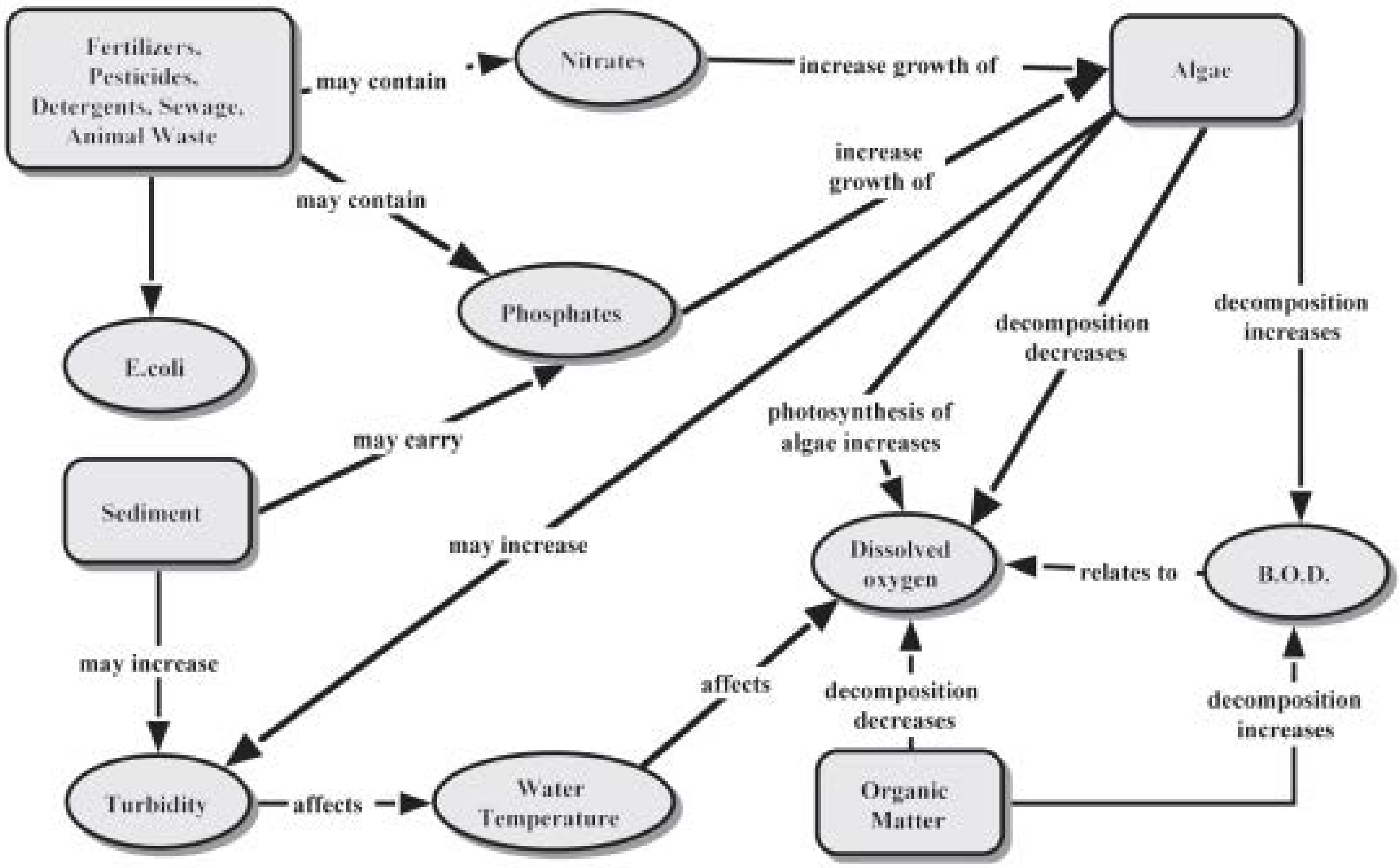


FIG. 6.1 | Cumulative impacts of water quality impairments (HRW)

NITROGEN OVERVIEW

"Nitrogen is a critical nutrient for plant growth, but too much nitrogen in the water can lead to eutrophication of streams and lakes. Nitrogen has also been identified as a major cause of hypoxia, or low oxygen, in the Gulf of Mexico. Sources of nitrogen include runoff from fertilized lawns, cropped fields, animal manure application and storage areas, wastewater treatment plants, failing septic systems, and industrial discharges. Nitrogen may be present in water in any of four forms: nitrate, nitrite, ammonia, or organic nitrogen. The sum of these four forms is known as "total nitrogen" (TN)."[1] Figure 6.2 shows the four major forms of nitrogen found in water.

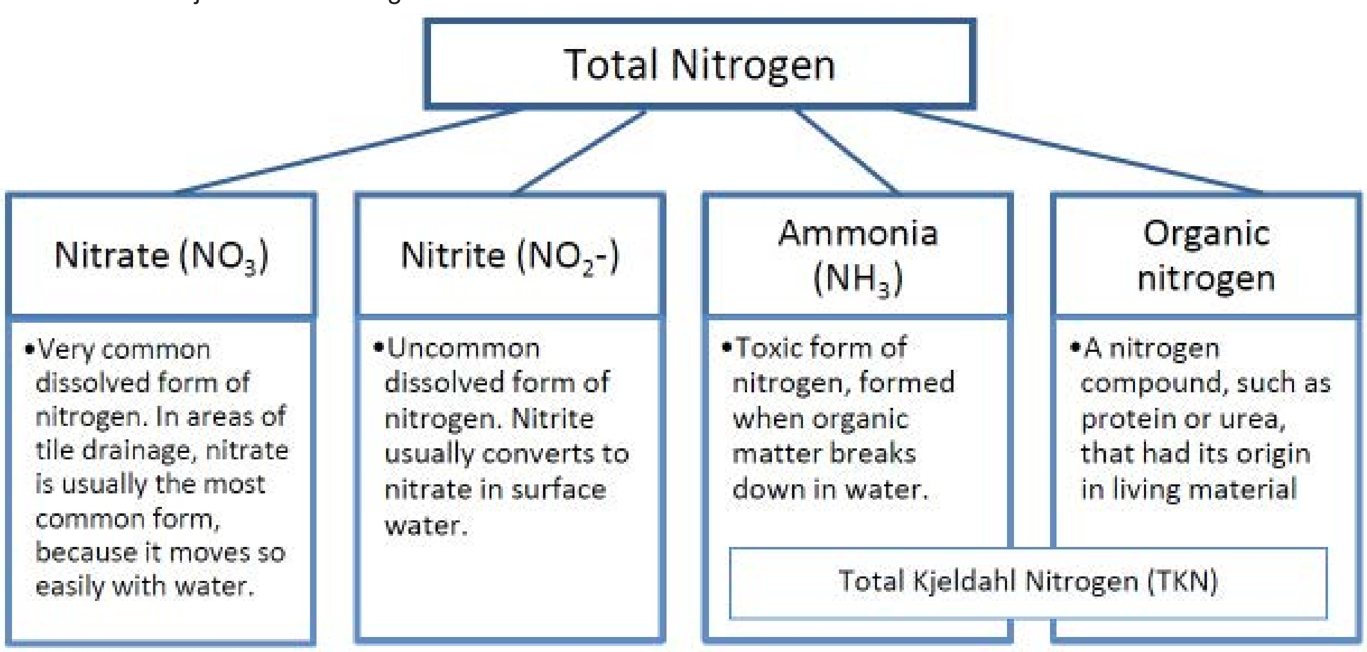


FIG. 6.2 | Chemical forms of nitrogen in water. (From Frankenberger, *Monitoring Water in Indiana*, 76.)

1 Frankenberger, *Monitoring Water in Indiana*, 76.

Ammonia Nitrogen
"Ammonia is a colorless gas with a strong pungent odor that is very soluble in water....Ammonia-N levels greater than approximately 0.1 mg/L usually indicate polluted waters. Plants are more tolerant of ammonia than animals, and invertebrates are more tolerant than fish. When ammonia-N levels reach 0.06 mg/L, fish can suffer gill damage. When levels reach 0.2 mg/L, sensitive fish like trout and salmon begin to die. As levels near 2.0 mg/L, even ammonia-tolerant fish like carp begin to die. Such levels are uncommon in Indiana waterways and usually only last for a short time, and are unlikely to be captured by infrequent monitoring. Ammonia is therefore usually not a good parameter for assessing nonpoint source impacts."[1]

Total Kjeldahl Nitrogen (Pronounced Kel-Däl)
"Total Kjeldahl Nitrogen (TKN) is the sum of organic nitrogen and ammonia in a water body. High concentrations of TKN typically result from sewage and manure discharges to surface waters. Sources of TKN include decay of organic material (plants, animal waste, urban and industrial disposal of sewage and organic waste).... TKN concentrations from the 176 Fixed Stations monitored by IDEM since 1990 were analyzed to provide an overview of TKN levels in Indiana. Ammonia was usually about 10% of TKN, meaning that organic nitrogen is about 90% of the TKN."[2] The median TKN concentration was 0.7 mg.L.

Nitrate Or Nitrate+Nitrite
"Nitrate is the major inorganic form of nitrogen, common in Indiana waters. Nitrate and nitrite are often combined, because analytic methods usually do not distinguish between these two forms of nitrogen. Because the nitrite portion is quickly converted to nitrate by bacteria, it is very uncommon in streams and lakes, so the total (nitrate plus nitrite) can be assumed to be close to the level of nitrate alone. A potential source of confusion is that nitrate can either be reported as mg/L of nitrogen in the form of nitrate (often called nitrate-N) or in terms of mg/L of the nitrate molecule itself, which is 4.4 times greater. It is very important to distinguish these two."[3] The concentrations in this watershed management plan are always for nitrate-N. "Nitrate is generally higher in streams that drain agricultural watersheds, particularly when a large area is drained by subsurface tile drains. The concentration of nitrate-N in tile drains themselves is often above 10 mg/L (Brouder et al., 2005), and tile drains usually lead to higher concentrations in the receiving stream."[4]

Total Nitrogen
"Total nitrogen is the sum of all forms of nitrogen including inorganic forms (nitrite, nitrate and ammonia) and organic nitrogen. Nitrogen can change forms, and total nitrogen is the analysis that provides information on all forms together."[5]

PHOSPHORUS OVERVIEW
"Phosphorus is a nutrient required for the basic processes of life, and is often the nutrient that limits the growth and biomass of algae in freshwater lakes and reservoirs. Nonpoint source phosphorus comes from runoff from urban areas, construction sites, agricultural lands, manure transported in runoff from feedlots and agricultural fields, and human waste from failing septic systems. Point sources are wastewater treatment plants, industrial wastewater, and confined animal feeding operations....Phosphorus is found in three major chemical forms in water, with the sum of the three known as total phosphorus."[6] Figure 6.3 describes the three major chemical forms of phosphorus found in water.

Total Phosphorus
"Total phosphorus is the measure of all forms of phosphorus, dissolved or particulate, found in a water sample. Phosphorus is usually the limiting nutrient in lakes and rivers, because it occurs in the least amount relative to the needs of plants. Eutrophication occurs when additional phosphorus is added to the water and excessive algae and aquatic plants are produced which use up oxygen when they die. Although only the dissolved inorganic form of phosphorus (orthophosphate) is readily available to algae or aquatic plants, other forms of phosphorus can be converted to orthophosphate. Therefore, total phosphorus is the most complete indicator of eutrophication potential, and is used in proposed nutrient criteria....Total phosphorus can be expressed as milligrams per liter (mg/L) or micrograms per liter (µg/L), which is 1000 times smaller."[7]

Orthophosphate (Also Known As Soluble (Or Dissolved) Reactive Phosphorus)
"Orthophosphate is an inorganic form of phosphorus, a nutrient required for the basic processes of life but which also causes eutrophication in lakes and streams. The concentration of orthophosphate constitutes an index of the amount of phosphorus immediately available for algal growth. Orthophosphate is easier to analyze than total phosphorus, which also includes organic forms of phosphorus, and is often used as the indicator of phosphorus concentration in a water body. Orthophosphate is a good indicator of eutrophication potential because it is the form of phosphorus that is readily available to algae. It is typically found in very low concentrations in unpolluted waters. Eutrophication occurs when additional phosphorus is added to the water and excessive algae and aquatic plants are produced which use up oxygen when they die. The orthophosphate concentration indicates the amount readily available to algae or aquatic plants....Orthophosphate is often reported in milligrams per liter (mg/L) or in units 1000 times smaller, micrograms per liter (µg/L). Indiana lakes monitored by the Indiana Clean Lakes Program during 2010-2011 were found to have a median concentration of SRP of 0.020 mg/L with a minimum concentration of 0.01 mg/L and a maximum concentration of 0.59 mg/L (Jones et al., 2012)."[8]

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1 Frankenberger, *Monitoring Water in Indiana*, 88
2 Ibid.
3 Ibid.
4 Ibid.
5 Ibid.
6 Ibid.
7 Ibid.
8 Ibid.

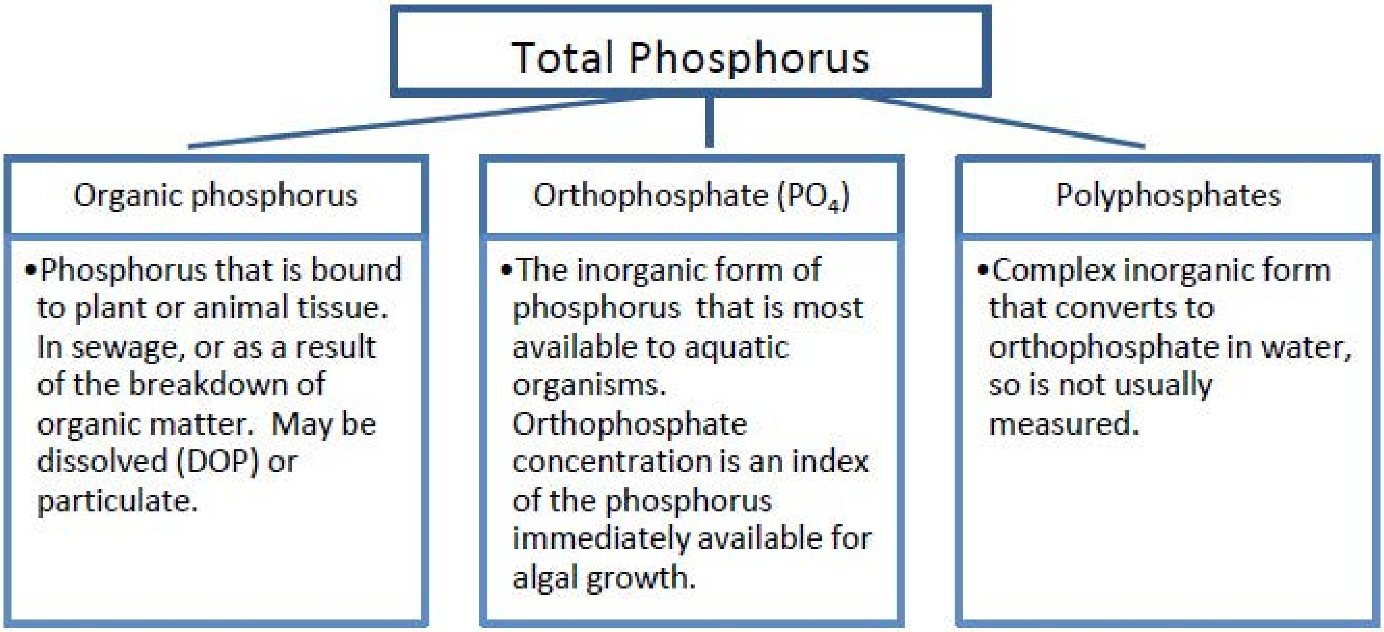

FIG. 6.3 | Chemical forms of phosphorus in water (From Frankenberger, *Monitoring Water in Indiana*, 76.)

6.3 THREATS TO RECREATION AND DOMESTIC DRINKING WATER

Many microbes (including bacteria, viruses, protozoa, fungi, and algae) are found naturally in Indiana streams and rivers and have little impact on human health. However, there are some that can cause harmful or deadly effects for those who drink or come into contact with water contaminated with these microbes.

PATHOGENS

Pathogens are a threat to recreational and public water supply uses. In biology, a pathogen in the broadest sense is anything that can produce disease. Typically the term is used to describe an infectious microbial agent (such as a virus, bacterium, prion, fungus, viroid, or parasite) that causes disease in its host. Certain pathogens can cause short-term illness, such as diarrhea, cramps, nausea, headaches or other symptoms. Severe reaction to pathogen infection can include kidney failure and possibly death. Pathogens pose higher risks for infants, young children, the elderly and others with compromised or weak immune systems.

E. coli is a type of fecal pathogen commonly monitored in Indiana streams. E. coli levels in exceedence of natural levels indicate that waters are contaminated with fecal wastes. E. coli is just one of many pathogens present in fecal wastes. However, rather than conducting time consuming and costly monitoring for all of these pathogens, the presence of E. coli indicates that their presence is likely. E. coli levels exceeding state standards can result in the closure of water bodies for recreation. Elevated E. coli levels can occur throughout the year; however, Indiana's water quality standards for E. coli only apply during the recreation season (April to October). Therefore the waterbody can only be considered "impaired" during that time period.

While E. coli sampling is the primary indicator for pathogens in the water, turbidity can also be a proxy or surrogate indicator for bacterial pollution. Particles in the water causing an increase in turbidity (sediments and organics) often provide food and shelter for pathogens. Human and animal waste (a mix of organic solids) are both sources of E. coli.

BLUE-GREEN ALGAE

Blue-green algae, also known as cyanobacteria, is a group of photosynthetic bacteria. They occur naturally in waters and their presence is noticed when rapid growth caused by favorable conditions causes a "bloom." Besides being a cause of reduced clarity and depleted oxygen levels (when eutrophication occurs), blue-green algae also produce a toxin that can be harmful to humans and animals who ingest the water. Symptoms can include stomach cramps, diarrhea, vomiting, headache, fever, muscle weakness, and difficulty breathing.[9] These toxins have been known to cause death in cattle and other animals.[10]

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9 Wisconsin Department of Natural Resources. [web page] Blue-Green Algae. http://dnr.wi.gov/lakes/bluegreenalgae/ Accessed 10 December 2015].

10 Lembi, Carole, A. Fact Sheet on Toxic Blue-green Algae. Department of Botany and Plant Pathology, Purdue University. November, 2012.

6.4 WATER QUALITY TARGETS

The pollutants described in this section (nutrients, sediment, and E. coli) are the most common nonpoint source pollutants in Indiana waterways. They are the major drivers of decreased clarity, increased temperature, and decreased dissolved oxygen, and are major factors in why many waters in Indiana are not meeting beneficial uses established by the state legislature. In order to understand the scope of water quality impairment and guide the interpretation of water quality data, different agencies have each established their own water quality targets for guiding state monitoring programs and watershed projects. The Project Manager considered these various targets and selected targets thought to be appropriate for each of the parameters monitored in this study. These targets are used as the basis of water quality interpretation for this WMP and are outlined in Table 6.1. Some targets used were more stringent than IDEM's draft TMDL targets. The following paragraphs provide the rationale for the selection of a number of these targets.

TABLE 6.1 | Water quality targets

Parameter	Target	Reference/Other Information
E. coli	Max: 235 CFU/ 100mL in a single sample	Indiana Administrative Code (327 IAC 2-1.5-8)
Total Suspended Solids (TSS)	Max: 25 mg/L	(Waters, T.F.,, 1995). Sediment in streams: sources, biological effects and control. American Fisheries Society, Bethesda, MD. 251 p.
Total Phosphorus	Max: 0.3 mg/L	IDEM draft TMDL target
Nitrate-N	Max: 1.0 mg/L	Ohio EPA recommended criteria for Warm Water Habitat (WWH) headwater streams in Ohio EPA Technical Bulletin MAS//1999-1-1 [PDF]
Biological Communities	IBI greater than or equal to 36; mIBI greater than or equal to 36.	Based on TMDL for Upper Mississinewa River Watershed. According to the TMDL, these scores indicate that aquatic life uses are fully supported.
Habitat Score (QHEI)	Greater or equal to 43 for headwater streams; greater or equal to 45 for larger streams.	OH EPA general narrative ranges for QHEI scores. These target values correspond with the low end of the narrative rating for FAIR.
pH	>6 or <9	Indiana Administrative Code (327 IAC 2-1-6)
Dissolved Oxygen (DO)	Min: 4.0 mg/L	Indiana Administrative Code (327 IAC 2-1-6)
Temperature	Dependant on time of year and whether stream is designated as a cold water fisheries. See Table 6.3 on p. 98.	Indiana Administrative Code (327 IAC 2-1-6)
Turbidity	Max: 25.0 NTU	Minnesota TMDL criteria for protection of fish/ macroinvertebrate health
	Max: 10.4 NTU	U.S. EPA recommendation

E. coli

The target for E. coli as defined by the Indiana Administrative Code is a maximum of 235 cfu/100mL in a single sample. This is the target that will be used for this plan (Table 6.1). Sampling for this WMP done by the Muncie Bureau of Water Quality was conducted on a monthly basis; since five samples need to be collected over a period of 30 days to calculate a geometric mean, a geometric mean could not be calculated. While sampling that was conducted concurrently by IDEM and used for analysis of water quality in this study did contain the appropriate data for calculating a geometric mean, the Project Manager elected not calculate a geometric mean for the sake of consistency. Rather, an average was calculated for each sample site, using data collected throughout the entire year. Although the IAC code specifies that the standard of 235 CFU/100mL is for a single sample, the Project Manager elected to use this standard for the annual mean calculated for each site.

TSS

Because a TSS concentration greater than 25mg/L is known to reduce fish concentrations, we selected a maximum of 25mg/L as our target for TSS (Table 6.1).

Nitrate-N

After examining various targets for nitrate-N, we concluded that the IDEM draft TMDL target of 10 mg/L is not adequate. Current loads calculated for each subwatershed using its average nitrate-N and average flow data from water quality monitoring (conducted for this plan monthly from 2014-2015) are below target loads calculated using the 10mg/L target, meaning no reductions in nitrate-nitrogen would be required by our plan. However, scientific evidence and public policy suggests that significant reductions in nutrients are needed. Excess nitrogen and phosphorus are contributing to the Gulf of Mexico's Dead Zone.

The Mississippi River Gulf of Mexico Watershed Nutrient Task Force is a group of several government agencies, including the US EPA and NRCS, that was created to address issues affecting the Gulf Dead Zone. In 2008 the Task Force created the Gulf Hypoxia Action Plan, which establishes a goal of at least a 45% reduction in total nitrogen and total phosphorus loads to the Gulf of Mexico.[1] The goal is to reduce the size of the dead zone from an average of nearly 6,000 square miles to 2,000 square miles. Scientific results support that this 45% reduction is needed to reach this goal.[2] Indiana is one of the top three states contributing nitrogen to the Gulf (Figure 6.4), suggesting that its nitrate-N loads are significant.

These conclusions have led us to adopt the Ohio EPA nitrate-nitrogen standard of 1.0 mg/L for Warm Water Habitat (Table 6.1). The US EPA also has a similar standard for the ecoregion that the UMRW is a part of (ECOregion IV). A similar target was also developed by the US EPA. The US EPA's reference condition for *Total Nitrogen* in our Ecoregion is 2.18 mg/L (Table 6.2). Nitrate-nitrogen, the parameter evaluated in this study, is one of many forms of nitrogen that make up Total Nitrogen, as shown in Figure 6.5. Because nitrate-nitrogen is only one form of nitrogen that is analyzed under Total Nitrogen, the nitrate-nitrogen concentration of the EPA target is less than 2.18 mg/L. Therefore, it stands to reason that if the US EPA made a recommendation for nitrate-nitrogen alone, based on the current standard of 2.18 mg/L for Total Nitrogen, it would be lower than 2.18 mg/L.

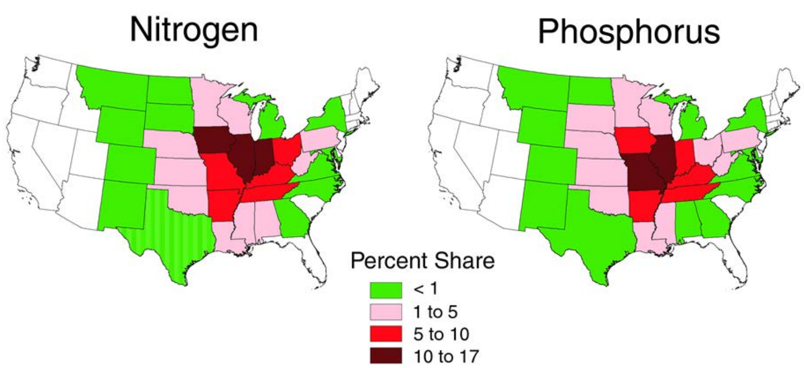

FIG. 6.4 | "Percent Share of Nitrogen and Phosphorus to the Gulf of Mexico based on SPARROW modeling."[3]

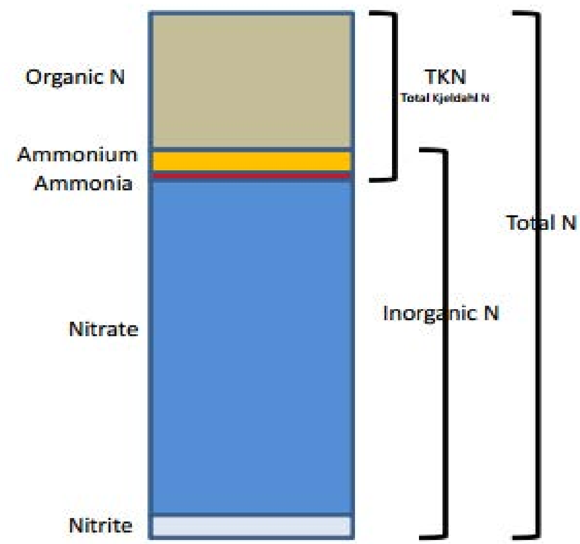

FIG. 6.5 | "Schematic diagram of the relative amount of different N forms commonly found in Minnesota surface waters with elevated N levels."[4]

TABLE 6.2 | Reference conditions for Ecoregion VI. Based on 25th percentiles* only[5]

Nutrient Parameters	Aggregate Nutrient Ecoregion VI Reference Conditions
Total phosphorus (μg/L)	76.25
Total nitrogen (mg/L)	2.18
Chlorophyll a (μg/L) (Fluorometric method)	2.7
Turbidity (NTU)	6.36

* Reference conditions are natural conditions, undisturbed by human impacts. Therefore, reference conditions are examined to gain an understanding of what the water quality of similar, human impacted streams should be. There are different methods for establishing the reference condition of streams. The 25th percentile method for establishing a reference condition is a statistical determination of reference conditions. In this instance, the 25th percentile was calculated using all data for Ecoregion VI found within the US STORET water quality database. 25% of sample values are lower than the 25th percentile value, meaning 75% of sample values are higher than the 25th percentile value. Values about the 25th percentile value may not produce water quality standards that will protect water quality.[6]

1 Iowa Department of Agriculture and Land Stewardship. Iowa Department of Natural Resources. Iowa State University College of Agriculture and Life Sciences. Iowa Nutrient Redution Strategy. A science and technology-based framework to assess and reduce nutrients to Iowa waters and the Gulf of Mexico. November 2012.
2 US EPA. States Develop New Strategies to Reduce Nutrient Levels in Mississippi River, Gulf of Mexico. News Release from Headquarters. 2/12/2015.
3 USGS. National Water-Quality Assessment (NAWQA) Program. Nutrient Delivery to the Gulf of Mexico. http://water.usgs.gov/nawqa/sparrow/gulf_findings/faq.html#1.
4 Wall, D., MPCA. Nitrogen in Minnesota Surface Waters. Minnesota Polution Control Agency. June 2013. p A2-2.
5 US EPA. Office of Water. Office of Science and Technology. Health and Ecological Criteria Division. Ambient Water Quality Criteria Recommendations. Information Supporting the Development of State and Tribal Nutrient Criteria.
6 United States EPA. EPA Response to Peer Review Comments... [webpage] https://www.epa.gov/sites/production/files/documents/ecoregions_peerrevlr.pdf

Total Phosphorus
IDEM's draft TMDL target of 0.3 mg/L for Total Phosphorus was adopted as the target for this plan (Table 6.1). Analysis of water quality data collected for this study showed that 25% of subwatersheds have average loads that are above this target. Applying BMPs to achieve these targets will result in an estimated 6% reduction for the entire UMRW. While this is much lower than the 45% reduction goal for phosphorus specified by the Gulf Hypoxia Action Plan, based on water quality results we believe that some of the major sources of phosphorus (septic systems) in the watershed fall outside the scope of this project's cost-share funding potential. While education will address these sources, we believe that like E. coli, it will be one of the more difficult targets to reach (based on allocation of cost-share funding) and therefore have elected to set what we see as a more realistic target.

Biological and Habitat Scores
A target IBI score of greater than or equal to 36 and a target mIBI greater than or equal to 36 were set by the Project Manager. These targets are based on the target scores for the TMDL for Upper Mississinewa River Watershed. According to the TMDL, these scores indicate that aquatic life uses are fully supported.

A target QHEI score of greater or equal to 43 for headwater streams and greater or equal to 45 for the Mississinewa River was set by the Project Manager. These targets are based on the OH EPA general narrative ranges for QHEI scores. These target values correspond with the low end of the narrative rating for FAIR.

Dissolved Oxygen, pH, Temperature, and Turbidity
Standards for dissolved oxygen, pH, and temperature were taken from the Indiana Administrative Code Title 327, Article 2-1-6. Water temperature targets vary from month to month and can be viewed below in Table 6.3. These physical parameters of streams are strongly tied to the health of biological communities in rivers and streams. Therefore, state water quality standards are set to ensure the protection of these biological communities.

Standards for turbidity are based on an EPA recommendation. Turbidity is also strongly tied to the health of biological communities in rivers and streams. High turbidity can impede gill function, possibly leading to death; reduce growth rate; reduce the availability of food; and harm the development of fish eggs and larvae.[1] Therefore, EPA recommendations are set to ensure the protection of fish and other aquatic organisms.

TABLE 6.3 | Water temperature limits, from IAC 327 2-1-6

Month	Ohio River Main Stem °F(°C)	Other Indiana Streams °F(°C)
January	50 (10.0)	50 (10.0)
February	50 (10.0)	50 (10.0)
March	60 (15.6)	60 (15.6)
April	70 (21.1)	70 (21.1)
May	80 (26.7)	80 (26.7)
June	87 (30.6)	90 (32.2)
July	89 (31.7)	90 (32.2)
August	89 (31.7)	90 (32.2)
September	87 (30.7)	90 (32.2)
October	78 (25.6)	78 (25.5)
November	70 (21.1)	70 (21.1)
December	57 (14.0)	57 (14.0)

1 Minnesota Pollution Control Agency. [web page] Turbidity: Description, Impact on Water Quality, Sources, Measures–A General Overview. Water Quality/Impaired Waters #3.21, March 2008. https://www.pca.state.mn.us/sites/default/files/wq-iw3-21.pdf [Accessed 10 January 2016].

7. HISTORIC WATER QUALITY

7.1 INTRODUCTION TO HISTORICAL WATER QUALITY DATA SETS

Although the Indiana Department of Environmental Management (IDEM) is the primary agency in Indiana engaged in water quality monitoring, other state/federal environmental agencies such as the Environmental Protection Agency (EPA), the United States Geological Survey (USGS) and the Indiana Department of Natural Resources (IDNR) collect water quality data as part of their own internal programs and initiatives. Additionally, universities, municipalities, private sector research groups and even private citizens collect data for their own intents and purposes.

In 2014, the Project Manager performed a desktop survey of existing water quality studies and monitoring efforts. Various relevant historical water quality datasets were acquired. Data was collected from a range of sources, which represented different time periods and locations on both the mainstem of the Mississinewa River and its tributaries. Data was collected specifically from the following four databases/sources:

1. IDEM Assessment Information Management System (AIMS) database.
Since 1990 IDEM data has been collected and maintained in a central repository called the Assessment Information Management System (AIMS). Much of IDEM's data comes from fixed station monitoring. The database also contains data from other agencies, such as the USGS. Data from a 23 year period (1991-2013), collected as part of target monitoring or probabilistic monitoring programs, was extracted from this database. Sampling frequency varied by site and parameter. Of the thirteen sites, one had only one sample collected, while others had as much as 250 samples collected for certain parameters.

2. EPA STORET - (short for STOrage and RETrieval)
STORET is a federal repository for water quality, biological, and physical data and is used nationally by state environmental agencies, other federal agencies, universities, private citizens and many others. Sampling frequency of this dataset varied by site and parameter. Of the fifteen sites, only one had one sample collected, while one site had 359 samples collected for a particular parameter. Data in this database was sampled from 1963 to present day. The information provided in the database does not include the particular sampling and analysis methodologies used.

3. IDNR Lake and River Enhancement Program (LARE diagnostic studies)
Data collected by the IDNR as part of the Lake and River Enhancement Program (plans generated from 2000-2012) was extracted, centralized in an UMRW-P database and also analyzed as part of this watershed historic water quality inventory. In general, water quality sampling frequency is low in LARE studies. Sampling for these studies is usually done only three or four times, sometimes over the course of more than one year. Chemical, biological, and habitat parameters were sampled in each LARE study. See Section 4.1, for specific information about each study's sampling program and methodology, as well as the dates sampling was conducted for each study.

4. Hoosier Riverwatch Database
The Hoosier Riverwatch is a program of the Indiana Department of Environmental Management Watershed Planning and Assessment Branch. The program began in Indiana to increase public awareness of water quality issues and concerns by training volunteers to monitor stream water quality. It provides universities, municipalities, private sector research groups and private citizens the opportunity to centralize individually collected data into an easily accessible state database.

The Hoosier Riverwatch data extracted for the UMRW included 75 sampling events at twelve sites from 2000 to 2012; chemical and physical parameters were measured at these sampling events. Parameters included pH, dissolved oxygen, BOD, temperate, orthophosphate, turbidity, nitrate, total phosphorus, nitrite, and E. coli. Frequencies varied from site to site, with some sites only being sampled once. The site sampled the most was sampled 27 times; at this site sampling took place from 2004-2008, and also in 2010 and 2012 (this site is located in Marion's Matter Park just downstream of the Boots Creek-Mississinewa River site sampled for the UMRW project). Biological communities were also sampled 54 times at 10 sites from 2000 to 2013. Frequency of sampling varied between sites. D-nets or Kick nets were used for invertebrate sampling. The Pollution Tolerance Index (PTI) was calculated using macroinvertebrate data.

CHALLENGES TO WATER QUALITY ASSESSMENT
The assessment of natural systems is inherently challenging due to the variable, dynamic nature of natural systems. Researchers do their best to minimize the uncertainty of results by increasing the frequency of sampling and eliminating temporal variables (e.g. seasonality) by increasing the duration of sampling. Even with their best efforts, there is some degree of uncertainty that results are representative of the water quality. Some of the historic data in this section was not collected at high frequency, making conclusions drawn from it tenuous at best. Some water quality monitoring initiatives have lacked accurately recorded sampling locations (ex. Hoosier Riverwatch), making it difficult to link results with nearby sources during analysis. In many previous studies, sampling locations were not the same as the ones used as part of UMRW-P sampling efforts, making comparative analysis even more difficult. Furthermore, most historic sample sites used by IDEM and other agencies (whose data is found in the STORET) were located on the mainstem of the Mississinewa River. The upstream drainage from these sites is too large to be able to determine which upstream HUC 12 subwatersheds (or smaller areas) are the likely sources of pollutants. Current water quality was collected in smaller drainage areas.

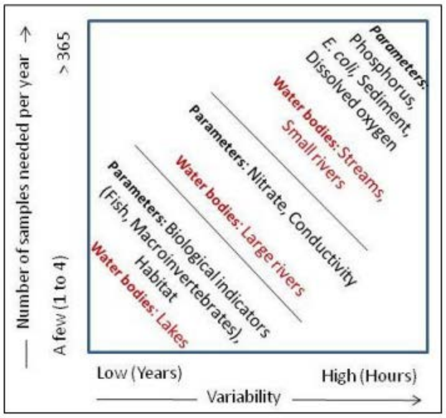

FIG. 7.1 | Sampling frequency recommendations

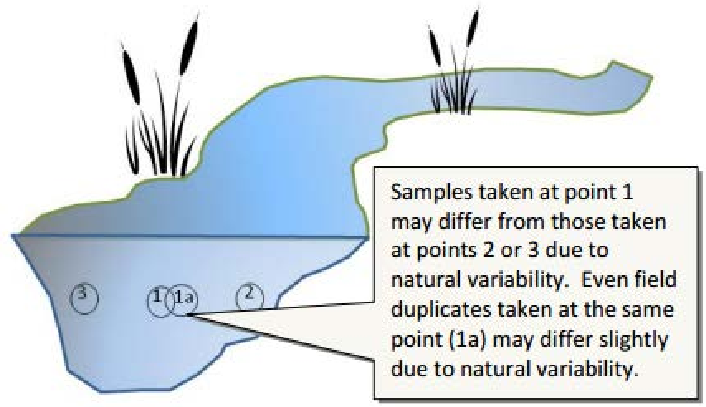

FIG. 7.2 | Parameters can very within a stream, even at the "same location" as defined by GPS coordinates.

Again, manipulating and interpreting data from these studies is challenging because of the nature of streams. Streams are highly variable, dynamic systems whose water quality is affected by factors such as seasonality, rainfall and location. A water sample from a stream represents only a single moment, in a single location, and can even vary based on its location within the stream cross section. Because of this ever-changing nature, collecting representative data with which to characterize streams is a challenge for researchers. The Hoosier Riverwatch Manual states, "To get an accurate picture of a stream's water quality, tests have to be performed on a regular basis, over a period of years." [1]

VARIABLES INFLUENCING WATER QUALITY DATA

Sampling methods and locations need to account for this variability within streams, with similar procedures being followed at each site. Sampling should be done regularly throughout the year to account for seasonal differences caused by rainfall, land use dependent practices, etc. For example, nitrate levels are strongly influenced by (a) land application of manure, which usually takes place in fall and spring, and (b) by side dressing, which usually occurs in late spring and early summer. Sampling throughout the year allows these changes to be properly characterized. Sampling should also be conducted at approximately the same time of the day to account for diurnal cycles. For example, the temperature drops during evening hours, resulting in a higher percentage of dissolved oxygen. When temperatures rise during the day, dissolved oxygen levels rise. It is also essential to collect flow data at the time of sampling. If flow is not measured, data cannot be separated into categories of high and low flow events. Averaging all data, without separating it according to flow, can result in an overestimation of annual pollutant loads. It can also hinder comparative analysis; if one site was sampled more often at high flow than another site, the first site will likely have a higher average. Figure 7.1 shows the general relationship between the frequency of sampling needed and the type of water body and parameter being monitored (Frankenberger 2012).

DATA LIMITATIONS

It is challenging to analyze historical data because sampling doesn't necessarily follow general guidelines listed in the previous three paragraphs. Data within these historical databases are often collected using varying sampling methods. It ranges multiple years, with different sample locations, sample frequencies and clustering of parameter types. As explained in the previous section, this limits the reliability and accuracy of the comparisons being made between sites as well as comparisons being made with data collected as part of this project.

Each contributing agency has unique approaches to sampling frequency driven by particular research programs or research questions. Some sub datasets were collected for a wide variety of locations at a low frequency, while some sub datasets were generated at a single site with a high sample frequency. Comparing data collected on the mainstem of the Mississinewa River is further complicated by the fact upstream and downstream sites vary significantly in contributing drainage areas. It is difficult to determine how much pollution entered the river at upstream sites and how this pollution is contributing to results at downstream sites. Despite these limitations, much of the data analyzed in subsequent sections use means, minimums, and maximums derived from these varied datasets. All the datapoints included in the following tables are the averages of water quality data generated by either (a) location, (b) year, or (c) geographic proximity (as noted in the table title and or accompanying narrative). For reference, we have included tables in Appendices H-J that outline the count, frequency, and year for the data sets, as well as tables and maps that include geographic locations and/or location clusters when applicable. To the extent possible, we have looked at the data in different frameworks/ perspectives in an attempt to draw general conclusions despite these limitations. In all cases, the mean assessments are meant for general comparisons used for educational purposes and should be interpreted with caution.

1 Indiana Department of Environmental Management. 2015. Volunteer Stream Monitoring Training Manual.

7.2 IDEM'S ASSESSMENT INFORMATION MANAGEMENT SYSTEM (AIMS) DATABASE

The primary data set analyzed comes from IDEM's Probabilistic Monitoring Program, which employs a stratified random sampling (probabilistic) design to generate a representative set of sampling locations for each basin. The probabilistic sampling results are used by IDEM to make comprehensive use support assessments, which are statistically valid statements about the overall water quality within a given watershed. The same data used to make comprehensive statistical assessments for a given basin are also applied to the specific stream or stream reach from which they were collected in order to make site-specific assessments.

IDEM has collected water chemistry data on the Mississinewa River from 1991 to 2013. Thirteen of IDEM's sites are upstream of the Mississinewa Reservoir Dam, and of these eleven are within the study area for this WMP. Data was extracted for all 13 established sampling sites upstream of the dam (Map H.1 and Table H.1 in Appendix H). While the extracted data contained a wide variety of parameters, parameters analyzed as part of this study were limited to dissolved oxygen, pH, temperature, turbidity, nitrate+nitrite, total phosphorus, TSS, and E. coli. Annual sample frequency and annual parameter averages can be found in Tables H.2 and H.3, respectively, in Appendix H. IDEM has also conducted biological and habitat sampling. This data can be found in Section 9, Biological Assessments, Table 9.1 on p. 149.

The data represents thirteen sample locations acquired from the IDEM probabilistic monitoring database. Sample locations are outlined in Appendix H (Map H.1 and Table H.1) and are clustered in the western part of the watershed (Mississinewa Lake to Eaton, IN). All sites within the UMRW study area are within Massey Creek HUC 10, with the exception of three located in Pike Creek HUC 10. There are no historic IDEM sample sites within three of the five HUC 10's in the UMRW study area. HUC 10's with no historic IDEM data are Big Lick Creek HUC 10, Halfway Creek HUC 10, and Headwaters Mississinewa HUC 10. Sample sites were analyzed based on (a) their total average and (b) the average of all sites classified by year (Table H.3).

IDEM MAINSTEM DATA ANALYSIS

The thirteen sampling sites are upstream of the Mississinewa Lake Reservoir from Jalapa to Eaton, Indiana. Sampling was conducted between 1991-2013, although the frequency and duration of sampling at each sites varies, with some only being sampled for two years or less. A map of the sampling site locations (H.1), along with their coordinates (TABLE H.1), are included in Appendix H. Annual sampling frequencies for each site (and for each parameter) varied and are shown in Table H.2 of Appendix H. The total samples taken (from 1991-2013) ranges from more than 250 samples collected both at site 1 and 3 (and more than 150 at site 12) to as few as 1 sample collected at site 5. Annual parameter averages for all sample sites are listed in table H.3 of appendix H.

TABLE 7.1 | Averages of combined data from sites sampled at the highest frequencies (data from IDEM AIMS database)

Site	DO	E. coli cfu/100ml	Ammonia NH3 mg/L	Nitrate+Nitrite mg/L	pH	T Phos mg/L	TSS mg/L	Temp.	Turbidity NTU
Sites 1,3, and 12	10.38	3101.69	0.18	3.38	8.10	0.18	43.38	13.97	24.59

TABLE 7.2 | Averages of data from sites sampled at the highest frequencies (data from IDEM AIMS database)

Site	DO	E. coli cfu/100ml	Ammonia NH3 mg/L	Nitrate+Nitrite mg/L	pH	T Phos mg/L	TSS mg/L	Temp.	Turbidity NTU
1	10.87	1390.63	0.18	3.40	8.13	0.18	46.71	13.55	
3	10.43	4691.61	0.19	3.31	8.05	0.17	42.31	14.59	24.86
12	9.71	------	0.19	3.43	8.12	0.19	39.93	13.57	24.33

Data from sites 2, 4, 5, 6, 7, 8, 9, 10, 11, and 13 has been disregarded by the UMRWP due to low annual sampling frequencies. These sites had been sampled for only two years or fewer, and none had been sampled since 2003, with the exception of site 6, which was sampled in 2008 (Tables H.2 and H.3 in Appendix H). However, three IDEM sample sites, relabeled by the UMRWP as sites 1, 3, and 12, were consistently sampled (for most parameters) either monthly or bimonthly for multiple consecutive years. Averages of total data (from all years) for these three sites are compared in Table 7.2. The E. coli average for site 12 was not included due to a low frequency of E. coli sampling at this site.

E. coli and TSS exceeded state standards for all sites (with the exception of E. coli at site 12, for which there was no data). Phosphorus exceeded the average of 0.076 mg/L recommended by the U.S. EPA (see Tables 6.1 and 6.2 for a list of water quality standards used in this study). Averages for each of these three sites are similar, with the exception of E. coli at sites 1 and 3. Site 3's E. coli average is significantly higher than site that of site 1. It is important to note that these sample sites are spread throughout the mainstem of the river and differ largely in their drainage area and in their proximity to urban and environmental landscape features (as discovered in the inventory and analysis process, major fluctuations in the river water quality can be driven by identified sources such as CSOs, high density agricultural areas, or highly unstable stream channels).

Averages for these three sites are also similar to the averages of all mainstem Mississinewa sites (Tables 7.6 and 7.9), calculated using data from all sampling events and all sites on the Mississinewa River. However, because of the disproportionate frequency of sampling between IDEM sites 1, 3, 12 and all other sites, the average of total data from all Mississinewa sites is likely driven by high frequency sampling of sites 1,3, and 12. The average of sites 1, 3, 12 will be used as a point of comparison for other Mississinewa River data in subsequent subsections (see Tables 7.6 and 7.9).

YEARLY TRENDS

IDEM parameters were also averaged based on the year of sampling regardless of their location on the western mainstem of the Mississinewa River (Table 7.3). A sample frequency table is included in Table H.2 of Appendix H. The same limitations apply as in other analysis due to frequency and location variability throughout the watershed. Figures 7.3 through 7.6 were developed to show general trend lines using these yearly averages. While the data represented in this way appears to suggest that E.coli and phosphorus levels are getting worse, this could be driven by the rate of sampling or proximity of sampling locations (during that particular year) to E. coli and phosphorus sources.

TABLE 7.3 | Annual Averages of All Samples Collected at All Thirteen Mainstem Mississinewa Sites*

Year	DO	E. coli cfu/100ml	Nitrate+Nitrite mg/L	pH	Phosphorus mg/L	TSS mg/L	Temp.	Turbidity NTU
1991		186.20	2.23	7.72	0.09	36.11	15.92	
1992		1001.13	3.84	7.63	0.04	42.88	13.47	
1993		1743.19	2.56	7.88	0.11	44.03	11.51	
1994		425.29	1.77	7.89	0.06	29.60	13.72	
1995	11.17	662.14	4.22	8.13	0.11	24.83	14.16	
1996	11.11	3943.75	4.43	8.11	0.10	29.61	13.24	
1997	10.89	4041.53	2.85	8.09	0.02	27.19	13.53	
1998	9.33	4343.00	2.84	8.03	0.26	41.29	18.82	
1999	11.20	267.50	2.59	8.35	0.10	27.69	14.25	
2000	10.36		5.21	8.16	0.17	31.10	12.88	
2001	10.33		3.57	8.16	0.14	24.92	14.00	
2002	10.34		2.53	8.12	0.16	40.83	13.88	46.86
2003	10.07		3.79	8.01	0.17	34.85	16.16	26.31
2004	10.65		3.62	7.99	0.22	52.34	12.78	47.17
2005	10.84		2.49	8.03	0.20	53.79	14.31	17.84
2006	10.61		3.77	7.98	0.24	42.27	12.46	25.60
2007	10.37		1.77	8.30	0.16	28.14	13.92	
2008	9.94		3.27	8.21	0.13	24.98	14.39	74.42
2009	9.39		3.44	8.27	0.15	25.12	12.20	
2010	11.39		3.20	8.49	0.16	37.73	9.08	
2011			3.12		0.22	52.20		
2012			3.07		0.09	20.25		
2013			3.84		0.27	78.82		
All years (1991– 2013)	10.34	2153.98	3.23	8.08	0.15	36.63	14.35	36.44

*See Appendix TABLE H.2 for Annual Sample Frequency at IDEM Sample Sites

IDEM WATER QUALITY DATA EXCEEDS WATER QUALITY STANDARDS

The water quality data of the Mississinewa River seems to be within consistent ranges for each parameter regardless of (a) overall averaging, (b) averaging of high frequency sampling sites, and (c) averaging of separate years. Despite the challenges in comparing data across varying drainage areas, and the inability to make conclusive claims about historic/yearly patterns, it is important to observe that E. coli has been consistently exceeding the water quality standard set forth in IAC 327 2-1-6 in all sampling instances over the past 20 years. These parameters have stable trend lines over the twenty year sample period. Furthermore, water quality targets set for this project (found in Table 6.1 on p. 98) are exceeded for the parameters TSS, E. coli, and nitrate + nitrite for both averages of combined data (Table 7.1), averages from sample sites with the highest frequency (Table 7.2), and sample sites averaged classified according to the years of the sampling program (Table 7.3 and Figures 7.3 through 7.6).

FIG. 7.3 - 7.6 | Yearly averages for E.coli, Nitrogen, TSS, and Phosphorus using IDEM data from all 13 sites upstream of the Mississinewa Lake Reservoir

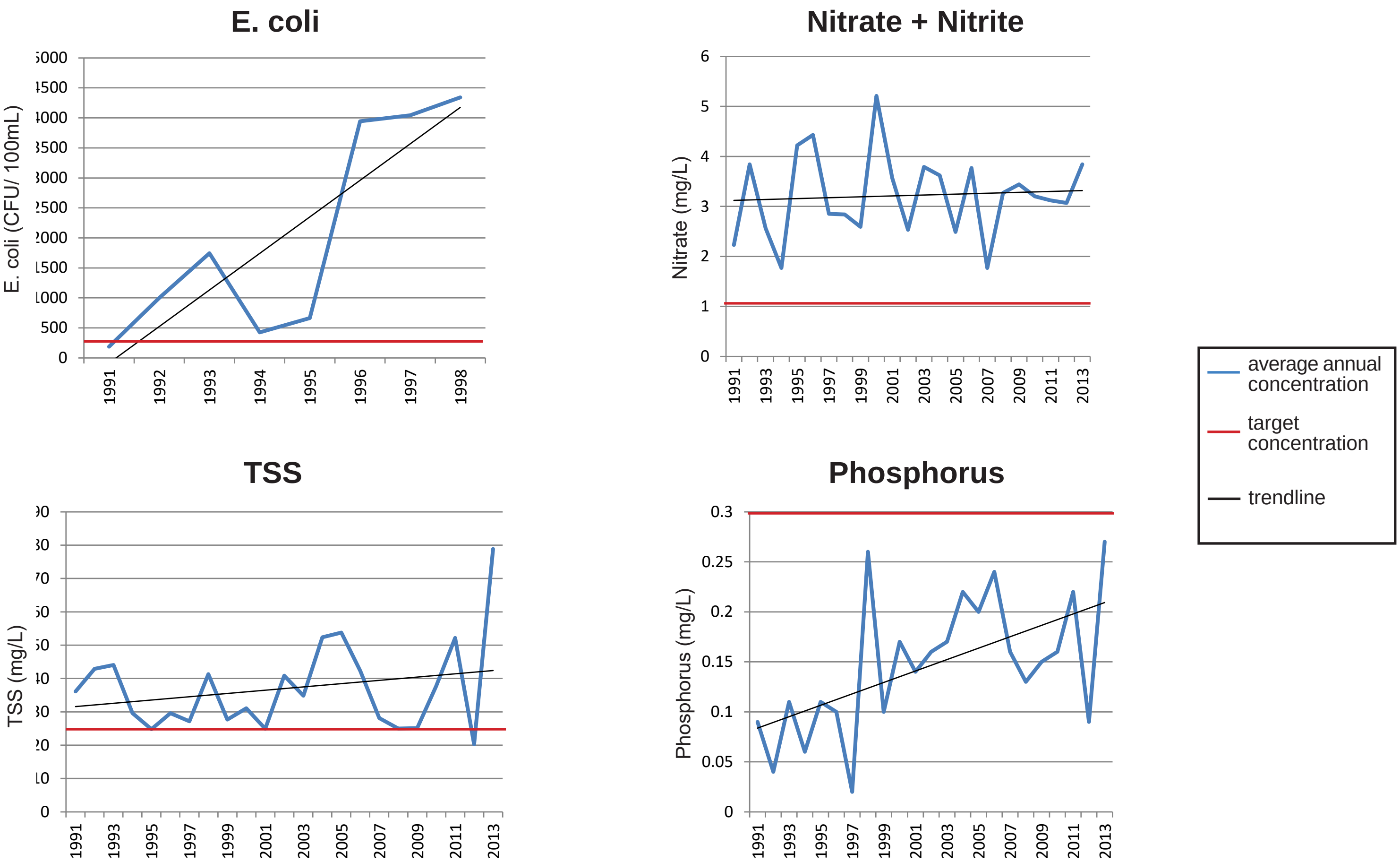

TABLE 7.4 | Parameter averages and rankings for 14 high quality recreational streams. Data obtained from IDEM AIMS database.									
River	E. coli cfu/100ml	E. coli rank	Nitrate mg/L	Nitrate rank	Phosphorus mg/L	Phosphorus rank	TSS mg/L	TSS rank	Avg Rank
Pigeon River	92.20	1	1.54	2	0.05	1	6.88	1	2
Kankakee River	444.41	5	1.67	3	0.08	2	20.30	3	4
Muscatatuck River	643.10	9	0.85	1	0.12	6	30.80	7	7
East Fork White River (North)	355.30	3	2.38	7	0.11	4	41.80	13	7
Whitewater River	188.30	2	2.97	9	0.10	3	42.88	14	8
Tippecanoe River (Upper)	826.80	11	2.22	6	0.14	10	13.20	2	8
FlatRock River	452.95	6	3.74	13	0.12	7	25.20	5	9
St. Joseph River	2252.50	16	1.88	4	0.12	5	34.50	10	10
White River (East Fork White)	371.30	4	2.01	5	0.21	13	86.00	16	10
Iroquis River	478.70	8	5.13	16	0.13	9	31.53	8	11
Eel River	1017.00	12	2.90	8	0.14	11	32.85	9	11
Sugar Creek	462.70	7	4.11	14	0.15	12	37.70	12	12
West Fork White River	1083.00	13	2.98	10	0.30	16	30.50	6	12
Mississinewa River	1539.62	15	3.31	11	0.17	8	35.90	11	12
Wildcat Creek	1209.70	14	4.48	15	0.23	15	23.50	4	13
Wabash River	730.80	10	3.68	12	0.21	14	57.90	15	14

7.3 A STATEWIDE COMPARISON OF RIVERS (USING IDEM'S DATA SET)

COMPARISON TO RECREATIONAL RIVERS

The UMRW-P conducted an independent analysis of water quality data from recreational streams in Indiana; the analysis compared historic Mississinewa data to data from other recreational streams. These streams were selected from a list of recreational streams found on the DNR's online "Indiana Canoeing Guide." The Indiana Canoeing Guide was published by the Division of Outdoor Recreation's Streams and Trails Section. The fifth edition was published in 1987 and afterwards the guide went out of print and was moved online in 1996. The UMRW-P Project Manager requested data from the IDEM AIMS data base for fourteen of these DNR advocated streams (stream watersheds are shown in Map H.2 of Appendix H). The UMRW-P averaged each major parameter for these streams and ranked streams based on these averages (Table 7.4). While the comparison of these rivers is problematic due to their locations in various parts of the state, and because of the limitations frequently mentioned regarding the development of averages across multipoint and multi-year datasets, some general and informative conclusions can still be drawn.

Each parameter was averaged based on the total available data, regardless of year, site location on the particular mainstem and seasonality factors. In all instances the Mississinewa River ranked poorly compared to other recreational streams in the state. The individual rankings for the Mississinewa River were 11th for nitrogen, 11th for sediment, 15th for E. coli and 8th for phosphorus. These individual rankings were averaged to develop an overall ranking for each stream (Table 7.4). Out of 14 streams, the Mississinewa River tied for 12th with three other streams. One of the biggest drivers for the overall ranking is the Mississinewa River's exceptionally poor E. coli ranking.

The UMRW-P created three cohorts (worst, average, best) and grouped streams based on their relative water quality rank. In all instances (for nitrogen, phosphorus, sediment, and e. coli averages), the Mississinewa river was in the worst cohort of DNR state canoeing streams. It is important to note that streams selected by the IDNR are considered high quality (compared to all state streams) for many factors (aesthetics being the most significant). Therefore, the Mississinewa is in the "worst cohort" of a select group of high quality recreational streams.

COMPARISON TO ECOREGION RIVERS

One factor making the comparison of recreational streams problematic is their location in relation to different types of land uses. For instance, many of the recreational streams that were compared to the Mississinewa River are located in areas of the state with a low percentage of agricultural land use and high percentage of naturalized adjacent land use. These natural adjacent land uses have a positive influence on water quality including buffering pollutants and mitigating major storm flows. Some of these recreational streams have experienced less hydromodifcation due to their location in natural landscapes.

Mindful of this, the UMRWP decided to compare the historic Mississinewa river data to streams in the same ecoregion. An ecoregion is "a relatively large unit of land that contains geographically distinct assemblage of natural communities with boundaries that approximate the original extent of the natural environment prior to major land use change."[1] Map H.3 (Appendix H) shows the location of ecoregions of in Indiana. An analysis and grouping of Indiana water quality data for ecoregional comparisons was developed in Monitoring Water in Indiana: - Purdue University by Jane Frankenberger and Laura Esman 2010. Data from that study has been included in Table 7.5.

In contrast to the IDNR canoeable rivers comparison, the streams included in the ecoregional dataset are not necessarily recreational or noted for their exceptional quality. Because they are in the same ecoregion as the Mississinewa (Central Till Plain Ecoregion), they are expected to have similar land uses (i.e., predominantly agricultural). Table 7.5 shows the median for each of the different parameters analyzed by Frankenberger and Esman.

TABLE 7.5 | Avg. Water Quality Results for Streams of the Central Till Plain Ecoregion (IDEM Fixed Station Data, 1990-010)[2]

Parameter	No. of Samples	Min (mg/L)	25% (mg/L)	Median (mg/L)	75% (mg/L)	Max (mg/L)
Ammonia Nitrogen	7578	0.01	0.1	0.2	0.3	162
TKN	26064	0.1	0.5	0.7	1.1	28
Nitrate+Nitrite*	14056	0.04	1.6	2.9	4.6	960
Total Phosphorus	27516	0.02	0.07	0.12	0.22	4.58
TSS	12842	1	9	19	42	2740
NTU	24400	0.0	7.9	15	35.6	2150
E. coli	2	70	210	670	1,204,000	

Using Table 7.5 as a representation of IDEM's Mississinewa River water quality data, it should be concluded that, in all instances, Mississinewa River water quality data exceeds the average ecoregional values. Therefore, according to this data set, the Mississinewa River is more impaired than other streams in the ecoregion.

1 Olsen et al. 2001. Terrestrial Ecoregions of the World. Bioscience. Vol. 51 No. 11

2 This study was completed by Purdue university, further detail as to site location and information is obtainable.

7.4 STORET DATASET

The second dataset that we reviewed was from the EPA STORET database. The US EPA water quality database STORET (STOrage and RETrieval) contains historic water quality data for the region. Similar to the IDEM dataset, the STORET dataset contains data from a variety of sampling sites, with much variance in sampling frequency, seasons, methodologies, and flow regimes, making a comparative analysis difficult. Furthermore, most of the sampling sites were located on the mainstem Mississinewa River, making this data useless for refining critical areas to the HUC 12 level or smaller. The STORET data may even contain some of the same data from the IDEM dataset. However, because the purpose of this analysis and comparison is to gain a general understanding of the Mississinewa River's water quality rather than to compare the water quality from site to site, the Project Manager did not deem it necessary to spend time separating out redundant data.

Data was collected in the Mississinewa River over 50 years from November 12, 1963 to March 19, 2014. Sampling frequencies can be found in Table I.1 of Appendix I. There were 20 sample sites, but six sites were duplicative (names differed from one sampling program to another) and therefore combined and analyzed as 13 unique sampling sites; however, unlike the IDEM data, these sites are more evenly distributed along the Mississinewa River. A map of the sites can be found in Appendix I, Map I.1. Parameters analyzed as part of this study are depicted in Table 7.6 and include E. coli, dissolved oxygen, pH, temperature, turbidity, nitrate+nitrite, total phosphorus, TKN, and TSS.

Similar to the IDEM data set, the UMRWP averaged sampling sites for educational comparison. We have included data from this analysis in Table 7.7, which breaks individual sample sites into historic mean averages, and Table 7.6, which averages all mainstem Mississinewa river data. Data ranges for the STORET dataset were comparable to data ranges for the IDEM database (Table 7.6).

TABLE 7.6 | STORET and IDEM Averages for Water Quality Parameters

Database	DO	E. coli cfu/100ml	Nitrate+Nitrite mg/L	Kjeldahl mg/L	pH	T Phos mg/L	TSS mg/L	Temp.	Turbidity NTU
STORET	9.3	2188	1.19	0.89	8.03	0.18	35.97	15.84	109.97
IDEM Data	10.38	3101	3.38		8.10	0.18	43.38	13.97	24.59

TABLE 7.7 | Averages for STORET Sample Sites*

Site*	Site Name	Ammonia NH3 mg/L	DO	E. coli cfu/100ml	Kjeldahl mg/L	Nitrate mg/L	pH	Phosphorus mg/L	Temp.	TSS mg/L	Turbidity NTU
	Mississinewa River		9.30	2188	0.89	1.19	8.03	0.18	15.84	35.97	109.97
1	INSTOR_WQX-5766		7.31				7.94		21.43		
2	IN033-402721085344001						8.20		21.93		
2	USGS-03326300					0.49	7.50		7.00		
3	INSTOR_WQX-8199		9.36		0.81		8.35	0.13	21.13	16.67	19.78
4	USGS-402339085293601			2648			7.90		21.36		166.00
4	INSTOR_WQX-7082		8.29	1413			8.00		21.30		179.23
5	INSTOR_WQX-5742		8.91				7.99		24.21		
5	USGS-03326050					0.43	7.50		6.50		
6	INSTOR-WMI030-0001	0.275	9.74	352	0.89		8.08	0.18	13.77	38.00	75.00
6	INSTOR_WQX-4447		7.96	3286			7.99		21.30		395.80
6	USGS-402026085221001			3286			8.00		21.28		244.75
7	USGS-03326000					0.37	7.40		5.00		
8	IN033-401823085181301						8.23		22.50		
8	INSTOR_WQX-11515		8.52	1755	1.16		7.92	0.17	21.67	19.33	91.85
9	USGS-03325800					0.25	7.50		5.50		
10	INSTOR_WQX-5721		9.25				8.03		24.12		
11	INSTOR_WQX-2275		7.96	2772			7.92		19.10		145.00
11	USGS-03325500			2772		1.29	7.85		13.76		145.00
12	USGS-401722084513201				0.45	4.99	7.90	0.24	15.60		
13	USGS-03325300					0.49	7.40		8.00		

*See Appendix Map I.1 for location of STORET mainstem sites

RELATIONSHIP BETWEEN DATA AND LAND-USE
Sample site averages were also plotted in a bar graph in Appendix I to illustrate changes in the river as sample sites move downstream (east to northwest) across the Upper Mississinewa River Watershed. This also illustrates that data varies based on its location in the watershed and its proximity to urban and environmental features and pollutant sources distributed throughout the watershed. Basic observations include: E. coli spiked at various points along the Mississinewa river, with the greatest increases at site 6, downstream of the town of Eaton. Nitrate ranged from 0.25-4.99 mg/L but had a significant spike at site 12, and sediment and phosphorus were inconsistent throughout the channel with little correlation. This type of study further illustrates how averaging data across a entire river skews results and fails to accommodate for the variation of nutrient flows driven by adjacent land use and contribution.

COMPARISON TO IDEM/STATE
The UMRWP did not acquire STORET data for the fourteen recreational streams advocated by the DNR in order for secondary analysis. However, because the STORET averages and the IDEM averages are in similar ranges, STORET further suggests that the Mississinewa River is in the "worst" cohorts for recreational rivers advocated by the DNR. The Mississinewa River would have a similar comparative ranking if STORET data replaced IDEM data in the comparison.

SUBWATERSHED DIFFERENTIATION
Thus far, we have examined the historic water quality of the Mississinewa River in order to establish that there is reason to take action to improve its water quality. However, with only data from the Mississinewa River itself it is difficult to precisely determine which tributary subwatersheds contribute the highest levels of pollutants to the Mississinewa River. The STORET dataset, unlike the IDEM dataset, also includes data collected from tributaries within the Upper Mississinewa River Watershed. While the data from tributaries can be compared, it does have the same limitations previously mentioned (low sampling duration, low sampling frequency, lack of sampling sites for each tributary, etc.). The data included is from 1963-2014. Fourteen tributaries were sampled (over the same time period that the Mississinewa River was sampled, but less frequently than the Mississinewa sites). Some of these tributaries were in drainage areas smaller than the HUC12 level (therefore, only a small percentage of the tributaries in the UMRW were sampled). Some of the subwatersheds were sampled less than 5 times a year, and in some instances only once in a 30 year period. Table 7.8 represents all subwatersheds with data from the STORET database, and Table I.2 in Appendix I lists the count/sampling frequency for each site. Map I.2 in the Appendix shows location of Subwatersehd sample sites. Streams with the highest frequency of sampling are highlighted in yellow in Table 7.8.

STORET data for the fourteen sites was categorized based on subwatershed boundaries. However, the only criteria the UMRW-P used is that the sample location must be included in the HUC12 subwatershed boundary. This is problematic because some of the sample locations (listed as representative of the entire subwatershed (Table 7.8) are not at the HUC12 pour point. Where there are multiple sample sites along the river in the subwatershed, those sample sites were averaged collectively as part of Table 7.8. Averaging data from upstream and downstream reaches of a tributary is equally as problematic as doing so on the mainstem (again, due to variation in drainage and adjacency to urban and environmental features). Diagrams I.7 through I.12, located in Appendix I, compare subwatersheds using STORET data. Each diagram depicts, at the subwatershed level, the average of all data for an individual parameter. Averages are calculated by subwatershed. Parameters include: ammonia, total kjeldahl nitrogen, phosphorus, E. coli, TSS, and turbidity. In each parameter's diagram, subwatersheds are ranked from lowest average concentration (green) to highest average concentration (red). Big Lick Creek has the greatest impairment for E. coli and phosphorus. Despite these cursory observations, it is difficult to use STORET data for water quality decision-making at the subwatershed level for all 28 subwatersheds.

TABLE 7.8 | Averages for impairment. Streams highlighted in yellow had the highest frequency of sampling.

Subwatershed Site	Ammonia NH3 mg/L	E. coli cfu/100ml	Kjeldahl mg/L	Phosphorus mg/L	TSS mg/L
Boots Creek	0.19	633	0.96	0.17	37.47
Branch Creek		3678	1.15	0.15	18.00
Bush Creek		641	0.71	0.10	7.00
Deer Creek		759	0.65	0.07	12.33
Fetid Creek	0.24	719	0.90	0.21	39.71
Holden Ditch	0.19	316	0.85	0.19	38.58
Hoppas Creek		125			-1.00
Jordan Creek		777	0.52	0.07	6.67
Lake Branch		192	0.81	0.13	16.67
Lick Creek	0.12	1959	1.73	0.46	4.63
Little Deer Creek					12.00
Little Lick Creek	1.43	949	6.81	0.63	50.05
Little Mississinewa River	0.09	1496	1.32	0.44	17.56
LIttle Walnut Creek					12.00
Mississinewa River	0.275	2188	0.89	0.18	35.97

7.5 LARE DATASET

There have been four LARE diagnostic studies completed in the Upper Mississinewa River Watershed (UMRW) since 2001. These plans have been created sequentially from the eastern reach of the watershed to the western extent (with the most recent study completed in 2012). A summary of diagnostic conclusions from these studies is included in Section 4. The only HUC 10 subwatershed lacking a LARE diagnostic study is the Big Lick Subwatershed. The Project Manager extracted the raw data from each of the LARE diagnostic studies. The following is an analysis of this data an a watershed-wide scale for comparative purposes (Table 7.10).

SUBWATERSHEDS

While the LARE studies provide data for nearly all of the subwatersheds in the UMRW (data missing from Big Lick Creek could be theoretically used from STORET as a point of comparison), researchers for the diagnostic studies unfortunately used the lowest sampling frequency of all the historical datasets. The LARE program requires only three samples over the course of the entire year, failing to address the problems associated with low frequency data collection. The limitation of data is even more drastic compared to the STORET dataset for most subwatersheds. Each sample location is included in Table J.1 through J.4 Appendix J, along with the average for each sample site. Similar to STORET, diagrams (Figures J.3 through J.6 in Appendix J) were developed in order to compare all subwatershed results on a spectrum of high impairment levels (red) to low impairment levels (green). The diagrams compare subwatersheds and sub-basins sampled during all four phases of LARE studies. The phase ranking is an attempt to show the relative weighting of subwatersheds in each phase (i.e. the worst in each phase) so that data could be compared using a similar season, year, sampling method. Figures J.3 through J.6 rank subwatersheds on a per phase basis.

MAINSTEM

In addition, the mainstem Mississinewa River data was extracted from all LARE plans for comparison. Averages are shown in Table 7.10 and represented graphically in Figures J.11 through J.12 (Appendix J). A figure of LARE mainstem sampling locations in also located in Appendix J, Figure J.4. These figures, similar to those created with STORET data, arrange sample sites geographically from west to east in an attempt to observe changes in water quality levels as water moves downstream. Different methods and parameters used in different LARE phases make comparison difficult. However, E. coli and turbidity sampling is consistent among all LARE phases. E. coli results were elevated at MR03 near Albany (Figure J.11) at 18,000 cfu/ml. One can graphically see the variation of the LARE water quality data as it moves geographically east to west. Many of the observed increases in E. coli averages are consistent with urban/suburban areas identified in the inventory and analysis; sites MR03 and 3 were both downstream of Albany and site MR02 was downstream of Eaton. Turbidity increases dramatically at site 22, which is downstream of Halfway Creek, a subwatershed which is elevated in both LARE and STORET data sets.

TABLE 7.9 | STORET, IDEM and LARE Averages for Eleven Water Quality Parameters

Row Labels	DO	E. coli cfu/100ml	Ammonia NH3 mg/L	Nitrate+Nitrite mg/L	Kjeldahl mg/L	pH	Total P mg/L	Ortho P mg/L	TSS mg/L	Temp.	Turbidity NTU
STORET	9.3	2188		1.19	0.89	8.03	0.18		35.97	15.84	109.97
IDEM	10.38	3101	0.18	3.38		8.1	0.18		43.38	13.97	24.59
LARE		1957	0.09	4	1.18		0.19	0.299			65.05

The averaging of mainstem Mississinewa water quality data utilizing these data sets is included in Table 7.10. As with the subwatersheds, there is limited amount of data (sites and frequency) from the LARE testing. The highest frequency sampling for E. coli was completed in in the LARE phase IV study. As with the other studies, most of the data is presented for educational purposes. Table 7.9 shows parameter averages for the combined data from mainstem Mississinewa River sites sampled in the LARE studies and compares them with the with the combined STORET averages and the combined IDEM averages for the Mississinewa River.

LARE MAINSTEM CONCLUSIONS

It is important to note that the overall averages are consistent with other STORET and IDEM data sets for the mainstem of the Mississinewa River (Table 7.9), consistently concluding (a) that water quality data exceeds state standards, (b) that the Mississinewa is in the worst cohort for recreational streams included in this study, and (c) that the Mississinewa river is more impaired than the overall average for its ecoregion.

TABLE 7.10 | LARE Mississinewa River averages (from all four LARE studies)											
Site ID	Phase	River	E. coli	Turbidity NTU	Ortho P mg/L	Total P mg/L	N+N mg/L	NO2/NO3 mg/L	NH3 mg/L	TN mg/L	NITRATE mg/L
14	4	Mississinewa River	607	39							
15	4	Mississinewa River	673	54.33							
16	4	Mississinewa River	601	50.1125							
17	4	Mississinewa River	422	106.16							
18	4	Mississinewa River	325	65.54							
19	4	Mississinewa River	268	110.5							
MR01	3	Mississinewa River	736	25.87		0.18		1.08		1.83	
20	4	Mississinewa River	450	77.24							
MR02	3	Mississinewa River	1263	25.43		0.28		1.47		2.38	
21	4	Mississinewa River	780	207.1							
22	4	Mississinewa River	305	701.24							
MR03	3	Mississinewa River	18600	28.3		0.33		1.97		2.88	
Site 18	2	Mississinewa River	16		0.27						1
Site 14	2	Mississinewa River	100		0.45						1.3
Site 3	2	Mississinewa River	2019	187.85	0.31	0.35			0.2		10.75
Site 15	2	Mississinewa River	12		0.1						1.3
Site 19	2	Mississinewa River	14		0.38						1.2
Site 20	2	Mississinewa River	14	0	0.32	0	0	0	0	0	1.1
Site 22	2	Mississinewa River	900	0	0.24	0	0	0	0	0	1.3
Site 2	2	Mississinewa River	820	191.6	0.32	0.36			0.15		11
Site 21	2	Mississinewa River	30	0	0.46	0	0	0	0	0	1
Site 1	2	Mississinewa River	922.5	126.4	0.14	0.21			0.2		10

7.6 HOOSIER RIVERWATCH DATASET

The final database containing Mississinewa water quality (data that the UMRW-P researched) is the Hoosier Riverwatch database. While the intent of the Hoosier River Watch Program is important and its potential great, its execution in the Upper Mississinewa River Watershed is poor. The data is extremely infrequent and often mislabeled. There is a lack of clarity about stream location and stream names are not consistent with state hydrology mapping. Sometimes methods and units used are also unclear. It appears that this particular program has not been active for some time in this region. Institutions that have been active in collecting data and adding it to the database include Taylor University, McCulloch Middle School (Marion), West Side Middle School (Union City), and The Kings Academy (Jonesboro). Select data from this database has been included for reference (Table 7.11) but will not be utilized to determine critical areas or as a means compare to compare other historic or contemporary water quality information. None of the data will be used as part of this watershed management planning process. However, biological data from the Hoosier Riverwatch database is included in Section 9, *Biological Assessments*, found on p.148. Habitat was assessed at Lugar Creek only. The habitat assessment process used was not specified.

TABLE 7.11 | Hoosier Riverwatch parameter averages							
River/Stream	E. coli cfu/100ml	Ortho P mg/L	Total P mg/L	NO3 mg/L	Nitrite mg/L	Turbity NTU	pH
Back Creek	157.1	0.24	1	8.14	0.59	21.50	7.95
Big Lick Creek	166.5	0.86		7.33	0.11	15.78	8.11
Fall Creek		0.1	0	2.2	0	15.67	
Hopcus Run	5000.0			0.45		14.99	8.4
Little Mississinewa River	130.4	0.16	0.2	2.3	0	21.06	7.77
Lugar Creek			0.8	5.14		29.25	8.03
Mississinewa River	837.3	0.37		7.34	0.19	26.08	7.61
Walnut Creek	442.7	0.8		2.165		19.68	7.95

8. CURRENT WATER QUALITY

INTRODUCTION

In order to assess current water quality, the Upper Mississinewa River Watershed Partnership (UMRW-P), in conjunction with the Indiana Department of Environmental Management's (IDEM) Total Maximum Daily Load program (TMDL), developed and conducted a water quality sampling program specifically for the Upper Mississinewa River Watershed (for water quality sampling locations, see Map 8.1 on p. 114).

The UMRW-P conducted sampling within the UMRW at four sites located in the headwaters of Randolph County, IN and Darke County, OH and eleven sites located in Grant County, IN. Seven of these sites were located on the mainstem of the Mississinewa and eight are located in tributary subwatersheds near pour points along the Mississinewa River. The MBWQ conducted chemical analysis of the samples for the UMRW-P.

IDEM conducted sampling as a part of its larger TMDL Baseline Study. IDEM sample sites were located in the central portion of the Mississinewa River and were selected using a modified geometric site selection and targeted site selection. In all, thirty-five sites were selected for analysis by the TMDL program. The objective of the TMDL was to perform baseline monitoring, which is "an intensive targeted watershed design that characterizes the current condition of an individual watershed [...] Selecting a spatial monitoring design with sufficient sampling density to accurately characterize water quality conditions is a critical step in the process of developing an adequate local scale watershed study."[1] Sample sites were selected "based on a geometric progression of drainage areas starting with the areas at the mouth of the main stem stream and working upstream through the tributaries to the headwaters."[2] Of these 35 sites sampled by IDEM, data collected at eight sites located on tributaries and at five sites located on the mainstem of the Mississinewa have been extracted and used along with UMRW-P data for comprehensive analysis. The data from only these 28 sites is analyzed in this section (Table 8.1).[3]

The 28 sampling sites used in this analysis represent the 28 HUC 12 subwatersheds within the Upper Mississinewa River Watershed and are identified as a mainstem or a tributary subwatershed of the Mississinewa River. Where delineated pour points were not easily accessible, sampling occurred near the most adjacent bridge. All samples were collected upstream of road crossings to avoid potential data interference by the road crossing structure. Individual procedures and methods used by each agency can be found in Table K.2 on p. A51 in Appendix K. Station ID, location and description are presented in Tables K.4 through K.6 on p. A52 (Appendix K). Map 8.1 on p. 114 shows subwatershed boundaries and site locations.

SAMPLING OBJECTIVES

Much of the narrative in the previous section included a discussion regarding the limits of historical datasets and their *inability* to provide enough detail and insight to characterize subwatershed water quality for the purposes of developing subwatershed impairment rankings and determining critical areas (discussed in Section 14, *Critical Areas*, on p. 221). Therefore, historical data *were not* used to compare subwatersheds and determine critical areas. Instead, in order to assess current water quality and select critical areas, the water sampling program described above was used. This sampling program was conducted from 2014-2015 and was designed to minimize the limitations found in historical datasets. The following are key attributes of the sampling program:

(a) In general, sampling was conducted monthly for one year. Samples were collected and analyzed monthly for an entire year at sites monitored by the UMRW-P. IDEM sites were not sampled every month. IDEM's mean sampling frequency for months sampled per year was 9.5 months per year and median sampling frequency was 10 months a year. The number of months sampled ranged from 7 to 11 months. IDEM sites were sampled three times in April and two times in May to determine a geometric mean for E. coli. Monthly samples collected at the 15 subwatershed sites monitored by the UMRW-P were collected over a 2 day time period that was typically the last week of the calendar month; E. coli and flow were sampled the first day and flow and all other parameters were sampled the following day. The 13 sites monitored by IDEM were sampled typically during the middle of the month.
(b) Each grouping was collected at the same time of the day each month.
(c) Where feasible, samples were collected at the same horizontal and vertical locations in the water column.
(d) Because the data was collected monthly during the same year, seasonal accountability can be given across all subwatersheds.
(e) While much of the historical data did not include the collection of flow data, all sample events measured flow (with the exception of two IDEM sites) except when flow was nonexistent or during freeze.
(f) Flow data, missing in historic data sets, allows for water quality data to be classified into high and low flow events and enables the development of loading estimates.

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1 Fields, Timothy. IDEM. 2014 Sampling an Analysis Workplan for Baseline Monitoring of the Upper Mississinewa River Watershed. www.in.gov/idem/nps/files/tmdl_mississinewa-upper_sampling_workplan.pdf.

2 Ibid.

3 Analysis of results for all sites sampled by IDEM as part of TMDL development can be found in the subwatershed discussions, starting on p. 128. IDEM sampled exclusively in three of the five HUC 10 watersheds in the study area: Big Lick Creek HUC 10, Pike Creek HUC 10, and Halfway Creek HUC 10.

TABLE 8.1 | Sample sites used in current water quality analysis	
Site Name	Agency/Group Who Conducted Sampling
Back Creek	UMRW-P
Barren Creek	UMRW-P
Bear Creek	IDEM
Big Lick Creek	IDEM
Bush Creek	IDEM
Campbell Creek	IDEM
Days Creek	IDEM
Deer Creek	UMRW-P
Halfway Creek	IDEM
Little Deer Creek	UMRW-P
Little Mississinewa River	UMRW-P
Little Walnut Creek	UMRW-P
Lugar Creek	UMRW-P
Boots Creek (Mississinewa River A)	UMRW-P
Branch Creek (Mississinewa River B)	UMRW-P
Lake Branch (Mississinewa River C)	UMRW-P
Hoppas Ditch (Mississinewa River D)	UMRW-P
Holden Ditch (Mississinewa River 1)	IDEM
Rees Ditch (Mississinewa River 2)	IDEM
Platt Nibarger Ditch (Mississinewa River 3)	IDEM
Fetid Creek (Mississinewa River 4)	IDEM
Mud Creek (Mississinewa River 5)	IDEM
Porter Creek (Mississinewa River X)	UMRW-P
Jordan Creek (Mississinewa River Y)	UMRW-P
Gray Branch (Mississinewa River Z)	UMRW-P
Pike Creek	IDEM
Upper Big Lick Creek	IDEM
Walnut Creek	UMRW-P

LIMITATIONS PERSIST – A DISCUSSION OF FREQUENCY FROM "MONITORING WATER IN INDIANA"

Due to limits of budget, staff, and capacity, monthly sampling was the maximum capacity for the project. The following paragraphs are an excerpt from *Monitoring Water in Indiana* by Frankenberger and Easman. It discusses creating a monitoring strategy that will yield representative data. The excerpt references a 1987 study by Richards & Holloway of Heidelberg College in Tiffin, Ohio and includes a table from the 1987 study containing precision values for unstratified fixed frequency sampling of various parameters.

> "The frequency needed depends on the variability of the data. Variability depends on the parameter being measured and also on the type of water body:
>
> - **Parameter effect on variability:** Chemical parameters need to be monitored more frequently than biological and habitat parameters (although E. coli is a biological parameter, its variability is more like the chemical parameters). In general, E. coli, total suspended solids, and phosphorus vary more day to day than nitrate. Biological monitoring is difficult each time it is done, but because organisms are able to aggregate water quality information over time it can be done less frequently with more accurate estimates of the average over time.
>
> - **Water body effect on variability:** Moving water (streams and rivers) vary more, and small streams vary the most. Water in lakes and reservoirs are much more stable, and therefore monitoring that takes place only monthly or less can often be representative. Figure 7.1 p. 102 suggests conceptually the relative variability of parameters, the differences between types of water bodies, and the resulting number of samples needed per year for representativeness.
>
> "More frequent sampling is better, but how much better? The few examples where monitoring has been done very frequently can help answer that question. Heidelberg College monitored several parameters four times per day for several years, then took subsamples of the complete data set to determine the effect on estimated annual load of various sampling frequencies. Results are shown in Table R.1 for a stream draining a 172 square-mile watershed with 83% cropland. These results are likely to be similar for streams in Indiana, although no similar analysis has been published.

Table R.1: Range of 95% confidence half-intervals of annual load calculated from various sampling frequencies [for Honey Creek,] a medium-sized agricultural stream [located near Tiffin, Ohio] (From Richards & Holloway, 1987).					
Sampling Frequency	Conductivity (dissolved solids) %	Nitrate-N %	Soluble Reactive Phosphorus %	Total Phosphorus %	Suspended Sediment %
Monthly	65	99	108	180	427
2 weeks	46	67	71	127	239
Weekly	26	41	47	96	160
Daily	4	4	6	12	28

"In this study, loads calculated from subsamples of the data at various frequencies (daily, weekly, biweekly and monthly) had low precision (large confidence intervals), showing the problems of collecting infrequent samples. Starting at the top left, for conductivity measured with monthly samples, the 95% confidence half-interval of 65% means that if the load from this watershed was estimated to be 100 lbs, there would only be a 95% chance that the true load is between 35 lbs and 165 lbs (alternatively, it could be stated that there is a 5% chance that the estimated load is off by more than 65%). The precision is even lower for the other parameters, with nitrate having a 5% chance of being off by 99%, soluble reactive phosphorus by 108%, total phosphorus by 180%, and suspended sediment by 427%. What does this tell us about estimating loads from monitoring data?

- If a monitoring program has a goal of estimating load **within 10% of the true load** (with 95% confidence), daily sampling is needed for conductivity, nitrate-N, and soluble reactive phosphorus, but even daily sampling would not be adequate [to] obtain loads with 10% for total phosphorus or suspended sediment.

- If the goal is to estimate load **within 100% of the true load** (with a 95% probability), which of course would not be adequate for most uses, conductivity and nitrate-N could be sampled monthly, soluble reactive phosphorus could be sampled every two weeks, total phosphorus would need to be sampled weekly, and suspended sediment would need to be sampled more than weekly. Even at these high sampling rates, the calculated load is likely to be lower than the actual load.

"This shows the great difficulty in collecting adequate data for reliable load estimates. It also suggests the value of collecting high-frequency data at a very limited number of sites, rather than monitoring at many sites, at least for chemical and physical parameters. Biological and habitat sampling can be done less often."[4]

LIMITATIONS PERSIST

(1) According to the study by Heidelberg College, monthly sampling is still limited and decreases the precision for certain project parameters. Despite efforts to address limitations, the monthly sampling conducted by the UMRWP still has low precision (Table R.1 above), but higher precision than almost all of the of historical data that has been collected within the UMRW. These observations are important to consider when analyzing loading data and averages described in subsequent sections.
(2) The type of flow measurement used for the project was based on a variation of Hoosier Riverwatch Flow methodology. While the detail and confidence of flow measurements was not maximized, our methodology allows for the categorization of the sample events into the different flow regimes and the averaging of the flow regimes for a comparative analysis. While the confidence level for the flow estimation is low, it allows for the categorization and generic estimates of loading.
(3) The relatively large sampling area results in a variety of flow regimes during the monthly sampling events driven by storm event duration and intensity over a given area. In other words, during a given month, some streams in the watershed may be experiencing a high flow event while others are experiencing a low flow event. This influences the month to month comparative analysis of streams. As we shall see, storm event is a significant driver of water quality results, which is further influenced by the respective land uses in the region.

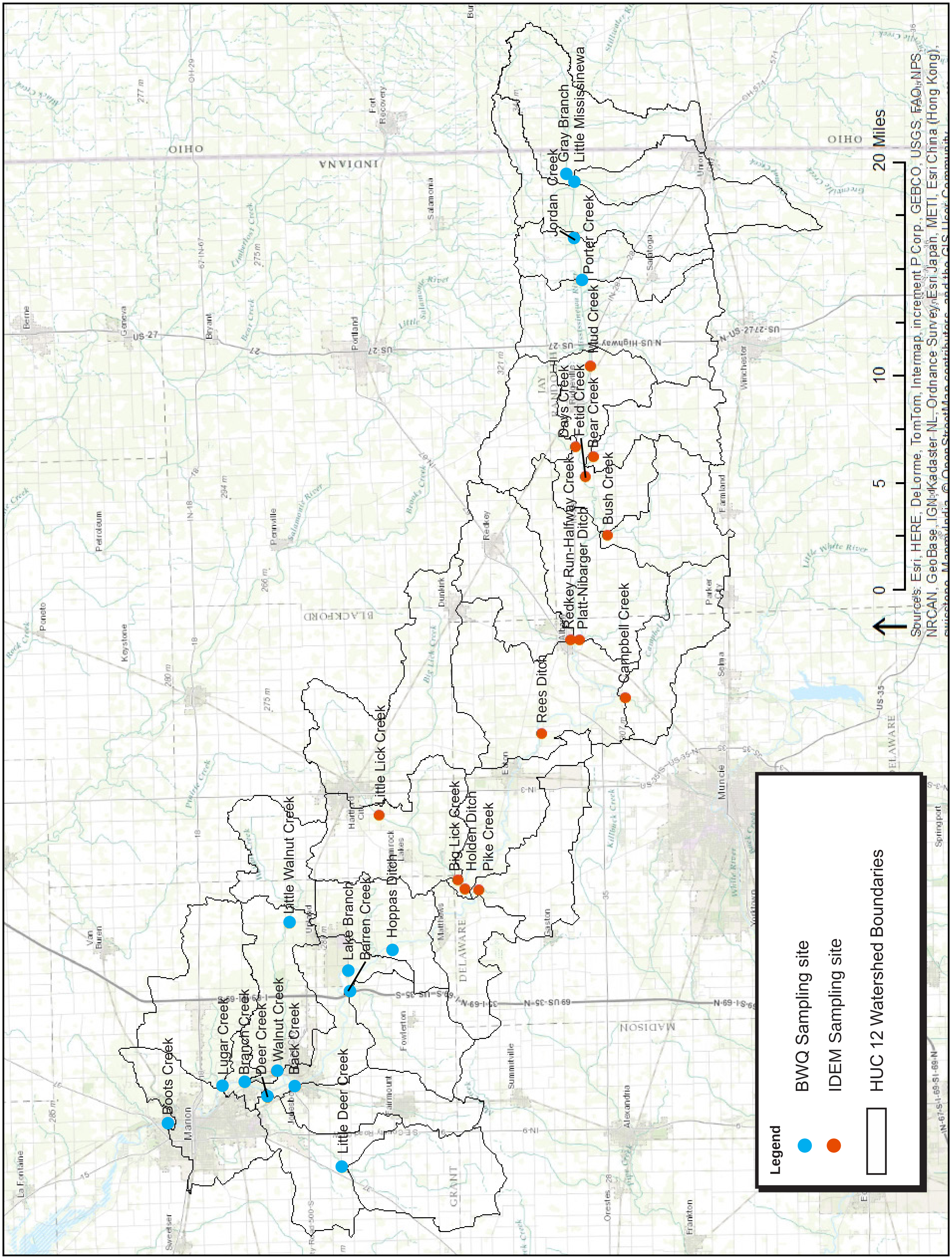
PHYSICAL PARAMETERS

Measurement of pH, temperature, conductivity, dissolved oxygen and discharge were conducted in the field by IDEM and UMRW-P staff. Data from analyses conducted in the field is available upon request. Dissolved oxygen, pH, and temperature were taken with a YSI Pro Plus instrument. Turbidity measurements were determined with a transparency/ turbidity tube.

CHEMICAL AND BACTERIOLOGICAL METHODS

Samples were collected just below the surface in the middle of the stream in sterile, pre-rinsed containers provided by the lab. All samples were placed in a cooler (on ice) immediately after collection and transported to the labs in Muncie or Indianapolis, Indiana for analysis no later than eight hours after collection. Total phosphorus, nitrate [N], total suspended solids, and E. coli were analyzed by the Muncie Bureau of Water Quality (MBWQ) and the Indiana Department of Environmental Management Laboratories. MBWQ and IDEM report sheets are available upon request.

4 Frankenberger, *Monitoring Water in Indiana*, 76.



MAP 8.1 | Watershed monitoring locations

Water quality monitoring was conducted following standard accepted practices for river and stream survey work consistent with the requirements of QAPP. Quality assurance and quality control procedures were followed for collection and processing of samples, including calibration of equipment, collection of field blanks and duplicate samples. No statistically significant differences were determined between the duplicate samples. The results of analysis of laboratory data are shown in Appendices L through O.

UNITS OF MEASURE

Results are often presented as concentrations in milligrams per liter (mg/L) or its equivalent of parts per million (ppm), and micrograms per liter (µg/L) or its equivalent of parts per billion (ppb). The various units of measure are related as follows: 1 mg/L = 1 ppm; 1 µg/L = 1 ppb, 1 ppm = 1,000 ppb, 0.020 mg/L (ppm) = 20 µg/L (ppb).

STREAMFLOW

Streamflow, also called discharge, is the volume of water flowing in a stream as a function of time, or the stream velocity multiplied by the cross-sectional area of the stream (width x depth). At sites monitored by the UMRW-P, stream velocity was measured by a floatation element and its travel speed over a set distance. The channel cross-section was measured once at each sampling site with a total station (a total station is an electronic device used for surveying; it measures distances and angles, as well as records the exact location at which data was collected). This allowed the channel cross-section to be plotted and visually represented in AutoCAD. Depth measurements taken during each sampling event and plotted on this cross section in AutoCAD allowed the cross-sectional area of the channel to be calculated (specific to the measured depth). Flow in cfs (cubic feet per second) was calculated using the cross-sectional area and velocity.

The flow rates measured during each sampling event at a site were averaged to determine mean streamflow for the site. For each site, events that were above mean flow were categorized as high flow events and events that were below mean flow were categorized as low flow events. The flow event and its relationship to the storm curve was not considered. The storm curve was not considered because the discharge rates are more accurate when measured at the sample site as opposed to the mainstem of the Mississinewa River. Flows in Grant County were calculated from flow and area data for the USGS Gauging Station 03326500 at Marion, Latitude 40°34’35”, Longitude 85°39’34”, Gage datum 774.21 feet above sea level. River flow at the two Mississinewa River stations was calculated using the following formula: CFS = Site Drainage Area x Marion Flow / Marion Drainage Area. Mississinewa River flows in Randolph and Darke County were calculated from flow and area data for the USGS Gauging Station 03325500 at Ridgeville in Randolph County, Latitude 40°16’48”, Longitude 84°59’33”, Gage datum 964.74 feet above sea level. River flow at the two Mississinewa River stations was calculated using the following formula: CFS = Site Drainage Area x Ridgeville Flow / Ridgeville Drainage Area. Streamflow hydrographs from the USGS gauging station on the Mississinewa River in Marion, Indiana were evaluated for the sample dates and preceding weeks to indicate overall discharge rates for the entire watershed during the sampling periods. The Mississinewa River hydrographs indicate the overall flow regime (base flow, low-storm flow and moderate-storm flow) during the separate sampling periods.

TABLE 8.2 | Average cfs, used as the division between high flow and low flow

Critical Area	Average cfs
Barren Creek	40.4
Big Lick Creek	39.7
Bush Creek	8.63
Campbell Creek	16.6
Deer Creek	111.3
Halfway Creek	25.6
Little Deer Creek	106.3
Little Mississinewa River	38.9
Little Walnut Creek	45.8
Lugar Creek	65.8
Gray Branch	38.9
Upper Big Lick Creek	29.9
Walnut Creek	121.6

SAMPLING DATES

Sampling occurred during the project cycle from April 2014-March 2015. Macroinvertebrate sampling, fish sampling and habitat evaluation was conducted once in the summer of 2014.

8.1 ANALYSIS OF CURRENT WATER QUALITY DATA

Water quality data from each sampling site was analyzed using seven methodologies (listed below). The tables and/or diagrams generated for each of these methodologies are included in Appendices L through O and separated individually into Nitrate [N], Total Phosphorus, TSS, and E. coli. Dissolved Oxygen, temperature, and pH were in acceptable ranges and are not discussed. These methodologies as a basis for interpreting the water quality discussions found in Sections 8.2 through 8.5. Water quality is further discussed at the HUC10 level in Section 10.

A. Data collected at each site was analyzed to determine the mean, min, and max for each subwatershed site and a basic standard deviation calculation from the mean (assuming standard bell curve). This data can be found in Tables L.1, M.1, N.1, and O.1 (in Appendices L, M, N, and O, respectively). Analysis shows the variability in the stream samples irrespective of flow regime.

B. Tables L.2, M.2, N.2, and O.2 (in Appendices L, M, N, and O, respectively) display parameter mean values at high flow and low flow (through a categorization described in previous paragraphs) and also provides the total average for all samples. It also includes the CFS averages for the low flow and high flow events and drainage area. It should be noted that some of the sampling events cannot be classified as high or low flow because flow data was not able to be collected (ice, no flow, other factors - note that IDEM did not collect any flow data for Bear Creek and Days Creek). While non classified samples are not reported in the individual columns for high/low flow averages, they are included in the overall total average. Therefore, in some instances mean flow averages can be higher than the high flow averages if unclassified events had significant elevated results.

C. Tables L.2, M.2, N.2, and O.2 (in Appendices L, M, N, and O, respectively) contain the total average (for all sampling events, regardless of flow) and averages for both high flow and low flow. Two bar graphs were developed for each parameter (Figures L.1 and L.2; M.1 and M.2; N.1 and N.2; and O.1 and O.2 in Appendices L, M, N, and O, respectively). They display parameter average values for high flow, low flow, and also the average parameter values for all flows combined. The first figure for each parameter compares mainstem Mississinewa sites and the second figure shows the subwatershed sites.

D. Water quality was evaluated for each parameter compared to available water quality targets as identified by IDEM (2012) in Indiana Administrative Code where an Indiana Water Quality Standard exists for a parameter of concern, or from other targets where a standard does not exist. See Table 6.1 on p. 98 for water quality targets used in this study. Targets were used to determine if there were exceedances of the water quality parameter. Tables L.3, M.3, N.3, and O.3 (in Appendices L, M, N, and O, respectively) include the number of exceedances during high flow, low flow, or during uncategorized flow. The total number of exceedances is included in the grand total. The table also includes the count of the total samples, and the % exceedance of samples compared to total samples.

E. In Figures L.3, M.3, N.3, and O.3 (in Appendices L, M, N, and O, respectively), monthly high flow values were charted for each month to visualize seasonal trends.

F. Loading calculations were generated using the IDEM Load Calculation Tool spreadsheet, which utilizes flow (CFS) and parameter averages (mg/l). The current loads (tons/year) were calculated utilizing both the high flow and the low flow data. In addition, using the same calculator, the parameter target selected for the project was modeled at the high and low flow CFS to determine a target loading (i.e. what the river would have been carrying in tons had all samples been at the target level). A average load reduction needed for low flow and high flow was calculated. This allows the Project Manager to consider the relative relationship between the target load and the actual load. The Project manager created comparable data: (1) X = X Times Target, how many times mean load exceeds target load, (2) % = Percent reduction needed to reach water quality targets and (3) TR = Tons/yr. reduction need to meet water quality target. This allows each subwatershed to be analyzed based on its own ideal loading. The formulas used for this analysis are illustrated in Fig. 8.1. This methodology is used to determine critical areas and is discussed further in Sections 14, Critical Areas. While exceedances are important, sometimes exceedances are marginal. A watershed may have less exceedance, but greater contribution from a loading metric.

G. In Figures L.4, M.4, N.4, and O.4 (in Appendices L, M, N, and O, respectively), the relationship between drainage area and pollutant load are shown. Blue represents subwatershed sites, and red represents mainstem sites. In Figures L.5, M.5, N.5, and O.5 (in Appendices L, M, N, and O, respectively), the relationship between drainage area, pollutant load, and flow is shown for mainstem sites. In Figures L.6, M.6, N.6, and O.6 (in Appendices L, M, N, and O, respectively), the relationship between drainage area, pollutant load, and flow is shown for tributary subwatershed sites.

8.2 NITRATE

Nitrogen is present in aquatic systems in four different forms: nitrate, nitrite, ammonia, and organic nitrogen. Nitrate was the only form tested for in this study. Sources of nitrates include fertilizer runoff, septic tank and sewer effluent, and erosion. High levels of nitrogen can cause fish kills through a process called eutrophication. This process is set in motion when high nitrogen levels cause excess algae growth, which is followed by algae death. Oxygen is used by microbes as they consume dead algae, resulting in the depletion of dissolved oxygen in the water. This depletion of oxygen can be harmful or fatal for fish and other aquatic organisms. We sampled for nitrate-N in this study and interpreted results based on a target nitrate level of 1 mg/L. This target was selected using the Ohio EPA recommended criteria for Warm Water Habitat (WWH) headwater streams for nitrate, which is a maximum of 1 mg/L.

Methods

The MBWQ sampled monthly from April 2014 to March 2015. Flow was measured on the same day or the following day. Flow was not measured at Bear Creek and Days Creek. Four other sites lacked flow data for one sampling event, but because the nitrate values measured were low and similar to other measurements for these sites, the Project Manager concluded that results based on flow were not significantly affected. Nitrate-N was the only form of nitrogen measured. Analysis followed EPA 353.2 methods for (NO3+NO2)-N. IDEM sampled monthly from April 2014 to March 2015.

Samples were analyzed for nitrate-N (which will hereafter be referred to as “nitrate” for simplicity’s sake). The Project Manager separated data for each site into high and low flow events and averaged data accordingly for each category. Total data, disregarding flow, was also averaged for each site. The total number of exceedances was tallied for each site. Nitrate loads were calculated for each site, as well the load reductions needed to reach target levels. All nitrate data was graphed by month in order to observe seasonal patterns. The nitrate target set by the Project Manager is a maximum of 1mg/L.

Results and Discussion

Results of nitrate sampling can be found in Appendix L. The month of June had the highest nitrate levels; this is generally when nitrogen is sidedressed on cropland. May, April, and November also saw high nitrate levels (spring application of manure and fall application of nitrogen may influence these levels). Nitrate levels were higher during high flow events than during low flow events. This is due to increased nitrogen leaching and runoff during rainfall events. In general, mainstem nitrate averages exceeded those of tributaries (Table 8.3). At all mainstem sites, average nitrate during both high flow and low flow events exceeded the target. At all tributary sites, average nitrate during high flow events exceeded the target. At five tributary sites, average nitrate during low flow events were below the target; average nitrate during low flow events exceeded the target at nine sites.

At mainstem sites, average nitrate during high flow generally decreased from east to west within the watershed. This correlates with decreases from east to west in (1) cropland acreage, (2) modeled nitrogen fertilizer contributions to streams (calculated by the Project Manager using the Export Coefficient Model; see p. 53), and (3) CFOs. Tributary sites show a similar pattern. Three tributary sites (Barren Creek, Little Deer Creek, and Deer Creek) located at the far western end of the study site are an exception; average nitrate levels during high flow were high at these sites. However, these sites are located in highly agricultural subwatersheds with cropland percentages and estimated nitrogen fertilizer contribution to streams that are more similar to those in the far eastern part of the watershed.

Average nitrate during low flow was also highest at sites in the eastern part of the watershed (Figure L.1, Appendix L). However, differences were less pronounced and levels dropped more quickly, remaining fairly consistent throughout the central and western part of the watershed. Levels were actually slightly lower in the central part of the watershed than in the western part of the watershed. This may be due to higher populations in the western part of the watershed. Subwatershed sites showed a similar pattern. Again, sites in the far western part of the watershed that have high percentages of cropland and high predicted rates of nitrogen application had relatively high nitrate levels.

Of the Mississinewa mainstem sites, Gray Branch had the highest average nitrate during high flow (Figure L.1, Appendix L). This is likely due to Gray Branch’s high estimated nitrogen fertilizer use and high number of CFOs. The next highest nitrate average during high flow events was at Fetid Creek. There are CFOs present within this subwatershed and a very high concentration of them just to the north of it. Land application of manure is likely contributing to these high levels. Boots Creek and Branch Creek had the lowest average levels during high flow, likely due to lower percentages of cropland and higher percentages of urban and ecological areas. During low flow events, Gray Branch, Porter Creek, and Jordan Creek had the highest average levels of nitrate.

Of the subwatershed sites, Bush Creek had the highest levels of nitrate on average for high flow events, followed by Little Mississinewa River, Barren Creek, Little Deer Creek, and Deer Creek respectively (Figure L.2, Appendix L). Flow data was not collected for Days and Bear Creek so it was not possible to separate them into high flow and low flow categories. However, Bear Creek had the highest overall average nitrogen levels and Days Creek had the third highest. Little Mississinewa River had the highest levels of nitrogen on average at low flow events, followed by Little Deer and Deer Creek. All of these sites are in highly agricultural areas. Some are near high concentrations of CFOs as well.

Within the watershed, three tributary subwatersheds flow into other tributary subwatersheds rather than into the mainstem. This means that two sites along the same tributary were monitored.

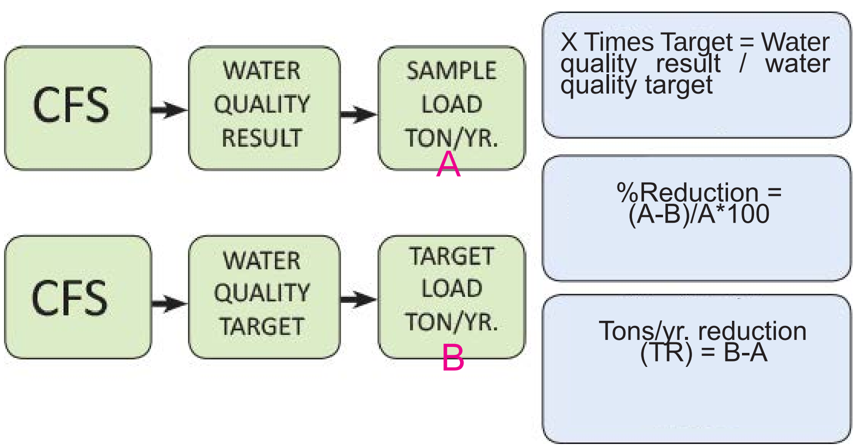
Changes in water quality from one site to the next can suggest which, if any, of the two tributary subwatersheds is the most impaired. These subwatersheds are: Big Lick Creek, Upper Big Lick Creek, Little Walnut Creek, Walnut Creek, Little Deer Creek, and Deer Creek. There was a slight decrease in nitrate concentrations from Little Walnut Creek to Walnut Creek at both high and low flow. There was was also a decrease in concentration from Little Deer Creek downstream to Deer Creek at both high and low flow, although the decrease at low flow was very slight. These relationships correlate to higher estimated nitrogen fertilizer use in the upstream subwatersheds. There was a slight increase in nitrates at high flow from Upper Big Lick Creek to Big Lick Creek. However, during low flow there was a slight decrease. The cause of these differences is unclear. CSOs within Hartford City drain into both of these creeks.

It is also important to note that while Days and Bear Creek lacked flow data, their overall averages ranked them 3rd and 1st, respectively, out of all tributary sites for highest nitrate levels. This was to be expected, as both are located in the eastern part of the watershed with high agricultural land use. While load reductions cannot be calculated, it is certain that implementing best management practices in these subwatersheds would be beneficial.

TABLE 8.3 | Nitrate averages for tributary subwatershed and mainstem subwatershed sites

Nitrate	X Times Target	% Reduction	Mg/L
Mississinewa River Mainstem Subwatershed high flow average	8.4	88%	7.21
Mississinewa River Mainstem Subwatershed low flow average	2.5	60%	2.45
Tributary Subwatershed high flow average	3.9	74%	4.7
Tributary Subwatershed low flow average	1.8	44%	1.78

See similar analysis of all subwatershed on subsequent pages.
X Times Target = how many times mean load exceeds target load
% Reduction = Percent reduction needed to reach water quality targets



Water Quality Targets

N = 1 MG/L
PHOSPHORUS = 0.3 MG/L
E. coli = 235 CFU/L
TSS = 25 MG/L

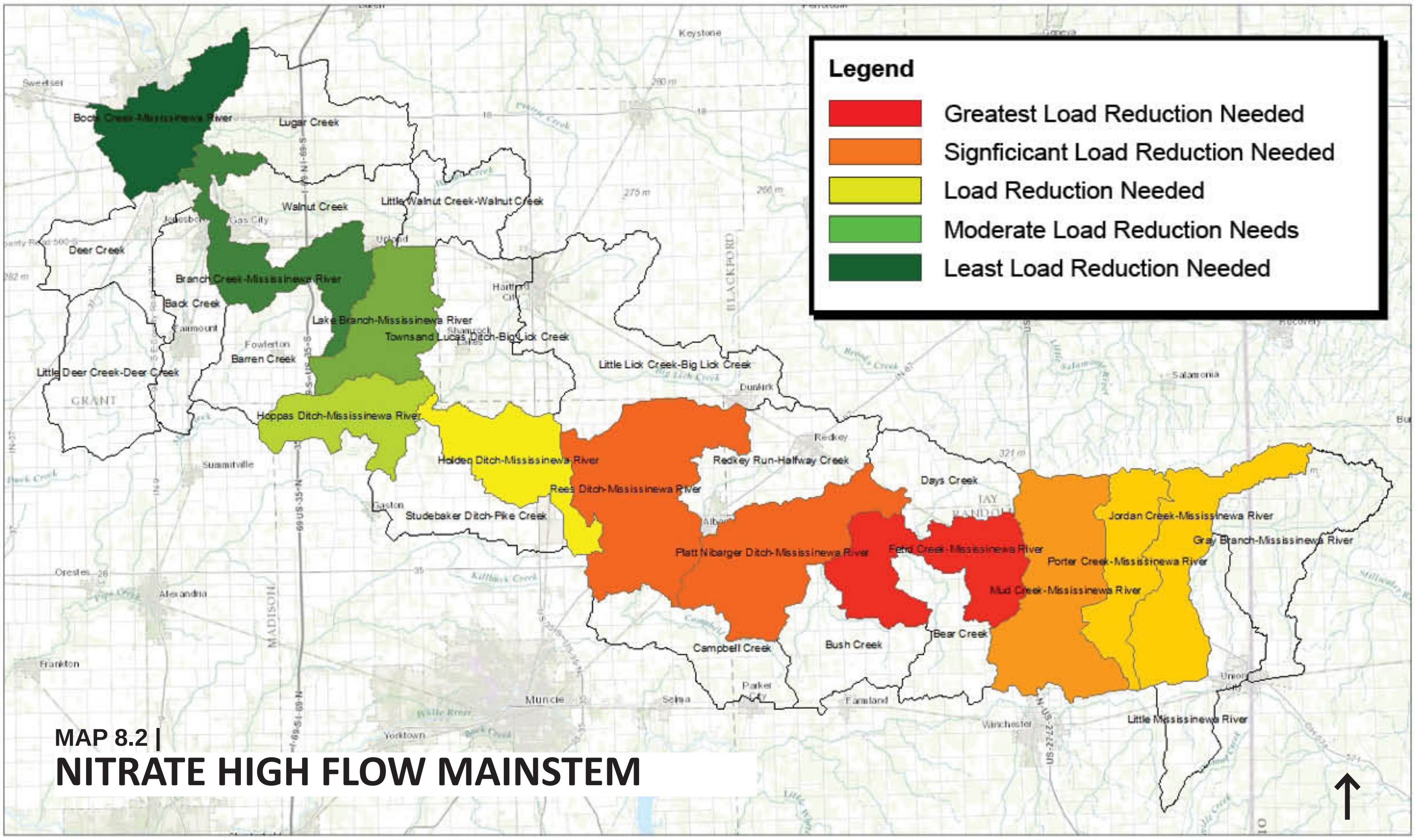
FIG. 8.1 | Illustration showing how water quality results, targets, and calculated loads are used to calculate X Times Target, % Reduction, and Tons/yr. reduction (TR).

TABLE 8.4 | Nitrate load reduction needed at tributary subwatershed sites									
		Average Flow		Nitrate at High Flow			Nitrate at Low Flow		
	Drainage (sq. mi.)	@ High Flow (cfs)	@ Low Flow (cfs)	Xtimes*	%Change**	TR***	Xtimes*	%Change**	TR***
Subwatershed	28.69	148.61	25.86	4.56	0.78	475.08	2.24	0.55	27.94
Back Creek	16.00	98.61	39.22	3.09	0.68	203.21	2.40	0.58	54.15
Barren Creek	21.00	89.21	15.99	6.96	0.86	523.15	2.69	0.63	26.57
Big Lick Creek	76.00	65.94	20.05	4.45	0.78	212.99	1.12	0.11	2.46
Bush Creek	20.00	20.11	2.90	8.10	0.88	147.40	1.02	0.02	0.04
Campbell Creek	20.00	35.43	4.03	5.72	0.83	147.29	0.99	-0.01	-0.02
Deer Creek	45.00	325.05	40.15	5.18	0.81	1335.26	2.86	0.65	73.65
Halfway Creek	25.00	62.06	9.93	4.73	0.79	261.97	1.62	0.38	5.33
Little Deer Creek	26.00	281.93	40.36	5.56	0.82	1264.78	3.07	0.67	82.19
Little Mississinewa River	21.00	118.46	12.35	5.32	0.81	503.59	6.35	0.84	65.01
Little Walnut Creek	17.00	145.85	8.46	4.39	0.77	486.76	1.78	0.44	6.46
Lugar Creek	30.00	204.29	31.35	3.00	0.67	401.32	1.15	0.13	5.19
Pike Creek	21.00	39.35	7.63	6.26	0.84	195.11	0.98	-0.02	-0.14
Upper Big Lick Creek	52.00	57.26	11.63	2.52	0.60	74.41	1.39	0.28	4.41
Walnut Creek	39.00	340.16	48.64	3.29	0.70	766.85	1.13	0.12	6.39

Current loads and target loads are included in Appendix L.
*X = X Times Target, how many times mean load exceeds target load
**%Change = Percent change in current load needed to reach water quality targets. Red represents highest % change needed; green the lowest.
***TR = Tons/yr. reduction need to meet water quality targets

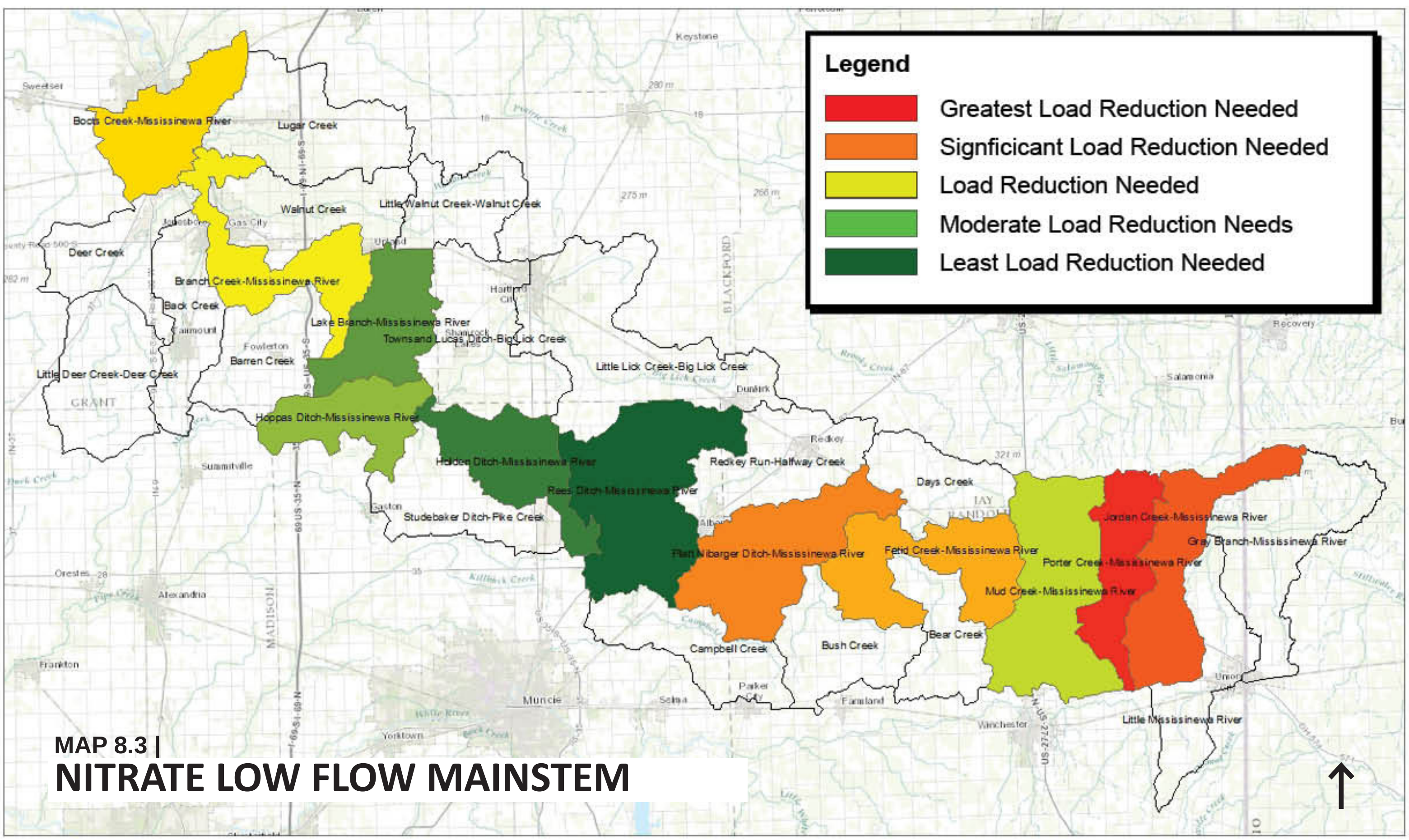
TABLE 8.5 | Nitrate load reduction needed at mainstem sites									
		Average Flow		Nitrate High			Nitrate Low		
	Drainage (sq. mi.)	@ High Flow (cfs)	@ Low Flow (cfs)	Xtimes*	%Change**	Difference ***	Xtimes*	%Change**	Difference ***
Mainstem	401.80	1585.23	214.29	4.73	0.79		2.80	0.64	
Boots Creek	681.00	2398.25	317.44	3.08	0.67	0.05	2.85	0.65	-0.03
Branch Creek	629.00	2923.33	354.67	3.66	0.73	0.03	2.59	0.61	-0.04
Lake Branch	486.00	2750.00	352.00	4.08	0.75	0.03	2.33	0.57	0.02
Hoppas Ditch	472.00	2740.00	355.67	4.62	0.78	0.07	2.47	0.59	-0.12
Holden Ditch	424.00	640.72	97.06	6.73	0.85	0.05	1.89	0.47	-0.08
Rees Ditch	311.00	591.17	121.56	10.14	0.90	0.00	1.65	0.39	0.33
Platt Nibarger Ditch	240.00	228.80	37.32	100.0	0.90	0.02	3.65	0.73	-0.07
Fetid Creek	179.00	337.92	33.39	13.01	0.92	-0.04	2.93	0.66	-0.06
Mud Creek	133.00	264.73	24.21	8.86	0.89	-0.01	2.50	0.60	0.23
Porter Creek	89.00	750.67	72.37	8.01	0.88	0.01	6.03	0.83	-0.02
Jordan Creek	79.00	1146.50	57.24	8.58	0.88	-0.01	5.39	0.81	0.04
Gray Branch	31.00	91.84	12.40	7.61	0.87		7.12	0.86	

Current loads and target loads are included in Appendix L.
*X = X Times Target, how many times mean load exceeds target load
**% Change = Percent change in current load needed to reach target load
***Difference = The difference between the percent changes needed at consecutive sites. Negative numbers indicate that the percent change needed has increased between the consecutive sites. Positive numbers indicate that the percent change needed has decreased between the consecutive sites. These values can be interpreted as an improvement or a decline in water quality between two sites. Red represents an increase in percent change needed; green a decrease.



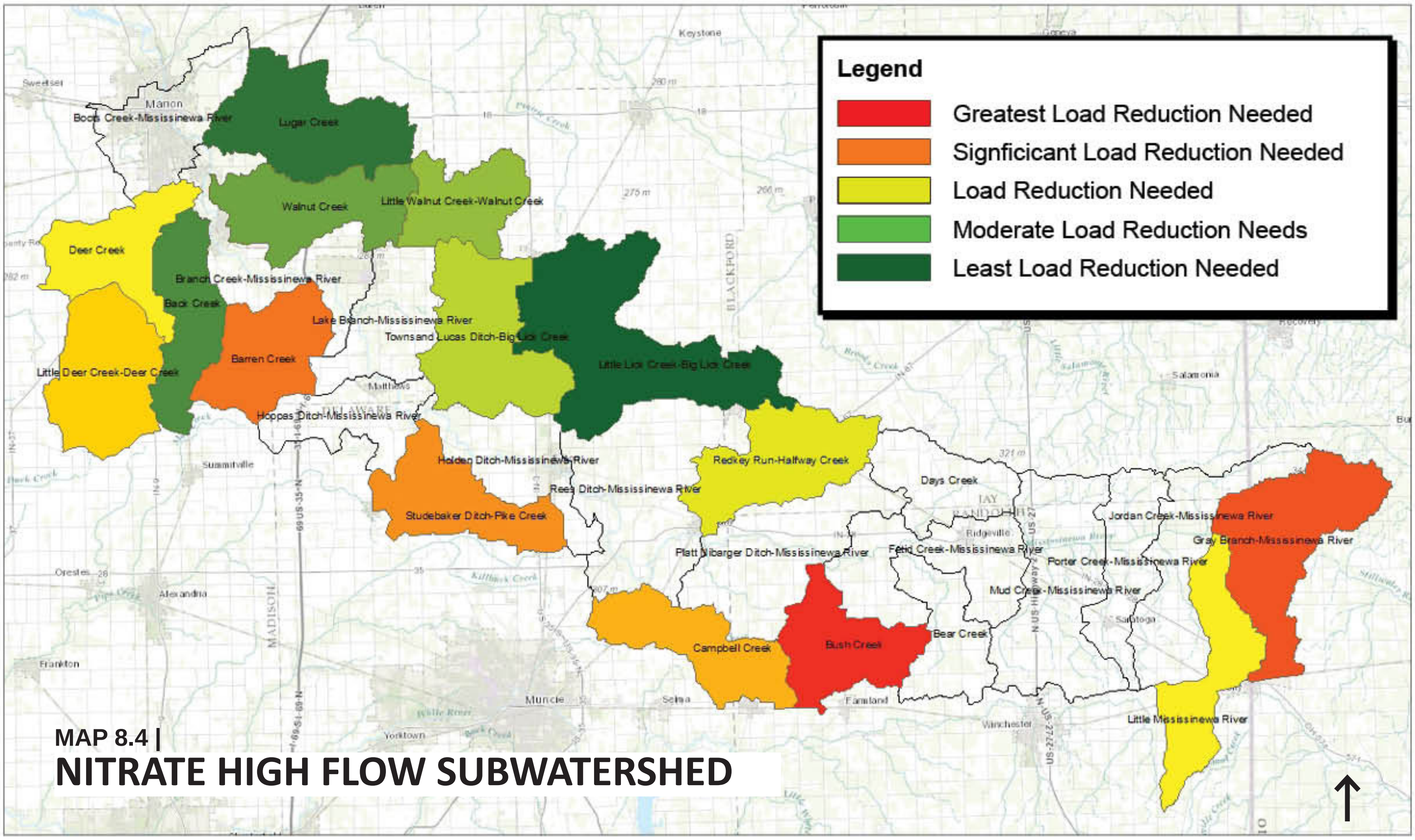
MAP 8.2 |

NITRATE HIGH FLOW MAINSTEM



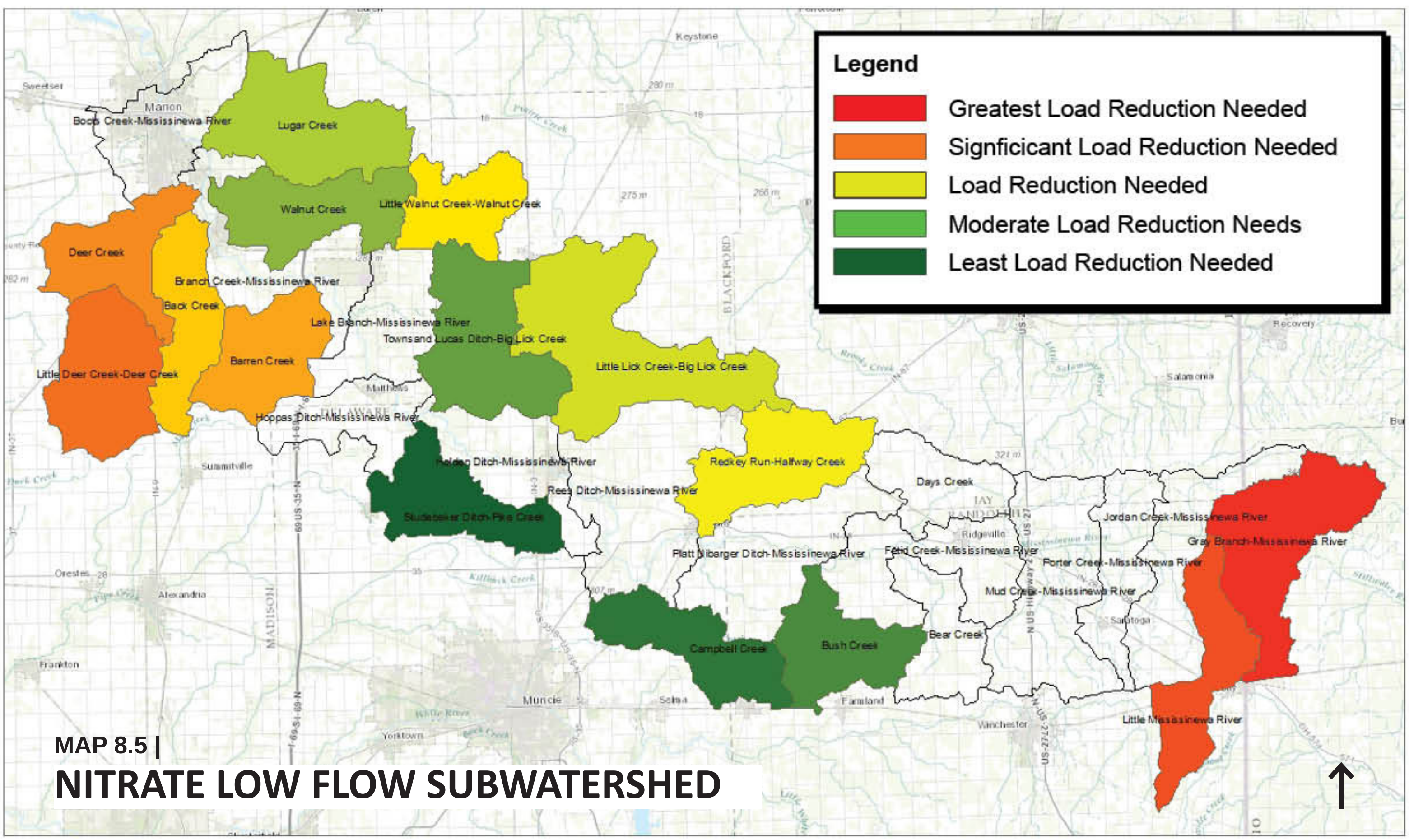
MAP 8.3 |

NITRATE LOW FLOW MAINSTEM



MAP 8.4 |

NITRATE HIGH FLOW SUBWATERSHED



MAP 8.5 |

NITRATE LOW FLOW SUBWATERSHED

8.3 PHOSPHORUS

Like nitrogen, excess phosphorus in surface waters can cause eutrophication which may lead to fish kills. Even very small amounts of phosphorus can lead to this process since phosphorus levels are a limiting factor in plant growth in many aquatic environments. A maximum level of 0.076 mg/L of phosphorus in waters is recommended by the US EPA. Sources of phosphorus found in surface water include soil and rocks, wastewater treatment plants, fertilizer runoff from agricultural and residential areas, failing septic systems, manure runoff, and disturbed land.

Research has suggested that agriculture may have more influence on phosphorus levels than septic systems and CSOs. A 1984 study estimated that 72% of phosphorus released into the environment came from fertilizer and manure applications from agriculture, 5% from wastewater plants, and 22% from nonpoint sources such as septic systems.[5] Phosphorus applied to agricultural fields in the form of fertilizer is most often broadcast rather than incorporated into the soil, causing phosphorus to build up in the top half inch of soil.[6] This leaves it more vulnerable to being carried by runoff and also suggests that levels of phosphorus are likely to be higher in runoff from agricultural fields than in eroded sediment from streambanks. Soil characteristics in the Mississinewa watershed may be limiting the ability of septic systems to function properly. While septic tanks remove some phosphorus through the settling of sludge, the remainder enters the drainage field where it often reacts with soil constituents in the drainage field and is immobilized.

However, calcerous, alkaline soils, such as those found in the area, are less capable of binding phosphorus ions.[7] This suggests that septic systems in the Mississinewa watershed are contributing phosphorus to waterways in higher levels than those sited on appropriate soils. Other factors in addition to this can cause septic systems to function improperly.[8]

Methods

The MBWQ sampled monthly from April 2014 to March 2015. Flow was measured on the same day or the following day. IDEM sampled monthly, with most sampling done from April 2014 to November 2014. Flow was measured on the same day or the following day. Bear Creek and Days Creek lacked flow data. Two other sites lacked flow data for one or two sampling events. Samples were analyzed for total phosphorus. The Project Manager selected a target of 0.3 mg/L for phosphorus, based on the IDEM draft TMDL target of 0.3 mg/L. The Project Manager separated each site's data according to flow (either high and low) and averaged data for both categories. Total data, disregarding flow, was also averaged for each site. The total number of times sample concentrations exceeded the target were tallied for each site. Phosphorus loads were calculated for each site, as well the load reductions needed to reach target levels. All phosphorus data collected was graphed by month in order to observe seasonal patterns.

Results and Discussion

Results of phosphorus sampling can be found in Appendix M. Three of the five highest phosphorus levels were measured in March (the other two were in February and September). The sites with these readings were in the far eastern part of the watershed, where there is some of the highest predicted phosphorus fertilizer contribution within the watershed (calculated by the Project Manager using the Export Coefficient Model; see p. 53). These measurements were taken during the highest recorded flows for these sites; in fact, they were some of the highest flows measured in the watershed during the sampling program, only exceeded by the four mainstem sites farthest downstream. Therefore, flow events of this magnitude may have been uncharacteristic for this area. The rain event causing these flow levels may have been the largest one during this study; it was likely isolated in this region of the watershed.

November and June also had a high number of samples with high concentrations of phosphorus. Phosphorus concentrations measured in June and November were similar to each other (in comparison to nitrate, which had much higher levels in June). Sites with the highest concentrations of phosphorus in November were generally in the western part of the watershed. The western part of the watershed also has the highest rates of conventional tillage, which is usually practiced in the fall, following harvest. There is also a higher risk of soil loss in this part of the watershed due to geomorphology and soil characteristics.

Phosphorus levels were higher during high flow events than during low flow events. This is likely due to increased soil and waste transport during rainfall events. In general, mainstem phosphorus averages exceeded those of tributaries (Table 8.3). Average phosphorus during high flow events exceeded the standard at 92% of mainstem sites and 64% of tributary sites. Average phosphorus during low flow events were below the standard for all sites except for one mainstem site (Branch Creek) and one a tributary site (Upper Big Lick Creek).

Phosphorus levels in surface water showed less correlation to the amount of phosphorus fertilizer usage (in each mainstem and tributary subwatershed) than was seen with nitrate levels in surface water and nitrogen fertilizer usage. In general, the eastern end of the watershed had high phosphorus levels measured in surface water and also some of the highest rates of phosphorus applied for agriculture (however, as mentioned before, manure application may be affecting these results as well). A decline in measured phosphorus in the central section of the watershed (Fig. M.1, Appendix M) correlated with a possible decrease in field application of manure and a predicted decrease in phosphorus fertilizer application (based on the Simple Coefficient Model).

5 National Environmental Service Center. [web page] Pipeline: Small Community Wastewater Issues Explained to the Public. Phosphorus and Onsite Wastewater Systems. 2013

6 Fisher, M. 2014. [webpage] Tile drains a major path for phosphorus loss, studies find. https://www.agronomy.org/science-news/tile-drains-major-path-phosphorus-loss-studies-find [Accessed 15 October 2015]

7 National Environmental Service Center. p.113

8 Ibid.

In general, while predicted phosphorus fertilizer application continued to decline in the western part of the subwatershed, measured phosphorus actually increased (Fig. M.1, Appendix M). This may be due to increases in 1) conventional tillage, 2) sediment transport prediction, and 3) septic systems in the western part of the watershed. As expected, due to phosphorus's soil binding property, sediment transport prediction and the predicted sediment contribution due to conventional tillage appear to have a large influence on the general trend of phosphorus levels in the watershed.

Low flow averages showed a similar pattern except that they generally didn't increase in the western part of the watershed (Fig. M.1, Appendix M). They were more similar to the levels in the central part of the watershed. A large spike at Branch Creek was the only exception.

Of the mainstem Mississinewa sites, average phosphorus levels at high flow were highest at Porter Creek and Hoppas Ditch (Fig. M.1, Appendix M). Lake Branch had the third highest average. Septic systems may be contributing to high phosphorus levels during high flow within Hoppas Ditch. While there are a relatively low number of septic systems in the area, their close proximity to the sampling site may be contributing to higher levels. Sampling should be done both upstream and downstream of the town of Matthews to determine its contribution to phosphorus. Sites with the lowest average at high flow were Fetid Creek, Mud Creek, and Holden Ditch, respectively.

During low flow, Branch Creek had the highest average followed by Jordan Creek and Porter Creek (Fig. M.1, Appendix M). An instream source may have caused this spike at Branch Creek. However, nitrogen and phosphorus data for September were identical (1.63 mg/L), suggesting that a data entry error may have occurred. This possibly incorrect phosphorus reading drove the average significantly higher. Therefore, it may be best to disregard the spike at Branch Creek. Sites with the lowest average at low flow were Boots Creek and Mud Creek, respectively.
Of the subwatershed sites, Little Walnut Creek had the highest average levels at high flow events followed by Walnut Creek, Campbell Creek and Halfway Creek, respectively (Fig. M.2, Appendix M). High levels were expected for Little Walnut and Walnut Creek since they are in the western part of the watershed. Additionally, comments from the president of the Walnut Creek Drainage Board at a stakeholder meeting on Nov. 18, 2015 indicated that severe erosion was occurring on Lugar and Walnut creeks. Although Campbell Creek and Halfway Creek are in the central part of the watershed (where mainstem levels dropped), these sites have more predicted fertilizer usage than mainstem sites in this area. There is also a fairly high concentration of highly erodible soils in these areas. Barren Creek had the lowest average levels at high flow, followed by Pike Creek.

A lack of flow data for some sites altered high and low flow averages. Therefore, it is necessary to observe overall averages (regardless of flow). Upper Big Lick Creek and Big Lick Creek had the highest overall averages for phosphorus (Fig. M.2, Appendix M). They would have likely had the highest high flow averages as well (the phosphorus readings that lacked flow data were very high). These two subwatersheds also have high levels of highly erodible soils and high levels of conventional tillage.

At low flow, the site with the highest average levels was Upper Big Lick Creek, followed by Little Mississinewa River and Big Lick Creek, respectively (Fig. M.2, Appendix M). Instream sources may be influencing results for these sites. Livestock were observed in streams in Upper Big Lick Creek and Big Lick Creek. All three sites have a high number of regulated point sources and fairly high population densities. Deer Creek and Little Deer Creek had the lowest average levels for low flow, followed by Barren and Walnut Creek, respectively. Finally, it should also be noted that there may be a correlation between levels of phosphorus and the agency doing the testing. IDEM sites had lower levels on average than MBWQ sites. This is noticeable on graphs of mainstem sites. Sampling during late-fall and winter was uncommon for IDEM on mainstem sites, while the MBWQ sampled every month during the year. Only 10 out of 65 samples collected by IDEM were collected from the months of November to March. Because sampling times and frequencies differed, results may be skewed. Further sampling can help determine if differences measured were accurate or due to other factors, such as sample frequency or time.

TABLE 8.6 | Phosphorus averages for tributary subwatershed and mainstem subwatershed sites

Phosphorus	X Times Target	% Reduction	Mg/L
Mississinewa River Mainstem Subwatershed high flow average	1.75	43%	0.52
Mississinewa River Mainstem Subwatershed low flow average	0.57	none	0.19
Tributary Subwatershed high flow average	1.3	23%	0.36
Tributary Subwatershed low flow average	0.43	none	0.13

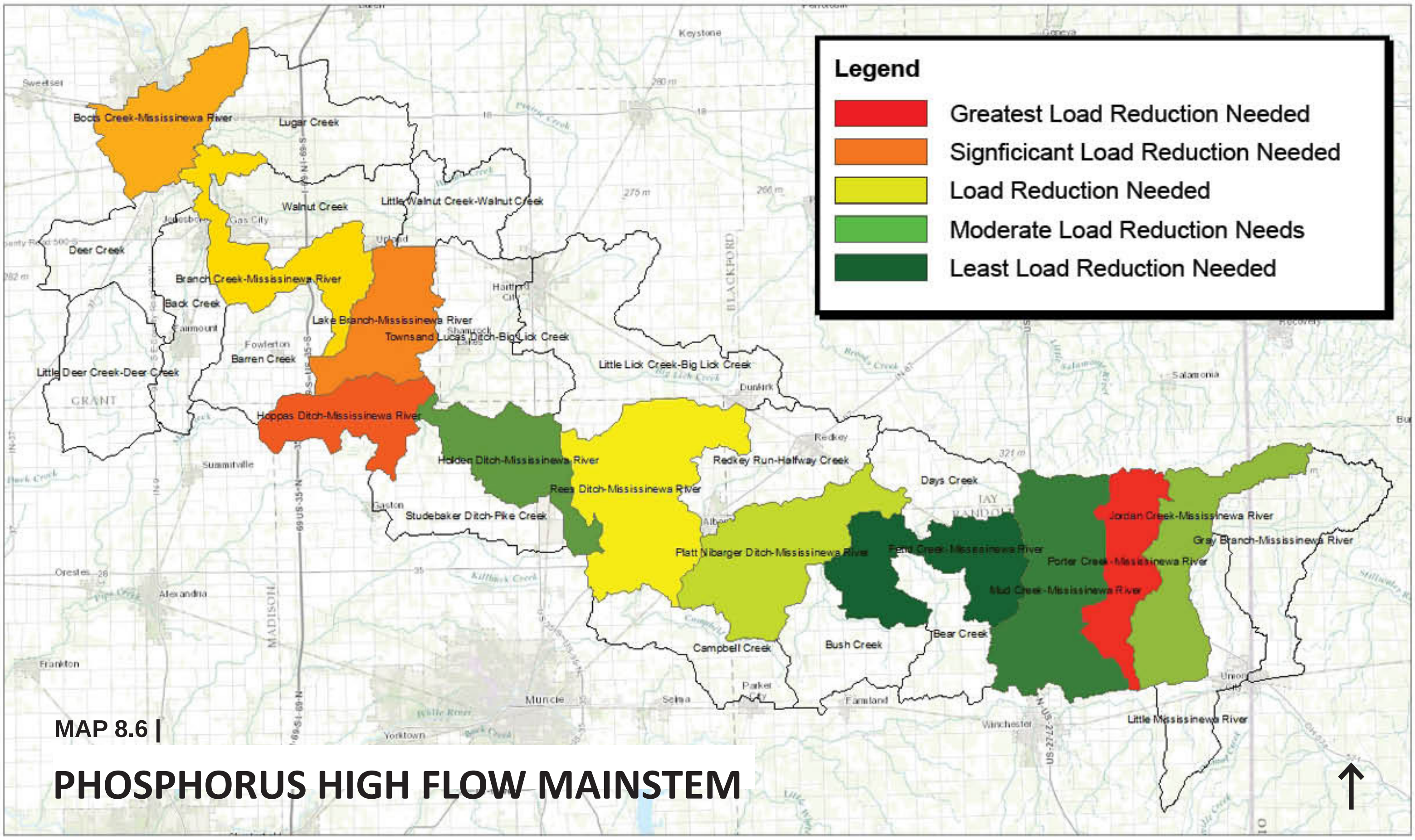
See similar analysis of all subwatershed on subsequent pages.
X Times Target = how many times mean load exceeds target load
% Reduction = Percent reduction needed to reach water quality targets

TABLE 8.7 | Phosphorus load reduction needed at tributary subwatershed sites									
		Average Flow		Phosphorus at High Flow			Phosphorus at Low Flow		
	Drainage (sq. mi.)	@ High Flow (cfs)	@ Low Flow (cfs)	Xtimes*	%Change**	TR***	Xtimes*	%Change**	TR***
Subwatershed	28.69	148.61	25.86	1.67	0.40	26.78	0.38	-1.61	-4.05
Back Creek	16.00	98.61	39.22	1.08	0.07	2.26	0.29	-2.47	-8.24
Barren Creek	21.00	89.21	15.99	0.65	-0.54	-9.19	0.14	-6.13	-4.06
Big Lick Creek	76.00	65.94	20.05	1.00	0.00	0.05	0.77	-0.30	-1.37
Bush Creek	20.00	20.11	2.90	0.90	-0.12	-0.65	0.72	-0.39	-0.24
Campbell Creek	20.00	35.43	4.03	2.11	0.53	10.40	0.44	-1.25	-0.66
Deer Creek	45.00	325.05	40.15	1.86	0.46	82.65	0.13	-6.98	-10.36
Halfway Creek	25.00	62.06	9.93	1.77	0.43	16.16	0.71	-0.41	-0.85
Little Deer Creek	26.00	281.93	40.36	1.70	0.41	57.97	0.12	-7.12	-10.44
Little Mississinewa River	21.00	118.46	12.35	2.16	0.54	40.56	0.64	-0.57	-1.33
Little Walnut Creek	17.00	145.85	8.46	2.28	0.56	55.15	0.48	-1.08	-1.29
Lugar Creek	30.00	204.29	31.35	1.51	0.34	30.61	0.90	-0.11	-0.93
Pike Creek	21.00	39.35	7.63	0.75	-0.34	-2.82	0.38	-1.63	-1.39
Upper Big Lick Creek	52.00	57.26	11.63	1.14	0.12	2.02	0.85	-0.18	-0.52
Walnut Creek	39.00	340.16	48.64	1.97	0.49	97.78	0.33	-2.06	-9.66

Current loads and target loads are included in Appendix M.
*X = X Times Target, how many times mean load exceeds target load
**%Change = Percent change in current load needed to reach water quality targets. Red represents highest % change needed; green the lowest.
***TR = Tons/yr. reduction need to meet water quality targets

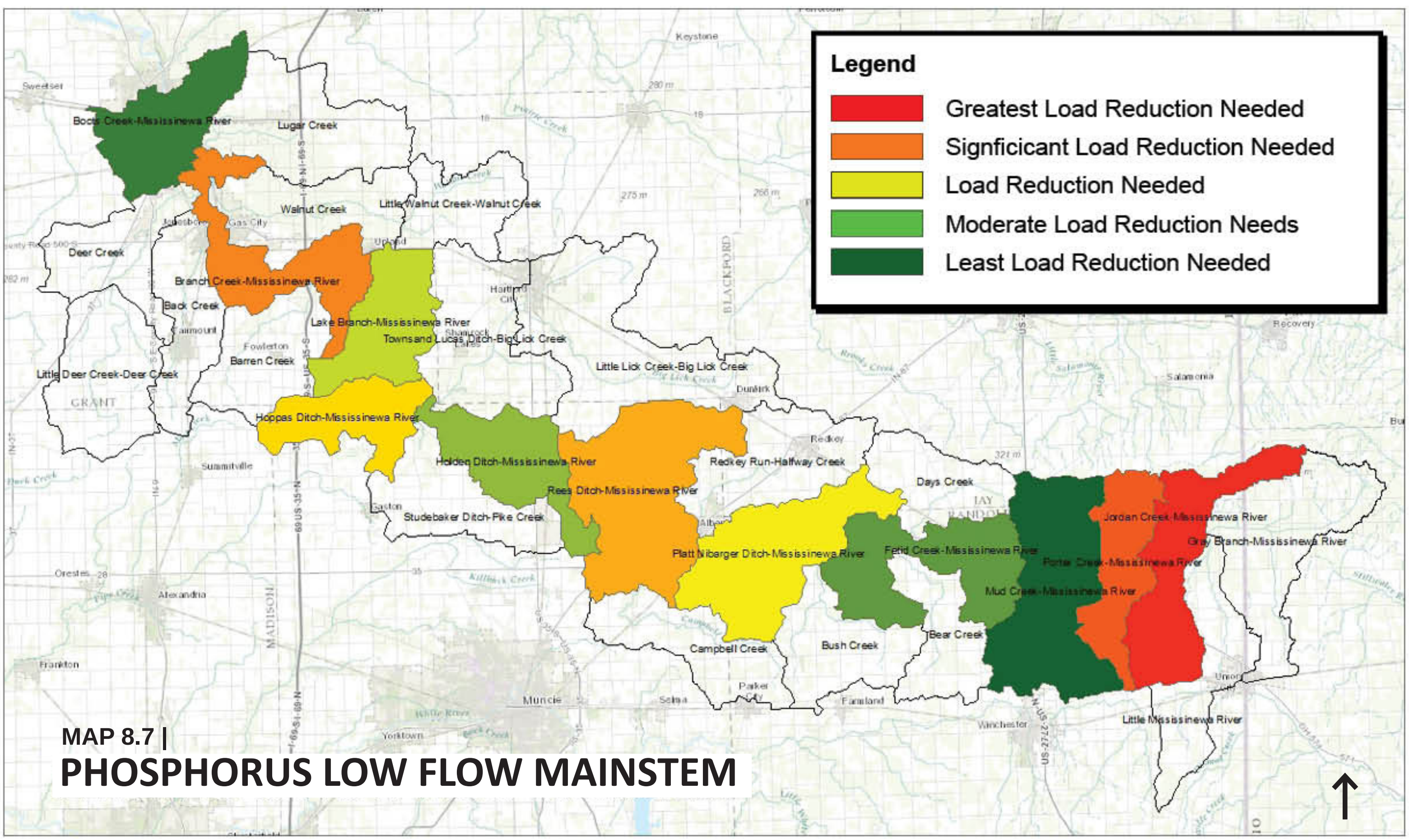
TABLE 8.8 | Phosphorus load reduction needed at mainstem sites									
		Average Flow		Phosphorus at High Flow			Phosphorus at Low Flow		
	Drainage (sq. mi.)	@ High Flow (cfs)	@ Low Flow (cfs)	Xtimes*	%Change**	Difference ***	Xtimes*	%Change**	Difference***
Mainstem	401.80	1585.23	214.29	2.20	0.54		0.71	-0.40	
Boots Creek	681.00	2398.25	317.44	2.25	0.56	-0.01	0.45	-1.24	1.39
Branch Creek	629.00	2923.33	354.67	2.20	0.55	0.02	1.17	0.14	-0.95
Lake Branch	486.00	2750.00	352.00	2.31	0.57	0.01	0.55	-0.81	0.28
Hoppas Ditch	472.00	2740.00	355.67	2.37	0.58	-0.23	0.65	-0.53	-0.52
Holden Ditch	424.00	640.72	97.06	1.53	0.35	0.16	0.49	-1.05	0.61
Rees Ditch	311.00	591.17	121.56	2.02	0.50	-0.05	0.70	-0.44	-0.27
Platt Nibarger Ditch	240.00	228.80	37.32	1.83	0.45	-0.39	0.59	-0.71	-0.48
Fetid Creek	179.00	337.92	33.39	1.07	0.06	0.16	0.46	-1.19	-0.18
Mud Creek	133.00	264.73	24.21	1.28	0.22	0.47	0.42	-1.37	1.61
Porter Creek	89.00	750.67	72.37	3.20	0.69	-0.27	1.30	0.23	0.18
Jordan Creek	79.00	1146.50	57.24	1.72	0.42	0.22	1.69	0.41	-0.84
Gray Branch	31.00	91.84	12.40	2.74	0.63		0.70	-0.43	

Current loads and target loads are included in the Appendix M.
*X = X Times Target, how many times mean load exceeds target load
**% Change = Percent change in current load needed to reach target load. Red represents highest % change needed; green the lowest.
***Difference = The difference between the percent changes needed at consecutive sites. Negative numbers indicate that the percent change needed has increased between the consecutive sites. Positive numbers indicate that the percent change needed has decreased between the consecutive sites. These values can be interpreted as an improvement or a decline in water quality between two sites. Red represents an increase in percent change needed; green a decrease.



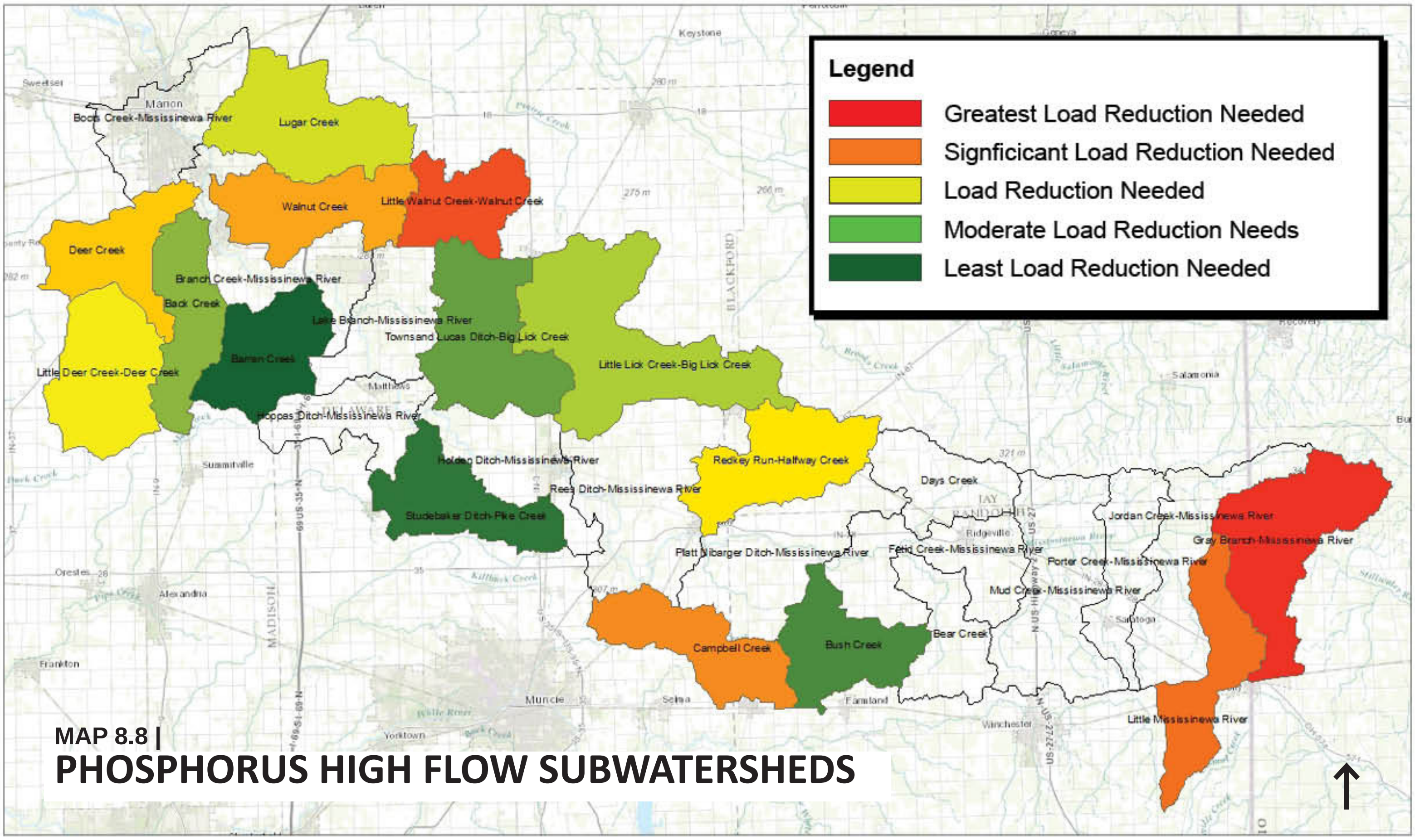
MAP 8.6 |

PHOSPHORUS HIGH FLOW MAINSTEM



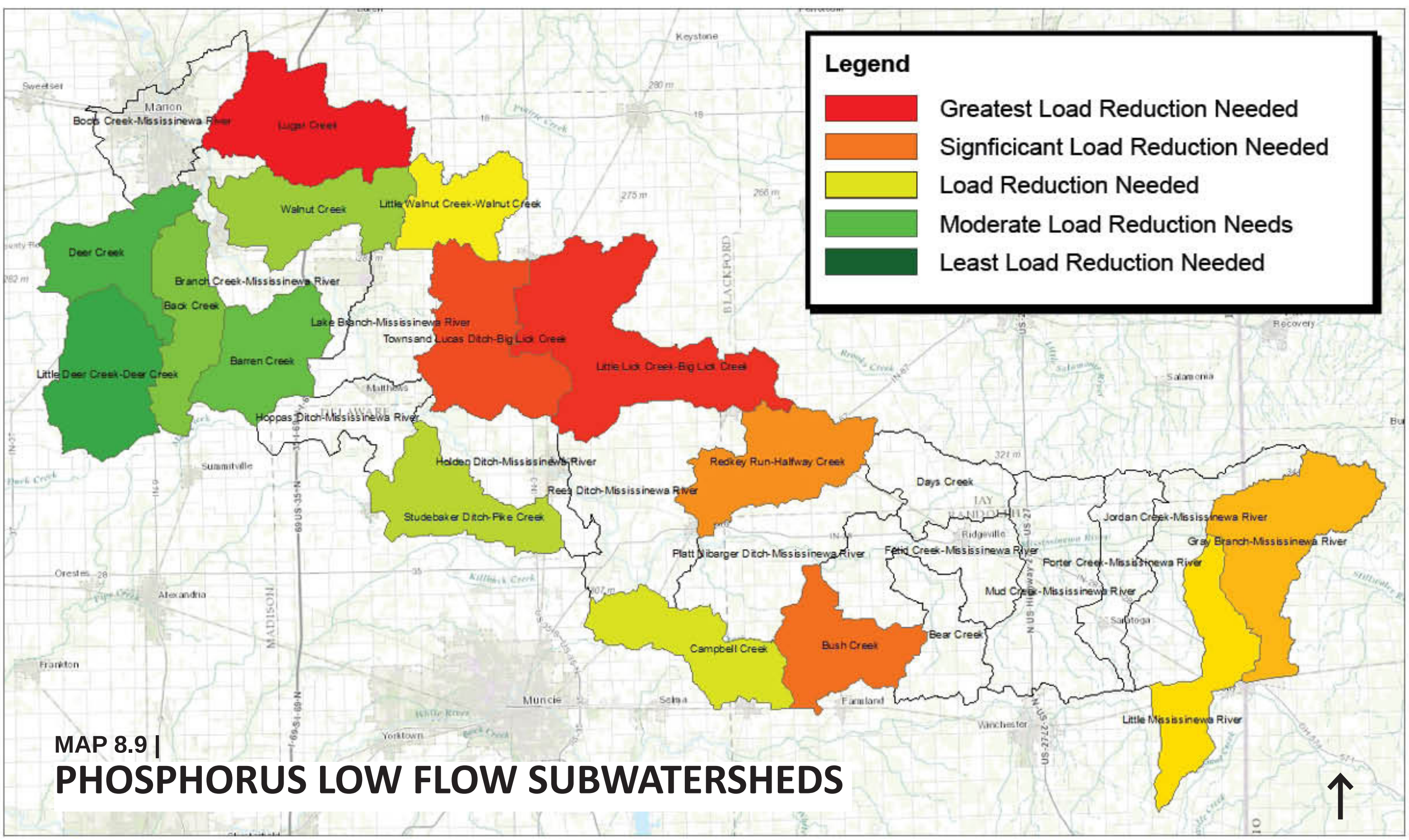
MAP 8.7 |

PHOSPHORUS LOW FLOW MAINSTEM



MAP 8.8 |

PHOSPHORUS HIGH FLOW SUBWATERSHEDS



MAP 8.9 |

PHOSPHORUS LOW FLOW SUBWATERSHEDS

8.4 SEDIMENT

High total suspended solids (TSS) causes high turbidity that can decrease oxygen levels in water by (1) blocking light, thereby decreasing photosynthesis in aquatic plants and (2) absorbing energy from light, thereby increasing water temperatures. Lower oxygen levels can adversely affect aquatic organisms. Suspended solids can also increase other pollutants, such as metals and bacteria, by providing attachment sites for them. Studies have shown that decreases in turbidity correspond with decreases in protozoa.[9] Sources of suspended solids in waterways include soil particles from runoff and erosion, organic matter from wastewater treatment facilities, and algae and other microorganisms. Suspended solids that are organic in form can indicate discharges from CSOs and other types of sewage treatment plants. Organic solids add nutrients to water that can cause algae blooms which lead to eutrophication.

Methods

The MBWQ sampled monthly from April 2014 to March 2015. Flow was measured on the same day or the following day. IDEM sampled monthly, mainly from April 2014 to October 2015 at sites identified for analysis in this study. The Project Manager separated data by site into high and low flow events and averaged data for each category. Total data, disregarding flow, was also averaged for each site. The TSS target set by the Project Manager was 25 mg/L, based on findings that at concentrations above this, fish concentrations are reduced.[10] The total number of times concentrations exceeded the target was tallied for each site. Load reduction for TSS at each site was calculated. TSS levels were graphed over time. Drainage area for each site was plotted against the number of times each site exceeded target load for both high flow and low flow events.

Results and Discussion

Results of TSS sampling can be found in Appendix N. The four highest TSS levels were measured in March, on the same dates that produced some of the highest phosphorus readings. The sites where these measurements were recorded were in the far eastern part of the watershed, where there is some of the highest phosphorus fertilizer usage within the watershed. These measurements were taken during the highest recorded flows for these sites; in fact, they were some of the highest flows recorded within the watershed, only exceeded by the four mainstem sites farthest downstream. Therefore, flow events of this magnitude may have been very uncharacteristic for this area. This rain event may have been the largest one during this study, and it was appears to have been isolated to this region of the watershed.

TSS levels were higher during high flow events than during low flow events (Figures N.1 and N.2 in Appendix N). This is due to increased soil and waste transport during rainfall events. In general, mainstem TSS averages exceeded those of tributaries (Table 8.4). TSS averages for high flow events exceeded the standard for all mainstem sites and 71% of tributary sites. TSS averages for low flow events were below the standard for all sites except for one a mainstem site (Hoppas Ditch).

In general, there appears to be some correlation between sediment transport prediction, conventional tillage sediment contribution, and the measured TSS. In general, sediment transport prediction and conventional tillage sediment contribution are higher on the western end of the watershed. Mainstem sites and many tributary sites have relatively high levels of TSS in this area. Sediment transport prediction and conventional tillage sediment contribution is generally lower in the central and eastern part of the watershed. While mainstem sites have lower TSS in the central area of the watershed, TSS is relatively high on the eastern end where correlation is weaker, suggesting that other factors may be strongly influencing results.

Out of mainstem Mississinewa sites, Porter Creek had the highest average TSS for high flow events followed by Jordan Creek and Hoppas Ditch (Fig. N.1 in Appendix N). There were a pronounced spikes from Pike Creek to Hoppas Ditch and from Jordan Creek to Porter Creek. It appears that an increase was expected at Hoppas Ditch due to its relatively higher sediment transport prediction. While the averages for Jordan and Porter were driven by excessively high rainfall that occurred in March, without this sampling event their averages still would have been relatively high.

Land application of manure from the high concentration of CFOs in this area, instream erosion due to channelization of the river, and a high number of septic systems within the town of Saratoga (located adjacent to Miller Creek within Porter Creek) are all factors that may be contributing to observed TSS values for these two sites.

Hoppas Ditch had the highest average TSS for low flow events, followed by Rees Ditch, Lake Branch, and Porter, respectively (Table N.1 in Appendix N). Rees Ditch and Lake Branch both have some of the highest numbers of septics of all subwatersheds; this could be contributing to high TSS levels during low flow.

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9 United States Geologic Survey (USGS). The USGS Water Science School. Turbidity. Last modified July 2015. http://water.usgs.gov/edu/turbidity.html

10 (Waters, T.F.,, 1995). Sediment in streams: sources, biological effects and control. American Fisheries Society, Bethesda, MD. 251 p.

Out of subwatershed sites Lugar Creek had the highest average TSS for high flow events, followed very closely by Little Mississinewa River (Fig. N.2 in Appendix N). Walnut Creek had the third highest levels. According to anecdotal evidence, both Lugar and Walnut Creek have significant bank erosion in some areas, which is increasing TSS levels. Additionally, failing septics are known to be a problem just upstream of Lugar Creek's sampling site. While Little Mississinewa River has low rates of conventional tillage, it has a relatively high sediment transport prediction as well as a relatively high population density, a high number of Regulated Point Sources, and a high number of CFOs--all possible contributors to TSS. However, further investigation is needed, as such high rates may be from streambank erosion.

Lugar Creek again had the highest average for low flow events followed by Little Mississinewa and then Little Walnut Creek (Fig. N.1 in Appendix N). Little Walnut Creek has a high sediment transport prediction as well as a relatively high number of conventionally tilled acres. Land use in Walnut Creek is more similar to that in the eastern part of the watershed. It has a low population density, a high percentage of cropland and some CFOs.

TABLE 8.9 | TSS averages for tributary subwatershed and mainstem subwatershed sites

TSS	X Times Target	% Reduction	Mg/L
Mississinewa River Mainstem Subwatershed high flow average	6.97	86%	151.23
Mississinewa River Mainstem Subwatershed low flow average	NA	NA	15.94
Tributary Subwatershed high flow average	2.5	60%	57.12
Tributary Subwatershed low flow average	NA	NA	8.52

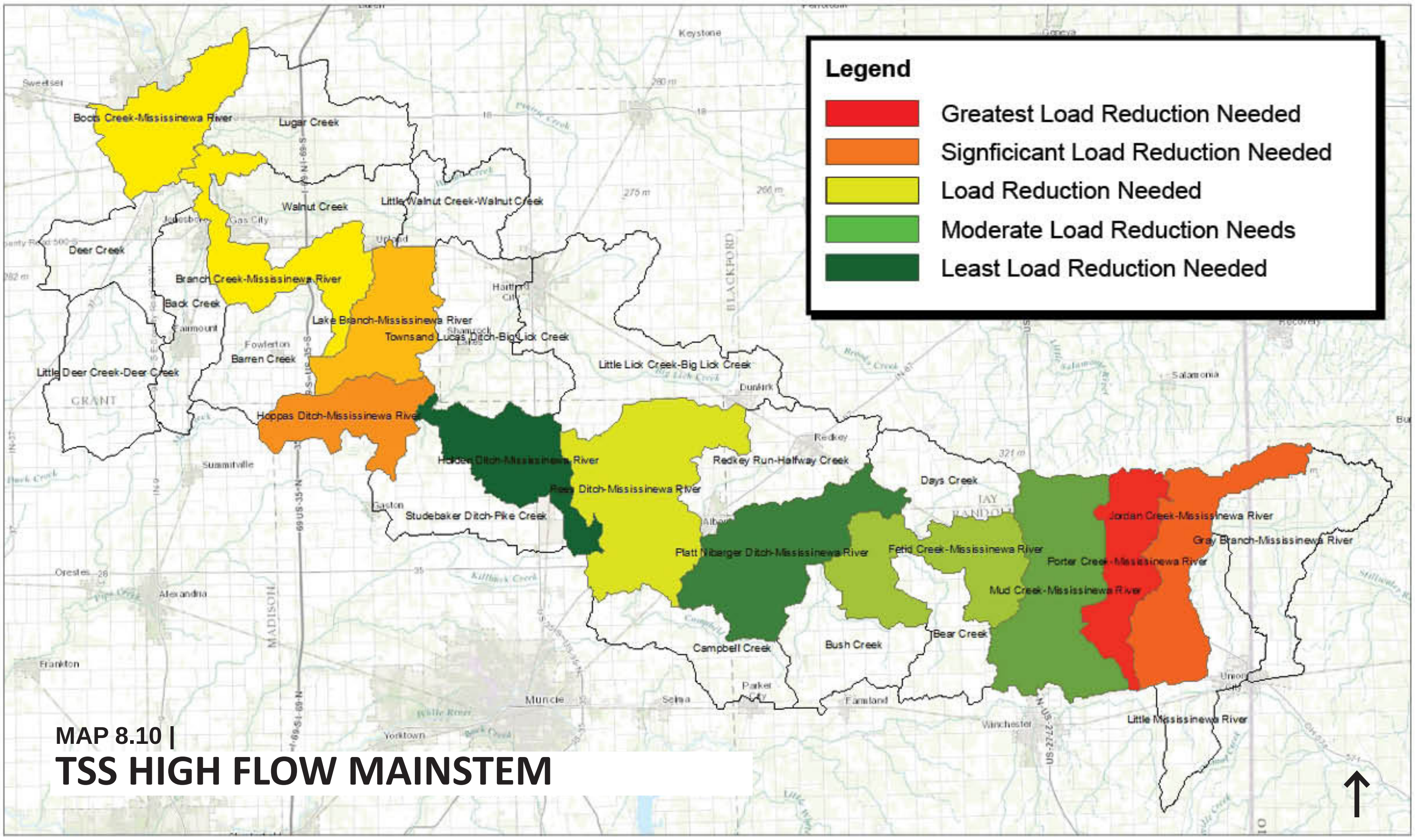
See similar analysis of all subwatershed on subsequent pages.
X Times Target = how many times mean load exceeds target load
% Reduction = Percent reduction needed to reach water quality targets

TABLE 8.10 | Sediment load reduction needed at tributary subwatershed sites									
		Average Flow		TSS at High Flow			TSS at Low Flow		
	Drainage (sq. mi.)	@ High Flow (cfs)	@ Low Flow (cfs)	Xtimes*	%Change**	TR***	Xtimes*	%Change**	TR***
Subwatershed	28.69	148.61	25.86	3.32	0.70	7751.08	0.47	-1.13	-290.25
Back Creek	16.00	98.61	39.22	2.31	0.57	3174.39	0.32	-2.17	-660.31
Barren Creek	21.00	89.21	15.99	1.62	0.38	1355.37	0.22	-3.61	-307.93
Big Lick Creek	76.00	65.94	20.05	1.22	0.18	345.13	0.32	-2.12	-335.09
Bush Creek	20.00	20.11	2.90	1.23	0.19	121.97	0.35	-1.89	-46.55
Campbell Creek	20.00	35.43	4.03	2.00	0.50	782.28	0.66	-0.52	-33.85
Deer Creek	45.00	325.05	40.15	2.05	0.51	8354.12	0.24	-3.24	-754.70
Halfway Creek	25.00	62.06	9.93	1.86	0.46	1504.44	0.62	-0.62	-93.42
Little Deer Creek	26.00	281.93	40.36	2.04	0.51	7197.50	0.26	-2.80	-731.10
Little Mississinewa River	21.00	118.46	12.35	11.64	0.91	31000.81	0.39	-1.60	-186.74
Little Walnut Creek	17.00	145.85	8.46	2.57	0.61	5620.65	0.60	-0.66	-82.38
Lugar Creek	30.00	204.29	31.35	5.59	0.82	23065.00	1.20	0.17	153.74
Pike Creek	21.00	39.35	7.63	0.62	-0.61	-352.07	0.12	-7.59	-165.79
Upper Big Lick Creek	52.00	57.26	11.63	0.58	-0.73	-516.39	0.34	-1.97	-189.57
Walnut Creek	39.00	340.16	48.64	4.59	0.78	30055.74	0.63	-0.59	-443.78

Current loads and target loads are included in Appendix N.
*X = X Times Target, how many times mean load exceeds target load
**%Change = Percent change in current load needed to reach water quality targets. Red represents highest % change needed; green the lowest.
***TR = Tons/yr. reduction need to meet water quality targets

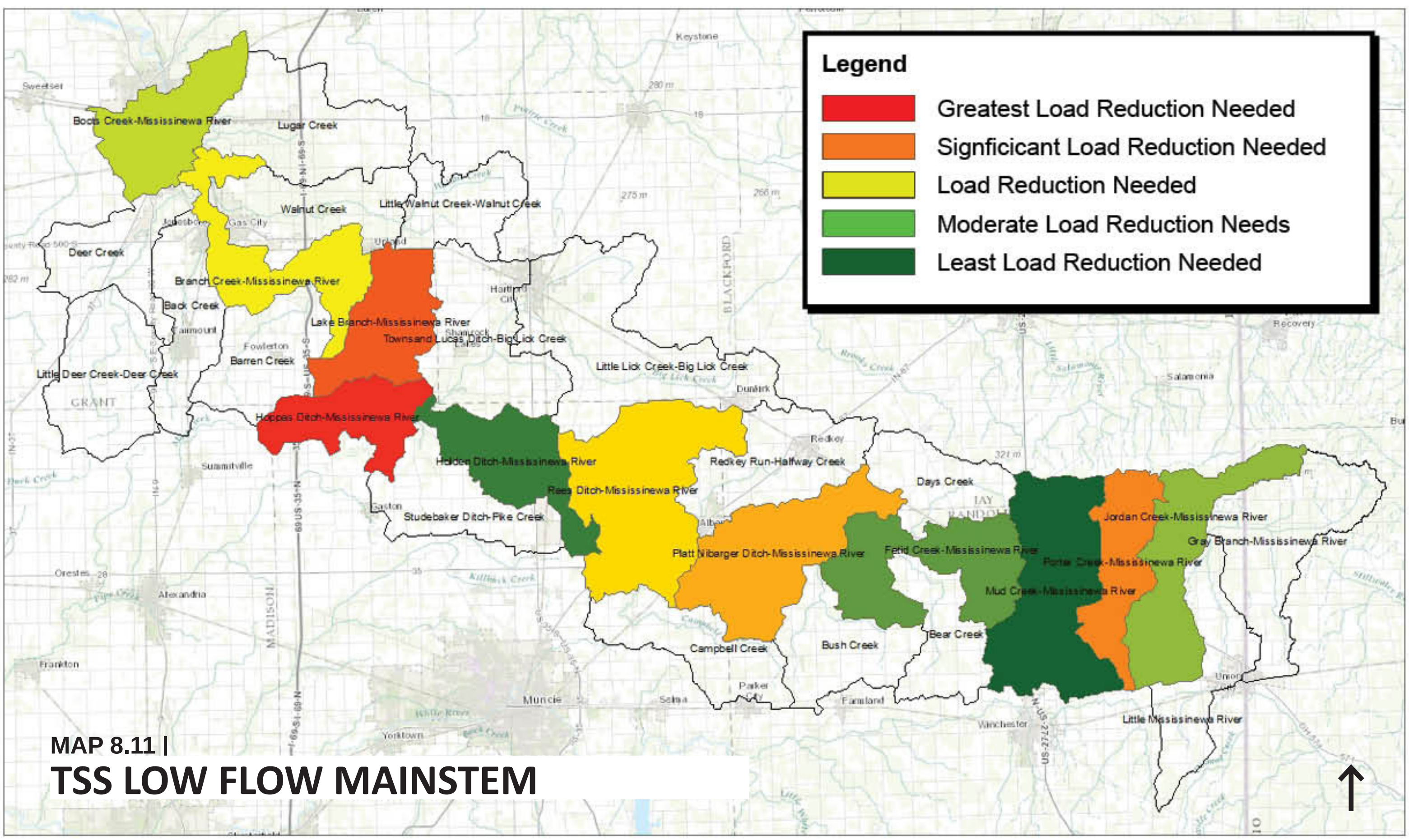
TABLE 8.11 | Sediment load reduction needed at mainstem sites									
		Average Flow		TSS at High Flow			TSS at Low Flow		
	Drainage (sq. mi.)	@ High Flow (cfs)	@ Low Flow (cfs)	Xtimes*	%Change**	Difference***	Xtimes*	%Change**	Difference***
Mainstem	401.80	1585.23	214.29	6.45	0.84		1.03	0.03	
Boots Creek	681.00	2398.25	317.44	5.66	0.82	0.00	0.68	-0.48	0.09
Branch Creek	629.00	2923.33	354.67	5.58	0.82	0.00	0.72	-0.39	0.34
Lake Branch	486.00	2750.00	352.00	5.72	0.83	0.03	0.96	-0.05	0.61
Hoppas Ditch	472.00	2740.00	355.67	7.01	0.86	-0.33	2.32	0.57	-4.66
Holden Ditch	424.00	640.72	97.06	2.11	0.53	0.16	0.20	-4.09	3.87
Rees Ditch	311.00	591.17	121.56	3.20	0.69	-0.15	0.82	-0.22	0.06
Platt Nibarger Ditch	240.00	228.80	37.32	2.16	0.54	0.13	0.86	-0.16	-2.99
Fetid Creek	179.00	337.92	33.39	2.99	0.67	-0.12	0.24	-3.15	-45.85
Mud Creek	133.00	264.73	24.21	2.20	0.55	0.41	0.02	-49.00	48.85
Porter Creek	89.00	750.67	72.37	20.98	0.95	-0.07	0.87	-0.15	-0.54
Jordan Creek	79.00	1146.50	57.24	8.86	0.89	0.03	0.59	-0.69	0.09
Gray Branch	31.00	91.84	12.40	12.55	0.92		0.62	-0.61	

Current loads and target loads are included in Appendix N.
*X = X Times Target, how many times mean load exceeds target load
**% Change = Percent change in current load needed to reach target load
***Difference = The difference between the percent changes needed at consecutive sites. Negative numbers indicate that the percent change needed has increased between the consecutive sites. Positive numbers indicate that the percent change needed has decreased between the consecutive sites. These values can be interpreted as an improvement or a decline in water quality between two sites. Red represents an increase in percent change needed; green a decrease.



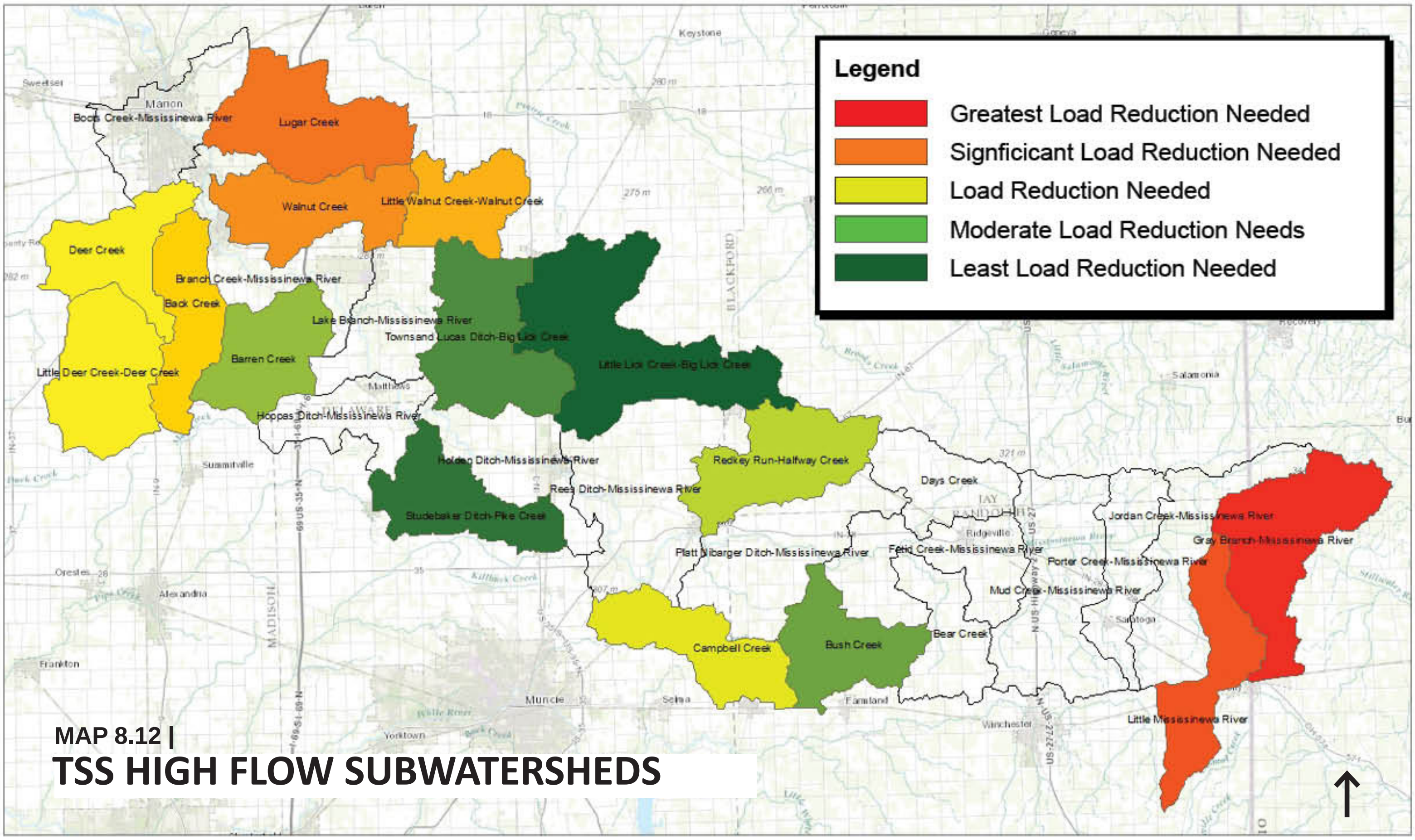
MAP 8.10 |

TSS HIGH FLOW MAINSTEM



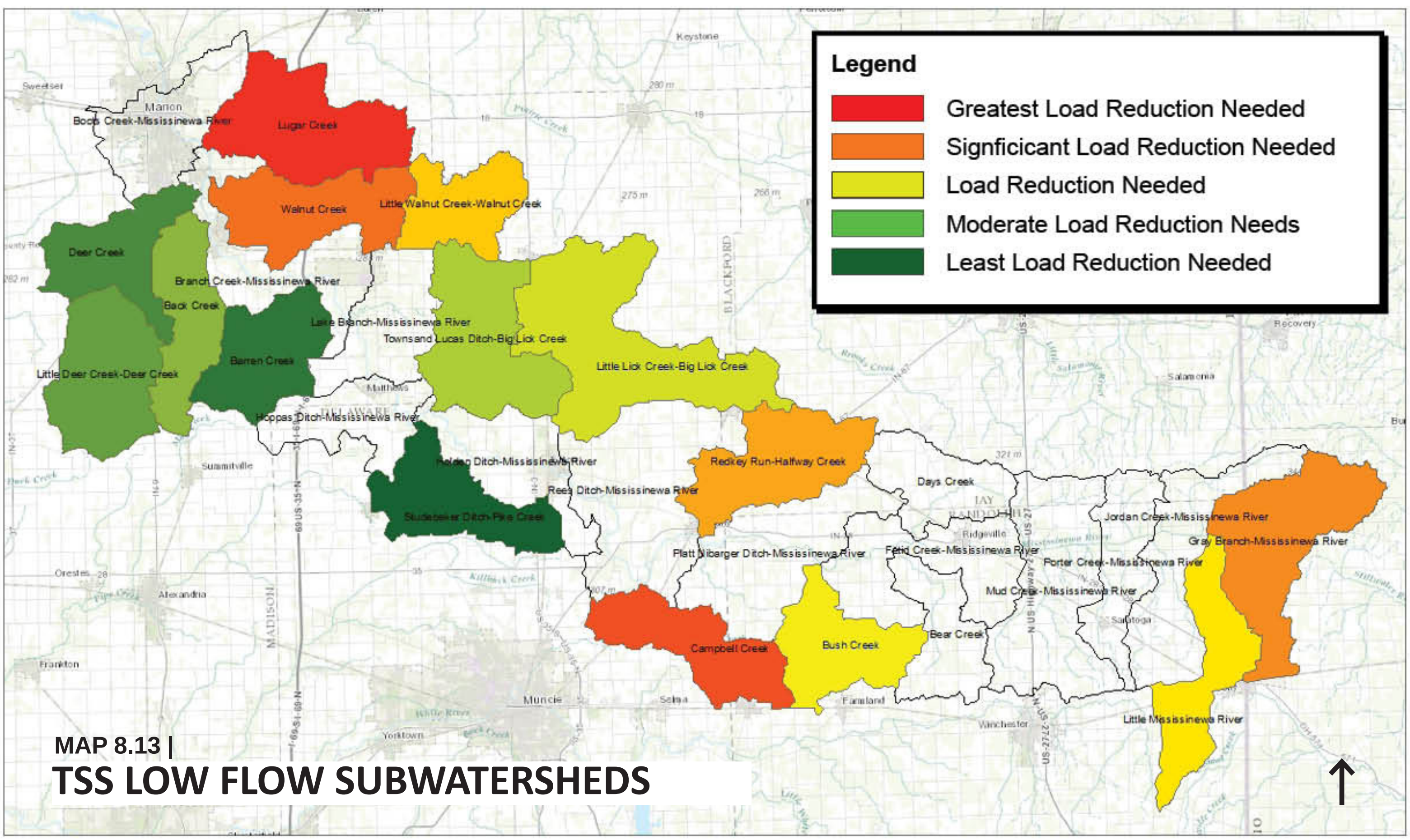
MAP 8.11 |

TSS LOW FLOW MAINSTEM



MAP 8.12 |

TSS HIGH FLOW SUBWATERSHEDS



MAP 8.13 |

TSS LOW FLOW SUBWATERSHEDS

8.5 BACTERIOLOGICAL

ESCHERICHIA COLI (E. COLI)

E. coli is a type of bacteria normally found in the intestines of people and animals. Although most strains of E. coli are harmless, some can cause illness or even death. Furthermore, human wastes contain other pathogens that can cause illness or death. It is not feasible or necessary to test for all of these pathogens. If E. coli is present in higher than normal levels, it can be inferred that other pathogens are likely present in higher than normal levels as well. Testing for E. coli is a simple, inexpensive process, making it an ideal parameter to test for. Although studies have found E. coli present in the gut of fish, there is no evidence to suggest that it is harmful to fish or other aquatic life. Controlling E. coli levels entering surface and ground waters is therefore done in the interest of human health and safety.

Sources of E. coli contribution to waterways include human wastes (from CSOs, SSOs, failing and/or improperly designed septic systems) and animal wastes (runoff from livestock manure and manure from other animals) within the landscape. Although most strategies for limiting E. coli contamination are outside of the scope of this study, findings will be passed on to municipalities.

Methods

Fifteen sites in the watershed were sampled for bacteria monthly from April 2014 to March 2015 by the Muncie Bureau of Water Quality using EPA method 1603. Thirteen sites were sampled as part of by IDEM's TMDL program five times over a span of 30 days (from April to May) in order to calculate a geometric mean.

The IAC (327 IAC 2-1-6) sets the E. coli standard for full body contact recreation uses at 235 cfu/100mL for any one sampling time and a geometric mean of 125 CFU/100mL from 5 equally-spaced samples over 30 days. The objective of this sampling was to get a picture of subwatershed E. coli by measuring levels at both high and low flow events. The Projects Manager felt that sampling monthly over a whole year would give results that are more representative of actual conditions than sampling over a one month period, which may be more influenced by seasonal variations in precipitation. Sampling conditions over a one month period may be characterized more by one particular flow regime rather than all of them, thus skewing results. Therefore, the standard for this project was set at 235 cfu/100mL. Stream flow rate and depth were also measured to characterize flow at the time of sampling as either low flow or high flow.

Results and discussion

Results of E. coli sampling can be found in Appendix O. E. coli levels were higher during high flow events than during low flow events (Fig. O.1 and O.2 in Appendix O). This is due to increased to increased waste transport during rainfall events. In general, tributary TSS averages exceeded those of the mainstem (Table 8.12). This is in contrast to all other parameters, for which mainstem averages exceeded tributary averages. E. coli averages for high flow events exceeded the standard for all mainstem and tributary sites. During low flow, all sites except Fetid Creek and Platt Nibarger (both main stem sites) exceeded standards.

While it appears that multiple factors drive E. coli levels, a few trends can be extracted from the data. In general, high flow averages for mainstem sites in the eastern part of the watershed were slightly higher than those for sites in the western part of the watershed (Fig. O.1 in Appendix O). This correlates with the higher predicted levels of manure application to land due to high CFO concentrations in this part of the watershed. It is likely that there is less land application of manure/sludge in the western part of the watershed. In contrast, E. coli levels during low flow on the mainstem were generally lower in the eastern part of the watershed than in the western part. High E. coli levels at low flow in the western part of the watershed are likely due to higher concentrations of septic systems, which are known to pollute streams during low flow.[11] At the subwatershed level, CSOs were one of the major factors causing high E. coli levels. While there are only 8 CSOs emptying into mainstem subwatersheds, there are 35 emptying into tributary subwatersheds (normal precipitation related discharges).

Of the Mississinewa mainstem sites, Lake Branch had the highest average E. coli levels at high flow, followed by Platt Nibarger Ditch and Gray Branch (Fig. O.1 in Appendix O). Lake Branch, a mainstem site, does not contain CSOs or CFOs and has a relatively moderate number of septics. Lake Branch is near a high concentration of CFO's that is located to the east of Upland in the Big Lick Creek and Little Walnut Creek subwatersheds. One livestock access point was found within Lake Branch. Sources of high E. coli at Platt Nibarger Ditch and Gray Branch are likely manure runoff from land application.

At low flow, Rees Ditch had the highest average level followed by Hoppas Ditch and Jordan Creek (Fig. O.1 in Appendix O). Because Rees Ditch had higher average levels at low flow than at high flow, it suggests that rainfall is not a driving levels and that something is happening instream. Rees Ditch has a high number of septics and a very low number of CFOs. Failing septics or cattle with direct access to the stream could be contributors. High levels at Hoppas Ditch may be due to livestock accessing streams. Three livestock access points, relatively close to the sampling site, were identified within Hoppas Creek.

11 Rose, Joan B. Septic tanks aren't keeping human sewage out of rivers and lakes. August 3, 2015. http://www.rose.canr.msu.edu/press-releases/2015/8/3/septic-tanks-arent-keeping-human-sewage-out-of-rivers-and-lakes

Of the subwatershed sites, Barren Creek had the highest average E. coli level at high flow, followed by Big Lick Creek, Lugar Creek, and Upper Big Lick Creek, respectively (Fig. O.2 in Appendix O). Livestock may be the cause of high levels in Barren Creek. In a desktop survey, three points where livestock were accessing streams were identified fairly close to the sampling site. Human waste is likely responsible for high levels at the other sites. Lugar Creek's sampling site is just downstream from a mobile home park that uses septic systems. Toilet paper was found in the Creek during sampling on one occasion. Both Upper Big Lick and Big Lick creeks have a high number of CSOs (from Hartford City) that empty into them. Hartford City has the second highest number of CSOs in the watershed (Back Creek has the highest). It is important to note that Upper Big Lick and Big Lick creeks would likely have had the highest levels at high flow were it not for incomplete flow data. The two sites had the highest overall averages (regardless of flow) of all subwatershed sites.

At low flow, Lugar Creek had the highest average E. coli level, followed by Upper Big Lick Creek, Little Walnut Creek, and Barren Creek (Table O.2 in Appendix O). High levels of E. coli during low flow conditions at Little Walnut Creek were unexpected due to its low number of septics and other factors.

TABLE 8.12 | *E. coli* averages for subwatershed and mainstem sites

E. coli	X Times Target	% Reduction	Cfu/100ML
Mississinewa River Mainstem Subwatershed high flow average	6.2	84%	1905.69
Mississinewa River Mainstem Subwatershed low flow average	3.75	73%	485.79
Tributary Subwatershed high flow average	9.06	89%	3081.94
Tributary Subwatershed low flow average	3.10	68%	743.05

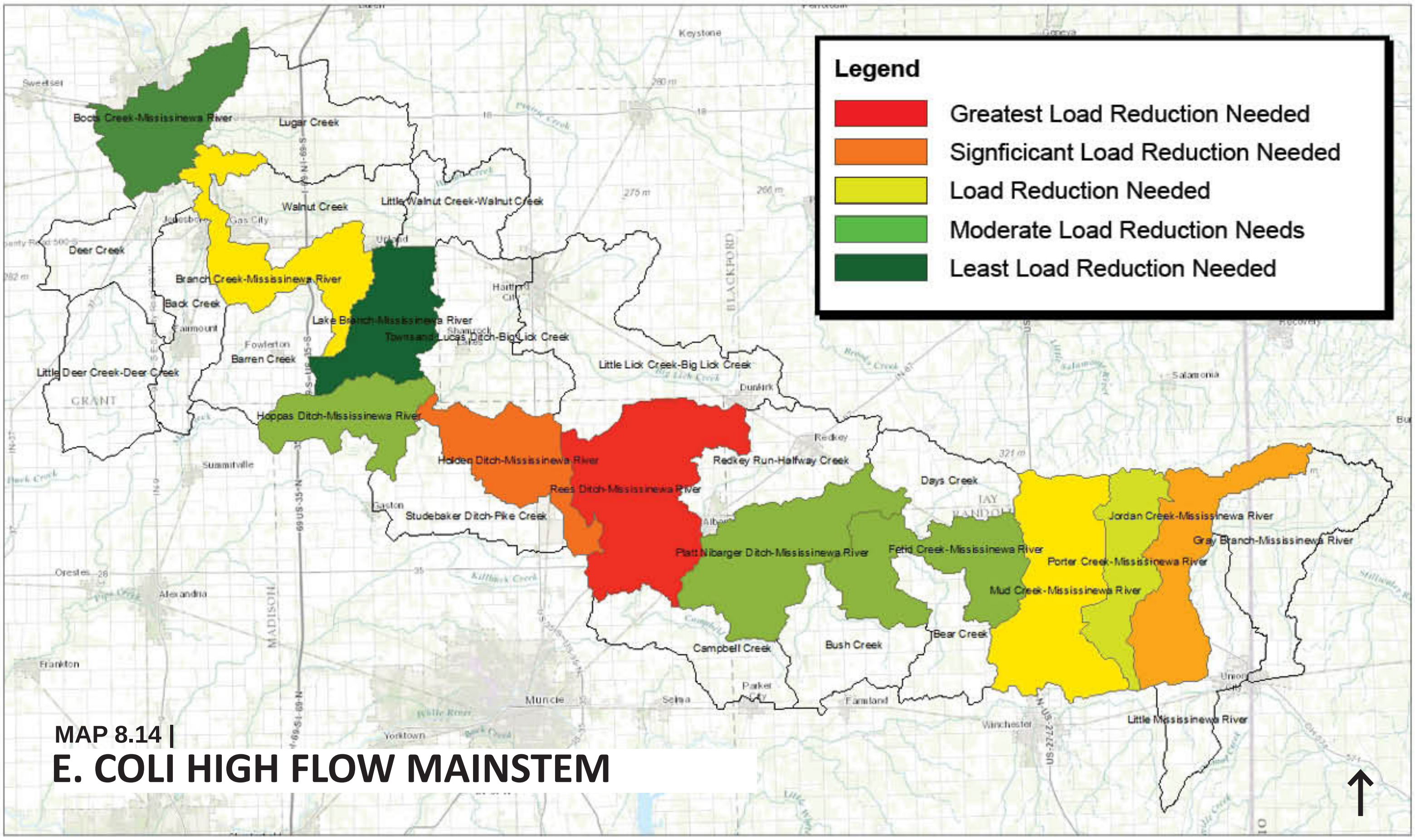
See similar analysis of all subwatershed on subsequent pages.
X Times Target = how many times mean load exceeds target load
% Reduction = Percent reduction needed to reach water quality targets

TABLE 8.13 | E. coli load reduction needed at tributary subwatershed sites									
		Average Flow		E. coli at High Flow			E. coli at Low Flow		
	Drainage (sq. mi.)	@ High Flow (cfs)	@ Low Flow (cfs)	Xtimes*	% Change**	TR***	Xtimes*	% Change**	TR***
Subwatershed	28.69	148.61	25.86	11.20	0.91	3.13E+15	3.75	0.73	1.31E+14
Back Creek	16.00	98.61	39.22	14.94	0.93	2.88E+15	2.69	0.63	1.39E+14
Barren Creek	21.00	89.21	15.99	28.84	0.97	5.21E+15	3.92	0.74	9.79E+13
Big Lick Creek	76.00	65.94	20.05	24.39	0.96	3.08E+15	5.96	0.83	1.52E+14
Bush Creek	20.00	20.11	2.90	4.69	0.79	1.63E+14	2.48	0.60	7.16E+12
Campbell Creek	20.00	35.43	4.03	6.75	0.85	4.36E+14	4.45	0.78	2.59E+13
Deer Creek	45.00	325.05	40.15	5.29	0.81	2.92E+15	1.17	0.14	1.41E+13
Halfway Creek	25.00	62.06	9.93	10.30	0.90	2.01E+15	3.19	0.69	4.65E+13
Little Deer Creek	26.00	281.93	40.36	10.16	0.90	5.42E+15	1.17	0.15	1.47E+13
Little Mississinewa River	21.00	118.46	12.35	6.58	0.85	1.39E+15	5.74	0.83	1.23E+14
Little Walnut Creek	17.00	145.85	8.46	6.03	0.83	1.54E+15	4.66	0.79	6.49E+13
Lugar Creek	30.00	204.29	31.35	13.52	0.93	5.36E+15	13.13	0.92	7.98E+14
Pike Creek	21.00	39.35	7.63	1.26	0.21	2.34E+13	2.21	0.55	1.72E+13
Upper Big Lick Creek	52.00	57.26	11.63	20.54	0.95	1.73E+15	4.92	0.80	8.62E+13
Walnut Creek	39.00	340.16	48.64	11.74	0.91	7.66E+15	2.22	0.55	1.24E+14

Current loads and target loads are included in Appendix O.
*X = X Times Target, how many times mean load exceeds target load
**%Change = Percent change in current load needed to reach water quality targets. Red represents highest % change needed; green the lowest.
***TR = Tons/yr. reduction need to meet water quality targets

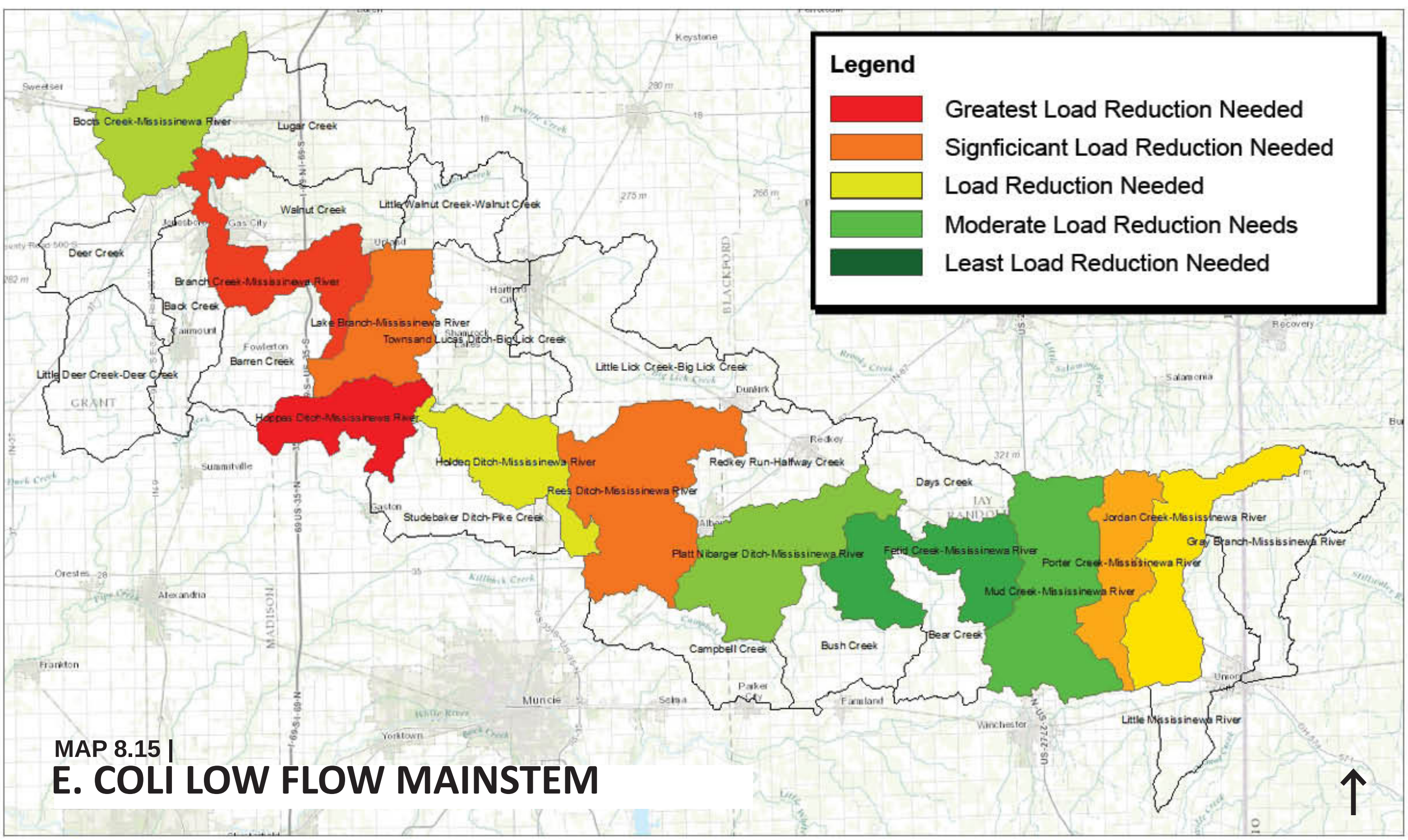
TABLE 8.14 | E. coli load reduction needed at mainstem sites									
		Average of CFS		E.Coli High			E. Coli Low		
	Drainage (sq. mi.)	@ High Flow (cfs)	@ Low Flow (cfs)	Xtimes*	%Change **	Downstream ***	Xtimes *	%Change **	Difference ***
Mainstem	401.80	1585.23	214.29	10.77	0.91		3.10	0.68	
Boots Creek	681.00	2398.25	317.44	11.81	0.92	-0.04	1.33	0.25	0.51
Branch Creek	629.00	2923.33	354.67	7.73	0.87	0.08	4.20	0.76	-0.02
Lake Branch	486.00	2750.00	352.00	18.86	0.95	-0.05	3.80	0.74	0.05
Hoppas Ditch	472.00	2740.00	355.67	9.72	0.90	-0.08	4.69	0.79	-0.36
Holden Ditch	424.00	640.72	97.06	5.33	0.81	-0.15	1.73	0.42	0.32
Rees Ditch	311.00	591.17	121.56	2.99	0.67	0.23	3.83	0.74	-0.78
Platt Nibarger Ditch	240.00	228.80	37.32	9.77	0.90	0.01	0.96	-0.04	-0.22
Fetid Creek	179.00	337.92	33.39	10.45	0.90	-0.03	0.79	-0.26	0.13
Mud Creek	133.00	264.73	24.21	7.68	0.87	0.01	0.88	-0.13	0.85
Porter Creek	89.00	750.67	72.37	8.19	0.88	-0.03	3.48	0.71	-0.05
Jordan Creek	79.00	1146.50	57.24	6.74	0.85	0.07	2.98	0.66	-0.29
Gray Branch	31.00	91.84	12.40	12.60	0.92		1.61	0.38	

Current loads and target loads are included in the Appendix O.
*X = X Times Target, how many times mean load exceeds target load
**% Change = Percent change in current load needed to reach target load
***Difference = The difference between the percent changes needed at consecutive sites. Negative numbers indicate that the percent change needed has increased between the consecutive sites. Positive numbers indicate that the percent change needed has decreased between the consecutive sites. These values can be interpreted as an improvement or a decline in water quality between two sites. Red represents an increase in percent change needed; green a decrease.



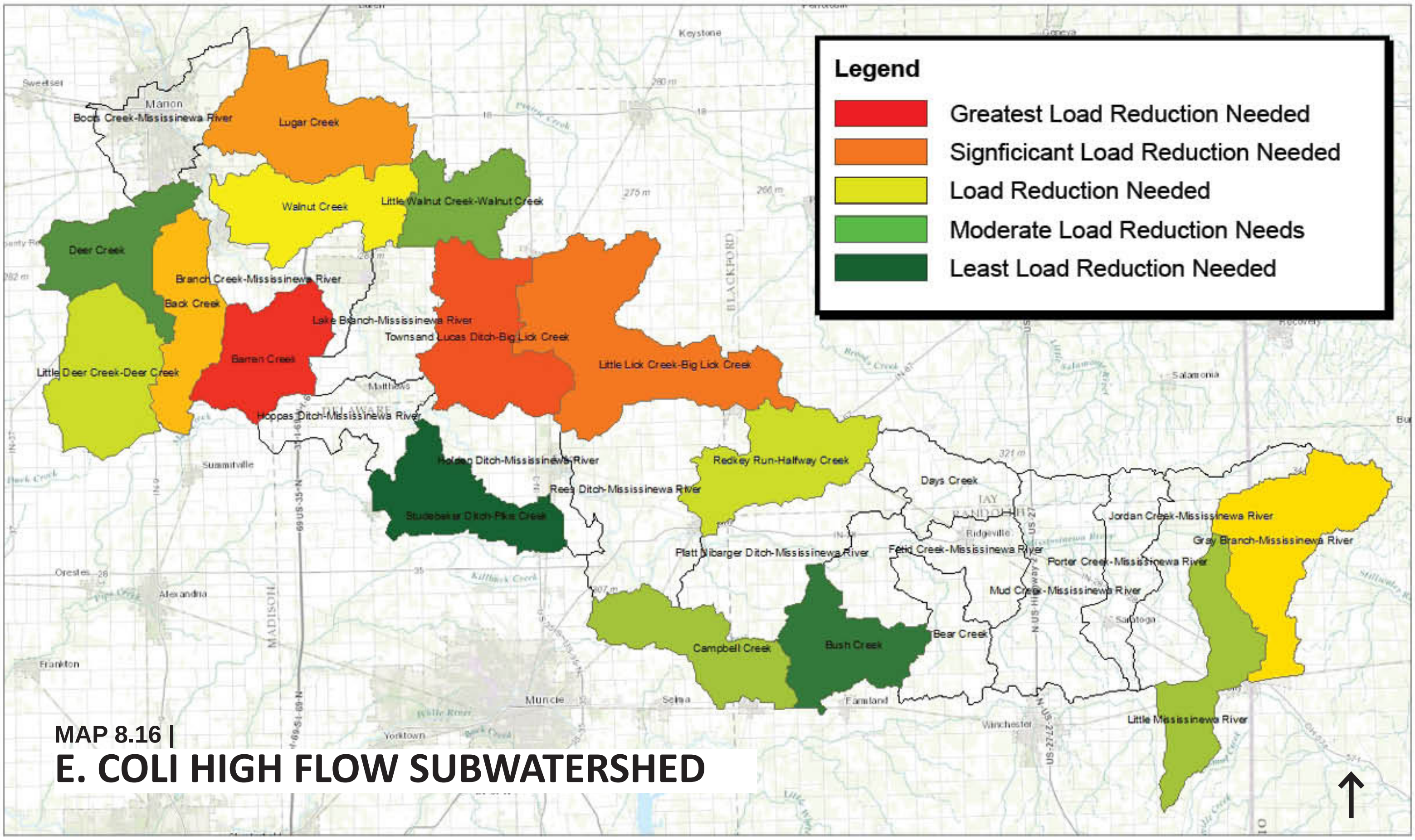
MAP 8.14 |

E. COLI HIGH FLOW MAINSTEM

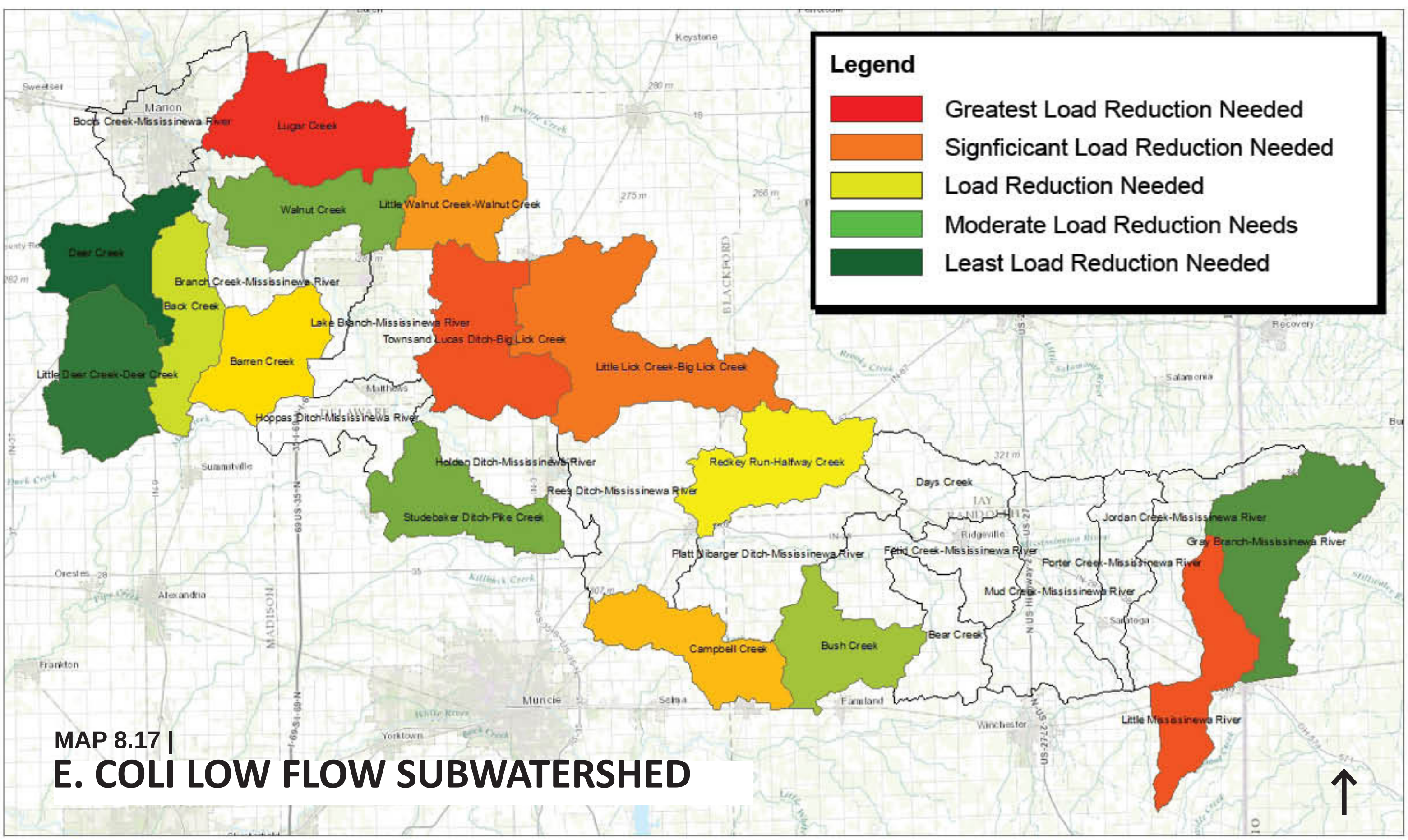


MAP 8.15 |

E. COLI LOW FLOW MAINSTEM



MAP 8.16 |
E. COLI HIGH FLOW SUBWATERSHED



MAP 8.17 |
E. COLI LOW FLOW SUBWATERSHED

8.6 DISSOLVED OXYGEN

Dissolved oxygen is essential for supporting aquatic life in streams. Without adequate levels of dissolved oxygen, fish and other aquatic organisms cannot survive. The Indiana Administrative Code 327 IAC 2-1-6 states that “dissolved oxygen concentrations...shall not be less than four (4.0) miligrams per liter at any time.” Very high levels of oxygen can also indicate a problem. Algae blooms release large amounts of dissolved oxygen into the water when the algae is actively blooming, resulting in abnormally high levels of dissolved oxygen being detected. However, during the night photosynthesis stops and the plants respire, causing the dissolved oxygen levels to dip below adequate levels. Furthermore, when the algae bloom dies and begins to be broken down by bacteria, the bacteria consume large amounts of dissolved oxygen, resulting in dissolved oxygen levels that are too low to support aquatic life. Water temperatures can also impact dissolved oxygen levels. The colder the water, the more dissolved oxygen it can hold, and the warmer the water, the less dissolved oxygen it can hold. Consequently, dissolved oxygen levels are usually higher in the winter and lower in the summer. Fish kills sometimes occur during hot summers in ponds that are being aerated properly.

Dissolved oxygen was measured for this project by the UMRW-P and also by IDEM (for the development of the TMDL for the Upper Mississinewa). Both groups used the sampling methodology set forth in the QAPP (available upon request). Concentrations below the minimum concentration for dissolved oxygen were measured at seven sampling sites: Fetid Creek (site T5), a tributary of Bush Creek (site T3), Little Lick Creek (site T40), Little Lick Creek (site T38), Townsand Lucas Ditch (site T34), a tributary of Campbell Creek (site T1), and Rees Ditch (site T21). Of these sites, Fetid Creek (site T5) had the lowest concentration (0.91mg/L), followed by LIttle Lick Creek (site T40; 2.21 mg/L). All of these concentrations occurred in July, August or September, with the exception of the concentration recorded at Fetid Creek (site T5). Ambient air temperatures and solar radiation are high during July, August, and September, which would cause an increase in water temperature. As water temperature increases, the amount of dissolved oxygen water can hold decreases. Average rainfall is usually lower during these months as well. Low levels of water flowing through the streams would be heated more quickly than deeper waters. Therefore, warm ambient temperatures, low flow, and solar radiation were likely a cause of low DO levels in these streams. Although low dissolved oxygen levels were measured at Fetid Creek near the end of October, comments on the field sheet recorded at the time of sampling indicate that the water at the site was stagnant and contained organic decay.

Figures 8.2 through 8.7 show dissolved oxygen concentrations measured at all TMDL and UMRWP sites. Tributary sites are organized by HUC 10 subwatershed, and mainstem sites are shown together, with the exception of mainstem sites within the Headwaters Mississinewa HUC 10. The mainstem sites within the Headwaters Mississinewa HUC 10 are grouped with the tributary sites for this HUC10.

Also contributing to low volumes of water is the location of the sampling sites. Four of the six sites were located very close to the streams’ origin. Therefore, the volume of water in the stream would have been much lower than at sample sites farther from the streams’ origins. The two streams that were longer had almost no trees on their banks. This was apparent when viewing the streams in Google Earth. Both of these streams were located in Blackford County.
The near absence of trees on the banks results in no shading of stream taking place, causing more solar radiation to reach the stream.

Dissolved oxygen exceedences are shown in Appendix P, Table P.1.

A maximum concentration of 12 mg/L of dissolved oxygen is the WQS (water quality standard) set by 327 Indiana Administrative Code 2-1-6. Dissolved oxygen concentrations above this level can indicate supersaturation of the water, which can cause gas bubble disease in aquatic organisms. High levels of photosynthesis is one cause of supersaturation, and is often the result of algae blooms, which indicate eutrophic conditions. Supersaturation can also be caused by increased pressure, such as behind a dam. However, the WQS maximum of 12 mg/L can be misleading in that it does not consider the effects of temperature on dissolved oxygen levels. At 0°C, saturated water can hold 14.6 mg/L of dissolved oxygen, an amount greater than allowed in the IAC Code. Because of the effect of temperature on dissolved oxygen, the two parameters should be analyzed together as the percent saturation, which is calculated by dividing the dissolved oxygen of a sample is by the maximum concentration of dissolved oxygen allowed at that temperature and multiplied by 100%.

Sites on Halfway Creek (T16, T14), Pike Creek (T30) and Bush Creek (T12) had the most samples exceeding the dissolved oxygen WQS of 12 mg/L. Only 2 of the 11 samples collected at site T14 had a % saturation below 100%; all other samples were supersaturated. Notes taken by the TMDL agent at site T14 read “excessive macrophytes” and “completely choked with algae” on 8/4/2014 and 8/18/2014, respectively. Since supersaturated conditions often occur as a result of eutrophication, one would expect to see dissolved oxygen levels fall below the WQS at some time due to plant die off and bacterial respiration during decomposition and/or normal fluctuation due to high plant respiration during night and high photosynthesis during the day. Although none of these sites had dissolved oxygen levels below the WQS of 4 mg/L, this may be due to sample collection taking place in the afternoon, when photosynthesis rates are high and would add oxygen to the water.

26% of samples collected had a % saturation above 100%. Months having the highest numbers samples exceeding 100% saturation were November (5 out of 7 samples exceeding 100%), May (32 out of 70 samples exceeding 100%), April (39 out of 105 samples exceeding 100%), and July (15 out of 52 samples exceeding 100%). Months in which no samples exceeded 100% were June (35 samples collected), January (9 samples collected), and March (10 samples collected). Based on the data, it does not appear that % saturation is influenced by seasonality.

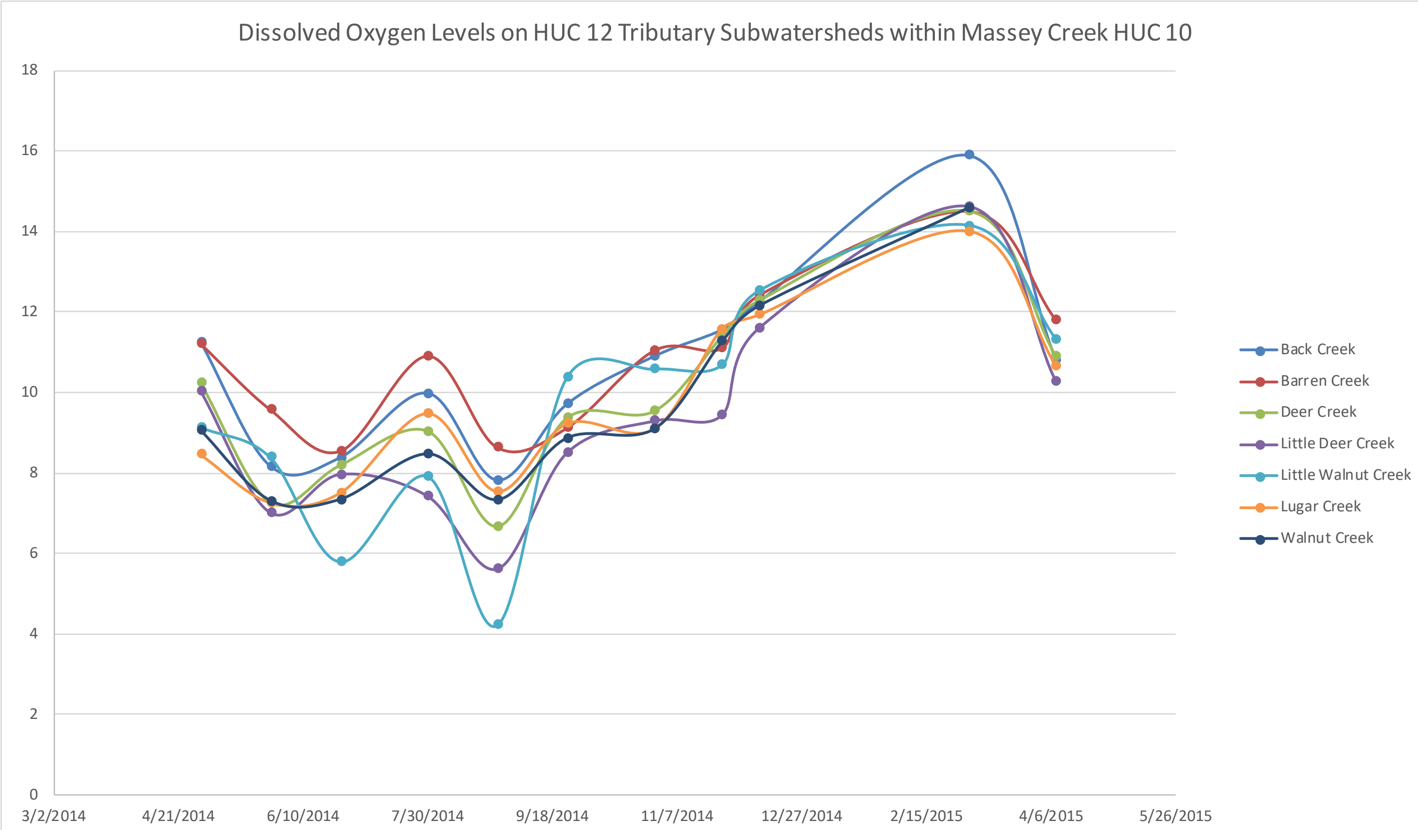


FIG. 8.2 | Dissolved Oxygen Levels on HUC 12 Tributary Subwatersheds within Massey Creek HUC10

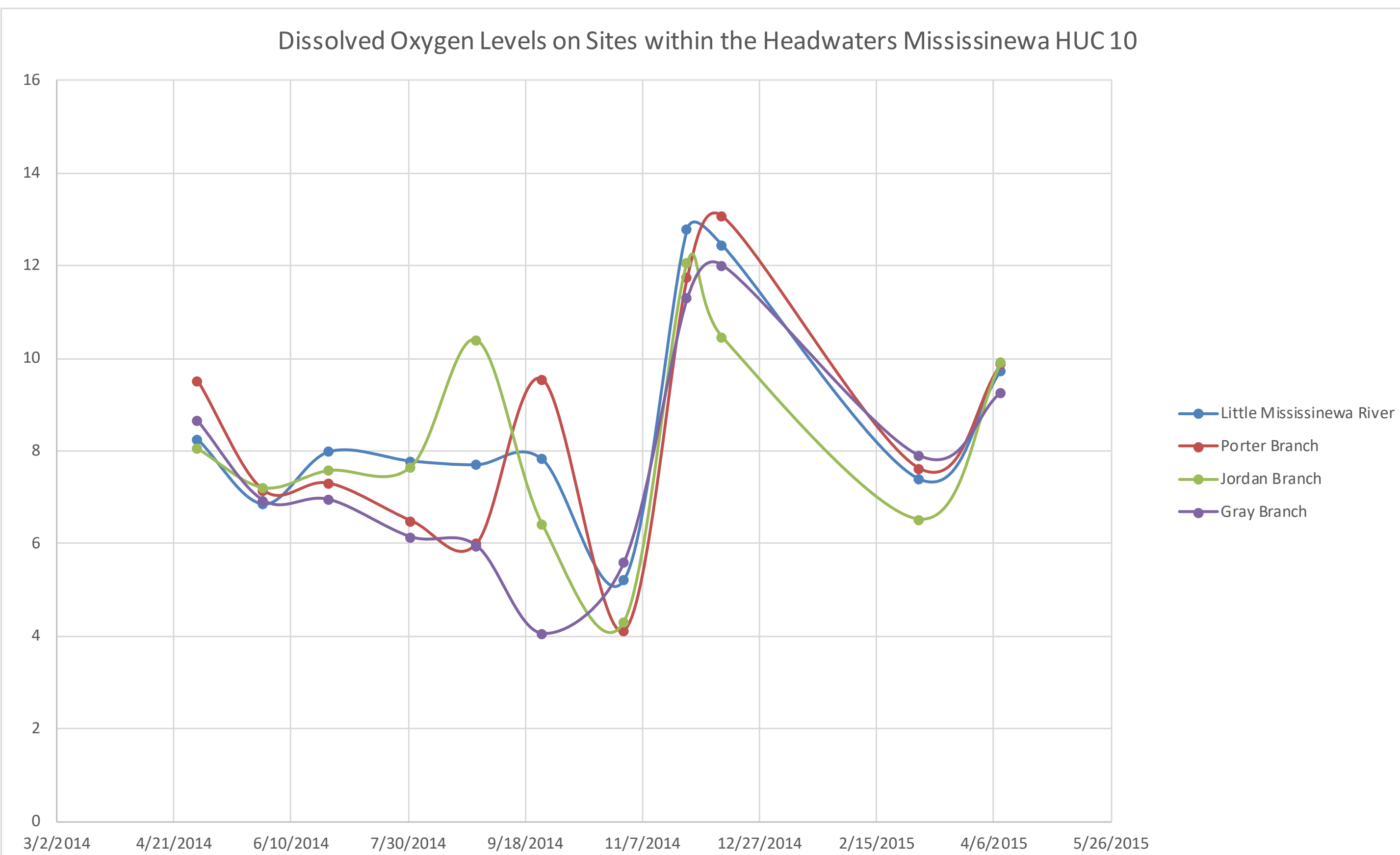


FIG. 8.3 | Dissolved Oxygen Levels on sites within the Headwaters Mississinewa HUC10

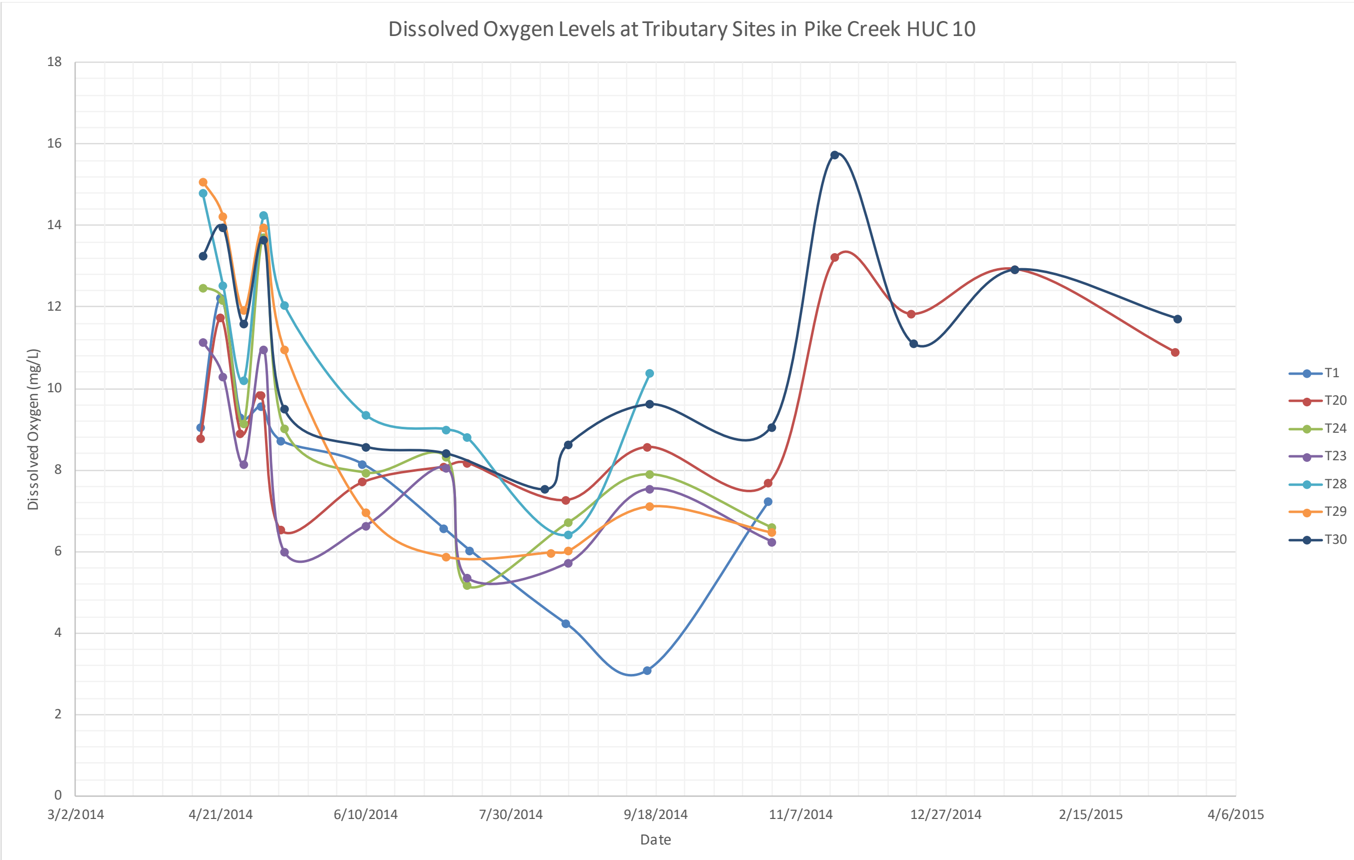


FIG. 8.4 | Dissolved Oxygen Levels at Tributary Sites in Pike Creek HUC10

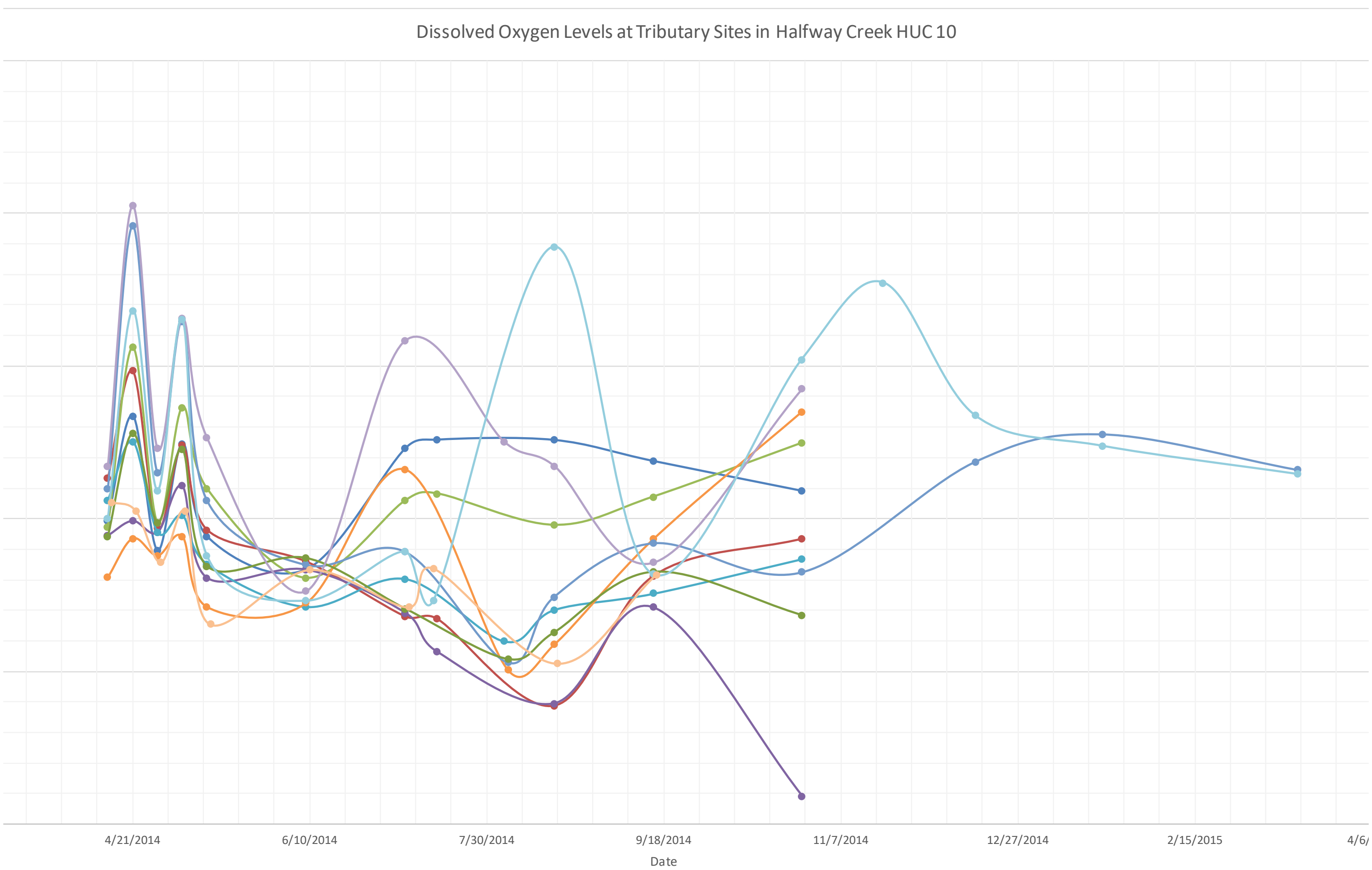


FIG. 8.5 | Dissolved Oxygen Levels at Tributary Sites in Halfway Creek HUC10

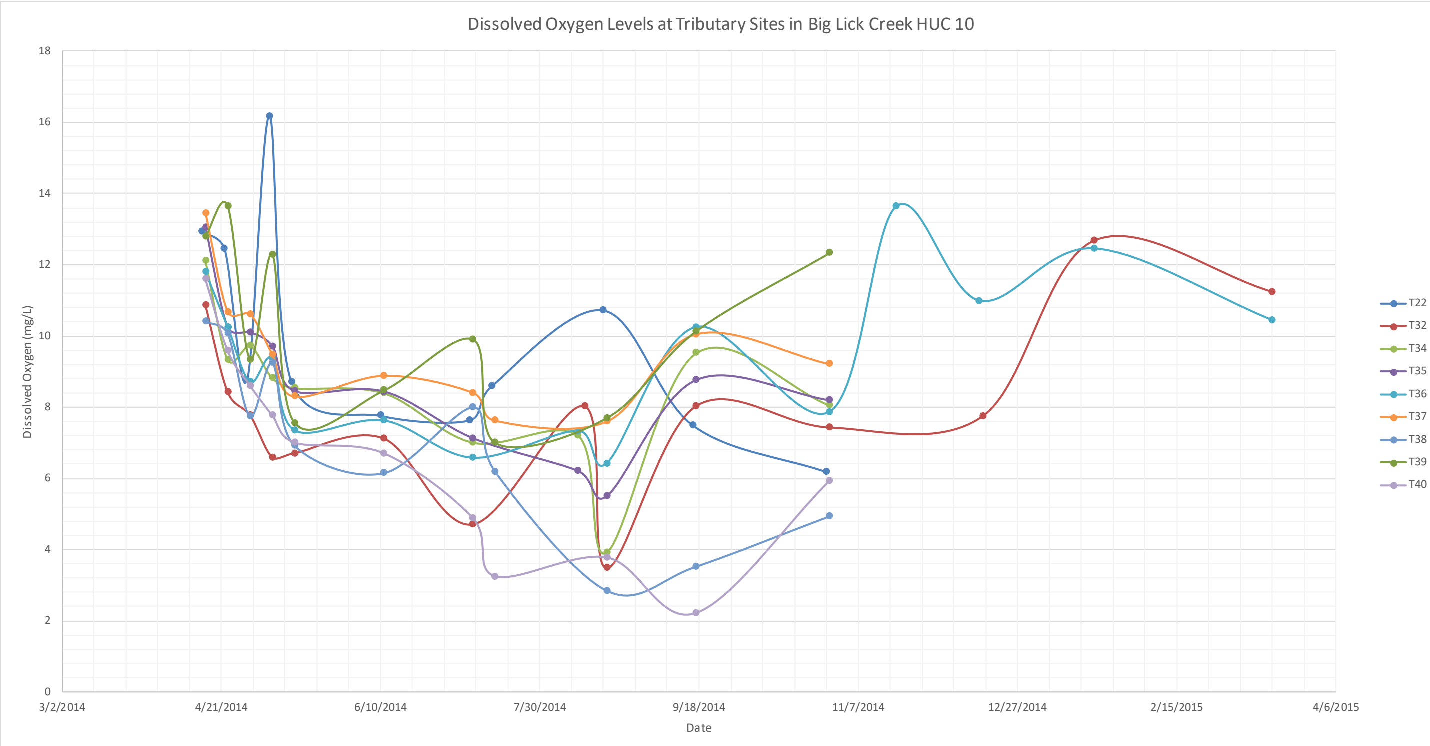


FIG. 8.6 | Dissolved Oxygen Levels at Tributary Sites in Big Lick Creek HUC10

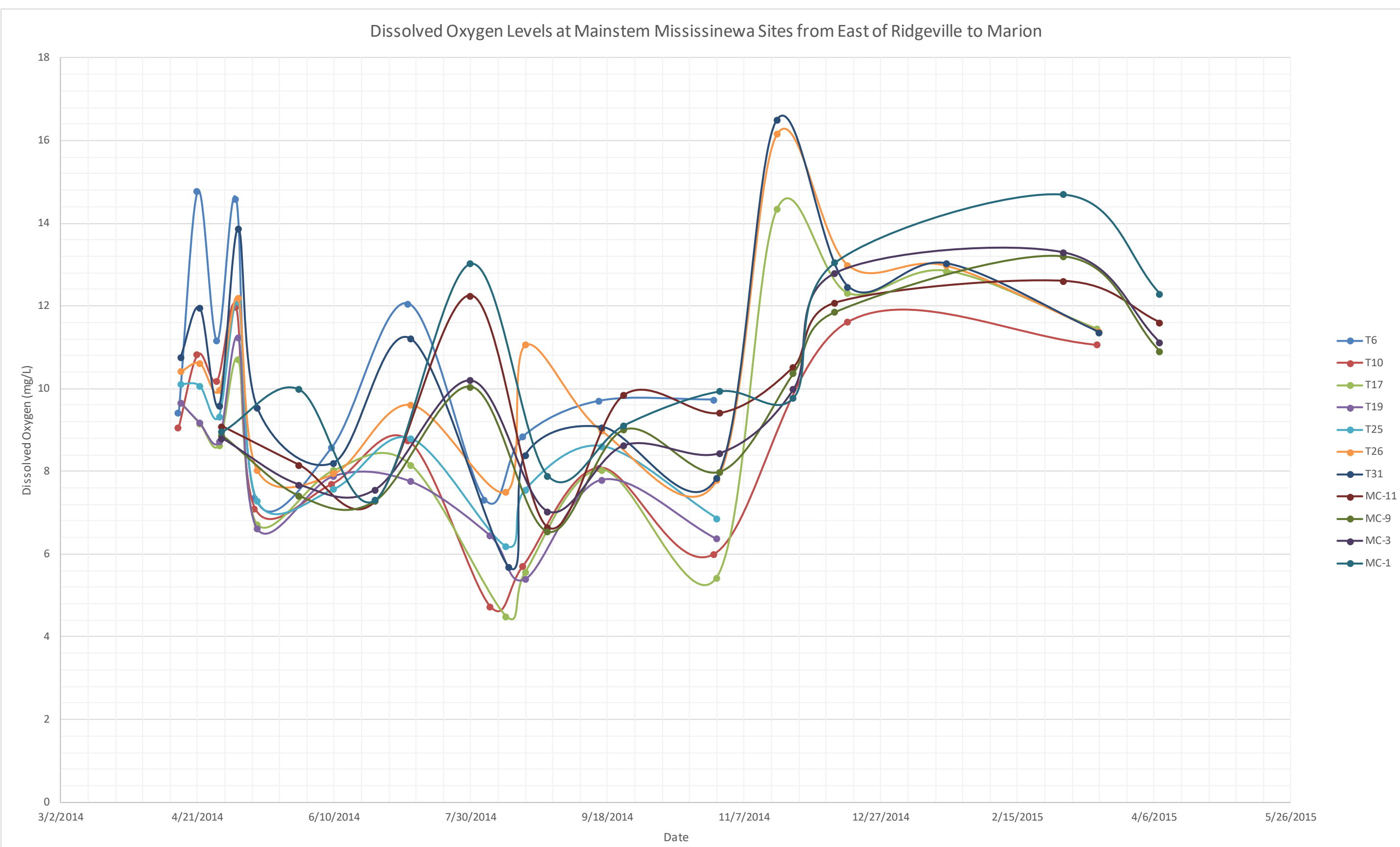


FIG. 8.7 | Dissolved Oxygen Levels at Mainstem Mississinewa Sites from East of Ridgeville to Marion

8.7 Temperature

As discussed above in Section 8.6, water temperature is important because it influences the concentration of dissolved oxygen in a stream. High water temperatures decrease dissolved oxygen concentrations, while low temperatures allow dissolved oxygen concentrations to increase. Many factors influence the temperature of surface waters, including depth, suspended sediments, shading by vegetation on streambanks and within streams, and season. Shallow water allows light to penetrate to the streambed, allowing the substrate to absorb and retain heat. Suspended sediments also absorb and retain heat. Branches of trees growing on the tops of streambanks can reach over the water, shading it from the hot sun. Streambanks with only grasses present do not provide any shading of the water. Warm air temperatures in the summer and higher intensity solar radiation cause water temperatures to increase. Water quality standards (WQS) for maximum temperature set by the 327 Indiana Administrative Code 2-1-7 are shown in Table 8.15 below.

TABLE 8.15 | 327 IAC 2-1-7 Surface water quality standards: maximum temperature

Month	Indiana Streams °F (°C)
January	50 (10.0)
February	50 (10.0)
March	60 (15.6)
April	70 (21.1)
May	80 (26.7)
June	90 (32.2)
July	90 (32.2)
August	90 (32.2)
September	90 (32.2)
October	78 (25.5)
November	70 (21.1)
December	57 (14.0)

Figures 8.8 through 8.13 show temperatures measured at all TMDL and UMRWP sites. Tributary sites are organized by HUC 10 subwatershed, and mainstem sites are shown together, with the exception of mainstem sites within the Headwaters Mississinewa HUC 10. The mainstem sites within the Headwaters Mississinewa HUC 10 are grouped with the tributary sites for this HUC10. None of the samples collected for the TMDL and by the UMRWP exceeded the WQS. All sample temperatures were below the maximum limit.

8.8 pH

pH is a measure of the alkalinity or acidity of a solution. pH is represented on a scale of 0 to 14, with numbers less than 7 being acidic and numbers greater than 7 being basic. What is really being measured in the solution are the negatively charged hydroxide ions and the positively charged hydrogen ions. It is the concentration of these ions and their interaction with other molecules in the water that is important to aquatic life. "The pH of water determines the solubility (amount that can be dissolved in the water) and biological availability (amount that can be utilized by aquatic life) of chemical constituents such as nutrients (phosphorus, nitrogen, and carbon) and heavy metals (lead, copper, cadmium, etc.). For example, in addition to affecting how much and what form of phosphorus is most abundant in the water, pH also determines whether aquatic life can use it. In the case of heavy metals, the degree to which they are soluble determines their toxicity."[1] There are many factors that influence pH. Carbon dioxide, sulfur dioxide and nitrogen oxides in the atmosphere lower the pH of precipitation. pH of precipitation is not the same throughout the United States. In general, pH of precipitation is lower in the eastern United States than in the western United States. pH of precipitation measured in Indiana in 2002 ranged from 4.6 to 4.8.[2] Temperatures can affect surface waters, with higher temperatures resulting in slighly lower pH values.[3] Algae growth can also affect pH. Algae blooms consume carbon dioxide—the loss of which can raise the pH of the water as high as 9.[4]

The Indiana Administrative Code 327 IAC 2-1-6 states pH should be greater than 6 and less than 9. pH measured by the UMRWP and IDEM's TMDL ranged from 6.51 to 8.8. These values fall within the acceptable range for pH. Figures 8.14 through 8.19 show the pH measured at all TMDL and UMRWP sites. Tributary sites are organized by HUC 10 subwatershed, and mainstem sites are shown together, with the exception of mainstem sites within the Headwaters Mississinewa HUC 10. The mainstem sites within the Headwaters Mississinewa HUC 10 are grouped with the tributary sites for this HUC10. All samples collected for the TMDL and by the UMRWP were within the acceptable range for pH.

1 United States Geological Survey. pH--Water properties. https://water.usgs.gov/edu/ph.html
2 United States Geological Survey. pH--Water properties. https://water.usgs.gov/edu/ph.html
3 Indiana Department of Environmental Management. 2015. Volunteer Stream Monitoring Training Manual.
4 Indiana Department of Environmental Management. 2015. Volunteer Stream Monitoring Training Manual.

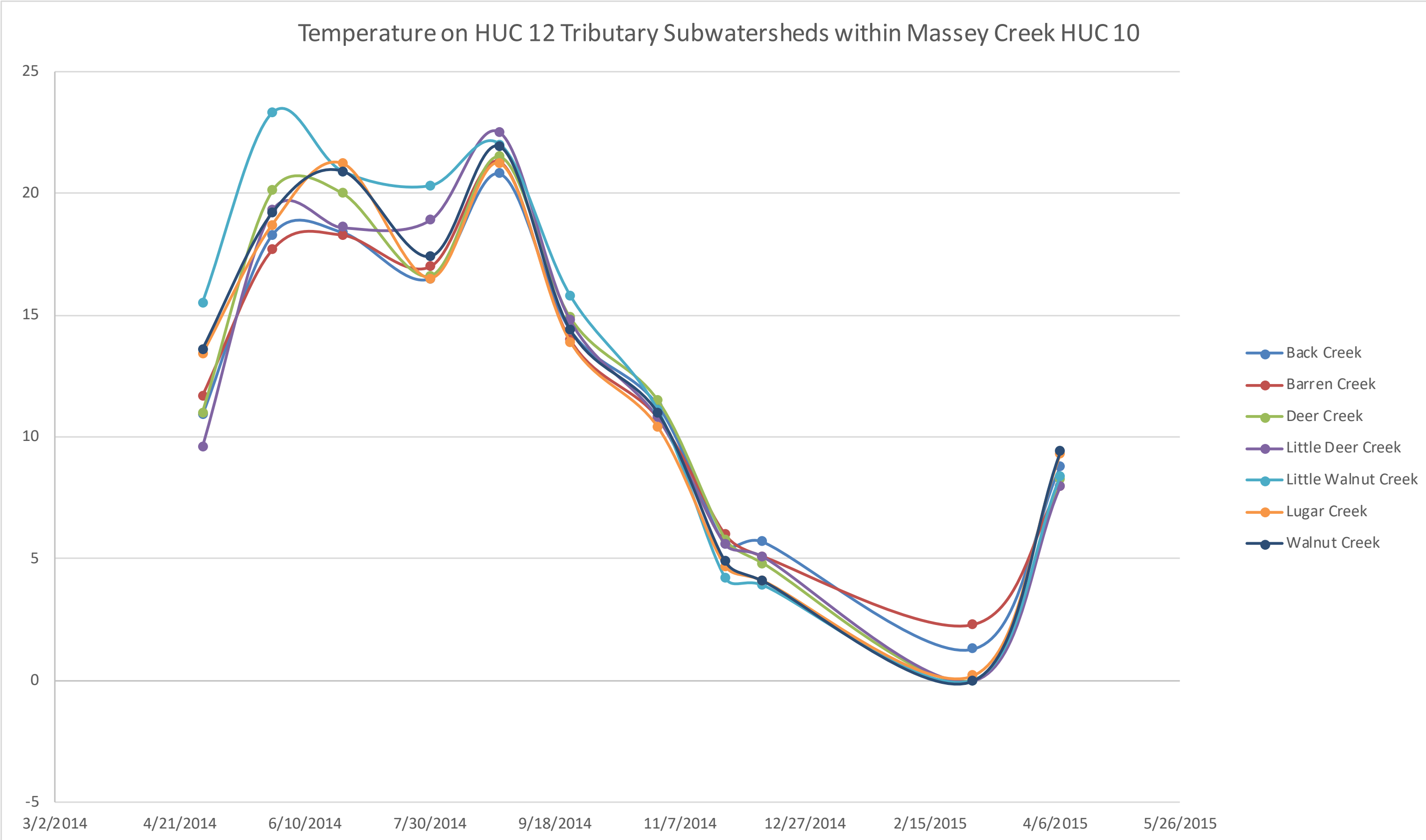


FIG. 8.8 | Temperature on HUC12 Tributary Subwatersheds within Massey Creek HUC10

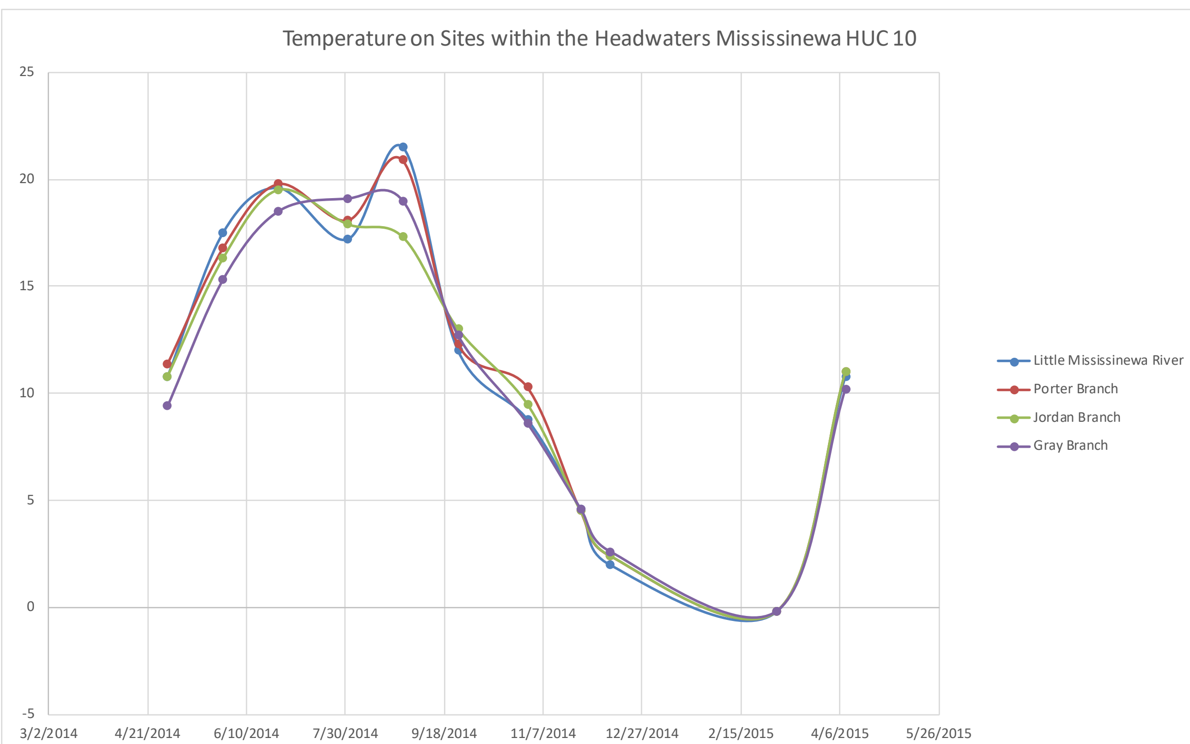


FIG. 8.9 | Temperature on Sites within the Headwaters Mississinewa HUC10

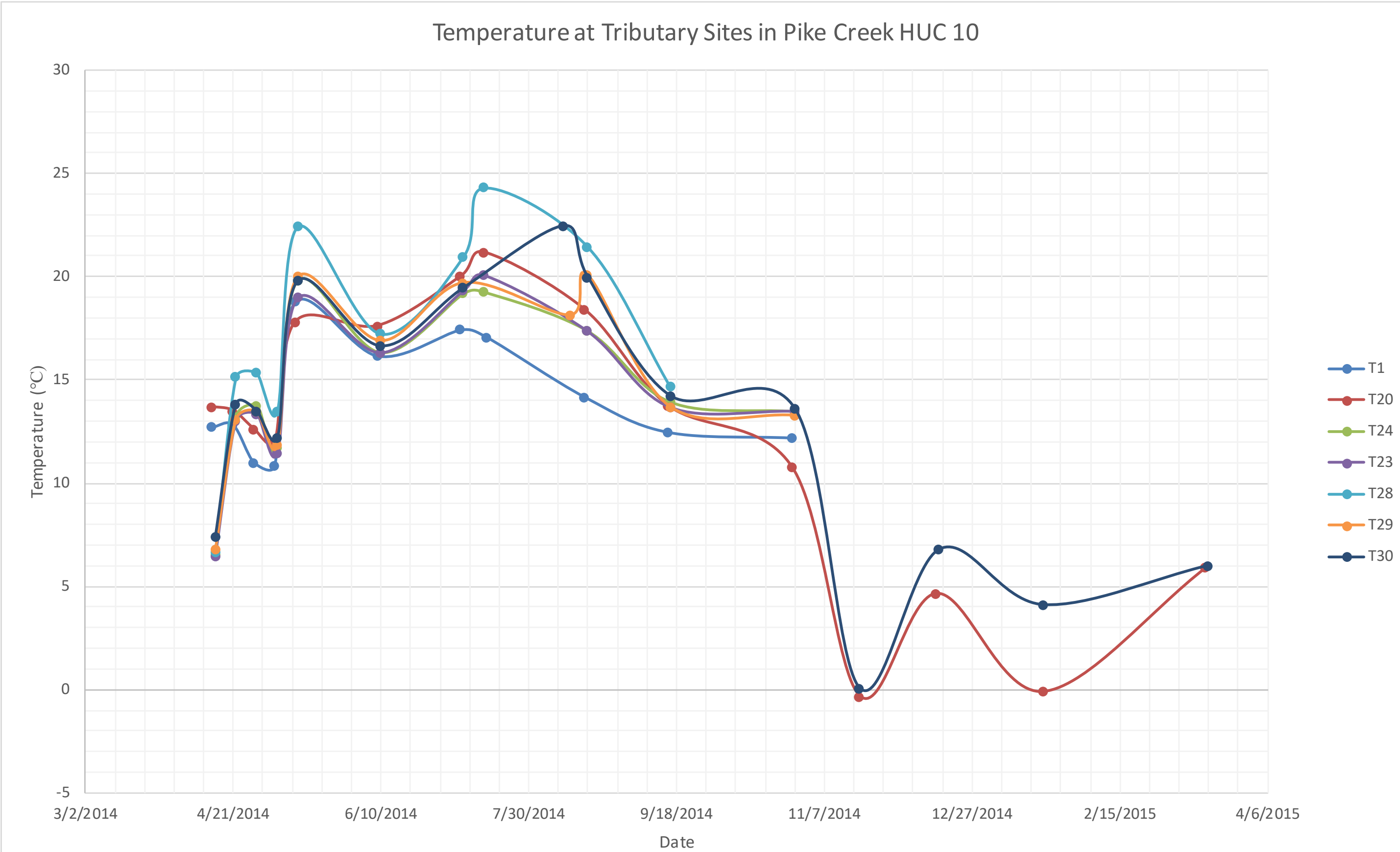


FIG. 8.10 | Temperature on Sites within the Pike Creek HUC10

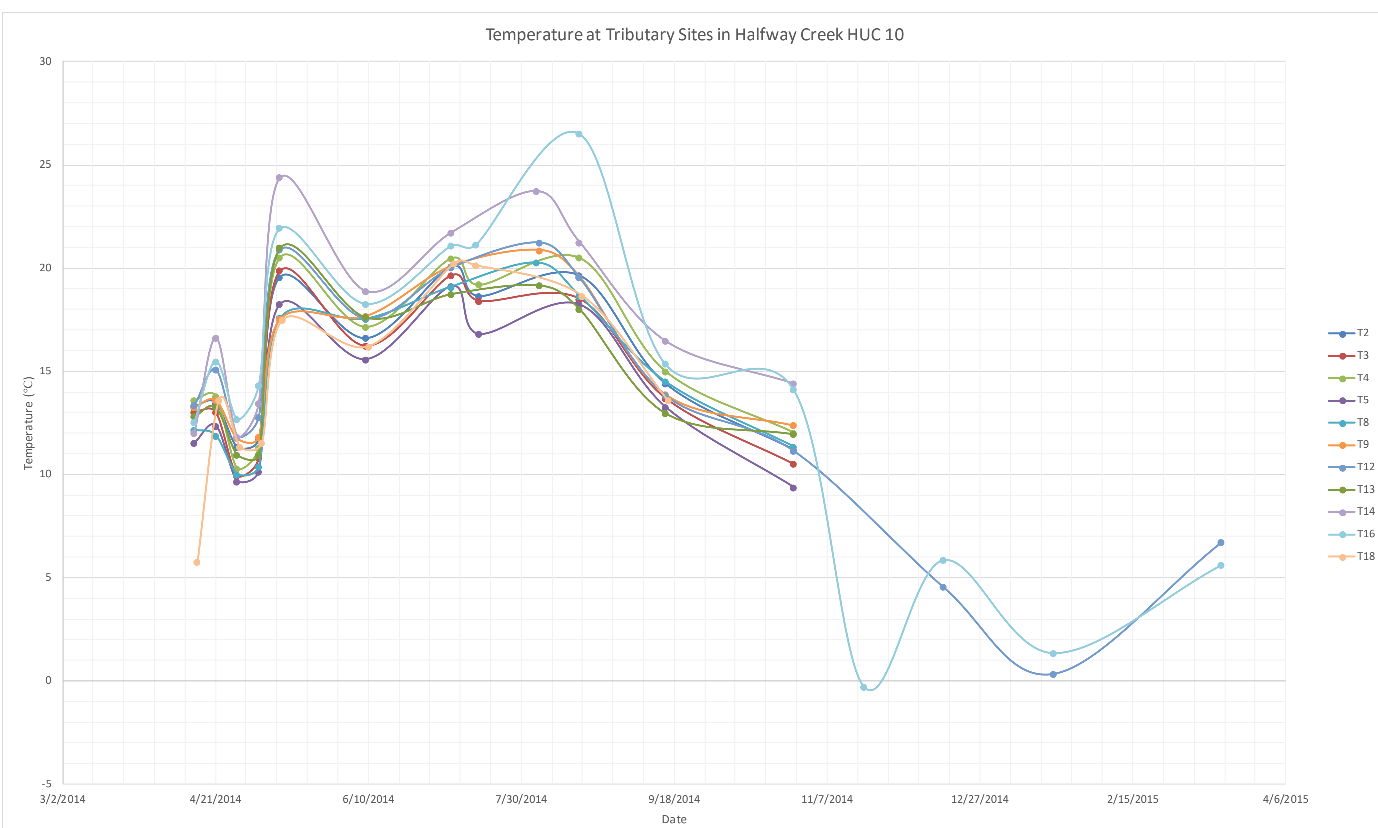


FIG. 8.11 | Temperature on Sites within the Halfway Creek HUC10

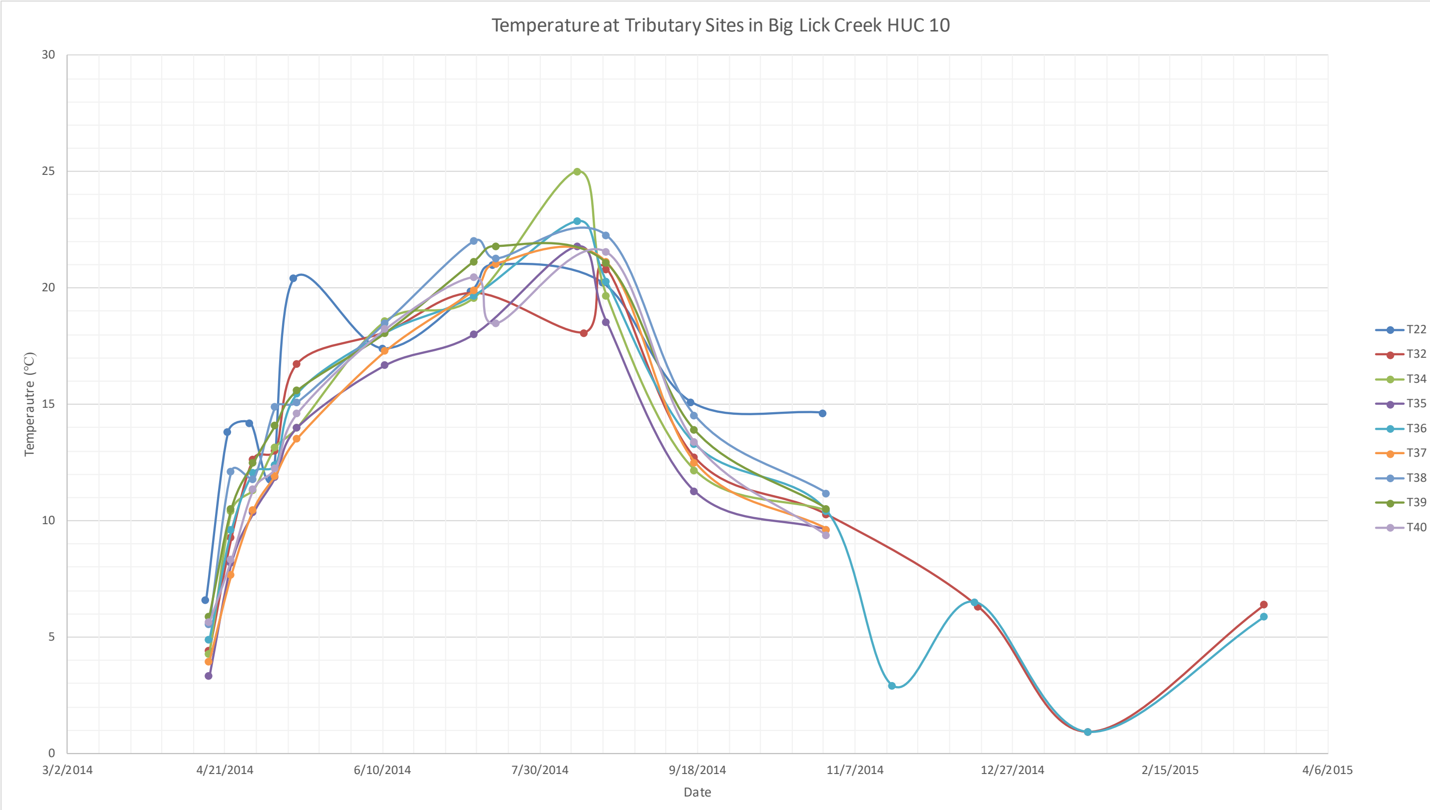


FIG. 8.12 | Temperature on Tributary Sites within the Big Lick Creek HUC10

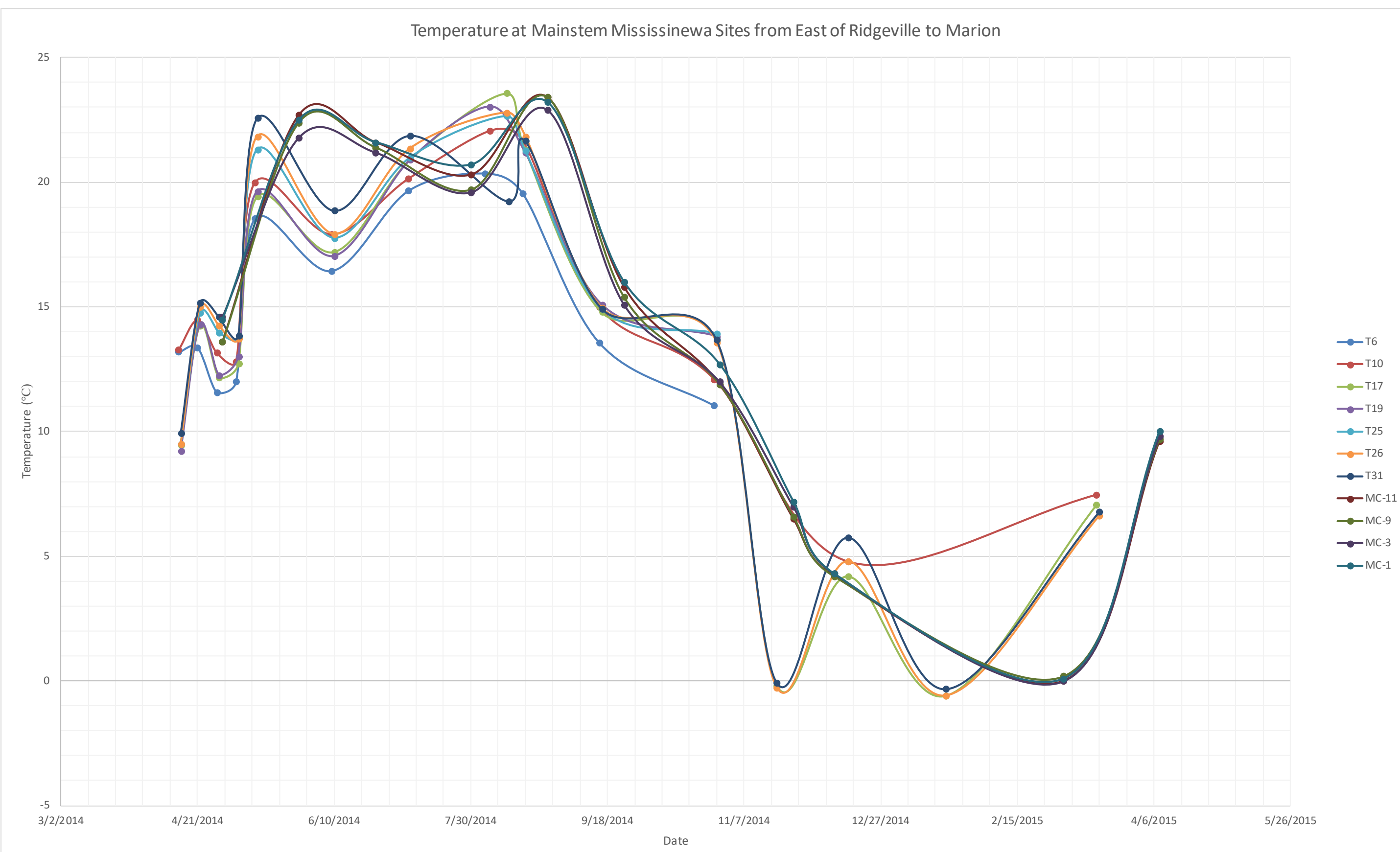


FIG. 8.13 | Temperature on Mainstem Mississinewa Sites from East of Ridgeville to Marion

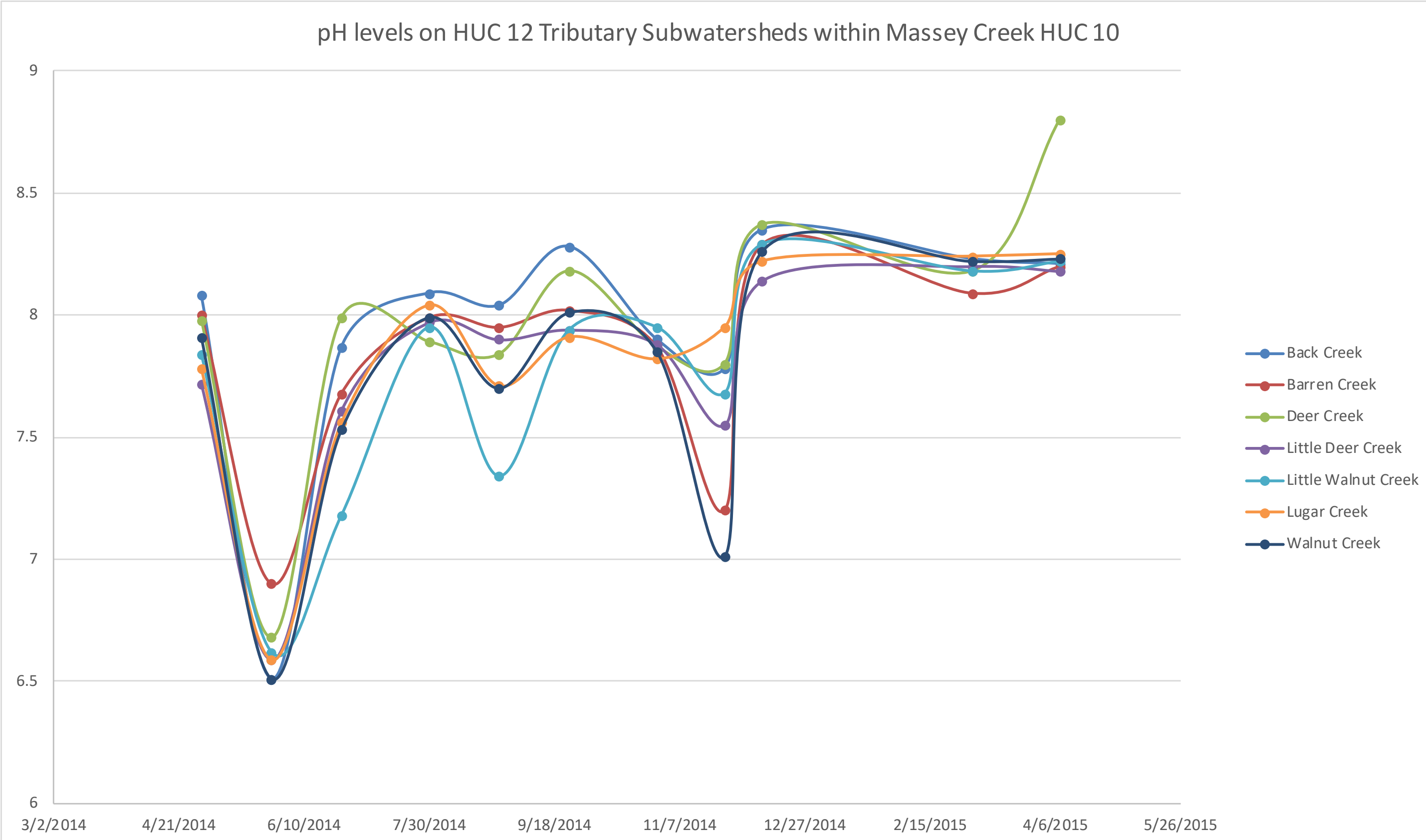


FIG. 8.14 | pH levels on HUC 12 Tributary Subwatersheds within Massey Creek HUC10

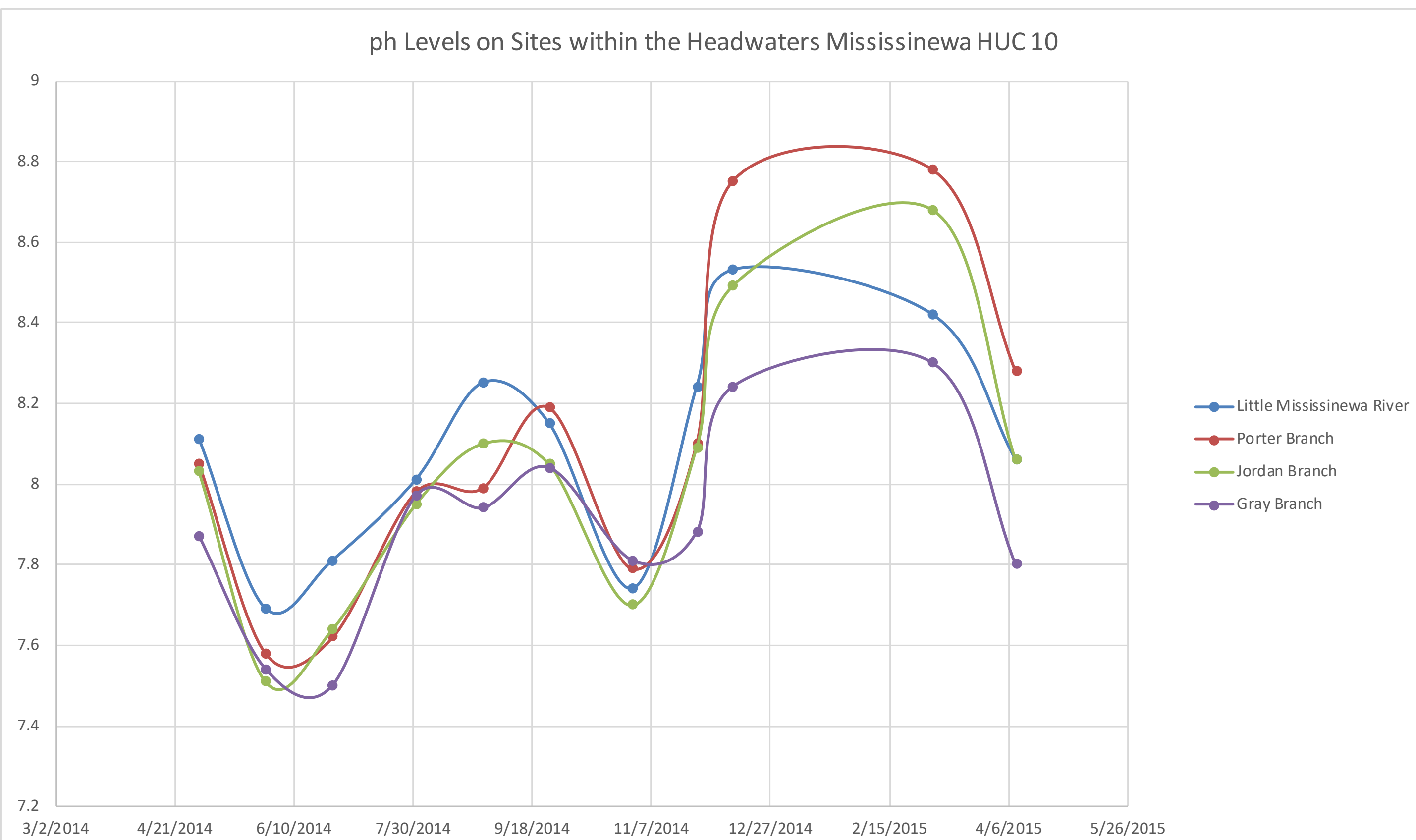


FIG. 8.15 | pH levels on Sites within the Headwaters Mississinewa HUC10

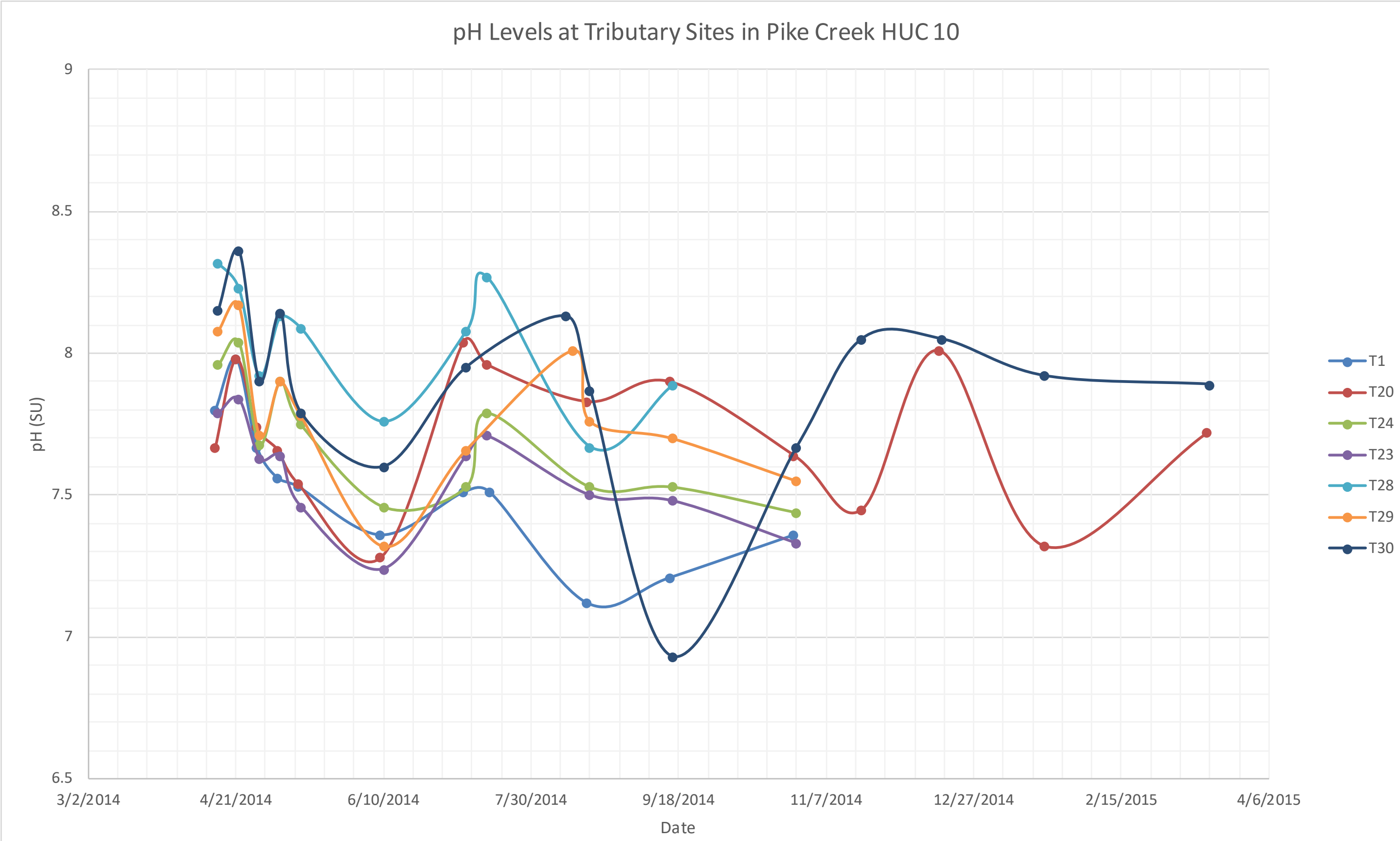


FIG. 8.16 | pH levels at Tributary Sites in the Pike Creek HUC10

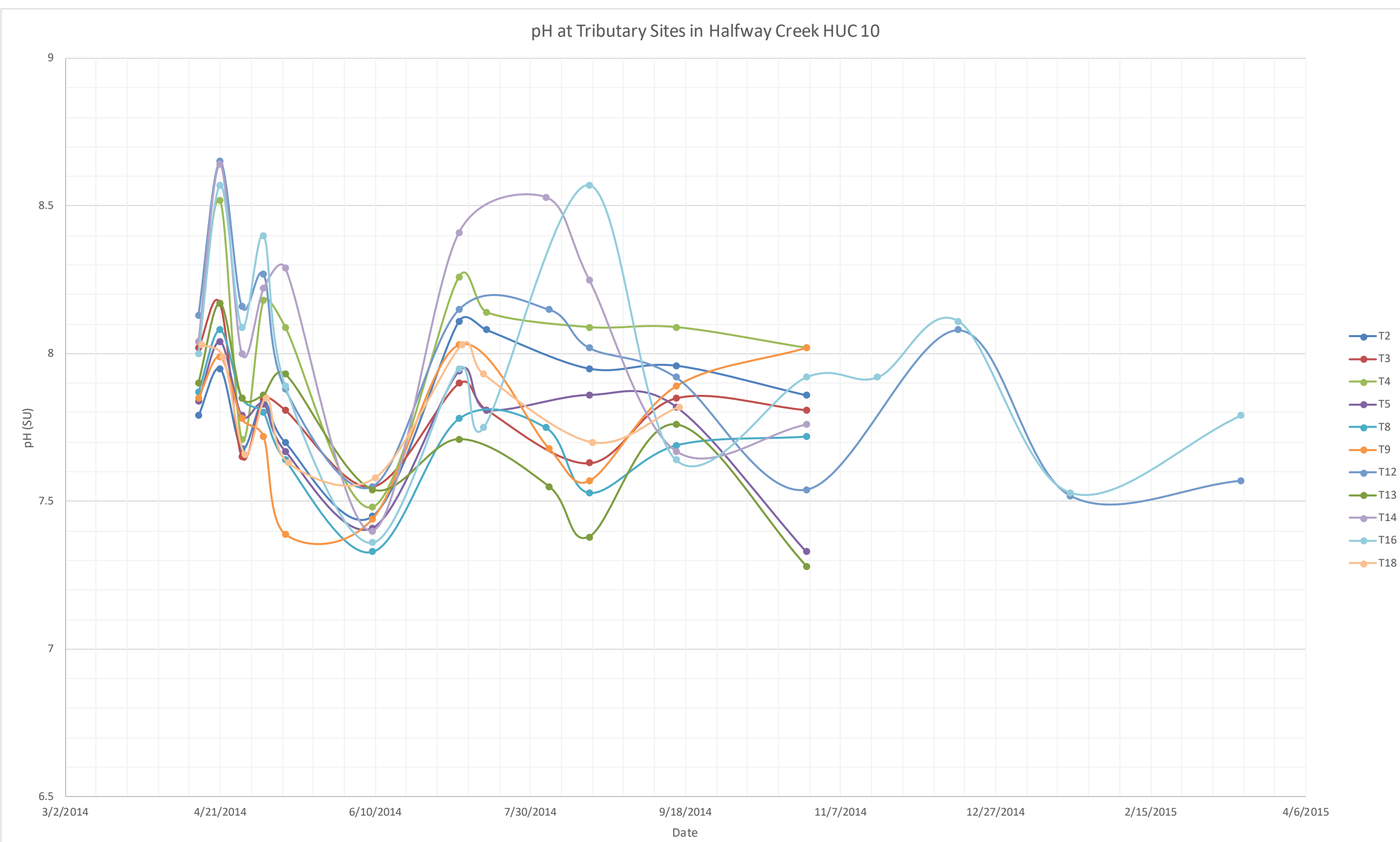


FIG. 8.17 | pH levels at Tributary Sites in the Halfway Creek HUC10

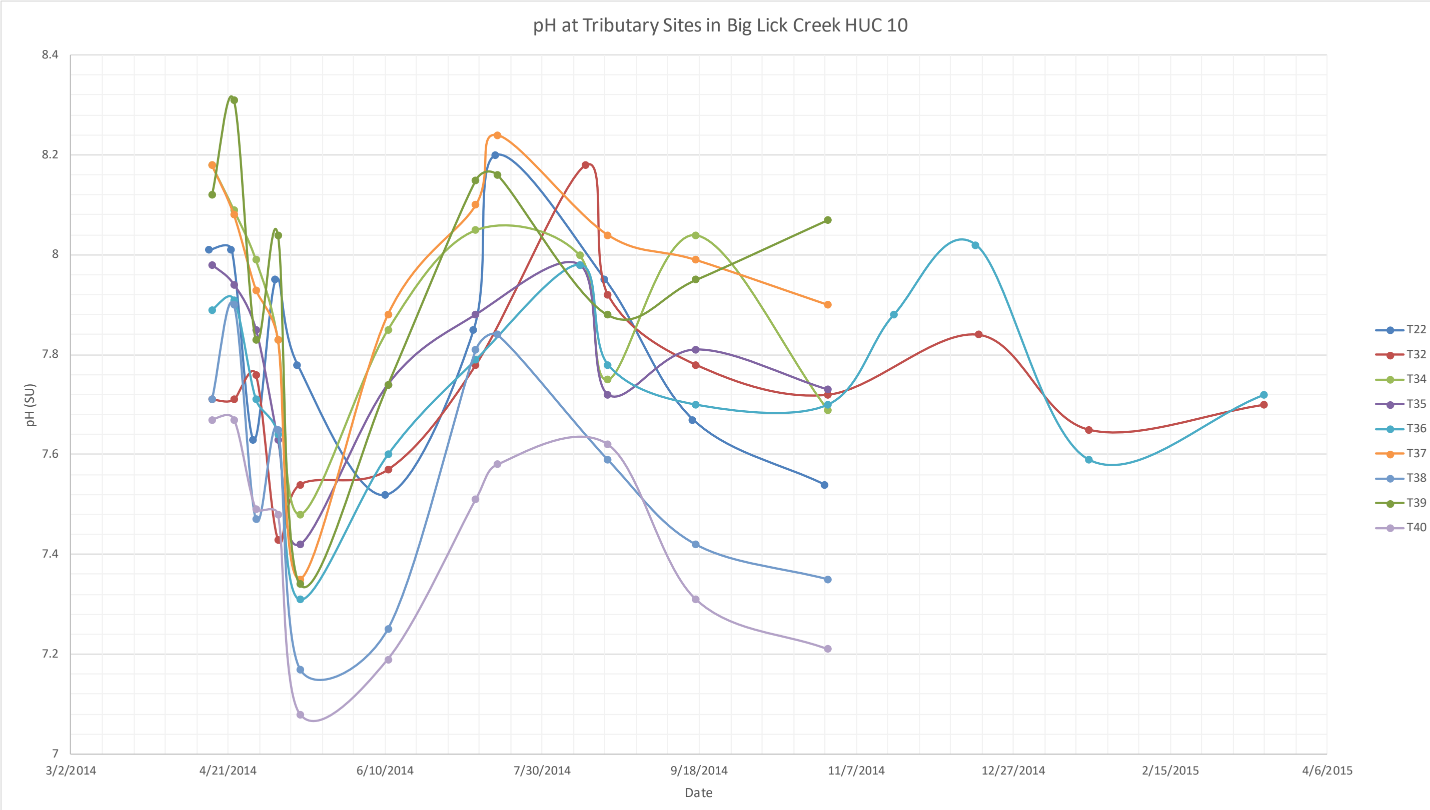


FIG. 8.18 | pH levels at Tributary Sites in the Big Lick Creek HUC10

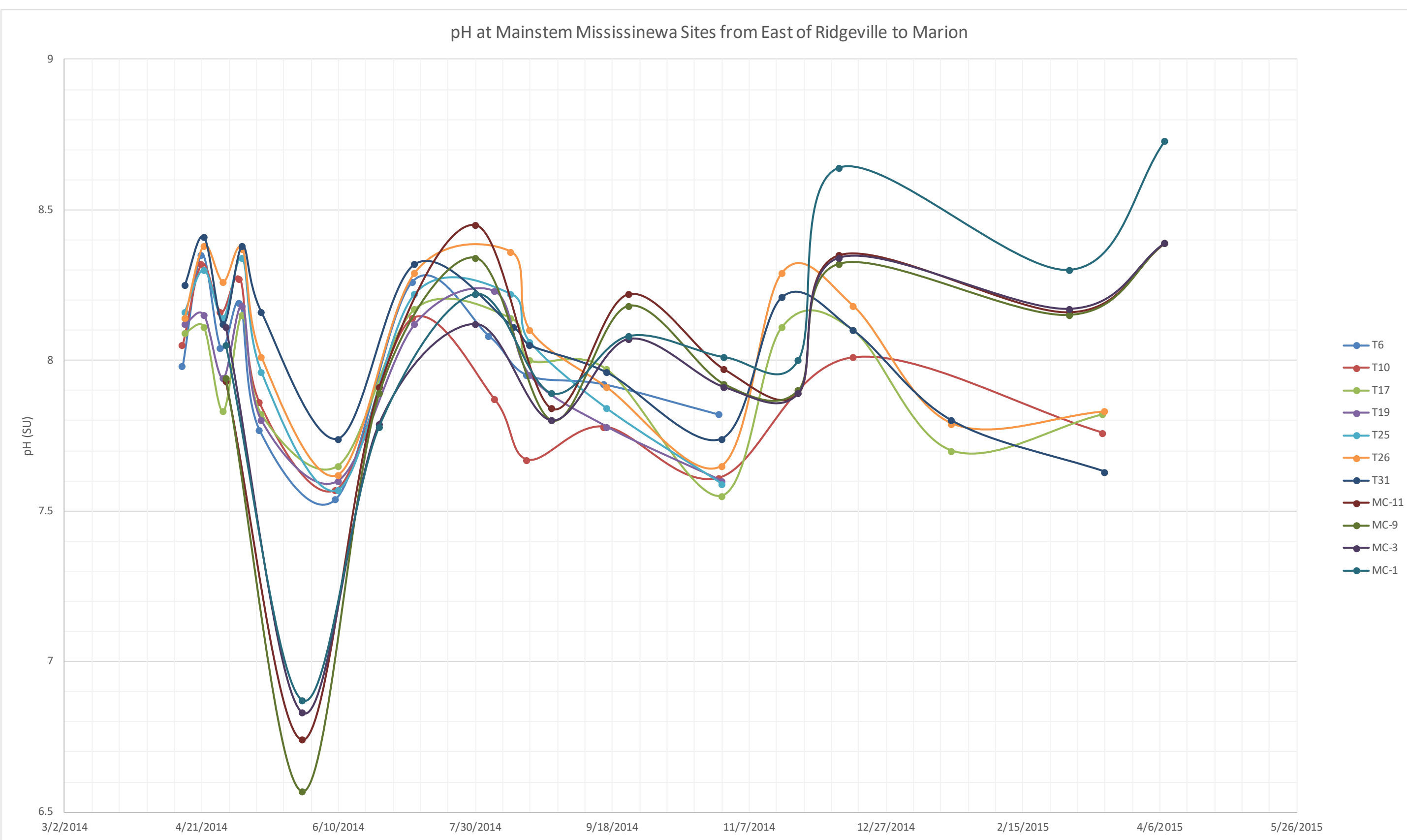


FIG. 8.19 | pH Levels at Mainstem Mississinewa Sites from East of Ridgeville to Marion

9. BIOLOGICAL ASSESSMENTS

9.1 BIOLOGICAL ASSESSMENTS

Determining the biological health of a waterway is another important component of assessing water quality. Rather than the single point in time snapshot that is gained by chemical testing, biological assessments reflect the health of a waterway over a long period of time. Biological assessments can detect impairments that chemical testing alone does not reveal (Fig. 9.1). Poor biological health can be an indicator of poor chemical water quality. However, chemical water quality is not the only variable that affects biological health. Habitat quality also affects biological health. Therefore, it is essential to also conduct a habitat assessment to determine which variable is most likely causing any poor biological results that are found.

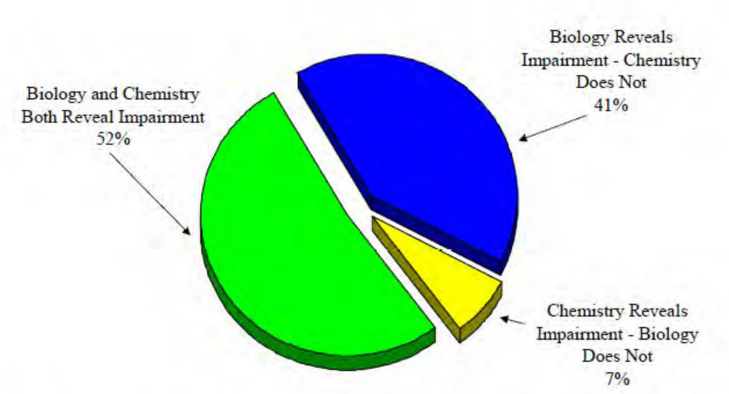


FIG. 9.1 | Efficacy of chemical and biological assessments in detecting stream impairment. (Adapted from Holloway, 2015. Bureau of Water Quality Annual Fish Community Report 2014).

Various biological assessments have been performed on the Mississinewa River and various tributaries. IDEM has collected data for the development of IBI and QHEI scores. IDEM data has been used for the development of its 303(d) List of Impaired Waters. IDEM has also sampled fish tissue for its Fish Tissue Contaminants Monitoring Program; data from this program is used in the development of the Indiana State Department of Health's Fish Consumption Advisory. Past assessment projects funded by the IDNR's (Indiana Department of Natural Resources) LARE (Lake and River Enhancement) grants have also been performed in four of the five HUC 10 watersheds in the UMRW.

Two current sampling programs were recently completed: one conducted by IDEM and the other by the Muncie Bureau of Water Quality. IDEM performed biological and habitat sampling for the development of a TMDL for the Upper Mississinewa; this area is composed of three of five HUC 10s within the study area of this watershed management plan. This data was obtained by the Project Manager and used, along with data from sampling conducted concurrently by the Muncie Bureau of Water Quality (at sites within the UMRW not sampled by IDEM), for an independent analysis of biological communities and habitat within the entire area this watershed management plan covers. The following subsections will describe results from both historic and current biological and habitat sampling programs.

IDEM FISH COMMUNITY DATA

Results of fish community sampling performed by IDEM from 1998 to 2008 were reviewed. Sampling took place on four different dates at four different sites on the Mississinewa River. Sampling was performed at the following dates and sites: August 19, 1998 at site 0013 within Branch Creek subwatershed; July 21, 1998 at site 0001 within Hoppas Ditch subwatershed; August 19, 2003 at site 0016 within Branch Creek subwatershed; and June 18, 2008 at site 0020 within Branch Creek subwatershed.

Moving from upstream to downstream, the order of the sites are as follows: 0001, 0013, 0016, and 0020. As the value of the site ID number increases, so does the drainage area. In other words, the smaller the site number is the farther upstream it is.

All sites within Branch Creek subwatershed had scores that rated at least "good" for biological integrity. The site in Hoopas Ditch subwatershed is considered as "not supporting" aquatic life uses; the score at this site rated "poor." All sites within Branch Creek subwatershed rated "excellent" for habitat, based on QHEI scores. The site in Hoopas Ditch subwatershed rated "good." Based on this score, a higher IBI score than was measured would be expected at Hoopas Ditch; this may indicate that chemical water quality was impacting fish populations at the time of sampling. However, habitat quality cannot be ruled out.

IBI scores were as follows: site 0001, 30; site 0013, 54; site 0016, 52; and site 0020, 48. QHEI scores were as follows: site 0001, 63; site 0013, 85; site 0016, 83; and site 0020, 70 (Table 9.1).

According to IDEM analysis, reasons for site 0001 having the lowest scores include: poor riffle run habitat, poor channel morphology, a high percentage of tolerant species present (63.45%), and a low number of sensitive species found (6). Species data was available for sites 0001, 0013 and 0020. The total number of species found at each site are as follows: site 001, 20 species; site 0013, 25 species; site 0020, 28 species. Bluntnose minnow was the most abundant species at each site. Although no more than five common carp were found at any site, at each site they made up the highest percentage of the total catch weight.

TABLE 9.1 | Biological results from IDEM

HUC 12	County	IBI	Qual	QHEI	Qual	Latitude	Longitude	Date
Hoppas Ditch-Mississinewa River	Grant	30	Poor	63	Fair	40.38027778	-85.47805556	7/1998
Branch Creek-Mississinewa River	Grant	54	Excellent	85	Good	40.49666667	-85.62305556	8/1998
Branch Creek-Mississinewa River	Grant	52	Good	83	Good	40.431798	-85.516297	8/2003
Branch Creek-Mississinewa River	Grant	48	Good	70	Fair	40.4559775	-85.57776278	6/2008
Town of Peoria-Mississinewa River	Miami	34	Poor	68	Fair	40.74527778	-86.01416667	9/1998

COMPARISON TO OTHER RECREATIONAL RIVERS

The historic IBI and QHEI data discussed in the previous section was used by the Project Manager to assess the Mississinewa River in relation to other recreational rivers in the state. Other recreational rivers were identified from the Indiana Department of Natural Resources' "Indiana Canoeing Trails" list, published on their website. Data for these recreational rivers was also obtained from IDEM for this comparison. Table 9.2 contains a comparison of IBI and QHEI scores. The Mississinewa River ranks 10th out of 17, with an average of good IBI scores and good QHEI scores. "Good" average IBI scores are expected with "good" average QHEI scores. Each stream was ranked according to QHEI and IBI scores. Their average ranking is included in Table 9.2 as "combined rank".

TABLE 9.2 | Statewide biological comparison

River	IBI	IBI QUAL	QHEI	QHEI QUAL	COMBINED RANK
Pigeon River	52	Good	80	Excellent	1
Eel River	52	Good	76	Excellent	2
Whitewater River	50	Good	78	Excellent	3
West Fork White River	47	Good	79	Excellent	5
FlatRock River	52	Good	72	Excellent	5
Sugar Creek	48	Good	74	Excellent	6
Sugar Creek 2	48	Good	74	Excellent	7
Wildcat Creek	41	Fair	77	Excellent	8
Mississinewa River	46	Good	67	Good	10
Tippecanoe River (Upper)	50	Good	63	Good	10
St. Joseph River	41	Fair	64	Good	11
East Fork White River	39	Fair	65	Good	12
Wabash River	37	Fair	67	Good	13
White River	39	Fair	59	Good	14
Kankakee River	38	Fair	52	Fair	15
Muscatatuck River	38	Fair	35	Poor	16
Iroquis River	37	Fair	44	Poor	17

303(d) LIST OF IMPAIRED WATERS

Five assessment units within the UMRW were identified as having Impaired Biotic Communities based on sampling conducted for IDEM's Integrated Water Monitoring and Assessment Report, which included the development of the 2014 303(d) List of Impaired Waters. The Integrated Water Monitoring and Assessment Report is submitted every two years to the US EPA. Approximately 38 miles of tributaries from 4 streams were listed as having impaired biotic communities. 3.78 miles of the Mississinewa River was listed as having impaired biotic communities. This segment begins in northern Delaware County and ends in Grant County downstream of the town of Matthews. Assessment units having impaired biological communities are within the following subwatersheds: Hoppas Ditch, Boots Creek (containing two streams), Jordan Creek (south of the Mississinewa River), and Bush Creek.

NPDES (NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM) SITES

According to the EPA's ECHO website, Cardinal Ethanol appears to have been in noncompliance for all 12 quarters in the last three years. The specific nature of the violations are unclear. They appear to be for the cause of acute or chronic toxicity to certain fish and aquatic species. Wastewater from this facility is discharged into a retention pond the drains into Shelly Ditch. Shelly Ditch is located in the Little Mississinewa River subwatershed. No IBI data exists for Shelly Ditch. Historical data was reviewed and neither IDEM or any other agency have conducted IBI sampling on Shelly Ditch. Shelly Ditch nor any waterbody within the Little Mississinewa River HUC 12 were included in the study area of the LARE diagnostic study completed by HARZA Engineering Company in 2001.

HOOSIER RIVERWATCH DATA

Fifty-eight macroinvertebrate sampling events were found in the Hoosier Riverwatch database. Sampling events took place at 10 different sites from November 11, 2000 to June 13, 2013. Different groups conducted the sampling, including The Kings Academy, West Side Middle School, Taylor University, McCulloch Middle School, BSA Troop 61 Ridgeville, and New Horizons. Macroinvertebrate data was interpreted using the Pollution Tolerance Index (PTI). Sixty-six percent of samples rated as excellent, 17% rated as good, and 16% rated as fair. Only one score rated as poor (this score should be disregarded, as the numerical value was listed as 0; a score of 0 is improbable, indicating that a transcription error may have been made). Sites with scores rating fair were on Lugar Creek, Little Mississinewa River, and Big Lick Creek. Sites with scores rating good were on Little Mississinewa River, Clear Creek, Lugar Creek, Mississinewa River, and Walnut Creek. Sites with scores rating excellent were on Walnut Creek, Clear Creek, Back Creek, Mississinewa River, Big Lick Creek, and Hopcus Run. Ninety-six percent (24/25) of samples on the Mississinewa River rated excellent. Little Mississinewa River, Lugar Creek, and Big Lick Creek had the lowest PTI scores, with averages of 16 (fair), 17.2 (good), and 21.3 (good), respectively.

FISH CONSUMPTION ADVISORY

The following section contains information from the Indiana State Department of Heatlh's webpage located on the website for the State of Indiana.[1] Because fish tissues can accumulate toxins, such as polychlorinated biphenyls (PCBs) and mercury, eating fish can pose a risk to human health. In order to protect the health of its citizens, three state agencies (Indiana Department of Environmental Management, Indiana State Department of Health, and Indiana Department of Natural Resources) work together to publish a list of public waters in the state of Indiana that contain contaminated fish. This list, known as the Fish Consumption Advisory, makes consumption recommendations for public waters based on the level of contaminants found in fish in these waters. The basis for the Fish Consumption Advisory comes from the Indiana Department of Environmental Management's Fish Tissue Contaminants Monitoring Program, which assesses the level of toxins found in fish in public waters.

Advisories are made for two separate segments of the population: the general population and the sensitive population. Members of the sensitive population include females under 50 years old (excluding adult females who are incapable of becoming pregnant), males under the age of 18, and people with compromised immune systems. All other persons not included in the sensitive population are included in the general population.

Fish can be categorized into five consumption groups (Table 9.3). Consumption recommendations for each of the five consumption groups varies based on whether a person is part of the sensitive or general population. Although these consumption groups have been included in Table 9.3 below, the following discussion does not refer to these specific groups, but rather discusses the specific recommendations for each population.

TABLE 9.3 | Consumption groups and advisories for fish consumption advisory

Group Number	Sensitive Population Advisory	General Population Advisory
1	1 meal per week	Unlimited Consumption
2	1 meal per month	1 meal per week
3	Do Not Eat	1 meal per month
4	Do Not Eat	1 meal every 2 months
5	Do Not Eat	Do Not Eat

The Project Manager reviewed advisories for the Mississinewa River and its tributaries, which were found on the State of Indiana's website. Findings are summarized in the following paragraphs.

Fish consumption advisories have been issued for the Mississinewa River throughout the UMRW. PCB is the contaminant responsible for these advisories. According to the US EPA, PCB contamination occurred due to industrial activities at the former Westinghouse and United Technologies Automotive Systems, Inc. sites located along the Little Mississinewa River in Union City. The former industrial site is now a Superfund site referred to as the Little Mississinewa River Superfund Site.[2]

Fish consumption advisories are the strictest for the Mississinewa River within Randolph County, presumably due to the closer proximity of the river to the Little Mississinewa River Superfund Site.

1 Indiana State Department of Health. [web page] Fish Consumption Advisory for Indiana.http://in.gov/isdh/26778.htm
2 U.S. Environmental Protection Agency. 2001. [web page] Little Mississinewa River Superfund Site. https://www3.epa.gov/region5/cleanup/mississinewa/pdf/lmr_fs_200108.pdf

The sensitive population should not consume fish from the Mississinewa in Randolph County; in Delaware and Grant counties the sensitive population can consumer fish once per month. The general population should limit consumption from the Mississinewa River in Randolph County to once per month; in Delaware and Grant counties fish can be consumed by the general population once per week.

Exceptions to these advisories exist for the general population. In general, these exceptions are for certain species of fish above a certain length; presumably because older, larger fish have accumulated higher levels of toxins in their tissues and therefore pose more of a risk to human health. For the Mississinewa River in Randolph County, certain species of fish of certain lengths should never be consumed. These “do not eat” advisories are for channel catfish (all sizes), common carp (all sizes), green sunfish (3” +), quillback (15”+), white crappie (10” +), and white sucker (10” +). For the Mississinewa in Dweller and Grant Counties, in general larger sizes of certain species should be consumed less often (1 meal every 2 months) and the smaller sizes of these species can be consumed more often than the larger sizes (1 meal every month) but still less often than fish not included on the list. Species that have stricter advisories in Delaware and Grant counties include channel catfish, common carp, flathead catfish, quillback, and white sucker. Conversely, consumption of one species in Delaware and Grant counties is unrestricted at a certain size; white crappie below 9 inches is unrestricted.

Only one tributary of the Mississinewa River was listed on the fish consumption advisory. Little Mississinewa River in Randolph County has a “do not eat” advisory for all fish for both general and sensitive populations. PCB is also the contaminant responsible for the advisory in these waters. The Little Mississinewa River Superfund Site is near the headwaters of the Little Mississinewa River.

PUBLIC HEALTH: INTEGRATED WATER MONITORING AND ASSESSMENT REPORT (IWMA)

According to the 2002 Indiana Integrated Water Quality Monitoring and Assessment Report, “The release of toxic materials into the aquatic environment can produce effects in several ways: (1) Contaminants present in acutely toxic amounts may kill fish or other aquatic organisms directly; (2) Substances present in lesser, chronically toxic amounts can reduce densities and growth rates of aquatic organisms and/or become concentrated in their body tissues. These substances can be further passed on to humans through consumption of the organism; and (3) Toxic materials in the water could potentially affect human health by contaminating public water supplies; although, at this time IDEM has no data to indicate that there have been any adverse human health effects due to toxic substances in surface water supplies.”

“In the last several years, advances in analytical capabilities and techniques and the generation of more and better toxicity information on chemicals have led to an increased concern about their presence in the aquatic environment and the associated effects on human health and other organisms. Because many pollutants are likely to be found in fish tissue and bottom sediments at levels higher than in the water, much of the data on toxic substances used for fishable use assessments in [the IWMA] report were obtained through the fish tissue and surficial aquatic sediment contaminants monitoring program.” [3]

Based on the information presented above, toxic materials are another variable that can limit the health of aquatic communities. Therefore, information from the Fish Consumption Advisory may be useful to consider when trying to explain any low biological results found in this study. Toxic materials are a variable that is not measured in this study. As stated above, chronic amounts of toxic materials can lead to reduced densities. In this study, if a site has good habitat scores and meets all water quality targets but has poor biological scores, one of the possible sources of this impairment could be toxic materials.

DRAFT TOTAL MAXIMUM DAILY LOAD (TMDL) REPORT FOR THE UPPER MISSISSINEWA RIVER WATERSHED

Biological and habitat sampling were performed by the Indiana Department of Environmental Management (as part of TMDL development) between June and October of 2014 within three HUC 10 watersheds--Halfway Creek, Big Lick Creek, and Pike Creek. Both fish and macroinvertebrate communities were sampled at 35 sample sites within this study area and assessed using the IBI and mIBI. Habitat quality was also assessed using the QHEI. Seven of the sites were located on the Mississinewa; the rest were located on tributaries. According to the report, “widespread biological impairments” were observed. Over 54% of sample sites had biological scores below the target of 36 during each sampling event. Sites with scores meeting this target are considered to be fully supporting aquatic life uses.

Sites on the Mississinewa River generally had IBI scores that rated good. Two “excellent” IBI scores were recorded, both on the Mississinewa River, in Holden Ditch and Rees Ditch subwatersheds. The lowest IBI scores were found on tributaries. Tributary sites generally had IBI scores that rated poor or fair. Flesher Creek, site T8, within Days Creek subwatershed, and Halfway Creek, site T14, within Halfway Creek subwatershed, had the lowest IBI scores. QHEI scores at these sites were also “poor.” Some sites had qualitative QHEI scores that were better than IBI scores. This suggests that water quality may be limiting the biological communities at these sites more than habitat quality. Townsand Lucas Ditch, site T34, located within Big Lick Creek, had an IBI score of 32, poor, with a QHEI score of 68, good. Campbell Creek, site T20, within Campbell Creek subwatershed, had an IBI score of 42, fair, and a QHEI score of 80, excellent. Pike Creek, site T30, within Pike Creek subwatershed, had an IBI score of 36, fair, and a QHEI score of 80, excellent.

mIBI scores on the Mississinewa River were generally poor to fair. QHEI scores calculated during macroinvertebrate sampling for the Mississinewa River were generally fair. mIBI scores on tributaries were also generally poor to fair. None of the sites sampled on tributaries had narrative ratings above fair.

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3 Indiana Department of Environmental Management. 2002. [webpage] Integrated water Quality Monitoring and Assessment Report. https://archive.epa.gov/nheerl/arm/web/pdf/in_surfacewater.pdf

The lowest mIBI scores were recorded on Rees Ditch, at sites T21 and T23. mIBI scores at both sites were 26, poor. Hedgeland Ditch, site T29, within Studebaker Ditch subwatershed, scored 28, poor; Big Lick Creek, site T32, within Big Lick Creek subwatershed, scored 27, poor; Townsand Lucas Ditch, site T34, within Big Lick Creek subwatershed, scored 28, poor; and Little Lick Creek, site T38, within Little Lick Creek subwatershed scored 28, poor. Similar to the IBI and QHEI scores, Townsand Lucas Ditch, site T34, had an mIBI score of 28, poor, and a QHEI score of 58, good.
In general, most sites did not have narrative scores of poor for *both* the IBI and the mIBI. Sites that did have scores of poor for both the mIBI and IBI were Flesher Creek, site T8, within Days Creek subwatershed; Little Lick Creek, site T38, within Little Lick Creek subwatershed; Townsand Lucas Ditch, site T34, within Big Lick Creek subwatershed; and Hedgeland Ditch, within Pike Creek subwatershed.

Possible reasons for low biological and habitat scores identified in the report included: reduced habitat and lower habitat diversity due to hydromodification, lower plant productivity due to high TSS blocking light penetration, lower visibility due to high TSS, high TSS causing adverse effects on health of fish, and decreases in oxygen levels due to high phosphorus causing excessive plant growth.

CURRENT BIOLOGICAL AND HABITAT ASSESSMENT FOR THIS WATERSHED MANAGEMENT PLAN
As part of the current watershed project, biological and habitat assessments were conducted on the Mississinewa River and its tributaries. The UMRW-P contracted the Muncie Bureau of Water Quality to perform biological and habitat assessments at 16 sites (8 mainstem and 8 tributaries). Data for the remaining 12 sites were obtained from the Indiana Department of Environmental Management (IDEM).

TABLE 9.4 | IBI results

Stream / River	Site #	IBI	IBI Qual
Boots Creek-Mississinewa River	MC-1	48	Good
Lugar Creek	MC-2	40	Fair
Branch Creek-Mississinewa River	MC-3	52	Good
Deer Creek	MC-4	28	Poor
Little Deer Creek-Deer Creek	MC-5	38	Fair
Back Creek	MC-6	32	Poor
Walnut Creek	MC-7	38	Fair
Little Walnut Creek-Walnut Creek	MC-8	36	Fair
Lake Branch-Mississinewa River	MC-9	48	Good
Barren Creek	MC-10	36	Fair
Hoppas Ditch-Mississinewa River	MC-11	46	Good
Little Lick Creek-Big Lick Creek	EM-1	42	Fair
Townsand Lucas Ditch-Big Lick Creek	EM-2	38	Fair
Holden Ditch-Mississinewa River	EM-3	42	Fair
Studebaker Ditch-Pike Creek	EM-4	36	Fair
Rees Ditch-Mississinewa River	EM-5	54	Excellent
Campbell Creek	EM-6	42	Fair
Redkey Run-Halfway Creek	EM-7	46	Good
Platt Nibarger Ditch-Mississinewa River	EM-8	52	Good
Bush Creek	EM-9	38	Fair
Fetid Creek-Mississinewa River	EM-10	42	Fair
Bear Creek	EM-11	34	Poor
Days Creek	EM-12	28	Poor
Mud Creek-Mississinewa River	EM-13	46	Good
Porter Creek-Mississinewa River	HM-1	50	Good
Jordan Creek-Mississinewa River	HM-2	42	Fair
Little Mississinewa River	HM-3	34	Poor
Gray Branch-Mississinewa River	HM-4	42	Fair

TABLE 9.5 | IBI scores and narratives

IBI score	Narrative Rating
53-60	Excellent
45-52	Good
35-44	Fair
23-34	Poor
12-22	Very Poor
<12	NO FISH FOUND

IDEM's biological and habitat sampling (conducted for the development of a TMDL for the Halfway Creek, Big Lick Creek, and Pike Creek HUC 10 watersheds) was concurrent with sampling for the current project. As set forth in the Quality Assurance Project Plan submitted to IDEM for the current watershed project, one objective of the current project is to "incorporate data from IDEM's Total Maximum Daily Load study in Big Lick Creek, Pike Creek, and Halfway Creek HUC10 watersheds." The IDEM TMDL data obtained by the Project Manager was from sample sites located near pour points.

FISH COMMUNITIES: METHODOLOGY AND RESULTS
Fish communities were sampled according to Environmental Protection Agency protocol for determination of Index of Biotic Integrity (IBI) scores (OEPA 1989; Simon and Dufour 1997). The MBWQ used methods based on the electrofishing guidelines provided by the U.S. and Ohio Environmental Protection Agency. Habitat assessments were conducted at each fish sampling event according to protocol for determination of Qualitative Habitat Evaluation Index (QHEI) scores (Rankin 1989).

"The IBI is composed of twelve metrics that measure functional aspects of fish communities including species composition, trophic composition, and fish condition. Each metric is scored according to the degree of deviation from a "healthy" or least impacted stream of comparable size (1= severe deviation, 3= moderate deviation, and 5= little or no deviation). The total score of 12 to 60 is used to assign a narrative description of very poor, poor, fair, good, or excellent to the biological integrity of the community within a sample's stream segment."[4] The IBI scale and corresponding narrative ratings is found in Table 9.5 on the previous page.

The Muncie Bureau of Water Quality (MBWQ) conducted fish sampling from July 14 to 25, 2014. Samples were collected by the MBWQ using a TBS (tote barge electrofisher) at wadable sites and a BPS (backpack system) at smaller tributaries where the TBS was too big to be handled by one person. Sampling by IDEM was conducted between June and October 2014. IBI results can be found in Table 9.4 on the previous page. Figure 9.2 on the previous page represents the relative IBI scores of all 28 subwatersheds.

Overall, IBI scores generally rated fair, ranging from 28 to 54 (Tables 9.4 and 9.5). In general, mainstem subwatershed sites scored better the tributary subwatershed sites. Sample sites with drainage >100 sq mi ranked fair or good, with the exception of Rees Ditch-Mississinewa River subwatershed (54 "excellent"). All of these sites were located on the Mississinewa River. Sample sites with drainage <100 sq mi had rankings of poor or fair, with the exception of Redkey Run-Halfway Creek subwatershed (good). Days Creek and Deer Creek were the most impaired with scores of 28. Back Creek scored 32 "poor" and Bear and Little Mississinewa River each scored 34 "poor." Three of the five subwatersheds that ranked "poor" had the smallest drainage areas in the study.

MACROINVERTABRATE COMMUNITIES: METHODOLOGY AND RESULTS
Macroinvertebrates were sampled according to the Indiana Department of Environmental Management's (IDEM) Multi-habitat Macroinvertebrate Collection Procedure (MHAB), for calculation of the macroinvertebrate Index of Biotic Integrity (mIBI). Each site was sampled once from July 17 to 23, 2014. Habitat assessments were conducted at each macroinvertebrate sampling event according to protocol for determination of Qualitative Habitat Evaluation Index (QHEI) scores (Rankin 1989). The mIBI scale can be found in Table 9.6 below. Figure 9.3 below represents the relative mIBI of all 28 subwatersheds.

Overal, mIBI scores generally rated as fair. In general, mainstem subwatershed sites scored better the tributary subwatershed sites. Scores were fair to good at sites on the Mississinewa mainstem, with the exception of Fetid Creek (30 poor). Branch Creek, Gray Branch, and Lake Branch had the highest scores, all 44 "good." Scores for the subwatersheds were mostly fair, with Little Deer Creek-Deer Creek rating the highest (48 good). Three subwatersheds had poor scores. Townsand Lucas Ditch-Big Lick Creek scored the lowest (24 poor). Little Lick Creek-Big Lick Creek and Lugar Creek scored 33 poor and 34 poor, respectively.

TABLE 9.6 | mIBI scores and narratives

Total Score	Narrative Rating
54-60	Excellent
44-53	Good
35-43	Fair
23-34	Poor
0-22	Very Poor

QHEI assessments conducted with mIBI generally rated from poor to fair. Sites with the lowest QHEI scores were Gray Branch, Days Creek, Little Lick Creek, and Halfway Creek. Sites with the highest QHEI scores were Campbell Creek, Deer Creek, Lugar Creek, Branch Creek, and Lake Branch. Back Creek, Campbell Creek, Deer Creek, Lugar Creek all had qualitative QHEI scores that were better than mIBI scores, indicating that water quality rather than habitat may be impacting macroinvertebrate communities more at these sites.

4 Holloway, D. Bureau of Water Quality. 2015. [web page] Annual Fish Community Report 2014. [Accessed 10 November 2015].

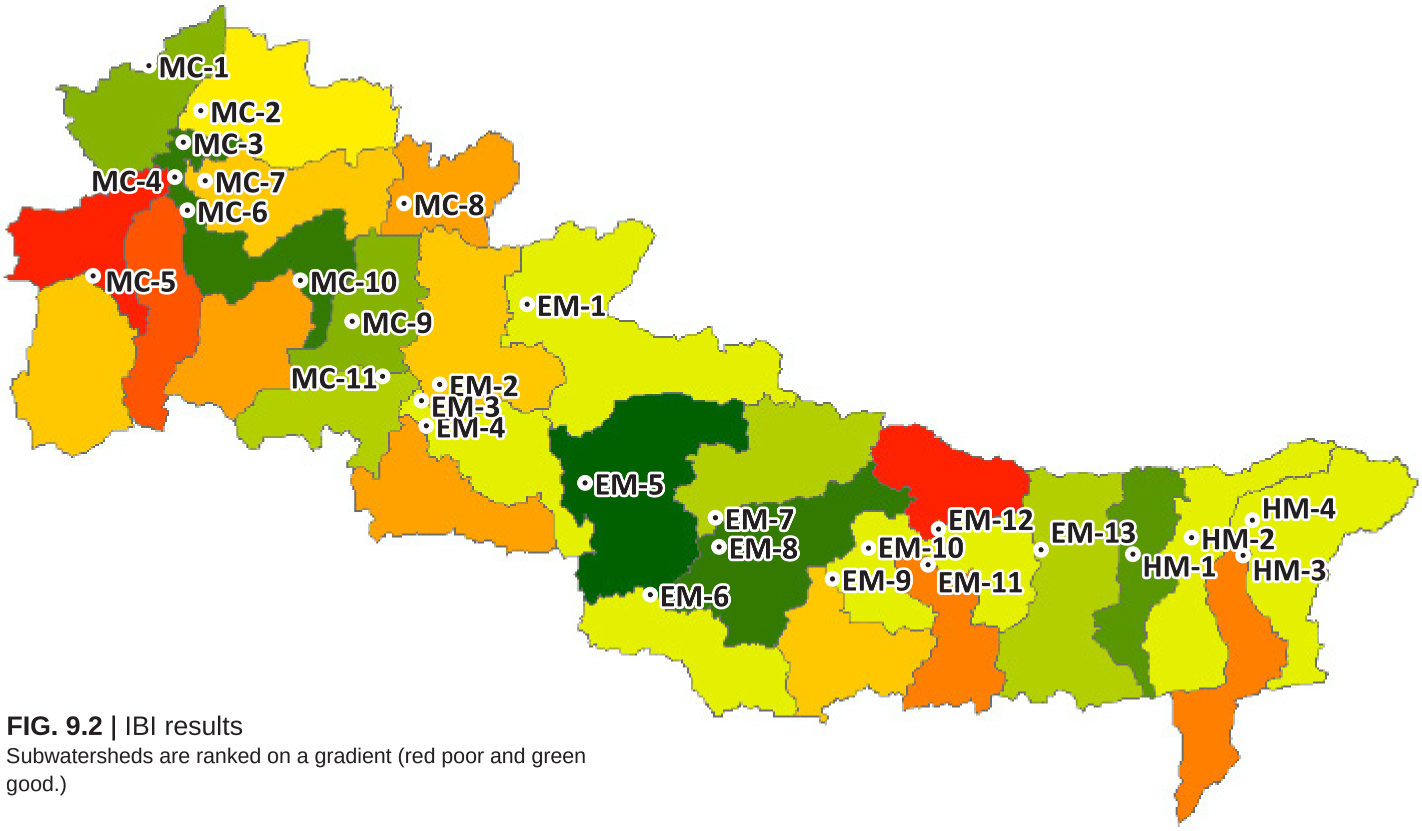


FIG. 9.2 | IBI results
Subwatersheds are ranked on a gradient (red poor and green good.)

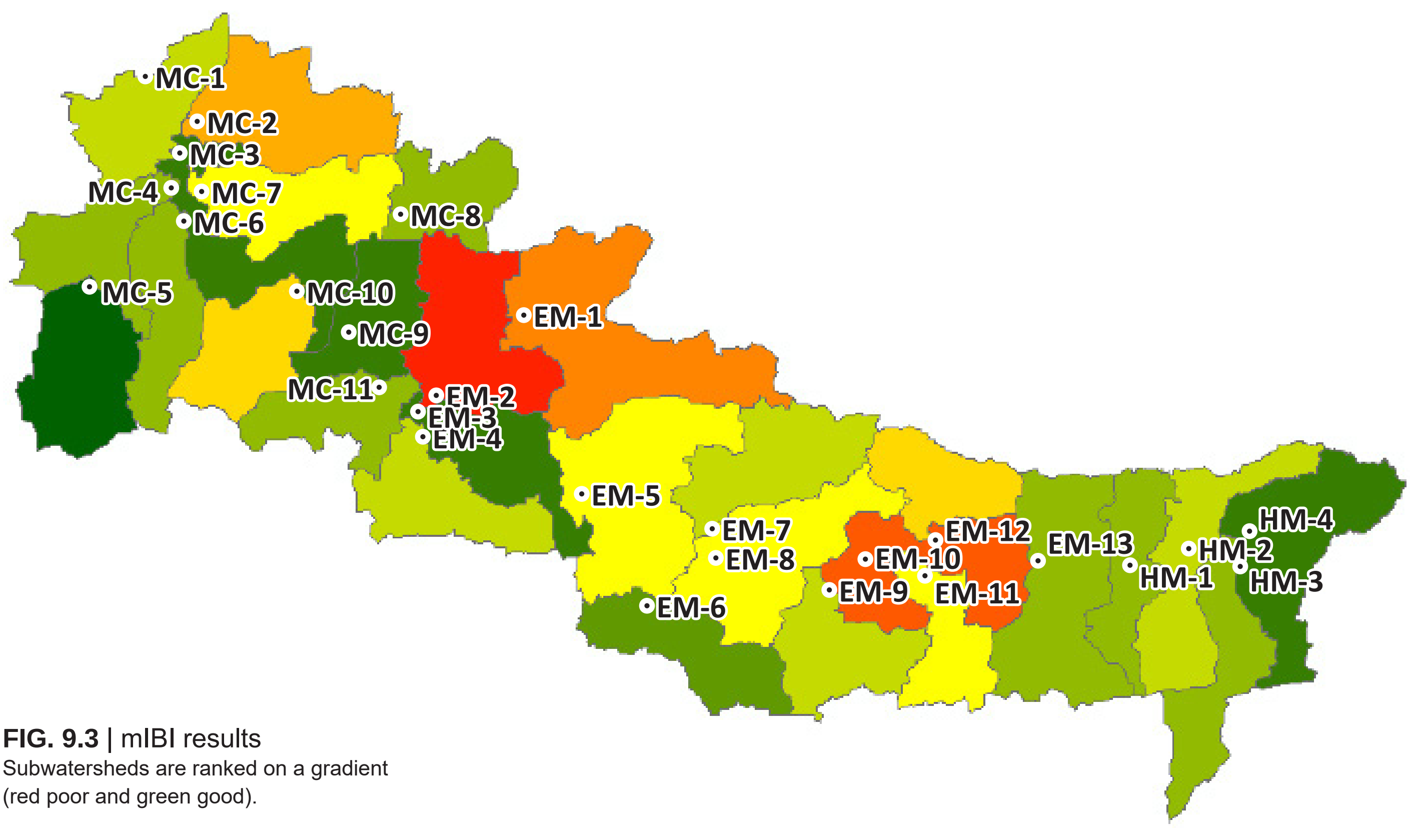


FIG. 9.3 | mIBI results
Subwatersheds are ranked on a gradient (red poor and green good).

HABITAT EVALUATION
As mentioned above, the Qualitative Habitat Evaluation Index (QHEI) was performed by both Muncie Bureau of Water Quality and IDEM at the same time biological assessments were conducted. The QHEI is used to evaluate the physical habitat and characteristics of a waterway with a six metric index including substrate, in-stream cover, channel, morphology, riparian zone and bank erosion, pool/glide and riffle/run quality, and the waterway gradient. The QHEI scores range from 0-100 (Table 9.10 on p. 128) and are used to determined if poor quality habitat is contributing stressors on aquatic biotic communities. QHEI data aids in interpretation and evaluation of habitat and macroinvertebrate data. Together, water quality, macroinvertebrate communities, and habitat analysis can help indicate the problem source of stream impairment. If habitat quality is high and macroinvertebrate community quality is low, then the problem source would likely be poor water quality and conversely if macroinvertebrate is low and water quality is inconclusive then it may indicate poor habitat. If both habitat and macroinvertebrate communities are impaired, discernment of the problem source becomes more difficult. QHEI was assessed at time of sampling for both macroinvertebrates and fish. Results are displayed in Table 9.7 below. An average QHEI was calculated. Four sites had good average QHEI scores. They were Campbell Creek, Deer Creek, Studebaker Ditch-Pike Creek, and Lake Branch. The following eight sites had poor average QHEI scores: Bear Creek, Days Creek, Little Lick Creek-Big Lick Creek, Little Walnut-Walnut Creek, Redkey Run-Halfway Creek,Townsand Lucas Ditch-Big Lick Creek, Fetid Creek-Mississinewa River, and Gray Branch-Mississinewa River. In Figure 9.5 on the following page, the average QHEI of all 28 subwatersheds are represented by a color gradient, with representing the lowest scores and green representing the highest.

TABLE 9.7 | QHEI results from the Bureau of Water Quality and IDEM

River/Stream	Site #	QHEI (mIBI)	QHEI Qual	QHEI (IBI)	QHEI Qual	QHEI Avg	QHEI Avg QUAL
Boots Creek-Mississinewa River	MC-1	65.5	Fair	66	Fair	65.75	Fair
Lugar Creek	MC-2	76	Good	65.5	Fair	70.75	Fair
Branch Creek-Mississinewa River	MC-3	74.25	Good	67.5	Fair	70.88	Fair
Deer Creek	MC-4	76	Good	70	Fair	73.00	Good
Little Deer Creek-Deer Creek	MC-5	47.75	Poor	58	Fair	52.88	Fair
Back Creek	MC-6	73.5	Good	65.5	Fair	69.50	Fair
Walnut Creek	MC-7	63.75	Fair	59	Fair	61.38	Fair
Little Walnut Creek-Walnut Creek	MC-8	48	Poor	52	Fair	50.00	Poor
Lake Branch-Mississinewa River	MC-9	74.4	Good	70	Fair	72.2	Good
Barren Creek	MC-10	58.25	Fair	56	Fair	57.13	Fair
Hoppas Ditch-Mississinewa River	MC-11	61.75	Fair	61.5	Fair	61.3	Fair
Little Lick Creek-Big Lick Creek	EM-1	43	Poor	56	Fair	50	Poor
Townsand Lucas Ditch-Big Lick Creek	EM-2	47	Poor	54	Fair	51	Poor
Holden Ditch-Mississinewa River	EM-3	58	Fair	74	Good	66	Fair
Studebaker Ditch-Pike Creek	EM-4	68	Fair	80	Good	74	Good
Rees Ditch-Mississinewa River	EM-5	52	Fair	88	Good	70	Fair
Campbell Creek	EM-6	75	Good	80	Good	78	Good
Redkey Run-Halfway Creek	EM-7	45	Poor	50	Poor	48	Poor
Platt Nibarger Ditch-Mississinewa River	EM-8	61	Fair	67	Fair	64	Fair
Bush Creek	EM-9	60	Fair	58	Fair	59	Fair
Fetid Creek-Mississinewa River	EM-10	49	Poor	44	Poor	47	Poor
Bear Creek	EM-11	47	Poor	37	Poor	42	Poor
Days Creek	EM-12	36	Poor	34	Poor	35	Poor
Mud Creek-Mississinewa River	EM-13	57	Fair	61	Fair	59	Fair
Porter Creek-Mississinewa River	HM-1	57	Fair	64	Fair	60.5	Fair
Jordan Creek-Mississinewa River	HM-2	63.5	Fair	54.5	Fair	59.00	Fair
Little Mississinewa River	HM-3	50.25	Poor	62.5	Fair	56.38	Fair
Gray Branch-Mississinewa River	HM-4	30.5	Poor	53	Fair	41.75	Poor

TABLE 9.8 | mIBI Results Drainage >100 sq. mi.			
Drainage >100 sq. mi.	Site #	mIBI	mIBIQual
Boots Creek-Mississinewa River	MC-1	40	Fair
Branch Creek-Mississinewa River	MC-3	44	Good
Lake Branch-Mississinewa River	MC-9	44	Good
Hoppas Ditch-Mississinewa River	MC-11	42	Fair
Holden Ditch-Mississinewa River	EM-3	44	Fair
Rees Ditch-Mississinewa River	EM-5	38	Fair
Platt Nibarger Ditch-Mississinewa River	EM-8	38	Fair
Fetid Creek-Mississinewa River	EM-10	30	Poor
Mud Creek-Mississinewa River	EM-13	42	Fair

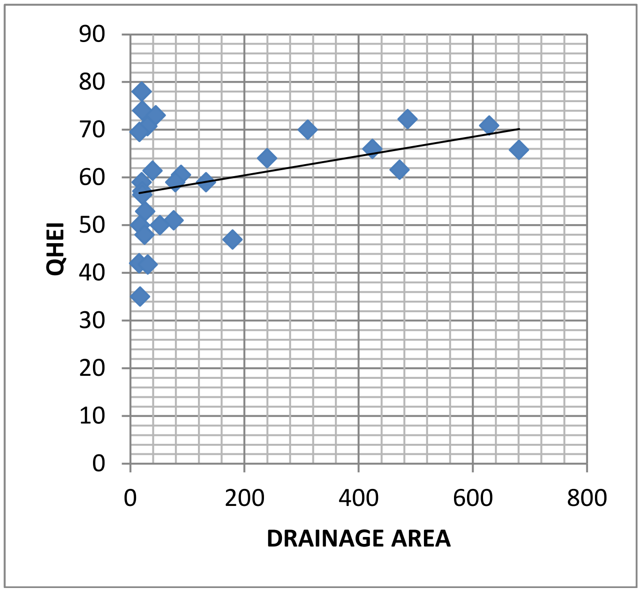


FIG. 9.4 | Relationship between QHEI and drainage area

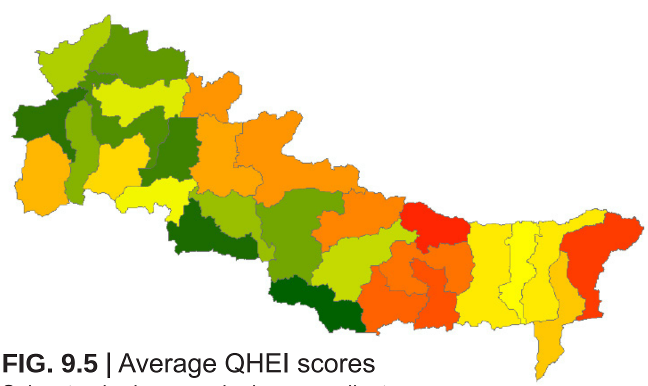


FIG. 9.5 | Average QHEI scores
Subwatersheds are ranked on a gradient (red poor and green good).

TABLE 9.9 | mIBI Results Drainage <100 sq. mi.			
Drainage <100 sq. mi.	Site #	mIBI	mIBIQual
Lugar Creek	MC-2	34	Poor
Deer Creek	MC-4	42	Fair
Little Deer Creek-Deer Creek	MC-5	48	Good
Back Creek	MC-6	42	Fair
Walnut Creek	MC-7	38	Fair
Little Walnut Creek-Walnut Creek	MC-8	42	Fair
Barren Creek	MC-10	36	Fair
Little Lick Creek-Big Lick Creek	EM-1	33	Poor
Townsand Lucas Ditch-Big Lick Creek	EM-2	24	Poor
Studebaker Ditch-Pike Creek	EM-4	40	Fair
Campbell Creek	EM-6	43	Fair
Redkey Run-Halfway Creek	EM-7	40	Fair
Bush Creek	EM-9	40	Fair
Bear Creek	EM-11	38	Fair
Days Creek	EM-12	36	Fair
Porter Creek-Mississinewa River	HM-1	42	Fair
Jordan Creek-Mississinewa River	HM-2	40	Fair
Little Mississinewa River	HM-3	42	Fair
Gray Branch-Mississinewa River	HM-4	44	Good

TABLE 9.10 | QHEI scores and narratives. Headwaters have drainage areas equal to or less than 20 sq. mi.		
Narrative Rating	QHEI Range	
	Headwaters	Larger Streams
Excellent	> 70	> 75
Good	55- to 69	60 to 74
Fair	43 to 54	45 to 59
Poor	30 to 42	30 to 44
Very Poor	< 30	< 30

*Ohio EPA's "Methods for Assessing Habitat in Flowing Waters: Using the Qualitative Habitat Evaluation Index (QHEI)"

CONCLUSIONS OF CURRENT ASSESSMENTS

Sites on the Mississinewa River generally scored the higher for all three indices (IBI, mIBI and QHEI) than did tributary subwatersheds (Table 9.12). This may be due to differences in drainage area as suggested by research conducted by the Muncie Bureau of Water Quality. Figure 9.4 shows the relationship between QHEI and drainage area; in general, as drainage area increases, so does habitat quality. In turn, better quality habitat should produce healthier biological communities. Again, the Mississinewa river scored higher in general than tributary sites. Table 9.8 and 9.9 show mIBI scores for sites with drainage areas greater than 100 sq. mi. and less than 100 sq. mi., respectively.

Correlation seemed to be strongest between mIBI and QHEI at sites with the largest drainage areas (mainstem Mississinewa River sites). The QHEI scores were the same as mIBI scores at these sites (with the exception of Gray Branch, which has a drainage area similar to the tributary subwatersheds). IBI at these sites seemed to be less influenced by habitat quality. 78% of sites with fair QHEI scores had good IBI scores. For the tributary subwatershed sites, QHEI and IBI had the opposite relationship in general. 31% of these sites had worse IBI scores than their QHEI scores (as compared to 8% for mainstem sites). Similarly, 37% of these sites had worse mIBI scores than their QHEI scores. These results suggest that chemical and physical water quality may have more influence on sites with smaller drainage areas.

In all, nine sites had biological ratings of poor. Only one of these sites was located on the Mississinewa River (within the Fetid Creek subwatershed). Table 9.11 lists all subwatershed sites that had biological ratings of poor.

Since IBI results are influenced by QHEI and water chemistry, IBI and QHEI scores were compared. Bear Creek and Days Creek had both poor QHEI scores and poor IBI scores. This is to be expected as there is generally a positive correlation between QHEI and IBI. However, Back Creek, Deer Creek, and Little Mississinewa River all had fair QHEI scores and poor IBI scores. This suggests that fish communities may be more limited by chemical water quality rather than habitat quality at these sites, while fish communities in Bear and Days Creek may be more limited by habitat quality. The average qualitative QHEI's were the same as each site's qualitative QHEI for IBI.

Comparisons of QHEI to mIBI can also be made. At sites that had poor mIBI, Townsend-Lucas Ditch-Big Lick Creek, Fetid Creek-Mississinewa River, and Little Lick Creek-Big Lick Creek all had both poor QHEI scores and poor mIBI scores. Lugar Creek had a poor mIBI score and a good QHEI score, again suggesting that poor chemical water quality is limiting macroinvertebrate communities at this site.

TSS levels may be a cause of poor biological scores measured on the Little Mississinewa River, Lugar Creek, and Back Creek. Sediment is known to clog fish gills and impede oxygen exchange. Average TSS concentration calculated from samples collected at all of these sites exceeded TSS standards.

TABLE 9.11 | Subwatersheds with poor biological scores

Subwatersheds with IBI score of Poor	Mainstem Subwatersheds with IBI score of Poor	Subwatersheds with mIBI score of Poor	Mainstem Subwatersheds with mIBI score of Poor
Days Creek Deer Creek Back Creek Bear Creek Little Mississinewa River	none	Townsand Lucas Ditch-Big Lick Creek Little Lick Creek-Big Lick Creek Lugar Creek	Fetid Creek

TABLE 9.12 | Biological and habitat results*

Name	mIBI	mIBIQual	QHEI	QHEIQual	IBI	IBIQual	QHEI	QHEIQual	QHEIAvg	QHEIAvgQUAL
Back Creek	42	Fair	73.5	Good	32	Poor	65.5	Fair	69.5	Fair
Barren Creek	36	Fair	58.25	Fair	36	Fair	56	Fair	57.125	Fair
Bear Creek	38	Fair	47	Poor	34	Poor	37	Poor	42	Poor
Bush Creek	40	Fair	60	Fair	38	Fair	58	Fair	59	Fair
Campbell Creek	43	Fair	75	Good	42	Fair	80	Good	78	Good
Days Creek	36	Fair	36	Poor	28	Poor	34	Poor	35	Poor
Deer Creek	42	Fair	76	Good	28	Poor	70	Fair	73	Good
Little Deer Creek-Deer Creek	48	Good	47.75	Poor	38	Fair	58	Fair	52.875	Fair
Little Lick Creek-Big Lick Creek	33	Poor	43	Poor	42	Fair	56	Fair	50	Poor
Little Mississinewa River	42	Fair	50.25	Poor	34	Poor	62.5	Fair	56.375	Fair
Little Walnut Creek-Walnut Creek	42	Fair	48	Poor	36	Fair	52	Fair	50	Poor
Lugar Creek	34	Poor	76	Good	40	Fair	65.5	Fair	70.75	Fair
Redkey Run-Halfway Creek	40	Fair	45	Poor	46	Good	50	Poor	48	Poor
Studebaker Ditch-Pike Creek	40	Fair	68	Fair	36	Fair	80	Good	74	Good
Townsand Lucas Ditch-Big Lick Creek	24	Poor	47	Poor	38	Fair	54	Fair	51	Poor
Walnut Creek	38	Fair	63.75	Fair	38	Fair	59	Fair	61.375	Fair
Name	mIBI	mIBIQual	QHEI	QHEIQual	IBI	IBIQual	QHEI	QHEIQual	QHEIAvg	QHEIAvgQUAL
Fetid Creek-Mississinewa River	30	Poor	49	Poor	42	Fair	44	Poor	47	Poor
Gray Branch-Mississinewa River	44	Good	30.5	Poor	42	Fair	53	Fair	41.75	Poor
Holden Ditch-Mississinewa River	44	Fair	58	Fair	42	Fair	74	Good	66	Fair
Jordan Creek-Mississinewa River	40	Fair	63.5	Fair	42	Fair	54.5	Fair	59	Fair
Hoppas Ditch-Mississinewa River	42	Fair	61.75	Fair	46	Good	61.5	Fair	61.625	Fair
Mud Creek-Mississinewa River	42	Fair	57	Fair	46	Good	61	Fair	59	Fair
Boots Creek-Mississinewa River	40	Fair	65.5	Fair	48	Good	66	Fair	65.75	Fair
Lake Branch-Mississinewa River	44	Good	74.4	Good	48	Good	70	Fair	72.2	Good
Porter Creek-Mississinewa River	42	Fair	57	Fair	50	Good	64	Fair	60.5	Fair
Branch Creek-Mississinewa River	44	Good	74.25	Good	52	Good	67.5	Fair	70.875	Fair
Platt Nibarger Ditch-Mississinewa River	38	Fair	61	Fair	52	Good	67	Fair	64	Fair
Rees Ditch-Mississinewa River	38	Fair	52	Fair	54	Excellent	88	Good	70	Fair

*The color gradient follows the visible spectrum: reds to oranges to yellows to greens. The highest values are represented by green and lowest values by red. Higher biological and habitat scores indicate higher quality biological communities and habitats. Lower biological scores indicate low quality biological communities and habitats.

10. SUBWATERSHED DISCUSSIONS

This section contains detailed individual analysis of each of the five HUC 10 watersheds within the Upper Mississinewa River Watershed. These analyses synthesize data from the Watershed and Water Quality Inventories.

The Project Manager felt that it wasn't feasible or worthwhile to create separate subwatershed discussions for all 28 HUC 12 subwatersheds that were part of this study. The Project Manager felt that is was possible to discuss all of the major geographical and land use characteristics affecting water quality at the HUC 10 scale. This is due to the fact that many of these characteristics are somewhat distinct in each HUC 10 subwatershed. Rather than each HUC 10 being a homogenous mixture of the same characteristics, one or more distinct characteristics stand out for each HUC 10 as major drivers of water quality. Therefore, the Project Manager felt that the most relevant information is being effectively discussed and outlined in these sections. For example, Headwaters Mississinewa generally has the highest concentration of cropland in the watershed. Fertilizer usage here is driving up nitrate averages in waterways. CFO concentration is also highest here, which is driving E. coli levels during high flow. Conventional tillage concentration also generally follows HUC 10 lines, with conventional tillage being the most concentrated in Big Lick Creek and Massey Creek HUC 10's. Conventional tillage is driving TSS levels in these watersheds and is of concern in them. While E. coli is an impairment in all HUC 10s, somewhat discrete population densities and CFO densities allow for focus to be split between the two different sources of E. coli: animal waste and human waste. The two eastern HUC 10's generally have low population densities and high concentrations of CFOs. Conversely, the three western HUC 10's generally have high population densities and low concentrations of CFOs.

Further justification for HUC 10 analysis is the fact that HUC 10's roughly follow county lines. Therefore, major geographical and land use characteristics affecting water quality in the UMRW roughly follow county lines. Because of this, this scale of analysis will be very useful to local government entities working to reduce nonpoint source pollution. For example, efforts to reduce conventional tillage in Blackford and Grant counties would be an effective strategy for reducing TSS.

Within each of the following discussions, subwatershed parameter averages from this study are displayed in a table for each HUC 10. The eight parameters shown in the tables are E. coli, Total phosphorus, Nitrate[N], Total Suspended Solids, QHEI, IBI, mIBI, and dissolved oxygen. If the average value for each parameter, based on data from this study, exceeded the target, then the average was highlighted in yellow. For comparative purposes, the sum of these exceedances was divided by the number of subwatersheds in the HUC10, resulting in an average number of exceedances per subwatershed. This equation is shown below.

$$\text{Average Exceedance per Subwatershed} = \frac{\text{Total Number ofTimes the Parameter Average Exceeded the Target}}{\text{Total Number of Subwatershed in HUC 10}}$$

The following is an example of this calculation is for Big Lick Creek:

$$6.5 = \frac{13}{2}$$

Table 10.1 below shows the average exceedance per subwatershed. The most average exceedences a HUC10 can have is eight, because there are only eight parameters. As you can see, some watersheds were exceeding for nearly every parameter, while others were exceeding for only a few. This method and Table 10.1 was included to allow for a very basic comparison of the five HUC 10's.

In the following HUC 10 discussions, HUC 10's will be referred to as *watersheds* in order to differentiate them from the HUC 12 subwatersheds that are within them.

TABLE 10.1 | Average exceedances per subwatershed

HUC 10 Watershed	Average Exceedances Per Subwatershed
Big Lick Creek	6.5
Headwaters Mississinewa River	4.2
Halfway Creek	3.5
Massey Creek	3.1
Pike Creek	2.25

10.1 BIG LICK CREEK HUC 10

Big Lick Creek HUC 10 (0512010303; 48,798 acres) contains two HUC 12 subwatersheds: Townsand Lucas Ditch Subwatershed (051201030302) and Little Lick Creek Subwatershed (051201030301). A majority of the watershed acreage is located in Blackford County (84%), with portions including Jay (6%), Delaware (8%) and Grant (2%) counties. The watershed begins in central Blackford county and drains southwesterly into northern Delaware County, where Big Lick Creek empties into the Mississinewa. The northern moraines run through the southwest portion of the subwatershed. This morainal region is characterized by varying topography. An average of specific geomorphic characteristic rankings predict low to moderate sediment transport potential for the watershed. The average grade change of the HUC 12 subwatersheds within this HUC 10 is 108 feet. There is a gross estimate of 9.59 billion cubic yards of unconsolidated aquifers in the watershed.

CURRENT WATER QUALITY AND HABITAT QUALITY SUMMARY

DATA COLLECTED FOR THIS WATERSHED MANAGEMENT PLAN[1]

Water quality sampling was conducted at two locations, with one in each of the two HUC 12 subwatersheds within Big Lick Creek HUC 10. Sites were sampled monthly from 2014-2015 by IDEM. Table 10.2 depicts water quality results for each parameter as well as the water quality target for each parameter. Water quality results show the average of all water quality data collected for each parameter, regardless of flow conditions at the time of sampling. Averages highlighted in yellow exceed the parameter water quality target set by the Project Manager. Both subwatersheds in the Big Lick Creek HUC 10 exceeded water quality targets for the following parameters: E. coli, total phosphorus, nitrate, total suspended solids, average QHEI, and mIBI. The only parameter for which they did not both exceed the target was IBI. Only Townsand Lucas Ditch did not meet the target for dissolved oxygen. In all, there were 13 exceedences for an average of 6.5 exceedences per subwatershed. This is the highest subwatershed exceedence average of all HUC 10's within the UMRW.[2]

TABLE 10.2 | Big Lick Creek HUC 10 subwatershed data exceeding water quality targets

Sample Site	E. coli (cfu/100mL)		Total Phosphorus (mg/L)		Nitrate [N] (mg/L)		Total Suspended Solids (mg/L)		Avg QHEI (Habitat Quality)		IBI (Fish Community Quality)		mIBI (Macro-invertebrate Community Quality)		Dissolved Oxygen Minimum (mg/L)	
	Avg	Target	Avg	Target	Avg	Target	Avg	Target	Score	Qual.	Score	Qual.	Score	Qual.	Min.	Target Min.
HUC pour point	3972	235	0.34	0.3	1.9	1	29.9	25.0	51	Poor	38	Fair	24	Poor	3.48	4
Subwatersheds																
Townsand Lucas Ditch (Big Lick Creek)	3972	235	0.34	0.3	1.9	1	29.9	25.0	51	Poor	38	Fair	24	Poor	3.48	4
Little Lick Creek (Upper Big Lick Creek)	4030	235	0.38	0.3	2.1	1	25.1	25.0	50	Poor	42	Fair	33	Poor	6.42	4

DRAFT TOTAL MAXIMUM DAILY LOAD (TMDL) REPORT FOR THE UPPER MISSISSINEWA RIVER WATERSHED

A draft TMDL report (Total Maximum Daily Load) was generated by IDEM (Indiana Department of Environmental Management) using water quality data the agency collected from 2014-2015 (in conjunction with the water quality data collected for this watershed management plan). In all, sampling was carried out at 35 sites within twelve HUC 12 subwatersheds. Nine sites within Big Lick Creek HUC 10 were sampled. The following chemical water quality parameters were analyzed: phosphorus, dissolved oxygen, TSS, and E. coli. IDEM sites were generally sampled from April 2014 to March 2015, but not every site was sampled every month. IDEM's mean sampling frequency for months sampled during the sampling year was 9.5 months and median sampling frequency was 10 months. The number of months sampled ranged from 7 to 11 months. E. coli was sampled weekly for over a period of 5 weeks at each site from April to May. Fish and macroinvertebrates were also sampled once between June and October 2014.

Within the draft TMDL report, the restoration potential of the HUC 12 subwatersheds was assessed. These twelve subwatersheds comprise three out of the five HUC 10 watersheds included in this plan (Big Lick HUC 10, Halfway Creek HUC 10, and Pike Creek HUC 10). This assessment of restoration potential takes into account a number of indicators, including biological and habitat scores. Subwatersheds with the highest restoration potential were also ranked as the highest potential priority implementation areas (PPIAs) in the draft TMDL. The draft TMDL recommends that these PPIAs be taken into consideration during the critical area selection process of this WMP.

1 Methods, sampling agency/group, etc. are discussed on p. 106 through 110. The following paragraph and table summarize results from Section 8, *Current Water Quality*, and Section 9, *Biological Assessments*.

2 Some of the raw data for this analysis was obtained from IDEM and was collected as part of IDEM's TMDL of the Upper Mississinewa.

Results of IDEM's draft TMDL report indicate that Townsand Lucas Ditch (Big Lick Creek) and Little Lick Creek rank 7 and 12, respectively, on the PPIA list. "Implementation activities for the highest ranked PPIAs [...] should focus on wet weather sources as the critical conditions in these subwatershed tend to center on wet weather flows." [3]

Although some data from the IDEM TMDL was used by the Project Manager in the independent analysis of water quality for this study (Table 10.2), water quality results presented in the Table 10.2 do not include data from all 35 sites monitored as part of the TMDL. Rather, data from sites near HUC 12 pour points was used; this was consistent with HUC 12 sample sites analyzed in the two HUC 10 subwatersheds not monitored as part of the TMDL. The following is a report and summary of data that pertains to concerns from all IDEM TMDL sites within Big Lick Creek HUC 10:

Biological, habitat and water quality assessments were performed at sites on Little Lick Creek, Big Lick Creek, Townsand Lucas Ditch, Little Joe Creek, and Moore Prong Creek.

- Biological scores (for both mIBI and IBI) rated either very poor, poor, or fair. Site T38 on Little Lick Creek had the worst biological scores, with an mIBI rating of poor and an IBI rating of very poor. Both QHEI scores rated very poor for this site. This site is just downstream of Hartford City. Biological ratings and QHEI ratings are both better at site T40 upstream (suggesting that sources or habitat quality within the city are lowering the quality of the water).
- Traveling from upstream to downstream along Big Lick Creek, there is a decrease in mIBI scores from one site to the next (over a total of four sites).
- Townsand Lucas Ditch (site T34) had scores that rated poor for both biological assessments. However, its QHEI scores rated good. Comments on the sampling sheet for this ditch indicated that interstitial pools and isolated pools were present during two separate sampling events in August. These drier conditions at certain times of the year could possibly limit biological communities.

- TSS was above target at all sites, generally needing a 65% to 85% reduction.
- Sites needing the highest percent reduction (based on the maximum concentration for a single sample) of total suspended solids also had the largest drainage areas (suggesting that in general TSS increased from upstream to downstream).
- Site T22, on Big Lick Creek northwest of Dunkirk, needed the lowest percent reduction of TSS (39%).

- Dissolved oxygen levels met the target at most sites.
- Sites T40 and T38 on Little Lick Creek were both more than 25% below the water quality standard for the minimum concentration of dissolved oxygen.

- The highest concentration of phosphorus was measured along Big Lick Creek. However, the percent reduction needed dropped from 69% near the headwaters to 17% near the pour point. These results may be due to dilution.
- Maximum concentrations of phosphorus from sites T38 and T40 along Little Lick Creek indicated that significant reductions may be needed at these sites as well. The maximum concentration of phosphorus in Little Lick Creek increased through Hartford City.
- Both Townsand Lucas Ditch (site T34) and Little Joe Creek (site T35) were below target, suggesting that no reductions in phosphorus are needed on these streams.

- All sites require reductions in E. coli based on the target for the calculated geometric mean.
- Little Joe Creek (site T35) had the highest percent reduction needed for E. coli (97%).

SUMMARY OF HISTORICAL WATER QUALITY STUDIES

303(D) LIST OF IMPAIRED WATERS, 2014

Waterways have been monitored as part of IDEM's 303(d) assessment. Impairments were found for E. coli on 6.82 miles of Little Lick Creek and 3.43 miles of Big Lick Creek.

LAND USE SUMMARY

Historic Conditions

Similar to other watersheds, the historic/natural conditions of the site were dominated by forest-wetlands and diffuse streams and rivers. There are 17,641 acres of hydric soils, making the historic presence of wetlands on these soils likely (36% of the watershed). The majority of soil types are ranked as moderately or poorly drained with 34,854 acres of NRCS category C soils and 17,205 acres of NRCS category D soils. There are 3,616 acres of land in the watershed (7%) that is considered prime ecological land due to its geomorphic and historical conditions. Some of this land is within urban areas or currently being farmed. There are 36 miles of National Hydrography Dataset mapped streams within the watershed. Data gather during a desktop survey indicated that an estimated thirty-three percent of these tributaries (12 mi.) need buffering (Table 10.4). Major streams include Big Lick Creek (6.2 mi.) and Townsand Lucas Ditch (5.5 mi.). Data from a desktop survey of the watershed can be found in Tables 10.3 and 10.4. For this desktop survey, various land use attributes were counted or measured using Google Earth. They include rills/gullies, construction sites, fertilized lawns, sports fields, runoff sites, erosion sites, and vehicle storage sites.

3 IDEM TMDL

TABLE 10.3 | Desktop Survey Results									
HU_12_NAME	Rills/Gullies	Rills/Gullies per cropland acre	Fertilized Lawns	Sport Fields	Bank Erosion sites	Runoff sites*	Junk storage sites	Sites where livestock are accessing stream	Mobile home sites
Little Lick Creek-Big Lick Creek	18592	0.81	103	18	22	25	25	4	21
Townsand Lucas Ditch-Big Lick Creek	9256	0.66	47	1	15	27	10	9	7
Total	27848	0.75	150	19	37	52	35	13	28

*Runoff sites are sites where rills/gullies are draining directly into waterways.

TABLE 10.4 | Desktop Survey Results								
HU_12_NAME	Tracks from recreational vehicles	Vehicle storage sites	Miles of NHD tributaries needing buffers	NHD tributaries needing buffers (percent)	Construction sites for new development	Quarry sites	Golf Courses	Derelict properties
Little Lick Creek-Big Lick Creek	3	11	6.23	34%	5	0	0	3
Townsand Lucas Ditch-Big Lick Creek	0	8	5.61	31%	3	0	3	3
Total	3	19	11.84	33%	8	0	3	6

Urban Population

The total population within the watershed is 10,697 with a population density of 140 persons per sq mi. While the majority of the population (82%) live in the incorporated towns of Hartford City (pop: 6,924), Dunkirk (pop: 1,689) and Shamrock Lakes (pop: 168) an additional 18% (1,917) of the population lives in diffuse areas throughout the watershed. There are 15 CSOs active in the watershed, all located within Hartford City. Both Big Lick Creek and Little Lick Creek have CSO discharge points along them. According to the 2010 census, there are approximately 4,730 housing units in the watershed. Based on known populations in urban areas (8,780) and rural areas (1,916), well count (555), and average household size for the region (2.25), it is estimated that there are 854 houses in non-incorporated areas using septic systems. Many of these rural homes are built in suburban developments or in high concentration areas outside incorporated towns. There are 818 acres of these septic "hot spots" located in the watershed, while there are only 175 total acres that are suitable for septics within the watershed. The urban area footprint includes 4,700 acres with an estimated impervious surface footprint of 912 acres. No areas slated for development were identified. There are 110 regulated point sources in the subwatershed, no brownfields and one voluntary remediation site. The subwatershed also includes eight landfill structures, one industrial park, and no ethanol plants. Of the 3,551 workers who live in the subwatershed area, 3,158 (89%) travel out of the subwatershed for work. The highest concentration of jobs that do remain are in the manufacturing, educational services and health care and social assistance sectors respectively.

Agriculture

The Big Lick Creek watershed consists of 76% cultivated cropland and 10% developed land (Map 10.1). Of the cultivated cropland, 59% (21,754 acres) is conventional tillage corn crops. Nineteen percent (7,143 acres) is conventional tillage soybean cropland (calculated based on the % tillage of each county transect data). Due to the amount of agricultural lands and particular types of tillage practices, there is an estimated 144,486 tons of sediment, 303 tons of nitrogen, and 81 tons of phosphorus discharged to the Mississinewa River annually.[4] These estimates are based on estimated fertilizer use on agricultural cropland (generated using the Export Coefficient Model). Throughout the study region, livestock grazing is limited due to the regional trend towards Combined Feeding Operations. There are 8 CFOs in the subwatershed and thirteen livestock access points to waterways were counted through a desktop surveys.

Ecological Areas and Open Spaces

There are 7,010 acres of existing ecological areas[5] in the watershed; a majority of this land is located in the watershed's 1,677 acres of floodplain. Big Lick Creek HUC 10 does not contain any of the Mississinewa River. Various types of open space exist within the watershed. Hartford City has five municipal parks, including Wilderness Park which contains a 1.5 mile recreational trail. Funding from the Bicentennial Nature Trust recently made the expansion of this park possible; it now covers 40 acres. Hartford City also has two community gardens, the Conger Street Garden and the Mill Street Garden, that have been created by the nonprofit Tori's Butterfly Garden Foundation, Inc in partnership with the city. There are four schools that have playgrounds and/or schoolyards. Seven cemeteries of various sizes are mainly located near the towns of Hartford City and Dunkirk. Three golf courses within the watershed offer additional recreational opportunities.

4 See Taylor University study for a more complete projection of sediment contribution.

5 In this watershed plan, forests, wetlands, grasslands, and pastures are considered "ecological lands."

SUMMARY OF DATA FROM REGULATED LAND USES

Various regulated land uses exist within the watershed. Data from the IDEM Virtual File Cabinet and from the IDEM SSO website was reviewed to determine the impact of these land uses on water quality. Although some overflows occurred during the time of this study, the Project Manager determined that these regulated point sources did not significantly impact water quality. Raw water quality data collected for this study was examined according to the dates on which violations occurred in order to make this determination.

SSO Overflows

Sanitary sewer systems (SSOs) are different from combined sewer systems (CSOs) in that they are designed to only convey sanitary wastewater and are not designed to also convey stormwater, as is a CSO. A list of SSO sewer bypass/ overflow incidents can be accessed on the website of the Indiana Department of Environmental Management. The lists for 2014 and 2015 were reviewed for facilities within Big Lick Creek HUC 10. These incidents *do not* include normal precipitation related discharges from authorized CSO outfalls.

There were 8 Sewer Bypass/Overflow Incident Reports at the Hartford City Waste Water Treatment Plant from January 1, 2014 to December 31, 2015 resulting in a discharge to surface waters, totaling 1,234,001gallons and two from Hartford Iron and Metal, resulting in a discharge to surface waters, totaling 850 gallons. The closest IDEM TMDL water quality sampling date was 25 days following an incident. Therefore, it is assumed that the overflow would not have been detected by project sampling. For data on these overflows, see Appendix V.

Sewage Sludge Disposal

According to the EPA ECHO website, all sludge from Hartford City WWTP is taken to a landfill for disposal. According to heavy metal test results for the sludge, there were numerous heavy metal present in it.

BIG LICK CREEK HUC10 WATERSHED CONCERNS

There were a number of stakeholder concerns identified for Big Lick Creek (Table 10.5). Many of these concerns have been validated by linking water quality data to desktop survey data and information from the watershed inventory. Through the synthesis of water quality data and watershed inventory data, causes were linked with sources. In most cases, these sources were identical to initial concerns. The following is a summary of the most significant characteristics of this watershed as they relate to water quality:

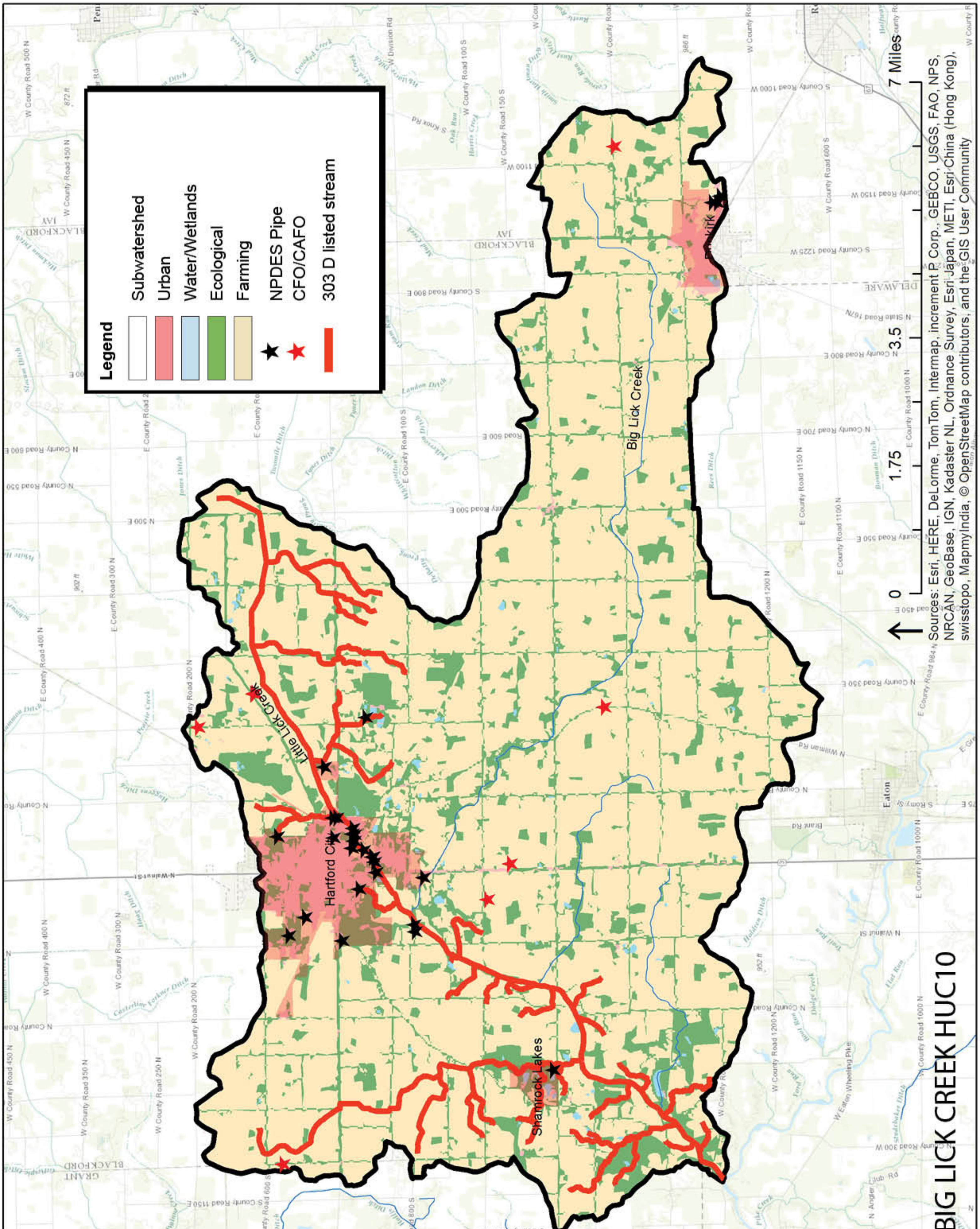
Big Lick Creek HUC 10 has two large urban areas but the land use is predominately cropland. For both sample sites, average concentrations of each parameter exceeded targets (with the exception of dissolved oxygen measured at Little Lick Creek).

Sources of nitrates and phosphorus found in surface water include agricultural fertilizers, livestock accessing waterways (Table 10.3), and field application of manure from CFOs. Urban areas may also be a source of nitrates and phosphorus found in surface water. Based on data from the desktop survey, the watershed has some of the highest numbers of fertilized lawns, sports fields, and golf courses in the watershed (Tables 10.3 and 10.4). Proper fertilization of turf should be promoted in this watershed. Other urban sources of nutrients include CSOs and failing septic systems.

Because phosphorus binds with soil particles, sources of TSS may also be sources of phosphorus. These sediment sources include high concentrations of rill and gully formations (Table 10.3), high levels of conventional tillage throughout the watershed, and bank erosion (Table 10.3). The watershed has a relatively high amount of highly erodible soils, which makes conventionally tilled fields more susceptible to surface erosion. BMPs that can address these issues include grassed waterways, filter stips, cover crops, and no-till equipment modification.

Urban areas are likely the main source of E. coli impairment within Big Lick Creek HUC 10. Hartford City has 15 CSOs, which are known to discharge untreated sewage during high rain events. A high number of septic systems, which are known to pollute waters with E. coli during low flow conditions (as well as high flow conditions), are present within the watershed. Agriculture has also likely contributed to E. coli impairments. The watershed has one of the highest numbers of observed livestock direct access points to streams in the UMRW, with 4 in Little Lick Creek subwatershed and 9 in Townsand Lucas Ditch subwatershed (Table 10.3). Many of these are located in the southwest to central part of the watershed. Land application of animal waste is another possible source of E. coli to waterways; eight CFOs are present in Big Lick Creek HUC 10.

TABLE 10.5 | Big Lick Creek HUC 10 watershed concerns		
Concerns	Cause of Concern	Subwatershed
Public Concerns		
Surface erosion on farm fields and covercrop usage	High TSS levels	Not specified
Erosion of waterways and headcuts in waterways	High TSS levels	Not specified
Land application of animal waste	High E. coli levels	Not specified
Project Manager Concerns		
High levels of conventional tillage	High phosphorus levels	Townsand Lucas Ditch-Big Lick Creek and Little Big Lick Creek
High levels of conventional tillage, high concentrations of rills and gullies, inadequate stream buffers in some areas	High TSS levels	Townsand Lucas Ditch-Big Lick Creek and Little Big Lick Creek
Combined sewage overflow system in Hartford City, failing septic systems, land application of manure, livestock in streams	High E. coli levels	Townsand Lucas Ditch-Big Lick Creek and Little Big Lick Creek
Combined sewage overflow system in Hartford City, septic systems, land application of manure	High nitrate levels	Townsand Lucas Ditch-Big Lick Creek and Little Big Lick Creek
Poor quality habitat	Poor biological scores (mIBI), poor QHEI scores	Townsand Lucas Ditch-Big Lick Creek and Little Big Lick Creek
Poor biological communities	Poor mIBI scores	Townsand Lucas Ditch-Big Lick Creek and Little Big Lick Creek



MAP 10.1 | Big Lick Creek HUC 10 Watershed

10.2 HALFWAY CREEK HUC 10

The HUC 10 Halfway Creek watershed (0512010302; 87,114 acres) contains 6 HUC12 subwatersheds: Bear Creek (051201030202), Bush Creek (051201030204), Days Creek (0512010301), Fetid Creek (051201030203), Platt Nibarger Ditch (051201030206) and Redkey Run Halfway Creek (051201030205). Two of these, Platt Nibarger Ditch and Fetid Creek, contain significant portions of the Mississinewa River. Halfway Creek HUC 10 is located in the east central part of the Upper Mississinewa River Watershed (UMRW). A majority of the watershed acreage is located in Randolph County (62.5%) with portions including Jay County (29.9%) and Delaware County (7.6%). The Mississinewa runs from east to west through the watershed, beginning west of State Road 27 in Randolph County and continuing to just south of Albany, where it continues its flow into the Pike Creek HUC 10 watershed.

Halfway Creek HUC 10 is located adjacent to the northern moraines and subsequently has a high concentration of topographic change. Geomorphic characteristic rankings for drainage density (Dd), stream frequency (Fu), and relief ratio (Rr) vary among the subwatersheds within this HUC10, resulting in a wide range of sediment transport potentials for the subwatersheds based on these geomorphic parameters. In general, areas with the highest sediment transport potential are located in the north and south part of the watershed. The average grade change of the subwatersheds is 108 feet. There is a gross estimate of 14.5 billion cubic yards of unconsolidated aquifers within the watershed.

CURRENT WATER QUALITY AND HABITAT QUALITY SUMMARY

DATA COLLECTED FOR THIS WATERSHED MANAGEMENT PLAN[1]

Water quality sampling was conducted at six locations, with one in each of the six HUC 12 subwatersheds within Halfway Creek HUC 10. Sites were sampled monthly from 2014-2015 by IDEM. Table 10.6 depicts water quality results for each parameter as well as the water quality target for each parameter. Water quality results show the average of all water quality data collected for each parameter, regardless of flow conditions at the time of sampling. Averages highlighted in yellow exceed the parameter water quality target set by the Project Manager. All subwatershed and mainstem sites in Halfway Creek HUC 10 exceeded water quality targets for E. coli and nitrate. Of the four tributary subwatershed sites, one was in exceedence for total suspended solids, three for average QHEI and two for IBI. Of the two mainstem sites, one site (Fetid Creek) had exceedences for total suspended solids, average QHEI, and mIBI. Phosphorus was the only parameter for which no sites were in exceedence. There were a total of 21 exceedences for an average of 3.5 exceedences per subwatershed/mainstem site.[2]

TABLE 10.6 | Halfway Creek HUC 10 Subwatershed data exceeding water quality targets

Sample Site	E. coli (cfu/100mL)		Total Phosphorus (mg/L)		Nitrate [N] (mg/L)		Total Suspended Solids (mg/L)		QHEI (Habitat Quality)		IBI (Fish Community Quality)		mIBI (Macro-invertebrate Community Quality)		Dissolved Oxygen Minimum (mg/L)	
	Avg	Target	Avg	Target	Avg	Target	Avg	Target	Score	Qual.	Score	Qual.	Score	Qual.	Min.	Target Min.
HUC pour point	640	235	0.22	0.3	3.7	1	22.1	25.0	64	Fair	52	Good	38	Fair	4.49	4
Subwatersheds																
Bear Creek	929	235	0.16	0.3	6.1	1	11.5	25.0	42	Poor	34	Poor	38	Fair	8.05	4
Bush Creek	497	235	0.18	0.3	2.3	1	9.5	25.0	59	Fair	38	Fair	40	Fair	5.3	4
Days Creek	886	235	0.24	0.3	4.1	1	28.8	25.0	35	Poor	28	Poor	36	Fair	5.04	4
Halfway Creek	798	235	0.23	0.3	1.7	1	13.6	25.0	48	Poor	46	Good	40	Fair	7.31	4
Mainstem Sites																
Fetid Creek	705	235	0.2	0.3	4.7	1	26.7	25.0	47	Poor	42	Fair	30	Poor	4.73	4
Platt Nibarger Ditch	640	235	0.22	0.3	3.7	1	22.1	25.0	64	Fair	52	Good	38	Fair	4.49	4

1 Methods, sampling agency/group, etc. are discussed on p. 106 through 110. The following paragraph and table summarize results from Section 8, *Current Water Quality*, and Section 9, *Biological Assessments*.

2 Some of the raw data for this analysis was obtained from IDEM and was collected as part of IDEM's TMDL of the Upper Mississinewa.

DRAFT TOTAL MAXIMUM DAILY LOAD (TMDL) REPORT FOR THE UPPER MISSISSINEWA RIVER WATERSHED

A draft TMDL report (Total Maximum Daily Load) was generated by IDEM (Indiana Department of Environmental Management) using water quality data the agency collected from 2014-2015 (in conjunction with the water quality data collected for this watershed management plan). In all, sampling was carried out at 35 sites within twelve HUC 12 subwatersheds. Nine sites within Big Lick Creek HUC 10 were sampled. The following chemical water quality parameters were analyzed: phosphorus, dissolved oxygen, TSS, and E. coli. IDEM sites were generally sampled from April 2014 to March 2015, but not every site was sampled every month. IDEM's mean sampling frequency for months sampled during the sampling year was 9.5 months and median sampling frequency was 10 months. The number of months sampled ranged from 7 to 11 months. E. coli was sampled weekly for over a period of 5 weeks at each site from April to May. Fish and macroinvertebrates were also sampled once between June and October 2014.

In IDEM's TMDL report, twelve HUC 12 subwatersheds were assessed and ranked as potential priority implementation areas. The rankings are as follows: Bear Creek 3rd, Days Creek 5th, Bush Creek 6th, Fetid Creek 8th, and Redkey Run 10th. According to the TMDL, "critical conditions for most pollutants for most locations occur during normal to very high flow regimes and therefore implementation of controls should be targeted for these conditions." (TMDL, p.172-173)

Although some data from the IDEM TMDL was used by the Project Manager in an independent analysis of water quality for this study, water quality results presented in Table 10.6 do not include data from all 35 sites monitored as part of the TMDL. Rather, data from sites near HUC 12 pour points was used; this was consistent with HUC 12 sample sites analyzed in the two HUC 10 subwatersheds not monitored as part of the TMDL. The following is an analysis and summary of data that pertains to concerns from all IDEM TMDL sites within Halfway Creek HUC 10:

Biological, habitat and water quality assessments were performed at sites on Days Creek, Flesher Creek, Bear Creek, Fetid Creek, Bush Creek, Elkhorn Creek, a tributary of Elkhorn Creek, Halfway Creek, Dinner Creek, Mud Creek, and the Mississinewa River. Fourteen sites were assessed.

- Biological scores (for both mIBI and IBI) generally rated either poor or fair on tributaries. Site T16 on Halfway Creek had the only IBI score that rated as good. Sites with the lowest biological and habitat scores were site T14, upstream on Halfway Creek, site T2 Elkhorn Creek, site T8 on Flesher Creek (in Days Creek subwatershed), and site T5 on Fetid Creek. Three other sites, Dinner Creek (site T13), Mud Creek (site T18), and Bear Creek (site T12), did not meet the target IBI score.
- Biological and habitat scores declined on the Mississinewa River from sites T6 to T10. Scores improved from sites T10 to T17. At site T10, the mIBI score rated as poor and the IBI score rated as fair.

- TSS was above target at all sites except for two, site T18, Mud Creek, and site T2, Elkhorn Creek.
- Of the tributary sites, sites T9 (Days Creek), T14 (Halfway Creek), and T5 (Fetid Creek) had the highest needed percent reductions for TSS. Site T9 is near the pour point. Site T14 is near the headwaters downstream of the town of Redkey. Site T5 is near a pour point.
- Sites located on the Mississinewa had the highest needed percent reductions for TSS out of all sites.
- Of the Mississinewa River sites, site T6 had the highest percent reduction needed. This site is on the downstream end of the Fetid Creek subwatershed and is located between the other two Mississinewa River sites.

- Dissolved oxygen levels met the target at all sites but two.
- Site T5 on Fetid Creek was 77% below the water quality standard for the minimum concentration of dissolved oxygen.

- All sites except one (site T3) had maximum phosphorus concentrations above the target.
- The highest concentrations of phosphorus at tributary sites were measured at sites T8 and T9 (Days Creek), site T5 (Fetid Creek), site T2 (Bush Creek), and site T14 (Redkey Run).
- Maximum concentrations of phosphorus decreased going downstream along Redkey Run from sites T14 to T16.
- Maximum concentrations of phosphorus decreased going downstream in Bush Creek subwatershed. Site T2 (Elkhorn Creek), had the highest measured concentration of phosphorus in the subwatershed.
- Maximum concentrations of phosphorus increased going downstream in Days Creek subwatershed from sites T8 to T9.

- All sites require reductions in E. coli based on the target for the calculated geometric mean.
- The sites with the highest percent reduction needed for E. coli were site T4 on Bear Creek, site T5 on Fetid Creek, site T13 on Dinner Creek, and site T16 on Halfway Creek.

In general, sites draining into the Mississinewa River between TMDL sites T6 and T10 had worse water quality than sites draining into the Mississinewa River between sites T10 and T17. In general, Days Creek had the worst water quality of all of the tributary sites. Site T5, Fetid Creek and site T14 on Halfway Creek also exceeded water quality standards for more than one parameter and had high maximum concentrations for these parameters. However, site T14 on Halfway Creek is near the headwaters; based on maximum concentrations at site T16 on Halfway Creek, water quality improved in general as it traveled downstream from site T14.

SUMMARY OF HISTORICAL WATER QUALITY STUDIES

LARE (LAKE AND RIVER ENHANCEMENT) STUDY PHASE II

The Mississinewa River (Phase 2) Watershed Diagnostic Study was conducted by Commonwealth Biomonitoring from 2002 to 2003 on the Upper Mississinewa watershed (HUC 5120103020) It includes the [Halfway Creek] watershed from Ridgeville to Albany with an area of approximately 85,760 acres (134 sq mi or 340 sq km). Twelve sites were sampled, including one site on a "reference stream." Sites selected were near pour points. Water quality samples were collected on May 29 and July 5, 2003 and analyzed for chemistry. The following chemical water quality parameters were analyzed: dissolved oxygen, pH, conductivity, temperature, chlorophyll A, turbidity, nitrate, ammonia, total phosphorus, and orthophosphorus. Samples were also analyzed for E. coli when chemical parameters were analyzed. Macroinvertebrate sampling and habitat analysis were conducted on August 4, 2003.

Results of the study indicated that habitat was generally good at most sites, especially on the Mississinewa. Nutrients were elevated at most sites, especially during wet weather. E. coli was also elevated during wet weather. Nutrients and E. coli were high on Fetid Creek. Elkhorn and Mud creeks had excessive sediments. Sites with high slopes near waterways were identified in these subwatersheds. High slopes near waterways were also identified along Days Creek. Platt Nibarger Ditch also had high nutrients. The plan also recommended making improvements to aquatic habitat along Halfway Creek and Heuss Ditch.

303(D) LIST OF IMPAIRED WATERS, 2014

On the 2014 303(d) List of Impaired Waters, the entire Mississinewa River throughout Halfway Creek HUC 10 had various impairments for E. coli, PCBs, and mercury. Impairements for E. coli and PCBs exist upstream and downstream of the town of Ridgeville in Fetid Creek subwatershed. In the western half of Fetid Creek subwatershed, there is only an impairment for PCBs. Through Platt-Nibarger subwatershed, the Mississinewa is impaired for PCBs only, with the exception of a 1.62-mile segment at the western end of subwatershed that is also impaired for mercury. One tributary within Halfway Creek HUC 10 was also impaired; the entire 7.01-mile Elkhorn Creek within Bush Creek subwatershed was listed as impaired for biological communties and E. coli.

LAND USE SUMMARY

Historic Conditions

Similar to other watersheds, the historic/natural conditions of the Halfway Creek HUC 10 were dominated by forest-wetlands and diffuse streams and rivers. There are 34,858 acres of hydric soils, making the historic presence of wetlands on these soils likely (40% of watershed). The majority of soil types are ranked as moderate or poorly drained with 72,035 acres of NRCS category C soils and 19,203 acres of NRCS category D soils. There are 6,703 acres of land in the watershed that is considered prime ecological land due to its geomorphic and historical conditions. There are 47 miles of National Hydrography Dataset mapped streams within the watershed. Data gather during a desktop survey indicated that an estimated twenty-five percent of these tributaries (12 mi.) need buffering. Major streams include Halfway Creek (9.2 mi.). Data from a desktop survey of the watershed can be found in Tables 10.7 and 10.8. For this desktop survey, various land use attributes were counted or measured using Google Earth. They include rills/gullies, construction sites, fertilized lawns, sports fields, runoff sites, erosion sites, and vehicle storage sites.

Urban Population

The total population within the watershed is 7,313, with a population density of 54 persons per sq mi. Approximately 72% of the population (4,527) live in the incorporated towns of Albany (pop: 1,915), Redkey (pop: 1,426), Ridgeville (pop: 842) Saratoga (pop: 287), and Dunkirk (pop: 57). There are 7 CSOs active in the subwatershed with 4 in Redkey and 3 in Ridgeville. However, according to information obtained from an SSO report on IDEM's website, the town of Redkey obtained a Rural Development Grant to fund a project to eliminate its CSOs. The project was estimated to be completed in 2016.

According to the 2010 census, there are approximately 3,086 housing units within Halfway Creek. Based on known populations in urban areas (4,527), well count (626), and average household size for the region (2.25), it is estimated that there are 1,127 houses in non-incorporated areas using septic systems. Many of these rural homes are built in suburban developments or in high concentration areas outside incorporated towns. There are 3,493 acres of these septic "hot spots" located in the watershed while there are only 112 acres that are suitable for septics within the watershed. The urban area footprint incudes 5,699 acres with an estimated impervious surface footprint of 716 acres. No areas slated for development were identified. There are 83 regulated point sources in the subwatershed and no brownfield or other remediation sites. The watershed also includes two landfill structures, one industrial park and no ethanol plants. Of the 2,827 workers who live in the watershed area, 2,783 (98.4%) travel out of the subwatershed for work. The highest concentration of jobs that do remain are in the wholesale trade, retail trade, agriculture and construction sectors, respectively.

Agriculture

The Halfway Creek HUC 10 watershed consists of 83% cultivated cropland and 6.5% developed land (Map 10.2). Of the cultivated cropland, 39% (28,340 acres) is conventional tillage corn crops. Approximately 8% (5,533 acres) is conventional tillage soybean cropland (calculated based on the % tillage of each county transect data). Due to the amount of agricultural lands and particular types of tillage practices, there is an estimated 168,364 tons of sediment, 564 tons of nitrogen, and 152 tons of phosphorus discharged to the Mississinewa River annually.[3] These estimates are based on estimated fertilizer use on agricultural cropland (generated using the Export Coefficient Model).

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3 See Taylor University study for a more complete projection of sediment contribution.

TABLE 10.7 | Desktop Survey Results									
HU_12_NAME	Rills/Gullies	Rills/ Gullies per cropland acre	Fertilized Lawns	Sport Fields	Bank Erosion sites	Runoff sites*	Junk storage sites	Sites where livestock are accessing stream	Mobile home sites
Bear Creek	3234	0.36	6	0	9	21	0	6	3
Bush Creek	4074	0.39	30	3	3	21	0	6	0
Days Creek	3618	0.38	9	0	0	9	9	0	0
Fetid Creek-Mississinewa River	5596	0.40	24	3	3	3	6	0	6
Platt Nibarger Ditch-Mississinewa River	6404	0.39	37	0	3	15	6	3	3
Redkey Run-Halfway Creek	9806	0.77	30	6	3	24	18	6	9
Total	32732	0.45	136	12	21	93	39	21	21

*Runoff sites are sites where rills/gullies are draining directly into waterways.

TABLE 10.8 | Desktop Survey Results								
HU_12_NAME	Tracks from recreational vehicles	Vehicle storage sites	Miles of NHD tributaries needing buffers	NHD tributaries needing buffers (percent)	Construction sites for new development	Quarry sites	Golf Courses	Derelict properties
Bear Creek	9	6	0.62	9%	0	0	0	0
Bush Creek	3	0	2.07	19%	0	0	3	0
Days Creek	0	0	2.09	22%	0	0	0	0
Fetid Creek-Mississinewa River	3	0	1.59	98%	0	3	0	0
Platt Nibarger Ditch-Mississinewa River	0	6	1.45	15%	3	3	0	0
Redkey Run-Halfway Creek	3	9	3.85	45%	3	0	3	0
Total	18	21	11.67	25%	6	6	6	0

Throughout the study region, livestock grazing is limited due to the regional trend towards Combined Feeding Operations. There are 32 CFOs in the watershed in the following subwatersheds: Bear Creek (6 CFOs), Bush Creek (2), Days Creek (5), Fetid Creek (6), Platt Nibarger Ditch (11) and Redkey Run-Halfway Creek (2). Twenty-one livestock access points to waterways were counted using GIS.

Ecological Areas and Open Spaces

There are 9,131 acres of existing ecological areas[4] in the watershed; a majority of this land is located in the watershed's 5,782 acres of floodplain. Recreational opportunities in the watershed are predominantly along the Mississinewa River. The subwatershed contains roughly 14 miles of the Mississinewa River.

Various types of open space exist within the watershed. McVey Memorial Forest, a 249 acre property located in Bush Creek subwatershed, has recreational trails and a boat launch site on the Mississinewa. Mike Kiley Forest Preserve, south of Albany, is a restored 35 acre riparian forest and wetland adjacent to the Mississinewa; it has one recreational trail. Hunting and fishing opportunities are available at Randolph County Wildlife, a nature preserve located within Fetid Creek subwatershed. The town of Albany has two parks, one containing baseball diamonds. There are two schools that have playgrounds and/or schoolyards. Thirteen cemeteries of various sizes are located throughout the watershed. Two golf courses within the watershed offer additional recreational opportunities.

SUMMARY OF DATA FROM REGULATED LAND USES

Various regulated land uses exist within the watershed. Data from the IDEM Virtual File Cabinet and from the IDEM SSO website was reviewed to determine the impact of these land uses on water quality. Although some overflows occurred during the time of this study, the Project Manager determined that these regulated point sources did not significantly impact water quality.

4 In this watershed plan, forests, wetlands, grasslands, and pastures are considered "ecological lands."

Raw water quality data collected for this study was examined according to the dates on which violations occurred in order to make this determination.

SSO Overflows
Sanitary sewer systems (SSOs) are different from combined sewer systems (CSOs) in that they are designed to only convey sanitary wastewater and are not designed to also convey stormwater, as is a CSO. A list of SSO sewer bypass/overflow incidents can be accessed on the website of the Indiana Department of Environmental Management. The lists for 2014 and 2015 were reviewed for facilities within Halfway Creek HUC 10. These incidents *do not* include normal precipitation related discharges from authorized CSO outfalls.

There was 1 Sewer Bypass/Overflow Incident Reports at the Redkey Waste Water Treatment Plan from January 1, 2014 to December 31, 2015 resulting in a discharge to surface waters. The incident discharged 136,500 gallons. The incident occurred following the close of the IDEM TMDL sampling program. Therefore, it is assumed that the overflow would not have been detected by project sampling. For data on these overflows, see Appendix V.

HALFWAY CREEK HUC 10 WATERSHED CONCERNS
There were a number of stakeholder concerns identified within Halfway Creek HUC 10. Many of these concerns have been validated by linking water quality data to desktop survey data and information from the watershed inventory. These concerns and their causes are outlined in Table 10.9. Through the synthesis of water quality data and watershed inventory data, causes were linked with sources. In most cases, these sources were identical to initial concerns. The following is a summary of the most significant characteristics of this watershed as they relate to water quality.

Cropland has a significant impact on water quality in this watershed. Average nitrate concentrations exceeded the target for all sites. High estimated nitrogen fertilizer use on cropland within the watershed is likely the main source of nitrate. Nitrogen application is especially high in Bear Creek, which also had the highest average nitrate level of all sites for this HUC 10. Land application of manure from CFOs in the watershed is also likely contributing to nitrate exceedences.

Average E. coli concentrations exceeded the target in all subwatersheds within Halfway Creek HUC 10. Possible sources of E. coli include but are not limited to 1) CSOs (located in Ridgeville and Redkey), 2) failing septic systems, 3) land application of manure, and 4) livestock accessing streams (Table 10.6). The current effort to eliminate CSOs in Redkey will likely improve water quality in the *subwatershed* of Halfway Creek.

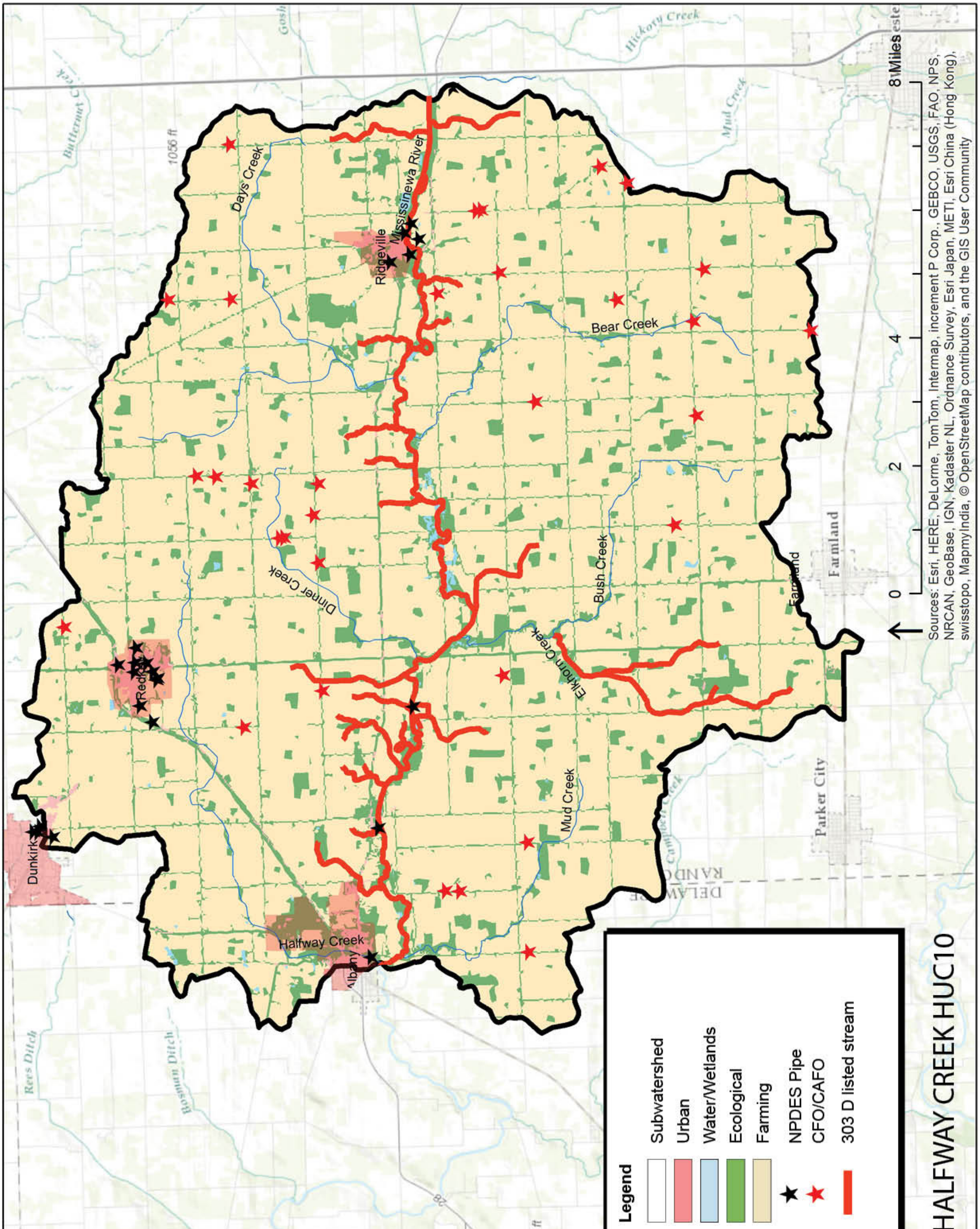
Average TSS concentrations at Days and Bear Creek subwatersheds exceeded this project's target. Sources of TSS include but are not limited to 1) the fairly high number of rills/gullies observed in the watershed (Table 10.7), 2) a fairly high rate of conventional tillage (248 acres/sq. mi.), 3) sites where livestock are entering streams (Table 10.7), 4) unbuffered streams (Table 10.8), and 5) runoff sites (Table 10.7).

Reasons for poor biological scores at Bear Creek, Days Creek, and Fetid Creek could include poor quality habitat (as evidenced by poor average QHEI scores), high TSS concentrations, and excess nutrients.

Increasing the amount of grassed waterways, filter strips, and conservation tillage in the watershed should help to reduce TSS levels. Furthermore, saturated buffers, drainage water management, and covercrops should help to reduce nitrate concentrations. Saturated buffers and drainage water management can also help to reduce flooding, which was a commonly expressed concern in this watershed.

TABLE 10.9 | Halfway Creek HUC 10 watershed concerns

Concerns	Cause of Concern	Subwatershed
Public Concerns		
Socioeconomic	Flooding	Not specified
Socioeconomic/Fish and Wildlife	Instream erosion	Not specified
Recreation and Public Water Supply/Fish and Wildlife	Logjams	Not specified
Project Manager Concerns		
High nitrate levels	Nitrogen application on farm fields, land application of manure from CFOs	Fetid Creek, Bear Creek, Days Creek
High E. coli levels	CSO discharge, failing septic systems	All subwatersheds and mainstem sites
High TSS levels	Conventional tillage	Days Creek and Fetid Creek
Poor biological scores	Poor habitat quality and/or poor chemical water quality	Days Creek, Bear Creek, Fetid Creek
Poor habitat quality	Channelization, sedimentation, lack of riparian buffer	Bear Creek, Days Creek, Halfway Creek, Fetid Creek



MAP 10.2 | Halfway Creek HUC 10 Watershed

10.3 PIKE CREEK HUC 10

The HUC 10 Pike Creek (0512010304; 66,067 acres) contains four HUC 12 subwatersheds: Rees Ditch (051201030402), Holden Ditch (051201030404), Campbell Creek (051201030401), and Studebaker Ditch-Pike Creek (051201030403). The Mississinewa River runs through two of these subwatersheds, Rees Ditch and Holden Ditch. The watershed is located in the west central part of the study area. A majority of the watershed acreage is located in Delaware County (92%) with portions including Randolph (6%) Jay County (2%). The Mississinewa River runs through two of the subwatersheds (Rees Ditch and Holden Ditch). It flows in a northwesterly direction from Albany to north of the town of Wheeling, where it enters Massey Creek HUC 10.

The watershed is located adjacent to the northern moraines and subsequently has topographic changes throughout it. Some areas are relatively flat, while some are gently rolling. Geomorphic characteristics rankings for drainage density (Dd), stream frequency (Fu), and relief ratio (Rr) vary within the watershed, resulting in a range (low, medium, and high) of sediment transport potential for the subwatersheds based on these geomorphic parameters. The lowest sediment transport potential was found in the northeast section (Rees Ditch) of the watershed. The average grade change of the subwatersheds is 122 feet. There is a gross estimate of 7.25 billion cubic yards of unconsolidated aquifers in the watershed.

CURRENT WATER QUALITY AND HABITAT QUALITY SUMMARY

DATA COLLECTED FOR THIS WATERSHED MANAGEMENT PLAN[1]

Water quality sampling was conducted at six locations, with one in each of the six HUC 12 subwatersheds within Pike Creek HUC 10. Sites were sampled monthly from 2014-2015 by IDEM. Table 10.10 depicts water quality results for each parameter as well as the water quality target for each parameter. Water quality results show the average of all water quality data collected for each parameter, regardless of flow conditions at the time of sampling. Averages highlighted in yellow exceed the parameter water quality target set by the Project Manager. All subwatershed and mainstem sites in Pike Creek HUC 10 exceeded water quality targets for E. coli and nitrate. Of the three mainstem sites, there was one exceedence for total suspended solids. There were no exceedences for phosphorus, average QHEI, IBI, or mIBI. There were a total of 9 exceedences for an average of 2.25 exceedences per subwatershed/mainstem site.[2]

TABLE 10.10 | Pike Creek HUC 10 Subwatershed data exceeding water quality targets

Sample Site	E. coli (cfu/100mL)		Total Phosphorus (mg/L)		Nitrate [N] (mg/L)		Total Suspended Solids (mg/L)		QHEI (Habitat Quality)		IBI (Fish Community Quality)		mIBI (Macro-invertebrate Community Quality)		Dissolved Oxygen Minimum (mg/L)	
	Avg	Target	Avg	Target	Avg	Target	Avg	Target	Score	Qual.	Score	Qual.	Score	Qual.	Min.	Target Min.
HUC pour point	626	235	0.24	0.3	2.70	1	19.1	25	66	Fair	42	Fair	44	Fair	5.68	4
Subwatersheds																
Campbell Creek	666	235	0.23	0.3	1.9	1	17.2	25.0	78	Good	42	Fair	43	Fair	6.52	4
Studebaker Ditch-Pike Creek	460	235	0.13	0.3	2.2	1	6.0	25.0	74	Good	36	Fair	40	Fair	7.52	4
Mainstem Sites																
Holden Ditch-Mississinewa River	626	235	0.24	0.3	2.7	1	19.1	25.0	66	Fair	42	Fair	44	Fair	5.68	4
Rees Ditch-Mississinewa River	927	235	0.29	0.3	3.9	1	31.2	25.0	70	Fair	54	Excel lent	38	Fair	6.19	4

DRAFT TOTAL MAXIMUM DAILY LOAD (TMDL) REPORT FOR THE UPPER MISSISSINEWA RIVER WATERSHED

A draft TMDL report (Total Maximum Daily Load) was generated by IDEM (Indiana Department of Environmental Management) using water quality data the agency collected from 2014-2015 (in conjunction with the water quality data collected for this watershed management plan). In all, sampling was carried out at 35 sites within twelve HUC 12 subwatersheds. Nine sites within Big Lick Creek HUC 10 were sampled. The following chemical water quality parameters were analyzed: phosphorus, dissolved oxygen, TSS, and E. coli. IDEM sites were generally sampled from April 2014 to March 2015, but not every site was sampled every month. IDEM's mean sampling frequency for months sampled during the sampling year was 9.5 months and median sampling frequency was 10 months. The number of months sampled ranged from 7 to 11 months. E. coli was sampled weekly for over a period of 5 weeks at each site from April to May. Fish and macroinvertebrates were also sampled once between June and October 2014.

1 Methods, sampling agency/group, etc. are discussed on p. 106 through 110. The following paragraph and table summarize results from Section 8, *Current Water Quality*, and Section 9, *Biological Assessments*.

2 Some of the raw data for this analysis was obtained from IDEM and was collected as part of IDEM's TMDL of the Upper Mississinewa.

In IDEM's TMDL report, twelve HUC 12 subwatersheds were assessed and ranked as potential priority implementation areas. The rankings are as follows: Campbell Creek 1st, Studebaker Ditch 2nd, Rees Ditch 4th, and Holden Ditch 9th. According to the TMDL, "critical conditions for most pollutants for most locations occur during normal to very high flow regimes and therefore implementation of controls should be targeted for these conditions." [3]

Although some data from the IDEM TMDL was used by the Project Manager in an independent analysis of water quality for this study, water quality results presented in Table 10.10 do not include data from all 35 sites monitored as part of the TMDL. Rather, data from sites near HUC 12 pour points was used; this was consistent with HUC 12 sample sites analyzed in the two HUC 10 subwatersheds not monitored as part of the TMDL. The following is an analysis and summary of data that pertains to concerns from all IDEM TMDL sites within Pike Creek HUC 10:

Biological, habitat and water quality assessments were performed at sites on the Mississinewa River, Bosman Ditch, Rees Ditch, Pike Creek, Hedgeland Ditch, Dodge Creek, Campbell Creek, and a tributary of Campbell Creek.

- All sites along the Mississinewa River needed reductions for TSS, phosphorus, and E. coli. Percent reductions needed for TSS were similar between sites, ranging from 66% to 75%. Percent reductions needed for phosphorus were similar between sites, ranging from 38% to 59%. Dissolved oxygen was in acceptable ranges at all sites. Percent reductions for E. coli decreased between sites T19 and T25 (from 65% to 26%); they remained at 26% at site T26 and increased at site T31 (61.57%).

- Most sites were above the water quality standard for dissolved oxygen. Only Rees Ditch, site T21 and Campbell Creek, site T1, were below the standard.

- Maximum concentrations of TSS varied at tributary sites throughout the watershed. Sites within Rees Ditch subwatershed needed the largest percent reductions, which ranged from 89% to 99%. Percent reductions of 65% (site T20) and 74% (site T1) are needed at the two sites within Campbell Creek. Tributary sites within Studebaker Ditch subwatershed (Pike Creek, site T30 and Hedgeland Ditch, site T29) and Holden Ditch subwatershed (Dodge Creek, site T28) were below target, meaning no reductions are needed.
- The tributary sites needing the largest percent reduction of TSS were sites T23 and T24. These sites are near the pour points of Rees Ditch and Bosman Ditch (site T24), respectively. Maximum concentrations measured at these sites were 3,000 mg/L and 2,500 mg/L, respectively.
- Tributary sites within Studebaker Ditch subwatershed (Pike Creek, site T30 and Hedgeland Ditch, site T29) and Holden Ditch subwatershed (Dodge Creek, site T28) were below target for TSS, meaning no reductions are needed.

- Maximum concentrations of phosphorus varied at tributary sites throughout the watershed. Sites within Rees Ditch subwatershed needed the largest percent reductions, which ranged from 62% to 69%. A percent reduction of 44% is needed at site T20, located near the pour point on Campbell Creek.
- Tributary sites within Studebaker Ditch subwatershed (Pike Creek, site T30 and Hedgeland Ditch, site T29) and Holden Ditch subwatershed (Dodge Creek, site T28) were below target for phosphorus, meaning no reductions are needed.
- The tributary sites needing the largest percent reduction of phosphorus were sites T23 and T24. These sites are near the pour points of Rees Ditch and Bosman Ditch, respectively.

- All tributary sites exceeded the water quality standard for E. coli. Sites T1 and T21 needed the largest percent reductions; they are located near the headwaters of Campbell Creek and Rees Ditch, respectively. Percent reductions needed for sites near pour points are as follows: site T28 (Dodge Creek), 89%; site T20 (Campbell Creek), 73%; site T30 (Studebaker Ditch), 73%; site T23 (Rees Ditch), 51%; and site T24 (Bosman Ditch), 58%.

- Both sites on Rees Ditch and the site on Bosman Ditch (site T24) all had poor mIBI scores and fair IBI scores. The site on Hedgeland Ditch (site T29) had poor mIBI and IBI scores. Sites on Campbell Creek (sites T1 and T20), Dodge Creek (site T28) and Pike Creek (site T30) all had fair mIBI and IBI scores.

SUMMARY OF HISTORICAL WATER QUALITY STUDIES

303(D) LIST OF IMPAIRED WATERS, 2014

Within Delaware County, a 3.78 mile assessment unit of the Mississinewa River was impaired for biotic communities. This stretch begins in northern Delaware County and ends in Grant County downstream of the town of Matthews. Three assessment units were impaired for E. coli and four were impaired for PCBs. No tributaries of the Mississinewa were impaired in Delaware County.

LARE (LAKE AND RIVER ENHANCEMENT) STUDY PHASE III

The Watershed Diagnostic Study of the Upper Mississinewa River Watershed, Phase III, was conducted by Cedar Eden Environmental. Sites were sampled on April 13 and August 11, 2004. Parameters included flow, dissolved oxygen, temperature, E. coli, pH, specific conductivity, turbidity, total phosphorus, soluble reactive phosphorus, nitrate+nitrite nitrogen, total Kjeldahl nitrogen, and ammonia. Additional sampling was done at high flow on September 16, 2005 but fewer parameters were used. Macroinvertebrate sampling and habitat assessments were conducted on August 11, 2004.

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3 IDEM TMDL for the Upper Mississinewa River Watershed

According to this study, high concentrations of nitrogen, phosphorus and E. coli were found within the watershed. The Mississinewa River's water quality generally improved as it traveled downstream through the watershed. The highest concentrations during low flow for most parameters were generally found at sites on the Mississinewa River. During high flow, however, tributary sites generally had the highest concentrations for most parameters (this may be due to a number of factors, such as a higher number of field tiles draining into ditches than into the Mississinewa River, wider buffers along the Mississinewa River than along ditches, the channelization of ditches, and upstream water quality).

Of the tributaries, Campbell Creek had some of the highest measured levels of E. coli, turbidity, total phosphorus, soluble reactive phosphorus, and TKN. The highest measured E. coli at low flow at a tributary site was at Campbell Creek Site 04. This was the site furthest upstream on Campbell Creek. Pike Creek had some of the highest measured levels of E. coli, total phosphorus, nitrate nitrogen, and soluble reactive phosphorus. The highest measured E. coli at high flow at a tributary site was at Pike Creek Site 04. This was the site furthest upstream on Pike Creek.

Turbidity measured at high flow was above the EPA's proposed criteria of 10.4 NTU for this ecoregion at 76% of tributary sites. Bosman Ditch, within the Rees Ditch subwatershed, had some of the highest measured turbidity concentrations during high flow. Pike Creek had some of the lowest measured turbidity concentrations at high flow, with three of the four sites falling below the proposed criteria of 10.4.

Macroinvertebrate communities were moderately impaired at 79% of the sites sampled. Pike Creek had the best scores; Site 01, which is near the pour point, had no impairment. Campbell Creek, Rees Ditch, Unnamed Ditch, and Bosman Ditch all were generally moderately impaired.

The level of impairment based on QHEI habitat scores varied from site to site along most creeks. This variation may be due to drainage size; the highest QHEI scores, which ranged from slightly impaired to unimpaired, were at sites located near pour points. In general, the lowest measured QHEI scores were on Campbell Creek and Rees Ditch.

LAND USE SUMMARY

Historic Conditions

Similar to other watersheds, the historic/natural conditions of the site were dominated by forest-wetlands and diffuse streams and rivers. There are 23,879 acres of hydric soils making the historic presence of wetlands on these soils likely (36% of subwatershed). The majority of soil types are ranked as moderate or poorly drained with 56,633 acres of NRCS category C soils and 6,751 acres of NRCS category D soils. There are 9,296 acres of land in the subwatershed that is considered prime ecological land due to its geomorphic and historical conditions. There are 29 miles of National Hydrography Dataset mapped tributaries within the watershed. Data gather during a desktop survey indicated that an estimated nineteen percent (5.3 mi) of these tributaries need buffering. Major streams include the Mississinewa River (20.1 mi.), Campbell (11.8 mi.), and Rees Ditch (8 mi.). Data from a desktop survey of the watershed can be found in Tables 10.11 and 10.12. For this desktop survey, various land use attributes were counted or measured using Google Earth. They include rills/gullies, construction sites, fertilized lawns, sports fields, runoff sites, erosion sites, and vehicle storage sites.

Urban Population

The total population within the watershed is 8,913 with a population density of 86 persons per square mile. While a majority of the population (4,938; 55%) live in unincorporated areas, many (3,975; 45%) live in the incorporated towns of Eaton (pop: 1602), Gaston (pop: 1,004), Dunkirk (pop: 897), Albany (pop: 451) and Parker City (20). The small community of DeSoto, while not incorporated, was recently annexed into the wastewater district of Muncie. Therefore septic numbers for this area may be slightly lower than reported. There are two CSOs active in the subwatershed, located in Eaton. According to the 2010 census, there are approximately 3,722 housing units. Based on known populations in urban areas (3,974), well count (736), and average household size for the region (2.25), it is estimated that there are 2,075 houses in non-incorporated areas using septic systems. Many of these rural homes are built in suburban developments or in high concentration areas outside incorporated towns. There are 14,161 acres of these septic "hot spots" located in the subwatershed, while only 83 acres within the watershed are suitable for septic systems. The urban area footprint includes 4,439 acres with an estimated impervious surface footprint of 561 acres. No areas slated for development were identified. There are 46 regulated point sources in the subwatershed and no brownfield or other remediation sites. The subwatershed also includes seven landfill structures, zero industrial parks, and zero ethanol plants. Of the 2,779 amount of workers who live in the subwatershed area, 2,604 travel out of the subwatershed for work. The highest concentration of jobs that do remain are in the manufacturing, healthcare and social assistance, and construction sectors respectively.

Agriculture

The Pike Creek watershed consists of 78.6% cultivated cropland and 6.7% developed land (Map 10.3). Of the cultivated cropland, 45% (23,460) acres is conventional tillage corn crops. Approximately two percent (775 acres) is conventional tillage soybean cropland (calculated based on the % tillage of each county transect data). Due to the amount of agricultural lands and particular types of tillage practices, there is an estimated 121,176 tons of sediment, 415 tons of nitrogen, and 111 tons of phosphorus discharged to the Mississinewa River annually.[4] These estimates are based on estimated fertilizer use on agricultural cropland (generated using the Export Coefficient Model). Throughout the study region, livestock grazing is limited due to the regional trend towards Combined Feeding Operations. There are five CFOs in the subwatersheds of Campbell Creek (3), Rees Ditch (1) and Studebaker Ditch-Pike Creek (1). Three livestock access points to waterways (all in Pike Creek) were counted using GIS (Table 10.11).

4 See Taylor University study for a more complete projection of sediment contribution.

TABLE 10.11 | Desktop Survey Results									
HU_12_NAME	Rills/ Gullies	Rills/ Gullies per cropland acre	Fertilized Lawns	Sport Fields	Erosion sites	Runoff sites*	Junk storage sites	Sites where livestock are accessing stream	Mobile home sites
Campbell Creek	8904	0.79	61	6	9	12	3	0	0
Holden Ditch-Mississinewa River	8388	0.88	69	6	15	12	15	0	12
Rees Ditch-Mississinewa River	13126	0.69	84	4	12	13	19	0	4
Studebaker Ditch-Pike Creek	5742	0.48	72	9	12	15	9	3	3
Total	36160	0.70	286	25	48	52	46	3	19

*Runoff sites are sites where rills/gullies are draining directly into waterways.

TABLE 10.12 | Desktop Survey Results								
HU_12_NAME	Tracks from recreational vehicles	Vehicle storage sites	Miles of NHD tributaries needing buffers	NHD tributaries needing buffers (percent)	Construction sites for new development	Quarry sites	Golf Courses	Derelict properties
Campbell Creek	0	0	1.55	14%	0	3	0	0
Holden Ditch-Mississinewa River	6	21	0.00	0%	0	3	3	0
Rees Ditch-Mississinewa River	1	16	1.10	15%	0	0	0	3
Studebaker Ditch-Pike Creek	0	6	2.70	27%	3	0	0	0
Total	7	43	5.34	19%	3	6	3	3

Ecological Areas and Open Spaces

There are 9,715 acres of existing ecological areas[5] in the subwatershed; a majority of this land is located in the subwatershed's 4,817 acres of floodplain. There are limited publicly accessible ecological resources in the subwatershed. The watershed contains roughly 13 miles of the Mississinewa River. There is a public access point for canoeing along St. Rd. 67 north of St. Rd. 28 (Taylor University, 2012).

Various types of open space exist within the watershed. There are four schools that have playgrounds and/or schoolyards. The town of Eaton has one park. The Gaston Lions Club Park is located outside the town of Gaston. Twelve cemeteries of various sizes are located throughout the watershed.

SUMMARY OF DATA FROM REGULATED LAND USES

Various regulated land uses exist within the watershed. Data from the IDEM Virtual File Cabinet and from the IDEM SSO website was reviewed to determine the impact of these land uses on water quality. Although some overflows occurred during the time of this study, the Project Manager determined that these regulated point sources did not significantly impact water quality. Raw water quality data collected for this study was examined according to the dates on which violations occurred in order to make this determination.

SSO Overflows

Sanitary sewer systems (SSOs) are different from combined sewer systems (CSOs) in that they are designed to only convey sanitary wastewater and are not designed to also convey stormwater, as is a CSO. A list of SSO sewer bypass/ overflow incidents can be accessed on the website of the Indiana Department of Environmental Management. The lists for 2014 and 2015 were reviewed for facilities within Pike Creek HUC 10. These incidents *do not* include normal precipitation related discharges from authorized CSO outfalls.

5 In this watershed plan, forests, wetlands, grasslands, and pastures are considered "ecological lands."

There was 1 Sewer Bypass/Overflow Incident Reports at the Albany Muncipal Waste Water Treatment Plan from January 1, 2014 to December 31, 2015 resulting in a discharge to surface waters. The incident discharged 30 gallons. The closest IDEM TMDL water quality sampling date was 28 days following an incident. Therefore, it is assumed that the overflow would not have been detected by project sampling. For data on these overflows, see Appendix V.

PIKE CREEK HUC 10 WATERSHED CONCERNS

There were a number of stakeholder concerns identified for Pike Creek. Many of these concerns have been validated by linking water quality data to desktop survey data and information from the watershed inventory. These concerns and their causes are outlined in Table 10.13. Through the synthesis of water quality data and watershed inventory data, causes were linked with sources. In most cases, these sources were identical to initial concerns. The following is a summary of the most significant characteristics of this watershed as they relate to water quality.

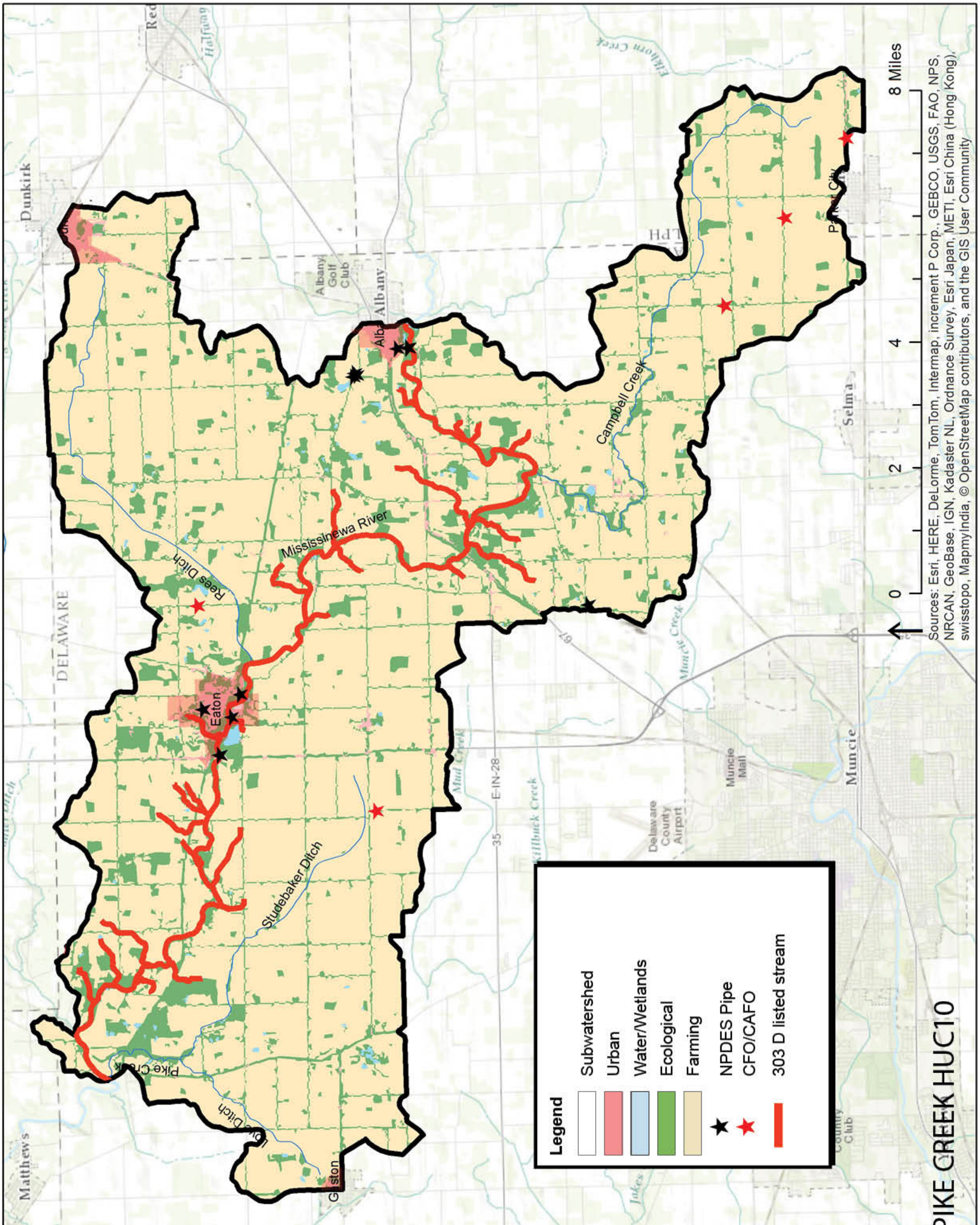
Of the five HUC 10 watersheds, Pike Creek HUC 10 has the lowest average number of exceedences. However, based on desktop survey data, there are a high number of possible sources of pollutants. Of the HUC 10 watersheds, Pike Creek HUC 10 has one of the highest number of rills/gullies per acre (Table 10.11). According to TMDL water quality data, extremely high maximum concentrations of TSS were measured at Rees and Bosman ditches within Rees Ditch HUC 12. High total suspended solids at Rees Ditch may also be due to its higher amounts of conventional tillage in comparison to other sites within this HUC 10. The desktop survey also identified a relatively high number of fertilized lawns, sports fields, and golf courses in this watershed (Tables 10.11 and 10.12). These sites may be sources of nutrients in waterways.

All subwatersheds within Pike Creek HUC 10 exceeded the targets for nitrate and E. coli. Possible contributors to high E. coli levels include failing septics, CSO discharges from the town of Eaton, and runoff from fields where manure was applied. Based on the desktop survbey, Pike Creek HUC 10 had three sites where livestock were accessing streams. Due to the presence of high percentages of cropland, fertilizer is likely the main source of nitrate in this watershed.

Pike Creek had the highest percentage of buffers of all HUC 10 watersheds (Table 10.12). Pike Creek also has relatively low rates of conventional tillage, another factor that may explain its relatively good water quality resulsts. Retention and expansion of buffers along fields should be encouraged, as well as the continued conversion from conventional tillage to conservation tillage and other soil conservation best management practices.

TABLE 10.13 | Pike Creek HUC 10 watershed concerns

Concerns	Cause(s) of Concern	Subwatershed
Public Concerns		
Socioeconomic	Flooding	Not specified
Socioeconomic/Fish and Wildlife	Erosion, loss of biodiversity	Not specified
Recreation and Public Water Supply/ Fish and Wildlife	Logjams	Not specified
Project Manager Concerns		
High nitrate levels	Nitrogen application on farm fields, land application of manure from CFOs, failing septic systems, CSO discharge	All subwatershed and mainstem sites
High TSS levels	Conventional tillage, lack of buffers along tributaries	Rees Ditch
High E. coli levels	CSO discharge, land application of manure from CFOs	All subwatershed and mainstem sites



MAP 10.3 | Pike Creek HUC 10 Watershed

10.4. HEADWATERS MISSISSINEWA HUC 10

The Headwaters Mississinewa River HUC 10 (0512010301; 83,635 acres) is located in the eastern end of the study area and contains 5 HUC 12 subwatersheds: Porter Creek (051201030104), Gray Branch (051201030102), Jordan Creek (051201030103), Little Mississinewa River (051201030101), and Mud Creek (051201030105). A majority of the watershed acreage is located in Randolph County (67%), with portions including Darke County, Ohio (23%) and Jay County (9%). The Mississinewa River flows from east to west through the north central regions of four of the five subwatersheds.

The watershed is located adjacent to the northern moraines and subsequently has topographic changes throughout it. Some areas are relatively flat, while some are gently rolling. Geomorphic characteristics rankings for drainage density (Dd), stream frequency (Fu), and relief ratio (Rr), vary within the watershed, resulting in a range (low, medium, and high) of sediment transport potential for the subwatersheds based on these geomorphic parameters. However, in general this watershed has a low to moderate sediment transport potential. The lowest sediment transport potential was found in the eastern section (Gray Branch) of the watershed. The average grade change of subwatersheds is 149 feet. There is a gross estimate of 12 billion cubic yards of unconsolidated aquifers in the watershed.

CURRENT WATER QUALITY AND HABITAT QUALITY SUMMARY

DATA COLLECTED FOR THIS WATERSHED MANAGEMENT PLAN[1]

As part of this watershed project, water quality sampling and biological and habitat assessments were conducted at six locations, with one in each of the five HUC 12 subwatersheds within Headwaters Mississinewa River HUC 10. The UMRW-P conducted sampling monthly from 2014-2015. Table 10.14 depicts water quality results for each parameter as well as the water quality target for each parameter. Water quality results show the average of all water quality data collected for each parameter, regardless of flow conditions at the time of sampling. Averages highlighted in yellow are exceeding the parameter water quality target set by the Project Manager. All subwatershed and mainstem sites in Headwaters Mississinewa River HUC 10 exceeded water quality targets for E. coli, nitrate and total suspended solids. The only subwatershed site for this HUC 10, Little Mississinewa River, also had exceedences for total suspended solids and IBI. Of the four mainstem sites, one site had an exceedence for average QHEI and three had exceedences for phosphorus. The mIBI was the only parameter for which no sites were in exceedence. There were a total of 21 exceedences for an average of 4.2 exceedences per subwatershed/mainstem site.

TABLE 10.14 | Headwaters Mississinewa River HUC 10 data exceeding water quality targets

Sample Site	E. coli (cfu/100mL)		Total Phosphorus (mg/L)		Nitrate [N] (mg/L)		Total Suspended Solids (mg/L)		AVG QHEI (Habitat Quality)		IBI (Fish Community Quality)		mIBI (Macro-invertebrate Community Quality)		Dissolved Oxygen Minimum (mg/L)	
	Avg	Target	Avg	Target	Avg	Target	Avg	Target	Score	Qual.	Score	Qual.	Score	Qual.	Min.	Target Min.
HUC 10 pour point	981	235	0.26	0.3	5.08	1	28.6	25	59	Fair	46	Good	42	Fair	6.65	4
Subwatersheds																
Little Mississinewa River	1063	235	0.31	0.3	5.26	1	50.5	25	56.4	Fair	34	Poor	42	Fair	5.22	4
Mainstem Sites																
Gray Branch-Mississinewa River	1027	235	0.30	0.3	6.65	1	66.2	25	41.8	Poor	42	Fair	44	Good	4.05	4
Jordan Creek-Mississinewa River	1075	235	0.37	0.3	5.62	1	85.9	25	59	Fair	42	Fair	40	Fair	4.32	4
Mud Creek-Mississinewa River	981	235	0.26	0.3	5.08	1	28.6	25	59	Fair	46	Good	42	Fair	6.65	4
Porter Creek-Mississinewa River	870	235	0.37	0.3	5.21	1	110.8	25	60.5	Fair	50	Good	42	Fair	4.12	4

1 Methods, sampling agency/group, etc. are discussed on p. 106 through 110. The following paragraph and table summarize results from Section 8, *Current Water Quality*, and Section 9, *Biological Assessments*.

HISTORICAL WATER QUALITY SUMMARY

303(D) LIST OF IMPAIRED WATERS, 2014

Various tributaries and sections of the mainstem had impairments within the Headwaters Mississinewa River HUC 10. Along seven assessment units of the Mississinewa River within Randolph County there was impairment for PCB's. Only one assessment unit was impaired for E. coli. Of the tributaries there were three impairments for PCBs, four for E. coli, and one for biotic communities. Within Gray Branch HUC 12, Mitchell Ditch was impaired for E. coli. Within Jordan Creek HUC 12, Harshman Creek and its tributary, Low's Branch, were impaired for E. coli. Harshman Creek was also impaired for biotic communities. Within Little Mississinewa River HUC 10, the Little Mississinewa River and two of its tributaries, Gettinger Ditch and Shelley Ditch, were all impaired for PCBs. The Little Mississinewa River was also impaired for E. coli.

LARE (LAKE AND RIVER ENHANCEMENT) STUDY PHASE I

The Upper Mississinewa River Watershed Diagnostic Study was authorized by the Randolph County SWCD on December 3, 1999. The study was conducted by HARZA Engineering Company. Water quality, habitat, and biological data were collected during baseflow at six sites in May 2000. Samples were collected again on October 6, 2000 during high flow conditions. Water quality data was collected for the following parameters: conductivity, dissolved oxygen, temperature, pH, nitrate + nitrite, TKN, dissolved phosphorus, total phosphorus, and turbidity. E. coli was sampled on June 30, 2000. Based on analysis, Jordan, Miller and Mud Creeks were determined to be the most impaired by nonpoint source pollution. The Family Biotic Index was used to interpret biological data. Jordan, Miller, and Mud had the highest FBI scores, which indicates biological communities in these streams were experiencing the highest levels of stress. These sites also had the lowest QHEI scores, indicating habitat at these sites is poor relative to the rest of the sites. Jordan Creek had the highest nitrate [N] concentration measured (16 mg/L). All sites were above the Indiana water quality standard for E. coli for a single sample. Dissolved oxygen concentrations measured at all sites ranged from 14.8 mg/L to 25.4 mg/L. Researchers concluded that they "measured very high dissolved oxygen concentrations in all six streams....We believe that these streams are subject to very high diurnal DO fluctuations that can be a stressor for aquatic animals."[2] Researchers also concluded that "improper animal waste management" had occurred in the Mud Creek subwatershed. This conclusion was based on high TKN and E. coli concentrations.

LAND USE SUMMARY

Historic Conditions

Similar to other watersheds, the historic/natural conditions of the site were dominated by forest-wetlands and diffuse streams and rivers. There are 38,908 acres of hydric soils making the historic presence of wetlands on these soils likely (47% of subwatershed). The majority of soil types are ranked as moderate or poorly drained, with 68,474 acres of NRCS category C soils and 20,488 acres of NRCS category D soils. There are 4,365 acres of land in the watershed that is considered prime ecological land due to its geomorphic and historical conditions. There are 115 miles of National Hydrography Dataset mapped tributaries within the watershed. Data gather during a desktop survey indicated that an estimated thirty-four percent (12 mi) of these tributaries need buffering. Major streams include the Little Mississinewa River (3 mi.), Harshman Creek (1.3 mi.), Miller Creek (7.4 mi.) and Porter Creek (3.4 mi.). Data from a desktop survey of the watershed can be found in Tables 10.15 and 10.16. For this desktop survey, various land use attributes were counted or measured using Google Earth. They include rills/gullies, construction sites, fertilized lawns, sports fields, runoff sites, erosion sites, and vehicle storage sites.

Urban Population

The total population within the watershed is approximately 7,879 with a population density of 60 persons per acre. Fifty-four percent of people (4,252) live in diffuse areas throughout the subwatershed. An additional 46% (3,627) live in the incorporated areas of Winchester (10) and Union City (3,617). There are no CSOs active in the subwatershed. According to the 2010 census, there are approximately 3,265 housing units. Based on known populations in urban areas (3,627), well count (549), and average household size for the region 2.25, it is estimated that there are 1,699 houses in non-incorporated areas using septic systems. Many of these rural homes are built in suburban developments or in high concentration areas outside incorporated towns. There are 2,085 acres of these septic "hot spots" are the watershed, while only 35 acres within the watershed are suitable for septic systems. The urban area footprint incudes 4,221 acres with an estimated impervious surface footprint of 836 acres. No areas slated for development were identified. There are 70 regulated point sources in the watershed and one brownfield. There is one ethanol plant and no landfill structures or industrial parks in the watershed. Of the 2,868 workers who live in the watershed area, 2,736 (95%) travel out of the watershed for work. The highest concentration of jobs that do remain are in the manufacturing and educational services sectors respectively.

Agriculture

The Headwaters Mississinewa River watershed consists of 81.5% cultivated cropland and 6% developed land (Map 10.4). Of the cultivated cropland, 35% (19,492 acres) is conventional tillage corn crops. Nine percent (5,276 acres) is conventional tillage soybean cropland (calculated based on the % tillage of each county transect data). Due to the amount of agricultural lands and particular types of tillage practices, there is an estimated 141,453 tons of sediment, 555 tons of nitrogen, and 151 tons of phosphorus discharged to the Mississinewa River annually.[3] These estimates are based on estimated fertilizer use on agricultural cropland (generated using the Export Coefficient Model). Throughout the study region, livestock grazing is limited due to the regional trend towards Combined Feeding Operations. There are 41 CFOs in the watershed located in the following subwatersheds: Gray Branch (20), Jordan Creek (12), Little Mississinewa River (6), Mud Creek (2) and Porter Creek (1).

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2 Harza Engineering Company. Upper Mississinewa River Watershed Diagnostic Study. 2001.

3 *See Taylor University study for a more complete projection of sediment contribution.

TABLE 10.15 | Desktop Survey Results									
HU_12_NAME	Rills/ Gullies	Rills/ Gullies per cropland acre	Fertilized Lawns	Sport Fields	Erosion sites*	Runoff sites	Junk storage sites	Sites where livestock are accessing stream	Mobile home sites
Gray Branch-Mississinewa River	4076	1.34	18	6	12	21	0	0	0
Jordan Creek-Mississinewa River	5952	0.49	9	0	12	24	9	3	3
Little Mississinewa River	3144	0.29	48	6	6	33	15	0	0
Mud Creek-Mississinewa River	9084	0.48	21	3	12	69	12	9	3
Porter Creek-Mississinewa River	4206	0.43	21	3	9	18	12	0	0
Total	26462	0.48	117	18	51	165	48	12	6

*Runoff sites are sites where rills/gullies are draining directly into waterways.

TABLE 10.16 | Desktop Survey Results								
HU_12_NAME	Tracks from recreational vehicles	Vehicle storage sites	Miles of NHD tributaries needing buffers	NHD tributaries needing buffers (percent)	Construction sites for new development	Quarry sites	Golf Courses	Derelict properties
Gray Branch-Mississinewa River	3	0	4.16	54%	0	0	0	0
Jordan Creek-Mississinewa River	0	9	6.02	25%	0	0	0	0
Little Mississinewa River	0	0	3.19	21%	0	3	0	0
Mud Creek-Mississinewa River	3	9	20.07	43%	0	0	0	0
Porter Creek-Mississinewa River	3	6	5.96	29%	0	0	0	6
Total	9	24	39.40	34%	6	9	6	6

Twelve livestock access points to waterways were counted using GIS and were located in the following subwatersheds: Mud Creek (9) and Jordan Creek (3).

Ecological Areas and Open Spaces
There are 13,624 acres of existing ecological areas[4] in the subwatershed; a majority of this land is located in the subwatershed's 5,889 acres of floodplain. There are limited publicly accessible ecological resources in the subwatershed. Recreational opportunities that do exist are predominately along the Mississinewa River (the highest recreational/canoeable stream on the waterway). There are roughly 10 miles of the Mississinewa River in the watershed. Various types of open space exist within the watershed. Harter Park, a 60 acre park in Union City, contains one recreational trail. The Little Mississinewa River runs through the park. There are four schools that have playgrounds and/or schoolyards. Nine cemeteries of various sizes are located throughout the watershed.

SUMMARY OF DATA FROM REGULATED LAND USES
Various regulated land uses exist within the watershed. Data from the IDEM Virtual File Cabinet and from the IDEM SSO website was reviewed to determine the impact of these land uses on water quality. Although some overflows occurred during the time of this study, the Project Manager determined that these regulated point sources did not significantly impact water quality. Raw water quality data collected for this study was examined according to the dates on which violations occurred in order to make this determination.

Cardinal Ethanol, LLC has three NPDES permits. Individual Permit IN0063177 is for discharge of non-process wastewater into the White River. The White River is not within the UMRW. Therefore, this data is not included in this report.

4 In this watershed plan, forests, wetlands, grasslands, and pastures are considered "ecological lands."

There is no water quality data for General Permit ING670054 and General Stormwater Permit INRM01125, which allow for the discharge of hydrostatic test water and the discharge of stormwater, respectively, to Shelly Ditch (a tributary of the Little Mississinewa River).

SSO Overflows
Sanitary sewer systems (SSOs) are different from combined sewer systems (CSOs) in that they are designed to only convey sanitary wastewater and are not designed to also convey stormwater, as is a CSO. A list of SSO sewer bypass/overflow incidents can be accessed on the website of the Indiana Department of Environmental Management. The lists for 2014 and 2015 were reviewed for facilities within Headwaters Mississinewa HUC 10. These incidents *do not* include normal precipitation related discharges from authorized CSO outfalls.

There were 6 Sewer Bypass/Overflow Incident Reports at the Union City Municipal Sewage Treatment Plant from January 1, 2014 to December 31, 2015, totaling 626,333 gallons discharged to surface waters. The closest UMRWP water quality sampling date was 17 days following an incident. Therefore, it is assumed that the overflow would not have been detected by project sampling. For data on these overflows, see Appendix V.

HEADWATERS MISSISSNEWA RIVER HUC10 WATERSHED CONCERNS
There were a number of stakeholder concerns identified for Headwaters of Mississinewa HUC 10. Many of these concerns have been validated by linking water quality data to desktop survey data and information from the watershed inventory. These concerns and their causes are outlined in Table 10.17. Through the synthesis of water quality data and watershed inventory data, causes were linked with sources. In most cases, these sources were identical to initial concerns. The following is a summary of the most significant characteristics of this watershed as they relate to water quality.

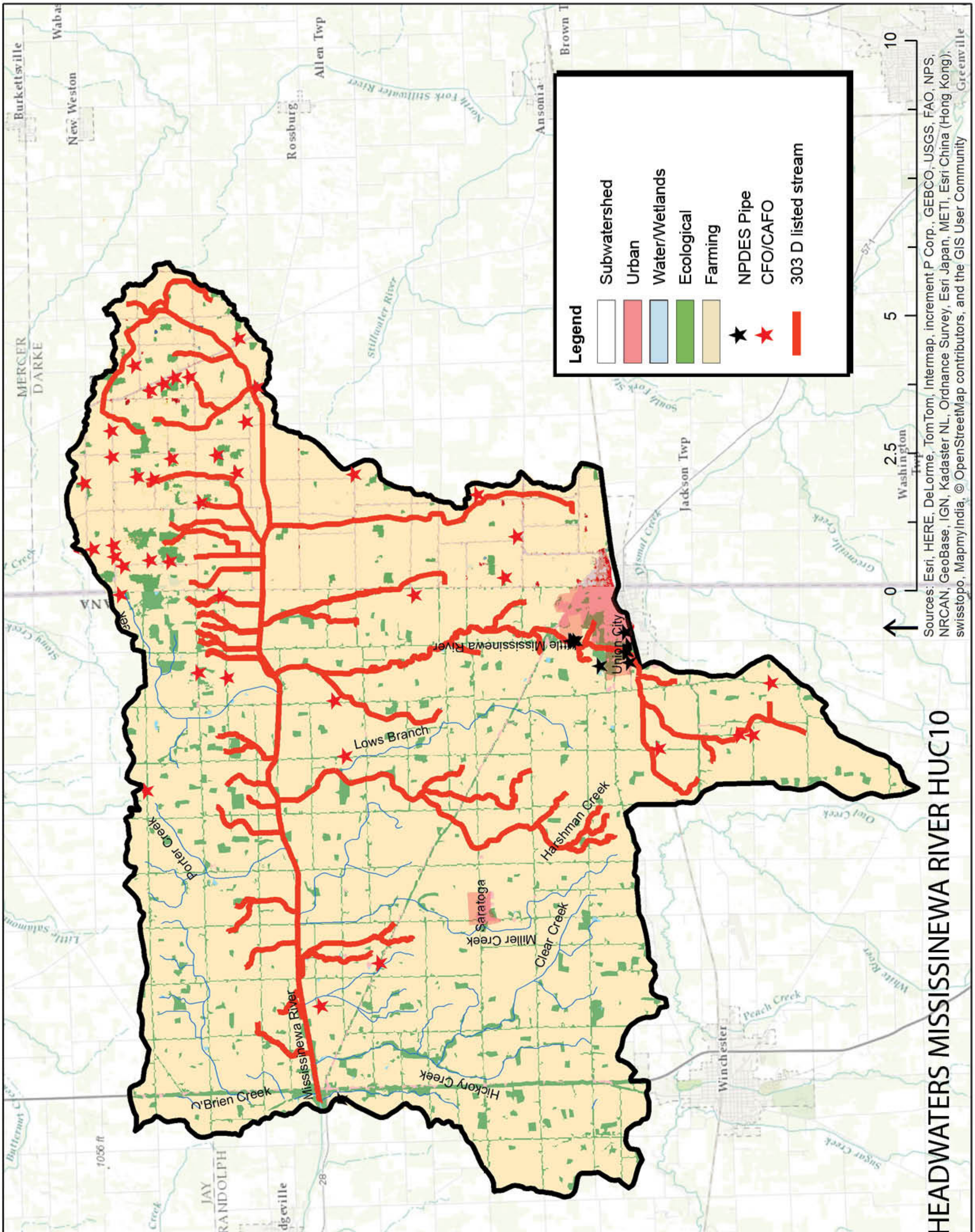
This HUC 10 had the second highest average number of exceedences, behind Big Lick Creek. Nitrate levels in this HUC 10 are generally up to two times higher than other HUC 10 sites. Lowering nitrate levels in water should be a priority in this watershed. High amounts of nitrogen applied to fields annually (due to the high percentage of cropland in the watershed) is likely main contributor of nitrate to surface waters. Other sources of nitrate include but are not limited to land application of manure (from the high concentration of CFOs in this watershed) and livestock accessing streams (Table 10.15). It is also likely that land application of manure and livestock accessing streams is also influencing E. coli levels during high flow via surficial runoff. Other possible E. coli sources include but are not limited to failing septic systems.

High TSS and phosphorus are another concern that may be caused by but are not limited to bank erosion and erosion through surficial runoff (see Table 10.15, “Rills/Gullies”). Conventional tillage is relatively low in this subwatershed but an average of 216 acres/sq mi indicates that a decrease in conventional tillage would likely have a positive effect on erosion caused by surficial runoff. Phosphorus fertilizer applied to agricultural fields is another source of phosphorus in waterways. Overapplication of phosphorus may also be occurring due to application of manure from CFOs.

Flooding was a concern expressed by stakeholders in this area. Data from this project did confirm the concern that heavy rains may be causing abnormal erosion. The five highest TSS readings recorded during this study were at sites within this watershed and occurred during a high flow event in March. The creation or restoration of wetlands and the installation of drainage water management or saturated buffer systems are all BMPs that could slow/reduce water entering waterways during storm events, thus decreasing erosion.

TABLE 10.17 | Headwaters Mississinewa River HUC 10 watershed concerns

Concerns	Cause of Concern	Subwatershed
Public Concerns		
Socioeconomic	Flooding	Not specified
Socioeconomic/Fish and Wildlife	Bank erosion; sloughing; heavy rain resulting in abnormal erosion.	Not specified
Recreation and Public Water Supply/ Fish and Wildlife	Logjams and beaver dams	Not specified
Project Manager Concerns		
High E. coli levels	Land application of manure, failing septic systems	All sites
High phosphorus levels	Conventional tillage, bank erosion above expected levels	Little Mississinewa, Gray Branch, Jordan Creek and Porter Creek
High nitrate levels	Nitrogen application on farm fields, land application of manure, failing septic systems	All sites
High TSS levels	Conventional tillage, bank erosion above expected levels	All sites
Poor biological scores	Poor habitat quality, poor chemical water quality	Little Mississinewa River
Poor habitat scores	Removal of riparian vegetation, sedimentation, channelization	Gray Branch



MAP 10.4 | Headwaters Mississinewa River HUC 10 Watershed

10.5 MASSEY CREEK HUC 10

The Massey Creek HUC 10 (0512010305; 150,192 acres) contains eleven HUC 12 subwatersheds: Back Creek (051201030504), Barren Creek (051201030503), Boots Creek (051201030511), Branch Creek (051201030510), Deer Creek (051201030508), Hoppas Ditch (051201030501), Lake Branch (051201030502), Little Deer Creek (051201030507), Little Walnut Creek (051201030505), Lugar Creek (051201030509), and Walnut Creek (051201030506). The watershed is located in the northwest part of the study area. Most of the watershed acreage is located in Grant County (86%) with the rest located in Delaware (5%), Blackford (5%), and Madison (4%) counties. The Mississinewa River flows in a northwest direction through four of the subwatersheds (Hoppas, Lake Branch, Branch, and Boots).

The watershed is located adjacent to the northern moraines and subsequently has topographic changes throughout it. An average of specific geomorphic characteristic rankings predict high, moderate and low sediment transport potential for different areas within the watershed. The average grade change of the subwatershed is 104 feet. There is a gross estimate of 345 billion cubic yards of unconsolidated aquifers in the watershed.

CURRENT WATER QUALITY AND HABITAT QUALITY SUMMARY

DATA COLLECTED FOR THIS WATERSHED MANAGEMENT PLAN[1]

Water quality sampling was conducted at eleven locations, with one in each of the eleven HUC 12 subwatersheds within Massey Creek HUC 10. The UMRW-P conducted sampling monthly from 2014-2015. Table 10.18 depicts water quality results for each parameter as well as the water quality target for each parameter. Water quality results show the average of all water quality data collected for each parameter, regardless of flow conditions at the time of sampling. Averages highlighted in yellow are exceeding the parameter water quality target set by the Project Manager. All subwatershed and mainstem sites in Massey Creek HUC 10 exceeded water quality targets for E. coli and nitrate and all mainstem sites exceeded water quality targets for total suspended solids. Of the seven tributary subwatershed sites, there were three exceedences for total suspended solids, one for average QHEI, two for IBI and one for mIBI. Of the four mainstem sites, one site was exceeding for phosphorus. There were no exceedances for mainstem sites for the parameters of average QHEI, IBI and mIBI. There were a total of 34 exceedances for an average of 3.1 exceedances per subwatershed/ mainstem site.

HISTORICAL WATER QUALTITY SUMMARY

303(D) LIST OF IMPAIRED WATERS, 2014

According to the 2014 303 (d) list, the entire length of the Mississinewa River within the watershed in Grant County is impaired for PCB's. Assessment units are impaired for PCBs are as follows: IB0352_01, IB035A_02, IB035A_03, and IB035B_01. It is also impaired for E. coli along four assessment units in Grant County. Creeks in three tributary subwatersheds had impairments. None of these impairments were for PCBs. Within Little Deer Creek tributary subwatershed, Little Creek was impaired for biotic communities. Within Deer Creek subwatershed, Deer Creek was impaired for E. coli. Within Boots Creek subwatershed, Boots and Massey Creeks were impaired for biotic communities.

LARE (LAKE AND RIVER ENHANCEMENT) STUDY PHASE IV

The Middle Mississinewa River Watershed Diagnostic Study was conducted by Taylor University faculty and students and funded by a grant obtained through the LARE program of the IDNR and a match from the Grant County SWCD. The study area consisted of eleven subwatersheds. Samples were taken at one site in each subwatershed located near the stream's confluence with the Mississinewa River. Samples were also taken to analyze water chemistry at four points along the Mississinewa River mainstem. Water samples were collected four times from 2007-2011 to determine chemical and physical water quality. Flow conditions at the different sampling times were baseflow (July), low flow (October and November), and moderate flow (April), the last being measured over a period of four days. Samples were measured for discharge, temperature, pH, dissolved oxygen, conductivity, turbidity, total nitrogen, nitrates, ammonia, total phosphorus, and orthophosphate. E. coli was sampled for separately, weekly over a period of five weeks. Biological sampling was conducted once in each subwatershed and evaluated using a combined modified ICI and EPT/C ratio. Stream physical quality was assessed through a QHEI survey conducted on 3 occasions from 2005 to 2010.

Results of the study indicated that Boots and Massey Creek had impaired biotic communities as well as poor quality habitat. Results of the study's water quality tests showed that turbidity was generally higher at sites north of the river (due to higher slope relief on the north side of the river). The study recommended that agricultural land along the Mississinewa River should receive sediment control practices (especially southwest of Upland). Boots Creek and Lake Branch had consistently high E. coli concentrations. It is important to note that all of the sites mentioned from this study were tributary sites. Although they may have the same names as mainstem Mississinewa sites in this study, they actually refer to a smaller tributary subwatershed within a particular subwatershed.

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1 Methods, sampling agency/group, etc. are discussed on p. 106 through 110. The following paragraph and table summarize results from Section 8, *Current Water Quality*, and Section 9, *Biological Assessments*.

TABLE 10.18 | Massey Creek HUC 10 Subwatershed data exceeding water quality targets																	
Sample Site	E. coli (cfu/100mL)		Total Phosphorus (mg/L)		Nitrate [N] (mg/L)		Total Suspended Solids (mg/L)		QHEI (Habitat Quality)		IBI (Fish Community Quality)		mIBI (Macro-invertebrate Community Quality)		Dissolved Oxygen Minimum (mg/L)	
	Avg	Target	Avg	Target	Avg	Target	Avg	Target	Score	Qual.	Score	Qual.	Score	Qual.	Min.	Target Min.
HUC 10 pour point	767	235	0.24	0.3	2.4	1	58.5	25.0	66	Fair	48	Good	40	Fair	7.31	4
Subwatersheds																
Back Creek	1523	235	0.15	0.3	2.5	1	29.6	25.0	69.5	Fair	32	Poor	42	Fair	7.81	4
Barren Creek	3631	235	0.08	0.3	3.6	1	16.1	25.0	57	Fair	36	Fair	36	Fair	8.55	4
Deer Creek	531	235	0.11	0.3	3.2	1	13.5	25.0	73	Good	28	Poor	42	Fair	6.67	4
Little Deer Creek-Deer Creek	1059	235	0.11	0.3	3.5	1	13.7	25.0	53	Fair	38	Fair	48	Good	5.62	4
Little Walnut Creek-Walnut Creek	1137	235	0.26	0.3	2.0	1	23.1	25.0	50	Poor	36	Fair	42	Fair	4.23	4
Lugar Creek	1844	235	0.18	0.3	1.2	1	41.4	25.0	71	Fair	40	Fair	34	Poor	7.27	4
Walnut Creek	1032	235	0.21	0.3	1.4	1	34.6	25.0	61	Fair	38	Fair	38	Fair	7.31	4
Mainstem Sites																
Boots Creek-Mississinewa River	767	235	0.24	0.3	2.4	1	58.5	25.0	66	Fair	48	Good	40	Fair	7.31	4
Branch Creek-Mississinewa River	759	235	0.41	0.3	2.7	1	51.3	25.0	71	Fair	52	Good	44	Good	7.03	4
Hoppas Ditch-Mississinewa River	1055	235	0.28	0.3	2.9	1	82.7	25.0	62	Fair	46	Good	42	Fair	6.65	4
Lake Branch-Mississinewa River	1511	235	0.25	0.3	2.7	1	55.2	25.0	72	Good	48	Good	44	Good	6.54	4

LAND USE SUMMARY

Historic Conditions

Similar to other subwatersheds, the historic/natural conditions of the site were dominated by forest-wetlands and diffuse streams and rivers. There are 42,488 acres of hydric soils making the historic presence of wetlands on these soils likely (28% of subwatershed). The majority of soil types are ranked as moderate or poorly drained with 591,369 acres of NRCS category C soils and 51,551 acres of NRCS category D soils. There are 10,210 acres of land in the subwatershed that is considered prime ecological land due to its geomorphic and historical conditions. There are 110 miles of National Hydrography Dataset mapped tributaries within the watershed. Data gather during a desktop survey indicated that an estimated thirty percent (33 mi) of these tributaries need buffering. Major streams include Sports Run (0.8 mi.), located in the Walnut Creek subwatershed.

Data from a desktop survey of the watershed can be found in Tables 10.19 and 10.20. For this desktop survey, various land use attributes were counted or measured using Google Earth. They include rills/gullies, construction sites, fertilized lawns, sports fields, runoff sites, erosion sites, and vehicle storage sites.

Urban Population

The total population within the watershed is 56,714 with a population density 241 persons per sq mi. 52% of the population (29,636) live incorporated towns of Marion (31,309), Gas City (pop: 5,937), Upland (pop: 3800), Fairmount (2,990), Jonesboro (1,882), Matthews (595) and Fowlerton (295). The remaining 48% of the population (27,058) of the population lives in diffuse areas throughout the subwatershed. There are 19 CSOs active in the subwatershed, with 16 in Back Creek (Fairmount) and 3 in Boots Creek (Marion). According to an article posted on 10/16/12 in the Indiana Economic Digest by Matt Troutman of the Chronicle-Tribune, “the Fairmount Town Council approved up to $6.2 million in bonds used to finance renovation and construction at its wastewater treatment plant…Fairmount has about 60 overflow events annually.” The article also indicated that the city of Jonesboro also upgraded its sewage system. “…The city has until 2014 to separate stormwater and sanitary sewers on its west and southwest sides.”

According to the 2010 census, there are approximately 23,551 housing units within the watershed. Based on known populations in urban areas 29,636), well count (3,264), and average household size for the region (2.25), it is estimated that there are 10,831 houses in non-incorporated areas using septic systems. Many of these rural homes are built in suburban developments or in high concentration areas outside incorporated towns. There are 20,479 acres of these septic “hot spots” in located in the watershed, while only 6 acres within the watershed are considered suitable for septic systems.

The urban area footprint incudes 20,911 acres with an estimated impervious surface footprint of 5,209 acres. No areas slated for development were identified. There are 332 regulated point sources in the subwatershed, two brownfields and six voluntary remediation sites. The subwatershed also includes 18 landfill structures, one industrial park, and no ethanol plants. Of the 18,440 workers who live in the subwatershed area, 14,780 (80%) travel out of the subwatershed for work. The highest concentration of jobs that do remain are in the health care and social assistance (20%), educational services (17%), retail trade (13%), and manufacturing (12%) sectors.

Agriculture

The Massey Creek Subwatershed consists of 73% cultivated cropland and 14% developed land (Map 10.5). Of the cultivated cropland, 85% or 92,804 acres is conventional tillage corn crops. 25% or 27,127 acres is conventional tillage soybean cropland (calculated based on the % tillage of each county transect data). Due to the amount of agricultural lands and particular types of tillage practices, there is an estimated 599,654 tons of sediment, 922 tons of nitrogen, and 244 tons of phosphorus discharged to the Mississinewa River annually.[2] These estimates are based on estimated fertilizer use on agricultural cropland (generated using the Export Coefficient Model). Throughout the study region, livestock grazing is limited due to the regional trend towards Combined Feeding Operations. There are 19 CFOs in the subwatershed located in Back Creek (2), Barren Creek (1), Branch Creek (1), Deer Creek (1), Hoppas Ditch (6), Little Walnut Creek (6) and Walnut Creek (2). 33 sites where livestock have direct access to streams were identified using GIS.

Ecological Areas and Open Spaces

There are 19,986 acres of existing ecological areas[3] in the subwatershed; a majority of this land is located in the subwatershed’s 3,795 acres of floodplain. Thirty percent (33 mi) of tributaries need buffering. The watershed contains roughly 18 miles of the Mississinewa River. There are limited publicly accessible ecological resources in this watershed. They predominately occur along the Mississinewa River. There are two public access sites along the Mississinewa for boats, one in Matthews and one in Gas City.

Various types of open space exist within the watershed. The Cardinal Greenway biketrail begins in Jonesboro and continues northwest, passing through Marion. There are roughly eight small to moderate size city parks (located in Marion, Jonesboro and Gas City) in the watershed. There are 22 schools that have playgrounds and/or schoolyards. Sixteen cemeteries of various sizes are located throughout the watershed. Two golf courses within the watershed offer additional recreational opportunities.

SUMMARY OF DATA FROM REGULATED LAND USES

Various regulated land uses exist within the watershed. Data from the IDEM Virtual File Cabinet and from the IDEM SSO website was reviewed to determine the impact of these land uses on water quality. Although some overflows occurred during the time of this study, the Project Manager determined that these regulated point sources did not significantly impact water quality. Raw water quality data collected for this study was examined according to the dates on which violations occurred in order to make this determination.

SSO Overflows

Sanitary sewer systems (SSOs) are different from combined sewer systems (CSOs) in that they are designed to only convey sanitary wastewater and are not designed to also convey stormwater, as is a CSO. A list of SSO sewer bypass/overflow incidents can be accessed on the website of the Indiana Department of Environmental Management. The lists for 2014 and 2015 were reviewed for facilities within Massey Creek HUC 10. These incidents *do not* include normal precipitation related discharges from authorized CSO outfalls.

There were 14 Sewer Bypass/Overflow Incident Reports at the Upland Municipal Waste Water Treatment Plant from January 1, 2014 to December 31, 2015, totaling 241,820 gallons discharged into surface waters. The closest UMRWP water quality sampling date was 26 days following an incident. Therefore, it is assumed that the overflow would not have been detected by project sampling. For data on these overflows, see Appendix V.

IDEM Virtual File Cabinet

According to VFC document #80013324 biosolids from Gas City Water Pollution Control have been applied at Hodupp Farms in Branch Creek since April 2010. As of September 2013 there are five sites totaling 272 acres available for nonsite-specific land application. The sites are adjacent and located near the intersection of Wheeling Pike and CR 450 E in Grant County. According to VCF document #80071002, a renewal of Permit No. IN LA 000077, issued to the Town of Fairmount, allows land application of wastewater treatment biosolids to farmland located in Grant County. For more information concerning the permit, contact Mr. Steve Deal, Certified Wastewater Treatment Plant Operator, at (765)948-4313 or fairmountwater@netzero.com.

2 See Taylor University study for a more complete projection of sediment contribution.

3 In this watershed plan, forests, wetlands, grasslands, and pastures are considered “ecological lands.”

TABLE 10.19 | Desktop Survey Results									
HU_12_NAME	Rills/ Gullies	Rills/ Gullies per cropland acre	Fertilized Lawns	Sport Fields	Bank Erosion sites	Runoff sites*	Junk storage sites	Sites where livestock are accessing stream	Mobile home sites
Back Creek	164	0.02	14	2	3	8	2	1	5
Barren Creek	179	0.02	1	0	5	7	1	1	1
Boots Creek-Mississinewa River	132	0.02	17	11	2	1	1	0	0
Branch Creek-Mississinewa River	206	0.02	43	7	15	10	1	2	3
Deer Creek	79	0.01	9	2	4	11	0	0	1
Hoppas Ditch-Mississinewa River	4524	0.52	24	6	6	24	15	27	0
Lake Branch-Mississinewa River	473	0.05	19	2	5	3	1	1	0
Little Deer Creek-Deer Creek	77	0.01	2	1	3	19	2	1	1
Little Walnut Creek-Walnut Creek	431	0.05	7	0	0	8	0	0	0
Lugar Creek	209	0.02	21	1	12	12	3	0	2
Walnut Creek	416	0.05	31	6	10	10	3	0	1
Total	6890	0.06	188	38	65	113	29	33	14

**Runoff sites are sites where rills/gullies are draining directly into waterways.

TABLE 10.20 | Desktop Survey Results								
HU_12_NAME	Tracks from recreational vehicles	Vehicle storage sites	Miles of NHD tributaries needing buffers	NHD tributaries needing buffers (percent)	Construction sites for new development	Quarry sites	Golf Courses	Derelict properties
Back Creek	0	2	3.67	43%	0	1	0	1
Barren Creek	0	1	0.39	3%	0	0	0	0
Boots Creek-Mississinewa River	1	0	2.98	33%	0	2	1	8
Branch Creek-Mississinewa River	0	2	0.00	0%	0	9	0	2
Deer Creek	1	2	4.83	44%	0	1	0	0
Hoppas Ditch-Mississinewa River	0	9	2.55	54%	0	0	0	3
Lake Branch-Mississinewa River	1	0	1.12	10%	0	0	0	0
Little Deer Creek-Deer Creek	0	1	7.88	43%	0	0	0	1
Little Walnut Creek-Walnut Creek	1	1	4.37	50%	0	0	0	0
Lugar Creek	1	0	2.85	18%	0	1	0	1
Walnut Creek	2	2	1.98	19%	1	7	1	3
Total	7	20	32.63	30%	1	21	2	19

MASSEY CREEK HUC10 WATERSHED CONCERNS

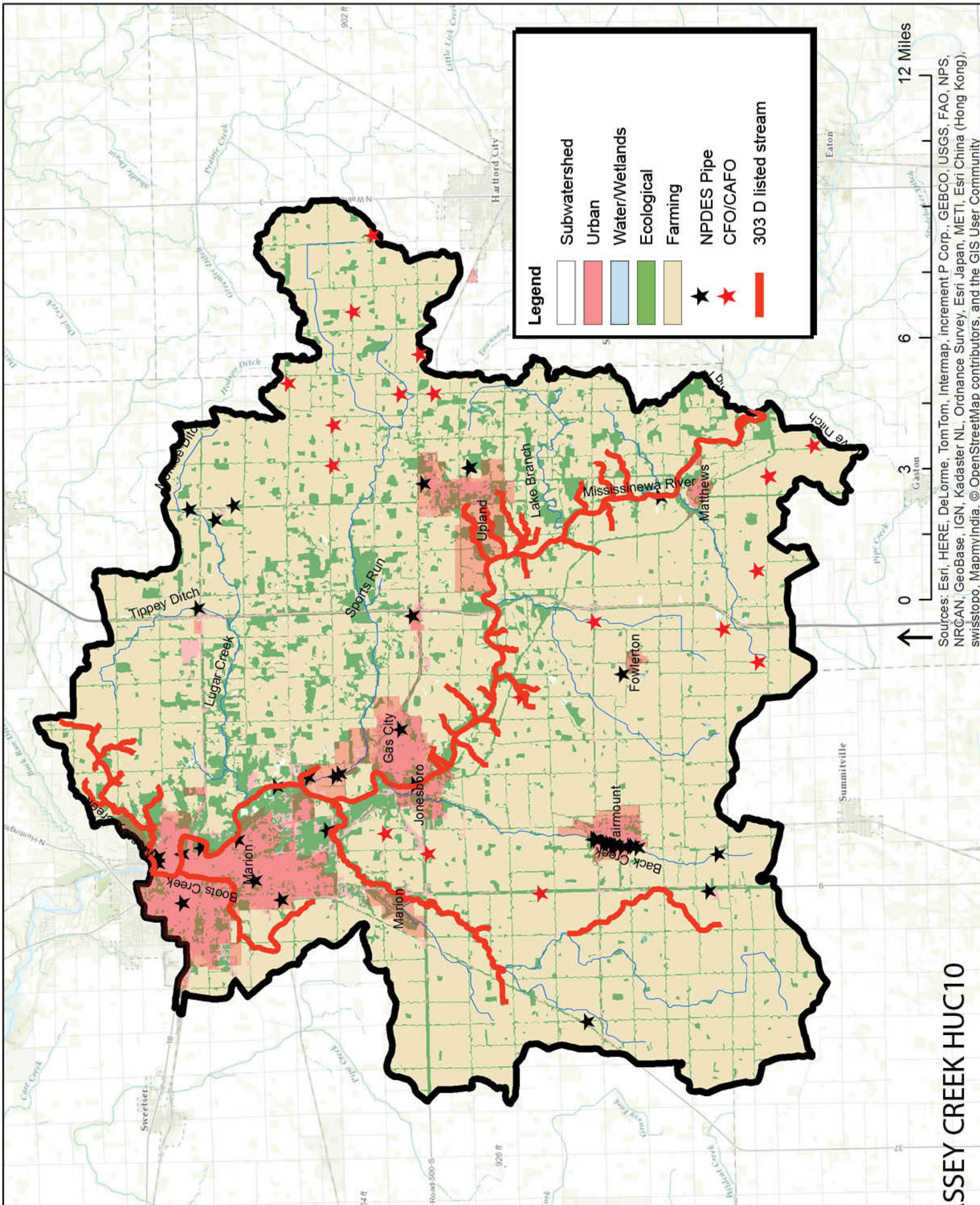
There were a number of stakeholder concerns identified for Massey Creek HUC 10. Many of these concerns have been validated by linking water quality data to desktop survey data and information from the watershed inventory. These concerns and their causes are outlined in Table 10.21. Through the synthesis of water quality data and watershed inventory data, causes were linked with sources. In most cases, these sources were identical to initial concerns. The following is a summary of the most significant characteristics of this watershed as they relate to water quality.

High nitrogen and E. coli levels at all sites are of concern. High nitrogen levels show some correlation with predicted levels of nitrogen applied to farmfields. The sites with the three highest averages also have the highest predicted amounts of nitrogen applied to fields. Failing septic systems and CSOs are likely sources contributing to high E. coli levels. The continued upgrade of CSOs will continue to help improve E. coli levels. Proper septic maintenance should be promoted within the region. Municipal sewer expansion should be explored. Failing septic systems and CSOs are also possible sources of phosphorus found in surface water.

Manure from livestock is another possible source of E. coli found in surface water. Barren Creek's high E. coli average may be due to livestock accessing streams (Table 10.19). Although only one livestock access point was noted in the desktop survey, it is located approximately 1 mile upstream of the sample site. Barren Creek has one WWTP, the Fowlerton WWTP, which only had one violation within the dates that sampling for this study occurred. The closest sampling date to the September 30, 2014 daily maximum violation was October 28, 2014. E. coli sampled on October 28 was 137 cfu/100mL. The monthly geometric mean at the Fowlerton WWTP was not in violation during September or October, nor any of the other months that sampling was conducted on Barren Creek. Barren Creek does not have a high number of septic systems. Septic density is 11.5/sq mi, which is lower than four of the other HUC 12 tributary subwatersheds in Massey Creek HUC 10. Barren Creek has only one of the nineteen CFOs located in Massey Creek HUC 10. Since CFO, CSO and septic system data does not suggest that it is the cause of high levels of E. coli in Barren Creek, it has been concluded that the close proximity of cattle entering the stream may be the cause of high E. coli levels on Barren Creek. Exclusion fencing cost share through the NRCS should be promoted in the Barren Creek and Hoppas Ditch subwatersheds; based on the desktop survey, Hoppas Ditch has the highest number of livestock access sites in the entire UMRW (Table 10.19). These two subwatersheds are adjacent. Holding a promotional event in Hoppas Ditch but near the border to Barren Creek may be ideal. Additionally, the desktop survey found the highest number of rills/gullies in Hoppas Ditch (Table 10.19). Although Hoppas Ditch is not designated as a critical area, it should be considered an area of special concern.

A high average rate of conventional tillage (511 acres/sqmi) in conjunction with a high sediment transport prediction for some subwatersheds and mainstem sites are likely contributing to high TSS and phosphorus averages at certain sites. Other sources of TSS and phosphorus include instream erosion (especially within Lugar and Walnut Creek subwatersheds; see Table 10.19) and livestock accessing streams. Cost share BMPs, such as filter strips, cover crops, and no-till equipment modifications will help to alleviate all nutrient and TSS concerns. Filter strips or riparian restoration will have the additional benefit of improving aquatic habitat, thereby improving impaired aquatic communities that are present in some streams.

TABLE 10.21 | Massey Creek HUC 10 watershed concerns		
Concerns	Cause of Concern	Subwatershed
Public Concerns		
Socioeconomic	Flooding, residue and tillage management	Not specified
Socioeconomic/Fish and Wildlife	Bank erosion	Not specified
Recreation and Public Water Supply/Fish and Wildlife	Logjams	Not specified
Project Manager Concerns		
High E. coli levels	CSO discharge, failing septic systems, land application of manure, livestock access to streams	All sites
High nitrate levels	Fertilizer application to farm fields, land application of manure	All sites
High phosphorus levels	Conventional tillage, erosion of banks above accepted levels	Branch Creek
High TSS levels	Convetional tillage, erosion of banks above accepted levels	Back Creek, Lugar Creek, Walnut Creek, Boots Creek, Branch Creek, Hoppas Ditch and Lake Branch
Poor biological scores	Poor habitat quality, poor chemical water quality	Back Creek, Deer Creek and Lugar Creek
Poor habitat quality	Removal of riparian vegetation, sedimentation, channelization	Little Walnut Creek



MAP 10.5 | Massey Creek HUC 10 Watershed

11. WATERSHED INVENTORY SUMMARY

The overall purpose of the Upper Mississinewa River Watershed Management Plan is to create a guide for improving the water quality of the Upper Mississinewa River for fish and wildlife and recreational uses. To do this, the plan attempts to identify areas with the worst water quality and their causes so that best management practices to help solve these problems can be implemented in these areas.

Development of the plan was initiated by community leaders and led primarily by the Project Manager, Flatland Resources LLC, and the Delaware County SWCD. While other attempts at watershed planning have taken place in the past (four LARE plans, each for one HUC 10 within the UMRW; Big Lick Creek HUC 10 is the only HUC 10 within the UMRW for which a LARE plan has not been developed), none are as comprehensive in scope as this current plan.

This watershed management plan strives to connect stakeholder concerns and interest in BMPs; information regarding the watershed's soils, hydrology, land use, etc; and watershed and water quality data (gathered as part of this study) in order to 1) identify critical areas (to which IDEM 319 cost-share funds will be directed) and 2) develop an action strategy to guide watershed activities and the allocation of 319 funds as well as the allocation of funds from additional sources.

The initial stages of this plan sought the input of community stakeholders primarily to 1) identify landowner water quality concerns and 2) identify landowner interest in best management practices to improve water quality (i.e., to address concerns). The most common concerns noted by stakeholders included concerns about logjams, flooding, and erosion (erosion concerns can be separated into concerns about erosion from agricultural fields and concerns about erosion from streambanks).

Logjams cannot be addressed using 319 implementation funds. While FOTG practice 580, Streambank and Shorline Protection, can be addressed using 319 funds, unlike most other FOTG practices it requires approval from IDEM and is considered a secondary practice, meaning that it "a BMP that may be implemented only after other BMPs have been implemented to address the pollutant of concern and supplementary BMPs are needed to fully address the concern. This practice will require prior approval by IDEM and will be approved on a case-by-case basis."[1] Despite these difficulties, there are other sources of funds available for these projects. Four out of the five LARE grants that have already been awarded to the Project Manager/DCSWCD/UMRW-P as a result of planning efforts undertaken for this WMP will target logjam or streambank problems. These four LARE grants will fund the following projects 1) removal of logjams on the Mississinewa River in Randolph County, 2) streambank stabilization along the Cardinal Greenway on Deer Creek, 3) BEHI/NBS assessment of Walnut Creek (TSS results verified stakeholder concerns that bank erosion was a problem on Walnut Creek), and 4) assessment of erosion problems on the Mississinewa River adjacent to the Marbook Campground located near Gas City. We will continue to identify the need for these types of projects and seek funding for them; such activities will be included in the action strategy in the following sections.

Based on land use and water quality data, (which will be discussed further in later paragraphs of this summary), we found that these stakeholder concerns were valid and concluded that they should be addressed. Furthermore, survey results showed that of the BMPs stakeholders are interested in, a high number of them address these stakeholder concerns.

Erosion from sheetflow on agricultural fields can be addressed by a number of agricultural BMPs, such as grassed waterways, cover crops, residue and tillage management, and filter strips. Landowner surveys resulted in the identification of 224 potential cost-share "projects" that 319 and other funds could be used to implement. The aforementioned agricultural BMPs that reduce erosion from sheetflow make up 33% of these potential cost-share projects, showing that there is both concern regarding erosion from sheetflow and interest in installing BMPs to mitigate it. Flooding can be addressed by a number of BMPs, such as drainage water management, stormwater runoff control, roof runoff structures, two-stage ditches, wetland restoration, and wetland creation. These BMPs that can reduce flooding make up 26% of potential cost-share projects identified through the survey. As with sheetflow erosion, we see that there is both concern regarding flooding and interest in installing BMPs to mitigate it.

We will continue to describe throughout the summary other but less frequently expressed stakeholder concerns when appropriate; many of these concerns are valid and activities that address them will be included in the action strategy in Section 16, Action Strategy, p. 251, following this summary.

This plan attempted to incorporate data and findings from past studies into its analysis. However, as shown in Section 7 (p. 101), past studies (datasets from four LARE plans at the HUC 10 level were analyzed and the studies' conclusions were also reviewed; the 303(d) List of Impaired Waters found within the state's Integrated Water Monitoring and Assessment Report was also reviewed) and monitoring efforts (datasets from EPA STORET, IDEM, and Hoosier Riverwatch databases were analyzed) contained data that is limited and variable (due to low frequency of sampling in some cases as well as differing methodologies, study areas and study scales), making their use for comparative purposes unsuitable.

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1 Indiana Department of Environmental Management. Section 319(h) Cost-Share Program Development Guidelines. Version 2. May 2015. http://www.in.gov/idem/nps/files/nps_compendium_fotg_practices.pdf

Therefore, this plan uses current water quality data collected from 2014-2015 by the UMRW-P and analyzed by the Muncie Bureau of Water Quality (within Massey Creek HUC 10 and Headwaters Mississinewa HUC 10) and the Indiana Department of Environmental Management (as part of TMDL development and within Big Lick Creek HUC 10, Pike Creek HUC 10 and Halfway Creek HUC 10) to compare subwatersheds and ultimately identify critical areas (subwatersheds) and develop an action strategy. Coordination between the Project Manager and IDEM resulted in the use of the same parameters and sampling methods, making it possible for the data to be used together for comparative purposes.

In order to focus conservation and restoration dollars in the most needed areas, this plan aims to gain a deeper understanding of the watershed. Because land use and the physical landscape directly influences water quality, an inventory of the land within the watershed was completed. The following narrative will summarize and synthesize the findings from the watershed inventory, while attempting to put it in the context of the concerns of stakeholders and community/project leaders:

LOCATION AND BACKGROUND

The Mississinewa River Watershed is in the upper headwaters of the Wabash watershed, which drains into the White and Ohio rivers before draining into the greater Mississippi River Basin, the most impaired regional watershed for sediment in the United States of America. The Upper Mississinewa River Watershed is approximately 415,000 acres encompassing 650 square miles and portions of six Indiana counties (Grant, Blackford, Madison, Delaware, Jay, and Randolph) as well as portions of Darke County, Ohio. There are approximately 924 miles of streams and ditches flowing into the Mississinewa along its 55 mile reach. Within the watershed, approximately 78% of the land is cropland, 9.7% is urban, 7.4% is forest, and 3.6% is pasture/grasslands. Only 0.5% are wetlands.

Of the 87,000 individuals living in the watershed region, only 4,000 individuals own parcels greater than 40 acres in size. This group of individuals control 66% or more of the total acres in the region and is the project's target audience. One thousand (1,000) individuals from the target audience (selected if parcels are adjacent to a waterway) were invited (through direct mail) to attend one of seven public input meetings. One hundred eighty-two (182) individuals either attended public meetings or provided comment through a response card system. The subwatershed areas with most vocal stakeholders were Fetid Creek-Mississinewa River, Platt Nibarger Ditch-Mississinewa River and Branch Creek-Mississinewa. The project had 150 concerns broadly categorized into (a) fish and wildlife, (b) health (drinking water/recreation), and (c) socioeconomic.

LANDSCAPE CHARACTERISTICS AND HISTORY

Glacial advance and retreat created two different landscapes in the UMRW: flat till and gently rolling moraines. Running in a general east-west direction throughout the northern part of the watershed, the moraine region has an increased slope gradient and is more susceptible to erosion than the flat till. Thirty-eight percent of the soils in the watershed are hydric, evidence of the forest wetlands that were abundant prior to European settlement of the area. These historic forest wetlands held a great deal of water on the land, allowing it to absorb into the ground and recharge aquifers. Some of this ground water surfaced again later along streams and rivers, providing them with baseflow. Along with European settlement in the region came an extreme alteration of this landscape. The land was cleared and drained for agriculture. This drainage was achieved through the installation of underground drainage tiles and the installation of ditches. The dredging and widening of streams was also necessary to accommodate the increased flow of water to the waterways. This hydromodification of the land has redistributed huge amounts of water to rivers and drainage ways, which can cause erosion and flooding along these waterways.

Despite the removal of surface level habitat, the foundation of the land within the watershed remains relatively intact; these foundational elements are high clay soils, hydric soils, gentle topography, and deep bedrock (all of which contributed to the historic forest-wetland landscape). The same surficial conditions that once resulted in wetland conditions continue to plague farmers today, despite efforts to drain land.

LAND USE

Cropland is by far the dominant land use within the UMRW, and very influential to water quality. Urban areas are the next most abundant land use, and also have a significant impact on water quality.

Geographic features (specifically, the moraine and flat till) roughly align with county boundaries as well as with the boundaries of the five HUC 10 watersheds within the UMRW. Because these features influence water quality, this relationship has made county by county (and HUC by HUC) descriptions easier, and allowed the Project Manager to identify somewhat distinct factors within each region that influence water quality. Furthermore, population densities are differential, with the highest population density in the western part of the watershed and the lowest in the eastern part of the watershed. Distinct characteristics accompany these differential population densities.

The non-moraine, flat till region in Delaware, Jay, and Randolph counties is relatively flat, with low sediment transport potential and a limited amount of highly erodible soils (HES). The flat landscape and relatively low population densities (especially in Jay and Randolph counties), have resulted in subwatersheds having the highest cropland percentages and subsequently the highest modeled fertilizer contribution to waterways in the entire watershed (besides Deer Creek and Little Deer Creek in Grant County). Conventional tillage rates are low in these areas. Low population densities have created an ideal setting for CFOs; their concentration is highest within Randolph county. Fewer urban areas have also resulted in these areas having the least amount of industrial point sources in the watershed. The population in this region is declining, with most of it spread diffusely across the landscape or in small communities, some of which are unsewered.

Therefore, there is a high number of septic systems in these areas. This region has the least amount of housing units, least amount of incorporation, least sprawl, and least amount of CSOs. Because of these characteristics, the region has high nitrate, phosphorus, and E. coli levels at certain times. It is important to preserve agricultural land in this region and strengthen production potential.

The presence of the moraine results in a slightly more undulating landscape in Grant County. It is an influencing factor as to why there is a relatively higher concentration of ecological lands in this area. This region has more drainage networks, higher sediment transport potential, and higher instream channel erosion due to the unconsolidated strata. This area also has greater aquifer capacity than other areas. The area also has a high percentage of conventionally tilled land, which increases the chance of erosion. It is a noteworthy region from a geological, land use, and ecological perspective. The overall "flat" geography of the land is the reason why the land is predominantly agricultural despite the slightly differentiated geology of the moraine. However, having the highest percentage of urban areas within the watershed causes this area to have a lower percentage of cropland than other regions. The area has a low number of CFO's and lower modeled fertilizer contribution to waterways since there is a lower percentage of cropland. Population density is high within this area, with some of the highest concentrations of septic systems in the watershed. There is also a high number of CSO's and other regulated point sources. A high concentration of CSO's are found within Back Creek subwatershed, with fewer in Boots Creek.

Blackford County has many similarities to Grant County. Both have the highest rates of conventional tillage and the highest percentage of D soils. Because Blackford County has more cropland than Grant County, the highest concentration of rills and gullies were found in Blackford County due to the aforementioned conventional tillage and D soils, as well as high concentrations of HES. Blackford County is less urban than Grant County, but still has a high number of CSOs and other regulated point sources. Areas within Blackford County also have high concentrations of septic systems.

Overall, land use change over a 10 year period indicates relatively stable land uses within the entire watershed. While the overall population is in decline, some areas are growing slightly, which may result in marginal changes to land-use. Also, cuts to governmental conservation practices may revert protected land to agricultural ones and high prices for crops may drive ecological areas to be converted to farmland. There is industrial growth in areas near I-69 intersections which is also having minor changes in land-use from agriculture to light industrial. In general, land-use breakdowns are stable.

HYDROMODIFICATION

Unstable streambanks due to hydromodifcation are the cause of high sediment levels in subwatersheds that have highly modified streams. Aerial and windshield surveys confirm extensive streambank erosion in these subwatersheds. The root structures of woody vegetation have the potential to strengthen destabilized streams. According to a desktop survey of NHD mapped streams, 30% percent of tributary and river miles lacked adequate buffers. Many floodplains have been found to lack agricultural buffers and cultivated cropland reaches the edges of the ordinary high water mark in some instances. The lack of vegetative buffer prohibits nutrient uptake potential. In addition, dredged and modified streams no longer have access to the floodplains that once helped impede flow and reduce stream velocity. Opportunities should be sought to expand floodplain access for streams or install water retention/detention features such as ponds or wetlands. Since ponds are potential nutrient sinks, the need for wetland plant materials in conjunction with these projects is necessary.

The mainstem Mississinewa River also has a series of levees and dams that disrupt natural stream habitat and confine aquatic organisms to specific reaches of the river. Dams are also sinks for phosphorus and other nutrients. Conventional volume control and conveyance, combined with poor soil infiltration, has resulted in an over widening or deepening (incision) of channels.

WATER QUALITY MONITORING

Two agencies (the Muncie Bureau of Water Quality and the Indiana Department of Environmental Management) conducted water quality sampling for this plan from April 2014-March 2015. Sampling was generally done on a monthly basis, although sampling time varied some between the two agencies. Four parameters were analyzed by both agencies throughout the sampling period: nitrates, total phosphorus, E. coli, and total suspended solids (TSS). Temperature, pH, dissolved oxygen, and flow were also measured. Flow data was used to classify sampling into either storm flow (high flow) or baseflow (low flow) events. Parameter data was divided based on flow, and averages calculated. Averages were also calculated for all events regardless of flow. Twenty-eight sites were assessed for this study, twelve located on the mainstem of the Mississinewa River and the other sixteen located on tributaries. Sites were divided into "mainstem" or "tributary" sites for analysis.

E. COLI

Average E. coli loads for the mainstem of the Mississinewa River were 8.2 times above targets, needing 84% reduction. Tributary subwatershed average loads was 9.6 times above target, needing 89% reduction.

One source of E. coli pollution is human waste from CSOs. Sample sites with the highest E. coli averages were typically downstream of waste water treatment facilities. The presence of CSOs in seven communities causes human waste discharge to the Mississinewa River or one of its tributaries during major rain events. Another source of E. coli to waterways is human waste from failing septic tanks; the highest concentrations of septic tanks are in proximity to small towns in the region including Fowlerton, Dunkirk, Eaton, and DeSoto as well as areas adjacent to the cities of Marion, Upland, and Union City. Because poorly draining soils underlie septic system leach beds, the systems are not able to function properly. A thicker layer of aerobic, unsaturated soil is necessary to remove E. coli.

The expansion/sprawl of unincorporated areas is of concern to stakeholders. Although there is an overall population decrease in the watershed, some rural census tracts adjacent to these urban areas are growing in population. Appropriate waste management systems need to be incorporated into any new growth in the future.

Another source of E. coli is waste from Combined Feeding Operations; the eastern portion of the watershed has the highest concentration of CFOs in the region. Darke County has the highest concentration of CFOs in Ohio. Improper field application of CFO waste is a stakeholder concern. Stakeholders were generally concerned about pathogen impact to recreation and drinking water quality. Waste from smaller animal feeding operations is also a concern. There were numerous identified points within the watershed where livestock are accessing streams.

E. coli levels were consistently higher during storm flow events in the eastern part of the watershed than in the western part. This correlates with the higher predicted levels of manure application to land due to high CFO concentrations in this part of the watershed. It is likely that there is less land application of manure/sludge in the western part of the watershed. In contrast, E. coli levels during base flow were generally lower in the eastern part of the watershed than in the western part. This is likely due to the lower concentrations of septics in the eastern part of the watershed. High E. coli levels at low flow in the western part of the watershed are likely due to higher concentrations of septic systems, which are known to pollute streams at base flow.[2] E. coli levels were also higher at tributary and main stem sites that were downstream of CSO's. There are few CSO's on the main stem of the Mississinewa. There were few or no recorded overflows of SSO's during the time of this study. Information about CSO overflows during the time of this study still needs to be gathered. Excessively high levels of E. coli where no CSOs and a low number of septics are present may be due to livestock in streams. Barren Creek was one such site that had unexpectedly high E. coli, but livestock were found to be present in streams not far from the sampling point.

While CSO's continue to be updated, thereby improving water quality, septic systems are a problem that aren't addressed as often. E. coli will likely continue to be a persistent problem due to high cost of new septic systems and CSO/SSO updates. In areas where sprawl is occurring, installation of appropriate septic systems is important. Mound septic systems may be necessary rather than traditionally designed systems. The creation of regional sewer districts or expansion of existing ones may be appropriate in areas of new development or in densely populated areas currently using septic systems.

It is also important to keep in mind that there are more complexities of waste treatment systems than are apparent that can be influencing E. coli levels. For instance, prior to the 1970's the septic systems of many homes were tied into agricultural ditches. Also, leaks in sewer lines could be contributing to E. coli levels.

SEDIMENT

Mainstem TSS averaged 151 mg/L, exceeding levels 6.7 times project targets; requiring an 86% load reduction. Despite the regions normatively "flat" terrain, there are discernible geographical subwatershed differences. A desktop survey identified rill and gully formations in agricultural fields and found a higher concentration in subwatersheds rated for elevated sediment transport potential based on (a) geological indicators, (b) presence of highly erodible soils, and (c) lack of conservation tillage. Streambanks are predicted to be a significant sediment source on Lugar Creek and Walnut Creek; both have high sediment loads during high flow events (20-40% greater other subwatersheds) while having a lower percentage of agricultural land-use (compared to other subwatersheds). Streambank erosion sites were identified on these tributaries using desktop surveys and public input. Stakeholder "fish and wildlife" concerns are related to the impact of turbidity/sediment on aquatic ecosystems. The loss of agricultural land (bank and surface erosion) was also a socioeconomic concern frequently cited by landowners.

Sediment levels were elevated during winter months, which may tie to agricultural land use contributions. However, the elevated levels in Lugar Creek and Walnut Creek, while influenced by tillage practices, may be more heavily influenced by the differences in the moraine and drainage features than differences in farming practices. It is likely that farmers in this region are not using "worse" practices or anything different than other farmers in the watershed. Therefore the geological attributes may be the most significant factor in sediment levels. Therefore, stream management may be a bigger factor in reducing sediment levels than field management practices. The stream management practices, similar to other counties in the region, may be more exposed by geological factors such as substrate, increase in number of streams, frequency of channelization, and potential higher volumes in this region. While conservation practices like cover crops and filterstips are important to advocate and will reduce sediment contributions (as well as nutrient contributions), data may suggest that stream stabilization projects in geographically problematic areas may have a greater impact.

Soil type may also influence how producers make decisions about conservation tillage practices. Poorly draining soils are often tilled to increase rate of surface drying. Also, in two fields where farmers are doing the same types of land management practices, the geological attributes and sediment transportation potential may result in a disproportionate contribution from the two. As mentioned, this polarization of the landscape into the moraine region, and non-moraine region is instructive and these factors are at play on Lugar Creek and Walnut Creek. The undulating landscape is more difficult to farm, which is why we see a greater percentage of ecological land use and conventional tillage.

The soils in the moraine region are hydric and have a "D" soils type drainage capacity (poorly draining soils) – which may result in a denser ditch/tile network, greater, hydromodification, and greater conventional tillage practices (for reasons noted above).

2 Rose, J. B. August 3, 2015. [web page] Septic tanks aren't keeping human sewage out of rivers and lakes. http://www.rose.canr.msu.edu/press-releases/2015/8/3/septic-tanks-arent-keeping-human-sewage-out-of-rivers-and-lakes [Accessed 10 December 2015]

NUTRIENTS

Mainstem nitrogen averaged 7.21 mg/L, 8.4 times target, requiring an 88% load reduction. Nitrogen was highest in subwatersheds with the largest percentage of agricultural land-use, consistent with pre-sampling modeling (Simple Coefficient Method, STEPL). Seasonal nitrogen levels showed a clear connection to agricultural land application patterns (pre-season application, side dress). Subwatersheds with the highest concentration of lawns, sports fields, and/or golf courses had lower nitrogen levels compared to predominantly agricultural subwatersheds. Local On-Farm Network®/ Infield Advantage data demonstrates that 85% of participating producers are applying optimal levels of nitrogen; excess nitrogen in waterways is likely driven by solubility, not over application. According to National Hydrology Dataset, 35% of surveyed river and tributary miles lacked a buffer or filterstrip on both sides of the channel. Stakeholders were concerned that excess nutrients/algae is causing stress to fish and other aquatic wildlife. Stakeholders were concerned about financial loss associated with nitrogen leaching. Based on the analysis of water quality, it is estimated that nitrogen levels are elevated in subwatersheds that have a higher percentage of farmland concentration. This is because many of the application rates farmers are using are standardized and there is little variance between farmers. Nitrogen application rates have continued to decline slightly nationwide. On-Farm Network®/Infield Advantage network cohort data also illustrates this standardization and results suggest optimal rates of application. Geography is also a factor in concentration of agricultural land; flatter subwatershed areas have higher concentration of farm fields due to ease of access. The fact that these areas have higher concentration of farm fields means greater nitrogen application tonnage per subwatershed stream. This also ties to phosphorus. Again, this is not because farmers in this region are doing anything wrong or different than farmers in other regions, but elevated levels in the river are a factor of geography and farm concentration when compared to other subwatersheds. In agriculture, chemical application rates have been reduced (through the guidance of the Purdue Extension Office) and no-till practices are on the rise in most counties in the watershed area. However, WQ studies continue to show the increase of Phosphorus, Nitrogen, and Sediment to the rivers during non-growing season which is consistent with national studies. This emphasizes the importance of cover crops and other plant material on the ground on both streambanks and agricultural land during the dormant months. This would help to minimize rill and gully erosion that was discovered throughout the watershed as well through the desktop survey. Based on survey data, 26 out of 92 respondents (28%) are interested in using covercrops. Phosphorus application rates are also standardized and were predicted using farming acreage and modeling using the simple coefficient method. However, while subwatersheds that had high nitrogen levels were predicted accurately by the models, phosphorus predictions did not tie to water quality results. Although there were a greater tonnage of phosphorus applied in watersheds with a greater amount of agricultural land use, the model does not consider other factors like (a) phosphorus attaches to sediment and so has a greater chance of transport in watershed with high sediment transport potential (b) phosphorus can also travel through tiles (c) phosphorus is also found in human waste and so could be present in subwatersheds with high human waste contribution. Phosphorous was higher in subwatersheds with higher total suspended solids levels. Again, going back to our previous discussion, the elevated levels of TSS may be driven by geological factors rather than differentiations in stream and/or land management practices. The major nitrogen observation is that geology again plays a factor, where non-moraine areas are more suitable for agriculture, and therefore these subwatersheds have a higher concentration of agricultural lands per subwatershed, less drainage density, frequency, and higher concentration of application.

PHOSPHORUS SEDIMENT CORRELATION

The Project Manager ran a simple coefficient model for phosphorus and it did not correlate to our actual results. The land use model predicted that phosphorus, like nitrogen, would be highest in subwatersheds with the highest concentration of agriculture. Because phosphorus attaches to soils, we found a greater correlation between watersheds with land application in concert with sediment transportation potential. The model had an inability to account for sediment transport potential. Future models should be selected for phosphorus to account for these considerations. Information generated form these studies could be fused with future models for greater calibration. There is modest correlation to sediment transport projection, sediment results, and phosphorus levels.

HISTORIC WATER QUALITY ANALYSIS

Although a review of existing data was conducted, it wasn't useful for identifying water quality problems at the tributary subwatershed scale. IDEM sampling with was done along the mainstem of the Mississinewa. There was no IDEM data on the tributaries of the Mississinewa. Furthermore, low sampling frequency, lack of flow data, and differing parameters were all aspects of the historical data (in addition to sampling sites being limited to the mainstem of the Mississinewa River within Grant and Delaware counties—there was no IDEM data within Blackford, Jay, and Randolph counties) that made it unsuitable for identifying HUC 12 critical areas. Only three of the historic IDEM sites within the study area had data after 2003. One of these was sampled in 2008 only and nitrate, phosphorus, and TSS were measured only 3 times each. However, historical data did indicate that E. coli and TSS levels were exceeding targets on the mainstem, something that was supported by data from this study. In addition, a comparison of historic data and contemporary data on the mainstem Mississinewa suggested consisted water quality results over the past 50 years (Table 11.1):

TABLE 11.1 | Mississinewa Means				
Data Source	E. coli (cfu/100ml)	Nitrate (mg/L)	P (mg/L)	TSS (mg/L)
STORET	2188.0	1.2	0.18	36.0
IDEM	3101.0	3.4	0.18	43.4
LARE	1957.0	4.0	0.19	
Miss205j - Avg	907.9	3.9	0.29	57.1
Miss205j - High	1905.69	7.21	0.52	151.23
Miss205j - Low	485.79	2.45	0.19	15.94

OTHER IMPORTANT INVENTORY FINDINGS

Low Impact Development

While population in the region is declining, some areas are experiencing growth. This is development that outpaces need. Based on these findings, this project seeks to limit sprawl. The project will advocate low impact development and the prevention of sprawl. Development that does occur should incorporate the best BMPs for stormwater absorption and filtration.

The UMRW-P also wants to develop conservation initiatives and will partner with conservation groups to enroll land into long-term conservation because ecological preservation is the best BMP there is from a water quality perspective. Maps generated for this study show the areas that have the highest ecological areas and the greatest percentage of ecological preservation potential. Much of the sprawl is occurring in areas of ecological value because people want to live in those areas for aesthetic and therapeutic purposes. Conservation of high quality ecological lands and advocacy of low impact development concurrently is a strategic objective. The area with the highest sprawl and development are census tracks between Marion, Gas City, and Upland.

Another way to advocate for the preservation of this area is through advocacy of recreational uses of the river. As public property, the increased availability of the river to citizens should be advocated.

These land use modifications are predicted to continue to change. Grant County and the City of Marion currently have no plans to mitigate abandoned (and non-polluted) impervious areas of the city on the east side. Therefore, inter-county relocation and sprawl in the eastern portion of Marion will continue to create impervious surfaces. It may be in the best interest of the city to explore the removal of abandoned impervious areas east of the city so that revitalization can occur where a infrastructure already exists than rather than developing areas where there is not currently infrastructure. This may be a more fiscally responsible action, as well as one that would be beneficial to water quality and would likely conserve important ecological and agricultural acreage.

Planning Efforts In The Watershed

Many planning efforts are happening community-wide and we will look to expand the role this WMP can serve as a strategic environmental plan to be used in conjunction with other community guidance documents. Several plans seek to improve water quality. Marion 2030 seeks to prevent development in floodplains, increase the city's tree canopy, incorporating LID stormwater practices, and branding itself as a “green city” by installing green roofs and other green practices and structures. Blackford County Comprehensive Plan seeks to protect and improve greenspace, build greenway trails, update floodplain ordinances to prohibit occupied structures, revitalize existing neighborhoods, remove blighted homes, and limit residential zones to areas with existing utilities. The Muncie-Delaware County Comprehensive Plan suggests that infill development should be focused around service area villages such as Eaton and Albany and seeks to preserve and maintain the health of agricultural land, the natural environment, greenways, and open space areas. Randolph County's Economic Strategic Plan seeks to maintain clean water sources and natural resources. Collaboration between Soil and Water Conservation Districts (SWCDs) and county and city governments and other organizations will be an important way to reach common goals.

Social Survey Overlay

The plan's social survey not only sought to understand landowner concerns, but also identify landowners interested in cost-share programs. Areas of the watershed that had the highest concentration of interested landowners were identified. The percent return rate was highest in the Randolph County areas. These social engagement factors will be another factor influencing where promotion of cost-share programs will be targeted.

The project continues to attempt to understand various types of audiences within the watershed. There are varying degrees of understanding of water quality issues and varying degrees of understanding and support of the project. Demographic information and values/preferences also play a factor in responses. Recreational habits are influential. To gain a better understanding of socioeconomic and demographic condition of the watershed, data from ESRI, a geographic information system company, was reviewed. ESRI's Tapestry Segmentation is a methodology for characterizing neighborhoods based on their socioeconomic and demographic composition. There are 67 Tapestry segments by which residential areas in the US can be described. This characterization can be further described by LifeMode groups. There are 14 LifeMode groups representing populations that share a common experience.

The most common ESRI demographic LifeMode group in the UMRWP, Factories and Farms, is characterized by mostly high school graduates with some college education. However, other demographic LifeMode groups are identified within the region. There is a SuperZip near Taylor university that is classified in the Upscale Avenues LifeMode group. Using these LifeMode statistics to develop marketing for different demographic users will be important to the project. Small communities in the region may still have a primarily agricultural identity despite the decrease in farm owners and farm families.

Activities enjoyed by three of the five LifeMode groups within the watershed include fishing and/or hunting. Enhancement of the Mississinewa River and watershed for these activities may be appealing to those groups.

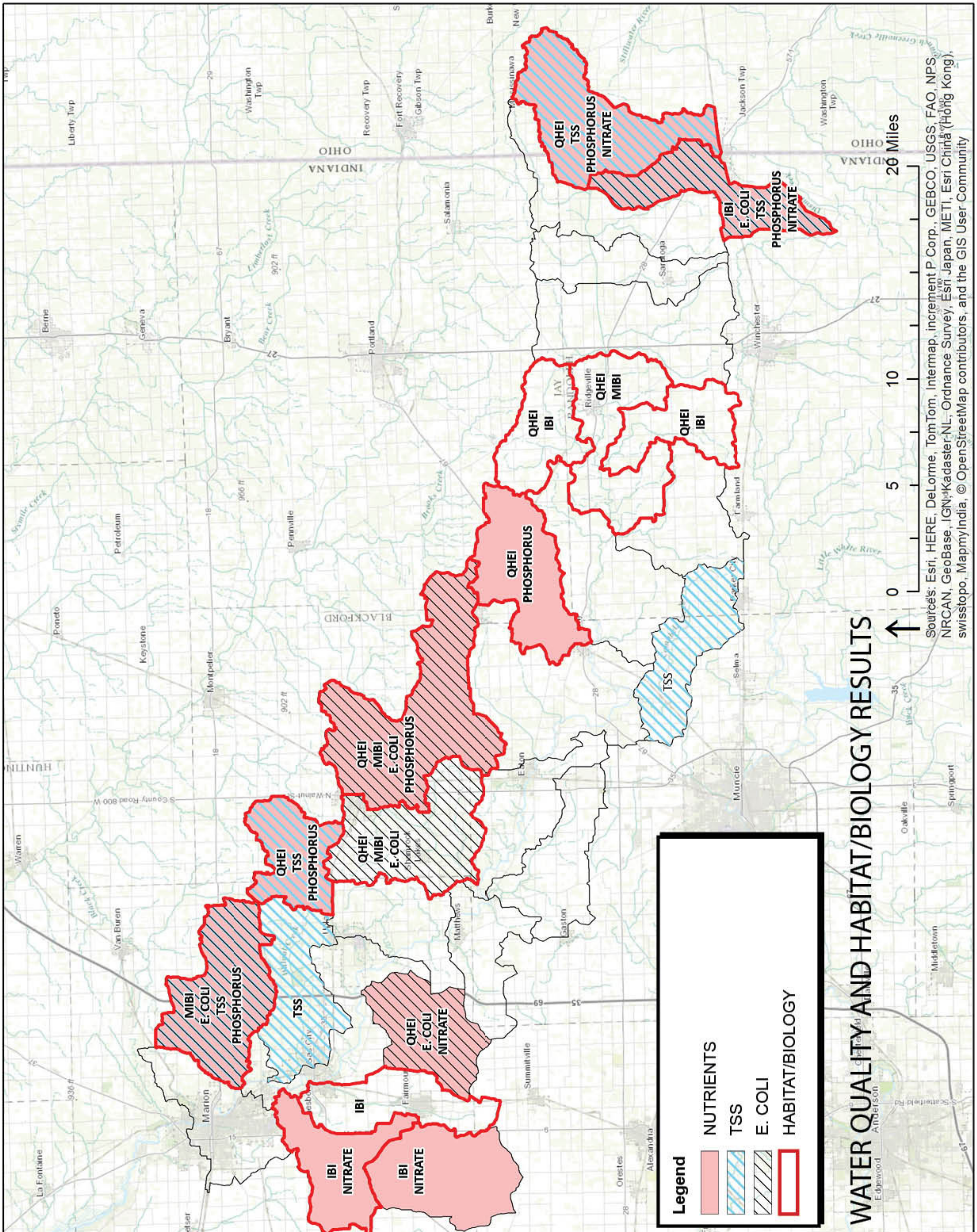
Recreational Message

One of the most important messages that we want to advocate is the importance of recreational opportunities. There may be a missed recreational opportunity and economic development opportunity for the Mississinewa River across the entire watershed. Enhancing and promoting recreational opportunities is a goal of the project. This may be one way to expand and enhance public affection for and ownership of the Mississinewa River.

FINAL SUMMARY

The watershed inventory and subwatershed discussions have allowed the Project Manager to draw numerous meaningful conclusions about the relationship of water quality to various land uses. In agricultural areas, fertilizer use, land application of manure, conventional tillage (especially on highly erodible soils and higher relief ground), and livestock entering streams are all contributing various pollutants to waterways. BMPs such as cover crops, filterstips, no-till equipment modifications and cattle exclusion fencing can address erosion, nutrient and E. coli concerns. In urban areas and areas with high population densities, CSOs and septic systems are contributing pathogens and nutrients to waterways. The promotion of proper septic maintenance, municipal sewage expansion and CSO elimination will address these pathogen and nutrient concerns. In all areas, streambank erosion (due to various factors, including channelization and increased flow) should continue to be assessed and addressed in order to further reduce sediment concerns. The reduction of stormwater runoff to already overloaded streams is also important in both urban and agricultural settings, and will reduce all pollutants of concern as well as potentially decrease bank erosion by reducing flow rate in waterways.

Map 11.1 shows the highest priority watersheds. Priority was determined for each parameter by identifying the five subwatersheds with the highest average concentrations during high and low flow conditions. This determination was made using the water quality sampling results obtained in 2014-2015 by IDEM TMDL and UMRW-P. If two subwatersheds tied for fifth, then both were selected as priority areas. Also included in this map are the subwatersheds with the worst IBI, mIBI, and QHEI scores.



MAP 11.1 | Priority Watersheds, Based on Water Quality and Habitat/Biology Results

12. STAKEHOLDER CONCERNS

As explained in previous sections, the concerns of local stakeholders and steering committee members were collected at the beginning of this watershed planning process. Steering committee concerns were also gathered throughout the process as the watershed inventory was developed and water quality data was collected. The Project Manager determined whether or not identified concerns have data to support them, if they are quantifiable, and if they are outside the project's scope. The data reviewed included current water quality data, land use data, windshield and desktop survey data, and anecdotal evidence. Finally, the Project Manager determined which concerns will be focused on. This information is detailed in Tables 12.3 through 12.5. Any evidence supporting each concern is also listed. While some concerns are outside the project's scope (meaning 319 funds cannot be used to address them), the Project Manager may still have chosen to focus on them (most likely by seeking funding other than 319 implementation funding).

Because there are a large number of concerns, they have been organized into three simplified categories. These three groups were derived from the state mandated beneficial uses that waterways must support. Beneficial uses are found in the State's Water Quality Standards IC 14-25-7-2. Stakeholder and steering committee member concerns are grouped according to the beneficial use they may be threatening. The beneficial use categories are public health, fish and wildlife, and socioeconomic uses. As shown in Tables 12.1 and 12.2 below, these three categories are the result of a simplification of the eleven beneficial uses. The UMRW-P has combined recreation and drinking supply into one category (public health); domestic, agricultural, industrial, commercial, power generation, energy conservation, waste assimilation, and navigation into a second grouping titled "socioeconomic" uses; and it has included fish and wildlife as a stand alone beneficial use.

The main rationale for this classification system is to provide clarity. Because many concerns are related, this grouping system clusters them in specific areas which may make them easier to find for stakeholders who are interested to see if their concern(s) will be addressed. Additionally, the Project Manager felt that it is beneficial to put concerns into this framework since the support of these state mandated beneficial uses is the main concern of this study and framing it thus allows stakeholders to better understand the purpose of actions generated by this plan.

TABLE 12.1 | State Mandated Beneficial Uses of Waterways

(1) Domestic	(7) Public water supply
(2) Agricultural, including irrigation	(8) Waste assimilation
(3) Industrial	(9) Navigation
(4) Commercial	(10) Fish and wildlife
(5) Power generation	(11) Recreational
(6) Energy conservation	

TABLE 12.2 | UMRWP's Simplified Beneficial Use Categories

(1) Public Health: Recreation and Public water supply (drinking water)
(2) Fish and wildlife
(3) Socioeconomic Uses

The UMRW-P decided to focus on almost all of the concerns listed. Although some of these concerns are outside the scope of this project, they can be indirectly addressed through education and other such initiatives. For example, although implementation funds for this project cannot be used to pay for maintenance of failing septic systems, they can be used to support educational initiatives centered on septic system maintenance, etc.

"Clean brush from rivers and waterways" is a concern that will not be focused on although there was evidence to support it. The UMRW-P recognizes that the presence of brush/debris in the river is in fact a natural aspect of river ecosystems and that it only becomes a problem when it forms an Condition 3 or 4 (embedded) logjam (one way debris is naturally processed and removed is through deposition on the floodplain during flooding). Therefore, not all debris is of concern. The UMRW-P also assumes that there is a public lack of understanding regarding debris/logjams since one public debris/logjam concern investigated by the Project Manager was not in fact an embedded logjam. However, the UMRW-P does regard embedded logjams as a concern and has already procured funding to remove a number of embedded logjams in Randolph County.

There is also a supported concern that beaver dams are inhibiting the function of drainage tiles. This concern will not be focused on. The Project Manager felt that this issue should be viewed on a case by case basis. Furthermore, the Project Manager felt that this issue is too contentious to be involved in. There are numerous other issues that can be focused on that the public has little or no resistance towards.

TABLE 12.3 | Fish and aquatic wildlife concerns					
Sediment (Streambank Sources) Concerns					
Concern	Supported by our Data?	Evidence	Quantifiable?	Outside Scope of Project?	Group Wants to Focus On It?
Streambank sediment loss	Y	Comments from president of Walnut Creek Drainage Board at meeting on Nov. 18, 2015. He referred specifically to Lugar and Walnut creeks. Also observed on canoe survey.	N	Y	Y
High near bank stress on channelized streams	Y	Observed in desktop and windshield surveys. Bank erosion observed at 20 sites on windshield survey.	N	N	Y
Lack of riparian habitat on stream segments	Y	33% (100 miles) of NHD mapped streams lack buffers.	Y	N	Y
Removal of gravel from riffles	Y	Observed on tributaries during sampling, specifically Walnut Creek	N	Y	Y
Disregard for the headwaters of stream systems	N	Not specific enough, but will advocate BMPs in headwaters	N	Y	Y
Altered floodplain with more hydromodifcation	Y	Historical dredging, widening and straightening of sections of the Mississinewa River and tributaries.	N	N	Y
Destabilized stream bank with removal of vegetation	Y	Observed banks with missing vegetation on windshield survey. Documented with photos.	Y	N	Y
Abutments and impoundments	Y	Area streams are cloudy and turbid	Y	Y	Y
Erosion of banks	Y	Comments from president of Walnut Creek Drainage Board at meeting on Nov. 18, 2015. He referred specifically to Lugar and Walnut creeks. Also bserved on canoe survey.	Y	N	Y
Channelized ditches eroding in watershed	Y	Area streams are cloudy and turbid.	N	Y	Y
Lack of vegetation/habitat along river systems	Y	33% (100 miles) of NHD mapped streams within the watershed lack buffers.	Y	N	Y
Concerned about covercrop usage.	Y	According to tillage transect data, cover crop usage ranges from 1% to 11% in counties within the UMRW.	N	N	Y
Surface erosion occurring on farm fields.	Y	130,092 rills and gullies identified in desktop survey.	Y	Y	Y
Concerned about residue and tillage management.	Y	An estimated 71% of cropland is farmed using conventional tillage	Y	N	Y
Sediment runoff from tilled fields.	Y	An estimated 71% of cropland is farmed using conventional tillage; area streams are cloudy and turbid	N	N	Y

TABLE 12.3 | Fish and aquatic wildlife concerns (continued)					
Sediment (Streambank Sources) Concerns (continued)					
Concern	Supported by our Data?	Evidence	Quantifiable?	Outside Scope of Project?	Group Wants to Focus On It?
The over application of crop protection products and fertilizer.	N/Y	The Project Manager assumes that farmers follow application rates recommended by agricultural researchers and do not over apply fertilizer; scientific literature suggests that excess phosphorus may be applied through manure application; in areas where CFO concentration is high, phosphorus levels exceeded standards	N	N	Y
Heavy rain resulting in abnormal erosion.	Y	High levels of TSS were recorded during high flow events.	Y	Y	Y
Concerned about a widespread increase in soil erosion.	N	Although soil erosion is a problem, TSS exceeds standards both currently and historically; no other evidence was gathered which would support this concern	Y	N	Y
Concerned about general water quality.	Y	At many sites, parameters exceeded standards	Y	N	Y
Fish and aquatic wildlife concerns—Sediment (Sheetflow Sources) Concerns					
Concern		Evidence	A	B	C
Poor sediment management strategies	Y	An estimated 71% of cropland is farmed using conventional tillage.	Y	Y	Y
Destabilization of soil due to ground cover removal	N	Although lack of ground cover destabilizes soil in agricultural fields, no other disturbances of ground cover were observed	N	Y	Y
Lack of BMP on tile intake points	Y	None. However, these were observed on windshield survey but not formally recorded.	N	Y	Y
Shrink swell	N	Not observed but likely due to the high clay soils in the watershed	N	Y	N
Poorly managed HES	Y	Area streams are very cloudy and turbid	N	Y	Y
Small or nonexistent buffer strips tributaries	Y	33% (100 miles) of NHD mapped streams lack buffers	Y	N	Y
Increase in impervious land cover	Y	Observed through aerial imagery, specifically in Lugar Creek subwatershed	Y	N	Y
Runoff from Urban Areas	Y	9% of the watershed is urban	N	Y	Y
Urban storm water system to outfalls in the river	Y	9% of the watershed is urban	N	Y	Y
Increased water discharge	N	None. However, we assume this is a valid concern due to increased popularity of systematic tiling and increases in impervious land cover	Y	N	Y

TABLE 12.3 | Fish and aquatic wildlife concerns (continued)					
Nutrients (Sheetflow Sources) Concerns					
Concern	Supported by our Data?	Evidence	Quantifiable?	Outside Scope of Project?	Group Wants to Focus On It?
Lack of wetlands for chemical processing	Y	Loss of historical wetlands; prevalence of tile ditch drainage systems	N	Y	Y
Lack of on site infiltration on farmland	Y	Area streams have nutrient levels exceeding the target set by this project; prevalence of tile ditch drainage systems	N	Y	Y
Chemicals from fertilizers and agricultural practices	Y	Area streams have nutrient levels exceeding the target set by this project	Y	N	Y
Lack of agricultural BMPs	Y	An estimated 71% of cropland is farmed using conventional tillage; a lack of cover crops on fields was observed during the windshield survey	N	N	Y
Ignorance of location of underground drainage tiles.	Y	County surveyor offices have indicated that they have incomplete records of tile locations	N	Y	Y
Pesticide usage on genetically engineered agriculture crops	N	None. Pesticides were not monitored in water quality testing.	N	Y	N
Runoff from the former industrial sites	Y	Abandoned industrial sites identified in desktop survey. Area streams have nutrient levels exceeding the target set by this project	N	Y	Y
Nutrient rich runoff from fertilizers used by golf courses	Y	Fourteen golf courses identified in desktop survey; area streams have nutrient levels exceeding the target set by this project	N	Y	Y
Nutrient rich runoff from sports fields	Y	112 sports fields were identified in the desktop survey; area streams have nutrient levels exceeding the target set by this project	N	Y	Y
Removal of forests and wetland systems	Y	Area streams have nutrient levels exceeding the target set by this project	Y	N	Y
Concerned about general water quality.	Y	Exceedences were observed for all water quality parameters.	Y	N	Y
Erosion occurring on sloped land and waterways.	Y	High concentrations of rills and gullies were observed in desktop study.	Y	Y	Y
Habitat quality of riparian zones and stream channels.	Y	Poor IBI, mIBI, and QHEI scores at some sites within watershed.	Y	N	Y
River bank erosion.	Y	Erosion was observed on canoe survey.	N	Y	Y
Erosion of waterways.	Y	20 sites with bank erosion were identified on the windshield survey;	N	Y	Y
Headcuts in streams and rivers.	Y	Headcuts were observed in canoe survey.	Y	N	Y
Soil stabilization in river bottom areas.	Y	Cropland observed in river bottom areas on canoe survey.	N	Y	Y

TABLE 12.3 | Fish and aquatic wildlife concerns (continued)					
Miscellaneous Fish and Aquatic Wildlife Concerns					
Concern	Supported by our Data?	Evidence	Quantifiable?	Outside Scope of Project?	Group Wants to Focus On It?
Larger rain events with climate change	N	While our data cannot indicate if climate change is occurring, high discharge rates were observed	N	Y	N
High stream temperatures	N	Temperatures were within normal ranges.	Y	N	N
Riparian Zones neglected	Y	33% (100 miles) of NHD mapped streams lack buffers	Y	N	Y
Disregard for historic natural systems	Y	Poor IBI, mIBI and QHEI scores in some areas; removal of the majority of native habitat for agriculture	N	Y	Y
Lack of Wildlife Diversity (threatened/endangered species, and invasive/exotic species)	Y	Widespread removal of communities; loss of historic habitat	Y	Y	Y
The absence of wildlife in river bottom areas.	N	None, it is assumed that some wildlife is present.	N	Y	N

TABLE 12.4 | Recreational/human health concerns					
E. coli Concerns					
Concern	Supported by our Data?	Evidence	Quantifiable?	Outside Scope of Project?	Group Wants to Focus On It?
Some farms lack manure management BMPs	Y	Area streams are impaired on IDEM's 303(d) list for E. coli; 60 livestock access points to streams were identified	N	Y	Y
Drinking well and river water is unhealthy	Y	Area streams are impaired on IDEM's 303(d) list for E. coli	Y	N	Y
E. coli from animal waste	Y	11% of lands (including pasture/grasslands) are ecological, which likely support wildlife; 105 CFO's within the watershed are likely to dispose of manure through land application	Y	N	Y
Public knowledge of high E. coli from TMDL studies	N	None. The public's knowledge of E. coli impairments was not assessed.	N	Y	Y
Livestock have access to streams at multiple points	Y	82 livestock access points identified in desktop survey.	Y	Y	Y
Reduced recreation opportunities due to fear of contaminants	Y	Area streams are impaired on IDEM's 303(d) list for E. coli	Y	N	Y
Geese – potential relationship between nutrients and E. coli contamination	N	No evidence of any high density goose populations was reported	N	Y	N
Water contact is unhealthy	Y	Area streams are impaired on IDEM's 303(d) list for E. coli	Y	N	Y

TABLE 12.4 | Recreational/human health concerns (continued)					
E. coli Concerns (continued)					
Concern	Supported by our Data?	Evidence	Quantifiable?	Outside Scope of Project?	Group Wants to Focus On It?
Failing septic systems, lack of septic system maintenance	Y	Toilet paper found in Lugar Creek during sampling; less than 0.1% of land is suitable for septic systems; positive correlation between septic system density and E. coli levels during low flow	N	Y	Y
Concerned about the application of animal waste on farm fields.	Y	E. coli levels exceeded standards at sites where CFO concentrations were high; E. coli levels were generally higher during high flow in areas with high CFO concentrations	Y	N	Y
Concerned about Combined Feeding Operations and their manure management.	Y	E. coli levels exceeded standards at sites where CFO concentrations were high; E. coli levels were generally higher during high flow in areas with high CFO concentrations	Y	N	Y
Recreational/human health concerns—Sediment Concerns					
Concern		Evidence	A	B	C
Destabilization of soil due to ground cover removal	Y	Area streams are very cloudy and turbid	Y	N	Y
Lack of BMP on tile intake points	Y	Observed lack of BMP around intake points during windshield survey	N	N	Y
Shrink swell	Y	Area streams are very cloudy and turbid; C and D soils are prevalent throughout the watershed	N	Y	Y
Poorly managed HES	Y	Tillage transect data indicates high levels of conventional tillage in some areas of watershed were HES were present.	Y	Y	Y
Erosion of the Mississinewa River	Y	Canoe survey identified areas of severe erosion.	Y	N	Y
Poor fish population for recreation such as fishing	Y	Specific streams and one section of river had poor IBI scores.	Y	N	Y
Bank erosion/sloughing is causing an increase in logjams.	Y	Observed falling trees as a result of erosion	Y	Y	Y
The flooding is destroying stream banks of streams and rivers in the watershed.	Y	Due to incision, recorded high flows correlated with high levels of TSS	Y	Y	Y
Concerned about the surface erosion and runoff.	Y	Rills and gullies identified in desktop survey.	Y	N	Y
Recreational/human health concerns—General Concerns					
Concern		Evidence	A	B	C
Concerned about general water quality.	Y	Exceedances of standards for all parameters were observed through water quality testing.	Y	N	Y
Concerned about missed economic opportunities with recreational canoeing.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey	N	N	Y

TABLE 12.4 | Recreational/human health concerns (continued)

Concern	Supported by our Data?	Evidence	Quantifiable?	Outside Scope of Project?	Group Wants to Focus On It?
Nutrient Concerns					
Non filtering drainage tiles	Y	Observed during canoe survey	N	Y	Y
Direct runoff from areas managed for recreation was brought up	Y	Area streams have nutrient levels exceeding the target set by this project; 9% of the watershed is urbanized	Y	Y	Y
Direct access to the stream for nutrients applied to the turfgrass.	Y	Area streams have nutrient levels exceeding the target set by this project; 9% of the watershed is urbanized	Y	Y	Y
Recreational/human health concerns—Public Education Concerns					
Concern		Evidence	A	B	C
Lack of education regarding nonstructural BMPs	N	While education is present, more may be required.	N	N	Y
Various illicit dumping areas	Y	Trash was observed at select sites during windshield survey	N	N	Y
Former buried landfils	N	No evidence, but it is possible that the IDEM database is incomplete	N	Y	N
The public doesn't know who to contact about watershed related concerns	N	While promotion is present, more may be required.	N	N	Y
Lack of Aesthetics	Y	Widespread removal of biotic communities; trash was observed at select sites during windshield survey	Y	N	Y
Recreational/human health concerns—Logjam Concerns					
Concern		Evidence	A	B	C
Logjams causing increased flooding and destroying crops.	Y	Observed through canoe and desktop surveys	Y	Y	Y
Keeping open ditches clean from debris and logjams.	Y	Debris was reported by multiple landowners	N	Y	Y
Clean brush from rivers and waterways.	Y	Not all logjams were Condition 4. Many were Condition 1 & 2, and will most likely be broken up and dispersed by storm flow events. One reported logjam was no longer present when the Project Manager traveled to the site to investigate.	N	Y	N
Sandbars and logjams forming in the channel.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey; sandbars observed on canoe survey	Y	Y	Y
Logs, brush, and trash clogging waterways.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey	Y	Y	Y
Trees damming the waterway causing bank erosion.	Y	Observed in canoe survey	Y	Y	Y

TABLE 12.4 | Recreational/human health concerns (continued)					
Logjam Concerns (continued)					
Concern	Supported by our Data?	Evidence	Quantifiable?	Outside Scope of Project?	Group Wants to Focus On It?
Concerned about the amount of logs/debris in streams.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey	Y	Y	Y
The Mississinewa needs drastic improvement. "It is the worst I have seen in my lifetime.	N	This concern is not specific enough to be analyzed.	N	Y	N
Remove log jams and sediment dams that don't allow water to drain.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey	Y	Y	Y
The Mississinewa River needs to be cleaned of logjams.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey	Y	Y	Y
There is a need for debrushing and the removal of logjams in the Mississinewa River and it's tributaries.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey	Y	Y	Y
An abutment from an Old Covered bridge is causing logjams in the mainstem of the Mississinewa River.	Y	Observed on canoe survey	Y	Y	Y
Stormwater runoff is destroying large trees that end up in the river blocking more water and adding to the problem.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey	Y	Y	Y
Logjams are a problem in the Mississinewa River.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey	Y	Y	Y
The Mississinewa river does not flow/drain properly due to multiple log jams. (Especially from Highway 27 to Albany, IN). This causes very poor drainage for all farms in the watershed because of the time it takes for the water to travel downstream.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey	Y	Y	Y
Streambank and adjacent property erosion.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey; anecdotal evidence concerning impeded drainage and erosion	N	Y	Y
Concerned about debris and tree roots impeding flow and drainage of tillable acreage.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey; anecdotal evidence concerning impeded drainage	N	Y	Y
Concerned about log jams and how to prevent them.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey	Y	Y	Y
Drainage issues related to logs in streams and rivers.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey; anecdotal evidence concerning impeded drainage	N	Y	Y

TABLE 12.5 | Socioeconomic concerns					
Sediment Concerns					
Concern	Supported by our Data?	Evidence	Quantifiable?	Outside Scope of Project?	Group Wants to Focus On It?
Drainage laws	N	This concern is not specific enough to be analyzed.	N	Y	Y
Poorly designed field ditches	Y	Straightened ditches were noted in desktop survey	N	Y	Y
Potential loss of fertile soils	Y	Area streams are cloudy and turbid	N	N	Y
Lack of no-till/grassed waterways throughout both watersheds	Y	130,092 rills/gullies were identified in desktop survey	Y	N	Y
Erosion control practices not used properly	Y	33% (100 miles) of NHD mapped streams lack buffers; an estimated 71% of cropland is farmed using conventional tillage	Y	N	Y
Sprawl	Y	Some development occurring around Upland and the I-69 corridor.	Y	Y	Y
Socioeconomic concerns—Nutrient Concerns					
Concern		Evidence	A	B	C
The public lacks education about fertilizer use	N	While education is present, more may be required.	N	N	Y
Increasing discharge rates collecting more surface pollutants	Y	Nutrient levels exceeding the target set by this project; aggressive tiling has been observed	Y	N	Y
Under appreciation of ecosystem services	Y	While education is present, more may be required; nutrient levels exceeding WQS	N	N	Y
An abutment from an Old Covered bridge is causing logjams in the mainstem of the Mississinewa River.	Y	Observed on canoe survey.	Y	Y	Y
Beaver dams in watershed tributaries are effecting capacity of farm tiles to function.	N	Did not observe any beaver dams.	N	Y	N
Concerned about a widespread increase in soil erosion.	N	Although soil erosion is a problem, TSS exceeds standards both currently and historically; no other evidence was gathered which would support this concern	N	Y	N
Concerned about the surface erosion and runoff.	Y	Area streams are cloudy and turbid; 130,092 rills/gulllies observed in desktop survey	Y	N	Y
Concerned that the removal of wetlands are leading to increased flooding.	N	None. However, it is assumed that this is a valid concern. Land use modeling suggests that this is a valid concern.	N	Y	N

TABLE 12.5 | Socioeconomic concerns (continued)					
Nutrient Concerns (continued)					
Concern	Supported by our Data?	Evidence	Quantifiable?	Outside Scope of Project?	Group Wants to Focus On It?
Erosion of waterways.	Y	Observed on canoe survey and desktop survey	Y	N	Y
Headcuts in streams and rivers.	Y	Observed on canoe survey	Y	N	Y
Increased upstream water contribution flooding landowner properties.	N	No formal study was done at this site.	N	N	Y
Remove log jams and sediment dams that don't allow water to drain.	Y	Seven Condition 3 and three Condition 4 logjams were identified on canoe survey	Y	Y	Y
River bank erosion.	Y	Observed in canoe survey	N	Y	Y
Streambank and adjacent property erosion.	Y	Observed in canoe, windshield, and desktop surveys	N	Y	Y
Surface erosion occurring on farm fields.	Y	Rills and gullies observed in desktop survey	Y	N	Y
The creation of headcuts at County tile outlets.	N	While this concern may be valid, not enough data was collected to determine if this is a widespread issue	N	Y	N
Socioeconomic concerns —Public Education Concerns					
Concern		Evidence	A	B	C
Watershed restoration is underfunded	N	While funded, more problems could be addressed if additional funding was offered	N	N	Y
Homogenized watershed planning	N	Efforts are being made to implement unique approaches to watershed planning	N	N	Y
Socioeconomic concerns—Limited BMP Concerns					
Concern		Evidence	A	B	C
Lack of low impact storm water planning	Y	Not included in many master plans in the UMRW	N	Y	Y
Lack of smaller scale planning efforts	N	Master plans exist for many counties and small towns	N	Y	Y
Best Management Practices not always considered in new developments	N	Not supported by our data	N	Y	N
Over-engineered water management solutions	N	Not specific enough to analyze	N	Y	N

13. ANALYSIS OF CONCERNS

13.1 DECISION-MAKING FRAMEWORK

Many of the concerns listed in the previous section are nearly identical. Because of the large quantity of individual concerns generated from a study of this scale, these concerns are not restated in this section. To eliminate redundancies, the Project Manager has combined repeated or similar concerns into the root concern that they address. Therefore, only these "key concerns" are listed (Table 13.1) and original concerns can be cross-referenced in their accompanying tables from the previous section (Tables 12.3-12.5); all concerns grouped under a key concern have the same related problem[1].

Table 13.1 outlines how these diverse concerns (from a dynamic group of community stakeholders) are reported collectively as quantifiable over arching "key concerns." This ensures all stakeholder concerns are represented as key/ collectively shared concerns that have a direct connection to problems and causes that can be easily quantified and studied. Furthermore, the categorization by beneficial use and by water quality parameter in the previous section (Section 12) already function to group like concerns together.

13.2 PROBLEMS AND CAUSES

Problems can be thought of as conditions that exist because of the concerns. Key concerns are listed in Table 13.1 along with the potential problems related to them. The tables were established to express the group's perception that there are four key causes (pollutants) of watershed problems: E. coli, TSS, nutrients, and excessive debris in the river. Since these pollutants/causes can be measured though water quality science (quantitative data) we can confirm that these four key pollutants are legitimate causes of the concerns. Stakeholder consensus built on the scientific method (showing that NPS data/concerns have been validated and legitimized by IDEM/Muncie BWQ data) sets the stage for rational plan implementation. Also included in Table 13.1 is the cause(s) of each problem. The table serves as a summary of the core problems and their causes within the watershed, supplying the UMRW-P with a basis for an action strategy.

Elevated Total Suspended Solids (TSS), E. coli, and nutrients were considered by the UMRW-P to be the primary causes of problems identified via key concerns and confirmed through the Water Quality Inventory (Sections 6 through 9). Other studies that further confirm the validity of these causes are listed below:

(1) The 2000 National Water Quality Inventory[2] states that agricultural nonpoint source pollution (nutrients) is the leading source of water quality impacts on surveyed rivers and lakes in some states (EPA 2005). These conclusions further the notion that nutrients are crucial stressors to Mississinewa streams and rivers.
(2) The Muncie Bureau of Water Quality (MBWQ) identifies sediment as the critical pollutant in water systems in East Central Indiana for aquatic life.
(3) The Hoosier Riverwatch program states that sediment is the most significant impairment to aquatic life in all Indiana streams and rivers.
(4) State (IDEM) data and studies (TMDL, 303(d)) indicate that E. Coli is the highest exceeding nonpoint source pollutant in the Middle Mississinewa TMDL program.

There are most likely additional causes of watershed/water quality problems within the UMRW. However, these causes were not monitored by this study and are beyond its scope. Table 13.2 represents a statewide inventory of causes of watershed/water quality problems in Indiana streams and rivers. The cause, "impaired biotic communities," represents streams for which the specific cause of impairment is not identified. The UMRW-P assumes that the primary causes of these impaired biotic communities in watersheds is sediment, based on MBWQ biological research and previous studies on Delaware County streams and rivers.

As demonstrated in Sections 7 and 8, E. coli, TSS and nutrients all historically and currently exceed state water quality standards in the subwatersheds of the UMRW. Each of these pollutants has a particular way of impacting state mandated beneficial uses of water.

1 For example: (a) many participants expressed, in different ways, a concern about E. coli in waterways. All of these concerns fall under the more specific key concern, which is that the Mississinewa River is not safe for full body recreational contact.

2 United States EPA. National Water Quality Inventory, 2000 Report. 2000. https://www.epa.gov/sites/production/files/2015-09/documents/2000_national_water_quality_inventory_report_to_congress.pdf

TABLE 13.1 | Key Concerns and their associated problem			
Designated Beneficial Use	Key Concerns	Problem	Potential Cause(s)
(1) Public Health: Recreation and Public water supply (drinking water)	The Mississinewa River is not safe for full body recreational contact.	People may become exposed to pathogens and develop illness as a result of contact with the waterways. The river may be under utilized as a recreational resource.	E. coli levels exceed state water quality standards
	Wells in the areas may be contaminated by failing septic systems or land application of manure.	Landowners may be unaware that their drinking water is contaminated.	E. coli levels exceed state water quality standards
	The Mississinewa River is unsafe to canoe due to the excessive amounts of debris and logjams in the river.	Individuals may encounter excessive danger when recreating on the Mississinewa River.	Condition 4 logjams are present in the river
(2) Fish and Wildlife	Fish and other aquatic organisms may be experiencing a degraded habitat due to excessive amounts of algae in the waterways.	The Mississinewa river fails to meet the state designated beneficial use for fish and wildlife.	Nutrient levels exceed state water quality standards
	Fish and wildlife may be experiencing a degraded habitat due to excessive amounts of sediments in the waterways.	Low IBI and mIBI scores were observed at some locations.	Total suspended sediment (TSS) levels exceed the target set by this project
(3)Socioeconomic Uses3	The degradation of agricultural land due to the loss of nutrients and organic matter.	Regional economic potential is compromised.	Nutrient levels exceed state water quality targets
	The degradation of agricultural land due to the loss of soils.	Regional economic potential is compromised.	Total suspended sediment (TSS) levels exceed the target set by this project
	The loss of agriculturally productive land due to unstable stream channels, bank erosion, and flooding.	Regional economic potential is compromised.	Total suspended sediment (TSS) levels exceed the target set by this project
	The river fails to meet its maximum recreational potential	Economic development opportunities are lost.	Condition 4 logjams are present in the river; E. coli levels exceed state water quality targets

TABLE 13.2 | Modified IDEM Inventory of Causes (of Watershed/Water Quality Problems)		
Watershed/Water Quality Problems)	river miles	% of total impaired river miles
Impaired Biotic Communities	2,469	14%
TDS, Siltation, Flow Alteration, Habitat Alteration	605	3%
Pesticides	7	0%
Toxic Organics	176	1%
Oil and grease	11	0%
Bioaccumulative Chemicals of Concern (PCB/Mercury)	4,897	27%
Metals	189	1%
Toxic Inorganics (metals excluded)	446	2%
Pathogens (E. coli indicator)	8,322	46%
Organic Enrichment (Sewage) Indicators	36	0%
Nutrient/Eutrophication Indicators/Algal	872	5%
Total	18,030	100%

13.3 SOURCES

Nonpoint source pollution (NPS), unlike point source pollution from industrial and wastewater treatment plants, comes from many diffuse sources. It is caused by rainfall, snowmelt, or water usage that is moving over or through the ground. As run-off moves, it picks up and carries away natural and human made pollutants, finally depositing them into lakes, rivers, wetlands, and even our underground sources of drinking water.[3]

"Sources are the activities that contribute pollutants or stressors to surface water resulting in impairment of designated uses in a waterbody."[4] The UMRW-P uses IDEM methodology to determine sources to waterways. "The structure of IDEM's assessment database, which was designed by U.S. EPA for states to use in their CWA section 305(b) reporting, requires that a source be identified for each assessment made whether or not specific sources are precisely known. For most assessments, the sources identified in the assessment database for a given impairment are not proven. Rather they represent those sources determined by IDEM staff to be the most likely sources given a variety of factors, including but not limited to: 1) Land uses (as indicated by field observations and land use data from published sources such as GAP, L-Thia, areal photography, etc.) 2) Field observations of potential sources such as illegal straight pipes, tillage to the stream's edge, livestock in the stream, etc. 3) The presence of permitted facilities within close proximity of the impaired stream in cases where the impairment is something that could reasonably be expected to be associated with the discharge of those facilities 4) Naturally occurring conditions that could contribute to impairment."[5]

"IDEM believes that by using best professional judgment, its scientists can apply these types of information to distinguish the most likely sources of impairment in the watershed, providing a starting point for a TMDL, watershed planning or other activities aimed at restoring the stream."[6] Lacking more detailed and resource-intensive sampling and analyses, accurately attributing a given impairment to specific sources is difficult at best and is, in many cases, impossible to do with a high degree of certainty. In 2004, IDEM implemented a second-year sampling strategy to address this issue.

According to IDEM, the activities listed in Table 13.3 represent the total state-wide stream miles impaired due to each potential source; it is included as a reference. Several potential sources may contribute to impairment of a single stream or stream reach, so the total miles in the table may be greater than the actual stream miles impaired reported elsewhere in IDEM reports. This table is included to guide Stakeholders in the source identification process. The UMRW-P will operate under IDEMs guidance and methodology for determining "the most likely" sources of Nonpoint Source pollution using Section 3's natural systems and land use inventories as a method of source determination.

To increase our effectiveness at implementing water quality improvements, the UMRW-P seeks to understand the sources of pollutants measured in this study. To affect the greatest impact the most significant source of the pollutant per basin needs to be known. For example, water quality studies indicate that sediment is a problem in Lugar Creek, but sediment can come from different sources (e.g. stream banks and surface runoff).To ensure effective planning, each potential pollutant source (identified in our studies) has been identified and relevant data analyzed to determine which source is likely a greater contributor than the other. This is a crucial step in the process of outlining an effective action strategy. Table 13.4 outlines causes of problems within the Upper Mississinewa River subwatersheds and the potential sources of these causes.

13.4 SOURCES: SEDIMENT

TSS levels exceed the target set by this project. Sediment comes from channel sources like sloughing, bed scouring and overland erosion in both agricultural and urban areas. Sediments in water pose as solids (like clay, silt and sand) for contaminants to bind to. Sediment is the loose clay, silt, sand, and other soil particles that settle at the bottom of a body of water. Sediment can come from soil erosion, from decomposition of plants and animals, from streams modified for quick drainage, and from the deterioration of structural infrastructure, like roads. Wind, water, and ice help carry these particles to rivers, lakes, and streams. Sediment is also a source of nutrient pollution; acting as nutrient collectors and carriers is one of the main concerns with sediment. "Nutrients and toxic chemicals may attach to sediment particles on land and ride the particles into surface waters where the pollutants may settle with the sediment or detach and become soluble in the water column."[7] (i.e. stop the flow of sediment and stop the flow of nutrients and pathogens). "Contaminated sediments do not always remain at the bottom of a water body. Anything that stirs up the water, such as dredging, can resuspend sediments. Resuspension may mean that all of the animals in the water, and not just the bottom-dwelling organisms, will be directly exposed to toxic contaminants."[8]

Knowing that TSS is exceeding the UMRW-P target throughout the Upper Mississinewa River Watershed, we begin to look at locations that may be sources of sediment. In support of this process, we reference back to the various desktop surveys performed during the inventory and analysis (Section 3, *Watershed Inventory and Appendix B,C, and E respectively*). In this analysis we discovered roughly 100 miles of stream that had no trees on either side of the stream bank.

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3 https://www.epa.gov/polluted-runoff-nonpoint-source-pollution/what-nonpoint-source

4 Indiana Department of Environmental Management. 2014. [web page] Indiana Integrated Water Monitoring and Assessment Report to the U.S. EPA. http://www.in.gov/idem/nps/files/ir_2014_report.pdf [Accessed 19 January 2016]

5 Ibid.

6 Ibid.

7 GoodGuide. [web page] Pollutants or Environmental Stressors Impained Water Quality. http://scorecard.goodguide.com/env-releases/def/cwa_cause_class_def.html [Accessed 12 June 2016].

8 Scorecard - Home. Web. 26 Sept. 2011. <http://scorecard.goodguide.com/>

TABLE 13.3 | Modified IDEM source table		
Source	Stream Miles	% of State Stream Miles Impaired by Source
Municipal and Industrial Point Sources	2419	16%
Package plants (small flows)	901	
Combined Sewer Overflow	402	
Collection System Failure	4	
Urban Runoff/Storm water	430	
Land Development	2	
Resource Extraction (Mining)	182	
Industrial Point Sources	333	
Illicit connections	165	
Agriculture	6,231	40%
Grazing Related Sources	1,465	
Animal Feeding Operations (NPS)	1,191	
Crop Production	1,473	
General Nonpoint Source	2102	
Land Application/Waste Disposal	3097	20%
Sludge Application or Disposal	1	
Landfills	7	
Illegal Dumps or Other Inappropriate Waste Disposal	45	
On site Wastewater Treatment Systems (septic systems)	768	
Hazardous waste	3	
Contaminated Sediments	165	
Groundwater Loadings	6	
General Nonpoint Source	2102	
Hydromodification & Streams	3695	24%
Channelization	179	
Dam Construction	16	
Upstream Impoundment	1	
Flow Regulation/Modification	383	
Habitat Alterations (not directly related to hydromodification)		
Loss of Riparian Habitat	549	
Bank or shoreline modification/destabilization	312	
Erosion and sedimentation	3	
Debris and Bottom deposits	18	
Natural sources	132	
General Nonpoint Source	2102	

TABLE 13.4 | Major sources per impairment	
Potential Cause(s)	Potential Source(s)
TSS levels exceed the target set by this project	(1) stream banks due to poor vegetative and structural integrity, channelization and increased sheer stress, dams and backwater pooling, ditching (2) sheet flow due to lack of ground cover and on site infiltration opportunities, lack of tile outlet BMPs, lack of buffer strips
Nutrient levels exceed the target set by this project	(1) chemical land application sheet flow due to lack of ground cover, lack of tile out let BMPs, lack of buffer strips, lack of ground cover and on site infiltration opportunities, overapplication of fertilizers (for turf, gardens, agriculture), poor timing in application of these fertilizers (2) human wastes from CSOs, SSOs, field application of WWTP sludge (3) animal wastes from AFOs, CFOs, land application of manure, wildlife, pets
E. coli levels exceed the water quality standard	pet waste, animal wastes from AFOs and CFOs, animal wastes from wildlife sources, septic tanks, CSOs, SSOs, land application of wastewater treatment sludge
Condition 4 logjams are present in the river	Improper management of forestry, icestorms, unstable streams.

We know from our studies that tree roots are an essential means of stabilizing stream banks. We can hypothesize that where vegetation is missing, TSS is being contributed to the water column at a greater rate than where vegetation is not missing (assuming the sheer stress is equal at these sites). We also know from our chemical studies that sediment levels are exceeding UMRW-P targets throughout the entire year. If soil contribution was predominantly from sheet flow, we would expect sediment to be higher during the nongrowing season. Because this wasn't the case, this leads us to the conclusion that stream banks are a significant source of sediment in the subwatersheds, especially Lugar Creek, Walnut Creek, and Little Mississinewa.

STREAM BANK SOURCES

Eroded stream banks can have negative impacts to aquatic life. Severely eroded stream banks can lead to the loss of riparian vegetation. A lack of vegetation on stream banks can compromise structural integrity of stream banks and lead to more erosion. Without trees and shrubs to shade the water, water temperatures increase, resulting in lower levels of dissolved oxygen. These changes can lead to a degradation of natural habitat. Additionally, bed scouring can lead to a loss of habitat for aquatic insects and other macroinvertebrates. The removal of the native herbaceous layer and the subsequent replacement with cool season grass can also reduce the biodiversity of the riparian area.

Erosion from agricultural drainage ditches can be an easily identifiable large source of sediment and nutrient pollution. The main difference between ditches and streams is magnitude. Agricultural ditches tend to be smaller, and therefore produce less pollution from erosion. Agricultural ditches also tend to have little to no filter strips flanking them and they often lack an overstory. Often, ditches were created in locations where no waterway was present before European settlement. The location and condition of the ditches is a major factor in their potential to supply and transport nonpoint source water pollution.

Stream bank erosion can occur due to near bank sheer stress, channelization, hydromodification, or other impairments that can cause an alteration of water's natural flow (e.g. log jams). This is often a result of changes in land use and/or the alteration of waterways. Modification or channelization of the natural channel can cause the pollutant levels to increase in a waterway. When a natural channel is modified and straightened into a drainage ditch (e.g. trapezoidal cross section, loss of floodplain, loss of sinuosity), the resulting changes to how water moves through the system results in increased erosion. For instance, the removal of a flood plain, the creation of a uniform channel depth, and the straightening of the channel, cause storm water to move through the waterway much faster, increasing the chance for erosion and long-distance sediment transport. As stated before, hydromodification can lead to serious problems by adversely affecting stream flow and gradient, the amount of sediment load, and the channel width to depth ratio.

Often overlooked, stream bank erosion is a significant contributor of sediment in our nation's waterways. According to the EPA Region 5 model for Estimating Load Reductions for Agricultural and Urban BMPs, an eroded 500 foot section of bank that is 10 feet high, with silt loam soils, would contribute over 4500 tons of sediment for every three inches of erosion. A recent study in a neighboring White River Subwatershed, Buck Creek, found stream banks contributing more tons per acre than sheet runoff. For the Lower Buck Creek drainage area it was estimated that on an annual basis, a total of 5,000 tons of sediment enter the river network from stream banks (with 20% of the sediment coming from only 867' of the total 20,000'). This is compared to 1,951 tons of sediment that enter the river system from sheet runoff in the same drainage basin. The amount of acres containing stream banks in the Buck Creek study reach is 4.59 acres compared to the 4,990 acres of land generating sheet runoff. Sediment contribution from channel modification and stream bank erosion can be easily identifiable using BEHI and NBS analysis. On Buck Creek streams, a loss of vegetation often was tied to an increase of erosion.

SHEET FLOW SOURCES

Rill erosion and gully formation, two types of sheet flow erosion, occur when stormwater runoff moves across the land, picking up soil particles as it moves. Rills, or small channels, begin to form. As the erosion continues, the rills get deeper and wider, causing gullies to form. These gullies can then become exacerbated if a head cut forms, forcing the channel to rapidly move uphill, eroding sediment as it goes. A lack of ground cover or other agricultural no-till practices (BMPs) on agricultural fields and ditches in the watersheds can cause excessive sediment pollution, degrading habitat and limiting the use of the waterways for recreation, drainage, and aesthetic purposes. A lack of drainage tile and ditch invert BMPs, along with the proximity of ditches and field tiles to agricultural fields, can provide sediment with direct access to the watershed's waterways. Best Management Practices can reduce the amount of the sediment that enters waterways.

The UMRW-P aerial photo analysis showed evidence for rill and gully formation. Rill and gully formations were the most concentrated in Blackford County and Delaware County. Highly erodible soils, conventional tillage, and sloping terrain may all be factors causing these relatively high concentrations of rills and gullies. Because the aerial photos began to identify the presence of surface erosion, we can conclude that sheetflow is a significant source of sediment contribution in these subwatersheds.

TABLE 13.5 | Sediment as leading pollutant	
Physical Changes in Streams Affected by Sediment	Resulting Direct and Indirect Effects on Aquatic Organisms
Heat is absorbed, resulting in increased water temperature	Metabolic rates of organisms increases; wasted energy not available for growth and reproduction
Water clarity is decreased; turbidity is increased; increased siltation and embeddedness on stream bottom	Reduction in visual feeding and visual mating; clogging of gills during breathing and feeding; smothering of nests and eggs; change in habitat and filling of crevices in bottom gravel
Excess organic debris carried with soil may result in increased biochemical oxygen demand and decreased dissolved oxygen	Oxygen sensitive species are detrimentally affected; pH is reduced (water becomes more acidic), causing phosphorus to becoming more available and ammonia to become more toxic; increased leaching of heavy metals
Excess phosphorus is attached to soil particles and is carried into streams	Phosphorus acts as a fertilizer, causing algal growth to increase, which causes higher daytime dissolved oxygen & lower nighttime dissolved oxygen; can upset normal feeding on the aquatic food chain
Heavy metals may be leached from soil, increasing toxicity	Developmental deformities; behavioral changes in feeding, mate attraction, activity and parental care
SOURCE: Hoosier Riverwatch - Volunteer Stream Monitoring Training Manual	

The UMRW-P acknowledges that efforts to remove sediment from our water bodies can have a synergistic impact to fish and wildlife concerns as well as socioeconomic concerns (agricultural capital). Keeping sediment on fields and streambanks alone will have the most significant positive impact to fish and other aquatic life communities, while simultaneously keeping positively charged nutrients (e.g. phosphorus and ammonia) on our fields. Furthermore, BMPs for sediment reduction, such as cover crops, filter strips, and bench wetlands, create opportunities for nutrient uptake when appropriate vegetation is planted in conjunction with these BMPs. These vegetative buffers also function as a “living wall,” blocking or filtering animal waste (from natural sources or from manure applications, etc.) that may contain pathogens harmful to human health. Because of these factors, the UMRW-P recognizes that sediment management is the “linchpin” in holistic water quality management. Table 13.5 outlines the negative impacts sediment can have on stream ecology.

Total suspended sediment (TSS) levels exceeded the target at many sites, contributing to low observed IBI and mIBI scores at some locations and compromising regional economic potential. Table 13.6 lists known sources within the watershed that are contributing to these problems.

While the reduction of each type of pollutant is important for the health and well being of our communities and aquatic ecosystems, sediment is especially significant in its impact for the following reasons:

(1) Soil (sediment) is agricultural capital and its preservation is directly linked to the economic viability of farmers.
(2) Sediment carries soil-bound nutrients with it. Therefore, reducing the amount of sediment entering waterways will also reduce the amount of nutrients entering them.
(3) Contaminated sediments can threaten creatures in the benthic environment, exposing worms, crustaceans and insects to hazardous concentrations of toxic chemicals. Some kinds of toxic sediments kill benthic organisms, reducing the food available to larger animals such as fish. Some contaminants in the sediment are taken up by benthic organisms in a process called bioaccumulation. When larger animals feed on these contaminated organisms, the toxins are taken into their bodies, moving up the food chain in increasing concentrations in a process known as biomagnification. As a result, fish and shellfish, waterfowl, and freshwater and marine mammals may accumulate hazardous concentrations of toxic chemicals.[9]
(4) According to the DNR/IDEM Hoosier Riverwatch Program, sediment is the number one source of water pollution by volume to Indiana streams and rivers. Soil erosion and sediment, as a result of poor construction, logging, landscaping, and agricultural practices, as well as eroding stream banks, cause many physical changes in streams that lead to decreased water quality.

9 Begum, A., S. HariKrishna, and Irfanulla Khan. 2009. Analysis of Heavy metals in Water, Sediments and Fish samples of Madivala Lakes of Bangalore, Karnataka. International Journal of ChemTech Research. 1(2):245-249.

TABLE 13.6 | Sediment (Total Suspended Solids) sources

Problem	Potential Cause(s)	Potential Source(s)
Low IBI and mIBI scores were observed at some locations.	TSS levels exceed the target set by this project	An estimated 71% of cropland is farmed using conventional tillage (the highest rates in Big Lick Creek and Massey Creek HUC 10's). See Appendix C, Figures C.7 through C.11 (Conventional Tillage Data). An estimated 30% (100 miles) of tributaries are in need of buffers (the majority of them in Headwaters Mississinewa HUC 10). The only water body that has relatively good shading and a riparian corridor lush with habitat is the Mississinewa River. See Figures 3.3 and 3.4 in Section 3 (Missing Buffers). High concentrations of rills and gullies were observed in Big Lick Creek and Pike Creek HUC 10's. See Figures 3.11 and 3.12. Erosion from channelized ditches. Based on windshield surveys, desktop surveys, and water quality results, section(s) of Lugar and Walnut creeks and Little Mississinewa River are experiencing extreme bank erosion. Seven Condition 3 and three Condition 4 logjams were identified on canoe survey (all occurring within Halfway Creek HUC 10, specifically in Fetid Creek and Platt-Nibarger HUC 12's). 105 CFOs within the watershed (the majority in Headwaters Mississinewa River and Halfway Creek HUC 10's). See Figure C.4 in Appendix C (CFOs). 82 livestock access points to streams identified (the majority in Halfway Creek HUC 10). See Figures 3.7 and 3.8 in Section 3. 43 CSOs identified (the majority in Massey Creek and Big Lick Creek HUC 10's). See Figure D.14 in Appendix D (CSOs). An estimated 16,586 septic systems in a watershed where 0.1% of the land is suitable for septic systems to function properly (the majority of the septic systems in Massey Creek and Pike Creek HUC 10's). See Figure D.15 in Appendix D (Estimated Septic Systems). Pet and wildlife waste contributes solids and likely increases with an increasing population density (the highest population densities are in Massey Creek and Big Lick Creek HUC 10's).
Regional economic potential is compromised.		

13.5 SOURCES: NUTRIENTS

Nutrient levels exceed the target set by this project. Table 13.7 lists known sources within the watershed that are contributing to these problems. The following paragraphs contain a general discussion of nutrient sources.

Nutrient pollutants come from decaying organic matter naturally but are also added to the environment through the usage of fertilizers, leaking septic tanks, manure, and surface run-off. Nutrients are placed into different categories: Phosphorus and Nitrates.

PHOSPHORUS

Phosphates enter water through the natural decay of organic matter or phosphorus rich bedrock, from human and animal waste, laundry detergents, cleaning solutions, industrial effluents, leaking septic tanks, and fertilizers. There are three forms of phosphates: orthophosphate, metaphosphate (or polyphosphate) and organically bound phosphate. Each compound contains phosphorous in a different chemical formula. Ortho forms are produced by natural processes and are found in sewage. Poly forms are used for treating boiler waters and in detergents. In water, they change into the ortho form. Organic phosphates are important in nature. Their occurrence may result from the breakdown of organic pesticides which contain phosphates. They may exist in solution, in particles, loose fragments or in the bodies of aquatic organisms in lakes, rivers, or even underground water sources.[1]

NITRATES

Nitrogen is essential for all living things. It exists in many forms in the natural environment and changes forms as it moves through the nitrogen cycle: nitrogen, nitrates, nitrites, nitrogen oxides, nitric acid, nitrous oxide, and ammonia. Nitrate-nitrogen is commonly found in groundwater due to point sources such as sewage disposal systems and livestock facilities, or non-point sources such as fertilized cropland, parks, golf courses, lawns, gardens, and naturally occurring sources. Nitrates in water are undetectable without testing because nitrogen is colorless, odorless, and tasteless. Annual testing is recommended in most areas. Typically nitrogen enters water systems through run-off or through leaching through the soil profile, usually from excessive fertilizer application.[2]

ANALYSIS OF NUTRIENT SOURCES

It is common knowledge that nutrients are applied as fertilizers by farmers and urban residents for either agricultural purposes or lawn care maintenance. Nutrients can also enter the water column through animal/human waste. As with NPS pollution in general, nutrients are difficult to track because of their diffuse usage in the Subwatersheds and because we do not have an effective method to survey usage of chemical fertilizers aside from county wide data (included in our Inventory and Analysis). We can confirm that these nutrients are being applied because they are detected by our water quality studies at levels higher than natural baselines. However, neither sources of information tell us where exactly they are being applied.

Aside from actually seeing farmers/urban residents applying these nutrients/fertilizers (at the time they are doing it) there is no way to quantify Subwatershed specific locations or their loading (with our available data resources). We know that we are not going to stop agriculture and urban users from applying fertilizers (as a non regulatory entity this sort of enforcement is not in our scope). Advocating a reduction in usage (only what is necessary) is one option for reducing nutrients in waterways.

We can also help to fund strategies that keep nutrients on site or help to filter nutrients out of the water as it leaves a chemical user’s property. Stream buffers are a best management practice that help to do this. Stream Buffer Analysis (Figure 3.3) helped us identify locations where there are zero agricultural/urban buffers on either side of the stream. We know that sites lacking buffers are weak points in storm water filtration. Additionally, the same applies for the streambank analysis. Trees and other riparian vegetation have the capacity to absorb water soluble nutrients. Furthermore, we know that phosphorus and other positively charged nutrients attach to sediment. Trees and other woody vegetation form an additional filtration medium and are more effective in sediment management than herbaceous buffers alone. Stabilizing sediment with stream bank vegetation, filter strips, and winter cover crops can do a lot to stop nutrient transport.

Finally, there is a persistent potential that phosphorus (applied in the past) may be embedded into soils that were once trapped by a streambank riparian zone. When we remove vegetation, streambank soils that are contaminated by phosphorus may finally have the opportunity to enter the water system. Furthermore, manure application rules only existed for nitrogen in the past. Phosphorus application rates (via manure) were not regulated until July, 2012, when a new rule stating that CFOs can’t apply manure to soil with phosphorus levels greater than 400 ppm.[3]

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1 Delaware County Soil and Water Conservation District. The White River Watershed Project. 2001-2010. http://whiteriverwatershedproject.org/WRWP/?page_id=153.

2 Ibid.

3 Maurer, Abigail. [web page] New CFO and CAFO rules require operational changes. Purdue University News Service. June 27, 2012. http://www.purdue.edu/newsroom/outreach/2012/120627NennichCFO.html [Accessed 6 October 2016]. http://www.purdue.edu/newsroom/outreach/2012/120627NennichCFO.html

Although one of the most significant contributors of nutrient pollutants in rural areas are agricultural producers, agricultural inputs remain unregulated under current law. We must continue to use methods for volunteer compliance with standards in order to find ways to reduce the impact of these agricultural processes. The 319 program, along with other programs administered though USDA/FSA, ISDA, and DNR will continue to play a role in implementing mitigations for these agricultural by products. Agricultural BMPs are the means of agricultural pre-treatment in the mechanism of nature's ecosystem service. If we begin seeing nature and the river as a large water pollution control facility we can see the need for some sort of buffer to the farming infrastructure discharge in the same way that we have programs for industrial processing units.

Nutrient input is a problem in locations with direct access to waterways via stormwater outfalls, swales, or areas directly adjacent to the streams through runoff. This is only an issue in those locations where people use fertilizers. This includes commercial, agricultural, and residential properties, and only those that apply too much fertilizers or at the inappropriate time, like before a rainfall.

Runoff provides nutrients (applied to the turfgrass or productive landscapes) direct access to streams. Nutrient rich runoff is predominantly from agricultural sources and exacerbated by the small or nonexistent buffer strips along ditches and the lack of no-till/grassed waterways throughout both watersheds. Non-agricultural concerns have also been expressed by stakeholders.

Animal waste improperly used on agricultural lands can be a major contributor to nutrient pollution in watersheds through runoff. One potential contributor to livestock waste pollution is farms, ranches and pastures that house livestock. Another potential contributor of animal waste pollution is the improper placement or timing of manure applications which can result in the movement of the wastes into the waterway through runoff. Assessment of manure management on agricultural fields is a long-term process; without undergoing an in-depth survey of all agricultural producers in the watershed, it is impossible to locate the specific sources of this problem. It is suggested that in the future, this data be uncovered using social survey techniques.

SHEETFLOW/DRAINAGE TILE FLOW
Erosion of agriculture fields in the watershed causes excessive nutrient (and sediment) pollution that is degrading habitat and limiting use of the waterways for recreation, drainage, and aesthetic purposes. Tile drainage systems also contribute excessive nutrient pollution to waterways. The current practice is for these tiles to discharge directly into the river. We believe that BMPs at tile inverts and outfalls may begin to buffer the systems from high concentrations of chemicals. Because there is a lack of knowledge of where tiles exist in their respective counties, steps need to be taken to identify all of these points. There is a general lack of filtering and onsite infiltration. Improperly applied manure, fertilizer, and pesticide applications can runoff into drainage ditches that then flow into the larger streams and rivers. Best Management Practices can reduce the frequency and amount of the pollutants that enters the waterway.

STREAMBANKS
Losses of nutrients (and sediment) via sheetflow could be decreased by adequate buffers and ground cover. Lack of ground cover is most likely caused by numerous human activities that have altered the natural chemical and physical environment of the riparian areas. These activities impair aquatic life communities by degrading habitat, disrupting natural processes like reproduction, and altering the chemical/physical properties of the water to a point where life struggles to survive.

TABLE 13.7 | Nutrient sources

Problem	Potential Cause(s)	Potential Source(s)
The Mississinewa river fails to meet the state designated beneficial use for fish and wildlife.	Nutrient levels exceed state water quality standards	HUC 10 cropland percentages range from 73% to 83% (the highest cropland percentages are in Halfway Creek and Headwaters Mississinewa HUC 10's and the southwestern part of Massey Creek HUC 10; the highest cropland percentages are in Little Deer Creek, Bear Creek, and Porter Creek HUC 12's). 105 CFOs within the watershed (the majority in Headwaters Mississinewa River and Halfway Creek HUC 10's). See Figure C.4 in Appendix C (CFOs). 82 livestock access points to streams identified (the majority in Halfway Creek HUC 10). See Figures 3.7 and 3.8 in Section 3. 43 CSOs identified (the majority in Massey Creek and Big Lick Creek HUC 10's). See Figure D.14 in Appendix D (CSOs). An estimated 16,586 septic systems in a watershed where 0.1% of the land is suitable for septic systems to function properly (the majority of the septic systems in Massey Creek and Pike Creek HUC 10's). See Figure D.15 in Appendix D (Estimated Septic Systems). An estimated 30% (100 miles) of tributaries are in need of buffers (the majority of them in Headwaters Mississinewa HUC 10). The only water body that has relatively good shading and a riparian corridor lush with habitat is the Mississinewa River. See Figures 3.3 and 3.4 in Section 3 (Missing Buffers). Pet waste (which contains nutrients) likely increases with an increasing population density (the highest population densities are in Massey Creek and Big Lick Creek HUC 10's). Lawn fertilization in urban areas is a source of nutrients. Nine percent of the watershed is urbanized. Seven golf courses and 36 schools were identified (the highest population densities are in Massey Creek and Big Lick Creek HUC 10's). See Figures E.9 through E.12 in Appendix E (Sports Facilities and Golf Courses) and Figures D.8 and D.9 in Appendix D (Housing Units). High concentrations of rills and gullies were observed in Big Lick Creek and Massey Creek HUC 10's. See Figures 3.11 and 3.12 (Rill and Gulley Inventory). An estimated 71% of cropland is farmed using conventional tillage (the highest rates in Big Lick Creek and Massey Creek HUC 10's). See Appendix C, Figures C.7 through C.11 (Conventional Tillage Data).
Regional economic potential is compromised.		

13.6 SOURCES: E. COLI

E. COLI LEVELS EXCEED WATER QUALITY STANDARDS

Historic water quality data shows high levels of pathogens present in waterways, regularly exceeding the state standard for a single sample of 235 cfu/100mL in both watersheds. Through water quality testing conducted for this watershed management plan, it was determined that E. coli is the worst impairment - by more than a 1000% in the Subwatersheds (and in the state of Indiana). E. coli levels exceed the target set by this project at all sites.

E. COLI & ITS SOURCES

E. coli is a fecal coliform bacteria that, when present in waterbodies, indicates human or animal waste contamination. Although not all E.coli are harmful to humans, testing for E. coli is relatively simple and easy. It's presence is therefore used as an indicator of other pathogenic bacteria and viruses found in human waste that could be present.

E. coli commonly enters waterbodies through stormwater run-off from failed, failing, or illegally hooked up septic systems, animal feeding operations, concentrated feeding operations, and sewage discharge. These sources can only be considered a threat if they are located directly adjacent to a waterway, or if there is a method for direct movement of the waste into the waterway, such as a pipe or swale. Wastes also include domestic pets and wildlife sources, but these sources are scattered throughout the watershed. Table 13.10 lists known sources of E. coli in surface waters within the watershed.

Sources of human waste are difficult, even impossible, for watershed groups to address because mitigation for these sources is costly; 319 grants will not fund septic system maintenance, CSO updates, etc. Mitigation for CSOs and failing septic systems will ultimately come from sources of funding other than the IDEM 319 funding. However, 319 funds can be used to provide education regarding proper maintenance of septic systems and raise the general awareness of problems associated with human waste and its disposal.

Grants will likely be able to fund more projects that address sources of animal waste. Livestock fencing along streams is a BMP funded by 319 grants. Minimal livestock crossings were identified during the desktop survey. Table 3.17 on p. 73 reports the amount of identified livestock access points in each HUC 12 subwatershed. Exclusion fencing BMPs cost share will be provided. Despite its low priority compared to other aforementioned E. coli sources (i.e. CSOs, failing septics), it is one of the only cost share opportunity available to mitigate point sources of E. coli. Educational programs can also be provided using 319 funds. For example, awareness of the fact that manure applications can be applied at the wrong times can be raised. Also, planting filter strips/buffers can help to filter pathogens from sheet flow (see Fig 3.3 and 3.4 on p. 47).

E. coli in domestic pet waste can also be a contributor of pollution to our streams. This is especially true in urban areas where people walk and house their animals and do not pick up their wastes. There is no way to accurately quantify the amount or areas where this is the biggest problem. Domestic pet sources, no matter the scale, have the potential to increase the amount of E. coli entering water bodies. Wastes left in areas where storm water flows have the potential to be picked up and moved into storm water conveyances and finally end up in the waterways. This is beyond the scope of this project. Wildlife is another potential nonpoint source of pathogen pollution. While E. coli from this source cannot be prevented, it is important to keep in mind the fact that not all E. coli found in surface waters comes from human sources. A study done for TMDL development for streams in a small Idaho watershed (they were on the state's 303(d) list for E. coli impairments) found that wildlife was the dominant source of E. coli overall. E. coli from human sources only made up 11% of total E. coli at some sites within the study.[1] Granted, the UMRW doesn't have near the ecological lands that Idaho has. But studies like this are a reminder that waste from wildlife really does have an impact on E. coli levels.

INTEGRATED WATER MONITORING AND ASSESSMENT REPORT (IR)

E. coli is one of the major impairments of rivers across the State of Indiana and is one of the most commonly used monitoring parameters. The Integrated Water Monitoring and Assessment Report is a biennial report of water quality assessments of the state's water resources required by the US EPA. The Indiana Department of Environmental Management (IDEM), using the combined report approach since 2002, generates two lists: Indiana's Consolidated List to fulfill the Section 305(b) requirements and the 303(d) List of Impaired Waters, which is a subset of the Consolidated List identifying only those impaired waters for which a total TMDL is required (IDEM, 2008b). IDEM monitors regional watersheds on a five-year rotation (so that approximately 20 percent of the state's watersheds are monitored every five years), and publishes the compiled results in every even year. The Upper Wabash watershed, which includes the nearly thirty monitoring stations of the Mississinewa watershed, was recently monitored in 2008, assessment in 2009-2010, and was published in the 2012 biennial Integrated Report. Following the assessment of water quality data based on state standards, waterbodies are assigned a category of usage (Table 12.1, p. 198). Waterbodies that do not meet their designated uses are proposed for listing on the impaired waterbodies list (303(d)). This list is used to identify impairments in waterbodies for which a total maximum daily load (TMDL) is needed. Total Maximum Daily Load is the amount of a pollutant that a water body can receive and still meet water quality standards. It is calculated by combining a sum of allowable loads from point sources and nonpoint sources plus a margin of safety. The TMDL study seeks to identify sources of water quality impairments and estimate needed reductions.

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1 Keith, K. and B. Steed. 2010. [web page] Idaho Department of Environmental Quality, Coeur d'Alene Regional Office. Identifying Bacterial Sources in Two North Idaho Streams. https://www.deq.idaho.gov/media/729052-cda-lake-tributaries-wag-identifying-bacteria-sources-1005.pdf [Accessed 18 December 2015].

STATE WIDE IMPLICATIONS

Figure 13.1 below shows the total amount of Category 5A and 5B streams listed on the IDEM 303(d) list for the Mississinewa River Watershed. Many smaller NHD mapped streams are not included on this list because they have yet to be analyzed as part of the IDEM assessment program. Only 291 miles (67%) of the 435 miles of NHD mapped streams have been assessed. It is likely that other, non assessed streams, are impaired or threatened for one or more designated uses. Figure 13.2 below shows the relative concentrations of 303(d) listed streams in the 28 subwatersheds. Mainstem watersheds have the highest concentrations (shown in red). E. coli is one of the primary impairments in the assessment of 303(d) lists. Many of the streams in the Mississinewa River watershed are impaired for E. coli using this metric. There are 156 miles of the Mississinewa River impaired and threatened for either E. coli, PCBs, or mercury. Numerous additional streams in the Upper Mississinewa Watershed have Category 5 listings. A list of all streams on the 303(d) list is included in Table 13.9 on the following page.

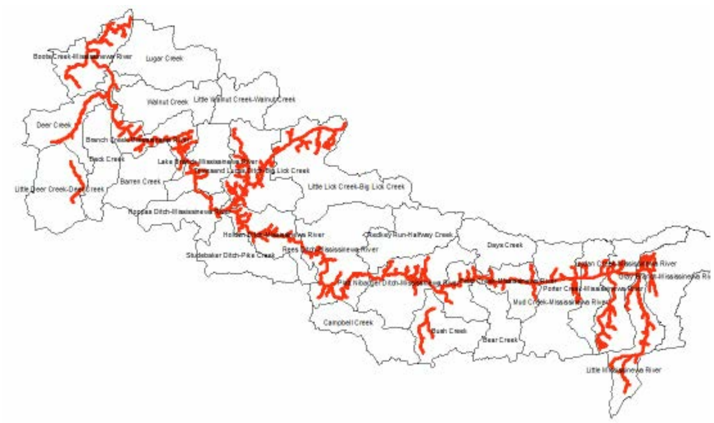


FIG. 13.1 | 303d Listed Streams

Stream highlighted in red are on the 303(d) List of Impaired Waters.

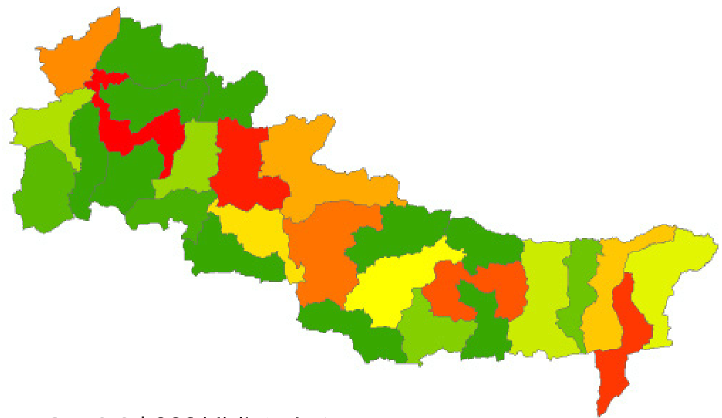


FIG. 13.2 | 303(d) listed streams

Subwatersheds are ranked on a gradient (red high and green low) based on the number of 303(d) listed stream miles.

TABLE 13.8 | Category of water usage (http://www.in.gov/legislative/iac/20120208-IR-318120053ONA.xml.html)

Category 1	Attaining the WQS for all designated uses and no use is threatened.
Category 2	Attaining some of the designated uses; no use is threatened; and insufficient data and information are available to determine if the remaining uses are attained or threatened.
Category 3	Insufficient data and information to determine if any designated use is attained.
Category 4	Impaired or threatened for one or more designated uses but does not require the development of a TMDL: A) TMDL has been completed that is expected to result in attainment of all applicable WQS and has been approved by U.S. EPA. B) Other pollution control requirements are reasonably expected to result in the attainment of the WQS in a reasonable period of time. C) Impairment is not caused by a pollutant.
Category 5	The WQS is not attained. A. The waters are impaired or threatened for one or more designated uses by a pollutant or pollutants, and require a TMDL. B. The waters are impaired due to the presence of mercury or PCBs, or both in the edible tissue of fish collected from them at levels exceeding Indiana's human health criteria for these contaminants.

TABLE 13.9 | 303(d) list			
Row Labels	HUC12	MILES	Category
BIG LICK CREEK	Townsand Lucas Ditch	18.83	5A - E. COLI
BOOTS CREEK	Boots Creek	5.74	5A - IBC
DEER CREEK	Deer Creek	9.45	5A - E. COLI
ELKHORN CREEK	Bush Creek	7.01	5A - IBC AND E. COLI
GETTINGER DITCH	Little Mississinewa River	2.74	5B - PCB IN FISH
HARSHMAN CREEK	Jordan Creek	14.56	5A - IBC AND E. COLI
LITTLE LICK CREEK	Little Lick Creek	19.82	5A - E. COLI
LITTLE MISSISSINEWA RIVER	Little Mississinewa River	12.47	5A - E.COLI, 5B - PCB AND MERC
MASSEY CREEK	Boots Creek	10.91	5A - IBC
MISSISSINEWA RIVER	Various	156.12	5A - E.COLI, 5B - PCB AND MERC
UNNAMED TRIBUTARY	Gray Branch	6.74	5A - E. COLI
MITCHELL DITCH	Gray Branch	3.71	5A - E. COLI
SHELLEY DITCH	Little Mississinewa River	7.49	5A - E.COLI, 5B - PCB AND MERC
TOWNSAND LUCAS DITCH	Townsand Lucas Ditch	11.25	5A - E. COLI
Grand Total		286.84	

TABLE 13.10 | E. coli sources		
Problem	Potential Cause(s)	Potential Source(s)
The river fails to meet its maximum recreational potential	E. coli levels exceed the target set by this project	105 CFOs within the watershed (the majority in Headwaters Mississinewa River and Halfway Creek HUC 10's). See Figure C.4 in Appendix C (CFOs). 82 livestock access points to streams identified (the majority in Halfway Creek HUC 10). See Figures 3.7 and 3.8 in Section 3. 43 CSOs identified (the majority in Massey Creek and Big Lick Creek HUC 10's). See Figure D.14 in Appendix D (CSOs). An estimated 16,586 septic systems in a watershed where 0.1% of the land is suitable for septic systems to function properly (the majority of the septic systems in Massey Creek and Pike Creek HUC 10's). See Figure D.15 in Appendix D (Estimated Septic Systems). An estimated 30% (100 miles) of tributaries are in need of buffers (the majority of them in Headwaters Mississinewa HUC 10). The only water body that has relatively good shading and a riparian corridor lush with habitat is the Mississinewa River. See Figures 3.3 and 3.4 in Section 3 (Missing Buffers). Waste from wildlife is a known contributor of E. coli (10-15% of each HUC 10 consists of ecological areas). See Figure C.3 in Appendix C (Ecological %). Pet waste is a known contributor of E. coli and likely increases with an increasing population density (the highest population densities are in Massey Creek and Big Lick Creek HUC 10's). See Figure D.18 in Appendix D (Population Density).
People may become exposed to pathogens and develop illness as a result of contact with the waterways. The river may be under utilized as a recreational resource.		
Landowners may be unaware that their drinking water is contaminated.		

14. CRITICAL AREAS

14.1 CRITICAL AREA SELECTION

Critical areas were selected based on water quality data as a means to effectively use grant funds and prioritize private sector initiatives. Critical areas are subwatersheds needing the most reduction of specific pollutants. Factors influencing the selection of critical areas include:

(a) Information collected, through the Inventory and Analysis process (land use information)
(b) Historic water quality data
(c) Analysis of concerns
(d) Analysis of contemporary water quality data and its exceedance of state and federal WQ standards and guidance
(e) The analysis of the sources of NPS stressors

SUBWATERSHED SELECTION PROCESS

Mainstem subwatersheds were not included in the critical area determination process. The Project Manager determined that reduction goals in these areas would be difficult to model (see Section 15, *Implementation*, on p. 241; also see see Appendix R) based on the high levels of load reduction needed (due to the volume of the Mississinewa River). Furthermore, the drainage area of any site on the Mississinewa includes all land upstream of that site. Water quality of a mainstem subwatershed can be influenced by factors outside of that mainstem subwatershed. This makes it difficult to determine the impact of the subwatershed's land-use and physical characteristics on water quality at these sites. Monitoring of smaller basins within these subwatersheds should be considered in future phases of the project.

Therefore, only HUC 12 tributary subwatersheds were considered as eligible to be selected as critical areas. In order to determine which HUC 12 subwatersheds would be designated as critical areas, current chemical and biological water quality data, historical water quality data, land use data, and desktop and windshield survey data were examined. The following 17 subwatersheds were considered during the critical area selection process: Deer Creek, Little Deer Creek, Back Creek, Barren Creek, Studebaker Ditch-Pike Creek, Campbell Creek, Bush Creek, Bear Creek, Little Mississinewa River, Gray Branch, Days Creek, Halfway Creek, Townsand Lucas Ditch-Big Lick Creek, Little Lick Creek, Walnut Creek, Little Walnut Creek, and Lugar Creek.

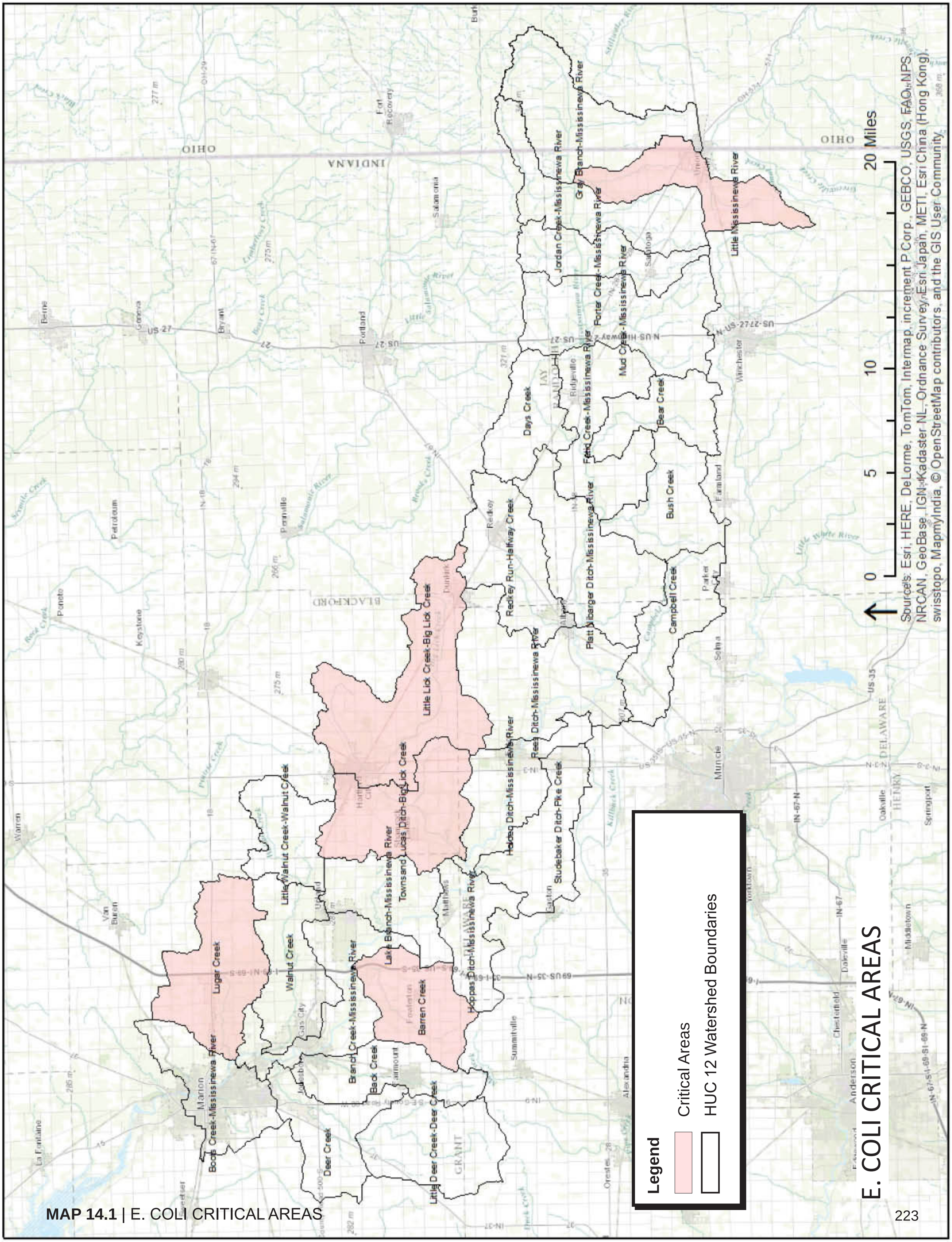
Subwatersheds were ranked according to the percent reduction needed (to reach target loads) for each parameter during high flow and also during low flow (TABLE 14.3). Within the rankings, "1" represents the highest priority subwatersheds, and "15" represents the lowest priority subwatersheds. Average rankings were calculated for each parameter based on samples collected at both low flow and high flow. The subwatersheds that ranked the worst in all categories (nitrogen, phosphorus, E. coli, and TSS) were selected as critical areas. In instances where there were ties for 5th place, both subwatershed were included. Maps 14.1-14.4 show the critical area subwatersheds for each parameter. Critical areas are listed based on the County in Table 14.1 below. Many sites were critical for multiple categories. For example, the Little Mississinewa River was in the critical group for all four water quality parameters.

TABLE 14.1 | Critical areas by county

Blackford	Darke (Ohio)	Delaware	Grant	Jay	Randolph
Big Lick Creek, Upper Big Lick Creek	Gray Branch	Campbell Creek	Barren Creek, Deer Creek, Little Deer Creek, Little Walnut Creek, Lugar Creek, Walnut Creek	Halfway Creek	Bush Creek, Campbell Creek, Gray Branch, Little Mississinewa

TABLE 14.2 | Overall ranking of mainstem subwatersheds, with "1" being the highest priority, and "15" being the lowest priority										
Mainstem Subwatershed	Nitrate High Flow Rank	Nitrate Low Flow Rank	Phosphorus High Flow Rank	Phosphorus Low Flow Rank	E.coli High Flow Rank	E. coli Low Flow Rank	TSS High Flow Rank	TSS Low Flow Rank	Overall Average	Overall Priority Rank
Porter Creek	5	1	1	2	6	5	1	3	3	1
Hoopas Ditch	8	8	2	5	3	1	3	1	4	2
Lake Branch	9	9	3	7	1	3	4	2	5	3
Jordan Creek	5	2	8	1	9	6	2	8	5	4
Branch Creek	10	6	5	3	7	2	5	6	6	5
Platt Nibarger Ditch	2	3	7	6	3	9	10	4	6	5
Rees Ditch	2	11	6	4	11	3	7	5	6	7
Boots Creek	11	5	4	10	2	8	5	7	7	8
Fetid Creek	1	4	11	9	3	11	8	9	7	9
Mud Creek	4	7	10	11	7	10	9	11	9	10
Holden Ditch	7	10	9	8	10	7	11	10	9	11

TABLE 14.3 | Overall ranking of tributary subwatersheds, with "1" being the highest priority, and "15" being the lowest priority										
Tributary Subwatershed	Nitrate High Flow Rank	Nitrate Low Flow Rank	Phosphorus High Flow Rank	Phosphorus Low Flow Rank	E.coli High Flow Rank	E. coli Low Flow Rank	TSS High Flow Rank	TSS Low Flow Rank	Overall Average	Overall Priority Rank
Gray Branch	2	1	1	6	6	13	1	4	4	1
Little Mississinewa River	7	2	3	7	10	2	2	7	5	2
Lugar Creek	14	10	9	1	4	1	3	1	5	3
Little Walnut Creek	11	7	2	8	12	5	5	6	7	4
Campbell Creek	5	14	4	9	10	6	9	2	7	5
Halfway Creek	9	8	7	5	8	8	10	5	8	6
Big Lick Creek	10	12	12	3	2	2	13	10	8	7 (tie)
Walnut Creek	12	11	5	11	7	11	4	3	8	7 (tie)
Upper Big Lick Creek	15	9	10	2	3	4	15	9	8	9
Barren Creek	3	5	15	13	1	7	11	14	9	10
Back Creek	13	6	11	12	5	9	6	11	9	11 (tie)
Little Deer Creek	6	3	8	15	8	14	7	12	9	11 (tie)
Bush Creek	1	13	13	4	14	10	12	8	9	13
Deer Creek	7	4	6	14	13	15	7	13	10	14
Pike Creek	4	15	14	10	15	11	14	15	12	15
Days Creek	-	-	-	-	-	-	-	-	-	-
Bear Creek	-	-	-	-	-	-	-	-	-	-


E. COLI CRITICAL AREAS
Legend
Critical Areas
HUC 12 Watershed Boundaries
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5
10
20 Miles
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
Boots Creek-Mississinewa River
Lugar Creek
Deer Creek
Little Deer Creek-Deer Creek
Walnut Creek
Little Walnut Creek-Walnut Creek
Branch Creek-Mississinewa River
Back Creek
Barren Creek
Lake Branch-Mississinewa River
Hoppas Ditch-Mississinewa River
Townsend Lucas Ditch-Big Lick Creek
Little Lick Creek-Big Lick Creek
Holdeg Ditch-Mississinewa River
Studebaker Ditch-Pike Creek
Rees Ditch-Mississinewa River
Redkey Run-Halfway Creek
Platt Inbarger Ditch-Mississinewa River
Campbell Creek
Bush Creek
Days Creek
Fetid Creek-Mississinewa River
Bear Creek
Mud Creek-Mississinewa River
Porter Creek-Mississinewa River
Jordan Creek-Mississinewa River
Gray Branch-Mississinewa River
Little Mississinewa River
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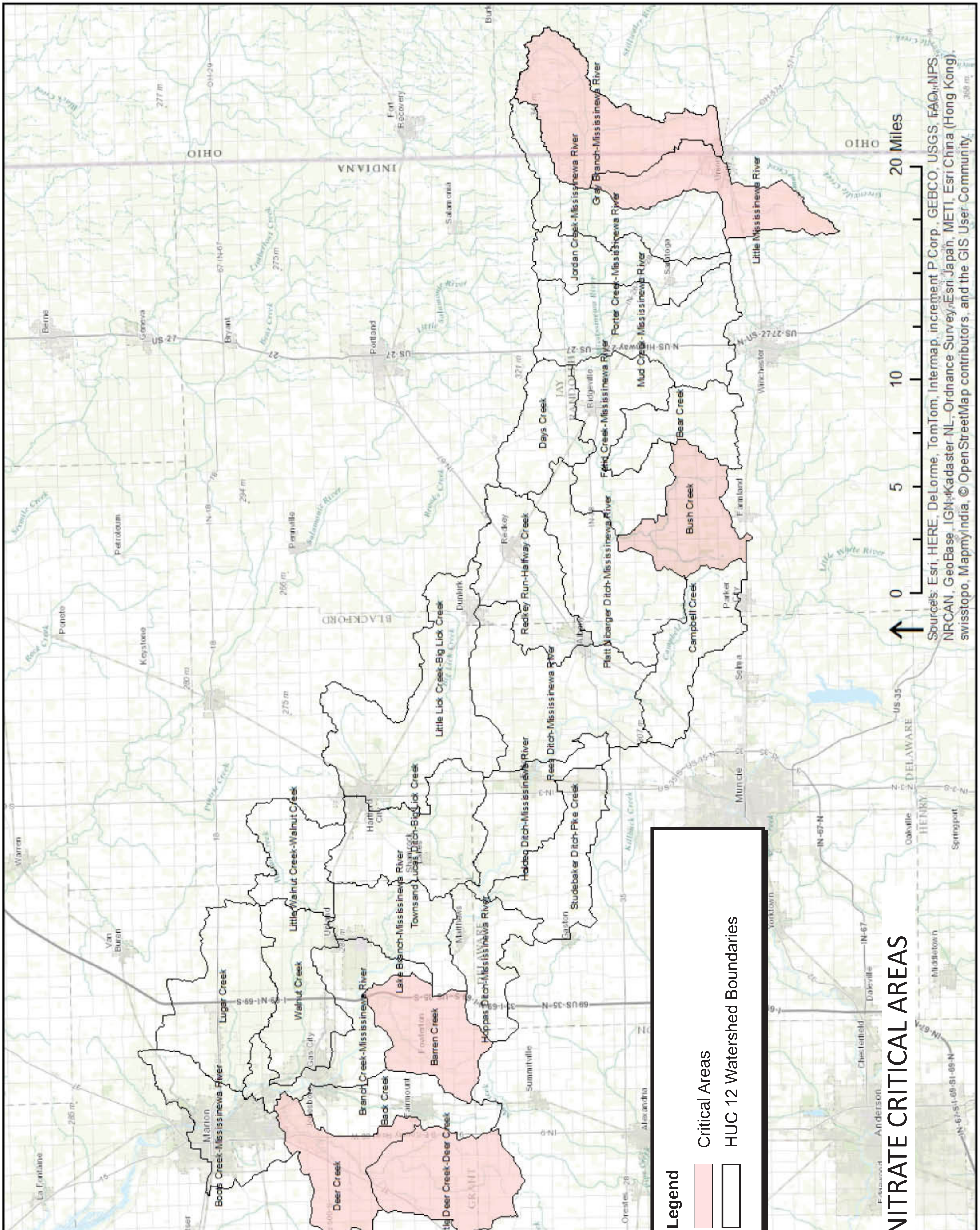
NITRATE CRITICAL AREAS
Legend
Critical Areas
HUC 12 Watershed Boundaries
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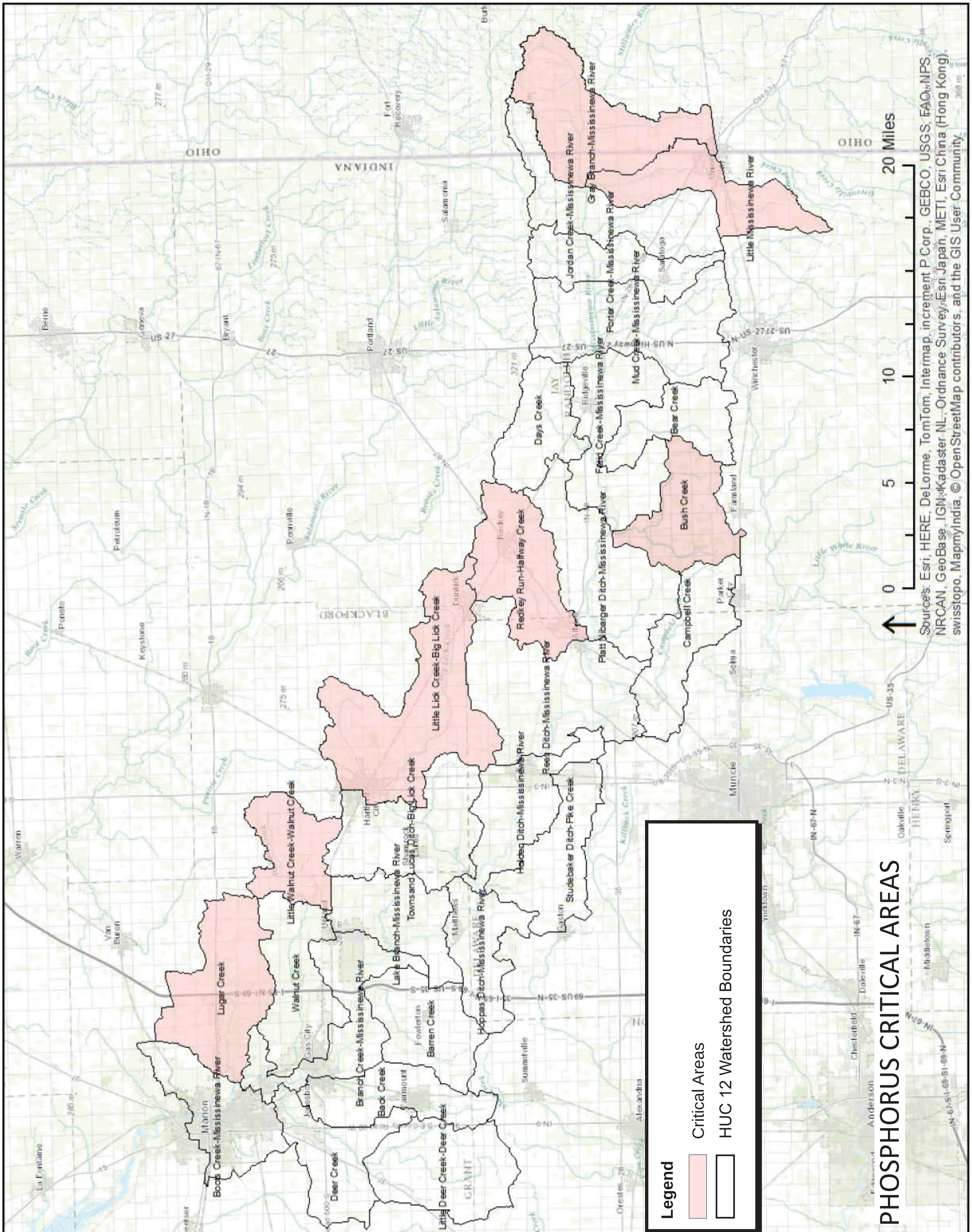
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
Jordan Creek-Mississinewa River
Gray Branch-Mississinewa River
Little Mississinewa River
Porter Creek-Mississinewa River
Mud Creek-Mississinewa River
Days Creek
Fetid Creek-Mississinewa River
Bear Creek
Bush Creek
Redkey Run-Halfway Creek
Platt Nibarger Ditch-Mississinewa River
Campbell Creek
Little Lick Creek-Big Lick Creek
Rees Ditch-Mississinewa River
Halfway Ditch-Mississinewa River
Studebaker Ditch-Pike Creek
Townsand Lucas Ditch-Big Lick Creek
Lake Branch-Mississinewa River
Hoppas Ditch-Mississinewa River
Little Walnut Creek-Walnut Creek
Walnut Creek
Lugar Creek
Branch Creek-Mississinewa River
Barren Creek
Back Creek
Boots Creek-Mississinewa River
Deer Creek
Little Deer Creek-Deer Creek
OHIO
INDIANA
Muncie
Winchester
Portland
Marion


PHOSPHORUS CRITICAL AREAS
Legend
Critical Areas
HUC 12 Watershed Boundaries
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20 Miles
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
Jordan Creek-Mississinewa River
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Redkey Run-Halfway Creek
Platt Niberger Ditch-Mississinewa River
Campbell Creek
Little Lick Creek-Big Lick Creek
Rees Ditch-Mississinewa River
Holdeg Ditch-Mississinewa River
Studebaker Ditch-Pike Creek
Townsand Lucas Ditch-Big Lick Creek
Little Walnut Creek-Walnut Creek
Lake Branch-Mississinewa River
Hoppas Ditch-Mississinewa River
Walnut Creek
Lugar Creek
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Back Creek
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INDIANA
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Muncie
Winchester
Marion
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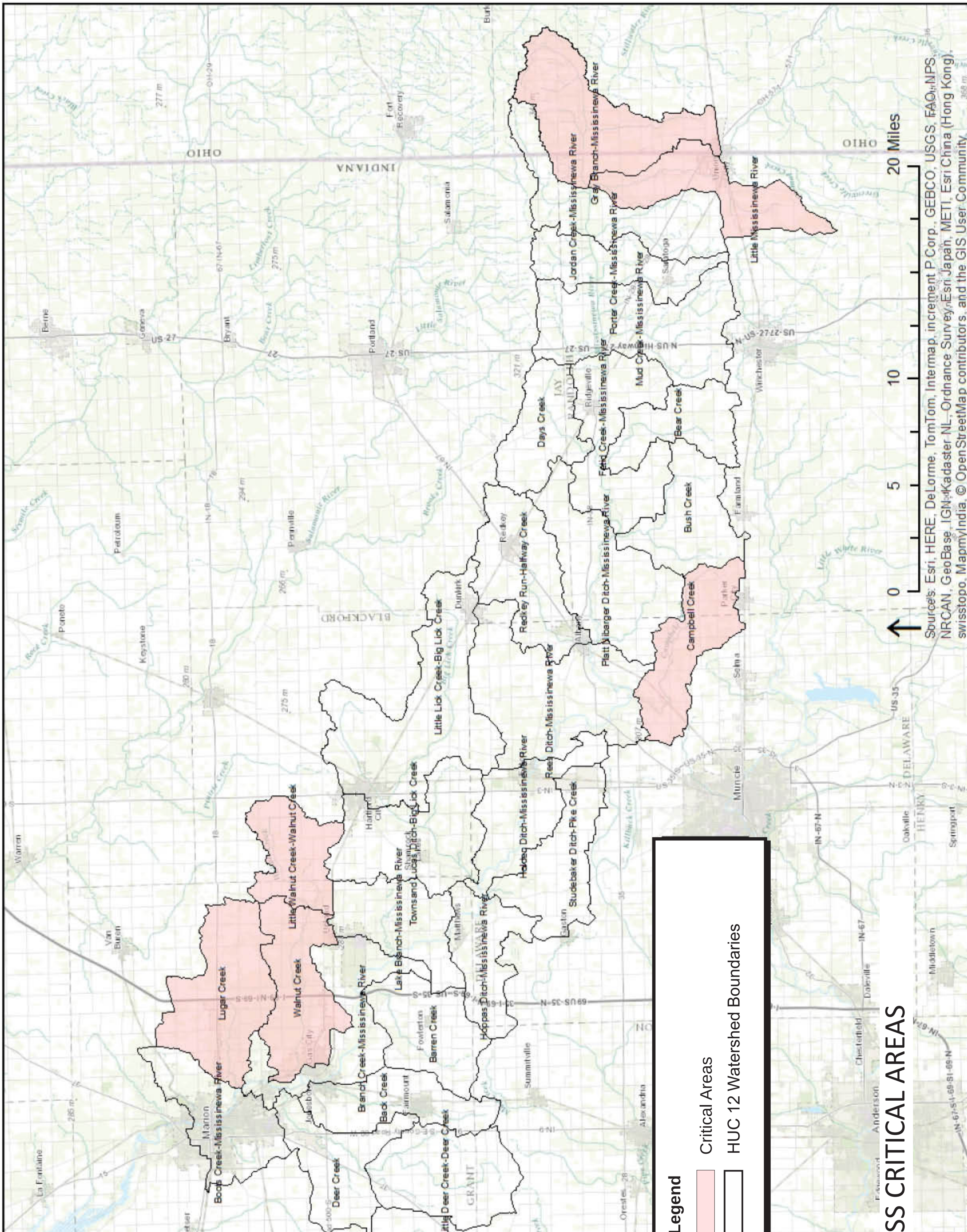


MAP 14.4 | TSS CRITICAL AREAS

14.2 PRIORITIZATION OF CRITICAL AREAS

In order to prioritize implementation, critical areas were further analyzed and organized into series of Tiers. Tier I (highest priority), II (medium priority), and III (low priority) (Table 14.4). Critical areas were organized into Tiers based on a holistic examination of current chemical and biological water quality data, historical water quality data, land use data, and desktop and windshield survey data. Tier I critical areas will receive 319 cost-share dollars first. Once funding is exhausted in Tier I areas, Tier II areas will be eligible for cost-share. Again, once funding is exhausted in Tier II areas, Tier III areas will be eligible for funding. See Maps 14.4 for TIER I critical area locations.

TABLE 14.4 | Critical tributary subwatersheds: Tier I, II, and III

Critical Tributary Subwatershed	Source of Impairment	Pollutant
Tier I		
Bush Creek	cropland; CFO's	nitrogen
Deer Creek	cropland	nitrogen
Gray Branch	cropland	nitrogen, phosphorus, TSS
Halfway Creek	cropland	phosphorus
Upper Big Lick Creek	areas where livestock have access to streams	phosphorus, E. coli
Tier II		
Campbell Creek	septic systems; eroding streambanks; cropland	TSS
Little Mississinewa River	cropland; CFO's	nitrogen, phosphorus, E. coli, TSS
Barren Creek	areas where livestock have access to streams	nitrogen, E. coli
Little Deer Creek	cropland	nitrogen
Tier III		
Lugar Creek	eroding streambanks	phosphorus, E. coli, TSS
Big Lick Creek	areas where livestock have access to streams	E. coli
Little Walnut	cropland; eroding streambanks	phosphorus, TSS
Walnut Creek	eroding streambanks; cropland	TSS

14.3 TIER I SELECTION RATIONALE

Many factors were considered when determining Tier I critical areas. The following list of information was compiled for Deer Creek, Bush Creek, Gray Branch, Upper Big Lick Creek, and Halfway Creek respectively. Tier II and Tier III were selected on a basis of ranking, county location, target pollutant, and funding opportunities:

Deer Creek Subwatershed

1. Deer Creek has a high percentage of missing stream buffers (FIG 3.4) when compared to other subwatersheds in the region. There are 5 miles of tributaries needing buffers (TABLE 3.17).
2. Deer Creek is located in proximity to Marion. Deer Creek subwatershed has a higher percentage of urban areas in the watershed (MAP 3.8), and a higher percentage of population density (FIG. D.19) when compared to other subwatersheds in the region. It has a higher percentage of incorporated housing units (FIG. D.9) and wells (FIG. D.11).
3. Deer Creek Subwatershed has Poor IBI results (38) and fair MIBI Results (TABLE 9.12).
4. Sediment load reduction is needed in Deer Creek Subwatershed during high flow events (Section 8).
5. Significant nitrogen load reduction is needed in Deer Creek Subwatershed during low flow events (Section 8)
6. Significant nitrogen load reduction is needed in Deer Creek Subwatershed during high flow events (Section 8)
7. Significant phosphorus load reduction is needed in Deer Creek Subwatershed during high flow events (Section 8).
8. Deer Creek has the highest ranking of nitrogen levels in Grant County during both high and low flow events (TABLE 16.6).
9. Deer Creek has a comparatively higher percentage of conventional tillage for both corn (FIG. 8) and soybean (FIG. C.9) when compared to other subwatersheds in the region.
10. Deer Creek has a comparatively higher surface soil erosion/loss estimate (FIG. C.12) when compared to other subwatersheds in the region. This was predicted in 2014, and through at Taylor University study (FIG. C.13).
11. Deer Creek has historically elevated levels of nitrogen according to LARE data, (FIG. J.4).
12. Deer Creek has an average Nitrate+Nitrae score of 3.24 mg/L and is highest during high flow samples (Table L.2). The highest amount of nitrogen exceedances occurred during low flow (Table L.3) and the stream needs a 70-80% reduction in nitrogen in order to meet water quality targets (TABLE 13.9).
13. There has been public input from neighborhood associations in the area and they are supportive of implementation efforts.

Bush Creek Subwatershed

1. Average TSS at Bush Creek was 9.50 mg/L and was highest during high flow samples (Table N.2). The highest amount of TSS exceedances occurred during high flow (Table N.3) and the stream needs an 19% reduction in TSS during high flow in order to meet water quality targets (Table 13.7).
2. Bush Creek has a high number of runoff areas (Fig 3.10) when compared to other subwatersheds in the region.
3. Bush Creek has a high relief ratio (FIG B.10) when compared to other subwatersheds in the UMRW.
4. Average Nitrate at Bush Creek's pour point was 2.31 mg/L and was highest during high flow samples (Table L.2). The highest amount of nitrate exceedances occurred during high flow (Table L.3) and the stream needs an 88% reduction in nitrate during high flow in order to meet water quality targets (Table 13.9).
5. When examining TMDL data, Bush Creek site T3 has high average nitrate + nitrite concentration when compared to other TMDL sites.
6. When examining TMDL data, Bush Creek site T3 has a high average E. coli concentration when compared to other TMDL sites.
7. Bush Creek has a high number of livestock accessing streams (FIG 3.8) when compared to other subwatersheds in the region.
8. The greatest nitrate load reduction is needed in Bush Creek subwatershed during high flow events (MAP 13.17).
9. Little Lick Creek has a high percentage of ecological lands (FIG C.3).
10. Bush Creek has a high number of vehicular track sites (FIG E.2) when compared to other subwatersheds in the region.
11. Bush Creek has the highest number of golf courses in the UMRW (FIG E.10)
12. LARE
    a. Bush Creek had high levels of E. coli (FIG J.5) when compared to other subwatersheds having LARE data.
    b. Bush Creek had high levels of turbidity (FIG J.6) when compared to other subwatersheds having LARE data.
    c. Bush Creek had high levels of phosphorus (FIG J.7) when compared to other subwatersheds having LARE data.
    d. Bush Creek had high levels of nitrogen (FIG J.8) when compared to other subwatersheds having LARE data.

Gray Branch Subwatershed

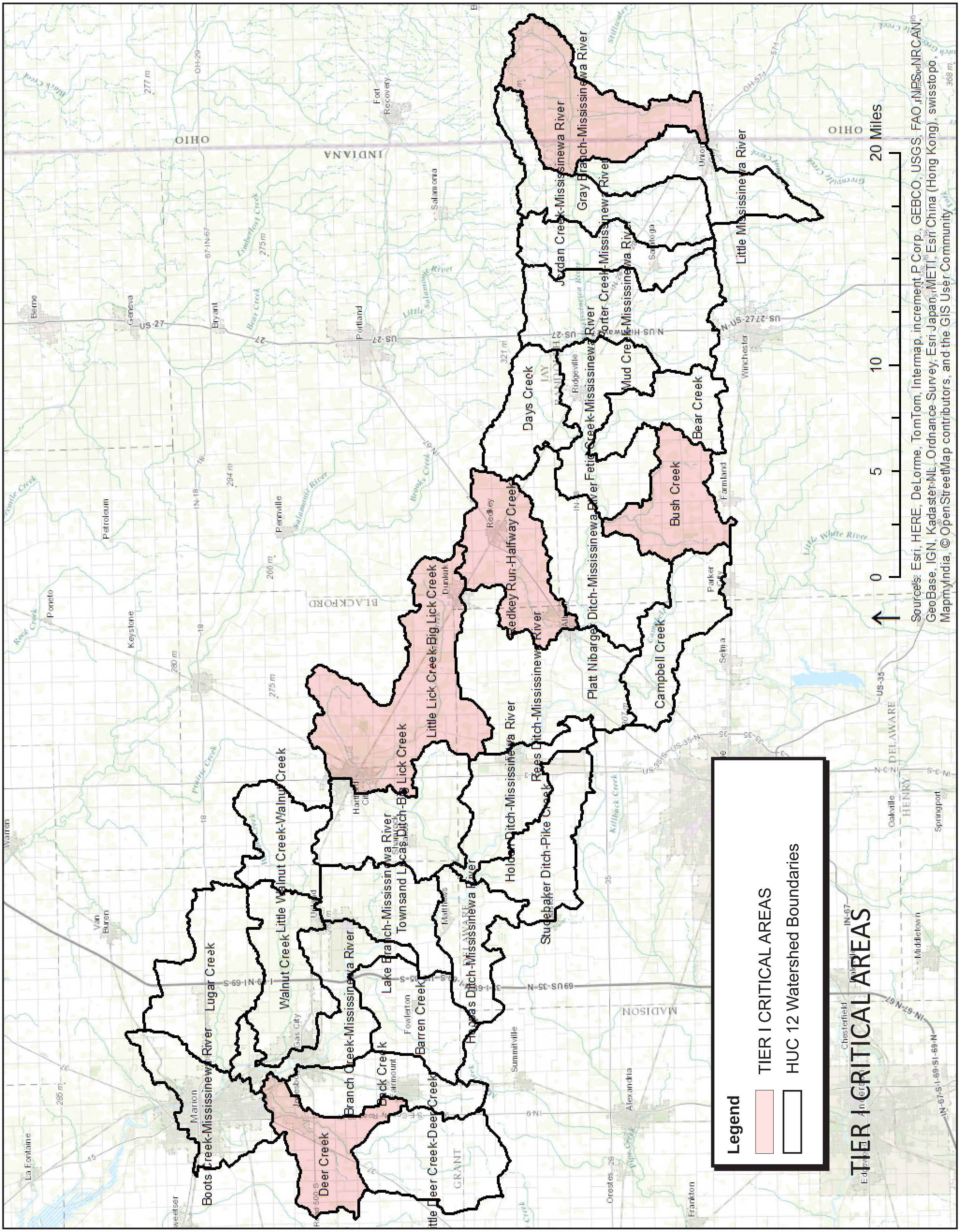
1. Average TSS at Gray Branch was 66.2 mg/L and was highest during high flow samples (Table N.2). The highest amount of TSS exceedances occurred during high flow (Table N.3) and the stream needs an 92% reduction in TSS during high flow in order to meet water quality targets (Table 13.8).
2. Significant TSS load reduction is needed in Gray Branch subwatershed during high flow events (MAP 13.3).
3. Gray Branch has a high number of points (22) where erosion was observed entering streams (Table 3.16, FIG 3.1) when compared to other subwatersheds.
4. Gray Branch has a high percentage of streams needing buffers (FIG 3.4) when compared to other subwatersheds in the region. There are 6 miles of tributaries needing buffers (Table 3.17).
5. Gray Branch has a high number of rills noted due to headcuts formed by culverts (Table 3.19).
6. Gray Branch has a high number of conventionally tilled soybeans acres (FIG C.11).
7. Gray Branch has a high percentage of hydric soils (FIG 5.1).
8. Average Phosphorus at Gray Branch was 0.30 mg/L and was highest during high flow samples (Table M.2). The highest amount of phosphorus exceedances occurred during high flow (Table M.3) and the stream needs an 63% reduction in phosphorus during high flow in order to meet water quality targets (Table 13.13).
9. Significant phosphorus load reduction is needed in Gray Branch subwatershed during high flow events (MAP 13.11).
10. Gray Branch has the highest number of CFOs in the UMRW (FIG C.4).
11. Gray Branch has a high number of estimated septic systems (FIG D.15) when compared to other subwatersheds in the region.
12. Average Nitrate at Gray Branch was 6.56 mg/L and was highest during high flow samples (Table L.2). The same number of nitrate exceedances occurred during low flow and high flow (Table L.3) and the stream needs an 87% reduction in nitrate during high flow and an 86% reduction during low flow in order to meet water quality targets (Table 13.10).
13. Significant nitrate load reduction is needed in Gray Branch subwatershed during low flow and high flow events (Section 8).
14. Gray Branch has one of the highest inputs of phosphorus and nitrogen due to its high percentage of agricultural land (FIG C.6 and C.7).
15. Gray Branch had POOR QHEI score when mIBI was sampled (Table 9.12).

Upper Big Lick Creek Subwatershed

1. Out of all 28 HUC 12 subwatersheds in the UMRW, Little Lick Creek has the highest number of points (22) where erosion was observed entering streams (Table 3.16, FIG 3.1).
2. Out of all 28 HUC 12 subwatersheds in the UMRW, Little Lick Creek has the highest number of rills and gullies (Table 3.16, FIG 3.12).
3. Little Lick Creek has a high percentage of streams needing buffers (FIG 3.4) when compared to other subwatersheds in the region. It is tied for third with three other subwatersheds. There are 6 miles of tributaries needing buffers (Table 3.17).
4. Little Lick Creek was listed as impaired for E. coli on the 2014 303d list.
5. Significant E. Coli load reduction is needed in Little Lick Creek subwatershed during high flow and low flow events (Section 8).
6. When examining TMDL data, all sites in Little Lick Creek have high average E. coli concentrations when compared to other TMDL sites.
7. Little Lick Creek has a high percentage of urban areas (FIG C.2).
8. Little Lick Creek has a high population density (FIG D.19).
9. Little Lick Creek has one of the highest numbers of incorporated housing units (FIG D.9).
10. It also has a high number of unincorporated housing units (FIG D.10).
11. The estimated number of septic systems in Little Lick Creek is high (FIG D.15).
12. Little Lick Creek has the second highest number of CSOs in the watershed (Table 3.14).
13. Little Lick Creek has a high number of livestock accessing streams (4) when compared to other subwatersheds in the region (Table 3.16).
14. Little Lick Creek has a high percentage of CFOs when compared to other subwatersheds in the UMRW (FIG C.4).
15. Little Lick Creek has the most mobile home sites (Table 3.17).
16. Little Lick Creek had a POOR mIBI score and a POOR QHEI score (Table 9.12).
17. Significant phosphorus load reduction is needed in Little Lick Creek subwatershed during low flow events (MAP 13.12).
18. Little Lick Creek has one of the highest concentrations of streams in the UMRW (FIG B.5).
19. Little Lick Creek has a high percentage of ecological lands (FIG C.3) when compared to other subwatersheds in the region.
20. Little Lick Creek has one of the highest number acres of corn planted using conventional tillage (FIG C.10).
21. Little Lick Creek has one of the highest number of acres of soybeans planted using conventional tillage (FIG C.11).
22. Little Lick Creek has one of the highest predicted amounts of sediment erosion due to conventional tillage (FIG C.12).
23. Little Lick Creek one of the highest percentages of C and D soils and hydric soils (FIG 5.1).
24. Little Lick Creek one of the highest percentages of highly erodible soils (FIG 5.1).
25. Little Lick Creek has a high number of residents who obtain their drinking water from private wells (D.13). Aquifer capacity in Little Lick Creek is among the highest in the watershed (FIG 3.5).
26. Storet Results (FIG I.7 – I.12)
    a. Little Lick Creek had high levels of ammonia, Kjeldahl nitrogen, phosphorus, and E. coli
    b. Big Lick Creek had high Kjeldahl nitrogen, phosphorus, E. coli, and turbidity
27. Average Nitrate at Little Lick Creek's pour point was 2.10 mg/L and was highest during high flow samples (Table L.2). The highest amount of nitrate exceedances occurred during low flow (Table L.3) and the stream needs an 60% reduction in nitrate during high flow and a 28% reduction during low flow in order to meet water quality targets (Table 13.9).
28. When examining TMDL data, Little Lick Creek site T22 has high average nitrate + nitrite concentration when compared to other TMDL sites.
29. Average Phosphorus at Little Lick Creek was 0.38 mg/L and was highest during high flow samples (Table M.2). This was the second highest average phosphorus of all 28 HUC 12 sites in the UMRW (second only to the mainstem subwatershed, Branch Creek). The highest amount of phosphorus exceedances occurred during high flow (Table M.3).
30. When examining TMDL data, all sites in Little Lick Creek have high average phosphorus concentrations when compared to other TMDL sites.
31. Average TSS at Little Lick Creek was 25.05 mg/L and was highest during high flow samples (Table N.2). Flow data was not collected for Little Lick Creek. This was the seventh highest average TSS of all tributary subwatershed sites.
32. When examining TMDL data, all sites in Little Lick Creek have high average nitrate + nitrite concentrations when compared to other TMDL sites.
33. Little Lick Creek has one of the highest number of regulated point sources (FIG D.16).
34. Little Lick Creek has one of the highest number of construction storage sites (FIG E.6).
35. Little Lick Creek has the highest number of lawns (103) and sports fields (18) in the watershed (Table 3.17).
36. Little Lick Creek has a high number of vehicle storage sites (11) when compared to other subwatersheds in the UMRW (Table 3.17).
37. Little Lick Creek has the highest number of junk storage sites (25) in the UMRW (Table 3.16).
38. According to the TMDL, Little Lick Creek has the highest estimated pet population within the TMDL study area. They used statistics from the 2007 U.S. Pet Ownership & Demographics Sourcebook to calculate estimation.

Halfway Creek Subwatershed

1. Average TSS at Halfway Creek was 13.55 mg/L and was highest during high flow samples (Table N.2). The highest amount of TSS exceedances occurred during high flow (Table N.3) and the stream needs an 46% reduction in TSS during high flow in order to meet water quality targets (Table 13.7).
2. Significant TSS load reduction is needed in Little Lick Creek subwatershed during low flow events (MAP 13.14).
3. Halfway Creek has a high percentage of streams needing buffers (FIG 3.4) when compared to other subwatersheds in the region. There are 6 miles of tributaries needing buffers (Table 3.17).
4. Halfway Creek has a high number of runoff areas (Fig 3.10) when compared to other subwatersheds in the region.
5. Halfway Creek has one of the highest number of rills and gullies (Table 3.16, FIG 3.12) when compared to other subwatersheds in the UMRW.
6. Little Lick Creek has one of the highest concentrations of streams in the UMRW (FIG B.5).
7. Halfway Creek has one of the highest frequencies of streams in the UMRW (FIG B.9).
8. Average Phosphorus at Halfway Creek's pour point was 0.23 mg/L and was highest during high flow samples (Table M.2). The highest amount of phosphorus exceedances occurred during high flow (Table M.3) and the stream needs an 43% reduction in phosphorus during high flow in order to meet water quality targets (Table 13.12).
9. Significant phosphorus load reduction is needed in Halfway Creek subwatershed during low flow events (Section 8).
10. When examining TMDL data, Halfway Creek site T14 had high average phosphorus concentration when compared to other TMDL sites.
11. When examining TMDL data, Halfway Creek site T14 had a high average E. coli concentration when compared to other TMDL sites.
12. Halfway Creek has the 3rd highest number of CSOs in the UMRW (Table 3.14).
13. Halfway Creek has a high number of livestock accessing streams (6) when compared to other subwatersheds in the region (Table 3.16).
14. LARE
    a. Halfway Creek had one of the highest levels of E. coli (FIG J.5) when compared to other subwatersheds having LARE data.
    b. Halfway Creek had one of the highest levels of turbidity (FIG J.6) when compared to other subwatersheds having LARE data.
    c. Halfway Creek had one of the highest levels of phosphorus (FIG J.7) when compared to other subwatersheds having LARE data.
    d. Halfway Creek had one of the highest levels of nitrogen (FIG J.8) when compared to other subwatersheds having LARE data.
15. Average Nitrate at Halfway Creek's pour point was 1.69 mg/L and was highest during high flow samples (Table L.2). The same number of nitrate exceedances occurred during low flow and high flow (Table L.3) and the stream needs an 79% reduction in nitrate during high flow and a 38% reduction during low flow in order to meet water quality targets (Table 13.9).
16. When examining TMDL data, Halfway Creek site T14 has high average nitrate + nitrite concentration when compared to other TMDL sites.
17. Halfway Creek had POOR QHEI scores when both mIBI and IBI were sampled (Table 9.12).
18. Halfway Creek has one of the highest percentages of urban land in the UMRW (FIG C.2).
19. Halfway Creek has a high number of incorporated housing units (FIG D.9) when compared to other subwatersheds in the UMRW.
20. Halfway Creek has a high number of regulated point sources (FIG D.16) when compared to other subwatersheds in the region.
21. Halfway Creek has a high population density (FIG D.19) when compared to other subwatersheds in the region.
22. Halfway Creek has a high number of vehicular track sites (FIG E.2) when compared to other subwatersheds in the region.
23. Halfway Creek has a high number of vehicular storage sites (FIG E.4) when compared to other subwatersheds in the region.
24. Halfway Creek has the second highest number of golf courses in the UMRW (FIG E.10)
25. Halfway Creek has a high number of sports facilities (FIG E.12) when compared to other subwatersheds in the region.
26. Halfway Creek has a high number of junk storage sites (FIG E.16) when compared to other subwatersheds in the region.


TIER I CRITICAL AREAS
Legend
TIER I CRITICAL AREAS
HUC 12 Watershed Boundaries
0
5
10
20 Miles
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
Jordan Creek-Mississinewa River
Gray Branch-Mississinewa River
Little Mississinewa River
Days Creek
Mud Creek
Bear Creek
Bush Creek
Redkey Run-Halfway Creek
Little Lick Creek-Big Lick Creek
Campbell Creek
Platt Nibarger Ditch-Mississinewa River
Rees Ditch-Mississinewa River
Big Lick Creek
Holden Ditch-Mississinewa River
Studebaker Ditch-Pike Creek
Little Walnut Creek-Walnut Creek
Walnut Creek
Lugar Creek
Barren Creek
Deer Creek
Little Deer Creek-Deer Creek
OHIO
INDIANA

14.4 HUC 12 SUBWATERSHED REDUCTION GOALS AND INDICATORS, ORGANIZED BY HUC 10

LOAD CALCULATIONS AND GOALS

Based on identified stakeholder concerns, water quality data, and potential sources of pollution, goal statements were developed for problems identified in each critical area. IDEM's Load Calculation Tool was used to generate load reductions based on water quality data collected for this study by the UMRW-P and on IDEM's TMDL data. Implementation of policies, cost-share programs, and practices will improve water quality and watershed conditions within the subwatersheds when guided by the goal statements. As part of this process (and the process to document effective implementation and effective results) we have – in Tables 14.5 - 14.11 – developed reduction goals (e.g., decrease loading by 30%) and the estimated loading reduction for all critical subwatersheds. This "reduction needed" is based on current load calculations and target loads (Tables 14.12 through 14.16).

The ultimate goal in each critical area is to reach the target load. However, due to magnitude of current loads and volume of achievable practices, this cannot be done in a reasonable time frame. Therefore, scaled goals that are attainable have been developed.

Each critical area has three load reduction goals listed for each parameter: average, high flow, and low flow. While the average load reduction needed (regardless of flow) will be used throughout the modeling and subsequent goal sections, high flow and low flow reductions are listed here so that they are readily available for comparison to water quality data collected in the future. The premise is, if water quality data is collected at the same sites and depth and velocity are measured at these sites using the same methods used by the UMRW-P, then calculated flows can be categorized into the high flow or low flow categories created by the UMRW-P as part of its water quality monitoring program. These categories are listed in Table 8.2 on p. 115. The rationale for this method is that we can see how close the new concentrations are to old concentrations taken under similar flow conditions. Although this is still a crude method, it may allow us to better determine if load reductions have been achieved.

TABLE 14.5 | Goals and indicators for HUC 12 subwatersheds within Pike Creek HUC 10 (Delaware County)

Cause	Goal(s)
TSS levels exceed the target set by this project (25 mg/L)	**Campbell Creek HUC 12, Tier II -** Excess TSS has been identified as a problem during high flow. Our goal is to reach the target TSS load within 30 years by reducing the subwatershed's high flow TSS load from 1348 tons per year to 1011 tons per year (a 25% reduction) in 15 years and to 871 tons per year (a 35% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. TSS will be tested for monthly at this site for one year, following the completion of the second implementation phase.
Phosphorus levels exceed the target set by this project (0.3 mg/L)	**Halfway Creek HUC 12, Tier I -** Excess phosphorus has been identified as a problem during high flow. Our goal is to reach the target phosphorus load within 30 years by reducing the subwatershed's high flow phosphorus load from 29 tons per year to 22 tons per year (a 25% reduction) in 15 years and to 18 tons per year (a 37% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. Total phosphorus will be tested for monthly at this site for one year, following the completion of the second implementation phase.

<table>
<tr><th colspan="2">TABLE 14.6 | Goals and indicators for HUC 12 subwatersheds within Headwaters Mississinewa (Darke and Randolph counties)</th></tr>
<tr><th>Cause</th><th>Goals</th></tr>
<tr><td rowspan="2">Phosphorus levels exceed the target set by this project (0.3 mg/L)</td><td>Gray Branch HUC 12, Tier I - Excess phosphorus has been identified as a problem during high flow. Our goal is to reach the target phosphorus load within 30 years by reducing the subwatershed’s high flow phosphorus load from 48 tons per year to 36 tons per year (a 25% reduction) in 15 years and to 27 tons per year (a 43% reduction) in 30 years.

Water quality data will be used as an indicator to demonstrate progress towards this goal. Total phosphorus will be tested for monthly at this site for one year, following the completion of the second implementation phase.</td></tr>
<tr><td>Little Mississinewa HUC 12, Tier II- Excess phosphorus has been identified as a problem during high flow. Our goal is to reach the target phosphorus load within 30 years by reducing the subwatershed’s high flow phosphorus load from 52 tons per year to 39 tons per year (a 25% reduction) in 15 years and to 33 tons per year (a 33% reduction) in 30 years.

Water quality data will be used as an indicator to demonstrate progress towards this goal. Total phosphorus will be tested for monthly at this site for one year, following the completion of the second implementation phase.</td></tr>
<tr><td>E. coli levels exceed the water quality target (235 cfu/100mL)</td><td>Little Mississinewa HUC 12, Tier II - Excess E. coli has been identified as a problem. Our ultimate goal is to reduce the subwatershed’s average flow E. coli load from 3.69E+14 cfu a year to 8.2E+13 cfu per year (a 78% reduction), its high flow E. coli load from 1.80E+15 cfu a year to 2.5E+14 cfu a year (a 86% reduction) and to reduce the subwatershed’s low flow E. coli load from 9.45E+13 cfu a year to 2.6E+13 cfu per year (an 72% reduction). However, because the goal for high flow conditions is not acheivable in a reasonable time frame, our scaled goal is as follows:

• Reduce Little Mississinewa River’s average E. coli loading from 3.69E+14 cfu per year to 3.51E+14 cfu per year (a 5% reduction) in 15 years and to 3.1E+14 tons per year (a 15% reduction) in 30 years.
• Reduce Little Mississinewa River’s average E. coli loading at high flow from 1.80E+15 cfu per year to 1.71E+15 cfu per year (a 5% reduction) in 15 years and to 1.5E+15 cfu per year (a 15% reduction) in 30 years.
• Reduce Little Mississinewa River’s average E. coli loading at low flow from 9.45E+13 cfu per year to 8.98E+13 cfu per year (a 5% reduction) in 15 years and to 8.0E+13 cfu per year (a 15% reduction) in 30 years.

Water quality data will be used as an indicator to demonstrate progress towards this goal. E. coli will be tested for monthly at this site for one year, following the completion of the second implementation phase.</td></tr>
</table>

<table>
<tr><th colspan="2">TABLE 14.7 | Goals and indicators for HUC 12 subwatersheds within Halfway Creek HUC 10 (Jay County)</th></tr>
<tr><th>Cause</th><th>Goal(s)</th></tr>
<tr><td>Phosphorus levels exceed the target set by this project (0.3 mg/L)</td><td>Halfway Creek HUC 12, Tier I - Excess phosphorus has been identified as a problem during high flow. Our goal is to reach the target phosphorus load within 30 years by reducing the subwatershed’s high flow phosphorus load from 29 tons per year to 22 tons per year (a 25% reduction) in 15 years and to 18 tons per year (a 37% reduction) in 30 years.

Water quality data will be used as an indicator to demonstrate progress towards this goal. Total phosphorus will be tested for monthly at this site for one year, following the completion of the second implementation phase.</td></tr>
<tr><td>Nitrate levels exceed the target set by this project (1 mg/L).</td><td>Bush Creek HUC 12, Tier I - Excess nitrate has been identified as a problem. Our ultimate goal is to reduce the subwatershed’s average nitrate load (disregarding flow) from 20 tons per year to 8 tons per year (a 57% reduction) and to reduce high flow nitrate load from 139 tons per year to 20 tons per year (a 86% reduction). However, because this is not acheivable in a reasonable time frame, our scaled goals are as follows:

• Reduce Bush Creek’s average nitrate loading from 139 tons per year to 119 tons per year (a 15% reduction) in 15 years and to 98 tons per year (a 30% reduction) in 30 years.

Water quality data will be used as an indicator to demonstrate progress towards this goal. Nitrate [N] will be tested for monthly at this site for one year, following the completion of the second implementation phase.</td></tr>
</table>

TABLE 14.8 | Goals and indicators for HUC 12 subwatersheds within Headwaters Mississinewa (Darke and Randolph counties)	
Cause	Goals
TSS levels exceed the target set by this project (25 mg/L)	**Gray Branch HUC 12, Tier I** - Excess TSS has been identified as a problem. Our ultimate goal is to reduce the subwatershed's average flow TSS load from 2,535 tons per year to 957 tons per year (a 62% reduction) and to reduce the subwatershed's high flow TSS load from 15,511 tons a year to 2,257 tons per year (an 85% reduction). However, because this is not achievable in a reasonable time frame, our scaled goals are as follows: • Reduce Gray Branch's average TSS loading from 2,535 tons per year to 1,901 tons per year (a 25% reduction) in 15 years and to 1,268 tons per year (a 50% reduction) in 30 years. • Reduce Gray Branch's high flow TSS loading from 15,511 tons per year to 11,633 tons per year (a 25% reduction) in 15 years and to 7,756 tons per year (a 50% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. TSS will be tested for monthly at this site for one year, following the completion of the second implementation phase.
	Little Mississinewa HUC 12, Tier II - Excess TSS has been identified as a problem. Our goal is to reduce the subwatershed's average flow TSS load from 1,933 tons per year to 957 tons per year (a 50% reduction) in 30 years and ultimately reduce the subwatershed's high flow TSS load from 18,967 tons a year to 2,910 tons per year (an 85% reduction). However, because the goal for high flow conditions is not achievable in a reasonable time frame, our scaled goal is as follows: • Reduce Little Mississinewa's high flow TSS loading from 18,967 tons per year to 14,226 tons per year (a 25% reduction) in 15 years and to 9,484 tons per year (a 50% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. TSS will be tested for monthly at this site for one year, following the completion of the second implementation phase.
Nitrate levels exceed the target set by this project (1 mg/L)	**Gray Branch HUC 12, Tier I** - Excess nitrate has been identified as a problem. Our ultimate goal is to reduce the subwatershed's average nitrate load (disregarding flow) from 251 tons per year to 38 tons per year (a 85% reduction), to reduce high flow nitrate load from 1,059 tons per year to 90 tons per year (a 91% reduction), and to reduce the subwatershed's low flow nitrate load from 49 tons per year to 12 tons per year (a 75% reduction). However, because this is not achievable in a reasonable time frame, our scaled goals are as follows: • Reduce Gray Branch's average nitrate loading from 251 tons per year to 213 tons per year (a 15% reduction) in 15 years and to 176 tons per year (a 30% reduction) in 30 years. • Reduce Gray Branch's average nitrate loading at high flow from 1059 to 901 tons per year (a 15% reduction) in 15 years and to 742 tons per year (a 30% reduction) in 30 years. • Reduce Gray Branch's average nitrate loading at low flow from 49 to 41 tons per year (a 15% reduction) in 15 years and to 34 tons per year (a 30% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. Nitrate [N] will be tested for monthly at this site for one year, following the completion of the second implementation phase.
	Little Mississinewa HUC 12, Tier II - Excess nitrate has been identified as a problem. Our ultimate goal is to reduce the subwatershed's average nitrate load (disregarding flow) from 201 tons per year to 38 tons per year (an 81% reduction), to reduce high flow nitrate load from 805 tons per year to 116 tons per year (an 86% reduction), and to reduce the subwatershed's low flow nitrate load from 58 tons per year to 12 tons per year (a 79% reduction). However, because this is not achievable in a reasonable time frame, our scaled goals are as follows: • Reduce Little Mississinewa's average nitrate loading from 201 tons per year to 171 tons per year (a 15% reduction) in 15 years and to 141 tons per year (a 30% reduction) in 30 years. • Reduce Little Mississinewa's average nitrate loading at high flow from 805 to 684 tons per year (a 15% reduction) in 15 years and to 563 tons per year (a 30% reduction) in 30 years. • Reduce Little Mississinewa's average nitrate loading at low flow from 58 to 49 tons per year (a 15% reduction) in 15 years and to 40 tons per year (a 30% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. Nitrate [N] will be tested for monthly at this site for one year, following the completion of the second implementation phase.

TABLE 14.9 | Goals and indicators for HUC 12 subwatersheds within Big Lick Creek HUC 10 (Blackford County)	
Cause	Goal(s)
E. coli levels exceed the water quality target (235 cfu/100mL)	**Upper Big Lick Creek HUC 12, Tier I -** Excess E. coli has been identified as a problem. Our ultimate goal is to reduce the subwatershed's average flow E. coli load from 1.07E+15 cfu a year to 6.3E+13 cfu per year (a 94% reduction), its high flow E. coli load from 2.07E+15 cfu a year to 1.2E+14 cfu a year (a 94% reduction) and to reduce the subwatershed's low flow E. coli load from 1.16E+14 cfu a year to 2.4E+13 cfu per year (an 79% reduction). However, because the goal for high flow conditions is not achievable in a reasonable time frame, our scaled goal is as follows: • Reduce Upper Big Lick Creek's average E. coli loading from 1.07E+15 cfu per year to 1.02E+15 cfu per year (a 5% reduction) in 15 years and to 9.1E+14 tons per year (a 15% reduction) in 30 years. • Reduce Upper Big Lick Creek's average E. coli loading at high flow from 2.07E+15 to 1.97E+15 cfu per year (a 5% reduction) in 15 years and to 1.8E+15 cfu per year (a 15% reduction) in 30 years. • Reduce Upper Big Lick Creek's average E. coli loading at low flow from 1.16E+14 to 1.10E+14 cfu per year (a 5% reduction) in 15 years and to 9.8E+13 cfu per year (a 15% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. E. coli will be tested for monthly at this site for one year, following the completion of the second implementation phase.
	Big Lick Creek HUC 12, Tier III - Excess E. coli has been identified as a problem. Our ultimate goal is to reduce the subwatershed's average flow E. coli load from 1.4E+15 cfu a year to 8.3E+13 cfu per year (a 94% reduction), its high flow E. coli load from 2.8E+15 cfu a year to 1.4E+14 cfu a year (a 95% reduction) and to reduce the subwatershed's low flow E. coli load from 1.7E+14 cfu a year to 4.2E+13 cfu per year (an 76% reduction). However, because the goal for high flow conditions is not achievable in a reasonable time frame, our scaled goal is as follows: • Reduce Big Lick Creek's average E. coli loading from 1.4E+15 cfu per year to 1.3E+15 cfu per year (a 5% reduction) in 15 years and to 1.2E+15 tons per year (a 15% reduction) in 30 years. • Reduce Big Lick Creek's average E. coli loading at high flow from 2.8E+15 to 2.7E+15 cfu per year (a 5% reduction) in 15 years and to 2.4E+15 cfu per year (a 15% reduction) in 30 years. • Reduce Big Lick Creek's average E. coli loading at low flow from 1.75E+14 to 1.66E+14 cfu per year (a 5% reduction) in 15 years and to 1.5E+14 cfu per year (a 15% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. E. coli will be tested for monthly at this site for one year, following the completion of the second implementation phase.
Phosphorus levels exceed the target set by this project (0.3 mg/L)	**Upper Big Lick Creek HUC 12, Tier I -** Excess phosphorus has been identified as a problem. Our goal is to reach the target phosphorus load in 30 years by reducing the subwatershed's overall phosphorus load (disregarding flow) from 11 tons per year to 9 tons per year (a 21% reduction), high flow phosphorus load from 18 tons per year to 17 tons per year (an 8% reduction), and low flow phosphorus load from 4 tons per year to 3 tons per year (a 3% reduction). Water quality data will be used as an indicator to demonstrate progress towards this goal. Total phosphorus will be tested for monthly at this site for one year, following the completion of the second implementation phase.
	Little Walnut Creek HUC 12, Tier III - Excess phosphorus has been identified as a problem during high flow. Our ultimate goal is to reduce the subwatershed's high flow phosphorus load from 94 tons per year to 43 tons per year (a 51% reduction). However, because this is not achievable in a reasonable time frame, our scaled goals are as follows: • Reduce Little Walnut Creek's high flow phosphorus load from 94 tons per year to 70 tons per year (a 25% reduction) in 15 years and to 47 tons per year (a 50% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. Total phosphorus will be tested for monthly at this site for one year, following the completion of the second implementation phase.
TSS levels exceed the target set by this project (25 mg/L)	**Little Walnut Creek HUC 12, Tier III -** Excess TSS has been identified as a problem at high flow. Our ultimate goal is to reduce the subwatershed's high flow TSS load from 7,976 tons a year to 3,591 tons per year (an 55% reduction). However, because the goal for high flow conditions is not acheivable in a reasonable time frame, our scaled goal is as follows: • Reduce Little Walnut Creek's high flow TSS loading from 7,976 tons per year to 5,982 tons per year (a 25% reduction) in 15 years and to 3,988 tons per year (a 50% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. TSS will be tested for monthly at this site for one year, following the completion of the second implementation phase.

TABLE 14.10 | Goals and indicators for HUC 12 subwatersheds within Massey Creek HUC 10 (Grant County)

Cause	Goal(s)
Nitrate levels exceed the target set by this project (1 mg/L)	**Deer Creek HUC 12, Tier I** - Excess nitrate has been identified as a problem. Our ultimate goal is to reduce the subwatershed's average nitrate load (disregarding flow) from 355 tons per year to 110 tons per year (a 69% reduction), to reduce high flow nitrate load from 1,848 tons per year to 320 tons per year (a 83% reduction), and to reduce the subwatershed's low flow nitrate load from 94 tons per year to 39 tons per year (a 58% reduction). However, because this is not achievable in a reasonable time frame, our scaled goals are as follows: • Reduce Deer Creek's average nitrate loading from 355 tons per year to 301 tons per year (a 15% reduction) in 15 years and to 248 tons per year (a 30% reduction) in 30 years. • Reduce Deer Creek's average nitrate loading at high flow from 1848 to 1571 tons per year (a 15% reduction) in 15 years and to 1294 tons per year (a 30% reduction) in 30 years. • Reduce Deer Creek's average nitrate loading at low flow from 94 to 80 tons per year (a 15% reduction) in 15 years and to 66 tons per year (a 30% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. Nitrate [N] will be tested for monthly at this site for one year, following the completion of the second implementation phase.
	Barren Creek HUC 12, Tier II - Excess nitrate has been identified as a problem. Our ultimate goal is to reduce the subwatershed's average nitrate load (disregarding flow) from 143 tons per year to 40 tons per year (a 72% reduction), to reduce high flow nitrate load from 586 tons per year to 88 tons per year (a 85% reduction), and to reduce the subwatershed's low flow nitrate load from 32 tons per year to 16 tons per year (a 51% reduction). However, because this is not achievable in a reasonable time frame, our scaled goals are as follows: • Reduce Barren Creek's average nitrate loading from 143 tons per year to 121 tons per year (a 15% reduction) in 15 years and to 100 tons per year (a 30% reduction) in 30 years. • Reduce Barren Creek's average nitrate loading at high flow from 586 to 498 tons per year (a 15% reduction) in 15 years and to 410 tons per year (a 30% reduction) in 30 years. • Reduce Barren Creek's average nitrate loading at low flow from 32 to 27 tons per year (a 15% reduction) in 15 years and to 23 tons per year (a 30% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. Nitrate [N] will be tested for monthly at this site for one year, following the completion of the second implementation phase.
	Little Deer Creek HUC 12, Tier II - Excess nitrate has been identified as a problem. Our ultimate goal is to reduce the subwatershed's average nitrate load (disregarding flow) from 361 tons per year to 105 tons per year (a 71% reduction), to reduce high flow nitrate load from 1,818 tons per year to 277 tons per year (a 85% reduction), and to reduce the subwatershed's low flow nitrate load from 97 tons per year to 40 tons per year (a 59% reduction). However, because this is not achievable in a reasonable time frame, our scaled goals are as follows: • Reduce Little Deer Creek's average nitrate loading from 355 tons per year to 301 tons per year (a 15% reduction) in 15 years and to 248 tons per year (a 30% reduction) in 30 years. • Reduce Little Deer Creek's average nitrate loading at high flow from 1848 to 1571 tons per year (a 15% reduction) in 15 years and to 1294 tons per year (a 30% reduction) in 30 years. • Reduce Little Deer Creek's average nitrate loading at low flow from 94 to 80 tons per year (a 15% reduction) in 15 years and to 66 tons per year (a 30% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. Nitrate [N] will be tested for monthly at this site for one year, following the completion of the second implementation phase.

TABLE 14.11 | Goals and indicators for HUC 12 subwatersheds within Massey Creek HUC 10 (Grant County)	
Cause	Goal(s)
TSS levels exceed the target set by this project (25 mg/L)	**Lugar Creek HUC 12, Tier III** - Excess TSS has been identified as a problem. Our goal is to reduce the subwatershed's average flow TSS load from 2,683 tons per year to 1,618 tons per year (a 40% reduction) in 30 years and ultimately reduce the subwatershed's high flow TSS load from 32,993 tons a year to 5,029 tons per year (an 85% reduction). However, because the goal for high flow conditions is not achievable in a reasonable time frame, our scaled goal is as follows: • Reduce Lugar Creek's high flow TSS loading from 32,993 tons per year to 24,745 tons per year (a 25% reduction) in 15 years and to 16,497 tons per year (a 50% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. TSS will be tested for monthly at this site for one year, following the completion of the second implementation phase. **Walnut Creek HUC 12, Tier III** - Excess TSS has been identified as a problem. Our goal is to reduce the subwatershed's average flow TSS load from 4,134 tons per year to 2,990 tons per year (a 28% reduction) in 30 years and ultimately reduce the subwatershed's high flow TSS load from 35,400 tons a year to 8,370 tons per year (an 76% reduction). However, because the goal for high flow conditions is not achievable in a reasonable time frame, our scaled goal is as follows: • Reduce Walnut Creek's high flow TSS loading from 35,400 tons per year to 26,550 tons per year (a 25% reduction) in 15 years and to 17,700 tons per year (a 50% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. TSS will be tested for monthly at this site for one year, following the completion of the second implementation phase.
E. coli levels exceed the water quality target (235 cfu/100mL)	**Barren Creek HUC 12, Tier II** - Excess E. coli has been identified as a problem. Our ultimate goal is to reduce the subwatershed's average flow E. coli load from 1.31E+15 cfu a year to 8.5E+13 cfu per year (a 94% reduction), its high flow E. coli load from 6.9E+15 cfu a year to 1.9E+14 cfu a year (a 97% reduction) and to reduce the subwatershed's low flow E. coli load from 1.57E+14 cfu a year to 3.4E+13 cfu per year (an 79% reduction). However, because the goal for high flow conditions is not achievable in a reasonable time frame, our scaled goal is as follows: • Reduce Barren Creek's average E. coli loading from 1.31E+15 cfu per year to 1.24E+15 cfu per year (a 5% reduction) in 15 years and to 1.1E+15 tons per year (a 15% reduction) in 30 years. • Reduce Barren Creek's average E. coli loading at high flow from 6.9E+15 to 6.5E+15 cfu per year (a 5% reduction) in 15 years and to 5.9E+15 cfu per year (a 15% reduction) in 30 years. • Reduce Barren Creek's average E. coli loading at low flow from 1.57E+14 to 1.49E+14 cfu per year (a 5% reduction) in 15 years and to 1.3E+14 cfu per year (a 15% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. E. coli will be tested for monthly at this site for one year, following the completion of the second implementation phase. **Lugar Creek HUC 12, Tier III** - Excess E. coli has been identified as a problem. Our ultimate goal is to reduce the subwatershed's average flow E. coli load from 1.1E+15 cfu a year to 1.4E+14 cfu per year (a 87% reduction), its high flow E. coli load from 7.9E+15 cfu a year to 4.3E+14 cfu a year (a 95% reduction) and to reduce the subwatershed's low flow E. coli load from 4.6E+14 cfu a year to 6.5E+13 cfu per year (an 86% reduction). However, because the goal for high flow conditions is not achievable in a reasonable time frame, our scaled goal is as follows: • Reduce Lugar Creek's average E. coli loading from 1.1E+15 cfu per year to 1.0E+15 cfu per year (a 5% reduction) in 15 years and to 9.2E+14 tons per year (a 15% reduction) in 30 years. • Reduce Lugar Creek's average E. coli loading at high flow from 7.9E+15 to 7.5E+15 cfu per year (a 5% reduction) in 15 years and to 6.7E+15 cfu per year (a 15% reduction) in 30 years. • Reduce Lugar Creek's average E. coli loading at low flow from 4.6E+14 to 4.4E+14 cfu per year (a 5% reduction) in 15 years and to 3.9E+14 cfu per year (a 15% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. E. coli will be tested for monthly at this site for one year, following the completion of the second implementation phase.
Phosphorus levels exceed the target set by this project (0.3 mg/L)	**Lugar Creek HUC 12, Tier III** - Excess phosphorus has been identified as a problem during high flow. Our goal is to reach the target phosphorus load within 30 years by reducing the subwatershed's high flow phosphorus load from 93 tons per year to 69 tons per year (a 25% reduction) in 15 years and to 60 tons per year (a 35% reduction) in 30 years. Water quality data will be used as an indicator to demonstrate progress towards this goal. Total phosphorus will be tested for monthly at this site for one year, following the completion of the second implementation phase.

14.5 LOAD REDUCTIONS NEEDED FOR CRITICAL AREAS, LISTED BY HUC 10

The current loads, target loads, and needed load reductions displayed in the following tables (Tables 14.12–14.16) were calculated using current water quality data collected by the UMRW-P and IDEM (for use in TMDL development). Three pieces of information is needed to calculate loads: the flow or average flow, a concentration or average concentration, and the project's target concentration. Flow was calculated for each sampling event through a multi-step process: measuring the depth in the center of the stream during each sampling event, measuring velocity of the stream at each sampling event, plotting each measured depth on stream cross sections plotted in AutoCAD to calculate the stream cross-sectional area at the time of each sampling event, and dividing the cross-sectional area by the stream velocity. Flow data was then averaged for each site; actual flow at any sampling events that were above the average were considered high flow events and averaged to create a high flow average and actual flow at any sampling events that were below the average were considered low flow events and averaged to create a low flow average. In other words, each site has an average flow (cfs) during high flow and an average flow during low flow. Parameter concentrations were likewise separated—parameter concentrations sampled during high flow events were averaged to obtain the average concentration at high flow, and concentrations sampled during low flow events were averaged to obtain the average concentration at low flow. These average flows and concentrations, separated into high and low flow categories, were then used to calculate the current load during high flow conditions and the current load during low flow conditions.

IDEM's 319 Load Calculation Tool was the tool used to actually calculate the different loads. This tool is an Excel spreadsheet that contains the necessary formulas for calculating loads. Parameter concentration, flow, and target concentration are input in the appropriate cells in the spreadsheet, and load calculations are automatically generated. The tool can be found at www.in.gov/idem/nps/files/319_load_calculation_tool.xls.

TABLE 14.12 | Big Lick Creek HUC 10 (Blackford County)

	Average of Current Phosphorus Load (ton/year)		Average of Phosphorus Target Load (ton/year)		Average of Phosphorus Load Reduction Needed (ton/year)	
Critical Area	High	Low	High	Low	High	Low
Little Walnut Creek, Tier III	98.19	1.20	43.05	2.50	55.15	no reduction needed
Upper Big Lick Creek, Tier I	16.72	2.91	14.70	3.43	2.02	-0.52
	Average of Current E. coli Load (ton/year)		Average of E. coli Target Load (ton/year)		Average of E. coli Load Reduction Needed (ton/year)	
Critical Area	High	Low	High	Low	High	Low
Big Lick Creek, Tier III	3.2E+15	1.8E+14	1.3E+14	3.1E+13	3.1E+15	1.5E+14
Upper Big Lick Creek, Tier I	1.8E+15	1.1E+14	8.9E+13	2.2E+13	1.7E+15	8.6E+13

TABLE 14.13 | Headwaters Mississinewa HUC 10 (Darke and Randolph counties)						
	Average of Current Nitrate Load (ton/year)		Average of Nitrate Target Load (ton/year)		Average of Nitrate Load Reduction Needed (ton/year)	
Critical Area	High	Low	High	Low	High	Low
Gray Branch, Tier I	687.11	86.83	90.35	12.20	596.77	74.63
Little Mississinewa River, Tier II	620.12	77.16	116.54	12.15	503.59	65.01
	Average of Current Phosphorus Load (ton/year)		Average of Phosphorus Target Load (ton/year)		Average of Phosphorus Load Reduction Needed (ton/year)	
Critical Area	High	Low	High	Low	High	Low
Gray Branch, Tier I	74.18	2.56	27.10	3.66	47.08	no reduction needed
Little Mississinewa River, Tier II	75.52	2.32	34.96	3.65	40.56	no reduction needed
	Average of Current TSS Load (ton/year)		Average of TSS Target Load (ton/year)		Average of TSS Load Reduction Needed (ton/year)	
Critical Area	High	Low	High	Low	High	Low
Gray Branch, Tier I	28356.74	189.76	2258.67	304.98	26098.08	no reduction needed
Little Mississinewa River, Tier II	33914.29	117.05	2913.47	303.78	31000.81	no reduction needed
	Average of Current E. coli Load (ton/year)		Average of E. coli Target Load (ton/year)		Average of E. coli Load Reduction Needed (ton/year)	
Critical Area	High	Low	High	Low	High	Low
Little Mississinewa River, Tier II	1.6E+15	1.5E+14	2.5E+14	2.6E+13	1.4E+15	1.2E+14

TABLE 14.14 | Halfway Creek HUC 10 (Jay County)						
	Average of Current Phosphorus Load (ton/year)		Average of Phosphorus Target Load (ton/year)		Average of Phosphorus Load Reduction Needed (ton/year)	
Critical Area	High	Low	High	Low	High	Low
Bush Creek, Tier I						
Halfway Creek, Tier I	37.23	2.08	21.07	2.93	16.16	no reduction needed

TABLE 14.15 | Massey Creek HUC 10 (Grant County)						
	Average of Current Nitrate Load (ton/year)		Average of Nitrate Target Load (ton/year)		Average of Nitrate Load Reduction Needed (ton/year)	
Critical Area	High	Low	High	Low	High	Low
Barren Creek, Tier II	610.91	42.30	87.77	15.73	523.15	26.57
Deer Creek, Tier I	1655.03	113.15	319.77	39.50	1335.26	73.65
Little Deer Creek, Tier II	1542.13	121.90	277.35	39.70	1264.78	82.19
	Average of Current Phosphorus Load (ton/year)		Average of Phosphorus Target Load (ton/year)		Average of Phosphorus Load Reduction Needed (ton/year)	
Critical Area	High	Low	High	Low	High	Low
Lugar Creek, Tier III	90.90	8.33	60.29	9.25	30.61	no reduction needed
Little Walnut Creek, Tier III	98.19	1.20	43.05	2.50	55.15	no reduction needed
	Average of Current TSS Load (ton/year)		Average of TSS Target Load (ton/year)		Average of TSS Load Reduction Needed (ton/year)	
Critical Area	High	Low	High	Low	High	Low
Little Walnut Creek, Tier III	9207.79	125.64	3587.14	208.03	5620.65	no reduction needed
Lugar Creek, Tier III	28089.21	924.80	5024.21	771.06	23065.00	153.74
Walnut Creek, Tier III	38421.69	752.49	8365.94	1196.27	30055.74	no reduction needed
	Average of Current E. coli Load (ton/year)		Average of E. coli Target Load (ton/year)		Average of E. coli Load Reduction Needed (ton/year)	
Critical Area	High	Low	High	Low	High	Low
Barren Creek, Tier II	5.4E+15	1.3E+14	1.9E+14	3.4E+13	5.2E+15	9.8E+13
Lugar Creek, Tier III	5.8E+15	8.6E+14	4.3E+14	6.6E+13	5.4E+15	8.0E+14

TABLE 14.16 | Pike Creek HUC 10 (Delaware County)						
	Average of Current TSS Load (ton/year)		Average of TSS Target Load (ton/year)		Average of TSS Load Reduction Needed (ton/year)	
Critical Area	High	Low	High	Low	High	Low
Campbell Creek, Tier II	1562.48	65.39	780.20	99.24	782.28	no reduction needed

15. IMPLEMENTATION

15.1 IMPLEMENTATION

The water quality monitoring program implemented as part of this planning process has helped provide a unique perspective on Upper Mississinewa River Watershed water quality. For the first time in history, resource managers of the Mississinewa River have been able to analyze a non point source water quality dataset at the subwatershed scale over a fixed, year long (monthly), sampling program (mindful of limitations expressed in Section 7). The analysis of this data has resulted in (a) the identification of subwatershed critical areas and (b) the development of goal statements (based on target load reductions) to meet water quality targets.

These critical areas provide geographical boundaries to guide the regional partnership (local SWCDs and other stakeholder groups and organizations) in focusing implementation efforts. At the very least, these critical areas serve as a broad-based mechanism for strategically responding and prioritizing the landowners concerns/interest ascertained through public input activities (public meetings and social surveys) during the 2014-2016 planning process. Approximately 10% of the respondents reside in project critical areas.

Because meeting ultimate goals is a tremendous challenge and not attainable in a reasonable time frame, the UMRW-P has created scaled goals (both ultimate and scaled goals are outlined in the goal statements in Tables 14.5-14.11). These scaled goals were created through the use of models which are described in Subsection 15.2. These models quantified (a) load reduction capabilities of BMPs, (b) the amount of land area required/available to implement BMPs (to meet water quality targets), and (c) the financial investment required by landowners to meet water quality load reduction targets. BMPs and load reductions needed to reach scaled goals are modeled in Appendix R (R.1 through R.10).

In addition to modeling BMPs needed to reach scaled goals, we also modeled BMPs needed to reach ultimate goals. These BMPs and load reductions are modeled in Appendix S (S.1 through S.10). Subsection 15.3, following the description of the models used, contains a final discussion that outlines the many of the challenges to reaching ultimate goals that were identified through modeling. Stakeholder attitudes regarding these challenges are also reported. The intention of this discussion is to provide a theoretical foundation for strategies and milestones outlined in Section 16.

Challenges of meeting ultimate goals include but are not limited to:

1. The sheer volume (expressed in tons) of each nonpoint source water quality parameter load reduction.
2. The non-regulatory intent of the project and volunteer nature of BMP implementation.
3. The limited load-reduction capacity of each individual Best Management Practice (BMP).
4. The cost of BMP implementation.
5. The inability to effectively quantify BMP load reduction capacity in aggregate applications.

15.2 INDIVIDUAL MODELING SCENARIOS

BMPs and load reductions were calculated individually for many of the subwatersheds for nitrate, phosphorus, and TSS. E. coli was not modeled—the rationale for this is expressed later in this section. BMPs and load reductions were also modeled for critical subwatersheds' collective loads for each parameter (i.e. the loads of all nitrate critical areas were totaled and this total was applied to the model; this was done to simplify goals created for the Action Register). All load reduction calculations were based on BMPs that could potentially be implemented within the watershed. As part of the load reduction study, we used current modeling tools (Region 5 Model) and the estimated load reductions achieved by various BMPs (Iowa Nutrient Reduction Strategy) to calculate load reductions achieved by specific volumes of BMPs. Models used for each parameter are described in the following paragraphs.

NITRATE REDUCTION MODELING

The nitrate reduction scenario(s) were modeled with a method devised by the Project Manager that is based on and utilizes BMP reduction percentages from the Iowa Nutrient Reduction Strategy (pp. 243-244). Any deviations from the nitrate reductions found on pp. 243-244 are described below. This method was used after concluding that the results of other models were less accurate (Region 5 does not account for dissolved nitrate, and STEP-L estimated loads were much lower than those generated from water quality data, which is what all current loads and load reductions used in this plan were based on). Using the Iowa Nutrient Reduction Strategy (INRS) document seemed to be a more valid approach for modeling nitrate reductions (and also for modeling phosphorus reductions, as described on pp. 243-244). The INRS provides a scientific assessment of the effectiveness of different management and land use practices for reducing nutrient loads.

Current water quality data (collected by the UMRW-P and also by IDEM for the development of a TMDL) was used to calculate current and target loads utilized in this nitrate model. Flow rates and nitrate concentrations were averaged for each site (for simplicity's sake, flow and pollutant concentrations were not categorized by high flow or low flow conditions as was done for the critical area reduction goals, Tables 14.4-14.10 on p. 205-209). Average flow, average parameter concentration, and the parameter target were entered into the 319 Load Calculation Tool (available at www.in.gov/idem/nps/files/319_load_calculation_tool.xls) to current calculate current loads and target loads.

The current nitrate load was assumed to be coming from the total acres of cropland in the subwatershed being modeled. Load reductions were calculated using the following equation: load reduction = load available for treatment by BMP (i.e. the total load) x percentage of cropland BMP is applied to x estimated % nitrate-N reduction (from pp. 243-244). The load available for treatment was adjusted after every BMP was applied since BMPs are not additive—this adjustment was made by subtracting the load reduction achieved by the BMP from the load available for treatment by BMPs.

Taking into account the non-additive nature of BMPs, reductions were calculated in the sequence in which they effect nitrate loads, starting from nitrate's application, and ending at its discharge into a stream. This can be thought of as a top down approach. As reductions at the "top" are made, concentrations decrease and less is available for treatment at the "bottom." In order to correct reduction efficiencies for this phenomenon, load reductions achieved by the topmost BMP/ measure were subtracted from the current load before calculating the load reduction of the next BMP, etc. The order that BMP reductions were calculated is shown in Figure 15.1 below.

FIG. 15.1 | "Top down" approach for BMP implementation

Corn is no longer produced, so nitrate is no longer applied to the land (wetland and prairie restoration, alternative crop rotations)

↓

Reduce application rates and time application to minimize leaching (MRTN, no fall application, sidedress)

↓

Capture nitrate in the field before it reaches drainage tiles (cover crops)

↓

Capturing nitrate from drainage tiles or preventing its entry into waterways (saturated buffers, drainage water management and denitrying bioreactor).

The model was based on the following set of assumptions. Although some of these assumptions may be imprecise, we believe that they do not result in wildly inaccurate conclusions. Rather, they give an approximation that is acceptable for our purposes.

1) "All nitrate in the watershed is coming from farmland." While this is not true, we estimate that agriculture is the largest contributor of nitrate by far. Since subwatersheds that are critical for nitrogen are highly rural (cropland making up 79%-83% of land area), we will focus load reduction estimations based on BMPs for agricultural non point sources.
2) "The BMPs prescribed here are not currently being implemented." Based on data, there are only very low levels these BMPs.
3) "Each acre of farmland contributes an equal portion of nitrate to the total load." While we know that this is not true due to different fertilization practices, insufficient data concerning fertilization practices makes it infeasible to characterize any differences.
4) "Not all BMPs are applicable throughout the entire watershed." Saturated buffers and drainage water management are two BMPs that can only be installed if the appropriate conditions are present. Saturated buffers were estimated to be applicable on 20% of Iowa cropland. Since this was the only figure found, we used it for our model. The actual percentage could be very different. The same approach was used for drainage water management, using NRCS data and maps to estimate percentages for each subwatershed (Appendix H; Map H.4).
5) "Wetlands, prairies, and filter strips aren't removing nitrate." Adjustments were made to the INRS estimated reductions for wetlands, prairies, and filter strips; because reductions from these practices were not scalable, it was simply assumed that nitrate is reduced by 100% on these lands through the termination of nitrogen applications. Therefore, these BMPs are likely to have more potential for reducing nitrate loads than is estimated here.

Based on current land use practices, BMPs, and BMP reduction estimates to date, it appears that reaching the target of 1.0 mg/L for nitrate (used for this project) is not realistic in most subwatersheds. In the scenarios modeled (Appendix R; Tables R.1 through R.20), we used the highest volume of BMPs that was possible based on the current data we found (for instance, cover crops can be planted on any cropland, so in our scenario we applied it to 100% of the cropland; saturated buffers, on the other hand, were estimated by some researchers to only be applicable on 20% of buffers, so we applied it to 20% of the buffers in our scenario). With multiple BMPs at high volumes, results suggested that up to an 83% reduction in nitrate could be achieved (Appendix R). While this reduction would be enough for most subwatersheds to reach their target load, the multitude and density of BMPs in these scenarios is likely not feasible. Further discussion on the challenges of meeting nitrate load reductions with current land-use practices is discussed in Section 15.3.

PHOSPHORUS REDUCTION MODELING

The nitrate reduction scenario(s) were also modeled using the modeling method described for nitrate; it utilizes BMP reduction percentages from the Iowa Nutrient Reduction Strategy (pp. 243-244). Based on results of the modeling scenarios, it appears that phosphorus target loads could be reached in the critical subwatersheds through the implementation of BMPs on 55% or less of farmland and by buffering 45% or less of streams. As with TSS, these results assume that phosphorus is mainly coming from surface runoff, rather than streambank erosion (historic/latent phosphorus sources). As with TSS, BMPs should be placed in contributing areas.

15.3 IOWA STRATEGY TO REDUCE NUTRIENT LOSS: PHOSPHORUS PRACTICES[1]

Practices below have the largest potential impact on phosphorus load reduction. Corn yield impacts associated with each practice also are shown, since some practices may increase or decrease corn production. If using a combination of practices, the reductions are not additive. Reductions are field level results that may be expected where practice is applicable and implemented.

TABLE 15.1 | Iowa Strategy To Reduce Nutrient Loss: Phosphorus Practices

	Practice	Comments	% P Load Reduction[a]	% Corn Yield Change[b]
			Average (SD[c])	Average (SD[c])
Phosphorus Management Practices	Phosphorus Application	Applying P based on crop removal – Assuming optimal STP level and P incorporation	0.6[d]	0
		Soil-Test P – No P applied until STP drops to optimum or when manure is applied to levels indicated by the P Index.	17[e]	0
	Source of Phosphorus	Liquid swine, dairy, and poultry manure compared to commercial fertilizer – Runoff shortly after application	46 (45)	-1 (13)
		Beef manure compared to commercial fertilizer – Runoff shortly after application	46 (96)	
	Placement of Phosphorus	Broadcast incorporated within 1 week compared to no incorporation, same tillage	36 (27)	0
		With seed or knifed bands compared to surface application, no incorporation	24 (46)	0
	Cover Crops	Winter rye	29 (37)	-6 (7)
	Tillage	Conservation till – chisel plowing compared to moldboard plowing	33 (49)	0 (6)
		No till compared to chisel plowing	90 (17)	-6 (8)
Land Use Change	Perennial Vegetation	Energy Crops	34 (34)	
		Land Retirement (CRP)	75	
		Grazed pastures	59 (42)	
Erosion Control Practices	Terraces		77 (19)	
	Buffers		58 (32)	
	Control	Sedimentation basins or ponds	85	

a - A positive number is P load reduction and a negative number is increased P load.

b - A positive corn yield change is increased yield and a negative number is decreased yield. Practices are not expected to affect soybean yield.

c - SD = standard deviation. Large SD relative to the average indicates highly variable results.

d - Maximum and average estimated by comparing application of 200 and 125 kg P O /ha, respectively, to 58 kg P O /ha (corn-soybean rotation requirements) (Mallarino et al., 2002).

e - Maximum and average estimates based on reducing the average STP (Bray-1) of the two highest counties in Iowa and the statewide average STP (Mallarino et al., 2011a), respectively, to an optimum level of 20 ppm (Mallarino et al., 2002). Minimum value assumes soil is at the optimum level.

f - P retention in wetlands is highly variable and dependent upon such factors as hydrologic loading and P mass input.

1 Page taken from Iowa State University Extension Publication, "Reducing Nutrient Loss: Science Shows What Works" by John Lawrence. June, 2016. This publication is part of the the initiative called the "Iowa Nutrient Reduction Strategy."

15.4 IOWA STRATEGY TO REDUCE NUTRIENT LOSS: NITROGEN PRACTICES[1]

This table lists practices with the largest potential impact on nitrate-N concentration reduction (except where noted). Corn yield impacts associated with each practice also are shown as some practices may be detrimental to corn production. If using a combination of practices, the reductions are not additive. Reductions are field level results that may be expected where practice is applicable and implemented.

TABLE 15.2 | Iowa Strategy To Reduce Nutrient Loss: Nitrogen Practices

	Practice	Comments	% P Load Reduction+	% Corn Yield Change++
			Average (SD*)	Average (SD*)
Nitrogen Management	Timing	Moving from fall to spring pre-plant application	6 (25)	4 (16)
		Spring pre-plant/sidedress 40-60 split Compared to fall-applied	5 (28)	10 (7)
		Sidedress – Compared to pre-plant application	7 (37)	0 (3)
		Sidedress - Soil test based compared to pre-plant	4 (20)	12 (22)
	Source	Liquid swine manure compared to spring-applied fertilizer	4(11)	0 (13)
		Poultry manure compared to spring-applied fertilizer	-3 (20)	-2 (14)
	Nitrogen application rate	Nitrogen rate at the MRTN (0.10 N:corn price ratio) compared to current estimated application rate. (ISU Corn Nitrogen Rate Calculator – http://extension.agron.iastate.edu/soilfertility/nrate.aspx can be used to estimate MRTN but this would change Nitrate-N concentration reduction)	10	-1
	Nitrification Inhibitor	Nitrapyrin in fall – Compared to fall-applied without Nitrapyrin	9 (19)	6 (22)
	Cover Crops	Rye	31 (29)	-6 (7)
		Oat	28 (2)	-5 (11)
	Living Mulches	e.g. Kura clover – Nitrate-N reduction from one site	41 (16)	-9 (32)
Land Use	Perennial	Energy Crops – Compared to spring-applied fertilizer	72 (23)	
		Land Retirement (CRP) – Compared to spring-applied fertilizer	85 (9)	
	Extended Rotations	At least 2 years of alfalfa in a 4 or 5 year rotation	42 (12)	7 (7)
	Grazed Pastures	No pertinent information from Iowa – assume similar to CRP	85	
Edge-of-Field	Drainage Water Management	No impact on concentration	33 (32)	
	Shallow Drainage	No impact on concentration	32 (15)	
	Wetlands	Targeted water quality	52	
	Bioreactors		43 (21)	
	Buffers	Only for water that interacts with the active zone below the buffer. This would only be a fraction of all water that makes it to a stream.	91 (20)	
	Saturated Buffers	Divert fraction of tile drainage into riparian buffer to remove Nitrate-N denititrifcation.	50 (13)	

+ A positive number is nitrate concentration or load reduction and a negative number is an increase.

++ A positive corn yield change is increased yield and a negative number is decreased yield. Practices are not expected to affect soybean yield.

* SD = standard deviation. Large SD relative to the average indicates highly variable results.

** This increase in crop yield should be viewed with caution as the sidedress treatment from one of the main studies had 95 lb-N/acre for the pre-plant treatment but 110 lb-N/acre to 200 lb-N/acre for the sidedress with soil test treatment so the corn yield impact may be due to nitrogen application rate differences.

1 Page taken from Iowa State University Extension Publication, "Reducing Nutrient Loss: Science Shows What Works" by John Lawrence. June, 2016. This publication is part of the the initiative called the "Iowa Nutrient Reduction Strategy."

Furthermore, this modeling approach likewise assumes that the total phosphorus load is coming primarily from agriculture. We know that this is not true, and that a significant portion of the load may come from septic systems. Therefore, it is possible that by applying the amount of BMPs prescribed (Appendix R; Tables R.5 and R.9) projected load reductions may not be achieved. Nonetheless, the application of BMPs prescribed to reduce phosphorus loss will still be beneficial; these BMPs reduce sediment and nitrate loss, too. It is also important to note that models for phosphorus were based on the subwatershed's flow rate and phosphorus concentrations at high flow events. Phosphorus only exceeds the project's target of 0.03 mg/L at a few sampling locations during average flow concentrations (indicating that a reduction was not needed in most instances). Because phosphorus is near the target level, addressing phosphorus loading directly will not be a primary strategy for this project at current load reduction targets (see Dead Zone narrative in Section 15.3). Because phosphorus attaches to sediment, we suggest that this parameter is addressed in conjunction with sediment reduction strategies.

TSS REDUCTION MODELING

The Region 5 Model was used to model TSS reductions. Based on results of the Region 5 model, it appears that TSS target loads could be reached in the critical subwatersheds through the implementation of BMPs on 10% or less of farmland (Tables R.1 and R.7). These results assume that TSS is mainly coming from surface runoff, rather than streambank erosion. However, results of water quality testing and windshield and desktop surveys suggest that in some subwatersheds (Walnut Creek, Lugar Creek, and Litte Mississinewa River) bank erosion is the primary source of the high TSS levels. In subwatersheds where streambank erosion is a problem, applying the amount of infield and edge of field BMPs prescribed by the modeling may not reduce sediment enough to reach target loads.

There is another caveat to this model. Although 10% or less of farmland needed BMPs in the modeled subwatersheds, these BMPs must be placed in "contributing areas," meaning they should be located in areas that drain directly into streams or rivers. This means that cover crops should be strategically placed and should be adjacent to a buffered stream or river. Therefore, cost-share funds should first be awarded to farmers who can plant them adjacent to streams, especially in watersheds where sediment is above the target level. In addition, methodologies/studies to quantify stream bank erosion such as BEHI/NBS should be used in future phases of this project to assist with TSS modeling. Until further analysis is completed, the Project Manager believes it is important to implement both surface BMPs and stream stabilization BMPs. Additional funds for streambank stabilization should also be sought for watersheds in which severe streambank erosion has been identified.

During the desktop survey, there was widespread evidence of both rill and gully formation and well as conventional tillage practices throughout the watershed. The adoption of conservation tillage practices and cover crops is more cost-effective than the financial investments required to solve stream instability issues. Again, if future modeling suggests that only 10% of the sediment source is surface erosion, then there is significant limits as to what can be achieved in target load reduction by addressing surface sources only. The financial requirements required to address stream instability issues (anywhere from $75 to $200 per linear foot) may also significantly limit the achievement of load reduction goals. The primary source of streambank instability is conventional ditch management practices; therefore, we will advocate systemic change to these methodologies as part of future implementation strategy. [1] [2]

E. COLI NOT MODELED

E. coli was not modeled as part of this study. After determining the load reduction required and analyzing the primary sources of E. coli to our rivers and streams, it was determined that securing local, state, or federal funding for E. coli load reduction is beyond the scope of our implementation strategy. The greatest source of E. coli to streams and rivers in the watershed are failing septic systems and municipal CSOs. Many of the E. coli sources are point source pollutants. We also observed that watershed soils are not suitable for conventional septic systems. Many of these conventional systems should be replaced with mound systems or have perimeter drains installed. There are an estimated 17 thousand septic systems in the watershed and the cost for replacing/modifying septic systems is estimated at approximately $15,000 a unit. This results in a required investment of approximately $255 million dollars to address E. coli sources from septic systems. In addition, IDEM has a long-term plan in place to remove all CSOs in the state of Indiana. The cost of removing a CSO is estimated to cost $80,000[3]. Therefore it would cost approximately $344 million dollars to separate the 43 CSOs in the watershed (See Section 3, Table 3.14). These types of financial undertakings are beyond the scope our project. Our implementation strategy will be limited to septic maintenance education and will form partnerships with Health Departments to address this issue.

Another source of E. coli is animal waste from farms. Many livestock operations have been concentrated in CFOs. Minimal free range access to rivers remain. It is assumed that CFO producers will follow waste management protocols which are designed to limit direct access of animal waste sources to rivers. Our implementation strategy will be limited to livestock exclusion BMPs on farms that continue to enable free range animal grazing. We also recommend the advocacy of slurry seeding cover crops with manure as part of future education and outreach efforts. We believe that all waste management systems (sanitary, septic, and CFO) should meet contemporary standards.

1 TSS is consistently over targets on both the main stem and tributary channels. The species of fish that have not returned to waterways are predominantly sediment intolerant species.

2 We believe that the driver to the "poor" fish and macroinvertebrate scores are sediments. County drainage funds and stormwater funds might be used to address sediment concerns identified through this project.

3 Muncie, IN has 25 CSOs. It is estimated to cost $200 million dollars to separate.

15.5 MODELING DISCUSSION—MEETING ULTIMATE GOALS

PARAMETER SOURCE PRIORITY CHART
Based on the analysis of (a) individual BMP load reduction potential, (b) pollutant sources, and (c) observations made from the load reduction scenarios, we have determined the following priority land use source for each parameter (Table 15.3 below). This table will be further discussed in Section 16, *Action Strategy*, as part of the cost-share BMP selection methodology.

The modeling scenarios helped the Project Manager to identify additional challenges to meeting water quality targets in regard to three separate aspects this plan's implementation. The following subsection will discuss financial limitations; implications of different nitrate targets for environmental issues as well as for farming practices; and considerations for selecting BMPs.

1. FINANCIAL LIMITATIONS
The analysis of load reduction scenarios suggested that there is a tremendous financial investment required to meet water quality targets selected for this plan. Appendix S includes financial estimates (Table S.6-S.7) for all load reduction scenarios modeled in Appendix S. These estimates should be interpreted mindful of the previous load reduction scenario discussion (Subsection 15.2). Table 15.4 below includes a representative Subwatershed (average reduction cost) for each parameter to be targeted with this project (Phosphorus, Nitrate, and TSS). As you can see in Table 15.4 below, even when (a) enough acreage is available to meet load reduction targets and (b) BMPs are capable to meet required load reduction requirements, the average cost required to meet load reduction targets is $1.8 million dollars per subwatershed.

TABLE 15.3 | Priority areas for nonpoint source reduction

	AGRICULTURAL	STREAM BANKS	URBAN
SEDIMENT	MODERATE	HIGEST PRIORITY	MODERATE
NUTRIENTS	HIGHEST PRIORITY	MODERATE	MODERATE
PATHOGENS	HIGHEST PRIORITY	LOW	HIGH

TABLE 15.4 | Financial requirements for nonpoint source reduction

Representative Subwatershed	Halfway Creek	Little Mississinewa	Lugar Creek
Parameter	Phosphorus	Nitrate	TSS
Wetland Restoration	$-	$218,100	$-
Prairie Restoration	$-	$99,236	$-
Cover Crops and Filter Strips*	$-	$465,862	$-
Drainage Water Management**	$-	$738,050	$-
Bioreactors	$-	$8,048	$-
Cover Crops	$127,050	$-	$35,280
Conservation Tillage	$72,419	$-	$5,700
Filter Strips****	$11,088	$-	$8,316
Total Cost	$210,557	$1,529,295	$49,296

Using these crude cost-prediction scenarios in aggregate, one can conclude that it would require approximately $16.5 million dollars in local investment to achieve project goals for reducing nitrate in subwatershed critical areas alone. Since all subwatersheds are failing to meet water quality targets for nitrate, it would follow that a $42 million dollar local investment would be required watershed wide for nitrate. Only by meeting target levels at the subwatershed scale can we expect the entire Mississinewa River proper to meet water quality targets. It could cost upward of $50-$100 million dollars to address the loading reduction required to meet water quality targets on the Mainstem Mississinewa River for Nitrate, Phosphorus, and TSS. As discussed in Section 2, *Public Input,* 4,000 landowners control approximately 66% of the land (~70 acres each). Each of these individuals would need to make a $10,000 - $18,000 dollar investment (in all the practices listed above) to meet water quality targets. An additional $600 million collective investment will need to be made in order to address CSO and septic sources of E. coli (discussed above); an additional investment of approximately $7,000 dollars per person or $17,000 per household.

2. THE INABILITY TO MEET NITRATE REDUCTION GOALS
As discussed in Section 6.4, there is a wide range of targets available for nitrate. IDEM documented targets range from 1.0 mg/l to 10 mg/l. Understanding the ramifications of this range of choices is important moving forward as it has significant influence on the characterization and urgency of the load reduction strategy. For example, If the UMWR-P would have selected 10 mg/L for this project, all streams, rivers, and waterways would be meeting water quality targets and would require no action. However, when using the target 1.0 mg/L (utilized as part of the water quality analysis) we

have extremely elevated levels and, as the modeling suggests, it is improbable to obtain the load reduction target in our current socioeconomic reality. This exceptional range of water quality targets for nitrate was a persistent discussion topic for project stakeholders. The decision to select a more stringent target level has direct impact on (a) the modeling scenarios, (b) realistic pathway to nitrate targets, (c) land area capacity to meet water quality load reductions, and (d) the financial limitations to meet goal attainment. The following are eight topics related to nitrate targets and load reduction scenarios discussed at stakeholder meetings. The Project Manager felt it was important to report these thematic discussion topics to rationalize selected nitrate reduction strategies outlined in Section 16. Many of these topics will guide further research and discussion in the watershed (Section 16).

A. NITRATE IS NOT LIKELY NEGATIVELY IMPACTING FUNCTIONAL USES LOCAL WATERSHED
After reviewing biological and chemical data, we have concluded that nitrate is not likely negatively impacting aquatic life in the watershed (as there is more toxicologic evidence that suggests sediment is negatively impacting aquatic species). This is largely because water-soluble nitrogen moves off fields and downstream quickly and does not have ample time to cause significant algae levels in the river system except for areas that have large backwater regions caused by dam or logjams. Nitrogen levels do not pose a major human health-risks for full body contact. In addition, the downstream Mississinewa Lake reservoir does not have an persistent algae bloom issue as reported by DNR Property Mangers.[4]

B. WATER MEETS WATER QUALITY TARGETS IF 10.0 MG/L TARGET IS USED
As mentioned, there would be no significant plan of action to reduce nitrate if 10.0 mg/L was used as a target. Therefore, there would be no critical areas for nitrate and no implementation efforts would be made to reduce nitrate in this scenario.

C. DEAD ZONE ISSUE
The Gulf of Mexico Dead Zone (Figure S.3, Appendix S) is commonly cited as a reason for a more stringent water quality target for nitrate in upstream contribution areas. Historic nitrate levels for the Mississinewa River are around 3.0 mg/L. The mainstem Mississinewa River high flow nitrate average was 7.21 mg/L and the low flow average was 2.45 mg/L during the 2014-2015 study. The Mississippi River is frequently sampled as part of the Gulf of Mexico management strategy. At sample sites upstream of the Mississippi Delta, average water quality has historically been around 3.0 mg/L. It follows that if a 3.0 mg/L contribution from the Mississippi River has historically been enough to contribute to the Dead Zone, then targets need to be less than 3.0 mg/L in order to stop or reverse Dead Zone impacts.

D. FEDERAL REGULATIONS | DISPROPORTIONATE AMOUNT OF RAIN WATER IN OHIO AND INDIANA
If the federal government decides to regulate upstream sources of the Gulf of Mexico's dead zone, it would likely require a 1.0-3.0 mg/L target for nitrate based on the logic presented in item C above. It is important to note that the Ohio River basin has the highest volume of water per acre in the entire Mississippi River basin due to rainfall patterns. It is likely that the State of Indiana and Ohio would be specifically targeted for nutrient reduction by federal initiatives to reduce nutrient sources to the dead zone.

E. DEMONSTRATE A CLEAR SOURCE: AGRICULTURE
Agriculture is commonly identified as the major sources of nitrogen to the rivers yet we are frequently hearing concerns about urban sources and their potentially greater contribution. Both are true to some extent. In the mid-west, urban areas are significant polluters of water and many parameters increase dramatically (upstream to downstream) due to impacts of CSOs. However on a watershed-wide basis, agriculture is the greatest source of nitrogen in the Upper Mississinewa River Watershed. As part of the desktop aerial survey, we identified lawns, sports fields, golf courses, etc. and ranked subwatersheds based on the greatest presence of these features. Similarly, we identified farmland and ranked subwatersheds based on percentages of agricultural land-use (applying a simple coefficient model). There was greater correlation between actual water quality results and the agricultural watershed ranking.

F. FARMERS ARE NOT OVER APPLYING NITROGEN
Despite poor soil quality, cornstalk sampling data form the On-farm Network program suggests that farmers are applying optimal levels of nitrogen. This suggests that farmers are not applying nitrogen recklessly, but are applying what is required to produce a crop in the current industrial paradigm (commodity crops). The vast majority of producers are not over applying nitrogen (80%).

G. INABILITY TO MEET 1.0 MG/L NITRATE TARGETS WITH BMP IMPLEMENTATION
As mentioned, UMRW-P modeling suggests that the region cannot meet 1.0 mg/L nitrate target using a best management practices approach (see Appendix R). This is despite significant financial investment in cover crops, buffer strips, saturated buffers, water control structures, and reduction in application rates (and potentially a reduction in yields).

H. MEET 1.0 MG/L NITRATE TARGET THROUGH AGRICULTURE PRODUCTION REFORM
An additional BMP to implement (in addition to the scenarios developed for 1.0 mg/L targeting) is behavioral BMPs such as fallow season rotations (or adding hay production into corn/soybean rotation without nitrogen application). A 1/3 reduction of nitrogen application per watershed (in addition to the aforementioned elements) may enable target achievement. Another approach would be a more widespread adoption of "organic farming" practices.

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4 There are many factors driving this issue and upstream sources of water may not be the most significant factor* See Geist, adjacent land use, depth, volume, buffer, type of drawdown, overshoot/undershoot.

A decentralization of farms designed to incorporate more intensive labor and soil management practices (as well as concurrent decentralization of livestock and composting) would also potentially reduce chemical application (rates common to pre-industrial farming practices). However, it is unlikely that government will consider regulating how producers grow crops (even if it is the most feasible option for meeting a 1.0 mg/L target and addressing the Dead Zone issue). The volunteer implementation of these additional BMPs will likely continue to be avoided due to the impacts on farm profitability and financial sustainability.

I. FOOD PRODUCTION REALITIES AND EXTERNALITIES

We have created an industrial food production system that requires nitrogen inputs to function (due to depleted soil health). This shift has been demanded by consumers seeking the cheapest prices for food. Contemporary farming operations (equipment, acreage, crop type, etc.) are built on specific yield margins. The Dead Zone is an unfortunate externality of the contemporary system and will likely remain well into the future. Stakeholders may need to let go of certain “environmental expectations” and accept the reality that we have transformed the landscape and developed industrial agricultural practices to meet the demand of an ever growing world population. The Dead Zone may be a reality we have to live with until new technology emerges. The Pre-European landscape has been radically transformed and it may be more important to enhance the remaining species/ecology that remains in the current agro-industrial landscape than expect radical reform. Consumer side advocacy for food products produced through low-impact petro-fertilizer methods may be a more realistic approach than government regulation.

J. REDUCED LOAD REDUCTION TARGET FOR NITROGEN

The model for reducing loads to meet ultimate goals assumes that there was no shortage of funding for BMPs. This is unrealistic, so below we have placed one of the nitrate reduction scenarios from Appendix S (Tables 15.5-15.6). This is typical of the load reduction models that goals were actually based on. This time, we are illustrating what is estimated to be needed to reach a reduction of 30% only. We think that this alternative scenario shows that significant reductions can still be achieved with a much lower volume of BMPs implemented/adopted.

TABLE 15.5 | Nitrate loading data

Total Nitrate Load (ton/yr)*	251
Load Reduction Needed (ton/yr)**	213
Acres of Cropland	16,931

TABLE 15.6 | BMPs, rates of use, and resulting nitrate load reductions

		Column A	Column B	Column C = Column A x B x D	Column D
BMPs	Volume of Practice Installed (acres)	Percentage of Cropland Used	Estimated % Nitrate-N Reduction	Load Reductions (tons/yr)	Load Available for Treatment by BMP (tons/yr)
Wetland Restoration	847	5%	100%	13	251
Prairie Restoration	-	0%	100%	0	238
Extended Rotations	-	0%	42%	0	238
Fertilizer Reduction Practices (MRTN, sidedress, no fall application)	16,085	100%	10%	24	238
Cover Crops and Filter Strips*	8,042	50%	25%	27	215
Drainage Water Management**	1,448	9%	33%	6	188
Saturated Buffer***	1,287	8%	50%	7	182
Bioreactors	-	0%	43%	0	175
		Total Load Reduction (ton/yr)		76	
		Percent Reduction Achieved		30%	
		Percent Reduction Needed		85%	
		Remaining Load Reduction Needed (tons)		175	
		Percent Progress Towards Goal		36%	

Table 15.5 and 15.6 on the previous page is intended to represent each critical subwatershed. While specific cropland acres and load reduction estimates won't be accurate for each subwatershed, the percentage of cropland needed for the BMPs and the percent reduction achieved can be applied to all the subwatersheds. You can multiply percentages of BMPs needed by any subwatershed's cropland acres (Table 15.6 on the previous page) to determine the area, in acres, needed for each BMP in order to achieve an estimated percent reduction.

In addtion, by comparing the tables from Appendix S and Table 15.6, you can also see how the cost-efficiency of BMPs decreases as more and more BMPs are installed. You can see that the more structural BMPs that are applied, the less cost-effective they become. This is because as nitrate concentrations decrease, less nitrate is available for edge of field BMPs (such as saturated buffers) to remove. When it isn't cost-effective to keep installing structural BMPs, we need to look at behavioral BMPs. Behavioral BMPs simply refer to changing the way you do something. Applying less fertilizer or applying fertilizer after planting so less leaches out of the soil are examples of behavioral BMPs. Planting alternative crops that need less nitrogen (such as alfalfa) are also behavioral BMPs. In conclusion, while significant reductions of nitrate are possible today, reaching target loads may only be realistic if we can find ways to reduce nitrogen inputs.

3. TYPES OF BEST MANAGEMENT PRACTICES

For all of the reasons stated in the load reduction scenario narrative, Agricultural Best Management Practices are the primary goal of the project, (although urban BMPs are promoted as a secondary educational objective). Agricultural BMPs are implemented on agricultural lands, typically row crop agricultural lands, in order to protect water resources and aquatic habitat while improving land resources and quality. These practices control nonpoint source pollutants and reduce their loading to the Mississinewa River by minimizing the volume of available pollutants. Potential agricultural Best Management Practices designed to control and trap agricultural nonpoint sources of pollution are listed in the Appendix T. The BMP summaries included in the Appendix T are provided as a reference and generally describe each measure and its design components; it is not meant to be an all-inclusive list.

As the modeling suggests, the right types of BMPs, when applied rationally and considerate of compounding effects, can help achieve the watershed goals (in most subwatersheds) assuming no financial limitation. Any effort to decrease the concentrations of sediment and nutrient loads identified in this WMP is important (despite varying feasibility to achieve goal attainment individually or collectively). Due to (a) the source prioritization table (Table 15.3) and (b) the rationale discussed in the modelling results, when choosing an appropriate BMP it is essential to determine in advance the objectives to be met by the BMP and to calculate the cost and related effectiveness of alternative BMPs. Once a BMP has been selected, expertise is needed to insure that the BMP is properly installed, monitored, and maintained over time. The U.S. EPA strongly recommends using a systems approach to a site whenever possible. When creating a system of BMPs, the goal is to position two or more BMPs on the landscape so they complement each other and create the maximum water quality benefit. For instance, reduced tillage combined with a water level control structure for drainage tiles not only reduces soil runoff but also decreases the flow of storm water and nutrients to streams.

The Steering Committee generated a series of tables (Tables 16.1 through 16.5 on pp. 230-232) that suggest BMPs to be implemented in each critical area. This was based on the following factors:

A. MODELING REDUCTION SCENARIOS

Based on estimated BMP efficiency, land use data, and stakeholder interests in BMPs (Table 16.1-16.5), we conclude that nutrient management, cover crops, filter strips (and grassed waterways), conservation tillage, drainage water management and saturated buffers should be highly promoted. Cost share applications for these BMPs will be receiving top priority for funding, with applications to install the BMP in a contributing area (i.e. adjacent to a stream or river being given priority over those that do not.

B. SOURCE PRIORITIZATION BASED ON SOURCE DISCUSSION (SECTION 13).

The data and source analysis in the previous section helped researchers determine Best Management Practices (BMPs) most suitable for each critical area land use.

C. PRIORITIZATION BASED ON FEEDBACK DURING OUR SOCIAL SURVEY CAMPAIGNS

Respondents indicated a desire for continued funding of conservation practices like conservation tillage, cover crops, filter strips, and grassed waterways; especially near floodplain areas (Figure 15.2 and Table 15.7 below). The interest in these practices will be analyzed based on their relationship to water quality data results at a HUC_12 delineation.

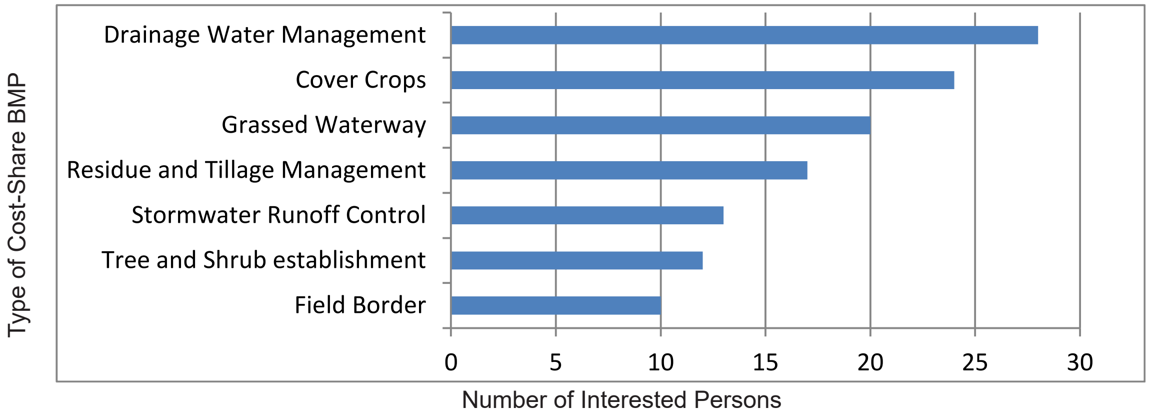

FIG.15.2 | BMPs, ordered by numbers of stakeholders within UMRW interested in them.

D. INABILITY TO MODEL CERTAIN BMPS

Furthermore, there are additional BMPs that can reduce nitrates and other pollutants that come from manure sources. These were not addressed in the model because manure's contribution to nitrate levels is difficult to assess. We found that there was some interest in livestock access control/fencing among stakeholders (Section 2, *Public Input*). Livestock access points to streams were identified in the desktop survey and discussed in the *Subwatershed Discussions* (Section 10). Therefore, livestock access control projects could contribute additional reductions in nitrates and other pollutants and should be funded despite never being modeled as part of the nutrient and TSS reduction scenarios.

E. BMPS NOT INCLUDED IN FOTG

Saturated buffers are an emerging BMP and are not currently part of the NRCS FOTG. Although they were modeled as part of the process, cost-share will not be available until they are added to FOTG. The same logic applies to other BMPs not currently included in the FOTG.

TABLE 15.7 | Landowner Interest in Best Management Practices

Best Management Practice	Number of Respondents Interested
Drainage Water Management	28
Cover Crops	24
Grassed Waterway	20
Residue and Tillage Management	17
Stormwater Runoff Control	13
Tree and Shrub establishment	12
Field Border	10

16. GOALS & ACTION STRATEGY

Setting goals and developing an action strategy is a crucial part of a watershed management plan. We have identified two broad goals that should guide watershed-centered actions. Ten unique objectives underlay these strategies. We feel that using these broad strategies and objectives as a basis for actions will help to provide effective and clear guidance rooted in load reduction modeling conclusions. Our ten objectives help highlight and emphasize key people and groups that we recognize as crucial to the future health of the watershed. By framing our objectives as such, it promotes communication and cooperation between community members and furthers the basic intention that watershed-centered actions should engage communities. Forming these fundamental relationships will open avenues to reach the wider public. The action items listed under each strategy's objectives contain milestones for achieving the objective. Each milestone will provide a measurable indicator that will demonstrate whether progress is being made toward achieving that objective. These objectives are general, addressing not only critical areas but the entire watershed as well. Strategies #1 and #2 are represented in more detail in Tables 16.6–16.17. These tables contain a timeframe for achieving milestones and a breakdown of estimated costs, possible partners, and sources of technical assistance for each action.

16.1 Goal #1: PROVIDE EDUCATION AND FORM PARTNERSHIPS

Objectives: (1) Build local capacity for volunteer monitoring; (2) Provide education and form partnerships with Agricultural Landowners, (3) Ecological Landowners, (4) Recreational Enthusiasts, (5) Local Health Departments, and (6) County Drainage Boards and Surveyors; and (7) Perform policy research and develop educational resources to promote citizen involvement in county/municipal planning and the policy-making.

Problem: There are currently few volunteers who conduct monitoring in the watershed. More monitoring is needed to understand if efforts to reduce nonpoint source pollution in the watershed are having an impact.
Goal #1, Objective #1: ***Build local capacity for volunteer monitoring***
Indicators:

- Number of brochures distributed to the public
- Number of persons visiting water quality booth at events, trade shows, etc.
- Number of attendees at Hoosier Riverwatch training workshop
- Number of active volunteer stream water quality monitors
- Data from 4-5 critical areas, collected monthly over one year
- Number of teachers attending meetings regarding developing local water quality curriculum
- Number of lesson plans taught using local water quality curriculum developed at meetings

Problem: There is currently no comprehensive system in place for engaging, educating, and connecting agricultural producers throughout the entire watershed about BMPs.
Goal #1, Objective #2: ***Provide education and form partnerships with Agricultural Landowners***
Indicators:

- Number of brochures about the Conservation Farming Directory distributed to landowners
- Number of farmers included in the Conservation Farming Directory
- Number of letters sent out promoting cost-share opportunities
- Number of persons who apply for cost-share opportunities
- Number of persons attending field days
- Number of persons participating in Infield Advantage due to watershed group's efforts
- Number of persons attending a "Women's Learning Circle" workshop
- Number of persons attending presentations concerning local policies and ordinances

Problem: There is currently no comprehensive system in place for engaging, educating, and connecting ecological landowners.
Goal #1, Objective #3: ***Provide education and form partnerships with Ecological Landowners***
Indicators:

- Number of persons assisted in applying for local Land Conservation Fund
- Number of acres enrolled in the Land Conservation Fund, including location (i.e., inside or outside of floodplain, etc.)
- Number of persons present at presentations about land conservation and Land Conservation Fund
- Number of persons receiving educational newsletter about Land Conservation Fund and land conservation, including location of property (i.e., inside or outside of floodplain, on highly erodible lands, etc)
- Number of persons attending land preservation forum
- Number of persons receiving educational newsletter about the importance of recharging aquifers and how preserving natural areas can help aquifer recharge, including location of property (i.e., in a location with high recharge capability)

Problem: There is currently no comprehensive system in place for engaging, educating, and connecting recreational enthusiasts.
Goal #1, Objective #4: ***Provide education and form partnerships with Recreational Enthusiasts***
Indicators:

Number of new or improved river access sites
Number of persons attending river and/or stream cleanups
Pounds of trash collected at river and/or stream cleanups
Number of persons attending canoe run event (which will start with a brief presentation about the watershed project)
Number of Category 3 and 4 logjams removed
Number of persons supporting dam removal
Number of dams removed
Number of persons using the Smart Recreation Web Guide
Number of persons volunteering at local land trust properties and local parks due to watershed group's efforts
Number of rain gardens installed in community gardens

Problem: There is currently no partnership between the watershed group and local health departments.
Goal #1, Objective #5: ***Provide education and form partnerships with Health Departments***
Indicators:

Number of health department officials that are present at meetings to share and discuss results of recent water quality sampling and possible partnership opportunities.
Number of persons receiving educational materials regarding septic system maintenance, including location of property (i.e., subwatershed)
Number of persons performing maintenance on their septic system due to the watershed group's efforts

Problem: There is currently no partnership between the watershed group and county surveyors and county drainage boards.
Goal #1, Objective #6: ***Provide education and form partnerships with County Drainage Boards/Surveyor***
Indicators:

Number of county surveyors and drainage board members that are present at meetings to share and discuss results of recent water quality sampling and possible partnership opportunities
Number of county surveyors attending 2-stage ditch or natural channel design workshops
The amount of 2-stage ditches installed (in linear feet)
The number of sites where natural channel design has been implemented
The number of students involved in BEHI/NBS assessments
The amount of streams/rivers assessed using BEHI/NBS (in linear feet)
Sediment modeling demonstrating load reduction due to 2-stage ditches and streambank stabilization projects
Miles of county drains mapped due to watershed group's efforts

Problem: There is currently a lack of understanding of public policy and county and municipal planning are impacting the watershed. There is also a lack of citizen engagement with public officials at this level.
Goal #1, Objective #7 (*Perform policy research and develop educational resources to promote citizen involvement in county/municipal planning and policy-making*)
Indicators:

Number of local officials/planning commission members attending meeting to share data and discuss sprawl and its impact on the watershed and water quality
Number of local officials attending meeting to hear watershed group's recommendations regarding ordinances, etc
Number and description of changes in local ordinances due to watershed group's efforts

16.2 Goal #2-#5: IMPROVE WATER QUALITY OF THE UPPER MISSISSINEWA RIVER AND ITS TRIBUTARIES

PROBLEMS, GOALS, AND INDICATORS
Problem: Excess nitrate has been identified as a problem.
Goal #2: The Tier I Critical Areas that have high levels of nitrate are Gray Branch, Bush Creek, and Deer Creek. Our goal is to reduce nitrate in these Tier I Critical Areas. Specific reduction goals for each TIer I critical area are listed below.
Indicators: Administrative indicators will be modeling completed using a modeling technique using the Iowa Nutrient Reduction Strategy (p. 243-244) at the end of the first round of implementation. Environmental indicators will be water quality monitoring conducted at the end of the second round of implementation. Social indicators will be the number of people applying for cost-share funds and implementing BMPs.

Gray Branch HUC 12 - Excess nitrate has been identified as a problem. Our ultimate goal is to reduce the subwatershed's average nitrate load (disregarding flow) from 251 tons per year to 38 tons per year (a 85% reduction), to reduce high flow nitrate load from 1,059 tons per year to 90 tons per year (a 91% reduction), and to reduce the subwatershed's low flow nitrate load from 49 tons per year to 12 tons per year (a 75% reduction). However, because this is not achievable in a reasonable time frame, our scaled goals are as follows:

- Reduce Gray Branch's average nitrate loading from 251 tons per year to 213 tons per year (a 15% reduction) in 15 years and to 176 tons per year (a 30% reduction) in 30 years.
- Reduce Gray Branch's average nitrate loading at high flow from 1059 to 901 tons per year (a 15% reduction) in 15 years and to 742 tons per year (a 30% reduction) in 30 years.
- Reduce Gray Branch's average nitrate loading at low flow from 49 to 41 tons per year (a 15% reduction) in 15 years and to 34 tons per year (a 30% reduction) in 30 years.

Water quality data will be used as an indicator to demonstrate progress towards this goal. Nitrate [N] will be tested for monthly at this site for one year, following the completion of the second implementation phase.

Deer Creek HUC 12 - Excess nitrate has been identified as a problem. Our ultimate goal is to reduce the subwatershed's average nitrate load (disregarding flow) from 355 tons per year to 110 tons per year (a 69% reduction), to reduce high flow nitrate load from 1,848 tons per year to 320 tons per year (a 83% reduction), and to reduce the subwatershed's low flow nitrate load from 94 tons per year to 39 tons per year (a 58% reduction). However, because this is not achievable in a reasonable time frame, our scaled goals are as follows:

- Reduce Deer Creek's average nitrate loading from 355 tons per year to 301 tons per year (a 15% reduction) in 15 years and to 248 tons per year (a 30% reduction) in 30 years.
- Reduce Deer Creek's average nitrate loading at high flow from 1848 to 1571 tons per year (a 15% reduction) in 15 years and to 1294 tons per year (a 30% reduction) in 30 years.
- Reduce Deer Creek's average nitrate loading at low flow from 94 to 80 tons per year (a 15% reduction) in 15 years and to 66 tons per year (a 30% reduction) in 30 years.

Water quality data will be used as an indicator to demonstrate progress towards this goal. Nitrate [N] will be tested for monthly at this site for one year, following the completion of the second implementation phase.

Bush Creek HUC 12 - Excess nitrate has been identified as a problem. Our ultimate goal is to reduce the subwatershed's average nitrate load (disregarding flow) from 20 tons per year to 11 tons per year (a 57% reduction) and to reduce high flow nitrate load from 139 tons per year to 20 tons per year (a 86% reduction). However, because this is not achievable in a reasonable time frame, our scaled goals are as follows:

• Reduce Bush Creek's average nitrate loading from 139 tons per year to 119 tons per year (a 15% reduction) in 15 years and to 98 tons per year (a 30% reduction) in 30 years.
• Reduce Deer Creek's average nitrate loading at high flow from 1848 to 1571 tons per year (a 15% reduction) in 15 years and to 1294 tons per year (a 30% reduction) in 30 years.

Water quality data will be used as an indicator to demonstrate progress towards this goal. Nitrate [N] will be tested for monthly at this site for one year, following the completion of the second implementation phase.

Problem: Excess TSS has been identified as a problem.
Goal #3: Gray Branch is a Tier I critical area for TSS. Our goal is to reduce TSS in this Tier I Critical Area. Specific reduction goals for Gray Branch subwatershed are listed below.
Indicator: Administrative indicators will be modeling completed using the Region 5 model (p. 224) at the end of the first round of implementation. Environmental indicators will be water quality monitoring conducted at the end of the second round of implementation. Social indicators will be the number of people applying for cost-share funds and implementing BMPs.

Gray Branch HUC 12 - Excess TSS has been identified as a problem. Our ultimate goal is to reduce the subwatershed's average flow TSS load from 2,535 tons per year to 957 tons per year (a 62% reduction) and to reduce the subwatershed's high flow TSS load from 15,511 tons a year to 2,257 tons per year (an 85% reduction). However, because this is not achievable in a reasonable time frame, our scaled goals are as follows:
• Reduce Gray Branch's average TSS loading from 2,535 tons per year to 1,901 tons per year (a 25% reduction) in 15 years and to 1,268 tons per year (a 50% reduction) in 30 years.
• Reduce Gray Branch's high flow TSS loading from 15,511 tons per year to 11,633 tons per year (a 25% reduction) in 15 years and to 7,756 tons per year (a 50% reduction) in 30 years.

Water quality data will be used as an indicator to demonstrate progress towards this goal. TSS will be tested for monthly at this site for one year, following the completion of the second implementation phase.

Problem: Excess phosphorus has been identified as a problem.
Goal #4: In Critical Areas reduce phosphorus loading by 31 tons/yr (25%) in 15 years and by 61 tons/yr (50%) in 30 years. The Tier I Critical Areas that have high levels of phosphorus are Gray Branch, Upper Big Lick Creek, and Halfway Creek. Our goal is to reduce phosphorus in these Tier I Critical Areas. Specific reduction goals for each TIer I critical area are listed below.

Indicator: Administrative indicators will be modeling completed using the Iowa Nutrient Reduction Strategy at the end of the first round of implementation. Environmental indicators will be water quality monitoring conducted at the end of the second round of implementation. Social indicators will be the number of people applying for cost-share funds and implementing BMPs.

Gray Branch HUC 12 - Excess phosphorus has been identified as a problem during high flow. Our goal is to reach the target phosphorus load within 30 years by reducing the subwatershed's high flow phosphorus load from 48 tons per year to 36 tons per year (a 25% reduction) in 15 years and to 27 tons per year (a 43% reduction) in 30 years.

Water quality data will be used as an indicator to demonstrate progress towards this goal. Total phosphorus will be tested for monthly at this site for one year, following the completion of the second implementation phase.

Halfway Creek HUC 12 - Excess phosphorus has been identified as a problem during high flow. Our goal is to reach the target phosphorus load within 30 years by reducing the subwatershed's high flow phosphorus load from 29 tons per year to 22 tons per year (a 25% reduction) in 15 years and to 18 tons per year (a 37% reduction) in 30 years.

Water quality data will be used as an indicator to demonstrate progress towards this goal. Total phosphorus will be tested for monthly at this site for one year, following the completion of the second implementation phase.

Problem: Excess E. coli has been identified as a problem.
Goal #5: In Critical Areas that have high levels of E. coli, reduce E. coli loading by 5% in 15 years and by 10% in 30 year. The Tier I Critical Area that has high levels of E. coli is Little Lick Creek.
Indicator: There is currently no available model for estimating E. coli reductions. Environmental indicators will be water quality monitoring conducted at the end of the second round of implementation. Social indicators will be the number of people applying for cost-share funds and implementing BMPs and the number of persons pledging to use BMPs.

RELATIONSHIP TO WATERSHED REDUCTION GOALS

Projects that are proposed for grant writing assistance or implementation will be selected based on the capacity to maximize the reduction of non point source pollutants (comparative to other applicants) in TIER I watershed critical areas. Applicants must be able to demonstrate pollutant reduction. The goals detailed in the Action Strategy represent both (a) the ultimate goal of reaching target pollutant concentrations identified by the monitoring committee and (b) the realistic potential for reaching a target goal:

1. Each selected project (either grant writing assistance or implementation) must advance overall subwatershed reduction goals.
2. Each cost-share project will be used as a means of tracking effectiveness to reach UMRW-P reduction goals.
3. Reduction estimation and post-installation monitoring will be used as means of determining indicators of goals achievement.

PROJECT SELECTION PROCESS

In addition to the TIER I critical area determinations, the UMRW-P has developed four priorities in determining projects to help assist with grant writing or implementation. These priorities were developed based on information gained from our inventory, analysis, source identification processes, and BMP load reduction scenarios. It should be emphasized that the prioritization of projects is not mandated but is created to serve as guidance for the UMRW-P cost-share steering committee. We will work with applicants to ensure applications are competitive and we are willing to suspend prioritization if valid arguments are made for BMP selection and location (so long as project is in critical areas).

1. Priority for lands adjacent to waterbodies
Projects will be prioritized if applicants own lands adjacent to waterbodies, especially if these lands lack sufficient buffers. Based on our source identification studies, we have concluded that within the TIER I Critical Areas boundaries, specific sites in the subwatershed lack vegetative buffers which may be functioning as gateways for water quality stressors to enter the waterways. These “gateways” are weak points in water filtration, sediment stabilization and nutrient uptake. Projects that seek to “fill these gaps” will be given priority if they address the weak points identified in the stream protection system.

2. Priority given to projects that demonstrate significant reduction in NPS pollutant loadings.
All projects that reduce NPS pollution will be considered, but projects that have greater load reduction estimates will be given preference. This “reduction needed” is based on current load calculations, target loads (Appendix R), and BMP load reduction modeling.

3. Priority given to projects that address primary sources identified through this WMP
Based on ongoing UMRW-P water quality studies we have created a table for priority BMP implementation (Table 15.3). Projects that seek to stabilize streambanks, reduce agricultural sources, and/or contribute to the reduction of E. coli, will be given priority over all projects.

4. Priority given to BMPs recommended at the Subwatershed level
Tabels 16.1-16.5 recommends BMPs at the subwatershed scale. This table will be used as priority guidance for reviewing applications. New BMPs will be added to the list if further research supports table modification.

5. *Comprehensive ranking table*
In the event that multiple cost-share applications meet priorities 1-4, the watershed comprehensive ranking table will be used to further prioritize project section. Table 14.3 ranks each tributary subwatershed and Table 14.2 ranks each mainstem subwatershed for each parameter. The individual parameter rankings are then summed and resorted/prioritized for each grouping (tributary subwatersheds and mainstem subwatersheds) based on the comprehensive rankings.

16.3 CRITICAL AREAS AND BMPS, LISTED BY COUNTY

TABLE 16.1 | Blackford County		
Critical Area	Reason For Being Critical	Bmp Or Measure
Upper Big Lick Creek, Tier I	Nutrient levels exceed the target set by this project	Covercrops Grassed Waterway Nutrient Management Plan Filter Strips and Riparian Zones Wetland Creation/Restoration
		Check Dams- Natural Implementation Grassed Waterway Water and Sediment Control Basins Bioretention/Rain Gardens Flow Splitters Level Spreader Storm water Pond Riser Modification Swales/Vegetated Swales Water Retention Ponds retrofits
Big Lick Creek, Tier III Upper Big Lick Creek, Tier II	E. coli levels exceed the water quality standard	Manure application BMPs
		Livestock Exclusion education and partnership with health department

TABLE 16.2 | Pike Creek HUC 10 (Delaware County)		
Critical Area	Reason For Being Critical	Bmp Or Measure
Campbell Creek, Tier II	TSS levels exceed the target set by this project	Covercrops Grassed Waterway No-till Equipment Modifications Vegetated Stream bank Stabilization
		Conservation Plan Development Strip cropping Grade Stabilization Structure Check Dams- Natural Implementation Flow Splitters Level Spreader Storm water Pond Riser Modification Swales/Vegetated Swales Water Retention Ponds retrofits Wetland Creation/Restoration Water and Sediment Control Basins
Bush Creek, Tier I	Nutrient levels exceed the target set by this project	Covercrops Grassed Waterway Nutrient Management Plan Filter Strips and Riparian Zones Wetland Creation/Restoration
		Check Dams- Natural Implementation Grassed Waterway Water and Sediment Control Basins Bioretention/Rain Gardens Flow Splitters Level Spreader Storm water Pond Riser Modification Swales/Vegetated Swales Water Retention Ponds retrofits

TABLE 16.3 | Massey Creek HUC 10 (Grant County)

Critical Area	Reason For Being Critical	Bmp Or Measure
Little Walnut, Tier II Lugar Creek, Tier III Walnut Creek, Tier III	TSS levels exceed the target set by this project	Covercrops Grassed Waterway No-till Equipment Modifications Vegetated Stream bank Stabilization 2-Stage Ditches (in Lugar and Walnut Creek only)
		Conservation Plan Development Strip cropping Grade Stabilization Structure Check Dams- Natural Implementation Flow Splitters Level Spreader Storm water Pond Riser Modification Swales/Vegetated Swales Water Retention Ponds retrofits Wetland Creation/Restoration Water and Sediment Control Basins
Barren Creek, Tier II Deer Creek, Tier I Little Deer Creek, Tier III Little Walnut, Tier II Lugar, Tier III	Nutrient levels exceed the target set by this project	Covercrops Grassed Waterway Nutrient Management Plan Filter Strips and Riparian Zones Wetland Creation/Restoration
		Check Dams- Natural Implementation Grassed Waterway Water and Sediment Control Basins Bioretention/Rain Gardens low Splitters Level Spreader Storm water Pond Riser Modification Swales/Vegetated Swales Water Retention Ponds retrofits
Barren Creek, Tier II Lugar Creek, Tier III	E. coli levels exceed the water quality standard	Manure application BMPs
		Livestock Exclusion education and partnership with health department

TABLE 16.4 | Halfway Creek HUC 10 (Jay County)

Critical Area	Reason For Being Critical	Bmp Or Measure
Halfway Creek, Tier I	Nutrient levels exceed the target set by this project	Covercrops Grassed Waterway Nutrient Management Plan Filter Strips and Riparian Zones Wetland Creation/Restoration
		Check Dams- Natural Implementation Grassed Waterway Water and Sediment Control Basins Bioretention/Rain Gardens Flow Splitters Level Spreader Storm water Pond Riser Modification Swales/Vegetated Swales Water Retention Ponds retrofits

TABLE 16.5 | Headwaters Mississinewa River HUC 10 (Darke and Randolph counties)

Critical Area	Reason For Being Critical	Bmp Or Measure
Little Mississinewa, Tier II Gray Branch, Tier I	TSS levels exceed the target set by this project	Covercrops Grassed Waterway No-till Equipment Modifications Vegetated Stream bank Stabilization 2-Stage Ditches
		Conservation Plan Development Strip cropping Grade Stabilization Structure Check Dams- Natural Implementation Flow Splitters Level Spreader Storm water Pond Riser Modification Swales/Vegetated Swales Water Retention Ponds retrofits Wetland Creation/Restoration Water and Sediment Control Basins
Little Mississinewa, Tier II Gray Branch, Tier I	Nutrient levels exceed the target set by this project	Covercrops Grassed Waterway Nutrient Management Plan Filter Strips and Riparian Zones Wetland Creation/Restoration
		Check Dams- Natural Implementation Grassed Waterway Water and Sediment Control Basins Bioretention/Rain Gardens low Splitters Level Spreader Storm water Pond Riser Modification Swales/Vegetated Swales Water Retention Ponds retrofits
Little Mississinewa, Tier II	E. coli levels exceed the water quality standard	Manure application BMPs
		Livestock Exclusion education and partnership with health department

TABLE 16.6 | Goal #1, Objective #1 (Build local capacity for volunteers for monitoring, etc.)

Action Item	Target Audience	Milestones	Cost	Possible Partners	Technical Assistance
Identify core narratives (involving NPS pollution and volunteer monitoring) to convey to the community. These core narrative will be based in part on our water quality results and will be distributed to the public through different mediums.	Students and adults	Within 6 months, begin partnering with Ball State University to create content for the booth.	$6,200	Ball State University	Ball State University—design and write content
		Within 6 months, partner with Ball State University to create video content	$1,100	Ball State University	Ball State University—produce video and publish to website
		By the end of year 3, publish video on watershed website.	$100		
		By the end of year 3, have a booth ready to go.	$6,200	Ball State University	Ball State University—assist in design
		By the end of year 3, have a publication completed.	$1,100	Ball State University	Ball State University—design and write content
Encourage training of interested volunteers	Volunteers	By the end of year 5, partner with Hoosier Riverwatch to host a volunteer training workshop in the watershed area	$1,700	Hoosier Riverwatch; Minnetrista; Muncie Public Library	Hoosier Riverwatch—conduct training workshop
Conduct water quality sampling	Volunteers	By the end of year 5, target sites near installed BMPs.	$22,000	Hoosier Riverwatch-trained volunteers; Cooper Audubon Society; volunteer groups; schools	Hoosier Riverwatch—will use the group's training manual and methods to conduct monitoring and seek assistance from group if needed
		Within 6 months, conduct water quality sampling as part of Delaware County SWCD well and pond testing initiative. Continue as needed.	$20,000		
		By the end of year 2, target subwatersheds where streambank erosion is suspected (Lugar and Walnut creeks and Little Mississinewa River); this should be at sub-basin level during high-flow events	$25,000		
Partner with local teachers to recruit student volunteers and encourage engagement of students of all ages.	Teachers	By the end of year 1, form a focus group to explore hindrances and opportunities. Organize meeting with local teachers to encourage teaching about watersheds and partnering to share ideas, etc.	$2,600	Local science teachers	Local science teachers—lead student groups in water quality monitoring, develop local water quality and watershed curriculum

TABLE 16.7 | Goal #1, Objective #2 (Provide education and form partnerships with Agricultural Landowners)

Action Item	Target Audience	Milestones	Cost	Possible Partners	Technical Assistance
Create a conservation farmer directory in order to identify possible partners and to encourage networking/information sharing between farmers.	Agricultural landowners	Within 6 months, begin work with NRCS, SWCD, and Purdue Agricultural Extension to identify and contact farmers who might be interested in being included in directory.	$260	NRCS, SWCDs, Purdue Extension	NRCS, SWCDs—promote directory to farmers, identify farmers who may be interested, assist with design
		By the end of year 3, create a brochure about conservation farming directory to promote it. Print 300 initially at $1.50 per sheet.	$1,230		
		Immediately begin to solicit agricultural producers who would be interested in inclusion in the directory when appropriate. This will be done at events or in one-on-one meetings.	$260	NRCS, SWCDs, Purdue Extension	NRCS, SWCDs—identify BMPs that should be included in directory
Promote cost-share opportunities	Agricultural landowners	Immediately and annually (for 30 years), partner with NRCS, SWCD, Purdue Extension Service to promote cost-share	$1,700	NRCS, SWCDs, Purdue Extension	NRCS, SWCDs—lend expertise about promotion strategies
Host field days	Agricultural landowners	By the end of years 2, 4, and 6, host a field day. Site location should be based on identified land use concerns or critical areas. A demonstration BMP should be on the site.	$3,400	NRCS, SWCDs, Purdue Extension, agricultural producers	NRCS, SWCDs—help organize and conduct field day
		Continue to promote Infield Advantage at field days and presentations.	$450	SWCDs	SWCDs—explain and share info about Infield Advantage
Hold landowner consulting forum with policy makers	Agricultural and non-agricultural landowners	By the end of year 1, explore holding a “Women’s Learning Circle” in the area	$1,500	SWCD and NRCS	SWCD and NRCS—advise about event
		If enough interest is generated, by the end of year 2 host a “Women’s Learning Circle”	$2,000	SWCD and NRCS	SWCD and NRCS—help organize event; primary leader of event
		By end of year 3, organize forum to be held independently or at a community event	$1,560	local government officials, agricultural economist	NRCS, SWCDs, Purdue Extension, government officials—assist in organizing event, share expertise at event
Conduct policy research to develop an understanding of nationwide and local policies and ordinances.	Agricultural landowners and non-agricultural landowners	By the end of year 2, complete policy research and complete a power point presentation to share findings.	$5,000	government officials, Muncie Action Planning and neighborhood groups	government officials—share expertise regarding policy
		When appropriate, give presentations concerning ordinances and seek adoption of ordinances that will enhance water quality	$1,000	government officials, Muncie Action Planning and neighborhood groups	government officials—help organize events or meetings

TABLE 16.8 | Goal #1, Objective #3 (Provide education and form partnerships with Ecological Landowners)

Action Item	Target Audience	Milestones	Cost	Possible Partners	Technical Assistance
Promote conservation of ecological lands	Non-agricultural and agricultural landowners	As projects are identified, assist with applications for Land Conservation Fund	$1,040	Red-tail Land Conservancy; Cooper Audubon Society; local planning commissions and local governments; NRCS; local colleges and universities	Red-tail Land Conservancy—advise regarding LCF and easements; NRCS— advise regarding conservation programs and enrollment in them
		As projects are identified, provide cost-share for easements	$12,000		
		Annually (for 30 years), talk to a government council and encourage conservation of ecological lands and prevention of sprawl. Promote the benefits of the Land Conservation Fund.	$1,040		
		By the end of year 3, encourage preservation of ecological areas along the river at an education event or through direct mailings	$1,040		
		If a critical mass of interested persons in reached, partner with local land preservation groups, such as Red-tail Land Conservancy, to hold a land preservation forum. Identify interested parties continuously.	$3,200		
Advocate the protection of the region's aquifers through the protection/enhancement of the region's forest-wetlands	Non-agricultural and agricultural landowners	By the end of year 4, provide education about the importance of recharging aquifers, about nature's role in this process, and about how environmental changes have altered it. Target Lugar and Walnut creeks specifically since hydric soils and D drainage in these areas are ideal for aquifer recharge.	$1, 200	Red-tail Land Conservancy; Cooper Audubon Society; local planning commissions and local governments; NRCS; local colleges and universities; Marion Utilities	Red-tail Land Conservancy—provide information and advice about land trusts, easements, conservation; NRCS—advise regarding conservation programs and enrollment in them

TABLE 16.9 | Goal #1, Objective #4 (Provide education and form partnerships with Recreational Enthusiasts)

Action Item	Target Audience	Milestones	Cost	Possible Partners	Technical Assistance
Create more river access sites	Landowners adjacent to river; conservation groups	As projects are identified, apply for grant funding	$1,600	Red-tail Land Conservancy	Red-tail Land Conservancy—assist in identifying, developing, and promoting sites
			$1,560		
Hold an annual McVey Canoe Run/Cookout/Cleanup	Volunteers, recreational enthusiasts, general public (especially residents of Farmland, Albany, Redkey, and Ridgeville)	Encourage the formation of volunteer groups by lending technical assistance if needed. Identify interested parties continuously.	$4,640	Red-tail Land Conservancy; Dunkirk News and Sun; The Star Press; Cooper Audubon Society	Red-tail Land Conservancy; Muncie Delaware Clean and Beautiful—lend expertise; assist with organizing event
Continue to seek funding for log jam removal	Landowners adjacent to river	Apply for LARE grants annually (for 30 years)	$1,560	SWCDs; county surveyors and drainage boards	Indiana DNR—advise on grant applications
Explore dam removal	Landowners adjacent to river	By the end of year 4, encourage continued community involvement through individual county meetings; discern local support for dam removal (e.g. dam in Marion)	$1,560	Army Corps of Engineers; IDEM; IDNR	Army Corps of Engineers; IDEM; IDNR—advise and assist with permits; provide guidance throughout process
		Lend expertise when requested. Facilitate forum if needed.	$1,040		
Create a Smart Recreation Web Guide with help from student volunteers	Recreational enthusiasts, schools	By the end of year 1, inventory similar publications already in existence to generate ideas.	$1,170	Ball State University; Taylor University; Indiana Wesleyan University	Ball State University; Taylor University; Indiana Wesleyan University—assist in identifying and creating content; assist with creation of web guide
		By the end of year 3, design and create the Smart Recreation Web Guide	$3,000		
Identify volunteer opportunities and coordinate a volunteer group or events	Recreational enthusiasts, schools	Within 6 months, Contact Red-tail Land Conservancy and municipal parks departments to discuss volunteer needs	$560	Red-tail Land Conservancy; municipal parks	Red-tail Land Conservancy—identify needs and develop volunteer schedule
		Within 6 months, contact stakeholders identified at meetings as possibly being interested in volunteering	$560		
		Help facilitate volunteer experience if needed	$5,200	Red-tail Land Conservancy; municipal parks	Red-tail Land Conservancy; municipal parks—train volunteers
Work with community garden organizations to achieve common goals, such as creating rain gardens or incorporating LID retrofits	Garden hobbyists	Contact Tori's Butterfly Garden Foundation, Inc. by the end of year 3 and present idea for collaborative raingarden butterfly garden; provide some cost share for project	$9,650	Tori's Butterfly Garden Foundation, Inc., Ball State Department of Landscape Architecture	Ball State Department of Landscape Architecture—advise on design

TABLE 16.10 | Goal #1, Objective #5 (Provide education and form partnerships with Health Departments)

Action Item	Target Audience	Milestones	Cost	Possible Partners	Technical Assistance
Seek assistance with future E. coli sampling	Health departments	Within 3 months, contact each health department to discuss a possible sampling program.	$1,040	Local health departments	Local health departments—advise on sampling program
Share findings regarding subwatershed E. coli levels within the watershed	Health departments	Within 3 months, contact each health department and present with copy of plan	$1,140	Local health departments	NA
Partner with health departments for distribution of educational materials	Homeowners, general public	Within two years, focus on septic system maintenance at community events	$560	Local health departments	Local health departments—advise on strategies; assist in creation of material

TABLE 16.11 | Goal #1, Objective #6 (Provide education and form partnerships with County Drainage Boards/Surveyor)

Action Item	Target Audience	Milestones	Cost	Possible Partners	Technical Assistance
Meet with county surveyors, drainage board members, and landowners	County surveyors and drainage boards	Within 6 months, share findings of water quality monitoring	$3,120	Landowners	NRCS—supports two-stage ditches through EQIP; FOTG CPS 582, "Open Channels"; The Nature Conservancy—power point presentations regarding two-stage ditches are available online from the TNC.
		Within 6 months, encourage the use of natural channel design and 2-stage ditches (where appropriate)	$1,040		
Conduct a BEHI/NBS of Lugar and Walnut creeks.	County surveyors, drainage boards, landowners	Continue partnership with Taylor University on this project; share findings with public officials and the general public.	$2,560	Taylor University	Taylor University—train students to do BEHI/NBS; assist with analysis
Provide 2-stage ditch and natural channel design training.	County surveyors, drainage boards, landowners	By the end of year 1, contact the NRCS and TNC to inquire about current programs; contact local surveyors to generate interest in these methods	$1.560	County surveyors, drainage boards, landowners	The Nature Conservancy—hosts workshops, presentations, and field days; contact kwamsley@tnc.org or call The Nature Conservancy at 574-946-7491; NRCS—help identify partners and strategies; provide information on 2 stage ditches
Seek funding to assist with mapping of county drains.	County planning agencies	Immediately, coordinate local funding and apply for grants	$2,080	County planning agencies; Delaware County stormwater board	County planning agencies—help identify funding opportunities; assist with applications

TABLE 16.12 | Goal #1, Objective #7 (Perform policy research and develop educational resources to promote citizen involvement in county/municipal planning and policy-making)

Action Item	Target Audience	Milestones	Cost	Possible Partners	Technical Assistance
Explore ordinances and policies for LID (low-impact development) to address stormwater runoff in urban areas.	Planning commissions	By the end of year 1, contact planning commissions in areas where sprawl is occurring (Grant County and Upland)	$3,120	Planning commissions	Planning commissions—provide information and explanations regarding ordinances
		By the end of 18 months, complete research and present recommendations to planning commissions	$3,250	Planning commissions	NA
Explore wastewater ordinances and share findings with public	Homeowners; landlords	By the end of 18 months, research ordinances regarding regional sewer districts	$3,120	Sanitary districts	Sanitary districts—provide information and explanations regarding ordinances
		By the end of 18 months, research ordinances regarding septic system upgrades with real estate transactions	$3,120		
Explore other ordinances, such as assessment rates, farm distance to stream, stream maintenance guidelines, floodplain enforcement, etc.	Landowners	Within 6 months, contact local government officials and seek assistance in researching these issues	$3,120	Drainage boards, surveyors, IDEM, IDNR	Drainage boards, surveyors, IDEM, IDNR—provide information regarding topics
Host events to educate public on ordinances and to generate public support for policy changes that would be beneficial to water quality/ecosystem quality.	General public	Within two years, organize educational event	$2,600	Local libraries	County or city officials; local health departments—help organize events; share expertise at events

TABLE 16.13 | Action Register for Gray Branch Subwatershed

Gray Branch Critical For: Total Suspended Solids, Phosphorus, and Nitrate–Tier I								
Action Item	**Target Audience**	**Milestones**	**Load Reduction - N (tons/yr)**	**Load Reduction - Phos (tons/yr)**	**Load Reduction - TSS (tons/yr)**	**Cost**	**Possible Partners**	**Technical Assistance**
Increase restored wetlands by 254 acres by 2033 and by 508 acres by 2048.	Agricultural and rural landowners	Develop cost-share program in 2018				$1,000	Red-tail Land Conservancy, IDNR and Wilbur Wright FWA managers, SWCDs, NRCS, TNC	IDNR, NRCS, SWCD—assist in identifying sites; advise on permitting, design, and installation
		Identify sites that could potentially be restored to wetlands by the end of year 1. Contact at least 8 landowners from the list annually for five years.				$6,000		
		Apply for additional grant funds for identified wetland restoration projects annually for 5 years.				$10,000		
		Enhance website with photos and descriptions of restored wetlands in the watershed annually for 5 years.				$3,000		
		Restore 17 acres of wetlands annually for 30 years.	8	0.3	364	$102,000 (3,400 annually)		
Increase restored prairies by 43 acres by 2033 and by 85 acres by 2048.	Agricultural and rural landowners	Develop cost-share program in 2018				$1,000	Red-tail Land Conservancy, IDNR and Wilbur Wright FWA managers, SWCDs, NRCS, TNC	IDNR, NRCS, SWCD—assist in identifying sites; advise on design and installation
		Identify sites that could potentially be restored to prairie by the end of year 1. Contact at least 15 landowners from the list annually for five years.				$6,000		
		Apply for additional grant funds for identified prairie restoration projects annually for 5 years.				$10,000		
		Enhance website with photos and descriptions of restored prairies in the watershed annually for 5 years.				$3,000		
		Restore 3 acres annually for 30 years	1	0.0935	111	$77,350 (2,578 annually)		
Increase the use of extended rotations by 43 acres by 2033 and by 85 acres by 2048.	Agricultural landowners	Identify landowners who may be most likely to adopt extended rotations				$2,000	NRCS, SWCD	NRCS, SWCD—advise on strategies for promoting practice
		Seek financial incentives for the adoption of extended rotations				$2,000		
		Hold field day to promote extended rotations by the end of year 3				$4,000		
		Implement 14 acres every 5 years for 30 years	1			none		

TABLE 16.13 | Action Register for Gray Branch Subwatershed (continued)

Action Item	Target Audience	Milestones	Load Reduction - N (tons/yr)	Load Reduction - Phos (tons/yr)	Load Reduction - TSS (tons/yr)	Cost	Possible Partners	Technical Assistance
Increase the use of MRTN on 8,127 acres by 2033 and on 16,254 acres by 2048.	Agricultural producers and landowners	Promote the use of MRTN at field days; promote the use of Iowa State's Corn Nitrogen Rate Calculator				$5,000	NRCS, SWCDs	NRCS, SWCDs—advise on how to promote practice
		Enhance website with information on MRTN and link to calculator by the end of year 1.				$2,500		
		Implement 542 acres of MRTN fertilizer application practice annually for 30 years	24	5.6		none		
Increase the use of cover crops by 4,063 acres by 2033 and by 8,127 by 2048.	Agricultural producers and agricultural landowners	Create a cost-share program in 2018.				$1,000	NRCS, SWCDs, Purdue Extension	NRCS, SWCDs, Purdue Extension—provide information on contractors who can seed and/or terminate cover crops, as well as information on what cover crops are successful locally; also provide list of producers who are currently using cover crops
		Create a list of contractors who seed covercrops and the methods they can use within the first 15 months.				$2,500		
		Seek additional cover crop funding annually for 15 years.				$2,500		
		Locate land in high-traffic areas for possible demonstration plot within the first 18 months. Contact landowners to see if any are interested in having a demonstration plot on their property. Develop signage for plot within the first two years. .				$7,500		
		Enhance website with information about the various types of cover crops, seeding and termination methods, as well as videos of area producers who've had success with cover crops within the first year.				$5,000		
		Implement 271 new acres of cover crops annually for 30 years.	32	5.12	1,795	$325,081 ($10,836 annually)		
Increase the use of filter strips by 25 acres by 2033 and by 50 acres by 2048	Agricultural producers; agricultural landowners; rural landowners	Create a cost-share program in 2018.				$1,000	NRCS, SWCDs	NRCS, SWCDs—provide information about NRCS cost-share programs, explain how these programs work; provide technical information for installation
		Create a list of landowners who may want filter strips. Contact at least 15 landowners from the list annually.				$2,500		
		Seek additional funds annually				$2,500		
		Implement 1.67 acres of filter strips annually	0.1205	0.0605	33	$23,000 (770 annually)		

TABLE 16.13 | Action Register for Gray Branch Subwatershed (continued)

Action Item	Target Audience	Milestones	Load Reduction - N (tons/yr)	Load Reduction - Phos (tons/yr)	Load Reduction - TSS (tons/yr)	Cost	Possible Partners	Technical Assistance
Increase the acres under drainage water management by 1,382 by 2033 and by 2,763 by 2047.	Agricultural producers and agricultural landowners	Create a cost-share program in 2018				$1,000	NRCS, SWCDs	NRCS, SWCDs—provide information about NRCS cost-share programs, explain how these programs work; provide design guidance; provide technical information for installation; assist in identifying land suitable for DWM
		Create a list of landowners whose land is suitable for drainage water management and contact 20 people on the list annually for five years.				$2,500		
		Seek additional funds annually for 10 years.				$2,500		
		Enhance the website by adding information on drainage water management; video local producers using DWM and add videos to website within the first year.				$5,000		
		Install enough drainage water management systems to treat 92 acres annually for 30 years.	10			$331,583 ($11,053 annually)		
Increase the acres being treated by bioreactors by 81 acres by 2033 and by 163 acres by 2047.	Agricultural producers and agricultural landowners	Create a cost-share program in 2018				$1,000	NRCS, SWCDs, Ivy Tech Marion, Indiana Wesleyan, Taylor University	NRCS, SWCDs—provide design assistance; share information at workshop
		Locate land in high-traffic areas for possible demonstration bioreactor within the first 18 months. Contact landowners to see if any are interested in having a demonstration bioreactor on their property. Develop signage for the bioreactor within the first two years.				$2,500		
		Seek additional funds annually for 10 years.				$2,500		
		Hold a bioreactor workshop at the demonstration bioreactor site by the end of year 3.				$5,000		
		Enhance website by adding information on bioreactors; video the installation of the demonstration bioreactor and add video to website within the first year.				$5,000		
		Install enough bioreactors to treat 5 acres annually for 30 years.	1			$32,508 ($1,084 annually)		

TABLE 16.13 | Action Register for Gray Branch Subwatershed (continued)

Action Item	Target Audience	Milestones	Load Reduction - N (tons/yr)	Load Reduction - Phos (tons/yr)	Load Reduction - TSS (tons/yr)	Cost	Possible Partners	Technical Assistance
Increase the use of Residue and Tillage Management - No Till "in contributing areas" by 600 acres by 2033 and by 1200 acres by 2048.	Agricultural producers and agricultural landowners	Develop cost-share program in 2018				$2,000	NRCS, SWCD	NRCS, SWCD—advise on strategies for promoting practice
		Apply for additional grant funds for no-till equipment modifications annually for 10 years.				$2,000		
		Hold field day to promote no-till by the end of year 4.				$4,000		
		Implement 40 acres of no-till annually for 30 years	2.7	1.37	1600	$22,800 ($760 annually)		
Provide education about appropriate times to spread manure.	Agricultural producers	Hold an educational event regarding proper manure storage and application where CFOs are the most concentrated in 2018.				$2,500	SWCDs, NRCS	NRCS, SWCD—provide information and share expertise at educational event
		Include information in BMP brochure that is distributed to stakeholders.				NA		
		Ask 10 producers annually for five years to sign pledge to follow recommended manure storage and application methods.				$200		
		TOTAL	79.8205	12.54	3903	$1,029,322		
		Required Load Reduction for Gray Branch (from Upper Mississinewa River WMP)	213	21	1578			
		Total Load of Gray Branch	251	48	2535			
		Percent Reduction Achieved	32%	26%	153%			

TABLE 16.14 | Action Register for Halfway Creek Subwatershed

Halfway Creek Critical For: Phosphorus–Tier I								
Action Item	**Target Audience**	**Milestones**	**Load Reduction - N (tons/yr)**	**Load Reduction - Phos (tons/yr)**	**Load Reduction - TSS (tons/yr)**	**Cost**	**Possible Partners**	**Technical Assistance**
Increase the use of MRTN on 4,000 acres by 2033 and on 8,000 acres by 2048.	Agricultural producers and landowners	Promote the use of MRTN at field days; promote the use of Iowa State's Corn Nitrogen Rate Calculator				$5,000	NRCS, SWCDs	NRCS, SWCDs—advise on how to promote practice
		Enhance website with information on MRTN and link to calculator by the end of year 1.				$2,500		
		Implement 542 acres of MRTN fertilizer application practice annually for 30 years	3	3		none		
Increase the use of cover crops in "contributing areas" by 4,000 acres by 2033 and by 8,000 acres by 2048.	Agricultural producers and agricultural landowners	Develop cost-share program in 2018				$1,000	SWCDs, NRCS	IDNR, NRCS, SWCD—assist in identifying sites
		Identify land that is in "contributing areas" adjacent to waterways. Contact 15 landowners from the list annually for 5 years.				$6,000		
		Apply for additional grant funds for cover crops annually for 5 years.				$10,000		
		Implement 131 acres of cover crops annually for 30 years.	6	5	1,800	$78,500 ($2,617 annually)		
Increase the use of filter strips in "collection zones" by 18 acres by 2033 and by 36 acres by 2048.	Agricultural producers, agricultural landowners, and rural landowners	Develop cost-share program in 2018				$1,000	Red-tail Land Conservancy, IDNR and Wilbur Wright FWA managers, SWCDs, NRCS, TNC	IDNR, NRCS, SWCD—assist in identifying sites; advise on design and installation
		Create a list of landowners who may want filter strips. Contact at least 15 landowners from the list annually for 5 years.				$6,000		
		Apply for additional grant funds for filter strips annually for 5 years.				$10,000		
		Implement 2 acres of filter strips annually for 30 years	0.067	0.034	55	$16,632 ($554 annually)		

TABLE 16.14 | Action Register for Halfway Creek Subwatershed (continued)

Increase the use of no till “in contributing areas” by 3,000 acres by 2033 and by 6,000 acres by 2048.	Agricultural producers and agricultural landowners	Develop cost-share program in 2018				$2,000	NRCS, SWCD	NRCS, SWCD—advise on strategies for promoting practice
		Apply for additional grant funds for no-till equipment modifications annually for 10 years.				$2,000		
		Hold field day to promote no-till by the end of year 4.				$4,000		
		Implement 40 acres of no-till annually for 30 years	6.7	3	4794	$11,400 ($380 annually)		
		TOTAL	15.77	11.034	6,649	$156,032		
		Required Load Reduction for Halfway Creek (from Upper Mississinewa River WMP)	17	11	none			
		Total Load of Halfway Creek	43	29	341			
		Percent Reduction Achieved	37%	38%	1949%			

TABLE 16.15 | Action Register for Deer Creek Subwatershed

Deer Creek Critical For: Nitrate–Tier I								
Action Item	**Target Audience**	**Milestones**	**Load Reduction - N (tons/yr)**	**Load Reduction - Phos (tons/yr)**	**Load Reduction - TSS (tons/yr)**	**Cost**	**Possible Partners**	**Technical Assistance**
Increase restored wetlands by 487 acres by 2033 and by 975 acres by 2048.	Agricultural and rural landowners	Develop cost-share program in 2018				$1,000	Red-tail Land Conservancy, IDNR and Wilbur Wright FWA managers, SWCDs, NRCS, TNC	IDNR, NRCS, SWCD—assist in identifying sites; advise on permitting, design, and installation
		Identify sites that could potentially be restored to wetlands. Contact at least 8 landowners from the list annually for five years.				$6,000		
		Apply for additional grant funds for identified wetland restoration projects annually for 5 years.				$10,000		
		Enhance website with photos and descriptions of restored wetlands in the watershed annually for 5 years.				$3,000		
		Restore 32 acres of wetlands annually for 30 years.	18	0.49	324	$194,920 (6,497 annually)		
Increase restored prairies by 48 acres by 2033 and by 97 acres by 2048.	Agricultural and rural landowners	Develop cost-share program in 2018				$1,000	Red-tail Land Conservancy, IDNR and Wilbur Wright FWA managers, SWCDs, NRCS, TNC	IDNR, NRCS, SWCD—assist in identifying sites; advise on design and installation
		Identify sites that could potentially be restored to prairie. Contact at least 15 landowners from the list annually for five years.				$6,000		
		Apply for additional grant funds for identified prairie restoration projects annually for 5 years.				$10,000		
		Enhance website with photos and descriptions of restored prairies in the watershed annually for 5 years.				$3,000		
		Restore 3.25 acres annually for 30 years				$88,689 (2,956 annually)		

TABLE 16.15 | Action Register for Deer Creek Subwatershed (continued)

Action Item	Target Audience	Milestones	Load Reduction - N (tons/yr)	Load Reduction - Phos (tons/yr)	Load Reduction - TSS (tons/yr)	Cost	Possible Partners	Technical Assistance
Increase the use of MRTN on 4,337 acres by 2033 and on 8,674 acres by 2048.	Agricultural producers and landowners	Promote the use of MRTN at field days; promote the use of Iowa State's Corn Nitrogen Rate Calculator				$5,000	NRCS, SWCDs	NRCS, SWCDs—advise on how to promote practice
		Enhance website with information on MRTN and link to calculator				$2,500		
		Implement 289 acres of MRTN fertilizer application practice annually for 30 years	34	3		none		
Increase the use of cover crops by 2,437 acres by 2033 and by 4,873 by 2048.	Agricultural producers and agricultural landowners	Create a cost-share program in 2018.				$1,000	NRCS, SWCDs, Purdue Extension	NRCS, SWCDs, Purdue Extension—provide information on contractors who can seed and/or terminate cover crops, as well as information on what cover crops are successful locally; also provide list of producers who are currently using cover crops
		Create a list of contractors who seed covercrops and the methods they can use.				$2,500		
		Seek additional cover crop funding annually.				$2,500		
		Locate land in high-traffic areas for possible demonstration plot. Contact landowners to see if any are interested in having a demonstration plot on their property. Develop signage for plot.				$7,500		
		Enhance website with information about the various types of cover crops, seeding and termination methods, as well as videos of area producers who have had success with cover crops.				$5,000		
		Implement 162 new acres of cover crops annually for 30 years.	38	1.95	2,428	$233,904 ($7,797 annually)		
Increase the use of filter strips by 25 acres by 2033 and by 50 acres by 2048	Agricultural producers; agricultural landowners; rural landowners	Create a cost-share program in 2018.				$1,000	NRCS, SWCDs	NRCS, SWCDs—provide information about NRCS cost-share programs, explain how these programs work; provide technical information for installation
		Create a list of landowners who may want filter strips. Contact at least 15 landowners from the list annually.				$2,500		
		Seek additional funds annually				$2,500		
		Implement 1.67 acres of filter strips annually	0.1205	0.0399	52	$23,000 (770 annually)		

TABLE 16.15 | Action Register for Deer Creek Subwatershed (continued)

Action Item	Target Audience	Milestones	Load Reduction - N (tons/yr)	Load Reduction - Phos (tons/yr)	Load Reduction - TSS (tons/yr)	Cost	Possible Partners	Technical Assistance
Increase the acres under drainage water management by 828 by 2033 and by 1,657 by 2047.	Agricultural producers and agricultural landowners	Create a cost-share program in 2018				$1,000	NRCS, SWCDs	NRCS, SWCDs—provide information about NRCS cost-share programs, explain how these programs work; provide design guidance; provide technical information for installation; assist in identifying land suitable for DWM
		Create a list of landowners whose land is suitable for drainage water management and contact 20 people on the list annually				$2,500		
		Seek additional funds annually				$2,500		
		Enhance the website by adding information on drainage water management; video local producers using DWM and add videos to website				$5,000		
		Install enough drainage water management systems to treat 55 acres annually for 30 years.	15			$198,818 ($6,627 annually)		
Increase the acres being treated by bioreactors by 146 acres by 2033 and by 292 acres by 2047.	Agricultural producers and agricultural landowners	Create a cost-share program in 2018				$1,000	NRCS, SWCDs, Ivy Tech Marion, Indiana Wesleyan, Taylor University	NRCS, SWCDs—provide design assistance; share information at workshop
		Locate land in high-traffic areas for possible demonstration bioreactor. Contact landowners to see if any are interested in having a demonstration bioreactor on their property. Develop signage for the bioreactor.				$2,500		
		Seek additional funds annually				$2,500		
		Hold a bioreactor workshop at the demonstration bioreactor site.				$5,000		
		Enhance website by adding information on bioreactors; video the installation of the demonstration bioreactor and add video to website				$5,000		
		Install enough bioreactors to treat 10 acres annually for 30 years.	3			$58,476 ($1,949 annually)		

TABLE 16.15 | Action Register for Deer Creek Subwatershed (continued)

Action Item	Target Audience	Milestones	Load Reduction - N (tons/ yr)	Load Reduction - Phos (tons/yr)	Load Reduction - TSS (tons/yr)	Cost	Possible Partners	Technical Assistance
		TOTAL	108	5.48	2,804	$896,807		
		Required Load Reduction for Deer Creek (from Upper Mississinewa River WMP)	245	83*	8,354			
		Total Load of Deer Creek	355	179*	16,348			
		Percent Reduction Achieved	30%	3%	17%			

TABLE 16.16 | Action Register for Bush Creek Subwatershed

Action Item	Target Audience	Milestones	Load Reduction - N (tons/yr)	Load Reduction - Phos (tons/yr)	Load Reduction - TSS (tons/yr)	Cost	Possible Partners	Technical Assistance
Bush Creek Critical For: Nitrate–Tier I								
Increase restored wetlands by 261 acres by 2033 and by 521 acres by 2048.	Agricultural and rural landowners	Develop cost-share program in 2018				$1,000	Red-tail Land Conservancy, IDNR and Wilbur Wright FWA managers, SWCDs, NRCS, TNC	IDNR, NRCS, SWCD—assist in identifying sites; advise on permitting, design, and installation
		Identify sites that could potentially be restored to wetlands. Contact at least 8 landowners from the list annually for five years.				$6,000		
		Apply for additional grant funds for identified wetland restoration projects annually for 5 years.				$10,000		
		Enhance website with photos and descriptions of restored wetlands in the watershed annually for 5 years.				$3,000		
		Restore 17 acres of wetlands annually for 30 years.	7	0.35	495	$194,920 (6,497 annually)		
Increase restored prairies by 261 acres by 2033 and by 521 acres by 2048.	Agricultural and rural landowners	Develop cost-share program in 2018				$1,000	Red-tail Land Conservancy, IDNR and Wilbur Wright FWA managers, SWCDs, NRCS, TNC	IDNR, NRCS, SWCD—assist in identifying sites; advise on design and installation
		Identify sites that could potentially be restored to prairie. Contact at least 15 landowners from the list annually for five years.				$6,000		
		Apply for additional grant funds for identified prairie restoration projects annually for 5 years.				$10,000		
		Enhance website with photos and descriptions of restored prairies in the watershed annually for 5 years.				$3,000		
		Restore 17 acres annually for 30 years	7	0.50	601	$88,689 (2,956 annually)		

TABLE 16.16 | Action Register for Bush Creek Subwatershed (continued)

Action Item	Target Audience	Milestones	Load Reduction - N (tons/yr)	Load Reduction - Phos (tons/yr)	Load Reduction - TSS (tons/yr)	Cost	Possible Partners	Technical Assistance
Increase the use of extended rotations by 261 acres by 2033 and by 521 acres by 2048.	Agricultural landowners	Identify landowners who may be most likely to adopt extended rotations				$2,000	NRCS, SWCD	NRCS, SWCD—advise on strategies for promoting practice
		Seek financial incentives for the adoption of extended rotations				$2,000		
		Hold field day to promote extended rotations				$4,000		
		Implement 17 acres annually for 30 years	3			none		
Increase the use of MRTN on 4,431 acres by 2033 and on 8,863 acres by 2048.	Agricultural producers and landowners	Promote the use of MRTN at field days; promote the use of Iowa State's Corn Nitrogen Rate Calculator				$5,000	NRCS, SWCDs	NRCS, SWCDs—advise on how to promote practice
		Enhance website with information on MRTN and link to calculator				$2,500		
		Implement 295 acres of MRTN fertilizer application practice annually for 30 years	9	3		none		
Increase the use of cover crops by 2,880 acres by 2033 and by 5,761 by 2048.	Agricultural producers and agricultural landowners	Create a cost-share program in 2018.				$1,000	NRCS, SWCDs, Purdue Extension	NRCS, SWCDs, Purdue Extension—provide information on contractors who can seed and/or terminate cover crops, as well as information on what cover crops are successful locally; also provide list of producers who are currently using cover crops
		Create a list of contractors who seed covercrops and the methods they can use.				$2,500		
		Seek additional cover crop funding annaully.				$2,500		
		Locate land in high-traffic areas for possible demonstration plot. Contact landowners to see if any are interested in having a demonstration plot on their property. Develop signage for plot.				$7,500		
		Enhance website with information about the various types of cover crops, seeding and termination methods, as well as videos of area producers who've had success with cover crops.				$5,000		
		Implement 192 new acres of cover crops annually for 30 years.	19	3	4,057	$233,904 ($7,797 annually)		

TABLE 16.16 | Action Register for Bush Creek Subwatershed (continued)

Action Item	Target Audience	Milestones	Load Reduction - N (tons/yr)	Load Reduction - Phos (tons/yr)	Load Reduction - TSS (tons/yr)	Cost	Possible Partners	Technical Assistance
Increase the use of filter strips by 25 acres by 2033 and by 50 acres by 2048	Agricultural producers; agricultural landowners; rural landowners	Create a cost-share program in 2018.				$1,000	NRCS, SWCDs	NRCS, SWCDs—provide information about NRCS cost-share programs, explain how these programs work; provide technical information for installation
		Create a list of landowners who may want filter strips. Contact at least 15 landowners from the list annually.				$2,500		
		Seek additional funds annually				$2,500		
		Implement 1.67 acres of filter strips annually	0.1205	0.0399	52	$23,000 (770 annually)		
Increase the acres under drainage water management by 487 by 2033 and by 975 by 2047.	Agricultural producers and agricultural landowners	Create a cost-share program in 2018				$1,000	NRCS, SWCDs	NRCS, SWCDs—provide information about NRCS cost-share programs, explain how these programs work; provide design guidance; provide technical information for installation; assist in identifying land suitable for DWM
		Create a list of landowners whose land is suitable for drainage water management and contact 20 people on the list annually				$2,500		
		Seek additional funds annually				$2,500		
		Enhance the website by adding information on drainage water management; video local producers using DWM and add videos to website				$5,000		
		Install enough drainage water management systems to treat 32 acres annually for 30 years.	4			$198,818 ($6,627 annually)		

TABLE 16.16 | Action Register for Bush Creek Subwatershed (continued)

Action Item	Target Audience	Milestones	Load Reduction - N (tons/yr)	Load Reduction - Phos (tons/yr)	Load Reduction - TSS (tons/yr)	Cost	Possible Partners	Technical Assistance
Increase the acres being treated by bioreactors by 177 acres by 2033 and by 355 acres by 2047.	Agricultural producers and agricultural landowners	Create a cost-share program in 2018				$1,000	NRCS, SWCDs, Ivy Tech Marion, Indiana Wesleyan, Taylor University	NRCS, SWCDs—provide design assistance; share information at workshop
		Locate land in high-traffic areas for possible demonstration bioreactor. Contact landowners to see if any are interested in having a demonstration bioreactor on their property. Develop signage for the bioreactor.				$2,500		
		Seek additional funds annually				$2,500		
		Hold a bioreactor workshop at the demonstration bioreactor site.				$5,000		
		Enhance website by adding information on bioreactors; video the installation of the demonstration bioreactor and add video to website				$5,000		
		Install enough bioreactors to treat 12 acres annually for 30 years.	2			$58,476 ($1,949 annually)		
		TOTAL	50	6.85	5,153	$875,807		
		Required Load Reduction for Bush Creek (from Upper Mississinewa River WMP)	147	none needed	122			
		Total Load of Bush Creek	168		641			
		Percent Reduction Achieved	30%		803%			

TABLE 16.17 | Action Register for Halfway Creek Subwatershed

Little Lick Creek Critical For: Phosphorus and E. Coli –Tier I								
Action Item	**Target Audience**	**Milestones**	**Load Reduction - N (tons/yr)**	**Load Reduction - Phos (tons/yr)**	**Load Reduction - TSS (tons/yr)**	**Cost**	**Possible Partners**	**Technical Assistance**
Install fencing to restrict livestock from streams. Install watering systems if needed.	Agricultural producers	Develop a cost-share program in 2018.				$1,000	SWCDs, NRCS, Purdue Extension	NRCS, SWCD—provide technical assistance in design and installation
		Contact landowners identified through desktop survey as having livestock that directly access streams.				$6,000		
		Apply for additional cost-share funds annually.				$10,000		
		Install fencing on two properties annually for 6 years.				$96,000 (6,000 annually)		
Provide education about appropriate times to spread manure.	Agricultural producers	Hold an educational event regarding proper manure storage and application where CFOs are the most concentrated in 2018.				$2,500	SWCDs, NRCS	NRCS, SWCD—provide information and share expertise at educational event
		Include information in BMP brochure that is distributed to stakeholders.				NA		
		Ask 10 producers annually to sign pledge to follow recommended manure storage and application methods.				$200		
Provide education on proper septic system maintenance.	Suburban/rural residents on septic systems	Hold an educational event regarding proper septic system maintenance in an area with a high concentration of septic systems in 2019.				$2,500	Local health departments	Local health departments—help develop brochures, assist in asking residents to pledge, provide information regarding businesses that pump septic systems and perform other maintenance and repair on septic systems.
		Include information in BMP brochure that is distributed to stakeholders.				NA		
		Ask 50 stakeholders annually to sign pledge to conduct routine maintenance on septic systems.				$1,000		

TABLE 16.17 | Action Register for Halfway Creek Subwatershed (continued)

Action Item	Target Audience	Milestones	Load Reduction - N (tons/yr)	Load Reduction - Phos (tons/yr)	Load Reduction - TSS (tons/yr)	Cost	Possible Partners	Technical Assistance
Provide education on proper pet waste disposal	Urban and suburban residents	Install an educational signs and pet waste bag dispensers at five city or suburban parks.				$2,500	Hartford City Parks Department, suburban neighborhood associations	Clean Water Indiana; local SWCD
		Include information about pet waste in urban BMP brochure that is distributed to stakeholders.				NA		
		Ask 50 stakeholders annually to sign pledge to properly dispose of pet waste.				$1,000		
Increase the use of MRTN on 4,000 acres by 2033 and on 8,000 acres by 2048.	Agricultural producers and landowners	Promote the use of MRTN at field days; promote the use of Iowa State's Corn Nitrogen Rate Calculator				$5,000	NRCS, SWCDs	NRCS, SWCDs—advise on how to promote practice
		Enhance website with information on MRTN and link to calculator by the end of year 1.				$2,500		
		Implement 542 acres of MRTN fertilizer application practice annually for 30 years	3	3		none		
Increase the use of cover crops in "contributing areas" by 4,000 acres by 2033 and by 8,000 acres by 2048.	Agricultural producers and agricultural landowners	Develop cost-share program in 2018				$1,000	SWCDs, NRCS	IDNR, NRCS, SWCD—assist in identifying sites
		Identify land that is in "contributing areas" adjacent to waterways. Contact 15 landowners from the list annually for 5 years.				$6,000		
		Apply for additional grant funds for cover crops annually for 5 years.				$10,000		
		Implement 131 acres of cover crops annually for 30 years.	6	5	1,800	$78,500 ($2,617 annually)		
Increase the use of filter strips in "collection zones" by 18 acres by 2033 and by 36 acres by 2048.	Agricultural producers, agricultural landowners, and rural landowners	Develop cost-share program in 2018				$1,000	Red-tail Land Conservancy, IDNR and Wilbur Wright FWA managers, SWCDs, NRCS, TNC	IDNR, NRCS, SWCD—assist in identifying sites; advise on design and installation
		Create a list of landowners who may want filter strips. Contact at least 15 landowners from the list annually for 5 years.				$6,000		
		Apply for additional grant funds for filter strips annually for 5 years.				$10,000		
		Implement 2 acres of filter strips annually for 30 years	0.067	0.034	55	$16,632 ($554 annually)		

TABLE 16.17 | Action Register for Halfway Creek Subwatershed (continued)

Action Item	Target Audience	Milestones	Load Reduction - N (tons/yr)	Load Reduction - Phos (tons/yr)	Load Reduction - TSS (tons/yr)	Cost	Possible Partners	Technical Assistance
Increase the use of no till "in contributing areas" by 3,000 acres by 2033 and by 6,000 acres by 2048.	Agricultural producers and agricultural landowners	Develop cost-share program in 2018				$2,000	NRCS, SWCD	NRCS, SWCD—advise on strategies for promoting practice
		Apply for additional grant funds for no-till equipment modifications annually for 10 years.				$2,000		
		Hold field day to promote no-till by the end of year 4.				$4,000		
		Implement 40 acres of no-till annually for 30 years	6.7	3	4794	$11,400 ($380 annually)		
		TOTAL	15.77	11.034	6,649	$156,032		
		Required Load Reduction for Halfway Creek (from Upper Mississinewa River WMP)	17	11	none			
		Total Load of Halfway Creek	43	29	341			
		Percent Reduction Achieved	37%	38%	1949%			

17. TRACKING EFFECTIVENESS

17.1 TRACKING EFFECTIVENESS

The success of implemented strategies shall be monitored using a variety of methods, dictated by the specific strategy or milestone being measured:

WATER QUALITY MONITORING AND MODELING
Water quality modeling and monitoring will be completed at a cost of $30,000 over two rounds of implementation (lasting a total of six years). Water quality data collected by other agencies and groups during the implementation phases will also be reviewed and analyzed. After six years, water quality goals should be 40% complete, meaning the modeled and monitored loads should be 40% of the modeled and monitored loads.

Water quality modeling will be completed after the first and second rounds of implementation (each round will last 3 years). Nitrate and phosphorus reductions will be modeled using BMP efficiencies from the Iowa Nutrient Reduction Strategy will be used to model reductions using the Project Manager's own modeling technique. Sediment reductions will be modeled using the Region 5 model.

SWCDs will track each BMP implemented along with acreage in an Excel spreadsheet—this will be used for the modeling. The Project Manager or one of the SWCDs within the UMRW-P will complete the models at a cost $2,500 each.

Following the second round of implementation, formal water quality monitoring will be conducted near the pour points of each HUC12 critical area. Sites will be sampled monthly for one year. The Project Manager or a private contractor will be contracted to conduct the monitoring, at a cost of $20,000. The parameters measured at each site will be as follows: temperature, pH, dissolved oxygen, depth, velocity, nitrate [N], total phosphorus, turbidity, TSS, and E. coli. All parameters will be measured at each site because many of the sites did not meet the target for more than one of the parameters, and many of the BMPs that will be funded can bring about reductions in a several parameters. Biological monitoring and a habitat assessment will also be conducted at each site. The water quality monitoring program will follow the QAPP used for water quality monitoring program completed for this watershed management plan, or a new QAPP will be completed. Technical assistance for the development of a new QAPP can be sought from IDEM's OWQ QA/QC Coordinator, Betty Ratcliff (ph. 317-308-3135).

A review of current water quality from other sources will be conducted at the end of each implementation phase by requesting data collected in the critical areas from the AIMS and STORET databases. Hoosier Riverwatch data will also be reviewed. All water quality data will be compiled in an Excel spreadsheet. The Project Manager or one of the SWCDs within the UMRW-P will conduct the reviews at an estimated cost of $2,500 each. Technical assistance from Jessica Faust (317-308-3190), IDEM's OWQ Watershed Specialist for this region, may be needed for obtaining data.

Modeling, monitoring, and the collection of current data from other agencies and groups should be repeated in this pattern unless a revision is made. As specified above, modeling and the review of other current data should be completed every three years. Formal water quality monitoring should be conducted every six years.

TRACKING ADMINISTRATIVE AND SOCIAL OBJECTIVES
Local NRCS and SWCDs will be asked to track (in a provided spreadsheet) those who receive cost-share funds, the practices and acreages for which the cost-share funds are distributed, the cost to install each practice, as well as the number of persons who would like to be included in the Conservation Farmer Directory. Local NRCS and SWCDs will track the number of cost-share applications they receive and also include the applicants' names, addresses, and the BMPs they were applying for in the spreadsheet. The Delaware County SWCD or the Project Manager will track attendance at field days, meetings, and other events hosted as part of implementation.

A variety of other partners will be asked to participate in tracking efforts. Local health departments will be asked to track the number of brochures that they distribute about septic system maintenance (brochures will either be created by the watershed group, supplied by the watershed group, or created as part of a joint effort). Red-tail Land Conservancy and other parks will be asked to track hours of volunteers who are volunteering as a result of the watershed group's efforts. Ball State and Taylor Universities will be asked to track the number of students working on projects for the watershed group and the number of hours spent working on the project. County surveyors will be asked to report any education or work that was influenced by the watershed group (i.e., attending a two-stage ditch workshop; two-stage ditch or stabilization project at a site prioritized through the watershed group's BEHI/NBS analysis but not funded through cost-share). Furthermore, sediment reduction estimates through these types of projects will be estimated by one of the project partners (most likely Taylor University since they are currently involved in BEHI/NBS analysis on Walnut Creek). Volunteer monitoring activity will be tracked through the Hoosier Riverwatch database.

All participating entities will also be asked to track the amount of time dedicated to each task performed. The outcomes will be weighed against the number of administrative hours to determine if certain actions are more cost-effective than others (e.g. if data shows that contacting stakeholders by phone is more effective at bringing about BMP implementation than hosting an educational event, in the future more resources may be devoted to reaching out to stakeholders by phone rather than hosting educational events).

The cost associated with all of these tracking efforts is minimal and regarded as part of task itself, which is already budgeted for in this watershed management plan. However, the creation of the Excel spreadsheet tracking form is estimated to cost $2,500. This spreadsheet will be created by the Delaware County SWCD or the Project Manager. Each of the eleven objectives list under Goal #1, *Provide Education and Form Partnerships*, and Goal #2, *Improve Water Quality of the Upper Mississinewa River and Its Tributaries*, will have a separate Excel spreadsheet. Each spreadsheet will have a separate sheet (i.e. tab at the bottom) for each action item. All partners participating in tracking outcomes will be asked to submit a copy of their spreadsheet via e-mail quarterly. Partners will be asked to participate on a voluntary basis without any financial compensation. The Excel tracking spreadsheet will be created by the Delaware County SWCD or the Project Manager once funding for the first round of implementation has been secured.

At the end of the second phase of implementation a social survey will be developed and distributed to stakeholders. The social survey will measure change in knowledge about how practices throughout the watershed impact water quality; change in attitude toward water quality and practices that can improve it; the level of awareness about the watershed group, its activities, and cost-share opportunities it promotes; and the stakeholder's level of confidence in the watershed group. The survey may measure other parameters and is not limited to these.

The Delaware County SWCD or the Project Manager will develop and distribute social surveys, enter data into an Excel spreadsheet, and analyze data. Data will be included in the final project report for the second phase of implementation. The estimated cost of the survey is $8,000.

TABLE 17.1 | Total Costs for Watershed Management Plan Goals

Goal #1, Objective #1 (Build local capacity for volunteers for monitoring, etc.)	$86,000
Goal #1, Objective #2 (Provide education and form partnerships with Agricultural Landowners)	$18,360
Goal #1, Objective #3 (Provide education and form partnerships with Ecological Landowners)	$19,520
Goal #1, Objective #4 (Provide education and form partnerships with Recreational Enthusiasts)	$32,100
Goal #1, Objective #5 (Provide education and form partnerships with Health Departments)	$2,740
Goal #1, Objective #6 (Provide education and form partnerships with County Drainage Boards/Surveyor)	$10,360
Goal #1, Objective #7 (Perform policy research and develop educational resources to promote citizen involvement in county/ municipal planning and policy-making)	$18,330
Goal #2 (In Critical Areas reduce nitrate loading by 204 tons/yr (15%) in 15 years and by 403 tons/yr (30%) in 30 years). *Assuming implementation begins in 2018.	$3,881,573.00
Goal #3 (In Critical Areas reduce TSS loading by 1,191 tons/yr (25%) in 15 years and by 2,381 tons/yr (50%) in 30 years). *Assuming implementation begins in 2018.	$148,532.00
Goal #4 (In Critical Areas reduce phosphorus loading by 31 tons/yr (25%) in 15 years and by 61 tons/yr (50%) in 30 years). *Assuming implementation begins in 2018.	$2,247,242.00
Goal #5 (In Critical Areas reduce E. coli loading by 2.6E+14 cfu/year (5%) in 15 years and by 7.87E+14 cuf/year (15%) in 30 years. *Assuming implementation begins in 2018.)	$119,200.00
Grand Total	**$6,583,957**

18. FUTURE ACTIVITY

The Project Manager will document what works well and what doesn't during the implementation phase. The Delaware County SWCD will formally review progress of the implementation phase annually, and determine if any revisions should be made to the action register of the plan. The WMP will be formally revised in 10 years by the Delaware County Soil and Water Conservation District (3641 N. Briarwood Lane Muncie, Indiana 47304 | 765. 747. 5531) and will be submitted to IDEM for approval.

ANNUAL PLAN REVISION

Because this watershed management plan has such a wide variety of goals and objectives, it is necessary to informally revise it every year based on the effectiveness of objectives, action items, and milestones. The effectiveness of each objective will be reviewed, and one of the following changes will be made if it is not viewed as effective: 1) Action Item will be removed if it is viewed as ineffective and possibly replaced with a new Action Item or 2) Milestone(s) will be removed, altered, or replaced if the Action Item is still regarded as sound but the steps identified for reaching it (i.e., Milestones) are ineffective. If certain Action Items intended to reach objectives are found to be highly effective, other Action Items that are less effective may be removed in order to focus efforts on the Action Item that is highly effective. Again, because there are so many objectives and Action Items identified in this watershed management plan, we expect that it will take at least 5 years to meet many of the administrative, educational, and social objectives, and even longer to reach water quality goals. At the end of the second round of implementation, if 80% of the action items pertaining to administrative, educational, and social objectives have been completed, then administrative, educational, and social objectives (Objectives #1-7) will be comprehensively revised. If not, then the Steering Committee should decide the next time to consider comprehensively revising the plan.

Data from the excel spreadsheets used to track the effectiveness of the plan will be compiled, summarized, and reported at Steering Committee meetings after each year of implementation has been completed. This data will aid the Steering Committee in determining the effectiveness of Action Items outlined in the Action Register.

Data from modeling and monitoring will be evaluated after each implementation phase to determine if any subwatershed water quality goals have been met. Once a goal has been met in a subwatershed, cost-share funding will no longer be directed to that subwatershed.

REVISION OF FINANCIAL COSTS OF PLAN IMPLEMENTATION

BMPs implemented through the cost-share program will be tracked in a spreadsheet. Costs of BMPs and acres treated will be recorded and used to calculate average costs per unit area treated for each BMP (or median cost per unit area). This data will be used to provide a new estimation of the financial cost to reach BMP objectives found on (see totals in Table 17.1) . While it will not immediately or necessarily replace the current estimate within the plan, it will be there for comparative purposes and may be used in future grant applications (i.e. "To date the drainage water management systems installed through cost-share programs have cost a total of x dollars and treated x acres of cropland, with an average cost of $x/acre treated). Tables displaying this data and a short explanation should be added to the plan one year after the implementation begins, and should be updated annually. Three years after implementation begins, the Steering Committee should consider if new estimates for BMP costs (#29) should be developed from current data from the cost-share program. This should be reconsidered on a three-year cycle, unless costs appear to be relatively stable, in which case revisions are not necessary until a comprehensive revision of the plan.

OTHER STEERING COMMITTEE ACTIVITIES

The Steering Committee will also continue to review and discuss the following: new non-point source pollutant concerns (e.g. zoning for a new development is pending, etc.), new watershed information (e.g., new planning efforts, such as city/county master plans, etc.), and new practices added to the Field Office Technical Guide (FOTG). Any other information relative to the watershed management plan should also be reviewed and discussed. If necessary, revisions to the plan will be made based on new information.

COMPREHENSIVE PLAN REVISION

After 10 years the watershed management plan will be comprehensively revised. Revisions will include but are not limited to supplemental water quality data collected through the tracking effectiveness strategy, the identification of any new critical areas based on water quality data collected through Hoosier Riverwatch or other monitoring efforts in the watershed, and an updated Action Register.

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A. PUBLIC INPUT

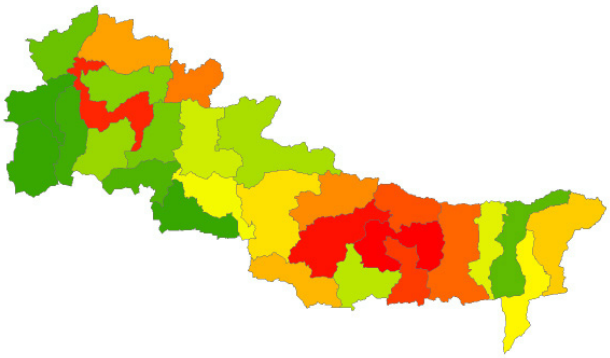


FIG. A.1 | HUC 12 landowner response percentage.
The color gradient follows the visible spectrum, moving from reds to oranges to yellows to greens. Highest values are represented by red and lowest values by green.

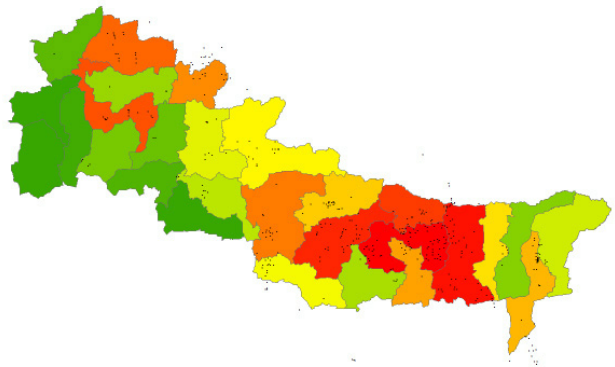


FIG. A.2 | Landowners response from mailing campaign.
The color gradient follows the visible spectrum, moving from reds to oranges to yellows to greens. Highest values are represented by red and lowest values by green. Dots indicate the properties of landowners who responded.

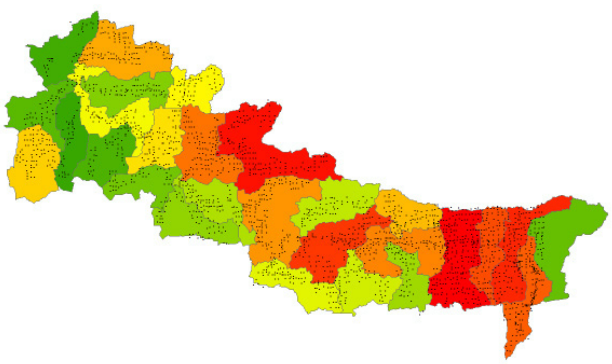


FIG. A.3 | Landowners targeted with mailing campaign.
The color gradient follows the visible spectrum, moving from reds to oranges to yellows to greens. Highest values are represented by red and lowest values by green. Dots indicate the properties of landowners who were targeted.

B. GEOLOGY & HYDROLOGY

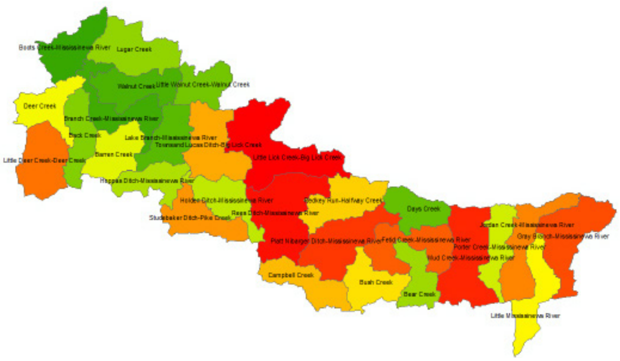


FIG. B.1 | D Soils

Subwatersheds are ranked on a gradient (red high and green low) based on the presence of D soil types. The highest percentage of poorly drained D soils are Blackford County and in the Tri-County Region.

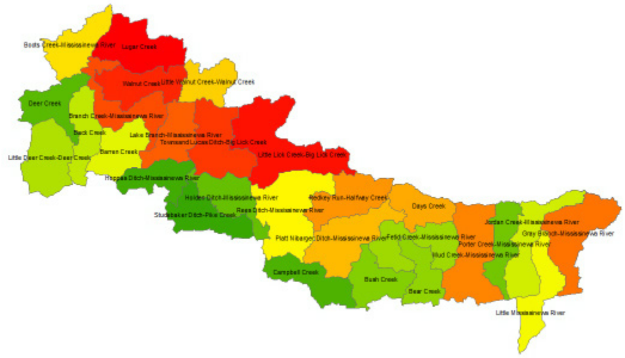


FIG. B.2 | C Soils

Subwatersheds are ranked on a gradient (red high and green low) based on the presence of C soil types. The highest percentage of moderately drained C soils are in the northwestern part of the watershed in Blackford and Grant County.

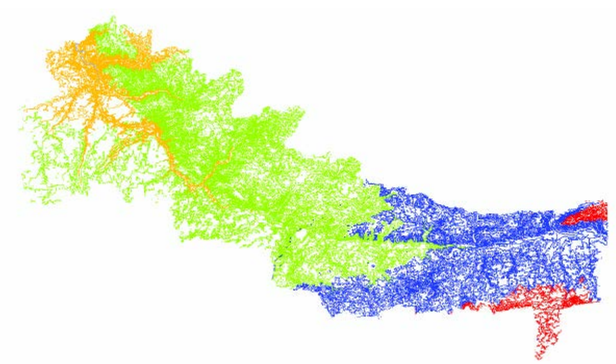


FIG. B.3 | Topography In 100 Foot Intervals

There is a 380 feet change in elevation over the course of the watershed. This change in elevation is represented in 100 foot intervals. The highest elevation is 1170 feet above sea level and lowest elevation is 790 feet above sea level.

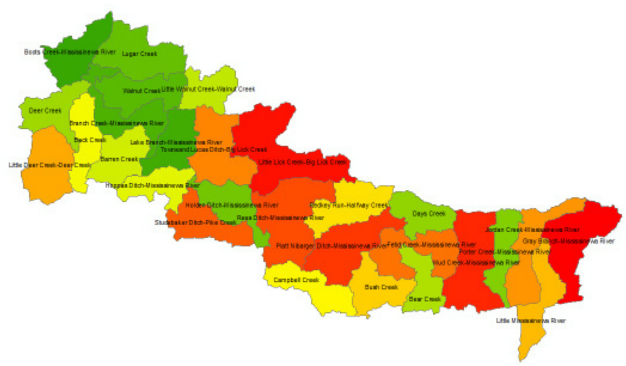


FIG. B.4 | Hydric Soils

Subwatersheds are ranked on a gradient (red high and green low) based on hydric soil percentage. Hydric soils are prevalent throughout the watershed region. Subwatersheds with limited grade have the highest concentration of hydric soils.

TABLE B.1 | Geomorphological Studies									
PARAMETERS	Rb	Dd	Fu	Rr	Rf	Rc	Re	RN	Rank (Dd, Fu,Rr)
Back Creek	2.1	9.7	80.2	7.8	0.3	0.4	1.2	970.9	14.0
Barren Creek	2.1	9.5	76.3	8.3	0.6	0.5	1.8	760.2	19.0
Bear Creek	2.1	9.3	81.6	12.4	0.4	0.3	1.4	1117.0	8.7
Boots Creek-Mississinewa River	1.9	9.7	80.3	22.8	2.4	0.4	3.6	1065.1	6.7
Branch Creek-Mississinewa River	2.0	9.3	75.5	8.5	0.2	0.1	1.1	1389.3	20.0
Bush Creek	2.0	9.1	80.0	16.2	0.8	0.4	2.1	1180.8	11.3
Campbell Creek	1.9	8.9	76.5	12.1	0.3	0.3	1.3	1392.5	16.3
Days Creek	1.9	10.1	83.0	14.0	1.1	0.4	2.2	910.1	3.0
Deer Creek	2.2	7.7	64.0	11.2	0.8	0.3	2.0	691.8	21.3
Fetid Creek-Mississinewa River	1.8	8.7	80.4	9.0	0.4	0.2	1.7	1038.3	16.0
Gray Branch-Mississinewa River	1.8	2.2	16.5	12.0	0.6	0.3	2.3	294.4	19.5
Holden Ditch-Mississinewa River	1.9	9.9	79.3	11.5	0.4	0.3	1.5	1290.4	10.7
Hoppas Ditch-Mississinewa River	2.1	9.8	79.4	14.0	1.0	0.3	2.1	879.9	9.0
Jordan Creek-Mississinewa River	2.0	8.2	71.1	17.4	1.0	0.2	2.6	1153.0	16.3
Lake Branch-Mississinewa River	2.2	9.4	80.5	24.9	2.2	0.4	3.3	1133.9	7.0
Little Deer Creek-Deer Creek	2.1	7.7	64.0	3.6	0.5	0.6	1.9	306.9	26.3
Little Lick Creek-Big Lick Creek	1.9	7.2	79.2	10.5	1.1	0.2	3.7	787.3	21.0
Little Mississinewa River	2.0	9.6	78.1	9.6	0.2	0.3	1.0	1626.7	16.0
Little Walnut Creek-Walnut Creek	2.2	9.6	81.9	8.7	0.7	0.4	1.7	674.5	10.7
Lugar Creek	1.9	8.4	80.5	10.9	0.5	0.4	1.9	1169.3	14.7
Mud Creek-Mississinewa River	2.0	7.6	79.9	16.6	1.0	0.4	3.0	1217.5	14.7
Platt Nibarger Ditch-Mississinewa River	2.0	7.9	81.4	8.6	0.7	0.3	2.4	712.5	16.7
Porter Creek-Mississinewa River	1.9	9.7	81.9	36.2	3.0	0.3	3.7	1357.2	3.0
Redkey Run-Halfway Creek	2.0	9.2	81.0	7.8	0.4	0.4	1.6	922.5	15.3
Rees Ditch-Mississinewa River	2.1	7.3	77.3	11.4	1.1	0.3	3.4	801.0	20.3
Studebaker Ditch-Pike Creek	2.0	9.6	78.4	7.5	0.4	0.3	1.5	862.4	18.0
Townsand Lucas Ditch-Big Lick Creek	2.0	7.9	79.6	10.7	0.6	0.4	2.2	952.6	17.7
Walnut Creek	1.9	9.0	82.3	11.7	0.4	0.3	1.5	1350.5	10.0

Bifurcation ratio (Rb) is the ratio of the number of stream segments of one order to the number of segments of the next higher order.[1]
Drainage density (Dd) is an areal morphometric relationship of the total length of streams per unit area.[2]
Stream frequency (Fu) is the total number of stream channels per unit area.[3]
Relief Ratio (Rr) measures the overall steepness of the watershed (Shumn, 1956).[4]
Form factor (Rf) is the ratio between the watershed area and the squared watershed length.
Circulatory Ratio (Rc) is the ratio between the area of the watershed and the area of the circle of the same perimeter as that of the watershed.[5]
Elongation Ratio (Re) is the ratio between the maximum length of the watershed and the diameter of the circle having the same area as that of the watershed.[6]

REGIONAL CHARACTERIZATION

Geomorphological rankings (Table B.1) correlate to observed topographical differences (based on 100 foot intervals, FIG B.3). Collectively, these studies have justified the categorization of the UMRW into five zones: Eastern Uplands, Tri-County Flatlands, Big Lick Creek, Grant County FlatLands, and the Northwestern Mississinewa River Moraine Valley. However, these categorizations are very similar to the HUC10 boundary delineations. Thefore, the HUC 10 delineations will be used as a basis of discussion in the subwatershed section and discussed in the final conclusions and recommendations.

1 Schumn, S.A. (1956). The evolution of drainage systems and slopes in bad lands at Perth, Amboi, New Jersey. Geol. Soc. Ame. Bull. 67 (5), pp. 597-646.
2 Horton RE (1932) Drainage basin characteristics. Trans Am Geophys Union 13:350–361
3 Ibid.
4 Schumn, S.A. (1956). The evolution of drainage systems and slopes in bad lands at Perth, Amboi, New Jersey. Geol. Soc. Ame. Bull. 67 (5), pp. 597-646.
5 Ibid.
6 Ibid.

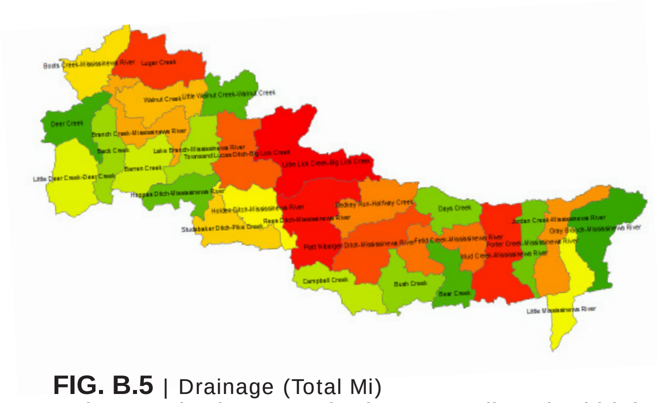


FIG. B.5 | Drainage (Total Mi)
Subwatersheds are ranked on a gradient (red high and green low) based on the presence of surficial drainage networks. The highest concentration of streams per Subwatershed are in Northern Grant County, Balckford County, and the Tri-county Region.

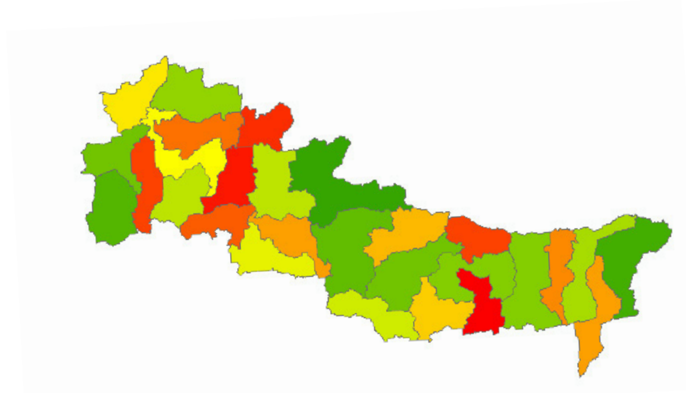


FIG. B.6 | Sediment Transport Prediction
Rankings for drainage density (Dd) stream frequency (Fu) and relief ratio (Rr) were averaged and subsequently ranked to prioritize subwatersheds with the greatest sediment transport potential (red high and green low).

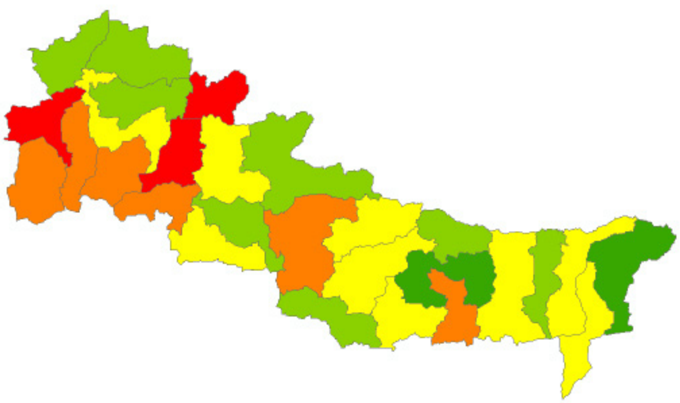


FIG. B.7 | Bifurcation Ratio
Subwatersheds are ranked on a gradient (red high and green low) based on the the ratio of the number of stream segments of one order to the number of segments of the next higher order. Definition of bifurcation ration taken from Ritter et al., 2011.

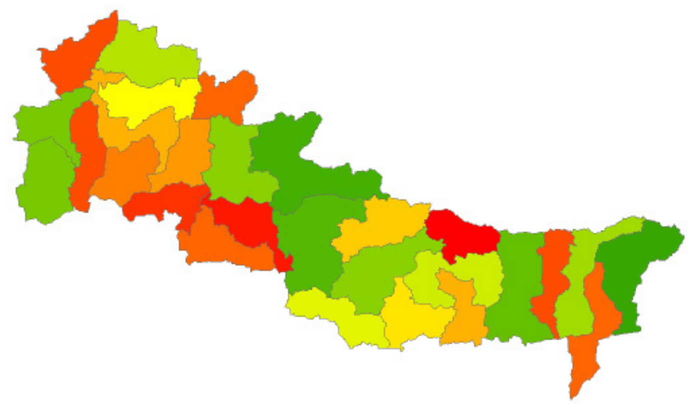


FIG. B.8 | Drainage Density
Subwatersheds are ranked on a gradient (red high and green low) based on the areal morphometric relationship of the total length of streams per unit area. Definition of drainage density taken from Ritter et al., 2011.

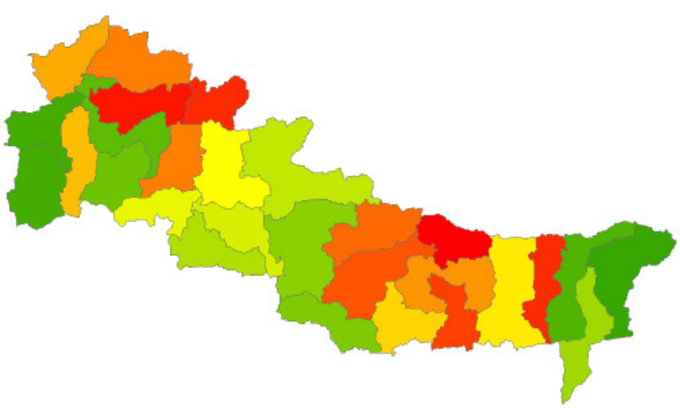


FIG. B.9 | Stream Frequency
Subwatersheds are ranked on a gradient (red high and green low) based on the total number of stream channels per unit area. Definition of stream frequency taken from Prasad, 2007.

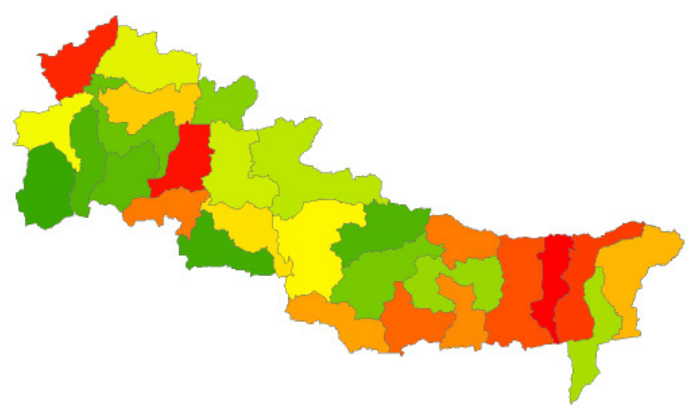


FIG. B.10 | Relief Ratio
Subwatersheds are ranked on a gradient (red high and green low) based on the measure of the overall steepness of the watershed. Definition of drainage density taken from Ritter et al., 2011.

C. LAND USE

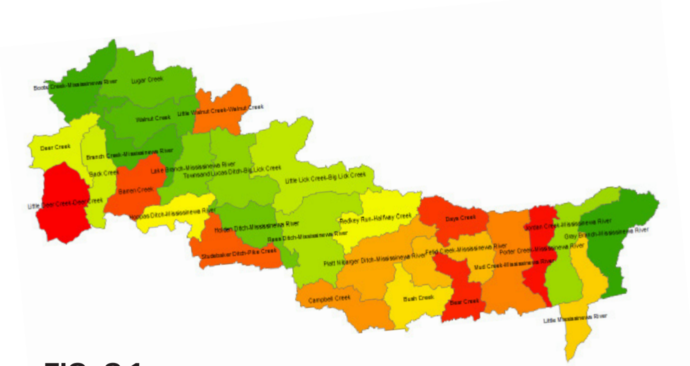


FIG. C.1 | Cropland %
Subwatersheds are ranked on a gradient (red high and green low) based on percentage of cropland. Subwatersheds with the highest percentage of crop land are Randolph and Jay Counties and in portion of southern Grant County.

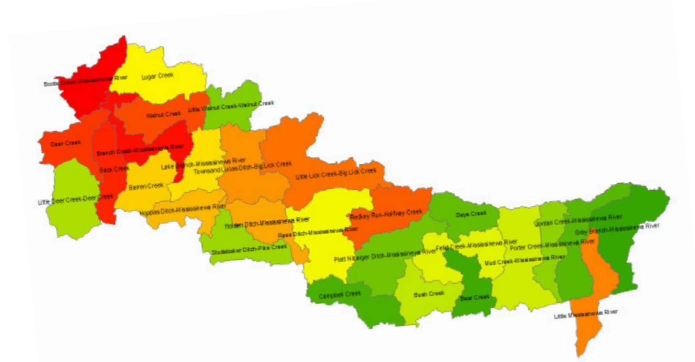


FIG. C.2 | Urban %
Subwatersheds are ranked on a gradient (red high and green low) based on percent Urbanized. The highest urban landuse is identified in Grant County Blackford County with elevated levels near Albany, Eaton, Desoto, Red Key. Little Mississinewa Subwatershed also has a high percentage of Urbanized lands.

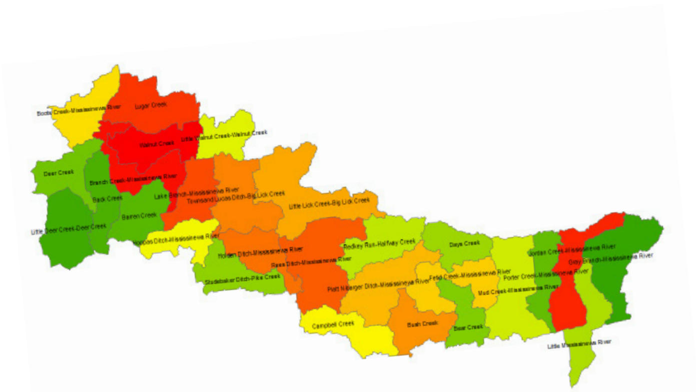


FIG. C.3 | Ecological %
Subwatersheds are ranked on a gradient (red high and green low) based on percent ecological. The highest concentration of ecological lands are in Grant County east of Marion. These lands are on poorly drained soils.

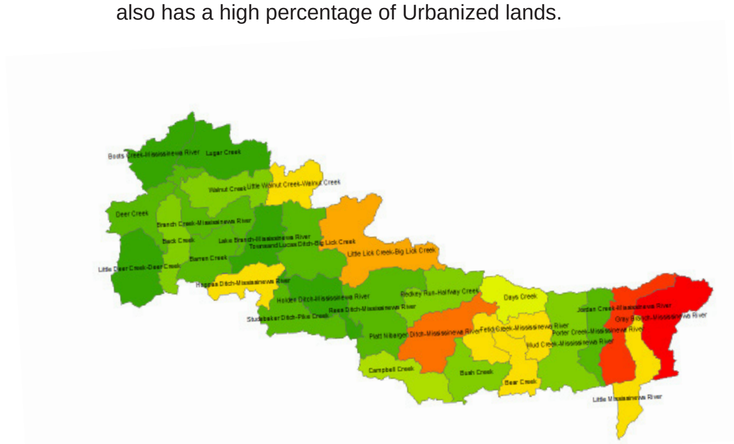


FIG. C.4 | CFO
Subwatersheds are ranked on a gradient (red high and green low) based on presence of CFOs. The highest percentage of CFOs are in Darke County.

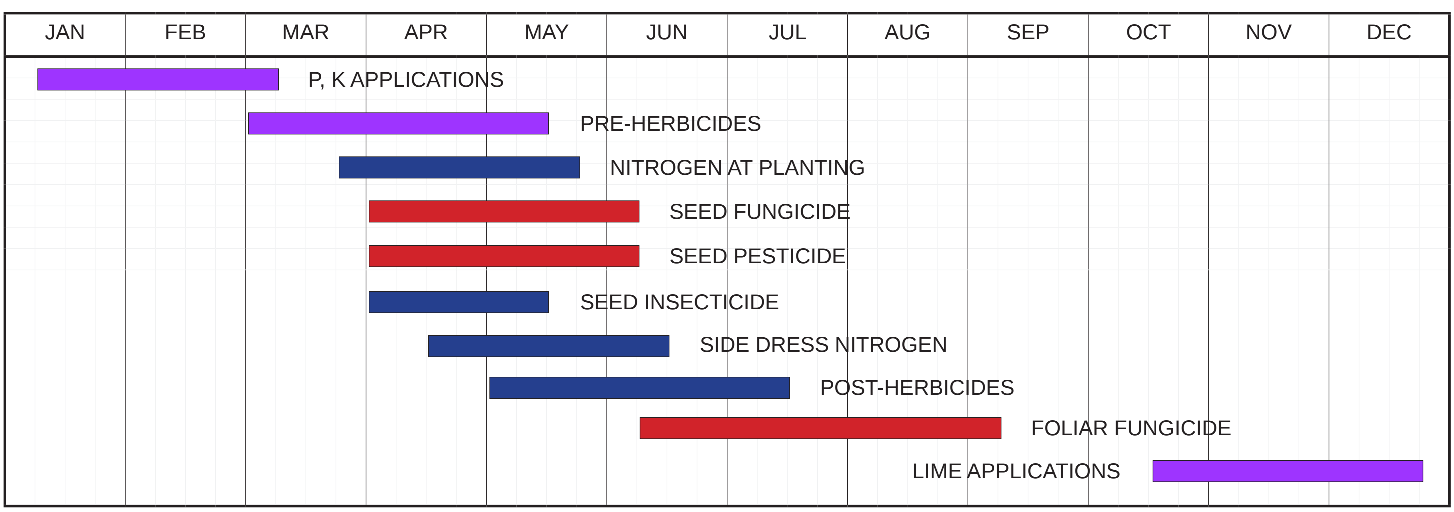


FIG. C.5 | Fertilizer and Pesticide Applications
Timing of field application for various agricultural fertilizers and pesticides. Bars indicate typical time frame in which product is applied.

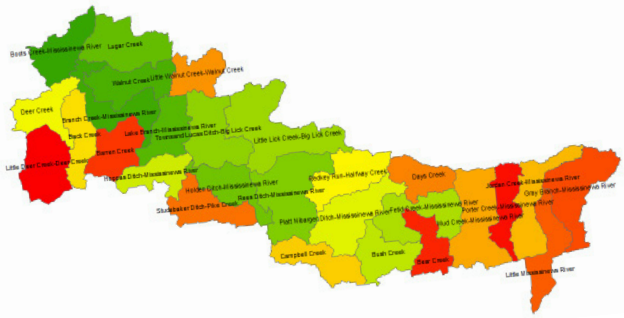


FIG. C.6 | Phosphorus Ton/Ac/Yr
Subwatersheds are ranked on a gradient (red high and green low) based on estimated Phosphorus discharge. Estimate is derived from acres of cropland.

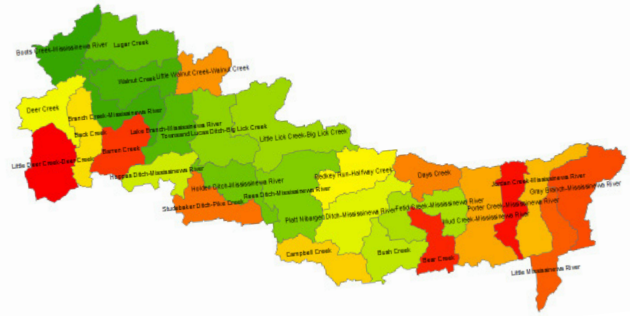


FIG. C.7 | Nitrogen Ton/Ac/Yr
Subwatersheds are ranked on a gradient (red high and green low) based on estimated Phosphorus discharge. Estimate is derived from acres of cropland.

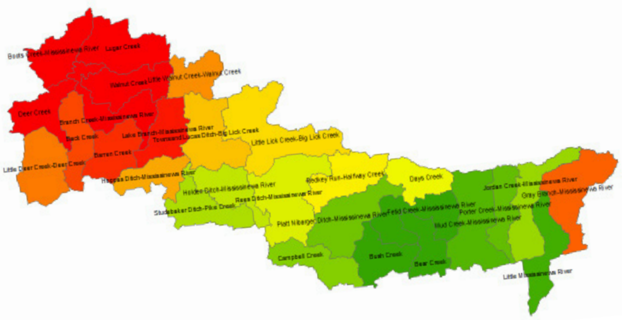


FIG. C.8 | Conventional Tillage Corn %
Subwatersheds are ranked on a gradient (red high and green low) based on conventional corn tillage percentage. State transect data for each county was averaged based on the percentage in each county.

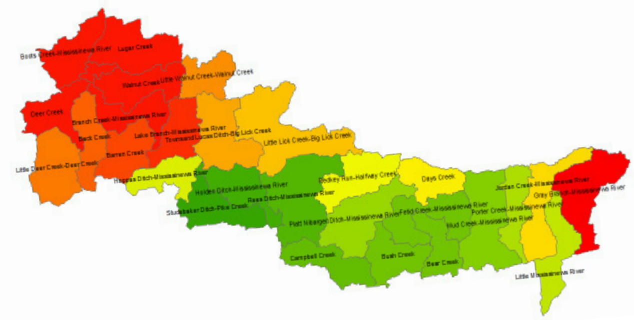


FIG. C.9 | Conventional Tillage Soybean %
Subwatersheds are ranked on a gradient (red high and green low) based on conventional soy tillage percentage. State transect data for each county was averaged based on the percentage in each county.

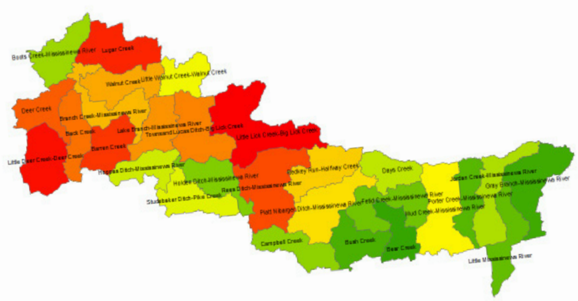


FIG. C.10 | Conventional Tillage Corn Ac
Subwatersheds are ranked on a gradient (red high and green low) based on conventional corn acreage. Subwatershed conventional tillage averages were assigned to acres of agricultural land use.

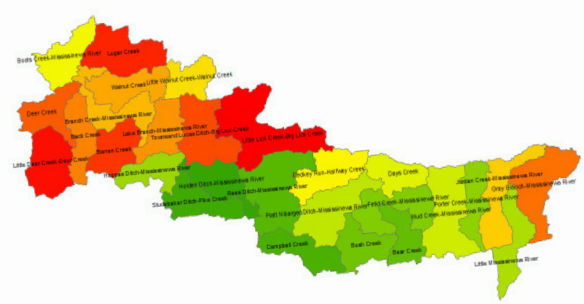


FIG. C.11 | Conventional Tillage Soybean Ac
Subwatersheds are ranked on a gradient (red high and green low) based on conventional soy acreage. Subwatershed conventional tillage averages were assigned to acres of agricultural land use.

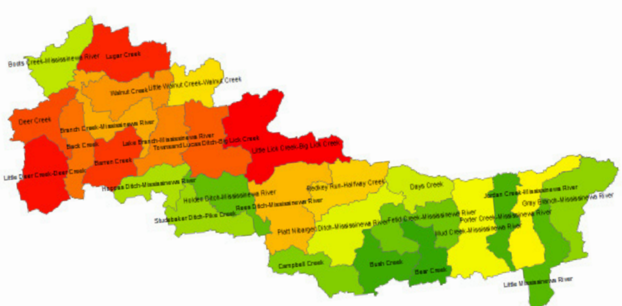


FIG. C.12 | Average Conventional Sediment Tons/Ac Year
Subwatersheds are ranked on a gradient (red high and green low) based on estimated sediment discharge from the conventionally tilled farm fields.

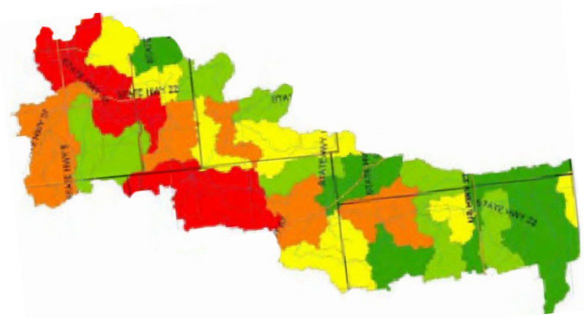


FIG. C.13 | 319 Sediment Study
A Taylor 319 study estimates sediment discharge higher in Grant County and also includes Hoppas, Studebaker, and Holden Ditch. This model also includes streambank erosion as a source increasing the relative rankings of these Subwatersheds (Buck Creek study).

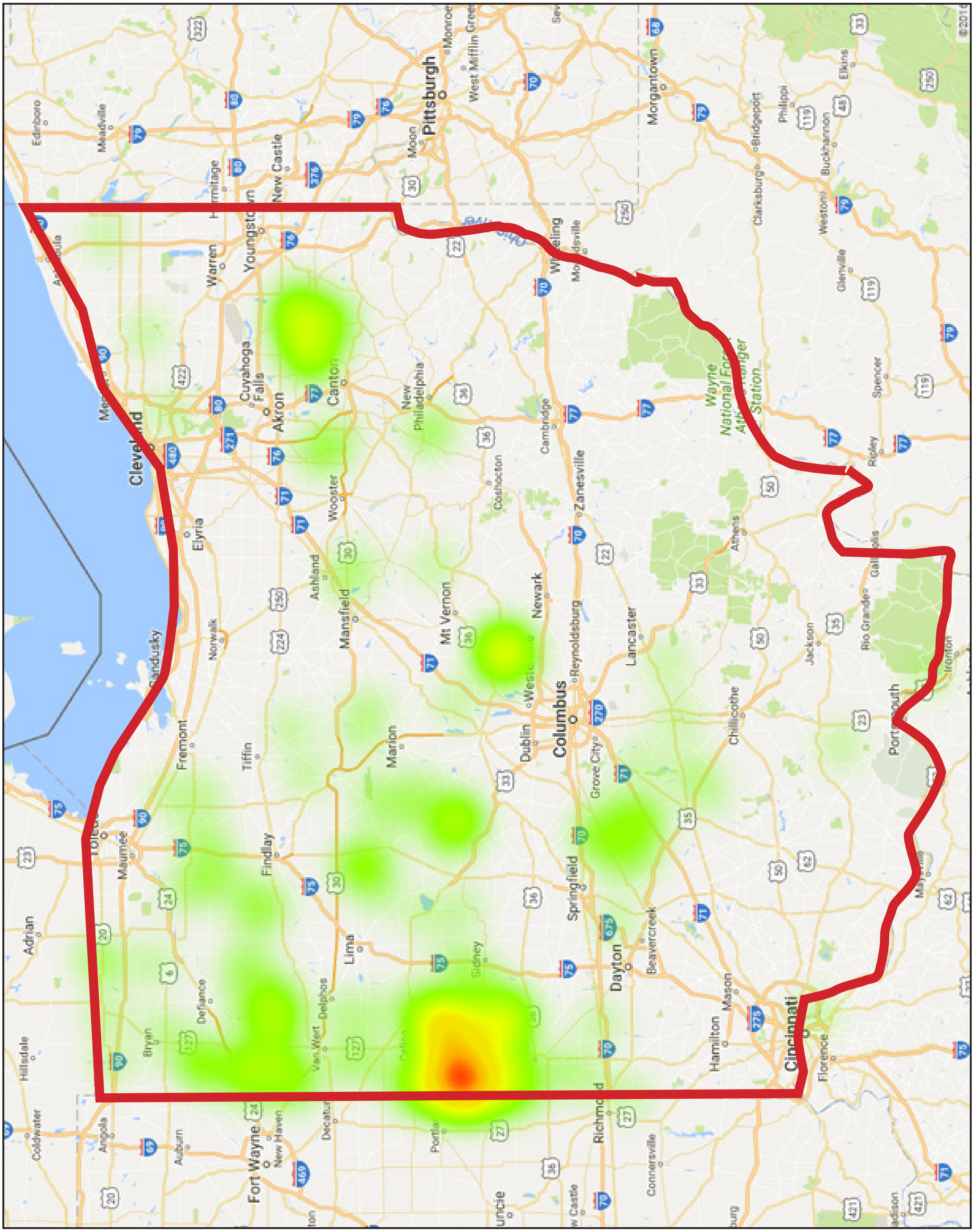


FIG C.14 | CFO Concentrations in Ohio

Heat density map representing CFO density in Ohio and bordering states. The color gradient follows the visible spectrum, moving from reds to oranges to yellows to greens. Highest values are represented by red and lowest values by green.

D. DEMOGRAPHICS

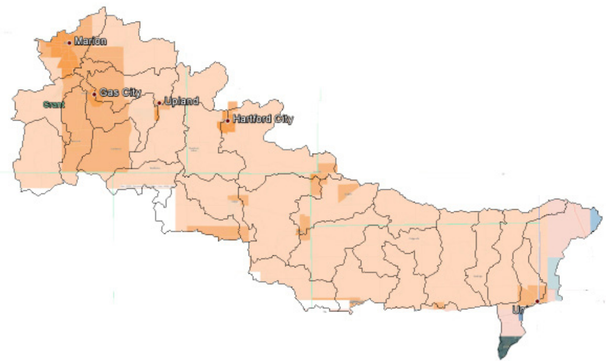


FIG. D.1 | Population Density
Population density map based on census Tracts. Darker colors show higher density. Further demographic discussion is found on page 60 of the WMP.

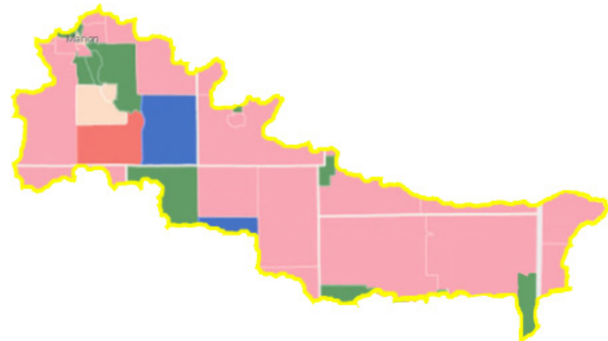


FIG. D.2 | ESRI Life Mode Groups
Table D.1 on the following page describes the life mode group represented by each color.

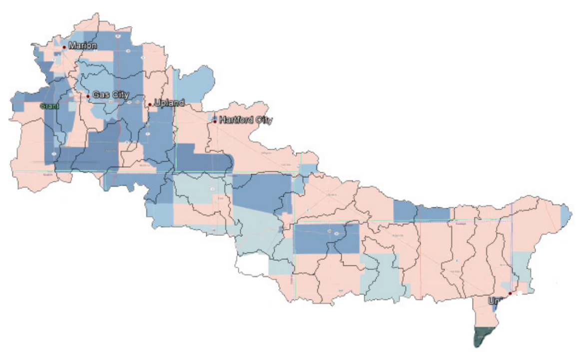


FIG. D.3 | Population Growth
Blue census tracts represent ares of growth within the watershed while beige colors represent zero growth or decline.

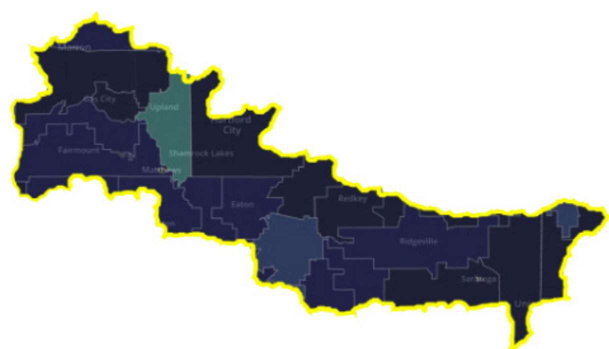


FIG. D.4 | ZIP Code Ranking
Lighter colored Zip Code areas have higher median household incomes. The Upland area zip code has the highest median income within the Upper Mississinewa River Watershed.

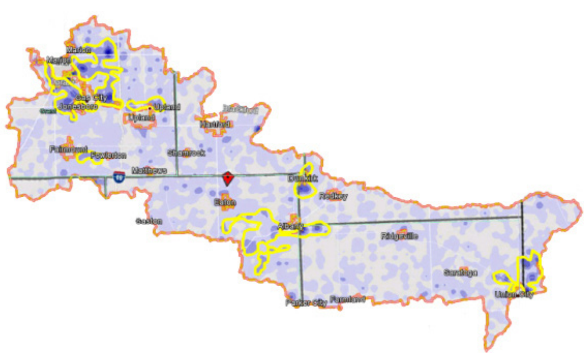
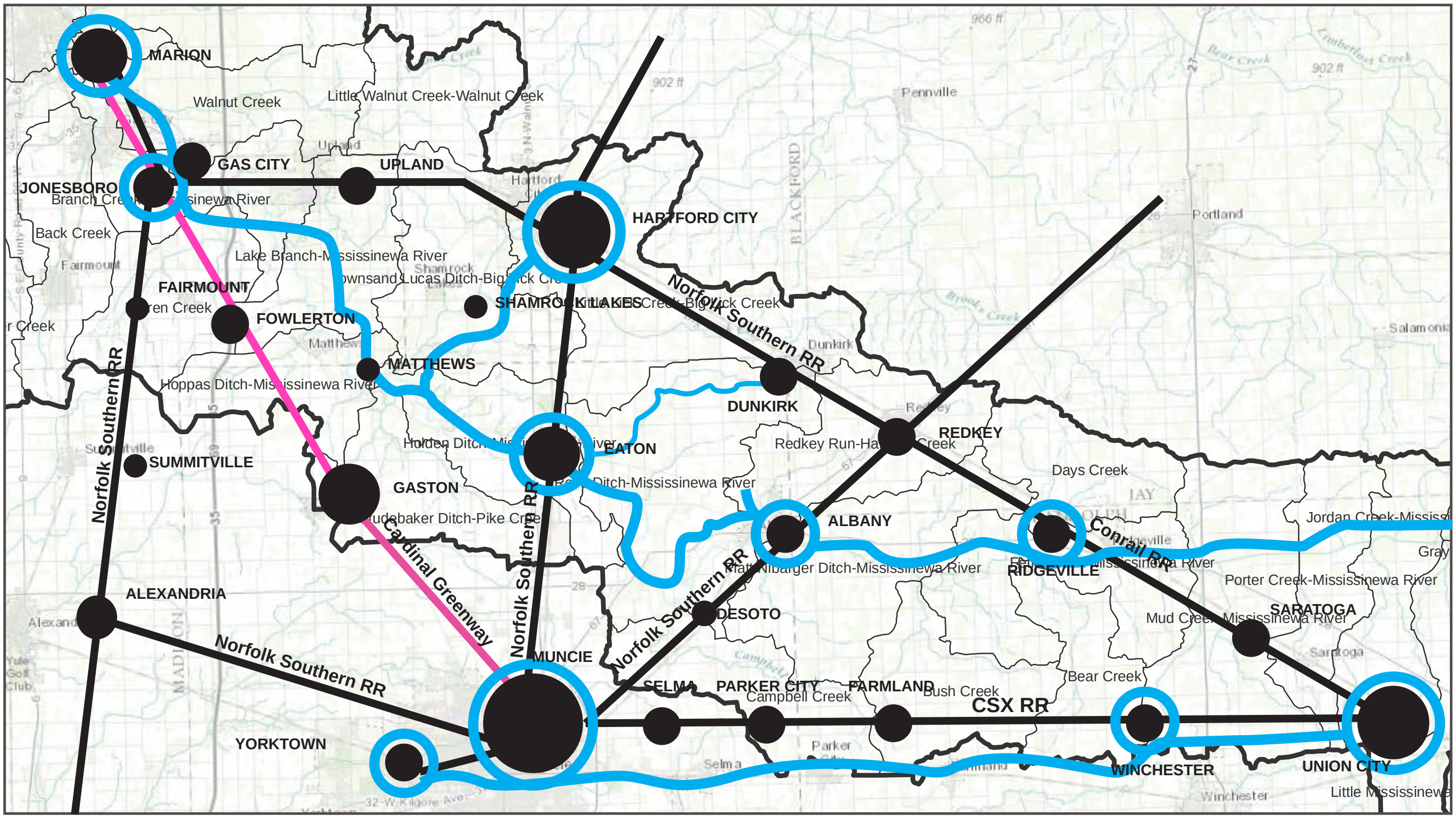


FIG. D.5 | Unincorporated Areas
Yellowed outlines high concentrations of homes in non-incorporated areas. There is high home density outside of Marion and outside of Albany.



MAP D.1 | Development of towns along major waterways and railways.

TABLE D.1 | ESRI LifeMode Groups

LifeMode Group	L11 Factories and Farms	L10 Traditional Living	L12 American Quilt	L2 Upscale Avenues	L5 Senior Styles
Names	Southern Satellites, Salt of the Earth, Home Town	Rustbelt Traditions	Rooted Rural	Gren Acres (Blue)	Simple Living, Rustbelt Retirees, Prosperous Empty Nesters, Heartland Communities
Household Type	Married-Couple Families, Mixed	Mixed	Married-Couple Families	Married-Couple Families	MC w/No Kids; Singles, Mixed
Median Age	40	36.2	44.4	42.8	43.7
Income	Lower Middle, Middle	Middle	Lower Middle	Upper Middle	Lower Middle, Middle, Upper Middle
Employment	Skilled/Prof/Mgmt/Services	Skilled/Prof/Mgmt/Srvc	Skilled/Prof/Mgmt/Srvc	Prof/Mgmt/Skilled	Prof/Mgmt/Skilled/Srvc
Education	No HS Diploma; HS Grad, Some College	HS Grad; Some College	No HS Diploma; HS Grad	Some College	No HS Diploma; HS Grad, Some College, Bach/Grad
Residential	Single Family; Mobile Home	Single Family	Single Family; Mobile Home	Single Family	Multiunits; Single Family
Race/Ethnicity	White	White	White	White	White
Activity	Shop at Wal-Mart, Gardening, outdoor projects, Play football, go fishing	Buy children's and baby products	Own dog(s)	Do gardening, wood-working	Go fishing, do furniture refinishing, Play bingo, Attend golf tournament, Work on lawn, garden, DIY projects
Financial	Use full-service bank, Own CD longer than 6 months, Have personal education loan	Use credit union	Use full-service bank	Have home equity credit line	Own annuities, Own CD longer than 6 months, Own shares in mutual fund (bonds)
Activity	Do gardening, go hunting, target shooting, Attend country music shows	Do painting, drawing	Go hunting, fishing, horseback riding	Attend country music shows	Order from QVC, Belong to fraternal orders, unions, etc., Refinish furniture, Order products from Avon
Media	Listen to country music, Watch CMT, Watch syndicated TV	Watch cable TV	Watch rodeos, tractor pulls on TV	Watch auto racing on TV	Watch syndicated TV, Watch news shows on TV, Read newspapers, Watch cable TV
VehicleSegment	Own/Lease truck, Own motorcycle, Own/Lease domestic vehicle	Own/Lease domestic vehicle	Own an ATV/UTV	Drive 20,000+ miles annually	Own/Lease domestic vehicle, Own/Lease Pontiac, Own/Lease Buick

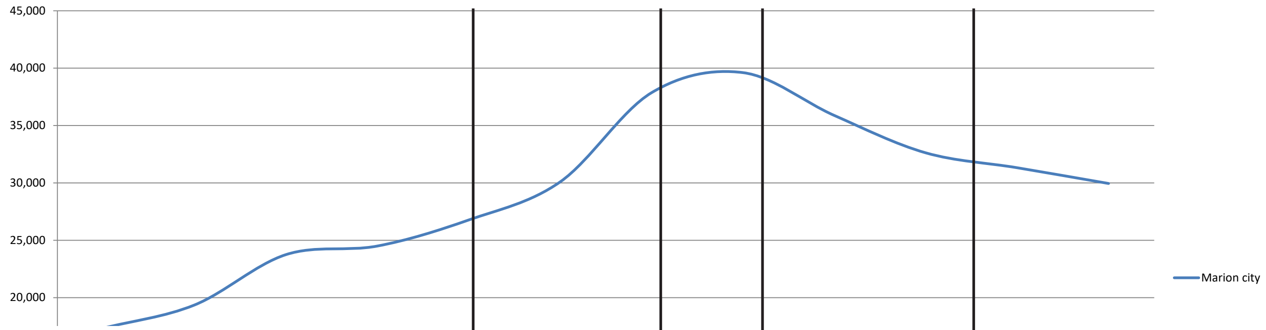


FIG. D.6 | Marion Population

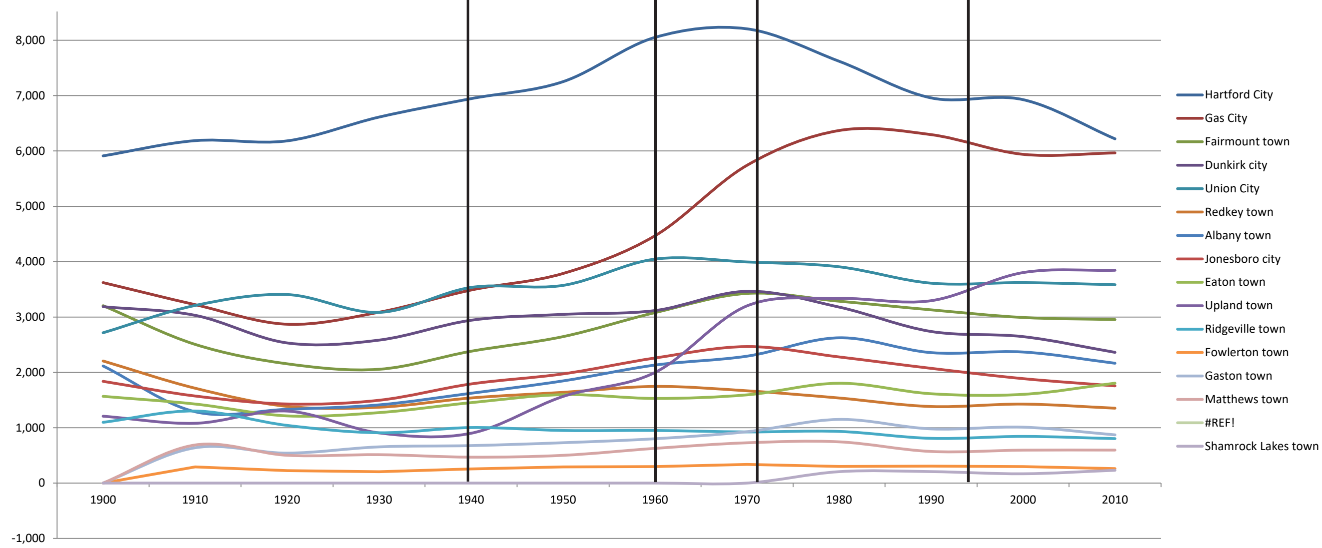


FIG. D.7 | Watershed Population

TABLE D.2 | Major Cities In Watershed Area

City	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010
Early Towns												
Marion City	17,337	19,359	23,747	24,496	26,767	30,081	37,854	39,607	35,874	32,618	31,320	29,948
Hartford City	5,912	6,187	6,183	6,613	6,946	7,253	8,053	8,207	7,622	6,960	6,928	6,220
Gas City (Harrisburg)	3,622	3,224	2,870	3,087	3,488	3,787	4,469	5,742	6,370	6,296	5,940	5,965
Upland town	1,208	1,080	1,301	906	900	1,565	1,999	3,202	3,335	3,295	3,803	3,845
Agricultural Towns												
Fairmount town	3,205	2,506	2,155	2,056	2,382	2,646	3,080	3,427	3,286	3,130	2,992	2,954
Dunkirk city	3,187	3,031	2,532	2,583	2,942	3,048	3,117	3,465	3,180	2,739	2,646	2,362
Union City	2,716	3,209	3,406	3,084	3,535	3,572	4,047	3,995	3,908	3,612	3,622	3,584
Redkey town	2,206	1,714	1,386	1,370	1,538	1,639	1,746	1,667	1,537	1,383	1,427	1,353
Albany town	2,116	1,289	1,333	1,413	1,623	1,846	2,132	2,293	2,625	2,357	2,368	2,165
Jonesboro city	1,838	1,573	1,429	1,496	1,791	1,973	2,260	2,466	2,279	2,073	1,887	1,756
Eaton town	1,567	1,428	1,214	1,273	1,453	1,598	1,529	1,594	1,804	1,614	1,603	1,805
Ridgeville town	1,098	1,302	1,042	909	1,003	950	950	924	933	808	843	803
Train Towns												
Fowlerton town	0	293	225	204	255	292	297	337	300	306	298	261
Gaston town	0	638	541	654	677	729	801	928	1,150	979	1,010	871
Matthews town	0	688	502	513	468	501	627	728	745	571	595	596
Shamrock Lakes town	0	0	0	0	0	0	0	0	206	207	168	231

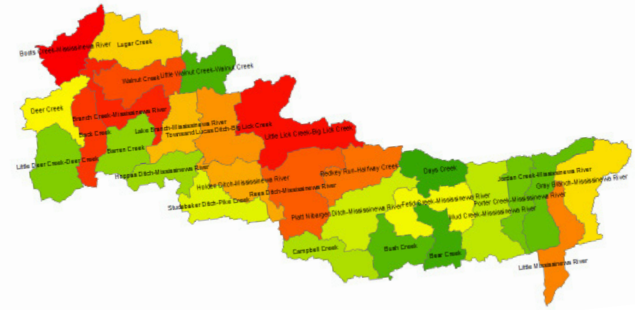


FIG. D.8 | Housing Units
Subwatersheds are ranked on a gradient (red high and green low) based on housing units.

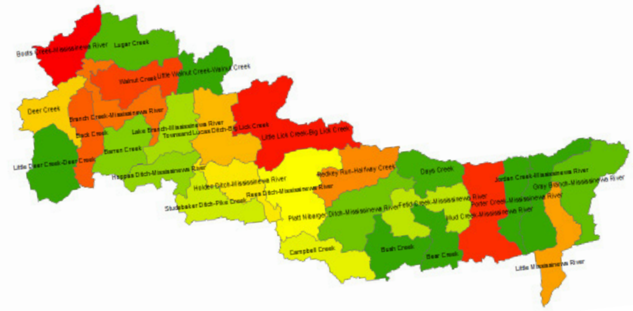


FIG. D.9 | Incorporated Housing Units
Subwatersheds are ranked on a gradient (red high and green low) based on acres of incorporated area.

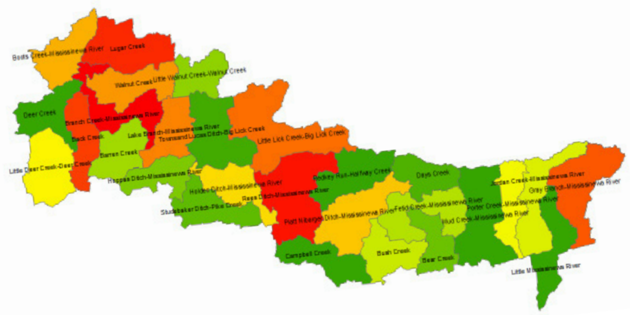


FIG. D.10 | Unincorporated Housing Units
Subwatersheds are ranked on a gradient (red high and green low) based on unincorporated housing units. High concentration in the west Albany area.

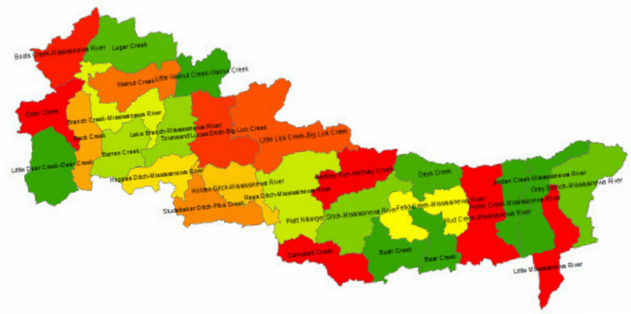


FIG. D.11 | % Incorporated
Subwatersheds are ranked on a gradient (red high and green low) based on % incorporated acres. Something is wrong here.

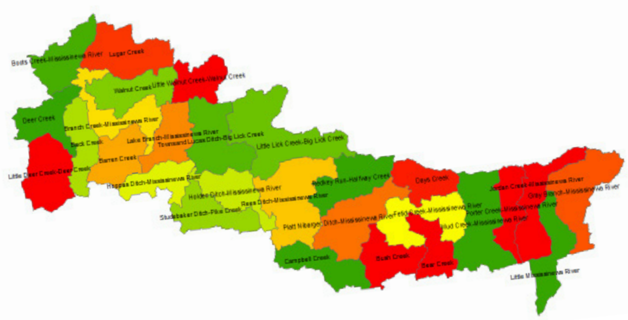


FIG. D.12 | % Unincorporated
Subwatersheds are ranked on a gradient (red high and green low) based on % incorporated acres. Something is wrong here.

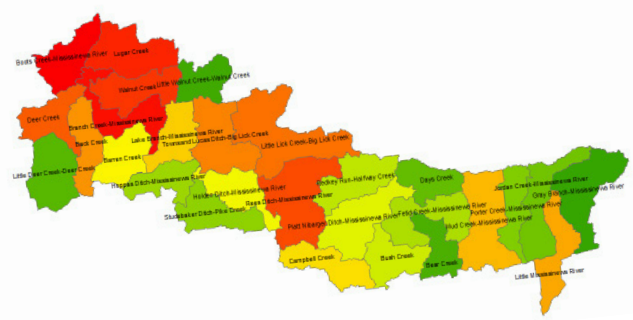


FIG. D.13 | Wells
Subwatersheds are ranked on a gradient (red high and green low) based on number of wells. Map ties to population density and household units.

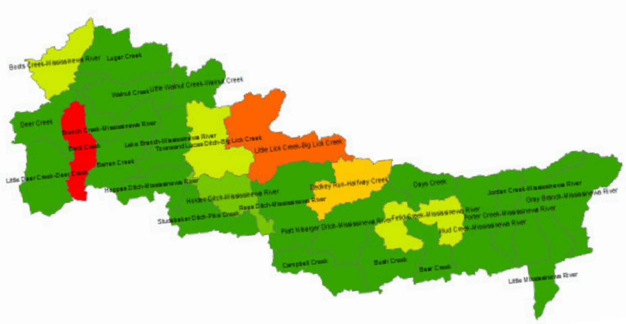


FIG. D.14 | CSO
Subwatersheds are ranked on a gradient (red high and green low) based on the number of CSO present.

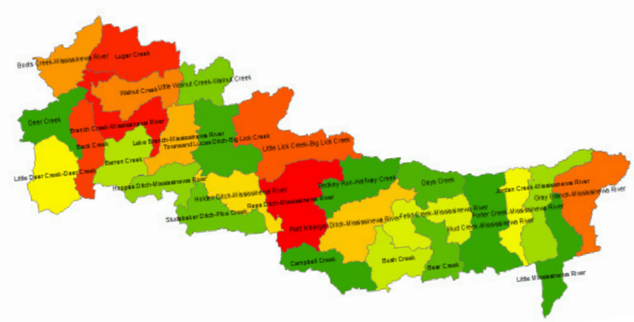


FIG. D.15 | Estimated Septic Systems
Subwatersheds are ranked on a gradient (red high and green low) based on estimated amount of septic systems. Derived from unincorporated housing units per subwatershed.

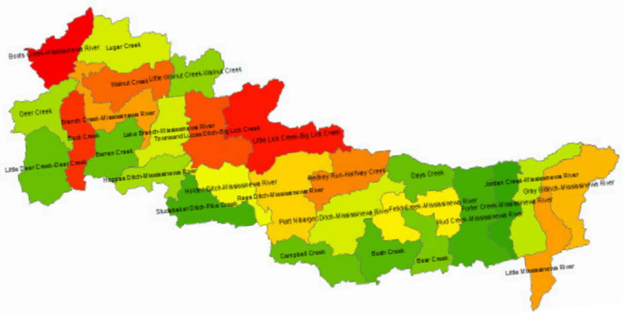


FIG. D.16 | Regulated Point Sources
Subwatersheds are ranked on a gradient (red high and green low) based on presence of Regulated Point Sources. The highest amount of point sources are in Hartford City and Marion.

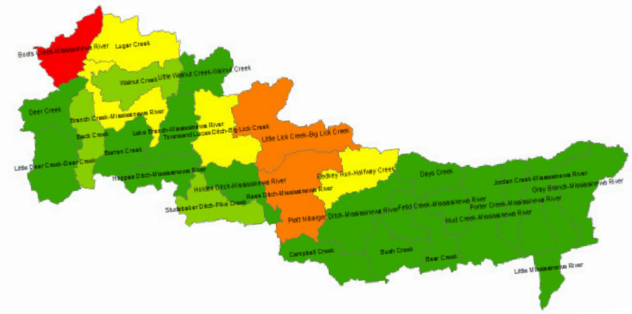


FIG. D.17 | Inst Control Landfill
Subwatersheds are ranked on a gradient (red high and green low) based on landfills and industrial controls. The highest concentrations are in Grant and Blackford Counties.

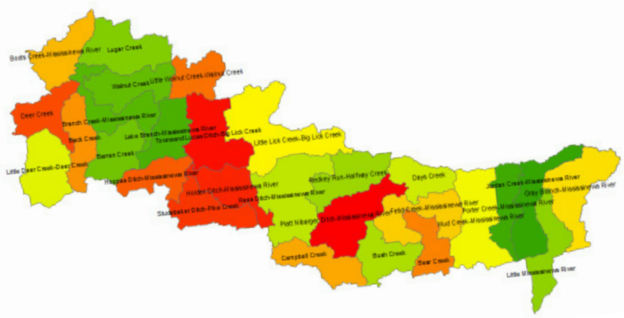


FIG. D.18 | Population Change
Subwatersheds are ranked on a gradient (red high and green low) based on acres of land with population increase. Areas that are seeing the highest population change are suburban areas around Albany and Upland.

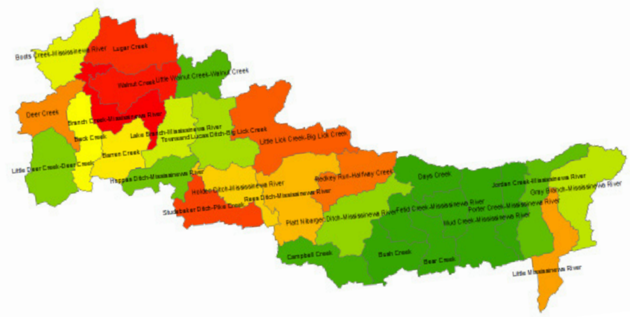


FIG. D.19 | Population Density
Subwatersheds are ranked on a gradient (red high and green low) based on acres of land with existing elevated population density. Subwatersheds northeast of Marion are ranked highest while unincorporated areas near Hartford City, Albany, Desoto, Eaton, and Redkey also have elevated levels.

E. DESKTOP SURVEY

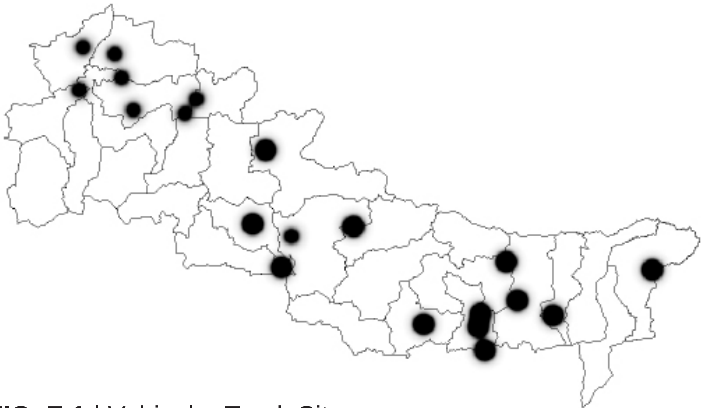


FIG. E.1 | Vehicular Track Sites
Black circles represent the location of vehicular track sites.

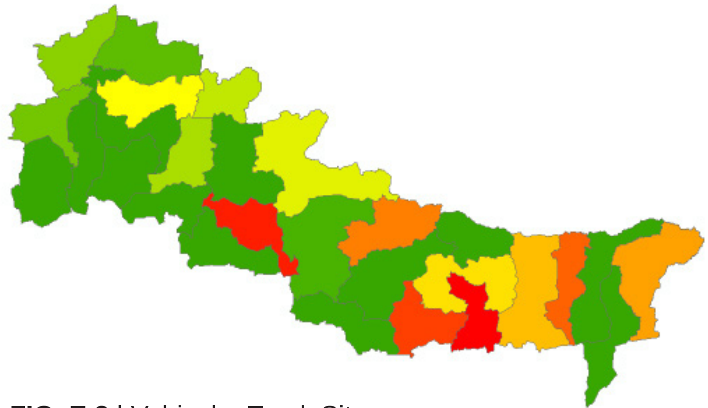


FIG. E.2 | Vehicular Track Sites
Subwatersheds are ranked on a gradient (red high and green low) based on the number of vehicular track sites identified.

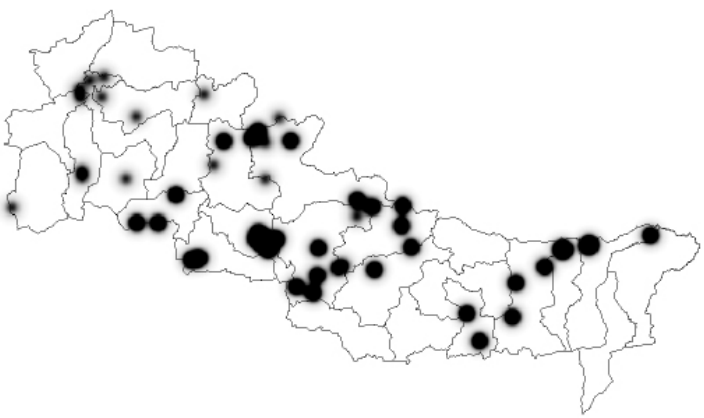


FIG. E.3 | Vehicular Storage Sites
Black circles represent the location of vehicular storage sites.

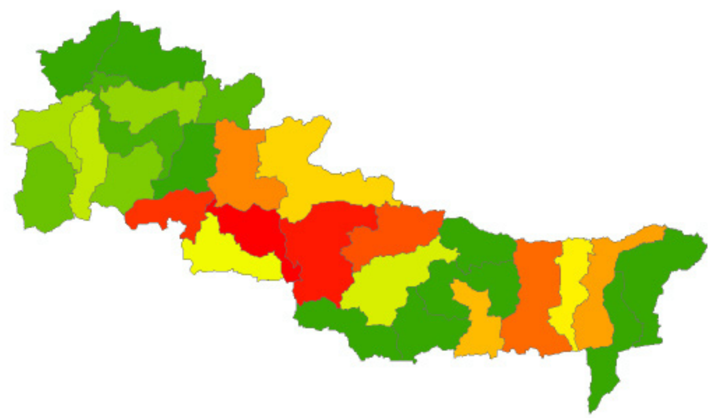


FIG. E.4 | Vehicular Storage Sites
Subwatersheds are ranked on a gradient (red high and green low) based on the number of vehicular storage sites identified.

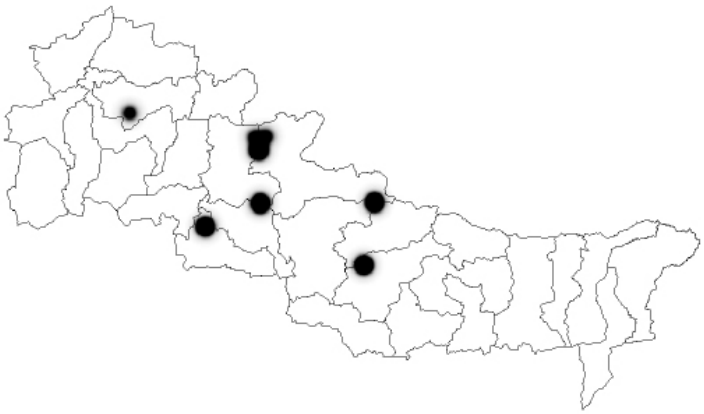


FIG. E.5 | Construction Storage
Black circles represent the location of construction storage sites.

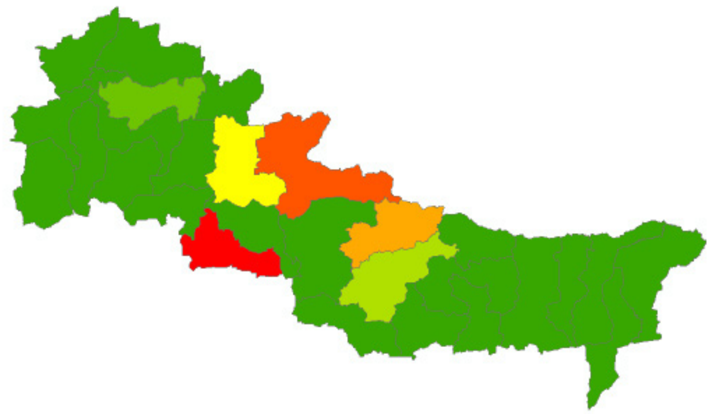


FIG. E.6 | Construction Storage
Subwatersheds are ranked on a gradient (red high and green low) based on the number of construction storage sites identified.

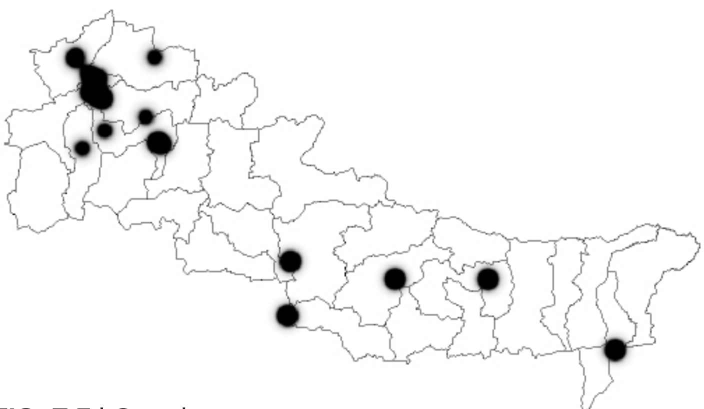


FIG. E.7 | Quarries
Black circles represent the location of quarries.

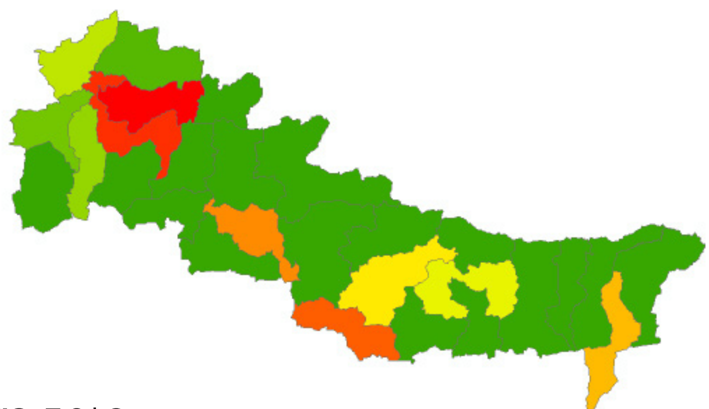


FIG. E.8 | Quarry
Subwatersheds are ranked on a gradient (red high and green low) based on the number of quarries identified.

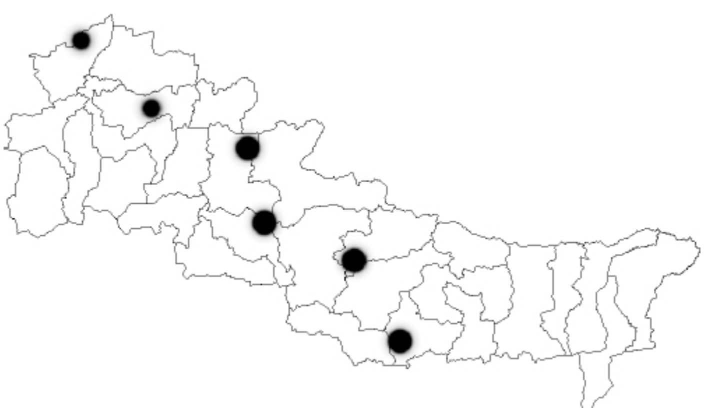


FIG. E.9 | Golf Courses
Black circles represent the location of golf courses.

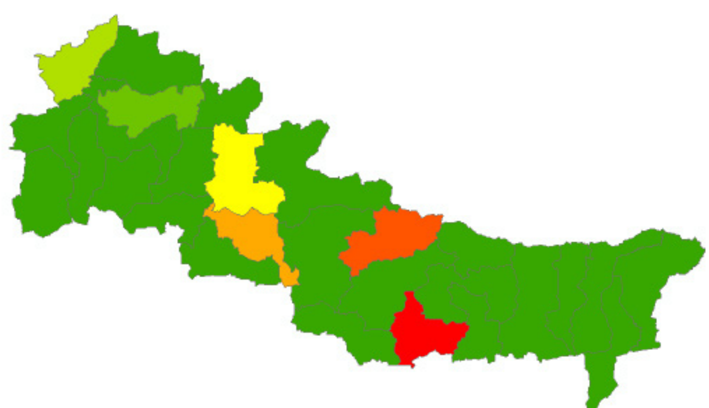


FIG. E.10 | Golf Courses
Subwatersheds are ranked on a gradient (red high and green low) based on the number of golf courses identified.

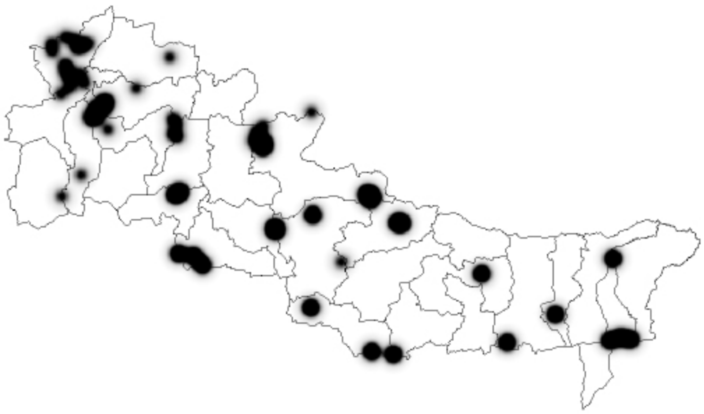


FIG. E.11 | Sports Facilities
Black circles represent the location of sports facilities.

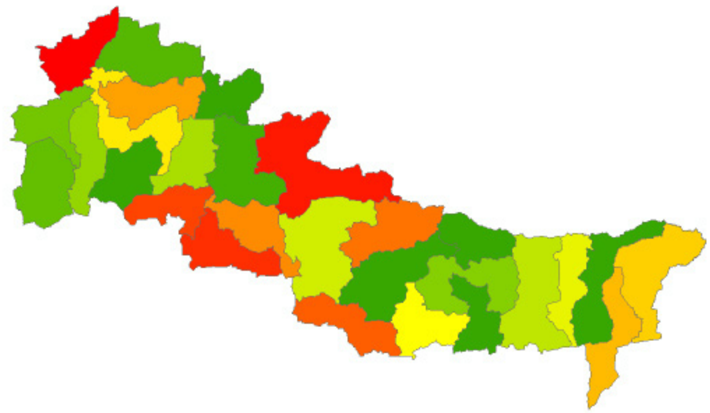


FIG. E.12 | Sports Facilities
Subwatersheds are ranked on a gradient (red high and green low) based on the number of sports facilities identified.

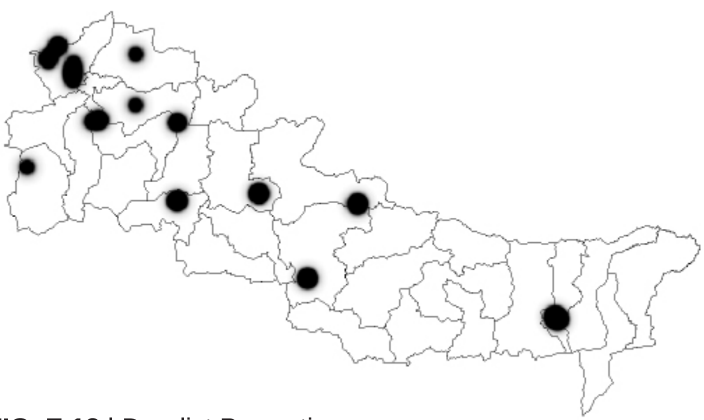


FIG. E.13 | Derelict Properties
Black circles represent the location of derelict properties.

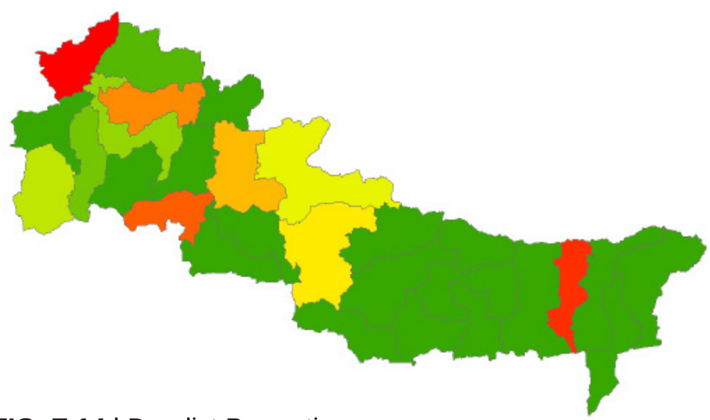


FIG. E.14 | Derelict Properties
Subwatersheds are ranked on a gradient (red high and green low) based on the number of derelict property identified.

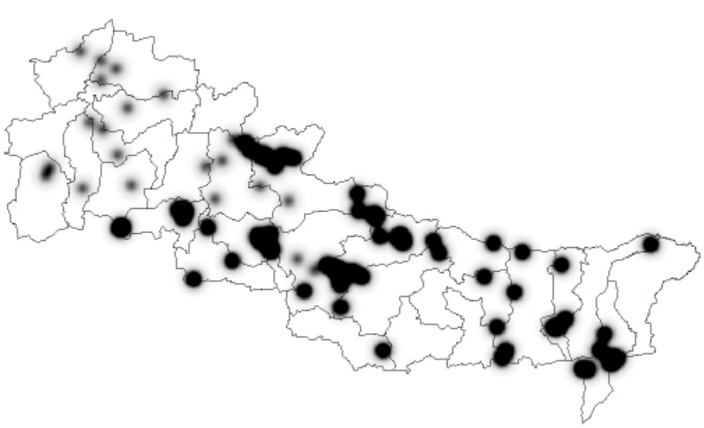


FIG. E.15 | Junk Storage Sites
Black circles represent the location of junk storage sites.

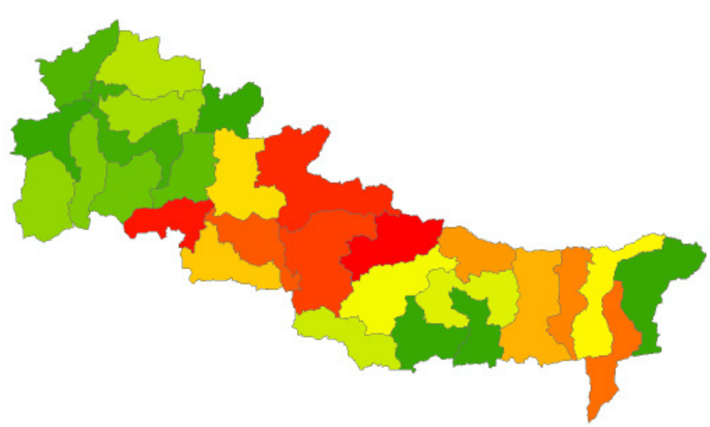


FIG. E.16 | Junk Storage Sites
Subwatersheds are ranked on a gradient (red high and green low) based on the number of junk storage sites identified.

F. ENDANGERED SPECIES

TABLE F.1 | State or Federally Endangered Species in Entire Watershed	
Mollusks	
Gomphus externus	Plains Clubtail
Epioblasma torulosa rangiana	Northern Riffleshell
Pleurobema clava	Clubshell
Villosa fabalis	Rayed Bean
Quadrula cylindrica cylindrica	Rabbitsfoot
Epioblasma triquetra	Snuffbox
Insect	
Macromia wabashensis	Wabash River Cruiser
Mammal	
Myotis sodalis	Indiana Bat or Social Myotis
Reptile	
Clemmys guttata	Spotted Turtle
Clonophis kirtlandii	Kirtland's Snake
Emydoidea blandingii	Blanding's Turtle
Sistrurus catenatus catenatus	Eastern Massasauga
Thamnophis butleri	Butler's Garter Snake
Bird	
Ardea herodias	Great Blue Heron
Lanius ludovicianus	Loggerhead Shrike
Nyctanassa violacea	Yellow-crowned Night-heron
Rallus elegans	King Rail
Cistothorus plaensis	Sedge Wren
Tyto alba	Barn Owl
Ammodramus henslowii	Henslow's Sparrow
Rallus limicola	Virginia Rail
Botaurus lentiginosus	American Bittern
Circus cyaneus	Northern Harrier
Cistothorus platensis	Sedge Wren
Ixobrychus exilis	Least Bittern
Nycticorax nycticorax	Black-crowned Night-heron
Vascular Plant	
Carex alopecoidea	Foxtail Sedge
Glyceria borealis	Small Floating Manna-grass
Trifloium stoloniferum	Running Buffalo Clover
Valerianelle chenopodiifolia	Goose-foot Corn-salad
Carex gravida	Heavy Sedge
Carataegus arborea	A Hawthorn
Melanthium virginicum	Virginia Bunchflower
Carex timida	Timid Sedge

TABLE F.2 | Endangered and Threatened Species Blackford County, IN			
Scientific Name	Common Name	Federal Status	State Status
Reptile			
Clonophis kirtlandii	Kirtland's Snake		Endangered
Mammal			
Mustela nivalis	Least Weasel		Special Concern
Myotis sodalis	Indiana Bat or Social Myotis	Endangered	Endangered
Vascular Plant			
Coeloglossum viride var. virescens	Long-bract Green Orchis		Threatened
Platanthera psycodes	Small Purple-fringe Orchis		Rare
High Quality Natural Community			
Forest-flatwoods central till plain	Central Till Plain Flatwoods		Significant
Forest-floodplain wet-mesic	Wet-mesic Floodplain Forest		Significant
Wetland-marsh	Marsh		Significant

TABLE F.3 | Endangered and Threatened Species Darke County, OH			
Scientific Name	Common Name	Federal Status	State Status
Mollusk:Bivalvia (Mussels)			
Etheostoma microperca	Least Darter		Special Concern
Gomphus externus	Plains Clubtail		Endangered
Lampsilis fasciola	Wavy-rayed Lampmussel		Special Concern
Lasmigona compressa	Creek Heelsplitter		Special Concern
Orconectes sloanii	Sloan's Crayfish		Threatened
Vascular Plant			
Agalinis gattingeri	Gattinger's-foxglove		Threatened
Cares atherodes	Wheat Sedge		Potentially Threatened
Cuscuta coryli	Hazel Dodder		
Iris brevicaulis	Leafy Blue Flag		Threatened
Liatris spuarrosa	Scaly Blazing-star		Potentially Threatened
Melanthium woodii	Wood's-heelebore		Threatened
Moehringia lateriflora	Grove Sandwort		Potentially Threatened
Rosa blanda	Smooth Rose		Potentially Threatened

TABLE F.4 | Endangered and Threatened Species Delaware County, IN			
Scientific Name	Common Name	Federal Status	State Status
Mollusk:Bivalvia (Mussels)			
Epioblasma torulosa rangiana	Northern Riffleshell	Endangered	Endangered
Lampsilis fasciola	Wavyrayed Lampmussel		Special Concern
Pleurobema clava	Clubshell	Endangered	Endangered
Pleurobema cordatum	Ohio Pigtoe		Special Concern
Ptychobranchus fasciolaris	Kidneyshell		Special Concern
Toxolasma lividus	Purple Lilliput		Special Concern
Villosa fabalis	Rayed Bean	Endangered	Special Concern
Reptile			
Clemmys guttata	Spotted Turtle		Endangered
Clonophis kirtlandii	Kirtland's Snake		Endangered
Emydoidea blandingii	Blanding's Turtle		Endangered
Sistrurus catenatus catenatus	Eastern Massasauga	Candidate	Endangered
Thamnophis butleri	Butler's Garter Snake		Endangered
Bird			
Ardea herodias	Great Blue Heron		
Botaurus lentiginosus	American Bittern		Endangered
Lanius ludovicianus	Loggerhead Shrike	No Status	Endangered
Nyctanassa violacea	Yellow-crowned Night-heron		Endangered
Nycticorax nycticorax	Black-crowned Night-heron		Endangered
Rallus elegans	King Rail		Endangered
Mammal			
Myotis sodalis	Indiana Bat or Social Myotis	Endangered	Endangered
Taxidea taxus	Anmerican Badger		Special Concern
Vascular Plant			
Carex alopecoidea	Foxtail Sedge		Endangered
Glyceria borealis	Small Floating Manna-grass		Endangered
Matteuccia struthiopteris	Ostrich Fern		Rare
Silene regia	Royal Catchfly		Threatened
Trichostema dichotomum	Forked Bluecurl		Rare
Trifloium stoloniferum	Running Buffalo Clover	Endangered	Endangered
Valerianelle chenopodiifolia	Goose-foot Corn-salad		Endangered
Wisteria macrostachya	Kentucky Wisteria		Rare
High Quality Natural Community			
Forest-flatwoods central till plain	Central Till Plain Flatwoods		Significant

TABLE F.5 | Endangered and Threatened Species Randolph County, IN			
Scientific Name	Common Name	Federal Status	State Status
Mollusk:Bivalvia (Mussels)			
Epioblasma torulosa rangiana	Northern Riffleshell	Endangered	Endangered
Lampsilis fasciola	Wavyrayed Lampmussel		Special Concern
Pleurobema clava	Clubshell	Endangered	Endangered
Ptychobranchus fasciolaris	Kidneyshell		Special Concern
Toxolasma lividus	Purple Lilliput		Special Concern
Villosa fabalis	Rayed Bean	Endangered	Special Concern
Villosa lienosa	Little Spectaclecase		Special Concern
Insect: Odonata (Dragonflies & Damselflies)			
Enallagma divagans	Turquoise Bluet		Rare
Reptile			
Clonophis kirtlandii	Kirtland's Snake		Endangered
Bird			
Ardea herodias	Great Blue Heron		
Cistothorus plaensis	Sedge Wren		Endangered
Lanius ludovicianus	Loggerhead Shrike	No Status	Endangered
Tyto alba	Barn Owl		Endangered
Mammal			
Myotis septentrionalis	Northern Myotis		Special Concern
Myotis sodalis	Indiana Bat or Social Myotis	Endangered	Endangered
Taxidea taxus	American Badger		Special Concern
Vascular Plant			
Carex gravida	Heavy Sedge		Endangered
Carataegus arborea	A Hawthorn		Endangered
Cypripedium calceolus var. parviflorum	Small Yellow Lady's-slipper		Rare
Cypripedium candidum	Small White Lady's- slipper		Watch List
Melanthium virginicum	Virginia Bunchflower		Endangered
Melica nitens	Three-flower Melic Grass		Threatened
Panax quinquefolius	American Ginseng		Watch List
Rudbeckia fulgida var. fulgida	Orange Coneflower		Watch List
Tofiedlia glutinosa	False Asphodel		Rare
Triglochin palustris	Marsh Arrow-grass		Rare
Viburnum molle	Softleaf Arrow-wood		Rare
High Quality Natural Community			
Forest-flatwoods central till plain	Central Till Plain Flatwoods		Significant
Wetland-fen	Fen		Significant

TABLE F.6 | Endangered and Threatened Species Grant County, IN			
Scientific Name	Common Name	Federal Status	State Status
Mollusk:Bivalvia (Mussels)			
Epioblasma torulosa rangiana	Northern Riffleshell	Endangered	Endangered
Obovaria subrotunda	Round Hickorynut		Special Concern
Pleurobema clava	Clubshell	Endangered	Endangered
Ptychobranchus fasciolaris	Kidneyshell		Special Concern
Quadrula cylindrica cylindrica	Rabbitsfoot	Candidate	Endangered
Toxolasma lividus	Purple Lilliput		Special Concern
Villosa fabalis	Rayed Bean	Endangered	Special Concern
Villosa lienosa	Little Spectaclecase		Special Concern
Reptile			
Clonophis kirtlandii	Kirtland's Snake		Endangered
Bird			
Ammodramus henslowii	Henslow's Sparrow		Endangered
Ardea herodias	Great Blue Heron		
Mniotilta varia	Black-and-white Warbler		Special Concern
Rallus limicola	Virginia Rail		Endangered
Mammal			
Mustela nivalis	Least Weasel		Special Concern
Taxidea taxus	American Badger		Special Concern
Vascular Plant			
Crataegus succulenta	Fleshy Hawthorn		Rare
Poa wolfii	Wolf Bluegrass		Rare
Stenanthium gramineum	Eastern Featherbells		Threatened
High Quality Natural Community			
Forest-flatwoods central till plain	Central Till Plain Flatwoods		Significant
Forest- upland mesic	Mesic Upland Forest		Significant

TABLE F.7 | Endangered and Threatened Species Jay County, IN			
Scientific Name	Common Name	Federal Status	State Status
Mollusk:Bivalvia (Mussels)			
Epioblasma triquetra	Snuffbox	Endangered	Endangered
Toxolasma lividus	Purple Lilliput		Special Concern
Insect: Odonata (Dragonflies & Dramselflies)			
Enallagma divagans	Turquoise Bluet		Rare
Macromia wabashensis	Wabash River Cruiser		Endangered
Amphibian			
Rana pipiens	Northern Leopard Frog		Special Concern
Reptile			
Clonophis kirtlandii	Kirtland's Snake		Endangered
Thamnophis proximus proximus	Western Ribbon Snake		Special Concern
Bird			
Ardea herodias	Great Blue Heron		
Botaurus lentiginosus	American Bittern		Endangered
Circus cyaneus	Northern Harrier		Endangered
Cistothorus platensis	Sedge Wren		Endangered
Ixobrychus exilis	Least Bittern		Endangered
Nycticorax nycticorax	Black-crowned Night-heron		Endangered
Tyto alba	Barn Owl		Endangered
Mammal			
Mustela nivalis	Least Weasel		Special Concern
Myotis sodalis	Indiana Bat or Social Myotis	Endangered	Endangered
Vascular Plant			
Carex timida	Timid Sedge		Endangered
High Quality Natural Community			
Forest-flatwoods central till plain	Central Till Plain Flatwoods		Significant
Forest-floodplain mesic	Mesic Floodplain Forest		Significant
Forest-upland dry-mesic	Dry-mesic Upland Forest		Significant
Prairie- dry-mesic	Dry-mesic Prairie		Significant
Prairie-mesic	Mesic Prairie		Significant
Prairie- wet	Wet Prairie		Significant
Wetland-marsh	Marsh		Significant

G. OTHER RELEVANT HISTORICAL STUDIES

An inventory of existing water quality studies in the region was recently completed by Taylor University as part of 2012 Middle Mississinewa River Watershed Diagnostic LARE Study. Excerpts from the inventory are included in the following section. “This section briefly describes previous studies that provide context for understanding the current conditions of the middle Mississinewa River. The reports and resources are described in the order of: (1) general watershed assessments that include the Boots Creek and surrounding watershed, (2) reports that include the Mississinewa River watershed resulting from the 1998 Upper Wabash River Assessment and, (3) reports that specifically address the Mississinewa River watershed. (Taylor Study).”

“Watershed Assessment Reports

“National Rapid Watershed Assessment
A Rapid Watershed Assessment (RWA) is presented in map and/or report format as an overview of conditions, such as natural features and land use that affect water quality in the watershed (USDA, 2011). The US Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) has led in the development of these rapid assessments. From their website:

> “The Natural Resources Conservation Service is encouraging the development of rapid watershed assessments in order to increase the speed and efficiency of generating information to guide conservation implementation, as well as the speed and efficiency of putting it into the hands of local decision makers.”
>
> “Rapid watershed assessments provide initial estimates of where conservation investments would best address the concerns of landowners, conservation districts, and other community organizations and stakeholders. These assessments help land-owners and local leaders set priorities and determine the best actions to achieve their goals. The assessments are conducted by watershed planning teams traveling through each watershed, meeting with landowners and conservation groups, inventorying agricultural areas, identifying conservation opportunities and current levels of resource management,
> and estimating impacts of these opportunities on the local priority resource concerns.

“While these rapid assessments provide less detail and analysis than full-blown studies, they do provide the benefits of NRCS locally-led planning in less time at a reduced cost. The benefits include:

- Quick and inexpensive plans for setting priorities and taking action
- Providing a level of detail that is sufficient for identifying actions that can be taken with no further watershed-level studies or analyses
- Actions to be taken may require further Federal or State permits or ESA or NEPA analysis but these activities are part of standard requirements for use of best management practices (BMPs) and conservation systems
- Identifying where further detailed analyses or watershed studies are needed
- Plans address multiple objectives and concerns of landowners and communities
- Plans are based on established partnerships at the local and state levels
- Plans enable landowners and communities to decide on the best mix of NRCS programs that will meet their goals
- Plans include the full array of conservation program tools (i.e. cost-share practices, easements, technical assistance. (USDA, 2011)

“While Rapid Watershed Assessments are available for eighteen of the thirty-eight watersheds in Indiana—including the Upper White River watershed to the south of the Mississinewa watershed and the Salamonie River watershed to the north—unfortunately, a USDA RWA for the Mississinewa River watershed is currently not available at the NRCS site (USDA, 2011).

“Indiana Rapid Watershed Assessment
“The Indiana Department of Agriculture (ISDA) has also developed a series of RWAs for all thirty-eight 8-digit HUC watersheds in Indiana (Indiana State Department of Agriculture, 2011). From their website:

The Rapid Watershed Assessments (RWAs) consists of geographically displayed data layers, along with printable tabular watershed reports including summary data and source information. The RWAs draw on statewide data layers, clipped to the Hydrological Unit Codes (HUC) 8 watershed boundaries, in order to provide a watershed view of resource concerns that can be compared on a statewide scope.

“The RWA layers compile the best readily-available statewide data, including:

- A general description of the location, size, and political units associated with the HUC 8 watershed.
- Physical description including land use/land cover, public lands, cropland types, common resource areas, stream flow data, etc.
- Potential resource concerns.
- Census and social data.
- References and data sources.

“The information is general in nature and is not sufficiently detailed to be used in lieu of an area-wide or watershed plan. However, the information will provide a solid starting point for local stakeholders to use should they decide to proceed with a more detailed area-wide or watershed planning effort.

“Maps and Tabular Watershed Reports (PDFs). While RWA is a mapped-based tool, detailed information about the data is also available in tabular watershed reports. In the watershed reports, county-based data is spatially distributed according to HUC 8 watershed boundaries. The RWA data is not real-time, but modified by user-defined parameters to create maps of specific interest. References to the data sources, including year, can be found in the watershed reports. (ISDA, 2011).

“The Indiana Rapid Watershed Assessment for the Mississinewa River is available as an interactive map and four-page tabular “Watershed Report” at the ISDA website.

“Reports of the Upper Wabash River Watershed Assessment
“1998 Watershed Monitoring Program Study of the Upper Wabash River Basin
“This report summarizes results of a probabilistic study of 64 randomly chosen sites and four predetermined sites in the Upper Wabash River Basin monitored for ambient chemical, nutrient, organic, and metallic analytes. The goal of the program was to collect one-time data that would represent the ambient surface water quality of the Basin during annual low flow conditions between July 1 and October 15, 1998 (Christensen, 1999).

“Seven random (and no pre-determined) sites were selected within the Mississinewa Watershed, of which five sites were selected within the current study area of the middle Mississinewa watershed in Grant County: Mississinewa River (at 1st Street in Marion and at CR 450 W), and one each on Hummel Creek (at Bocock Road), Little Creek (tributary to Deer Creek at CR 100 S), and Walnut Creek (at CR 400 S). The other two sites were upstream on the Mississinewa River in Randolph County (at CR 900 N) and downstream of the reservoir (at Frances Slocum Trail) (Christensen, 1999).

“The data from all sites for each analyte were compiled to determine ambient conditions and create a metric classification including High, Upper Ambient, Ambient, Lower Ambient and Low. Compared to the ambient conditions of all 68 sites in the Upper Wabash River Basin, the Mississinewa River received Upper Ambient classifications for aluminum, chloride, total phosphorus, potassium, sodium, and suspended solids. All other tests were Ambient or Lower Ambient (Christensen, 1999).

“However, the watershed comparisons had low statistical strength due to the low number of observations within some watersheds, including the Mississinewa River, which had only seven observations. As a result, while some parameters have different ambient classifications between watersheds, they were found not to be statistically significant. Related to the Upper Ambient classifications for the Mississinewa River, values for chloride and suspended solids were not statistically different (Christensen, 1999)

“Two limited conclusions of the report are worth noting. First, the reservoirs on the Salamonie and Mississinewa Rivers had a noticeable impact on water quality as it passed through them. That is, most parameters either decreased or maintained the same classification when comparing monitoring sites upstream and downstream of the reservoirs. This is likely due to dilution, biotic uptake, and settling as the velocity decreases in the reservoir (Christensen, 1999).

“Second, eight monitoring sites near the Ohio border were noticeably high in most parameters (High or Upper Ambient classes), although the one site in the Mississinewa watershed was typically among the lowest of the eight sites in most parameters. However, the linkage between these elevated concentrations to agricultural land use is uncertain due to variability of nutrients (nitrate, total phosphorus and TKN) among the eight sites (Christensen, 1999).

“Concentrations of Escherichia Coli in Streams in the Upper Wabash River Watershed in Indiana, June-September 1998
“Five water samples collected over a 30-day period from June through September 1998 from 46 sites in the Upper Wabash River Basin were analyzed for concentrations of Escherichia coli (E., coli). Concentrations in five-sample geometric means were above Indiana bacteriological quality standard of 125 colonies per 100 milliliters (cfu/100ml) for 43 of the 46 sites. The five-sample geometric means for all 46 sites ranged from 17 to 4,800 cfu/100 ml. In addition, a statistically significant positive correlation was found between discharge and E. coli concentrations (Silcox,2000).

“Five of the 46 sites were located on the Mississinewa River, including two located within the middle Boots Creekrea of this diagnostic study in Grant County (Site 14 at CR 950 E near Matthews and Site 15 at Highland Avenue at Marion). The five-sample geometric means of E. coli concentrations of the five sites from upstream to downstream locations were: 1600, 1000, 790, 840, and 1700 cfu/100ml, respectively (Appendix A). The values in the Mississinewa were generally higher than concentrations in four of the other five watersheds in the Upper Wabash River Basin; only the Salamonie watershed had higher geometric mean concentrations of E. coli at its three sample sites (4,800, 3,000 and 1,600 cfu/100 ml) (Silcox, 2000).

“An Assessment of Pesticides in the Upper Wabash River Basin

“Surface water samples from twenty-two sites in the Upper Wabash River Basin were analyzed for pesticides, pesticide degradation products, and urban chemicals during April 1 through July 31, 1998, the time of year when pesticides are most often applied. The goals of the study were:
(1) identify the occurrence and amount of selected pesticides and semi-volatile chemical compounds in surface waters of the Upper Wabash River Basin, (2) provide benchmark information for long-term trend analysis and correlation with other ambient monitoring programs within the state, (3) determine which tributaries contribute the greatest pesticide load to the Upper Wabash River Basin, and (4) compare pesticide loading from individual sampling sites (McDuffee, 2001).

“Of the twenty-two sample locations in the study, three were USGS gauging stations located on the Boots Creek: Ridgeville (MS-100), Marion (MS-36), and near Peru (MS-7). All sample sites were sampled once a week for 15 weeks for 142 chemicals including 110 pesticides (77.4 percent of the sampled chemicals). Of the 110 pesticides, only nineteen were above detection limits. Of the 19 pesticides detected, 13 were herbicides with atrazine, metolachlor and acetochlor being the more frequently detected.

“The average concentrations during the 15-week sampling period were compared to Drinking Water Standards maximum contaminant levels (MCL) in the absence of surface water standards for these pesticides. The highest single date concentrations of these three most abundant pesticides were all three detected on the Boots Creekt Ridgeville (Table 2.1).

“An estimate of percent pesticide runoff was determined for each sample station by combination of USGS gaging station flow data and mathematical calculations involving a Geographic Information System assessment of crop acreage of each watershed, application rates of pesticides, and the pesticide loading in pounds. This value was then compared to the percentage of land area of each of the seven watersheds sampled in this study. The Mississinewa River watershed, which represents 11.2 percent of the Upper Wabash River Basin, was found to contribute a proportionally greater percentage of runoff of all three pesticides: atrazine (13.3 percent), metolachlor (20.8 percent), and acetochlor (18.8 percent). However, the elevated
percentage of pesticide runoff from the Mississinewa River watershed in this study may have been caused by the fact that sampling was conducted following a major localized rain event that may have caused the pesticide runoff levels to increase and contribute a greater load to the Wabash River. (This concept is supported by data collected from an additional sampling event following a major rain event. The entire Wildcat Creek was sampled during this event which resulted in a three-fold increase in herbicide runoff from 3 percent to over 9 percent).

“Trend Analysis of Fixed Station Water Quality Monitoring Data in the Upper Wabash River Basin 1998

“This study of monthly samples during 1998 at thirty-five fixed stations generated 372 samples analyzed for nine Total Recoverable Metals: arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, and zinc. Out of 2,976 discrete analytical test, 100 exceeded stream standards for Chronic Aquatic Criteria, mostly for Lead and Mercury. Only four sites also exceeded the Acute Aquatic Criteria (Holdeman et al., 2003).

“Of the thirty-five stations monitored in this study, five were located on the Boots Creekt: Ridgeville (MS-99), Eaton (MS-68), Marion (MS-36), Jalapa (MS-28) and near Peru (MS-1). Only the Marion station is located in the current study area for this diagnostic study of the middle Mississinewa watershed in Grant County. The study also sampled for basic nutrients and flow at each station, including the Marion station.

“1998 Upper Wabash River Basin Sampling Sites and Stream Standard Violations

“This report summarizes water quality violations from sampling results of three previously discussed water monitoring programs in the Upper Wabash River Basin: The Watershed Monitoring Program, the Fixed Station Monitoring Program, and the E. coli Monitoring Program (along with a Total Maximum Daily Load (TMDL) study of the Wildcat Creek watershed). Two
stations within the current study area of the middle Mississinewa River watershed (HUC 5120103050) registered violations (McFall et al., 2000).

“The Mississinewa River (at CR 950 W) near Matthews violations:

- for E. coli standards on June 18, 1998 (790 cfu/100ml as 5-sample geometric mean).
- The Boots Creekt Highland Avenue in Marion (MS-36 and 24-02) recorded violations:
- for lead on November 25, 1996 (15 mg/L) and January 22, 1997 (11 mg/L),
- for mercury on April 20, 1998 (0.2 mg/L),
- for cyanide on June 18, 1998 (0.007 mg/L), and
- for E. coli from June 2 through 29, 1998 (842 cfu/100ml as 5-sample geometric mean)

“Nutrient, Habitat, and Basin-Characteristics Data and Relations with Fish and Invertebrate Communities in Indiana Streams, 1998-2000

“This USGS report explored the statistically significant relationships between existing nutrient, habitat, basin-characteristics and biological-community (fish and invertebrate) data from 1998-2000 for 58 sites in the Upper Wabash River Basin, Lower Wabash River Basin and tributaries to the Great Lakes and Ohio River Basins (Frey and Caskey, 2007). The study found fish community composition was most influenced by habitat and land use but not by nutrients. The invertebrate-community composition was most influenced by habitat, land use, soils, and one nutrient (TKN).

“Four sampling sites were located in the Mississinewa River watershed, three of which occurred within the middle Mississinewa study area: Walnut Creek at CR 400S (study site 41), Boots Creekt First St., Marion (42), and Hummel Creek at Bocock Rd (43), and which received good to excellent QHEI scores of 67, 85, and 71, respectively (Frey and Caskey, 2007).

“A Waste Load Assimilation Study of Mississinewa River

“This report was conducted for the Mississinewa River including Grant County between August 1977 and August 1978, with the goals to (1) create and verify a dissolved oxygen model for the river and (2) use the model to determine alternative for future waste loadings that would ensure that the stream meets Indiana water quality standards for low flow conditions. While a model was developed, the field data were insufficient to verify the model (Wilber et al., 1979).

“However, preliminary studies indicated that algal photosynthesis and nitrification were significant factors affecting the dissolved oxygen concentrations in the river. The stream natural reaeration capacity alone was insufficient to maintain the state standard of 5 mg/l dissolved oxygen concentration, and therefore could not assimilate the waste biochemical oxygen demand during summer low flows. During winter low flows, ammonia toxicity was the limiting water quality criterion. The report suggested that future wastes in the Mississinewa River would have to be discharged in Marion in the reach downstream from the Mill dam where the natural aeration (due to the turbulent low flow) is significantly greater than in the reach above the dam.

“Land Use and Sediment Loading in the Mississinewa Watershed

“[“Land Use and Sediment Loading in the Mississinewa Watershed,” funded by a 319 grant,] created a field-validated model for prioritizing sediment loading in the forty-eight HUC-14 watersheds of the Mississinewa watershed (Taylor University, 2005). Rainfall and ten stream sites were monitored: five in each of Walnut Creek (representing the northern subwatersheds) and Barren Creek (representing the southern sub-watersheds. At each site, channel cross-sections and periodic discharge measurements were used to establish a stage discharge relationship. Multiple suspended sediment samples were collected during base flow and storm flow events to measure sediment concentration and calculate sediment loading. The Revised Universal Soil Loss Equation (RUSLE) model was implemented in this study by use of a GIS interface and was calibrated by the stream data of the two sub-watersheds. The output of the calibrated model (tons/acre) was correlated to the field data through a delivery ratio. Each of the forty-eight sub-watersheds were then ranked by sediment loading and placed into five categories of least to most tons/acre sediment yield (Figure 2.1).

“Map G.1. Prioritization of the forty-eight sub-watersheds in the Mississinewa River watershed based on field-validated RUSLE model results of sediment loading in tons/acre (Taylor, 2005).

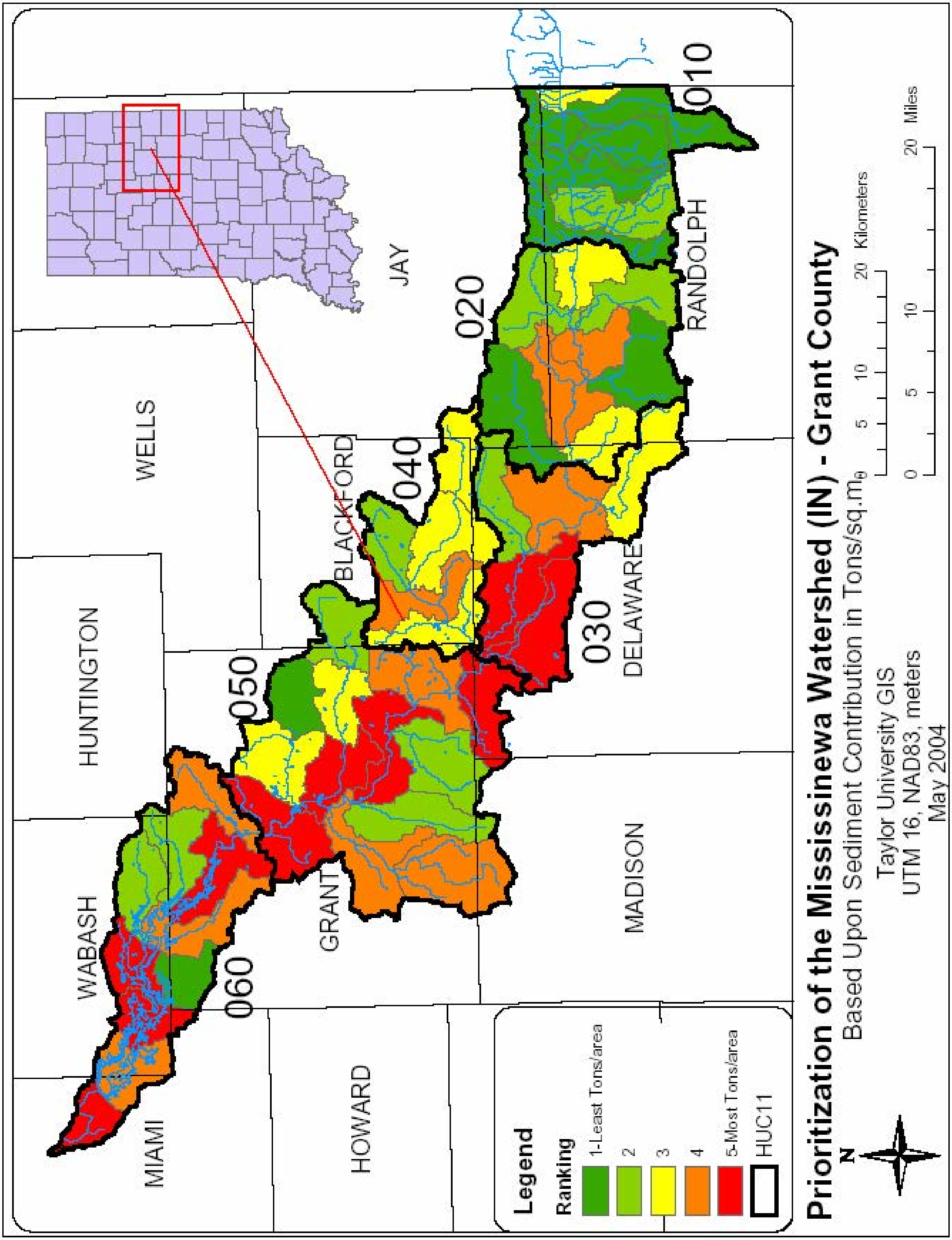
“Implementing landscape indices to predict stream water quality in an agricultural setting: (An assessment of the Lake and River Enhancement (LARE) protocol in the Mississinewa River watershed, East-Central Indiana)

“This study assessed the link between landscape indices to stream water quality parameters from thirty 14-digit HUC subwatersheds from this and three previous LARE diagnostic studies in the Mississinewa River watershed (Shiels and Guebert, 2010). Six indices were developed, three representing natural area extent characteristics (Extent of Natural Cover, Extent of River-Stream Corridor Integrity, and Wetland Extent) and three representing natural area disturbance characteristics (Extent of Drained Land Index, Percent of Agriculture on Slopes Index, Proximity of CAFO’s to Streams). The indices were correlated to water quality variables (Total Phosphorus, Nitrate, E. coli, and macroinvertibrate EPT/C scores (Shiels and Guebert, 2010).

“While this study was unable to identify a defined set of landscape indices that could predict water quality in the Mississinewa River watershed, the results do indicate some correlation with differences in landscape features that could impair water quality as previously identified in this study [...]. For example, the results of the landscape indices for the middle Mississinewa subwatersheds tend to cluster in ranking based on location on either the northern or southern side of the Mississinewa River. The northern subwatersheds tend to score better (lower priority for water quality management) in five of six indices, with the exception of percent agriculture on slopes (due to the greater slopes of the morainal subwatershed) and the unusually high number of [CFOs] in proximity to streams in Walnut Creek [...]. Landscape indices and stream quality variables for the middle Mississinewa.

“Fisheries and Water Quality Surveys of the Mississinewa River

“The Indiana Department of Environmental Management maintains a database of water quality monitoring sites that include data on fish community and habitat, fish tissues, macroinvertebrates, and lake data. The database includes information for selected sites and locations on the Boots Creeknd tributaries in Grant County. IBI scores ranged from good to excellent in the Mississinewa River, but poor to fair in the tributaries (Hoppas Ditch and upstream portions of Walnut Creek and Deer Creek (Sobat, 2011).



MAP G.1 | Prioritization of the Mississinewa Watershed (IN)

"The IDNR Divison of Fish and Wildlife completed three fisheries surveys of the Mississinewa River in 1982 (Braun, 1982), 1990 (Braun, 1991) and in 1998 (Braun, 1999). All three studies sampled thirteen to fourteen sites on the Mississinewa and Little Mississinewa Rivers to determine current status of the fish population, determine distribution of smallmouth bass and walleye, and assess current water quality and fish habitat. The Qualitative Habitat Evaluations Index (QHEI) was assessed and scores ranged from good to excellent except at the extreme upstream station (Braun, 1999). The Index of Biotic Integrity (IBI) was determined for each sample location and ranged from 36 to 56, showing improvement over the period between\ surveys. The best scores occurred in the middle reach of the river, while the upper reaches of the rivers in Randolph County maintained a group 5 fish consumption advisory (do not eat fish from these waters) due to PCB contamination from an industrial sites in Union City (Braun, 1999).

"INDIANA UNIFIED WATERSHED ASSESSMENT
In 2000-2001, the Indiana Unified Watershed Assessment program conducted an analysis of watershed conditions statewide at the HUC-11 scale using available fishery, habitat assessment, and water quality data (IDEM OWM 2001c). Hydrologic Unit Scores for the Phase I, Phase II, and Phase III watersheds are presented [in the table below].

TABLE G.1 | Hydrologic Unit Scores for the Upper Mississinewa Watershed

(range 1-5, with 1 indicating minimum impairment and 5 indicating severe impairment)

Parameter	Phase III	Phase II	Phase I
Critical Biodiversity Resource	2	2	2
Aquifer Vulnerability	5	5	4
Pop. Using Surface Water for Drinking Water	2	2	2
Residential Septic System Density	4	1	2
Degree of Urbanization	2	2	2
Livestock Density	3	4	4
Percent Cropland	4	4	4
Mineral Extraction Activities	2	2	2

"FISHERIES
"The DNR Division of Fish & Wildlife has conducted several fisheries surveys and reports that included the Upper Mississinewa area. They are:
A Fisheries Survey of the Mississinewa River in Indiana. E. Braun, 1982.
A Fisheries Survey of the Mississinewa River, E. Braun, 1990.
A Fisheries Survey of the Mississinewa River Upstream of Mississinewa Reservoir and the Little Mississinewa River, E. Braun, 1998.
Mississinewa River Rainbow Trout Introduction WP#202120 – 2003 Progress Report, E. Braun, 2004.

"The Randolph County Wildlife Management Area lies just upstream of Albany, southeast of State Road 1 and State Road 28. This area is technically outside of the watershed in this study but indicative of the high quality of water resources that is possible in the area. In 2002 and 2003, the river segment in this area was found to be one of only a few locations in Indiana which is suitable for trout survival. Water quality was monitored upstream of the State road 1 bridge in Randolph County monthly from April to June, 2003 and 2004, and was compared to 2002 data. While turbidity was high during a storm event (432 NTU), dissolved oxygen and cold water temperatures were less than desirable, but adequate to support a trout fishery.

"In the most recent fishery survey (1998), four sampling sites were within the portion of the watershed included in this diagnostic study at River Mile 64.68, RM 69.2, RM 75.8 and RM 82.4. Parameters measured were stream average width, average and maximum depth, subjective and aesthetic ratings, all metrics for the Qualitative Habitat Evaluation Index (describing fish habitat quality), and an electrofishing survey. The QHEI scored the lowest at the site in Wheeling (58.5 out of 100 possible points) and ranged from 70 to 74 in the other sites. Pool habitat was limited in some sites where bedrock was the dominant bottom type.

"The number of species captured at these sites ranged from 25 to 33 including the highest numbers of species sensitive to water quality (12-14 per site). Fewer carp were found in these stations that at other sites along the river. Orangespotted sunfish, brindled madtom, mottled sculpin, and six darter species were collected. Three species of redhorse sucker (golden, black and silver) and northern hogsucker were found in these segments. Central stonerollers were found at stations above Wheeling; this herbivore prefers shallow rocky substrate with some algal growth.

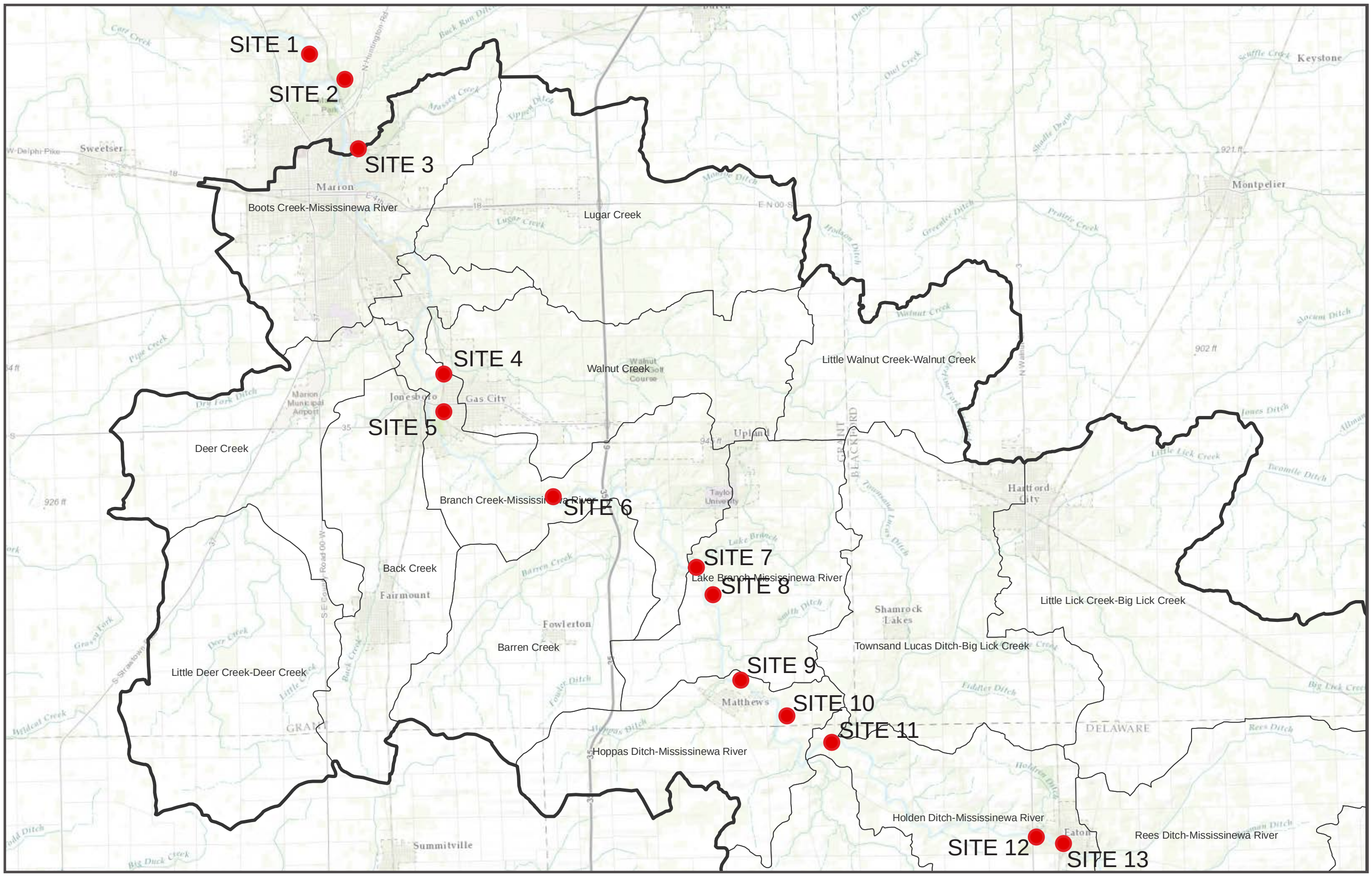
"Total Index of Biotic Integrity (IBI) scores ranged from 48 to 56 along these sites. Interpretation of these scores rates these fish communities in the "good" class approaching "excellent" at the upper end but showing some stress. Presence of tolerant species, omnivores, lower numbers of carnivores, and fewer lithophilic (gravel-loving) spawners lowered the scores.

This middle section of the river showed higher quality fish communities than either the downstream urban areas or the upstream channelized reaches. At three of the sites, fish community scores showed improvement from 1990 to 1998. Smallmouth and rock bass populations were substantially better than in previous surveys. Instream and riparian habitat was reasonably good and did not seem to be a major impairment, suggesting that other factors such as turbidity and nutrients may be affecting the fisheries resource. Implementation of conservation practices could be a key factor in maintaining and enhancing the high quality fish community that appears to be possible along this portion of the river.

"A fish community assessment was conducted via electrofishing on June 8, 1994 by IDEM Biological Studies Section that included three stations within Delaware County (Sobat 2004). Locations within the Mississinewa River Phase III watershed included Campbell Creek at CR500 E, Boots Creekt the 700N bridge, and the Boots Creekt the Granville bridge OR CR370 Bridge at Station MR01 (Location given as Granville bridge but coordinates given are for CR370 bridge, Phase III station MR01). In addition, since the coordinates are in question, Granville bridge could refer either to the bridge near the intersection of Old Granville Road and Gregory Road or the one lane bridge where Gregory Road crosses the river.
"In Campbell Creek, 491 individuals from 15 species were caught. The dominant species were creek chub (36 percent), bluntnose minnow (22 percent) and green sunfish (18 percent). This station had a fish IBI of 38. In the Boots Creekt the 700N bridge, 691 individuals from 28 species were caught. The dominant species were bluntnose minnow (23 percent) and rainbow darter (13 percent). This station had a fish IBI of 46. In the Boots Creekt the Granville bridge, 528 individuals from 27 species were caught. The dominant species were bluntnose minnow (23 percent), longear sunfish (16 percent), rock bask (16 percent), and spotfin shiner (13 percent). This station had a fish IBI of 50.

"An IBI score of 28 – 24 equates to a biotic integrity rating of poor due to the scarcity or absence of top carnivores and many expected species and dominance of omnivores and tolerant species. An IBI score of 40 – 44 equates to a biotic integrity rating of fair due to the absence of intolerant and sensitive species and a skewed trophic structure. An IBI score of 48 – 52 equates to a biotic integrity rating of good due to a decreased species richness dominated by intolerant species, with sensitive species present. (Karr et al. 1986). Based on these ranges, Campbell Creek at CR500 had a biotic integrity of poor to fair, the Boots Creekt 700N bridge had a biotic integrity of fair to good, and the Boots Creekt Granville bridge hat a biotic integrity of good. IDEM considers a fish IBI greater than 36 as fully supporting aquatic life use in rivers and streams (IDEM 2006). The Indiana Department of Natural Resources Fisheries Section conducted a fisheries survey in 1998."

H. EXISTING IDEM DATA



MAP H.1 | Idem Sampling Locations Extracted from the IDEM AIMS Database

TABLE H.1 | IDEM Sampling Sites			
IDEM Site Name	Renamed Site Name	lat	long
WMI060-0004	1	40.62805556	-85.73583333
WMI060-0002	2	40.61194444	-85.69277778
WMI060-0012	2	40.61166667	-85.69305556
WMI060-0001	3	40.57611111	-85.65944444
WMI060-0005	3	40.57611111	-85.65972222
WMI060-0010	3	40.57666667	-85.65944444
WMI050-0013	4	40.49666667	-85.62305556
WMI050-0007	5	40.4875	-85.62583333
WMI050-0020	6	40.4559775	-85.57776278
WMI050-0016	7	40.431798	-85.516297
WMI050-0006	8	40.42222222	-85.50861111
WMI050-0012	9	40.39430556	-85.49352222
WMI050-0001	10	40.38027778	-85.47805556
WMI030-0007	11	40.37222222	-85.45694444
WMI030-0001	12	40.34388889	-85.38833333
WMI030-0002	13	40.34055556	-85.36944444

TABLE H.2 | Annual Sample Frequency at IDEM Sample Sites

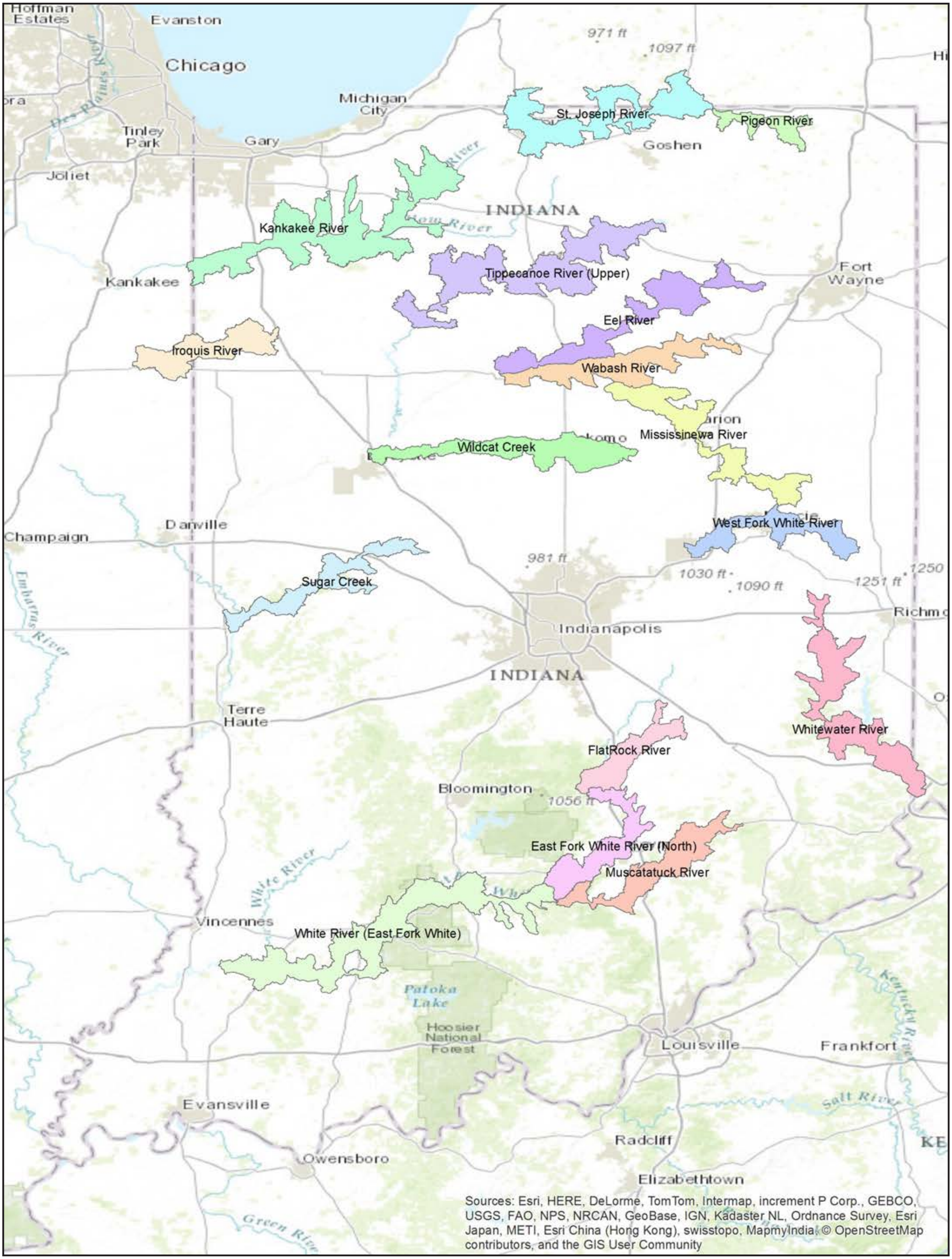
Site and Year	DO	E. coli	Ammonia	Nitrate+Nitrite	pH (Field)	Phosphorus	(TSS)	Temp.	NTU
1									
1991		11.00	1.00	12.00	8.00	11.00	11.00	9.00	
1992		8.00	1.00	10.00	9.00	10.00	10.00	10.00	
1993		9.00	4.00	12.00	8.00	11.00	9.00	8.00	
1994		8.00	5.00	11.00	11.00	10.00	9.00	11.00	
1995	12.00	12.00	2.00	12.00	12.00	12.00	10.00	12.00	
1996	12.00	12.00	4.00	12.00	12.00	12.00	12.00	12.00	
1997	12.00	11.00	3.00	12.00	12.00	12.00	9.00	12.00	
1998	17.00	9.00	1.00	12.00	17.00	12.00	12.00	17.00	
1999	12.00		2.00	12.00	12.00	12.00	12.00	12.00	
2000	12.00		2.00	12.00	12.00	12.00	10.00	12.00	
2001	12.00		1.00	13.00	12.00	13.00	11.00	12.00	
2002	11.00		1.00	11.00	11.00	12.00	10.00	11.00	
2003	12.00		2.00	12.00	12.00	12.00	11.00	12.00	
2004	12.00			10.00	12.00	12.00	10.00	12.00	
2005	12.00			12.00	12.00	12.00	11.00	12.00	
2006	12.00		1.00	12.00	12.00	12.00	12.00	12.00	
2007	12.00		2.00	11.00	12.00	9.00	10.00	12.00	
2008	11.00		1.00	11.00	11.00	11.00	9.00	11.00	
2009	11.00		2.00	11.00	11.00	11.00	11.00	11.00	
2010	5.00			12.00	5.00	12.00	10.00	5.00	
2011				10.00		10.00	10.00		
2012			1.00	12.00		12.00	12.00		
2013				7.00		8.00	8.00		
2									
1991					1.00			1.00	
2003	4.00				5.00			5.00	5.00
3									
1991		11.00	4.00	9.00	9.00	11.00	10.00	9.00	
1992		11.00	3.00	12.00	9.00	11.00	10.00	10.00	
1993		8.00	4.00	11.00	8.00	10.00	10.00	8.00	
1994		10.00	6.00	8.00	10.00	9.00	9.00	10.00	
1995	12.00	12.00	2.00	11.00	12.00	12.00	11.00	12.00	
1996	12.00	12.00	7.00	11.00	12.00	12.00	12.00	12.00	
1997	12.00	12.00	5.00	11.00	12.00	10.00	10.00	12.00	
1998	40.00	17.00	3.00	12.00	40.00	12.00	12.00	40.00	
1999	12.00		4.00	11.00	12.00	12.00	12.00	12.00	
2000	12.00		4.00	11.00	12.00	12.00	11.00	12.00	
2001	12.00		2.00	11.00	12.00	12.00	12.00	12.00	
2002	10.00		3.00	10.00	10.00	11.00	9.00	10.00	
2003	16.00		4.00	12.00	17.00	12.00	12.00	17.00	5.00
2004	11.00			10.00	11.00	11.00	10.00	11.00	
2005	12.00		1.00	11.00	12.00	11.00	10.00	12.00	
2006	12.00		1.00	11.00	12.00	12.00	12.00	12.00	
2007	12.00		1.00	11.00	12.00	9.00	11.00	12.00	
2008	12.00		1.00	10.00	12.00	11.00	10.00	12.00	
2009	12.00		1.00	10.00	12.00	12.00	11.00	12.00	
2010	4.00			8.00	4.00	11.00	10.00	4.00	
2011				9.00		10.00	9.00		
2012				12.00		12.00	12.00		
2013				7.00		8.00	8.00		
4									
1998	1.00		1.00	2.00	1.00	2.00	1.00	1.00	
5									
1991					1.00			1.00	
6									
2008	11.00			2.00	11.00	3.00	3.00	11.00	11.00
7									
2003	4.00			3.00	4.00	3.00	3.00	4.00	4.00
8									
1991					1.00			1.00	
2003	5.00				5.00			5.00	5.00
9									
1998	5.00	5.00			5.00			5.00	
2003	5.00				5.00			5.00	5.00
10									
1998	1.00		1.00	2.00	1.00	2.00		1.00	
11									
1991					1.00			1.00	
1998	1.00				1.00			1.00	
12									
1998	10.00	2.00		10.00	10.00	10.00	8.00	10.00	
1999	12.00	2.00	3.00	12.00	12.00	12.00	10.00	12.00	
2000	12.00		1.00	10.00	12.00	11.00	10.00	12.00	
2001	12.00		1.00	11.00	12.00	11.00	9.00	12.00	
2002	12.00			11.00	12.00	12.00	10.00	12.00	
2003	16.00		1.00	11.00	16.00	11.00	10.00	16.00	5.00
2004	12.00		1.00	11.00	12.00	12.00	10.00	12.00	
2005	12.00		1.00	12.00	12.00	12.00	11.00	12.00	
2006	12.00		1.00	12.00	12.00	12.00	12.00	12.00	
2007	11.00		1.00	11.00	11.00	10.00	11.00	11.00	
2008	12.00		1.00	10.00	12.00	11.00	9.00	12.00	
2009	11.00			11.00	11.00	11.00	10.00	11.00	
2010	4.00			9.00	4.00	10.00	8.00	4.00	
2011				10.00		10.00	10.00		
2012				12.00		12.00	9.00		
2013			2.00	9.00		9.00	8.00		
13									
1998	5.00	5.00			5.00			5.00	

TABLE H.3 | Annual Parameter Averages at IDEM Sample Sites

Site and Year	DO	E. coli	Ammonia	Nitrate+Nitrite	pH	Phosphorus	TSS	Temp.	NTU
1									
1991		204.55	0.20	2.58	7.58	0.12	44.91	13.64	
1992		286.25	0.20	4.21	7.51	0.10	22.30	14.96	
1993		2683.33	0.20	2.68	7.94	0.24	84.00	10.15	
1994		562.50	0.28	2.01	7.89	0.16	41.56	13.58	
1995	11.22	1496.67	0.15	4.59	8.21	0.16	34.40	13.75	
1996	10.86	1201.67	0.13	4.34	8.12	0.19	34.83	12.84	
1997	11.01	1522.73	0.20	2.79	8.07	0.15	39.11	13.30	
1998	9.78	3214.44	0.10	3.44	8.08	0.21	66.75	17.15	
1999	11.42		0.10	2.81	8.51	0.18	28.92	14.05	
2000	10.79		0.15	5.29	8.22	0.18	37.60	12.90	
2001	10.22		0.20	3.66	8.19	0.16	28.00	13.52	
2002	10.49		0.11	2.80	8.19	0.21	60.40	14.35	
2003	10.69		0.20	3.68	7.95	0.17	44.64	12.35	
2004	11.28			3.92	8.06	0.22	59.30	12.39	
2005	11.91			2.48	8.12	0.23	73.36	14.56	
2006	11.04		0.10	3.46	8.07	0.25	49.92	12.69	
2007	11.69		0.16	2.06	8.50	0.16	36.30	14.20	
2008	10.47		0.20	3.29	8.30	0.14	31.44	13.80	
2009	10.07		0.25	3.58	8.47	0.18	29.00	12.89	
2010	12.10			3.51	8.57	0.16	46.10	9.01	
2011				3.30		0.27	77.70		
2012			0.10	3.57		0.13	24.25		
2013				4.56		0.26	97.88		
2									
1991					7.80			22.76	
2003	10.81				8.29			22.10	15.12
3									
1991		242.73	0.15	2.18	7.50	0.14	43.20	16.13	
1992		2377.27	0.13	3.59	7.53	0.14	54.50	14.43	
1993		1750.00	0.15	2.56	7.92	0.17	38.90	11.89	
1994		663.00	0.27	1.94	7.87	0.14	34.00	13.30	
1995	11.37	368.33	0.20	4.43	8.10	0.15	30.18	13.76	
1996	10.60	10554.17	0.16	4.25	8.04	0.15	34.00	13.15	
1997	10.38	10690.83	0.24	2.50	7.97	0.14	29.20	13.18	
1998	9.19	7500.59	0.17	3.43	8.04	0.20	58.58	19.87	
1999	10.76		0.15	2.38	8.21	0.13	29.50	13.92	
2000	10.38		0.18	5.68	8.06	0.17	31.18	12.92	
2001	10.48		0.30	3.54	8.16	0.16	28.58	13.73	
2002	11.02		0.14	2.38	8.15	0.20	57.44	13.22	
2003	10.34		0.20	3.61	8.02	0.16	39.75	15.19	24.86
2004	11.13			3.88	8.07	0.22	65.40	13.63	
2005	11.11		0.20	2.38	8.05	0.22	70.30	14.25	
2006	10.62		0.10	3.69	8.04	0.24	47.75	12.83	
2007	11.53		0.13	1.75	8.40	0.14	29.18	14.47	
2008	10.71		0.20	3.44	8.25	0.13	30.70	12.96	
2009	9.58		0.20	3.77	8.22	0.15	30.73	11.95	
2010	11.08			4.16	8.41	0.16	43.60	11.05	
2011				2.98		0.17	39.78		
2012				3.25		0.12	29.75		
2013				4.27		0.26	99.25		
4									
1998	7.22		0.60	0.65	8.09	0.23	9.00	22.10	
5									
1991					7.94			21.43	
6									
2008	8.11			1.98	7.97	0.15	21.00	22.14	74.42
7									
2003	9.36			2.23	8.35	0.13	16.67	21.13	19.78
8									
1991					7.76			21.42	
2003	9.07				8.12			21.24	29.99
9									
1998	7.58	2648.00			7.89			21.40	
2003	9.00				8.10			21.20	25.67
10									
1998	6.46		0.22	0.91	6.61	1.53		25.48	
11									
1991					8.00			23.26	
1998	9.02				7.98			25.15	
12									
1998	9.16	215.00		3.16	8.17	0.14	27.13	16.58	
1999	11.00	500.00	0.20	2.55	8.24	0.18	45.40	14.18	
2000	9.79		0.20	5.55	8.20	0.19	27.80	12.98	
2001	9.83		0.40	3.52	8.12	0.20	24.44	13.70	
2002	9.86			2.87	8.09	0.19	43.40	13.62	
2003	9.41		0.40	4.46	8.00	0.16	28.20	16.18	24.33
2004	9.70		0.10	4.65	8.04	0.23	66.10	12.60	
2005	9.63		0.10	2.63	7.93	0.26	68.18	13.41	
2006	9.76		0.10	3.15	7.81	0.25	44.50	12.18	
2007	8.67		0.10	1.69	8.29	0.16	23.45	13.60	
2008	10.04		0.20	3.48	8.32	0.13	20.89	12.17	
2009	9.28			3.70	8.22	0.13	18.50	12.26	
2010	10.50			3.50	8.40	0.17	38.50	10.41	
2011				3.34		0.26	58.10		
2012				3.31		0.11	16.89		
2013			0.15	3.79		0.32	85.88		
13									
1998	7.96	3286.00			7.99			21.30	

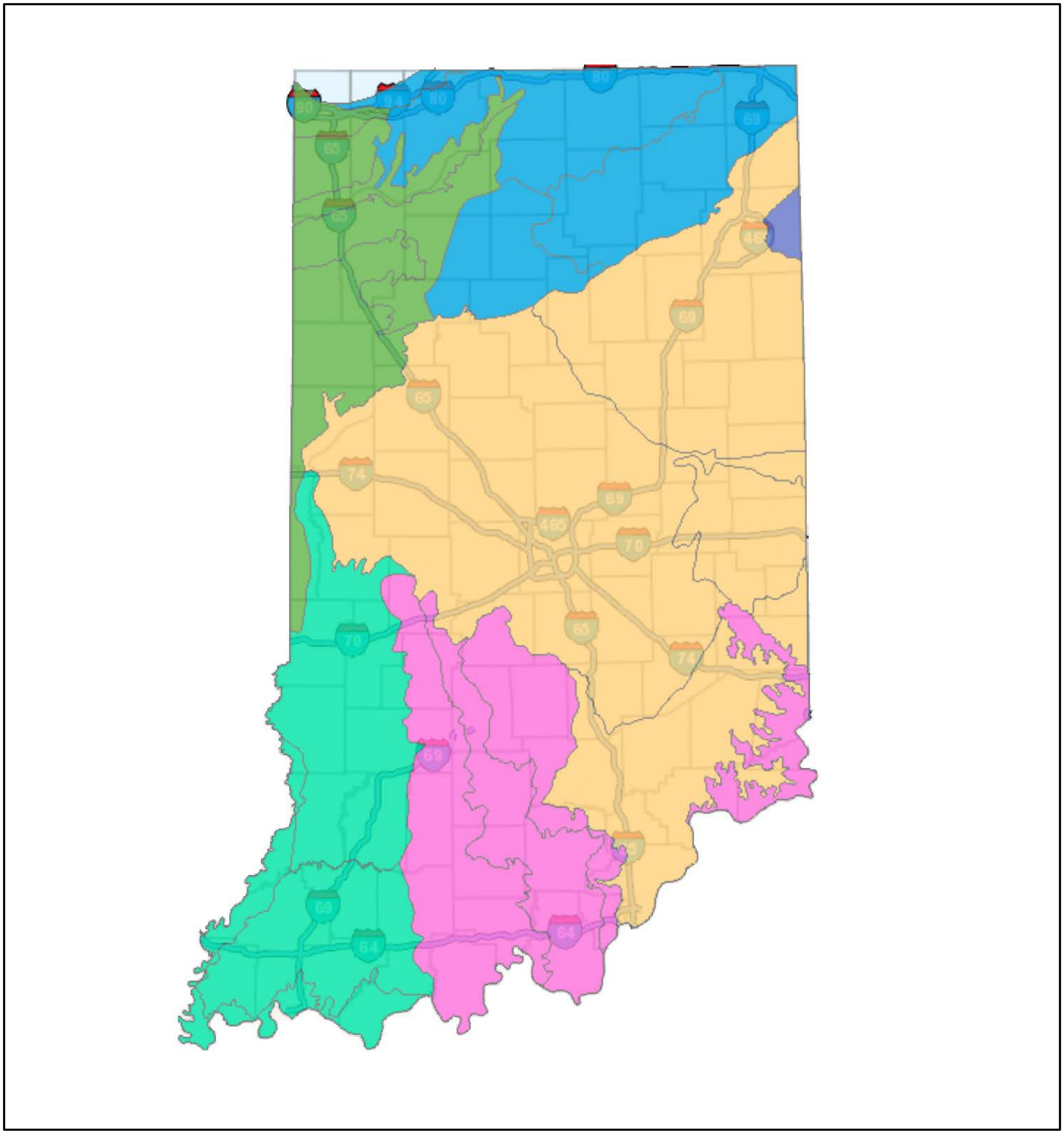
TABLE H.4 | Major IDEM Sampling Site Averages

Year and Site	DO	E. coli	Ammonia	Nitrate+Nitrite	pH (Field)	Phosphorus	(TSS)	Temp.	NTU
1991									
1		204.55	0.20	2.58	7.58	0.12	44.91	13.64	
3		242.73	0.15	2.18	7.50	0.14	43.20	16.13	
1992									
1		286.25	0.20	4.21	7.51	0.10	22.30	14.96	
3		2377.27	0.13	3.59	7.53	0.14	54.50	14.43	
1993									
1		2683.33	0.20	2.68	7.94	0.24	84.00	10.15	
3		1750.00	0.15	2.56	7.92	0.17	38.90	11.89	
1994									
1		562.50	0.28	2.01	7.89	0.16	41.56	13.58	
3		663.00	0.27	1.94	7.87	0.14	34.00	13.30	
1995									
1	11.22	1496.67	0.15	4.59	8.21	0.16	34.40	13.75	
3	11.37	368.33	0.20	4.43	8.10	0.15	30.18	13.76	
1996									
1	10.86	1201.67	0.13	4.34	8.12	0.19	34.83	12.84	
3	10.60	10554.17	0.16	4.25	8.04	0.15	34.00	13.15	
1997									
1	11.01	1522.73	0.20	2.79	8.07	0.15	39.11	13.30	
3	10.38	10690.83	0.24	2.50	7.97	0.14	29.20	13.18	
1998									
1	9.78	3214.44	0.10	3.44	8.08	0.21	66.75	17.15	
3	9.19	7500.59	0.17	3.43	8.04	0.20	58.58	19.87	
12	9.16	215.00		3.16	8.17	0.14	27.13	16.58	
1999									
1	11.42		0.10	2.81	8.51	0.18	28.92	14.05	
3	10.76		0.15	2.38	8.21	0.13	29.50	13.92	
12	11.00	500.00	0.20	2.55	8.24	0.18	45.40	14.18	
2000									
1	10.79		0.15	5.29	8.22	0.18	37.60	12.90	
3	10.38		0.18	5.68	8.06	0.17	31.18	12.92	
12	9.79		0.20	5.55	8.20	0.19	27.80	12.98	
2001									
1	10.22		0.20	3.66	8.19	0.16	28.00	13.52	
3	10.48		0.30	3.54	8.16	0.16	28.58	13.73	
12	9.83		0.40	3.52	8.12	0.20	24.44	13.70	
2002									
1	10.49		0.11	2.80	8.19	0.21	60.40	14.35	
3	11.02		0.14	2.38	8.15	0.20	57.44	13.22	
12	9.86			2.87	8.09	0.19	43.40	13.62	
2003									
1	10.69		0.20	3.68	7.95	0.17	44.64	12.35	
3	10.34		0.20	3.61	8.02	0.16	39.75	15.19	24.86
12	9.41		0.40	4.46	8.00	0.16	28.20	16.18	24.33
2004									
1	11.28			3.92	8.06	0.22	59.30	12.39	
3	11.13			3.88	8.07	0.22	65.40	13.63	
12	9.70		0.10	4.65	8.04	0.23	66.10	12.60	
2005									
1	11.91			2.48	8.12	0.23	73.36	14.56	
3	11.11		0.20	2.38	8.05	0.22	70.30	14.25	
12	9.63		0.10	2.63	7.93	0.26	68.18	13.41	
2006									
1	11.04		0.10	3.46	8.07	0.25	49.92	12.69	
3	10.62		0.10	3.69	8.04	0.24	47.75	12.83	
12	9.76		0.10	3.15	7.81	0.25	44.50	12.18	
2007									
1	11.69		0.16	2.06	8.50	0.16	36.30	14.20	
3	11.53		0.13	1.75	8.40	0.14	29.18	14.47	
12	8.67		0.10	1.69	8.29	0.16	23.45	13.60	
2008									
1	10.47		0.20	3.29	8.30	0.14	31.44	13.80	
3	10.71		0.20	3.44	8.25	0.13	30.70	12.96	
12	10.04		0.20	3.48	8.32	0.13	20.89	12.17	
2009									
1	10.07		0.25	3.58	8.47	0.18	29.00	12.89	
3	9.58		0.20	3.77	8.22	0.15	30.73	11.95	
12	9.28			3.70	8.22	0.13	18.50	12.26	
2010									
1	12.10			3.51	8.57	0.16	46.10	9.01	
3	11.08			4.16	8.41	0.16	43.60	11.05	
12	10.50			3.50	8.40	0.17	38.50	10.41	
2011									
1				3.30		0.27	77.70		
3				2.98		0.17	39.78		
12				3.34		0.26	58.10		
2012									
1			0.10	3.57		0.13	24.25		
3				3.25		0.12	29.75		
12				3.31		0.11	16.89		
2013									
1				4.56		0.26	97.88		
3				4.27		0.26	99.25		
12			0.15	3.79		0.32	85.88		



MAP H.2 | Recreational rivers in Indiana analyzed in conjunction with the Historic Water Quality discussion (Section 7)

Ecoregions of Indiana



August 2, 2016

1:2,500,000

0 20 40 80 mi

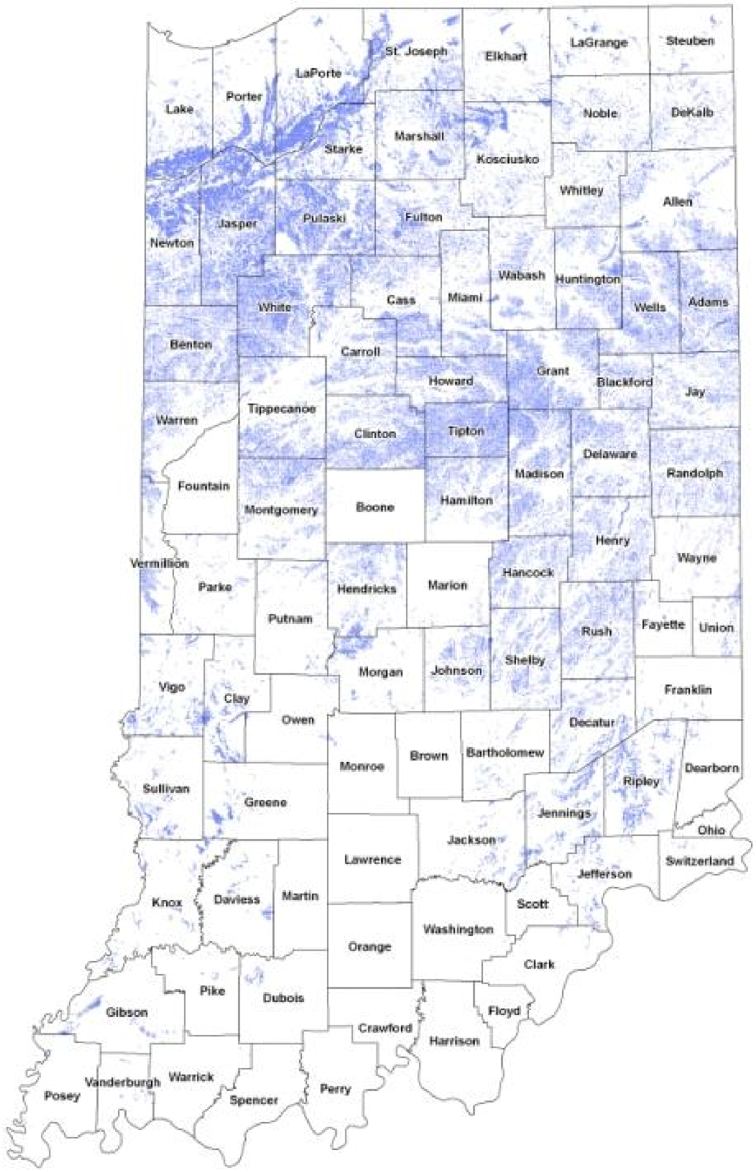
0 30 60 120 km

Ecoregions

- Central Corn Belt Plains
- Eastern Corn Belt Plains
- Huron/Erie Lake Plains
- Interior Plateau
- Interior River Valleys and Hills
- Southern Michigan/Northern Indiana Drift Plains

Indiana Department of Transportation (INDOT), U.S. Census Bureau (USCB), Indiana Geographic Information Council (IGIC), UITS, Indiana Spatial Data Portal
U.S. Environmental Protection Agency, U.S. Geological Survey

Suitable Soils for Drainage Water Management
Indiana



Geoprocessing Procedure
Soils Spatial and Tabular data obtained from the Soil Data Mart 8/24/2011
Selection Criteria:
1. Major Components. Percent Composition > 40%
2. Representative slope <= 1 percent.
3. Representative value of the Hydric Definition Growing Season Minimum Depth of Water Table < 18 inches depth.
Extent of Cultivated Crops obtained from the 2006 National Land Cover Dataset (NLCD), USGS.
The soil map units selected were converted to 30 meter raster data and intersected with the reclassified Cultivated Cropland extracted from the NLCD.
Coincident areas less than 15 acres were deleted.

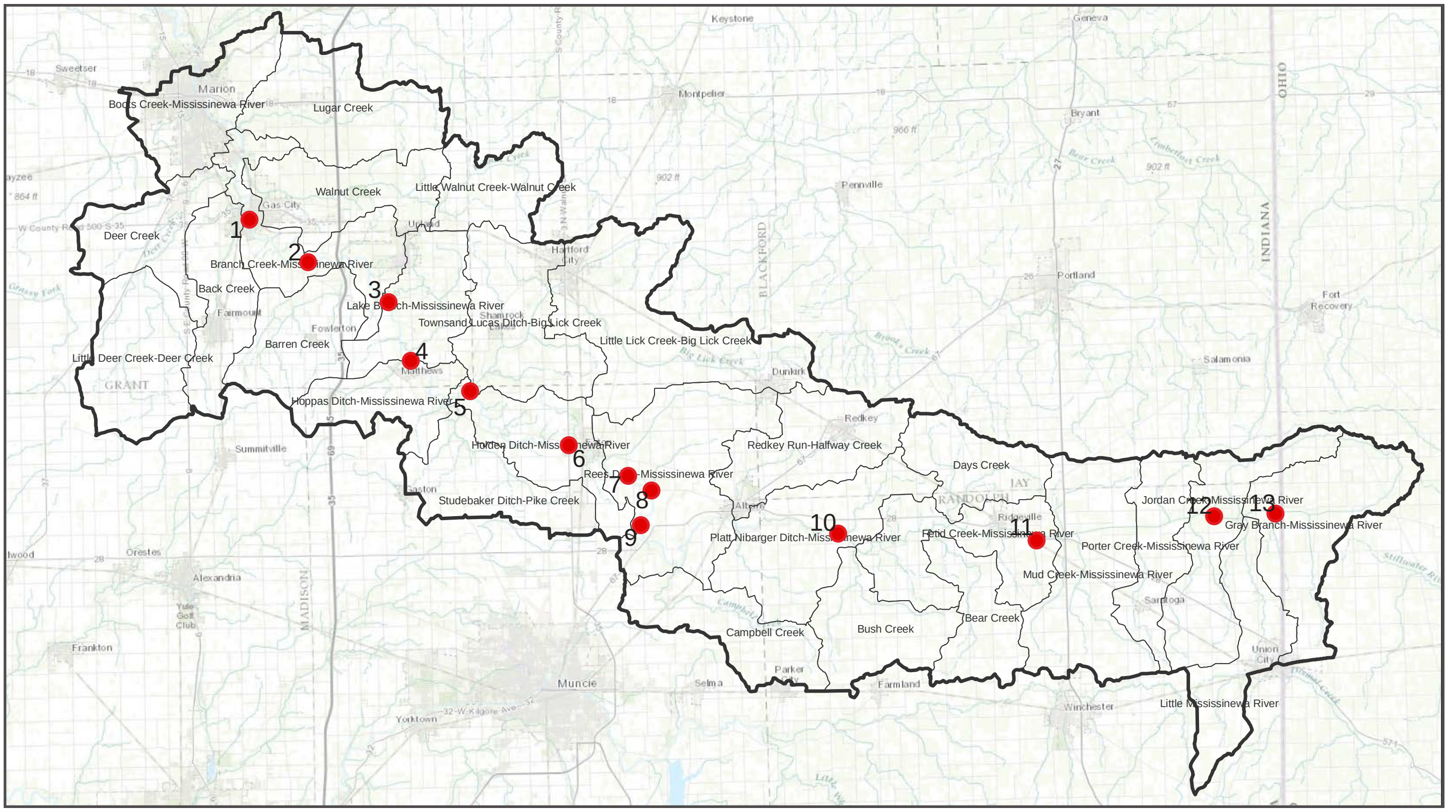
1:1,500,000

Coordinate System: USA Contiguous Albers Equal Area Conic USGS version
Projection: Albers
Datum: North American 1983
False Easting: 0.0000
False Northing: 0.0000
Central Meridian: -96.0000
Standard Parallel 1: 29.5000
Standard Parallel 2: 45.5000
Latitude Of Origin: 23.0000
Units: Meter

November 16, 2011
Central National Technology Support Center
Fort Worth, TX Map 2012- 25

MAP H.4 | Suitable Soils for Drainage Water Management

I. EXISTING STORET DATA



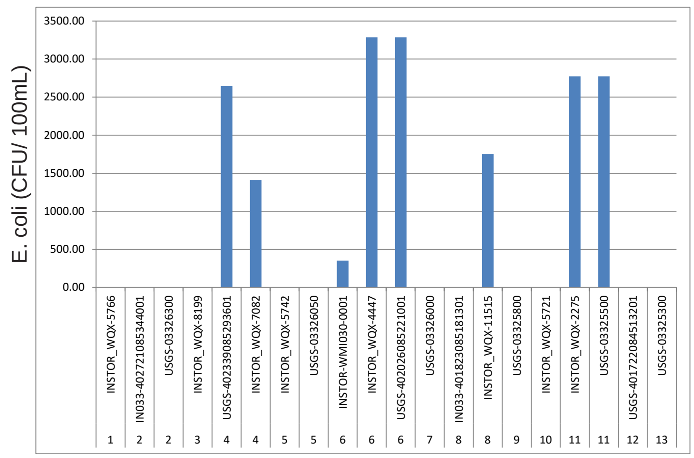
MAP I.1 | STORET MAINSTEM SITES

TABLE I.1 | Count of sampling events found in STORET database

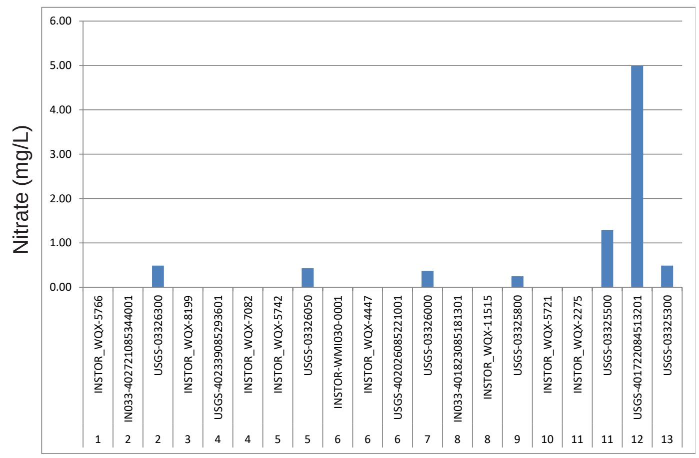
STORET NAME	Site #	Escherichia coli	*Nitrate*	Kjeldahl nitrogen	Total suspended solids	Phosphorus	Turbidity	Total number of laboratory analyses performed
INSTOR_WQX-5766	1							0
IN033-402721085344001	2							0
USGS-03326300	2		2					2
INSTOR_WQX-8199	3			3	3	3	4	13
INSTOR_WQX-7082	4	10					10	20
USGS-402339085293601	4	5					4	9
INSTOR_WQX-5742	5							0
USGS-03326050	5		2					2
INSTOR_WQX-4447	6	5					5	10
INSTOR-WMI030-0001	6	5		38	53	38	77	211
USGS-03326000	7		2					2
IN033-401823085181301	8							0
INSTOR_WQX-11515	8	5		3	3	3	10	24
USGS-03325800	9		2					2
INSTOR_WQX-5721	10							0
INSTOR_WQX-2275	11	5					5	10
USGS-03325500	11	5	2				5	12
USGS-401722084513201	12		2	2		2		6
USGS-03325300	13		2					2

FIG. I.1 - I.6 | Storet Subwatershed Averaging

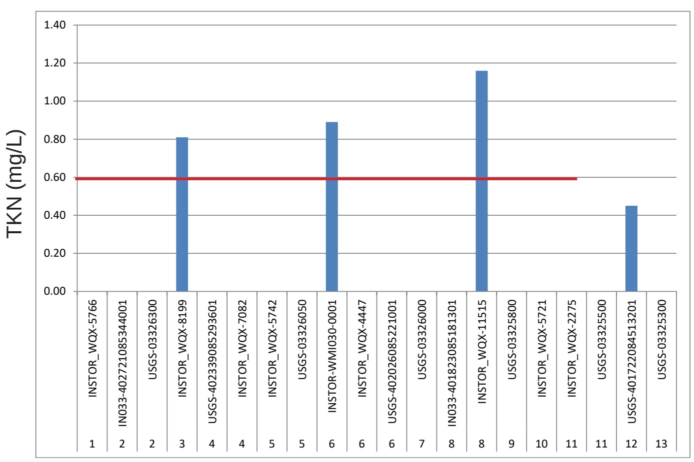
Mainstem Mississinewa River data was extracted from the STORET data set and analyzed independently. These sites also include multiple year averages, with great inconsistency in season, methodology, and storm events. Data in this database was sampled from 1963 to present day. Sample site locations are shown in MAP J.1. Average sample values are meant to characterize the mainstem of the Mississinewa River as it flows westward through predominantly agricultural areas to urban areas. Using this data set, we can make gross conclusions that nitrogen is higher in the upstream agricultural area (Site 12), phosphorus and sediment are relatively consistent (most limited amount of comparable data) and that E. coli, NTU, and TSS spikes at Site 6 downstream of Albany, Indiana.



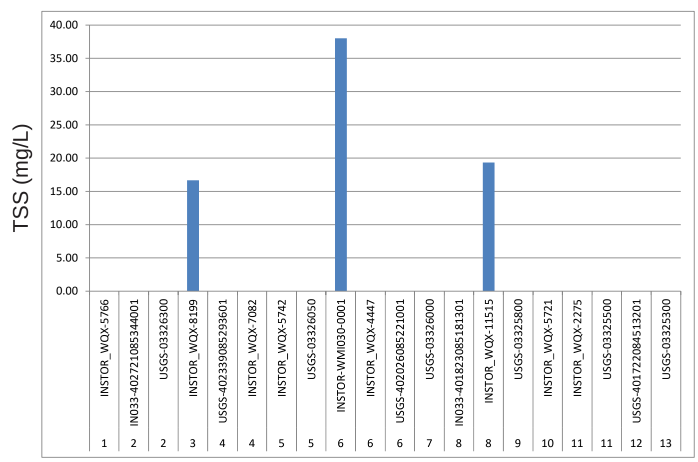
E. coli



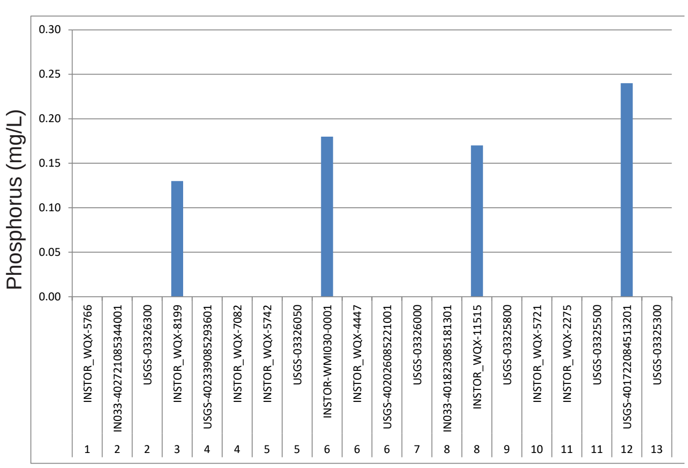
Nitrate



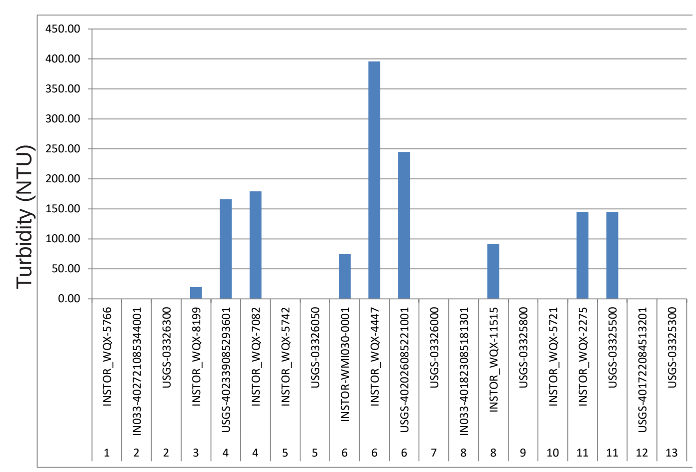
Kjeldahl Nitrogen



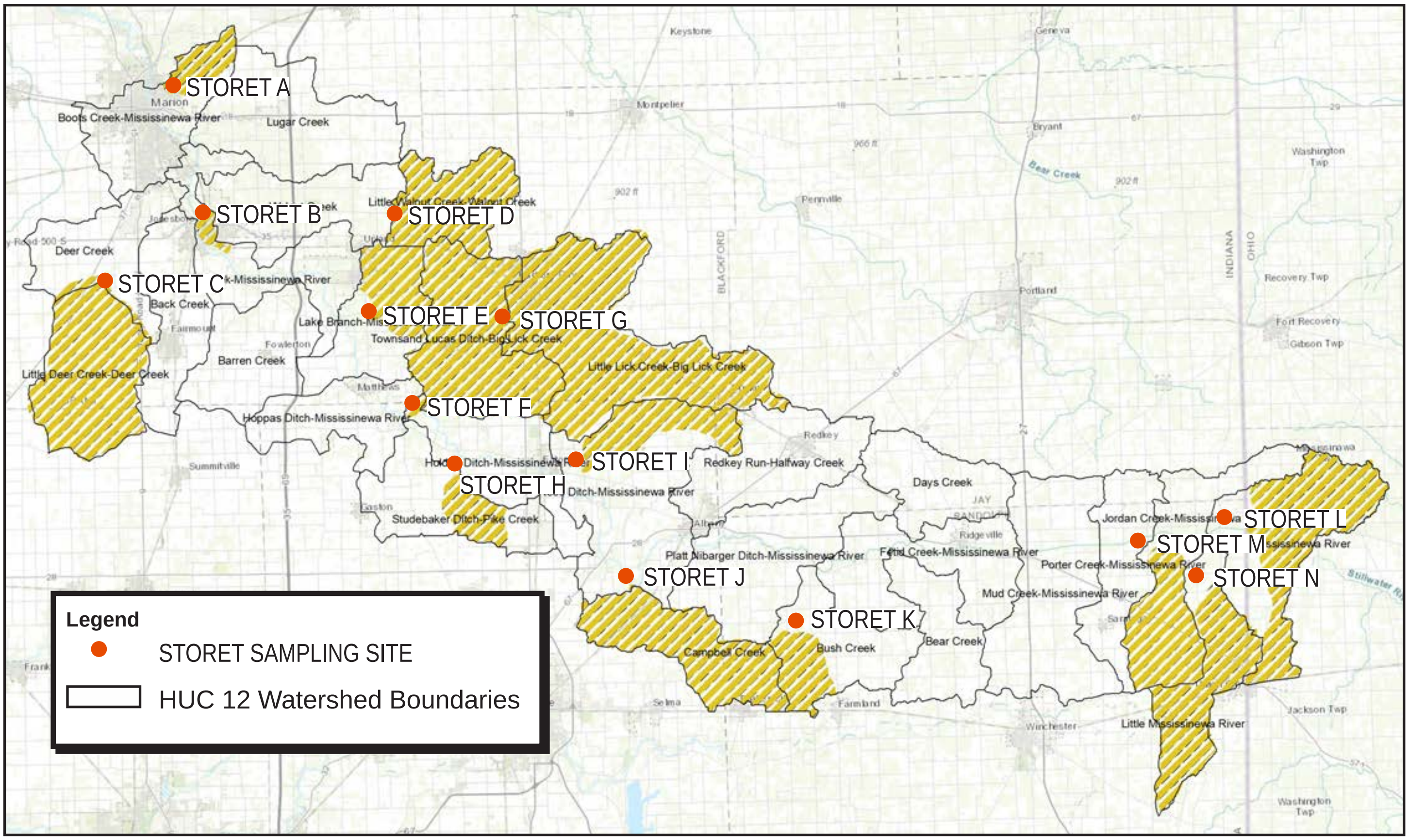
TSS



Phosphorus



Turbidity



MAP I.2 | STORET SUBWATERSHED SITES

TABLE I.2 | Count of sampling events found in STORET database								
Row Labels	Site #	Ammonia as NH3	*E. coli*	Kjeldahl nitrogen	Phosphorus	Total suspended solids	Turbidity	Total number of laboratory analyses performed
Boots Creek	A	24	10	53	54	156	119	416
Branch Creek	B	0	5	2	3	4	12	26
Little Deer Creek	C	0	0	0	0	1	1	2
Little Walnut Creek	D	0	0	0	0	1	1	2
Lake Branch	E	0	9	3	3	3	12	30
Big Lick Creek	F	5	7	4	5	4	13	38
Little Lick Creek	G	58	60	68	67	62	125	440
Studebaker Ditch	H	0	0	0	0	0	0	0
Rees Ditch	I	0	0	0	0	0	3	3
Campbell Creek	J	0	0	0	0	0	0	0
Bush Creek	K	0	10	4	4	4	15	37
Gray Branch	L	0	0	0	0	0	0	0
Jordan Creek	M	0	10	5	5	6	18	44
Little Mississinewa River	N	5	10	7	8	8	22	60

FIG. I.7 - I.12 | Storet Ranking Diagrams
Generated from Subwateshed Data extracted from STORET Database. See Table 7.8 in WMP.

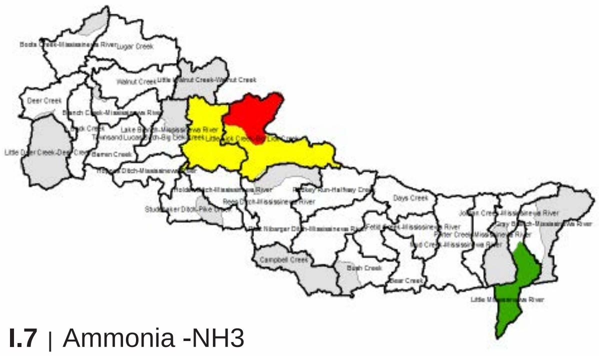


FIG. I.7 | Ammonia -NH3
Subwatersheds are ranked on a gradient (red high and green low; white no data) based on the average concentration of ammonia calculated using data from STORET database.

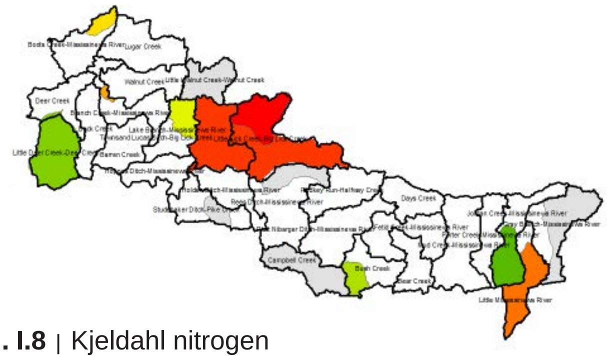


FIG. I.8 | Kjeldahl nitrogen
Subwatersheds are ranked on a gradient (red high and green low; white no data) based on the average concentration of Kjeldahl nitrogen calculated using data from STORET database.

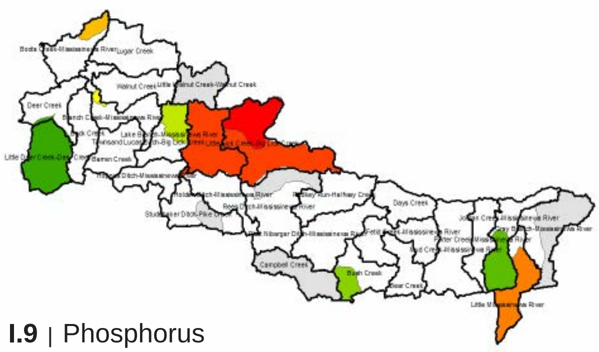


FIG. I.9 | Phosphorus
Subwatersheds are ranked on a gradient (red high and green low; white no data) based on the average concentration of phosphorus calculated using data from STORET database.

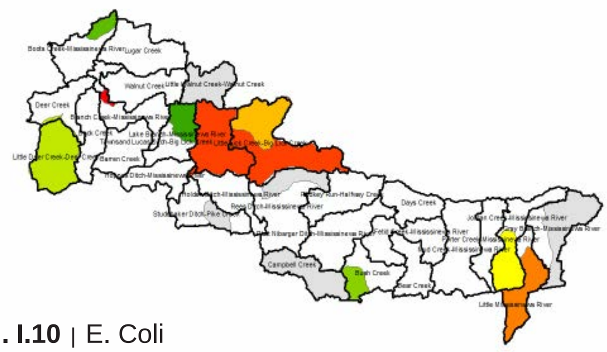


FIG. I.10 | E. Coli
Subwatersheds are ranked on a gradient (red high and green low; white no data) based on the average concentration of E. coli calculated using data from STORET database.

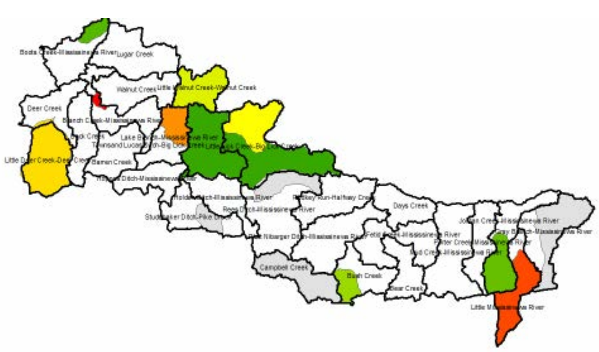


FIG. I.11 | TSS
Subwatersheds are ranked on a gradient (red high and green low; white no data) based on the average concentration of E. coli calculated using data from STORET database.

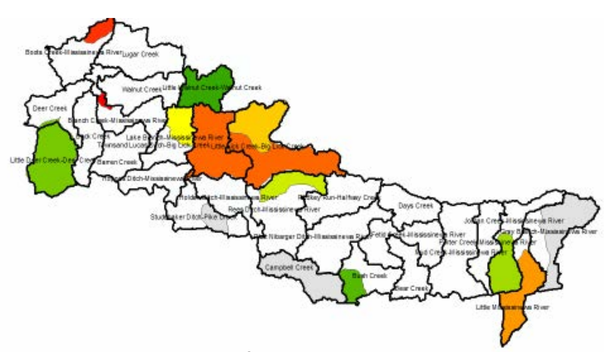


FIG. I.12 | Turbidity (NTU)
Subwatersheds are ranked on a gradient (red high and green low; white no data) based on the average concentration of phosphorus calculated using data from STORET database.

J. EXISTING LARE DATA

TABLE J.1 | LARE Phase One Site Locations and Water Quality Averages (For Tributary Subwatersheds Only). Data reported in 1999.

SITE ID	PHASE	SITE NAME	COUNTY	LAT.	LONG.	E. COLI (mg/100L)	Turbidity (NTU)	Total P (mg/L)	N+N (mg/L)
UM1	1	Mud Creek	Randolph	0	0	20,490.00	37.95	0.35	9.40
UM2	1	Clear Creek	Randolph	0	0	24,943.33	50.75	0.25	7.80
UM3	1	Miller Creek	Randolph	0	0	3,683.33	48.60	0.25	5.90
UM4	1	Harshman Creek	Randolph	0	0	1,356.67	46.95	0.21	3.60
UM5	1	Jordan Creek	Randolph	0	0	5,110.00	31.55	0.38	16.00
UM6	1	Goshen Creek	Randolph	0	0	483.33	46.15	0.29	9.90

TABLE J.2 | LARE Phase Two Site Locations and Water Quality Averages (For Tributary Subwatersheds Only). Data reported in 2003.

SITE ID	PHASE	SITE NAME	COUNTY	LAT.	LONG.	E. COLI (mg/100L)	Turbidity (NTU)	Orthophos-phate (mg/L)	Total P (mg/L)	Ammonia (mg/L)	NITRATE (mg/L)
Site 10	2	Days Creek	Randolph	40.17.48	85.04.00	198.00	106.90	0.33	0.39	0.20	9.75
Site 11	2	Platt Nibarger Ditch	Randolph	40.17.64	85.08.60	1,041.50	74.85	0.39	0.47	0.30	14.50
Site 12	2	Halfway Creek	Delaware	40.19.27	85.13.69	3,119.00	90.55	0.37	0.41	0.30	15.25
Site 13	2	Ridge Run	Randolph	40.16.66	85.02.19	2,835.50	120.35	0.29	0.38	0.10	2.65
Site 23	2	Acid Creek		0	0	23		0.46			0.4
Site 16	2	Halfway Creek		0	0	750		1.0			2.5
Site 17	2	Halfway Creek		0	0	25		.56			.7
Site 4	2	Fetid Creek	Randolph	40.16.77	85.01.61	2,345.00	118.40	0.43	0.48	0.25	6.85
Site 5	2	Bear Creek	Randolph	40.16.77	85.04.53	1,524.50	114.15	0.34	0.40	0.15	3.90
Site 6	2	Heuss Ditch	Randolph	40.16.50	85.07.36	1,372.50	164.60	0.31	0.36	0.20	5.55
Site 7	2	Bush Creek	Randolph	40.15.00	85.08.34	861.50	159.65	0.29	0.34	0.20	4.55
Site 8	2	Elkhorn Creek	Randolph	40.15.00	85.09.13	3,064.00	83.65	0.38	0.43	0.20	12.25
Site 9	2	Mud Creek	Delaware	40.17.25	85.14.16	276.00	68.15	0.41	0.46	0.20	7.50

TABLE J.3 | LARE Phase Three Site Locations and Water Quality Averages (For Tributary Subwatersheds Only). Data reported in 2009.

SITE ID	PHASE	SITE NAME	COUNTY	LOCATION (UTM)		E. COLI (mg/100L)	Turbidity (NTU)	Total P (mg/L)	NO2/NO3 (mg/L)	Ammonia (mg/L)	*TN (mg/L)
BD01	3	Bosman Ditch	Delaware	644078.19	4463946.07	1,050.00	20.63	0.19	1.33		2.28
BD02	3	Bosman Ditch	Delaware	645610.66	4466036.65	1,960.00	26.40	0.22	2.06		2.96
BD03	3	Unamed Trib to Bosman Ditch	Delaware	645624.11	4465350.45	1,835.00	24.80	0.27	1.98		2.79
CC01	3	Campbell Creek	Delaware	645735.20	4458409.78	3,686.67	25.47	0.50	0.75		2.12
CC02	3	Campbell Creek	Delaware	647625.14	4455961.50	3,380.00	29.67	0.33	0.76		1.83
CC03	3	Campbell Creek	Delaware	650974.05	4454365.90	1,730.00	14.90	0.24	0.81		1.80
CC04	3	Campbell Creek	Delaware	650829.96	4454271.69	5,910.00	17.20	0.29	0.89		1.86
HD01	3	Holdren Ditch	Delaware	638651.61	4466847.43	1,366.67	5.70	0.31	1.57		2.24
PC01	3	Pike Creek	Delaware	630998.66	4468984.82	529.33	4.43	0.07	0.62		1.05
PC02	3	Hedgeland Ditch	Delaware	630353.89	4466875.82	1,019.33	4.23	0.18	1.47	0.14	2.19
PC03	3	Studebaker Ditch	Delaware	633882.63	4465914.65	2,703.33	4.67	0.09	1.63		2.15
PC04	3	Studebaker Ditch	Delaware	636950.17	4462873.50	11,666.67	7.27	0.32	2.90	0.14	3.54
RD01	3	Rees Ditch	Delaware	641335.92	4466030.61	3,333.33	17.07	0.15	0.78		1.43
RD02	3	Unnamed Trib to Reese Ditch	Delaware	641063.19	4466054.63	100.00	14.35	0.19	0.25		0.85
RD03	3	Reese Ditch	Delaware	645132.96	4469323.30	1,133.33	19.13	0.11	0.62		1.22
RD04	3	Reese Ditch	Delaware	651134.76	4469761.10	3,000.00	12.23	0.20	2.65	0.22	3.55
UD01	3	Unnamed Ditch	Delaware	634494.76	4467552.70	1,073.33	3.37	0.05	0.87	0.14	1.48

TABLE J.4 | LARE Phase 4 Water Quality Averages (For Tributary Subwatersheds Only). Data reported in 2012.										
SITE ID	PHASE	NAME	COUNTY	LAT	LONG	E. COLI*	NTU	ORTHO-PHOS	TotalP	NITRATE
1	4	Buck Creek	Grant	40°35'17.47"N	85°39'37.52"W	672.56	16.63	0.08	0.06	2.83
2	4	Massey Creek	Grant	40°34'16.93"N	85°39'02.62"W	161.7	20.48	0.03	0.04	1.97
3	4	Lugar Creek	Grant	40°32'19.96"N	85°37'40.00"W	555.32	12.80	0.11	0.04	2.07
4	4	Walnut Creek	Grant	40°30'07.13"N	85°36'55.89"W	570.32	14.65	0.05	0.05	1.80
5	4	Lake Branch	Grant	40°25'56.50"N	85°30'49.85"W	723.08	11.98	0.09	0.06	4.57
6	4	Smith Ditch	Grant	40°24'09.04"N	85°29'32.64"W	0	53.70	0.04	0.05	2.40
7	4	Boots Creek	Grant	40°33'41.60"N	85°39'42.81"W	1276.38	12.63	0.02	0.02	2.10
8	4	Deer Creek	Grant	40°30'30.29"N	85°38'14.72"W	413.14	3.63	0.04	0.03	2.53
9	4	Back Creek	Grant	40°29'25.39"N	85°37'36.19"W	248.9	6.28	0.07	0.05	3.50
10	4	Barren Creek	Grant	40°27'07.52"N	85°32'42.46"W	304.16	8.83	0.02	0.02	3.23
11	4	Hoppas Ditch	Grant	40°23'39.95"N	85°30'03.70"W	917.14	14.35	0.10	0.06	2.70

FIG. J.1 - J.4 | LARE Rankings: All phase subwatersheds ranked per phase.

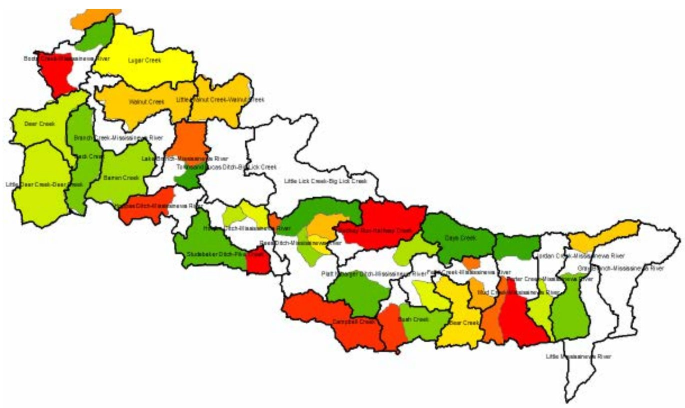


FIG. J.1 | E. Coli Ranking
Subwatersheds are ranked on a gradient (red high and green low) based on surface water E. coli concentrations.

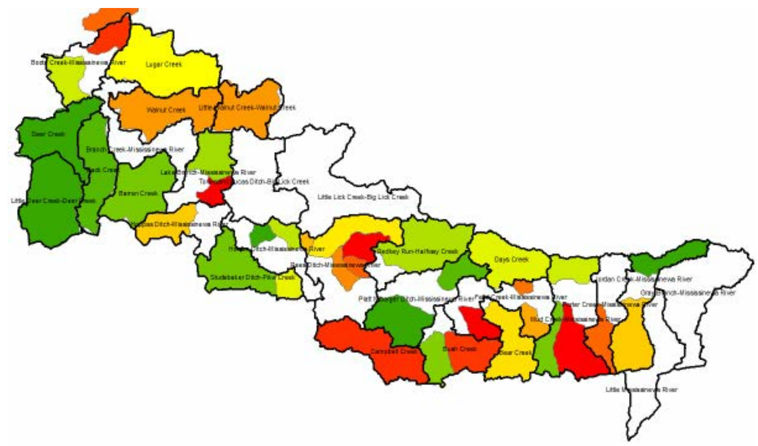


FIG. J.2 | NTU Ranking
Subwatersheds are ranked on a gradient (red high and green low) based on surface water NTUs.

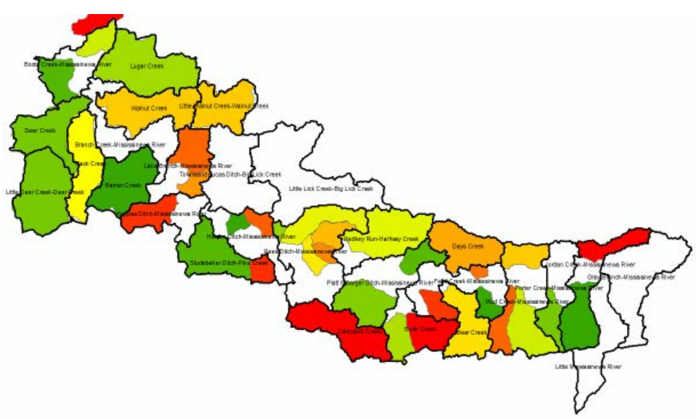


FIG. J.3 | Phosphorus Ranking
Subwatersheds are ranked on a gradient (red high and green low) based on surface water phosphorus concentrations.

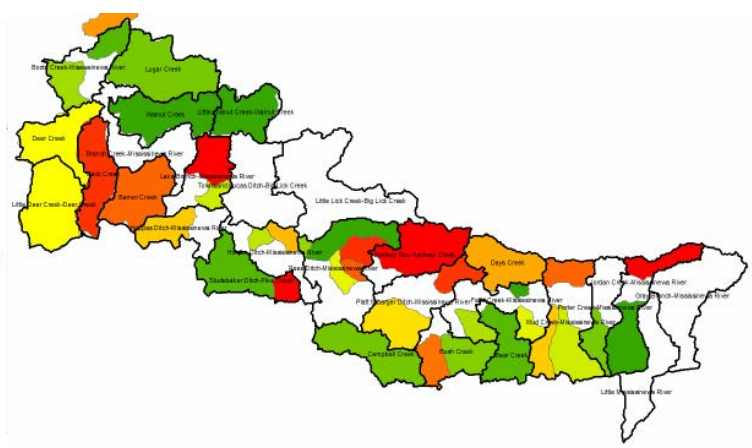


FIG. J.4 | Nitrogen Ranking
Subwatersheds are ranked on a gradient (red high and green low) based on surface water nitrogen concentrations.

FIG. J.5 - J.8 | LARE Rankings: All phase subwatersheds ranked collectively across phases.

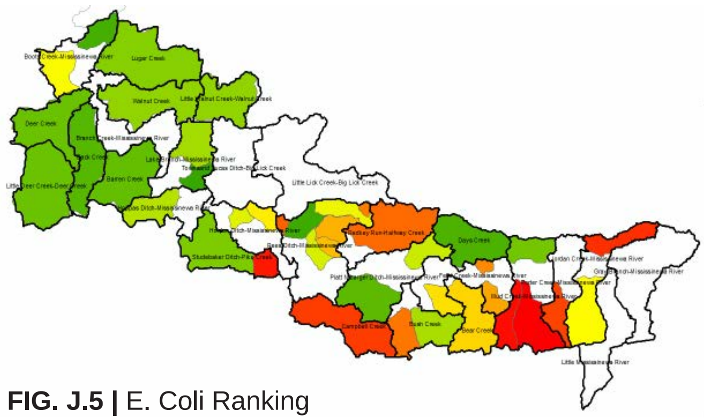


FIG. J.5 | E. Coli Ranking
Subwatersheds are ranked on a gradient (red high and green low) based on surface water E. coli concentrations.

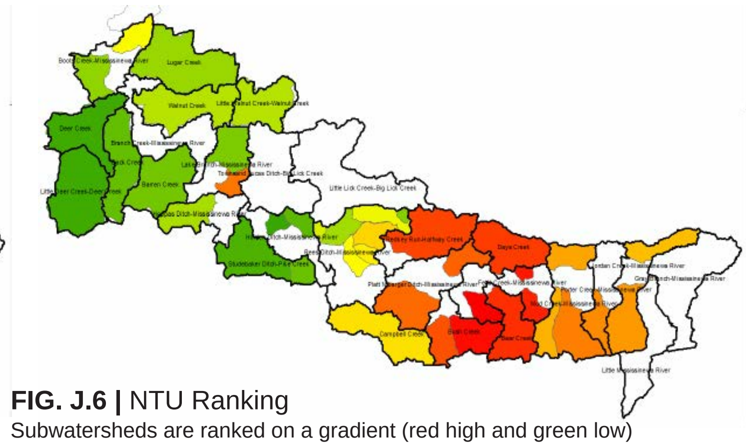


FIG. J.6 | NTU Ranking
Subwatersheds are ranked on a gradient (red high and green low) based on surface water NTUs.

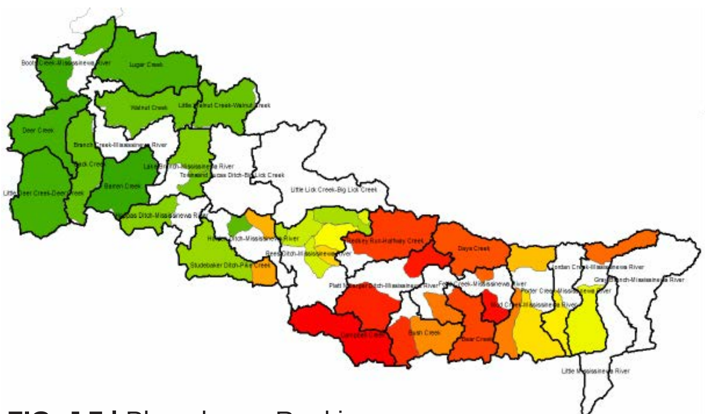


FIG. J.7 | Phosphorus Ranking
Subwatersheds are ranked on a gradient (red high and green low) based on surface water phosphorus concentrations.

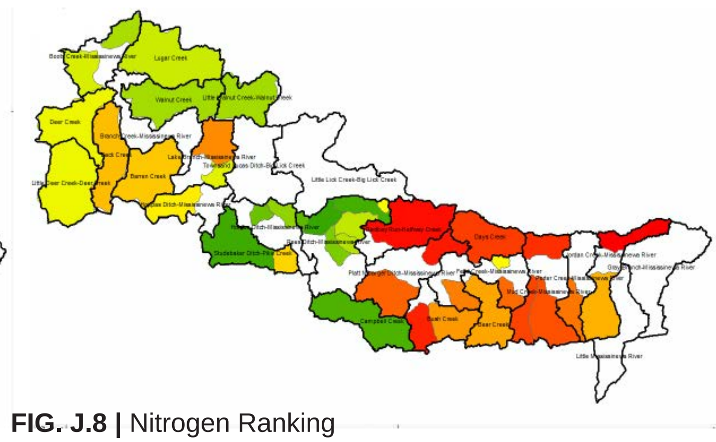


FIG. J.8 | Nitrogen Ranking
Subwatersheds are ranked on a gradient (red high and green low) based on surface water nitrogen concentrations.

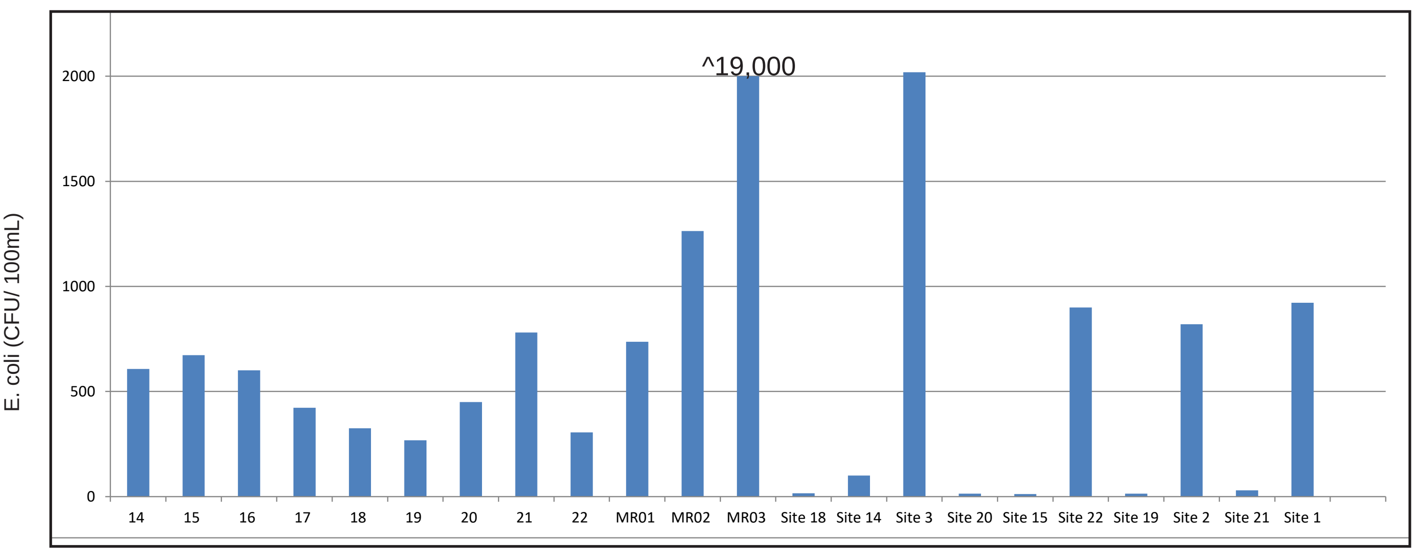


FIG. J.9 | E. coli (MR03 as 2000)
Average E. coli results from LARE mainstem sites (all phases) represented from west to east. See FIG J.4.

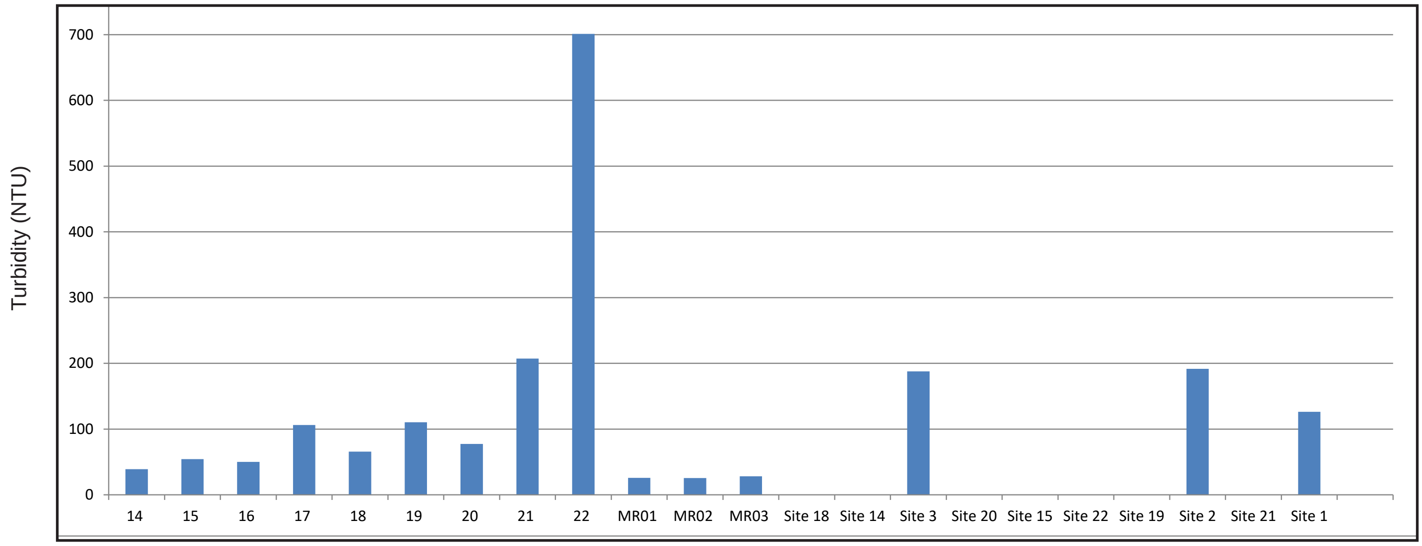
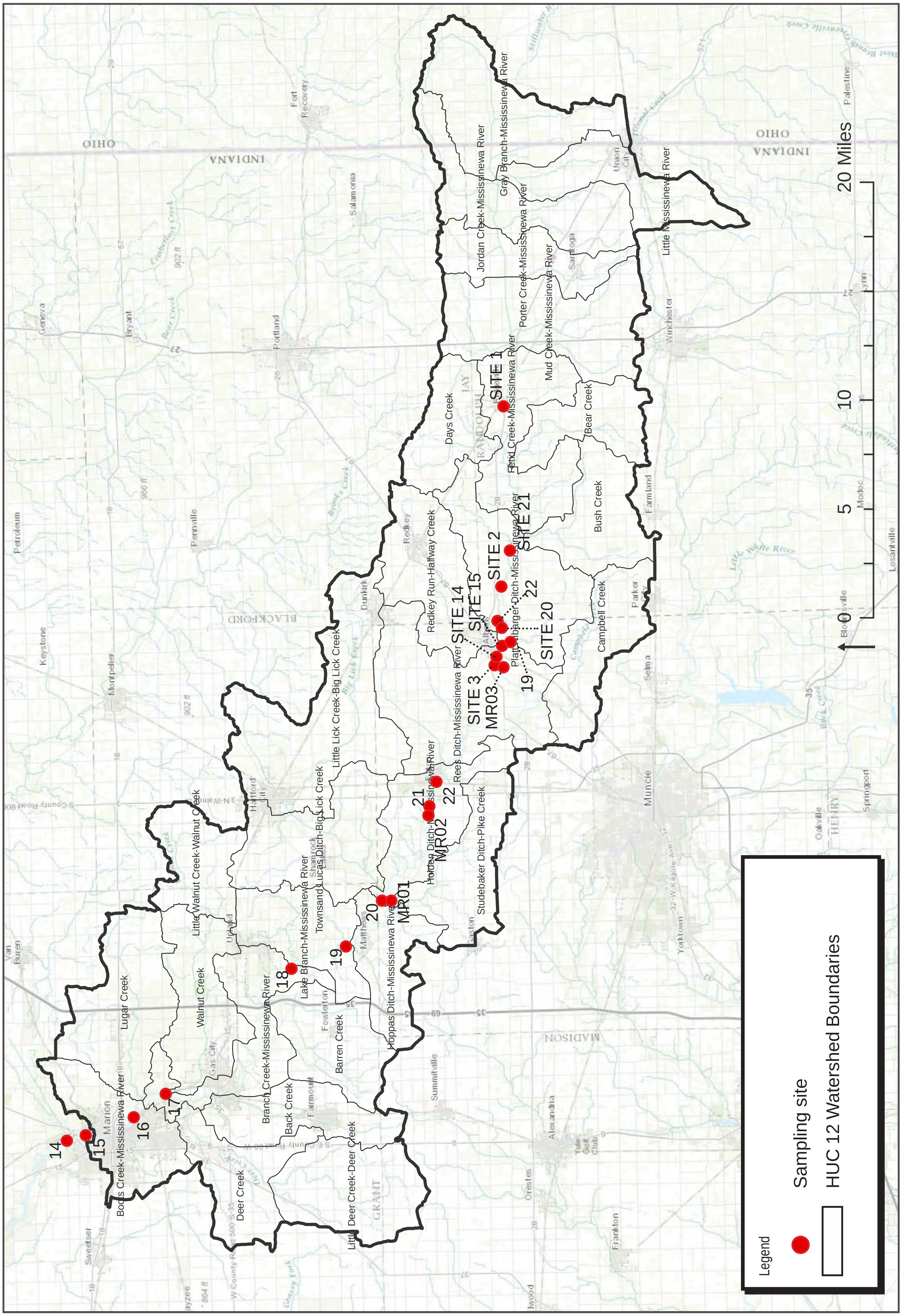


FIG. J.10 | Turbidity (NTU)
Average Turbidity results from LARE mainstem sites (all phases), represented from west to east. See FIG J.4.

TABLE J.5 | STORET and LARE Subwatershed Counts

Row Labels	Ammonia as NH3	E. coli	Nitrate	Nitrite	Nitrogen	Phosphorus	TSS	Total number of laboratory analyses performed
Fetid Creek		86				313	359	758
Holden Ditch		11				186	162	359
Boots Creek		10				54	156	220
Little Lick Creek		60				67	62	189
Mississinewa River	4	45	14	2	9	46	59	175
Little Mississinewa River		10			5	8	8	31
Deer Creek		10			3	6	6	25
Jordan Creek		10				5	6	21
Bush Creek		10				4	4	18
Lick Creek		7				5	4	16
Lake Branch		9				3	3	15
Branch Creek		5				3	4	12
Hoppas Creek		4	2				1	7
Big Lick Creek			2		3			5
Elkhorn Creek					3			3
Harshman Ditch					3			3
Little Deer Creek							1	1
LIttle Walnut Creek							1	1
Total number of laboratory analyses performed from samples collected at all sites		277	18	2	26	700	836	1859



MAP J.1 | LARE Mississinewa mainstem sites

K. SAMPLE SITE DATA

The following tables identify schedule, parameters, and equipment sensitivity for data collected as part of this Watershed Management Planning process. “Current Water Quality Data” discussed in Section 8 of the WMP. Total suspended solids, phosphorus, nitrate and E. coli were analyzed in the lab. PH, dissolved oxygen, and temperature were analyzed in the field using a YSI Pro Plus instrument. Turbidity was measured in the field via a transparency/turbidity tube. Habitat analysis, fish and macroinvertebrates were analyzed in the field.

TABLE K.1 | Study Schedule (See Section 8 in WMP)			
Activity	Frequency	Start Date	End Date
Chemical Sample collection: Nitrate, Total Phosphorus, Total Suspended Solids	Monthly	April 2014	March 2015
Flow (monthly all sites)	Monthly	April 2014	March 2015
Physical (monthly all sites) Turbidity, Dissolved Oxygen, pH, Temperature	Monthly	April 2014	March 2015
Bacteriological sampling (monthly all sites) e. coli via lab	Monthly	April 2014	March 2015
Macroinvertebrate sampling	One Sample	Summer 2014	Summer 2014
Habitat Evaluation	One Sample	Summer 2014	Summer 2014
Fish sampling	One Sample	Summer 2014	Summer 2014

TABLE K.2 | Study Parameters				
Parameter	Method	Method Detection Limit	Units	Holding Time
pH	EPA 150.1	NA	S.U.	Analyze within 15 min
DO*	SM 18th, 4500-O G.	0.1	mg/L	Analyze within 15 min
Temperature*	EPA 170.1	0.1	OC	Analyze within 15 min
TSS	SM 2540D	10.0/250 ml	mg/L	7 days
PO4-3-P	ASTM D515-88	0.0016	mg/L	28 days
(NO3+NO2)-N	EPA 353.2	0.07	mg/L	24 hrs
E. coli	EPA 1603	1/100 ml	CFUs/100 ml	8 hours
Flow	Buchanan & Somers	NA	m3/s	
Habitat Analysis	Rankin, 1989	NA	NA	
Fish	Ohio and US EPA	NA	Narrative	
Macroinvertebrates	IDEM mIBI	NA	Narrative	

TABLE K.3 | Sensitivity Of In Field Equipment		
Parameter	Instrument	Detection Limit
pH	YSI Pro Plus	0-14 units
DO	YSI Pro Plus	0-50 mg/l
Temp	YSI Pro Plus	-5 to 70ºC

TABLE K.4 | Headwaters Mississinewa River				
Site #	Latitude	Longitude	Stream Name	Description
HM-1	40°17'6.47"N	84°55'9.83"W	Gray Branch-Mississinewa River	Located on the N 300 E Bridge at the intersection of the Mississinewa River.
HM-2	40°17'21.82"N	84°52'53.12"W	Mud Creek-Mississinewa River	Located at the N 500 E Bridge at the intersection of the Mississinewa River.
HM-3	40°17'16.46"N	84°49'55.60"W	Porter Creek-Mississinewa River	Located at the E 850 N Bridge at the intersection of Porter Creek.
HM-4	40°17'36.45"N	84°49'27.83"W	Jordan Creek-Mississinewa River	Located on the N 800 E Bridge at the intersection of the Mississinewa River.

TABLE K.5 | Massey Creek-Mississinewa River				
Site #	Latitude	Longitude	Stream Name	Description
MC- 1	40°34'34.77"N	85°39'34.41"W	Mississinewa River	Intersection of the W Highland Ave Bridge and the Branch Cree-ketween North Washington Street and N Matter Park Road.
MC- 2	40°32'19.98"N	85°37'39.52"W	Lugar Creek	Stone Road bridge North of Stonecrest Manor Mobile Home 2801 Stone Rd, Marion, IN 46953.
MC- 3	40°31'26.30"N	85°37'27.24"W	Mississinewa River	East 38th Street Bridge located between Riverside Ave and Stone Road
MC- 4	40°30'30.16"N	85°38'14.88"W	Deer Creek	Bridge at South Lincoln Blvd located between E 49th Street and E 54th Street.
MC- 5	40°27'31.37"N	85°42'3.47"W	Little Deer Creek-Deer Creek	Sampling site at CO Rd 650 S Bride located between Strawtown Pike and S 100 W.
MC- 6	40°29'20.99"N	85°37'43.93"W	Back Creek	Sampling site located in the Southwest intersection of the East Jonesboro Bypass and State Road 15.
MC- 7	40°30'7.48"N	85°36'55.41"W	Walnut Creek	Bridge near intersection of S Garthwaite Road and E Tulip Drive. North of Mississinewa High School.
MC- 8	40°29'30.24"N	85°29'1.03"W	Little Walnut Creek- Walnut Creek	Site located on S 1000 E Bridge south of Co Road 400 S.
MC- 9	40°27'7.72"N	85°31'35.51"W	Mississinewa	Site located on the Co Road 700 S Bridge just west of South 800 E.
MC-10	40°27'7.63"N	85°32'42.42"W	Barren Creek	Sampling site located on Co Road 700 S Bridge between US35 and S 700 E.
MC-11	40°25'21.47"N	85°30'30.38"W	Mississinewa	26 Bridge just east of Wheeling Pike

TABLE K.6 | IDEM Sample Sites For TMDL					
Site #	IDEM Site #	Latitude	Longitude	Stream Name	Description
EM-1	WMI-03-0006	40°25’47.28”N	85°23’20.95”W	Upper Big Lick Creek	Located at CR 100 W.
EM-2	WMI-03-0009	40°22’37.62”N	85°26’52.32”W	Big Lick Creek	Located at CR 1275 N.
EM-3	WMI-04-0012	40°22’20.85”N	85°27’23.16”	Mississinewa River-Holden	Located at CR 364 W.
EM-4	WMI-04-0011	40°21’47.35”N	85°27’25.75	Pike Creek	Located on Eaton-Wheeling Pike
EM-5	WMI-04-0017	40°19’7.85	85°19’10.26”	Mississinewa River-Rees	Located at CR 371 E.
EM-6	WMI-04-0014	40°15’39.93	85°17’21.55	Campbell Creek	Located on Schindel Road.
EM-7	WMI-02-0017	40°17’52.10	85°14’13.45	Halfway Creek	Located on Water Street.
EM-8	WMI-02-0018	40°17’30.21	85°14’14.83	Mississinewa River-Platt	Located on Strong Road.
EM-9	WMI-02-0009	40°16’17.70	85°8’42.17	Bush Creek	Located at CR 750 N.
EM-10	WMI-02-0007	40°17’6.76	85°5’33.82	Mississinewa River-Fetid	Located at CR 600 W.
EM-11	WMI-02-0012	40°16’45.83	85°4’32.05	Bear Creek	Site is located at CR 800 N just upstream of pour point of Bear Creek subwatershed.
EM-12	WMI-02-0006	40°17’29.43	85°	Days Creek	Site is located at St Rd 28 just upstream of pour point of Days Creek subwatershed.
EM-13	WMI020-0002			Mississinewa River -Fetid	Located at CR 100 W, near Ridgeville.

L. NITRATE DATA

TABLE L.1 | Descriptive Statistics for Nitrate (mg/L) Data Collected at UMRW Sites								
Subwatersheds	Drainage	Average of Nitrate	Count of Nitrate	Min of Nitrate	Max of Nitrate	StdDev of Nitrate	75th	25th
Back Creek	16.00	2.49	12.00	1.27	4.72	1.09	3.23	0.31
Barren Creek	21.00	3.59	12.00	0.11	9.23	2.85	5.51	-0.13
Bear Creek	15.00	6.07	6.00	0.10	24.00	9.01	12.15	-2.13
Big Lick Creek	76.00	1.90	8.00	0.80	5.90	1.69	3.04	-0.15
Bush Creek	20.00	2.31	8.00	0.05	11.00	3.66	4.78	-0.91
Campbell Creek	20.00	1.85	9.00	0.05	8.50	2.67	3.65	-0.61
Days Creek	17.00	4.10	6.00	0.20	13.00	5.07	7.52	-0.98
Deer Creek	45.00	3.24	12.00	0.37	6.80	2.01	4.59	0.14
Halfway Creek	25.00	1.69	9.00	0.05	6.10	1.80	2.91	-0.27
Little Deer Creek	26.00	3.45	12.00	0.02	8.21	2.42	5.08	0.02
Little Mississinewa River	21.00	5.26	12.00	0.78	11.10	3.38	7.54	0.17
Little Walnut Creek	17.00	2.03	12.00	0.03	8.41	2.29	3.58	-0.38
Lugar Creek	30.00	1.17	12.00	-	5.60	1.63	2.27	-0.36
Holden Ditch	424.00	2.74	8.00	0.50	11.00	3.42	5.04	-0.67
Rees Ditch	311.00	3.88	6.00	0.80	12.00	4.32	6.80	-0.71
Platt-Nibarger Ditch	240.00	3.67	9.00	0.05	16.00	4.97	7.02	-1.07
Fetid Creek	179.00	4.69	7.00	0.30	16.00	5.47	8.38	-0.97
Mud Creek	133.00	5.08	7.00	0.05	18.00	6.19	9.25	-1.17
Boots Creek	681.00	2.43	24.00	0.02	4.83	1.42	3.38	0.14
Branch Creek	629.00	2.66	12.00	0.50	5.76	1.52	3.68	0.17
Lake Branch	486.00	2.69	12.00	0.06	7.00	1.96	4.01	-0.02
Hoppas Ditch	472.00	2.85	12.00	0.38	6.15	1.88	4.11	0.07
Porter Creek	89.00	5.21	12.00	0.19	14.50	4.35	8.14	-0.29
Jordan Creek	79.00	5.62	12.00	0.32	15.20	4.47	8.64	-0.21
Gray Branch	31.00	6.56	12.00	0.04	17.90	6.07	10.65	-0.63
Pike Creek	21.00	2.20	9.00	0.10	9.10	2.89	4.15	-0.60
Upper Big Lick Creek	52.00	2.10	9.00	0.70	5.10	1.62	3.19	-0.05
Walnut Creek	39.00	1.42	12.00	0.07	6.70	1.84	2.66	-0.38
Grand Total	192.60	3.24	293.00	-	24.00	3.54	5.63	-0.56

TABLE L.2 | Nitrate Averages Separated by Flow Rate							
Subwatersheds	Drainage Area (sq mi)	Average flow rate (cfs)			Average of Nitrate (mg/L)		
		High Flow	Low Flow	Overall Avg. Flow	High Flow Samples	Low Flow Samples	Total Samples
Mainstem Subwatershed	401.80	1585.23	214.29	623.71	7.21	2.45	3.85
Holden Ditch	424.00	640.72	97.06	291.23	6.40	1.52	2.74
Rees Ditch	311.00	591.17	121.56	249.64	8.75	1.45	3.88
Platt-Nibarger Ditch	240.00	228.80	37.32	88.38	9.30	2.06	3.67
Fetid Creek	179.00	337.92	33.39	127.09	11.45	1.98	4.69
Mud Creek	133.00	264.73	24.21	124.43	9.83	1.51	5.08
Boots Creek	681.00	2398.25	317.44	1011.04	2.95	2.17	2.43
Branch Creek	629.00	2923.33	354.67	996.83	4.06	2.19	2.66
Lake Branch	486.00	2750.00	352.00	951.50	4.96	1.93	2.69
Hoppas Ditch	472.00	2740.00	355.67	951.75	5.22	2.05	2.85
Porter Creek	89.00	750.67	72.37	241.94	9.49	3.78	5.21
Jordan Creek	79.00	1146.50	57.24	420.33	9.55	3.65	5.62
Gray Branch	31.00	91.84	12.40	38.88	11.74	3.97	6.56
Tributary Subwatershed	28.69	148.61	25.86	63.38	4.70	1.78	2.73
Back Creek	16.00	98.61	39.22	63.97	2.95	2.17	2.49
Barren Creek	21.00	89.21	15.99	40.40	6.67	2.05	3.59
Bear Creek							6.07
Big Lick Creek	76.00	65.94	20.05	39.72	4.05	1.33	1.90
Bush Creek	20.00	20.11	2.90	8.63	7.05	0.52	2.31
Campbell Creek	20.00	35.43	4.03	16.59	4.27	0.75	1.85
Days Creek							4.10
Deer Creek	45.00	325.05	40.15	111.37	5.78	2.39	3.24
Halfway Creek	25.00	62.06	9.93	25.57	3.65	1.06	1.69
Little Deer Creek	26.00	281.93	40.36	106.24	6.56	2.44	3.45
Little Mississinewa River	21.00	118.46	12.35	38.88	6.91	4.70	5.26
Little Walnut Creek	17.00	145.85	8.46	45.93	3.69	1.53	2.03
Lugar Creek	30.00	204.29	31.35	65.94	3.72	0.71	1.17
Pike Creek	21.00	39.35	7.63	19.16	5.13	0.73	2.20
Upper Big Lick Creek	52.00	57.26	11.63	29.88	2.63	1.83	2.10
Walnut Creek	39.00	340.16	48.64	121.52	3.10	0.86	1.42

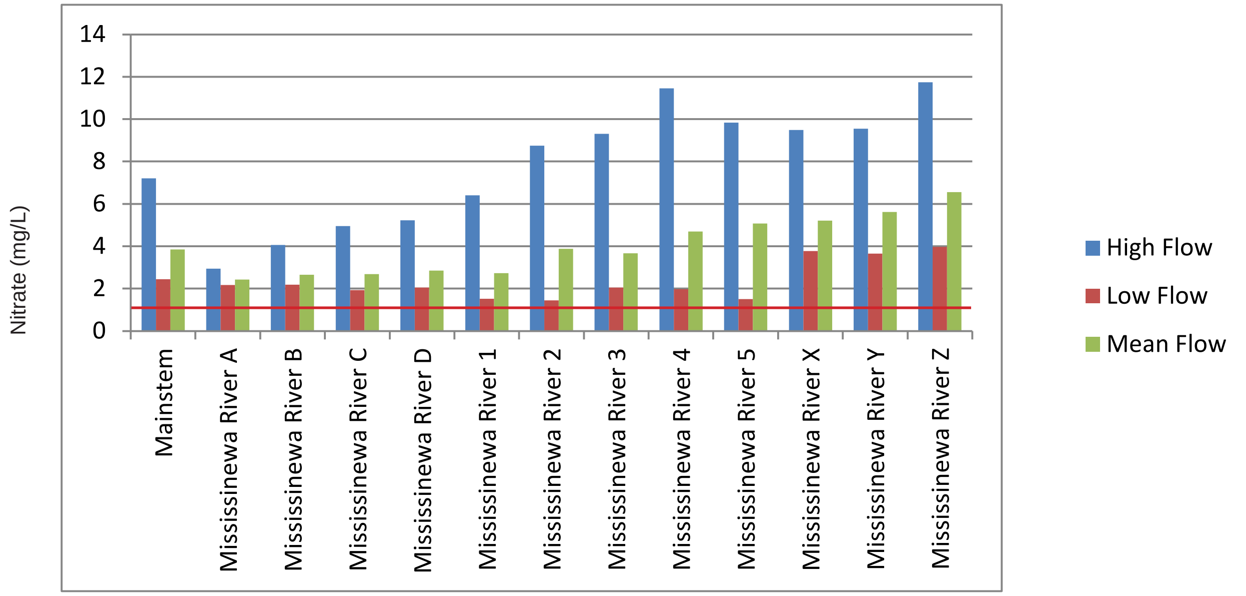


FIG. L.1 | Mainstem Subwatershed Averages for Nitrate

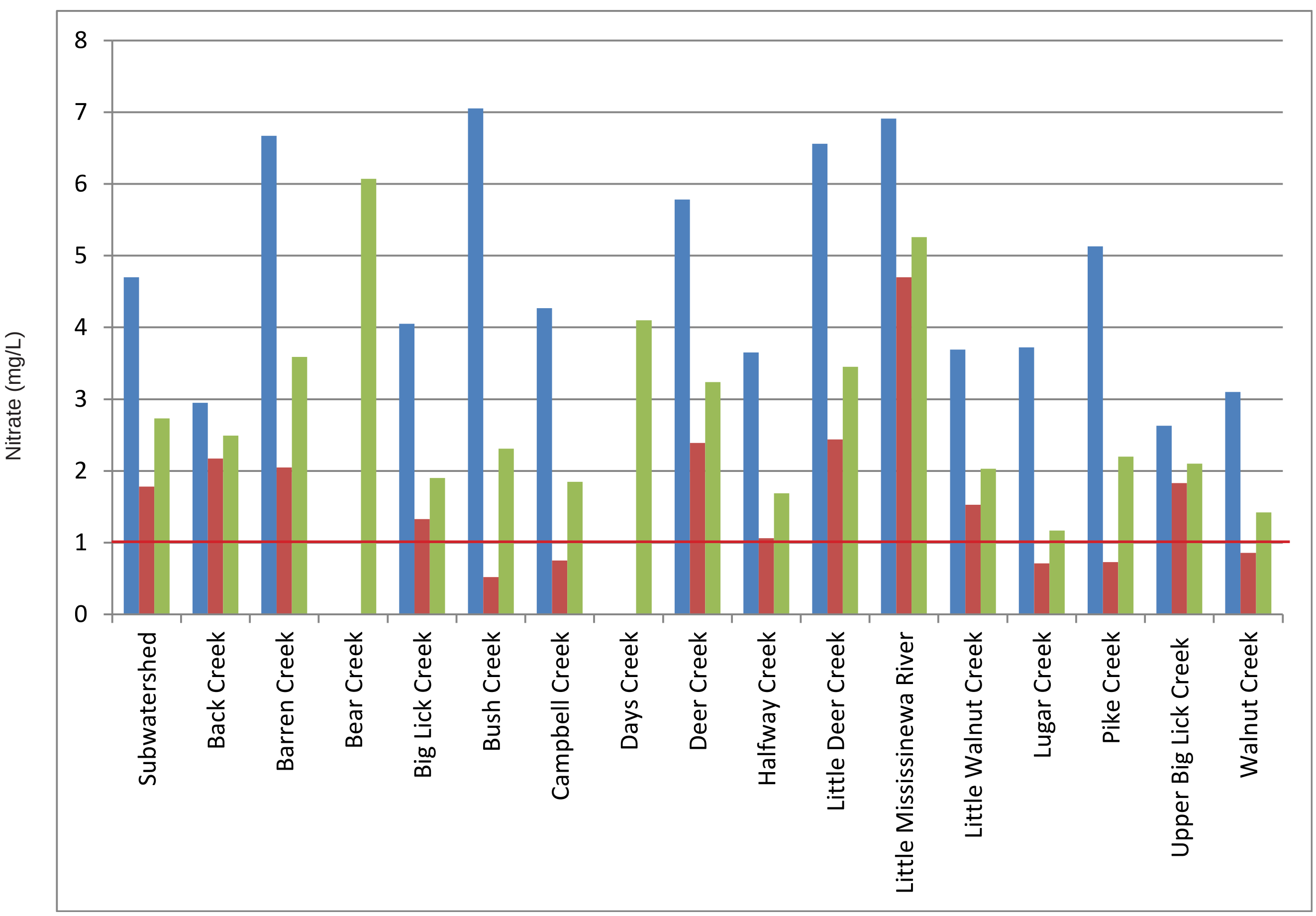


FIG. L.2 | Tributary Subwatershed Averages for Nitrate

TABLE L.3 | Count of Exceedances[1] for Nitrate				
Subwatershed	Number of Exceedences during High Flow	Number of Exceedences during Low Flow	No Flow Data Collected	Total Number of Exceedances
Back Creek	5.00	7.00		12.00
Barren Creek	4.00	5.00		9.00
Bear Creek	---	---	5.00	5.00
Big Lick Creek	2.00	2.00		4.00
Bush Creek	2.00	1.00	1.00	4.00
Campbell Creek	3.00	2.00		5.00
Days Creek	---	---	4.00	4.00
Deer Creek	3.00	6.00		9.00
Halfway Creek	2.00	2.00	1.00	5.00
Little Deer Creek	3.00	6.00	1.00	10.00
Little Mississinewa River	3.00	8.00		11.00
Little Walnut Creek	2.00	6.00	1.00	9.00
Lugar Creek	2.00	2.00		4.00
Holden Ditch	2.00	4.00		6.00
Rees Ditch	2.00	3.00		5.00
Platt-Nibarger Ditch	2.00	4.00		6.00
Fetid Creek	2.00	3.00		5.00
Mud Creek	3.00	2.00		5.00
Boots Creek	8.00	12.00		20.00
Branch Creek	3.00	8.00		11.00
Lake Branch	3.00	7.00		10.00
Hoppas Ditch	3.00	7.00		10.00
Porter Creek	3.00	8.00		11.00
Jordan Creek	4.00	7.00		11.00
Gray Branch	4.00	4.00		8.00
Pike Creek	3.00	2.00		5.00
Upper Big Lick Creek	2.00	4.00		6.00
Walnut Creek	2.00	2.00		4.00
Totals for all sites combined	77.00	124.00	13.00	214.00

TABLE L.4 | Counts and percentages of nitrate exceedances at high and low flows			
Flow	Total Count of Exceedances for Nitrate (for all sites)	Total Count of Samples Analyzed for Nitrate (for all sites containing flow data)	Percent of Samples in Exceedance (for all sites containing flow data)
High	77	80	96%
Low	124	192	65%

1 When an individual sample is above the target set for this watershed management plan, it is considered to be in exceedance. The target concentration for nitrate is 1 mg/L.

TABLE L.5 | Calculated Nitrate Loads: Current Load, Target Load, and Load Reduction Needed

	Drain-age area (sq. mi.)	Average flow (cfs)		Average nitrate (mg/L)		Nitrate current load (ton/year)		Nitrate Target (mg/L)	Nitrate target load (ton/year)		Nitrate load reduction needed (ton/year)	
Subwatershed		High	Low	High	Low	High	Low	High	High	Low	High	Low
Mainstem Subwatershed	401.80	1585.23	214.29	7.21	2.45	6718.04	502.35	1.00	1420.43	179.14	5297.60	323.22
Holden Ditch	424.00	640.72	97.06	6.40	1.52	4785.36	157.34	1.00	710.66	83.05	4074.69	74.29
Rees Ditch	311.00	591.17	121.56	8.75	1.45	6078.05	142.36	1.00	599.36	86.33	5478.69	56.04
Platt-Nibarger Ditch	240.00	228.80	37.32	9.30	2.06	2193.55	125.51	1.00	214.21	34.41	1979.34	91.09
Fetid Creek	179.00	337.92	33.39	11.45	1.98	4239.44	71.12	1.00	325.87	24.31	3913.57	46.81
Mud Creek	133.00	264.73	24.21	9.83	1.51	2669.25	26.10	1.00	301.25	10.45	2368.01	15.65
Boots Creek	681.00	2398.25	317.44	2.95	2.17	7255.93	888.49	1.00	2359.31	312.28	4896.62	576.21
Branch Creek	629.00	2923.33	354.67	4.06	2.19	10539.53	904.24	1.00	2875.86	348.91	7663.67	555.33
Lake Branch	486.00	2750.00	352.00	4.96	1.93	11039.91	807.43	1.00	2705.35	346.28	8334.56	461.14
Hoppas Ditch	472.00	2740.00	355.67	5.22	2.05	12466.20	862.67	1.00	2695.51	349.89	9770.69	512.78
Porter Creek	89.00	750.67	72.37	9.49	3.78	5916.58	428.96	1.00	738.48	71.19	5178.10	357.77
Jordan Creek	79.00	1146.50	57.24	9.55	3.65	9680.09	303.65	1.00	1127.88	56.31	8552.21	247.34
Gray Branch	31.00	91.84	12.40	11.74	3.97	687.11	86.83	1.00	90.35	12.20	596.77	74.63
Tributary Subwatershed	28.69	148.61	25.86	4.70	1.78	608.51	50.39	1.00	133.43	22.45	475.08	27.94
Back Creek	16.00	98.61	39.22	2.95	2.17	300.22	92.74	1.00	97.01	38.59	203.21	54.15
Barren Creek	21.00	89.21	15.99	6.67	2.05	610.91	42.30	1.00	87.77	15.73	523.15	26.57
Bear Creek												
Big Lick Creek	76.00	65.94	20.05	4.05	1.33	274.74	22.18	1.00	61.75	19.72	212.99	2.46
Bush Creek	20.00	20.11	2.90	7.05	0.52	168.17	1.77	1.00	20.77	1.73	147.40	0.04
Campbell Creek	20.00	35.43	4.03	4.27	0.75	178.50	2.94	1.00	31.21	2.96	147.29	-0.02
Days Creek												
Deer Creek	45.00	325.05	40.15	5.78	2.39	1655.03	113.15	1.00	319.77	39.50	1335.26	73.65
Halfway Creek	25.00	62.06	9.93	3.65	1.06	332.20	13.85	1.00	70.22	8.53	261.97	5.33
Little Deer Creek	26.00	281.93	40.36	6.56	2.44	1542.13	121.90	1.00	277.35	39.70	1264.78	82.19
Little Mississinewa River	21.00	118.46	12.35	6.91	4.70	620.12	77.16	1.00	116.54	12.15	503.59	65.01
Little Walnut Creek	17.00	145.85	8.46	3.69	1.53	630.25	14.78	1.00	143.49	8.32	486.76	6.46
Lugar Creek	30.00	204.29	31.35	3.72	0.71	602.29	39.29	1.00	200.97	34.10	401.32	5.19
Pike Creek	21.00	39.35	7.63	5.13	0.73	232.20	6.68	1.00	37.09	6.82	195.11	-0.14
Upper Big Lick Creek	52.00	57.26	11.63	2.63	1.83	123.41	15.85	1.00	49.00	11.44	74.41	4.41
Walnut Creek	39.00	340.16	48.64	3.10	0.86	1101.49	54.24	1.00	334.64	47.85	766.85	6.39

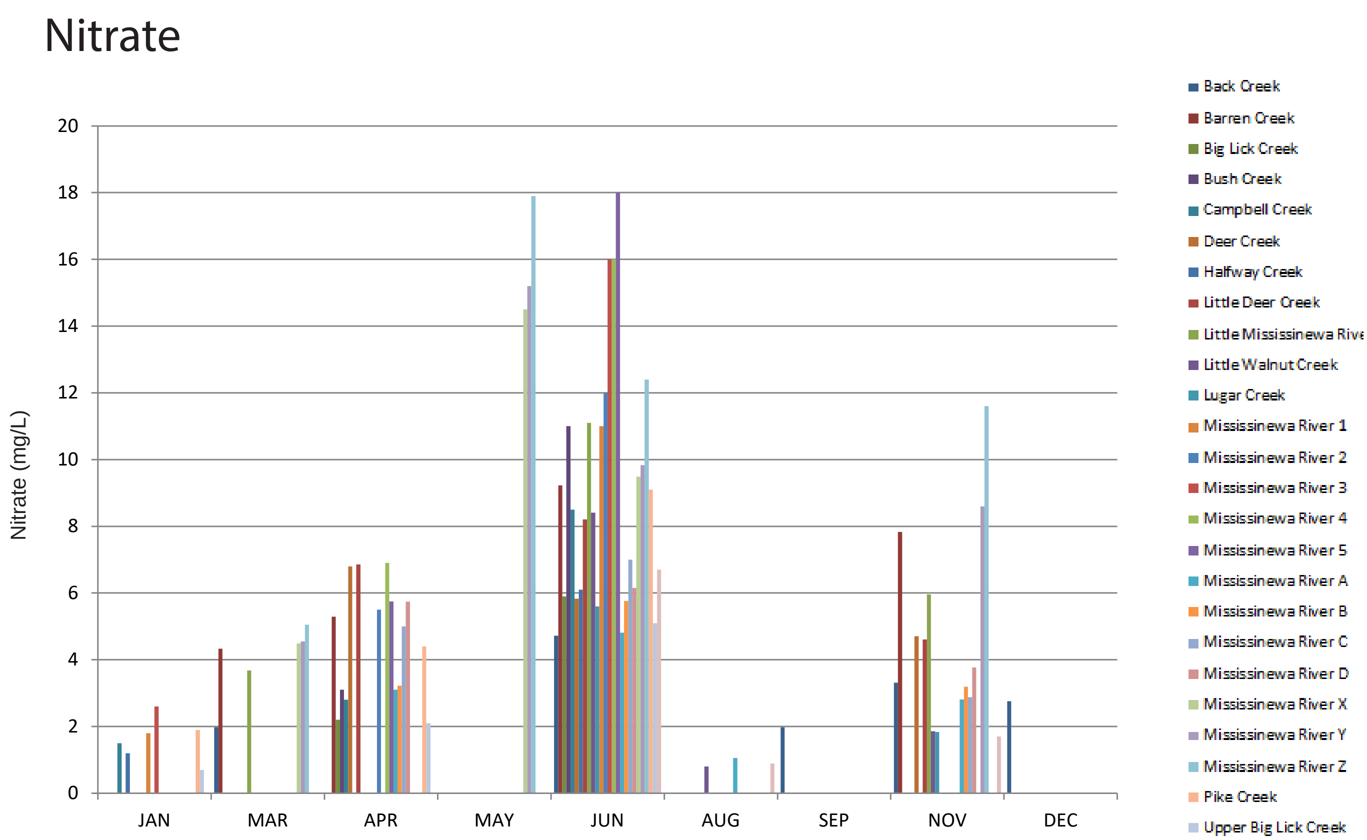


FIG. L.3 | Monthly Nitrate Samples for samples classified as high flow events.

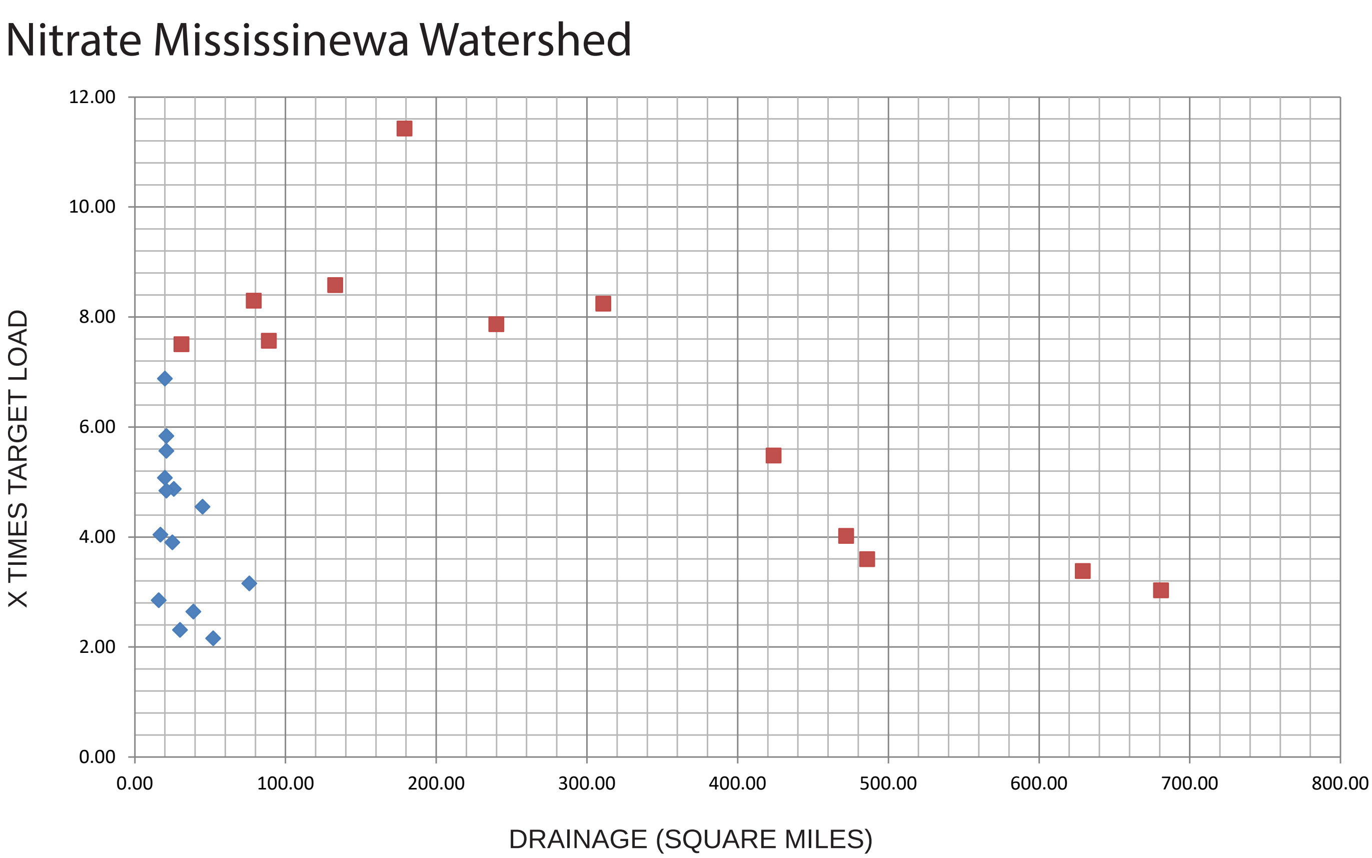


FIG. L.4 | Drainage size vs. X times target load.
"X times" represents how many times the average load (of all sample events) exceeds the target load.
Mainstem sites are represented by red squares and tributary sites by blue diamonds.

Nitrate Mississinewa Mainstem

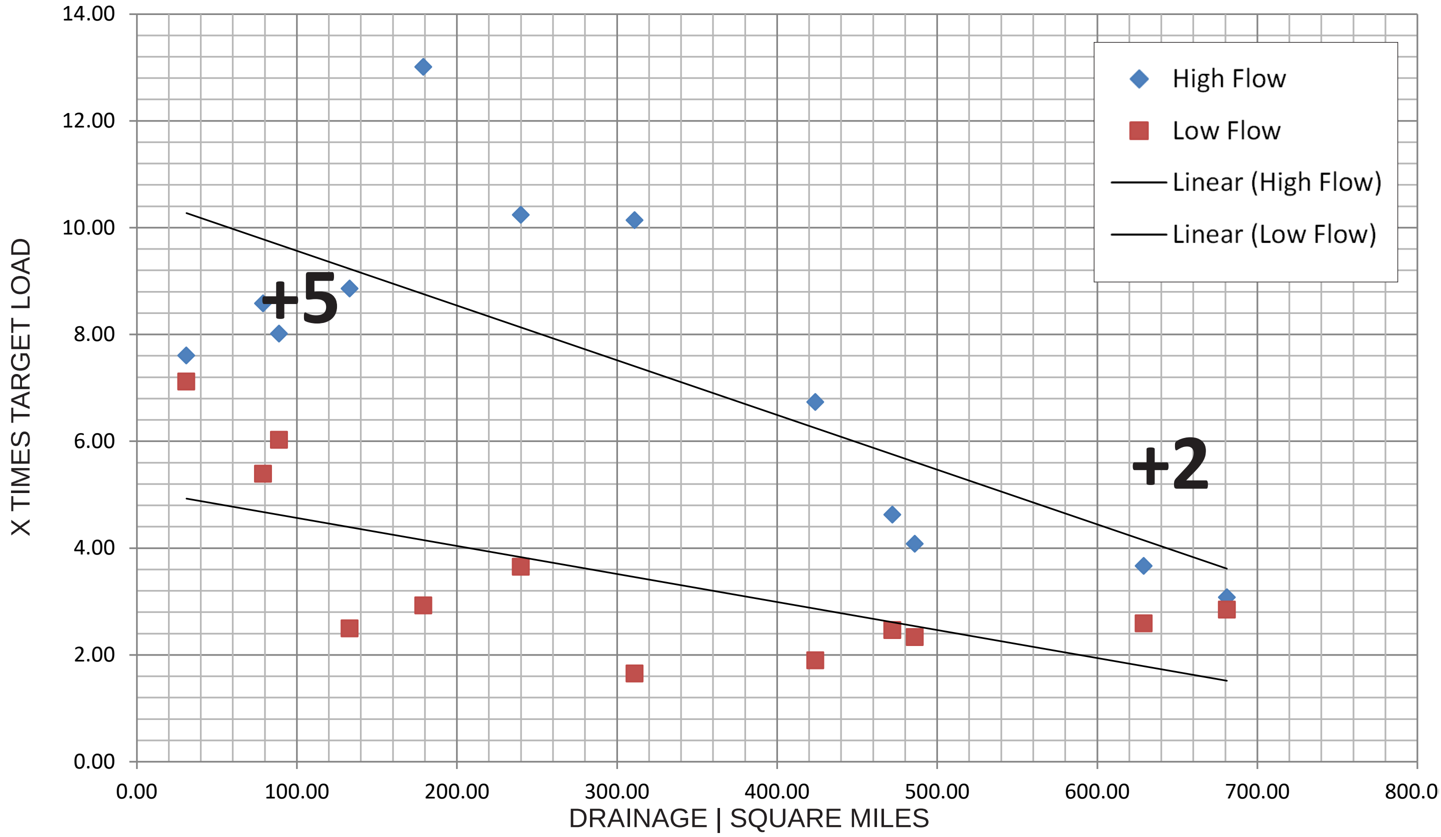


FIG. L.5 | Drainage size vs. X times target load for Mainstem Subwatersheds at High Flow and Low Flow events.

Nitrate+Nitrite Mississinewa ***Subwatersheds***

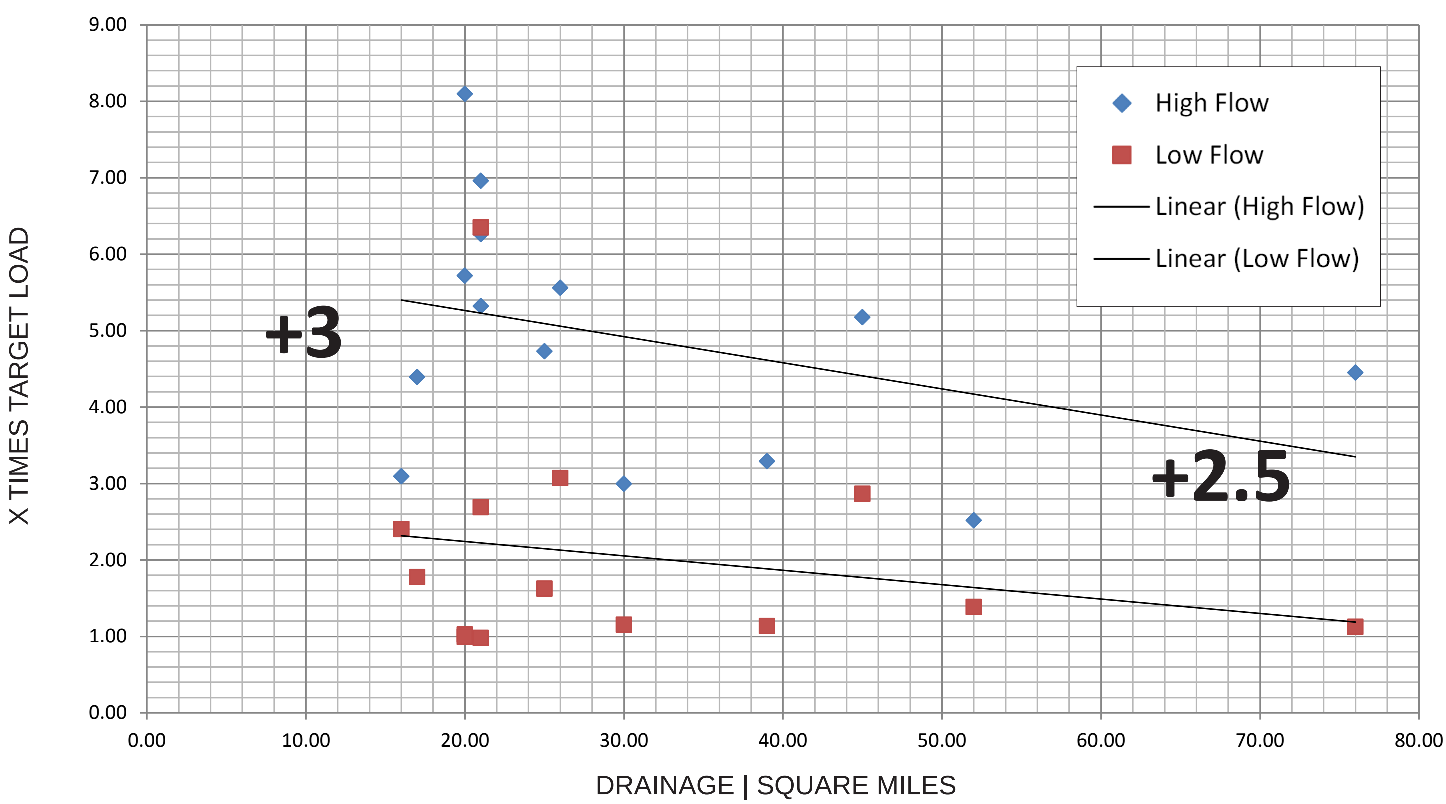


FIG. L.6 | Drainage size vs. X times target load for Tributary Subwatersheds at High Flow and Low Flow events.

M. PHOSPHORUS DATA

TABLE M.1 | Descriptive Statistics for Phosphorus (mg/L) Data Collected at UMRW Sites								
Row Labels	Drainage	Average of PHOS	Count of PHOS	Min of PHOS	Max of PHOS	StdDev of PHOS	75th	25th
Back Creek	16.00	0.15	12.00	0.03	0.59	0.16	0.26	-0.02
Barren Creek	21.00	0.08	12.00	0.02	0.28	0.08	0.14	-0.01
Bear Creek	15.00	0.16	7.00	0.08	0.40	0.11	0.23	0.00
Big Lick Creek	76.00	0.34	9.00	0.16	0.98	0.25	0.51	-0.01
Bush Creek	20.00	0.18	9.00	0.08	0.34	0.11	0.25	0.01
Campbell Creek	20.00	0.23	10.00	0.03	0.80	0.25	0.40	-0.04
Days Creek	17.00	0.24	7.00	0.07	0.73	0.24	0.40	-0.03
Deer Creek	45.00	0.11	12.00	0.01	0.75	0.20	0.25	-0.06
Halfway Creek	25.00	0.23	10.00	0.07	0.60	0.16	0.34	0.00
Little Deer Creek	26.00	0.11	12.00	0.01	0.70	0.19	0.24	-0.05
Little Mississinewa River	21.00	0.31	12.00	0.07	0.83	0.20	0.44	0.01
Little Walnut Creek	17.00	0.26	12.00	0.06	0.78	0.26	0.44	-0.03
Lugar Creek	30.00	0.18	12.00	0.01	0.49	0.20	0.32	-0.03
Holden Ditch	424.00	0.24	9.00	0.06	0.63	0.18	0.36	0.00
Rees Ditch	311.00	0.29	7.00	0.16	0.74	0.20	0.42	0.00
Platt-Nibarger Ditch	240.00	0.22	10.00	0.03	0.73	0.20	0.36	-0.02
Fetid Creek	179.00	0.20	8.00	0.10	0.42	0.10	0.27	0.02
Mud Creek	133.00	0.26	8.00	0.08	0.67	0.20	0.39	-0.01
Boots Creek	681.00	0.24	24.00	0.03	0.88	0.25	0.41	-0.04
Branch Creek	629.00	0.41	12.00	0.05	1.63	0.47	0.73	-0.08
Lake Branch	486.00	0.25	12.00	0.06	0.82	0.23	0.41	-0.02
Hoppas Ditch	472.00	0.28	12.00	0.06	0.81	0.24	0.44	-0.02
Porter Creek	89.00	0.37	12.00	0.05	1.20	0.39	0.64	-0.06
Jordan Creek	79.00	0.37	12.00	0.05	1.21	0.39	0.63	-0.06
Gray Branch	31.00	0.30	12.00	0.08	1.08	0.27	0.48	-0.03
Pike Creek	21.00	0.13	10.00	0.03	0.28	0.07	0.18	0.01
Upper Big Lick Creek	52.00	0.38	10.00	0.15	0.98	0.26	0.56	0.01
Walnut Creek	39.00	0.21	12.00	0.03	0.76	0.24	0.37	-0.04
Grand Total	192.60	0.24	306.00	0.01	1.63	0.25	0.41	-0.03

TABLE M.2 | Phosphorus Averages Separated by Flow Rate							
Subwatersheds	Drainage Area (sq mi)	Average flow rate (cfs)			Average of Phosphorus (mg/L)		
		High Flow	Low Flow	Overall Average Flow	High Flow Samples	Low Flow Samples	Total Samples
Mainstem Subwatershed	401.80	1585.23	214.29	623.71	0.52	0.19	0.29
Holden Ditch	424.00	640.72	97.06	291.23	0.41	0.16	0.24
Rees Ditch	311.00	591.17	121.56	249.64	0.51	0.20	0.29
Platt-Nibarger Ditch	240.00	228.80	37.32	88.38	0.52	0.15	0.22
Fetid Creek	179.00	337.92	33.39	127.09	0.29	0.15	0.20
Mud Creek	133.00	264.73	24.21	124.43	0.40	0.12	0.26
Boots Creek	681.00	2398.25	317.44	1011.04	0.49	0.11	0.24
Branch Creek	629.00	2923.33	354.67	996.83	0.54	0.36	0.41
Lake Branch	486.00	2750.00	352.00	951.50	0.60	0.14	0.25
Hoppas Ditch	472.00	2740.00	355.67	951.75	0.64	0.15	0.28
Porter Creek	89.00	750.67	72.37	241.94	0.77	0.24	0.37
Jordan Creek	79.00	1146.50	57.24	420.33	0.56	0.27	0.37
Gray Branch	31.00	91.84	12.40	38.88	0.53	0.18	0.30
Tributary Subwatershed	28.69	148.61	25.86	63.38	0.36	0.13	0.20
Back Creek	16.00	98.61	39.22	63.97	0.25	0.08	0.15
Barren Creek	21.00	89.21	15.99	40.40	0.16	0.05	0.08
Bear Creek							0.16
Big Lick Creek	76.00	65.94	20.05	39.72	0.29	0.25	0.34
Bush Creek	20.00	20.11	2.90	8.63	0.25	0.14	0.18
Campbell Creek	20.00	35.43	4.03	16.59	0.53	0.12	0.23
Days Creek							0.24
Deer Creek	45.00	325.05	40.15	111.37	0.31	0.04	0.11
Halfway Creek	25.00	62.06	9.93	25.57	0.48	0.18	0.23
Little Deer Creek	26.00	281.93	40.36	106.24	0.32	0.04	0.11
Little Mississinewa River	21.00	118.46	12.35	38.88	0.45	0.26	0.31
Little Walnut Creek	17.00	145.85	8.46	45.93	0.65	0.14	0.26
Lugar Creek	30.00	204.29	31.35	65.94	0.46	0.15	0.18
Pike Creek	21.00	39.35	7.63	19.16	0.20	0.10	0.13
Upper Big Lick Creek	52.00	57.26	11.63	29.88	0.33	0.31	0.38
Walnut Creek	39.00	340.16	48.64	121.52	0.57	0.08	0.21

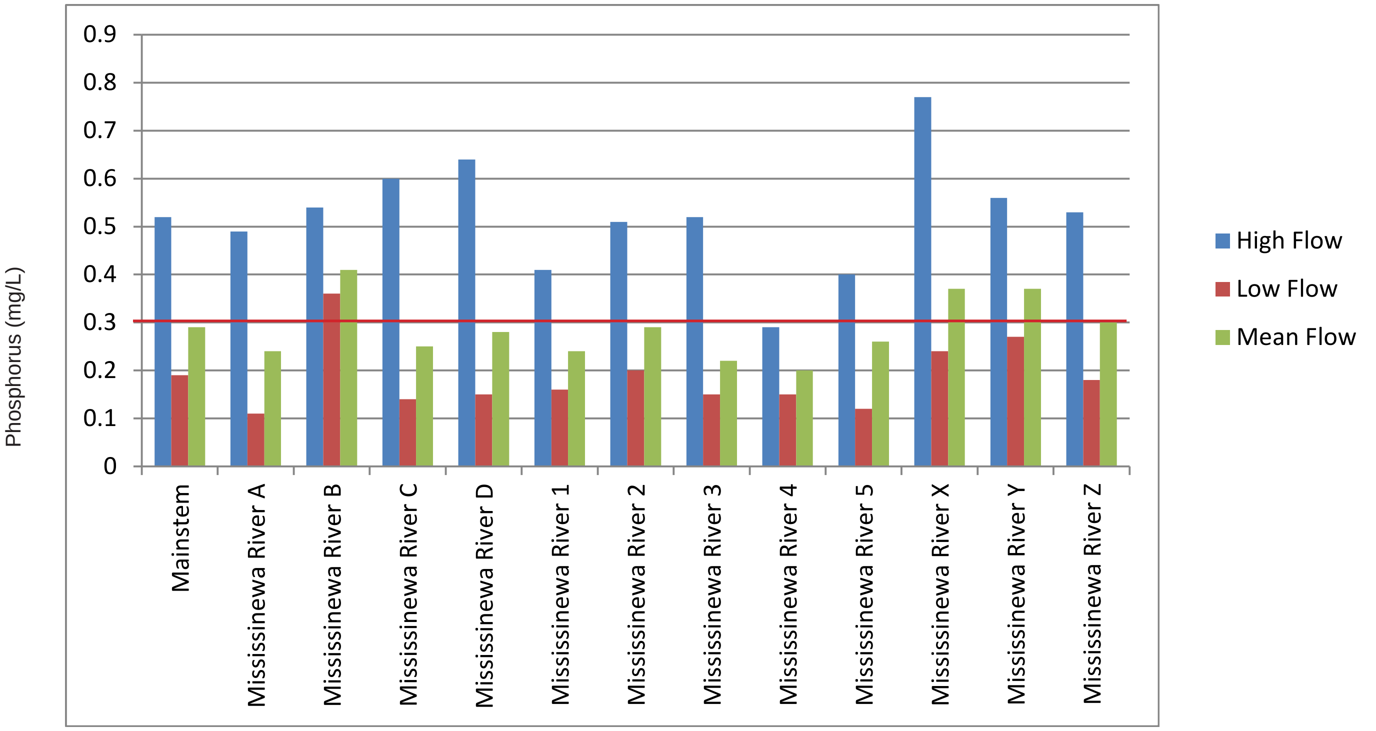


FIG. M.1 | Mainstem Subwatershed Averages for Phosphorus

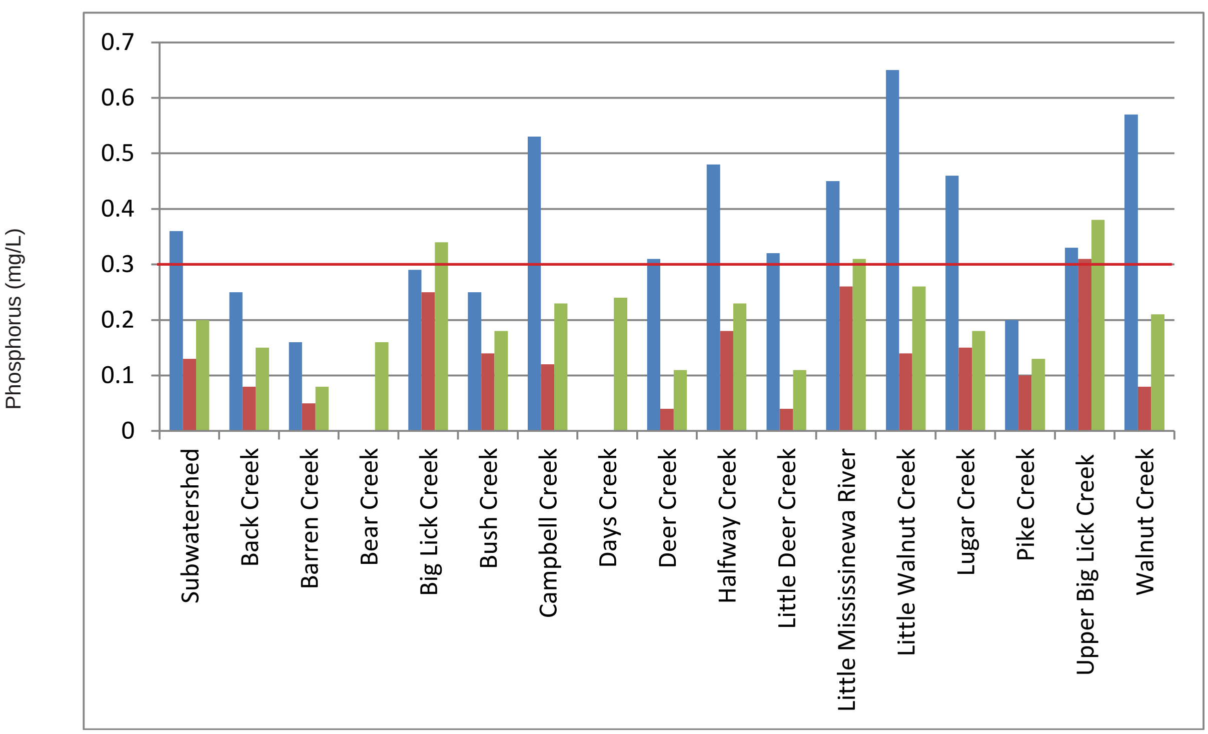


FIG. M.2 | Tributary Subwatershed Averages for Phosphorus

TABLE M.3 | Count of Exceedances[1] for Phosphorus				
Subwatershed	Number of Exceedences during High Flow	Number of Exceedences during Low Flow	No Flow Data Collected	Total Number of Exceedances
Back Creek	1.00			1.00
Bear Creek			1.00	1.00
Big Lick Creek	1.00	1.00	2.00	4.00
Bush Creek	1.00	1.00		2.00
Campbell Creek	2.00			2.00
Days Creek			2.00	2.00
Deer Creek	1.00			1.00
Halfway Creek	2.00			2.00
Little Deer Creek	1.00			1.00
Little Mississinewa River	1.00	5.00		6.00
Little Walnut Creek	3.00	1.00		4.00
Lugar Creek	2.00	2.00		4.00
Holden Ditch	2.00			2.00
Rees Ditch	1.00			1.00
Platt-Nibarger Ditch	2.00			2.00
Fetid Creek	1.00			1.00
Mud Creek	2.00			2.00
Boots Creek	6.00			6.00
Branch Creek	2.00	2.00		4.00
Lake Branch	3.00			3.00
Hoppas Ditch	3.00	1.00		4.00
Porter Creek	2.00	1.00		3.00
Jordan Creek	2.00	1.00		3.00
Gray Branch	3.00	1.00		4.00
Upper Big Lick Creek	2.00	1.00	1.00	4.00
Walnut Creek	3.00			3.00
Totals for all sites combined	49.00	17.00	6.00	72.00

1 When an individual sample is above the target set for this watershed management plan, it is considered to be in exceedance. The target concentration for phosphorus is 0.3 mg/L.

TABLE M.4 | Calculated Phosphorus Loads: Current Load, Target Load, and Load Reduction Needed

	Drainage area (sq. mi.)	Average flow (cfs)		Average phosphorus (mg/L)		Phosphorus current load (ton/year)		Phospho-rus Target (mg/L)	Phosphorus target load (ton/year)		Phosphorus load reduction needed (ton/year)	
Row Labels		High	Low	High	Low	High	Low	High	High	Low	High	Low
Mainstem	401.80	1585.23	214.29	0.52	0.19	883.13	38.27	0.30	401.97	53.61	481.16	-15.33
Holden Ditch	424.00	640.72	97.06	0.41	0.16	272.54	12.15	0.30	177.78	24.92	94.76	-12.76
Rees Ditch	311.00	591.17	121.56	0.51	0.20	362.96	24.72	0.30	179.81	35.56	183.15	-10.84
Platt-Nibarger Ditch	240.00	228.80	37.32	0.52	0.15	117.70	6.78	0.30	64.26	11.59	53.44	-4.81
Fetid Creek	179.00	337.92	33.39	0.29	0.15	93.17	3.33	0.30	87.31	7.29	5.86	-3.96
Mud Creek	133.00	264.73	24.21	0.40	0.12	115.94	1.32	0.30	90.36	3.14	25.58	-1.82
Boots Creek	681.00	2398.25	317.44	0.49	0.11	1592.92	41.74	0.30	707.79	93.68	885.12	-51.94
Branch Creek	629.00	2923.33	354.67	0.54	0.36	1897.94	122.32	0.30	862.76	104.67	1035.18	17.65
Lake Branch	486.00	2750.00	352.00	0.60	0.14	1876.82	57.45	0.30	811.60	103.89	1065.22	-46.44
Hoppas Ditch	472.00	2740.00	355.67	0.64	0.15	1918.40	68.52	0.30	808.65	104.97	1109.75	-36.45
Porter Creek	89.00	750.67	72.37	0.77	0.24	708.49	27.81	0.30	221.54	21.36	486.95	6.45
Jordan Creek	79.00	1146.50	57.24	0.56	0.27	581.02	28.53	0.30	338.36	16.89	242.66	11.64
Gray Branch	31.00	91.84	12.40	0.53	0.18	74.18	2.56	0.30	27.10	3.66	47.08	-1.10
Subwatershed	28.69	148.61	25.86	0.36	0.13	66.81	2.51	0.30	40.03	6.56	26.78	-4.05
Back Creek	16.00	98.61	39.22	0.25	0.08	31.36	3.33	0.30	29.10	11.58	2.26	-8.24
Barren Creek	21.00	89.21	15.99	0.16	0.05	17.14	0.66	0.30	26.33	4.72	-9.19	-4.06
Bear Creek												
Big Lick Creek	76.00	65.94	20.05	0.29	0.25	18.57	4.55	0.30	18.53	5.92	0.05	-1.37
Bush Creek	20.00	20.11	2.90	0.25	0.14	5.58	0.61	0.30	6.23	0.85	-0.65	-0.24
Campbell Creek	20.00	35.43	4.03	0.53	0.12	19.76	0.53	0.30	9.36	1.19	10.40	-0.66
Days Creek												
Deer Creek	45.00	325.05	40.15	0.31	0.04	178.58	1.49	0.30	95.93	11.85	82.65	-10.36
Halfway Creek	25.00	62.06	9.93	0.48	0.18	37.23	2.08	0.30	21.07	2.93	16.16	-0.85
Little Deer Creek	26.00	281.93	40.36	0.32	0.04	141.18	1.47	0.30	83.20	11.91	57.97	-10.44
Little Mississinewa River	21.00	118.46	12.35	0.45	0.26	75.52	2.32	0.30	34.96	3.65	40.56	-1.33
Little Walnut Creek	17.00	145.85	8.46	0.65	0.14	98.19	1.20	0.30	43.05	2.50	55.15	-1.29
Lugar Creek	30.00	204.29	31.35	0.46	0.15	90.90	8.33	0.30	60.29	9.25	30.61	-0.93
Pike Creek	21.00	39.35	7.63	0.20	0.10	8.31	0.86	0.30	11.13	2.25	-2.82	-1.39
Upper Big Lick Creek	52.00	57.26	11.63	0.33	0.31	16.72	2.91	0.30	14.70	3.43	2.02	-0.52
Walnut Creek	39.00	340.16	48.64	0.57	0.08	198.17	4.70	0.30	100.39	14.36	97.78	-9.66

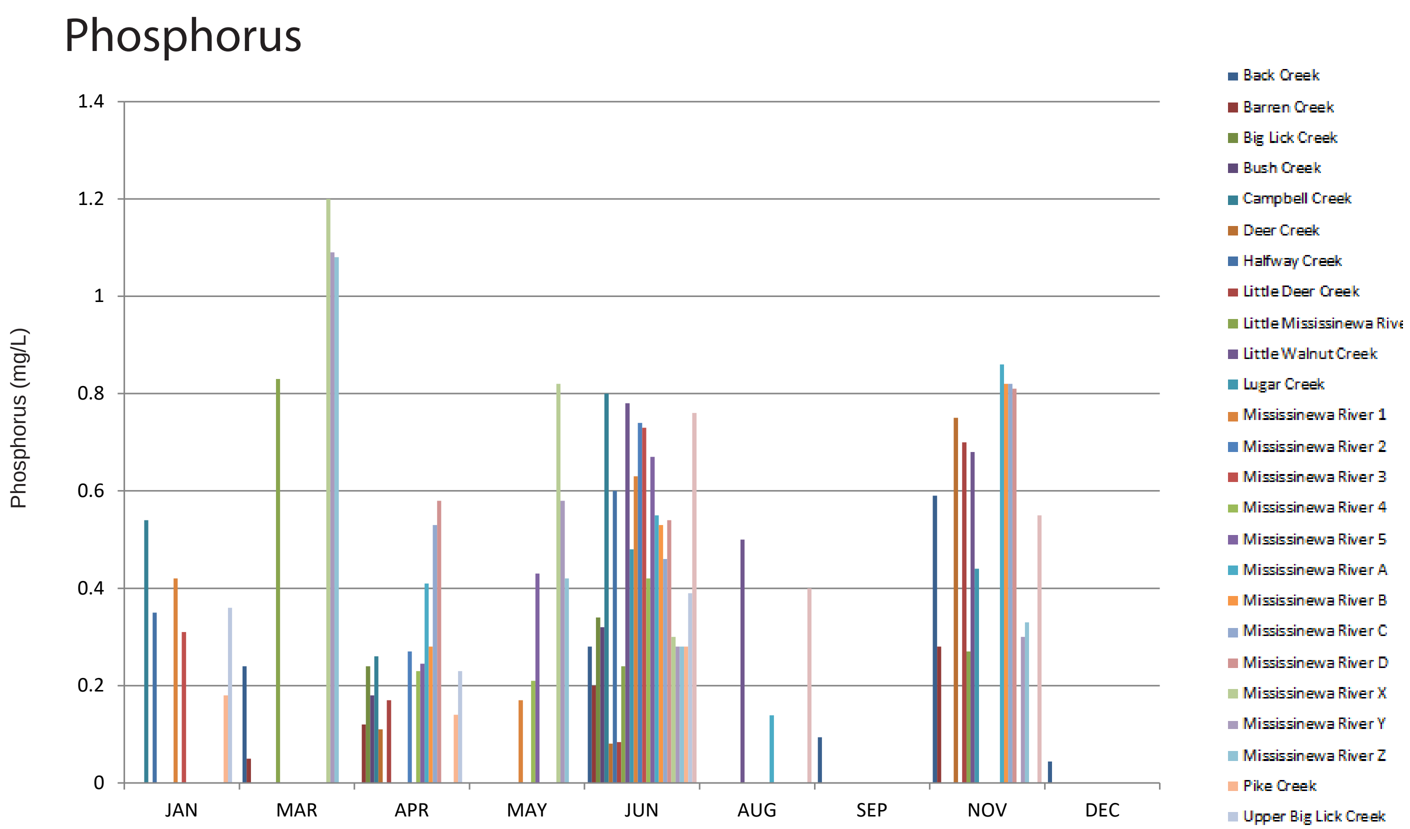


FIG. M.3 | Monthly Phosphorus Samples for samples classified as high flow events.

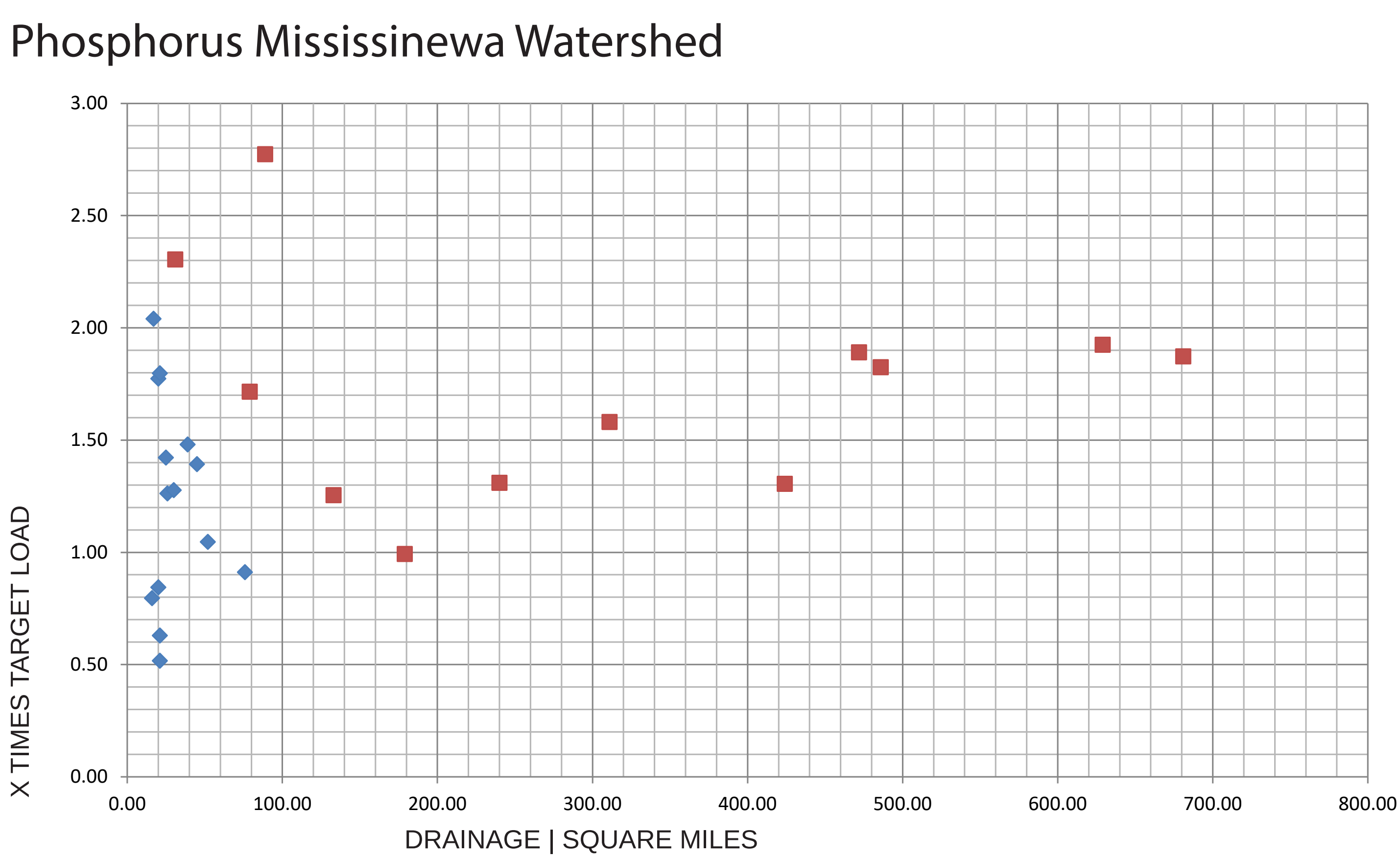


FIG. M.4 | Drainage size vs. X times target load.
"X times" represents how many times the average load (of all sample events) exceeds the target load.
Mainstem sites are represented by red squares and tributary sites by blue diamonds.

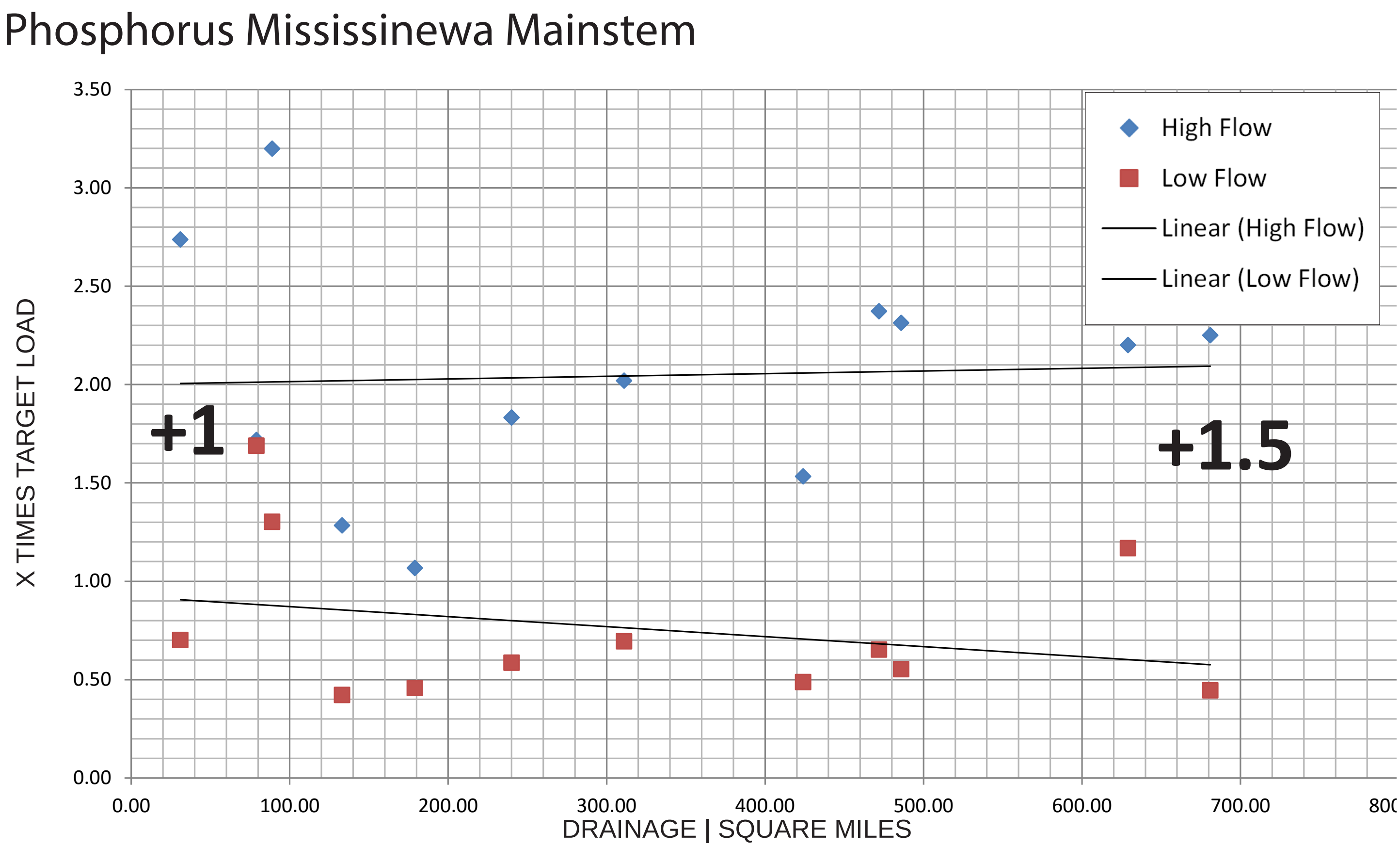


FIG. M.5 | Drainage size vs. X times target load for Mainstem Subwatersheds at High Flow and Low Flow events.

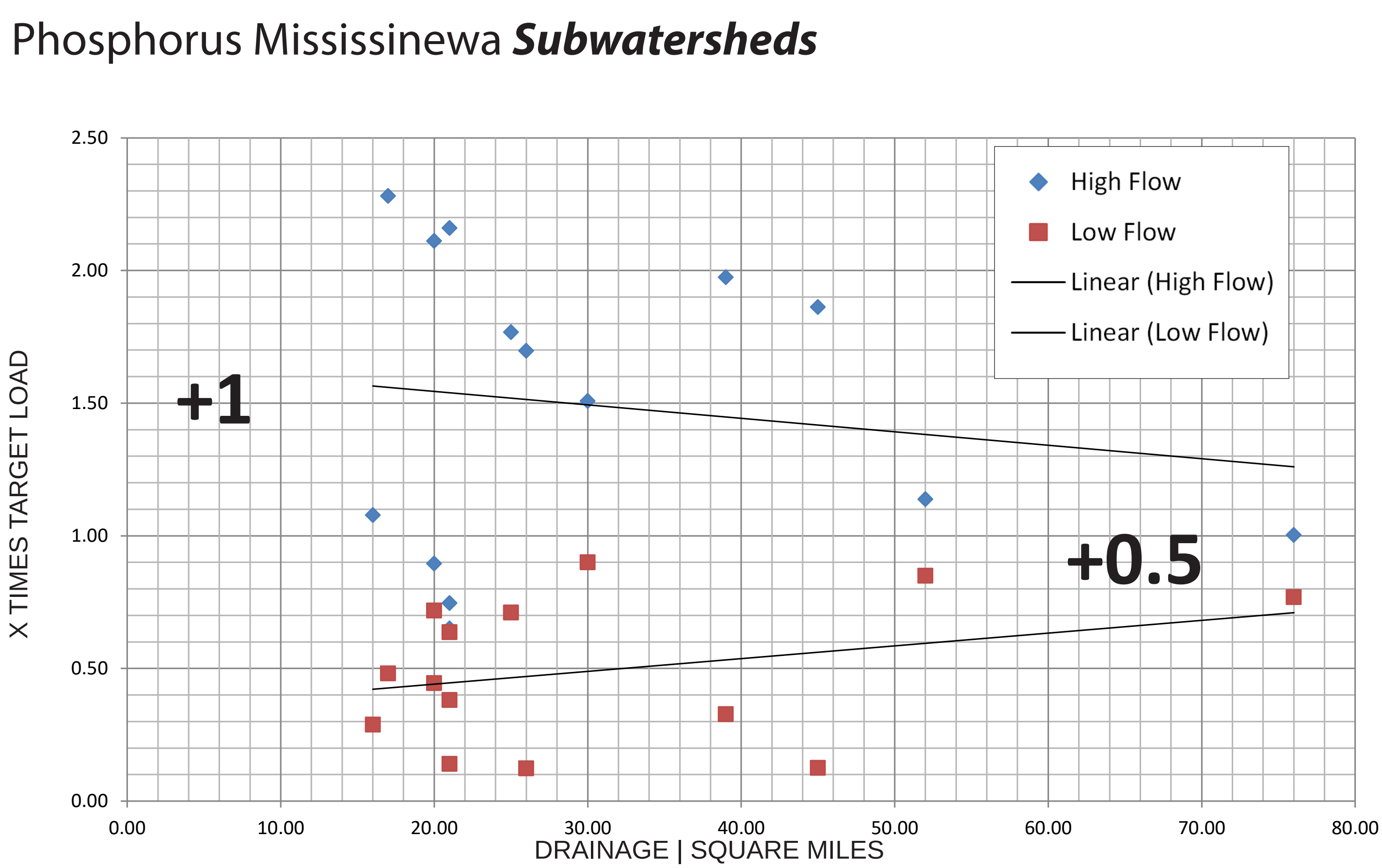


FIG. M.6 | Drainage size vs. X times target load for Tributary Subwatersheds at High Flow and Low Flow events.

N. TSS DATA

TABLE N.1 | Descriptive Statistics for TSS Data (mg/L) Collected at UMRW Sites								
Row Labels	Drainage	Average of TSS	Count of TSS	Min of TSS	Max of TSS	StdDev of TSS	75th	25th
Back Creek	16.00	29.64	12.00	0.80	177.00	52.63	65.17	-14.35
Barren Creek	21.00	16.11	12.00	2.00	64.00	20.20	29.74	-3.97
Bear Creek	15.00	11.50	7.00	0.50	44.00	19.01	24.33	-4.92
Big Lick Creek	76.00	29.89	9.00	0.50	160.00	51.07	64.36	-13.55
Bush Creek	20.00	9.50	9.00	0.50	43.00	14.12	19.03	-3.35
Campbell Creek	20.00	17.15	10.00	0.50	72.00	23.46	32.98	-5.11
Days Creek	17.00	28.79	7.00	0.50	90.00	38.83	55.00	-8.34
Deer Creek	45.00	13.52	12.00	1.60	61.00	17.70	25.46	-3.67
Halfway Creek	25.00	13.55	10.00	0.50	59.00	18.40	25.97	-3.98
Little Deer Creek	26.00	13.65	12.00	2.40	67.00	17.81	25.67	-3.68
Little Mississinewa River	21.00	50.50	12.00	2.00	405.00	113.12	126.85	-35.13
Little Walnut Creek	17.00	23.12	12.00	5.60	87.00	27.21	41.49	-4.88
Lugar Creek	30.00	41.44	12.00	0.80	227.00	65.82	85.87	-16.52
Holden Ditch	424.00	19.11	9.00	0.50	95.00	30.02	39.38	-7.47
Rees Ditch	311.00	31.21	7.00	0.50	100.00	32.22	52.96	-4.53
Platt-Nibarger Ditch	240.00	22.10	10.00	0.50	79.00	25.10	39.04	-4.25
Fetid Creek	179.00	26.69	8.00	0.50	110.00	37.67	52.11	-8.49
Mud Creek	133.00	28.63	8.00	0.50	89.00	36.95	53.57	-7.53
Boots Creek	681.00	58.46	24.00	0.25	363.00	97.00	123.94	-25.19
Branch Creek	629.00	51.28	12.00	4.00	250.00	72.70	100.35	-16.46
Lake Branch	486.00	55.17	12.00	1.60	201.00	73.35	104.68	-15.49
Hoppas Ditch	472.00	82.74	12.00	3.20	342.00	115.18	160.49	-25.59
Porter Creek	89.00	110.82	12.00	4.80	710.00	215.67	256.40	-62.25
Jordan Creek	79.00	85.87	12.00	4.00	615.00	176.90	205.28	-52.69
Gray Branch	31.00	66.22	12.00	4.40	445.00	126.25	151.43	-36.00
Pike Creek	21.00	6.00	10.00	0.50	20.00	7.59	11.12	-1.51
Upper Big Lick Creek	52.00	25.05	10.00	0.50	160.00	47.91	57.39	-13.69
Walnut Creek	39.00	34.57	12.00	1.60	207.00	59.00	74.39	-15.65
Grand Total	192.60	38.58	306.00	0.25	710.00	82.95	94.57	-25.25

TABLE N.2 | TSS Averages Separated by Flow Rate							
Subwatersheds	Drainage Area (sq mi)	Average flow rate (cfs)			Average of TSS (mg/L)		
		High Flow	Low Flow	Overall Average Flow	High Flow Samples	Low Flow Samples	Total Samples
Mainstem Subwatershed	401.80	1585.23	214.29	623.71	151.23	15.94	57.12
Holden Ditch	424.00	640.72	97.06	291.23	45.33	6.00	19.11
Rees Ditch	311.00	591.17	121.56	249.64	65.00	17.70	31.21
Platt-Nibarger Ditch	240.00	228.80	37.32	88.38	50.00	15.13	22.10
Fetid Creek	179.00	337.92	33.39	127.09	62.67	5.10	26.69
Mud Creek	133.00	264.73	24.21	124.43	56.75	0.50	28.63
Boots Creek	681.00	2398.25	317.44	1011.04	143.30	16.05	58.46
Branch Creek	629.00	2923.33	354.67	996.83	155.43	16.56	51.28
Lake Branch	486.00	2750.00	352.00	951.50	168.00	17.56	55.17
Hoppas Ditch	472.00	2740.00	355.67	951.75	221.00	36.66	82.74
Porter Creek	89.00	750.67	72.37	241.94	391.67	17.20	110.82
Jordan Creek	79.00	1146.50	57.24	420.33	232.10	12.75	85.87
Gray Branch	31.00	91.84	12.40	38.88	171.85	13.40	66.22
Tributary Subwatershed	28.69	148.61	25.86	63.38	57.46	8.52	23.36
Back Creek	16.00	98.61	39.22	63.97	60.98	7.26	29.64
Barren Creek	21.00	89.21	15.99	40.40	37.23	5.55	16.11
Bear Creek							11.50
Big Lick Creek	76.00	65.94	20.05	39.72	28.00	4.63	29.89
Bush Creek	20.00	20.11	2.90	8.63	26.50	3.25	9.50
Campbell Creek	20.00	35.43	4.03	16.59	38.67	9.17	17.15
Days Creek							28.79
Deer Creek	45.00	325.05	40.15	111.37	38.60	5.16	13.52
Halfway Creek	25.00	62.06	9.93	25.57	36.50	8.86	13.55
Little Deer Creek	26.00	281.93	40.36	106.24	34.60	5.85	13.65
Little Mississinewa River	21.00	118.46	12.35	38.88	162.93	13.02	50.50
Little Walnut Creek	17.00	145.85	8.46	45.93	55.53	13.01	23.12
Lugar Creek	30.00	204.29	31.35	65.94	164.00	17.56	41.44
Pike Creek	21.00	39.35	7.63	19.16	13.67	2.71	6.00
Upper Big Lick Creek	52.00	57.26	11.63	29.88	14.33	7.92	25.05
Walnut Creek	39.00	340.16	48.64	121.52	105.73	10.84	34.57

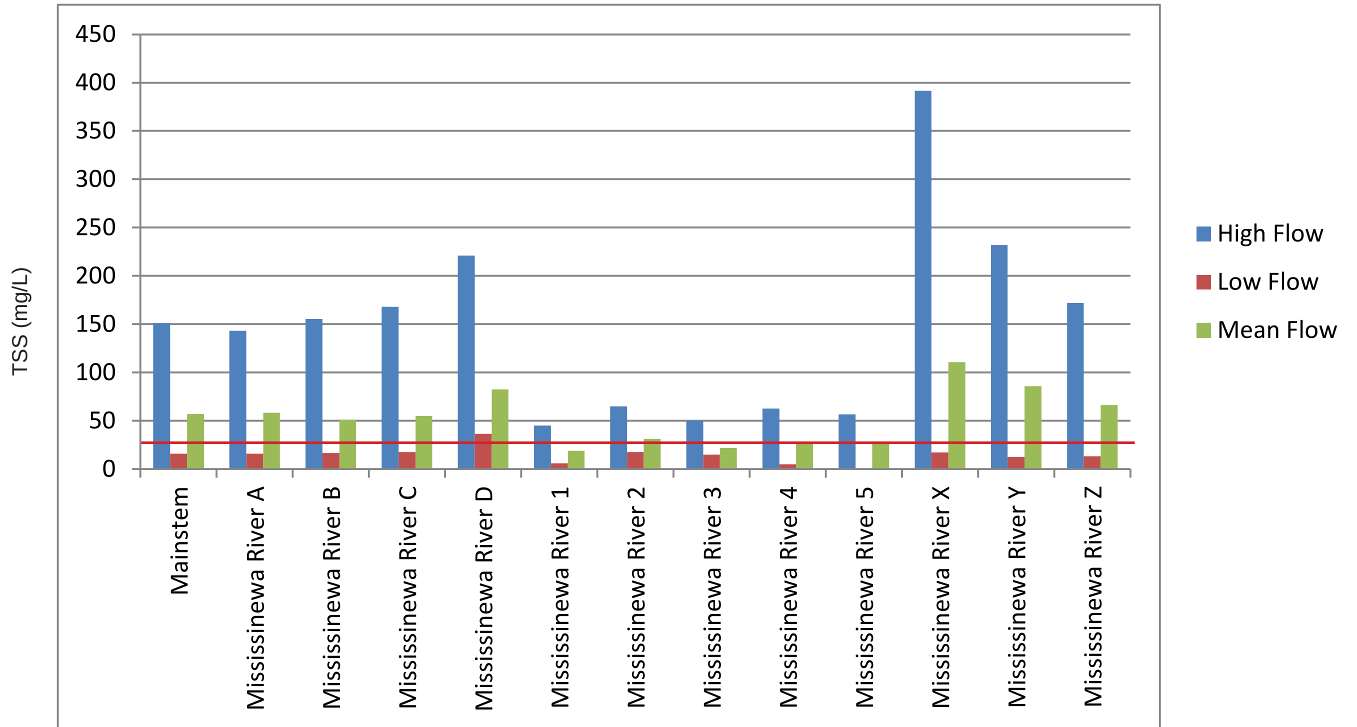


FIG. N.1 | Mainstem Subwatershed Averages for TSS

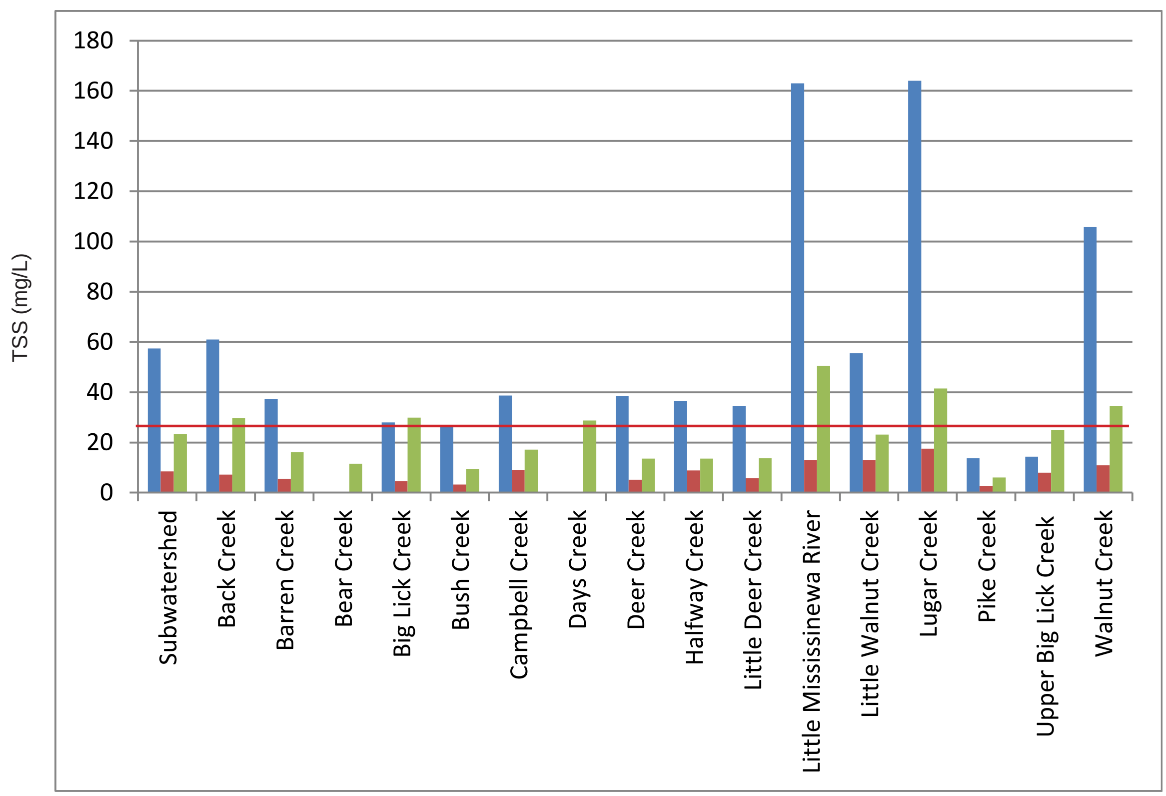


FIG. N.2 | Tributary Subwatershed Averages for TSS

TABLE N.3 | Count of Exceedances[1] for TSS				
Subwatershed	Number of Exceedences during High Flow	Number of Exceedences during Low Flow	No Flow Data Collected	Total Number of Exceedances
Back Creek	3.00			3.00
Barren Creek	3.00			3.00
Bear Creek			2.00	2.00
Big Lick Creek	1.00		2.00	3.00
Bush Creek	1.00			1.00
Campbell Creek	2.00	1.00		3.00
Days Creek			2.00	2.00
Deer Creek	2.00			2.00
Halfway Creek	1.00			1.00
Little Deer Creek	1.00			1.00
Little Mississinewa River	3.00	1.00		4.00
Little Walnut Creek	2.00	1.00		3.00
Lugar Creek	2.00	1.00		3.00
Holden Ditch	1.00			1.00
Rees Ditch	2.00	2.00		4.00
Platt-Nibarger Ditch	1.00	2.00		3.00
Fetid Creek	3.00			3.00
Mud Creek	4.00			4.00
Boots Creek	6.00	4.00		10.00
Branch Creek	3.00	1.00		4.00
Lake Branch	3.00	1.00		4.00
Hoppas Ditch	3.00	2.00		5.00
Porter Creek	3.00	2.00		5.00
Jordan Creek	4.00			4.00
Gray Branch	4.00	1.00		5.00
Upper Big Lick Creek			1.00	1.00
Walnut Creek	3.00	1.00		4.00
Totals for all sites combined	61.00	20.00	7.00	88.00

1 When an individual sample is above the target set for this watershed management plan, it is considered to be in exceedance. The target concentration for TSS is 25 mg/L.

TABLE N.4 | Calculated TSS Loads: Current Load, Target Load, and Load Reduction Needed

	Drainage area (sq. mi.)	Average flow (cfs)		Average TSS (mg/L)		TSS current load (ton/year)		TSS Target (mg/L)	TSS target load (ton/year)		TSS load reduction needed (ton/year)	
Subwatershed	High	High	Low	High	Low	High	Low	High	High	Low	High	Low
Mainstem Subwatershed	401.80	1585.23	214.29	151.23	15.94	215939.78	4603.05	25.00	33497.46	4467.33	182442.32	135.73
Holden Ditch	424.00	640.72	97.06	45.33	6.00	31227.66	408.14	25.00	14814.80	2076.35	16412.86	-1668.21
Rees Ditch	311.00	591.17	121.56	65.00	17.70	47936.26	2426.69	25.00	14983.92	2963.58	32952.33	-536.89
Platt-Nibarger Ditch	240.00	228.80	37.32	50.00	15.13	11582.27	831.90	25.00	5355.35	965.82	6226.92	-133.92
Fetid Creek	179.00	337.92	33.39	62.67	5.10	21729.82	146.35	25.00	7275.74	607.86	14454.08	-461.51
Mud Creek	133.00	264.73	24.21	56.75	0.50	16599.21	5.23	25.00	7529.84	261.31	9069.37	-256.09
Boots Creek	681.00	2398.25	317.44	143.30	16.05	333563.31	5276.49	25.00	58982.67	7807.07	274580.64	-2530.58
Branch Creek	629.00	2923.33	354.67	155.43	16.56	400998.40	6293.76	25.00	71896.60	8722.69	329101.81	-2428.93
Lake Branch	486.00	2750.00	352.00	168.00	17.56	387070.96	8277.68	25.00	67633.63	8657.10	319437.33	-379.43
Hoppas Ditch	472.00	2740.00	355.67	221.00	36.66	472343.44	20252.13	25.00	67387.69	8747.28	404955.75	11504.84
Porter Creek	89.00	750.67	72.37	391.67	17.20	387423.47	1544.05	25.00	18461.93	1779.79	368961.54	-235.74
Jordan Creek	79.00	1146.50	57.24	232.10	12.75	249930.52	831.57	25.00	28197.08	1407.70	221733.44	-576.13
Gray Branch	31.00	91.84	12.40	171.85	13.40	28356.74	189.76	25.00	2258.67	304.98	26098.08	-115.22
Tributary Subwatershed	28.69	148.61	25.86	57.46	8.52	11086.92	256.74	25.00	3335.84	546.99	7751.08	-290.25
Back Creek	16.00	98.61	39.22	60.98	7.26	5599.62	304.32	25.00	2425.23	964.64	3174.39	-660.31
Barren Creek	21.00	89.21	15.99	37.23	5.55	3549.52	85.33	25.00	2194.15	393.26	1355.37	-307.93
Bear Creek												
Big Lick Creek	76.00	65.94	20.05	28.00	4.63	1888.94	158.03	25.00	1543.81	493.12	345.13	-335.09
Bush Creek	20.00	20.11	2.90	26.50	3.25	641.24	24.66	25.00	519.27	71.22	121.97	-46.55
Campbell Creek	20.00	35.43	4.03	38.67	9.17	1562.48	65.39	25.00	780.20	99.24	782.28	-33.85
Days Creek												
Deer Creek	45.00	325.05	40.15	38.60	5.16	16348.40	232.74	25.00	7994.28	987.44	8354.12	-754.70
Halfway Creek	25.00	62.06	9.93	36.50	8.86	3260.05	150.76	25.00	1755.60	244.18	1504.44	-93.42
Little Deer Creek	26.00	281.93	40.36	34.60	5.85	14131.19	261.50	25.00	6933.70	992.60	7197.50	-731.10
Little Mississinewa River	21.00	118.46	12.35	162.93	13.02	33914.29	117.05	25.00	2913.47	303.78	31000.81	-186.74
Little Walnut Creek	17.00	145.85	8.46	55.53	13.01	9207.79	125.64	25.00	3587.14	208.03	5620.65	-82.38
Lugar Creek	30.00	204.29	31.35	164.00	17.56	28089.21	924.80	25.00	5024.21	771.06	23065.00	153.74
Pike Creek	21.00	39.35	7.63	13.67	2.71	575.14	21.84	25.00	927.21	187.63	-352.07	-165.79
Upper Big Lick Creek	52.00	57.26	11.63	14.33	7.92	708.62	96.40	25.00	1225.01	285.97	-516.39	-189.57
Walnut Creek	39.00	340.16	48.64	105.73	10.84	38421.69	752.49	25.00	8365.94	1196.27	30055.74	-443.78

TSS

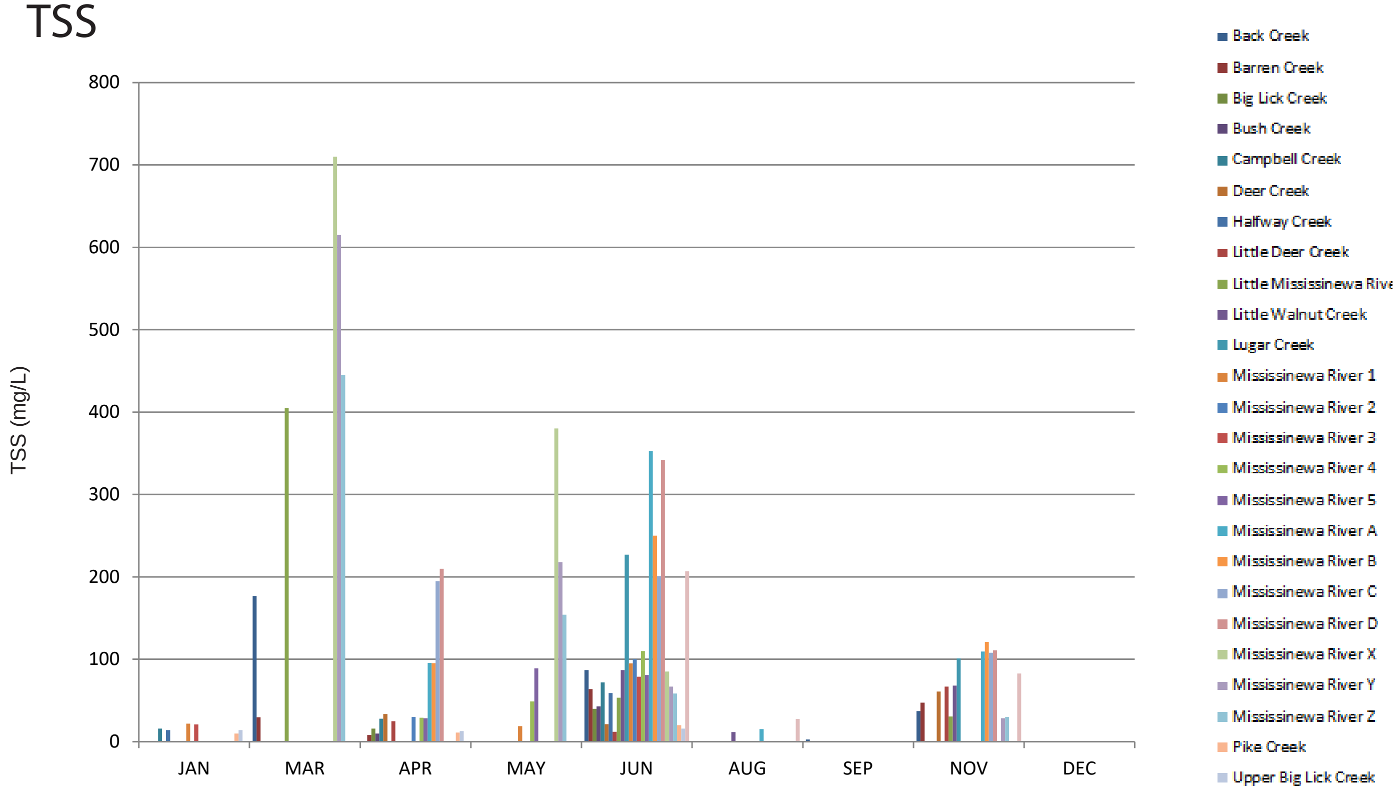


FIG. N.3 | Monthly TSS Samples for samples classified as high flow events.

TSS Mississinewa Watershed

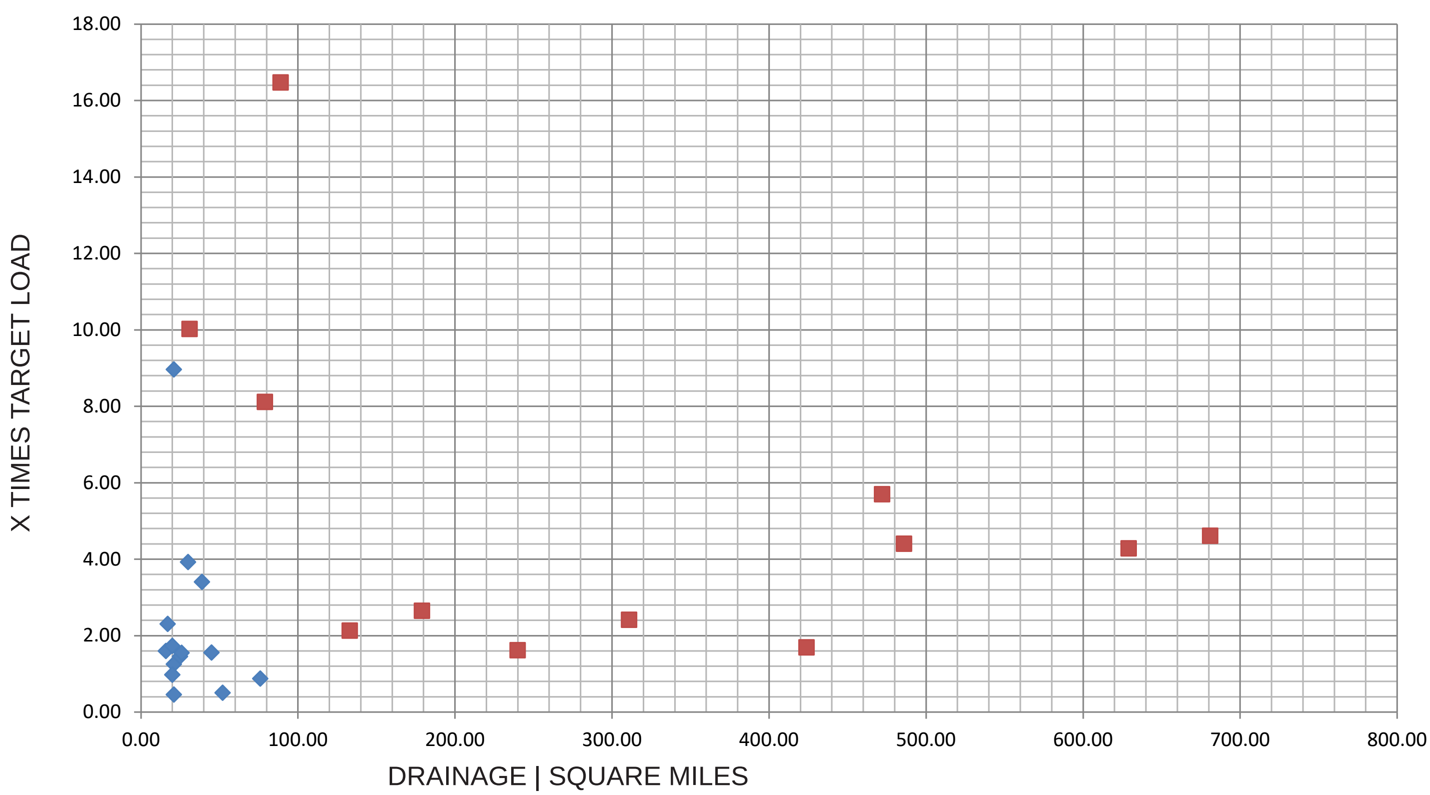


FIG. N.4 | Drainage size vs. X times target load.
"X times" represents how many times the average load (of all sample events) exceeds the target load.
Mainstem sites are represented by red squares and tributary sites by blue diamonds.

TSS Mississinewa Mainstem

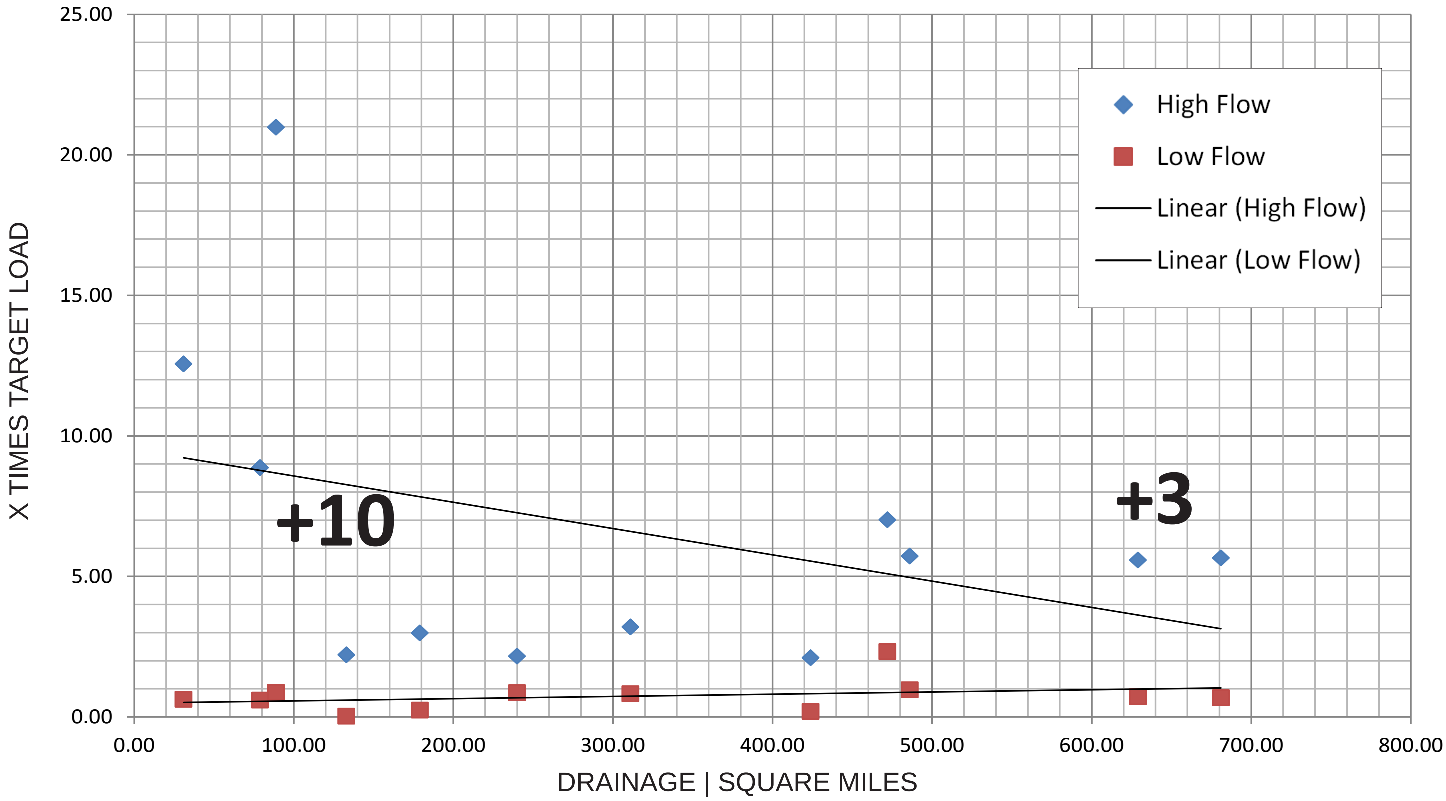


FIG. N.5 | Drainage size vs. X times target load for Mainstem Subwatersheds at High Flow and Low Flow events.

TSS Mississinewa *Subwatersheds*

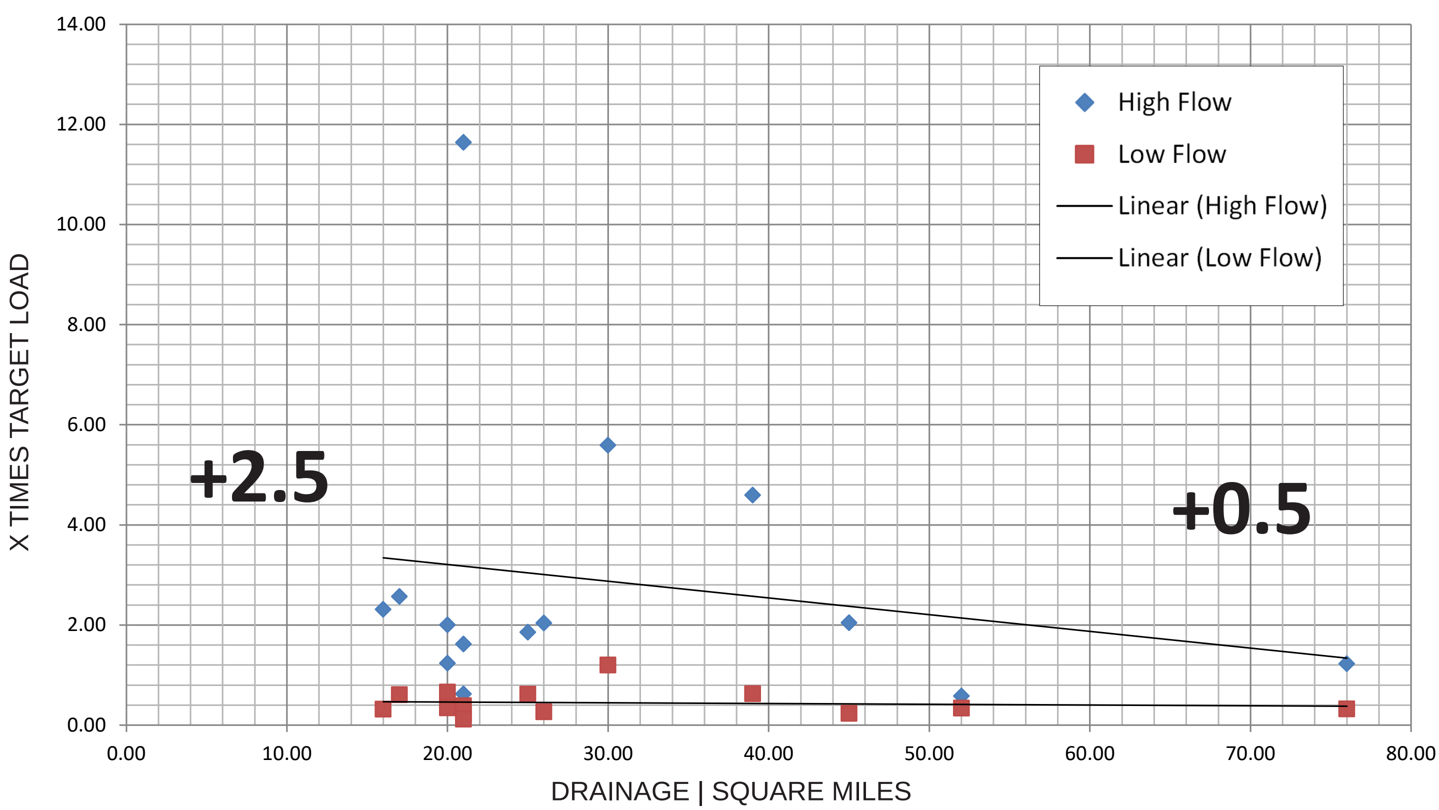


FIG. N.6 Drainage size vs. X times target load for Tributary Subwatersheds at High Flow and Low Flow events.

O. *E. COLI* DATA

TABLE O.1 | Descriptive Statistics for E. Coli Data (cfu/100mL) Collected at UMRW Sites

Row Labels	Drainage	Average of E. COLI	Count of E. COLI	Min of E. COLI	Max of E. COLI	StdDev of E. COLI	75th	25th
Back Creek	16.00	1523.25	12.00	117.00	6400.00	1739.21	2697.22	-297.37
Barren Creek	21.00	3630.83	12.00	47.00	29700.00	8419.32	9313.88	-2656.03
Bear Creek	15.00	929.27	10.00	83.00	2419.60	820.60	1483.18	-71.88
Big Lick Creek	76.00	3971.86	10.00	148.30	17329.00	5948.21	7986.90	-1419.30
Bush Creek	20.00	497.16	10.00	59.10	1553.10	495.59	831.69	-64.23
Campbell Creek	20.00	665.93	10.00	59.10	1986.30	709.05	1144.54	-106.63
Days Creek	17.00	886.30	10.00	53.80	4352.00	1339.63	1790.55	-322.32
Deer Creek	45.00	531.42	12.00	57.00	1600.00	536.64	893.65	-71.80
Halfway Creek	25.00	798.39	11.00	35.00	2419.60	771.29	1319.01	-91.94
Little Deer Creek	26.00	1059.42	12.00	103.00	8740.00	2435.33	2703.26	-765.29
Little Mississinewa River	21.00	1063.42	12.00	77.00	3500.00	1086.44	1796.76	-149.40
Little Walnut Creek	17.00	1137.42	12.00	10.00	7050.00	2012.20	2495.65	-547.15
Lugar Creek	30.00	1844.33	12.00	20.00	7330.00	2696.70	3664.60	-629.27
Holden Ditch	424.00	625.95	10.00	52.00	1986.30	719.51	1111.62	-124.40
Rees Ditch	311.00	927.21	10.00	46.40	6131.00	1859.78	2182.56	-546.02
Platt-Nibarger Ditch	240.00	640.11	11.00	43.50	3255.00	991.68	1309.49	-243.80
Fetid Creek	179.00	704.61	10.00	115.30	4106.00	1257.65	1553.52	-344.02
Mud Creek	133.00	981.20	11.00	71.70	4884.00	1479.51	1979.87	-355.21
Boots Creek	681.00	767.00	24.00	1.00	4100.00	1202.60	1578.75	-298.66
Branch Creek	629.00	758.58	12.00	47.00	3420.00	1151.50	1535.85	-278.11
Lake Branch	486.00	1510.83	12.00	30.00	6940.00	2219.87	3009.25	-520.41
Hoppas Ditch	472.00	1054.75	12.00	50.00	3400.00	1285.38	1922.38	-242.86
Porter Creek	89.00	870.08	12.00	37.00	2350.00	795.66	1407.16	-79.75
Jordan Creek	79.00	1075.00	12.00	113.00	2200.00	795.88	1612.22	-13.25
Gray Branch	31.00	1026.75	12.00	103.00	3400.00	1084.82	1759.00	-160.58
Pike Creek	21.00	459.95	11.00	228.20	866.40	203.78	597.51	56.64
Upper Big Lick Creek	52.00	4029.80	11.00	108.60	24196.00	7167.23	8867.68	-1955.89
Walnut Creek	39.00	1031.67	12.00	7.00	4800.00	1574.70	2094.59	-382.18
Grand Total	192.60	1235.19	327.00	1.00	29700.00	2729.21	3077.41	-842.06

TABLE O.2 | E. coli Averages Separated by Flow Rate							
Subwatersheds	Drainage Area (sq mi)	Average flow rate (cfs)			Average of E. coli (cfu/100 mL)		
		High Flow	Low Flow	Overall Average Flow	High Flow Samples	Low Flow Samples	Total Samples
Mainstem Subwatershed	401.80	1585.23	214.29	623.71	1905.69	485.79	907.92
Holden Ditch	424.00	640.72	97.06	291.23	1172.27	391.81	625.95
Rees Ditch	311.00	591.17	121.56	249.64	624.07	1057.13	927.21
Platt-Nibarger Ditch	240.00	228.80	37.32	88.38	2493.95	228.14	640.11
Fetid Creek	179.00	337.92	33.39	127.09	1893.43	195.11	704.61
Mud Creek	133.00	264.73	24.21	124.43	1843.82	262.35	981.20
Boots Creek	681.00	2398.25	317.44	1011.04	1789.63	255.69	767.00
Branch Creek	629.00	2923.33	354.67	996.83	1078.00	652.11	758.58
Lake Branch	486.00	2750.00	352.00	951.50	4017.67	675.22	1510.83
Hoppas Ditch	472.00	2740.00	355.67	951.75	2033.33	728.56	1054.75
Porter Creek	89.00	750.67	72.37	241.94	2016.67	487.89	870.08
Jordan Creek	79.00	1146.50	57.24	420.33	1852.50	686.25	1075.00
Gray Branch	31.00	91.84	12.40	38.88	2352.50	363.88	1026.75
Tributary Subwatershed	28.69	148.61	25.86	63.38	3081.94	743.05	1505.79
Back Creek	16.00	98.61	39.22	63.97	2794.60	615.14	1523.25
Barren Creek	21.00	89.21	15.99	40.40	8696.50	1098.00	3630.83
Bear Creek							929.27
Big Lick Creek	76.00	65.94	20.05	39.72	4776.40	976.93	3971.86
Bush Creek	20.00	20.11	2.90	8.63	939.30	361.18	497.16
Campbell Creek	20.00	35.43	4.03	16.59	1198.45	562.94	665.93
Days Creek							886.30
Deer Creek	45.00	325.05	40.15	111.37	956.67	389.67	531.42
Halfway Creek	25.00	62.06	9.93	25.57	2419.60	535.80	798.39
Little Deer Creek	26.00	281.93	40.36	106.24	3324.67	304.88	1059.42
Little Mississinewa River	21.00	118.46	12.35	38.88	1700.00	851.22	1063.42
Little Walnut Creek	17.00	145.85	8.46	45.93	1600.00	1099.00	1137.42
Lugar Creek	30.00	204.29	31.35	65.94	4330.00	1662.38	1844.33
Pike Creek	21.00	39.35	7.63	19.16	276.85	463.83	459.95
Upper Big Lick Creek	52.00	57.26	11.63	29.88	4058.50	1113.08	4029.80
Walnut Creek	39.00	340.16	48.64	121.52	2983.33	381.11	1031.67

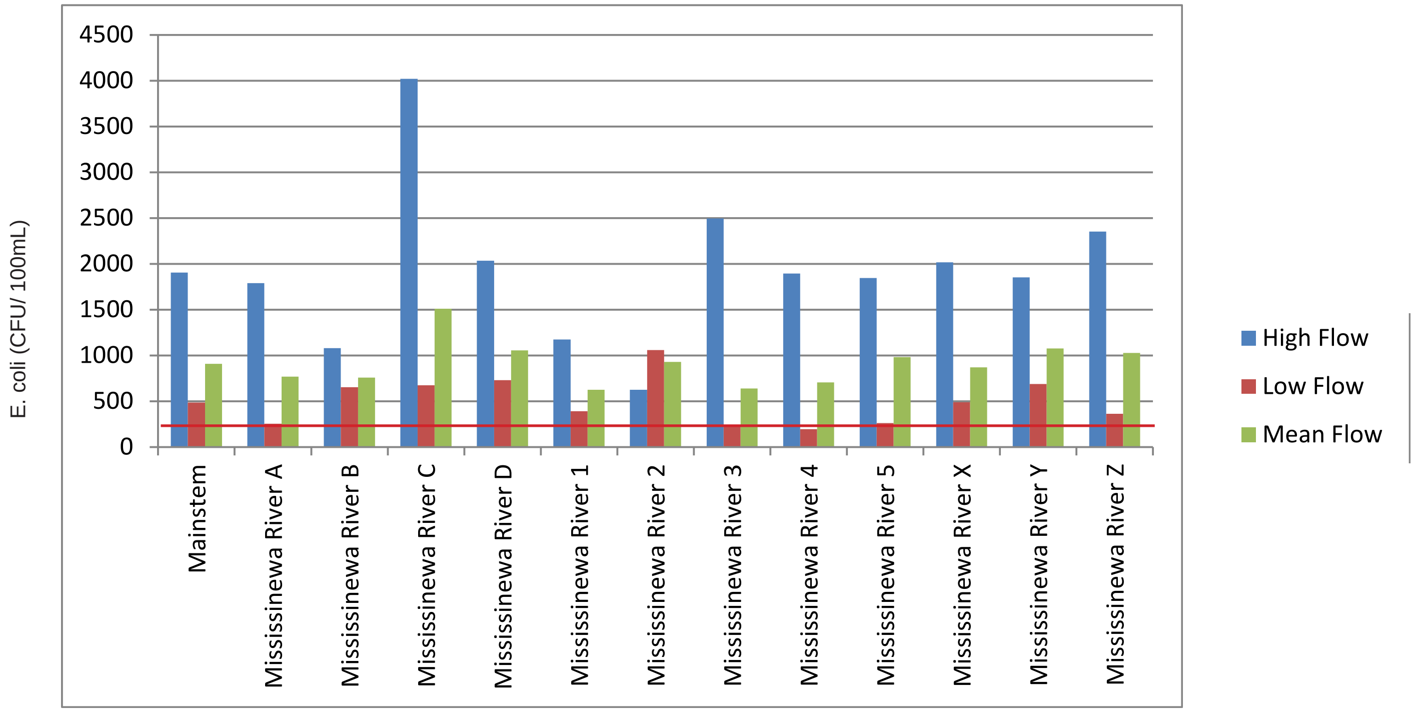


FIG. O.1 | Mainstem Subwatershed Averages for E. coli

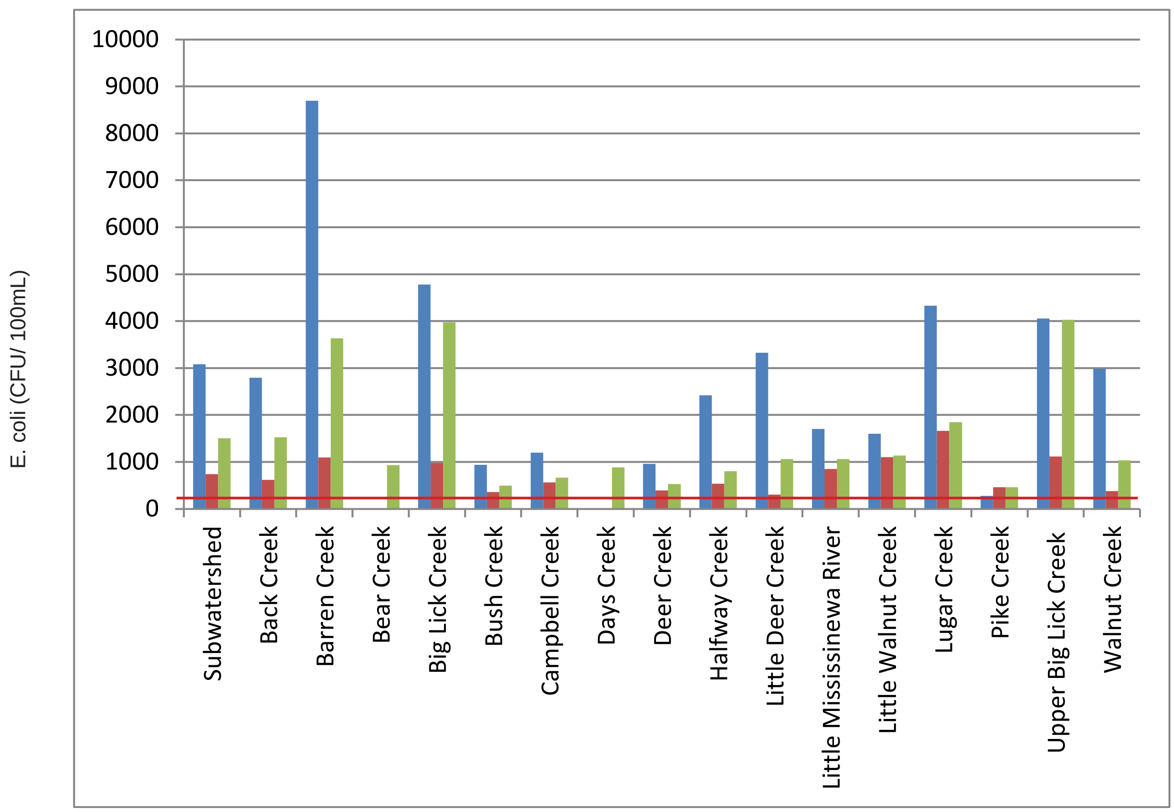


FIG. O.2 | Tributary Subwatershed Averages for E. coli

TABLE O.3 | Count of Exceedances[1] for E. coli				
Subwatershed	Number of Exceedences during High Flow	Number of Exceedences during Low Flow	No Flow Data Collected	Total Number of Exceedances
Back Creek	5.00	5.00		10.00
Barren Creek	3.00	5.00		8.00
Bear Creek			9.00	9.00
Big Lick Creek	2.00	2.00	3.00	7.00
Bush Creek	2.00	3.00	1.00	6.00
Campbell Creek	2.00	2.00	1.00	5.00
Days Creek			5.00	5.00
Deer Creek	3.00	4.00		7.00
Halfway Creek	1.00	4.00	3.00	8.00
Little Deer Creek	3.00	3.00	1.00	7.00
Little Mississinewa River	3.00	7.00		10.00
Little Walnut Creek	3.00	5.00		8.00
Lugar Creek	2.00	5.00		7.00
Holden Ditch	3.00	2.00		5.00
Rees Ditch	2.00	3.00		5.00
Platt-Nibarger Ditch	2.00	3.00		5.00
Fetid Creek	2.00	2.00		4.00
Mud Creek	4.00	3.00		7.00
Boots Creek	6.00	3.00		9.00
Branch Creek	2.00	3.00		5.00
Lake Branch	2.00	4.00		6.00
Hoppas Ditch	2.00	4.00		6.00
Porter Creek	3.00	6.00		9.00
Jordan Creek	4.00	6.00		10.00
Gray Branch	4.00	5.00		9.00
Pike Creek	1.00	6.00	3.00	10.00
Upper Big Lick Creek	2.00	4.00	2.00	8.00
Walnut Creek	3.00	2.00		5.00
Totals for all sites combined	71.00	101.00	28.00	200.00

1 When an individual sample is above the target set for this watershed management plan, it is considered to be in exceedance. The target concentration for E. coli is 235 mg/100 L.

TABLE O.4 | Calculated E. coli Loads: Current Load, Target Load, and Load Reduction Needed

	Drain-age area (sq. mi.)	Average flow (cfs)		Average E. coli (mg/L)		E. coli current load (ton/year)		E. coli Target (mg/L)	E. coli target load (ton/year)		E. coli load reduction needed (ton/year)	
Subwatershed		High	Low	High	Low	High	Low	High	High	Low	High	Low
Mainstem Subwatershed	401.80	1585.23	214.29	1905.69	485.79	3.0E+16	1.1E+15	235.00	2.8E+15	3.7E+14	2.7E+16	7.7E+14
Holden Ditch	424.00	640.72	97.06	1172.27	391.81	6.3E+15	3.5E+14	235.00	1.2E+15	2.0E+14	5.1E+15	1.5E+14
Rees Ditch	311.00	591.17	121.56	624.07	1057.13	3.7E+15	1.1E+15	235.00	1.2E+15	2.8E+14	2.5E+15	7.9E+14
Platt-Nibarger Ditch	240.00	228.80	37.32	2493.95	228.14	4.0E+15	7.3E+13	235.00	4.1E+14	7.7E+13	3.6E+15	-3.2E+12
Fetid Creek	179.00	337.92	33.39	1893.43	195.11	6.5E+15	5.7E+13	235.00	6.2E+14	7.1E+13	5.9E+15	-1.5E+13
Mud Creek	133.00	264.73	24.21	1843.82	262.35	4.3E+15	5.1E+13	235.00	5.6E+14	5.8E+13	3.7E+15	-6.8E+12
Boots Creek	681.00	2398.25	317.44	1789.63	255.69	5.9E+16	8.9E+14	235.00	5.0E+15	6.7E+14	5.4E+16	2.2E+14
Branch Creek	629.00	2923.33	354.67	1078.00	652.11	4.7E+16	3.1E+15	235.00	6.1E+15	7.4E+14	4.1E+16	2.4E+15
Lake Branch	486.00	2750.00	352.00	4017.67	675.22	1.1E+17	2.8E+15	235.00	5.8E+15	7.4E+14	1.0E+17	2.1E+15
Hoppas Ditch	472.00	2740.00	355.67	2033.33	728.56	5.6E+16	3.5E+15	235.00	5.7E+15	7.5E+14	5.0E+16	2.7E+15
Porter Creek	89.00	750.67	72.37	2016.67	487.89	1.3E+16	5.3E+14	235.00	1.6E+15	1.5E+14	1.1E+16	3.8E+14
Jordan Creek	79.00	1146.50	57.24	1852.50	686.25	1.6E+16	3.6E+14	235.00	2.4E+15	1.2E+14	1.4E+16	2.4E+14
Gray Branch	31.00	91.84	12.40	2352.50	363.88	2.4E+15	4.2E+13	235.00	1.9E+14	2.6E+13	2.2E+15	1.6E+13
Tributary Subwatershed	28.69	148.61	25.86	3081.94	743.05	3.4E+15	1.8E+14	235.00	3.1E+14	4.8E+13	3.1E+15	1.3E+14
Back Creek	16.00	98.61	39.22	2794.60	615.14	3.1E+15	2.2E+14	235.00	2.1E+14	8.2E+13	2.9E+15	1.4E+14
Barren Creek	21.00	89.21	15.99	8696.50	1098.00	5.4E+15	1.3E+14	235.00	1.9E+14	3.4E+13	5.2E+15	9.8E+13
Bear Creek												
Big Lick Creek	76.00	65.94	20.05	4776.40	976.93	3.2E+15	1.8E+14	235.00	1.3E+14	3.1E+13	3.1E+15	1.5E+14
Bush Creek	20.00	20.11	2.90	939.30	361.18	2.1E+14	1.2E+13	235.00	4.4E+13	4.9E+12	1.6E+14	7.2E+12
Campbell Creek	20.00	35.43	4.03	1198.45	562.94	5.1E+14	3.3E+13	235.00	7.6E+13	7.5E+12	4.4E+14	2.6E+13
Days Creek												
Deer Creek	45.00	325.05	40.15	956.67	389.67	3.6E+15	9.8E+13	235.00	6.8E+14	8.4E+13	2.9E+15	1.4E+13
Halfway Creek	25.00	62.06	9.93	2419.60	535.80	2.2E+15	6.8E+13	235.00	2.2E+14	2.1E+13	2.0E+15	4.6E+13
Little Deer Creek	26.00	281.93	40.36	3324.67	304.88	6.0E+15	9.9E+13	235.00	5.9E+14	8.5E+13	5.4E+15	1.5E+13
Little Mississinewa River	21.00	118.46	12.35	1700.00	851.22	1.6E+15	1.5E+14	235.00	2.5E+14	2.6E+13	1.4E+15	1.2E+14
Little Walnut Creek	17.00	145.85	8.46	1600.00	1099.00	1.8E+15	8.3E+13	235.00	3.1E+14	1.8E+13	1.5E+15	6.5E+13
Lugar Creek	30.00	204.29	31.35	4330.00	1662.38	5.8E+15	8.6E+14	235.00	4.3E+14	6.6E+13	5.4E+15	8.0E+14
Pike Creek	21.00	39.35	7.63	276.85	463.83	1.1E+14	3.1E+13	235.00	8.9E+13	1.4E+13	2.3E+13	1.7E+13
Upper Big Lick Creek	52.00	57.26	11.63	4058.50	1113.08	1.8E+15	1.1E+14	235.00	8.9E+13	2.2E+13	1.7E+15	8.6E+13
Walnut Creek	39.00	340.16	48.64	2983.33	381.11	8.4E+15	2.3E+14	235.00	7.1E+14	1.0E+14	7.7E+15	1.2E+14

E. coli

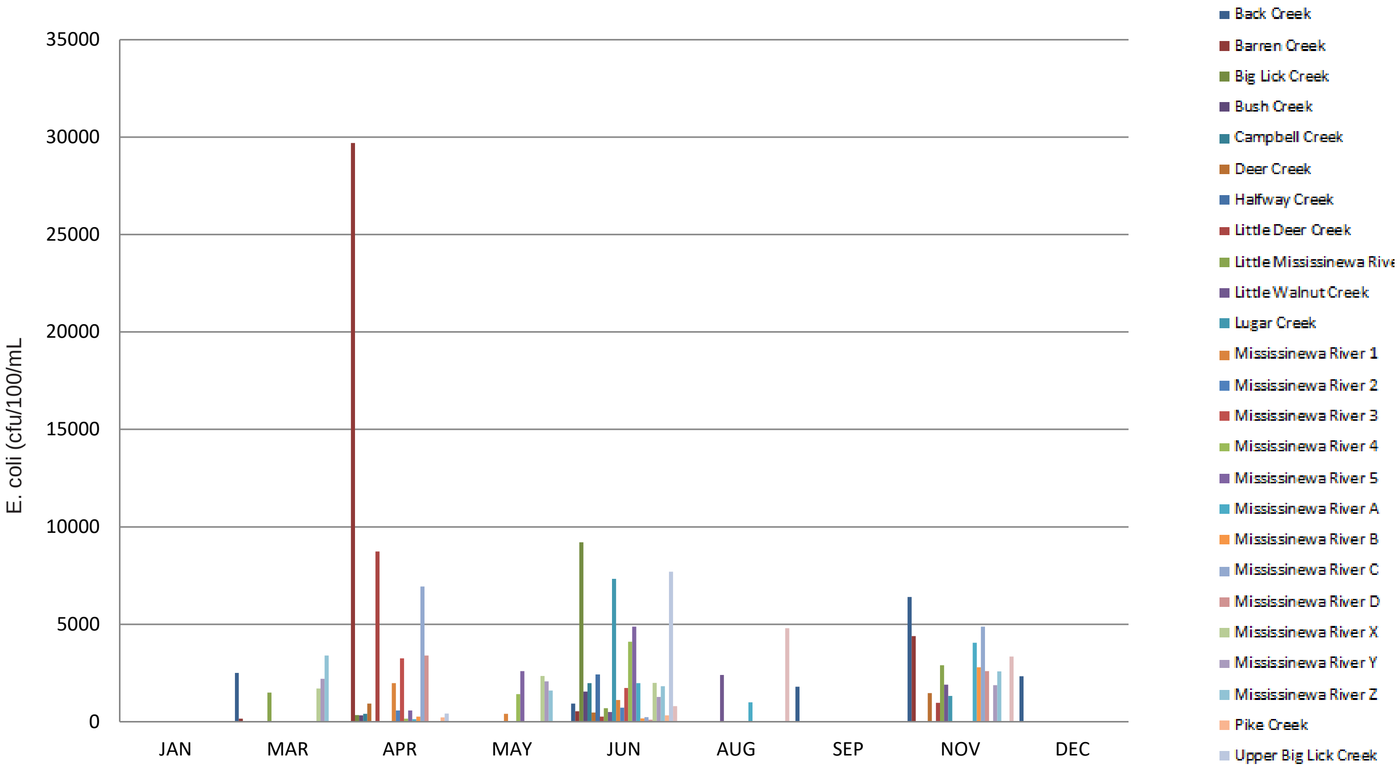


FIG. O.3 | Monthly E. coli Samples for samples classified as high flow events.

E. coli Mississinewa Watershed

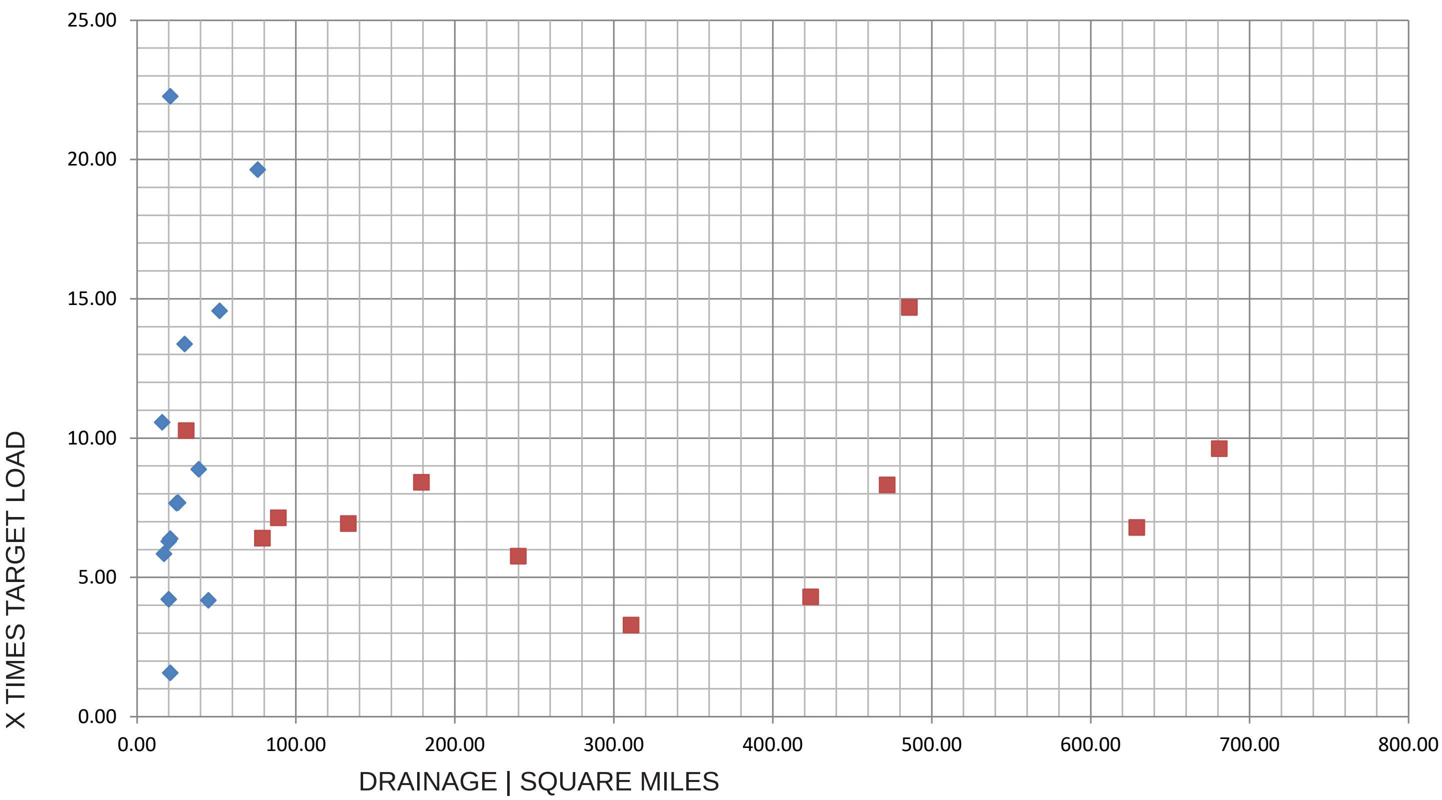


FIG. O.4 | Drainage size vs. X times target load.
"X times" represents how many times the average load (of all sample events) exceeds the target load.
Mainstem sites are represented by red squares and tributary sites by blue diamonds.

E. coli Mississinewa Mainstem

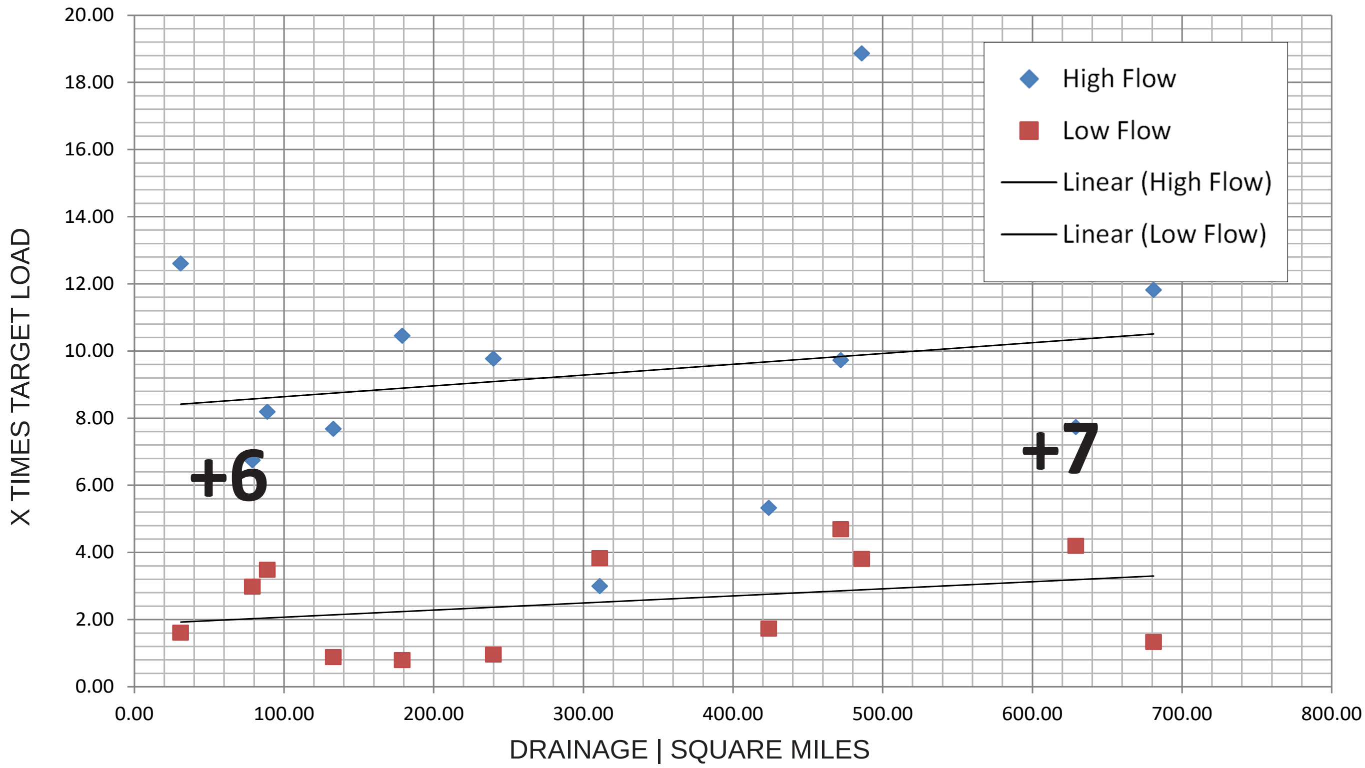


FIG. O.5 | Drainage size vs. X times target load for Mainstem Subwatersheds at High Flow and Low Flow events.

E. coli Mississinewa ***Subwatersheds***

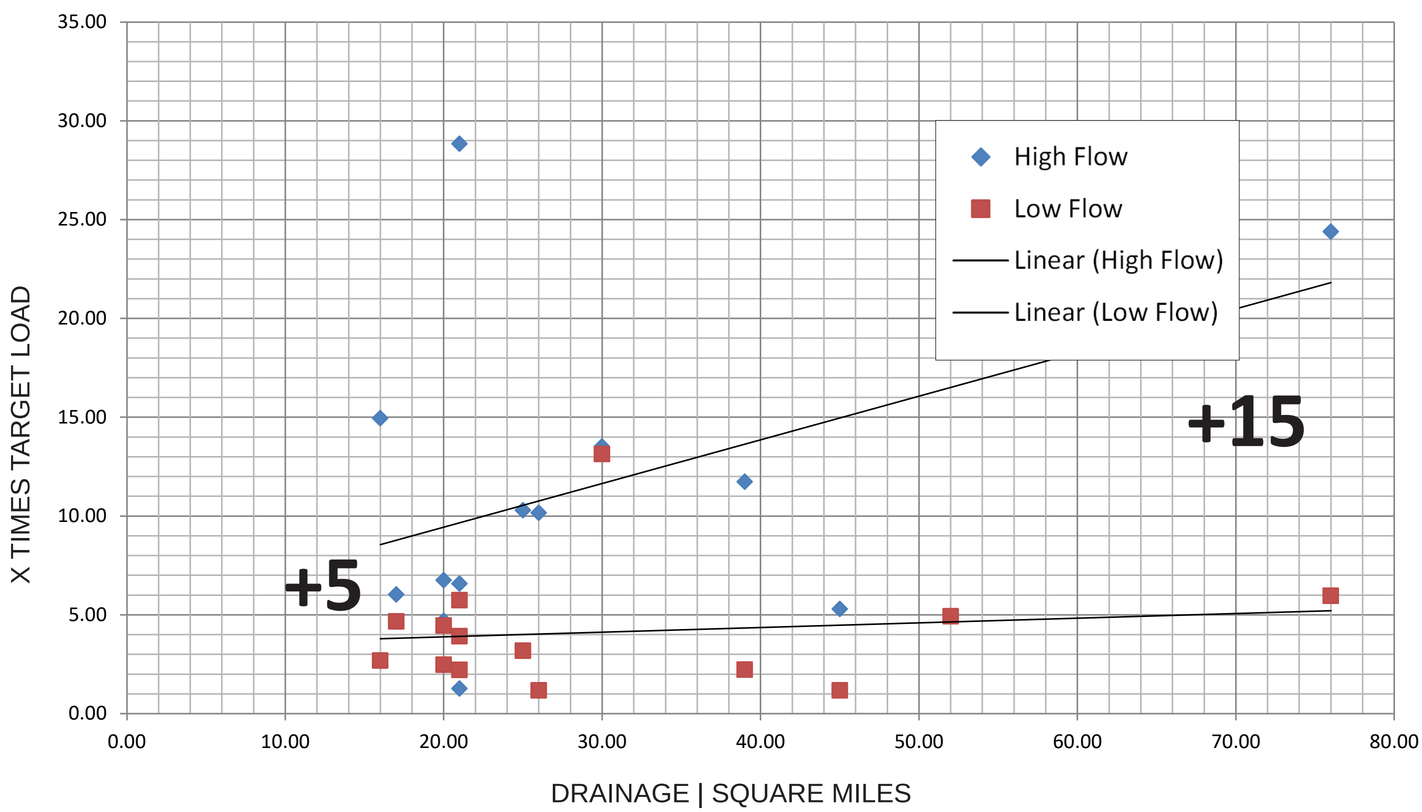


FIG. O.6 | Drainage size vs. X times target load for Tributary Subwatersheds at High Flow and Low Flow events.

P. DISSOLVED OXYGEN DATA

TABLE P.1 | Count of Exceedances for Dissolved Oxygen (Separated by Flow)			
Subwatershed	High Flow	Low Flow	No Flow Data Collected
Back Creek	1.00	1.00	
Barren Creek		2.00	
Bear Creek			3.00
Big Lick Creek		1.00	1.00
Bush Creek			3.00
Campbell Creek	1.00		1.00
Days Creek			1.00
Deer Creek		2.00	
Halfway Creek	1.00	3.00	3.00
Little Deer Creek			1.00
Little Mississinewa River	1.00	1.00	
Little Walnut Creek		2.00	
Lugar Creek			1.00
Holden Ditch	1.00	3.00	
Rees Ditch		1.00	
Platt-Nibarger Ditch	1.00	2.00	
Mud Creek		3.00	
Boots Creek		8.00	
Branch Creek		2.00	
Lake Branch		1.00	
Hoppas Ditch		3.00	
Porter Creek		1.00	
Jordan Creek	1.00		
Gray Branch		1.00	
Pike Creek	2.00	1.00	2.00
Upper Big Lick Creek	1.00	1.00	
Walnut Creek		2.00	
Grand Total	10.00	41.00	16.00

Q. BIOLOGICAL DATA

HBI

The Muncie Bureau of Water Quality also used the Hilsenhoff Biotic Index (HBI) to provide a water quality assessment. Species and community data gathered for the mIBI was also applied to the HBI. The Hilsenhoff Biotic Index (HBI) evaluates organic and nutrient stream pollution. The scale assigns tolerance levels for macroinverebrate families from 0 to 10, 0 being intolerant and 10 being the most tolerant of organic pollution. HBI scores are determined by multiplying the total number of individuals for each family by the family tolerance values. The sum of all products for a site is divided by the total number of individuals to determine the HBI score.

TABLE Q.1 | HBI scores and narratives (Macros only)

Total Score	Narrative Rating	Indication
0.00-3.5	Excellent	No apparent organic pollution
3.51-4.5	Very Good	Possible slight organic pollution
4.51-5.5	Good	Some organic pollution
5.51-6.5	Fair	Fairly significant organic pollution
6.51-7.5	Fairly Poor	Significant organic pollution
6.51 – 7.25	Poor	Very substantial pollution likely
7.26 – 10	Very Poor	Severe organic pollution likely

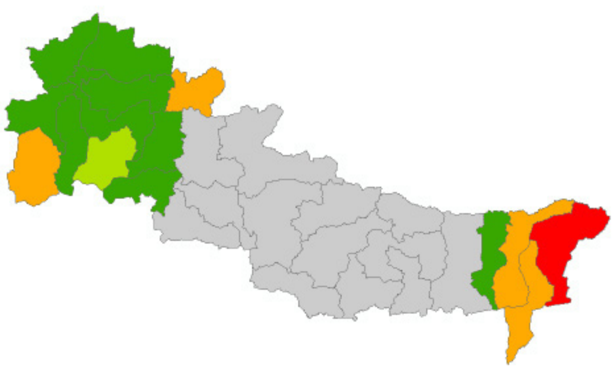


FIG. Q.1 | HBI Qual

Subwatersheds are ranked on a gradient (red high and green low) based on HBI scores. High scores indicate poor water quality; low scores indicate good water quality.

TABLE Q.2 | Results From The Bureau Of Water Quality

	HBI	HBI-Qual
Porter Creek-Mississinewa River	5.4	Good
Jordan Creek-Mississinewa River	5.63	Fair
Little Mississinewa River	5.87	Fair
Gray Branch-Mississinewa River	6.56	Fairly Poor
Boots Creek-Mississinewa River	3.39	Good
Lugar Creek	5.25	Good
Branch Creek-Mississinewa River	5.36	Good
Deer Creek	4.82	Good
Little Deer Creek-Deer Creek	5.65	Fair
Back Creek	5.43	Good
Walnut Creek	4.65	Good
Little Walnut Creek-Walnut Creek	5.76	Fair
Lake Branch-Mississinewa River	5.03	Good
Barren Creek	4.3	Very Good
Hoppas Ditch-Mississinewa River	5	Good

R. LOAD REDUCTION SCENARIOS

R.1 MASSEY CREEK HUC 10: LUGAR CREEK HUC 12—TSS

TABLE R.1 | TSS (sediment) loading data for Lugar Creek	
Total TSS Load (ton/yr)*	2,683
Load Reduction Needed (ton/yr)**	1,064
Acres of Cropland	13,600

*Based on high flow average cfs and high flow average TSS concentration
**Calculated using 319 Load Calculation Tool (found at www.in.gov/idem/nps/files/319_load_calculation_tool.xls) and based on a target concentration of 25 mg/L

TABLE R.2 | BMPs, BMP efficiencies, rates of use, and resulting TSS load reductions for Lugar Creek

BMPs	Volume of Practice Installed (acres)	Percentage of Cropland Used*	Load Reductions (tons/yr)
Cover Crops and Filter Strips*	900**	8%	900
No Till***	220	2%	172
		Total Load Reduction (ton/yr)	1,072
		Percent Reduction Achieved	40%
		Percent Reduction Needed***	40%
		Remaining Load Reduction Needed (tons)	0
		Percent Progress Towards Goal	100%

*This scenario was created using Region 5. Region 5 reductions are based on BMPs placed in "contributing areas," meaining they are adjacent to a stream or river and their runoff enters these bodies of water. Load reductions from cover crops and filter strips are calculated together.
**This figure includes acreage for both cover crops and filter strips. Waterways adjacent to contributing areas where cover crops are planted should also have appropriately sized buffers. If appropriate buffers are already present, their area should be calculated and a buffer of equivalent size or greater should be planted elsewhere.
***No Till acres must also be implemented in "contributing areas" in order to cause estimated reductions.

R.2 HEADWATERS MISSISSINEWA RIVER HUC 10: GRAY BRANCH HUC 12—NITRATE

TABLE R.3 | Nitrate loading data for Gray Branch	
Total Nitrate Load (ton/yr)*	251
Load Reduction Needed (ton/yr)**	213
Acres of Cropland	16,931

*Based on average cfs and average nitrate concentration
**Calculated using 319 Load Calculation Tool (found at www.in.gov/idem/nps/files/319_load_calculation_tool.xls) and based on a target concentration of 1 mg/L

TABLE R.4 | BMPs, rates of use, and resulting nitrate load reductions for Gray Branch					
		Column A	Column B	Column C = Column A x B x D	Column D
BMPs	Volume of Practice Installed (acres)	Percentage of Cropland Used	Estimated % Nitrate-N Reduction	Load Reductions (tons/yr)	Load Available for Treatment by BMP (tons/yr)
Wetland Restoration	508	3%	100%	8	251
Prairie Restoration	85	1%	100%	1	226
Extended Rotations	85	1%	42%	1	224
Fertilizer Reduction Practices (MRTN, sidedress, no fall application)	16,254	100%	10%	24	130
Cover Crops	8,127	50%	25%	32	117
Filter Strips	13		25%		117
Drainage Water Management**	2,763	17%	33%	10	88
Saturated Buffer***		0%	50%	0	82
Bioreactors	163	1%	43%	1	74
			Total Load Reduction (ton/yr)	76.17	
			Percent Reduction Achieved	30%	
			Percent Reduction Needed	85%	
			Remaining Load Reduction Needed (tons)	174.9	
			Percent Progress Towards Goal	36%	

*Not all cropland is suitable for drainage water management. Percentages are based on figures and maps generated by the NRCS. Percentages estimate the maximum amount of land suitable for drainage water management.
**Not all buffers are suitable for converting into saturated buffers. Researchers in Iowa estimated that 20% of that state's buffers were suitable for conversion to saturated buffers. We used the same figure here. Actual percentages may vary.

R.3 HEADWATERS MISSISSINEWA RIVER HUC 10: LITTLE MISSISSINEWA RIVER HUC 12—NITRATE

TABLE R.5 | Nitrate loading data for Little Mississinewa River	
Total Nitrate Load (ton/yr)*	201
Load Reduction Needed (ton/yr)**	163
Acres of Cropland	10,905

*Based on average cfs and average nitrate concentration
**Calculated using 319 Load Calculation Tool (found at www.in.gov/idem/nps/files/319_load_calculation_tool.xls) and based on a target concentration of 1 mg/L

TABLE R.6 | BMPs, rates of use, and resulting nitrate load reductions for Little Mississinewa River					
BMPs	Volume of Practice Installed (acres)	Percentage of Cropland Used	Estimated % Nitrate-N Reduction	Load Reductions (tons/yr)	Load Available for Treatment by BMP (tons/yr)
Wetland Restoration	327	3%	100%	6	201
Prairie Restoration	55	1%	100%	1	195
Extended Rotations	55	1%	42%	0	194
Fertilizer Reduction Practices (MRTN, sidedress, no fall application)	10,523	100%	10%	19	194
Cover Crops	5,262	50%	29%	25	174
Filter Strips	12				
Drainage Water Management**	1,789	17%	33%	8	149
Saturated Buffer***	-	0%	50%	0	141
Bioreactors	105	1%	43%	1	141
			Total Load Reduction (ton/yr)	61	
			Percent Reduction Achieved	30%	
			Percent Reduction Needed	75%	
			Remaining Load Reduction Needed (tons)	140	
			Percent Progress Towards Goal	37%	

*Not all cropland is suitable for drainage water management. Percentages are based on figures and maps generated by the NRCS. Percentages estimate the maximum amount of land suitable for drainage water management.
**Not all buffers are suitable for converting into saturated buffers. Researchers in Iowa estimated that 20% of that state's buffers were suitable for conversion to saturated buffers. We used the same figure here. Actual percentages may vary.

R.4 HALFWAY CREEK HUC 10: HALFWAY CREEK HUC 12—NITRATE

TABLE R.7 | Nitrate loading data for Halfway Creek	
Total Nitrate Load (ton/yr)*	43
Load Reduction Needed (ton/yr)**	17
Acres of Cropland	12,705

*Based on average cfs and average nitrate concentration
**Calculated using 319 Load Calculation Tool (found at www.in.gov/idem/nps/files/319_load_calculation_tool.xls) and based on a target concentration of 1 mg/L

TABLE R.8 | BMPs, rates of use, and resulting nitrate load reductions for Halfway Creek

		Column A	Column B	Column C = Column A x B x D	Column D
BMPs	Volume of Practice Installed (acres)	Percentage of Cropland Used	Estimated % Nitrate-N Reduction	Load Reductions (tons/yr)	Load Available for Treatment by BMP (tons/yr)
Wetland Restoration	381	3%	100%	1	43
Prairie Restoration	64	1%	100%	0	42
Extended Rotations	64	1%	42%	0	42
Fertilizer Reduction Practices (MRTN, sidedress, no fall application)	12,260	100%	10%	4	41
Cover Crops	6,130	50%	29%	5	37
Filter Strips					
Drainage Water Management	2,084	17%	33%	2	32
Saturated Buffer**	-	0%	50%	0	30
Bioreactors	123	1%	43%	0	30
			Total Load Reduction (ton/yr)	13	
			Percent Reduction Achieved	30%	
			Percent Reduction Needed	75%	
			Remaining Load Reduction Needed (tons)	30	
			Percent Progress Towards Goal	77%	

*Not all cropland is suitable for drainage water management. Percentages are based on figures and maps generated by the NRCS. Percentages estimate the maximum amount of land suitable for drainage water management.
**Not all buffers are suitable for converting into saturated buffers. Researchers in Iowa estimated that 20% of that state's buffers were suitable for conversion to saturated buffers. We used the same figure here. Actual percentages may vary.

R.5 HALFWAY CREEK HUC 10: HALFWAY CREEK HUC 12—PHOSPHORUS

TABLE R.9 | Phosphorus loading data for Halfway Creek	
Total Phosphorus Load (ton/yr)*	29
Load Reduction Needed (ton/yr)**	11
Acres of Cropland	12,705

*Based on high flow average cfs and high flow average phosphorus concentration
**Calculated using 319 Load Calculation Tool (found at www.in.gov/idem/nps/files/319_load_calculation_tool.xls) and based on a target concentration of 0.3 mg/L

TABLE R.10 | BMPs, BMP efficiencies, rates of use, and resulting phosphorus load reductions for Halfway Creek

BMPs	Volume of Practice Installed (acres)	Percentage of Cropland Used*	Estimated % Phosphorus Reduction	Load Reductions (tons/yr)	Load Available for Treatment by BMP (tons/yr)
Fertilize Based on Soil Test Phosphorus	12,705	100%	no data	no data	29
Cover Crops	4,066	32%	29%	3	29
Conservation Tillage	4,447	35%	33%	8	27
Filter Strips	16		58%		18
			Total Load Reduction (ton/yr)	11	
			Percent Reduction Achieved	38%	
			Percent Reduction Needed***	38%	
			Remaining Load Reduction Needed (tons)	0	
			Percent Progress Towards Goal	100%	

*Percentage of cropland used, or percentage of area that is appropriate for the BMP. For example, "100%" is listed for buffers. This means 100% of land appropriate for a buffer, rather than 100% of the cropland.
**Acreage needed for buffers is difficult to assess. However, 45% of NHD mapped streams in Halfway Creek need a buffer; this percentage was used to calculate the load reduction.
***This is based on high flow averages, which results in an overestimation of the total phosphorus load.

R.6 PIKE CREEK HUC 10:
STUDEBAKER DITCH-PIKE CREEK HUC 12—NITRATE

TABLE R.11 | Nitrate loading data for Pike Creek	
Total Nitrate Load (ton/yr)*	41
Load Reduction Needed (ton/yr)**	23
Acres of Cropland	11,975

*Based on average cfs and average nitrate concentration
**Calculated using 319 Load Calculation Tool (found at www.in.gov/idem/nps/files/319_load_calculation_tool.xls) and based on a target concentration of 1 mg/L

TABLE R.12 | BMPs, rates of use, and resulting nitrate load reductions for Pike Creek

		Column A	Column B	Column C = Column A x B x D	Column D
BMPs	Volume of Practice Installed (acres)	Percentage of Cropland Used	Estimated % Nitrate-N Reduction	Load Reductions (tons/yr)	Load Available for Treatment by BMP (tons/yr)
Wetland Restoration	359.25	3%	100%	1	41
Prairie Restoration	60	1%	100%	0	40
Extended Rotations	60	1%	42%	0	40
Fertilizer Reduction Practices (MRTN, sidedress, no fall application)	11,556	100%	10%	4	39
Cover Crops	5,778	50%	25%	5	36
Filter Strips					
Drainage Water Management	1,964	17%	33%	2	30
Saturated Buffer**	-	0%	50%	0	29
Bioreactors	116	1%	43%	0	29
			Total Load Reduction (ton/yr)	12	
			Percent Reduction Achieved	30%	
			Percent Reduction Needed	75%	
			Remaining Load Reduction Needed (tons)	29	
			Percent Progress Towards Goal	54%	

*Not all cropland is suitable for drainage water management. Percentages are based on figures and maps generated by the NRCS. Percentages estimate the maximum amount of land suitable for drainage water management.
**Not all buffers are suitable for converting into saturated buffers. Researchers in Iowa estimated that 20% of that state's buffers were suitable for conversion to saturated buffers. We used the same figure here.
Actual percentages may vary.

R.7 PIKE CREEK HUC 10:
CAMPBELL CREEK HUC 12—TSS

TABLE R.13 | TSS (sediment) loading data for Campbell Creek	
Total TSS Load (ton/yr)*	1562
Load Reduction Needed (ton/yr)**	782
Acres of Cropland	11,304

*Based on high flow average cfs and high flow average TSS concentration
**Calculated using 319 Load Calculation Tool (found at www.in.gov/idem/nps/files/319_load_calculation_tool.xls) and based on a target concentration of 25 mg/L

TABLE R.14 | BMPs, BMP efficiencies, rates of use, and resulting TSS load reductions for Campbell Creek

BMPs	Volume of Practice Installed (acres)	Percentage of Cropland Used*	Load Reductions (tons/yr)
Cover Crops and Filter Strips*	500**	4%	700
No Till***	80	2%	88
		Total Load Reduction (ton/yr)	788
		Percent Reduction Achieved	50%
		Percent Reduction Needed***	50%
		Remaining Load Reduction Needed (tons)	0
		Percent Progress Towards Goal	100%

*This scenario was created using Region 5. Region 5 reductions are based on BMPs placed in "contributing areas," meaining they are adjacent to a stream or river and their runoff enters these bodies of water. Load reductions from cover crops and filter strips are calculated together.
**This figure includes acreage for both cover crops and filter strips. Waterways adjacent to contributing areas where cover crops are planted should also have appropriately sized buffers. If appropriate buffers are already present, their area should be calculated and a buffer of equivalent size or greater should be planted elsewhere.
***No Till acres must also be implemented in "contributing areas" in order to cause estimated reductions.

R.8 BIG LICK CREEK HUC 10:
LITTLE LICK CREEK HUC 12—NITRATE

TABLE R.15 | Nitrate loading data for Little Lick Creek	
Total Nitrate Load (ton/yr)*	62
Load Reduction Needed (ton/yr)**	32
Acres of Cropland	23,051

*Based on average cfs and average nitrate concentration
**Calculated using 319 Load Calculation Tool (found at www.in.gov/idem/nps/files/319_load_calculation_tool.xls) and based on a target concentration of 1 mg/L

TABLE R.16 | BMPs, rates of use, and resulting nitrate load reductions for Little Lick Creek

		Column A	Column B	Column C = Column A x B x D	Column D
BMPs	Volume of Practice Installed (acres)	Percentage of Cropland Used	Estimated % Nitrate-N Reduction	Load Reductions (tons/yr)	Load Available for Treatment by BMP (tons/yr)
Wetland Restoration	691.53	3%	100%	2	62
Prairie Restoration	115	1%	100%	0	60
Extended Rotations	115	1%	42%	0	60
Fertilizer Reduction Practices (MRTN, sidedress, no fall application)	22,244	100%	10%	6	60
Cover Crops	11,122	50%	25%	8	54
Filter Strips					
Drainage Water Management	3,782	17%	33%	3	46
Saturated Buffer**	-	0%	50%	0	43
Bioreactors	222	1%	43%	0	43
			Total Load Reduction (ton/yr)	19	
			Percent Reduction Achieved	30%	
			Percent Reduction Needed	75%	
			Remaining Load Reduction Needed (tons)	43	
			Percent Progress Towards Goal	59%	

*Not all cropland is suitable for drainage water management. Percentages are based on figures and maps generated by the NRCS. Percentages estimate the maximum amount of land suitable for drainage water management.
**Not all buffers are suitable for converting into saturated buffers. Researchers in Iowa estimated that 20% of that state's buffers were suitable for conversion to saturated buffers. We used the same figure here.
Actual percentages may vary.

R.9 BIG LICK CREEK HUC 10:
LITTLE LICK CREEK HUC 12—PHOSPHORUS

TABLE R.17 | Phosphorus loading data for Little Lick Creek	
Total Phosphorus Load (ton/yr)*	19
Load Reduction Needed (ton/yr)**	2
Acres of Cropland	23,051

*Based on high flow average cfs and high flow average phosphorus concentration
**Calculated using 319 Load Calculation Tool (found at www.in.gov/idem/nps/files/319_load_calculation_tool.xls) and based on a target concentration of 0.3 mg/L

TABLE R.18 | BMPs, BMP efficiencies, rates of use, and resulting phosphorus load reductions for Little Lick Creek

		Column A	Column B	Column C = Column A x B x D	Column D
BMPs	Volume of Practice Installed (acres)	Percentage of Cropland Used*	Estimated % Phosphorus Reduction	Load Reductions (tons/yr)	Load Available for Treatment by BMP (tons/yr)
Fertilize Based on Soil Test Phosphorus	23,051	100%	no data	no data	19
Cover Crops	4,149	18%	29%	1	19
Conservation Tillage	2,766	12%	33%	1	18
Filter Strips**			58%		17
			Total Load Reduction (ton/yr)	2	
			Percent Reduction Achieved	9%	
			Percent Reduction Needed***	9%	
			Remaining Load Reduction Needed (tons)	0	
			Percent Progress Towards Goal	100%	

*Percentage of cropland used, or percentage of area that is appropriate for the BMP. For example, "100%" is listed for buffers. This means 100% of land appropriate for a buffer, rather than 100% of the cropland.
**Acreage needed for buffers is difficult to assess. However, 45% of NHD mapped streams in Little Lick Creek need a buffer; this percentage was used to calculate the load reduction.
***This is based on high flow averages, which results in an overestimation of the total phosphorus load.

S. MEETING ULTIMATE GOALS—MODELS

S.1 MASSEY CREEK HUC 10: LUGAR CREEK HUC 12—TSS

TABLE S.1 | TSS (sediment) loading data for Lugar Creek	
Total TSS Load (ton/yr)*	2,683
Load Reduction Needed (ton/yr)**	1,064
Acres of Cropland	13,600

*Based on high flow average cfs and high flow average TSS concentration
**Calculated using 319 Load Calculation Tool (found at www.in.gov/idem/nps/files/319_load_calculation_tool.xls) and based on a target concentration of 25 mg/L

TABLE S.2 | BMPs, BMP efficiencies, rates of use, and resulting TSS load reductions for Lugar Creek

BMPs	Volume of Practice Installed (acres)	Percentage of Cropland Used*	Load Reductions (tons/yr)
Cover Crops and Filter Strips*	900**	8%	900
No Till***	300	2%	234
		Total Load Reduction (ton/yr)	1,134
		Percent Reduction Achieved	42%
		Percent Reduction Needed***	40%
		Remaining Load Reduction Needed (tons)	0
		Percent Progress Towards Goal	100%

*This scenario was created using Region 5. Region 5 reductions are based on BMPs placed in "contributing areas," meaining they are adjacent to a stream or river and their runoff enters these bodies of water. Load reductions from cover crops and filter strips are calculated together.
**This figure includes acreage for both cover crops and filter strips. Waterways adjacent to contributing areas where cover crops are planted should also have appropriately sized buffers. If appropriate buffers are already present, their area should be calculated and a buffer of equivalent size or greater should be planted elsewhere.
***No Till acres must also be implemented in "contributing areas" in order to cause estimated reductions.

S.2 HEADWATERS MISSISSINEWA RIVER HUC 10: GRAY BRANCH HUC 12—NITRATE

TABLE S.3 | Nitrate loading data for Gray Branch	
Total Nitrate Load (ton/yr)*	251
Load Reduction Needed (ton/yr)**	213
Acres of Cropland	16,931

*Based on average cfs and average nitrate concentration
**Calculated using 319 Load Calculation Tool (found at www.in.gov/idem/nps/files/319_load_calculation_tool.xls) and based on a target concentration of 1 mg/L

TABLE S.4 | BMPs, rates of use, and resulting nitrate load reductions for Gray Branch

		Column A	Column B	Column C = Column A x B x D	Column D
BMPs	Volume of Practice Installed (acres)	Percentage of Cropland Used	Estimated % Nitrate-N Reduction	Load Reductions (tons/yr)	Load Available for Treatment by BMP (tons/yr)
Wetland Restoration	1,693	10%	100%	25	251
Prairie Restoration	169	1%	100%	2	226
Extended Rotations	15,069	100%	42%	94	224
Fertilizer Reduction Practices (MRTN, sidedress, no fall application)	15,069	100%	10%	13	130
Cover Crops and Filter Strips*	15,069	100%	25%	29	117
Drainage Water Management**	3,048	18%	33%	5	88
Saturated Buffer***	3,386	20%	50%	8	82
Bioreactors	15,069	100%	43%	32	74
			Total Load Reduction (ton/yr)	209	
			Percent Reduction Achieved	83%	
			Percent Reduction Needed	85%	
			Remaining Load Reduction Needed (tons)	4	
			Percent Progress Towards Goal	98%	

*Cover crops and filter strips are combined for ease of calculations since assessing total acreage needing filterstrips is difficult. Filter strips are regarded as having equal or greater effects on nitrate reductions.
They can capture some of the small percentage of dissolved nitrate in surface flow. Furthermore, conversion of cropland to a filterstrip means a 100% reduction in nitrogen fertilizer on that land.
**Not all cropland is suitable for drainage water management. Percentages are based on figures and maps generated by the NRCS. Percentages estimate the maximum amount of land suitable for drainage water management.
***Not all buffers are suitable for converting into saturated buffers. Researchers in Iowa estimated that 20% of that state's buffers were suitable for conversion to saturated buffers. We used the same figure here.
Actual percentages may vary.

S.3 HEADWATERS MISSISSINEWA RIVER HUC 10: LITTLE MISSISSINEWA RIVER HUC 12—NITRATE

TABLE S.5 | Nitrate loading data for Little Mississinewa River	
Total Nitrate Load (ton/yr)*	201
Load Reduction Needed (ton/yr)**	163
Acres of Cropland	10,905

*Based on average cfs and average nitrate concentration
**Calculated using 319 Load Calculation Tool (found at www.in.gov/idem/nps/files/319_load_calculation_tool.xls) and based on a target concentration of 1 mg/L

TABLE S.6 | BMPs, rates of use, and resulting nitrate load reductions for Little Mississinewa River

BMPs	Volume of Practice Installed (acres)	Percentage of Cropland Used	Estimated % Nitrate-N Reduction	Load Reductions (tons/yr)	Load Available for Treatment by BMP (tons/yr)
Wetland Restoration	1,091	10%	100%	20	201
Prairie Restoration	109	1%	100%	2	181
Extended Rotations	9,705	100%	42%	75	179
Fertilizer Reduction Practices (MRTN, sidedress, no fall application)	9,705	100%	10%	10	104
Cover Crops and Filter Strips*	9,705	100%	25%	23	94
Drainage Water Management**	6,150	18%	33%	4	70
Saturated Buffer***	2,050	20%	50%	7	66
Bioreactors	161	80%	43%	20	59
			Total Load Reduction (ton/yr)	162	
			Percent Reduction Achieved	81%	
			Percent Reduction Needed	81%	
			Remaining Load Reduction Needed (tons)	1	
			Percent Progress Towards Goal	100%	

*Cover crops and filter strips are combined for ease of calculations since assessing total acreage needing filterstrips is difficult. Filter strips are regarded as having equal or greater effects on nitrate reductions.
They can capture some of the small percentage of dissolved nitrate in surface flow. Furthermore, conversion of cropland to a filterstrip means a 100% reduction in nitrogen fertilizer on that land.
**Not all cropland is suitable for drainage water management. Percentages are based on figures and maps generated by the NRCS. Percentages estimate the maximum amount of land suitable for drainage water management.
***Not all buffers are suitable for converting into saturated buffers. Researchers in Iowa estimated that 20% of that state's buffers were suitable for conversion to saturated buffers. We used the same figure here.
Actual percentages may vary.

S.4 HALFWAY CREEK HUC 10:
HALFWAY CREEK HUC 12—NITRATE

TABLE S.7 | Nitrate loading data for Halfway Creek	
Total Nitrate Load (ton/yr)*	43
Load Reduction Needed (ton/yr)**	17
Acres of Cropland	12,705

*Based on average cfs and average nitrate concentration
**Calculated using 319 Load Calculation Tool (found at www.in.gov/idem/nps/files/319_load_calculation_tool.xls) and based on a target concentration of 1 mg/L

TABLE S.8 | BMPs, rates of use, and resulting nitrate load reductions for Halfway Creek

		Column A	Column B	Column C = Column A x B x D	Column D
BMPs	Volume of Practice Installed (acres)	Percentage of Cropland Used	Estimated % Nitrate-N Reduction	Load Reductions (tons/yr)	Load Available for Treatment by BMP (tons/yr)
Wetland Restoration	381	3%	100%	1	43
Prairie Restoration	-	0%	100%	0	41
Fertilizer Reduction Practices (MRTN, sidedress, no fall application)	12,324	100%	10%	4	41
Cover Crops and Filter Strips	10,475	85%	25%	8	37
Drainage Water Management	1,906	15%	33%	1	29
Saturated Buffer	2,541	20%	50%	3	28
Bioreactors	-	0%	43%	0	25
			Total Load Reduction (ton/yr)	18	
			Percent Reduction Achieved	41%	
			Percent Reduction Needed	41%	
			Remaining Load Reduction Needed (tons)	0	
			Percent Progress Towards Goal	100%	

*Cover crops and filter strips are combined for ease of calculations since assessing total acreage needing filterstrips is difficult. Filter strips are regarded as having equal or greater effects on nitrate reductions.
They can capture some of the small percentage of dissolved nitrate in surface flow. Furthermore, conversion of cropland to a filterstrip means a 100% reduction in nitrogen fertilizer on that land.
**Not all cropland is suitable for drainage water management. Percentages are based on figures and maps generated by the NRCS. Percentages estimate the maximum amount of land suitable for drainage water management.
***Not all buffers are suitable for converting into saturated buffers. Researchers in Iowa estimated that 20% of that state's buffers were suitable for conversion to saturated buffers. We used the same figure here.
Actual percentages may vary.

S.5 HALFWAY CREEK HUC 10:
HALFWAY CREEK HUC 12—PHOSPHORUS

TABLE S.9 | Phosphorus loading data for Halfway Creek	
Total Phosphorus Load (ton/yr)*	29
Load Reduction Needed (ton/yr)**	11
Acres of Cropland	12,705

*Based on high flow average cfs and high flow average phosphorus concentration
**Calculated using 319 Load Calculation Tool (found at www.in.gov/idem/nps/files/319_load_calculation_tool.xls) and based on a target concentration of 0.3 mg/L

TABLE S.10 | BMPs, BMP efficiencies, rates of use, and resulting phosphorus load reductions for Halfway Creek

BMPs	Volume of Practice Installed (acres)	Percentage of Cropland Used*	Estimated % Phosphorus Reduction	Load Reductions (tons/yr)	Load Available for Treatment by BMP (tons/yr)
Fertilize Based on Soil Test Phosphorus	12,705	100%	no data	no data	29
Cover Crops	3,176	25%	29%	2	29
Conservation Tillage	3,812	30%	33%	3	27
Filter Strips	no data**	45%	58%	6	24
			Total Load Reduction (ton/yr)	11	
			Percent Reduction Achieved	38%	
			Percent Reduction Needed***	38%	
			Remaining Load Reduction Needed (tons)	0	
			Percent Progress Towards Goal	100%	

*Percentage of cropland used, or percentage of area that is appropriate for the BMP. For example, "100%" is listed for buffers. This means 100% of land appropriate for a buffer, rather than 100% of the cropland.
**Acreage needed for buffers is difficult to assess. However, 45% of NHD mapped streams in Halfway Creek need a buffer; this percentage was used to calculate the load reduction.
***This is based on high flow averages, which results in an overestimation of the total phosphorus load.

S.6 PIKE CREEK HUC 10:
STUDEBAKER DITCH-PIKE CREEK HUC 12—NITRATE

TABLE S.11 | Nitrate loading data for Pike Creek	
Total Nitrate Load (ton/yr)*	41
Load Reduction Needed (ton/yr)**	23
Acres of Cropland	11,975

*Based on average cfs and average nitrate concentration
**Calculated using 319 Load Calculation Tool (found at www.in.gov/idem/nps/files/319_load_calculation_tool.xls) and based on a target concentration of 1 mg/L

TABLE S.12 | BMPs, rates of use, and resulting nitrate load reductions for Pike Creek					
		Column A	Column B	Column C = Column A x B x D	Column D
BMPs	Volume of Practice Installed (acres)	Percentage of Cropland Used	Estimated % Nitrate-N Reduction	Load Reductions (tons/yr)	Load Available for Treatment by BMP (tons/yr)
Wetland Restoration	1,198	10%	100%	4	41
Prairie Restoration	240	2%	100%	1	37
Fertilizer Reduction Practices (MRTN, sidedress, no fall application)	10,538	100%	10%	4	37
Cover Crops and Filter Strips	10,538	100%	25%	8	33
Drainage Water Management	2,108	20%	33%	1	22
Saturated Buffer	2,108	20%	50%	2	25
Bioreactors	2,529	24%	43%	2	21
			Total Load Reduction (ton/yr)	23	
			Percent Reduction Achieved	55%	
			Percent Reduction Needed	55%	
			Remaining Load Reduction Needed (tons)	0	
			Percent Progress Towards Goal	100%	

*Cover crops and filter strips are combined for ease of calculations since assessing total acreage needing filterstrips is difficult. Filter strips are regarded as having equal or greater effects on nitrate reductions.
They can capture some of the small percentage of dissolved nitrate in surface flow. Furthermore, conversion of cropland to a filterstrip means a 100% reduction in nitrogen fertilizer on that land.
**Not all cropland is suitable for drainage water management. Percentages are based on figures and maps generated by the NRCS. Percentages estimate the maximum amount of land suitable for drainage water management.
***Not all buffers are suitable for converting into saturated buffers. Researchers in Iowa estimated that 20% of that state's buffers were suitable for conversion to saturated buffers. We used the same figure here.
Actual percentages may vary.

S.7 PIKE CREEK HUC 10:
CAMPBELL CREEK HUC 12—TSS

TABLE S.13 | TSS (sediment) loading data for Campbell Creek	
Total TSS Load (ton/yr)*	1562
Load Reduction Needed (ton/yr)**	782
Acres of Cropland	11,304

*Based on high flow average cfs and high flow average TSS concentration
**Calculated using 319 Load Calculation Tool (found at www.in.gov/idem/nps/files/319_load_calculation_tool.xls) and based on a target concentration of 25 mg/L

TABLE S.14 | BMPs, BMP efficiencies, rates of use, and resulting TSS load reductions for Campbell Creek

BMPs	Volume of Practice Installed (acres)	Percentage of Cropland Used*	Load Reductions (tons/yr)
Cover Crops and Filter Strips*	500**	4%	700
No Till***	100	2%	110
		Total Load Reduction (ton/yr)	810
		Percent Reduction Achieved	52%
		Percent Reduction Needed***	50%
		Remaining Load Reduction Needed (tons)	0
		Percent Progress Towards Goal	100%

*This scenario was created using Region 5. Region 5 reductions are based on BMPs placed in "contributing areas," meaining they are adjacent to a stream or river and their runoff enters these bodies of water. Load reductions from cover crops and filter strips are calculated together.
**This figure includes acreage for both cover crops and filter strips. Waterways adjacent to contributing areas where cover crops are planted should also have appropriately sized buffers. If appropriate buffers are already present, their area should be calculated and a buffer of equivalent size or greater should be planted elsewhere.
***No Till acres must also be implemented in "contributing areas" in order to cause estimated reductions.

S.8 BIG LICK CREEK HUC 10:
LITTLE LICK CREEK HUC 12—NITRATE

TABLE S.15 | Nitrate loading data for Little Lick Creek	
Total Nitrate Load (ton/yr)*	62
Load Reduction Needed (ton/yr)**	32
Acres of Cropland	23,051

*Based on average cfs and average nitrate concentration
**Calculated using 319 Load Calculation Tool (found at www.in.gov/idem/nps/files/319_load_calculation_tool.xls) and based on a target concentration of 1 mg/L

TABLE S.16 | BMPs, rates of use, and resulting nitrate load reductions for Little Lick Creek					
		Column A	Column B	Column C = Column A x B x D	Column D
BMPs	Volume of Practice Installed (acres)	Percentage of Cropland Used	Estimated % Nitrate-N Reduction	Load Reductions (tons/yr)	Load Available for Treatment by BMP (tons/yr)
Wetland Restoration	2,305	10%	100%	6	62
Prairie Restoration	-	0%	100%	0	56
Fertilizer Reduction Practices (MRTN, sidedress, no fall application)	20,746	100%	10%	6	56
Cover Crops and Filter Strips	20,746	100%	25%	13	50
Drainage Water Management	4,564	22%	33%	3	38
Saturated Buffer	4,149	20%	50%	3	35
Bioreactors	2,904	14%	43%	2	31
			Total Load Reduction (ton/yr)	32	
			Percent Reduction Achieved	52%	
			Percent Reduction Needed	52%	
			Remaining Load Reduction Needed (tons)	0	
			Percent Progress Towards Goal	100%	

*Cover crops and filter strips are combined for ease of calculations since assessing total acreage needing filterstrips is difficult. Filter strips are regarded as having equal or greater effects on nitrate reductions.
They can capture some of the small percentage of dissolved nitrate in surface flow. Furthermore, conversion of cropland to a filterstrip means a 100% reduction in nitrogen fertilizer on that land.
**Not all cropland is suitable for drainage water management. Percentages are based on figures and maps generated by the NRCS. Percentages estimate the maximum amount of land suitable for drainage water management.
***Not all buffers are suitable for converting into saturated buffers. Researchers in Iowa estimated that 20% of that state's buffers were suitable for conversion to saturated buffers. We used the same figure here.
Actual percentages may vary.

S.9 BIG LICK CREEK HUC 10:
LITTLE LICK CREEK HUC 12—PHOSPHORUS

TABLE S.17 | Phosphorus loading data for Little Lick Creek	
Total Phosphorus Load (ton/yr)*	19
Load Reduction Needed (ton/yr)**	2
Acres of Cropland	23,051

*Based on high flow average cfs and high flow average phosphorus concentration
**Calculated using 319 Load Calculation Tool (found at www.in.gov/idem/nps/files/319_load_calculation_tool.xls) and based on a target concentration of 0.3 mg/L

TABLE S.18 | BMPs, BMP efficiencies, rates of use, and resulting phosphorus load reductions for Little Lick Creek

		Column A	Column B	Column C = Column A x B x D	Column D
BMPs	Volume of Practice Installed (acres)	Percentage of Cropland Used*	Estimated % Phosphorus Reduction	Load Reductions (tons/yr)	Load Available for Treatment by BMP (tons/yr)
Fertilize Based on Soil Test Phosphorus	12,705	100%	no data	no data	19
Cover Crops	-	0%	29%	0	19
Conservation Tillage	2,305	10%	33%	1	19
Filter Strips	no data**	11%	58%	1	18
			Total Load Reduction (ton/yr)	2	
			Percent Reduction Achieved	9%	
			Percent Reduction Needed***	9%	
			Remaining Load Reduction Needed (tons)	0	
			Percent Progress Towards Goal	100%	

*Percentage of cropland used, or percentage of area that is appropriate for the BMP. For example, "100%" is listed for buffers. This means 100% of land appropriate for a buffer, rather than 100% of the cropland.
**Acreage needed for buffers is difficult to assess. However, 45% of NHD mapped streams in Little Lick Creek need a buffer; this percentage was used to calculate the load reduction.
***This is based on high flow averages, which results in an overestimation of the total phosphorus load.

S.10 MASSEY CREEK HUC 10:
DEER CREEK HUC 12—NITRATE

TABLE S.19 | Nitrate loading data for Deer Creek	
Total Nitrate Load (ton/yr)*	355
Load Reduction Needed (ton/yr)**	245
Acres of Cropland	9,746

*Based on average cfs and average nitrate concentration
**Calculated using 319 Load Calculation Tool (found at www.in.gov/idem/nps/files/319_load_calculation_tool.xls) and based on a target concentration of 1 mg/L

TABLE S.20 | BMPs, rates of use, and resulting nitrate load reductions for Deer Creek

		Column A	Column B	Column C = Column A x B x D	Column D
BMPs	Volume of Practice Installed (acres)	Percentage of Cropland Used	Estimated % Nitrate-N Reduction	Load Reductions (tons/yr)	Load Available for Treatment by BMP (tons/yr)
Wetland Restoration	975	10%	100%	36	355
Prairie Restoration	97	1%	100%	3	320
Fertilizer Reduction Practices (MRTN, sidedress, no fall application)	8,674	100%	10%	32	316
Cover Crops and Filter Strips*	8,674	100%	25%	71	285
Drainage Water Management**	6,072	70%	33%	49	214
Saturated Buffer***	1,735	20%	50%	16	164
Bioreactors	4,944	57%	43%	36	148
			Total Load Reduction (ton/yr)	243	
			Percent Reduction Achieved	69%	
			Percent Reduction Needed	69%	
			Remaining Load Reduction Needed (tons)	2	
			Percent Progress Towards Goal	99%	

*Cover crops and filter strips are combined for ease of calculations since assessing total acreage needing filterstrips is difficult. Filter strips are regarded as having equal or greater effects on nitrate reductions.
They can capture some of the small percentage of dissolved nitrate in surface flow. Furthermore, conversion of cropland to a filterstrip means a 100% reduction in nitrogen fertilizer on that land.
**Not all cropland is suitable for drainage water management. Percentages are based on figures and maps generated by the NRCS. Percentages estimate the maximum amount of land suitable for drainage water management.
***Not all buffers are suitable for converting into saturated buffers. Researchers in Iowa estimated that 20% of that state's buffers were suitable for conversion to saturated buffers. We used the same figure here.
Actual percentages may vary.

T. MISC TABLES/FIGURES

TABLE T.1 | Water Quality Results for Tributary Subwatersheds (average of all samples)											
			Nitrogen			Phosphorus			TSS		
Site	mi2	CFS	X	%	TR	X	%	TR	X	%	TR
Subwatershed mean	28	63	3.9	74%	160	1.3	23%	4.79	2.5	60%	2,015
Upper Big Lick Creek	52	29	2.16	54%	27	1.05	4%	0.33	0.5	-99%	-298
Lugar Creek	30	65	2.31	57%	93	1.28	22%	5.38	3.92	74%	4,735
Walnut Creek	39	121	2.64	62%	196	1.48	32%	17.2	3.4	71%	7,181
Back Creek	16	63	2.85	65%	116	0.8	-26%	-3.87	1.6	37%	937
Big Lick Creek	76	39	3.15	68%	72	0.91	-10%	-0.9	0.87	-15%	-108
Halfway Creek	25	25	3.9	74%	69	1.42	30%	2.93	1.45	31%	261
Little Walnut Creek	17	45	4.04	75%	137	2.04	51%	14.1	2.3	57%	1,472
Deer Creek	45	111	4.55	78%	389	1.39	28%	12.89	1.56	36%	1,522
Pike Creek	21	19	4.84	79%	64	0.63	-59%	-1.82	0.46	-118%	-221
Little Deer Creek	26	106	4.87	79%	404	1.26	21%	8.22	1.55	35%	1,431
Campbell Creek	20	16	5.07	80%	55	1.77	44%	3.03	1.73	42%	238.2
Little Mississinewa	21	38	5.57	82%	174	1.8	44%	9.15	8.96	89%	7,610
Barren Creek	21	40	5.83	83%	192	0.52	-94%	-5.77	1.25	20%	246
Bush Creek	20	8	6.88	85%	42	0.84	-19%	-0.34	0.98	-2%	-4.42

X = X Times Target, how many times mean load exceeds target load
% = Percent reduction needed to reach water quality targets
TR = Tons/yr. reduction need to meet water quality targets

TABLE T.2 | Comparison of Loading Data at Mississinewa River Sites and Subwatershed Sites			
	X Times Target	**% Reduction**	**Ton Reduction**
Nitrate+Nitrite			
Boots Creek average	8.4	88%	1339.55
Subwatershed average	3.9	74% (**-14%**)	160.79
Phosphorus			
Boots Creek average	1.75	43%	41.89
Subwatershed average	1.3	23% (**-20%**)	4.79
TSS			
Boots Creek average	6.97	86%	27,703.05
Subwatershed average	2.5	60% (**-26%**)	2,015.31

Individual sites are similarly analyzed in Part 13 of the WMP.
X = X Times Target, how many times mean load exceeds target load
% = Percent reduction needed to reach water quality targets
TR = Tons/yr. reduction need to meet water quality targets

White River Comparison (Albany drainage)

TABLE T.3 | Rivers Mean[1]	**N**	**P**	**TSS**	***E. coli***
Mississinewa	3.31	0.17	38.32	2085
White River	2.98	0.3	30.5	1083
Target	1	0.3	25	235

TABLE T.4 | Rivers Mean[2]	**N**	**P**	**TSS**	***E. coli***
Mississinewa	3.85	0.29	57	907
White River	2.35	0.27	53	2,101
Target	1	0.3	25	235

While averages vary, in same general cohorts for both data set with the exception of White River TSS, which was more impaired. All streams analyzed as part of the "Recreational Stream Study" (Part 7 of WMP) were grouped into three cohorts per parameter. The White and the Mississinewa River were in the worst cohort (red) and moderate cohort (orange) as depicted above. Neither the White or the Mississinewa were in the best cohort for any parameter.

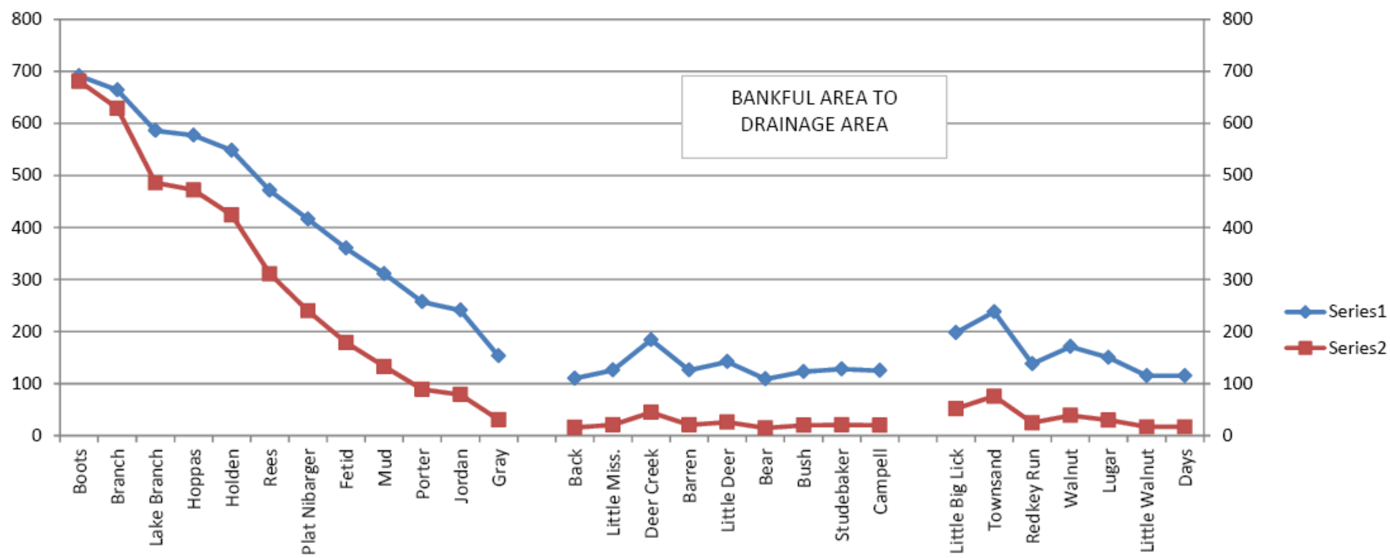


FIG. T.1 | Subwatershed Drainage Areas

Mississinewa Lake Water Quality

TABLE T.5 | Mean Values for Various Water Quality Parameters		
EPA STORET Lake Sampling	**Mean**[3]	**Indiana Max**[4]
Ammonia-nitrogen	0.31	22.5
Depth, Secchi disk depth	32.5	32.8
Dissolved oxygen (DO)	3.9	3-5
Inorganic nitrogen (nitrate and nitrite)	5.3	9.4
Kjeldahl nitrogen	1.18	27.05
Orthophosphate	0.008	
pH	7.8	
Phosphorus	0.12	2.81
Total suspended solids	9.6	
Turbidity	17.9	

[3]EPA STORET 1990-2015. Mean of all data points on Mississinewa Lake
[4]Data for 456 Indiana lakes collected during July and August 1998-2004 under the Indiana Clean Lakes Program.

DNR property managers at the Mississinewa Lake Reservoir indicated the following statements for consideration in our comparative analysis of Mississinewa Lake Reservoir and Geist Reservoir:
1. No consecutive *E. coli* impairments (swimming)
2. No blue green algae reported illnesses
3. Never exceeded moderate (yellow) threat level for algae
4. Fish cleaning station on site
5. The Mighty Mississinewa Triathlon has never been canceled for water quality reasons.

Geist Reservoir

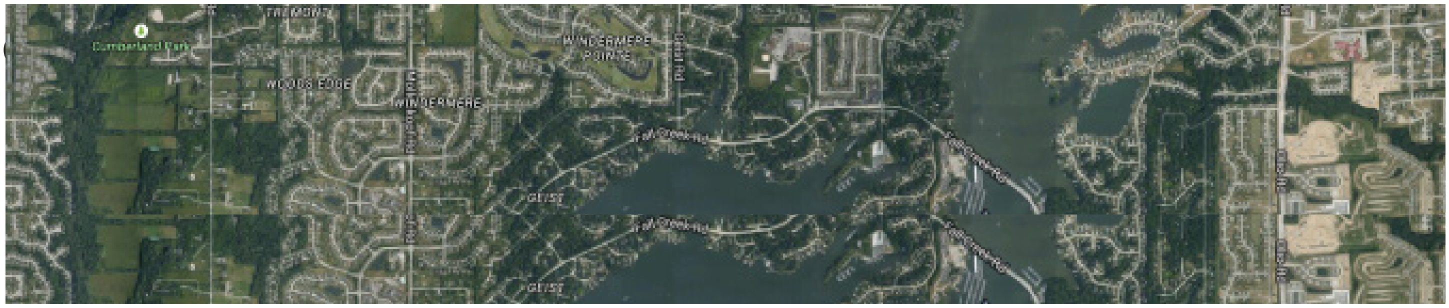


TABLE T.6 | Water Quality Data for Fall Creek			
Fall Creek at Southeastern Parkway	EPA STORET	Mean[2]	Units
Ammonia-nitrogen	0.14		mg/l
Chlorophyll a - Phytoplankton (suspended)	1.12		
Dissolved oxygen (DO)	9.37		mg/l
Escherichia coli	344.32	2,101	cfu/100ml
Inorganic nitrogen (nitrate and nitrite)	2.52	2.35	mg/l
Kjeldahl nitrogen	0.50		mg/l
pH	8.05		
Phosphorus	0.08	0.27	mg/l
Total suspended solids	22.82	53	mg/l
Turbidity	21.47		NTU

A wide variety of conditions, including geography, morphometry (lake depth, area, shoreline length, etc.), time of year, and watershed characteristics, can influence the water quality of lakes. -Interpreting Lake Data | Indiana Clean Lakes Program

TABLE T.7 | Parameter	Value
Contributing drainage area in square miles.	218
Percent of area covered by water and wetland	2.27
Percent of area covered by urban land cover	5.8

Geist Reservoir Management Plan
1. Nutrient Concerns (Algea)
2. Greater Sedimentation Issues
3. *E. coli* levels greater concern

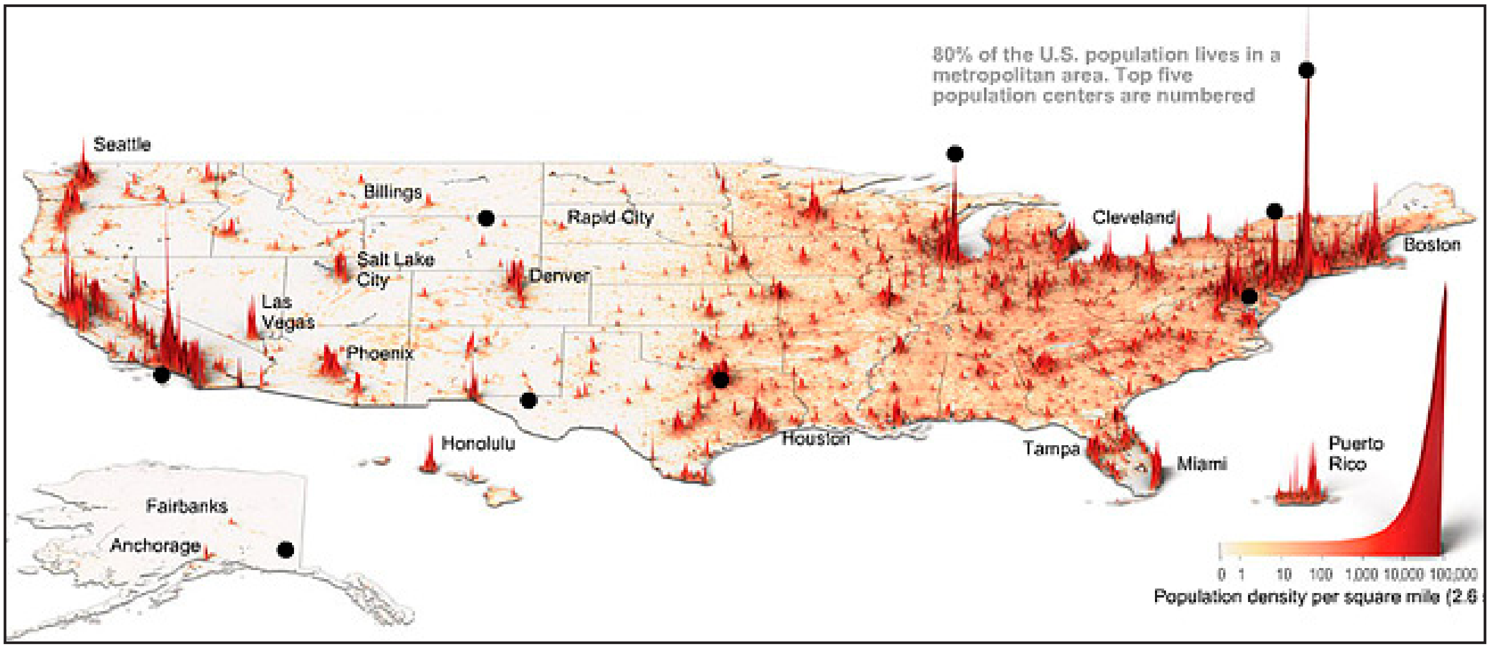


FIG. T.2 | Population Decentralization in Eastern United States

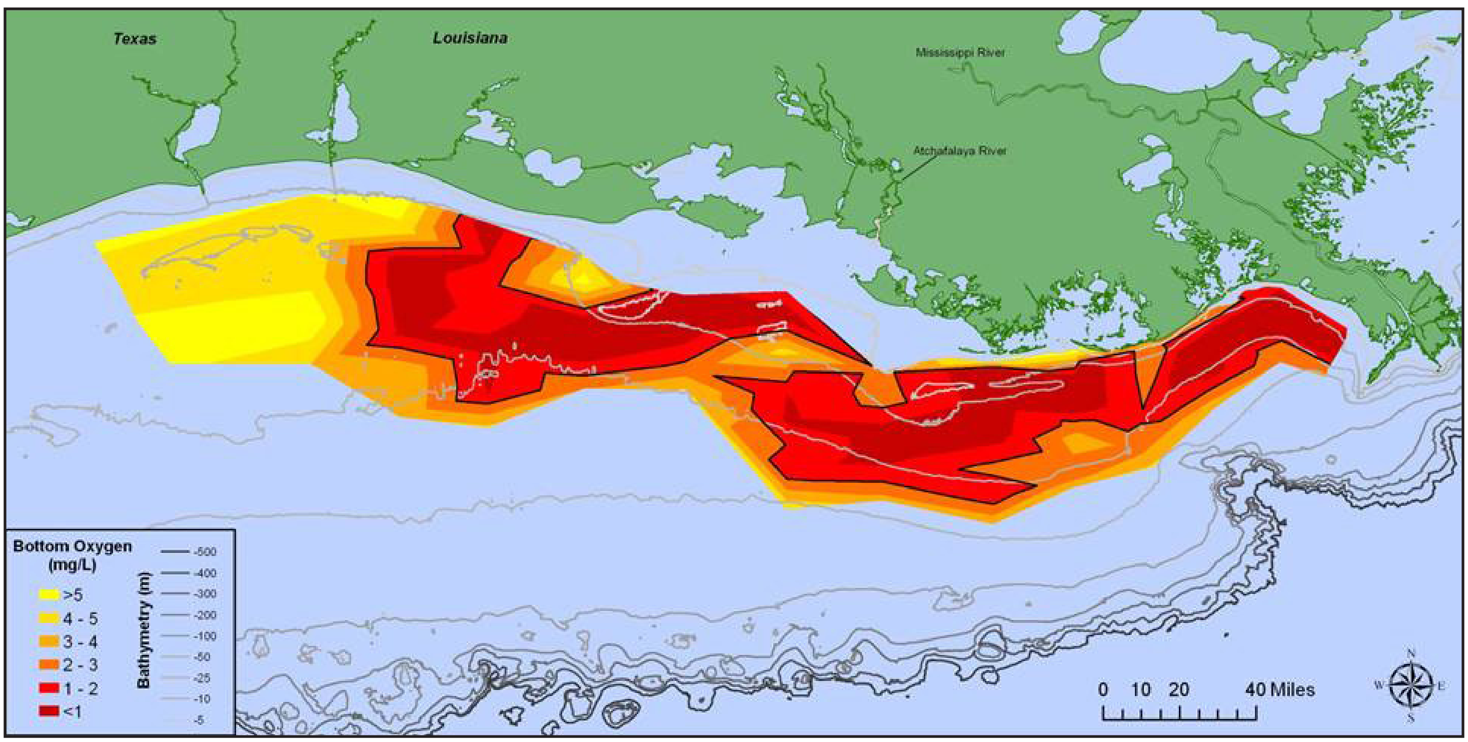


FIG. T.3 | Dead Zone

Map showeing distribution of bottom-water dissolved oxygen from July 28 to August 3, west of the Mississippi River delta. Black lined areas — areas in red to deep red — have very little dissolved oxygen. (Data: Nancy Rabalais, LUMCON; R Eugene Turner, LSU. Credit: NOAA) http://www.noaanews.noaa.gov/stories2015/080415-gulf-of-mexico-dead-zone-above-average.html

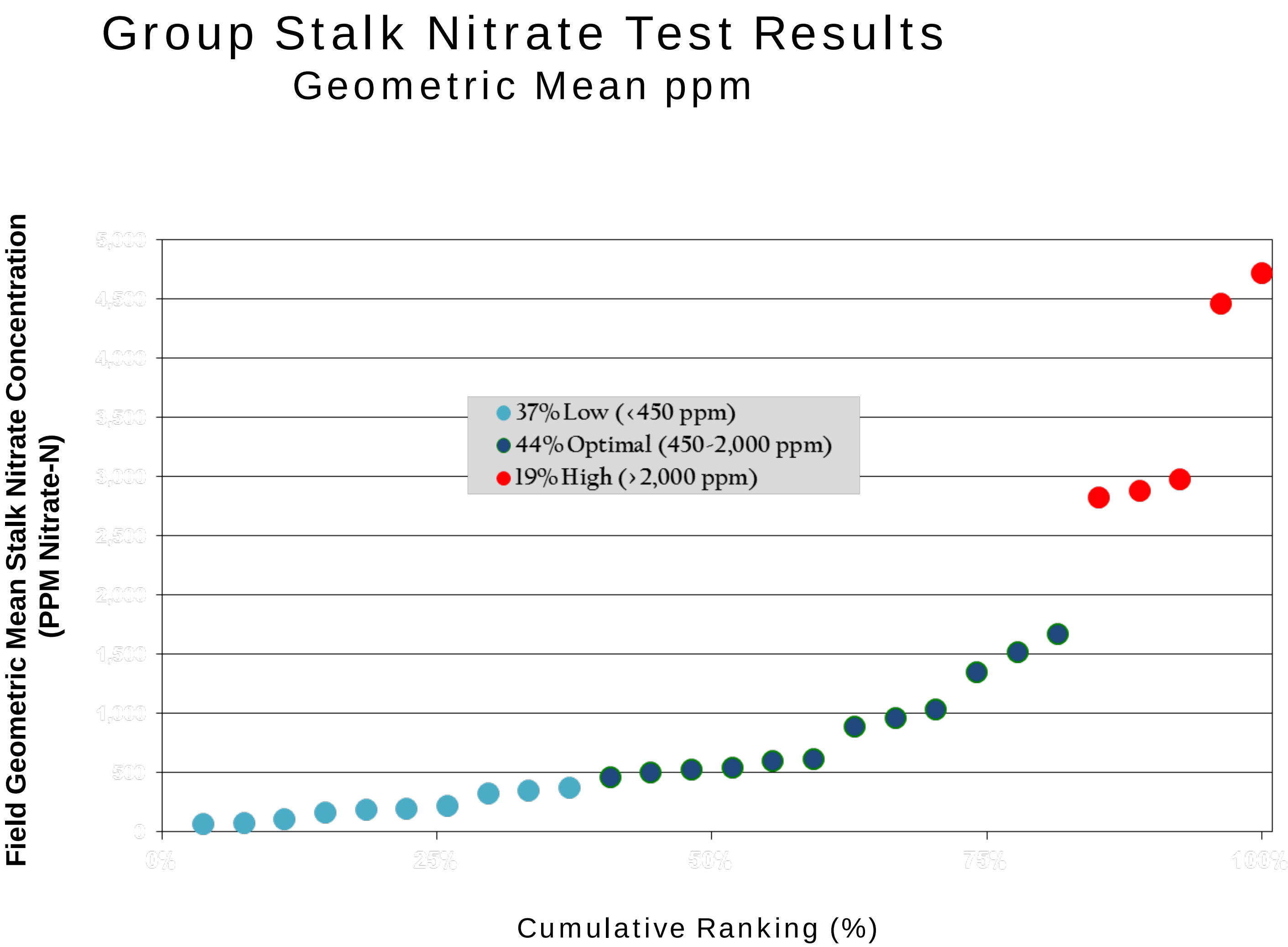


FIG. T.4 | Sample On-farm Network Data

TABLE T.8 | Load Reduction Cost-estimates (Appendix S)

	Gray Branch (nitrate)	Deer Creek (nitrate)	Little Mis-sissinewa (nitrate)	Halfway Creek (phosphorus)	Little Lick Creek (phosphorus)	Campbell Creek (TSS)	Lugar Creek (TSS)	Halfway Creek (nitrate)	Pike Creek (nitrate)	Little Lick Creek (nitrate)
Wetland Restoration	$338,626	$194,920	$218,100	$-	$-	$-	$-	$76,230	$239,500	$461,020
Prairie Restoration	$154,075	$88,689	$99,236	$-	$-	$-	$-	$-	$-	$-
Extended Rotations	$-	$-	$-	$-	$-	$-	$-	$-	$-	$-
Fertilizer Reduction Practices (MRTN, side-dress, no fall application)	$-	$-	$-	$-	$-	$-	$-	$-	$-	$-
Cover Crops and Filter Strips*	$723,312	$291,444	$465,862	$-	$-	$-	$-	$502,813	$505,824	$995,803
Drainage Water Man-agement**	$365,716	$208,175	$738,050	$-	$-	$-	$-	$228,690	$252,912	$547,692
Saturated Buffer***	$84,657	$123,604	$51,254	$-	$-	$-	$-	$63,525	$52,690	$103,730
Bioreactors	$753,443	$-	$8,048	$-	$-	$-	$-	$-	$126,456	$145,221
Cover Crops	$-	$-	$-	$127,050		$19,520	$35,280	$-	$-	$-
Conservation Tillage	$-	$-	$-	$72,419	$43,797	$1,900	$5,700	$-	$-	$-
Filter Strips****	$-	$-	$-	$11,088	$16,632	$5,544	$8,316	$-	$-	$-
Total Cost	$2,419,828	$906,831	$1,580,549	$210,557	$60,429	$26,964	$49,296	$871,258	$1,395,327	$2,253,466

TABLE T.9 | Alternative Scenario Cost-estimate

	Gray Branch (nitrate)
Wetland Restoration	$1,000
Prairie Restoration	$-
Extended Rotations	$-
Fertilizer Reduction Practic-es (MRTN, sidedress, no fall application)	$-
Cover Crops and Filter Strips*	$406,231
Drainage Water Management**	$162,492
Saturated Buffer***	$38,084
Total Cost	$607,808

U. BEST MANAGEMENT PRACTICES

COMPREHENSIVE NUTRIENT MANAGEMENT PLAN (NUTRIENTS & PATHOGENS) INDIANA NRCS FOTG NUTRIENT MANAGEMENT (590)

A nutrient management plan aids in applying the correct amount and form of plant nutrients for optimum yield and minimum impact on water quality. Soil tests are performed, yield goals are determined, past applications are considered, and short and long-term goals are set for nutrient application. This process can be applied in a variety of methods. Whether they are broadcast, starter, surface band, or injection, they aid in providing the proper application of the nutrient in spring or fall to the fields. In the spring, nitrogen testing is appropriate for corn when it is 6-12 inches tall. In the fall, refrain from applying commercial Nitrogen except when associated with Phosphorus application. Avoid applying manure on frozen or snow-covered ground as this causes extreme nutrient run-off. Applying the proper nutrient at the proper time through the proper method prevents over application of commercial fertilizers and animal manure that could infiltrate the water supply. Retesting soils, monitoring fields, and analyzing nutrient applications along with establishing a maintenance program provides quality care of the land, water supply, and ensures quality yield.

FILTER STRIPS (SEDIMENT & NUTRIENTS) INDIANA NRCS FOTG FILTER STRIP (393)

Strips of grass, trees and/or shrubs or filter strips, filter and slow runoff and remove contaminants before they reach water bodies or sources. The vegetation collects sediment, chemicals, and nutrients. These sources are absorbed so they cannot enter the water bodies. In addition, these strips provide habitat for a variety of birds and animals, remove row crop operations further from the water body to reduce added risk, and reduce soil erosion. Filter strips are most effective on slopes of 5% or less. If the strip is steeper, it should also be wider. A minimum of 15 foot wide strips should be used for cropland and minimum 50 foot wide for forestland. These strips become less effective during frozen conditions. Controlled grazing can occur as long as it is monitored.

GRADE STABILIZATION STRUCTURE (SEDIMENT & NUTRIENTS) GRADE STABILIZATION STRUCTURE (410)

An earthen, wooden, concrete, or other structure built across a drainageway aides in grade stabilization to prevent gully erosion and reducing water flow. These structures drop water from one stabilized grade to another by providing a water outlet and improving water quality. This prevents nutrients and sediment from contaminating a potential water source created by an embankment or field. Ensure that all permits are obtained and construction specifications considered before construction. Remove all trees and shrubs within 30 feet of the structure and any debris approximately 50 feet downstream from the outlet during construction.

CHECK DAMS- NATURAL IMPLEMENTATION (NUTRIENTS & PATHOGENS)

There are many different techniques to make check dams using natural materials. These techniques are fast, and given local supplies, relatively inexpensive. Some of the natural methods are coir fascines, wattle fences, straw bale, Sediment STOP, and Nilex GeoRidge. Coir fascines are formed by taking willow branches and laying them in a long pile that is generally the length of the channel. The pile should be 18-30" in height. Tie the bundle along its entire length, compacting the bundle as you go. Place this in a pre-dug channel approximately 3-6" deep. Stake the fascines using twine or wire to prevent them from floating away. Place soil or sphagnum moss on top of the bundles to allow the willow branches to grow. Wattle fences are formed by pounding the stems of dogwood or some other wood approximately 8" apart. Take long branches of dogwood or willow and weave them through the stakes like a basket. Make sure to push the branches into a tight bundle. A second technique is to make two rows of stakes and weave a basket with an opening in the middle. This can be filled with more sticks, creating thicker check dam. Wattle fences are an effective and economical alternative to silt fence or straw bales. Fertile topsoil, organic matter, and native seeds are then trapped behind the wattle to provide a stable medium for germination and increase stability. Straw bale check dams are simply created by placing straw bales in a row in the channel. Stake them down using hardwood stakes. This is a fast but effective method if stabilization is required in a short period of time. Sediment STOP is a specially designed straw mat that is rolled and staked in place. Sediment STOP is composed of a straw and coconut fiber matrix reinforced with 100% biodegradable netting. It is water permeable and has greater filtration capabilities than other check dam techniques. This creates a highly effective, temporary, three-dimensional, sediment-filtration structure. Nilex GeoRidge is a permeable ditch berm designed for erosion and sediment control. By acting as an energy dissipater, GeoRidge reduces flow velocities and provides a smoother, less damaging release of water. All of these natural techniques and others are effective in creating check dams and other erosion controls for storm water.

NO-TILL EQUIPMENT MODIFICATIONS (SEDIMENT & NUTRIENTS)

Indiana NRCS FOTG Residue and Tillage Management- No Till/Strip Till/Direct Seed (329) Modifications to farm equipment can be added to aid in no-till practices. Leaving last year's crop residue on the surface before planting operations provides cover for the soil at a critical time of the year. Equipment modifications can vary and include no-till, mulch till and ridge till. These techniques prevent soil erosion, protect water quality, improve soil tilth, add organic matter to the soil, and reduce compaction with fewer tillage trips.

COVER CROPS

By planting cover crops, producers protect their topsoil during the winter months, see an increase in soil nutrient levels—and a decrease in fertilizer needs—and protect their fields from weeds and insects. The economic incentive of cover crops can be calculated by weighing their cost against the nutrients and herbicides a landowner would typically apply.

GRASSED WATERWAY (SEDIMENT & NUTRIENTS) INDIANA NRCS FOTG GRASSES WATERWAY (412)
A grassed waterway is a natural way to prevent gullies from forming. By analyzing the existing natural drainageways, the waterway should be graded and shaped to form a smooth, bowl-shaped channel that is deep and wide enough to carry the peek runoff from a 10-year frequency, 24-hour storm. The NRCS design charts can aid in determining these measurements. After the channel is complete, plant sod-forming grass ¼ to ½ inches deep in a figure eight pattern to avoid erosion. An outlet can then be installed at the base of the drainageway to prevent a new gully from forming. This grass covered strip provides stabilization to prevent erosion, may act as a filter for runoff, and could provide cover for small animals. To maintain this waterway, avoid using it as a roadway for machinery, and fertilize and mow as needed (wait until after July 15 to mow so birds have had a chance to leave nests).

LIVESTOCK EXCLUSION (NUTRIENTS & PATHOGENS) INDIANA NRCS FOTG FENCE (382)
Providing fencing and other natural barriers around water bodies ensures that animal contamination does not run-off into these sources or fields. If livestock need to cross streams, provide a controlled stream crossing. The stream bottom should be covered with coarse gravel to provide animals with firm footing, while discouraging them from congregating or wallowing in the stream. In high sensitive areas, high tensile fence, solar-powered electric fences, or woven fence can be inexpensive alternatives to keep livestock from streams or to allow them a limited number of access points.

STRIP CROPPING (SEDIMENT & NUTRIENTS) INDIANA NRCS FOTG STRIPCROPPING (585)
Crops are arranged so that a strip of meadow or small grain such as oats, grass or legumes, is alternated with a strip of row crop such as corn or soybeans to create strip cropping. These strips should be nearly the same width. These alternative strips slow runoff, increase infiltration, trap sediment and provide surface cover. Ridges formed by contoured rows slow water flow which reduces erosion. Rotating these crops allows nutrients to be recharged by other legumes or grains and can reduce fertilizer costs. In addition, grass and legumes should serve as the field borders to help establish waterways. Slopes must be considered to accommodate equipment width and to maintain proper stripcropping width.

VEGETATED STREAM BANK STABILIZATION (BIOENGINEERING) (SEDIMENT & NUTRIENTS) INDIANA NRCS FOTG STREAM BANK AND SHORELINE PROTECTION (580)
Grass, riprap, gabions, and other methods are installed along the edges of a stream to buffer the banks from heavy streamflow and reduce erosion. A buffer zone of at least 15-25 feet of vegetation along the stream bank filters runoff and may also absorb excess nutrients and chemicals. Remove brush that adversely affects the desired vegetation of the bank. Fencing may be added to prevent cattle from trampling banks, destroying vegetation and stirring up sediment.

WATER AND SEDIMENT CONTROL BASINS (SEDIMENT & NUTRIENTS) INDIANA NRCS FOTG WATER AND SEDIMENT CONTROL BASINS (638)
A short earthen dam built across a drainageway (where a terrace is impractical), though it usually is part of a terrace system that directs runoff into a control basin. This basin traps sediment and water running off farmland above the structure, preventing it from reaching farmland below to reduce erosion and improve water quality. The area draining into the basin should not exceed 50 acres. The basin should be large enough to control a 10-year storm and ensure there is a tile or infiltration outlet for potential overflow. Fill material should contain little to no debris and contain the correct moisture content for adequate compaction. Seeding the embankment to maintain vegetative cover, reduce erosion, and provide cover for wildlife provides for a strong control basin.

2-STAGE DITCHES (SEDIMENT & NUTRIENTS) NRCS' STREAM RESTORATION DESIGN MANUAL, CHAPTER 1- & JOURNAL OF SOIL AND WATER CONSERVATION 62(4) 277-296
When a ditch is modified to a two-stage design, benches are added to both sides of the stream. These benches create room for water to collect during high flows and the stream to more naturally meander. As water flows onto the benches and slows down, pollutants drop out, scouring decreases, and the soils and vegetation on the benches cleanse the water. Benefits to the landowner include a more stable stream with less undercutting of trees (due to reduced scouring during high flow) and increased wildlife habitat (due to reduced sedimentation). Two-Stage Ditches may also significantly decrease the need to dredge the ditches. Information on Two-Stage Ditches can be found at: NRCS' Stream Restoration Design Manual, Chapter 10 and G. E. Powell, et. al. "Two stage channel systems: Part 1, a practical approach to sizing agricultural ditches" Journal of Soil and Water Conservation. Volume 62, Number 4, pgs. 277-296.

CONSERVATION EASEMENTS/PROPERTY PURCHASE
Conservation easements provide lasting protection to land and can be a valuable watershed management tool. While Section 319 cannot reimburse property owners for property value lost due to an easement, certain administrative costs associated with creating the easement are eligible. Likewise, certain administrative costs associated with purchasing land so it can be permanently protected are eligible. See IDEM's Urban BMP Guidance for details and more information.

CONSERVATION PLAN DEVELOPMENT (SEDIMENT & NUTRIENTS) INDIANA NRCS CPA-52 CONSERVATION PLANNING FORM
Conservation Plan Development is a process that outlines management decisions and conservation practices that are currently in use or planned for an area. This plan discusses long and short-term goals and objectives; collects information and data regarding nutrient and pest management, soil, water, and other resources; identifies problems and potential solutions; and develops an implementation and maintenance plan. A Conservation Plan creates the best decisions and actions for the land and the landowner.

V. SSO OVERFLOWS

TABLE V.1 | **SSO Overflows in Headwaters Mississinewa HUC 10 from 2014-2015**

Source	NPDES Pemit #	Begin Date	End Date		Units	Location	Receiving Waterbody
UNION CITY MUNICIPAL SEWAGE TREATMENT PLANT	IN0020982	2/20/2014 19:30	2/21/2014 8:52	50,000	gal- lons	Jackson Lift Station	
UNION CITY MUNICIPAL SEWAGE TREATMENT PLANT	IN0020982	4/4/2014 15:30	4/4/2014 18:00	150	gal- lons	Walnut St	
UNION CITY MUNICIPAL SEWAGE TREATMENT PLANT	IN0020982	4/4/2014 15:30	4/4/2014 18:00	750	gal- lons	Debolt Ave.	
UNION CITY MUNICIPAL SEWAGE TREATMENT PLANT	IN0020982	6/27/2015 19:06	6/28/2015 16:20	44,100	gal- lons	Overflow Pipe	
UNION CITY MUNICIPAL SEWAGE TREATMENT PLANT	IN0020982	7/13/2015 23:00	7/14/2015 12:00		gal- lons	Overflow weir	
UNION CITY MUNICIPAL SEWAGE TREATMENT PLANT	IN0020982	7/14/2015 0:00	7/14/2015 12:00		gal- lons	Overflow Weir	

TABLE V.2 | **SSO Overflows in Massey Creek HUC 10 from 2014-2015**

Source	NPDES Permit #	Begin Date	End Date	Quantity	Units	Location	Receiving Waterbody
Upland Municipal Waste Water Treatment Plant	IN0036978	2/20/2014 0:00	2/21/2014 0:00	360	gallons	West Lift Station	
Upland Municipal Waste Water Treatment Plant	IN0036978	2/20/2014 21:00	2/21/2014 0:00	360	gallons	North Lift Station	
Upland Municipal Waste Water Treatment Plant	IN0036978	2/20/2014 21:00	2/21/2014 0:00	360	gallons	North Lift Station	
Upland Municipal Waste Water Treatment Plant	IN0036978	2/20/2014 23:00	2/21/2014 0:00	120	gallons	Manhole at Plant Site	
Upland Municipal Waste Water Treatment Plant	IN0036978	2/24/2014 4:00	2/24/2014 8:00	480	gallons	North Lift Station	
Upland Municipal Waste Water Treatment Plant	IN0036978	3/12/2014 7:00	3/12/2014 8:00	120	gallons	North Lift Station	
Upland Municipal Waste Water Treatment Plant	IN0036978	4/3/2014 10:00	4/3/2014 19:00	1,080	gallons	North Lift Station	
Upland Municipal Waste Water Treatment Plant	IN0036978	4/3/2014 10:00	4/3/2014 15:00	600	gallons	West Lift Station	
Upland Municipal Waste Water Treatment Plant	IN0036978	4/9/2015 12:30	4/9/2015 14:00	180	gallons	North Lift Station	
Upland Municipal Waste Water Treatment Plant	IN0036978	6/17/2015 7:00	6/17/2015 10:00	360	gallons	North Lift Station	
Upland Municipal Waste Water Treatment Plant	IN0036978	6/27/2015 5:00	6/27/2015 10:30	56,000	gallons	WWTP front manhole	
Upland Municipal Waste Water Treatment Plant	IN0036978	7/13/2015 11:30	7/13/2015 14:30	21,600	gallons	North Lift Station	
Upland Municipal Waste Water Treatment Plant	IN0036978	7/13/2015 12:30	7/15/2015 18:30	150,000	gallons	West Lift Station	
Upland Municipal Waste Water Treatment Plant	IN0036978	12/28/2015 21:00	12/29/2015 2:00	10,200	gallons	NORTH LIFT STATION WEST LIFT STATION	

TABLE V.3 | SSO Overflows in Big Lick Creek HUC 10 from 2014-2015

Source	NPDES Permit #	Begin Date	End Date	Quantity	Units	Location	Receiving Waterbody
HARTFORD CITY WASTE WATER TREATMENT PLANT	IN0021628	1/31/2014 0:00	1/31/2014 20:00	212500	gallons	Jefferson St overflow	
HARTFORD CITY WASTE WATER TREATMENT PLANT	IN0021628	1/31/2014 10:00	1/31/2017 20:00	212500	gallons	Old Plant Lift Station	
HARTFORD CITY WASTE WATER TREATMENT PLANT	IN0021628	1/31/2014 16:00	1/31/2014 20:00	50000	gallons	3M LS	
HARTFORD CITY WASTE WATER TREATMENT PLANT	IN0021628	2/4/2014 0:00	2/4/2014 0:00	275000	gallons	Old Plant LS @ S Monroe St	
HARTFORD CITY WASTE WATER TREATMENT PLANT	IN0021628	2/14/2014 0:00	2/14/2014 0:00	275000	gallons	Old Plant RR @ S Monroe St	
HARTFORD IRON & METAL	INP000612	7/7/2015 10:45	7/7/2015 19:00	490	gallons	Storm drain at W. Chestnut Street & Division Street Inter-section	
HARTFORD IRON & METAL	INP000612	7/8/2015 14:00	7/8/2015 20:00	360	gallons	Storm Drain at W. Chestnut St. & Divi-sion St. Intersection	
HARTFORD CITY WASTE WATER TREATMENT PLANT	IN0021628	8/17/2015 9:00	8/18/2015 8:00	1	gallons	3m railroad CSO#5 S.spring -man-hole-divbox	
HARTFORD CITY WASTE WATER TREATMENT PLANT	IN0021628	8/18/2015 9:00	8/18/2015 14:00	190000	gallons	3mls at crossroad & St.Rd 26	
HARTFORD CITY WASTE WATER TREATMENT PLANT	IN0021628	8/18/2015 9:00	8/18/2015 14:00	19000	gallons	3 mls at Cross Road and State Rd. 26	

TABLE V.4 | SSO Overflows in Halfway Creek HUC 10 from 2014-2015

Source	NPDES Permit #	Begin Date	End Date	Quantity	Units	Location	Receiving Waterbody
Redkey Waste Water Treatment Plant	IN0024406	7/7/2015 16:00	7/7/2015 22:30	136500	gallons	#8 location of release Manholes #: 12 14 15 19 22 26 27 33A 33B and 52	

TABLE V.5 | SSO Overflows in Pike Creek HUC 10 from 2014-2015

Source	NPDES Permit #	Begin Date	End Date	Quantity	Units	Location	Receiving Waterbody
Albany Municipal Waste Water Treatment Plant	IN0022136	3/18/2014 19:45	3/18/2014 22:00	30	gallons	SR67 & SR 167 Wastewater manhole overflow.	