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INSTITUTE FOR THE ENVIRONMENT & SUSTAINABILITY

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FOUR MILE CREEK WATERSHED INVENTORY

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EXECUTIVE SUMMARY

This report is the result of a two semester Professional Service Project completed by six graduate students from Miami University's Institute for the Environment and Sustainability from August 2012 – May 2013. The project involved the development of a watershed inventory for the Four Mile Creek Watershed (FMCW), which covers parts of Butler (44%), Preble (45%), Union (9%), and Wayne (1%) counties in Ohio and Indiana. A comprehensive inventory of the FMCW would enable state and county agencies to effectively manage the watershed. The clients, Bob Lentz from the Butler County Storm Water District, and Kevin Fall and Lynn White from Butler Soil and Water Conservation District, were seeking a broader understanding of the characteristics of the watershed, especially those that most directly impact water quality.

The project team compiled the inventory in accordance with the Ohio Environmental Protection Agency's (Ohio EPA) "A Guide to Developing Local Watershed Action Plans in Ohio." The Ohio EPA guide outlines the categories of information that are most relevant in developing a comprehensive understanding of a watershed. These categories include natural features and habitats, water quality, human use and influence, and the effects of local point and nonpoint source pollutants within the FMCW. In addition to gathering this information, the team used a geographic information system (GIS) to create 26 maps that provide visual depictions of the watershed characteristics.

Research indicates a distinct difference in land use practices between the northern and southern portions of the FMCW. In the north, a majority of the land is used for cultivated crops whereas the south is comprised of pasture and developed urban areas. Data from the 2005 Ohio EPA Biological and Water Quality Survey indicate that most of the streams in the FMCW are meeting full or partial attainment of their designated use. This reflects the overall high quality of the watershed. Streams that were impaired or not fully meeting their designated uses were affected by the following four sources: in the north, unrestricted cattle access; in the south, Acton Lake outflow, runoff from the city of Oxford, and discharge from the Oxford Waste Water Treatment Plant.

The team compiled a list of recommendations for further analysis of the FMCW. Recommendations include the following: 1) continued data collection to supplement this inventory (70% of the categories in the Ohio EPA guidebook are provided in this report); 2) seek updated water quality information from Ohio EPA by tracking progress of the Total Maximum Daily Load report; 3) maintain water quality through conservation efforts; 4) address causes of impairment; and 5) create additional GIS maps.

CHAPTER ONE: BACKGROUND

"When the well's dry, we know the worth of water."
- Benjamin Franklin, (1706-1790), Poor Richard's Almanac.

A. *Introduction*

Water is essential for survival of all organisms, as it is used for habitat, reproduction, and physiological processes. Since only 2.5% of the earth's water supply is freshwater, it is important to protect this limited resource (USGS, 2013c). Effective protection requires an understanding that water is part of an integrated system that can be impacted by multiple variables as it flows through an ecosystem.

This was first recognized in the 1890's when the U.S. Inland Waterways Commission reported to Congress that the use of rivers should be regulated in a holistic manner (Perez, 1997). In the 1940's, the Federal Water Pollution Control Act emphasized protection of water quality. This law placed limits on the discharge of pollutants directly into waterways and created a permitting and monitoring process to regulate this discharge. In 1972, the act was expanded and renamed the Clean Water Act (USEPA, 2013b).

As a result of this legislation, water resource managers now recognize the importance of taking an integrated approach to the improvement and protection of water quality. This is known as the watershed approach, a comprehensive analysis that involves characterizing water resources within natural topographic boundaries rather than just political boundaries (Perez, 1997).

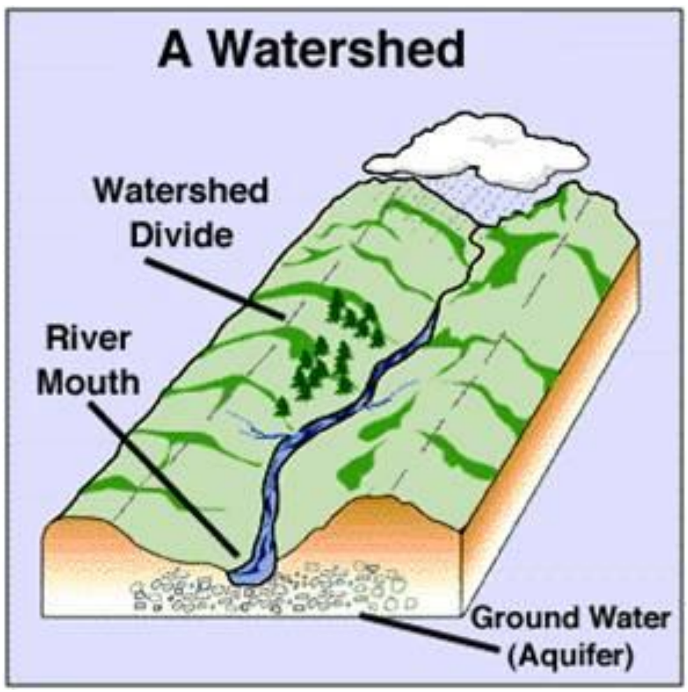

Figure 1. Physical features of a watershed (KDW, 2013).

A watershed is defined as a geographical area bounded by the watershed divide, which is the highest ridge of the landscape that separates adjacent watersheds (Figure 1). Within these boundaries, all surface water and ground water drains to a common outlet, such as a stream, river, or lake (Perez, 1997). Thus, the watershed approach allows resource managers to determine the quality of the water resource by examining environmental indicators of the watershed as a whole, including the physical, chemical, biological, and anthropological characteristics of the water body (Perez, 1997).

Managing such a complex and integrated system requires collaboration among multiple political, social, and economic interest groups. In order to effectively manage a watershed, the Ohio EPA suggests that resource managers follow the six steps outlined in Figure 2 below (Perez, 1997).

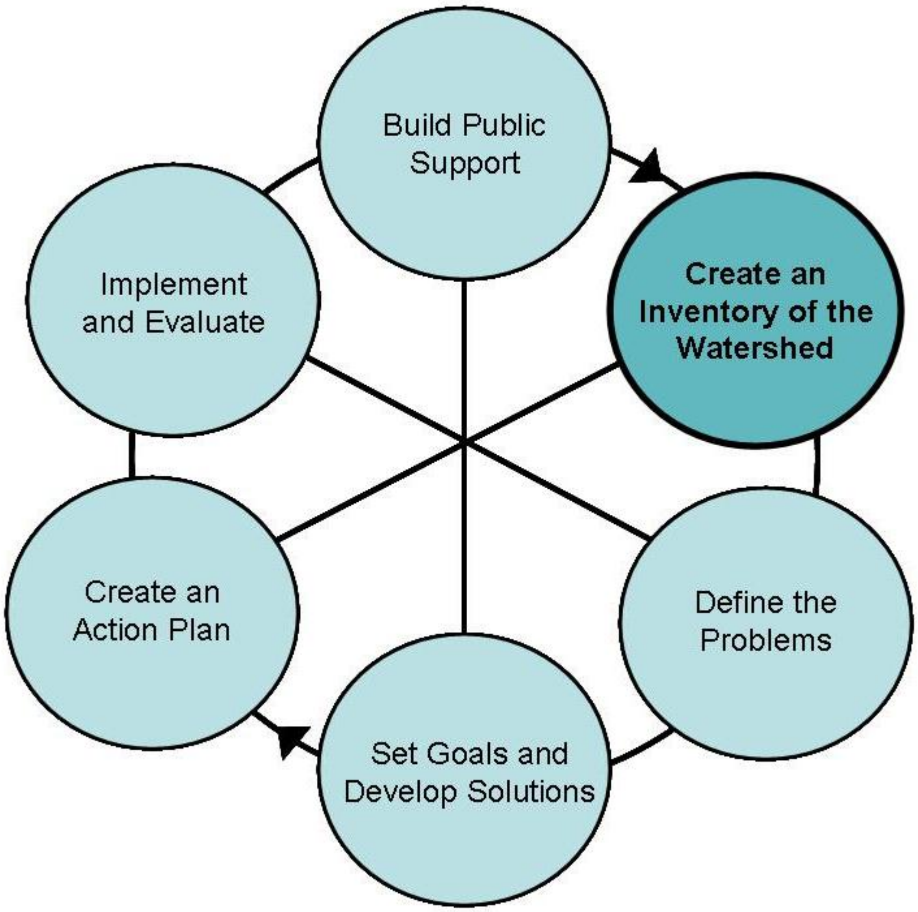

Figure 2. Watershed management wheel (adapted from Perez, 1997).

One of the first steps is to compile available information about a watershed into one central inventory. This information can be used to define the problems in the watershed, set goals, and develop solutions. Subsequently, a watershed action plan (WAP) allows managers and involved parties to set priorities, establish time frames, and assign tasks. One key benefit to developing a WAP is that it increases opportunities for grant funding. For instance, Section 319 of the Clean Water Act authorizes the EPA to award grants to states in order to implement projects designed to reduce nonpoint source pollution and improve program effectiveness (USEPA, 2003a). Implementation of a WAP should result in improvement of water quality and requires continuous monitoring. This process may take several years and involves many dedicated stakeholders.

In many cases, creating a watershed inventory can be an important first step for watershed management because it provides a baseline description of the features of the watershed. A watershed inventory details physical features, biological habitat, cultural resources, and land use characteristics of a watershed. Data for the inventory comes from many sources, including research and reports conducted by a variety of organizations. This information can help identify impairments and potential areas of concern as well as high quality areas and protected lands.

The Ohio EPA provides a guidebook for watershed managers and stakeholders working on a watershed inventory (Perez, 1997). This guidebook presents useful resources and ideas on what data to include in the inventory as well as suggestions for locating this data (See Appendix A for the list of categories to include in an inventory).

B. Project Focus

This report was compiled by a team of graduate students from the Institute for the Environment and Sustainability at Miami University. The purpose of this research project was to compile a comprehensive watershed inventory of the Four Mile Creek Watershed (FMCW) in accordance with the Ohio EPA guidelines. State and county agencies can use this report to effectively manage water quality in the FMCW. This inventory can also be used as a guide to determine areas of the watershed where further research is needed.

The FMCW covers an area of 322 square miles in Butler and Preble counties in Ohio, and Union and Wayne counties in Indiana (OEPA, 2012b). It is one of many smaller watersheds that flow into the Great Miami River near Hamilton, Ohio (Figures 3 and 4). The Great Miami River Watershed collects water from southwest Ohio and then drains into the Ohio River. The Ohio River meets the Mississippi River to the west, and then travels to the Gulf of Mexico. This demonstrates that land use practices in the FMCW could affect water quality in the lower Mississippi River and the Gulf of Mexico. It is important to track these changes in water quality locally in order to improve water quality regionally.

Figure 3. Great Miami River Watershed (blue) and FMCW (purple), located in southwest Ohio (OEPA, 2012b).

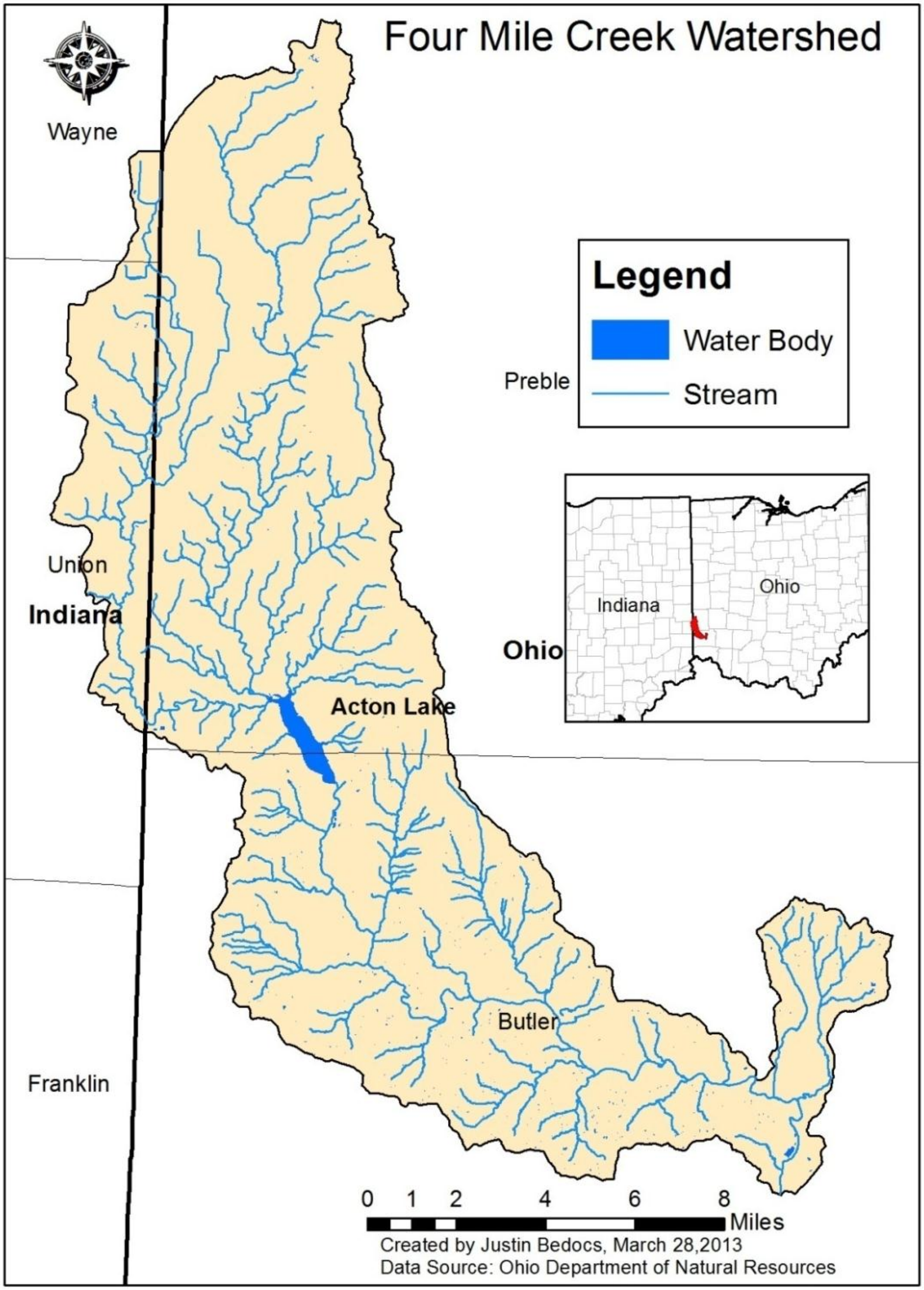

Figure 4. The FMCW physical and political boundaries. The bold line indicates the state boundary and the fine lines indicate county boundaries.

Objectives

These objectives were designed to help the team draft the watershed inventory in a manner that reflects the criteria outlined in Ohio EPA's "A Guide to Developing Local Watershed Action Plans in Ohio" (Perez, 1997). This will help ensure that the inventory can be used in the future to manage the watershed in accordance with Ohio EPA guidelines.

1. Describe the natural elements of the FMCW including the climate, geology, and biological features.
2. Describe the characteristics of FMCW water resources, including surface water, groundwater supply, and floodplain areas.
3. Provide a summary of water resource quality for lakes, streams, and wetlands in FMCW.
4. Describe the human activities that affect water quality in the FMCW, including permitted pollutant dischargers, land use and development, and protected land of cultural or recreational value.
5. Use a geographic information system (GIS) to visually represent the data.
6. Provide an account of previous and complementary efforts to meet water quality standards in the FMCW.
7. Provide recommendations to the clients that will assist with their efforts to manage the FMCW.

C. Methods

The compilation of the FMCW inventory was the collaborative effort of the team and multiple stakeholders, including state and local government agencies, private interest groups, and university faculty and affiliates. The team relied on the Ohio EPA-"A Guide to Developing Local Watershed Action Plans in Ohio" as well as "Watershed Inventory Workbook for Indiana," both of which offer guidance on where to find relevant data as well as how to organize the data into an effective report (Perez, 1997; Frankenberger, 2002) (Appendix B). The team also reviewed several Ohio and Indiana WAPs to examine data sources and reporting methods, and to understand the components of a successful watershed inventory. If the team was unable to find the data needed using the resources suggested by the state guides and WAPs, then the next step was to search local government websites, including Ohio EPA, Ohio Department of Natural Resources (ODNR), and Indiana Department of Natural Resources(IDNR). Additionally, team members reviewed research conducted by Miami University researchers.

A geographic information system (GIS) was used as a tool to display various spatial data for the entire watershed. These GIS maps were created using ArcMap software available from Esri. In order to display data from two states and four counties, the team downloaded GIS data from a variety of reliable sources and obtained comparable data from each political jurisdiction. When data from multiple sources matched, it was "merged" to create a single data file. Because the data collected were often relevant to an area wider than the FMCW, it was necessary to "clip" the original data by boundaries of the watershed so that analyses of data relevant to the area of interest were possible.

D. Clients

This inventory was compiled for the Butler County Storm Water District and the Butler Soil and Water Conservation District. The Storm Water District, developed in 2002, has the mission to protect public health and the environment using storm water management practices (BCSWD, 2013). The Soil and Water Conservation District, established in 1942, has the mission to locally reduce soil erosion, improve overall water quality and provide the public with access to data and educational resources needed to increase awareness and improve conservation (BSWCD, 2010). These organizations work diligently to manage and protect the watersheds in Butler County and beyond. The FMCW inventory will help both agencies gain a better understanding of the water quality of their jurisdiction, and to fund projects that address areas of concern in the watershed.

CHAPTER TWO: BOUNDARIES AND NATURAL FEATURES OF FMCW

A description of the physical and natural characteristics of FMCW will help stakeholders understand a complex and interactive system. This chapter will discuss the political boundaries, climate, geology, and biological features of the watershed.

A. Political and Physical Boundaries

The FMCW encompasses parts of Butler and Preble counties in Ohio, and Union and Wayne counties in Indiana (Figure 5). Percentages of the watershed in each county are:

- Butler - 44.57%
- Preble - 45.56%
- Union - 8.95%
- Wayne - 0.92%
  (USDA, 2006)

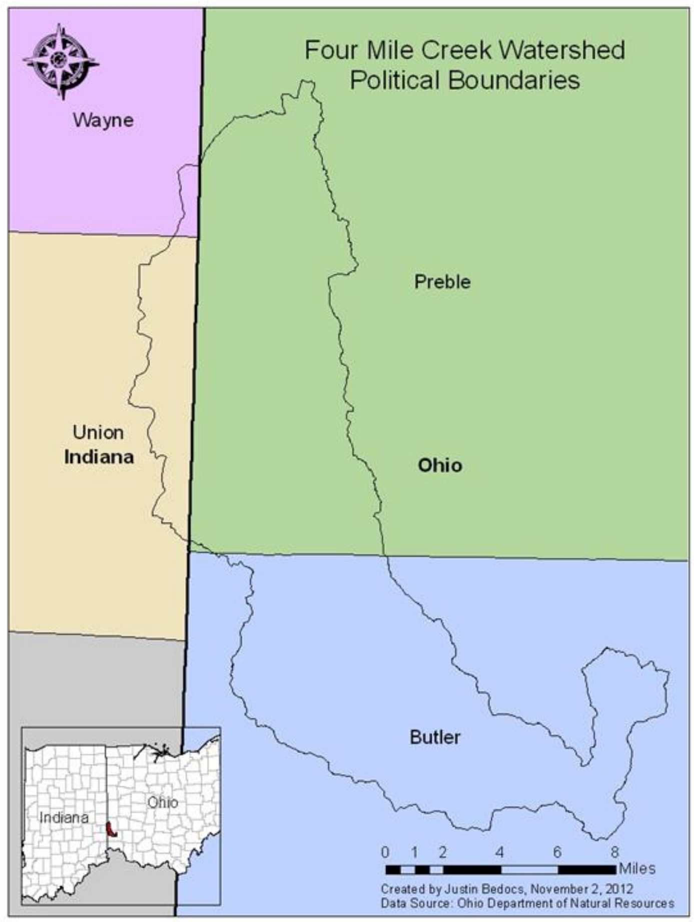

Figure 5. The FMCW and Butler, Preble, Union, and Wayne county boundaries.

There are 13 civil townships within the watershed and 14 designated United States Geological Survey "populated places" (USGS, 2013c) (Table 1). A populated place is an area with a permanent human population and permanent infrastructure, and includes cities, settlements, towns, and villages (USGS, 2013c). It is different from a township because it does not necessarily have defined legal boundaries.

Political jurisdictions differ in regulation and governance, and thus can impact funding availability and stakeholder involvement. WAP standards for development, implementation, and funding can vary by state. This could present challenges for developing a WAP for the FMCW. According to Greg Nageotte, the Watershed Program Manager of ODNR Division of Soil and Water Resources, there are only two Ohio watershed planning initiatives that have crossed state lines; Pymatuning (Ohio/Pennsylvania), which did not receive state endorsement, and Upper Maumee River Watershed (Ohio/Indiana), which is an effort in progress. In order to create a comprehensive watershed inventory, differences in the state standards for watershed planning must be carefully considered.

Table 1. Townships and populated places in FMCW (USDA, 2006).

<table>
<tr><th colspan="3">Ohio</th></tr>
<tr><td colspan="2">Butler County</td><td>Preble County</td></tr>
<tr><td>Cherokee Park
Darrtown
Hanover Township
Jericho
Madison Township
Milford Township
McGonigle</td><td>New Miami
Reily Township
St. Clair Township
Oxford
Oxford Township
Williamsdale</td><td>Campbellstown
Dixon Township
Fairhaven
Israel Township
Jackson Township
Morning Sun
Somers Township
Talawanda Springs
West Florence</td></tr>
<tr><th colspan="3">Indiana</th></tr>
<tr><td colspan="2">Union County</td><td>Wayne County</td></tr>
<tr><td colspan="2">Center Township
Five Points
Goodwins Corner
Harrison Township</td><td>Boston Township</td></tr>
</table>

The team took into consideration the Ohio and Indiana watershed guides (Perez, 1997; Frankenberger, 2002) as well as several examples of Ohio watershed action plans and Indiana watershed management plans. In general, both states require the same information for watershed plans, but each state report must follow different formatting requirements.

When possible, the team collected data from both states, but because only 22 square miles (<10%) of the watershed lie within Indiana, this report is tailored to Ohio standards. If the watershed inventory is used to develop a WAP in the future and is submitted to the Indiana Department of Environmental Management (IDEM) for funding, then all the provided data will still be relevant.

In addition to these political boundaries, the FMCW can be defined by its natural and physical boundaries. The FMCW is a part of the larger Great Miami River Watershed, but it is a nested system which can also be subdivided into smaller units called subwatersheds. There are five subwatersheds located within the larger FMCW. These units can be used to examine smaller scale processes for locally based management. The FMCW subwatersheds from north to south include, Four Mile Creek Headwaters, Little Four Mile Creek, East Fork, Acton Lake Dam, and Cotton Run (Figure 6).

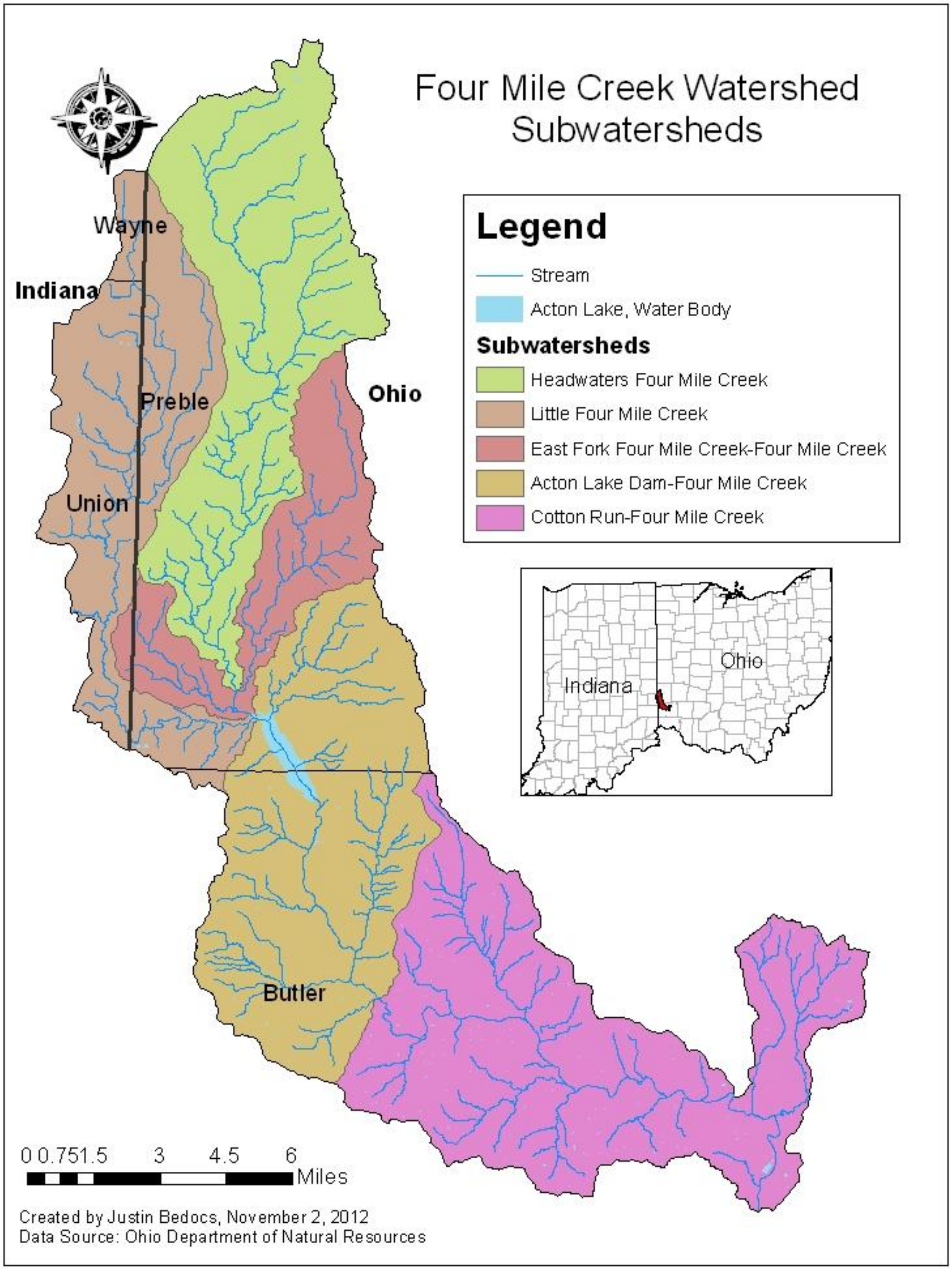

Figure 6. The FMCW is divided into five smaller subwatersheds, highlighted above.

B. Climate and Precipitation in FMCW

Climatic data is key for assessing a watershed because it provides insight into the wet and dry seasons. The climate influences water temperatures, the biotic communities, as well as the stream flow timing and magnitude after storm events. The FMCW is located in temperate southwest Ohio, has four distinct seasons throughout the year, and is marked by moderately cold winters and hot, humid summers (Vanni, 2001). The annual average temperature is 50.1°F, with an average high of 72°F in July and low of 24°F in January (NCDC, 2012). The region averages 39.54 inches of precipitation every year, with 4.72 inches in May and 2.26 in February (NCDC, 2012) (Appendix C).

Precipitation patterns can also affect runoff, which is defined as the flow of water overland. In a 17 year study, temporal patterns of runoff were studied in the northern portions of FMCW (Renwick, 2008). The authors found the highest mean runoff (60mm/month) in May and the lowest mean runoff (5 mm/month) in September, numbers that parallel monthly precipitation averages below (Renwick, 2008) (Figure 7).

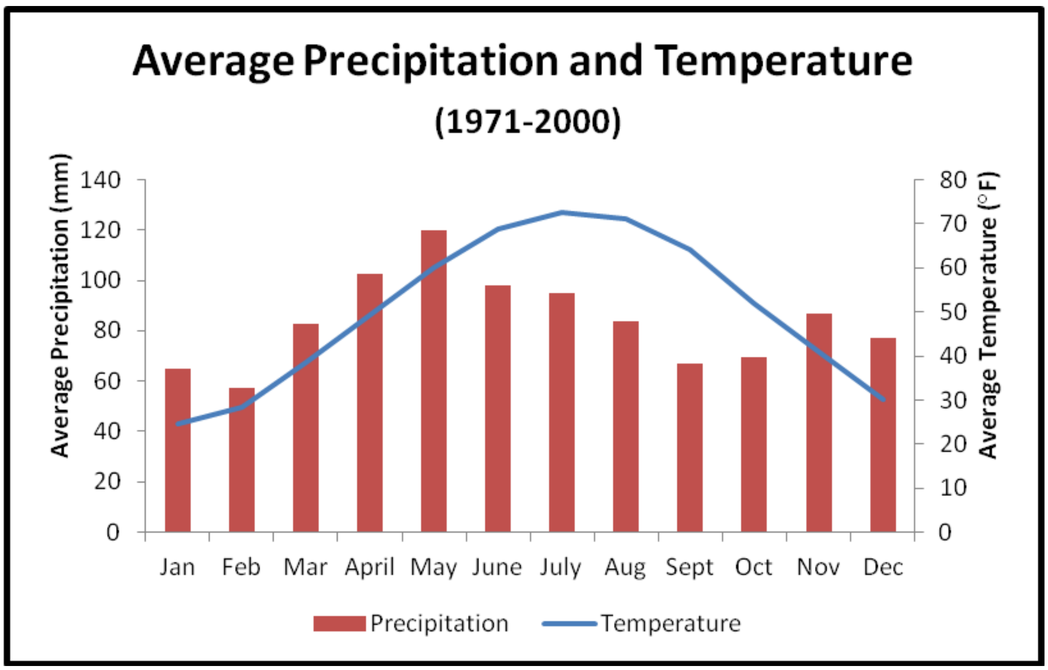

Figure 7. Average precipitation (mm) and average temperature (°F) for Eaton, Ohio (NCDC, 2012-precipitation source data converted from inches to millimeters for this figure).

C. Geology and Soils

Geology influences elevation, soils, and water flow regime, all of which play a role in determining the distribution of vegetation and wildlife throughout the watershed.

Topography

The FMCW flows south, from 374 meters at its highest point to 174 meters at its outflow into the Great Miami River, a total change in elevation of 200 meters (Figure 8). This gradient, which affects the flow of sediments and nutrients in the watershed, is determined by the underlying soils and bedrock geology.

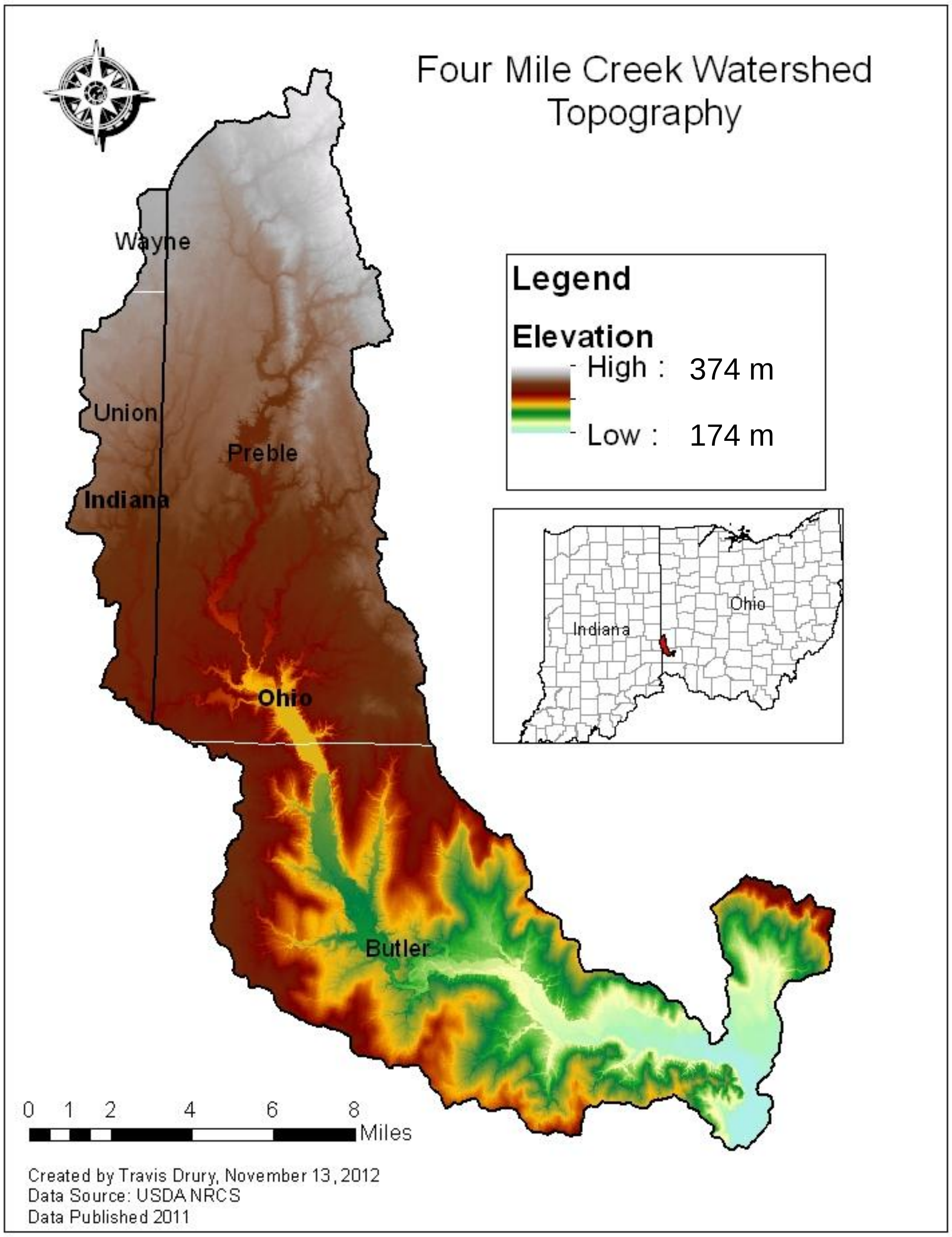

Figure 8. The FMCW elevation, ranging from 374 meters at the highest point to 174 meters at its lowest point.

Soils

The dominant soils in the FMCW consist of the Bennington-Cardington-Centerburg group, which are poorly to moderately drained (Figure 9). However, in the northern portions of the watershed, hydric (saturated) soils are more prominent (Figure 10). Hydric soils create favorable conditions for wetlands in the upper FMCW.

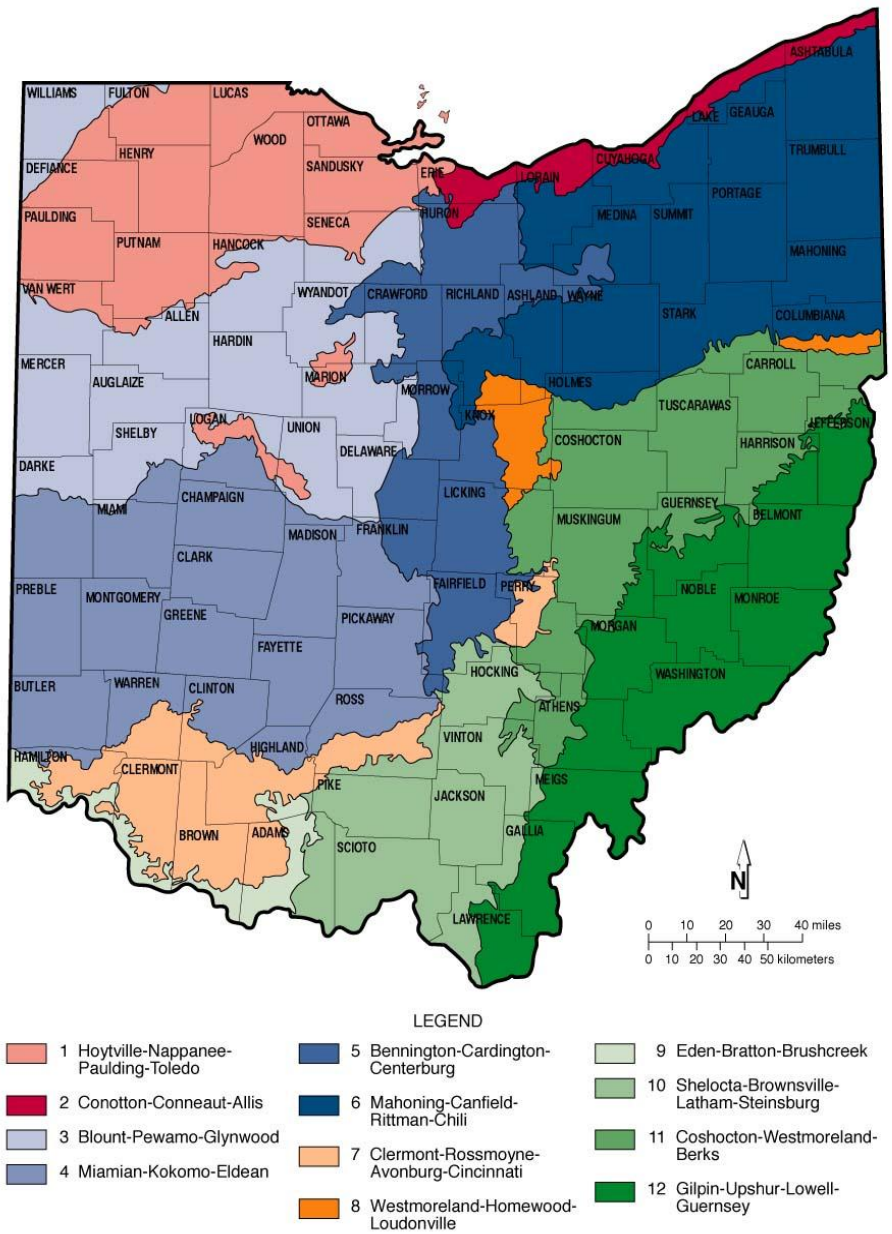

Figure 9. Soils map of Ohio. Butler and Preble counties in SW Ohio are largely dominated by soil class 5; Bennington-Cardington-Centerburg soils. These soils are poorly to moderately drained (TOSU, 2013).

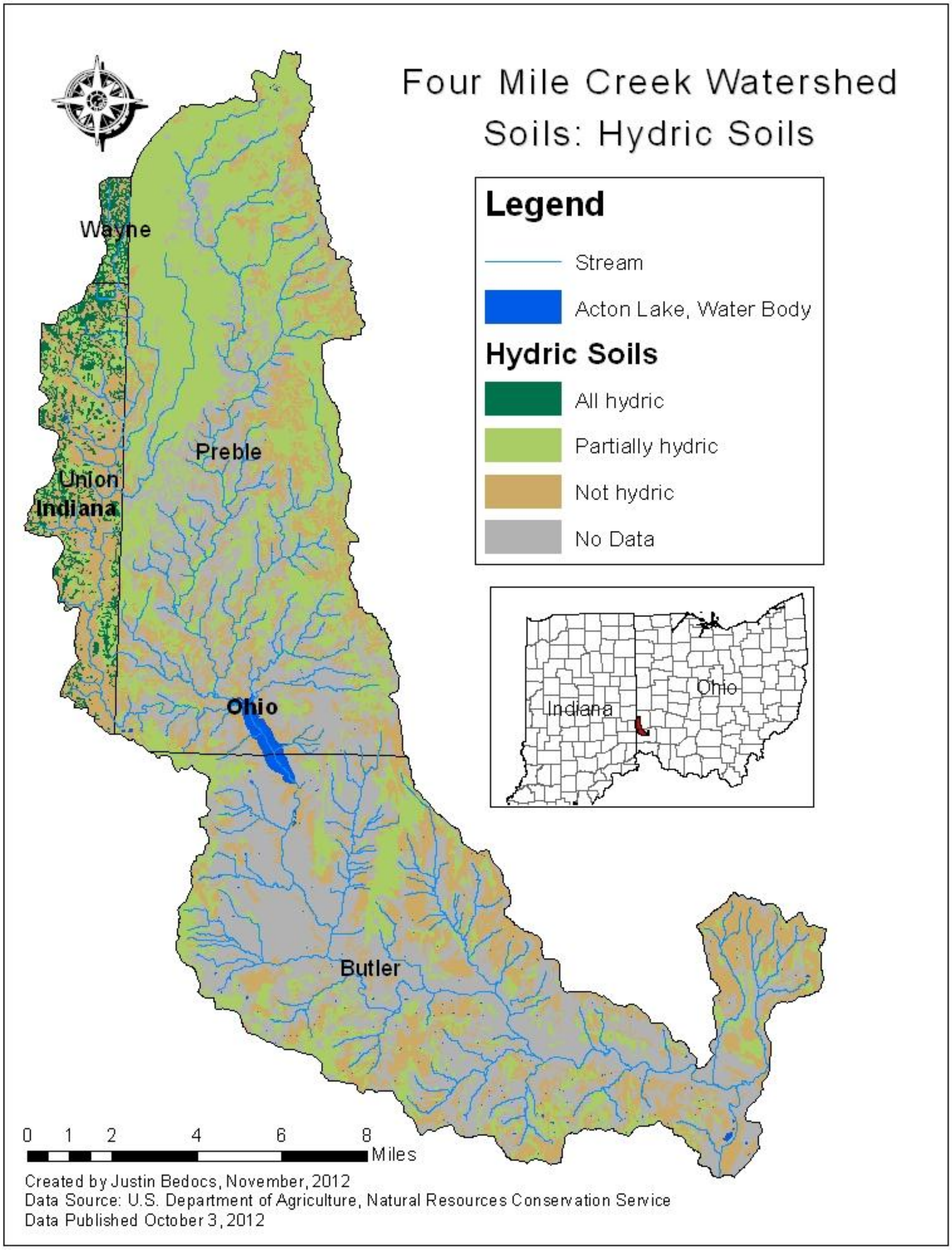

Figure 10. Distribution of hydric (saturated) soils in the FMCW.

Wetlands

In the FMCW, 1,536 acres of land (1.3%) contain wetlands and deepwater habitat (USFWS, 2013b) (Figure 11) (See Appendix D for percentages by subwatershed). A wetland is an area that is inundated or saturated by surface or ground water and supports a prevalence of vegetation typically adapted for life in saturated soil conditions (USACE, 1987). Wetlands can store water and filter sediments, which reduces flooding and prevents pollutants from entering the water. According to the U.S. Fish and Wildlife Services, a deepwater habitat is an area of land that is permanently flooded and does not support typical shallow water wetland vegetation (USFWS, 1979). Despite these differences, the National Wetlands Inventory combines wetlands and deepwater habitat in their dataset and so both are included in Figure 11.

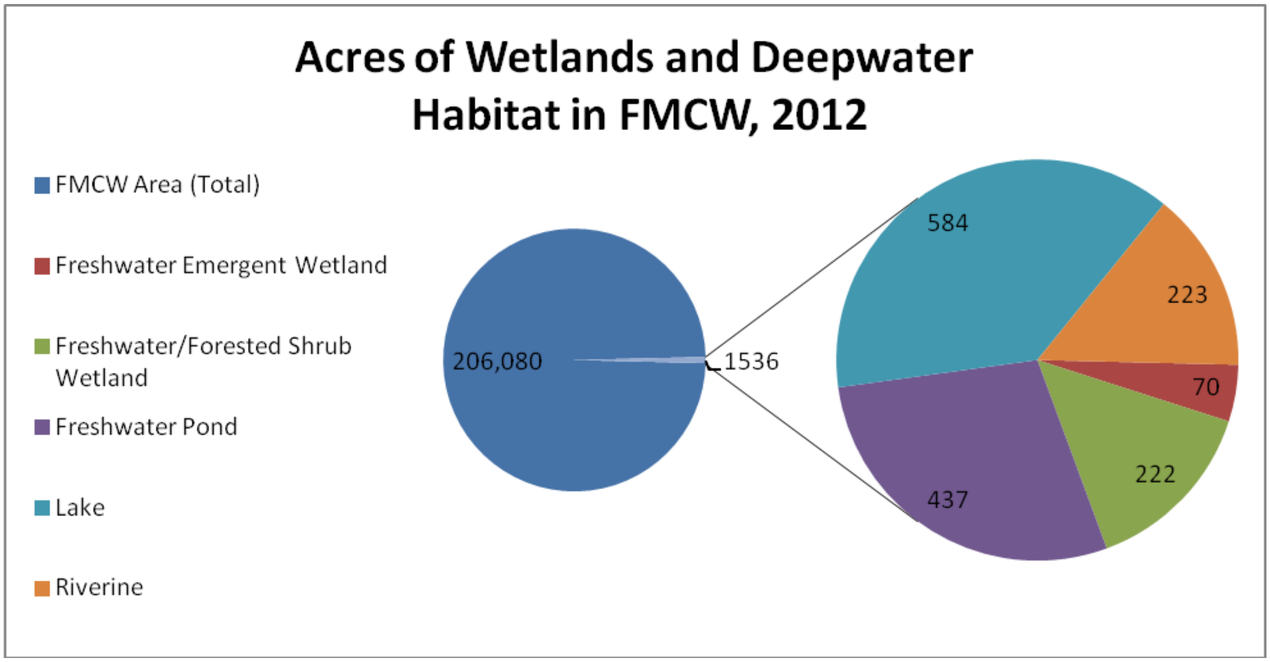

Figure 11. Total acres of wetland and deepwater habitat in the FMCW, displayed by type, 2012 (USFWS, 1979).

Figure 12 depicts the soils in the FMCW that are more or less suitable for the support of wetlands. Soils in the northern portion of the FMCW are better suited for these habitats. Wetlands can be utilized for nutrient and pollutant uptake if situated appropriately within the watershed (Hathaway and Hunt, 2010). While soils most suitable for wetlands within the FMCW are found upstream, Best Management Practices (BMPs) suggest developing wetlands downstream from pollution sources (Hathaway and Hunt, 2010).

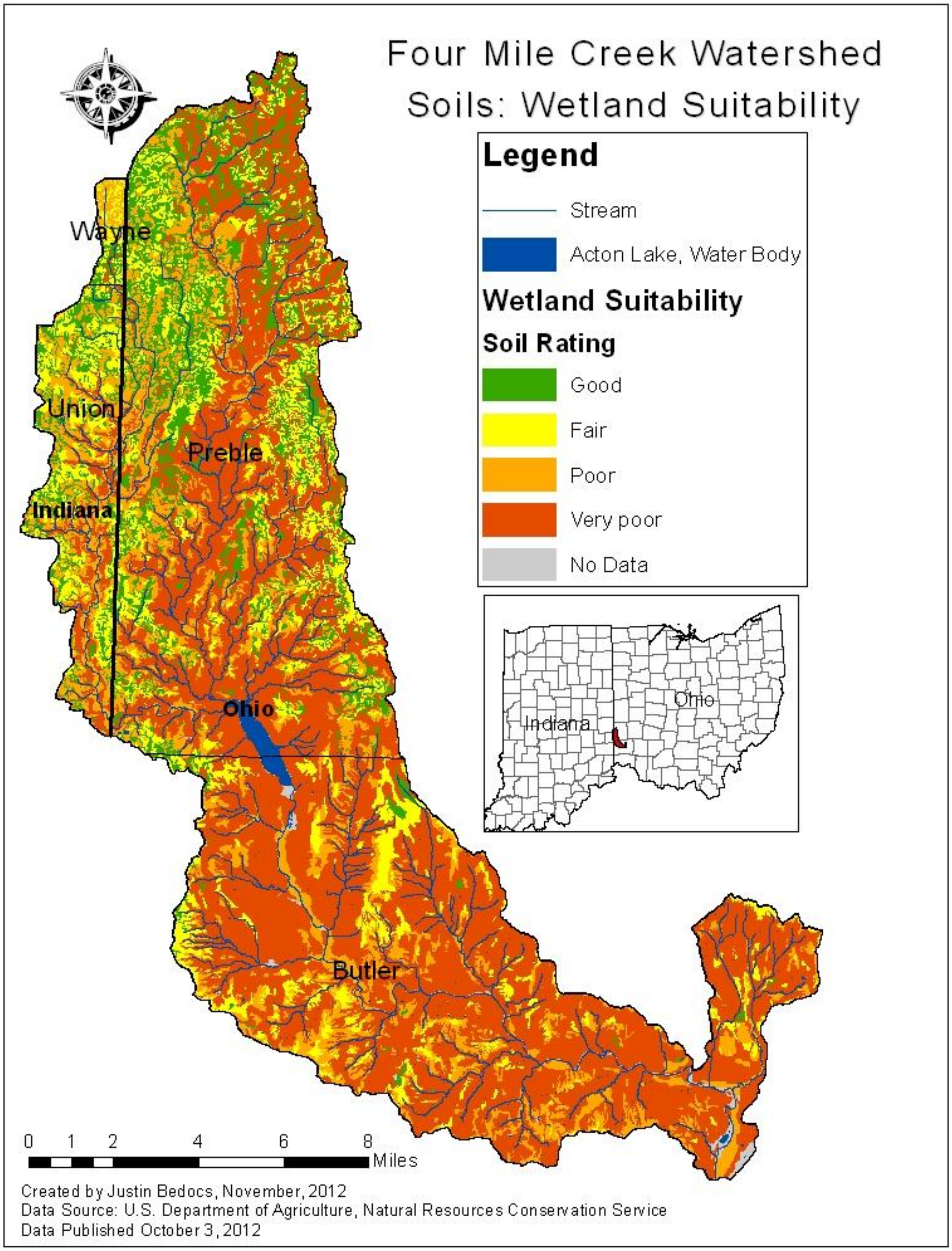

Figure 12. Soils rated by ability to support wetland habitat. Soils rated "Good" are concentrated in the northern area.

Runoff

Runoff potential is greatest in the southern half of the watershed, although it is present throughout the entire FMCW (Figure 13). Runoff is water that flows overland and occurs when soils are saturated or when soils are not suitable for water infiltration (i.e. clay). Hydrologic soils are grouped according to their relative runoff potential and infiltration rates. These groups range from low runoff potential and high infiltration rates (A) to high runoff potential and low infiltration rates (D) (Figure 14). Water runoff can contribute to soil erosion in the FMCW.

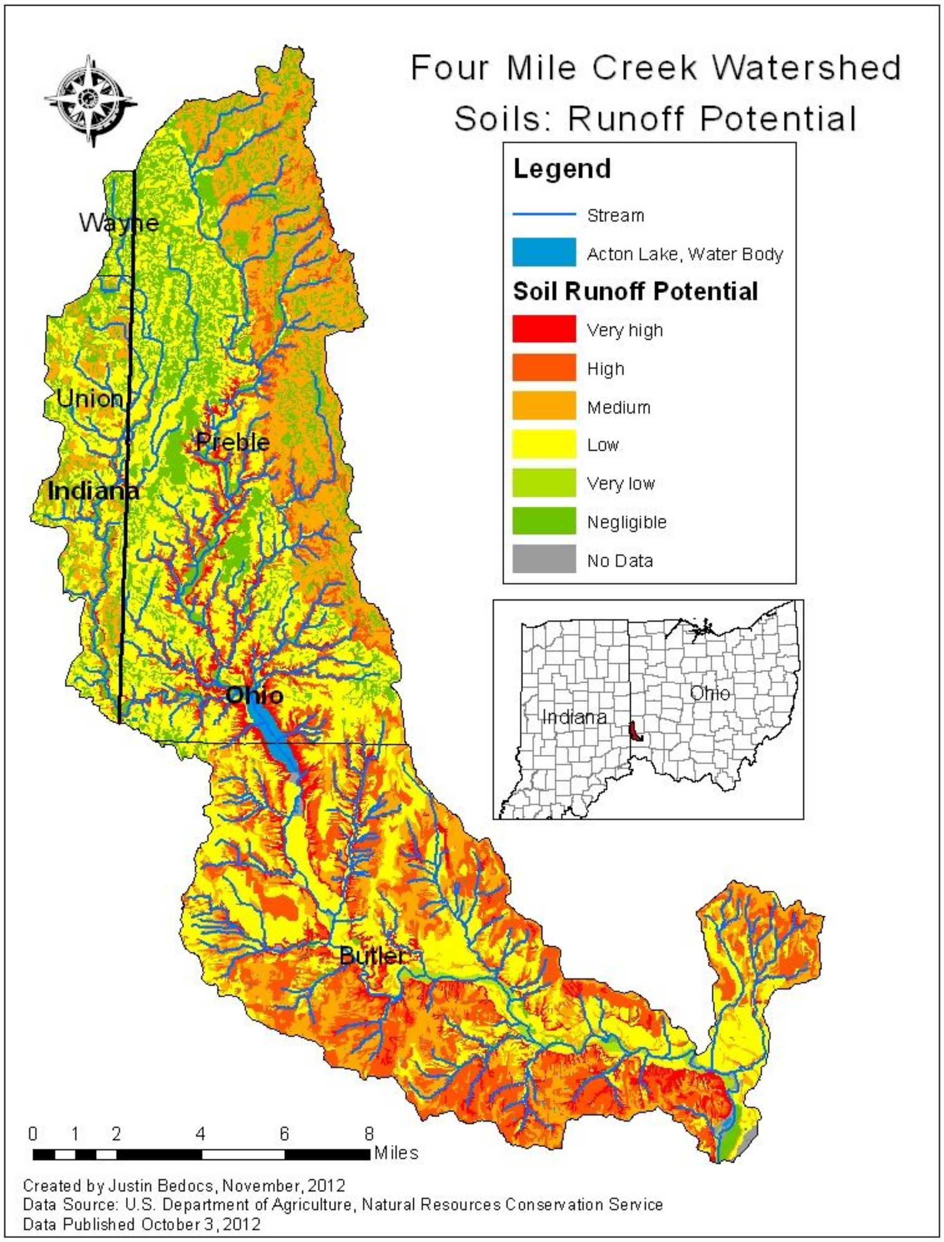

Figure 13. Soils that are prone to surface water runoff within the FMCW.

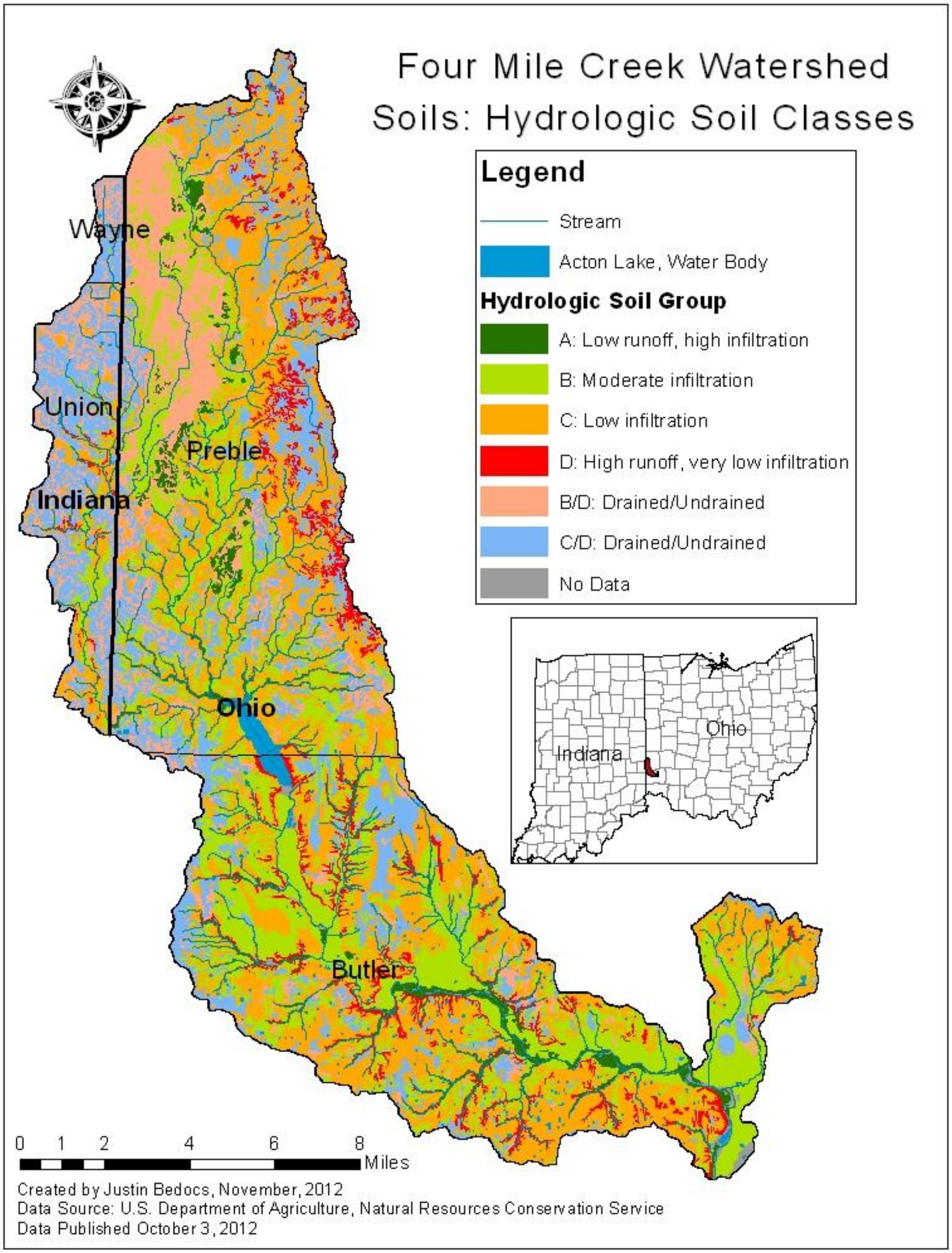

Figure 14. Hydrologic soil groups range from low runoff potential and high infiltration rates (A) to high runoff potential and low infiltration rates (D).

Erosion

Highly erodible soils in the FMCW are found predominately alongside rivers and stream banks, where the slope is steep (Figure 15). The potential erosion hazard is also highest along the banks of rivers and streams, indicating a relationship between slope and erosion (Figure 16).

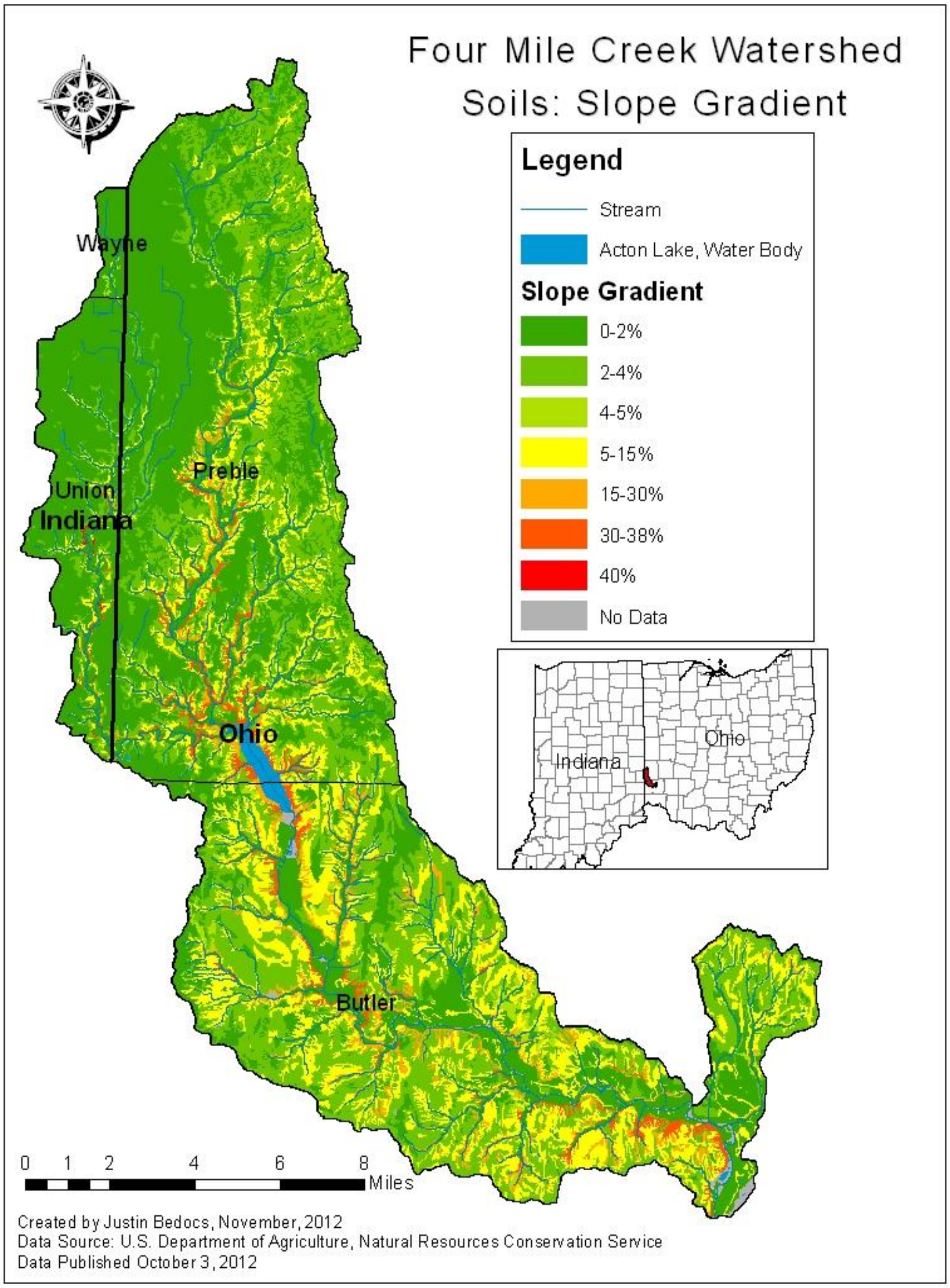

Figure 15. Slope gradients in the FMCW. Slope gradient is steepest along stream banks.

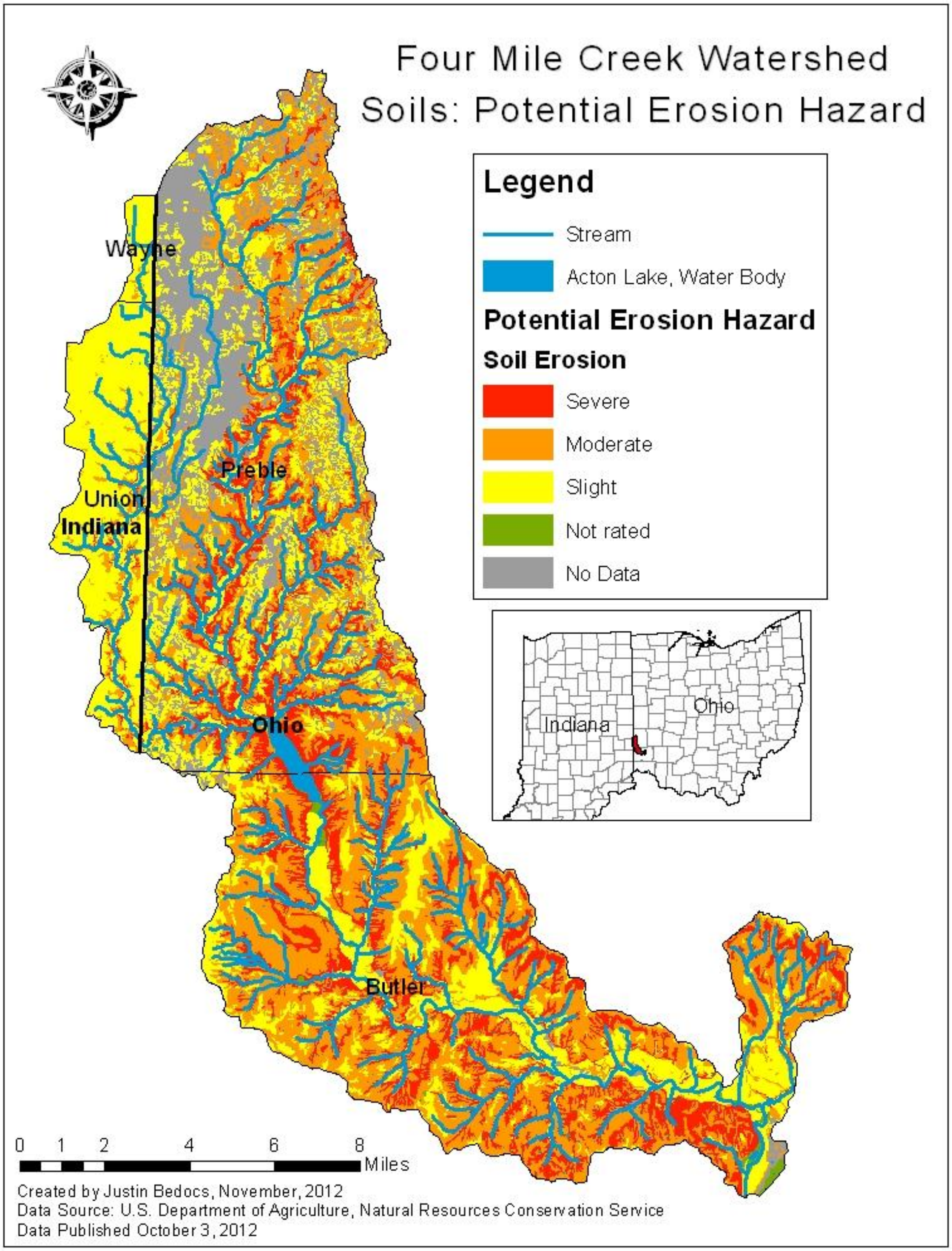

Figure 16. Potential erosion hazard, ranging from slight to severe. Soils with severe potential erosion hazard are typically adjacent to streams.

Glacial History

The FMCW was once a glaciated region, scoured by the Wisconsinan age glacial event between 14,000-24,000 years ago (Figure 17). These events deposited mostly glacial till and a very small portion of the southern FMCW is alluvial till (Figure 18). Dominant glacial landforms in the FMCW are ground moraines and end moraines, which are long, finger-like hills of sediment left behind by glaciers (Figure 17).

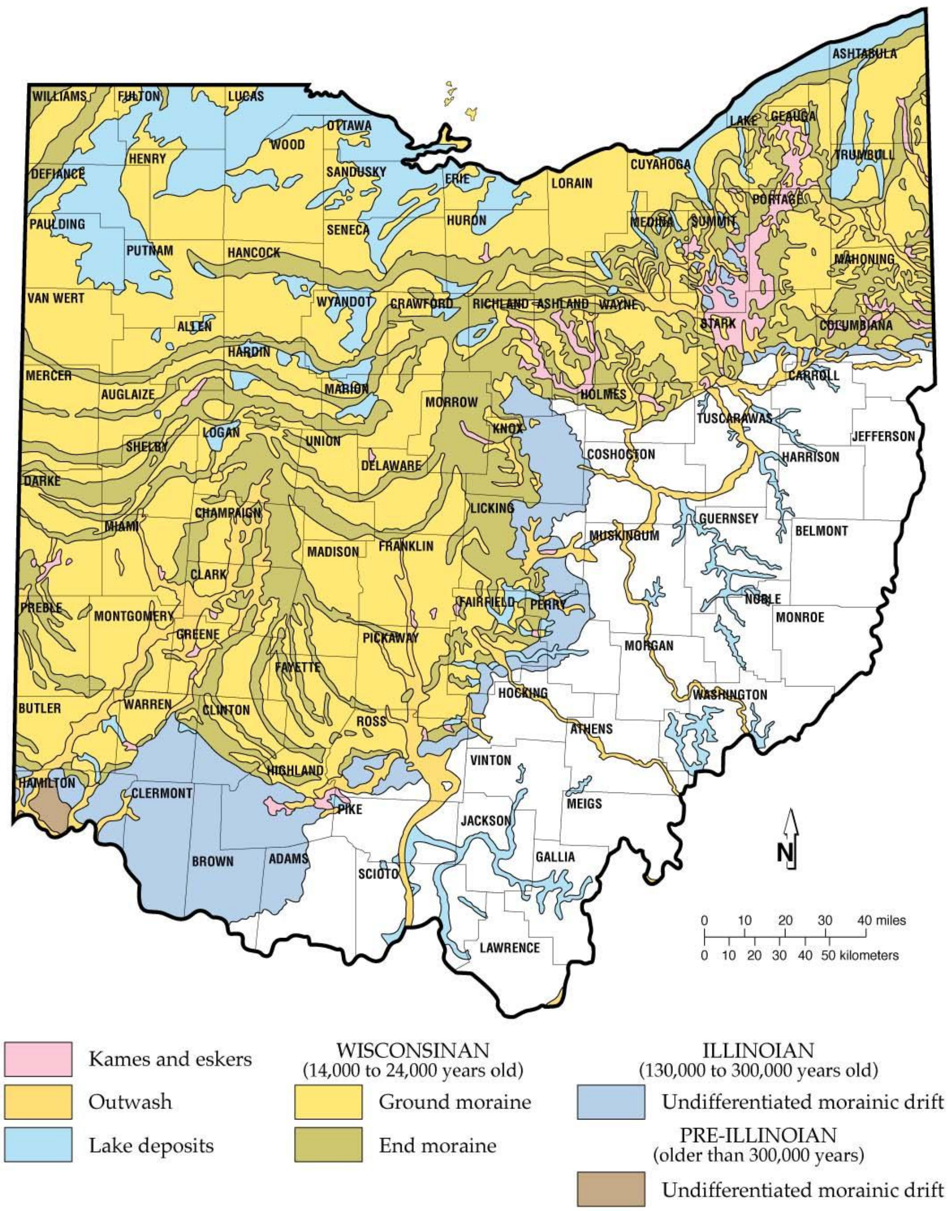

Figure 17. Glacial map of Ohio illustrating that Butler and Preble counties are largely composed of glacial outwash, ground moraines, and end moraines (TOSU, 2013).

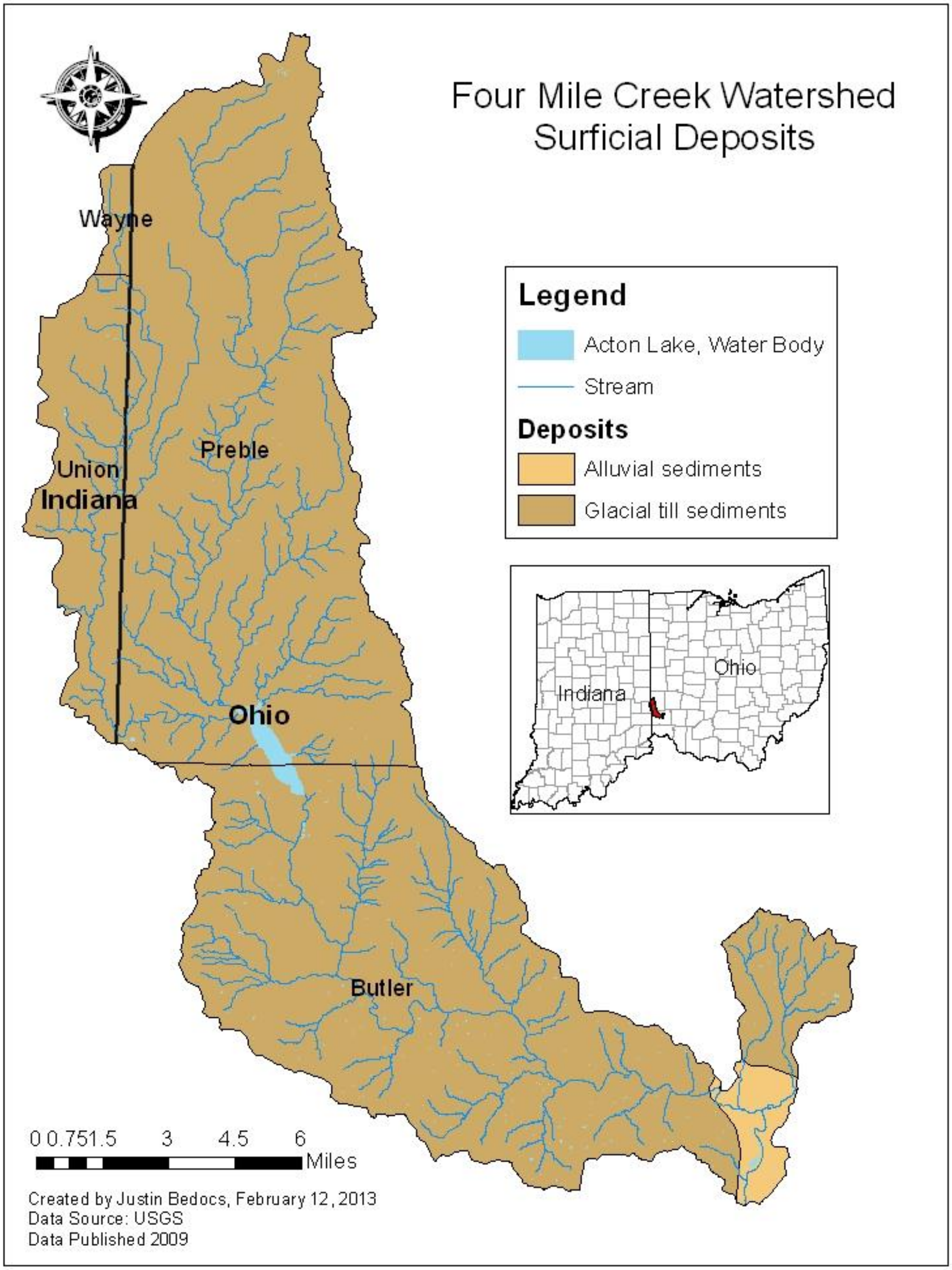

Figure 18. The FMCW glacial deposits, the majority of which are glacial till sediments.

Bedrock Type and Age

Underlying these surficial glacial till deposits is the region's bedrock. The FMCW has two major bedrock types: Ordovician (500-440 million years ago) and Silurian (440-408 million years ago) (Figure 19). Both are composed of alternating limestone and shale typical of a marine environment with shallow and deep sea cycles (Hansen, 1997; Hansen, 1998). Bedrock type affects local hydrologic patterns, and can influence the type and presence of ground water aquifers (See Chapter 3). It can also influence the vegetation types and typical species found in the region.

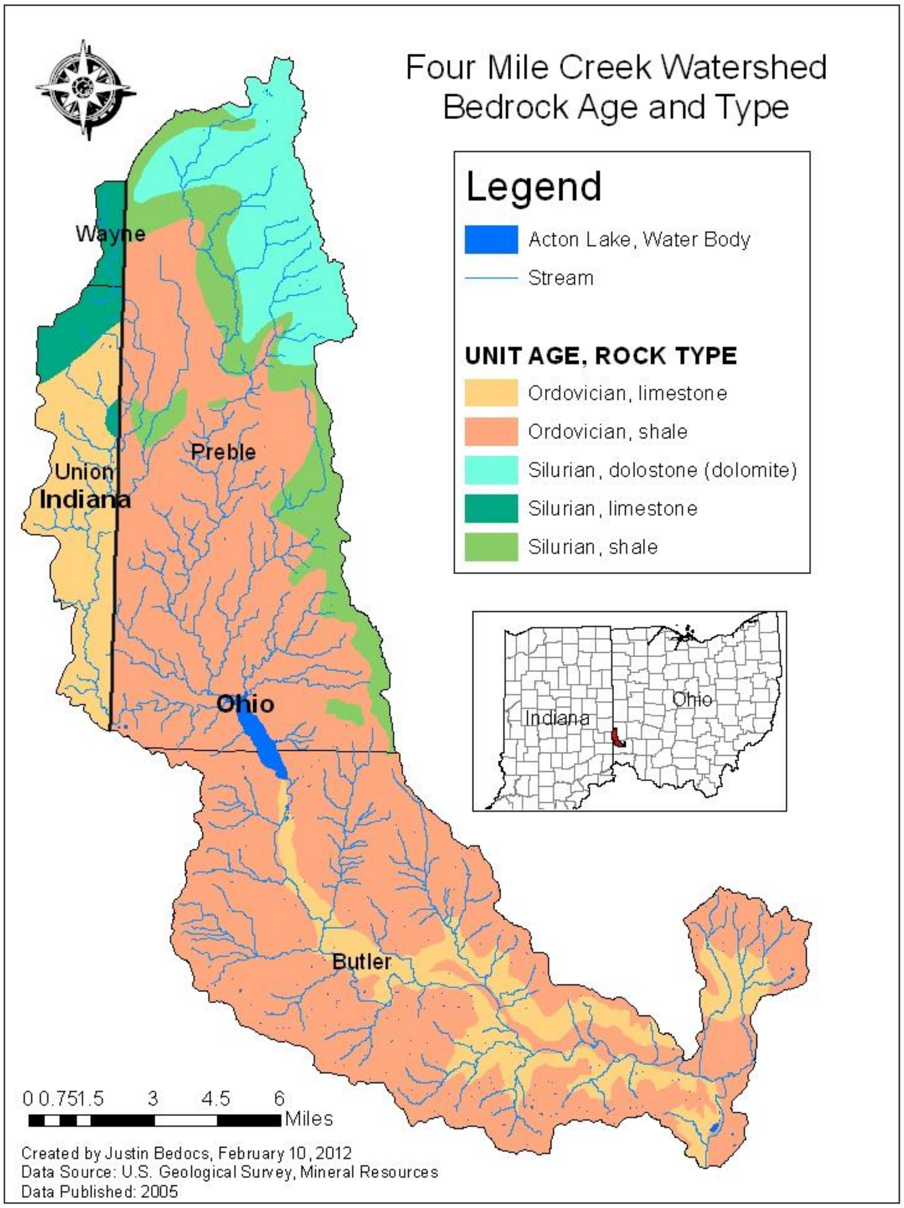

Figure 19. Distribution of bedrock age and types, largely dominated by Ordovician shale.

D. Biological Features

The FMCW supports diverse aquatic communities including 63 species of fish and 334 taxa of macro invertebrates (OEPA, 2012b). Because biodiversity indicates environmental health, it is important for a stream to support a variety of different species. To ensure appropriate watershed planning, it is imperative to be aware of any species that may be threatened, rare, or endangered. Knowing which species are at risk can aid in the designation of protected areas.

Threatened and Endangered Species

Federal and State Listed Species

Federally listed species are threatened or endangered throughout all or a significant portion of their geographic range. Federally listed species are protected under the Endangered Species Act (ESA) of 1973. The purpose of the act is to protect both the species and the habitat it depends on. In addition to the ESA, the Bald and Golden Eagle Protection Act prevents the "take" of the birds, their nests, or eggs by anyone who does not yield a proper permit (USFWS, 2013a). Additional regulations may be implemented by state governments in areas where species are locally endangered, threatened, or rare.

Both Ohio and Indiana also provide additional protection under state laws (Ohio Rev. Code §1531; Indiana Code §14-22-34-12). State listed species are defined as native species or subspecies whose survival is in jeopardy within the boundaries of the state (ODNR, 2013e). While it is important to protect federally listed species, it is equally important to protect state listed species because they are at risk of becoming locally extinct. Local extinction can lower biodiversity within the state and negatively impact state ecosystems.

The Bald Eagle, which can be found in Butler and Union counties, has been federally delisted. Therefore, it is no longer protected under the federal ESA. However, it is currently protected under the Bald and Golden Eagle Protection Act of 1940 (USFWS, 2013a).

Table 2 shows the federally protected and listed species along with state endangered, threatened, and candidate species which inhabit areas of Butler, Preble, Union, and Wayne counties (See Appendix E for the complete lists for Ohio and Indiana by county).

Table 2. Federally threatened and endangered species, and state threatened and endangered species (USFWS, 2012a & 2012c; IDNR 2012; ODNR, 2012b).

	Federal	Endangered (OH)	Threatened (OH)	Endangered (IN)
Mammal	Indiana Bat – *Endangered*			
Mollusk	Rayed Bean - *Endangered*			
Amphibians		Cave Salamander		
Birds	Bald Eagle – Bald Eagle Protection Act *found in Butler and Union counties*		Upland Sandpiper, Peregrine Falcon, Least Bittern, Black-crowned Night-heron, Osprey	Upland Sandpiper, Sedge Wren, Cerulean Warbler, Least Bittern, Black-crowned Night-heron, Osprey, Barn Owl, King Rail
Fish			Tonguetied Minnow	
Insects		Plains Clubtail, Blue Corporal		Cobblestone Tiger Beetle, Brown Spiketail, Wabash River Cruiser,Northern Casemaker Caddisfly
Invertebrates			Sloan's Crayfish	
Plants		Midland Sedge, Timid Sedge, Five-angled Dodder, Pale Umbrella-sedge, Burhead, Snowy Campion	Missouri Gooseberry, Soft-leaved Arrow-wood	Heavy Sedge, Heart-leaved Plantain, Calamint, Eastern Featherbells
Reptiles	Eastern Massasauga – Federal Candidate		Kirtland's Snake	Kirtland's Snake, Blanding's Turtle, Butler's Garter Snake, Redside Dace, Variegate Darter

Non-Native and Invasive Species

Non-native species are animals or plants that are not naturally found in the region (ODNR, 2012a). While many non-native species were accidentally introduced, some have been intentionally introduced for such purposes as erosion control or horticulture. A non-native species is considered invasive if it causes harm to human health or the environment, or if it affects the economy (ODNR, 2013c). Invasive species have few natural predators or controls and they can alter natural habitat and displace native species (ODNR, 2013c).

The following information is currently available about invasive and non-native species (Table 3):

- There are 213 non-native **plant species** in Butler, Preble, Wayne, and Union counties (EDDMapS, 2013a,b,c,d) (Appendix E).
- There are 103 non-native **aquatic animal species** in Ohio and 73 in Indiana (USGS, 2013a,b) (Appendix E).
- No information is currently available for **terrestrial animal species** in Ohio though the ODNR site indicates that this information should be available soon (ODNR, 2012a).
- The Granulate Ambrosia Beetle and Soybean Aphid have been found in both Wayne and Union counties in Indiana; and the Pine Shoot Beetle has been found in Wayne County and is designated as one of the **Most Unwanted Plant Pests** in Indiana (Purdue University, 2013).

Table 3. Invasive non-native species designated by ODNR as "Top Ten" and by IDNR as "Most Unwanted" (ODNR, 2013c; Purdue University, 2013), X indicates that the species was found in the marked county.

Species	Butler	Preble	Wayne	Union
Garlic Mustard (*Alliaria petiolata*)	X	X	X	X
Autumn-olive (*Elaeagnus umbellata*)	X	X	X	X
Japanese Honeysuckle (*Lonicera japonica)*	X		X	X
Amur Honeysuckle (*Lonicera maackii*)	X		X	X
Purple Loosestrife (*Lythrum salicaria*)	X			
Reed Canarygrass (*Phalaris arundinacea*)	X	X	X	X
Common Reed (*Phragmites australis australis*)			X	
Japanese Knotweed (*Polygonum cuspidatum*)		X	X	X
European Buckthorn (*Rhamnus cathartica*)	X			
Multiflora Rose (*Rosa multiflora*)	X	X	X	X

CHAPTER THREE: CHARACTERISTICS OF WATER RESOURCES

Water resources are affected by the geology of the land and the soils within the FMCW. These soils determine how water flows above and below ground. The ground water and surface water of the FMCW are directly affected by the amount of precipitation and infiltration that occurs at the soil level. Therefore, the information about soil types and climate in the previous chapter creates a framework with which to examine surface water and ground water in the FMCW.

A. Surface Water

Lakes and Reservoirs

In the FMCW, there is one large reservoir, called Acton Lake, located in the center of Hueston Woods State Park (USACE, 1980). The Four Mile Creek was dammed in 1956, creating a long and narrow reservoir in a flooded stream valley (Figure 20). Water drains from a large area and flows through the lake at a high rate. The dam at the outflow of Acton Lake allows water to exit over the spillway and keeps the water level relatively constant (Vanni, 2006).

<u>Acton Lake</u>
Surface Area: 232 hectares
Mean Depth: 3.9 meters
Length: 2.7 miles

Figure 20. Aerial view of Acton Lake. Photo taken by Bill Renwick.

There is one other identified reservoir in the FMCW, the Trenton Sportsman Club Lake, located in the southern portion of the watershed (USACE, 1980). There are also numerous small unnamed ponds throughout the FMCW.

Streams

There are 26 named streams within the FMCW, stretching a total of 150 miles (Figure 21) (Table 4). Four Mile Creek is the longest stream and the main branch of the FMCW. Two major tributaries to the Four Mile Creek main stem are the Little Four Mile Creek and the East Fork Four Mile Creek. There are also several small unnamed tributaries shown in FMCW (Figure 21).

Table 4. Streams in the FMCW with name, length (mi), and corresponding map label (USGS, 5).

Stream Name	Length(mi)
1. Becketts Run	2.6
2. Brenners Run	1.6
3. Bull Run	2.8
4. Church Creek	1.5
5. Collins Creek	3.5
6. Cotton Run	5.4
7. Coulters Run	3.0
8. Curlane Run	2.0
9. Darrs Run	6.6
10. Dixon Branch	4.0
11. East Fork Four Mile Creek	9.7
12. Fleisch Run	8.0
13. Four Mile Creek	41.5
14. Goodwins Creek	1.4
15. Harkers Run	5.5
16. Lick Run	2.8
17. Little Four Mile Creek	21.3
18. Mutton Run	5.2
19. Radar Creek	1.7
20. Railsback Creek	1.1
21. Scotts Run	2.1
22. Sevenmile Creek	5.5
23. Square Run	1.0
24. Stony Run	4.4

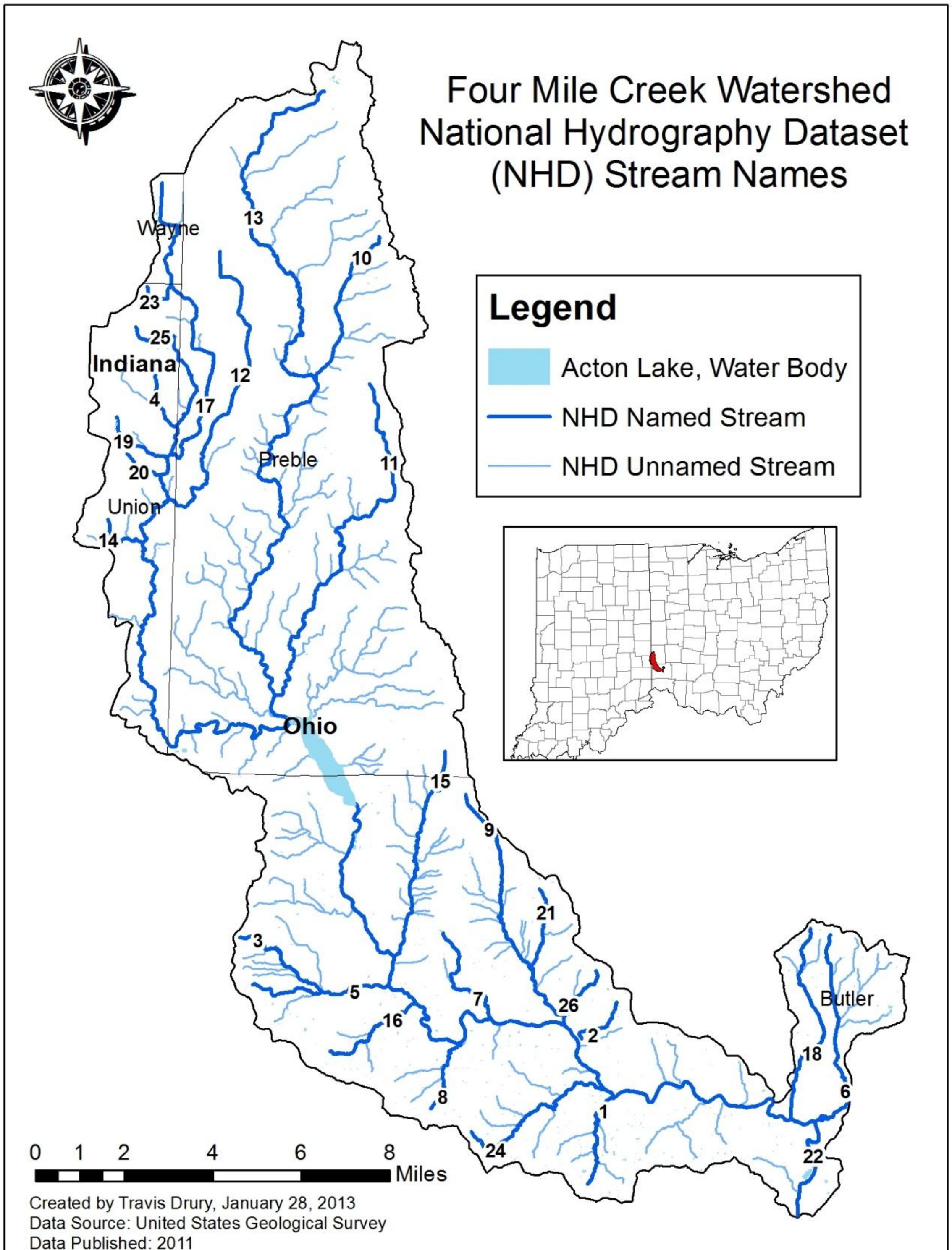

Figure 21. Streams within the FMCW with names corresponding to Table 4.

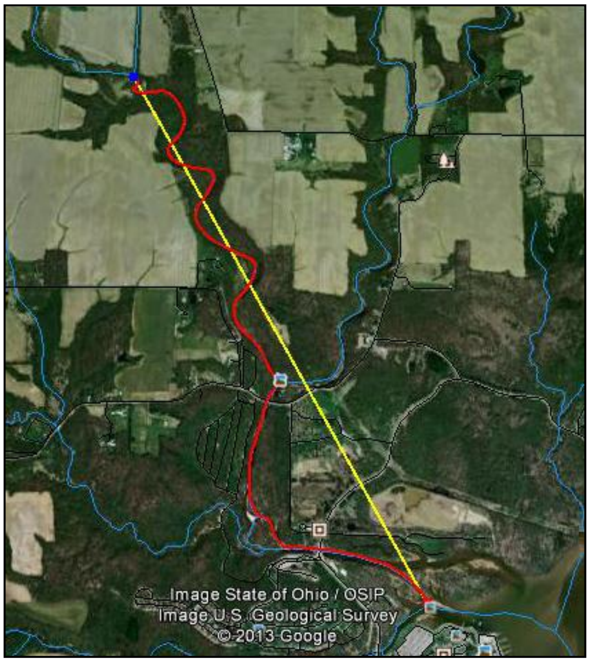

Figure 22. Google Earth image of the Four Mile Creek (red) and the total distance between two points (yellow), used to determine the sinuosity of the stream.

Stream length, sinuosity (curvature of the stream), and discharge (the amount of water flowing through the stream) can be useful for watershed management.

Sinuosity

Sinuosity is the ratio of total river length between two points divided by the straight distance between those same two points: the higher the ratio, the more sinuous the stream. A stream with a higher sinuosity ratio has a larger surface area and provides greater opportunity for water and sediment interactions (ODNR, 2013d). A stream or channel with a sinuosity ratio greater than 1.5 is considered meandering (high), whereas a stream with a sinuosity ratio of less than 1.5 is considered a straight channel (ODNR, 2013d).

There is no data readily available on sinuosity for the FMCW; however, the team calculated this ratio for four segments of streams in the watershed.

Four Mile Creek at the Acton Lake inflow (Figure 22):

$$\frac{3{,}772\ m}{2{,}922.5\ m} = 1.29$$

Four Mile Creek, just south of the dam:

$$\frac{2{,}994\ m}{2{,}600\ m} = 1.15$$

East Fork Four Mile Creek, near the confluence of the Four Mile Creek:

$$\frac{3{,}194\ m}{2{,}475\ m} = 1.29$$

Little Four Mile Creek, near the inflow of Acton Lake:

$$\frac{3{,}109\ m}{2{,}076\ m} = 1.50$$

Discharge

Discharge is the amount of water flowing past a single point (often a gage) within a stream (ODNR, 2013d). Stream discharge is strongly correlated with the concentration of nutrients and sediments in the water and is therefore an important parameter to consider when assessing water quality (Renwick, 2008). Acton Lake discharge was recorded at three gaging stations from 1994 to 2013 by researchers from Miami University. These gaging stations measured water volume flowing from three uniquely identified subwatersheds (Renwick, 2008) (Figure 23). Annual discharge (1994-2011) for the three subwatersheds is depicted in Figure 24, while average total discharge over this period is depicted for each subwatershed in Figure 25. As both figures illustrate, the larger the subwatershed, the higher the discharge rate (Renwick, 2008) (Note: The three watersheds analyzed by Miami researchers and depicted in Figure 23 were defined differently from the subwatersheds described in Chapter Two).

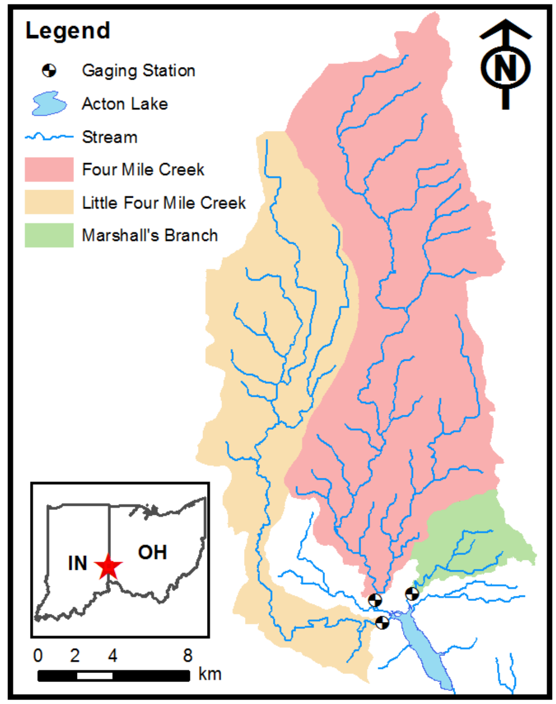

Figure 23. Three subwatersheds studied within the Acton Lake Watershed, with gaging stations indicated (Renwick, 2008).

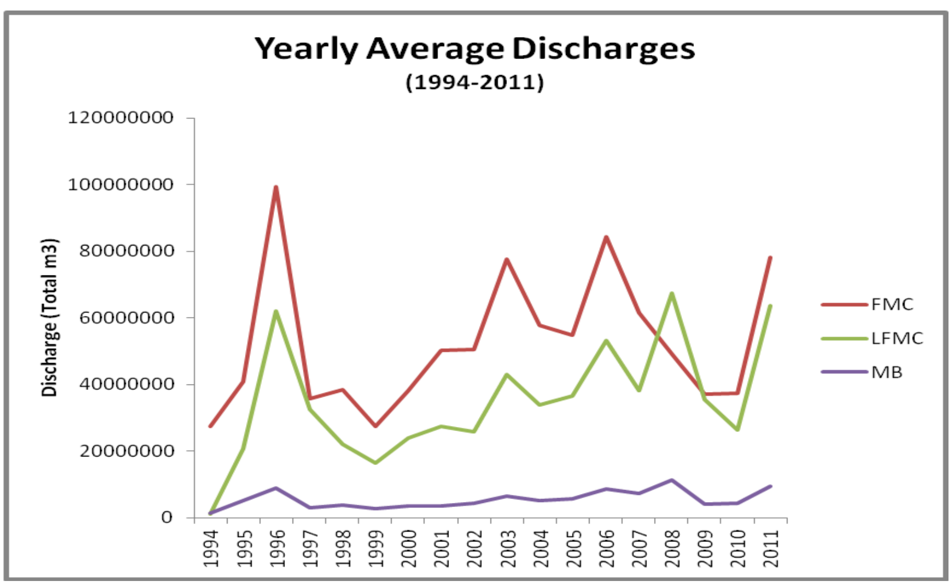

Figure 24. Yearly average discharge for Four Mile Creek Subwatershed (FMC), Little Four Mile Creek Subwatershed (LFMC), and Marshall's Branch Subwatershed (MB), presented in total cubic meters, over a 17 year time frame (Renwick, 2008).

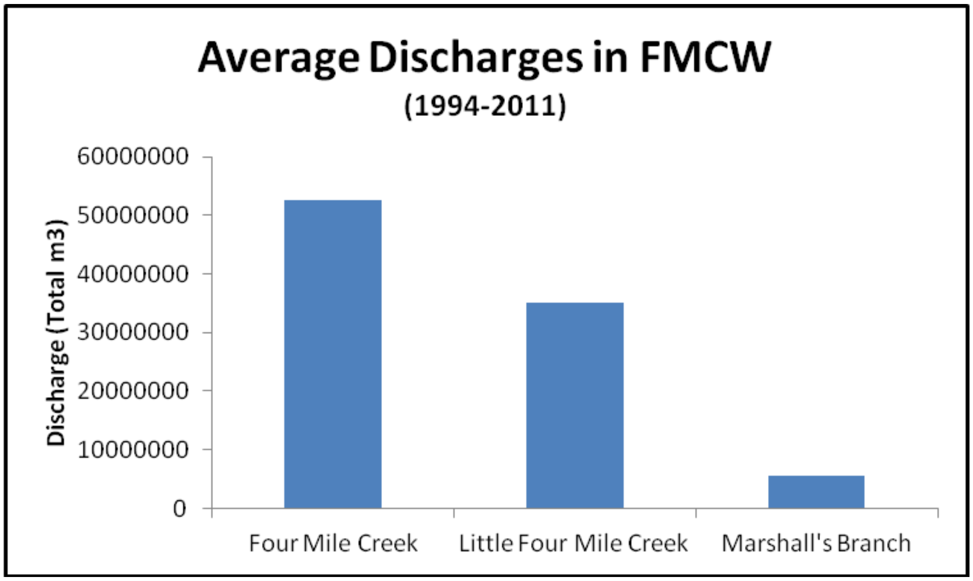

Figure 25. Average total discharge for the three subwatersheds over a 17 year time frame (Renwick, 2008).

B. Ground Water

Ground water exists below the surface of the land, filling pore spaces between particles, sand grains, or cracks in rocks. An aquifer is a collection of ground water that is capable of yielding usable quantities of water (OEPA, 2013c). These sources of water are often utilized in agricultural, industrial, and domestic settings.

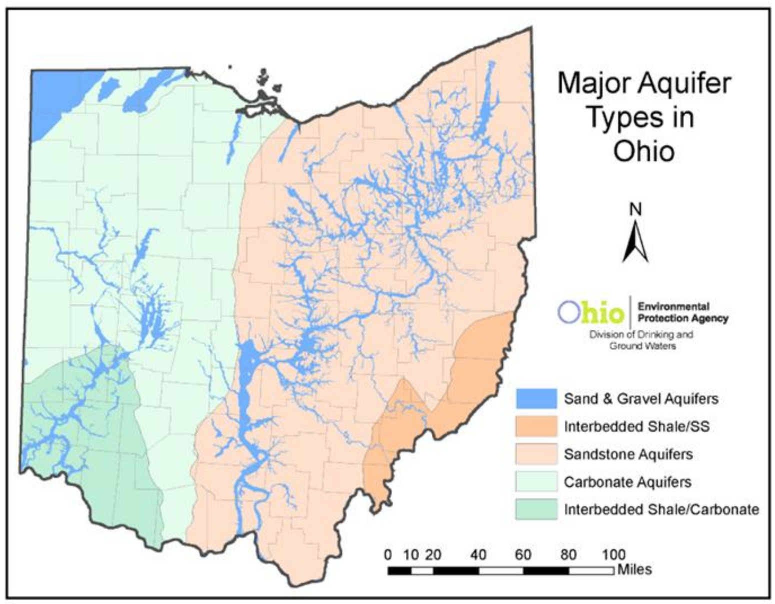

Figure 26. Major aquifer types in Ohio (OEPA, 2013c).

There are two types of aquifers: unconsolidated and consolidated. Unconsolidated aquifers are aquifers made up of loose materials, often sands and gravels; in the FMCW they are composed of glacial till (USGS, 2012a). Consolidated aquifers are composed of bedrock; in the FMCW these are shale and carbonate rocks (Figure 26). Both types of aquifers are valuable, however unconsolidated aquifers tend to produce higher useable water quantities than consolidated aquifers (ODNR, 2012c).

Unconsolidated aquifers in the FMCW are named according to glacial events, locations, or types of glacial till. This naming system is not always the same between states, and in Indiana and Ohio the unconsolidated aquifers were uniquely identified (Figures 27 and 28).

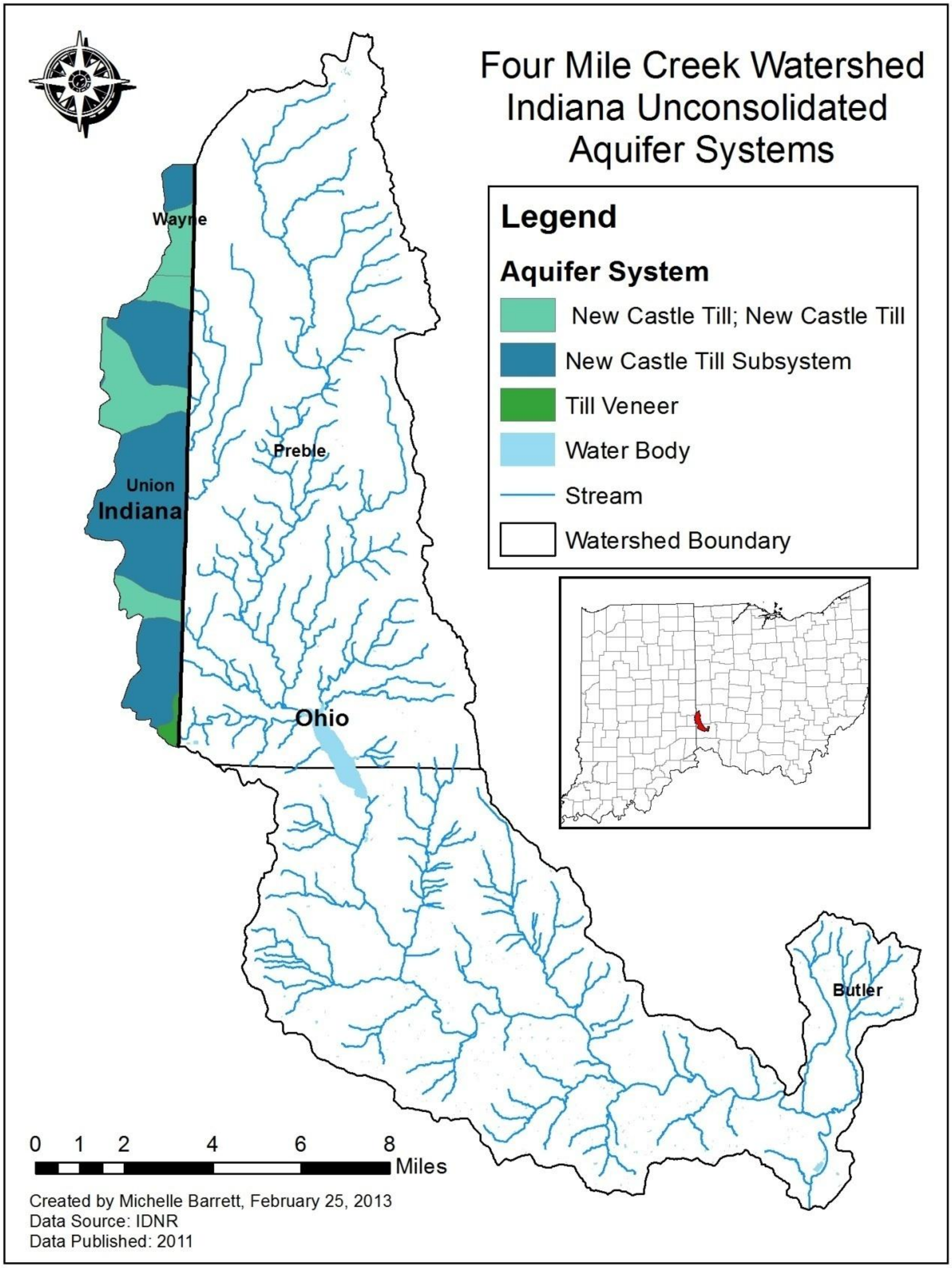

Figure 27. Unconsolidated aquifer systems in the FMCW, Indiana.

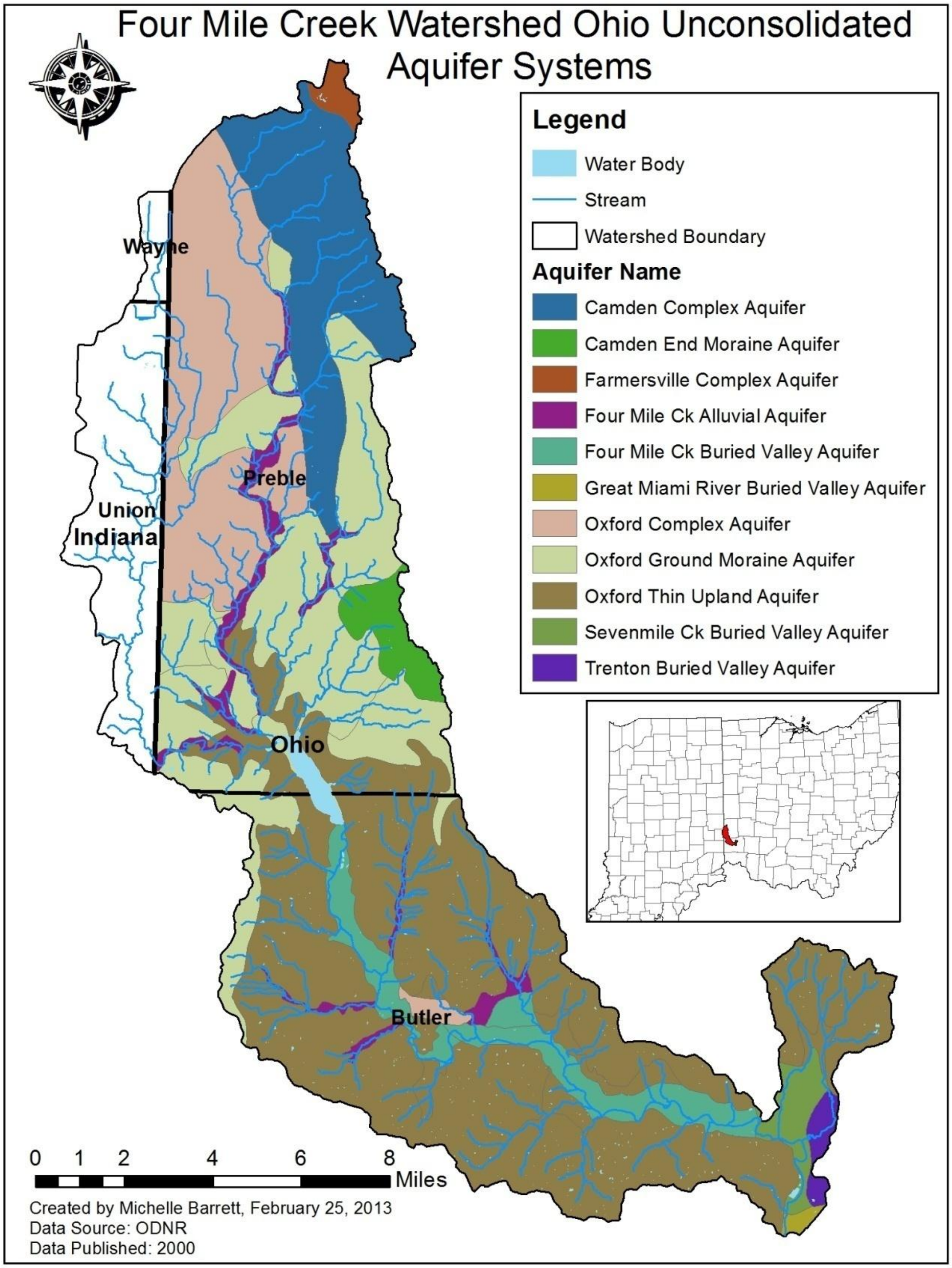

Figure 28. Unconsolidated aquifer systems in the FMCW, Ohio.

There are two consolidated aquifers in the FMCW: the Ordovician bedrock aquifer, and the Silurian bedrock aquifer. These aquifers correspond to the bedrock geology types of the FMCW (Figure 29).

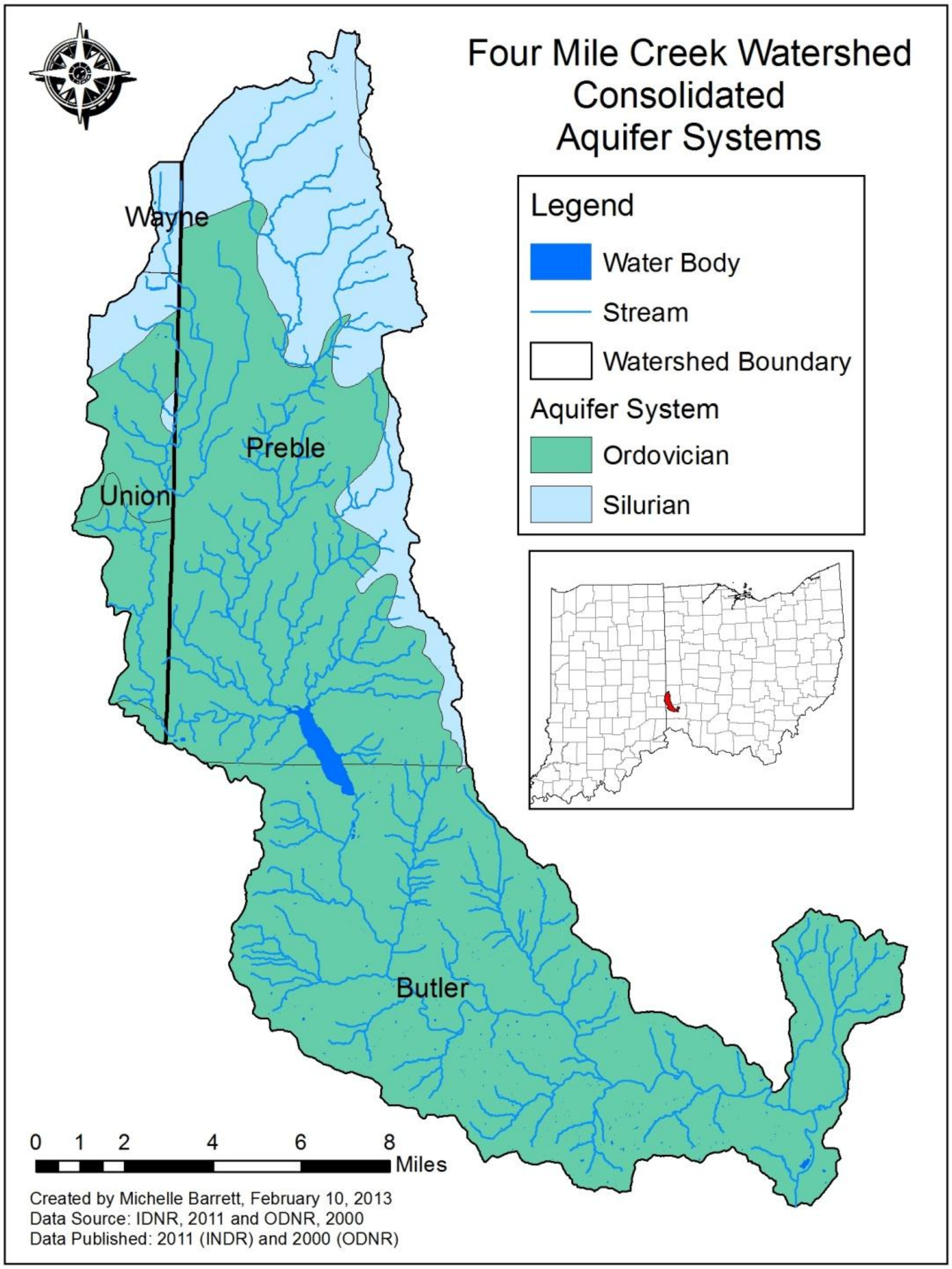

Figure 29. Consolidated aquifer systems in the FMCW.

Ground Water Pollution Potential

Many communities rely on ground water for agricultural, industrial, or domestic water supply, so it is important to carefully monitor sources of ground water. The ODNR uses a weighted scoring system to categorize ground water pollution potential for specific locations. This system is called DRASTIC (*Depth* to Water, Net *Recharge*, *Aquifer* Media, *Soil* Media, *Topography*, *Impact* of the Vadose Zone Media, *Conductivity* of the Aquifer). The DRASTIC scale ranges from 0 to 223; the lower the number, the lower the pollution potential (ODNR, 2013a). Figure 30 indicates that there is higher ground water pollution potential along the Four Mile Creek. Note that the highest DRASTIC score recorded was 211. Comparable data from Indiana was not obtained.

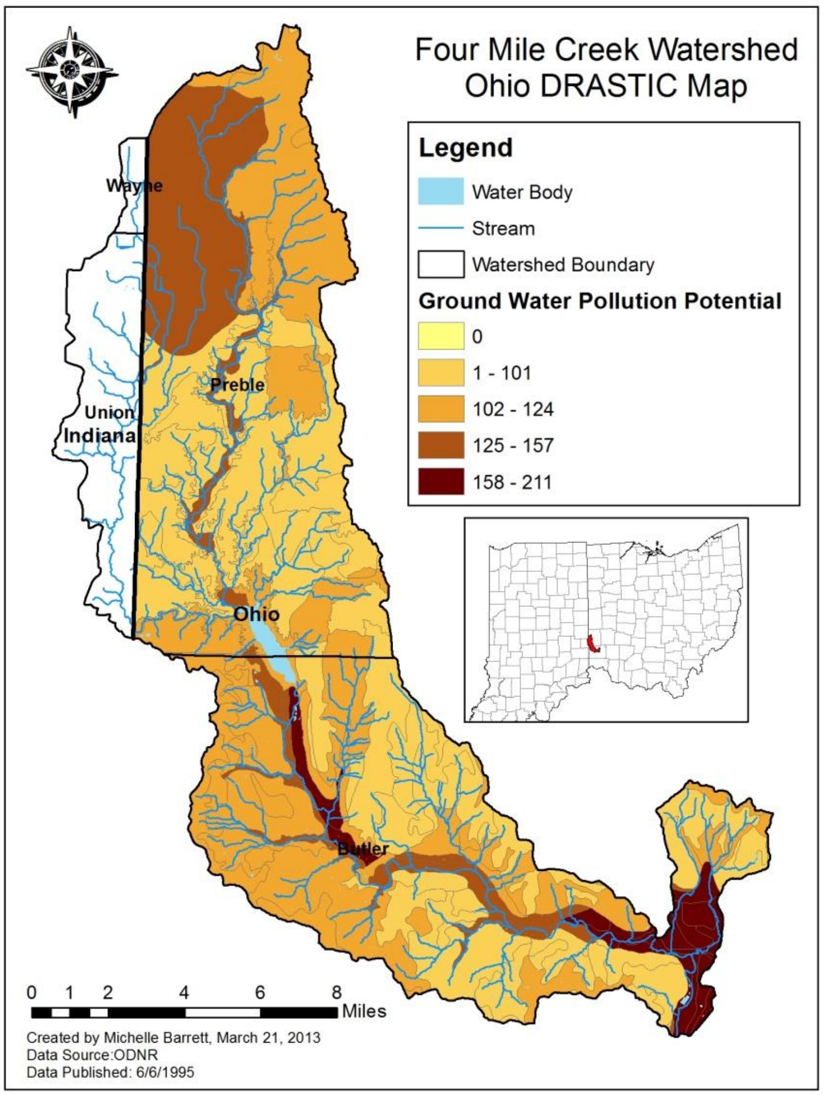

Figure 30. Ground water pollution potential using ODNR's DRASTIC scoring system for the FMCW. Low scores indicate a lower pollution potential, high scores indicate a higher pollution potential.

When a community uses an aquifer that is susceptible to pollution, there are programs available to protect the water quality. Source Water Assessment Plan (SWAP) is a program by the Ohio EPA that assists communities with protecting sources of drinking water from contamination. SWAP is made up of two phases: assessment and protection. The assessment phase determines if any wells in a public water system need protection. Activities or facilities that pose a potential threat of contamination are recorded. The second phase includes the actions of public water suppliers and other interested parties to protect the identified water sources (OEPA, 2013d).

Preble County has SWAP reports for 11 communities; however none of these areas are in the FMCW. There are SWAP reports for 15 communities in Butler County, only two of which are in the FMCW (OEPA, 2013d). These include Oxford and New Miami.

The Oxford SWAP report has two separate wellfields found in Four Mile Creek and Seven Mile Creek, with a total of seven wells. The Four Mile Creek wellfield is located northeast of Oxford. It consists of three wells that pump an average of 2.2 million gallons per day from the Four Mile Creek aquifer system (OEPA, 2012a). Two of the wells are Ranney horizontal collector wells; the other well is a vertical well. The Seven Mile Creek wellfield is located east of Oxford and consists of four wells that pump an average of 220,000 gallons per day. All four wells are vertical wells. The Four Mile Creek and Seven Mile Creek wellfield are both highly susceptible to contamination for the following reasons:

1) Both aquifers lack protective, impervious layers above them (unconsolidated);
2) The aquifers are shallow (less than 20 feet below ground surface);
3) There are several potential contaminant sources present near the wellfields, including petroleum aboveground storage tanks, septic systems, fertilizer, and herbicides; and
4) Nitrate was detected in drinking water at concentrations exceeding levels of concern (2mg/L) on eight occasions since 2000 (OEPA, 2012a).

The city of New Miami obtains water from the Great Miami Buried Valley Aquifer System (Figure 28). The New Miami SWAP report rated the wellfield highly susceptible to contamination for the following reasons:

1) The Great Miami Aquifer System has a thin and discontinuous layer of clay;
2) The aquifer system is shallow (20-30 feet below the surface); and
3) There are several potential contaminant sources within the protected area (OEPA, 2003).

Sole Source Aquifers (SSA) are aquifers that supply 50% or more of the drinking water consumed in the overlying area (OEPA, 2006). The SSA located in portions of Butler and Preble counties is known as the Greater Miami SSA (OEPA, 2006) (Figure 31). These aquifers are also considered in the SWAP process; however the SSA program is controlled by the U.S. EPA and is authorized by §1424(e) of the Safe Drinking Water Act. The SSA program protects ground water resources by requiring U.S. EPA to review certain proposed projects in the area, since many of these areas have no alternative water source.

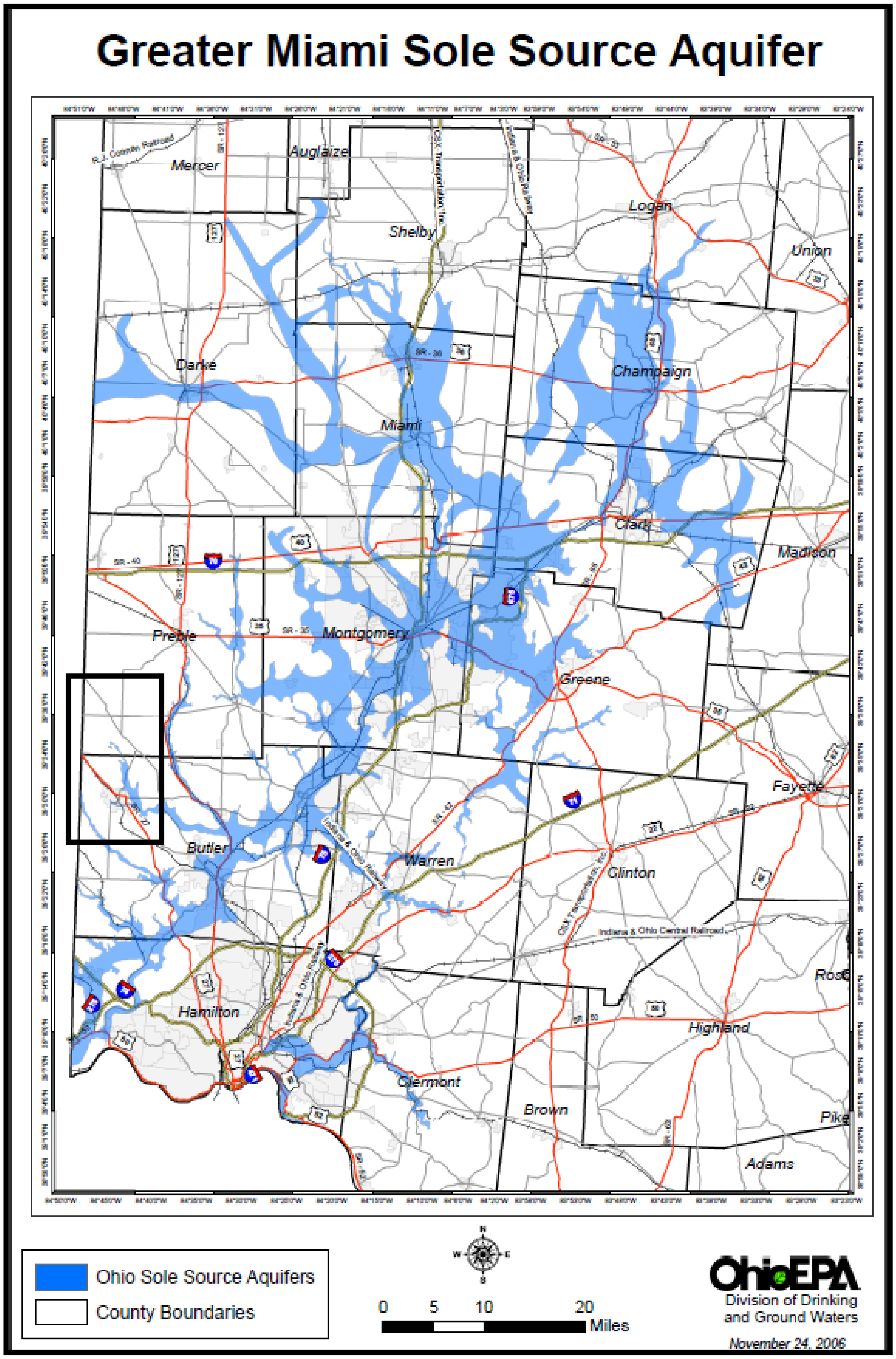

Figure 31. Map of the Greater Miami Sole Source Aquifer (SSA), (OEPA, 2006).

C. Flood Frequency

Floodplains influence ground water levels; when water velocity slows down, it allows for increased infiltration, which recharges the aquifers (ODNR, 2013d). Floodplains also help to reduce flood velocity, reduce erosion, and stabilize soils. With increased development and decreases in riparian ecosystems, floodplains have been drastically changed and significantly altered by these anthropogenic actions (ODNR, 2011).

The highest frequency of flooding in the FMCW occurs along the Four Mile Creek itself (Figure 32). The other large tributaries, such as Little Four Mile Creek and Sevenmile Creek also experience some occasional flooding. The majority of the watershed experiences little to no flooding at all.

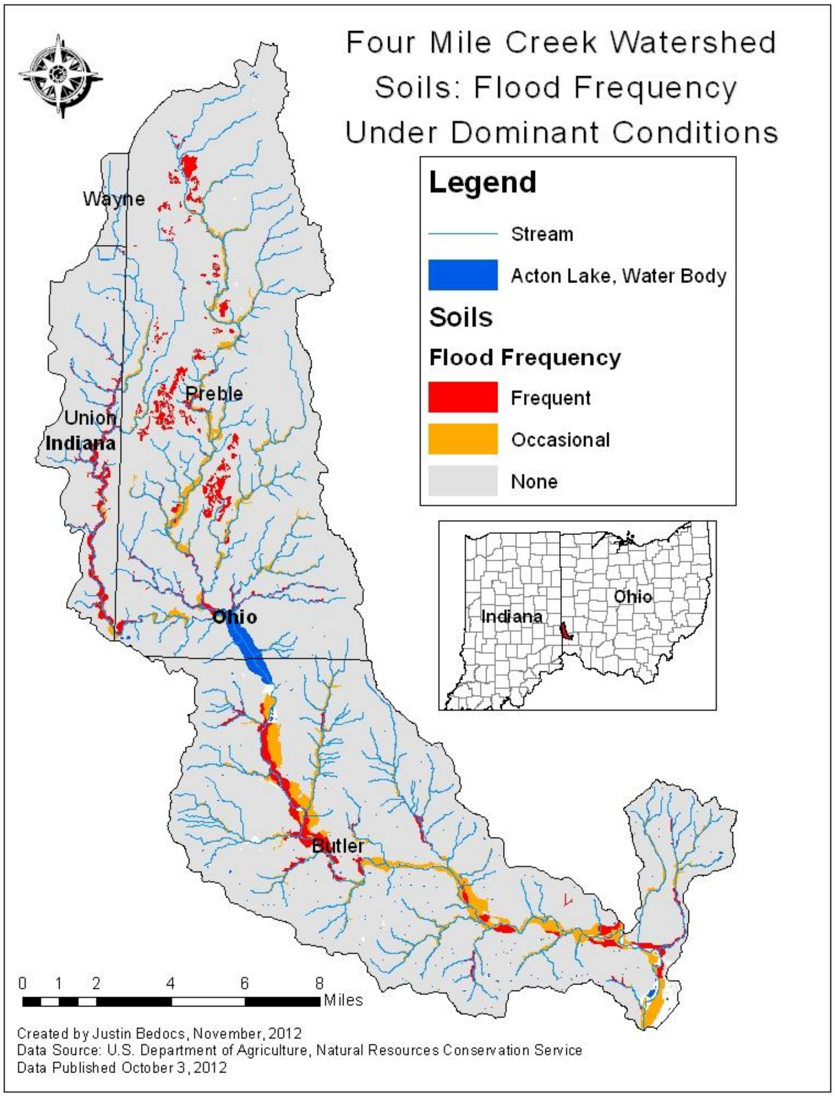

Figure 32. Map illustrating flood frequency within FMCW, ranging from "none" to "frequent."

CHAPTER FOUR: INDICATORS OF WATER RESOURCE QUALITY

A. Water Quality Standards

Standards for water quality are determined by the Ohio EPA Division of Surface Water. These standards are based upon measurable and consistent physical, chemical, and biological criteria (OEPA, 2008). The standards set for a waterway identify its designated uses. These use designations are then divided into two main categories for assessment: Aquatic Life and Non-Aquatic Life uses (Recreational & Water Supply).

To determine use designations, the Ohio EPA samples along the streams at established stations. The use designations are assigned to each station. Therefore, streams with multiple stations may have several use designations. These sample stations are then graded based on specific physical, chemical, and biological indicators of water quality at that particular station. If all required criteria are met for its designated uses, the station is assigned a full attainment status. A partial attainment status is given if only some of the required criteria are met.

In 2005, the Ohio EPA conducted a biological and water quality survey (published in 2008) of the Four Mile Creek, Indian Creek, and select tributaries (OEPA, 2008). This study represents an interdisciplinary monitoring assessment of a specific watershed and its streams (OEPA, 2008). Below are the results from this survey.

B. Aquatic Life

Most of the aquatic life use designations in the FMCW are Warm Water Habitats (WWH), meaning they can support and sustain a healthy and diverse community of warm water aquatic species (USEPA, 2012b). Two stations in the FMCW are designated Exceptional Warm Water Habitat (EWH), meaning they can support a community of exceptional or unusual warm water aquatic species (USEPA, 2010b).

The physical aquatic habitat criteria are measured using the Qualitative Habitat Evaluation Index (QHEI), which assigns a score (20-100) based on the overall viability, diversity, and functionality of aquatic faunas (OEPA, 2008). A WWH generally scores within a 45-60 on the QHEI spectrum.

Out of the 26 stations sampled in the FMCW, 18 stations were in full attainment (72%) and 7 were partially attaining their designated uses. Four of the seven stations not in full attainment were impacted by natural causes (low or interstitial flow) (OEPA, 2008). Biological communities were classified as “good” or “exceptional” with an average QHEI score of 73.4 along the Four Mile Creek main stem (OEPA, 2008). Most sampling locations have improved or remained comparable to previous sampling efforts (1996). Additionally, three streams were listed as State Resource Waters (SRW), indicating they lie within a state park, and are waters of exceptional recreational and ecological significance (OEPA, 2013f) (Table 5).

Biological criteria were also recorded for these stations using three different indices. These are The Index of Biotic Integrity (IBI), Modified Index of Well-Being (MIwb), and the Invertebrate Community Index (ICI), which measure fish and macroinvertebrate community response to stream conditions.

Table 5. Aquatic life water quality assessment for the FMCW streams (OEPA, 2008).

Station	IBI	MIwb	ICI	QHEI score	Use Designation	Attainment Status	Causes	Sources
Four Mile Creek (State Resource Water)								
Station 1	40	-	MG	44.5	WWH	Full	Nitrate/nitrite, riparian removal, siltation	Unrestricted cattle access
Station 2	54	-	G	65.5	WWH	Full		
Station 3	46	-	46	72.0	WWH	Full		
Station 4	48	9.7	52	71.0	WWH	Full		
Station 5	42	8.9	G	68.5	WWH	Full		
Station 6	-	-	G	--	WWH	-	Ammonia, D.O., Sedimentation	Acton Lake outflow
Station 7	50	10.5	38	81.5	WWH	Full		
Station 8	56	10.0	52	78.5	WWH	Full		
Station 9	53	11.0	48	74.0	WWH	Full		
Station 10	54	10.0	G	92.5	WWH	Full		
Station 11	52	10.2	40	74.0	EWH	Partial	Phosphorus	Oxford WWTP
Station 12	56	10.4	VG	83.0	EWH	Full		
Station 13	42	9.9	G	76.5	WWH	Full		
Dixon Branch (SRW)								
	48	-	G	63.0	WWH (recommended)	Full		
East Fork Four Mile Creek								
Station 1	44	-	G	64.5	WWH	Full		
Station 2	40	-	E	70.0	WWH	Full		
Little Four Mile Creek (SRW)								
Station 1	44	-	E	74.5	WWH	Full		
Station 2	50	8.4	G	78.0	WWH	Full		
Fleisch Run								
	34	-	G	41.5	WWH (recommended)	Partial	Channelization riparian removal, siltation, D.O., ammonia, bacteria	Unrestricted cattle access
Morning Sun								
Station 1 Trib N	58	-	G	79.5	WWH (recommended)	Full		

Station	IBI	MIwb	ICI	QHEI score	Use Designation	Attainment Status	Causes	Sources
Station 2 Trib S	28	-	G	69.0	WWH (recommended)	Partial	Transition between headwater and primary headwater habitat	Natural
Elams Run								
	50	-	G	65.0	WWH	Full		
Harkers Run								
	36	-	F	67.5	WWH	Partial	Low to interstitial stream flow	Natural
Collins Creek								
	50	-	F	60.5	WWH (recommended)	Partial	Metals (Cu, Fe, Ba) increase in flow extremes	Urban runoff from Oxford
Darrs Run								
	44	-	F	54.5	WWH	Partial	Interstitial stream flow	Natural
Stony Run								
	54	-	Low F	52.0	WWH (recommended)	Partial	Interstitial stream flow	Natural
SRW=State Resource Water, WWH=Warm Water Habitat, EWH=Exceptional Warm Water Habitat.								

C. Non-Aquatic Life Uses

Recreational Use

Recreational uses of water can be divided into three categories: Bathing Water Recreation (BWR), Primary Contact Recreation (PCR), or Secondary Contact Recreation (SCR). Acton Lake is designated BWR because it is heavily used for recreation and maintains a bath house on site. The majority of streams in the FMCW have PCR use designations, meaning the waters are suitable for full body contact such as wading, swimming, boating, and canoeing (OEPA, 2008) (Table 6). Only one stream, Elams Run, is designated SCR, because its waters result in minimal exposure to potential water borne pathogens and are rarely used for water-based recreation (USEPA, 2010b). However, the Ohio EPA suggests that the designation for this particular stream be changed to PCR, because development nearby will encourage more frequent exposure (OEPA, 2008).

Recreational use attainment was assessed using fecal coliform and *E.coli* bacteria as indicator organisms. When certain numbers of *E.coli* are present, there is confirmation that the water has been contaminated with warm blooded animal feces. The lower the *E.Coli* count per 100mL the higher the water quality. Class A is the best rating for Primary Contact Recreation (USEPA, 2010b). Four Mile Creek is designated as Class A, and is a popular paddling stream suitable for frequent primary contact recreation activities with identified public access points (USEPA, 2010b).

Table 6. Recreational use attainment status for FMCW (OEPA, 2008).

Station	Use Designation	Attainment Status
Acton Lake		
	BWR, PWS	-
Four Mile Creek (State Resource Water)		
Station 1	PCR	Full
Station 2	PCR	Full
Station 3	PCR	Partial
Station 4	PCR	Full
Station 5	PCR	Full
Station 6	PCR	Partial
Station 7	PCR	Full
Station 8	PCR	Full
Station 9	PCR	Full
Station 10	PCR	Full
Station 11	PCR	Full
Station 12	PCR	Full
Station 13	PCR	Full
Dixon Branch (SRW)		
	PCR (recommended)	Full
East Fork Four Mile Creek		
Station 1	PCR	Full
Station 2	PCR	Full
Little Four Mile Creek (SRW)		
Station 1	PCR	Full
Station 2	PCR	Full
Fleisch Run		
	PCR (recommended)	Partial
Morning Sun		
Tributary N -Station 1	PCR (recommended)	Full
Tributary S - Station 2	PCR (recommended)	Partial
Elams Run		
	PCR	Full
Harkers Run		
	PCR	Full
Collins Creek		
	PCR (recommended)	Full
Darrs Run		
	PCR	Full
Stony Run		
	PCR (recommended)	Full
BWR=Bathing Water Recreation, PCR=Primary Contact Recreation, SCR=Secondary Contact Recreation		

Most streams within the FMCW met their recreational use designation, however a few streams did not meet full attainment criteria: Four Mile Creek (Stations 3 & 6), Fleisch Run, and Morning Sun (Tributary S - Station 2) (OEPA, 2008) (Table 6). Attainment status was not recorded for Acton Lake, but elevated levels of ammonia-N and low dissolved oxygen were present.

Water Supply

Although no water is withdrawn from the FMCW for drinking water, Acton Lake is still designated as a Public Water Supply (PWS) (OEPA, 2008). It is designated as such because all publicly owned lakes are considered public waters, even if there are no water supply intakes (OEPA, 2008). The streams in the FMCW are designated as Agricultural Water Supply (AWS) and Industrial Water Supply (IWS) (OEPA, 2008). Because water used for agriculture and industry is not held to the same expectations as public waters, the Ohio EPA assumes attainment is met for these two designations unless proven otherwise.

CHAPTER FIVE: HUMAN ACTIVITIES AFFECTING WATER RESOURCE QUALITY

A. Point Sources of Pollution

A point source is defined broadly by the Clean Water Act, in which it is considered an identifiable conveyance from which pollutants may be currently or potentially discharged, such as pipes, ditches, and channels (USEPA, 2012a). Other point sources include vessels that may discharge pollution and animal feeding operations, in which animals are kept and fed.

The National Pollutant Discharge Elimination System (NPDES) is a permit program authorized by the Clean Water Act starting in 1972 (USEPA, 2012a). There are two types of NPDES permits: individual permits and general permits (OEPA, 2013e).

Individual permits are specified for each industrial and municipal facility that discharges pollutants directly to surface waters. Locations that use separate municipal storm sewer systems, also called MS4s, often collect storm water from the surrounding area and are therefore required to obtain a NPDES permit (USEPA, 2005). As part of the permit requirements, MS4 sites are also required to create a management strategy that includes Best Management Practices (BMPs) such as public education and illicit discharge detection and elimination.

General permits are required when facilities have similar operations and types of discharge. This kind of permit is used to cover discharges that have minimal effects on the environment.

NPDES permits are also required for facilities that discharge their wastewaters to a publicly owned treatment works (USEPA, 2013a). These are called indirect discharge permits.

In the FMCW, there are seven individual permits, one general permit, and one indirect discharge permit for the NPDES requirements (Table 7). The location of individual NPDES permit holders is shown in Figure 33. Four of the seven individual permits are Waste Water Treatment Plants (WWTP) that expel treated wastewater into the FMCW. Although each facility holds an NPDES permit, there is still potential for adverse impacts on aquatic environments.

In particular, the Oxford WWTP has been shown to degrade the macroinvertebrate communities up to 15 miles downstream from the point source (OEPA, 2008). Oxford's sanitary and storm sewers are separate; however overflow and/or WWTP bypass occurs when the system is subject to excessive infiltration and inflow (OEPA, 2008). This allows excess nutrients and sediments to enter the stream, creating numerous problems for aquatic life.

Total phosphorus concentrations downstream from the Oxford WWTP have consistently been above the 90^{th} percentile reference concentration (0.22 mg/L), even though it has gradually decreased from 1991 to 2005 (2.38 mg/L to 0.71 mg/L) (OEPA, 2008). The total suspended solid concentration however, was found to have increased during the same time frame, possibly because nutrient enrichment encouraged suspended algae growth. As a result, incremental declines in sensitive macroinvertebrate taxa have been measured downstream from the WWTP discharge (OEPA, 2008).

Table 7. Individual NPDES permit holders (OEPA, 2012c), general permit holders (OEPA, 2013b), and indirect discharge permit holders (OEPA, 2013c) in the FMCW.

County	Ohio Permit No.	Permit Type	Facility	Effective Date	Expiration Date
Individual Permit Holders					
Preble	1PP00002	Municipal	Hueston Woods State Park Beach & Marina	8/1/2008	7/31/2013
Preble	1PP00005	Municipal	Hueston Woods State Park Lodge & Cabins WWTP	8/1/2008	7/31/2013
Butler	1PP00004	Municipal	Hueston Woods State Park Golf Course	8/1/2008	7/31/2013
Butler	1IX00090	Industrial	New Miami WTP	9/1/2010	8/31/2015
Butler	1PB00023	Municipal	New Miami WWTP	2/1/2011	2/28/2015
Butler	1PD00007	Municipal	Oxford WWTP	7/1/2008	6/30/2013
Butler	1PX00041	Municipal	Woodland Country Manor	2/1/2009	1/31/2014
General Permit Holder					
Butler	1GS00005	General	Marshall Elementary	2/1/2010	N/A
Indirect Discharge Permit Holder					
Butler	1DP00003	Indirect	City of Oxford Sanitary Landfill	7/1/2009	6/30/2014

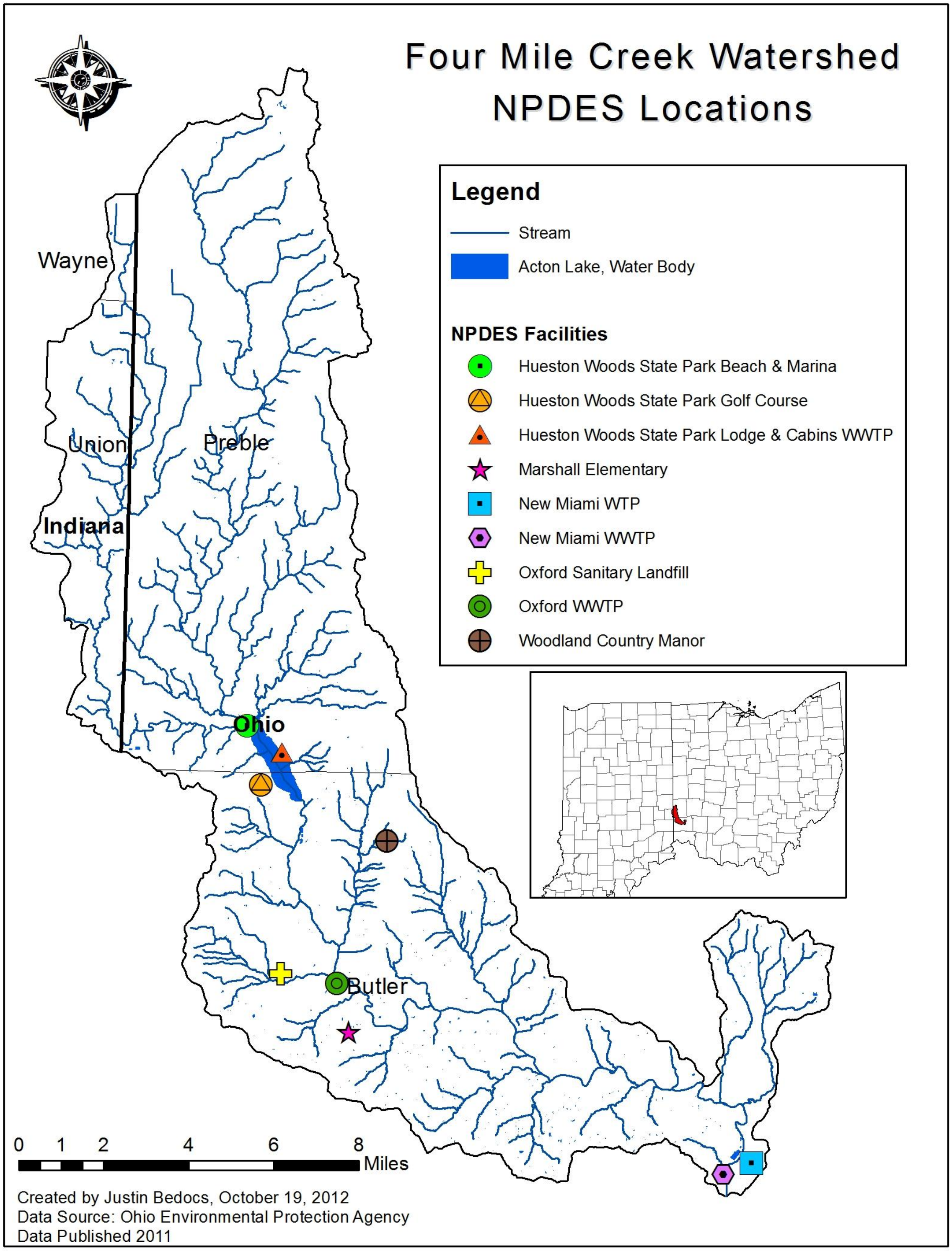

Figure 33. Individual, general and indirect discharge NPDES permit locations in the FMCW.

B. Nonpoint Sources of Pollution

Nonpoint source pollution is any source of water pollution that is not isolated, confined, or discernible, such as land runoff and precipitation (USEPA, 2012c). Polluted runoff is produced when rain and snow events move chemicals through the ground or over the surface (USEPA, 2012c). The Clean Water Act and the Safe Drinking Water Act establish a regulatory framework that addresses nonpoint pollution; but it remains difficult to identify and regulate these sources.

The results of the Ohio EPA 2005 biological and water quality survey of the FMCW were reported to the U.S. EPA in an integrated report (OEPA, 2008; USEPA, 2008). This integrated report outlines the causes of impairment in the FMCW (Table 8) and also identifies the need for Total Maximum Daily Loads (TMDLs). TMDLs set the amount of a pollutant that can enter the water on a daily basis. They are created by evaluating the causes of impairment in a watershed, and can be used to ensure that the watershed reaches water quality standards (OEPA, 2012b). Currently there is no TMDL report for the FMCW. However, monitoring is scheduled for 2020 in all subwatersheds of the FMCW, which will be used to develop TMDLs by 2023 (OEPA, 2013f). Table 8 summarizes the causes of impairment. Using this information, the team created Figure 34, which is a map of estimated areas of impairment.

Table 8. Impairment category (USEPA, 2008), causes, locations, and potential sources of impairment in FMCW (OEPA, 2008).

Impairment Category	Causes of Impairment in FMCW	FMCW Stream & Stations Impaired	Potential Sources of Impairment
Habitat Alterations	Alteration in Stream-Side or Littoral Vegetative Covers	Fleisch Run	Unrestricted Cattle Access
Radiation	Barium	Collins Creek	Urban Runoff from Oxford
Metals other than Mercury	Copper, Iron	Collins Creek	Urban Runoff from Oxford
Organic Enrichment/Oxygen Depletion	Dissolved Oxygen	Four Mile Creek (Station 6)	Acton Lake Outflow
		Fleisch Run	Unrestricted Cattle Access
Flow Alteration(s)	Flow Alteration(s)	Fleisch Run	Unrestricted Cattle Access
Pathogens	Pathogens	Fleisch Run	Unrestricted Cattle Access
Nutrients	Total Phosphorus	Four Mile Creek (Station 10)	Oxford WWTP
Sediment	Sedimentation/Siltation	Four Mile Creek (Station 6)	Acton Lake Outflow
		Fleisch Run	Unrestricted Cattle Access
Ammonia	Total Ammonia	Four Mile Creek (Station 6)	Acton Lake Outflow &
		Fleisch Run	Unrestricted Cattle Access

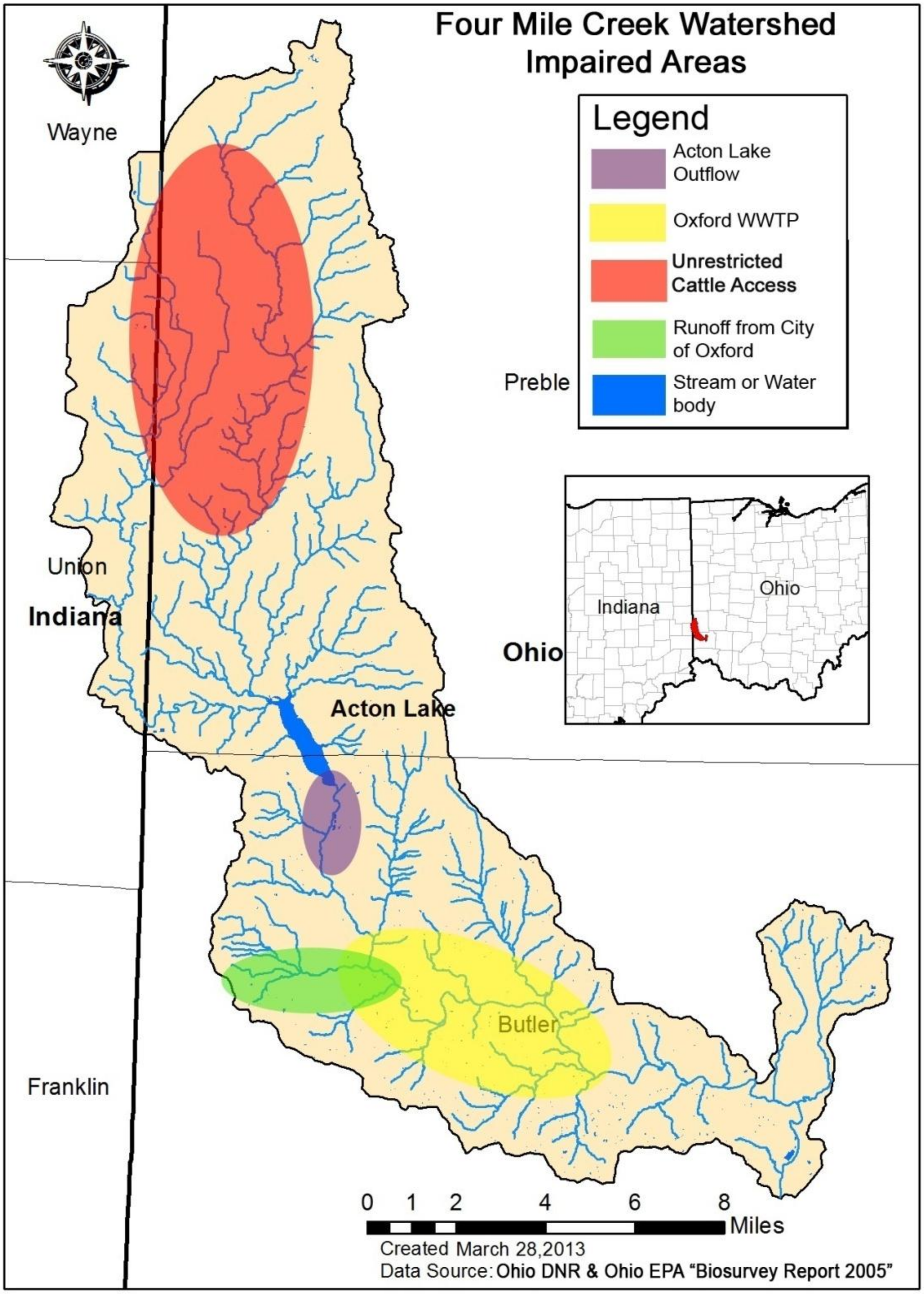

Figure 34. Estimated areas of impairment in FMCW (OEPA, 2008).

Land Use

The way that humans interact with land can directly impact water quality. Figure 35 shows the major land cover types in FMCW. In the FMCW, a majority of the land is used for growing crops which require fertilizers and/or pesticides. Additionally, the land is used to raise livestock which may require management of manure. The land is also used for domestic purposes, which require paved driveways and sewage systems. All of these land use practices have their own water quality concerns. The best way to examine the land use in the FMCW is to first understand the watershed's land cover as a whole, and then more closely examine the individual components.

The land use land cover percentages were determined for the entire watershed (Figure 35). The four dominant land use types in the FMCW are cultivated crops (57%), forest (16%), pasture and hay (16%), and developed land (10%) (USDA, 2006) (See Appendix F for a list of crop type and Appendix G for a complete list of land cover class definitions).

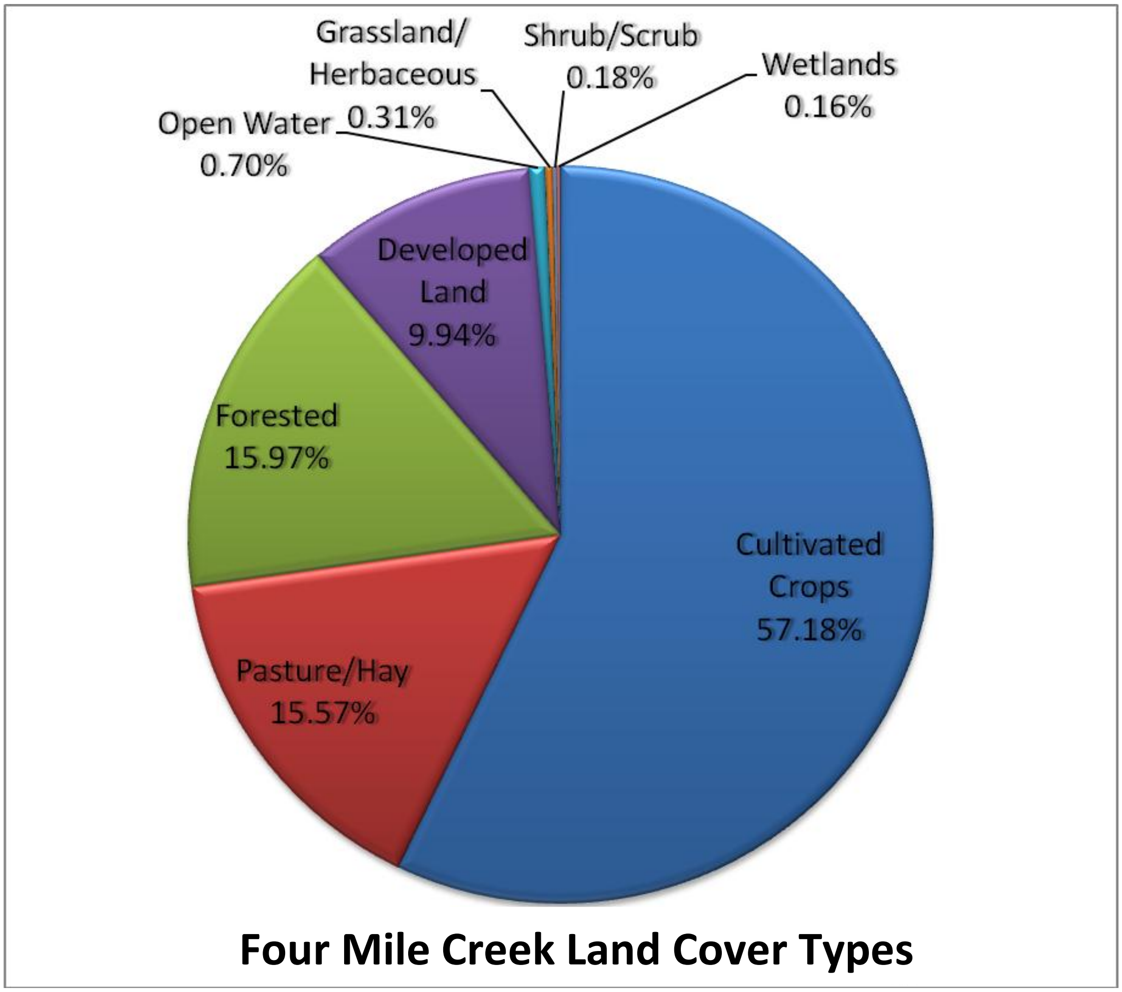

Figure 35. Percent of land use/land cover types in the FMCW (USDA, 2006).

Crop Types

The FMCW is a highly agricultural region. Crop cover and pasture encompasses 72.9% of the watershed's total area. The top two crops produced in Preble and Butler counties in 2012 were corn and soybeans (Figure 36). Hay, winter wheat, and alfalfa are cultivated in much smaller quantities, along with several other reported crops (Appendix F). Figure 37 is a map showing the distribution of each crop type in the FMCW.

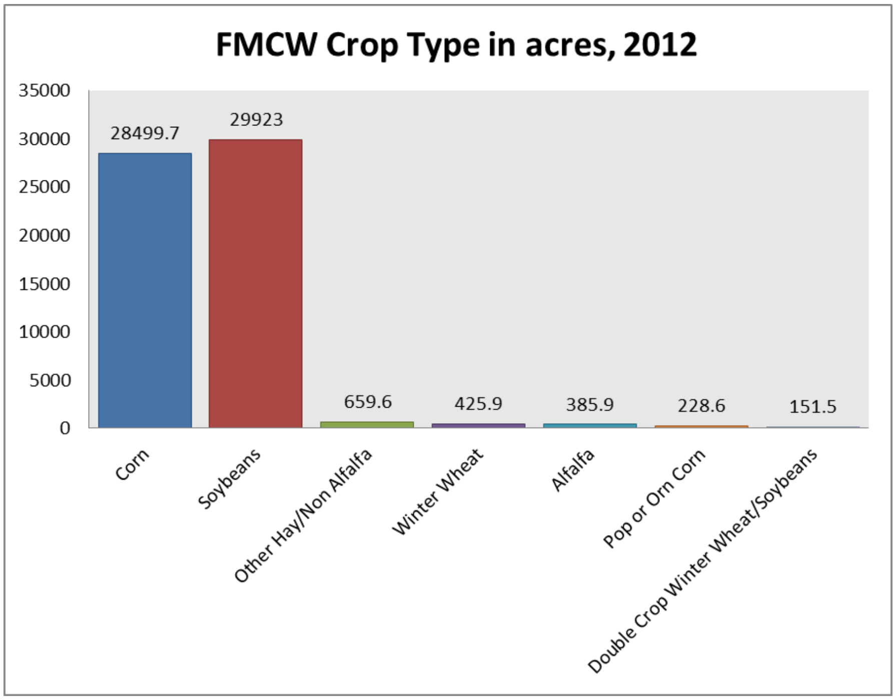

Figure 36. Crop types in the FMCW. The two dominant types are corn and soybeans (USDA, 2007b).

Nearby streams can be impacted by nutrient and sediment loading as a result of agriculture. Agricultural practices have the potential to degrade soil quality and increase erosion rates. Certain lands are more susceptible to erosion hazard than others. Highly erodible land is defined as cropland, hayland, or pasture that has the potential to erode excessively and has an erodibility index of eight or more (NRCS, 2013). If a producer's land is classified as highly erodible, they are required to develop and maintain a conservation system of practices that substantially reduce soil loss (NRCS, 2013). This information can be useful in understanding patterns of nonpoint source pollution and identifying areas of potential concern.

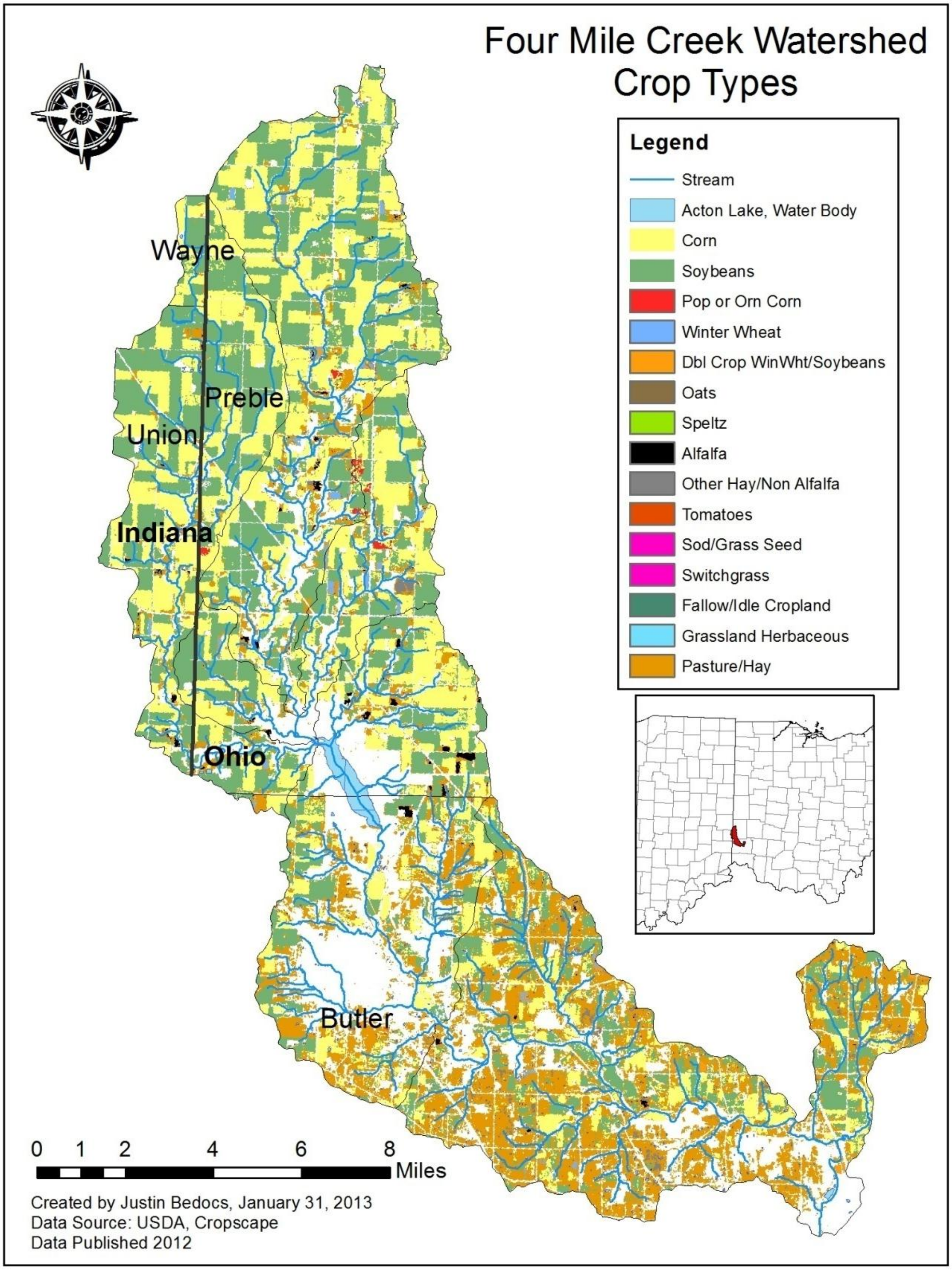

Figure 37. The spatial distribution of land use land cover types in the FMCW.

Tillage and Rotations

Tillage practices can have a significant impact on surrounding water bodies because of the large portion of the watershed in crop production. One such practice, conservation tillage, leaves at least 30% crop residue on the field after harvest (Vanni, 2012). Table 9 represents countywide data on the number of farms practicing conservation tillage in FMCW. Promoting conservation tillage is important for water quality but also for long term soil productivity. According to the U.S. EPA, increased energy savings and significant soil quality improvement has led to increased conservation tillage use in the Midwest (USEPA, 2012b). The use of tillage conservation practices can also reduce agricultural sediment runoff and limit soil crusting and nutrient loss (Figure 38). Not only does this improve field fertility and crop yields, it also protects local water quality by reducing nitrogen and phosphorus contamination.

Table 9. Tillage practices in Butler, Preble, Union, and Wayne counties, 2007 (USDA, 2007a).

Tillage Practices, 2007 (farms)	Counties			
	Butler	Preble	Union	Wayne
Used conservation methods	287	551	119	415

Figure 38. Illustrates the difference between conventional and conservation tillage. The field on the left has a higher percentage of exposed soils and is more vulnerable to erosion and its associated problems than the field on the right (Vanni, 2012).

Fertilizers and Irrigation

The application of fertilizer in agricultural systems is vital because it replaces nutrients that have been removed from the land by previous plant growth (USEPA, 2010a). It is also essential in achieving economically realistic yields. In 2007, 426,556 total acres of land were treated with commercial fertilizers, lime, and soil conditioners and 23,332 acres were treated with manure in Butler, Preble, Wayne and Union counties (Table 10).

Additionally, some producers utilize irrigation. In the Ohio River Basin, 15% of the total crop production must be irrigated, mainly for horticultural and vegetable crops (Figure 39). The remaining water needs are typically met through annual rainfall. For example, in 2007 only 11,899 acres of land were irrigated in the four counties present in the FMCW (Table 10).

Table 10. Fertilizers and Irrigation for the four counties in FMCW, 2007 (USDA, 2007a).

Fertilizers and Chemicals Applied, 2007 (acres)	**Counties**			
	Butler	**Preble**	**Union**	**Wayne**
Commercial fertilizers, lime and soil conditioners	75,194	175,289	59,545	116,528
Manure	6,168	9,221	1,878	6,065
Irrigation, 2007 (acres)				
Land in irrigated farms	1,536	5,805	N/A	4,558

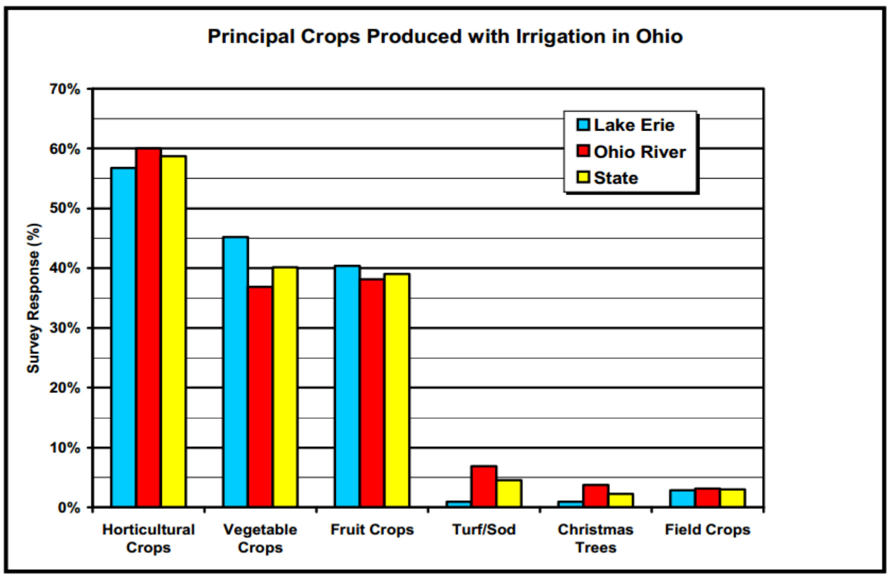

Figure 39. Principal crops produced in Ohio with the aid of irrigation, 2006 (OFBF, 2006).

Livestock Inventory

In addition to nutrient loading from crop production, animal operations can be a potential source of pollution throughout the watershed. When livestock are placed in close, concentrated quarters they can expel large amounts of nutrients via their excrements. Precipitation can carry these nutrients into surface water bodies, resulting in a depletion of dissolved oxygen and excess nutrient enrichment which can harm aquatic life and degrade water quality (Perez, 1997). Large livestock facilities are of particular concern in regards to water quality.

Table 11 lists heads of cattle, pigs, poultry and horses in Butler, Preble, Union and Wayne counties. The top livestock items are pigs in Preble County, at 47,000 heads, followed by 22,715 pigs counted in Wayne and 16,000 cattle heads in Preble (USDA, 2007a).

Table 11. Livestock inventory of cattle, pigs, poultry, and horses in the four counties in the FMCW (USDA, 2007a).

Livestock Inventory (heads)	Counties			
	Butler	Preble	Union	Wayne
Cattle	15,771	16,133	3,126	13,645
Pigs	6,482	47,049	14,207	22,715
Poultry	1,138	7,506	699	1,391
Horses	2,234	1,461	195	1,016

There are two types of facilities that contain large quantities of livestock, Confined Animal Feeding Operations (CAFO) and Confined Animal Feeding Facilities (CAFF). CAFFs confine fewer heads of livestock than CAFOs and/or they confine livestock that fall below the CAFO weight standard. CAFOs are considered point sources and require a NPDES permit. CAFFs are considered nonpoint sources of pollution and therefore do not require a NPDES permit. However, they are regulated by the Ohio Department of Agriculture (ODA) which requires a Permit-to-Install and a Permit-to-Operate (OEPA, 2013a).

There are no CAFOs in the FMCW but there is one CAFF, Jordan Farms. It is located at 654 North State Lane Road in Jackson Township, Preble County. The facility has the capacity to confine 7,159 swine weighing over 55 pounds and 2,800 swine weighing less than 55 pounds (ODA, 2010). In total, this facility has the capacity to confine 9,959 heads of swine.

The Permit-to-Operate for this facility includes the following management plans: 1) a manure management plan to reduce the amount of waste runoff; 2) a mortality management plan for proper disposal of deceased livestock; 3) an insect and rodent management plan to minimize the adverse effects of these pest species; 4) and an emergency management plan to protect the surrounding resources during accidents/emergencies (ODA, 2013).

The Permit-to-Operate has been approved by the ODA until 2015 (ODA, 2010). The facility is subject to inspection by the ODA at least two times annually (ODA, 2013). If all procedures are followed, Jordan Farms will remain in good standing. Because the FMCW does not have a TMDL report, it is difficult to determine whether this facility is impacting water quality.

Land Cover by Subwatershed

In order to gain a more detailed understanding of land cover distribution, GIS land cover maps were created for each subwatershed (Figures 40-44). Examining land use at the subwatershed scale may reveal relationships between land use and water quality, and could identify potential problem areas for future management (See Appendix H for a breakdown of land use by watershed and subwatershed).

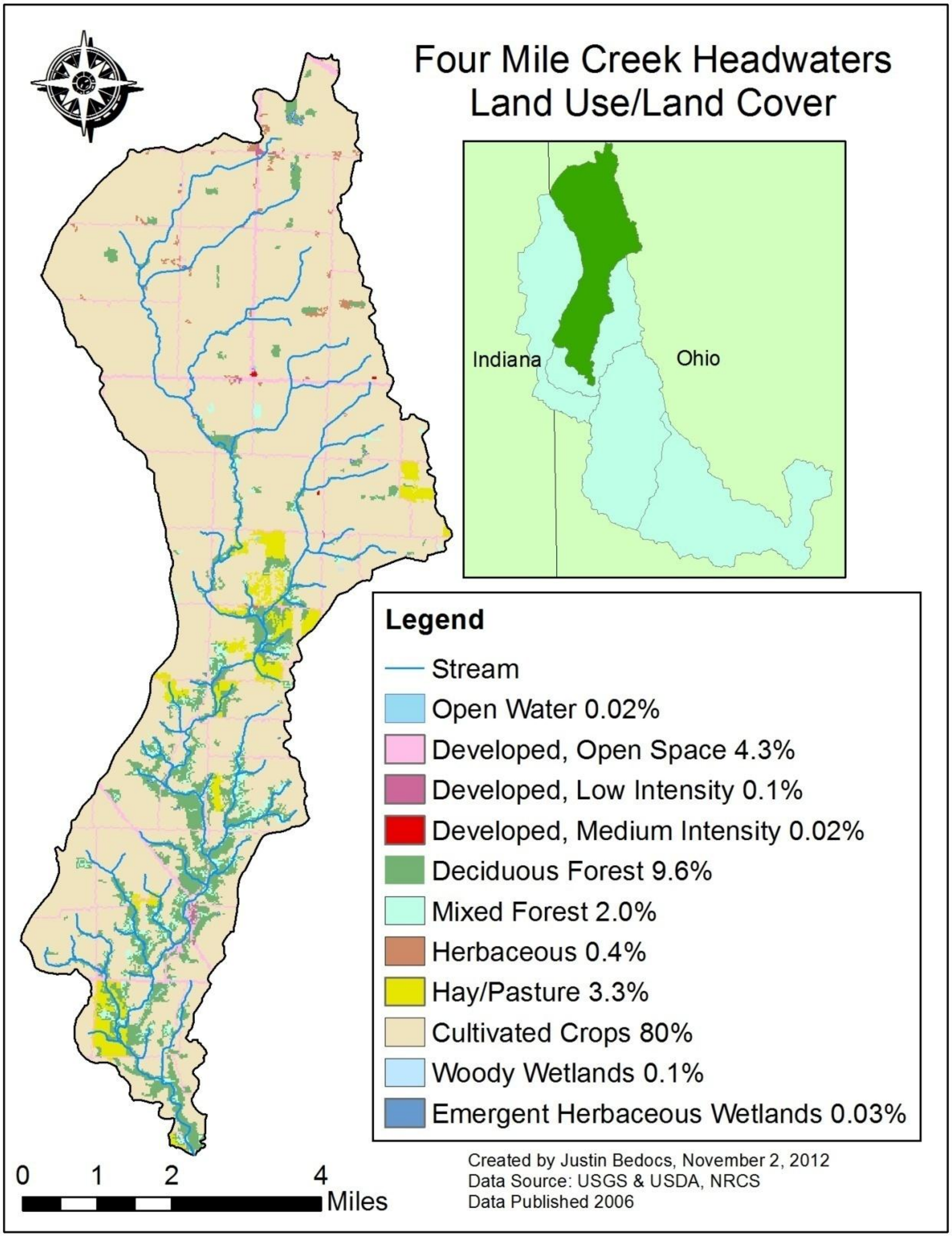

Figure 40. Land use land cover data for Four Mile Creek Headwaters subwatershed, 2006.

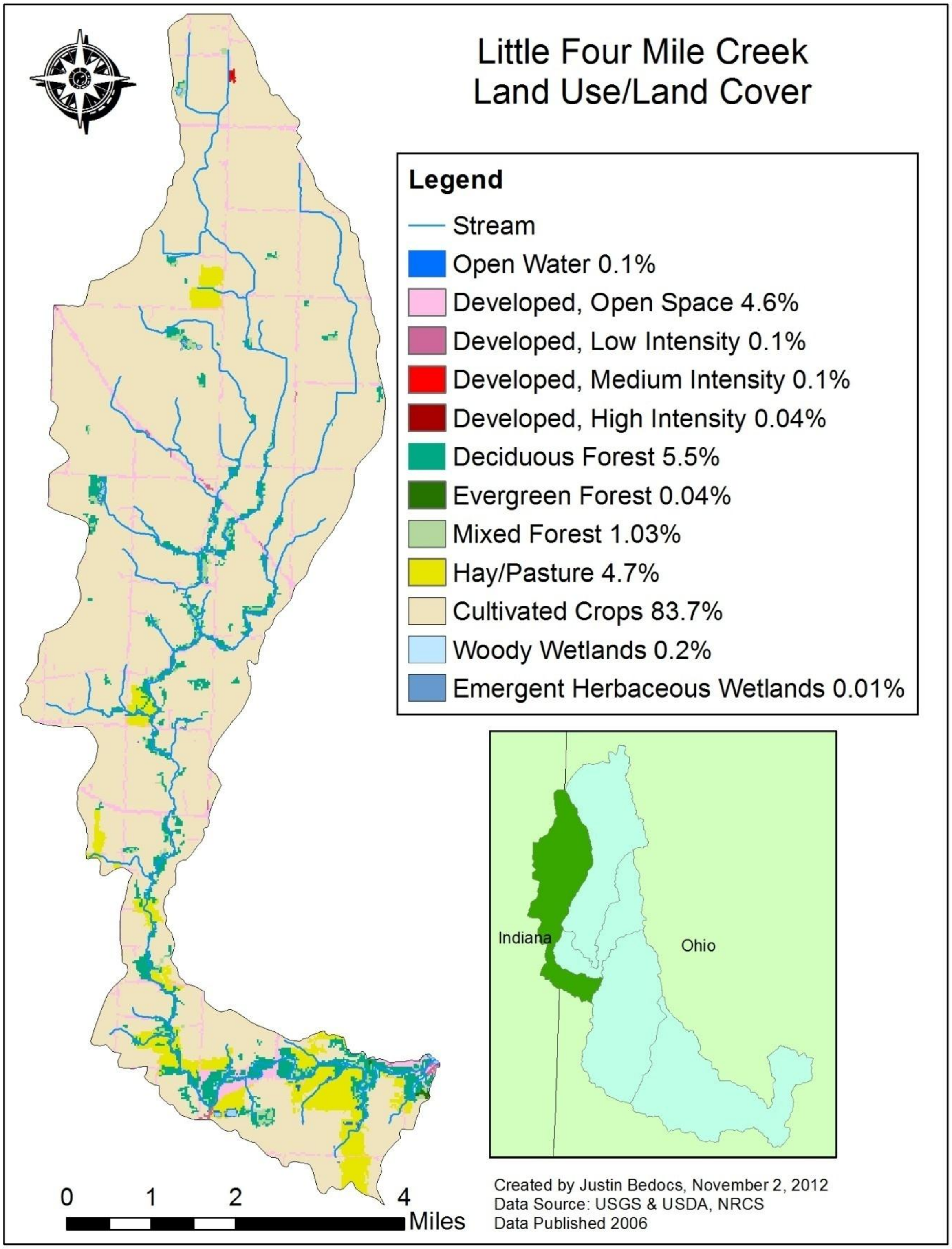

Figure 41. Land use land cover data for Little Four Mile Creek subwatershed, 2006.

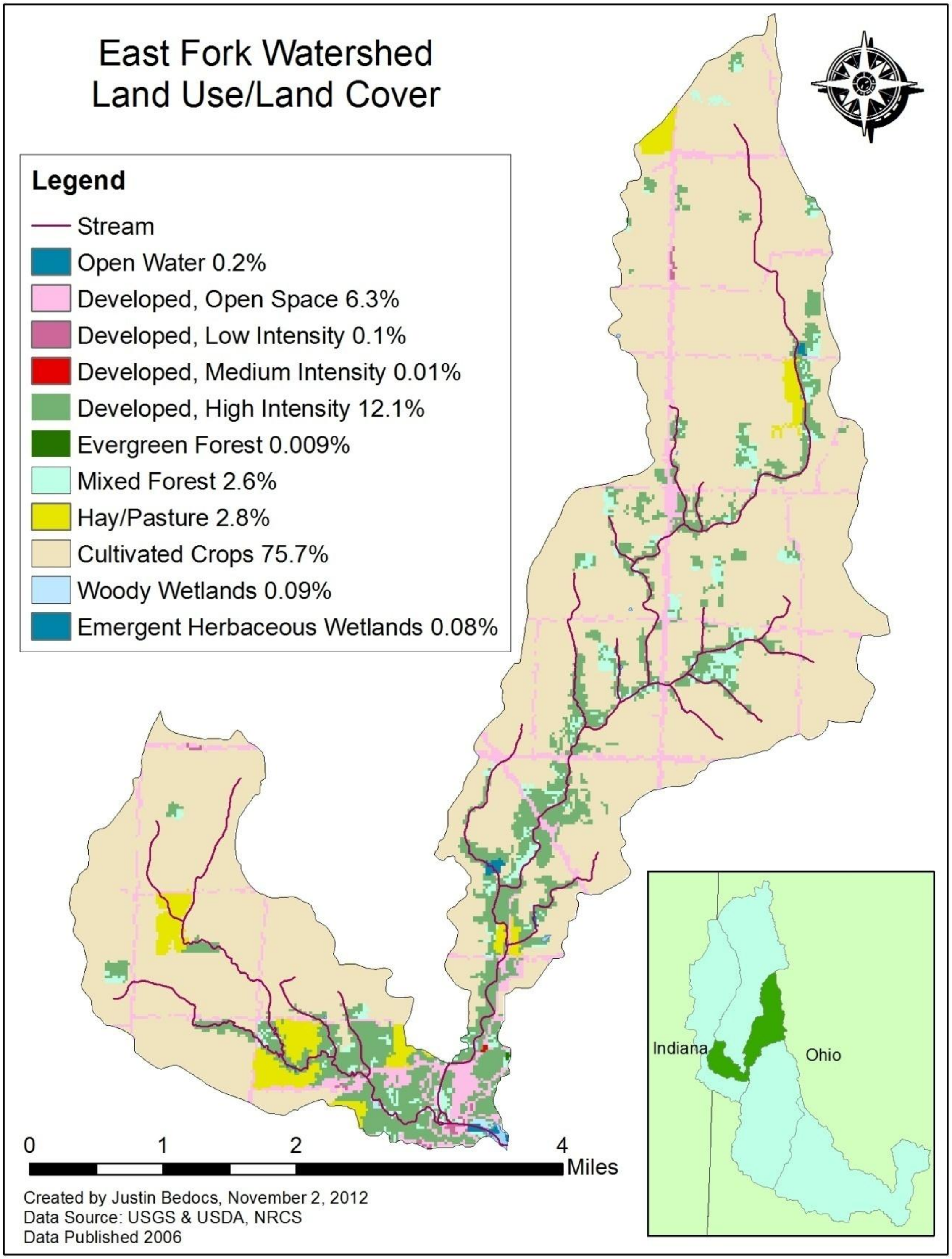

Figure 42. Land use land cover data for East Fork subwatershed, 2006.

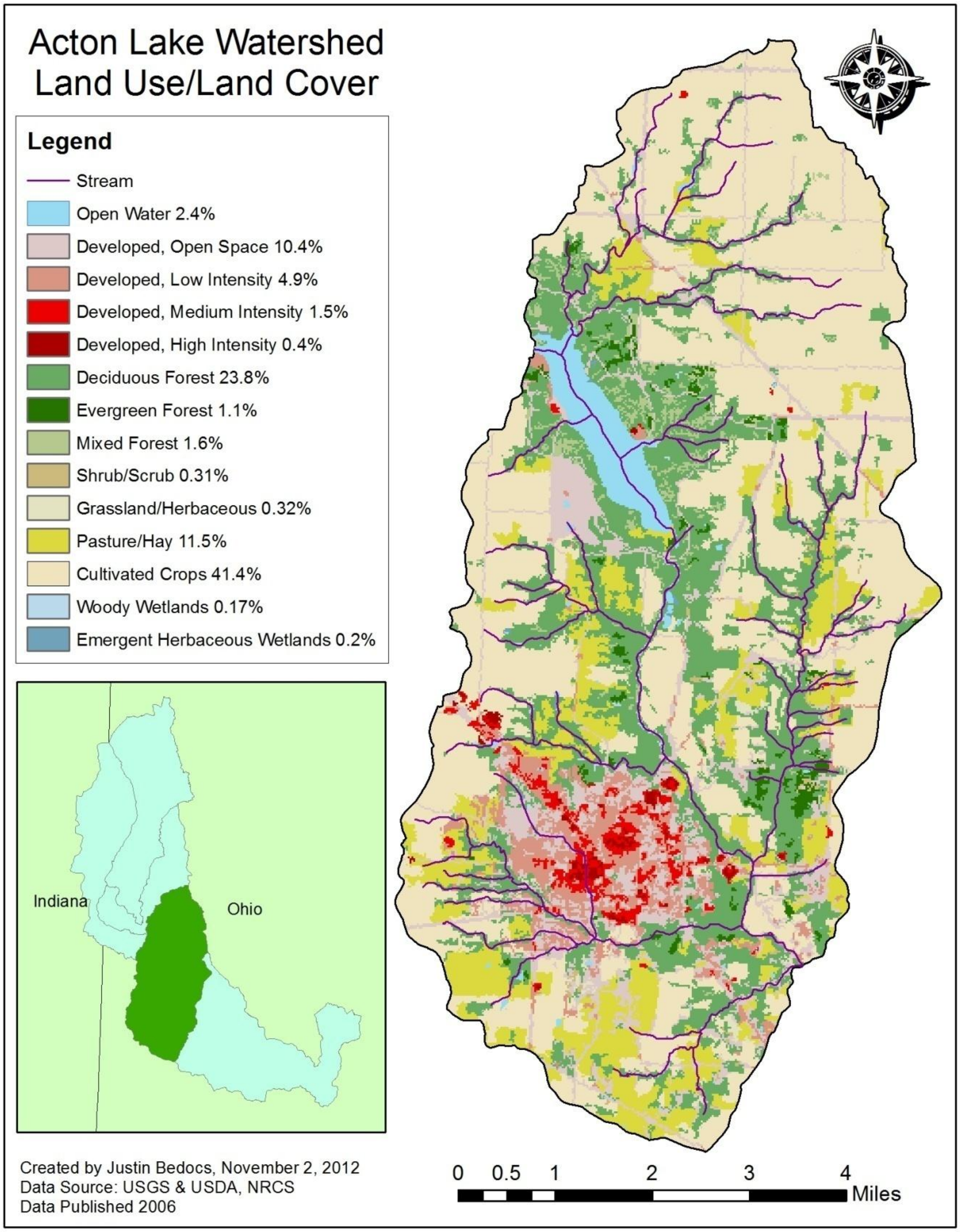

Figure 43. Land use land cover data for Acton Lake subwatershed, 2006.

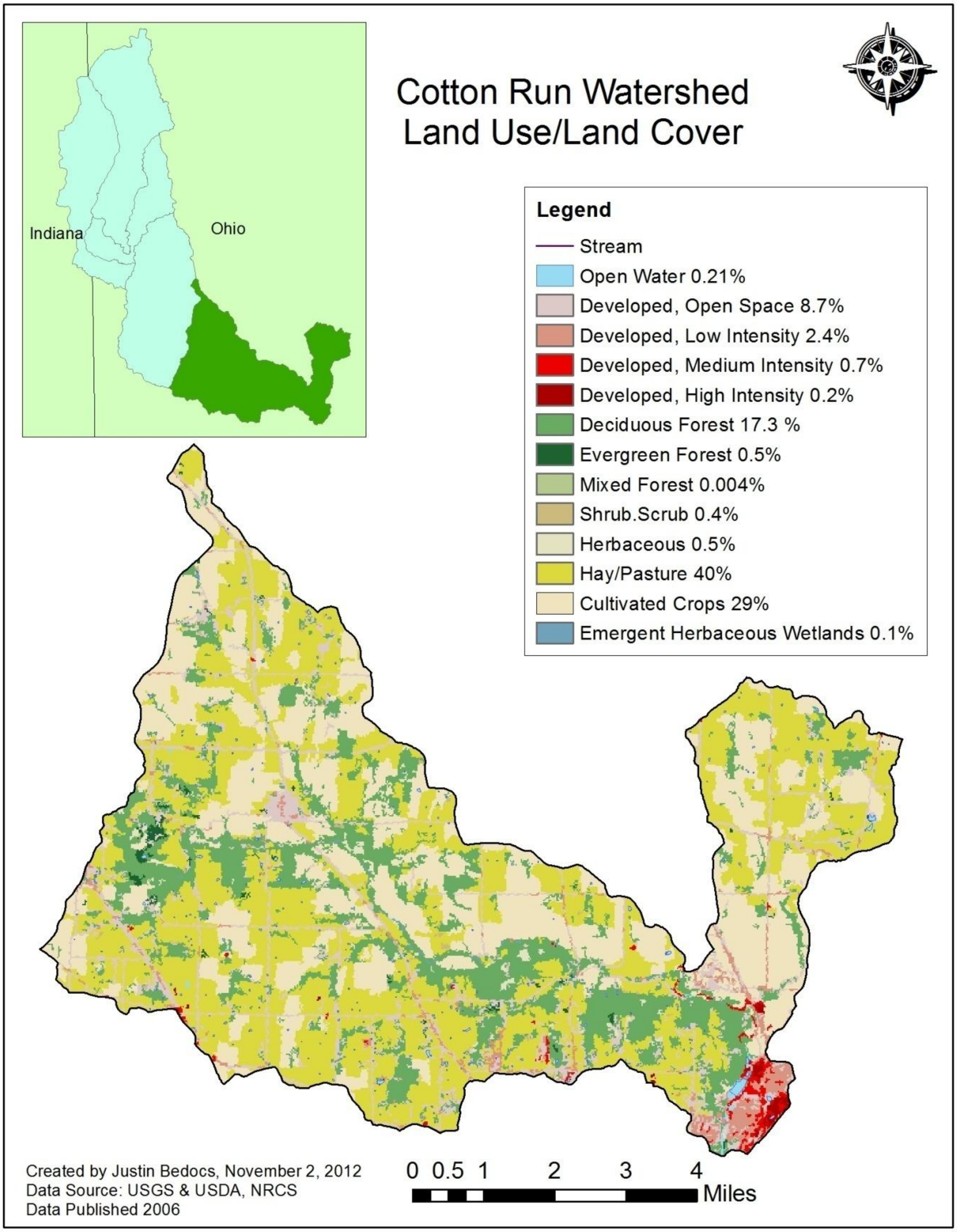

Figure 44. Land use land cover for Cotton Run subwatershed, 2006.

Development & Impervious Surfaces

Developed and urban areas make up 10% of the FMCW. Development and construction can contribute to nonpoint source pollution by producing sediment loads and excess storm runoff from impervious surfaces. Additionally, land development can lead to the construction of culverts and channelization of streams. These alterations can create areas of restriction which interfere with the natural flow of water and result in irregular flooding.

The total developed surface for each subwatershed of FMCW was determined by the sum of Developed Open Spaces, Developed Low Intensity, Developed Medium Intensity, and Developed High Intensity land (Appendix G).

Developed Land in FMCW

Four Mile Creek Headwaters: 4%
East Fork: 19%
Cotton Run: 12%
Little Four Mile Creek: 9%
Acton Lake: 17%

Various land cover types have different proportions of impervious surface, referred to as impervious fractions. According to the Watershed Inventory Workbook for Indiana, the typical impervious fractions for developed lands are 0.4 for high intensity development and 0.3 for low intensity development (Frankenberger, 2002). Therefore, in an area of high intensity development, 40% of the land is impervious, and in an area of low intensity development, 30% of the land is impervious. Forest and agricultural land cover has a much lower impervious fraction of 0.01. Using these fractions, the total estimated percentage of impervious surface cover in the FMCW is 3%. According to the Ohio EPA, stream degradation occurs at impervious surface levels of 10% (Perez, 1997). This means that on the scale of the entire watershed, impervious surfaces will not significantly impact the water quality of the FMCW. However, it is important to consider that development is often concentrated locally, and may be at levels above 10% in highly populated regions, such as Oxford and New Miami (Figures 43 and 44).

Construction Permits

One way of determining new development is to examine the number of new building permits that are issued in the area of interest. Between 2008 and 2011, Butler County issued 1,329 building permits in the townships of Hanover, Madison, Milford, Oxford, and New Miami (BCOBC, 2011) (Table 12).

Table 12. Building permits issued in Butler County 2008-2011 (BCOBC, 2011).

	2008	2009	2010	2011	TOTAL
Hanover	120	124	100	90	434
Madison	86	115	109	76	386
Milford	73	43	65	50	231
Oxford	50	37	44	34	165
New Miami	28	28	36	21	113
Yearly Total	**357**	**347**	**354**	**271**	**1329**

Culverts

The construction associated with urban and suburban development can interrupt natural stream flow. In order to minimize the obstruction of stream flow, culverts can be built where roadways cross the water body. A culvert is a closed conduit used to carry water from one region to another, usually from one side of a road to the other side (USEPA, 2003b). There are two main ways to classify culverts: 1) stream crossing culverts which overpass a stream; or 2) runoff management culverts. Stream crossing culverts allow water to pass downstream when a thoroughfare crosses a stream channel. Runoff management culverts are strategically placed in order to manage and route roadway runoff (USEPA, 2003b).

Butler County has 1,023 culverts that are currently maintained within its boundaries (BCEO, 2013). In the 2011 Capital Improvements Report, the Butler County Engineer's Office proposed the replacement of 24 culverts on county roads and 5 culverts on township roads (BCEO, 2011). No comparable data was available for Preble, Union, and Wayne counties.

These structures can be used to manage runoff, thereby improving water quality. Strategically placed culverts can reduce roadway flooding and erosion by distributing runoff to riparian filter areas. Culverts are also necessary to insure the continuity of stream flow to avoid points of restriction. Additionally, some designs can be utilized to avoid impedance on aquatic organisms (USEPA, 2003b).

Unsewered Areas

In some cases, certain structures can contribute to nonpoint source pollution even after their initial construction. Home sewage treatment systems can become an issue when they malfunction or when they begin to fail. Systems are designed to last for an average of 30-40 years under ideal conditions (ODH, 2008). Failing systems can discharge raw waste into surrounding soils and eventually into rivers and lakes. It is estimated that around one in four homes in the United States have a decentralized septic system, and 10-20% of them experience malfunctions each year (USEPA, 2012d). Most often they fail due to system age, system abuse or overloading, poor positioning, design, or lack of maintenance. Butler and Preble County Health Departments do not publically list residential sewage system locations. Therefore, the number of systems and failing systems in the FMCW has not been specifically identified.

According to an Ohio Department of Health (ODH) survey administered in 2008 to 76 health districts, 23% of septic systems are failing and 13% are projected to fail in the next five years. The SW Ohio, where the FMCW is located, has the largest number of existing systems (33%) and the largest number of systems projected to fail (27%) (ODH, 2008) (Table 13).

Table 13. Summary of system data collected from local health district surveys (ODH, 2008).

Status	Southwest Ohio
Existing Systems	174,139 (33%)
Failing Systems	19,707 (16%)
Future Failing Systems (5 yrs)	18,070 (27%)

The ODH and Ohio EPA collaborated to obtain a Section 303(d) watershed and large river assessment list of impaired and impacted streams (ODH, 2008). Based on this information, ODH concluded that failing septic systems may be an contributing factor to stream impairment.

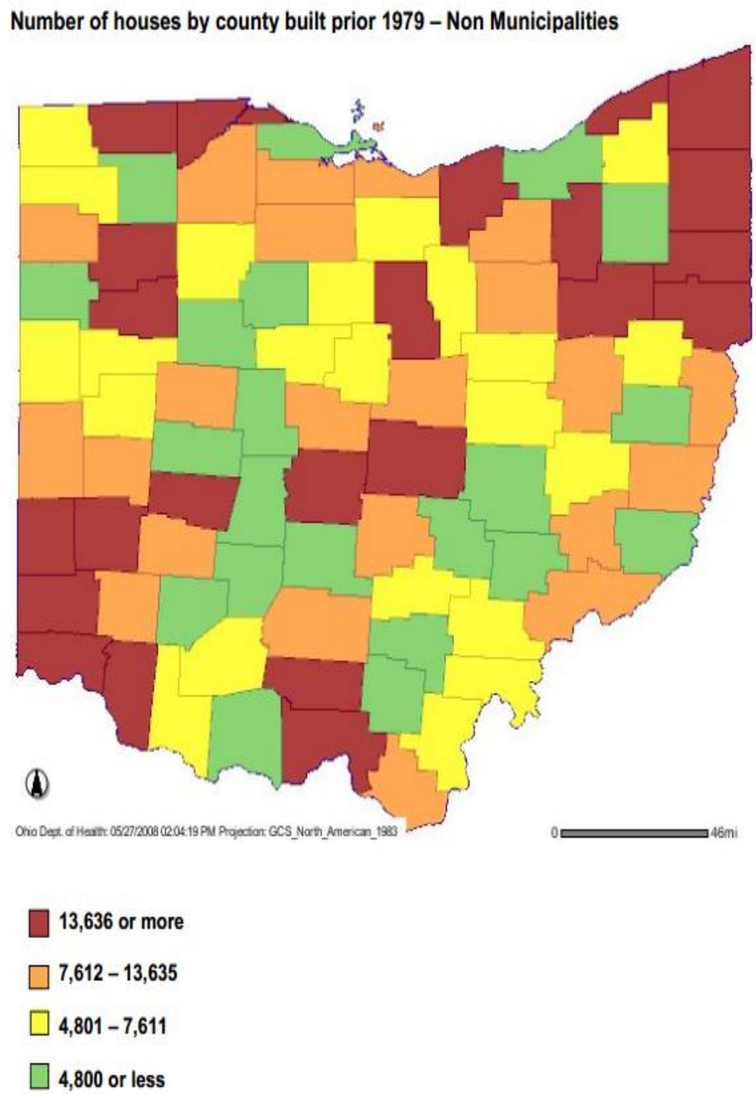

Figure 45. Number of houses built prior to 1979, by county (ODH, 2008).

TMDL reports help watershed managers assess the impact of septic systems on water quality. Because the FMCW does not currently have a TMDL report, it is difficult to quantify the influence that septic systems are having in the FMCW. Additionally, there is no record of the location of home septic systems that were built prior to 1980. Because more than 13,636 houses were built prior to 1979 and the average septic system life-time is 30-40 years (Figure 45), it is possible that septic systems built prior to this time could be failing.

C. Social Influences in FMCW

Places of Cultural and Recreational Significance

Places of cultural and recreational significance in the FMCW can bring visitors to the area and promote interest in the watershed. There are multiple attractions in the FMCW, including historic sites, recreational parks, and nature preserves. These resources are protected and are important to recognize.

National Register of Historic Places

Throughout the townships and populated places of the FMCW, there are resources of historical, cultural, and recreational significance. The Ohio Historic Preservation Office National Register of Historic Places (NRHP) is a list of federally recognized historical sites. The NRHP lists 22 historical sites in the townships and populated places within the FMCW (OHS, 2013a). This list includes sites of historical significance to the local community, the state, or the entire nation. If a site is deemed nationally significant to history and culture in the United States, it is designated a National Historic Landmark (OHS, 2013a). In the FMCW, the following two sites hold this designation:

- Langstroth Cottage, Oxford
- McGuffy/Willam H. House, Oxford

Additionally, three historical sites in the FMCW are considered significant not only for local communities, but to the state of Ohio:

- Elliot and Stoddard Halls, Miami University, Oxford
- Pugh's Mill Covered Bridge, Oxford
- Harshman Covered Bridge, Fairhaven

There are no historical sites registered within the FMCW boundaries in Union and Wayne counties in Indiana (NRHP, 2013). To be eligible to be listed on the NRHP, a site must be over 50 years old and hold some type of historical or local importance; however it may not be a cemetery, a moved/reconstructed site, or be primarily religious in nature (OHS, 2013b) (See Appendix I for a complete list of federally recognized historical sites in the FMCW).

The Ohio Historic Inventory provides information for the sites that are not eligible for the NRHP, but are still of cultural importance to the state of Ohio. There are 39 sites in the townships and populated places in Butler County (OHS, 2013b). There are no listed sites for Preble, Union, and Wayne counties (See Appendix J for a complete list of cultural sites by county).

Protected Lands

There are approximately 5,345 acres of land in the FMCW that are designated as protected, either in a park, a nature preserve, or a land easement (ODNR, 2013b; MU, 2013; BC MetroParks, 2013; TVCT, 2013). This is only 2.6% of the total area of the watershed, but these areas are important resources in the watershed.

Parks and Preserves

There are three major parks and preserves in the FMCW. All three include trail systems and other amenities to engage visitors in the wildlife and surroundings.

- Hueston Woods State Park & Nature Preserve (3,000 acres)
    - 200 acre state nature preserve
    - National Natural Landmark (established 1967)
    - Old growth forest

    - Lodging, camping, trails, swimming, boating, fishing, golf, hunting (ODNR, 2013c)
- Miami University Natural Areas (1,000 acres)
    - 400 acre old growth forest
    - University research
    - Hiking trails, birding (MU, 2013)
- Four Mile Creek Butler County MetroParks, Antenen Nature Preserve (132 acres)
    - Birding, fishing (BC MetroParks, 2013)

Conservation Easements

There is a total of 1,213 acres of land easements maintained by Three Valley Conservation Trust (TVCT) that lie within FMCW (TVCT, 2013). A conservation or agricultural land easement is a legal agreement made by the property owner to permanently restrict development in designated areas for the protection of natural and/or agricultural values (TVCT, 2013). The land owner retains all other rights, and can sell or transfer the property. Future land owners, however, are also bound by this contract. Conservation trusts may obtain easements through purchase, discount purchase, or donation. Once an agreement is reached, the trust establishes a monitoring program for each site. The FMCW easements are largely located in Butler County.

- Indiana: 100 acres
    - 100 acres in Union County
- Ohio: 1,113 acres
    - 771 acres in Butler County
    - 342 acres is Preble County

TVCT's mission is to protect and enhance regional waterways, woodlands, and farmland for the mutual benefit of the landscape and community (TVCT, 2013) (See Appendix K for a complete list of easements maintained by TVCT).

CHAPTER SIX: CURRENT AND COMPLEMENTARY EFFORTS

A. Miami University Research

Researchers from Miami University have studied Acton Lake from 1994-2013. Drs. Maria Gonzalez, Michael Vanni, and William Renwick have collaborated to examine the long term impacts of declining nutrient inputs on Acton Lake's water quality.

In 1994, subsidies were provided to farmers in the upper portions of the FMCW to encourage the conversion to conservation tillage. These changes in agricultural practices have dramatically reduced the amount of sediment and nutrient loads entering the lake (Renwick, 2008). However, these changes have also directly impacted the ecology of Acton Lake (Pilati, 2009).

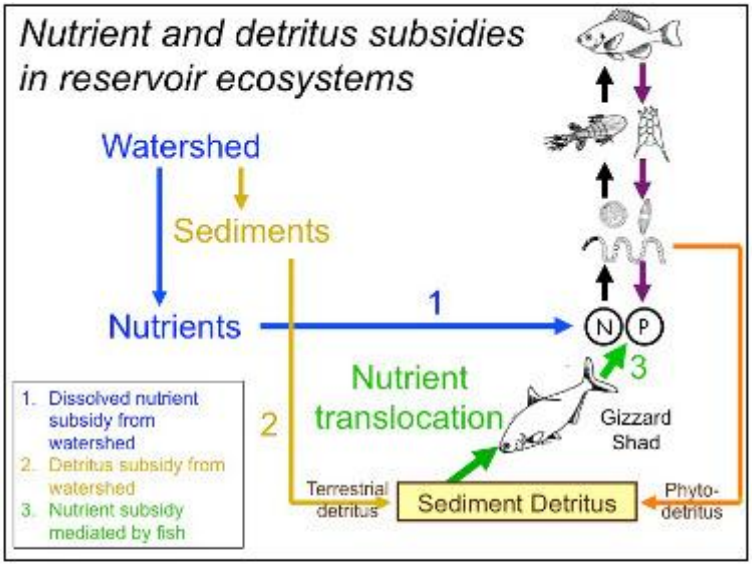

Figure 46. Ecological interactions in Acton Lake. Although fewer nutrients and sediments are entering the watershed, Gizzard Shad are re-suspending nutrients and detritus (decaying materials), allowing continued algae growth (Vanni, 2012).

One unique ecological interaction is the influence of Gizzard Shad on water quality and other organisms in Acton Lake. Gizzard Shad are fish that eat detritus, the dead and decaying materials on the bottom of the lake. When doing so, they re-suspend nutrients back into the water column (which fuels primary production) that would have otherwise been trapped in the lake sediments (Figure 46). This process is called translocation of nutrients, and is prolonging the time it takes for the positive effects of conservation tillage to become evident.

Despite the changes in agricultural practices, Acton Lake is still defined as a hypereutrophic reservoir (with very high amount of primary production). These researchers are carefully tracking and documenting these changes (OEPA, 2008). The water near the bottom is still often anoxic with high levels of ammonia-N concentrations (1.01, 0.856 mg/l) (OEPA, 2008). However, they have determined that suspended sediments and Soluble Reactive Phosphorus (SRP) levels have declined significantly in Acton Lake inflow streams from 1994 through 2006 (Renwick, 2008).

The project is ongoing and is currently funded by a NSF Long-Term Research in Environmental Biology (LTREB) grant.

B. Butler County Stream Team

Butler County Stream Team is a citizen science program where volunteers collect, analyze, and report water quality data retrieved from many sample locations throughout Butler County since 2006 (BCST, 2013). Samples are taken once a month and analyzed in a laboratory on Miami University's campus. This organization analyzes water quality by testing chemical variables; nitrate, total reactive phosphorus, turbidity, total dissolved solids, bacteria (coliform and *E.Coli*), conductivity, and pH (BCST, 2013). Stream Team data is classified as Level 2 credible data by the Ohio EPA.

A graduate student in the Institute for the Environment and Sustainability at Miami University worked with Steam Team data from sample years 2006-2011. This student completed three projects to help analyze the data collected from the Stream Team volunteers. Below are the projects that were completed to analyze the existing data:

1. **Data Preparation:** Condensing four existing documents into just one file. This required finding input errors, ensuring consistency in data, and identifying missing information.
2. **Trend Analysis:** Conducted for eight water quality parameters on 24 samples sites within FMCW. Statistical output such as regression models and Lowess smoothing techniques were used to display trends.
3. **Nested-Watershed Test:** To determine if a nested-watershed or a buffer-zone method of land use land cover (LULC) is more strongly correlated with water quality. Results showed that a nested-watershed approach is strongly correlated with water quality, but statistically, there was little difference between the two land use methods (more research is required).

After analyses were conducted, it was determined that the trends appear to be relatively stable over time (Figure 47). Changes that were observed for phosphate, turbidity, total dissolved solids, conductivity, and pH trends were shown to have occurred during or directly after periods of heavy precipitation (storm events) in 2008 (Figure 48). It appears that nitrates are increasing when using a small span for regression (Lowess span of 0.10). However, nitrates appear to be returning to a lower baseline over the larger span on the final months of 2008. In early 2010 and 2011, fecal coliform shows an increasing trend when using both the small and larger spans through the end of 2011. *E. Coli* trends appear to be relatively stable when using the small span Lowess. (For more information about these studies, contact IES).

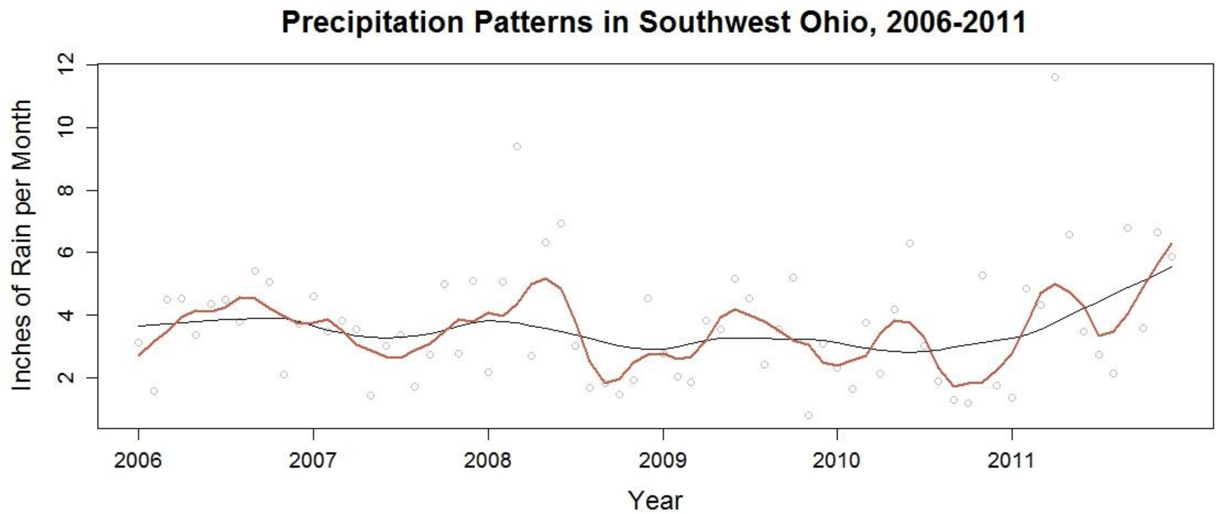

Figure 47. Precipitation patterns (inches per month) in SW Ohio, 2006-2011.

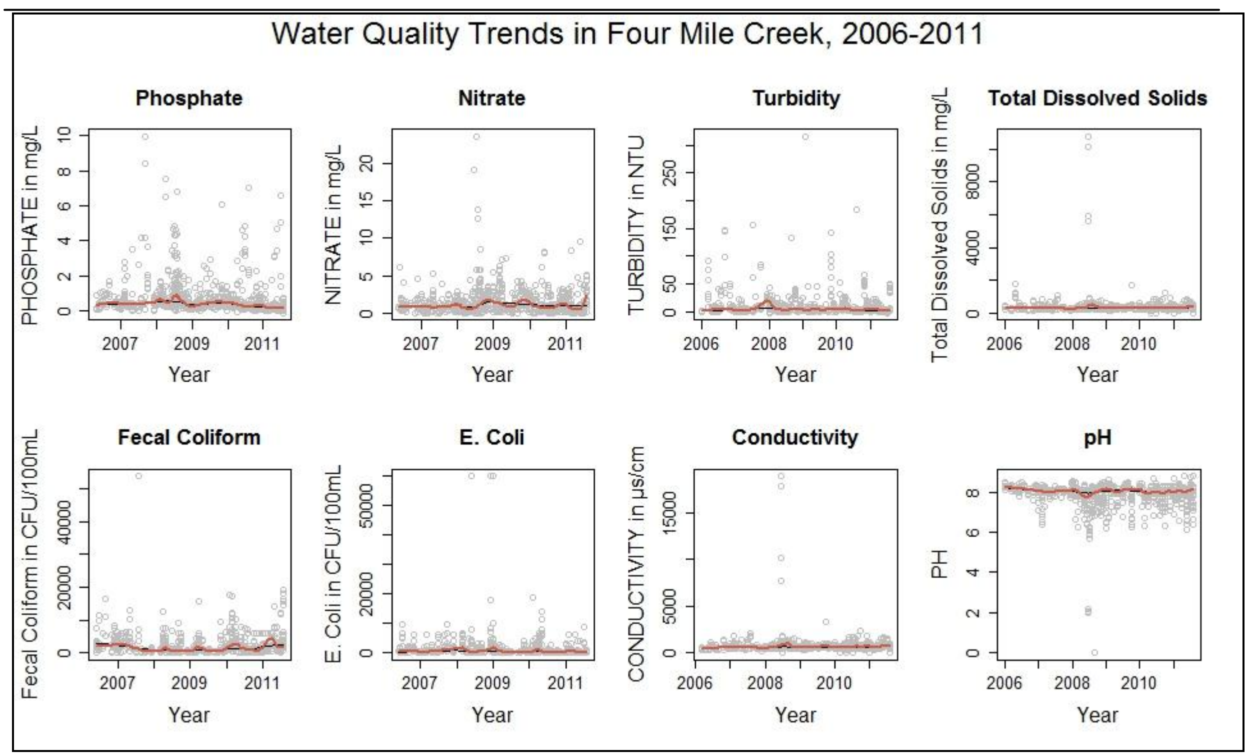

Figure 48. FMCW Water quality trends for eight variables, 2006-2011.

A second graduate student from Miami University in the Institute for the Environment and Sustainability conducted an additional analysis. The purpose of this project was to provide a clean and concise overview of the data by creating basic visuals that can be interpreted by a general audience. This will provide easily accessable tables and figures that have a small number of variables and are arranged in relevant groupings.

As a result of this project, generated figures and tables fell into three categories: 1) whole data set characterization; 2) watershed and subwatershed analysis; and 3) regional percent land-type visualization. Figure 49 identifies the frequency of sampling by subwatershed (Note: Four Mile Creek (FMC) and Indian Creek (IC) are sampled much more frequently than others, suggesting possible over sampling in those specific subwatersheds). (For more information about these studies, contact IES).

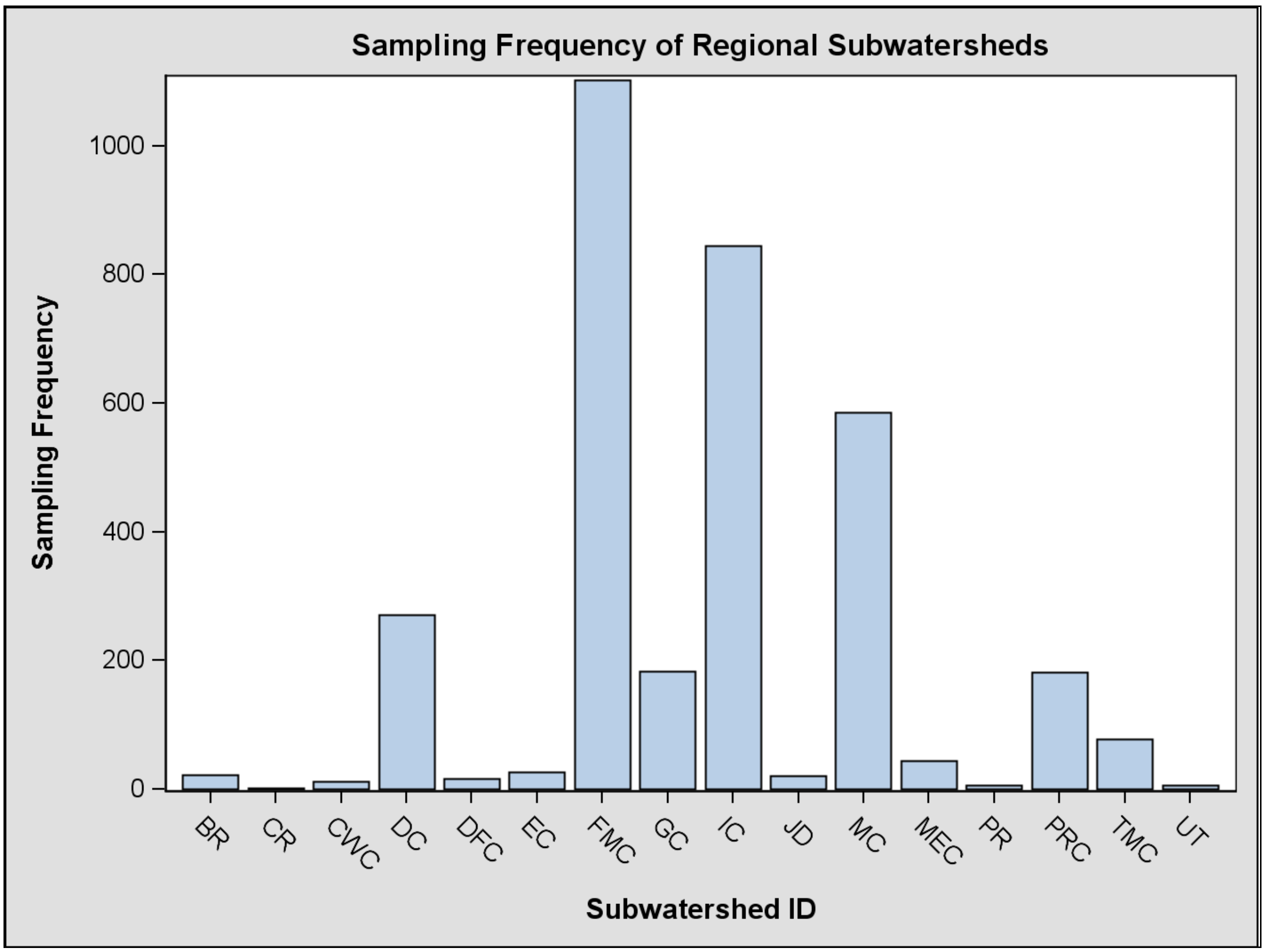

Figure 49. Sampling frequency by subwatersheds in Butler County.

CHAPTER SEVEN: SUMMARY AND RECOMMENDATIONS

A. Summary

The FMCW drains 322 square miles and lies within four counties in two different states. It has five subwatersheds. The northern portion of the watershed is highly agricultural, comprised mainly of cultivated crops such as corn and soybeans. The southern portion consists of mainly pasture and hay with pockets of high development in Oxford and New Miami, Ohio. There are many sites of cultural and recreational significance throughout the watershed. Soils within the FMCW are poorly to moderately drained, and are more susceptible to erosion and runoff in areas of steep slope along stream banks.

The most recent data from the Ohio EPA indicates that the majority of streams tested in the FMCW are in full or partial attainment of their designated uses (OEPA, 2008). The areas in the northern portion that are impacted or impaired are affected by unrestricted cattle access. In the southern portion of the watershed, areas that are impacted or impaired are affected by outflow from Acton Lake, runoff from the City of Oxford, and the Oxford WWTP.

B. Recommendations

After reviewing the data gathered and presented in this inventory, the team developed the following list of recommendations for future watershed management efforts:

1. *Continue data collection to supplement this inventory*

   Approximately 70% of the categories in the Ohio EPA guidebook were researched and presented in this report. All categories were not completed because the data was either unavailable or did not exist. Data was often available by county or state, but was not specific to the FMCW. It is also important to note that government databases are frequently updated and the information collected in this report is subject to change. It will be necessary to check for the most recent revisions when using this data for watershed management efforts. Our team found this to be a valuable learning experience, and we recommend further research and collaboration with Miami University students. (See Progress Table in Appendix L for a status report on inventory categories)

2. *Track progress of TMDL report*

   Monitoring for Total Maximum Daily Load (TMDL) is scheduled for 2020 in all subwatersheds of the FMCW. The TMDL report can provide a baseline against which to measure pollutant loads in the watershed. Once the TMDL report is complete, watershed coordinators can revisit this inventory and use the new information to further manage causes and sources of pollution in the FMCW.

3. *Maintain water quality through conservation efforts*

   Projects can be implemented to maintain the habitat and water quality in the FMCW. The Ohio EPA found that the majority of the stations analyzed in the watershed are in full attainment of their designated uses. This attainment status should be maintained and protected. Focusing on the location of Exceptional Warm Water Habitats and stations in full attainment, as well as places of cultural and recreational significance can help determine where to focus conservation efforts.

4. *Address causes of impairment*

   The Ohio EPA recommends that Fleisch Run and the headwaters of Four Mile Creek are fenced to prevent cattle access. The Ohio EPA also recommends upgrading the Oxford Waste Water Treatment Plant and repairing failing septic systems. In urban areas, funding can be applied to incorporate bioretention areas to reduce storm water runoff (OEPA, 2008).

5. *Create additional GIS maps*

   The team created 26 GIS maps to help visualize and convey the data that was collected. These maps are included in the inventory report, but were also provided to the clients on a CD, along with the metadata and original datasets, which accompanies this report. Map creation was sometimes limited by incompatible formatting and lack of data pertaining to the FMCW. Additionally, there were no spatial data available for every section of the inventory. We recommend that future watershed managers create additional GIS maps of the FMCW, including maps of cultural resources, building permits, or recreational use in the area.

The various characteristics of the FMCW, from the soil composition to use attainment status, played a vital role in creating this comprehensive watershed inventory. It was essential for the team to examine all aspects of the watershed in order to understand the health and importance of the system as a whole. This report can act as a baseline for watershed coordinators to establish their goals and objectives for the future of the FMCW, as this project moves forward.

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Originator: The Indiana Department of Natural Resources (IDNR). Publication date: 2011. Title: Aquifer Systems Maps 80-A and 80-B: Bedrock Aquifer Systems of Union County, Indiana. Online Linkage: http://www.in.gov/dnr/water/6438.htm

Originator: The Indiana Department of Natural Resources (IDNR). Publication date: 2011. Title: Aquifer Systems Maps 83-A and 83-B: Bedrock Aquifer Systems of Wayne County, Indiana. Online Linkage: http://www.in.gov/dnr/water/6607.htm

Originator: The Ohio Department of Natural Resources (ODNR), Division of Water. Publication date: 2000. Title: Consolidated Aquifers of Ohio. Online Linkage: http://www.dnr.state.oh.us/water/samp/sampbddl/tabid/4224/Default.aspx

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Originator: The Ohio Department of Natural Resources (ODNR). Publication date: 1995. Title: Ground Water Pollution Potential – Preble County. Online Linkage: http://www.dnr.state.oh.us/ERINHome/AbouttheData/tabid/23290/Default.aspx

Land Use Land Cover Maps. Originator: USDA/NRCS - National Geospatial Management Center. Publication date: 2006. Title: National Land Cover Dataset. Online Linkage: http://www.mrlc.gov/index.php

Soils Maps. Originator: U.S. Department of Agriculture, Natural Resources Conservation Service. Publication Date: October 3, 2012. Title: Soil Survey Geographic (SSURGO) database for Butler County & Preble County, Ohio and Union & Wayne County, Indiana. Publication Place: Fort Worth, Texas. Publisher: U.S. Department of Agriculture, Natural Resources Conservation Service. Online Linkage: URL:http://SoilDataMart.nrcs.usda.gov/

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Originator: The Indiana Department of Natural Resources (IDNR). Publication date: 2011. Title: Aquifer Systems Maps 80-A and 80-B: Unconsolidated Aquifer Systems of Union County, Indiana. Online Linkage: http://www.in.gov/dnr/water/6438.htm
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Unconsolidated OH Aquifers Map. Originator: The Ohio Department of Natural Resources (ODNR), Division of Water. Publication date: 2000. Title: Unconsolidated Aquifers of Ohio. Online Linkage: http://www.dnr.state.oh.us/water/samp/uncon_coverages/tabid/4230/Default.aspx

Wetlands Map. Originator: U.S. Fish and Wildlife Service, Branch of Habitat Assessment. Publication date: September 24, 2012. Title: Conus Public Historic Map Info. Online Linkage: http://www.fws.gov/wetlands/

APPENDIX

Appendix A

A Guide to Developing Local Watershed Action Plans in Ohio - Appendix 8

(Perez, 1997)

4. WATERSHED INVENTORY
   1. Description of the watershed
      a. Geology
         i. Topography
         ii. Geology
         iii. Soils
         iv. Glacial History
      b. Biological Features
         i. Rare, threatened and endangered species
            1. Fish
            2. Mussels
            3. Invertebrates
            4. Mammals
            5. Birds
            6. Reptiles & amphibians
            7. Plants
         ii. Invasive nonnative species and their potential impacts
      c. Water resources
         i. Climate and Precipitation
         ii. Surface Water
            1. Wetlands
            2. Streams (include map/description of subwatersheds)
               a. Tributary name, length and watershed size, cfs, 10 year low flows, floodplain areas, sinuosity and entrenchment indices
               b. Tributary use designation, utilizing Ohio's water quality standards.
            3. Lakes and reservoirs (size, uses, watersheds, detention time).
         iii. Ground Water
            1. Aquifers (location, recharge rates, uses)
               a. Flow regime
               b. Source Water Assessment Plan (SWAP) information
               c. What do DRASTIC maps say about sensitivity of groundwater to local sources of contamination?
   2. Land Use
      a. Land cover description (with percentages by subwatershed)
         i. Urban

            1. Impervious surfaces
            2. Home sewage treatment systems location
        ii. Forest
        iii. Agriculture
            1. Crop type
            2. Tillage
            3. Rotations
            4. Livestock Inventory
            5. Grazing
            6. Chemical use patterns
            7. Irrigation
        iv. Water
        v. Non-forested wetlands
        vi. Barren
    b. Protected Lands
        i. City, county, district, state or national public forests and/or parks
        ii. Land protected by private foundations or land trusts
    c. Status and Trends (Historical, current, projected).
3. Cultural Resources
    a. Sites of historical, cultural or recreational significance
4. Previous and Complementary Efforts
    a. History of previous water quality efforts in the watershed
    b. A listing of current efforts that will help to meet water quality standards that are occurring in the watershed.
5. Physical attributes of streams and floodplain areas that support habitat, recreation, water quality, etc. (aka Habitat modification inventory on a subwatershed or stream segment basis)
    a. Early settlement conditions
    b. Channel and floodplain condition. (does the channel have access to its floodplain?)
    c. Forested riparian corridor assessment
    d. Number of miles with forested natural riparian buffer (describe)
    e. Number of miles with permanent protection
    f. Miles of natural channel (Never modified or fully recovered)
    g. Miles & location of modified channel
    h. Dams
    i. Channelization
    j. Streams with unrestricted livestock access
    k. Eroding banks (number and severity of sediment produced)
    l. Floodplain connectivity
    m. Riparian levees
    n. Entrenched miles
    o. Status and Trends
        i. expected residential/commercial development
        ii. expected road, highway, bridge construction

6. Water Resource Quality (to meet the requirements of the Clean Water Act, lakes, streams and wetland must be included in this assessment)
    a. Locationally-referenced use designations/use attainment
        i. Number of waterbodies/miles in full attainment
        ii. Number of threatened miles
            1. Number of waterbodies/miles in partial attainment
            2. Number of segments/miles in non-attainment
            3. Number of streams designated but not monitored
            4. Lakes/quality
            5. Wetlands/quality
            6. Groundwater/quality
    b. Causes and sources of impairment or threats as presented in the 305(b) 303 (d) integrated water quality report for the above-listed waterbodies/miles. (See Attachment A for a listing of causes and sources). Keep in mind that sources as presented in Ohio EPA's documents do not represent the level of definition/detail needed to identify and target technical solutions. Please consult with your Area Assistance Team for more detail on source identification.
    c. Point sources (by subwatershed or stream segment)
        i. Permitted discharges (NPDES)
        ii. Spills and illicit discharges
    d. Nonpoint sources (by subwatershed or stream segment)
        i. An inventory of home sewage treatment systems, and a projected number of failing systems.
        ii. Number of new homes being built.
        iii. Number and size of animal feeding operations.
        iv. Acres of Highly Erodible Land and potential soil loss.
        v. Is the stream culverted?
        vi. Channelized?
        vii. Levied?
        viii. Exhibiting little human impact?
        ix. What's the effluent volume?
        x. Dammed? (How many stream miles are impounded)
        xi. Officially classified and/or unofficially maintained as petition ditches?
    e. Status and trends (areas where water quality is in attainment, but local information indicates that the current situation, if unchanged, will likely result in water quality degradation.)

Appendix B

Guides for Developing Watershed Action Plans

Ohio:

Perez J, "A Guide to Developing Local Watershed Action Plans in Ohio," Ohio Environmental Protection Agency, 1997.
http://www.epa.ohio.gov/portals/35/nps/wsguide.pdf

Indiana:

Frankenberger J, McLoud S, and Faulkenburg A, "Watershed Inventory Workbook for Indiana." Purdue University, March 2002.
https://engineering.purdue.edu/SafeWater/watershed/inventoryf.pdf

Appendix C

Average Temperature and Precipitation, Eaton, Ohio

(NCDC, 2012)

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Yr. Avg
Avg. Temp (F)	24.5	28.4	38.6	49.3	60.0	68.9	72.7	71.1	64.2	52.0	40.9	30.1	50.1
Avg. Precp. (inches)	2.55	2.26	3.25	4.03	4.72	3.86	3.74	3.30	2.64	2.74	3.41	3.04	39.54

Appendix D

Acreage and Percentages of Wetlands and Deepwater Habitats Presented by Subwatershed

(USFWS, 2013b)

Watershed	**Watershed Size (acres)**	**Wetlands and Deepwater Habitats (acres)**	**Percent wetlands and deepwater habitats**
Acton Lake	26482.05644	775.442975	2.928182623
Cotton Run	32855.50613	451.447338	1.374038605
East Fork	10534.2587	39.223156	0.372339024
Four Mile Creek Headwaters	24522.42326	58.069615	0.236802107
Little Four Mile Creek	19615.90744	211.522432	1.078320912

Appendix E

Classification of Organisms

(USFWS, 2012b)

Term	Meaning
Endangered	Organisms in danger of extinction within the foreseeable future throughout all or a significant portion of its range.
Threatened	Organisms likely to become endangered within the foreseeable future throughout all or a significant portion of its range.
Candidate	Organisms that the FWS has studied and concluded should be proposed for addition to the federally endangered and threatened species list.

State Listed Threatened, Rare, and Endangered Species

(IDNR 2012, ODNR, 2012b)

	Ohio Counties		**Indiana Counties**	
	Butler	**Preble**	**Wayne**	**Union**
Mammal				
Bobcat (*Lynx rufus*)			State Special Concern	
American Badger (*Taxidea taxus*)			State Special Concern	State Special Concern
Bird				
Upland Sandpiper (*Bartramia longicauda*)	State Endangered		State Endangered	
Sedge Wren (*Cistothorus platensis*)				State Endangered
Black Vulture (*Coragyps atratus*)		State Special Concern		
Cerulean Warbler (*Dendroica cerulea*)			State Endangered	State Endangered
Peregrine Falcon (*Falco peregrinus*)	State Threatened *listed as Federal Special Concern by ODNR			
Bald Eagle (*Haliaeetus leucocephalus*)				State Endangered
Least Bittern (*Ixobrychus exilis*)	State Threatened		State Endangered	
Black-crowned Night-heron (*Nycticorax nycticorax*)	State Threatened		State Endangered	
Osprey (*Pandion haliaetus)*				State Endangered

Sora Rail (*Porzana carolina*)	State Special Concern			
King Rail (*Rallus elegans*)			State Endangered	
Barn Owl (*Tyto alba)*			State Endangered	
Hooded Warbler (*Wilsonia citrina*)			State Special Concern	
Reptile				
Kirtland's Snake (*Clonophis kirtlandii*)	State Threatened *listed as Federal Special Concern by ODNR	State Threatened *listed as Federal Special Concern by ODNR	State Endangered	
Blanding's Turtle (*Emydoidea blandingii*)			State Endangered	
Butler's Garter Snake (*Thamnophis butleri*)			State Endangered	
Amphibian				
Cave Salamander (*Eurycea lucifuga*)	State Endangered			
Northern Leopard Frog (*Rana pipiens*)			State Special Concern	
Fish				
Redside Dace (*Clinostomus elongates*)				State Endangered
Least Darter (*Etheostoma microperca*)		State Special Concern		
Variegate Darter (*Etheostoma variatum*				State Endangered
Tonguetied Minnow (*Exoglossum laurae*)	State Threatened			
Invertebrate				
Sloan's Crayfish (*Orconectes sloanii*)	State Threatened	State Threatened		
Mussel				
Kidneyshell *(Ptychobranchus fasciolaris)*				State Special Concern
Insect				
Cobblestone Tiger Beetle (*Cicindela marginipennis*)			State Endangered	
Brown Spiketail (*Cordulegaster bilineata*)			State Endangered	
Baltimore (*Euphydryas phaeton*)			State Rare	
Plains Clubtail (*Gomphus externus*)	State Endangered			
Blue Corporal (*Ladona deplanata*)	State Endangered			
Wabash River Cruiser (*Macromia wabashensis*)			State Endangered	
Northern Casemaker Caddisfly (*Pycnopsyche rossi*)			State Endangered	
Clamp-tipped Emerald (*Somatochlora tenebrosa*)			State Rare	

Gray Petaltail (*Tachopteryx thoreyi*)			State Rare	
Plants				
Southern Hairy Rock Cress (*Arabis hirsuta var. adpressipilis*)	State Potentially Threatened			
Prairie Brome (*Bromus kalmii*)	State Potentially Threatened			
Heavy Sedge (*Carex gravida)*				State Endangered
Midland Sedge (*Carex mesochorea*)	State Threatened	State Threatened		
Timid Sedge (*Carex timida*)	State Threatened			
Five-angled Dodder (*Cuscuta pentagona*)	State Threatened			
Pale Umbrella-sedge (*Cyperus acuminatus*)	State Potentially Threatened			
Burhead (*Echinodorus berteroi*)	State Threatened			
Ground Juniper (*Juniperus communis*)			State Rare	
Heart-leaved Plantain (*Plantago cordata)*			State Endangered	
Missouri Gooseberry (*Ribes missouriense*)	State Threatened			
Carolina Willow (*Salix caroliniana*)	State Potentially Threatened			
Calamint (*Satureja glabella var. angustifolia*)			State Endangered	
Snowy Campion (*Silene nivea*)	State Endangered			
Shining Ladies'-tresses (*Spiranthes lucida*)			State Rare	
Eastern Featherbells (*Stenanthium gramineum)*				State Threatened
Three-birds Orchid (*Triphora trianthophora*)		State Potentially Threatened		
Soft-leaved Arrow-wood (*Viburnum molle*)	State Threatened	State Threatened	State Rare	
Barren Strawberry (*Waldsteinia fragarioides*)			State Rare	

State Listed Nonnative Plant Species

(EDDMapS 2013a,b,c,d)

	Ohio Counties		Indiana Counties	
Species	**Butler**	**Preble**	**Wayne**	**Union**
Velvetleaf (*Abutilon theophrasti*)	X	X	X	X
Hedge Maple (*Acer ginnala*)	X			
Amur Maple (*Acer ginnala*)	X			
Norway Maple (*Acer platanoides*)	X		X	X
Jointed Goatgrass (*Aegilops cylindrica*)	X	X		
Bishops Goutweed (*Aegopodium podagraria*)	X			
Corn Cockle (*Agrostemma githago*)	X		X	
Redtop (*Agrostis gigantea*)	X	X	X	X
Tree-of-heaven (*Ailanthus altissima*)	X	X	X	X
Carpet Bugle (*Ajuga reptans*)	X		X	X
Hollyhock (*Alcea rosea*)			X	X
Garlic Mustard (*Alliaria petiolata*)	X	X	X	X
Redroot Pigweed (*Amaranthus retroflexus*)			X	
Common Ragweed (*Ambrosia artemisiifolia*)	X		X	X
Annual Ragweed (*Ambrosia artemisiifolia var. elatior*)	X		X	X
Stinking Chamomile (*Anthemis cotula*)	X	X	X	
Common Burdock (*Arctium minus*)	X		X	
Thymeleaf Sandwort (*Arenaria serpyllifolia*)	X			
Absinth Wormwood		X		

(*Artemisia absinthium*)				
Yellow Rocket (*Barbarea vulgaris*)	X	X	X	
Japanese Barberry (*Berberis thunbergii*)	X	X		
Hoary Alyssum (*Berteroa incana*)	X	X		
Indian Mustard (*Brassica juncea*)	X			
Black Mustard (*Brassica nigra*)	X	X	X	X
Birdsrape Mustard (*Brassica rapa*)			X	
Field Brome (*Bromus arvensis*)	X	X		X
Smooth Brome (*Bromus inermis*)	X	X		
Bald Brome (*Bromus racemosus*)			X	
Cheatgrass (*Bromus tectorum*)	X	X	X	X
Corn Gromwell (*Buglossoides arvensis*)	X	X	X	
Smallseed Falseflax (*Camelina microcarpa*)	X			
Marijuana (*Cannabis sativa*)		X	X	X
Shepherd's-purse (*Capsella bursa-pastoris*)	X	X	X	
Musk Thistle (*Carduus nutans*)	X		X	
Spotted Knapweed (*Centaurea stoebe ssp. micranthos*)	X		X	
Common Mouse-ear Chickweed (*Cerastium fontanum*)	X	X	X	X
Big Chickweed (*Cerastium fontanum ssp. vulgare*)	X	X	X	X
Greater Celandine (*Chelidonium majus*)			X	

Nettleleaf Goosefoot (*Chenopodium murale*)	X		X	
Chicory (*Cichorium intybus*)	X		X	X
Canada Thistle (*Cirsium arvense*)	X		X	X
Bull Thistle (*Cirsium vulgare*)	X	X	X	
Asiatic Dayflower(*Commelina communis*)		X	X	X
Poison-hemlock (*Conium maculatum*)	X		X	X
European Lily of the Valley (*Convallaria majalis*)			X	X
Field Bindweed (*Convolvulus arvensis*)	X	X	X	X
Piedmont Bedstraw (*Cruciata pedemontana*)	X			
Black Dog-strangling Vine (*Cynanchum louiseae*)		X		
Bermudagrass (*Cynodon dactylon*)			X	
Houndstongue (*Cynoglossum officinale*)	X	X	X	
Orchardgrass (*Dactylis glomerata*)	X		X	
Jimsonweed (*Datura stramonium*)	X	X	X	X
Queen Anne's Lace, Wild Carrot (*Daucus carota*)	X	X	X	X
Deptford Pink (*Dianthus armeria*)	X	X		
Common Teasel (*Dipsacus fullonum*)	X	X	X	X
Cutleaf Teasel (*Dipsacus laciniatus*)	X			
Spring Whitlowgrass (*Draba verna*)	X		X	
Indian Mock-strawberry (*Duchesnea indica*)			X	X

Mexicantea (*Dysphania ambrosioides*)	X	X	X	
Barnyardgrass (*Echinochloa crus-galli*)	X	X	X	X
Blueweed (*Echium vulgare*)	X		X	
Anchored Waterhyacinth (*Eichhornia azurea*)			X	
Autumn-olive (*Elaeagnus umbellata*)	X	X	X	X
Goosegrass (*Eleusine indica*)		X	X	X
Quackgrass (*Elymus repens*)	X	X	X	
Stinkgrass (*Eragrostis cilianensis*)			X	
Winged Burning Bush (*Euonymus alatus*)	X			
Winter Creeper (*Euonymus fortunei*)	X		X	X
Cypress Spurge (*Euphorbia cyparissias*)	X		X	X
Petty Spurge (*Euphorbia peplus*)			X	
Wild buckwheat (*Fallopia convolvulus*)	X		X	
Japanese Knotweed (*Fallopia japonica*)		X	X	X
Mulberryweed (*Fatoua villosa*)	X			
Meadow Fescue (*Festuca pratensis*)		X	X	
Sheep Fescue (*Festuca trachyphylla*)		X		
Fig Buttercup (*Ficaria verna*)			X	
Hairy Galinsoga (*Galinsoga quadriradiata*)	X		X	
Smooth Bedstraw (*Galium mollugo*)			X	
Cutleaf Geranium (*Geranium dissectum*)			X	

Ground Ivy (*Glechoma hederacea*)	X	X	X	X
English Ivy (*Hedera helix*)			X	X
Tawny Daylily (*Hemerocallis fulva*)			X	
Damesrocket (*Hesperis matronalis*)	X	X	X	X
Rose of Sharon (*Hibiscus syriacus*)			X	X
Venice Mallow (*Hibiscus trionum*)	X	X	X	
Meadow Hawkweed (*Hieracium caespitosum*)	X			
Mouseear Hawkweed (*Hieracium pilosella*)	X			
Common St. Johnswort (*Hypericum perforatum*)	X	X	X	X
Elecampane (*Inula helenium*)	X		X	
Ivyleaf Morningglory (*Ipomoea hederacea*)	X	X		X
Tall Morningglory (*Ipomoea purpurea*)	X	X	X	X
Mexican Fireweed (*Kochia scoparia*)		X	X	
Willowleaf Lettuce (*Lactuca saligna*)	X			X
Prickly Lettuce (*Lactuca serriola*)	X	X	X	X
Henbit (*Lamium amplexicaule*)		X	X	X
Purple Deadnettle (*Lamium purpureum*)		X	X	X
Everlasting Peavine (*Lathyrus latifolius*)			X	X
Motherwort (*Leonurus cardiaca*)	X	X	X	
Oxeye Daisy (*Leucanthemum vulgare*)	X	X	X	X

Border Privet (*Ligustrum obtusifolium*)			X	X
European Privet (*Ligustrum vulgare*)	X			X
Yellow Toadflax (*Linaria vulgaris*)	X	X	X	
Perennial Ryegrass (*Lolium perenne*)			X	
Japanese Honeysuckle (*Lonicera japonica*)	X		X	X
Amur Honeysuckle (*Lonicera maackii*)	X		X	X
Morrow's Honeysuckle (*Lonicera morrowii*)	X		X	
Bell's Honeysuckle (*Lonicera x bella*)			X	X
Birdsfoot Trefoil (*Lotus corniculatus*)			X	X
Annual Honesty (*Lunaria annua*)				X
Scarlet Pimpernel (*Lysimachia arvensis*)	X		X	
Moneywort (*Lysimachia nummularia*)	X		X	X
Purple Loosestrife (*Lythrum salicaria*)	X			
Japanese Flowering Crabapple (*Malus floribunda*)	X			
Paradise Apple (*Malus pumila*)	X	X		
Common Mallow (*Malva neglecta*)	X	X	X	
White Horehound (*Marrubium vulgare*)	X		X	
Pineapple-weed (*Matricaria discoidea*)	X		X	X
Black Medic (*Medicago lupulina*)	X	X	X	X
Yellow Sweetclover (*Melilotus officinalis*)	X	X	X	X

Water Mint (*Mentha aquatica*)	X		X	
Spearmint (*Mentha spicata*)	X	X	X	X
Gingermint (*Mentha x gracilis*)	X			
Peppermint (*Mentha x piperita*)	X		X	
Japanese Stiltgrass (*Microstegium vimineum*)			X	
Thoroughwort Pennycress (*Microthlaspi perfoliatum*)	X	X		
White Mulberry (*Morus alba*)	X	X	X	X
Common Grape Hyacinth (*Muscari botryoides*)			X	X
True Forget-me-not (*Myosotis scorpioides*)	X			
Water Starwort (*Myosoton aquaticum*)	X			
Eurasian Watermilfoil (*Myriophyllum spicatum*)			X	
Brittleleaf Naiad (*Najas minor*)		X		
Watercress (*Nasturtium officinale*)	X		X	
Catnip (*Nepeta cataria*)	X	X	X	
Tree Tobacco (*Nicotiana glauca*)	X			
Redsepal Evening-primrose (*Oenothera glazioviana*)				X
Scotch Thistle (*Onopordum acanthium*)	X	X		
Star-of-Bethlehem (*Ornithogalum umbellatum*)	X		X	X
Wild Parsnip (*Pastinaca sativa)*	X	X	X	X
Perilla Mint (*Perilla frutescens*)		X		
Oriental Lady's Thumb (*Persicaria longiseta*)	X			

Ladysthumb (*Persicaria maculosa*)	X		X	
Princess-feather (*Persicaria orientalis*)	X	X		
Reed Canarygrass (*Phalaris arundinacea*)	X	X	X	
Timothy (*Phleum pratense*)	X	X	X	
Common Reed (*Phragmites australis australis*)			X	
Buckhorn Plantain (*Plantago lanceolata*)	X	X	X	
Annual Bluegrass (*Poa annua*)	X	X	X	
Bulbous Bluegrass (*Poa bulbosa*)	X	X		
Canada Bluegrass (*Poa compressa*)	X	X	X	X
White Poplar (*Populus alba*)			X	
Sulfur Cinquefoil (*Potentilla recta*)	X	X	X	
Mahaleb Cherry (*Prunus mahaleb*)	X	X		
Weeping Alkaligrass(*Puccinellia distans*)	X			
Callery Pear (Bradford pear) (*Pyrus calleryana*)	X	X	X	X
Common Pear (*Pyrus communis*)	X	X		
Radish (*Raphanus sativus*)	X			
European Buckthorn (*Rhamnus cathartica*)	X			
Jetbead (*Rhodotypos scandens*)	X			
Yellow Fieldcress (*Rorippa sylvestris*)	X			
Dog Rose (*Rosa canina*)		X		
Sweetbriar Rose (*Rosa eglanteria*)		X		

Multiflora Rose (*Rosa multiflora*)	X	X	X	X
Red Sorrel (*Rumex acetosella*)	X		X	
Curly Dock (*Rumex crispus*)		X	X	
Curly Dock (*Rumex crispus ssp. crispus*)		X	X	
Broadleaf Dock (*Rumex obtusifolius*)	X	X	X	
White Willow (*Salix alba*)		X		
Crack Willow (*Salix fragilis*)				X
Russian-thistle (*Salsola tragus*)	X			X
Bouncingbet (*Saponaria officinalis*)	X	X	X	X
Crownvetch (*Securigera varia*)	X		X	X
Giant Foxtail (*Setaria faberi*)	X	X	X	X
Yellow Foxtail (*Setaria pumila*)			X	X
Bristly Foxtail (*Setaria verticillata*)	X		X	
Green Foxtail (*Setaria viridis*)	X	X		X
Green Bristlegrass (*Setaria viridis var. viridis*)	X	X		X
White Campion (*Silene latifolia*)	X			
Bladder Campion (*Silene latifolia*)	X			
Nightflowering Catchfly (*Silene noctiflora*)	X		X	
Tumble Mustard (*Sisymbrium altissimum*)				X
Wild Mustard (*Sinapis arvensis*)	X	X		
Hedge Mustard (*Sisymbrium officinale*)	X	X		

Bittersweet Nightshade (*Solanum dulcamara*)	X		X	
Perennial Sowthistle (*Sonchus arvensis*)			X	
Moist Sowthistle (*Sonchus arvensis ssp. uliginosus*)			X	
Spiny Sowthistle (*Sonchus asper*)	X		X	X
Annual Sowthistle (*Sonchus oleraceus*)	X		X	X
Sorghum (*Sorghum bicolor*)	X		X	X
Johnsongrass (*Sorghum halepense*)	X		X	X
Common Chickweed (*Stellaria pallida*)	X		X	
Common Tansy (*Tanacetum vulgare*)	X		X	
Japanese Yew (*Taxus cuspidata*)	X			
Field Pennycress (*Thlaspi arvense*)	X		X	
Hedgeparsley (*Torilis arvensis*)	X		X	
Spreading Hedgeparsley (*Torilis arvensis ssp. arvensis*)	X		X	
Western Salsify (*Tragopogon dubius*)	X		.X	X
Meadow Salsify (*Tragopogon lamottei*)	X		X	
Large Hop Clover (*Trifolium campestre*)	X		X	
Alsike Clover (*Trifolium hybridum*)			X	
Red Clover (*Trifolium pratense*)	X	X	X	
White Clover (*Trifolium repens*)	X	X	X	
Narrowleaf Cattail (*Typha*			X	

angustifolia)				
Siberian Elm (*Ulmus pumila*)			X	
Moth Mullein (*Verbascum blattaria*)	X	X	X	X
Common Mullein (*Verbascum thapsus*)	X		X	
Corn Speedwell (*Veronica arvensis*)	X	X	X	
Thymeleaf Speedwell (*Veronica serpyllifolia*)	X		X	
European Cranberrybush (*Viburnum opulus*)	X	X	X	
European Cranberrybush (*Viburnum opulus var. opulus*)	X	X	X	
Bird Vetch (*Vicia cracca*)			X	
Japanese Snowball (*Viburnum plicatum*)	X			
Hairy Vetch (*Vicia villosa*)			X	
Common Periwinkle (*Vinca minor*)	X	X	X	X

Appendix F

Crop Type Spread Sheet

(USDA, 2006)

FMCW 2012 Crop Type			
Value	Category	Count	Acreage
1	Corn	128149	28499.7
5	Soybeans	134549	29923
13	Pop or Orn Corn	1028	228.6
24	Winter Wheat	1915	425.9
26	DblCrop WinWht/Soybeans	681	151.5
28	Oats	1	0.2
30	Speltz	2	0.4
36	Alfalfa	1735	385.9
37	Other Hay/Non Alfalfa	2966	659.6
54	Tomatoes	1	0.2
59	Sod/Grass Seed	3	0.7
60	Switchgrass	1	0.2
61	Fallow/Idle Cropland	1	0.2
111	Open Water	3367	748.8
121	Developed/Open Space	36901	8206.6
122	Developed/Low Intensity	9791	2177.5
123	Developed/Medium Intensity	3259	724.8
124	Developed/High Intensity	866	192.6
131	Barren	17	3.8
141	Deciduous Forest	81349	18091.6
142	Evergreen Forest	568	126.3
143	Mixed Forest	1239	275.5
152	Shrubland	159	35.4
171	Grassland Herbaceous	1375	305.8
181	Pasture/Hay	102700	22839.9
190	Woody Wetlands	19	4.2
195	Herbaceous Wetlands	25	5.6
Total			**114014.5**

Appendix G

Land Cover Class Definitions

(USGS, 2010)

Developed Areas - characterized by a high percentage (30 percent or greater) of constructed materials (e.g. asphalt, concrete, and buildings).

> Low Intensity - Includes areas with a mixture of constructed materials and vegetation. Constructed materials account for 30-80 percent of the cover. Vegetation may account for 20 to 70 percent of the cover.

> High Intensity - Includes highly developed areas where people reside in high numbers. Examples include apartment complexes and row houses. Vegetation accounts for less than 20 percent of the cover. Constructed materials account for 80 to 100 percent of the cover.

Forested Upland - Areas characterized by tree cover (natural or semi-natural woody vegetation, generally greater than 6 meters tall); tree canopy accounts for 25-100 percent of the cover.

> Deciduous Forest - Areas dominated by trees where 75 percent or more of the tree species shed foliage simultaneously in response to seasonal change.

` Evergreen Forest - Areas dominated by trees where 75 percent or more of the tree species maintain their leaves all year. Canopy is never without green foliage.

> Mixed Forest - Areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the cover present.

Grasslands/Herbaceous - Areas characterized by natural or semi-natural herbaceous vegetation and dominated by upland grasses and forbs; herbaceous vegetation accounts for 75-100 percent of the cover. These areas are not subject to intensive management, but they are often utilized for grazing.

Open Water - all areas of open water, generally with less than 25% cover of vegetation/land cover.

Planted/Cultivated - Areas characterized by herbaceous vegetation that has been planted or is intensively managed for the production of food, feed, or fiber; or is maintained in developed settings for specific purposes. Herbaceous vegetation accounts for 75-100 percent of the cover.

> Pasture/Hay - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.

> Cultivated Crops - Areas used for the production of crops, such as corn, soybeans, vegetables, tobacco, and cotton.

Shrubland - Areas characterized by natural or semi-natural woody vegetation with aerial stems, generally less than 6 meters tall, with individuals or clumps not touching to interlocking. Both evergreen and deciduous species of true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions are included.

Wetlands - Areas where the soil or substrate is periodically saturated with or covered with water.

> Woody Wetlands - Areas where forest or shrubland vegetation accounts for 25-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.
>
> Emergent Herbaceous Wetlands - Areas where perennial herbaceous vegetation accounts for 75-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.

Appendix H

Land Use/ Land Cover Type Percentages by Subwatershed

(NLCD, 2006)

	Percentage % by subwatershed					
Land Use/Land Cover Type	Four Mile Creek Total	Four Mile Creek Headwaters	Little Four Mile Creek	East Fork	Acton Lake	Cotton Run
Cultivated Crops	57.3%	80.0%	83.7%	75.7%	41.4%	29.0%
Pasture/Hay	15.6%	3.3%	4.7%	2.8%	11.5%	40.0%
Deciduous Forest	14.4%	9.6%	5.5%	0%	23.8%	17.3%
Developed (Open Space)	7.3%	4.3%	4.6%	6.3%	10.4%	8.7%
Developed (Low Intensity)	1.9%	0.1%	4.6%	0.1%	4.9%	2.4%
Mixed Forest	1.2%	2.0%	1.0%	2.6%	1.6%	0.004%
Open Water	0.7%	0.02%	0.1%	0.2%	2.4%	0.21%
Developed (Medium Intensity)	0.6%	0.02%	0.1%	0.01%	1.5%	0.7%
Evergreen Forest	0.4%	0%	0.04%	0.01%	1.1%	0.5%
Grassland/ Herbaceous	0.31%	0.4%	0%	0%	0.32%	0.5%
Shrub/Scrub	0.18%	0%	0%	0%	0.31%	0.4%
Developed (High Intensity)	0.16%	0%	0.04%	12.1%	0.04%	0.2%
Woody Wetlands	0.09%	0.1%	0.2%	0.09%	0.17%	0%
Herbaceous Wetlands	0.07%	0.03%	0.01%	0.08%	0.02%	0.1%

Appendix I

List of Federally Recognized Historical Sites by County

(OHS, 2013a)

County	Name	Address	Reference No.	City	Applicable Criteria
Butler:	Alexander, Dr. William S., House	22 N College Ave	86003498	Oxford	A, B, C
	Austin-Magie Farm and Mill District	Section 14, Oxford Twp	82001360	Oxford	A, C
	Dewitt, Zachariah Price, Cabin	E of Oxford on US 73	73001392	Oxford	C
	Elliott and Stoddard Halls, Miami University	Miami University campus	73001391	Oxford	C
	Fisher Hall (DELISTED)	Miami University campus	71000634	Oxford	A, C
	Herron Gymnasium (DELISTED)	Miami University campus	79001788	Oxford	A, C
	Hunting Lodge Farm	5349 Coulter Lane	82001361	Oxford	B, C
	Kumler, Elias, House	120 S Main St	80002948	Oxford	C
	Lane's Mill Historic Buildings	S of Oxford at 3884 Wallace Rd	80002950	Oxford	A
	Langstroth Cottage	303 Patterson Ave	76001378	Oxford	B
	Maltby, Henry, House	216 E Church St	79001789	Oxford	A, B, C
	McGuffey, William H., House	401 E Spring St	66000605	Oxford	B
	Oxford Female Institute	High St & College Ave	76001379	Oxford	A
	Oxford Railroad Depot and Junction House	S Elm & W Spring St	80002949	Oxford	A, C
	Pugh's Mill Covered Bridge	1 mi N of Oxford off SR 732	75001336	Oxford	C
	Sigma Alpha Epsilon Chapter House of Miami University	310 N Tallawanda Rd	5000022	Oxford	C

	Unzicker-Cook House	2975 Oxford-Middletown Rd	74001404	Oxford	A, C
	Western Female Seminary	Rts 27 & 73	9000083	Oxford	A
	Hidley, James P., Cottage	1820 Oxford-Reily Rd	80002951	Reily	C
Preble:	Bunker Hill House	7919 SR 177	1001062	Fairhaven	A, C
	Harshman Covered Bridge	N of Fairhaven on Concord-Fairhaven Rd	76001517	Fairhaven	A, C
	Historic Associate Reformed Church & Cemetery	6471 Camden-College Corner Rd	8000161	Morning Sun	A, C

Appendix J

List of Ohio Cultural Importance Sites

(OHS, 2013b)

County	Name	Address	City
Butler	The Felix Fryman Farm House: the David M. Magie Farm House	Morning Sun Rd at Somerville	Oxford
	The oldest frame house in Oxford Township	Todd Rd and US 27	Oxford
	Oxford Water Plant	5223 Bonham Rd	Oxford
	Adams Pioneer Cemetery	Off Buckley Rd	Oxford
	The Austin Pioneer Cemetery	Corso Rd	Oxford
	District 2-the Doty School: Oxford Township School House	Brown Rd, half mile S of Doty Rd	Oxford
	Sub. District School No. 3-the Bethel School: Oxford Township School House	6588 Taylor Rd	Oxford
	The Bonham School-District No. 6: Oxford Township School House	5000 Bonham Rd	Oxford
	The Girton School: Oxford Township School House Sub-District No. 7	7523 Brookville Rd	Oxford
	Oxford Township School House Subdistrict No. 8	4000 Millville-Oxford Rd (US 27)	Oxford
	Oxford Township Schoolhouse No. 9	4191 Reily Rd at Brookville Rd	Oxford
	Duncan McVicker House	Rt 177 W of Four Mile Creek	Darrtown
	William Cooley House	4185 Hamilton-Richmond Rd	Darrtown
	Cornelius W. Lane House	W of Cochran Rd	Hanover
	The Hueston Farm	1320 Four Mile Creek Rd	Hanover
	Leffler Farm: Walther Farm	3600 Oxford-Reily Rd.	Hanover
	Dorman House	2363 Hamilton-Richmond Rd	Hanover

	Samuel Augspurger House	1659 Wayne-Madison Rd	St. Clair
	Augspurger Paper Company Row House #3	5320 Kennedy Rd	St. Clair
	Augsperger Grist Mill	Wayne Madison & Great Miami	St. Clair
	John Kennel Jr. Farm	2251 Wayne-Madison Rd	St. Clair
	The Good House	Off SR 37, S of Hwy	St. Clair
	Hickory Flat Cemetery	Morganthaler Rd at Wehr Rd	St. Clair
	Hickory Flat Church	Morganthaler Rd at Wehr Rd	St. Clair
	Martin House	4775 SR 73	St. Clair
	Lawless Residence: McLain/LeSourd/Bennett House	6331 Cincinnati-Dayton Rd	Jericho
	William Anderson/Lewis Chance House	7485 Princeton Rd	Jericho
	Taylor School	NW corner of Huston & Taylor Rd	Milford
	Lane’s Mill	Wallace Rd and Lanes Mill Rd	Milford
	The Kyger Cabin	Schollenbarger Rd at Lanes Mill	Milford
	Elliot’s Mill	Lanes Mill Rd and Wallace Rd	Milford
	Abandoned Log House	Schollenbarger Rd at Lanes Mill	Milford
	Lane-Manrod House	3884 Wallace Rd	Milford
	Muehlenhard Farm: Hickman Farm, McCoy Farm	5751 McCoy Rd	Reily
	Conrad Farm: Welliver Farm, Welliver Post Office	1190 Bunker Hill Woods Rd	Reily
	Tincher Farm: Andrew King Farm	7650 King Rd	Reily
	Herbert W. Muehlenhard Farm: Elijah Van Ness Farm	2474 Oxford-Reily Rd	Reily
	Steamboat Gothic House: James P. Hidlay House	Rt 732 and Stillwell Rd	Reily
	Logan C. Linville House: James P. Hidlay House	1820 Oxford-Reily Rd	Reily

Contact Information

-Ohio State Historic Preservation Office-
800 E. 17th Ave. Columbus, OH 43211
(614) 297-2300
http://www.ohiohistory.org/ohio-historic-preservation-office

-Butler County Historical Society-
327 North Second St., Hamilton, OH 45011, (513) 896-9930
E: bcomuseum@fuse.net
http://www.bchistoricalsociety.com/

-Preble County Historical Society-
7693 Swartsel Road- Eaton, OH 45320 - 937-787-4256
e: preblecountyhistoricalsociety@frontier.com
http://preblecountyhistoricalsociety.com/

-Indiana Department of Natural Resources: Division of Historic Preservation and Archaeology-
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Appendix K

Breakdown of TVCT Land Easement

(TVCT, 2013)

County	Name	Acres	Township	Year Recorded
Butler	Hueston Farms	250	Hanover	2006
	Beck	148	Oxford	2003
	Duvall	109	Oxford	2007
	Butterfield (Smith)	88.123	Oxford	2010
	Taylor Family Farm	77	Oxford	2003
	Dubois	42	Oxford	2007
	Hoelle	18.3	St. Clair	2009
	Ruder Preserve	13.5	Oxford	1996
	Millar	9	Oxford	2005
	Silvoor Preserve	6.5	Oxford	2001/2005
	Hollenbaugh	5	Oxford	2001
	Reid	3.3	Oxford	2000
	Falke	1	Oxford	1994
	Puff	0.5	Oxford	2005
Preble	Howard	233	Dixon	2003
	Bruns	119.3	Isreal	2008
Union	Boyles	52	Washington	2007
	Morris	48	Washington	2007

Appendix L

FOUR MILE CREEK WATERSHED INVENTORY
PROGRESS TABLE
Miami University
Institute for the Environment and Sustainability
Professional Service Project
May 10, 2013

The table is meant to be a tool for cataloging the data collected by the Four Mile Creek Watershed Inventory team. The table contains a complete list of sections from the Ohio EPA's Appendix 8 of "A Guide to Developing Local Watershed Action Plans in Ohio." The completion status column indicates whether a section is complete or not. The completion status column is color coded: green=completion; yellow =partial completion; and red=incomplete. The last column contains the team's recommendations to address sections of Appendix 8.

Appendix 8: Watershed Inventory Sections		**Completion Status**	**Recommendations**
DESCRIPTION OF WATERSHED			
Geology	**Topography**	Complete (Ch 2, pg 10)	
	Geology	Complete. See Ch 2: Runoff (pg 16), Erosion (pg 18), and Bedrock and Age (pg 22)	
	Soils	Complete (Ch2, pg 12)	
	Glacial History	Complete (Ch 2, pg 20)	
Biological Features	**Rare, threatened and endangered species – fish, mussels, invertebrates, mammals, birds, reptiles, amphibians, plants**	Complete (Ch 2, pg 23)	The Federal and State status of species should be check every couple years since the status can change.
	Invasive non-native Species and potential impacts	Complete (Ch 2, pg 25)	Were unable to locate a complete invasive nonnative species (animal or plant) by county. More research is needed on non-native and/or animal species and non-native pathogens.
Water resources	**Climate and precipitation**	Complete (Ch 2, pg 10)	
	Surface water: Wetlands	Complete (Ch 2, pg 14)	
	Surface Water: Streams (subwatersheds too)	Partial (Ch 3, pg 27)	Sinuosity was calculated for three small portions of Four Mile Creek. We recommend calculation of the sinuosity ratios for all 26 named streams in FMCW for a more comprehensive assessment.

	Surface Water: Lakes and Reservoirs (size, uses, watersheds, detention time)	Complete (Ch 3, pg 26)	
	Ground water: Aquifers (location, recharge rates, uses)	Partial (Ch 3, pg 31)	Research is needed for flow regime. We recommend looking into the Indiana equivalent of DRASTIC and SWAP.
Land Use			
Land Cover Description (with % by watershed)	**Urban: impervious surfaces**	Complete (Ch 5, pg 60)	
	Urban: Home sewage treatment systems location	Complete (Ch 5, pg 61)	
	Forest	Complete (Ch 5, pg 49) See figure 35	
	Agriculture: Crop type	Complete (Ch 5, pg 50) See figure 37	
	Agriculture: Tillage	Complete (Ch 5, pg 52)	
	Agriculture: Rotations	Incomplete	Further data is needed to make better conclusion of rotation patterns in FMWC.
	Agriculture: Livestock inventory	Complete (Ch 5, pg 53)	
	Agriculture: Grazing	Incomplete	Data needed.
	Agriculture: Chemical use patterns	Partial	Research on specific chemical types is needed. Watershed-specific information was not available.
	Agriculture: Irrigation	Complete (Ch 5, pg 52)	
	Water	Complete (Ch 5, pg 49) See Figure 35	
	Non-forested wetlands	Complete (Ch 5, pg 49) See Figure 35 and (Ch 2, pg 14)	
	Barren	Complete (Ch 5, pg 49) See Figure 35	
Protected lands	**City, county, district, state or national public forest and /or parks**	Complete (Ch 5, pg 63)	
	Land protected by private foundations or land trusts	Complete (Ch 5, pg 64)	
Status and trends	**Historical**	Partial (Ch 5)	No trends were predicted from the data collected.
	Current	Partial (Ch 5)	No trends were predicted from the data collected.
	Projected	Partial (Ch 5)	No trends were predicted from the data collected.
CULTURAL RESOURCES			
Historical, cultural or recreational	**Sites of historical, cultural or recreational significance**	Complete (Ch 5, pg 62)	

PREVIOUS AND COMPLEMENTARY EFFORTS			
Water quality efforts	**History of previous water quality efforts in the watershed**	Complete (Ch 6, pg 65)	
Efforts that will help meet water quality standards	**Listing of current efforts that will help meet water quality standards occurring in watershed**	Complete (Ch 6, pg 65)	
PHYSICAL ATTRIBUTES OF STREAMS AND FLOODPLAIN AREAS THAT SUPPORT HABITAT, RECREATION, WATER QUALITY, ETC			
Settlement	**Early settlement conditions**	Incomplete	Further research is needed.
Channel and floodplain condition	**Channel and floodplain condition (does channel have access to floodplain)**	Incomplete	Unable to locate this data, further research is needed.
Corridor	**Forested riparian corridor assessment**	Incomplete	Riparian corridors were researched but nothing conclusive for FMCW was determined. Further research is needed.
Riparian buffer	**Number of miles with forested natural riparian buffer (describe)**	Incomplete	Riparian corridors were researched but nothing conclusive for FMCW was determined. Further research is needed.
Permanent protection	**Number of miles with permanent protection**	Complete (Ch 5, pg 63)	
Natural channel	**Miles of natural channel (never modified or fully recovered)**	Incomplete	Unable to locate this data, further research is needed.
Modified channel	**Miles & location of modified channel**	Incomplete	Unable to locate this data, further research is needed.
Dams	**How many dams?**	partial (Ch 3, pg 26)	
Channelization	**Is there channelization?**	Partial	No specific data was located about the amount of channelization in Four Mile Creek. Further research is needed.
Unrestricted livestock access	**Streams with unrestricted livestock access**	Complete (Ch 5, pg 47) See figure 34	
Eroding banks	**Eroding banks (number and severity of sediment produced)**	Incomplete	Unable to locate this data, further research is needed.
Floodplain connectivity	**Floodplain connectivity**	Incomplete	Unable to locate this data, further research is needed.
Riparian levees	**Riparian levees**	Incomplete	Unable to locate this data, further research is needed.
Entrenched miles	**Number of entrenched miles**	Incomplete	Unable to locate this data, further research is needed.
Status and trends	**Expected road, highway, bridge construction**	Incomplete	Unable to locate data to determine possible trend or status, further research is needed.
	Expected resid/commercial development	Complete (Ch 5, pg 60)	

WATER RESOURCE QUALITY			
Locationally-referenced use designations/use attainment	**Number of waterbodies/miles in full attainment**	Complete (Ch 4) See Table 5 and 6	
	Number of threatened miles: waterbodies/miles in partial attainment	Complete (Ch 4) See Table 5 and 6	
	Number of threatened miles: segments /miles in non-attainment	Complete (Ch 4) See Table 5 and 6	
	Number of threatened miles: streams designated but not monitored	Incomplete	Further research is needed.
	Number of threatened miles: Lakes/quality	Complete (Ch 3, 4)	
	Number of threatened miles: Wetlands/quality	Incomplete	Further research is needed.
	Number of threatened miles: Groundwater/quality	Complete (Ch 3, pg 35) See DRASTIC and SWAP data	
Causes and sources of impairments or threats as presented by 305(b)303(d) integrated water quality report for the above listed waterbodies/miles	**Keep in mind that sources as presented in Ohio EPA documents do not represent the level of definition/detail needed to identify and target technical solutions. Please consult with your area assistance team for more detail on source identification**	Partial (Ch 5, pg 48) See Table 8	Have a list of causes of impairment in FMCW from Reporting Year 2008 but further research is needed to compare findings to 305(b)303(d).
Point sources (by subwatershed or stream segment)	**Permitted discharges (NPDES)**	Complete (Ch 5, pg 44)	
Non point sources by subwatershed or stream segment	**Inventory of home sewage treatment systems and projected number of failing systems**	Partial (Ch 5, pg 61)	Because the FMCW does not have a TMDL report at this time, it is very difficult to quantify the influence that these systems are having in our area. Additionally, there is no record of the location of home septic systems that were built prior to 1980. The information in this section are from the 2008 report and there is now a 2012 report available. Further research is recommended.
	Number of new homes being built	Partial (Ch 5, pg 60)	Could only locate the number of building permit from Butler County. More research is needed.
	Number and size of animal feeding operations	Complete (Ch 5, pg 53)	
	Acres of highly erodible land and potential soil loss	Partial (Ch 2, pg 18; Ch 5, pg 50)	Information is not specific to the FMCW. More research is needed.

	Is the stream culverted?	Partial (Ch 5, pg 61)	Could only locate the number of culverts for Butler County.
	Channelized?	Partial	See Channelization in PHYSICAL ATTRIBUTES OF STREAMS above.
	Levied?	Complete, there was none so it wasn't mention in report	
	Exhibiting little human impact	Incomplete	Unable to locate this data, further research is needed.
	What's the effluent volume?	Incomplete	Unable to locate this data, further research is needed.
	Dammed (how many stream miles are impounded)	Incomplete	Unable to locate this data, further research is needed.
	Officially classified and/or unofficially maintained as petition ditches?	Incomplete	Unable to locate this data, further research is needed.
Status and trends	**Areas where water quality is in attainment, but local info indicates that the current situation, if unchanged, will likely result in water quality degradation.**	Partial (Ch 4, pg 49; Ch 6, pg 66) See also Table 5 and 6	

Perez J, "A Guide to Developing Local Watershed Action Plans in Ohio," Ohio Environmental Protection Agency, 1997. http://www.epa.ohio.gov/portals/35/nps/wsguide.pdf