VFC Index - Watershed (Plan)

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Project Name: Central Muscatatuck WMP

Plan Type: Watershed Management Plan

HUC Code: 05120207 Muscatatuck

Sponsor: Historic Hoosier Hills RC&D

Contract #: 7-87

County: Jefferson

Cross Reference ID: 15792905

Comments: Jackson, Jennings, Ripley, Scott

Additional WMP Information

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Fiscal Year: 2006

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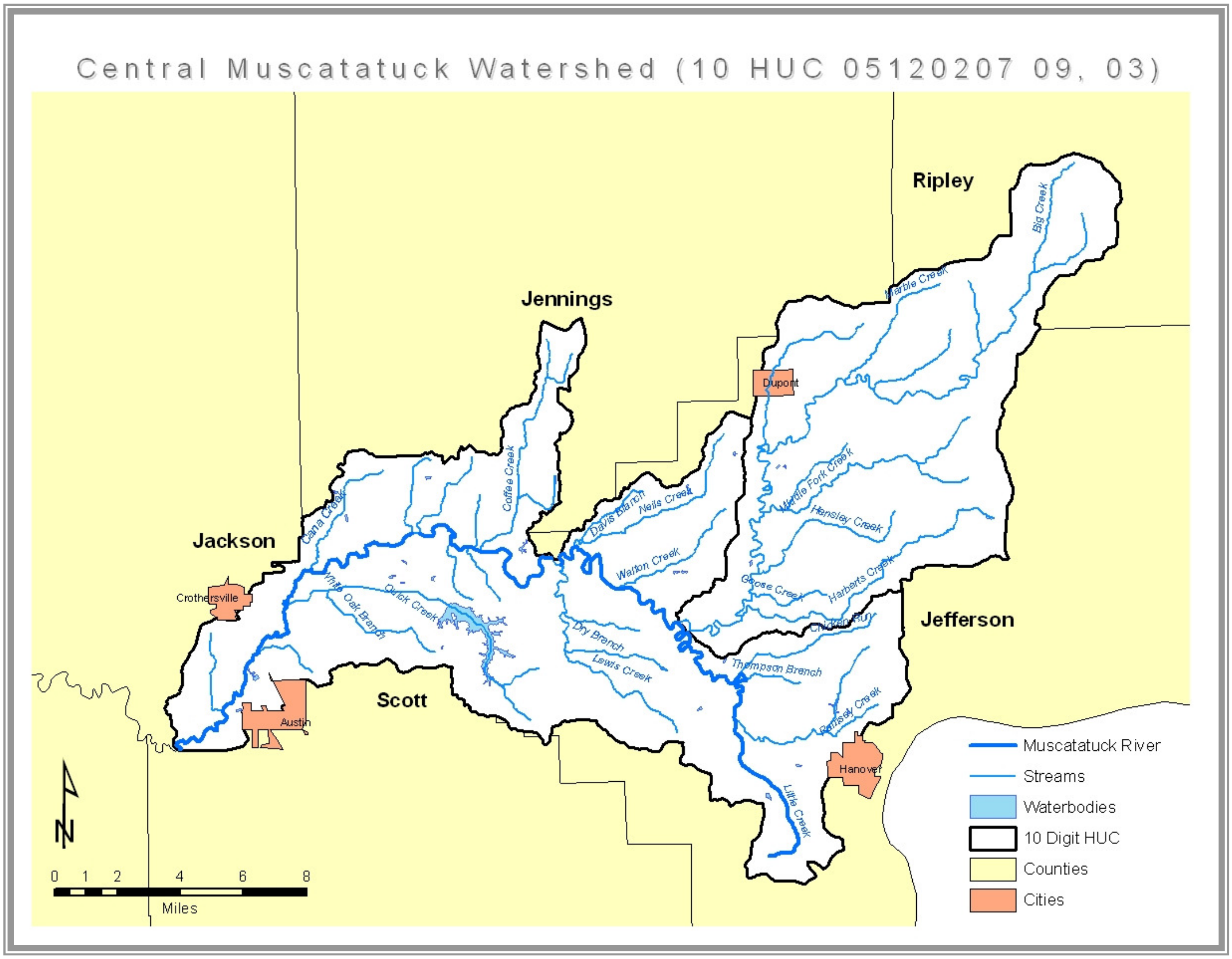
EPA Approval Date:

Project Manager: Leanne Whitesell

CENTRAL MUSCATATUCK WATERSHED PROJECT

WATERSHED MANAGEMENT PLAN



Central Muscatatuck Watershed Project
3382 W. SR 56
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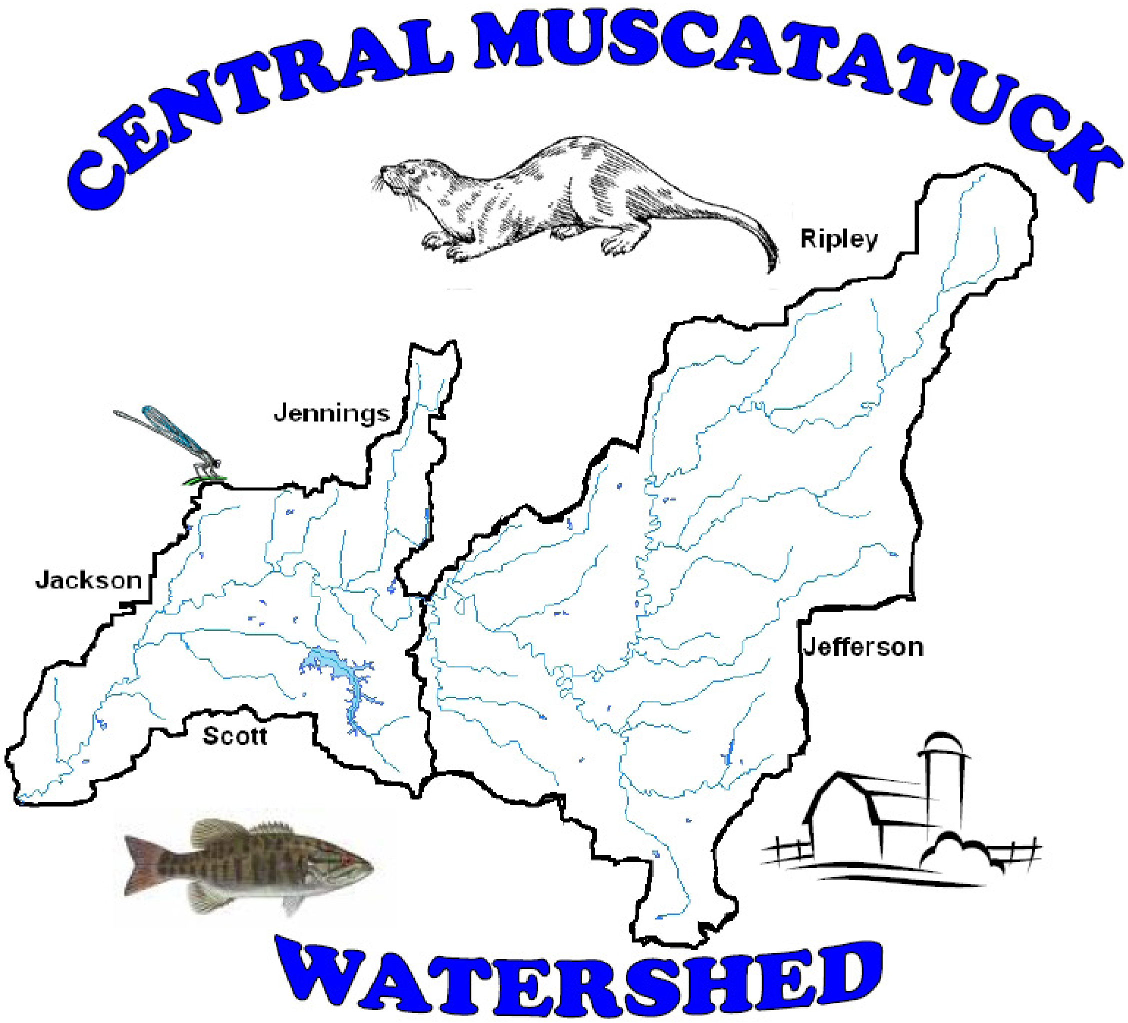
8/14/09

Vision and Mission Statement

Vision:

"To improve and sustain water quality within the Central Muscatatuck Watershed in harmony with all watershed uses"



Mission:

"Develop a management plan through water quality testing & community outreach activities to improve and sustain water quality in the Central Muscatatuck Watershed."

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Project Introduction

This section describes the process the community went through when developing the plan, lists the parties involved, and summarizes any important issues that influences how the plan emerged.

The Central Muscatatuck Watershed Project (CMWP) is a regional initiative in Southeastern Indiana working to improve water quality by completing a watershed inventory and management plan within the five county area of Jackson, Jefferson, Jennings, Ripley, and Scott Counties that fall within the Central Muscatatuck Watershed.

1.1 Project Inception

The growing community concern for the water quality within the Central Muscatatuck Watershed prompted Historic Hoosier Hills RC&D, Jefferson County Soil and Water Conservation District (SWCD) and the Friends of Muscatatuck River Society (FMRS) to propose this project to gather data and develop a management plan for the watershed. While there was data pertaining to this watershed from previous water quality sampling to show the presence of water bodies on the 303(d) impaired waters list for *E. coli,* little was known as to the extent, sources, and causes of the water quality pressures within the watershed at the time of the project's inception. The 303(d) list is a federally mandated list per the Clean Water Act that mandates states to list all impaired and threatened waters. Refer to Figure 5 and 33 for a map and table of impaired waters in the watershed.

Agriculture accounts for approximately sixty percent (60%) of the land use in the watershed. Other types of land uses include forest, ponds, pasture, recreation, residential, and some (a minor portion) urban development. Agriculture in the watershed is typified by row cropping, tobacco production, and pasture (cattle, hog, goat, and horse). The potential exists for nutrient and sediment impact loads to surface waters, stream bank erosion, and degradation of aquatic habitat by way of livestock access to streams, lack of fencing, traditional tillage practices, and contamination from poorly functioning septic systems. Many of the small towns within in the watershed are not connected to a sewer and may have failing or a lack of septic systems.

In 2005 the Central Muscatatuck 319 grant committee, which consisted of the FMRS Board, Historic Hoosier Hills RC&D and The Jefferson County SWCD, conducted several meetings to discuss the project and come to agreement on the grant. The Jefferson County SWCD initially indicated that *E. coli* source tracking (genetically tracking the source of *E. coli*) was a major priority for the success of the project. Through the process of the grant proposal it was decided that *E. coli* tracking was too cost prohibitive for the management planning phase and that focusing on gaining a clearer overall picture of water quality would be more beneficial.

The Federal Clean Water Act Section 319(h) provides funding for various types of projects that work to reduce nonpoint source water pollution. Indiana Department of Environmental Management's (IDEM) Section 319 Nonpoint Source Program provides funding and technical assistance to groups that work on the watershed level with citizens to develop locally-based solutions to nonpoint source pollution. Specific ways to address nonpoint source water pollution include education/outreach on watershed management, information gathering activities such as conducting watershed inventories and water quality assessments for the purpose of developing comprehensive watershed management plans and implementing those plans, including implementation of best management practices that directly reduce sources of nonpoint source pollution.[1]

[1] Indiana Department of Environmental Management, 2009 Section 319 Grant Solicitation Announcement & Guidance, http://www.in.gov/idem/files/319solicitationguidance2009.pdf

The grant agreement for the project was approved by IDEM on February 15, 2007. Historic Hoosier Hills formed a hiring committee to interview possible candidates for the Watershed Coordinator position and hired a coordinator to start on August 6, 2007. The objectives of the planning phase grant are to be completed by August 14, 2009.

1.2 Partners and Stakeholders

The partners involved with the project where able to provide in kind matching resources such as administrative support, supplies, volunteer time, and technical assistance. These sources must provide a twenty five percent match of the grant funds. The following partners listed are those parties involved with the project: IDEM; United States Department Agriculture (USDA)-Natural Resources Conservation Service (NRCS); Indiana State Department of Agriculture (ISDA); Indiana Department of Natural Resources (IDNR) Hardy Lake; Hoosier Riverwatch; Project Wet; SWCDs; Health Departments; Citizens; Commissioners in Jennings, Jefferson, Scott & Ripley Counties; Jennings County Sheriff Department; Jennings County Probation Department; Jennings County Prosecuting Office; Jennings County Highway Department; FMRS; Hanover College and the Rivers Institute; Indiana University Southeast; Friends of Hardy Lake; Southeast Indiana Solid Waste District; Deputy and Johnson Volunteer fire departments; Coffee Creek Conservation Club; Big Oaks National Wildlife Refuge; Historic Hoosier Hills RC&D; North Vernon Police Department; Quick Creek Steering Committee, Muscatatuck National Wildlife Refuge; and Central Muscatatuck Watershed landowners. Please refer to figure 1 to review a comprehensive list of all partners involved.

Historic Hoosier Hills RC&D is the official sponsor of the CMWP. Historic Hoosier Hills is governed by a Board of Directors that are local residents who determine the services Historic Hoosier Hills provides. The RC&D operates as a 501(c)3 umbrella for the project offering facilitated planning assistance, organizational structuring, budget development, and administrative support.

1.3 Outreach Efforts

The CMWP held several meetings and activities as a kick-off to the project. A presentation describing the watershed and the grant program was given. A survey was distributed during the meetings to encourage participation from local citizens and to gain information regarding their watershed concerns. The initial outreach efforts provided forums for citizens to discuss and express their concerns for watershed issues. All issues discussed during outreach efforts were reviewed and discussed by the Steering Committee and led to the development of action items. The results of the surveys are discussed in detail in section 3.

1.3.1 Presentations

The CMWP conducted several programs for local groups and at events such as: SWCD annual meetings, FMRS's annual meeting, county fairs, civic groups, local conservation field days, and local schools such as Hanover and Southeastern High School. These programs were designed to highlight the goals of the project and to promote watershed protection. The programs were free to the public and were announced in newspapers, newsletters, public service announcements, and through personal contact.

1.3.2 Literature

The CMWP produced a literature pamphlet and articles to promote the watershed and the project's mission. The informational articles to promote the project were released to the local media as well as the watershed's partnership newsletters for the SWCDs, Friends of Hardy Lake, and the FMRS.

1.3.3 Public Participation

Various opportunities for the community were presented to be involved with the CMWP. Programs such as the Hoosier Riverwatch volunteer water quality monitoring program trained several individuals to conduct water quality testing in the watershed and involved them directly to gain information on the health of the watershed. Approximately 25 volunteers participated in the water quality monitoring training and project. CMWP has also participated in and supported the Hardy Lake Sweep where several tons of waste from roads surrounding Hardy Lake and the watershed area is picked up. More than 150 volunteers participate in this event. Input has also been sought from community members through public meetings, surveys and participation in the forming of the CMWP steering committee. The steering committee is comprised of approximately 45 supporting steering committee volunteer members who receive regular updates on the project and provide varied levels of participation and expertise. From the 45 steering committee members, there is a core group, approximately 6-12 active steering committee members, who participate in meetings and activities on a fairly regular basis.

1.3.3.a Steering Committee

The primary goal of forming the steering committee was to gather a diverse and representative group of individuals that function within the watershed. Parties targeted were SWCD board members within each county, landowners involved with the SWCDs and NRCS, Hanover College which provided potential volunteers and technical assistance, and interest groups within the watershed such as Friends of Hardy Lake and FMRS. The process used to create the steering committee was to first contact all known individuals with a known interest in the project and meet with them personally to explain the goals of the project. Additional steering committee members were recruited from public meetings and through advertisement of the project.

Key Members of the Steering Committee

- Friends of Muscatatuck River Society
- Friends of Hardy Lake
- Members of the County SWCD Boards
- Hanover College and Rivers Institute
- Private Landowners & Producers
- Big Oaks National Wildlife Refuge
- Hardy Lake State Reservoir
- Future Farmers of America, Purdue Extension
- Scott County and Jefferson County Health Department
- Muscatatuck National Wildlife Refuge

1.3.3.b Technical Committee

The technical committee is comprised of NRCS, ISDA, SWCD employees, Hanover College Professors, State and Federal Biologists, and watershed community members. This committee is responsible for determining best management practices (BMPs) and administering technical watershed advice to resolve watershed issues.

1.3.3.c Water Monitoring Committee

The Water Monitoring committee consists of the watershed coordinator, Environmental Labs monitoring and lab analysis team, Hanover College students and faculty, and local Hoosier Riverwatch Monitoring volunteers. The responsibilities of this committee are to conduct water quality sampling and analyze water quality data.

Figure 1: Key Partners and Stakeholders

Partner	*What Partner Can Provide*	*Benefits to the Partner*	*Contact Person*	*Subcommittee in Charge of Communicating with Contact*
Historic Hoosier Hills RC&D	Funding and Supervision for the Project	Helps them to achieve their goals	Terry Stephenson	Watershed Coordinator
Indiana Department of Environmental Management	Guidance and Funding for Grant	Assist in achieving their goals	Leanne Whitesell Kathleen T. Hagan	Watershed Coordinator
Friends of Muscatatuck	Dedicated volunteers as well as knowledge about existing water quality	Increased community involvement for the society, and help to achieve their goals	Kevin Jayne Troy Jackson Tom Moore Simeon Stearns	Steering Committee Chair
Scott County Drainage Board	Knowledge of problem areas on Muscatatuck	Assist in achieving goals of cleaner water ways	Bob Tobias	Local Leaders and decision makers
Jefferson County Extension Agents			Lonnie Mason	Education/Outreach
SWCD Districts: Jefferson Jackson Scott Ripley Jennings	Information, publicity, administrative, and technical support	Assist them in providing technical assistance, conservation planning, education and program information support to private land users. This is to improve land use practices to help manage Indiana's natural resources.	 Lisa Jones Rebecca Lauster Linda Phillips Judy Taylor Brad Ponsler	Watershed Coordinator
Friends of Hardy Lake	Past water quality data and committed volunteers	Accomplish their goals	Jim Mummert	Volunteer Monitoring
Hardy Lake State Recreation Area	Technical Assistance	Accomplish the Goals of DNR	Terry Davis	Watershed Coordinator
USDA-Natural Resources Conservation Service	Technical Assistance and Data collecting equipment	Accomplish their goals	Jenny Vogel Tim Schwipps Robert Zupansic Pat Larr	Watershed Coordinator
Health Departments	Technical and resource assistance, *E. coli* testing	PR and accomplishing their goals		Local leaders and decision makers
Water Utilities (Stucker Fork)	Technical Assistance	PR and accomplishing their goals	Larry Mcintosh	Local leaders and decision makers
Hoosier River Watch Volunteers	Water Quality Sampling	Knowledge and experience	Riverwatch Volunteer List maintained by Watershed Coordinator	Volunteer Monitoring
Hanover College Rivers Institute	Provide student interns, technical assistance and assistance with special projects	Knowledge and outreach experience	Dr. Daryl Karns	Biology Department Professor

Partner	*What Partner Can Provide*	*Benefits to the Partner*	*Individual Contact Person*	*Subcommittee in Charge of Communicating with Contact*
Storm Water Boards from surrounding Counties				Local leaders and decision makers
Farm Bureau	Technical advice	Accomplish their goals	Brad Ponsler	Agricultural Decisions
Big Oaks National Wildlife Refuge	Past Water Quality Data and technical assistance	Publicity to the community and accomplish their own goals	Joe Robb	Watershed Coordinator/ Volunteer Monitoring
Local High Schools	Water Quality Testing	Hands on Experience	Greg Schneider	Education/Outreach
FFA	Volunteers, educational opportunities	Projects community outreach, career networking	Lonnie Mason Purdue Extension	Education/Outreach
Local Legislators	Support & cooperation	Good PR, votes		Local leaders and decision makers
Media	Publicity	Good stories	Madison Courier North Vernon Sun Giveaway Osgood Journal	Watershed Coordinator
Waste Water Treatment Plants	Data, and education	Publicity and accomplish their goals	Austin	Local leaders and decision makers
Land Owners	Apply practices, and information about watershed	Cost Share, Better Property Values, Improved WQ		Agricultural Decisions
Boy Scouts	Publicity, volunteers,	Community service, career networking		Education/Outreach Coordinator/ Volunteer Monitoring
Public TV and Radio	Free PR	Community Stories	Madison Courier	Watershed Coordinator
Municipalities	Political support, funds	Enhanced communities, improved resources, PR		Local leaders and decision makers

The Watershed

This section describes information gathered through data research in order to provide basic background information for the reader. Information includes descriptions of watershed topography, geology, soils, hydrology, wetlands, climate, and natural history.

2.1 Origin of Name

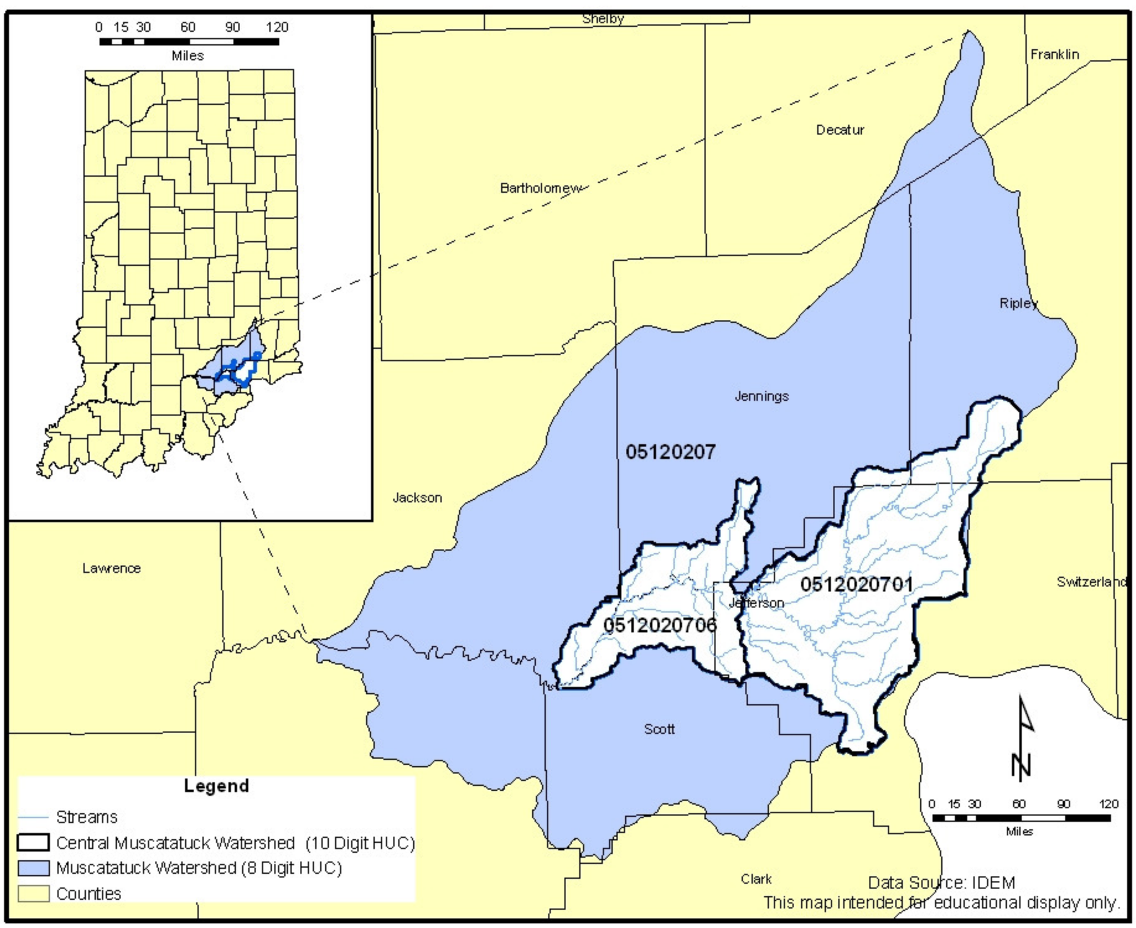
The name Muscatatuck is a Native American word meaning "land of winding waters." The Muscatatuck River winds its way from the hills of Jefferson County formed by the junction of Little Creek, Big Creek, and Big Graham Creek. Along with other major tributaries it flows southwest and west through the Muscatatuck Bottoms and into the East Fork of the White River.

2.2 Describing the Watershed

A watershed is an area of land that water flows over and under on its way to a particular body of water. In the United States, watersheds are identified using a hierarchical coding system, Hydrologic Unit Codes (HUC). HUCs are used as a way of cataloguing portions of the landscape according to drainage. Larger watersheds are identified by shorter codes, and smaller watersheds are identified by longer codes, designed to be more specific. The CMW falls in the Muscatatuck Watershed 8 digit HUC, 05120207, the largest outlined area shown in the figure 2.

The 10 digit HUCs for the Central Muscatatuck Watershed include numbers 0512020706 (100,637.62 acres) and 0512020701 (63,559.25 acres). The two HUCs are located in five counties including Jackson, Jefferson, Jennings, Ripley, and Scott Counties. The two 10 digit watersheds comprise approximately 164,196.87 acres.

<u>Figure 2: Location of Central Muscatatuck Watershed</u>



2.2.1 Climate

Historical climate information was gathered from three counties, Jennings, Scott and Jefferson County, where the majority of the watershed is located. The data was averaged to provide a general summation of the climate for the watershed. Data for each county are provided in the following tables to provide a more specific overview of the temperature ranges.

The 24 hour average temperature is 54.1°F. The average maximum temperature is 65°F; the hottest month is July with an average temperature of 86.8°F. The average minimum temperature is 43.2°F; the coldest month is January with an average temperature of 19.9°F. Based on comparing the following data, in general there is little variation between the counties and average temperatures are fairly consistent overall within the watershed.

<u>24-hr Average Temperature</u>

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
°F	29.8	33.6	44.1	54.1	63.9	72.1	76.3	74.7	68.4	56.7	45.9	35.1	54.5

Jefferson County

°F	29.5	33.4	44.6	54.9	63.7	72.0	75.4	73.8	67.6	56.3	45.5	34.5	54.1

Jennings County

°F	28.4	32.2	43.3	53.8	63.5	72.1	75.9	73.9	67.5	55.4	44.6	33.8	53.8

Scott County

<u>Average Maximum Temperature</u>

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
°F	38.3	43.2	54.7	65.7	75.2	83.3	86.5	85.1	79.0	68.0	55.2	43.7	64.8

Jefferson County

°F	38.7	43.7	55.6	67.1	76.1	83.8	86.7	85.1	79.5	68.5	55.2	43.3	65.3

Jennings County

°F	37.9	42.8	54.3	65.8	75.6	83.8	87.3	86.0	80.1	68.5	55.4	43.0	64.9

Scott County

<u>Average Minimum Temperature</u>

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
°F	21.2	24.3	33.6	42.4	52.3	61.0	65.8	64.0	57.6	45.1	36.1	26.6	44.1

Jefferson County

°F	19.9	23.5	33.6	42.8	51.3	59.9	63.9	62.2	55.9	44.1	35.8	25.9	43.2

Jennings County

°F	18.7	21.6	32.2	41.7	51.3	60.3	64.4	61.9	54.7	42.1	34.0	24.6	42.3

Scott County

The average annual precipitation is 43-44 inches of precipitation. The average annual snowfall is 12 inches. The amount of rainfall during a specific rain event can vary greatly between locations within the watershed. The upper section of the watershed is prone to flash flooding while the lower section of the watershed is prone to high flooding within the Muscatatuck bottomlands flood plains. For specific daily rain events refer to http://www.cocorahs.org/.

Average Rainfall

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Inches	2.8	3.0	4.4	4.2	4.7	3.8	4.2	3.5	3.0	3.2	3.7	3.4	43.8

Jefferson County

Inches	2.8	2.7	4.7	4.0	4.6	4.4	4.2	3.2	3.1	3.1	3.9	3.0	43.8

Jennings County

Inches	3.5	2.8	4.4	4.0	4.1	4.1	4.0	3.8	2.9	3.0	3.2	3.2	43.1

Scott County

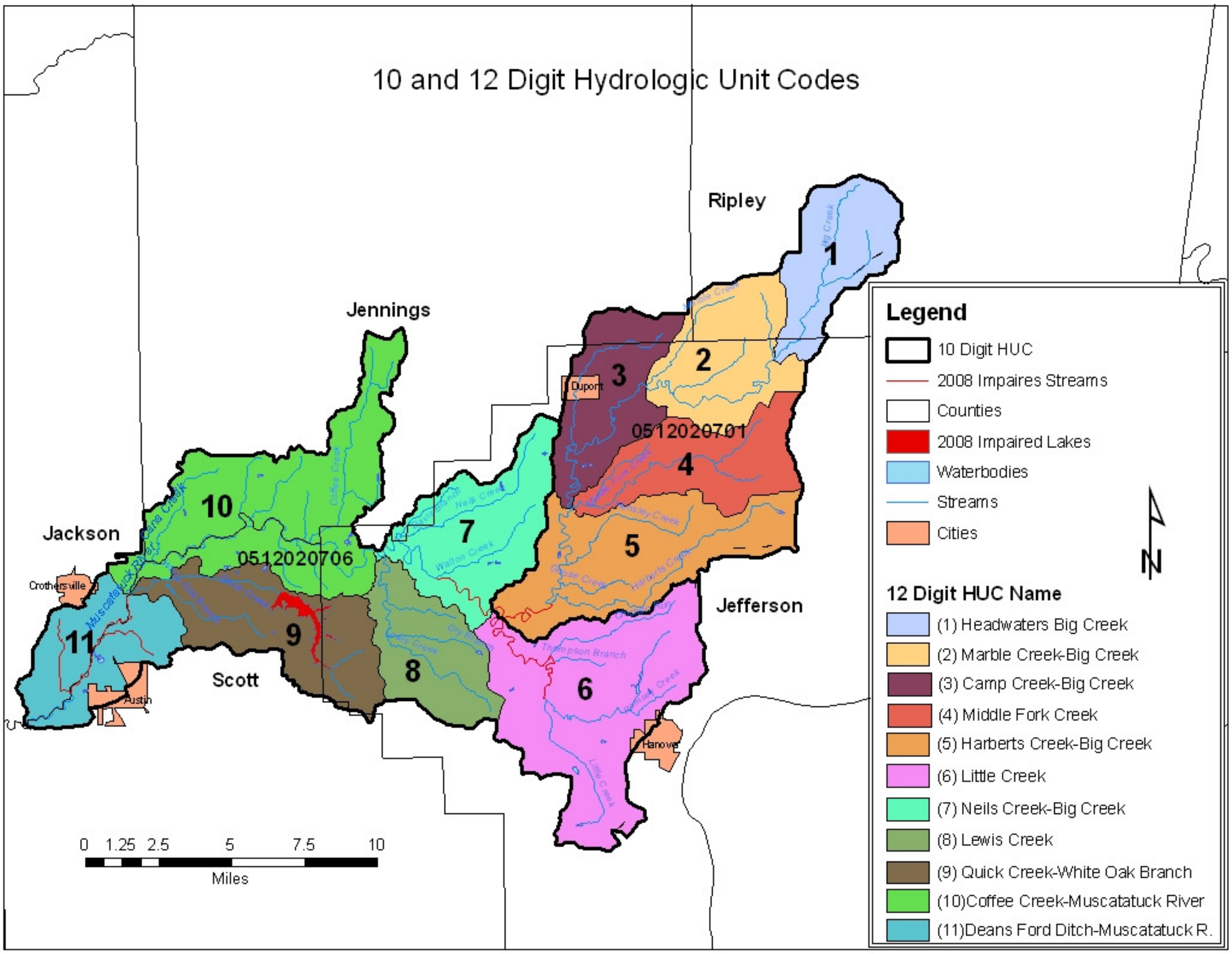
The average relative humidity in mid-afternoon is approximately 60 percent for the watershed. Humidity is higher at night, and the average at dawn is about 80 percent. The sun shines 70 percent of the time in the summer and 40 percent in the winter. The prevailing wind is from the south, with an average wind speed of 10 miles per hour and is typically the highest in the spring.[2]

2.2.2 Hydrology

Defined as the total area of land draining to a particular water body, watersheds are delineated utilizing topography which indicates areas of elevation and natural divides. Drainage areas typically coincide with stream size. Just as smaller streams combine to form larger streams, smaller watersheds converge within larger watersheds. For this reason, watersheds are identified by scale and are coded as such. Watersheds are broken down into smaller portions called sub watersheds. During the course of the project, the HUC classification used changed from 14 and 11 digit sub watersheds to 12 and 10 digit sub watersheds. Some of the initial data collected was based upon the 14 digit sub watersheds and some data was based upon the 12 and 10 digit classifications. Due to this change during the project, maps showing both 12 and 10 and 14 and 11 digit HUC sub watersheds are shown in the Figure 3 and 4. The CMW is comprised of eleven - 12 digit or eighteen - 14 digit sub watersheds that specify a mainstream segment or major contributing tributary to the Muscatatuck River. Despite these changes, however, the project area has not changed.

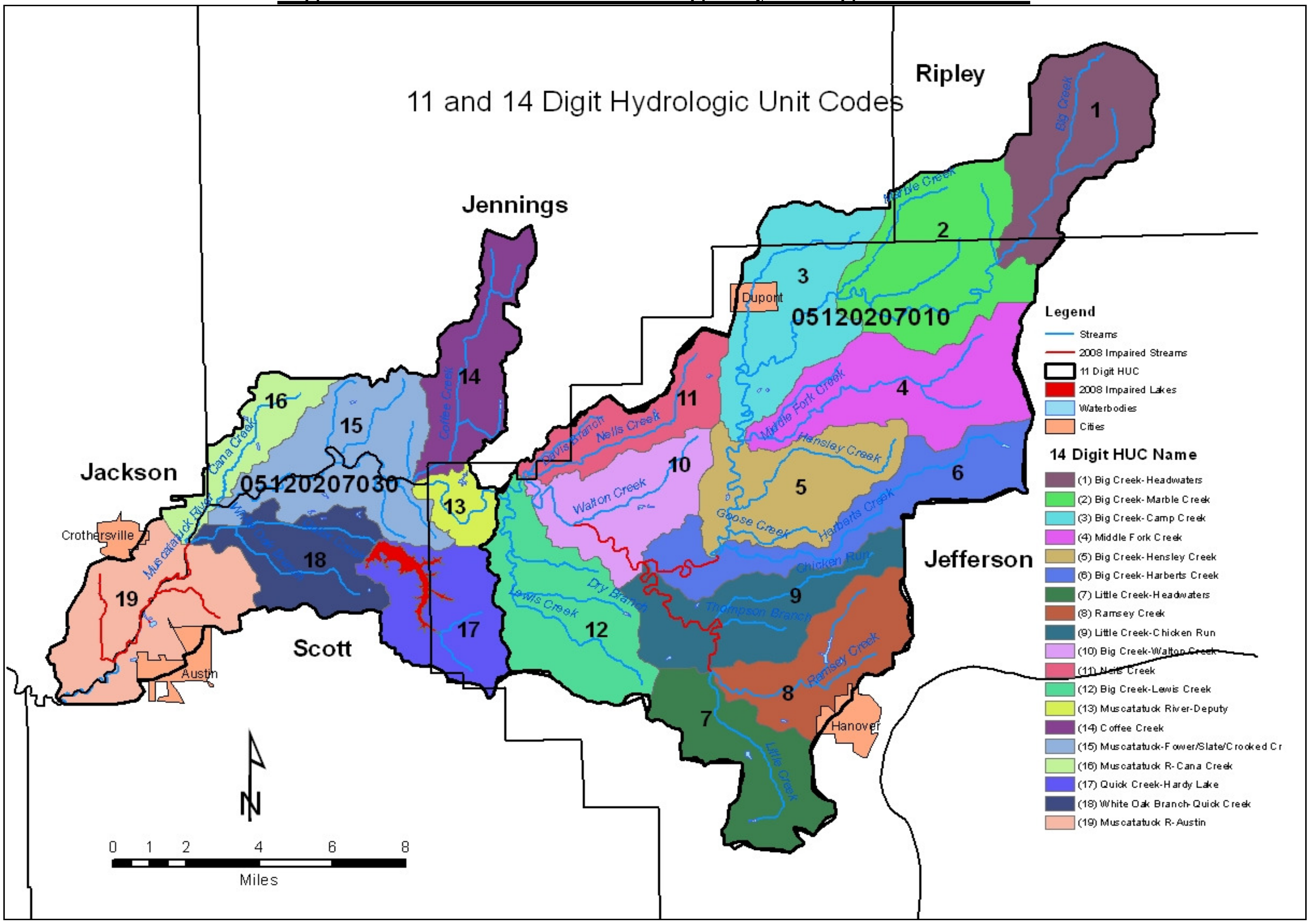
[2] http://www.worldclimate.com/cgi-bin/data.pl?ref=N38W085+1308+125237C

Figure 3: Sub Watershed 12 Digit Hydrologic Unit Codes



Map ID #	Sub Watershed Name	12 Digit HUC	Acres
1	Headwaters Big Creek	051202070101	10,098.73
2	Marble Creek – Big Creek	051202070102	12,380.58
3	Camp Creek – Big Creek	051202070104	10,977.31
4	Middle Fork Creek	051202070103	11,307.3
5	Harberts Creek – Big Creek	051202070105	18,795.33
6	Little Creek	051202070601	25,078.68
7	Neils Creek – Big Creek	051202070603	14,019.91
8	Lewis Creek	051202070602	10,269.92
9	Quick Creek – White Oak Branch	051202070604	14,550.16
10	Coffee Creek – Muscatatuck River	051202070605	25,187.64
11	Dean Ford's Ditch – Muscatatuck River	051202070606	11,531.31

Figure 4: Sub Watershed 14 Digit Hydrologic Unit Codes



Map ID #	Sub Watershed Name	14 Digit HUC	Acres
1	Big Creek-Headwaters	05120207010010	10094.9
2	Big Creek-Marble Creek	05120207010020	12373.6
3	Big Creek-Camp Creek	05120207010030	10976.6
4	Middle Fork Creek	05120207010040	11302.5
5	Big Creek-Hensley Creek	05120207010050	9368.7
6	Big Creek-Harberts Creek	05120207010060	9412.3
7	Little Creek-Headwaters	5120207010070	8111.3
8	Ramsey Creek	05120207010080	7842.6
9	Little Creek-Chicken Run	05120207010090	9122.7
10	Big Creek-Walton Creek	05120207010100	7849.8
11	Neils Creek	05120207010110	5812.4
12	Big Creek-Lewis Creek	05120207010120	10616.8
13	Muscatatuck River-Deputy	05120207030010	2246.5
14	Coffee Creek	05120207030020	7338.0
15	Muscatatuck-Fowler/Slate/Crooked Creek	05120207030030	11223.0
16	Muscatatuck R-Cana Creek	05120207030040	4367.1
17	Quick Creek-Hardy Lake	05120207030050	7708.6
18	White Oak Branch-Quick Creek	05120207030060	6833.0
19	Muscatatuck R-Austin	05120207030070	11526.4

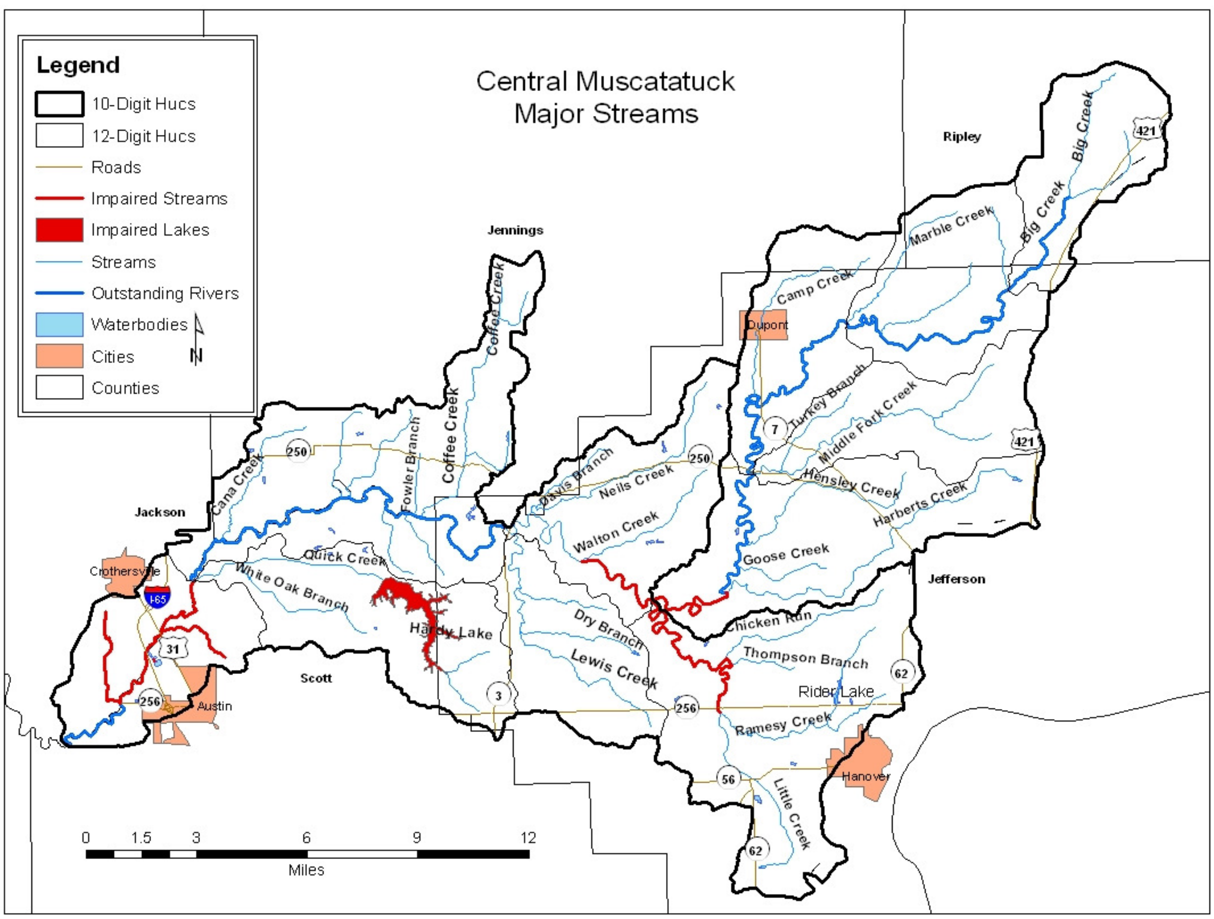
2.2.3 Major and Significant Streams

The major stream, river, and lake names are: Muscatatuck River, Big Creek, Marble Creek, Camp Creek, Middle Fork Creek, Harberts Creek, Hensley Creek, Goose Creek, Chicken Run, Thompson Branch, Ramsey Creek, Walton Creek, Neils Creek, Davis Branch, Dry Branch, Lewis Creek, Fowler Branch, Cana Creek, White Oak Branch, Coffee Creek, Quick Creek, and Hardy Lake.

In order to help identify the rivers and streams that have particular environmental or aesthetic interest, a special listing has been prepared by the Division of Outdoor Recreation of the Department of Natural Resources. The listing is a corrected and condensed version of a listing compiled by American Rivers. There are about 2,000 river miles included on the listing, an amount that represents less than 9% of the estimated 24,000 total river miles in Indiana. The Natural Resources Commission has adopted the listing as an official recognition of their resource values of these waters. [3]

The outstanding streams found within the watershed include the section of Big Creek from the east side of Big Oaks National Wildlife Refuge boundary to Graham Creek located from Ripley to Jefferson County and a section of the Muscatatuck River from the confluence of Graham Creek and Big Washington Creek to confluence with East Fork White River located in Jefferson, Scott and Jackson counties. The Natural Resources Commission report identified the Muscatatuck River as qualified as part of the National Wild and Scenic Rivers System, and Big Creek is identified by the state as having outstanding ecological, recreational, or scenic importance.

Figure 5: Central Muscatatuck Major Streams



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[3] Natural Resources Commission Outstanding Rivers, Indiana Register, http://www.in.gov/legislative/register/20070530-IR-312070287NRA.xml.pdf.

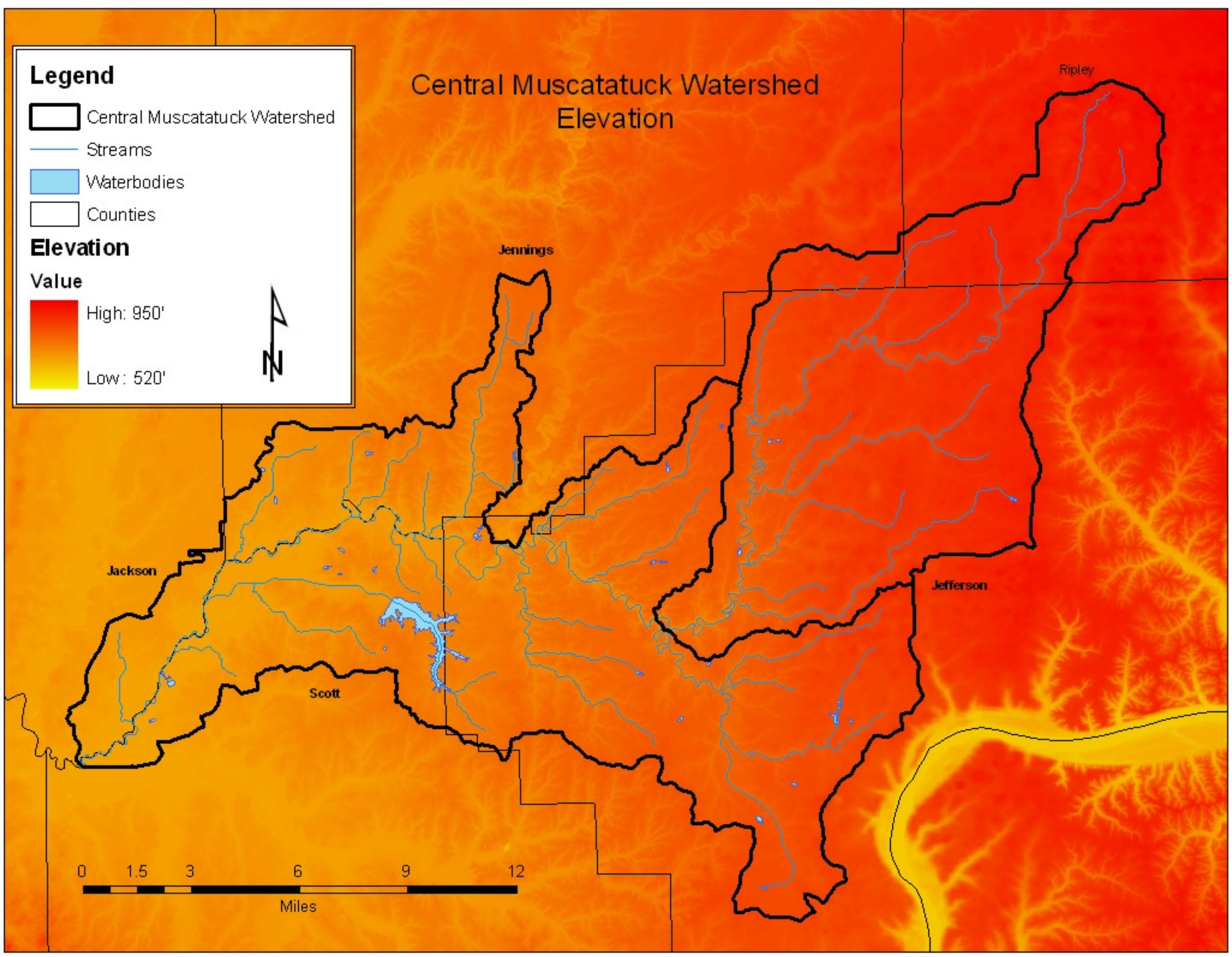
Figure 6: Length of Streams in Miles

Length of Streams in Miles				
Muscatatuck River- 27.8	Middle Fork- 8.0	Ramsey Creek- 5.9	Cana Creek- 4.4	Davis Branch- 2.8
Big Creek- 29.6	Coffee Creek- 7.6	Chicken Run- 5.0	Quick Creek- 4.4	Thompson Branch- 2.0
Little Creek- 11.9	Neils Creek- 6.7	Marble Creek- 4.7	Dry Branch- 3.3	Fowler Branch- 1.6
Harberts Creek- 10.3	Camp Creek- 6.0	Walton Creek- 4.6	Turkey Branch- 2.9	**Total Miles of Named Streams= 172.2**
Lewis Creek- 9.4	Hensley Creek- 5.9	White Oak Branch- 4.6	Goose Creek- 2.8	

2.2.4 Topography

The headwaters of Big Creek in Ripley County is the watershed's highest elevation at 950 feet above sea level, located in the upper northeast section of the watershed. The portion of the watershed within Ripley County east of Big Oaks National Wildlife Refuge is mostly flat and level characterized by a 0 to 25 percent slope with deep, moderately well drained soils. The elevation within Jefferson County drastically drops off in the form of sporadic slopes and cliffs and it drains into the main stem of the Muscatatuck River. The land slope in the southwest portion of the watershed gradually declines to its lowest point, 520 feet above sea level. The bottom lands area is characterized by a 0 to 2 percent slope with poorly drained soils.

Figure 7: Central Muscatatuck Topography



2.2.5 Soils

The CMW is underlain with shale, siltstone, and limestone that originated as sediments in an ancient warm shallow sea. Formations from the Devonian system are visible as limestone outcrops throughout the watershed and along the Muscatatuck River.

The soils of the CMW, as with any watershed, dictate what land uses are successful and how the watershed's health is impacted by different land uses. The number of individual soil types within the watershed is too great to list due to the large area of land. The following soil type descriptions provide general soil regions and more specific soil associations.

The CMW is made up of two soil regions. The first major soil region comprises most of the watershed and is part of the Illinoian glacial till region. Even though its name suggests that the glacial drift occurred during the Illinoian time recent investigations suggest that the drift may have been deposited earlier. This plain consists of broad, very flat surfaces cut by sharp ravines. Soils were formed on this glacial drift during the warmer interglacial time, and many of them were later eroded. This eroded surface was later covered by approximately 40 to 100 inches of loess during the Wisconsinan period. The present soils on the loess-covered plains have very light colored surface horizons due to its lack of organic matter. Soil wetness features are present near the surface in the Clermont (Cobbsfork) soils on the till plain interior. They become progressively deeper in the Avonburg soils as the edge of the till plain, and in the Cincinnati soils on the shoulder of the till plain. Fragipans are present in these three soils, but they are lacking in Grayford soils on the steeper back slopes.

Beech and white oak were the predominant species on all soils. The wetter soils supported more tulip tree and sweet-gum, and the better-drained soils, Avonburg, Cincinnati, and Grayford, had more sugar maple. The soils on the broad flats of this till plain are used mainly for row-crop agriculture, but poor soil conditions and compaction by farm equipment are special concerns (INHJackson 53).

The second major soil region within the watershed accounts for a very small percentage of the soil type but makes up the very important region of the Muscatatuck bottoms region. This is the major flood plain of the CMW as the elevation drops to its lowest point. These alluvial and outwash deposits are frequently flooded and vary from well drained to poorly drained soils that may be high in natural fertility and vary from highly acidic to neutral. Although these soils may be high in natural fertility they are often difficult to cultivate due to spring flooding that causes crusting of the soil (INHJackson 49).

There are seven different types of soil associations within the watershed. A soil association is a landscape comprised of a distinctive pattern of individual soils in defined proportions. The soil is named for the most prevalent soil types within the association. The following soil associations mapped on figure 8 should be taken into account to determine appropriate land use and critical watershed areas. When determining appropriate land use the other soil characteristics that should be taken into account are soil moisture content (referred to as hydric soil types or wetlands), highly erodible lands (HELs), and septic system suitability.

Figure 8: Soil Associations

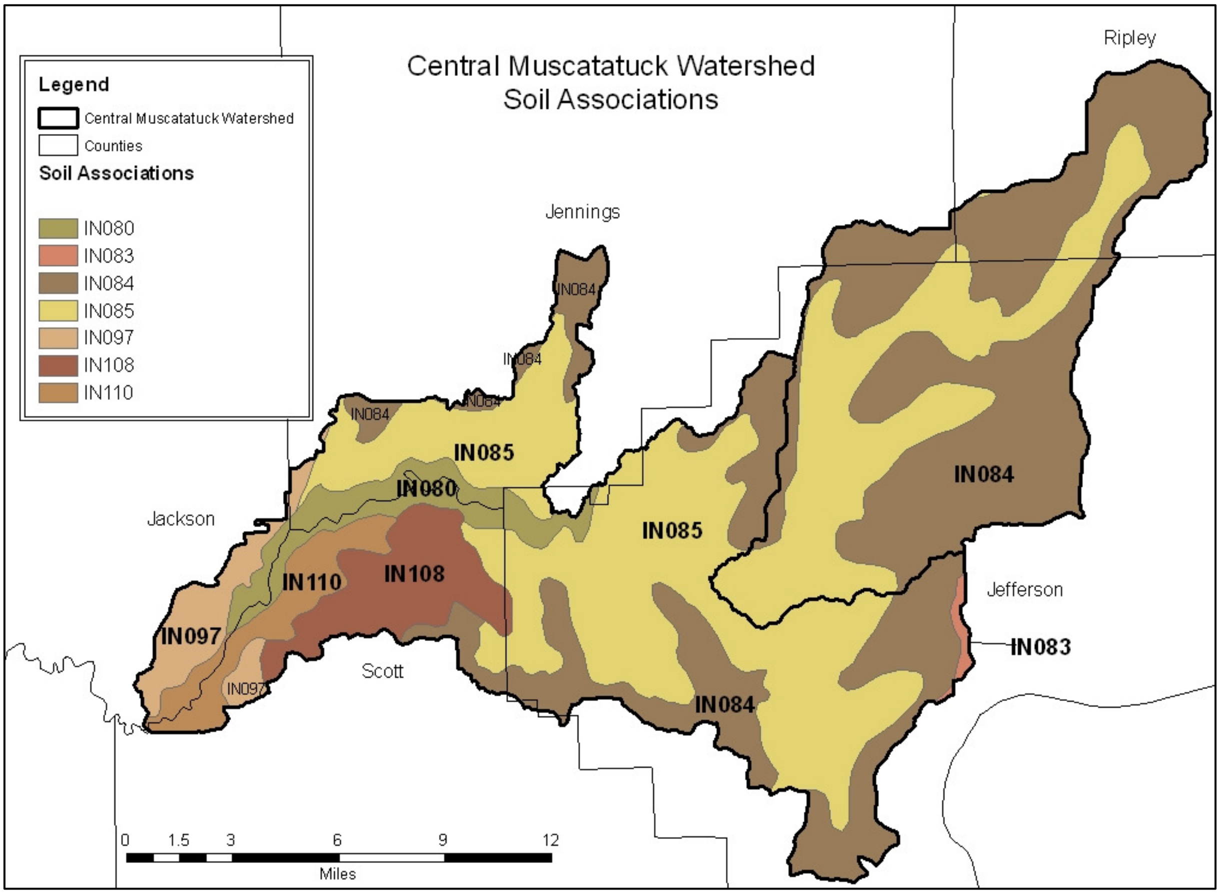


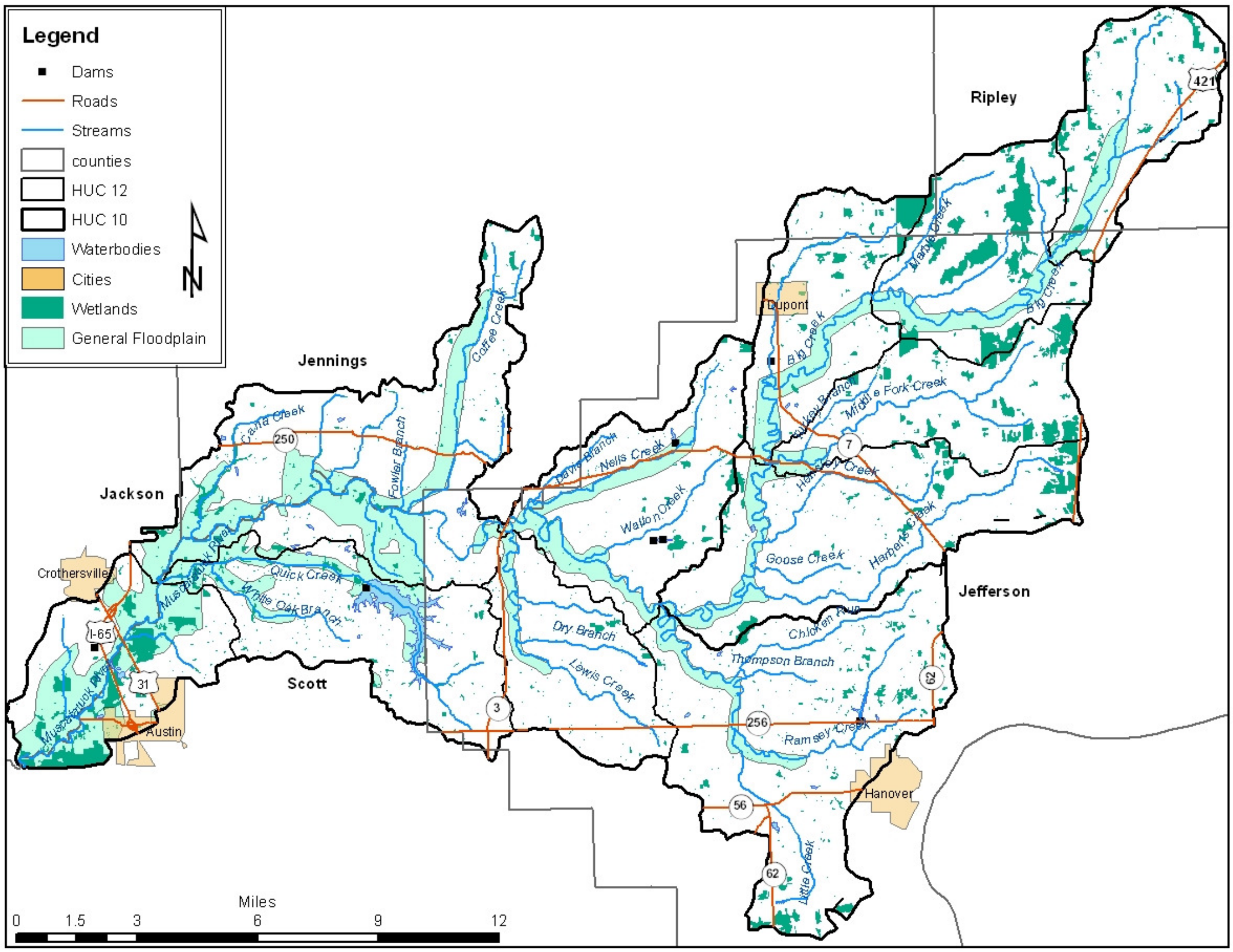
Figure 9: Central Muscatatuck Soil Associations

Soil Association Number on Map	*Soil Name*	*Soil Description*
IN 080	Wakeland-Haymond	Deep, nearly level, well drained soils formed in silty and loamy alluvium; on bottom land
IN 083	Rossmoyne-Cincinnati-Bonnell	Deep, nearly level to strongly sloping, well drained soils formed in a thin mantle of loess and in the underlying glacial drift and limestone residuum; on uplands
IN 084	Rosmoyne-Cobbsfork-Avonburg	Deep, nearly level and gently sloping, poorly drained and somewhat poorly drained soils formed in a thin mantle of loess and in the underlying glacial drift; on uplands
IN 085	Rossmoyne-Hickory-Cincinnati	Deep, nearly level to very steep, well drained soils formed in a thin mantle of loess and in the underlying glacial drift; on uplands
IN 097	Peoga-Otwell-Haubstadt-Dubois	Soils on bottom lands and terraces; acid, deep, poorly drained to well-drained soils low in natural fertility
IN 108	Trappist-rarden-Jennings-Cincinnati	Deep, poorly drained to moderately well drained soils developed from glacial till and having a depth of about 2 feet
IN 110	Stendal- Bonnie	Soils on bottom lands; medium acidity to neutral, deep, imperfectly drained to well-drained soil high in fertility

2.2.5.a Hydric Soils

The wetlands and hydric soils within the watershed vary greatly from the bottom lands adjacent to the main stem of the Muscatatuck River to spring seeps and wet woodlands that form from high clay content. Wetlands are lands where soil saturation is the dominant factor in determining the nature of soil development and the types of plant and animal communities present in a given habitat. The natural function of wetlands make them an important element of every ecosystem and very important to a healthy functioning watershed. They provide habitat for fish and wildlife, protect water quality, prevent erosion, act as flood water storage, and provide recreation. Hydric soils are defined by the National Technical Committee as soils that are formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions. The following map shows general wetlands and general floodplains. This map indicates that there are 12,887.3 acres or 7.85% of the watershed that are wetlands and 28,353.4 acres or 17.3% of the watershed that is a general floodplain. It should be noted that there are more wetlands and floodplains than indicated on this map, and specific designations of wetlands are determined by on site visits determined by the Natural Resource Conservation Service.

<u>Figure 10: Wetlands and Floodplains</u>



2.2.5.b Highly Erodible Lands (HELs)

Highly erodible lands should be taken into account when deciding what land use is appropriate for a given soil due to the fact that soil erosion is one of the largest contributors to water quality degradation.
The Food Security Act of 1985 required that soil survey map units be separated into three categories based on the potential erodibility due to wind erosion and sheet rill erosion. This designation can be found only on each individual county soil map as designated to original soil classifications. Therefore the NRCS county soil amendment and correlation document for each counties soil must be used to correlate the HEL

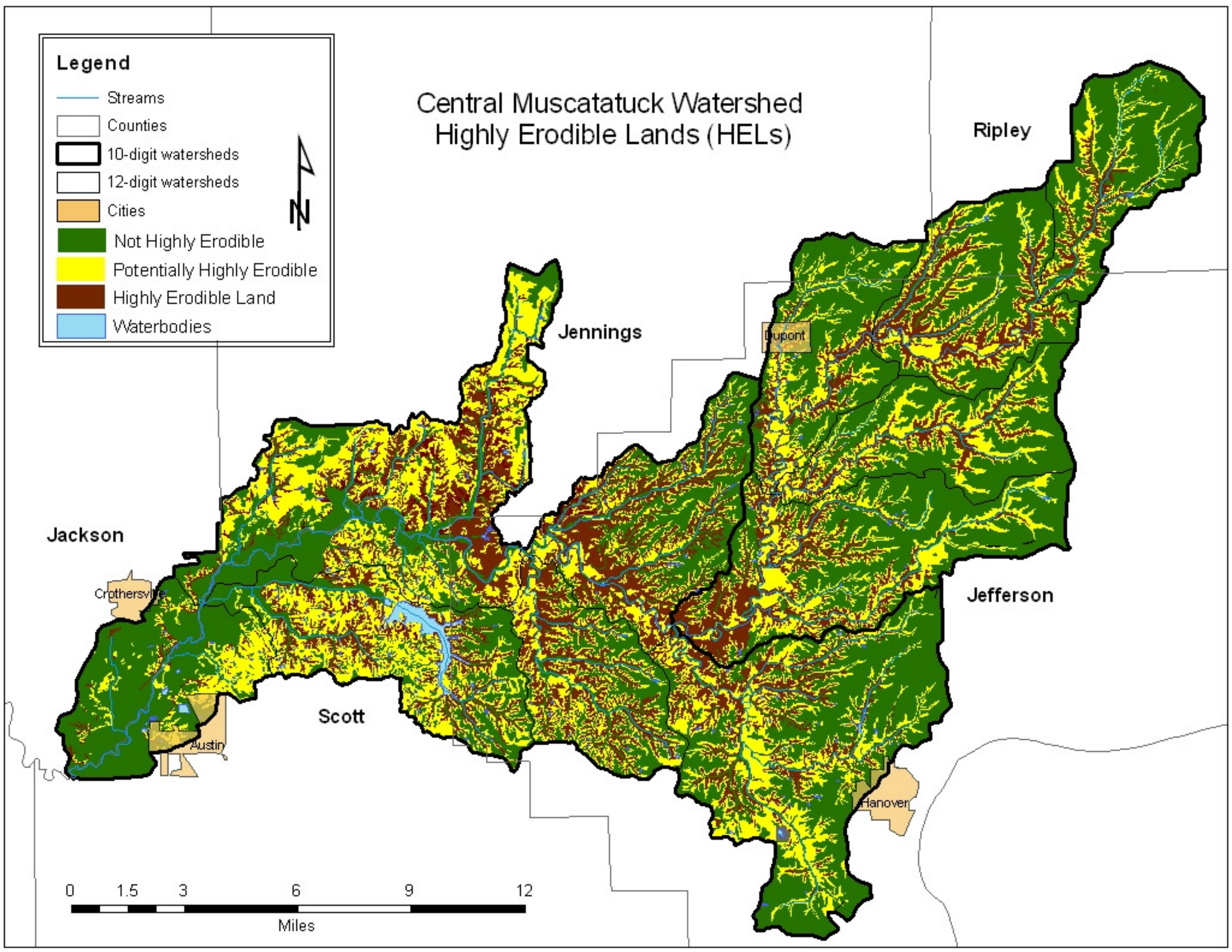
determination for current soils. The equation for determining potential erodibility from sheet and rill erosion is[4]:

$$A = \frac{RK(LS)}{T}$$

(A=soil loss in tons per acre, R=rainfall, K=soil erodibility, LS=slope length and steepness factor, and T=tolerable soil loss in tons per acre)

The individual soils are rated as a highly erodible, potentially erodible, and not highly erodible land. Each soil unit is designated as highly erodible if the value A is equal to or greater than 8 when the minimum slope length and minimum slope percent are used. A soil unit is designated as potentially erodible if A is less than 8 when the minimum slope length and minimum slope percent are used but equal to or greater that 8 when the maximum slope length and maximum slope percent are used. A soil is designated as not highly erodible if A is less than 8 when the maximum slope length and maximum slope percent are used.

Figure 11: Highly Erodible Lands



4 Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey online at http://websoilsurvey.nrcs.usda.gov

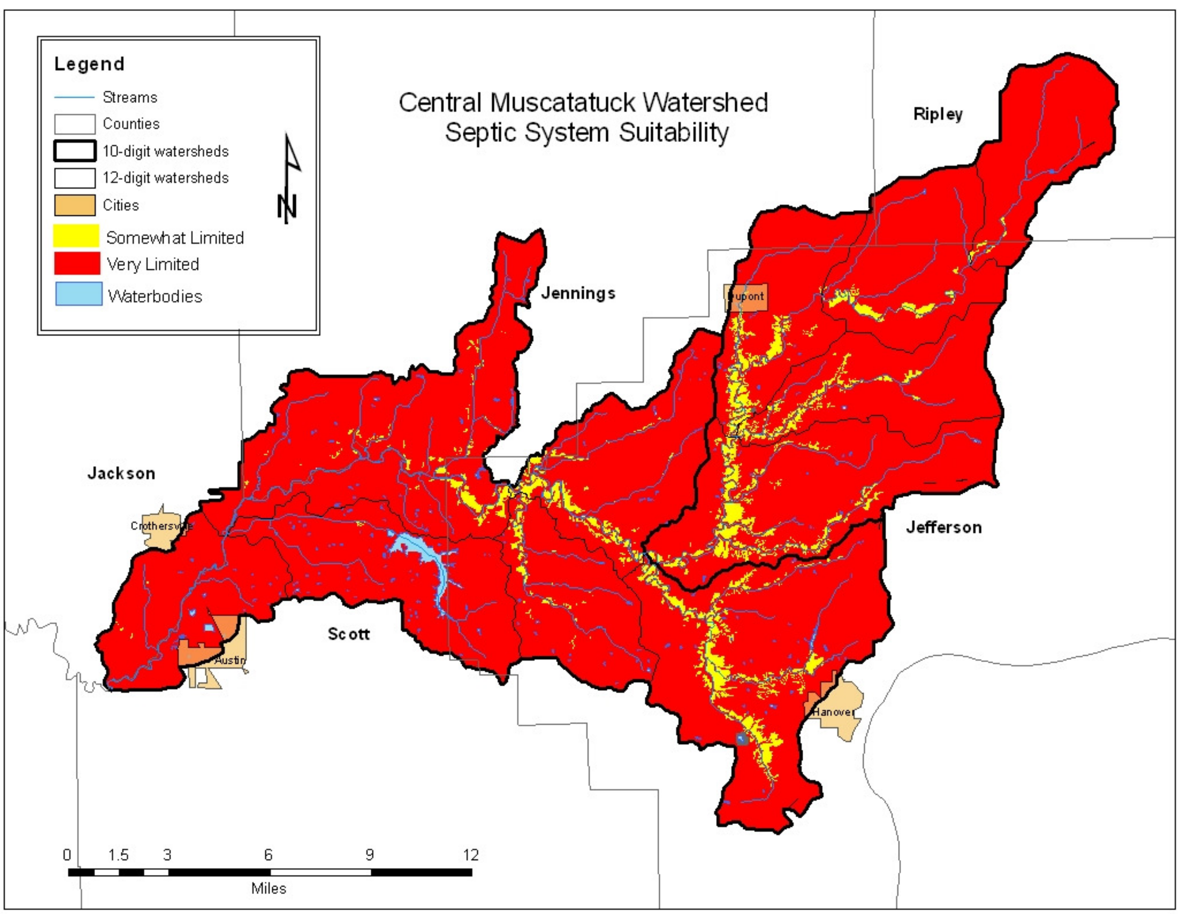
2.2.5.c Soils Septic System Suitability

Septic tank absorption fields are areas in which effluent from a septic tank is distributed into the soil through subsurface tiles or perforated pipe. Only that part of the soil between depths of 24 and 60 inches is evaluated for septic system suitability. The ratings are based on the soil properties that affect absorption of the effluent, construction, maintenance of the system, and public health. The properties of the soil which affect absorption of the septic effluent are saturated hydraulic conductivity, depth to water table, ponding, depth to bedrock or cemented pan, and flooding. Excessive slope may cause lateral seepage and surfacing of the effluent in down slope areas. The properties of the soil which interfere with the installation of septic systems are stones and boulders, ice, and bedrock or a cemented pan. Some soils are underlain by loose sand and gravel or fractured bedrock at a depth of less than four feet which will not allow the effluent to adequately filter particularly on a new system. These problems may cause the systems to malfunction allowing effluent to contaminate surface and ground water.

The following map in figure 12 shows ratings that indicate the extent to which the soils are suitable for the functional operation of a septic system. Almost the entire watershed is rated as very limited indicated in red and a very small percentage is rated as somewhat limited in yellow. "Very limited" indicates that the soil type has one or more limitation. These limitations generally can not be overcome without major soil reclamation or expensive installation designs. Many of the small towns within the watershed have houses with very small lots which originally utilized pit toilets and they now do not have two acres as mandated or the appropriate soil types to construct functioning septic systems.

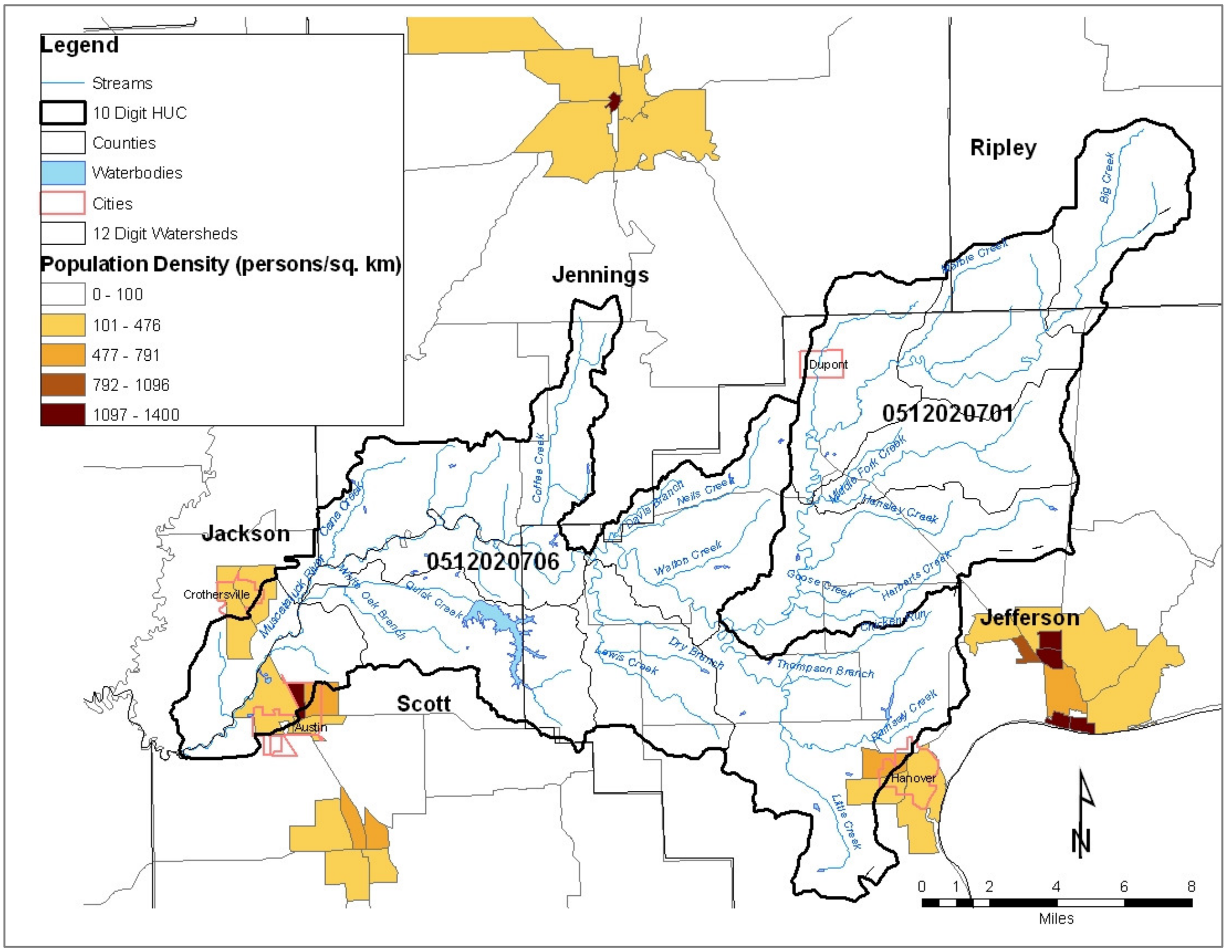
There are known and observed straight pipe discharges to waterbodies throughout the watershed, as will be further noted during discussion of the windshield data survey, specifically in Jackson County where public sewer is not offered.

Figure 12: Soil Septic System Suitability



In general, there is not a high population density throughout the watershed, the majority of the watershed having a population of 0-100 persons per square kilometer, as provided by 2000 census data (see Figure 13).[5] The highest population densities in the watershed are shown to be in Jackson County, where public sewer is not offered.

Figure 13: Population Density



2.2.6 Natural History

The Central Muscatatuck Watershed is located within the Bluegrass Natural Region as described in the Natural Heritage of Indiana; "Limestone Ledges and Crawfish Flats". Charles C. Deam in his *Flora of Indiana* noted that an Appalachian flora was present and documented that there is level, poorly drained flats which are dominated by beech, tulip tree, and black gum on the higher sites and by sweet gum, red maple, swamp chestnut, swamp white oak, and pin oak in the lower areas. The Bluegrass Natural Region was glaciated during the Illinoian glacial period, and its northern boundary approximates the southern boundary of the Wisconsinan glaciation. The bedrock is overlain with a relatively thin layer of glacial till.

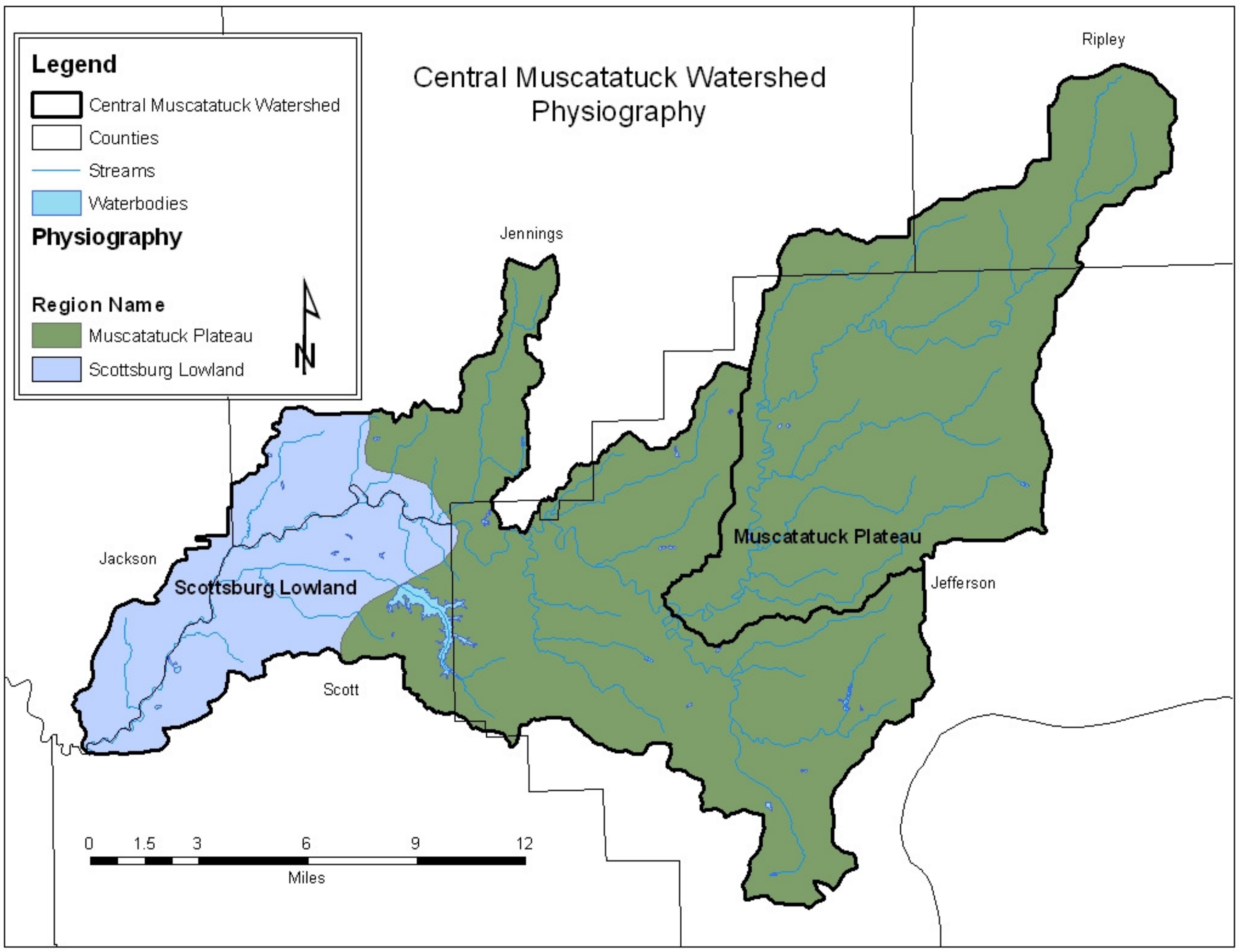
2.2.7 Physiography

The Central Muscatatuck Watershed spans two distinct physiographic regions: The Muscatatuck Plateau and the Scottsburg Lowland (see Figure 14). The majority of the Central Muscatatuck Watershed is classified as the Muscatatuck Plateau. The Muscatatuck Plateau slopes gradually downward from the

[5] Indiana Population Density 2000, U.S. Census Bureau, http://inmap.indiana.edu/dload_page/demographics.html

Switzerland Hills section on the east towards the Scottsburg Lowland Section to the west at about 12 feet per mile. The upper sections are covered with a layer of drift which can be up to 150 feet thick. The uplands are mostly level to gently undulating plains that are dissected by steep sided, moderately deep valleys where streams have cut their way down through the bedrock and overlaying soils. Minor areas of karst topography with sinkholes and caves are found along the valley borders as shown in figure 16. The bedrock consists of Silurian and Devonian age limestone as well as dolomites. The outlet of the watershed in the lower southwest section of the watershed is classified as the Scottsburg Lowland. This region includes broad outwash plains and terraces in addition to wide bottomlands.

Figure 14: Physiography

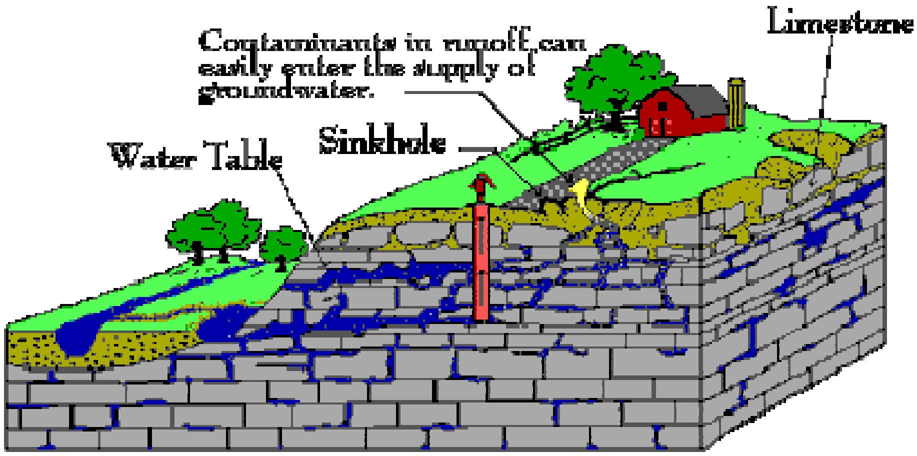


2.2.8 Karst Topography

Karst topography is a landscape created by groundwater dissolving sedimentary rock such as limestone. See Figure 15 for a description of karst topography. This creates land forms such as shafts, tunnels, caves, and sinkholes. Groundwater seeps into and through these land forms. The result is a scenic landscape which is beautiful but fragile, and vulnerable to erosion and pollution.[6]

[6] watersheds.org, http://www.watersheds.org/earth/karst.htm

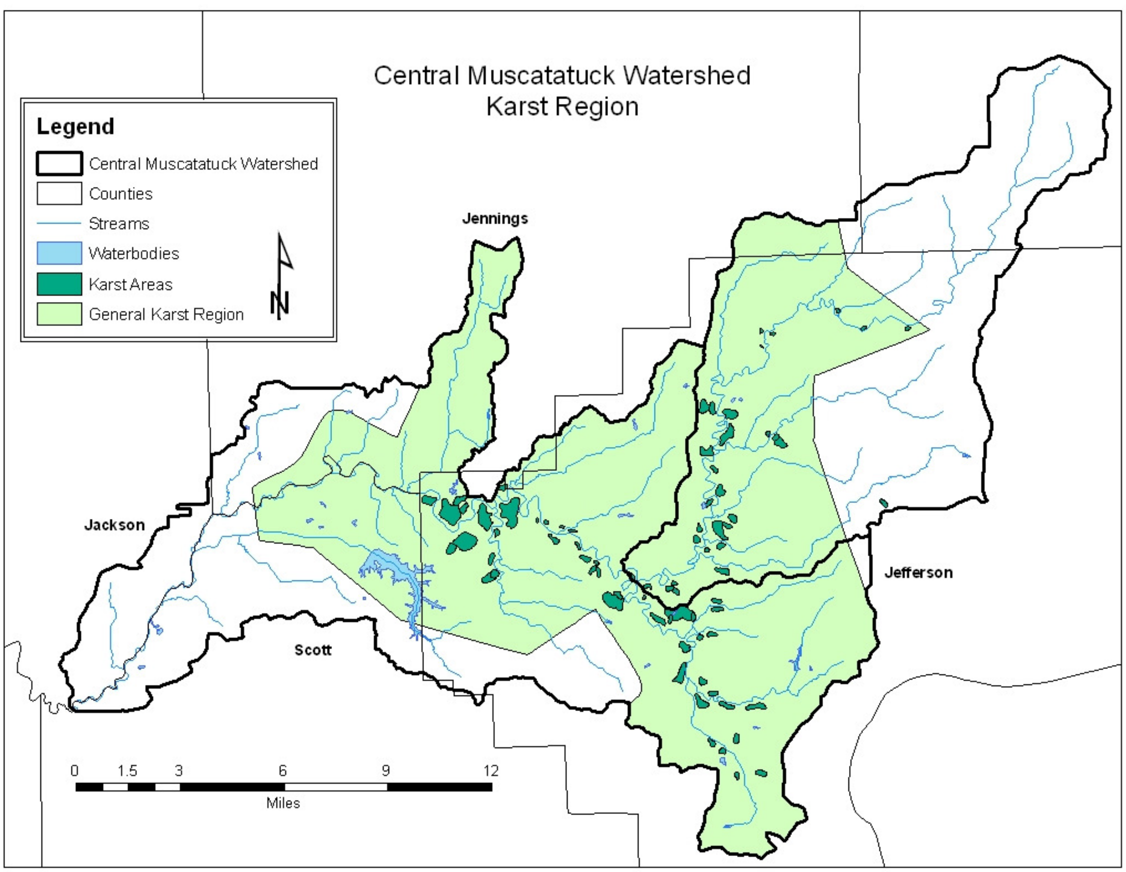
Figure 15: Karst Topography Description



Source: Hallberg, ETAL, 1984 (http://www.purdue.edu/envirosoft/inject/images/karst.gif)

Karst topography is an important factor to be considered within the Central Muscatatuck Watershed. Karst topography has the potential to affect approximately 61,187 acres out of 164,000 total acres which is approximately 37% of the watershed. Pollutant runoff from agriculture or failing septic systems that drains into sinkholes may be deposited directly into water sources. Many of these sinkholes supply underground aquifers and/or drain directly into streams. The following map shows the area of concern as well as direct karst area in relation to streams.

Figure 16: Karst Topography in Watershed

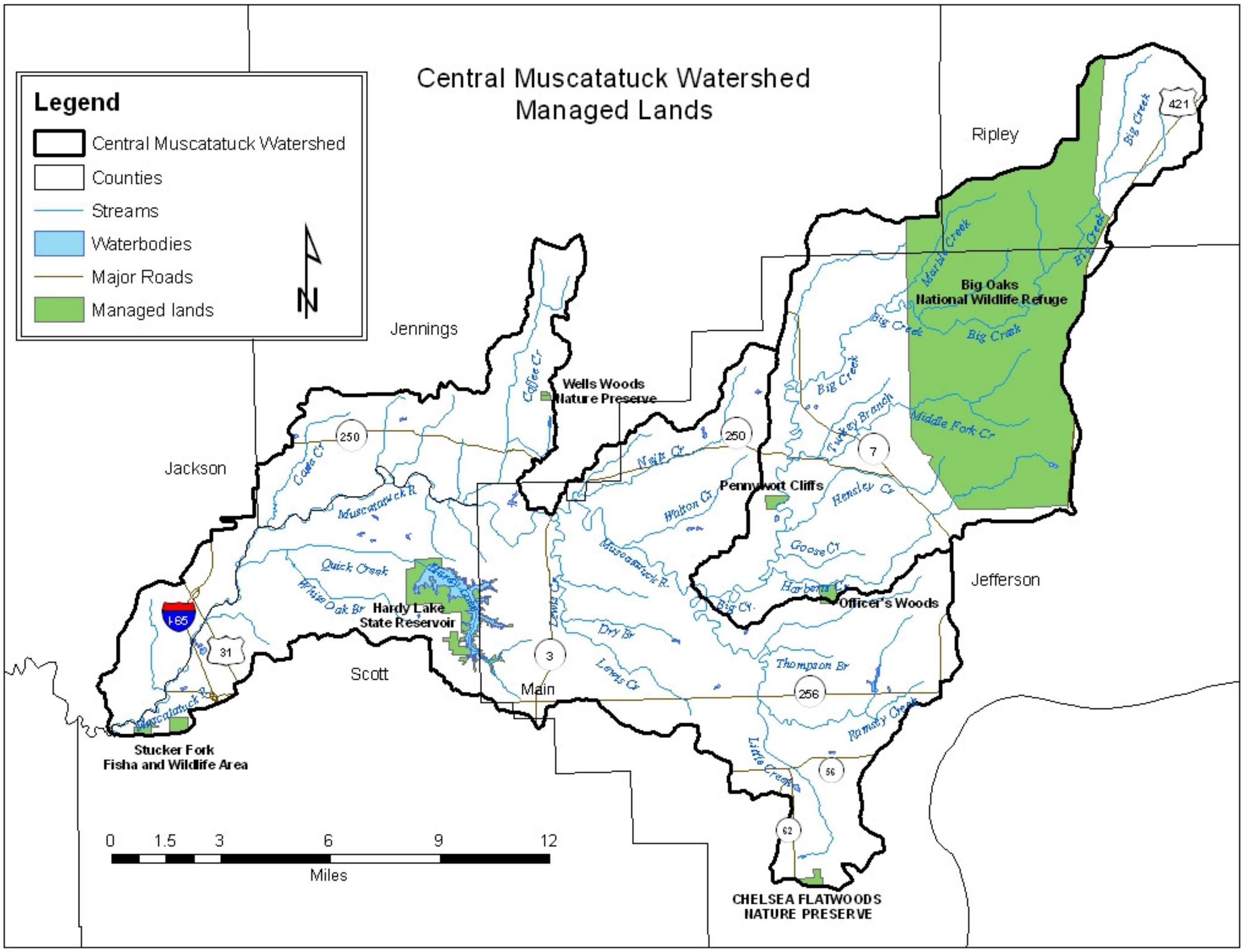


Indiana Karst Conservancy: http://ikc.caves.org/index.shtml

2.2.9 Public Lands

The Central Muscatatuck Watershed holds six different public lands within the boundaries of the watershed (see figure 17). These public lands range from State and Federally owned property to nature preserves and conservation clubs. These public lands not only serve as natural refuges areas, but they also host important interest groups involved in natural resource conservation activities.

Figure 17: Managed Lands



Chelsea Flatwoods in Jefferson County is owned and managed by The Nature Conservancy. The 388-acre nature preserve resides partially at the very southern tip of the Little Creek Headwaters sub watershed.

These flatwoods are classified as the Bluegrass Tillplain Flatwoods type and are not normally subjected to flooding by stream overflow. Soils associated with this type of flatwoods are distinctive, being poorly drained and acidic. This area has not been cleared for agriculture primarily due to the conditions of this landscape. Some of the unique plants found in this habitat include Wolfe spikerush, splendid large whorled pogonia orchid, and Virginia meadow-beauty. There are also many ferns that occur here that are more typical of northern Indiana including New York fern, sensitive fern, marsh fern, and blunt-lobe grape fern. The trees occurring in this habitat include sweet gum, swamp white oak, American beech, and southern red oak. The occurrence of the southern red oak is unusual, existing here at the northern limit of its range.[7]

Pennywort Cliffs in Jefferson County is owned and managed by The Nature Conservancy. The 216 acre nature preserve is located near the town of Lancaster off 800W on Big Creek. This preserve is a great example of Midwest moist limestone/dolostone cliff community and supports the American water pennywort for which the preserve is named. This property is one of the first classified forests in Indiana. It was classified by the Department of Conservation (now the DNR) in 1931. During the severe drought of 1936 the forest contained the only source of open water in the area due to the springs. Permission was granted to allow farmers to drive their livestock to the spring for water. The animals were allowed to drink as long as they left without grazing since grazing was prohibited in a classified forest.[8]

Wells Woods Nature Preserve is an impressive 20 acre tract of old growth forest in Jennings County in southeastern Indiana. There is no parking area or trail system for this preserve. These tracts of woods contain great, mature trees; a hardwood forest in Indiana that contains trees 150 to 200 years old and older is often considered an old growth forest. For more information contact the Division of Nature Preserves: http://www.in.gov/dnr/forestry/pdfs/indianaoldgrowthforests.pdf.

Hardy Lake State Reservoir in Scott and Jefferson counties is accessible from State Roads 3 and 256. Hardy Lake is the smallest state operated reservoir. The dam was constructed on Quick Creek in 1970 for the purpose of water supply and outdoor recreation. Hardy Lake was constructed in accordance with the long range program developed by Stucker Fork Conservancy District of Scott County to provide water for the surrounding community. The property's total acreage consists of 2,449 acres including a water surface area of 741 acres. Hardy Lake is owned and operated by the Indiana Department of Natural Resources: http://www.in.gov/dnr/parklake/properties/maps/2007/hardy_lake_trail.pdf.

Stucker Fork Fish and Wildlife area is located at the southwestern most tip of the watershed just outside of the town of Austin. It is approximately 1,528 acres and is managed by the Department of Natural Resources Fish and Wildlife. For more information on this property contact: Crosley Fish and Wildlife Refuge at (812)346-5596.

Big Oaks National Wildlife Refuge is situated on approximately 50,000 acres in southeastern Indiana. Big Oaks NWR is the largest of the three national wildlife refuges in Indiana. Big Oaks NWR encompasses 50,000 acres in three counties (Jefferson, Jennings, and Ripley) and overlays that portion of the former Jefferson Proving Ground (JPG) that lies north of the historic firing line. The Indiana Air National Guard operates an air-to-ground bombing range on the remaining 1,033 acres of the former proving ground north of the firing line and this property is surrounded by, but not designated as, part of the refuge.

JPG was established by the Army in 1940 as an ordinance testing installation and closed in 1995. In 1996, the U.S. Fish and Wildlife Service began managing the wildlife resources of JPG. Big Oaks NWR was established in June 2000 as an "overlay" national wildlife refuge through a 25-year real estate permit from the U.S. Army. As an overly refuge, the Army retains ownership and the FWS manages the property as Big Oaks NWR. It is now one of over 540 refuges in the country forming the National Wildlife Refuge System, a vast network of lands and waters set aside to be protected and managed for wildlife.

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[7] The Nature Conservancy, *The Nature Conservancy's Guide to Indiana Preserves,* (2006, Quarry Books), 44.
[8] The Nature Conservancy, 182.

Big Oaks NWR hosts a variety of different habitat types, providing for a diversity of wildlife species. The refuge is unique in that it contains one of the largest contiguous forest blocks and grassland complexes in southeast Indiana, providing breeding habitat for a variety of rare birds. A landscape mosaic of habitats comprised of grasslands, shrub land, forests, and wetlands provides opportunities for viewing a variety of wildlife species while visiting the refuge. Also offered are a host of other recreational activities, including fishing, hunting, bird watching and field trips, wildlife photography, refuge tours, educational opportunities and hiking. For more information about Big Oaks NWR visit: http://www.fws.gov/midwest/bigoaks/.

2.2.10 Species of Special Concern

These species are known to inhabit some of the sensitive habitats that are present within the watershed. Some of these species are Federally or State endangered, or may be a species of special concern within the State of Indiana.

2.2.10.a Mammals

- River Otter *(Lutra canadensis)*: This species of *special concern* was recently removed from the state endangered list. River otters were released in the Big Oaks Wildlife Refuge and soon took hold along the rivers and streams they inhabit. Signs of river otter have been noted while conducting water quality testing.

- Bobcat (*Lynx Rufus)*: This species of *special concern* was recently removed from the endangered species list. Although it is a rather secretive animal and rarely seen, their known habitat is characterized as remote, well forested areas of rugged topography with cliffs, bluffs or rocky outcrops. The unglaciated region of south central Indiana seems to provide the best bobcat habitat in the Hoosier state. Limestone caves found in this region, as well as rocky outcrops, hollow trees and logs could be used as den sites. Bottomland hardwood forests along river systems bounded by large bluffs and timbered slopes are also considered appropriate bobcat habitat. A bobcat population has been documented in the Big Oaks National Wildlife Refuge. http://www.in.gov/dnr/fishwild/3357.htm

- Indiana Bat *(Myotis sodalist)*: The Indiana Bat is a *Federally and State Endangered species* The population of the Indiana bat in Indiana is estimated to be approximately 244,000 which is about 23% of the entire population. These social bats dwell in caves in very large groups only during the winter; however, there are few caves that provide the conditions necessary for hibernation. None of these are known to be within the watershed, although the watershed may provide important summer time habitat in the form of Shagbark Hickory trees along stream banks which provide cover while the bats raise their young. http://www.in.gov/dnr/fishwild/3357.htm

2.2.10.b Reptiles and Amphibians

- Kirtland's Snake *(Clonophis kirtlandii)*: The Kirtland's snake is a *State Endangered* species and was once commonly found statewide in wet prairies and meadows. Loss of habitat such as prairies and wetlands are the major contributors to the detriment of this species. It can be found within the watershed in the Scottsburg Lowland Region.


Photo © Jim Harding

- Copperbelly Water Snak*e (Nerodia erythrogaster neglecta)*: The Copperbelly is listed as *State Endangered*. This species prefers shrubby swamps and slow moving streams associated with floodplain woods. The Muscatatuck Bottoms in the lower south west portion of the watershed offers ideal habitat for this snake.

- Four-toed Salamander *(Hemidactylium scutatum)*: This *State Endangered* species is only found in isolated populations. This salamander typically inhabits undisturbed forested areas adjoining springs, seeps, woodland ephemeral wetlands, and bogs. Although none have been specifically noted in the watershed, Big Oaks National Wildlife Refuge hosts a large area of suitable habitat for this species which is documented to be found directly south of the watershed and it is listed specifically as a State Endangered species for Jackson County. The greatest contributors to the decline of this salamander may be due to the destruction of wetlands, climate alteration, and habitat alteration.

- Crawfish Frog *(Rana areolata)*: The crawfish frog is a *State Endangered* species and is for the most part limited to the southwestern part of the state along the Wabash River. These frogs typically inhabit open, grassy, damp areas where there are burrows of the large chimney-building crayfish. An isolated population exists within Big Oaks National Wildlife Refuge, it is undetermined if this is a natural or introduced population.

2.2.10.c Birds

- Barn Owl (*Tyto alba)*: This nocturnal raptor is a *State endangered* species. Barn owls need large areas of pasture, hayfields, grasslands or wet meadows which host healthy populations of meadow voles, their favorite food. For breeding habitat, feeding areas must be near a nest site consisting of a suitable hollow or cavity in a tree or an appropriate man-made substitute. Most recent nests known have been in the southern half of the Indiana, especially in counties along the Ohio River such as Jefferson County which is where a large portion of the watershed lies. http://www.in.gov/dnr/fishwild/3382.htm

- Osprey *(Pandion haliaetus)*: This diurnal raptor is a *State endangered* species. Ospreys are widely found around lakes and rivers in Indiana during migration and their diet consists primarily of fish. Osprey are currently being reintroduced to parts of Indiana and the habitat within the watershed, specifically Hardy Lake, would be areas to help support an osprey population. http://www.in.gov/dnr/fishwild/3357.htm

- Bald Eagle *(Haliaeetus leucocephalus)*: Designated as the national bird of the United States in 1782, the bald eagle nested throughout the nation. Today, it is classified as a *State endangered* species. Biologists believe that a loss of wetland habitat caused the drastic decline of the bald eagle in Indiana. The watershed is home to a pair of nesting eagles located near Hardy Lake State Reservoir.

- Loggerhead Shrike *(Lanius ludavicianus)*: This small predatory bird is *State endangered.* Shrikes require open land with lookout perches for hunting, preferring areas with short vegetation such as pastures, lawns and freshly-plowed fields. They seem to prefer sites with a variety of different types of land uses.

- Henslow's Sparrow (*Ammorodramus henslowii)*: The Henslow's sparrow is a *State endangered* bird. The grasslands at the Jefferson Proving Ground in southern Indiana is the summer home to approximately 1,000 breeding pairs. The Henslow's Sparrow is a secretive bird that breeds in moist, shrubby grasslands and winters in the fields and open grassy areas of the pine forests of the southeastern US. http://www.wbu.com/chipperwoods/photos/hsparrow.htm

2.2.10.d Mollusks

Freshwater mussels are one of the most endangered groups of animals in North America. Among the factors thought to be responsible for the decline are; overharvest, siltation of their habitat from agriculture, poor land management, channelization, impoundments, competition from exotics, and pollution from herbicides, pesticides, and other chemicals. It is illegal to collect or disturb any native species of mussels in Indiana. The following list of mussels may be found in the watershed and are all listed as *State Endangered:*

- Snuffbox (*Epioblasma triquetra)*
- Sheepnose (*Plethebasus cyphyus)*
- Pyramid Pigtoe *(Pleurobema rubrum)*
- Rabbitsfoot *(Quadula cylindrical)*
- Fanshell *(Cyprogenia stegaria)*
- Tubercled Blossom *(Epioblasma torulosa)*

Other species may inhabit the watershed.

2.2.10.e Insects

- Beaverpond Baskettail *(Epitheca canis)*: This *State endangered* dragonfly has only been noted to inhabit a beaver pond found in Jackson County. All dragonflies spend their first years which could be from one to five years living in streams and ponds in the nymph stage. They require clean water with un-silted bottoms and can be indicators of good or poor water quality.

2.2.10.f Vascular Plants

Vascular plants are those plants that have special tissues for conducting water, minerals, and photosynthetic products through the plant. Water transport carries inorganic solutes upward toward the leaves from the roots and organic solutes throughout the plant. Vascular plants are very sensitive to water quality due to the distribution of water throughout the entire plant. There are a number of endangered species of vascular plants listed for each county in the watershed. A few of them that may be found in the watershed are listed below. Protected areas that offer unique habitats conducive to vascular plant life within the watershed are Big Oaks National Wildlife Refuge, Pennywort Cliffs and Chelsea Flatwoods.

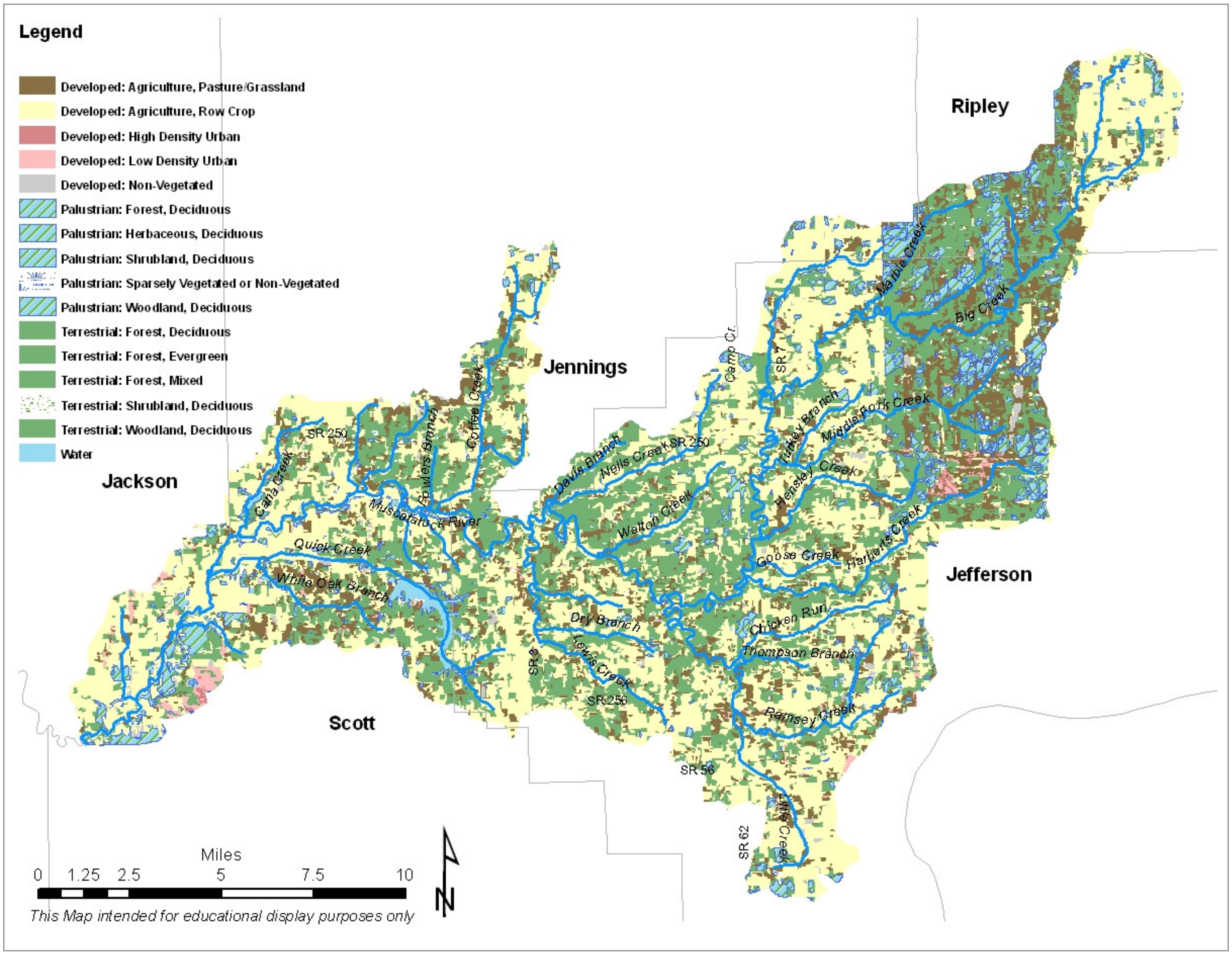
- American water pennywort (*Hydrocotyle americana* L.)
- Broom Panic Grass (*Panicum scoparium)*
- Climbing Fern (*Lygodium palmatum*)
- Divided Toothwort *(Dentaria multifida)*
- Swamp Sunflower *(Helianthus angustifolius)*

2.2.11 Land Use Inventory

2.2.11.a Spatial Assessment by Region

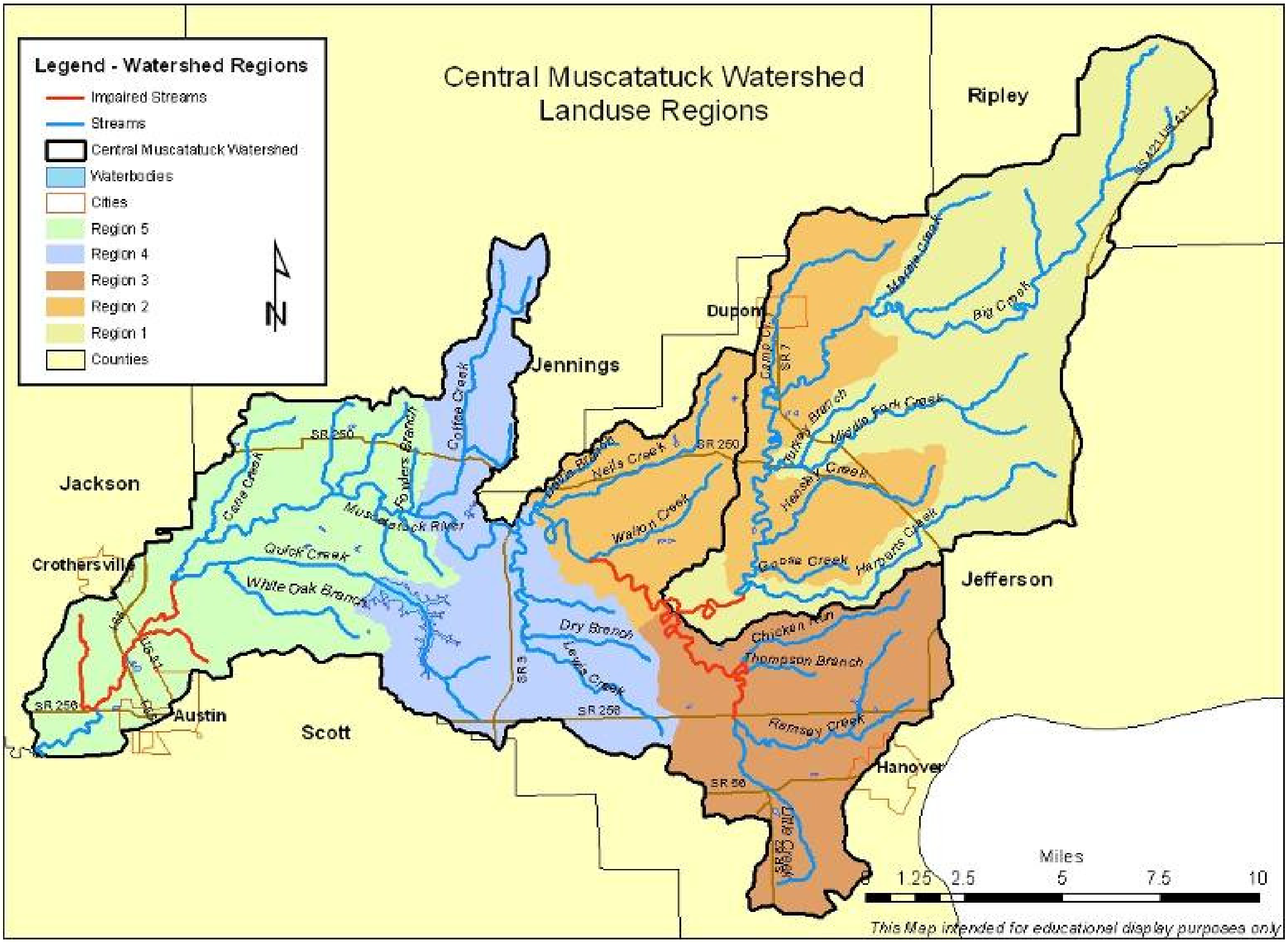
Land use within the Central Muscatatuck Watershed is, overall, comprised of approximately 42% row crop, 36% forest, 15% pastureland, 6% wetland, with less than 1% urban or non-vegetated land, and less that 1% surface water. Overall land use for the watershed is shown in figure 18.

Figure 18: Central Muscatatuck Watershed Land Use



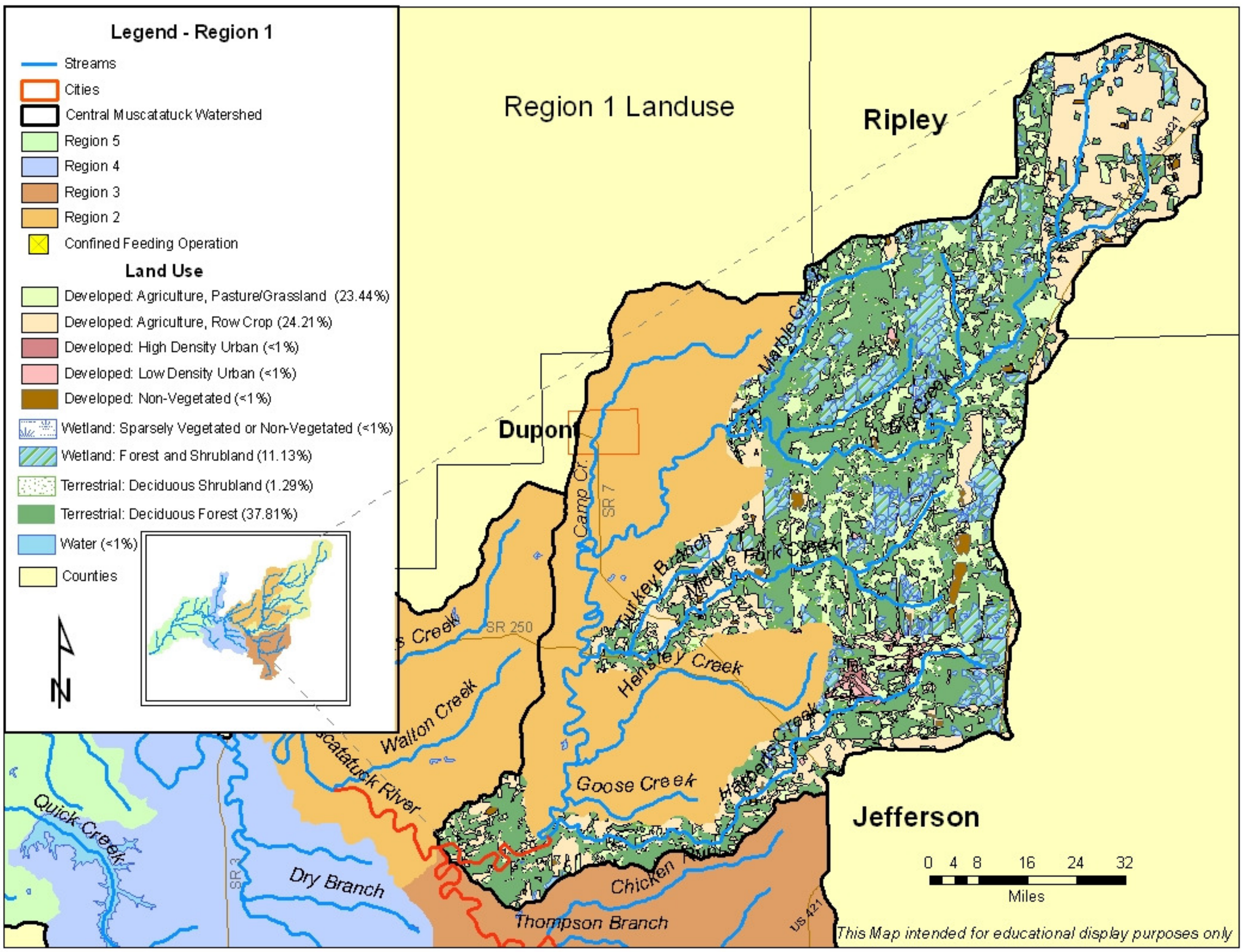
Due to the large area of the watershed, it has been divided into five common drainage regions and each region will be discussed. These drainage regions are based upon 14 digit HUC areas, as shown in figure19, and reflect similar land use practices, hydrology, and topography.

Figure 19: Five Common Drainage Areas in Central Muscatatuck Watershed



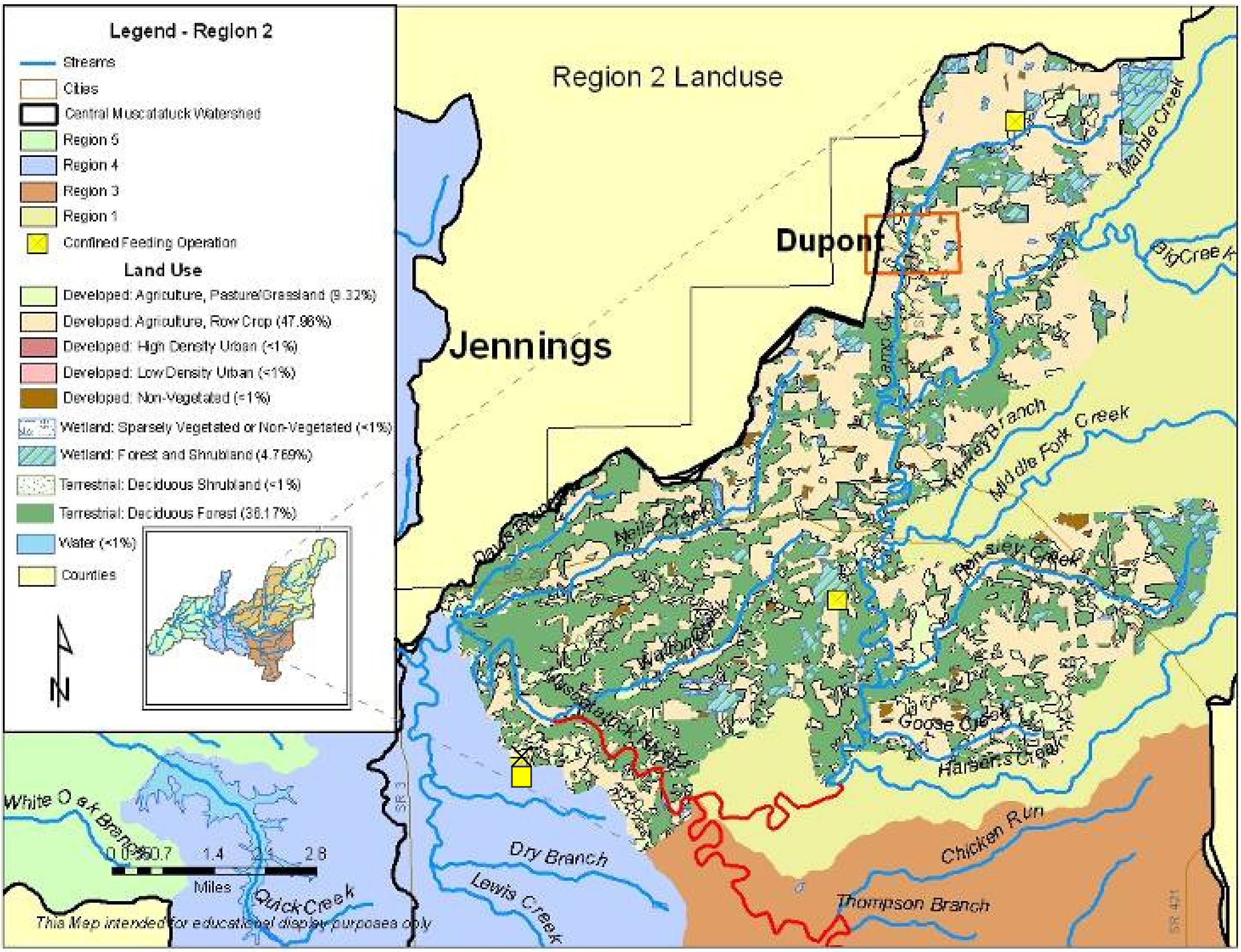
Region 1 – This region is characterized by the headwaters of Big Creek and the common land use of the Big Oaks National Wildlife Refuge. It contains the following major waterways; Big Creek Headwaters, Marble Creek, Middle Fork Creek, Turkey Branch, and Harberts Creek. The largest land use within this region by percentage of acres is terrestrial deciduous forest at 37.81%. This is due to the tract of land dominated by Big Oaks National Wildlife Refuge. The refuge acts as a filter due to the large amount of wetlands and forested areas. The area outside of the refuge is dominated by row crop - 24.21% and pastureland - 23.44%, although some row crop is practiced on private land within the wildlife refuge boundaries as well as some rural homes and farm homesteads. The section of Big Creek within this region is on the IDEM 303(d) list for Impaired Waters for high levels of *E. coli*.

Figure 20: Region 1 Land Use



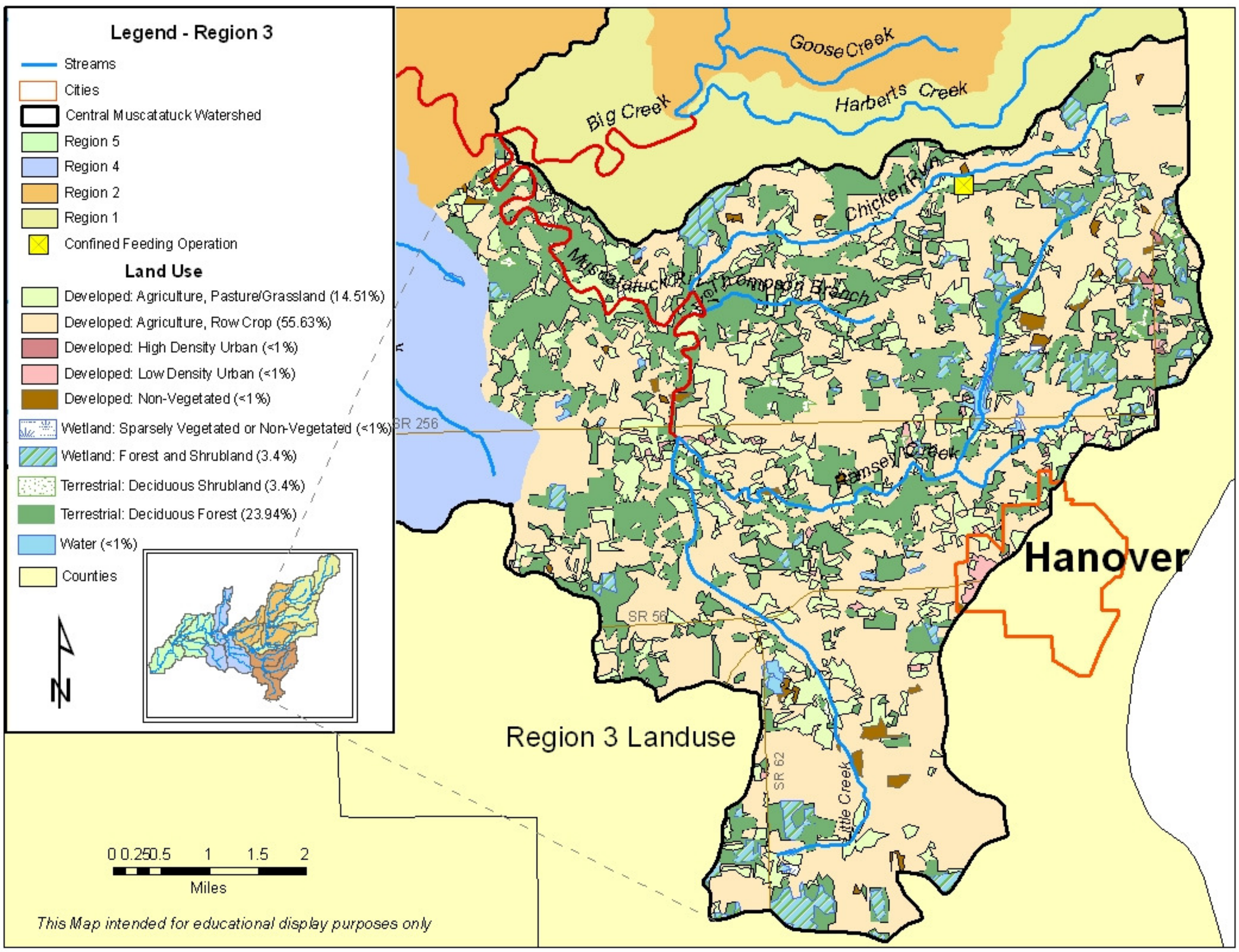
Region 2 – This region is encompasses the rural town of Dupont as well as agricultural land to the west of Big Oaks National Wildlife Refuge. It also contains a large portion of the drainage area where Big Creek flows into the Muscatatuck River. The following major waterways are found in this region; Camp Creek, Neils Creek, Davis Branch, Walton Creek, Hensley Creek, Goose Creek, and part of the Muscatatuck River. The primary land use by percentage of acres is row crop at 47.96%. Due to the topography, the southwestern section is predominantly, approximately 36.17%, deciduous forest. There are two confined feeding operations within this region. The section of the Muscatatuck River within this region is on the 303(d) list of Impaired Waters listed for high levels of *E. coli*.

<u>Figure 21: Region 2 Land Use</u>



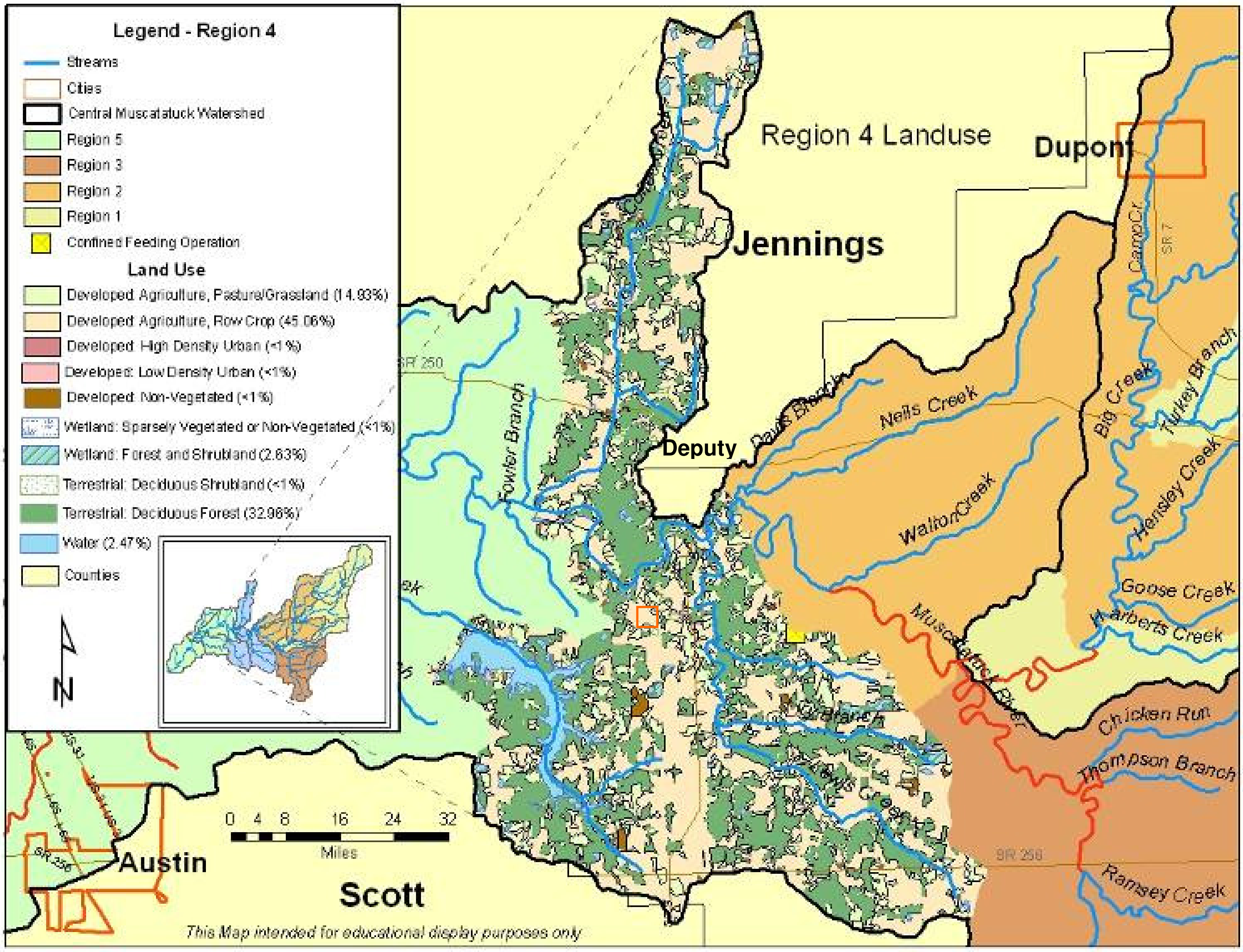
***Region 3* –** This region is characterized primarily by row crop and deciduous forest. It is also the main drainage area for Little Creek which feeds into Big Creek to form the Muscatatuck River. It contains the following major waterways; Chicken Run, Thompson Branch, Little Creek, and Ramsey Creek. The land use by percentage of acres in this region is; row crop - 55.63%, deciduous forest - 23.94%, and pasture land - 14.51%. Much of the pasture land along Little Creek was noted to allow cattle access to the creek during the windshield surveys. The topography is highly influenced by karst topography. The outskirts of Hanover as well as some of the small rural towns such as Kent may have an influence on water quality within this region due to failing or non-existent septic systems. There is one confined feeding area within this region. The section of Little Creek within this region is on the 303(d) list of Impaired Waters for high levels of *E. coli*.

Figure 22: Region 3 Land Use



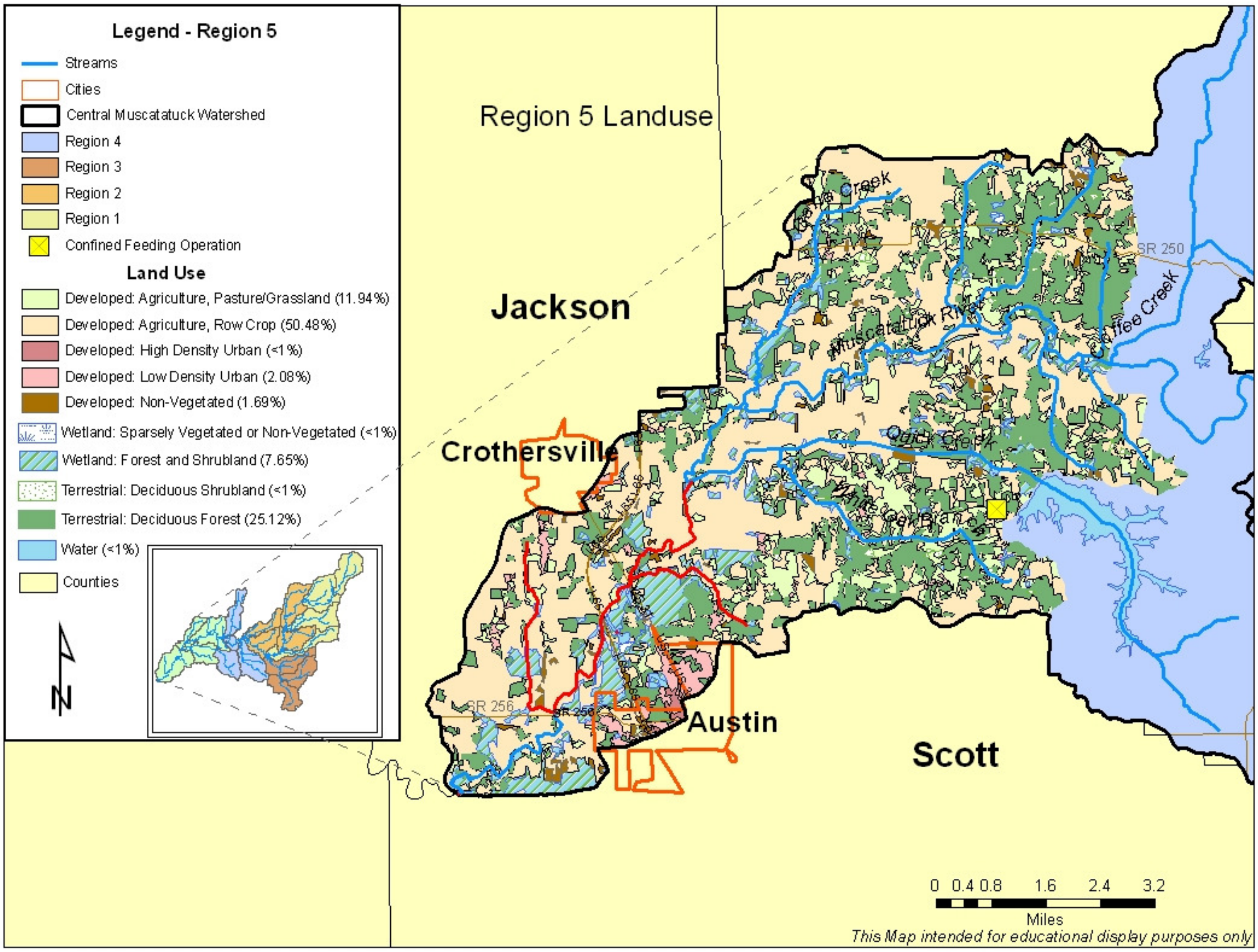
Region 4 – This region is characterized by row crop, deciduous forest, and some pasture land which can be viewed along State Road 3. It contains the following major waterways; Coffee Creek, Dry Branch, Lewis Creek, Hardy Lake, and a section of the Muscatatuck River. The land use by percentage of acres in this region is row crop - 45.06%, deciduous forest - 32.96%, pasture land - 14.93%, and water - 2.47%. Region 4 has the advantage of the Lake and River Enhancement (LARE) funded project for the Quick Creek-Hardy Lake sub watershed which was completed in 2002. The rural community of Deputy also lies along State Road. 3. There is one confined feeding operation along the border of this region. The elevation slopes downward to the flatter lands of the Muscatatuck Bottoms toward Austin.

Figure 23: Region 4 Land Use



Region 5 – The elevation in the watershed decreases drastically in this region and it receives the upper reaches of the watershed's drainage. Much of this region is characterized by bottomlands and the towns of Austin and Crothersville border the edge of the watershed. It contains the following major waterways; Cana Creek, Quick Creek, White Oak Branch, and the Muscatatuck River. The land use by percentage of acres in this region is; row crop - 50.48%, deciduous forest - 25.12%, pasture lands - 11.94%, and wetland forest and shrub land - 7.65%. There is one confined feeding operation in this region. A section of the Muscatatuck River and its tributaries within this region are listed on the 303(d) Impaired Waterbodies List for *E. coli* and dissolved oxygen levels. The bordering towns of Austin and Crothersville make up approximately 2.08% of the land use with some small industry along U.S. 31.

Figure 24: Region 5 Land Use

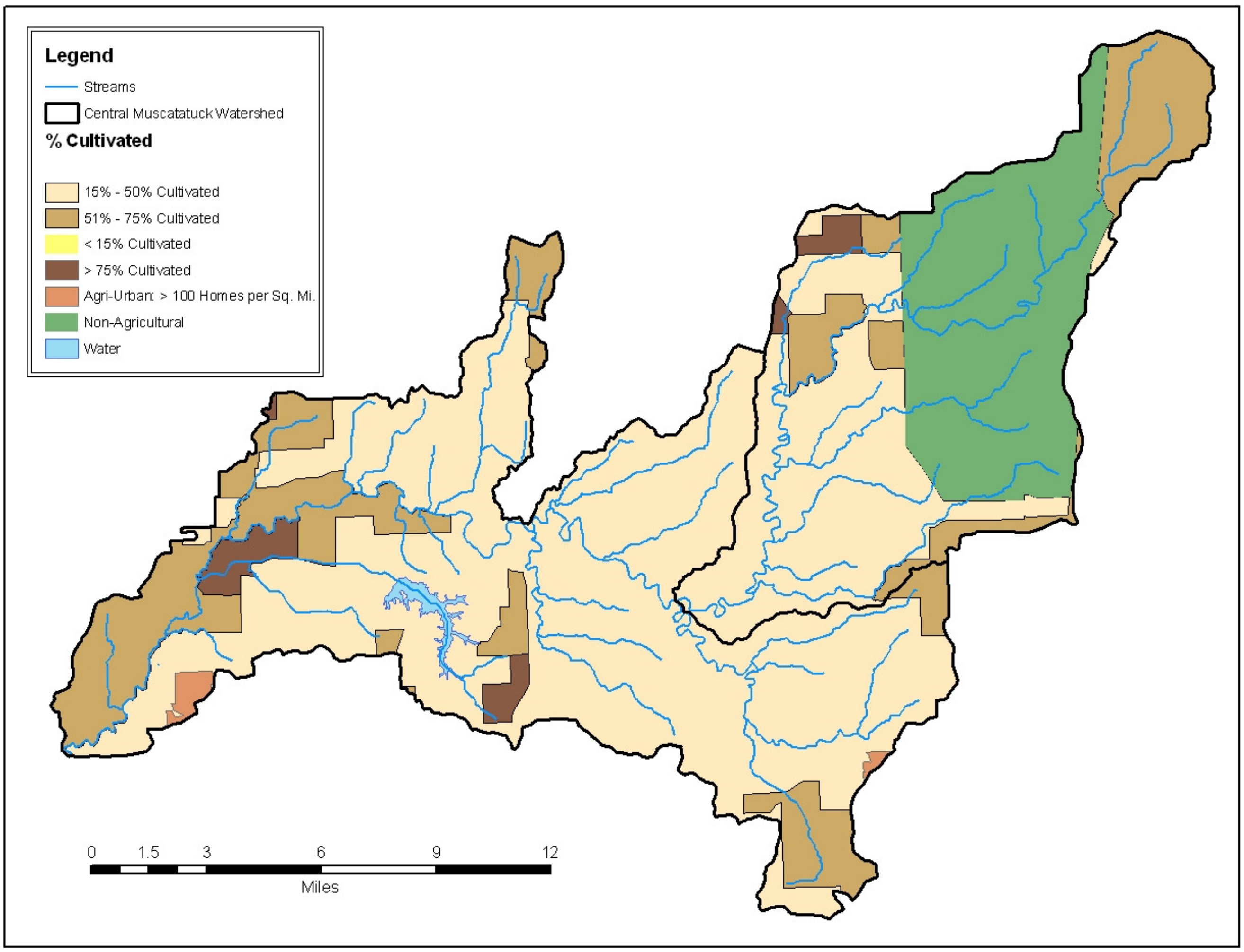


2.2.11.b Percentage of Cultivated Land

The large majority of land in the Central Muscatatuck Watershed shows a percentage of cultivation with the exception of Big Oaks National Wildlife Refuge which is the portion of the map in figure 25 shown as non-agricultural. There is also a small agricultural-urban area in the southern portion of the watershed in Austin. Figure 25 shows a further representation of the refuge acting as a filter area for the lower portion of the watershed as previously mentioned in section 2.2.10.a-Region 1. This data was observed and confirmed during the windshield data survey.

The land in the central portion of the watershed is between 15% - 50% cultivated. Areas on the outer portion of the watershed are documented as being between ≤1% - 75% cultivated and some areas are >75% cultivated.

Figure 25: Percentage of Cultivated Land



Identifying Problems, Causes, and Stressors

This section identifies the process of how information regarding known or probable causes of water quality impairments, threats and concerns was gathered from watershed community members and were further discussed, outlined and prioritized by the watershed project steering committee.

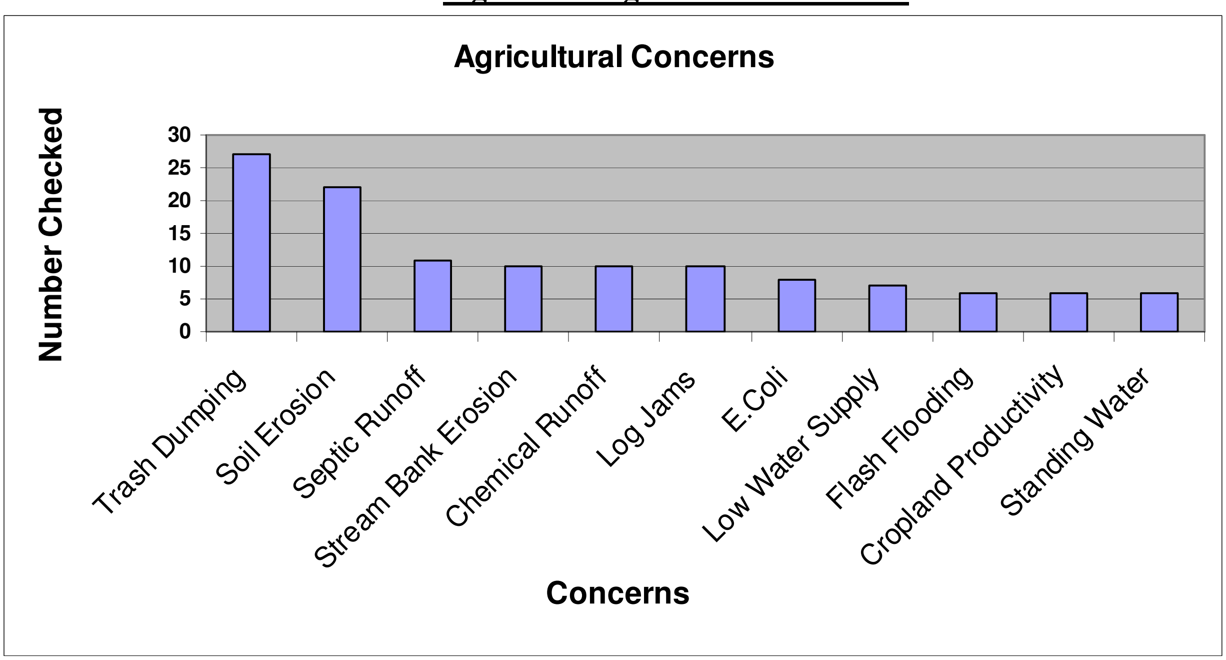
3.1 Identifying Local Concerns

The steering committee helped the coordinator compile a preliminary questionnaire. During the public meetings to introduce the project the questionnaire was distributed which asked attendees and steering committee member attendees what their top three concerns for the watershed are and why is it a concern. The overall goal of the meetings and questionnaire was to gather public concerns and gain more interested volunteers within the community. A total of 17 questionnaires were returned providing 35 responses.

Due to minimal agricultural community attendance at the public meetings, in order to gather information from this demographic, a second agricultural questionnaire was presented to attendees of the Jefferson, Scott, Jennings, and Jackson Counties' annual Soil & Water Conservation District meetings. The agricultural survey was created by the steering committee to gain more input from agricultural producers and landowners within the watershed. During these meetings the project goals were presented to the attendees. The agricultural concerns survey was then distributed.

Approximately 210 surveys were distributed. A total of 30 surveys were returned. As reflected by the survey; 60% of the respondents felt that water quality was less than it should be, 10% felt it was fine and 30% responded as unsure. The survey also listed possible concerns where agriculture and watershed health are linked. They were asked to note which factors they saw as a concern on their farm/land. Based upon the 30 surveys completed, the graph in figure 26 depicts the distribution of concerns noted. Illegal dumping of trash and soil erosion are the two greatest concerns for agricultural landowners.

Figure 26: Agricultural Concerns



Then the steering committee met and discussed all of the information gathered from both the public and agricultural community meetings' surveys. Based upon the concerns voiced in the surveys, the committee members noted and agreed upon three general categories where the specific concerns would be placed. Within the three prioritized categories, specific public concerns were then prioritized. Each of the 10 committee members present submitted five votes for the specific public concerns they felt were primary, for each of the three categories. The final results indicated three primary areas of concern, in ranked order: I.) Water quality, II.) Land use and, III.) Education. Under each area is listed the steering committee's prioritized specific concerns. This information and the process of grouping and prioritizing the public concerns helped to verify and steer towards projected goals.

Public Concerns Prioritized by Steering Committee:

I. Water Quality

1) Trash dumped into water
2) Heavy metals
3) Low water supply
4) Need more enforcement of public dumping laws
5) Soil erosion
6) Handling of run-off
7) Pollution
8) Flash flooding
9) *E. coli*
10) Maintaining biodiversity in and near streams and wetlands
11) Drinking water quality
12) Healthy water ways for recreation, fishing, swimming, etc.
13) Sinkhole pollution

II. Land Use

1) No-till farming, round-up ready, herbicides
2) Pesticide contamination
3) Septic tank runoff
4) Buffers and filter strips
5) Logging and forestry
6) Livestock
7) Row crops
8) Standing water
9) Log jams
10) Cropland productivity
11) Confined feeding animal operations
12) Chemical runoff
13) Urban development
14) Stream bank erosion
15) Former US Army Jefferson Proving Grounds (JPG) Contamination

III. Education

1) Do places like the power plant affect the watershed?
2) Do people know how they affect their watershed?
3) Is the drinking water really clean?
4) Is the water healthy?
5) Education of children/public
6) Everyone knowing their watershed and protecting it
7) Public involvement
8) Safe and healthy water ways for recreation, fishing, swimming, etc.

9) Need more testing and public awareness

After the steering committee determined the categorization and prioritization of public concerns, they then discussed and decided upon a list of causes/sources for the concerns stated above in order to assist in the categorization and summary of the concern/problem areas voiced by the public surveys. A brief example of the outcome of this process is that the committee determined the publicly voiced concern/problem areas of pollution, urban development, and soil erosion can be caused by improper prevention of storm water pollution or be a source of storm water pollution.

3.2 Identifying Potential Stressors and Developing Problem Statements

The potential stressors were designated by the committee for each cause. Water Quality stressors are defined by The United States Environmental Protection Agency as "any physical, chemical, or biological entity or phenomenon that can induce an adverse effect [on aquatic systems] either directly or as one step in a chain of causation." Figure 27 shows the causes and corresponding potential stressors.

The steering committee then took the next step and to explain problems created by the concerns voiced in the public survey by developing a statement for each concern. In order to make the planning process run smoothly, the group categorized their concerns by potential stressor. Figure 27 outlines the potential stressors, causes, concerns/problem areas and problem statements as determined by the steering committee based on the information gathered and outlined in section 3.1.

Figure 27: Preliminary Discussion – Potential Stressors, Causes, and Problems

Concern/Problem Area Water Quality	Concern/Problem Area Land Use	Concern/Problem Area Education	Cause/Source	Potential Stressor	Problem Statement
5. Soil Erosion 7. Pollution 8. Flash Flooding 11. Drinking Water Quality 12. Healthy Water Ways for Recreation 13. Sinkhole Pollution	11. Confined Feeding Animal Operations 12. Chemical Runoff 13. Urban Development 14. Stream Bank Erosion	2. Do people know how they affect their watershed? 3. Is the drinking water really clean? 5. Education of children/public 6. Everyone knowing their watershed and protecting it 7. Public involvement	Improper Storm Water Pollution Prevention	Sedimentation and Excess Nutrients	Contractors using inadequate erosion control practices on construction sites can lead to excess soil loss entering nearby waterbodies. Sedimentation can lead to increased turbidity which can increase water temperature through heat absorbed particles, thus lowering dissolved oxygen. Sediment may also kill aquatic life by clogging gills or smothering habitats. During and after rain events, improperly handled or excess manure from confined feeding operations can lead to excess nitrogen and phosphorous levels in nearby waterbodies which also impacts dissolved oxygen levels.
5. Soil Erosion 7. Pollution 8. Flash Flooding 10. Maintaining Biodiversity – streams/ wetlands 12. Healthy Water Ways for Recreation 13. Sinkhole Pollution	6. Livestock 8. Standing Water 9. Log Jams 14. Stream Bank Erosion	2. Do people know how they affect their watershed? 6. Everyone knowing their watershed and protecting it 7. Public involvement 8. Safe and healthy water ways for recreation 9. Need more testing and Public Awareness	Lack of Riparian Buffers Trampling of Stream Banks by Livestock	Sedimentation and Excess Nutrients	Livestock with uncontrolled access to waterbodies, the lack of protective riparian groundcover, and the presence of log jams reduces stream bank stability and increases sediment in local waterbodies through stream bank erosion. Log jams can promote areas of pooling or standing water and can impede flow of a stream which could divert water and cause flash flooding.
5. Soil Erosion 6. Handling of Runoff 7. Pollution 8. Flash Flooding 10. Maintaining Biodiversity – streams/ wetlands 13. Sinkhole Pollution	1. No-Till Farming, Round-up ready herbicides 2. Pesticide Contamination 4. Buffers and Filter Strips 7. Row Crops 8. Standing Water 9. Log Jams 10. Cropland Productivity 12. Chemical Runoff 14. Stream Bank Erosion	2. Do people know how they affect their watershed? 3. Is the drinking water really clean? 4. Is the water healthy? 5. Education of children/public 6. Everyone knowing their watershed and protecting it 7. Public Involvement 8. Safe and Healthy Water Ways for Recreation 9. Need More Testing and Public Awareness	Lack of Conservation Tillage	Sedimentation and Excess Nutrients	Farmlands not using a high residue cropping system may cause an increase of sedimentation and excess nutrients in local waterbodies from storm runoff.
6. Handling of Runoff 7. Pollution 10. Maintaining Biodiversity– streams/ wetlands 11. Drinking Water Quality 12. Healthy Water Ways for Recreation 13. Sinkhole Pollution	1. No-Till farming, Round-up ready herbicides 2. Pesticide Contamination 4. Buffers and Filter Strips 6. Livestock 7. Row Crops 10. Cropland Productivity 11. Confined Feeding Animal Operations 12. Chemical Runoff 13. Urban Development	2. Do people know how they impact their watershed? 3. Is the drinking water really clean? 4. Is the water healthy? 5. Education of children/public 6. Everyone knowing their watershed and protecting it 7. Public involvement 8. Safe and healthy water ways for recreation 9. Need more testing & public awareness	Improper Nutrient Management	Sedimentation and Excess Nutrients	Improper nutrient management on farmland and suburban lawns can lead to nutrient overload in nearby waterbodies which can lead to increased algal blooms, thus decreasing dissolved oxygen.

Concern/Problem Area Water Quality	Concern/Problem Area Land Use	Concern/Problem Area Education	Cause/Source	Potential Stressor	Problem Statement
1.Trash Dumped into Water 2. Heavy Metals 3. Low Water Supply 4. More Enforcement of Public Dumping Laws 5. Soil Erosion 6. Handling of Runoff 7. Pollution 9. *E. coli* 10. Maintaining Biodiversity – streams/ wetlands 11. Drinking Water Quality 12. Healthy Water Ways for Recreation 13. Sinkhole Pollution	12. Chemical Runoff 13. Urban Development	2. Do people know how they affect their watershed? 3. Is the drinking water really clean? 4. Is the water healthy? 5. Education of children/public 6. Everyone knowing their watershed and protecting it 7. Public involvement 8. Safe and healthy water ways for recreation 9. Need more testing and public awareness	Increased Impervious Areas Malfunctioned Industrial Areas Suburban Lawns	Hazardous Chemicals (ie – oil, gas, pesticides, herbicides)	Hazardous chemical runoff from parking lots, roads, industrial buildings and suburban lawns entering local waterbodies increases pollutants harmful to aquatic and human life. Increased demand from residential and commercial development could lead to decreased water supplies. Heavy metals may be present in our water sources due to ammunition testing from the former U.S. Army Jefferson Proving Grounds and other industrial activities.
6. Handling of Runoff 7. Pollution 10. Maintaining Biodiversity in and near Streams and Wetlands 11. Drinking Water Quality 12. Healthy Water Ways for Recreation 13. Sinkhole Pollution	1. No-Till Farming, Round-up ready Herbicides 2. Pesticide Contamination 7. Row Crops 10. Cropland Productivity 11. Confined Feeding Animal Operations 12. Chemical Runoff 13. Urban Development	2. Do people know how they affect their watershed? 3. Is the drinking water really clean? 4. Is the water healthy? 5. Education of children/public 6. Everyone knowing their watershed and protecting it 7. Public Involvement 8. Safe and Healthy Water Ways for Recreation 9. Need More Testing and Public Awareness	Improper Application of Herbicides and Pesticides	Hazardous Chemicals (ie – oil, gas, pesticides, herbicides, heavy metals)	Improper application of agricultural chemicals may enter waterbodies through runoff and lead to endocrine/hormone disruption.
6. Handling of Runoff 7. Pollution 9. *E. coli* 10. Maintaining Biodiversity in and near Streams and Wetlands 11. Drinking Water Quality 12. Healthy Water Ways for Recreation	3. Septic Tank Runoff 13. Urban Development	2. Do people know how they affect their watershed? 3. Is the drinking water really clean? 4. Is the water healthy? 5. Education of children/public 6. Everyone knowing their watershed and protecting it 7. Public Involvement 8. Safe and Healthy Water Ways for Recreation 9. Need More Testing and Public Awareness	Combined Sewer Overflows	*E. coli*	An increase in population will lead to more wastewater, which could result in more sewer overflows during rain events.

Concern/Problem Area Water Quality	Concern/Problem Area Land Use	Concern/Problem Area Education	Cause/Source	Potential Stressor	Problem Statement
1. Trash Dumped into Water 4. Need More Enforcement of Public Dumping Laws 6. Handling of Runoff 7. Pollution 9. *E. coli* 11. Drinking Water Quality 12. Healthy Water Ways for Recreation	3. Septic Tank Runoff 13. Urban Development	2. Do people know how they affect their watershed? 3. Is the drinking water really clean? 4. Is the water healthy? 5. Education of children/public 6. Everyone knowing their watershed and protecting it 7. Public Involvement 8. Safe and Healthy Water Ways for Recreation 9. Need More Testing and Public Awareness	Failing or Lack of Septic Systems	*E. coli*	The soil types in the watershed are not conducive to septic systems which cause systems to fail. Improper maintenance of septic systems also leads to failure and this causes pathogens to enter nearby waterbodies and leads to health problems in humans.
6. Handling of Runoff 7. Pollution 9. *E. coli* 11. Drinking Water Quality 12. Healthy Water Ways for Recreation	4. Buffers and Filter Strips 6. Livestock 11. Confined Feeding Animal Operations	2. Do people know how they affect their watershed? 3. Is the drinking water really clean? 4. Is the water healthy? 5. Education of children/public 6. Everyone knowing their watershed and protecting it 7. Public Involvement 8. Safe and Healthy Water Ways for Recreation 9. Need More Testing and Public Awareness	Livestock Access to Streams	*E. coli*	Livestock with uncontrolled access to waterbodies may lead to an increase in pathogens from animal waste which can result in digestive and other health problems for humans.
1.Trash Dumped into Water 4. More Enforcement of Public Dumping Laws 5. Soil Erosion 6. Handling of Runoff 7. Pollution 8. Flash Flooding 9. *E. coli* 10. Maintaining Biodiversity-streams/wetlands 11. Drinking Water Quality 12. Healthy Water Ways for Recreation 13. Sinkhole Pollution	4. Buffers and Filter Strips 6. Livestock 8. Standing Water 9. Log Jams	1. Do places like the Power Plant affect the watershed? 2. Do people know how they affect their watershed? 3. Is the drinking water really clean? 4. Is the water healthy? 6. Everyone knowing their watershed and protecting it 7. Public Involvement 8. Safe and Healthy Water Ways for Recreation 9. Need More Testing and Public Awareness	Increased Impervious Areas Non-Conforming Industrial Areas	Elevated Water Temperature	Runoff from impervious areas and discharge from industrial buildings may cause an increase of temperature, lowering dissolved oxygen levels in nearby waterbodies.

Concern/Problem Area Water Quality	Concern/Problem Area Land Use	Concern/Problem Area Education	Cause/Source	Potential Stressor	Problem Statement
5. Soil Erosion 8. Flash Flooding 10. Maintaining Biodiversity in and near Streams and Wetlands 12. Healthy Water Ways for Recreation	4. Buffers and Filter Strips 5. Logging and Forestry 6. Livestock 7. Row Crops 9. Log Jams 10. Cropland Productivity 13. Urban Development 14. Stream Bank Erosion	1. Do places like the Power Plant affect the watershed? 2. Do people know how they affect their watershed? 3. Is the drinking water really clean? 4. Is the water healthy? 5. Education of children/public 6. Everyone knowing their watershed and protecting it 7. Public Involvement 8. Safe and Healthy Water Ways for Recreation 9. Need More Testing and Public Awareness	Lack of Forested Area Lack of Riparian Buffers	Elevated Water Temperature	The lack of protective riparian canopy from tree cover and lack of stream buffers may increase water temperature in local streams
8. Flash Flooding	4. Buffers and Filter Strips 5. Logging and Forestry 6. Livestock 7. Row Crops 9. Log Jams 10. Cropland Productivity 13. Urban Development 14. Stream Bank Erosion	2. Do people know how they affect their watershed? 3. Is the drinking water really clean? 4. Is the water healthy? 5. Education of children/public 6. Everyone knowing their watershed and protecting it 7. Public Involvement 8. Safe and Healthy Water Ways for Recreation 9. Need More Testing and Public Awareness	Lack of Riparian Buffers and Headwaters Protection	Increased Flow Rate	An increase of impervious and limited riparian buffer areas, specifically near headwaters areas, reduces groundwater recharge, which increases flow rate and causes streams to flood more frequently and banks to erode more quickly.
1. Trash Dumped into Water 4. More Enforcement of Public Dumping Laws 7. Pollution 11. Drinking Water Quality 12. Healthy Water Ways for Recreation 13.Sinkhole Pollution	4. Buffers and Filter Strips 13. Urban Development	2. Do people know how they affect their watershed? 3. Is the drinking water really clean? 4. Is the water healthy? 5. Education of children/public 6. Everyone knowing their watershed and protecting it 7. Public Involvement 8. Safe and Healthy Water Ways for Recreation 9. Need More Testing and Public Awareness	Improper Trash Disposal	Illegal Dumping of Trash	Improper disposal of garbage in parks, river, roadsides, sink holes, and other areas causes unsightly views and health risks for humans and aquatic life.

TESTING PARAMETERS

This section explains the chemical and biological stream monitoring tests which were used to gauge water quality in the Central Muscatatuck Watershed throughout the project.

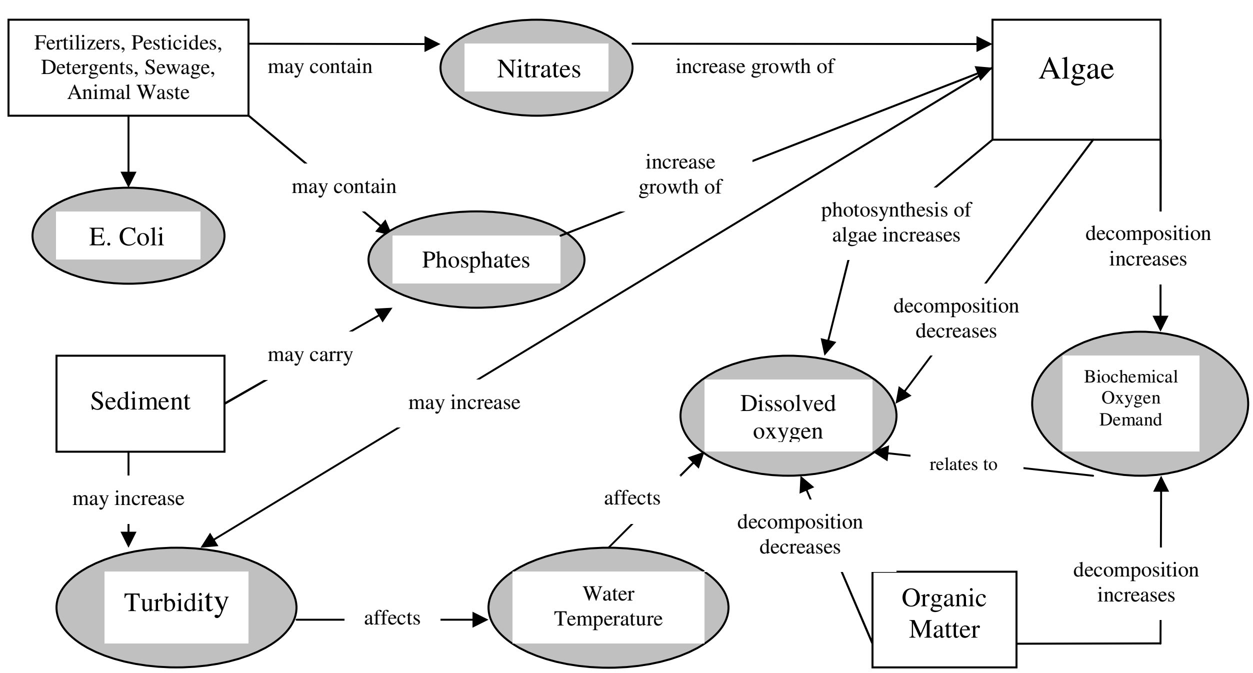
In order to further investigate, document and provide conclusions to issues within the CMW presented in section 3, professional and volunteer water quality monitoring was conducted during this project. The data gathered during the watershed quality monitoring will be further discussed in section 5. This section discusses and provides background regarding the water quality tests performed during water quality monitoring for the CMWP.

4.1 General Water Quality Tests & Parameters

The Hoosier Riverwatch standards for quality assurance and quality control were in effect for this volunteer water quality monitoring program. Only data collected by trained Hoosier Riverwatch volunteers was accepted. Volunteer water monitors attended Hoosier Riverwatch Stream Monitoring training and followed the testing methods, standards and parameters set by Hoosier Riverwatch, which is a program of the Indiana Department of Natural Resources Division of Fish and Wildlife. More information about Hoosier Riverwatch may be found at: www.in.gov/dnr/nrec/8561.htm. These standards and parameters will be discussed in figure 28 and the primary source for the technical information and figures in the discussion is derived from the Hoosier Riverwatch Volunteer Stream Monitoring Training Manual.[9]

Aquatic chemistry is complex and is influenced by many interrelated factors. Figure 28 shows the correlations between different factors to aid understanding of these relationships in an aquatic environment. The rectangles represent watershed inputs into a river or stream, while the circles represent chemical parameters used to measure and determine water quality.

Figure 28: Interrelation of Water Monitoring Parameters



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[9] Indiana Department of Natural Resources, Hoosier Riverwatch; http://www.in.gov/dnr_old/riverwatch/pdf/manual/.

Dissolved Oxygen

Dissolved oxygen (DO) analysis measures the amount of gaseous oxygen (O_2) dissolved in an aqueous solution. DO is one of the most important parameters in aquatic systems because it is a requirement for the metabolism of aerobic organisms and it also influences inorganic chemical reactions. DO is an important measure of stream health. The presence of O_2 is a positive sign and the absence of O_2 is an indicator of water pollution. Lack of sufficient DO or super saturation (too much DO) can harm or kill aquatic organisms.

Factors that influence DO are:

- Temperature – cold water holds more dissolved oxygen
- Altitude/atmospheric pressure
- Turbulence
- Plant growth/photosynthesis – O_2 levels rise during the day and fall at night
- Amount of decaying or organic material - Rapid decomposition of organic materials, such as dead algae, wastewater or manure, decreases oxygen
- High ammonia concentrations - This uses up oxygen in the process of oxidizing ammonia (NH_{4+}) to nitrate (NO_{3-}) through nitrification

Dissolved oxygen levels below 3 ppm are stressful to most aquatic life, levels below 2 or 1 parts per million (ppm) will not support fish, levels of 5 to 6 ppm are usually required for healthy growth and activity of aquatic life.

Decreased DO Level - Causes:

Loss of shading by trees in the riparian zone and the watershed
Runoff from fields, roads and parking lots
Stream bank erosion

DO: State Standard: Avg > 5mg/L, not < 4mg/L
Typical Range: 5.4 to 14.2 mg/L
Indiana Average: 9.8 mg/L

Water Temperature

Water temperature varies naturally over the course of a day, with the change of seasons, the amount of rain fall and flow rates. The maximum daily water temperature is usually several hours after noon and the minimum is around day break. Temperature is monitored due to:

- Dissolved Oxygen Levels - Aquatic organisms have narrow optimal temperature ranges and warmer water holds less dissolved oxygen. Lower oxygen levels weaken fish and aquatic insects, making them more susceptible to illness.

Increased Water Temperatures - Causes:

- Loss of shading by trees in the riparian zone and forested areas in the watershed
- Agriculture – Manure discharge
- Urban developments

Temperature: State Standard < 5°F change downstream (approximately 2.8°C)

Biochemical Oxygen Demand-Over 5 Days (BOD_5)

This is a measure of the amount of oxygen used by oxygen-consuming bacteria as they break down organic waste over five days. Polluted streams, or streams with a lot of plant growth and decay, generally have high BOD_5 levels which means the bacteria is robbing other aquatic organisms of oxygen needed to live.

Increased BOD_5 Level – Causes:

- Pollution from high levels of organic matter such as fertilizer, animal waste, garbage, sewage from poor functioning septic systems or combined sewer overflows and some ions (ammonia in particular) can lead to rapid exhaustion of dissolved oxygen.

BOD_5 Levels Generally Indicate:

1-2 mg/L BOD_5	Clean water with little organic waste
3-5 mg/L BOD_5	Fairly clean with some organic waste
6-9 mg/L BOD_5	Lots of organic material with bacteria
10+ mg/L BOD_5	Very poor water quality & very large amounts of organic material in water

Typical Range	0 to 6.3 mg/L
Indiana Average	1.5 mg/L

pH

pH is the most common analyses in water testing and determines if the water is acidic (scale range of 0 for most acidic), basic (scale range of 14 for most basic) or neutral (scale range of 7 is neutral). Each change in pH unit represents a tenfold change in acidity. Aquatic organisms, especially during reproduction and young organisms are very sensitive to pH levels. A pH range of 6.5 to 8.2 is optimal for most organisms. Due to high concentrations of limestone in the watershed, the water is typically more basic.

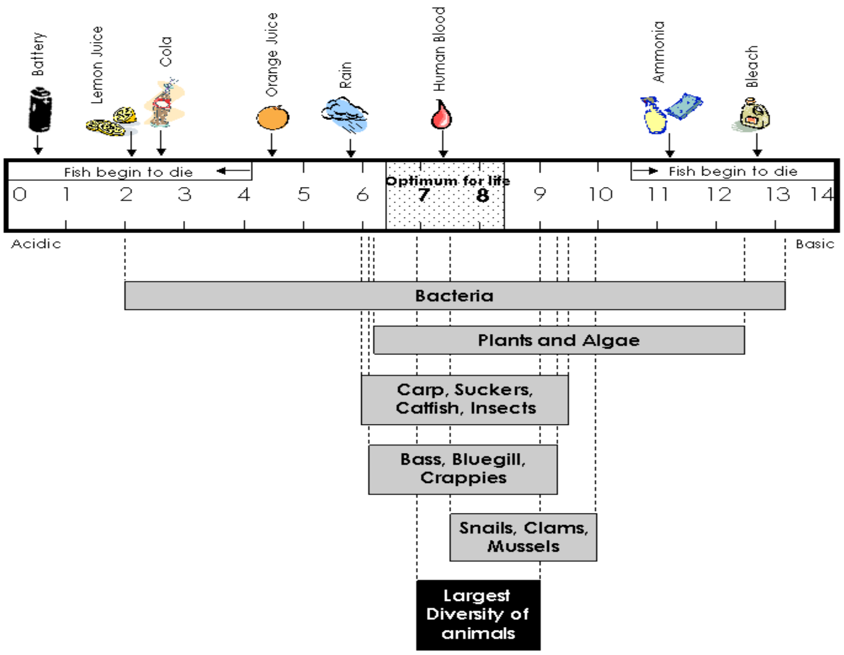
High pH values tend to facilitate the solubilization of ammonia, heavy metals and salts. Low pH levels tend to increase carbon dioxide and carbonic acid concentrations.

Variations in pH – Causes:

- Agriculture – Runoff of fertilizers, pesticides, etc.
- Acidic precipitation - Acid rain
- Natural Processes – Higher temperatures have slightly lower pH values, Algal blooms may raise the pH to 9 or more

pH:	State Standard	6 to 9
	Indiana Average	8.0
	Typical Range	7.2 to 8.8

Figure 29: pH Range Impacts



Air pollution contributes to acid rain which increases acidity of falling rain. Runoff of heavy metals from mines or other industrial areas may dissolve in the water and become toxic to aquatic organisms. The former Jefferson Proving Grounds is a potential impact source of heavy metal dissolution in the watershed due to the remnants of military munitions testing in the Big Oaks National Wildlife Refuge.

Orthophosphate

Phosphorous is essential to plant and animal life and its presence in the environment is natural. However, it can be the most limiting nutrient to plant growth in freshwater. Phosphorous water pollution issues result from the presence of excessive amounts and it is not toxic to plants or humans unless high levels are present. Naturally, healthy aquatic ecosystems develop with low levels of phosphorous and the addition of seemingly small amounts of phosphorous can lead to problematic algal blooms. Algae consume oxygen needed to support other aquatic life. When the extra algae die and decompose, they continue to consume oxygen. When excessive amount of oxygen are depleted in the water it is called hypoxia, and that can lead to fish kills. Eutrophication (depicted in figure 30) occurs when high phosphorous levels cause excessive plant growth, also called nutrient overload.

Figure 30: Eutrophication

Increased Phosphorous Level – Causes:

- Organic matter (where it is naturally present) such as: soil, dead plants, animals or animal waste
- Man-made products such as detergents, fertilizers and industry wastes (the addition of phosphates to detergents is illegal in Indiana)
- Fertilizer – Agricultural or lawn
- Manure sources
- Municipal wastewater/septic tank effluent

Orthophosphate:	State Standard	Max: 0.3 mg/L (IDEM draft TMDL target)
	Indiana Average	0.05 mg/L
	Typical Range	0 to 0.85 mg/L

Nitrogen – Nitrate, Nitrite and Ammonia

Nitrogen makes up about 80% of the air we breathe, it is found in all living things and it occurs in water as nitrate (NO_3), nitrite (NO_2), and ammonia (NH_3). Ammonia is the most reduced inorganic form of nitrogen in water, a small component of the nitrogen cycle, however, at high levels is toxic to aquatic life.

Bacteria in water quickly convert nitrites and nitrates, using oxygen to do so. "Brown blood" disease in fish, where the blood does not carry enough oxygen and can suffocate the fish despite sufficient oxygen levels in the water, is caused by excessive concentrations of nitrates. Nitrates can also react directly with hemoglobin in the blood of humans and other warm-blooded animals to cause a condition known as "blue-baby" syndrome. This is a potentially fatal blood disorder in infants under six months of age where there is a reduction in the oxygen-carrying capacity.

Nitrates are essential for plant growth, are a main ingredient in fertilizers and can lead to increased or excessive aquatic plant growth and eutrophication. Unpolluted waters generally have a nitrate level below 4 ppm and water is considered unsafe for drinking when nitrates exceed certain levels.

Increased Nitrogen Level – Causes:

- Sewage from lack of adequate or properly maintained septic systems is the primary source of nitrates in Indiana's surface water
- Runoff of commercial and agricultural fertilizers
- Decomposing organic matter and manure

Nitrate:	State Standard	Max. 10 mg/L in waters designated as drinking water source
	Indiana Average	12.32 mg/L
	Typical Range	0 – 36.08 mg/L
Nitrite:	State Standard	Max. 1 mg/L in waters designated as a drinking water source
Ammonia:	State Standard	Exists, but is temperature and pH dependent

Turbidity

Turbidity is the relative clarity of the water and is measured by shining light through the water. Turbid water looks cloudy and is caused by suspended matter including clay, silt, organic and inorganic matter and algae. Particles in turbid water absorb heat from the sun which can raise water temperatures and lowers dissolved oxygen levels. Photosynthesis decreases with limited light. Suspended solids in turbid water can clog fish gills, reduce growth rates, decrease resistance to disease, and prevent egg and larval development.

Increased Turbidity – Causes:

- Soil erosion – Stream bank erosion or agricultural field erosion run off
- Algal blooms
- Sediment disturbances from abundant bottom feeding fish

Turbidity:	Indiana Average	36 NTU
	Typical Range	0 to 173 NTU

E. coli

E. coli, or fecal coliform, are bacteria found in the feces of warm-blooded animals, including humans, livestock and waterfowl. They are naturally found in the digestive tracts of animals, but are rare in unpolluted waters. The bacteria can enter the body through the mouth, nose, eyes, ears or cuts in the skin and can cause illness, sometime serious illness, in humans.

Increased *E. coli* Level – Causes:

- Human waste from poorly functioning, non-existent or inadequate septic systems
- Wastewater treatment systems
- Combined sewer overflows
- Animal waste – Livestock or manure runoff from fields

E. coli:	State Standard	<235 CFU/100 ml for total body contact recreation
	Indiana Average	645 CFU/100 ml
	Typical Range	133 to 1,157 CFU/100 ml

Water Flow (Discharge)

Flow is the volume of water flowing through a point in the stream per second. Flow measurements are critical to calculating the amount of contaminants in a stream. It also influences the ability of a stream to dilute pollutants. Higher velocities and flows generate higher levels of turbulence which in turn, cause more air to be in the flowing water affecting the available oxygen levels in the water as well as other physical, chemical and biological factors in the stream. A high discharge rate may indicate a rainfall or snowmelt event which can carry sediments and nutrients to the stream. A low discharge rate may indicate drought conditions which affect water quality and aquatic life. Base flow is the amount of water that would drain absent any precipitation inputs and is usually from groundwater. The stream flow is calculated by multiplying the average width, depth and velocity of the stream in feet.

Flow:	Standards	None – flow is completely site dependent

Conductivity

Electrical conductivity of water samples is used as an indicator of how salt-free, ion-free, or impurity-free the sample is; the purer the water, the lower the conductivity. Specific conductance is an important water-quality measurement because it gives a good idea of the amount of dissolved material in the water. High specific conductance indicates high dissolved-solids concentration; dissolved solids can affect the suitability of water for domestic, industrial, and agricultural uses. High conductance readings can come from rainwater, fertilizer application, industrial pollution or urban run off -- water running off of roads, buildings, and parking lots. Extended dry periods and low flow conditions also contribute to higher specific conductance readings due to evaporation. [10]

Metals and Fish

Metals found in water that are observed to indicate water quality are calcium, magnesium, and iron which play major roles in water chemistry and other metals such as, aluminum, barium, cadmium, chromium, lead, manganese, sodium, and zinc, which tend to be present in smaller amounts. Metal ions are dissolved in groundwater and surface water when the water comes in contact with rock or soil containing the metals, usually in the form of metal salts or can also enter with discharges from sewage treatment plants, industrial plants, and other non-point source pollution. Metal concentrations may be very low, however, aquatic organisms and fish can bioaccumulate (or concentrate) certain metals (for example, mercury, lead, and cadmium). If more metals are absorbed than excreted, the levels can then build up over time to a toxic level impacting aquatic organisms, fish or something that consumes them, to the point of illness or even death.[11]

Windshield Data Survey

Some general characteristics of the watershed are best to be observed directly. This data is collected, usually in pairs, by driving the roads of the watershed using maps and forms to record what is observed. This allows specific water quality issues to noted, provide support for and be compared to data collected through other methods.

Macroinvertebrates

Biological monitoring focuses on the aquatic organisms that live in streams and rivers. Macroinvertebrates are animals that are big enough to be seen with the naked eye, lack backbones and live at least part of their lives in or on the bottom of a body of water. Observed changes that occur in the total number or types of organisms present in a stream system can help to determine the richness of the biological community and may indicate the effects of human activity on the stream. Different species react to pollution in different ways and the presence or lack of presence of certain species is an

[10] United States Geological Survey, Water Science for Schools, http://ga.water.usgs.gov/edu/characteristics.html#Conductance.

[11] Kentucky Water Watch, Water Quality Parameters, http://kywater.org/ww/ramp/rmmetals.htm.

indirect measure of pollution. When a stream becomes polluted, pollution-sensitive organisms decrease in number or disappear; pollution-tolerant organisms increase in variety and number.

Macroinvertebrate sampling is advantageous for a variety of reasons: It is relatively easy and can be done by trained volunteers, macroinvertebrates are immobile, unlike fish that can escape pollution by swimming away, and they are a critical part of the food web by connecting aquatic plants, algae, and leaf litter to the fish species in streams. They are also continuous indicators of environmental quality because they spend the majority of their time in the same place, their progression or deterioration can be observed. This provides a picture of the stream over a period of time rather than only a description of water quality at a particular moment in time which can be done through chemical testing.

These chemical tests were conducted at seven volunteer monitoring sites on a monthly basis for a 2 year time period during the sampling season of April through October. These tests provided baseline data and helped to validate the problems, concerns and causes previously discussed in section 3. The data was entered into the Hoosier Riverwatch database and water quality index rating was calculated. Water quality experts have developed common units for all of the previously discussed water quality tests called the Q-value. Hoosier Riverwatch uses the Q-value ratings to provide a water quality index value to be tracked and compared over a period of time to indicate whether the water is becoming more polluted or cleaner. This will allow future tests to determine improving or declining water quality for the duration of the watershed project.

4.2 Professional Water Quality Tests & Parameters

In January of 2008, chemical and biological water monitoring was contracted to Environmental Laboratories, Inc. of Madison, Indiana. The same tests listed for the volunteer water monitoring were conducted for the professional water quality monitoring. Professional water quality monitoring was conducted bi-monthly sampling from April 2008 to April 2009 for a total of 7 sampling periods at 15 locations in the watershed by the contract laboratory. A macroinvertebrate study was also performed collecting samples two times per year at six locations to assess the ecological health of the creek.

The general methods used for the professional monitoring are as follows:

Water Chemistry

Water chemistry samples (nitrite-nitrate, total phosphorus, total suspended solids, pH, dissolved oxygen, and conductivity) were collected 5 times at 15 sites during 2008. Specific details of the methods are detailed in the Quality Assurance Project Plan[12].

Aquatic Community

Because they are considered to be more sensitive to local conditions and respond relatively rapidly to change, benthic (bottom-dwelling) organisms were considered to be the primary tool to document the biological condition of the streams. The U.S. Environmental Protection Agency (EPA) has recently developed a "rapid bioassessment" protocol[13] which has been shown to produce highly reproducible results that accurately reflect changes in water quality. We used a modification of this protocol developed by Ohio EPA[14]. This protocol relies upon comparison of the aquatic community to a

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[12] Central Muscatatuck River Monitoring Quality Assurance Project Plan. ARN A305-7-87. Prepared for Indiana Department of Environmental Management, Office of Water Management, Watershed Management Section. Indianapolis, Indiana.

[13] Plafkin. J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers. U.S. EPA Office of Water, Washington, D.C. EPA/444/4-89-001.

[14] Ohio EPA. 1987. Biological criteria for the protection of aquatic life: Vol. II. Users manual for biological field assessment of Ohio surface waters. Div. of Water Quality Monitoring and Assessment, Columbus, OH.

"reference" condition. A reference site is a stream of similar size in the same geographic area which is least impacted by human changes in the watershed.

Habitat Evaluation

The aquatic habitat at each study site was evaluated according to the method described by Ohio EPA[13]. This method's results assigns values to various habitat parameters (e.g. substrate quality, riparian vegetation, channel morphology, etc.) and results in a numerical score for each site. Higher scores indicate higher aquatic habitat value. The maximum value for habitat using this assessment technique is 100.

Sample Collection (Macroinvertebrates)

Macroinvertebrate samples in this study were collected by dip net in riffle areas where current speed approached 30 cm/sec. All samples were preserved in the field with 70% isopropanol. Samples were collected twice, on May 21 and October 29, 2008.

Laboratory Analysis (Macroinvertebrates)

In the laboratory, a 100 organism subsample was prepared from each site by evenly distributing the animals collected in a white, gridded pan. Grids were randomly selected and all organisms within grids were removed until 100 organisms had been selected from the entire sample.

Each animal was identified to the lowest practical taxon (usually genus or species) using standard taxonomic references[15,16]. As each new taxon was identified, a representative specimen was preserved as a "voucher." All voucher specimens will ultimately be deposited in the Purdue University Department of Entomology collection.

Data Analysis (Macroinvertebrates)

Following identification of the animals in the sample, ten "metrics" are calculated for each site. These metrics are based on knowledge about the sensitivity of each species to changes in environmental conditions and how the benthic communities of unimpacted ("reference") streams are usually organized. For example, mayflies and caddis flies are aquatic insects which are known to be more sensitive than most other benthic animals to degradation of environmental conditions. A larger proportion of these animals in a sample receive a higher score. The sum of all ten metrics provides an individual "biotic score" for each site. The metrics used in this study were adapted from Ohio EPA. Because Ohio EPA uses a larger sample size in its macroinvertebrate protocol, some of the metrics were modified to more closely correspond to a 100 organism sample. In addition, since a separate qualitative sample was not taken, the U.S. EPA metric "% Dominant Taxon" was substituted for the "EPT Qualitative Taxa" metric used in Ohio.

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[15] Simpson, K.W. and R.W. Bode. 1980. Common Larvae of Chironomidae (Diptera) from New York State Streams and Rivers. Bull. No. 439. NY State Museum, Albany, NY. 105 pp.

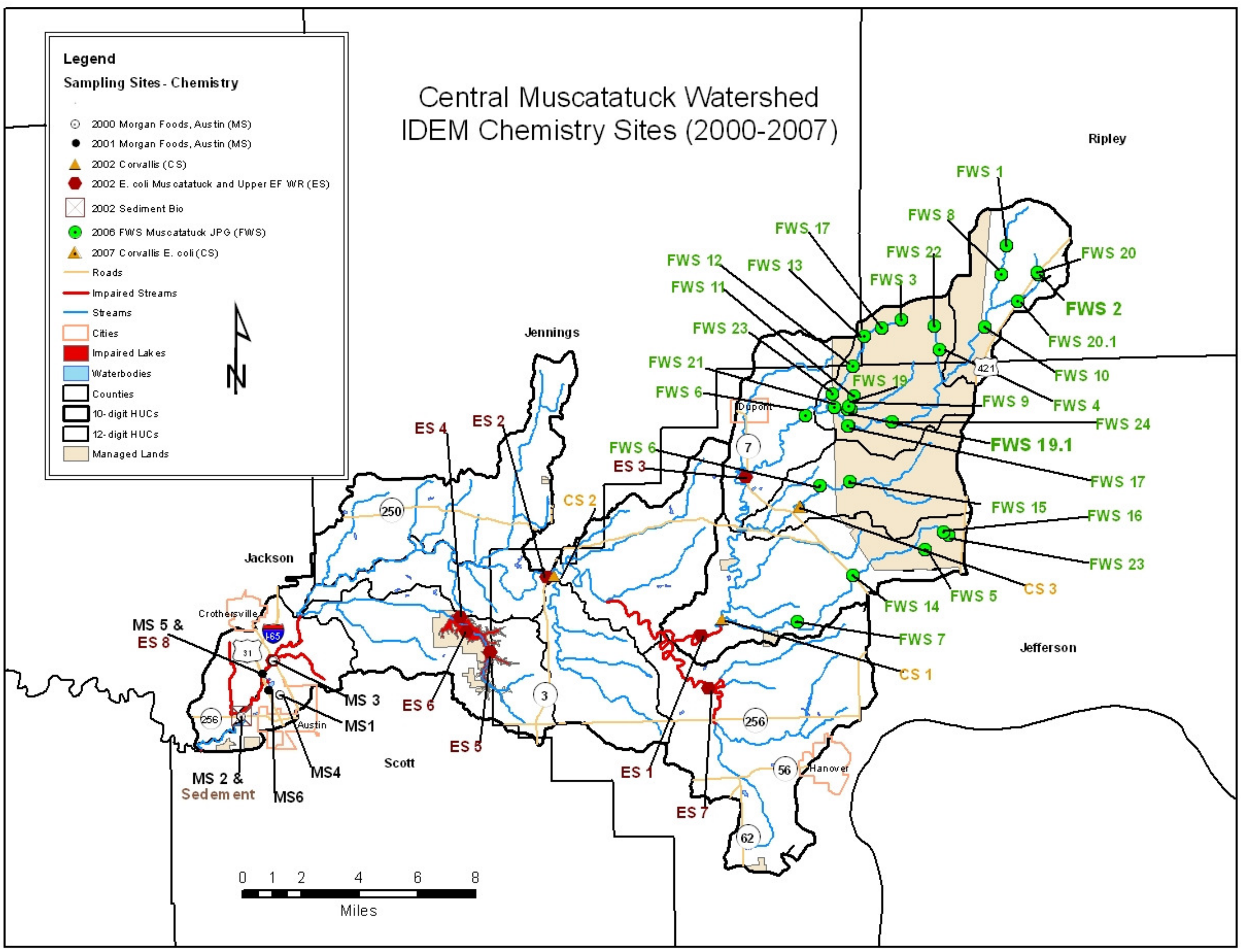
[16] Merritt, R.W. and K.W. Cummins. 1996. An Introduction to the Aquatic Insects of North America. Third Edition. Kendall/Hunt Publishing Company, Dubuque, Iowa. 862 pp.

Establishing Benchmarks

This section identifies water body impairments, water quality threats and baseline data for water quality and biological community parameters.

There is existing data available from a number of previous studies and projects that pertain to the CMW. Data collected during and prior to this project will be summarized and examined to evaluate previously discussed public concerns. Some of the data has been collected by the Indiana Department of Environmental Management (IDEM) as fulfillment of the federal Clean Water Act requirements as well as by a variety. Data is also presented from a variety of other groups and agencies, such as the US Fish and Wildlife Service, Quick Creek-Hardy Lake Watershed Project, and the Hanover College Internship Program participants. In addition, the previously discussed volunteer and professional monitoring conducted specifically for the CMWP will be further discussed. The following figure 31, provides a map depicting the locations and the groups responsible for data collected at various sites within the watershed. Further data details and cross-reference of site numbers can be found in Appendix A.

<u>Figure 31: IDEM Water Quality Data Sites</u>



5.1 Previous Watershed Basin Surveys

5.1.1 IDEM Previous Watershed Basin Surveys

IDEM's Office of Water Quality Assessment Branch is responsible for assessing the quality of the state's rivers, streams, and lakes. Monitoring is conducted in order to identify stream reaches, watershed basins or segments where physical, chemical, or biological quality support designated uses or do not support designated uses due to impairments by either point or non-point source pollution.

The Toxicology and Chemistry Section develops and maintains the Quality Assurance Project Plan (QAPP) for Indiana Surface Water Quality Monitoring Programs and outlines the parameters for testing. This QAPP serves as a guide to laboratory staff charged with the analysis of environmental samples (water, sediments, and biological) in order to provide results that will meet the data quality objectives for the individual water quality monitoring project. Successful collection of precise, accurate, and complete data provides good quality data to be used for regulatory decisions and to implement programs to improve and maintain clean waters in the State of Indiana.[17]

Every five years, representatives from IDEM performed water quality tests at four locations within the Muscatatuck Watershed. The Chemistry Site locations tested from 2000-2007 is shown in the map in figure 31: The Morgan Foods National Pollutant Discharge Elimination System (NPDES) sites are designated by 'MS' followed by a number, the Corvallis data sites are designated by 'CS' followed by a number and the *E. coli* Upper Muscatatuck data sites are designated by 'ES' followed by a number. The complete chemical data for surface water sampling for each of the site numbers shown on the CMW may be found in Appendix A. The Assessment Branch provided information for the following; Big Creek, Middle Fork, Upper Muscatatuck River, Hardy Lake, Little Creek and the Muscatatuck River.

5.1.2 IDEM Integrated Report

Through United States Environmental Protection Agency (USEPA) guidance, states are encouraged to monitor, assess and develop comprehensive listings of all water bodies within the state. The listing is based on the state's 305(b) assessment and 303(d) listing methodology. Two lists are called for in this format:

- Indiana's Consolidated List contains assessment information for all waters of the state, which is developed to fulfill the Clean Water Act Section 305(b) requirements
- The 303(d) List of Impaired Waters is a subset of the Consolidated List and identifies only those waters that are impaired for which a TMDL (Total Maximum Daily Load) is required
    - TMDLs have not been developed for impairments in the CMW, but are to be completed within the next 5 years.

The 303(d) list was developed using the 305(b) Assessment Database (ADB), which stores all of IDEM's water quality assessment information. Interpretation of the data and listing decisions takes into account USEPA guidance and IDEM's Consolidated Assessment and Listing Methodology (CALM). In developing the Consolidated List, each water body assessment unit (AU), which may consist of an entire water body or part of a larger water body, is placed into one or more of five (5) categories depending on the degree to which it supports its designated uses as determined by IDEM's assessment process.[18] Figure 32 provides a summary of the five categories:

[17] IDEM, Office of Water Quality, Surface Water Quality Assessment Program, http://www.in.gov/idem/files/tox_chem_qapp_iwq.pdf
[18] Indiana Department of Environmental Management Website: http://www.in.gov/idem/4679.htm.

Figure 32: IDEM Impairment Category Definitions

Category	Definition
1	All designated uses are supported and no use is threatened[19].
2	Available data and/or information indicate that some, but not all of the designated uses are supported.
3	There is insufficient available data and/or information to make a use support determination.
4	Available data and/or information indicate that at least one designated use is impaired or threatened, but a TMDL is not needed.
4A	A TMDL has been completed that is expected to result in attainment of all applicable WQS and has been approved by U.S. EPA.
4B	Other pollution control requirements are reasonably expected to result in the attainment of the WQS in a reasonable period of time.
4C	Impairment is not caused by a pollutant.
5	Available data and/or information indicate that at least one designated use is not supported impaired or is threatened, and a TMDL is needed.
5A	The water body assessment unit is impaired or threatened for one or more designated uses by a pollutant(s) and require a TMDL.
5B	The water body assessment unit is impaired due to the presence of mercury and/or PCBs in the edible tissue of fish collected from them at levels exceeding Indiana's human health criteria for these contaminants.

Figure 33 is a list of the 2006 303(d) List of Impaired waters which fall into the Central Muscatatuck Watershed Project and consists of all impairments listed in Category 5.

Figure 33: IDEM 303(d) 2006 Integrated Report Listing

MAJOR BASIN	14-DIGIT HUC	COUNTY	ASSESSMENT UNIT ID	ASSESSMENT UNIT NAME	CAUSE OF IMPAIRMENT	IRCAT*
WEST FORK WHITE	5120207010060	JEFFERSON CO	INW0716_00	BIG CREEK-HARBERTS CREEK	*E. COLI*	5A
EAST FORK WHITE	5120207010090	JEFFERSON CO	INW0719_00	LITTLE CREEK	*E. COLI*	5A
EAST FORK WHITE	5120207010100	JEFFERSON CO	INW071A_00	BIG CREEK (UPSTREAM – WALTON CREEK)	*E. COLI*	5A
EAST FORK WHITE	5120207030050	SCOTT CO	INW07P1040_00	HARDY LAKE	Mercury in Fish Tissue	5B
EAST FORK WHITE	5120207030050	SCOTT CO	INW07P1040_00	HARDY LAKE	PCBs in Fish Tissue	5B
EAST FORK WHITE	5120207030070	JACKSON CO	INW0737_00	AUSTIN AND OTHER TRIBUTARYS	*E. COLI*	5A
EAST FORK WHITE	5120207030070	JACKSON CO	INW0737_T1008	MUSCATATUCK RIVER	*E. COLI*	5A
EAST FORK WHITE	5120207030070	JACKSON CO	INW0737_T1009	MUSCATATUCK RIVER	DISSOLVED OXYGEN	5A
EAST FORK WHITE	5120207030070	JACKSON CO	INW0737_T1009	MUSCATATUCK RIVER	*E. COLI*	5A

Section 305(b) of the federal Clean Water Act (CWA) requires states to prepare and submit a water quality assessment report of state water resources to the USEPA every two years. Within the framework of the state's water quality monitoring strategy, IDEM monitors and assesses Indiana's surface waters to ensure they meet the state WQS for designated uses. The WQS are designed to ensure that all waters of

[19] EPA recommends that states consider as threatened those waters that are currently attaining WQS, but are projected as the result of applying a valid statistical methodology to exceed WQS by the next listing cycle (every two years). IDEM recognizes the federal requirement to list waterbodies that meet U.S. EPA's definition of "threatened". However, IDEM has not determined the appropriate predictive models for the purposes of identifying future impairment. Based on this and the uncertainty associated with such models, IDEM does not assess waterbodies as "threatened" for the purposes of 303(d) listing. Waters for which there is reason to suspect a declining trend in water quality are so noted in IDEM's assessment process and in the IDEM's assessment database so that they may be prioritized for future monitoring when resources allow.

the state, unless specifically exempted, are safe for full body contact recreation and are protective of aquatic life, wildlife, and human health. Figure 34 is a list of the category ratings for areas assessed that are associated with the CMW.

Figure 34: IDEM 305(b) 2006 Integrated Report Listing

			Category Rating					
HUC - 14	**County**	**Assessment Name**	**Recreational Use**	**Fishing Use**	**Drinking Water Use**	**Aquatic Life Use**	**# of Impairments**	**Impairment**
05120207010010	JEFFERSON	BIG CREEK-HEADWATERS (RIPLEY)	3	3		2		
05120207010020	JEFFERSON	BIG CREEK-MARBLE CREEK	3	3		2		
05120207010030	JEFFERSON	BIG CREEK	2	3		2		
05120207010030	JEFFERSON	CAMP CREEK	3	3		2		
05120207010040	JEFFERSON	MIDDLE FORK CREEK (JEFFERSON)	3	3		2		
05120207010050	JEFFERSON	BIG CREEK-HENSLEY CREEK	3	2		2		
05120207010060	JEFFERSON	BIG CREEK-HARBERTS CREEK	5A	2		2	1	ECOLI
05120207010060	JEFFERSON	HARBERTS CREEK	3	3		2		
05120207010070	JEFFERSON	LITTLE CREEK-HEADWATERS (JEFFERSON)	3	3		2		
05120207010080	JEFFERSON	RAMSEY CREEK	3	3		2		
05120207010080	JEFFERSON	HEREFORD LAKE	3	3		3		
05120207010090	JEFFERSON	LITTLE CREEK	5A	3		2	1	ECOLI
05120207010090	JEFFERSON	THOMPSON BRANCH	3	3		2		
05120207010090	JEFFERSON	CHICKEN RUN	3	3		2		
05120207010100	JEFFERSON	BIG CREEK (UPSTREAM OF WALTON CREEK)	5A	2		2	1	ECOLI
05120207010100	JEFFERSON	BIG CREEK (DOWNSTREAM - WALTON CREEK)	2	2		2		
05120207010100	JEFFERSON	WALTON CREEK	3	3		2		
05120207010110	JEFFERSON	NEILS CREEK	2	3		2		
05120207010110	JEFFERSON	PARADISE ACRE LAKE	3	3		3		
05120207010120	JEFFERSON	BIG CREEK	2	2		2		
05120207010120	JEFFERSON	LEWIS CREEK	3	2		2		
05120207010120	JEFFERSON	DRY BRANCH	3	2		2		
05120207010120	JEFFERSON	LEWIS CREEK-UNNAMED TRIBUTARY	3	2		2		
05120207030010	SCOTT	MUSCATATUCK RIVER-DEPUTY	2	3		2		
05120207030020	JENNINGS	COFFEE CREEK	3	3		2		
05120207030020	JENNINGS	KIMBERLY LAKE	3	3		3		
05120207030030	SCOTT	MUSCATATUCK-FOWER/SLATE/CROOKED CR	2	3		2		
05120207030040	SCOTT	MUSCATATUCK R-CANA CREEK	2	3		2		
05120207030050	SCOTT	QUICK CREEK-HARDY LAKE	3	3		2		
05120207030050	SCOTT	HARDY LAKE	3	5B		3	2	HG,PCB
05120207030060	SCOTT	WHITE OAK BRANCH-QUICK CREEK	3	3		2		
05120207030070	JACKSON	AUSTIN AND OTHER TRIBUTARYS	5A	3		2	1	ECOLI
05120207030070	JACKSON	MUSCATATUCK RIVER	5A	3		2		
05120207030070	JACKSON	MUSCATATUCK RIVER	5A	3	5A	2	1	ECOLI
05120207030070	JACKSON	MUSCATATUCK RIVER	5A	3		5A	2	ECOLI, DO

The IDEM designated areas of impairment are consistent with the data findings conducted by the CMWP. *E. coli* is a repeatedly noted and prevailing issue for Big and Little Creek in the central portion of the watershed as well as in the Muscatatuck River and tributaries in the Jackson County area.

5.1.3 Fish Consumption Advisory

As listed on the Indiana State Department of Health's "2008 Indiana Fish Consumption Advisory" species of fish are designated in an area by the following groups: [20]

Figure 35: Groups of the Indiana Fish Consumption Advisory

Group 1	Unrestricted consumption. **One meal per week for women who are pregnant or breast-feeding, women who plan to have children, and children under the age of 15.**
Group 2	Limit to one meal per week (52 meals per year) for adult males and females. **One meal per month for women who are pregnant or breast-feeding, women who plan to have children, and children under the age of 15.**
Group 3	Limit to one meal per month (12 meals per year) for adult males and females. **Women who are pregnant or breast-feeding, women who plan to have children, and children under the age of 15 do not eat.**
Group 4	Limit to one meal every 2 months (6 meals per year) for adult males and females. **Women who are pregnant or breast-feeding, women who plan to have children, and children under the age of 15 do not eat.**
Group 5	**No consumption (DO NOT EAT)**

The following advisories apply to streams in the CMW:

Carp Advisory for all Indiana Rivers and Streams: Generally, carp are contaminated with PCBs. *Unless noted otherwise, carp in all Indiana rivers and streams fall under the following risk groups:*

Carp 15-20 inches	Group 3
Carp 20-25 inches	Group 4
Carp over 25 inches	**Group 5**

Location	Species	Fish Size (inches)	Contaminant	Group
Jackson County Streams & Rivers	*Golden Redhorse*	13+	PCBs	3
	Bigmouth Buffalo	18+	PCBs	3
	Carp	Up to 18		1
		18-23	PCBs	2
		23+	PCBs	3
	Channel Catfish	Up to 14		1
	Flathead Catfish	Up to 13		1
	Golden Redhorse	14-16	PCBs	3
		16+	PCBs	4
	Silver Redhorse	14-16	PCBs	3
	Smallmouth Bass	13+	PCBs	3
	Smallmouth Buffalo	19-26	PCBs	3
		26+	PCBs	4
Muscatatuck River Jackson County	*Bigmouth Buffalo*	26+	PCBs	3
	Carp	23+	Mercury	3
	Channel Catfish	Up to 21		1
	Smallmouth Buffalo	23+	Mercury & PCBs	3
Hardy Lake Scott County	*Black Crappie*	Up to 9		1
	Channel Catfish	Up to 22		1
	Redear Sunfish	Up to 9		1
	Striped Bass	Up to 14		1
	Walleye	Up to 16		1
		22+		3

[20] Indiana State Department of Health Website: http://www.in.gov/isdh/files/2008_FCA_Booklet.pdf.

5.1.4 Morgan Foods – NPDES Permit Site

Morgan Foods, Inc. owns and operates a food canning and processing facility on West Morgan Street, located in Austin, Scott County, Indiana. Morgan Foods is a NPDES site permitted to discharge treated wastewater to an unnamed tributary of the Muscatatuck River. IDEM has jurisdiction over both parties in this matter. IDEM has been monitoring the effects of the discharged wastewater. IDEM sample data collected in 2000, 2001 and 2003 at sites along the Muscatatuck River where it may have been impacted by the discharge of Morgan Foods is included in Appendix A.

As stated in the State of Indiana Agreement Order[21], Morgan Foods, Inc. had been noncompliant with the effluent limitations for discharge from their wastewater treatment plant as set in the terms of the NPDES permit for periods of time during August 1999 to May 2002. The maximum load limitations that were exceeded were total suspended solids, biological oxygen demand, ammonia nitrate, and pH. During this period of time, the Muscatatuck River was impacted by this particular point source pollution.

As further set in the state agreement order between Morgan Foods, Inc and IDEM, enforcement of the NPDES permit terms was and is actively pursued. Due to Morgan Foods, Inc.'s history in regards to lack of compliance, IDEM Enforcement measures prevail concerning the minimization of impact from this point source pollutant.

There are two professional monitoring sites along the Muscatatuck River located in the Austin area that would potentially detect pollution impact from the permitted discharge. However, that section of the Muscatatuck River is identified as impaired primarily due to high *E. coli* levels, which is not a pollutant specifically identified to be discharged by Morgan Foods, Inc. NPDES sites are not within the scope of the CMWP due to its point source classification. However, it is noted as having a potential to impact the water quality within the watershed and data found to indicate further pollution believed to be linked to Morgan Foods, Inc. will be noted and the proper authorities informed.

5.1.5 U.S. Fish & Wildlife Preliminary Diagnoses – Big Oaks National Wildlife Refuge (BONWR)

The U.S Fish and Wildlife Service conducted preliminary diagnoses of contaminant patterns in streams and rivers of national wildlife refuges in Indiana. BONWR was previously used as a military ammunition testing ground for approximately 50 years until the mid 1990s. Remnants and residue of exploded and unexploded ammunition are present and rather prevalent at certain locations on the land and streams in the refuge.

The goals of the study were to measure biological integrity of the watershed and determine all factors affecting the ecosystem. It was found that previous to these surveys little historical data had been gathered for this area. The samplings conducted were fish, crayfish and macroinvertebrate assemblages as well as general chemistry, and heavy metals samplings within the watershed of the BONWR during 2006 and 2007.

Three contaminant responses were identified on the refuge. The first contaminant was noted by the observed grouping of fish linked to arsenic distribution. Arsenic was found to be fairly widespread and concentrations were found around the headwaters and tributaries of Big Creek.

The second contaminant was identified by observation of crayfish groupings in 2006 from nutrient and wastewater treatment from the headwaters of Little Graham Creek. Phosphorus, nitrate + nitrite, sodium, chloride, fluoride, and sulfate emanated from the uppermost site on Little Graham Creek. These contaminants

[21] Indiana Department of Environmental Management website: http://www.state.in.us/idem/oe/cause/AO/10609-W.htm

impaired the Little Graham Creek watershed downstream. Further investigation during 2007 found that the source of the problem was land application of sludge from the City of Versailles that apparently was running off the fields into the adjacent creek. This land application of sludge impacting the nearby creek is not directly occurring in the CMW, however, it does occur in the watershed adjacent, directly north, of it and nutrients may be carried to the waterbodies within the watershed during flooding periods. This single source of nutrient pollution accounted for the majority of the observed refuge contaminant issues and half of the watershed issues in the vicinity of BONWR.

The third contaminant response noted was based on the groupings of macroinvertebrates which were based on the distribution of lead, manganese, and barium, that originated on the refuge in the vicinity of the unnamed tributary of Big Creek. This response may be a result of heavy metal exposure from artillery ordnance on the refuge.[22]

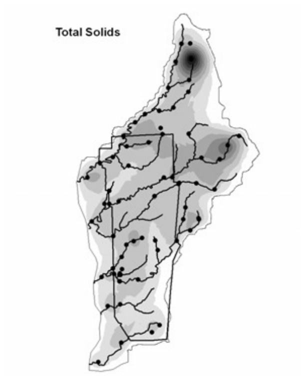
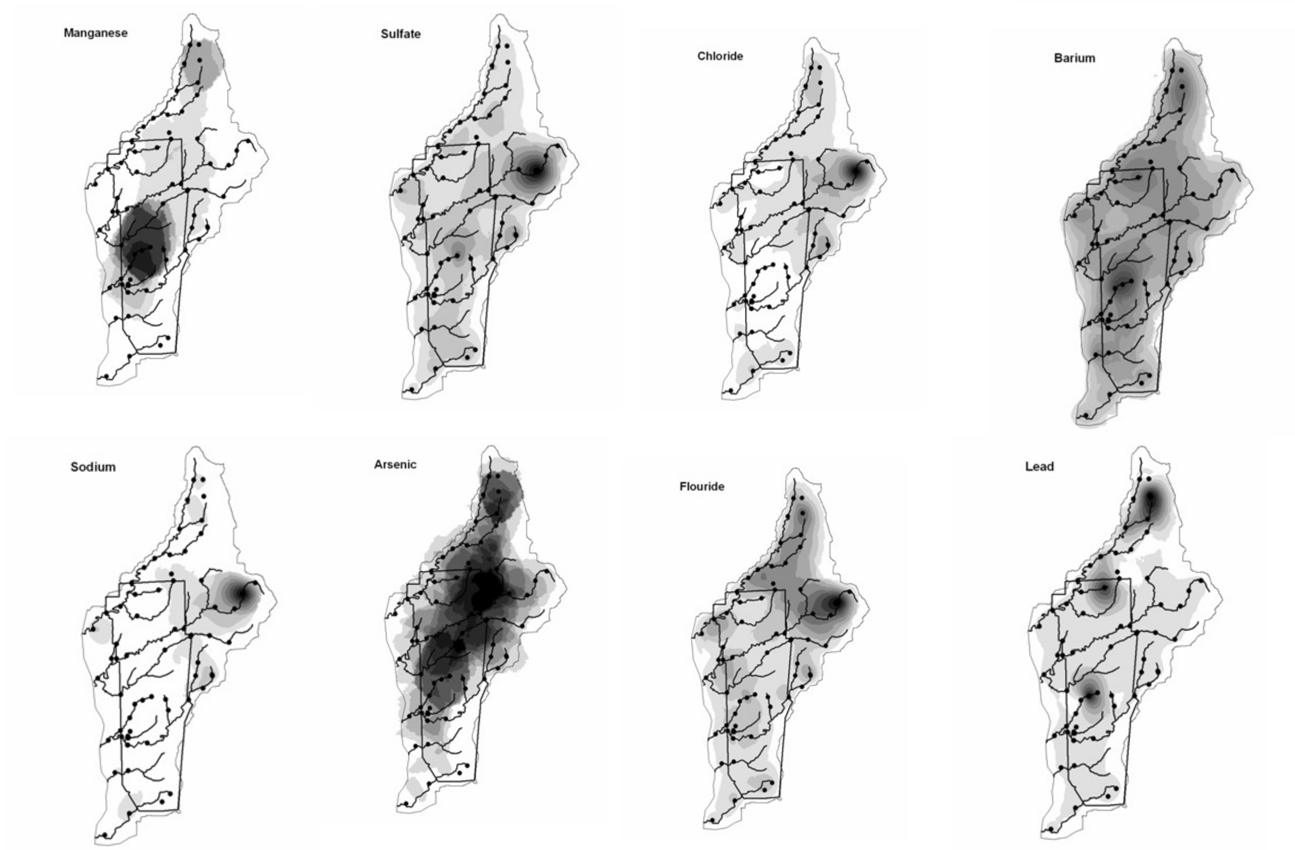


Figure 36: Relative Concentrations

Significant water quality, habitat, and land use chemistry variables that were predictive of fish, macroinvertebrate and crayfish assemblage clustering using kriging and spline smoothed bathymetric methods. Darker regions represent relatively higher concentrations of the variable associated with that area or lower habitat quality. All concentrations are presented on a relative (percentage of range) scale.



[22] Preliminary Diagnosis of Contaminant Patterns in Streams and Rivers of National Wildlife Refuges in Indiana, Biological Contaminants Program & Division of Ecological Services, Fish & Wildlife Service, US Department of Agriculture, Bloomington Office, June 2008.

5.1.6 Quick Creek/Hardy Lake Watershed Project

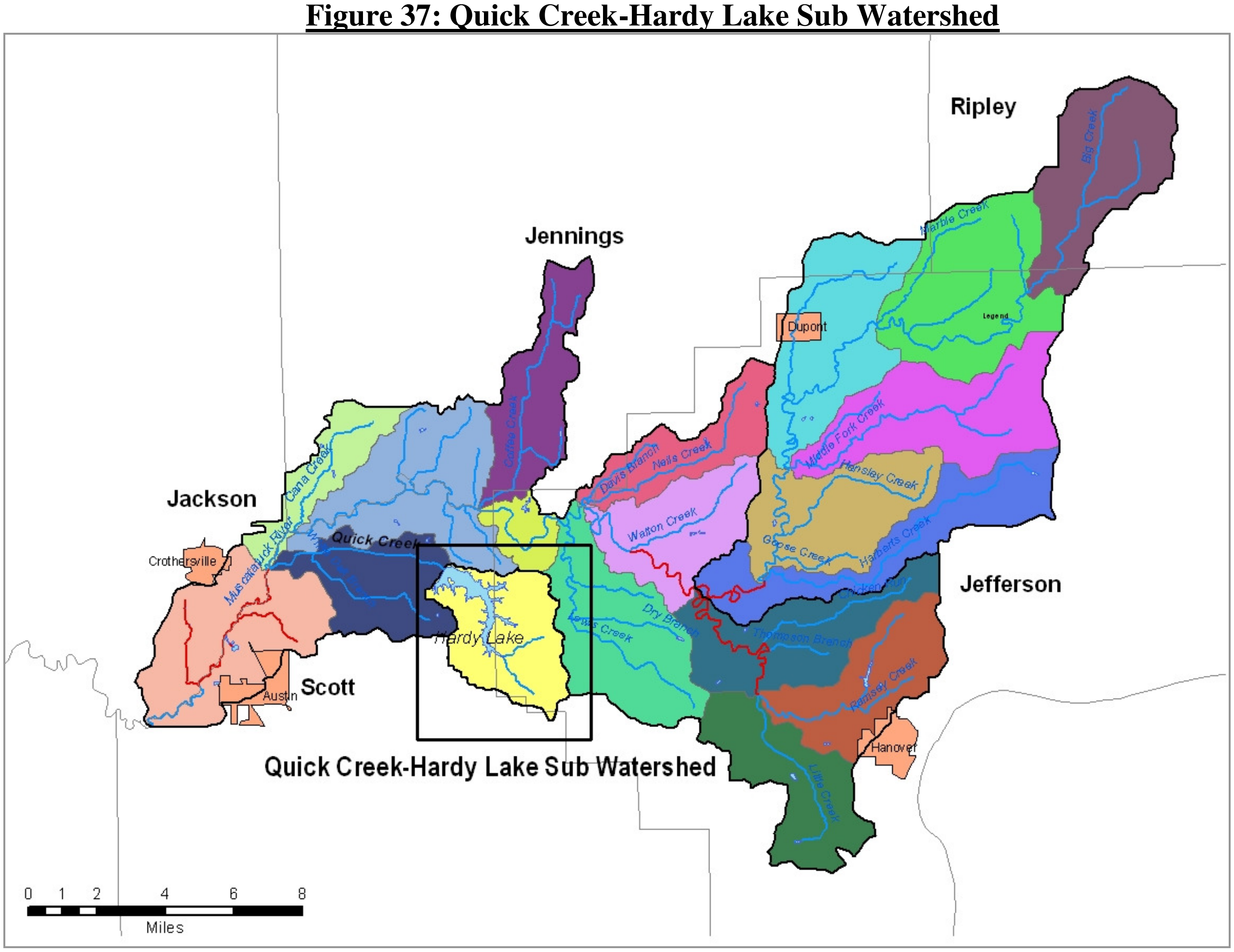
The Quick Creek Watershed Project was a local initiative started in February 1996 by concerned residents, SWCDs, DNR and NRCS staff. The concern was that the 741 acre Hardy Lake was showing advanced signs of eutrophification. In 1999 the concerned partners sponsored a year long diagnostic study within the Quick Creek watershed which was completed by EnviroScience, Inc.

In 2000, EnviroScience, Inc. provided ecological monitoring services to the Jefferson and Scott County SWCDs for the purpose of conducting a diagnostic water quality and land use study of the Hardy Lake watershed, located in southeastern Indiana. The watershed is approximately 7,500 acres (3,035.1 hectares) with the lake contributing 741 acres (299.9 hectares). The study was jointly funded by Jefferson and Scott Counties through a grant from the Indiana Department of Natural Resources, Division of Water, and Water Resources Development Fund.

Land managers, lake managers, land owners, fishermen, and other lake users had become concerned over a perceived decline in the Hardy Lake water quality. The majority of the concerns focused on suspected sediment and nutrient loading, a declining fishery, macrophyte overabundance, and land use. The primary goals of this study were directed toward identifying problem areas of the lake and watershed.

The study focused on the tributaries and sub watersheds of Hardy Lake, with some limited lake sampling to characterize the current status of the lake.

Figure 37: Quick Creek-Hardy Lake Sub Watershed



Select tributaries and the outlet of Hardy Lake were sampled for biological, analytical, and physical parameters. Sites were selected based on their drainage area, proximity to possible problem areas, and location within the watershed. One round of fish sampling, two rounds of macroinvertebrate sampling, and a habitat evaluation were performed at each of the 5 sites using Federal EPA Rapid Bioassessment and Ohio EPA methods. The biological results were analyzed using various multi-metric indices including the Index of Biotic Integrity (IBI), the Family Biotic Index (FBI) and the Hilsenhoff Biotic Index (HBI). In-field and analytical chemistry, as well as flow and turbidity data were collected at 8 stream stations on selected Hardy Lake tributaries.

Lake monitoring was conducted at 6 sites on Hardy Lake. The "Deep Hole" site was analyzed for the calculation of TSI indices, and 5 sites at various inlets were used to investigate nutrient and sediment loads from various tributaries. A detailed aquatic plant survey of the lake was conducted to identify problem species and special interest species distributions.

A secondary source review was jointly conducted by EnviroScience and the Scott and Jefferson SWCDs to investigate existing historical data for the watershed. Indiana Department of Natural Resources fishery reports, USFWS National Wetland Inventory Maps, digital aerial photographs, and other information were compiled for future reference.

A detailed land use analysis of the Hardy Lake watershed was conducted by EnviroScience. A Geographic Information System (GIS) was created for Hardy Lake using information gained from all aspects of the project including secondary source review, biological, and chemical sampling data. Land use was characterized for each major watershed based on aerial photographs, NWI maps, USGS topographical maps, and field verifications. The watersheds were then evaluated using various models to identify potential problem areas and areas of importance.

It was concluded that all sub watersheds studied were somewhat impaired by sedimentation due to land use practices, and select watersheds were impaired by nutrient loading due to agricultural practices. However, overall the watershed was considered in "good" condition with some problem areas. Some sub watersheds were identified as having problem areas in need of restoration or in need of protection. It was determined that because the lake was currently in a state of mild eutrophy, a restoration of problem sub watersheds could result in a noticeable improvement in overall lake quality.

A volunteer monitoring program was recommended to encourage community support of lake restoration. Because of the drought conditions during 1999, continued stream monitoring was recommended to supplement the results of the 1999 study and to monitor any changes within the watershed or lake itself.

<u>Summary of Project Findings</u>
As in many rural watersheds, environmental stressors to the Hardy Lake watershed are predominantly associated with agricultural practices. All subwatersheds studied exhibited some degree of impairment due to sedimentation from land use practices, and some select watersheds were somewhat impaired by loading of organic wastes. However, based on the data collected in 1999, the Hardy Lake watershed should be considered in "good" condition relative to other lakes in Indiana, with a few problem areas. The macrophytes present in the lake were generally not problematic, and both the fish and macroinvertebrate community were comprised of intolerant species. Chemical parameters in the lake and watershed streams were normal for this region of Indiana accounting for seasonal variation. Considering that Hardy Lake proper was found to be mildly eutrophic, there exists strong potential for watershed restoration projects to have measurable effects on improving the lake's overall water quality. This means that improvements in the water quality of a few selected inputs could result in noticeable benefits to Hardy Lake.

If improperly managed, agriculture can result in stream and lake impairment for many reasons. The primary sources of agricultural non-point source pollution are sediment, nutrients, animal wastes, and pesticides. Sediments are eventually transported downstream and deposited in wetlands at the interface with Hardy Lake and/or directly into the lake itself. Such sedimentation will eventually cause premature filling of the lake.

Nutrient loadings can occur from animal waste, faulty septic systems, and fertilizer applications. Nutrient inputs can enter streams directly or indirectly via attachment to sediment particles. As with sediments, excess nutrients can eventually enter Hardy Lake. Phosphorus and nitrogen are the two primary nutrients associated with agricultural non-point pollution. If excessive nutrient loadings occur in the lake, these nutrients will cause problematic algal blooms and/or aquatic plant growth. Excess plant growth can reduce the amount of light reaching bottom vegetation that serves as an important food source for some wildlife, and habitat and refugia for many other biota. The resulting biological oxygen demand from decomposition of the plants and algae at the end of the growing season will result in a decrease in the levels of oxygen available to aquatic life, and can result in an increase in less desirable fish species which are tolerant to low dissolved oxygen levels. As excess plant growth decomposes year after year, the resulting detritus can shorten the life span of the lake as well.

Hardy Lake exhibited characteristics of a mildly to moderately eutrophic lake in 1999 based on the Trophic State Index values. This data suggests that phosphorus may be limited by the aquatic plant community, at least during dry periods. Most of its tributaries also showed the effects of moderate nutrient loads. However, 1999 was one of the hottest, driest years on recent record. During the summer months there were few rain events significant enough to cause the torrential stream flows in the tributaries normal to the region. In effect, the normal hydrological processes were interrupted. This condition made characterization of the lake difficult. However, the biological fish and macroinvertebrate data collected seemed to work well at categorizing the tributaries and identifying problem areas.

The aquatic plant survey completed in July showed that a diverse plant community exists in Hardy Lake, with some possible nuisance plant growth occurring in certain areas later in the year. Controlling plant growth in these nuisance areas could improve fishery production and boat access. However, because phosphorus may be limited by aquatic plants, control should be moderate and over a period of time to prevent accelerated eutrophication. Also, the long term effects of stocked white amurs (grass carp) on the aquatic plant community have probably not yet reached an equilibrium. EnviroScience recommended that a modest weed control program be initiated in the southern end of the lake. There are many types of weed control products available for safe use in drinking water supply reservoirs. A weed control program may be effective.

Overall, the study suggested: That phosphorus is a limiting factor in Hardy Lake. There are a few sub watersheds that EnviroScience believes are contributing the majority of the phosphorus input to Hardy Lake. There are also specific sub watersheds which provide a large percentage of the inflowing water each year and future rehabilitation and protection efforts should focus on protecting them from further development. Based on the surrounding land use, some sub watersheds are comprised of a large proportion of agricultural land, some of which is in close proximity to the stream. Therefore, there should be a concentrated effort on preserving adequate riparian zones in these areas.

Due to extremely dry conditions in 1999, the results of this study must be considered preliminary. Little rainfall during 1999 meant that no high-flow data were collected from the tributary streams, and that samples from all the chemistry sites were collected only one time. Based on the torrential nature of Hardy Lake's tributaries, it is likely that most of the nutrient and sediment input into the lake occurs during two or three extremely high flow events each year. Such events should be sampled in order to develop more robust sediment and nutrient models. This study did not obtain data on such events, but it does provide a guide to as which sub watershed areas are most important to lake health, and which areas would provide the most benefit from restoration.

Implementation

Best management practices addressed sediment and nutrient concerns within specific sub watersheds. Using the Indiana Department of Natural Resources Lake and River Enhancement (INDNR LARE) funding and United States Department of Agriculture (USDA) – Conservation Reserve Program (CRP) together provided funding for farmers to implement grassed filter strips in cropland fields that are located along streams, creeks and permanent watershed bodies throughout the watershed. The filter strips reduced sediment, nutrients and other contaminants from entering watercourses and provide excellent wildlife habitat.

The diagnostic study determined there were approximately 346 acres of pasture within the watershed. LARE funding was used by producers and livestock owners to develop well-managed pastures with denser forage to trap sediments and nutrients and decrease erosion to improve water quality. Funding was also used to fence livestock off sensitive areas such as stream banks, to reduce sediment and nutrient loading in the streams, improve heavy use feeding areas, as well as for utilization of rotational grazing techniques, development of water systems, and improvement of forage bases.

Erosion problems occur in waterways, a channel where precipitation drains naturally from the land, when appropriate ground cover is disturbed. Cost share programs were available to landowners to assist with the installation or repair of grassed waterways while providing an annual payment for the land.[23]

5.2 Hoosier Riverwatch Volunteer Water Quality Monitoring

During Hoosier Riverwatch volunteer water monitoring conducted for the Quick Creek/Hardy Lake Watershed Project there were four separate testing sites that have been identified as being in the CMW. The following sites have monitoring activity as early as 2001 to the present. Sites identified by the Hoosier Riverwatch ID number are as follows, Quick Creek site numbers 294, 256, and 1280, Little Creek site number 1274. Review of the Hoosier Riverwatch data collected during this time did not show any significant data that would indicate impaired waters.

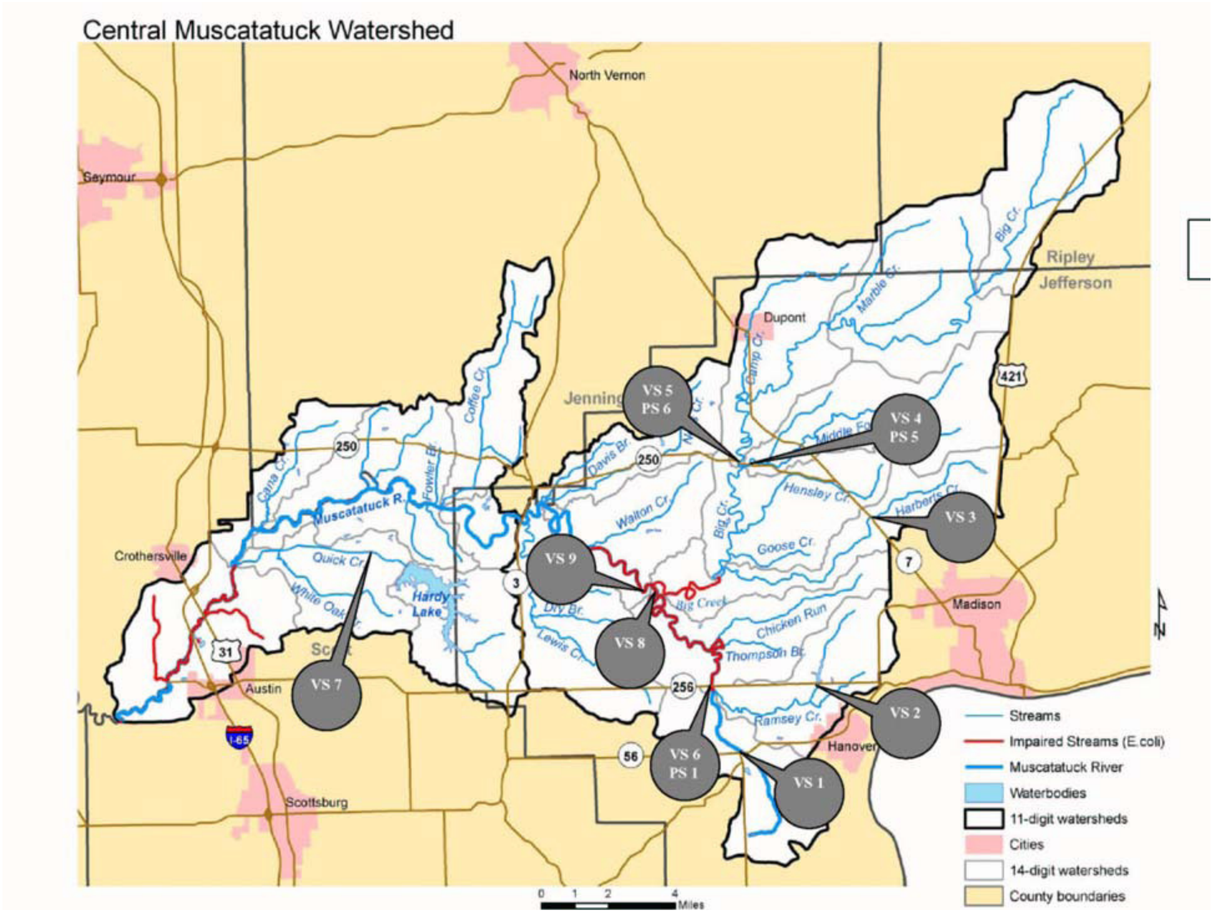
The CMWP expanded the Hoosier Riverwatch volunteer water quality monitoring program to gain more information about water quality within the watershed. The goals of the monitoring program to collect data to be used by the CMW steering committee, to meet the goal of more extensively characterizing what the water quality is within the watershed, are outlined below:

- Evaluate current conditions in waters on the 303(d) List;
- Identify sources and causes of impairments;
- Address data gaps; and
- Support development of the Central Muscatatuck Watershed Plan.

Based on these goals the steering committee discussed and decided upon a total of seven sites within the watershed to conduct water sampling. Five sampling sites were monitored by both volunteers and professionals (the sample dates did not overlap). Volunteer sites are designated by the initials VS while professional sites are designated by the initials PS in Figure 38:

[23] Final Report, Hardy Lake Watershed Diagnostic Study, 2000, EnviroScience, Inc., 3781 Darrow Rd., Stow, Ohio. Full report may be found at: http://www.in.gov/dnr/fishwild/files/Hardy_Lake_Wtrshd_DiagJefferson_Scott_June_2000.pdf

Figure 38: 2008 Volunteer Testing Sites



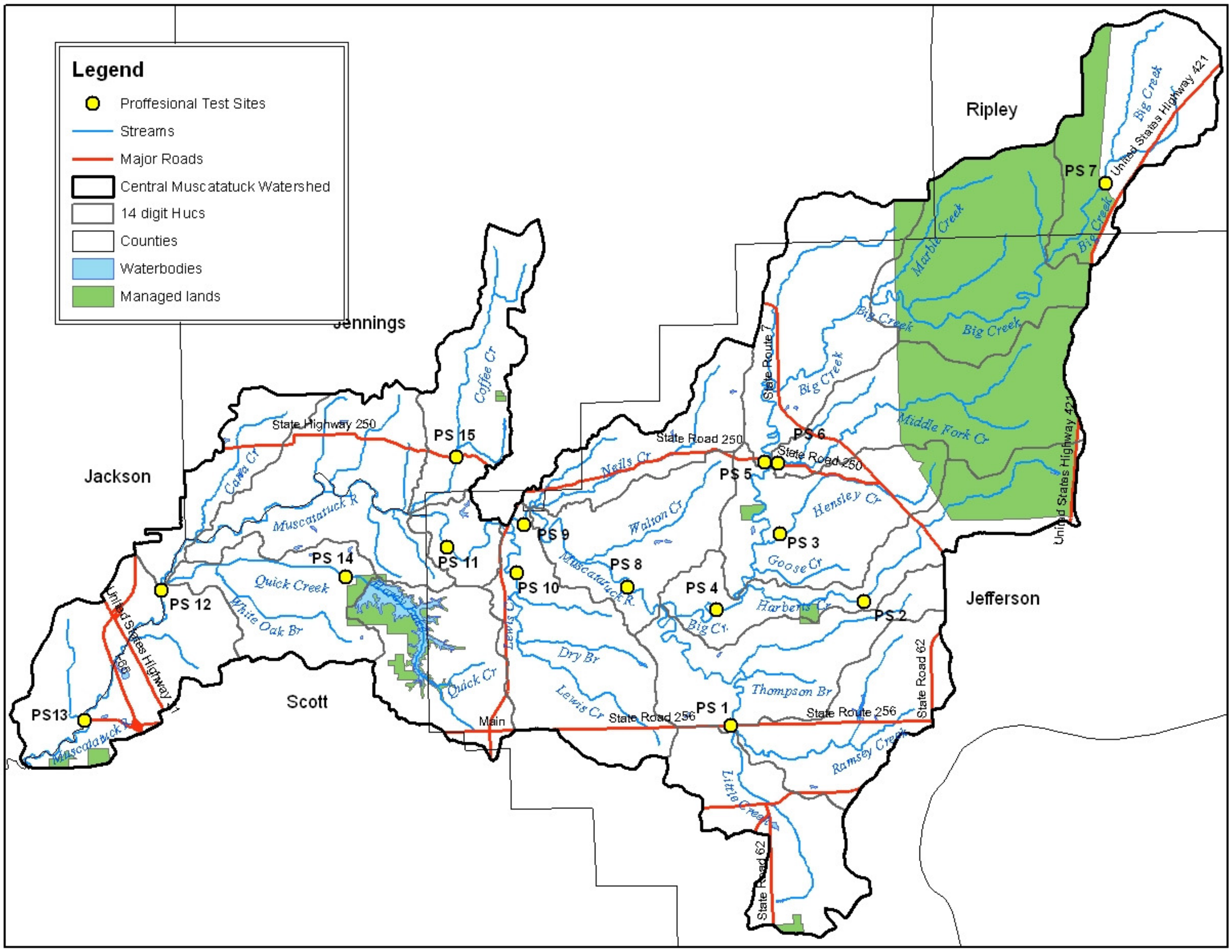
Volunteer chemical sampling was conducted during the 2008 sampling season, April through October, on a monthly basis. Macroinvertebrate sampling was conducted by volunteers two times during 2008 to assess the ecological health of the stream. This sampling was done one time in the spring and one time in the fall. For details on the parameters and chemical sampling tests conducted please refer to section 3. The full volunteer monitoring data is included in Appendix C.

There were 33 volunteer samples and 25 professional samples collected at these five sites. Volunteer water monitoring was also conducted for a second season for baseline comparison purposes for the same time periods and locations in 2009. Records will be maintained, however, full sampling data will not be completed until after the submittal of this management plan. Full chemical data results for 2008 samples can be found in Appendix C and will be further discussed in this management plane regarding comparison to the professional monitoring findings.

5.3 Central Muscatatuck Watershed Project Diagnostic Study

Figure 39 shows where the professional water quality monitoring sites were located. The criteria and goals used to select these sites were the same as was used to select the volunteer monitoring sites discussed in section 5.2. Complete detailed chemical data information for the Central Muscatatuck Watershed Contractual Water Quality Monitoring may be found in Appendix B. A summary of the findings are provided in this section.

Figure 39: Professional Water Quality Monitoring Sites



5.3.1 Nutrient Levels – Phosphorous and Nitrogen

Nutrient levels (phosphorous and nitrogen) at most sites were quite low compared to other Indiana streams.[24] The Indiana Average for phosphorous is 0.05 mg/L and nitrogen is 12.32 mg/L.

Figure 40: Average Phosphorus Levels

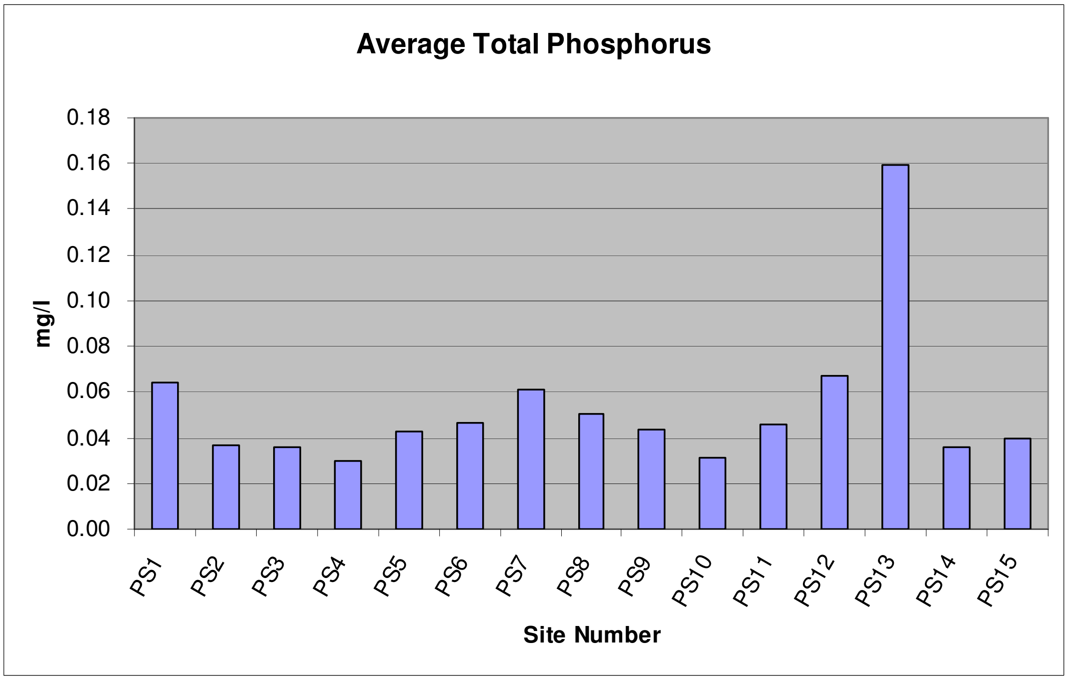
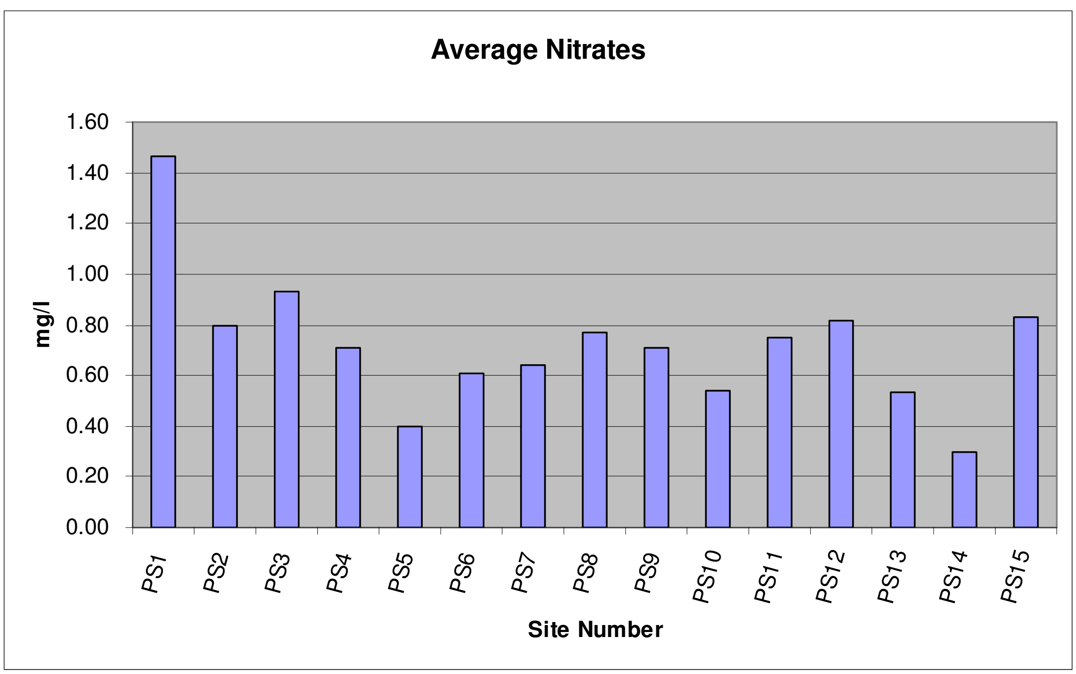


Figure 41: Average Nitrate Levels

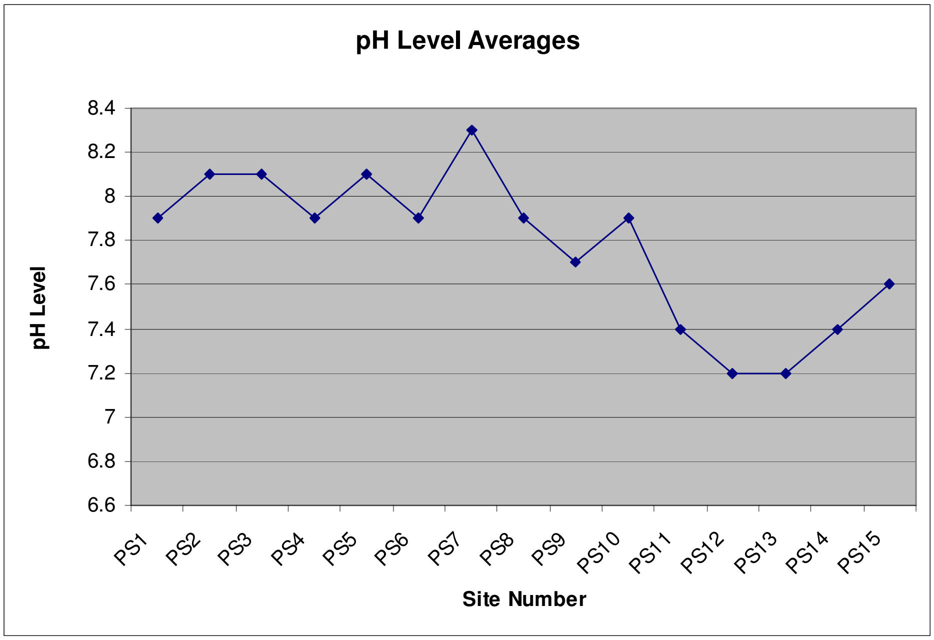


[24] Christensen, C., 1998. Indiana fixed station statistical analysis. Indiana Dept. Environ. Mgmt., Office of Water, Indianapolis, IN. (IDEM/32/02/005/1998)

5.3.2 pH

pH levels for the watershed sample sites currently tested within the Indiana Water Quality Standard of between 6 – 9.

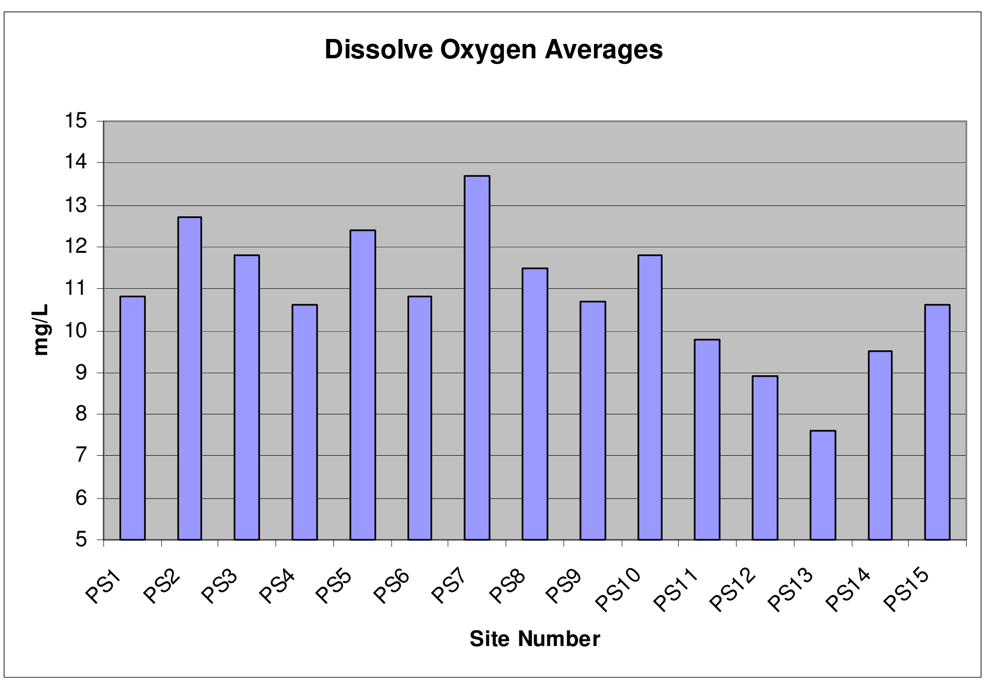
Figure 42: pH Level Averages



5.3.3 Dissolved Oxygen

Dissolved oxygen levels at site 13, the Muscatatuck River downstream from Austin, fell below the Indiana water quality standard of 5 mg/L on two sample dates. Overall, all other sites sampled showed dissolved oxygen levels met the Indiana Water Quality Standards.

Figure 43: Dissolved Oxygen Level Averages



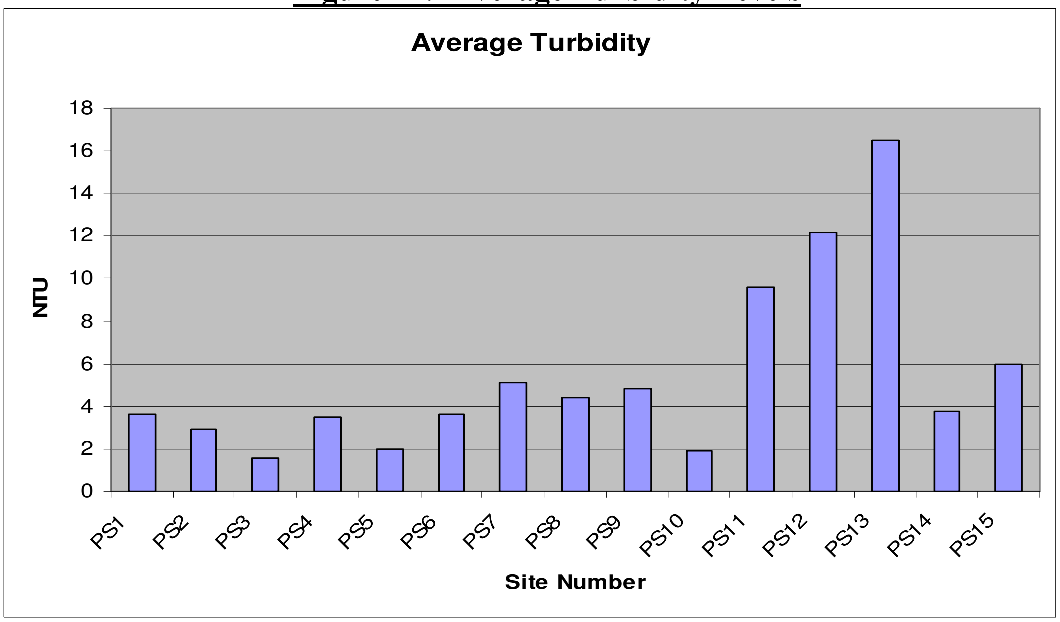
5.3.4 Biological Oxygen Demand

Biological oxygen demand tested over 5 days levels generally fell in the 1-2 mg/L range. This indicates little organic waste in the water. There were samples that were found to be in the 3-5 mg/L range which indicates some organic waste at site 8, 11 and 13 along the Muscatatuck River.

5.3.5 Turbidity

In general, Big Creek was very clear, as measured by NTU turbidity measurements. The Muscatatuck River sites were much more turbid.

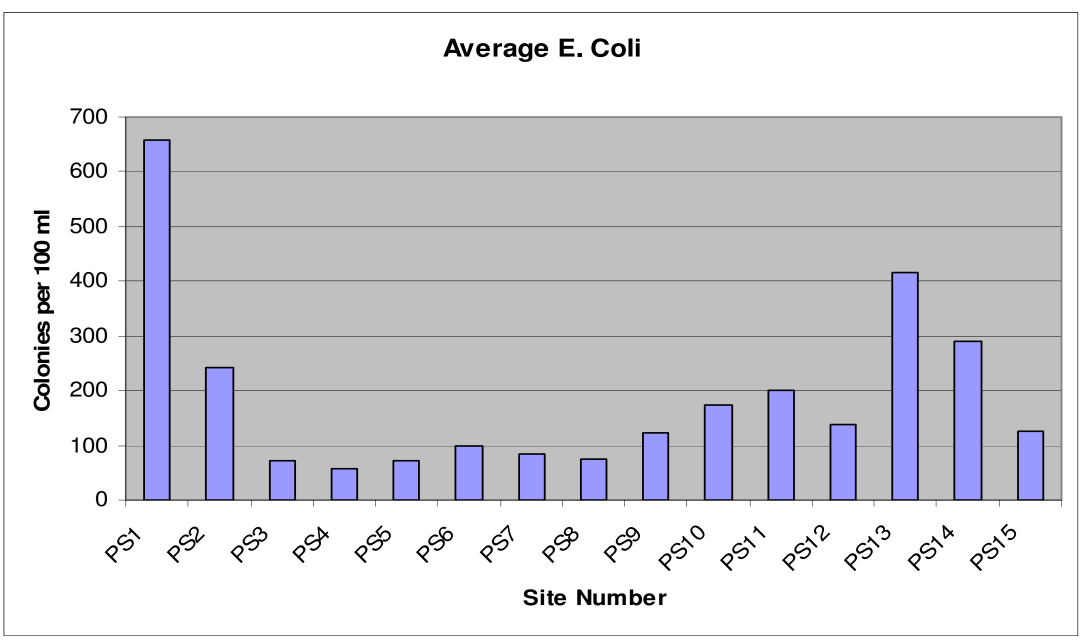
Figure 44: Average Turbidity Levels



5.3.6 E. *coli*

E. coli concentrations were generally low. However, the standard for whole body recreational uses (a maximum of 235 CFU/100 ml) was regularly exceeded at 3 sites (sites 1, 13 and 14). The Little Creek sub watershed has somewhat degraded water quality, especially for *E. coli*.

Figure 45: Average *E. coli* Levels



5.3.7 Macroinvertebrate Organisms

A rapid bioassessment of the macroinvertebrate community was conducted at six sites in the Central Muscatatuck Watershed in Jefferson and Scott Counties. The largest streams in this watershed are Big Creek and the Muscatatuck River, from its confluence with Big Creek to downstream from Austin, Indiana.

Of the two streams, Big Creek is in better ecological health. Its biotic integrity scores were close to what would be expected based on the habitat available and both the habitat and aquatic communities are among the best in Indiana. Upper areas of Big Creek are somewhat impacted and deserve attention with establishment of best management land use practices that preserve the riparian zone.

Macroinvertebrate Communities

The family-level mIBI and species-level mIBI scores are shown in figure 46.

Figure 46: Biological Integrity Scores by Site Numbers

		Family Level mIBI		Species Level mIBI	
Site	**Water body**	**Spring '08**	**Autumn '08**	**Spring '08**	**Autumn '08**
4	Big Creek	4.8	5.8	63	60
6	Big Creek	4.4	3.6	47	47
8	Big Creek	5.6	5.6	67	70
9	Big Creek	6.6	4.4	73	77
11	Muscatatuck	4.6	2.4	70	33
13	Muscatatuck	2.8	2.6	23	30

IDEM considers mIBI scores greater than 2.2 to indicate "fully supporting" uses for aquatic life. All of the mIBI scores exceeded 2.2. However, there were clear differences between sites. On Big Creek, the upper part of the watershed above site 6 had scores that were lower than predicted by the habitat present. This usually indicates some kind of environmental perturbation. Big Creek scores increased downstream from site 6 and indicated very good biological conditions at the stream's confluence with Muscatatuck River. Big Creek sites had higher scores than the Muscatatuck sites. The lowest score among all sites occurred at site 13- the Muscatatuck River downstream from Austin.

5.3.8 Aquatic Habitat

Figure 47 shows the results of the Quantitative Habitat Evaluation Index (QHEI) values for each site in the study. Aquatic QHEI scores ranged form 51 to 88. Half the sites have "excellent" habitat (values greater than 70). The remaining half have "fair" (values between 50 and 70).

Figure 47: Aquatic Habitat Values (QHEI) of each study site

Site	Water body	QHEI
1	Little Creek	65
2	Harbert's Creek	54
3	Hensley Creek	70
4	Big Creek	88
5	Middle Fork	65
6	Big Creek	76
7	Big Creek	70
8	Big Creek	51
9	Big Creek	77
10	Lewis Creek	74
11	Muscatatuck	68
12	Muscatatuck	62
13	Muscatatuck	53
14	Quick Creek	73
15	Coffee Creek	76

5.3.9 Conclusion

Of the two 10 digit watersheds, Big Creek is in better ecological health. Its biotic integrity scores were close to what would be expected based on the habitat available and both the habitat and aquatic communities are among the best in Indiana. Upper areas of Big Creek are somewhat impaired and deserve attention with establishment of best management practices that preserve or enhance the riparian zone. The Little Creek sub watershed has somewhat degraded water quality, specifically for *E. coli.*

The lower Muscatatuck River is clearly degraded, having biotic integrity scores much lower than its habitat would allow. Low dissolved oxygen in this river appears to be contributing to the degradation of water quality. Sources of oxygen-consuming substances in this area could not be determined from the data collected in this study. Soft sediments in the area may exert a "sediment oxygen demand" that may contribute to the problem.

5.4 Professional and Volunteer Monitoring Comparison

As part of a watershed management plan, the Historic Hoosier Hills RC&D commissioned a study of data collected by both volunteer and professional analysts. The purpose of the study was to determine comparability and usefulness of volunteer data for making decisions about water quality in the watershed planning process.

5.4.1 Water Chemistry and Biological Comparison Details

Samples were collected in the CMW of Jefferson and Scott Counties in Indiana. Five sites in this watershed were sampled by volunteers using Hoosier Riverwatch methods and also by professionally-trained scientists using state-of-the-art biological and chemical analyses performed in a laboratory. These sites are shown in section 5.3, figure 39. Although the sampling dates for volunteer and professional analyses were not identical, the results are still useful for determining the validity of the decision-making process.

Volunteer chemical monitoring over-estimated water quality degradation in this study. For example, volunteers measured dissolved oxygen at or below 5 mg/l (the state water quality minimum average value) 15% of the time. None of the professional samples were this low. Volunteer sampling phosphorus levels greater than 0.1 mg/l in 42% of their samples. No professional samples were this high. For nitrate analysis, the volunteer samples exceeded 2 mg/l 30% of the time. Professional samples found only 12% of the samples above 2 mg/l. The pH measurements of volunteers were below 7 in 24% of the samples. Only 4% of the professional samples were below 7. Volunteer *E. coli* samples were greater than 100 colonies per 100 ml (a level at which recreational uses begin to be impaired) 82% of the time. Only 48% of the professional samples exceeded 100 colonies per 100 ml.

Volunteer methods determined that 80% of the monitored sites had "medium" water quality while professional methods determined that all five sites had "good" water quality. Although the two methods disagreed on which site was of the highest quality (VS4 for professional monitoring, VS9 for volunteer monitoring), both agreed that VS6 had the lowest water quality based on the sample data based primarily on the high *E. coli* levels. In addition, both methods determined that of all the parameters monitored, *E. coli* contamination was the greatest water quality problem present.

Biological monitoring using macroinvertebrates was done at two sites in the Big Creek watershed by volunteers. Both volunteer biological samples indicated excellent water quality. These volunteer sites were not sampled by professional biologists. However, professional sampling within Big Creek also showed that biological communities are in good condition. Aquatic habitat analysis by volunteers and professionals generally found close agreement. It is probable that the volunteers overestimated habitat quality significantly at one site, VS4. Deviations in sample data between professional and volunteer monitoring are attributed primarily to professional monitoring equipment and methods being more highly and scientifically calibrated and accurate and less prone to human or equipment error than the volunteer equipment and methods.

Although no identical sites were sampled for macroinvertebrates by both volunteers and professionals, two volunteer sites within the Big Creek watershed found communities characterized by "excellent" water quality. Professional biological monitoring agreed that environmental and water quality conditions in the Big Creek watershed are generally good.[25]

[25] Commonwealth Biomonitoring, "A Comparison of Water Quality Monitoring Results Collected by "Volunteer" and Professional" Analysts", January 2009.

Figure 48: Data Comparison Summary

	VS4	PS5	VS5	PS6	VS6	PS1	VS7	PS14	VS9	PS8
Dissolved Oxygen	8.43	11.00	8.29	9.60	6.58	9.96	7.93	8.36	10.00	10.20
pH	6.43	8.10	6.93	7.90	7.33	7.86	6.86	7.46	7.42	7.88
BOD5	2.43	2.00	2.93	2.04	1.33	2.06	2.00	2.02	13.50	2.20
OP	0.13	0.01	0.10	0.02	0.13	0.02	0.03	0.03	0.12	0.02
NO3	0.47	0.64	0.31	1.13	2.93	1.41	0.00	1.59	2.20	1.18
E. coli	806.57	53.40	407.29	122.60	3525.00	731.80	119.00	395.40	149.83	66.40
Water Quality Index	71.45	85.00	71.05	80.00	63.02	70.00	73.25	75.00	72.74	80.00
Rating	Medium	Good	Medium	Good	Medium	Good	Medium	Good	Good	Good

Percent of all samples analyzed by the two methods

	DO<5	pH<7	P>0.1	NO3>2	*E. coli*>235
33 Volunteer Samples	15	30	42	30	57
25 Professional Samples	0	4	0	3	24

5.4.2 Aquatic Habitat Analysis

	Volunteer Results	Professional Results
PS1/VS6	62-79	65
PS5/VS4	96	65
PS6/VS5	84-103	76
PS8/VS9	81	77
PS1/VS7	86	73

5.4.3 Macroinvertebrate Community Analysis

Volunteer Data

VS1 Biotic Values 23-34 (excellent)
VS3 Biotic Value 38 (excellent)

Professional Data

4 sites on Big Creek Biotic Values (25% fair)
(50% good)
(25% excellent)

5.5 Windshield Data Survey Inventory

The CMW utilized the summer 2008 Hanover College interns and the volunteer water quality monitoring team to conduct windshield surveys while conducting other monitoring activities. The following is a summary of documented land uses that could potentially impair the watershed or events of special concern which help to identify impairments within the watershed. Also documented are indicators of healthy land use. The windshield documentation was conducted throughout the project, but the majority of data was collected during March of 2008 to August of 2008. The windshield surveys are categorized according to which 12 digit HUC (refer to sub watershed map figure 3) the event or land use was documented in.

5.5.1 Headwaters of Big Creek - 051202070101

- Extreme flash flooding in the fall of 2007 east of the wildlife refuge, this event was severe enough to carry a field of large round hay bails through the fence of the wildlife refuge at the point where Big Creek first enters the refuge.
- Very little livestock documented within the sub-watershed.
- The majority of the land use documented is conservation tillage.

5.5.2 Marble Creek-Big Creek - 051202070102

- This sub watershed is located within Big Oaks National Wildlife Refuge and is noted to be mostly protected.
- Testing conducted by the Headwater Sampling project attempted to test headwaters within the refuge and found that most were dammed, acting more as sediment traps and regulating the flow from runoff. This could be the main factor as to why the wildlife refuge is able to act as a major filter for the runoff of the Big Creek headwaters.

5.5.3 Middle Fork Creek - 051202070103

- The headwaters section of this sub watershed is located within the wildlife refuge.
- Within the refuge there is some crop land owned by a private land owner and it was noted that the majority of the cropped land is conventionally tilled.
- There are some housing and old military buildings within the refuge or located on the now privately owned former Jefferson Proving Grounds property which are currently used for residences, limited industry and storage. It was documented that the sewage within the residential and industrial area of this property often backs up and flows out of combined sewer overflows during storm events.
- Some conventional tillage was noted along Big Creek as well as limited tobacco production.

5.5.4 Camp Creek- Big Creek - 051202070104

- It is noted that the town of Dupont is within this sub watershed as well as a school.
- Some cattle with access to the stream were noted along Camp Creek just off of St.R.7.
- Many small overgrazed lots containing horses were noted. Although this may not be a major concern it could be a small percentage of overgrazed pasture acreage that contributes to sediment runoff.

5.5.5 Harberts Creek-Big Creek - 051202070105

- The land uses in the headwaters section of Big Creek apply to those in Middle Fork; both begin within the wildlife refuge.
- It was noted by Hoosier Riverwatch volunteers that some increased algae growth was noted during the summer, but this may be attributed to periods of low flow.
- Cattle with access to stream along Harberts Creek were noted during the fall of 2007; however the numbers seemed to have decreased by 2008.

5.5.6 Little Creek - 051202070601

- Little Creek is noted to have fairly heavy crop acreage in the upper headwater section, mostly in conservation tillage. Some small scale tobacco farming was noted within this sub watershed.
- It was noted that Little Creek is bordered by cattle with access to streams along the stretch of creek from SR 56 up to the intersection Little Creek and Thompson Bridge.

- Little Creek was noted to appear very turbid with sediment during fairly low rainfall amounts.
- Hoosier Riverwatch volunteers noted dead fish in the Ramsey Creek and trash dumped below the bridge.
- It was noted that the town of Kent has a ditch system that carries raw sewage and black water from residential houses without septic systems directly to Little Creek.
- The Hanover Headwaters study noted cattle afterbirth in headwater stream that flowed directly from a cattle lot.

5.5.7 Neils Creek-Big Creek - 051202070603

- Cattle grazing along hillsides and woodlots were noted within this watershed.
- One farm house and cattle lot was noted as actually being in the creek bed and along the adjacent hillside.

5.5.8 Lewis Creek - 051202070602

- Some cattle with access to streams were noted.
- The town of Deputy is located within this subwatershed and was noted to have failing or non existing septic systems with sewage waste draining directly to streams.

5.5.9 Quick Creek-White Oak Branch - 051202070604

- Some dumped trash was noted along the outlet of Hardy Lake.

5.5.10 Coffee Creek-Muscatatuck River - 051202070605

- Cattle with very visible access to streams were noted along St. R. 3 on Coffee Creek.
- Most of the tillage along the Muscatatuck River is conventional tillage.
- Many log jams were noted with very deep cut banks and little vegetation along river banks.
- Major problems with illegal dumping were noted along the Muscatatuck River, particularly at the Tobias Bridge site along County Rd. 800 in Jennings County.

5.5.11 Dean Ford's Ditch - 051202070606

- Major flooding along the bottoms area was noted during the spring of 2008 with unusually high rain fall events.
- Most tillage is conventional tillage.
- Major issues with illegal dumping was also noted along the Scott County side of the Muscatatuck River due west of Austin.

A second windshield data survey for 2009 was conducted by Hanover College Student interns. Their final report was not complete prior to the submission date of this plan. However, the data will be kept on file with all other project documentation and the data will be considered and utilized during the implementation portion of the grant.

5.6 Headwater Assessment

The Central Muscatatuck Watershed Project conducted a study of headwaters which are small creeks and/or streams that are the source of larger creeks, streams and rivers within the watershed during the summer of 2008. The idea for the project stemmed from the Ohio EPA's Primary Headwater Habitat program in which it conducts assessment of the health of headwater streams utilizing a volunteer monitoring program. To date the Indiana Department of Environmental Management does not conduct any headwater assessment to determine the health or classification of headwaters.

The Central Muscatatuck headwater assessment project was adopted by Ross Alexander of Hanover College, a sophomore Biology major as a summer internship, sponsored by The Hanover Rivers Institute. The project goal was to determine the state of health of the headwaters within the watershed.

To be categorized as a headwater, the body of water must have a defined bed and/or bank, and cannot exceed 40cm in depth (Ohio Administrative Code 3745-1-02). According to the Ohio EPA Handbook on Headwater Habitats[26], these small surface waters are categorized into three separate classes according to size, flow, and the make up of species found within the stream.

- Class III: Primary headwater habitat is determined by: perennial streams, cold water conditions, being groundwater fed, containing species of animals that have adapted to the constant presence of cool water such as, salamanders, fish, and other macro invertebrates.
- Class II: Headwater habitat is identified by the perennial of intermittent flow of warmer water, being fed by subsurface flow, and fauna species that are adapted to warmer water.
- Class I: Headwater habitat is easily overlooked because at most times throughout the year little of no water flows within its banks. These are ephemeral or intermittent streams consisting of warm water, when water is present

Headwaters are understudied yet they are very important to the formation of larger streams and rivers that affect everything down stream and because they can function to help control flooding, regulate nutrient loads in the water, control water born sediments, and can provide varied habitats for rare and endangered species.

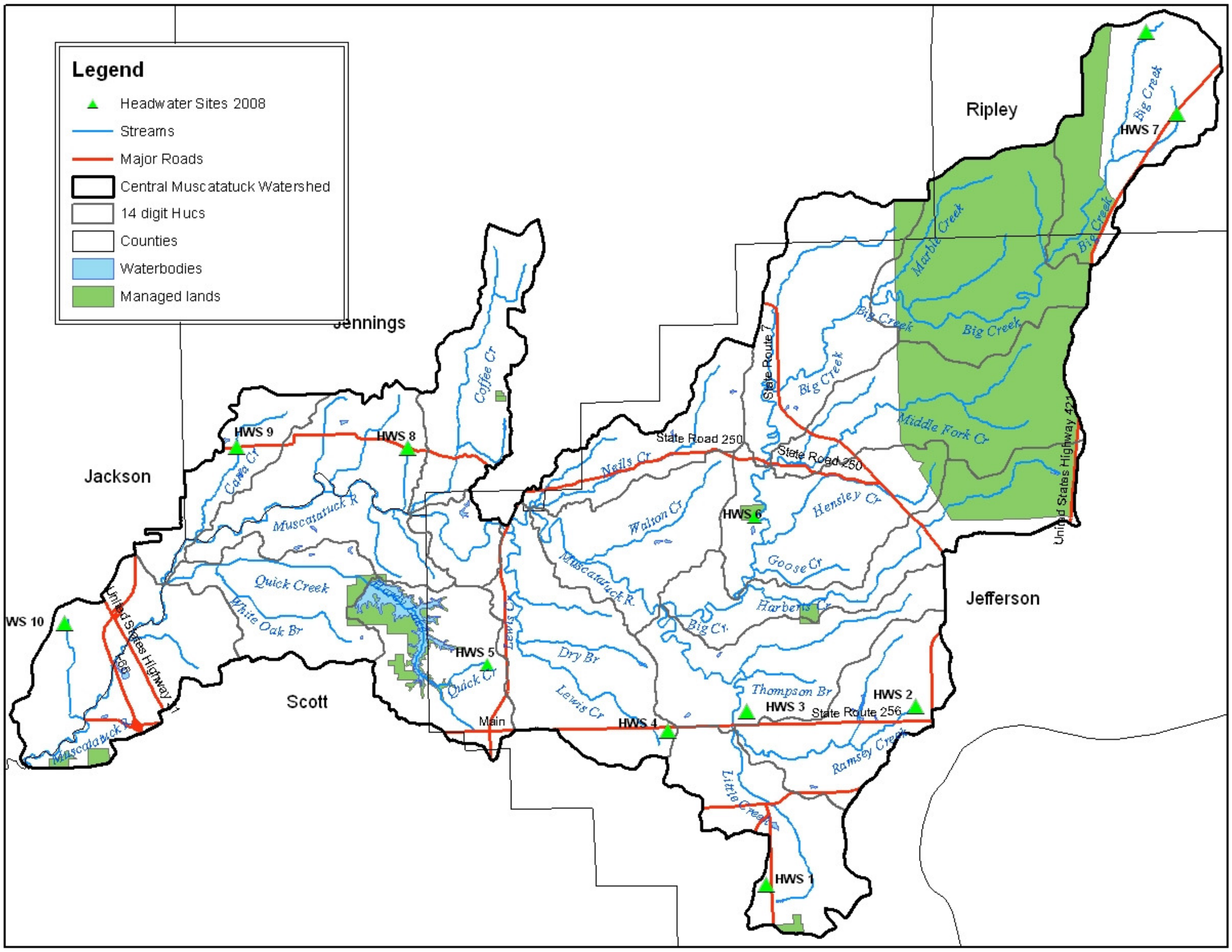
5.6.1 Methods of the Project

A total of nine headwater testing sites were determined using topography maps of the CMW and GIS mapping taking into account previously identified critical streams, size of selected streams, and accessibility of the stream. The sites were sampled a total of four times, each once a month starting early in June and ending is early September. This study utilized Hoosier Riverwatch volunteer monitoring protocol due to ease of use and minimal cost[27]. Additionally, salamander populations were sampled to help indicated the health of each individual stream habitat by conducting a stone search method due to the low flows.

Figure 49 shows the testing sites for the headwater monitoring. The water quality data gathered and assessed can be found in Appendix D.

[26] Ohio Environmental Protection Agency, http://www.epa.state.oh.us/water.html.
[27] Indiana Department of Natural Resources, Hoosier Riverwatch Water Monitoring, http://www.in.gov/dnr/nrec/3001.htm.

Figure 49: Headwater Testing Sites



5.6.2 Headwaters Study Conclusion

By monitoring the nine selected sites over a four month period an indication of the health of each headwater stream was determined taking into account all testing parameters and the habitat within the watershed. Sites PW1, PW2, and PW3 (those lying within Pennywort Cliffs) were determined to have the best habitat compared to the others, having CQHEI scores of 88, 87, and 87 respectively. Overall these sites tended to have a higher water quality than any other sites having a mean water quality scores of 71.5, 75.0, and 75.3, respectively. However PW1 had the highest mean biodiversity score of 15, compared to 11.5 and 8.75, at sites PW2 and PW 3, respectively. This is due to the lack of cover and consistent flow on sites PW2 and PW3. Overall the Pennywort sites were the most healthy and pristine of any of the other sites, which provide a sound baseline sample of headwater sites that have proper land use and are well buffered with vegetation.

HWS3 along the Thompson Branch displayed the poorest results in terms of water quality and biodiversity. This site was chosen as a worst case scenario due to the fact that the entire headwater up stream of the testing site is unbuffered and the land use is a cattle feeding lot and cattle barn. The mean water quality score for this site was 49.9, this ranked as medium water quality level by the Hoosier Riverwatch guide. The worst water quality rating for this site, on one particular sample date, was 33.24

which is considered poor water quality and during this sampling cattle afterbirth was found in the stream along with evidence of cattle lot runoff. These conditions severely limit the organisms able to live in the stream, and the only macroinvertebrates found were pollution tolerant organisms such as blood midges and planaria. Dead fish were also observed on this site the same date of the lowest water quality score was observed. Additionally, this headwater dumps directly into the main stem of Little Creek which directly affects the overall pollution loading of the stream.

5.7 Riparian Buffer Survey

Riparian buffers are defined as strips of grass, shrubs, and/or trees along the banks of rivers and streams which filter polluted runoff and provide a transition zone between water and human land use. They provide several benefits to water quality such as preserving a stream's natural characteristic, improving wildlife and aquatic habitat, cooling water temperature and catching and filtering sediment, nutrients, and debris.

In order to gain first hand supporting documentation of problem areas along the main stem of the Muscatatuck River the coordinator conducted a photo survey along selected sections of the Muscatatuck River. The following photo documentation was gained by kayaking down the river and documenting lack of riparian buffers, eroding banks, and major log jams by taking a GPS point and a photo to document the problem area. The goal was not to document all problem areas, rather to show examples and the extent of the problems.

5.7.1 Photo Documentation

The photo documentation form was followed from the DES Watershed Assistance section[28]. The survey started at the old steel bridge located on County Road 1350 and ended approximately a mile past the Dixon Ford Road Bridge. The following figures outline the points at which the photos were taken, what the documented problems were at each point and present a photo for each location. Points along the Muscatatuck River are designated by a "MP" and points along Big Creek are designated by a "BP" followed by a number.

[28] New Hampshire Department of Environmental Science, Watershed Assistance Section, http://des.nh.gov/organization/divisions/water/wmb/was/index.htm.

Figure 50: Muscatatuck River Riparian Buffer Survey

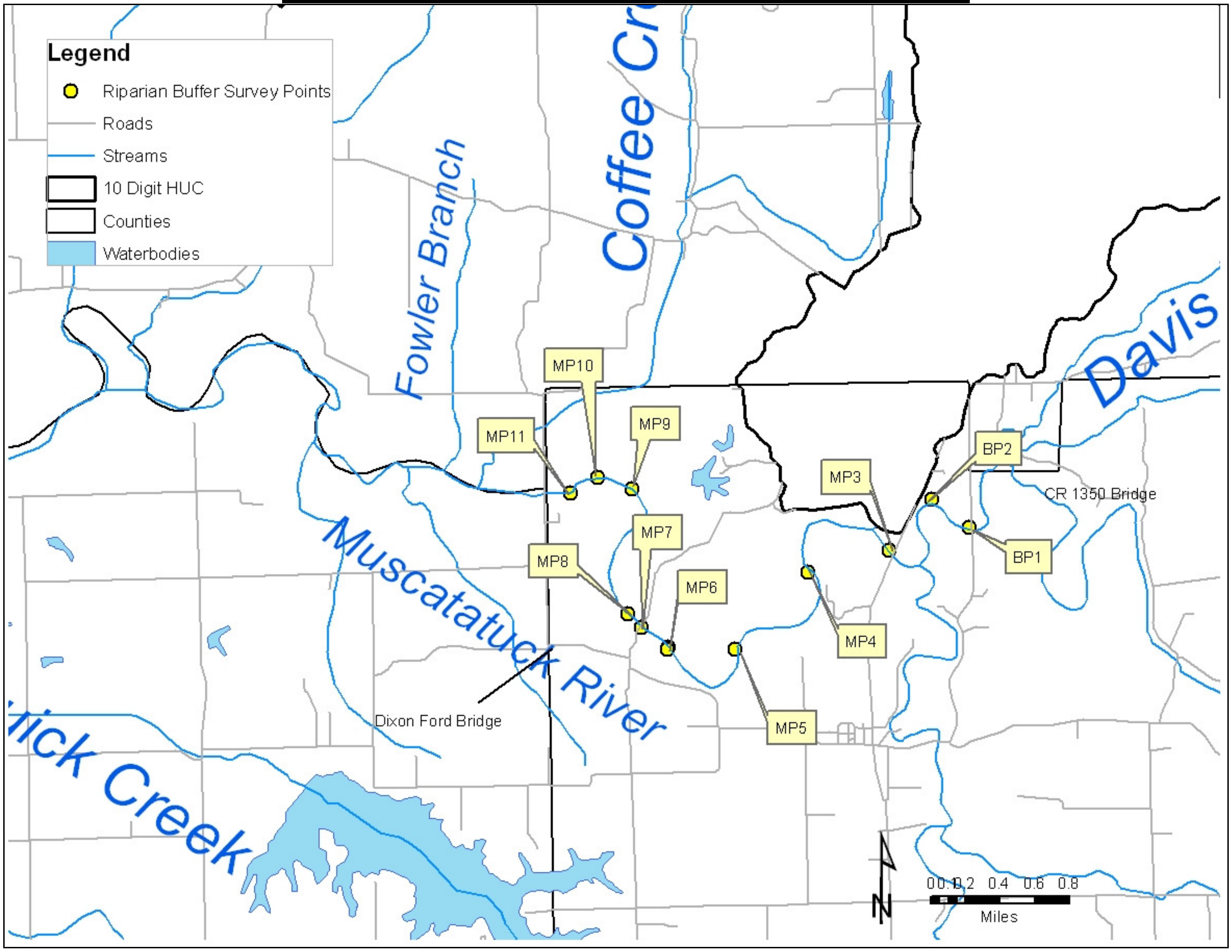
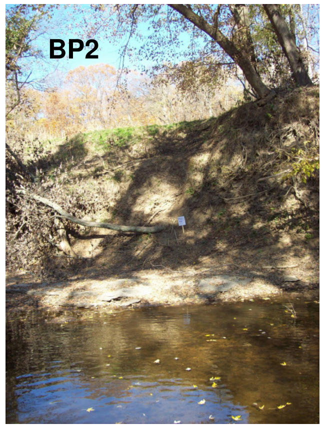


Photo Point ID	Time	Bearing to Subject	Photo Point Location	Subject Description
BP1	11:45am	S	Big Cr. 1350 Bridge	Start at bridge, good riparian buffer on S. side and low buffer on N. side along field
BP2	12:02pm	S	Big Cr.	Bank erosion
MP3	12:30pm	N	Muscatatuck	Low riparian buffer
MP4	1:00pm	N	Muscatatuck	Eroded banks 8' high
MP5	1:46pm	S	Muscatatuck	Highly eroded banks, no buffer
MP6	2:19pm	NW	Muscatatuck	Low riparian buffer
MP7	2:35pm	NW	Muscatatuck Dixon Ford Bridge	Low riparian Buffer
MP8	2:47pm	S	Muscatatuck	Erosion, log jam, no buffer. Field to the N. is row cropped with no buffer along stream
MP9	3:26pm	N	Muscatatuck	Low riparian buffer
MP10	3:40pm	S	Muscatatuck	No riparian buffer, bank erosion,
MP11	3:53pm	S	Muscatatuck	No riparian buffer, bank erosion, row crop


BP1

BP2

MP3

MP4

MP5

MP6

MP7

MP8

MP9

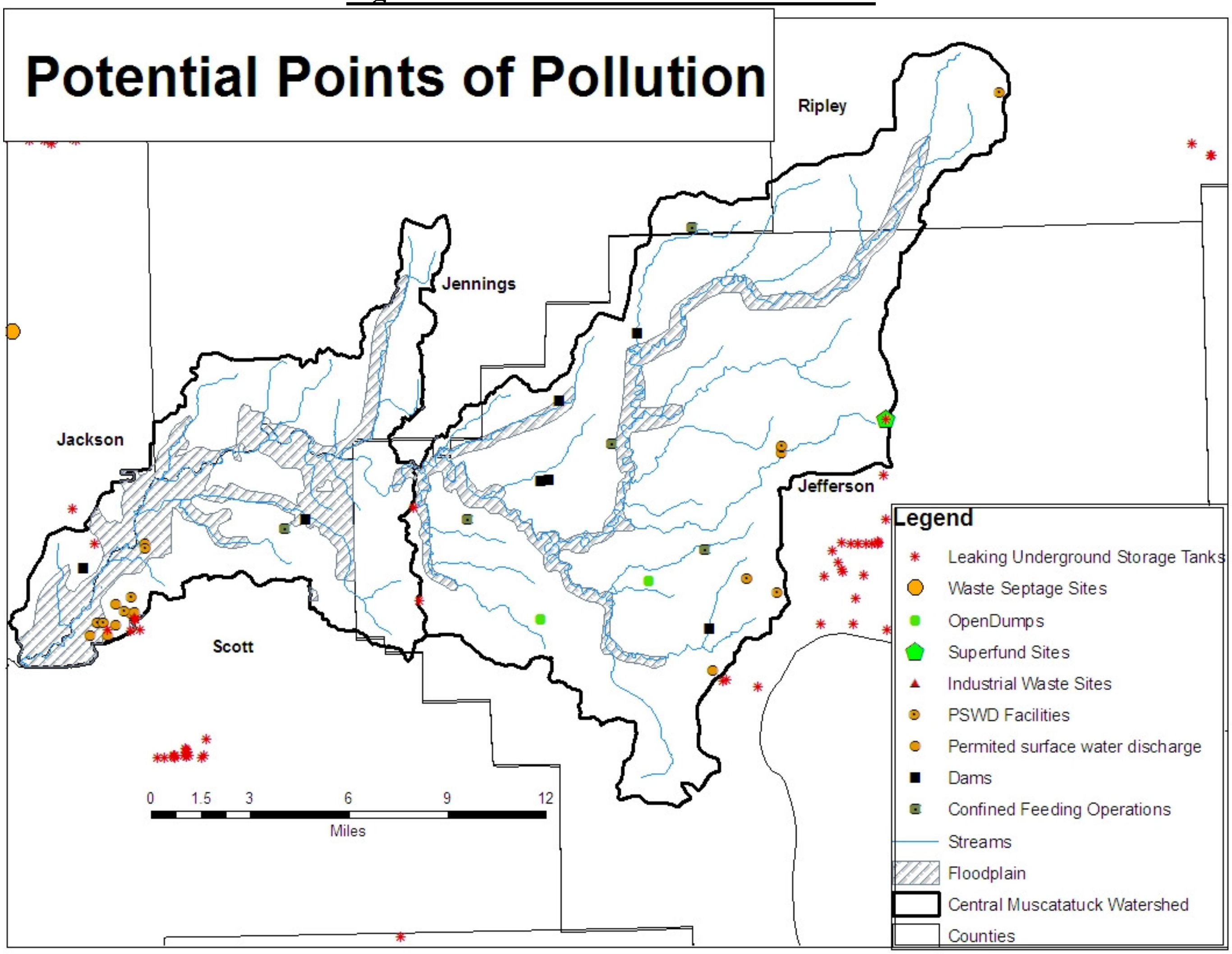
MP10

MP11

5.8 Potential Watershed Issue Sites

The figure 51 provides the location of potential problem area sites in the watershed taken from IDEM and GIS data sources. Potential pollution of area waterbodies are associated with these types of operation such as confined feeding operations, industrial waste sites, leaking underground storage tanks, open dumps and other discharge operations. All of these things are found in the CMW. Dammed water bodies present water quality concerns. Dammed lakes or ponds may contain sediment or pollution from various sources such as surrounding land owner practices (i.e. excessive fertilization) around the lake or recreation on the lake where pollution from the lake or pond is passed to the watershed through streams located downstream.

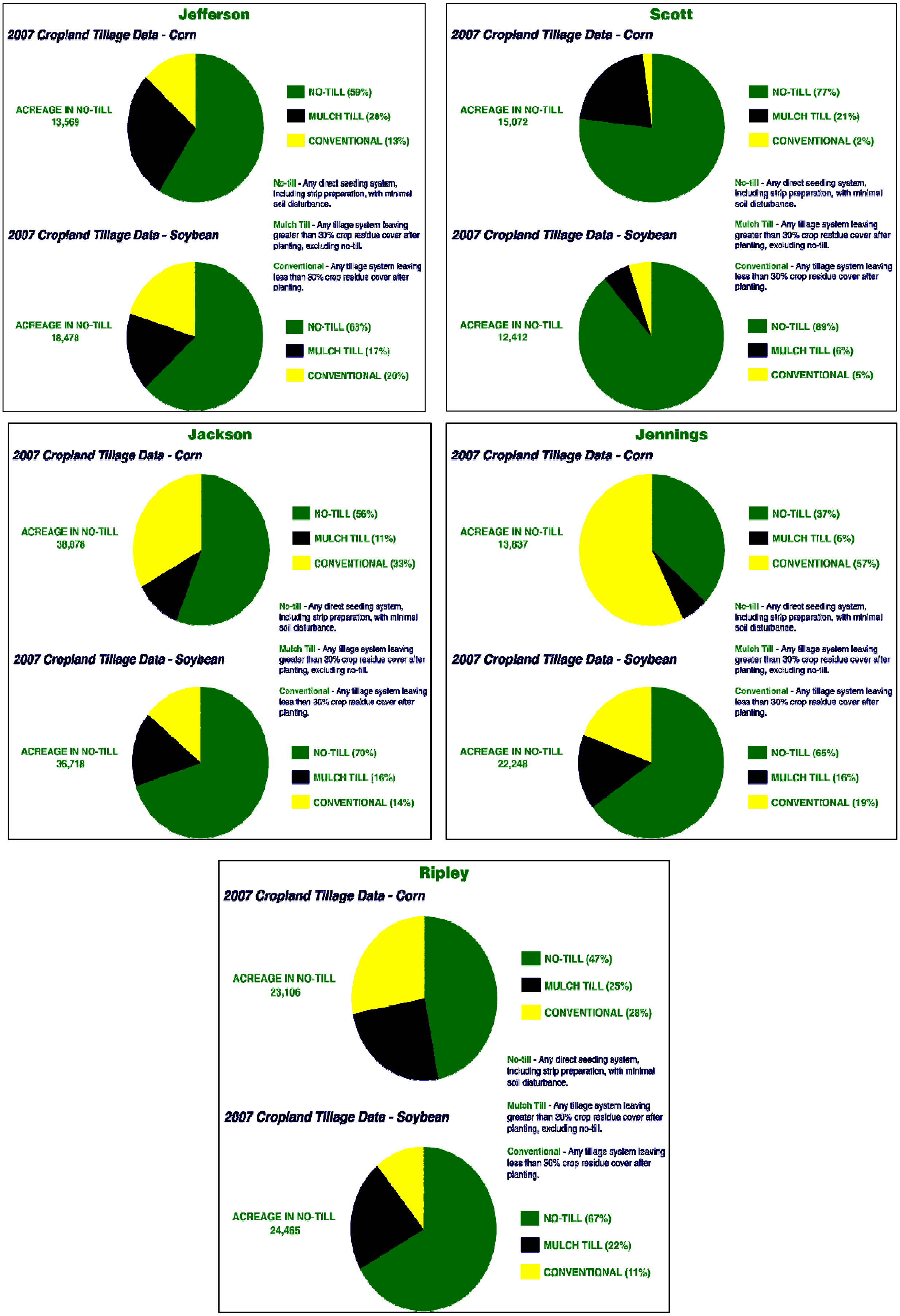
Figure 51: Potential Watershed Issue Sites



5.9 Conservation Tillage Data

How the land is tilled by landowners for crops may have a great impact on water quality in a watershed due to the amount of soil disturbed that can be washed into the nearby waterbodies causing sedimentation. Since the primary land use in the watershed is agriculture, the 2007 County Cropland Tillage Data has been included as a benchmark in figure 52. This data is collected on a regular basis and trends in this data can assist in determining target areas where conservation tillage is not commonly practiced as well as assist in the determination as to whether or not sedimentation issues could potentially be caused due to a lack of conservation tillage in a particular area.

Figure 52: County Cropland Tillage Data



5.10 Summary of Data

Overall the past and current water quality data presented for the CMW confirms consistent water quality issues. The Lower Muscatatuck River in the Jackson County area, Big Creek upstream from Walton Creek, Big Creek-Harberts Creek and Little Creek have been in the past (as shown by IDEM data presented from 2000-2007) and are presently identified (as shown by recent professional and volunteer data presented) as impaired for high *E. coli* levels. This is the reason for the listing of these creeks on IDEMs 305(b) and 303(d) Integrated Report Listings.

The professional, volunteer and headwaters water quality data provided confirmation of *E. coli* issues in the water bodies that are noted on IDEMs impaired waterbodies listings. The windshield data survey provided probable explanations for the elevated *E. coli* levels in the Harberts-Big Creek, Little Creek and Middle Fork Creek. These findings relatively coincide with the biological integrity scores provided during the professional monitoring with the lowest scores being in the Muscatatuck River, particularly downstream from Austin.

Agricultural land use within the watershed is prevalent. The Quick Creek/Hardy Lake Watershed Project confirmed nutrient loading and sedimentation water quality issues which are similarly identified during the CMWP windshield data survey. These are water quality issues associated with agricultural land use that were addressed in the smaller Quick Creek/Hardy Lake Watershed Project that will need to be addressed within the CMWP on a larger scale which could positively impact remaining issues within the Quick Creek/Hardy Lake Watershed.

Identifying Sources

This section discusses, confirms or dismisses, & identifies, the sources of the stressors, causes and concerns previously presented in section 3.

The validity of each cause and problem statement shown in figure 27, section 3 was discussed by the steering committee. The chart is presented again reflecting their validity determinations and each of the stressors will be further discussed. The statements that were not validated were researched and determined by the steering committee to not be a current problem within the CMW. However, as record of public concern, it was decided that they hold the potential to be valid in the future and remain in the plan as being noted and possibly researched and re-verified at a later point during the project.

6.1 Validity Determination of Stressors, Causes, and Problems

Figure 53: Validity Determination of Stressors, Causes, and Problems

Cause/Source (Activity/Behavior)	Stressor	Problem Statement	Concern Validated?	Specific Concerns Validated	Indicators	Benchmark/Baseline Data
Improper Storm Water Pollution Prevention	Sedimentation and Excess Nutrients	Contractors using inadequate erosion control practices on construction sites can lead to excess soil loss entering nearby waterbodies. Sedimentation can lead to increased turbidity which can increase water temperature through heat absorbed particles, thus lowering dissolved oxygen. Sediment may also kill aquatic life by clogging gills or smothering habitats. During and after rain events, improperly handled or excess manure from confined feeding operations can lead to excess nitrogen and phosphorous levels in nearby waterbodies which also impacts dissolved oxygen levels.	No	N/A	Turbidity Levels Nutrient Levels	There were no observed areas where contractors were using inadequate erosion control practices at construction sites. Presently, there is a limited amount of construction in the watershed. One area that may be of concern and warrants further investigation as the population grows and expands would be the Austin and Crothersville area within the 12 digit sub watershed 0512020709 where turbidity levels were higher than at other sites tested in the watershed. Through professional and volunteer sampling, excess nutrients were not found to be a major issue in the watershed at this time. Areas near confined feeding operations will continued to be monitored due to their inherent potential of negative impact to water quality if manure is improperly managed.

Cause/Source (Activity/Behavior)	Stressor	Problem Statement	Concern Validated?	Specific Concerns Validated	Indicators	Benchmark/Baseline Data
Lack of Riparian Buffers	Sedimentation and Excess Nutrients	Livestock with uncontrolled access to waterbodies, the lack of protective riparian groundcover, and the presence of log jams reduces stream bank stability and increases sediment in local waterbodies through stream bank erosion. Log jams can promote areas of pooling or standing water and can impede flow of a stream which could divert water and cause flash flooding.	Yes	• Soil Erosion • Pollution • Flash Flooding • Maintaining Biodiversity – streams/ wetlands • Healthy Water Ways for Recreation • Livestock • Standing Water • Log Jams • Stream Bank Erosion • Do people know how they affect their watershed? • Everyone knowing their watershed and protecting it • Public involvement • Safe and healthy water ways for recreation • Need more testing and Public Awareness	Stream bank Erosion Turbidity Levels	Primary evidence of the lack of riparian buffers was provided by the riparian buffer survey. This survey provided photographic evidence of erosion issues along Big Creek and the Muscatatuck River where riparian buffers were lacking. Erosion of the stream banks is readily visible in the photographs. During the kayak survey log jams were also noted and will continue to be monitored. At sampling sites along the Muscatatuck River where turbidity levels were recorded as being highest, there is also a lack of adequate riparian buffers.
Trampling of Banks from Livestock						Access of livestock to streams can cause damage and problems to stream banks that are not well vegetated. Hoof impacts can destroy stream bank vegetative cover and physically breakdown stream banks. These impacts occur when livestock traverse repeatedly or congregate in large numbers in a small area for water, shade, or other streamside attractions. Unstable stream banks easily wash into the stream. This causes sediment to be added to the water body and may lead to channel widening or down cutting. Channel widening and down cutting can result in more shallow and warmer streams which degrades aquatic habitat and may destroy important streamside wildlife habitat. Trampling of banks and areas near streams is especially detrimental where overgrazing of pastures and paddocks occurs and is another contributor to sedimentation that was noted in the 2008 windshield data survey. It was determined by the steering committee that patterns of overgrazing specifically continue to be monitored due to compounding negative impact regarding sedimentation. The windshield data survey documented cattle access to more than half of the creeks noted in the survey. Allowing livestock access to streams is a common agricultural practice in the area and the steering committee agreed that significant signs of bank erosion due to this practice, particularly where overgrazing was noted, were observed within the following 12 digit subwatersheds: 051202070104, 051202070105, 051202070601, 051202070603, 051202070602, and the Coffee Creek Watershed.

Cause/Source (Activity/Behavior)	Stressor	Problem Statement	Concern Validated?	Specific Concerns Validated	Indicators	Benchmark/Baseline Data
Lack of Conservation Tillage	Sedimentation and Excess Nutrients	Farmlands not using a high residue cropping system may cause an increase of sedimentation and excess nutrients in local waterbodies from storm runoff.	Yes	• Soil Erosion • Handling of Runoff • Pollution • Flash Flooding • Maintaining Biodiversity – streams/ wetlands • Sinkhole Pollution • No-Till Farming, Round-up ready herbicides • Pesticide Contamination • Buffers and Filter Strips • Row Crops • Standing Water • Log Jams • Cropland Productivity • Chemical Runoff • Stream Bank Erosion • Do people know how they affect their watershed? • Is the drinking water really clean? • Is the water healthy? • Education of children/public • Everyone knowing their watershed and protecting it • Public Involvement • Safe and Healthy Water Ways for Recreation • Need More Testing and Public Awareness	Turbidity	The Indiana cropland tillage data from 2007 for each county is provided in section 5. Due to the fact that parts of five different counties lie in the watershed, the data has been averaged to provide a general estimate of the amount of conservation tillage in the watershed. For corn the percentage where no-till cropping is used is 55%, mulch till is 18% and conventional tilling is 27%. For soybean the percentage where no-till cropping is used is 71%, mulch till is 15% and conventional till is 14%. Approximately 44.6% of the watershed lies in Jefferson County and the data shows that it has a median percentage rate of conventional tillage compared to the other counties for both corn and soybean. Jennings and Jackson Counties have the highest rate of conventional tillage for both corn and soybean. Scott County shows relatively low conventional tillage percentages, however, there remains a high rate of conventional tillage along the Muscatatuck River bottoms due to the fact that many producers in the area feel or express the necessity to break up flooded soils to break up cresting for successful yields. This is common for all counties along the main stem of the Muscatatuck River. Conventional tillage occurs in each county of the watershed statistically and has been observed through windshield data collection. Conventional tillage contributes to higher sediment and nutrient loading (where the soil being washed into the creeks has been fertilized) in nearby waterbodies. Overall, the lack of conservation tillage throughout the watershed can be identified as contributing to increased sedimentation in the watershed, as specifically observed in the Jackson County area where conventional tillage rates are high and turbidity rates were higher.

Cause/Source (Activity/Behavior)	Stressor	Problem Statement	Concern Validated?	Specific Concerns Validated	Indicators	Benchmark/Baseline Data
Improper Nutrient Management	Sedimentation and Excess Nutrients	Improper nutrient management on farmland and suburban lawns can lead to nutrient overload in nearby waterbodies which can lead to increased algal blooms, thus decreasing dissolved oxygen.	No	N/A	Nitrate Levels Phosphorous Levels	IDEM data showed that in 2002 Big creek had nitrate (NO_3) levels as high as 1.2mg/L and total phosphorus levels as high as 0.091 mg/L. Professional monitoring showed levels of nitrates as high as 2.17mg/L and total phosphates as high as 0.195 mg/L. Unprotected headwaters tested by Hanover College volunteers showed levels of orthophosphates as high as 10ppm and a very impaired benthic community. Phosphorous levels higher than 0.3ppm contributes to increased plant growth. Algal blooms have been noted by Hoosier Riverwatch volunteers in several streams. A high runoff rate within the floodplain along the main stem of the Muscatatuck River where conventional tillage is common practice would contribute to significant loadings of nitrogen and phosphorus, which can lead to eutrophication causing a decrease in dissolved oxygen and can lead to possible fish kills. Although some elevated levels of nitrates and phosphorous have been noted during certain sampling periods, overall improper nutrient management was determined to not be a major contributor, at this time, to degraded water quality in the CMW. Nutrients will continued to be monitored periodically to note any changes in nutrient levels indicating improper nutrient management that may be addressed at that time.
Increased Impervious Areas Malfunctioned Industrial Areas Fertilization of Suburban Lawns	Hazardous Chemicals (ie – oil, gas, pesticides, herbicides, heavy metals)	Hazardous chemical runoff from parking lots, roads, industrial buildings and suburban lawns entering local waterbodies increases pollutants harmful to aquatic and human life. Increased demand from residential and commercial development could lead to decreased water supplies. Heavy metals may be present in our water sources due to ammunition testing from the former U.S. Army Jefferson Proving Grounds and other industrial activities.	No	N/A	Pesticide & Herbicide Levels Presence of Macroinvertebrate Species	The steering committee discussed impervious areas, malfunctioned industrial areas, suburban lawn application, and improper application of herbicides and pesticides. In regards to improper application of herbicides and pesticides it was specifically concluded by the steering committee that due to the current price of herbicides and pesticides, users of these chemicals were more than likely adhering to proper application amounts. Generally, it was the committee's consensus that presently none of these issues were identified currently as major problems within the watershed. The Central Muscatatuck Project did not conduct testing within the water quality sampling to be able to identify these problems. Preliminary benchmark data was presented regarding the USFWS study of heavy metals on Big Oaks National Wildlife Refuge. The steering committee will continue to consider and become updated with further investigation regarding these levels and impacts on water quality in the watershed.
Improper Application of Herbicides and Pesticides		Improper application of agricultural chemicals may enter waterbodies through runoff and lead to endocrine/hormone disruption.				

Cause/Source (Activity/Behavior)	Stressor	Problem Statement	Concern Validated?	Specific Concerns Validated	Indicators	Benchmark/Baseline Data
Combined Sewer Overflows	*E. coli*	An increase in population will lead to more wastewater, which could result in more sewer overflows during rain events.	No	N/A	*E. coli* Levels Phosphorous Levels	It was documented in the windshield data survey that sewage within the residential and industrial areas (previously military buildings) of the old Jefferson Proving Grounds often backs up. It then flows out of combined sewer overflows during storm events which may be a contributing factor to nearby Middle Fork Creek watershed. Overall, the steering committee did not deem this as a prevailing issue at the present time due to current population levels. It is felt that parts of Austin may become a contributor to watershed *E. coli*, but not specifically within the watershed.
Failing or Lack of Septic Systems	*E. coli*	The CMW soils are not conducive to septic systems. This causes systems to fail and pathogens from human waste to enter waterbodies. These pathogens may cause digestive and other health problems in humans. Improper maintenance of septic systems leads to failure causing pathogens to enter nearby waterbodies and leading to health problems in humans.	Yes	• Handling of Runoff • Pollution • *E. coli* • Healthy Water Ways for Recreation • Septic Tank Runoff • Urban Development • Do people know how they affect their watershed? • Is the drinking water really clean? • Is the water healthy? • Education of children/public • Everyone knowing their watershed and protecting it • Public Involvement • Safe and Healthy Water Ways for Recreation • Need More Testing & Public Awareness	*E. coli* Levels Phosphorous Levels	Failing septic systems or lack of any system have been documented by the Jefferson and Scott County Health Departments. The health departments have documented discharging into the nearby tributaries that drain into the Muscatatuck River. In the Little Creek watershed, the town of Kent was observed to have a ditch system that carries raw sewage and black water from residential houses without septic systems, directly to the creek. A similar circumstance in the town of Deputy may be an additional contributor of *E. coli* to the Lewis Creek watershed. According to available data the steering committee recognized Failing or lack of septic systems as one of the two major contributers to high *E. coli* levels in the watershed.

Cause/Source (Activity/Behavior)	Stressor	Problem Statement	Concern Validated?	Specific Concerns Validated	Indicators	Benchmark/Baseline Data
Livestock Access to Streams	*E. coli*	Livestock with uncontrolled access to waterbodies may lead to an increase in pathogens from animal waste which can result in digestive and other health problems for humans.	Yes	• Handling of Runoff • Pollution • *E. coli* • Healthy Water Ways for Recreation • Buffers and Filter Strips • Livestock • Do people know how they affect their watershed? • Is the drinking water really clean? • Is the water healthy? • Education of children/public • Everyone knowing their watershed and protecting it • Public Involvement • Safe and Healthy Water Ways for Recreation • Need More Testing and Public Awareness	*E.coli* Levels Phosphorous Levels	Based on the USDA quick stats data there are a total of 11,100 head of cattle within Jefferson County; of which approximately 4,950 are estimated to be within the watershed. The water quality data indicates that high *E. coli* levels are found within the same region where high numbers of cattle with access to the stream have been observed. During the windshield data survey conducted in 2008, visual observations of cattle access to creeks were noted in; Camp Creek, Harberts Creek, Little Creek, Neils Creek, Lewis Creek and Coffee Creek. According to available data the steering committee recognized livestock access as one of the two major contributers to high *E. coli* levels in the watershed.
Increased Impervious Areas	Elevated Water Temperature	Runoff from impervious areas and discharge from industrial buildings may cause an increase of temperature, lowering dissolved oxygen levels in nearby waterbodies	No	N/A	Water Temperature/ Dissolved Oxygen Levels Phosphorous Levels	The steering committee found that impervious areas were not presently a major current concern within the watershed. Although, they did recognize that the 12 digit sub watersheds of 051202070606 with the towns of Austin & Crothersville & 051202070601 with the bordering town of Hanover posing a potential for growth and high road travel into Madison along 256 and 56.
Non-conforming Industrial Areas			No	N/A		The 12 digit sub watersheds of 051202070606 and 051202070103 were identified as possible concern areas for future malfunctioned industrial areas; the factories in Austin & the operations of the former Jefferson Proving Grounds now the Big Oaks Wildlife Refuge by the steering committee. However, no recent data shows any current documented threat from malfunctioned industrial areas.

Cause/Source (Activity/Behavior)	Stressor	Problem Statement	Concern Validated?	Specific Concerns Validated	Indicators	Benchmark/Baseline Data
Lack of Forested Areas Lack of Riparian Buffers	Elevated Water Temperature	The lack of protective riparian canopy from tree cover and lack of stream buffers may increase water temperature in local streams	Yes	• Soil Erosion • Flash Flooding • Maintaining Biodiversity in and near Streams and Wetlands • Healthy Water Ways for Recreation • Buffers and Filter Strips • Logging and Forestry • Livestock • Row Crops • Log Jams • Cropland Productivity • Urban Development • Stream Bank Erosion • Do places like the Power Plant affect the watershed? • Do people know how they affect their watershed? • Is the drinking water really clean? • Is the water healthy? • Education of children/public • Everyone knowing their watershed and protecting it • Public Involvement • Safe and Healthy Water Ways for Recreation • Need More Testing and Public Awareness	Water Temperature/ Dissolved Oxygen	The major cause of elevated water temperatures is identifited to be lack of forested areas and lack of riparian buffers. Approximately 36% of the watershed is forested, however, a major portion of this percentage is concentrated in the Big Oaks National Wildlife Refuge area. Large sections along the Muscatatuck River and its tributaries are unbuffered and allow for elevated levels of sediment and lack of shade from trees. These conditions can cause low levels of dissolved oxygen; values as low as 4.0 ppm in the main stem of the Muscatatuck River have been reported.

Cause/Source (Activity/Behavior)	Stressor	Problem Statement	Concern Validated?	Specific Concerns Validated	Indicators	Benchmark/Baseline Data
Lack of Riparian Buffers and Headwaters Protection	Increased Flow Rate	An increase of impervious and limited riparian buffer areas reduces groundwater recharge, which increases flow rate, causing streams to flood more frequently and banks to erode quicker.	Yes	• Flash Flooding • Buffers and Filter Strips • Row Crops • Cropland Productivity • Stream Bank Erosion • Do people know how they affect their watershed? • Is the drinking water really clean? • Is the water healthy? • Education of children/public • Everyone knowing their watershed and protecting it • Public Involvement • Safe and Healthy Water Ways for Recreation • Need More Testing and Public Awareness	Flow Rate	The initial cause of increased flow rate, according to public concern, was identified as being non-conforming industrial areas. It was determined, upon review of land use data, water quality data, and the headwater study data provided by Hanover College students, the more probable cause of incresed flow rate is the lack of riparian buffers and lack of headwater protection. In addition to the limited riparian buffers throughout the watershed, it is also believed that the more dramatic topography of the Big Oaks National Wildlife Refuge area where a large area of headwaters are located is noted as a contributor to the increased flow rate.

Cause/Source (Activity/Behavior)	Stressor	Problem Statement	Concern Validated?	Specific Concerns Validated	Indicators	Benchmark/Baseline Data
Improper Trash Disposal	Illegal Dumping of Trash	Improper disposal of garbage in parks, river, roadsides, sink holes, and other areas causes unsightly views and health risks for humans and aquatic life.	Yes	• Trash Dumped into Water • More Enforcement of Public Dumping Laws • Pollution • Healthy Water Ways for Recreation • Sinkhole Pollution • Buffers and Filter Strips • Do people know how they affect their watershed? • Is the drinking water really clean? • Is the water healthy? • Education of children/public • Everyone knowing their watershed and protecting it • Public Involvement • Safe and Healthy Water Ways for Recreation • Need More Testing and Public Awareness	Visual Observation	Improper dumping of trash is observed and is a widespread problem throughout the watershed with bridges and county roads being an easy target. The bottom lands of the Muscatatuck River and west of Austin has a particular problem with dumping; there are many side roads that lead to the river that allow for easy dumping access. Karst topography and sink holes were also identified by the steering committee as key areas for illicit dumping.

Some of the initial specific concerns stated in figure 27, were not carried forward due to no specific data supporting the concern being found at the present time. For example, drinking water quality was not identified specifically as a current issue during the course of data collection for the management plan. The steering committee did not carry these concerns forward in the management plan; however, they remain in the initial section of the plan as record, for future consideration and possible validation.

Identifying Critical Areas

This section provides information on estimated existing loads for pollutants to assist with prioritization. It then provides information on targeted areas within the watershed where stressors are causing the most damage, and where applying treatment measures will have the greatest effect.

7.1 Load Statistics & Calculations

Estimated load reductions for the management measures identified in this plan are required by the Section 319 grant in order to obtain cost-share funding for implementation. This is to provide baseline current load concentrations in order to gauge estimated pollutant load reductions that may result from implementation of best management practices discussed within this watershed management plan. Complete data for the sampling used in calculations in figure 54 below may be found in Appendix B – Professional Data Testing Results. State standards and recommended guidelines were utilized to determine the target load amounts of pollutants the stream can absorb under average flow conditions and meet state water quality standards.

Figure 54: Water Quality Standards and Targets

Parameter	Target Concentration
TSS*	< 80 mg/L
N**	< 10 mg/L
P*	< 0.3 mg/L
*E. coli****	< 235 cfu/100 ml

* Recommended guidelines
** State standard for nitrate/nitrogen in drinking water
*** State standard for *E. coli* (single sample)

7.1.1 Nutrient Concentrations

The following nutrient concentrations were collected on a bi-monthly basis over a 12 month period. The values in the following figure include the average concentration and the maximum concentration taken during the testing period. Concentrations highlighted in red indicate values over the recommended state target concentrations.

Figure 55: Existing Load Data - Average and High Concentrations

	Nitrogen Concentration (mg/L)		Phosphorous Concentration (mg/L)		E. Coli Concentration (colonies/100ml)	
	Average	High	Average	High	Average	High
PS1	1.47	2.27	0.06	0.12	658.13	1986
PS2	0.80	2.06	0.04	0.06	554.09	2419
PS3	0.93	1.96	0.04	0.07	61.92	161
PS4	0.71	1.20	0.03	0.04	57.94	129
PS5	0.40	0.70	0.04	0.16	70.97	225
PS6	0.61	1.30	0.05	0.07	109.04	345
PS7	0.64	1.31	0.06	0.11	84.36	148
PS8	0.77	1.76	0.05	0.14	92.69	194
PS9	0.71	2.02	0.04	0.07	123.00	219
PS10	0.54	1.55	0.03	0.04	150.16	816
PS11	0.75	1.50	0.05	0.07	199.80	517
PS12	0.81	1.76	0.07	0.12	137.77	238
PS13	0.54	1.20	0.16	0.29	417.10	1203
PS14	0.29	1.03	0.04	0.09	288.96	1203
PS15	0.83	2.08	0.04	0.09	125.40	411
			Exceeds Indiana Average - 0.05 mg/L		Exceeds Indiana Target - <235 CFU/100 ml	

Existing loads were calculated using recent professional water quality monitoring data and IDEM's Load Calculation Tool. [29] The calculation is based on the amount of the pollutant presence taken in the water sample, the flow of the river at the time of the sample and the target concentration. Based on existing load data, reductions were warranted for *E. coli* levels in the watershed. There were a number of sites where one or more samples exceeded target loads and the calculated load reduction for the sample that exceeded the target load is reflected.

Nutrient concentration sample results did not exceed state water quality standards or targets for nitrogen or phosphorus. Some levels of phosphorous were above the Indiana average. Test sites where *E. coli* levels exceeded state standards were located along Big Creek and the Lower Muscatatuck River.

Professional water quality monitoring provides data to calculate existing loads; however, a limitation of this data is that it provides only a snapshot of chemistry data. Although the data presented shows nutrient concentration levels primarily below target loads, it is possible that this may be attributed to testing parameter error and/or due to the fact that this data only represents conditions at specific testing site for a specific duration, in other words, snapshots of data. Overall, the data representing areas where load reductions are warranted for *E. coli* is consistent with IDEM's 2006 impaired waterbodies listings.

Figure 56: Existing Load Data – Average Estimated Pollutant Load Based on Stream Flow

	Nitrogen Concentration (mg/L)	Phosphorous Concentration (mg/L)	E. Coli Concentration (colonies/100ml)	N Current Load ton/yr	P Current Load ton/yr	E. Coli Current Load cfu/yr	Average Stream Flow cf/second
PS1	1.47	0.06	658.13	12.06	0.36	3.95E+13	6.7
PS2	0.80	0.04	554.09	4.58	0.13	4.96E+12	4.0
PS3	0.93	0.04	61.92	3.05	0.10	4.47E+11	2.8
PS4	0.71	0.03	57.94	26.16	7.00	2.21E+12	33.4
PS5	0.40	0.04	70.97	2.16	0.50	3.02E+12	5.9
PS6	0.61	0.05	109.04	7.55	0.80	5.29E+12	15.1
PS7	0.64	0.06	84.36	1.56	0.12	4.02E+12	1.9
PS8	0.77	0.05	92.69	19.63	0.85	2.03E+12	38.3
PS9	0.71	0.04	123.00	34.52	2.11	2.25E+13	47.3
PS10	0.54	0.03	150.16	2.32	0.18	4.81E+11	5.6
PS11	0.75	0.05	199.80	110.60	6.13	4.55E+13	129.7
PS12	0.81	0.07	137.77	117.66	8.38	4.89E+13	145.4
PS13	0.54	0.16	417.10	69.04	17.39	3.95E+14	154.7
PS14	0.29	0.04	288.96	0.93	3.62	3.26E+12	6.3
PS15	0.83	0.04	125.40	26.17	0.14	3.48E+12	4.0

[29] Indiana Department of Environmental Management, Load Calculation Tool, http://www.in.gov/idem/files/319_load_calculation_tool.xls.

Figure 57: Reductions needed to meet standard

	E. Coli Concentration % Load Reduction
PS1	88.20%
PS2	90.30%
PS3	
PS4	
PS5	
PS6	31.80%
PS7	
PS8	
PS9	
PS10	71.20%
PS11	54.60%
PS12	19.20%
PS13	80.50%
PS14	80.50%
PS15	42.80%

7.2 Long Term Hydrologic Impact Assessment (L-THIA)

Estimates were developed using Purdue University's Long-Term Hydrologic Impact Assessment model (L-THIA)[30], in order to gain more specific information regarding geographic sources and potential impacts of pollutant loading in the watershed. This tool assists in evaluating likely effects of land use change and assists in identifying impacts to the natural environment. The model estimates run off volume and pollutant concentrations based on soil characteristics, land use, climate and rainfall data.

According to the L-THIA models the main land use for the CMW is agriculture which is 58.22% of the total watershed. Pasture/Grassland comprises 15.32% and row crop comprise 42.90% of the agricultural land usage in the watershed. Deciduous, evergreen, or mixed forest or shrub land is the second highest land use in the watershed at 32.68%. These land uses account for the majority, more than 90%, of the land use within the watershed. Approximately 7% of the land in the watershed is water or wetland and approximately 2% represents developed land with the majority of this percent being low density urban areas.

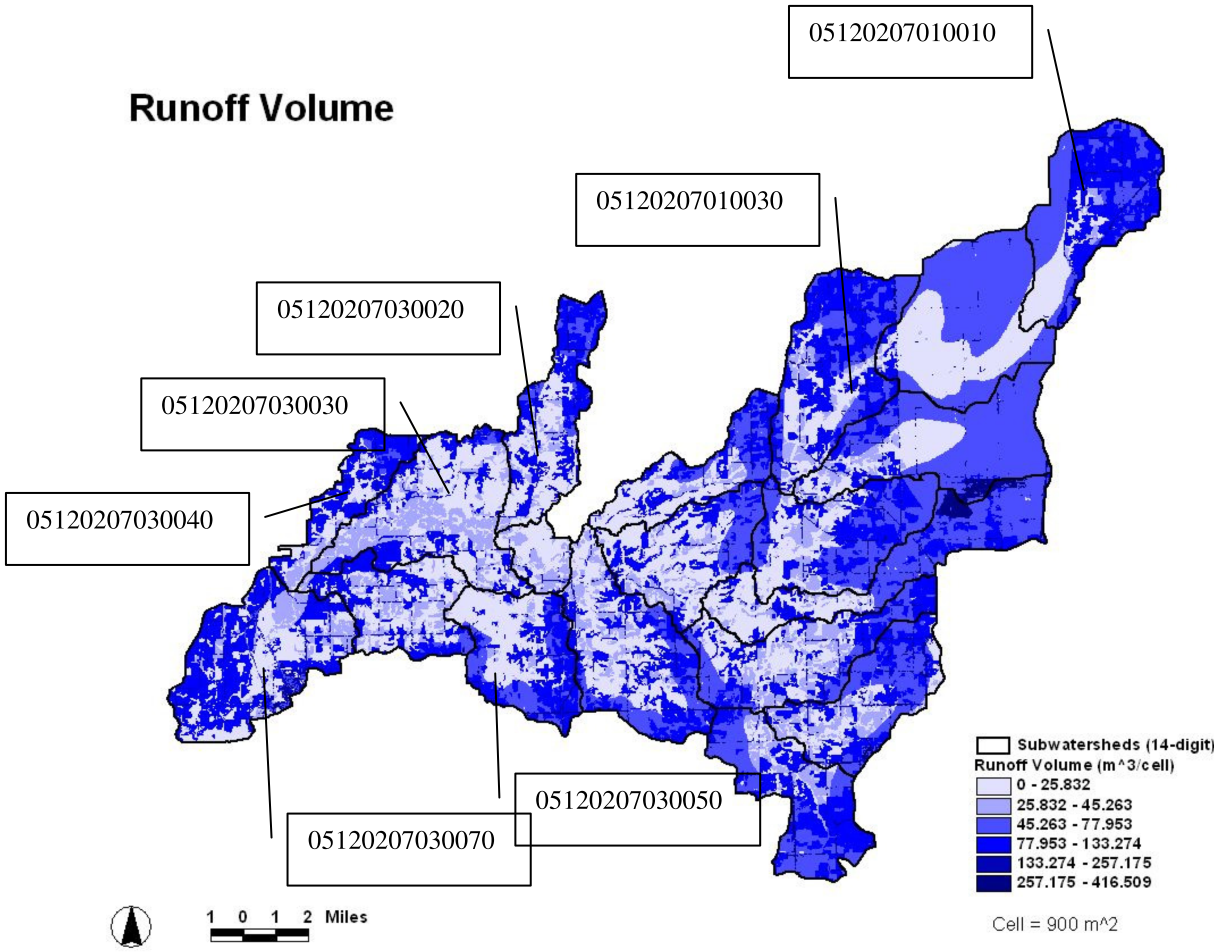
The L-THIA models for total phosphorous, nitrogen, total suspended solids and run off volume are presented in this section along with figures representing the information. Full L-THIA model data may be found in Appendix E.

[30] Long Term Hydrologic Impact Assessment Tool, Purdue University. Online Watershed Delineation; http://www.ecn.purdue.edu/runoff/lthianew/

7.2.1Run Off Volume

Due to the limited amount low and high density urban developed land, run off volume due to impervious surfaces is, overall, not estimated to be an issue in the watershed at this time and is shown on the L-THIA model in figure 58.

<u>Figure 58: L-THIA Model – Run Off Volume</u>

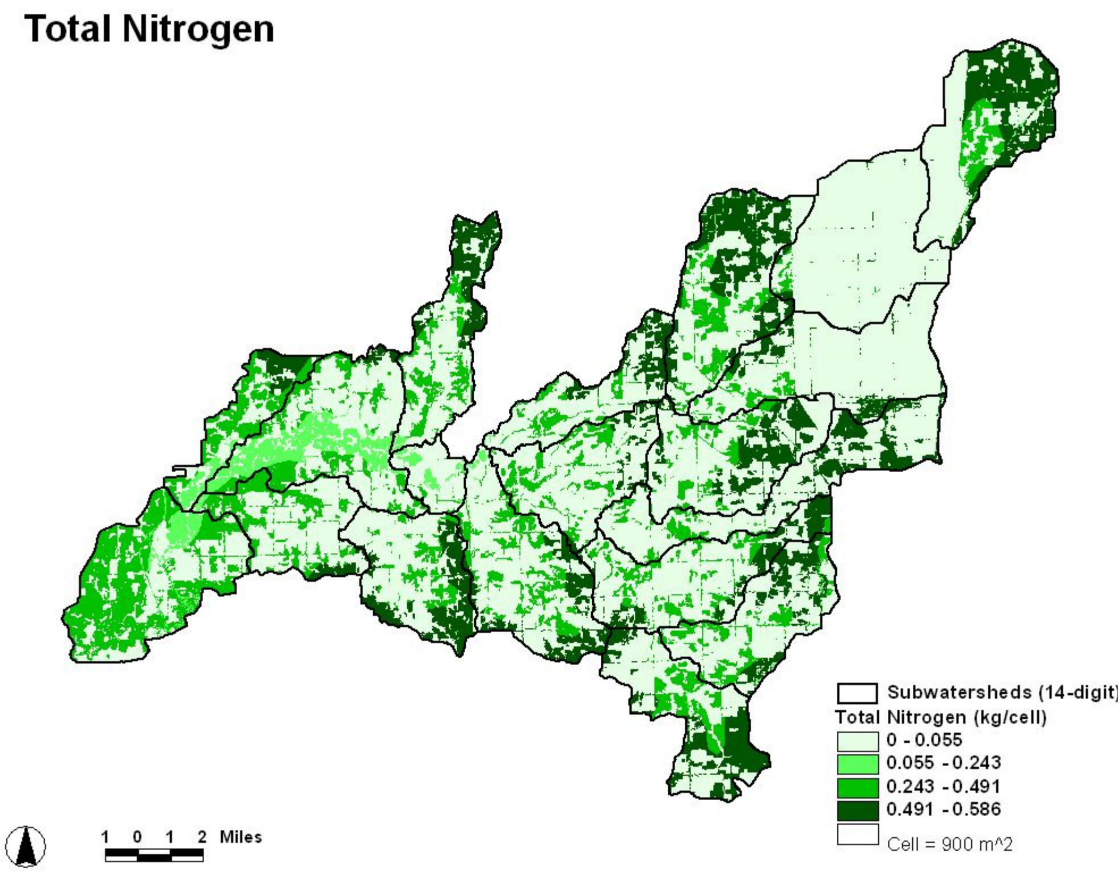


Based on the L-THIA models, the critical area locations for elevated levels of total phosphorous and TSS are 14 digit sub watersheds, 05120207010010, 05120207010030, 05120207030020, 05120207030030, 05120207030040, 05120207030050, 05120207030070. These same sub watersheds did not have levels of total nitrogen that exceeded the Indiana Water Quality Standard, however, they did have the highest levels of total nitrogen in the watershed. Agriculture crop land use is the primary, consistent land use association with the critical areas based on the L-THIA models. The impacts of agricultural land use in the above listed sub watersheds coincides with the professional and volunteer water quality data, windshield survey data and IDEM impaired waters listing to identify the critical areas of the watershed.

7.2.2 Nitrogen

The highest estimated L-THIA nitrogen loads are in the sub watersheds where the percentage of row crop land use is at least 40-50%. The sub watersheds with the highest estimated nitrogen loads correspond to the counties, Jennings, Jackson and Ripley, with greater percentages of conventional tillage as shown in the cropland tillage data in section 6. Agriculture is the main contributor to nitrogen loads throughout the watershed. The overall watershed average for nitrogen concentration in runoff is 2.66 mg/L. The Indiana Water Quality Standard is less than 10 mg/L and the model shows that levels do not presently exceed this standard.

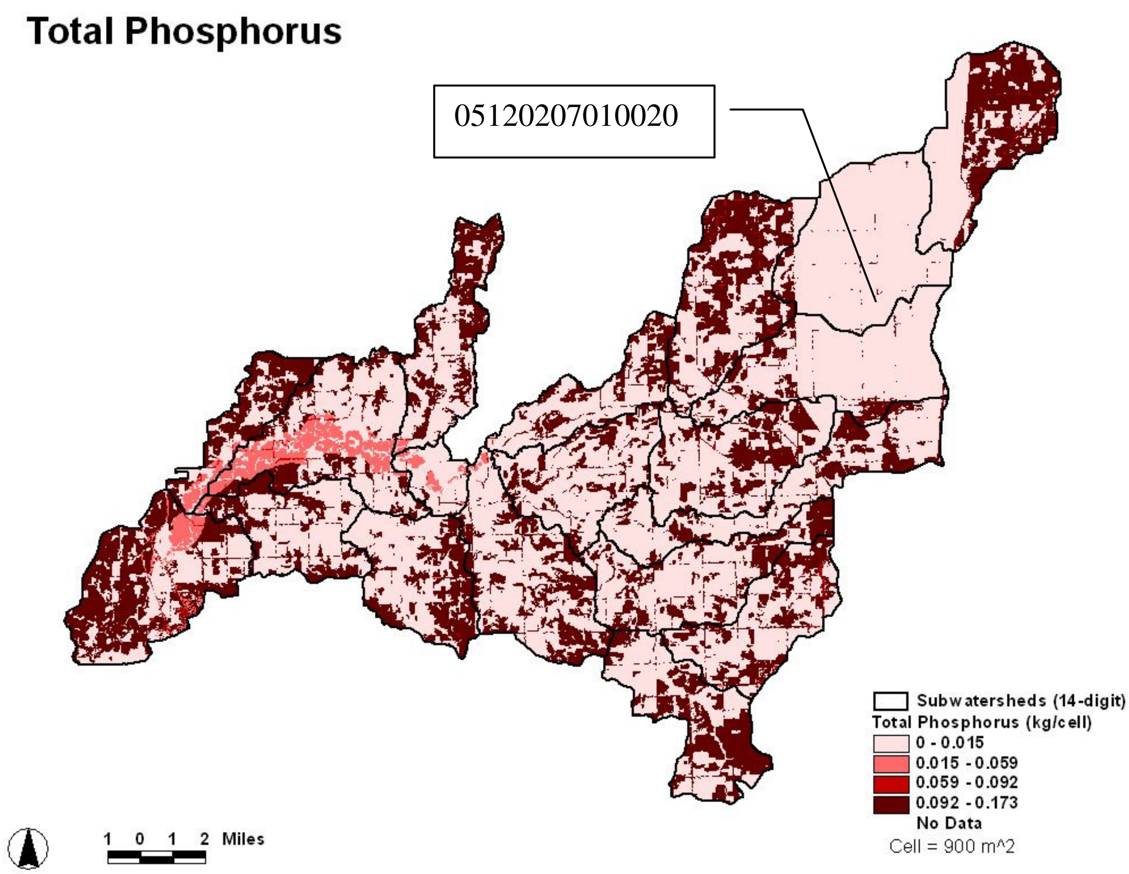
Figure 59: L-THIA Model - Nitrogen



7.2.3 Phosphorous

The highest phosphorous L-THIA estimates directly reflect a very similar sub watershed pattern as the nitrogen load model reflected. The highest estimated phosphorous loading areas in the watershed are, again, where the percentage of row crop land use is highest. Agricultural land use is the primary cause for increased loading of phosphorous throughout the watershed. The overall watershed average for estimated phosphorous concentration in runoff is 0.72 mg/L. The Indiana Water Quality target for phosphorous is less than 0.3 mg/L and the model shows that all but sub watershed 05120207010020, exceeds this standard.

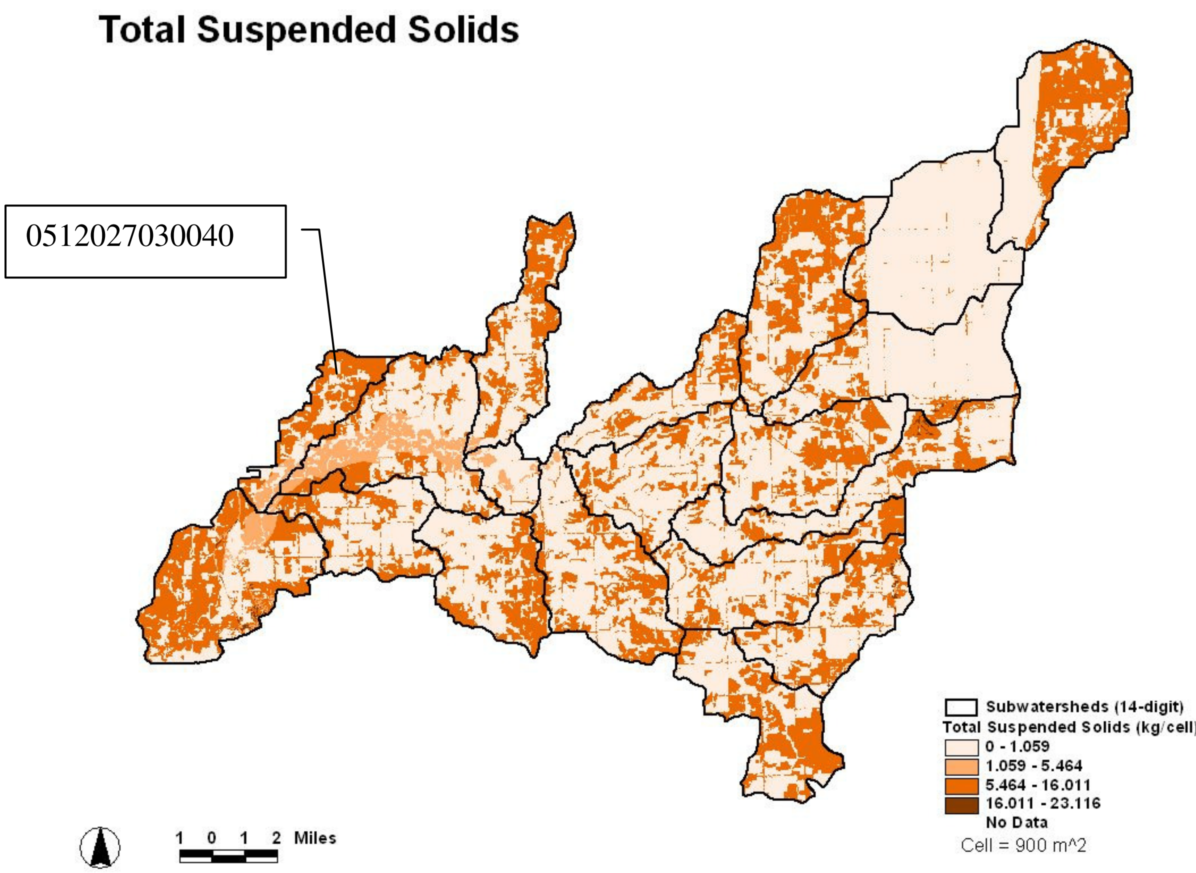
Figure 60: L-THIA Model - Phosphorous



7.2.4 Total Suspended Solids (TSS)

For the highest L-THIA estimated TSS loads, there is little variation from the agricultural based sub watersheds noted for the highest nitrogen and phosphorous loading. TSS pollutant loads in the watershed are directly related to the sub watersheds where agricultural land use is the primary land use. The watershed average for TSS concentration in runoff is 58.91 mg/L. The project target for TSS is 80 mg/L or less. The model shows that sub watershed 0512027030040 exceeded this standard and there were six other sub watersheds 11 mg/L or less below the standard.

Figure 61: L-THIA Model – Total Suspended Solids



7.3 Critical Area/Issue Designations

A number of water quality issues have been confirmed throughout this plan. The following critical area/issue designations were identified by analyzing all collected project data, current geological data, IDEM, USDA, committee knowledge, and windshield survey data within the watershed to determine the issues and areas that are most critical in the watershed and that are feasibly able to be addressed within the scope of 319 grant implementation funding.

The steering committee prioritized the following critical area/issue designations, which are presented in order of their priority, through discussion, their knowledge and analysis of the compiled project data. It is not the steering committee's intention that critical area/issue designations preclude all other best management practice measures within the watershed in non-critical areas/issues, should opportunities arise that would improve the health of the watershed, upon situational review. However, implementation funding and efforts will be primarily focused and ranked on the following main, specific critical area/issue designations within the watershed:

Figure 62: Critical Area/Issue Designations

Cause/Source (Activity/Behavior)	Indicators	Benchmark/Supporting Data Sources	Critical Area/Issue	High Priority Locations In watershed
Trampling of Stream Banks from Livestock	Stream Bank Erosion	Windshield Data Survey	Cattle access to creeks was observed in more than ½ of the creeks in the survey	Priority locations to reduce trampling of banks by livestock are the following 14 digit subwatersheds: 05120207010030-Camp Creek-Big Creek 05120207010060-Harberts Creek-Big Creek 05120207010070-Little Creek-Headwaters 05120207010080-Ramsey Creek 05120207010090-Little Creek-Chicken Run 05120207010100-Big Creek-Walton Creek 05120207010110-Neils Creek 05120207010120-Big Creek/Lewis Creek 05120207030020-Coffee Creek
	Turbidity Levels	Professional& Volunteer Water Quality Monitoring	Turbidity levels, indicating sedimentation, were greater at the lower Muscatatuck River testing sites resulting from upstream cattle access to tributaries	
Livestock Access to Streams	*E. coli* Levels	Professional & Volunteer Water Quality Monitoring	There were a number of sites where the state water quality *E. coli* levels were exceeded during professional and volunteer water quality monitoring.	Based on collected project data, the steering committee recognized livestock access to streams as a major contributer to elevated *E. coli* levels in the watershed. Due to the nature of the impact of this source and that it is a widespread issue, the source itself is considered critical. The critical location is: Anywhere in the watershed where cattle have access to creeks.
		IDEM Impaired Waterbodies Listing	The primary 2006 IDEM 303d impairment for waterbodies in the watershed was due to *E. coli.*	
		Windshield Data Survey	During the windshield data survey conducted in 2008, some specific visual observations of cattle access to creeks were noted in; Camp Creek, Harberts Creek, Little Creek, Neils Creek, Lewis Creek and Coffee Creek.	

Cause/Source (Activity/Behavior)	Indicators	Benchmark/Supporting Data Sources	Critical Area/Issue	High Priority Locations In watershed
Lack of Conservation Tillage	Conventional Tillage Percentages	ISDA 2007 Tillage Data	• 2007 Conventional tillage percentage rates for corn are: Jackson – 33% Jennings – 57% Ripley – 28% • 2007 Conventional tillage percentage rates for soybean are: Jefferson – 20% Ripley – 28% Jennings – 19% Jackson – 14% There are large percentages of conventional tillage within the watershed that contributes to and promotes erosion, sedimentation during runoff which increases turbidity levels in nearby creeks.	Priority locations for lack of conservation tillage are the following 12 digit HUCs: 051202070605-Coffee Creek/Muscatatuck River 051202070606-Dean Ford's Ditch/Muscatatuck 051202070604-Quick Creek/White Oak Branch 051202070601-Little Creek
	Observed Sedimentation	Windshield Data Survey	Conventional tillage was observed in each county of the watershed. Sediment can be observed in the Muscatatuck River after periods of rain and storm events Conventional tillage was observed as the primary method used in the floodplains or "bottoms" along the Muscatatuck River in Scott, Jefferson and Jackson Counties	
	Chemical Data Levels	Professional water quality monitoring	There were areas where turbidity and total suspended solids levels were higher than in the rest of the watershed and where the dissolved oxygen levels were lower due to sediment run off from conventionally tilled fields.	

Cause/Source (Activity/Behavior)	Indicators	Benchmark/Supporting Data Sources	Critical Area/Issue	High Priority Locations In watershed
Lack of Riparian Buffers and Forested Areas	Stream Bank Erosion	Windshield Data Survey Riparian Buffer Survey	The major cause of elevated water temperatures is identifited to be lack of forested areas and lack of riparian buffers. Large sections along the Muscatatuck River and its tributaries were observed as unbuffered. Stream bank erosion was readily visible in many of these areas.	Priority locations for lack of riparian buffers are the following 12 digit HUCs: 051202070601-Little Creek 051202070602-Lewis Creek 051202070604-Quick Creek/White Oak Branch 051202070605-Coffee Creek/Muscatatuck River 051202070606-Dean Ford's Ditch/Muscatatuck 051202070101-Headwaters/Big Creek 051202070104-Camp Creek/Big Creek
	Increased Flow Rate	Headwaters Study	The probable cause of incresed flow rate is the lack of riparian headwater protection and the more dramatic topography of the Big Oaks National Wildlife Refuge area where a large area of headwaters are located is noted as a contributor to the increased flow rate.	
	Increased Flow Rate Elevated Water Temperature/Low Dissolved Oxygen Levels	Professional Water Quality Monitoring	These conditions can cause low levels of dissolved oxygen; values as low as 4.0 ppm in the main stem of the Muscatatuck River have been reported.	
	Observed Lack of Stream Bank Buffers	Aerial Imagery Photograph Analysis	Review of USGS aerial imagery shows very poor buffering along the main stem of the Muscatatuck River.	
Failing or Lack of Septic Systems	*E. coli* Levels	Professional and Volunteer Water Quality Monitoring 2006 IDEM Impaired Waterbodies 303d List	Although comprehensive, costly testing is required to fully determine the source of *E. coli* when elevated levels are detected, it is known that high levels of *E. coli* are present in the watershed.	Combining the testing and IDEM data with health department advisement areas for concern for lack or Failing or lack of septic systems with the windshield data, the following 12 digit sub watershed locations are designated to be critical for septic system issues contributing to *E. coli* levels in the watershed: 051202070103-Middle Fork Creek 051202070601-Little Creek 051202070602-Lewis Creek 051202070606-Dean Ford's Ditch/Muscatatuck
	County Health Department Advisements	Windshield Data Survey	Soil types, lot sizes & location of some towns in the watershed limit development of proper functioning septic systems. The health department and windshield data survey identified the towns of Kent, Austin and Deputy and areas of the former Jefferson Proving Grounds property for lacking appropriate septic systems & noted as having some sewage drained directly to nearby waterbodies.	

Cause/Source (Activity/Behavior)	Indicators	Benchmark/Supporting Data Sources	Critical Area/Issue	High Priority Locations In watershed
Illegal Dumping of Trash	County Health Department Advisements	Windshield Data Survey & River/Lake Clean-up Statistics	Illicit dumping of garbage causes debris to enter waterways. It is an unsightly and damaging form of pollution. The items that are illegally dumped may contain damaging pollutants that may seep into the waterways. Debris can also cause storm drains and waterways to clog and water to flow over areas it is not intended to flow and/or lead to flooding. Karst topography and sink holes were also identified by the steering committee as common areas for illicit dumping.	The bottom lands of the Muscatatuck River have been noted specifically during the 2008 and 2009 windshield data survey for having many areas where illegal dumping is commonly and easily visible. The following 12 digit sub watershed, primarily located in Jackson County, is considered critical for illegal dumping of trash, however, it is a widespread issue that will be addressed wherever it is found throughout the watershed and specifically karst areas which are found throughout the watershed. 051202070606 – Dean Ford's Ditch/Muscatatuck River

Applying Measures

This section describes what needs to be implemented or changed to achieve the goals of the CMWP Management Plan using BMPs.

8.1 Best Management Practices (BMP)

The CMW Technical Steering Committee reviewed the water quality data and the critical areas/issues designated by the steering committee. The watershed data was considered in regards to the current watershed land uses and the steering committee agreed upon the following BMPs that would improve water quality in the watershed and would be offered to land owners during an implementation period. The following BMPs in this section are the applicable implementation items to be installed according to NRCS guidelines and specifications as outlined in the Field Office Technical Guide (FOTG).[31] For each critical area/issue, the applicable BMPs have been decided upon by the technical steering committee and each practice is explained further and referenced by a code listed after each practice name following figure 63. The FOTG reference specifies the technical requirements of each practice.

Figure 63: BMP Application

Critical Area/Issue Cause/Source	Stressor	Applicable BMPs
Trampling of Stream Banks by Livestock	Sedimentation	1. Critical Area Planting 2. Education and Outreach 3. Filter Strips 4. Heavy Use Protection 5. Interior Fencing 6. Ponds 7. Prescribed Grazing 8. Riparian Forest Buffers 9. Stream Bank Fencing 10. Stream Crossing 11. Spring Developments 12. Tree Establishment
Livestock Access to Streams	*E. coli*	1. Critical Area Planting 2. Education and Outreach 3. Filter Strips 4. Heavy Use Protection 5. Interior Fencing 6. Ponds 7. Roof Runoff Structure 8 Spring Developments 9. Stream Bank Fencing 10. Stream Crossing 11. Waste Utilization
Lack of Conservation Tillage	Sedimentation	1. Critical Area Planting 2. Education and Outreach 3. Filter Strips 4. Grassed Waterways 5. Residue & Tillage Management Mulch Till 6. Residue & Tillage Management No Till/Strip Till/Direct Seed 7. Residue & Tillage Management Ridge Till

[31] Natural Resources Conservation Service, Field Office Technical Guide; http://www.nrcs.usda.gov/technical/efotg/.

Critical Area/Issue Cause/Source	Stressor	Applicable BMPs
Lack of Riparian Buffers	Sedimentation Elevated Water Temperature Increased Flow	1. Critical Area Planting 2. Education and Outreach 3. Filter Strips 4. Riparian Forest Buffers 5. Stream Bank Fencing 6. Tree Establishment
Lack of Forested Areas	Elevated Water Temperature	1. Riparian Forest Buffers 2. Tree Establishment
Failing or Lack of Septic Systems	*E. coli*	1. Education and Outreach

8.2 BMP Descriptions

8.2.1 Critical Area Planting (Code 342)

Critical area planting includes planting vegetation such as trees, shrubs, vines, grasses, or legumes on highly erodible or critically impaired eroding areas. The vegetation provides a filtering effect on runoff and will improve water quality by reducing erosion rates and the movement of sediment carried by runoff from construction sites. The purpose of critical area plantings are to:

1. Stabilize areas with existing or expected high rates of soil erosion by wind or water
2. Restore degraded sited that cannot be stabilized through normal methods
3. Rehabilitate and re-vegetate degraded sites that cannot be stabilized through normal farming practices
4. Stabilize riparian areas

8.2.2 Education and Outreach

The CMWP Steering Committee also discussed the importance and overriding best management practice to produce results within the watershed as education and outreach. Throughout the implementation process the Watershed Coordinator in conjunction with partner groups and committee members will continue to provide educational programs, activities, and workshops for schools and community groups.

Emphasis on the importance of education and outreach is affirmed by the EPA in reference to NPS guidance where it is stated, "Continue public participation. Stakeholder involvement should begin early in the restoration process and should continue throughout. An effective and inclusive communication strategy ensures that all potential participants have an opportunity to become aware of the progress of restoration. As the process evolves, the goals and objectives may change. Changes in goals and objectives should be articulated to stakeholders. Develop community support through publicity and the use of volunteers."[32] The purpose of education and outreach is to:

1. Increase knowledge of watershed issues
2. Increase concern of watershed issues
3. Increase knowledge of conservation practice importance
4. Improve attitudes towards taking action and working towards improving water quality within the watershed

[32] U.S. Environmental Protection Agency: http://www.epa.gov/owow/nps/wetmeasures/pdf/ch5.pdf.

8.2.3 Filter Strips (Code 393)

Filter strips are areas of herbaceous vegetation situated between cropland, grazing land, or disturbed land (including forest land) and environmentally sensitive areas. The purpose of filter strips is to:

1. Reduce sediment, particulate organic matter, and absorb sediment from runoff to keep it from entering into waterways
2. Reduce dissolved contaminant loading in runoff
3. Restore, create or enhance herbaceous habitat for wildlife and beneficial insects
4. Maintain or enhance watershed functions and values

8.2.4 Grassed Waterways (Code 412)

Grassed waterways are natural or constructed channels that are shaped or graded and established with suitable vegetation. The purpose of grassed waterways is to:

1. Convey runoff from terraces, diversions, or other water concentrations without causing erosion, flooding, or ponding
2. Reduce gully erosion
3. Protect or improve water quality

8.2.5 Heavy Use Protection Area (Code 561)

A heavy use protection area is the stabilization of areas frequently and intensively used by people, animals, or vehicles by establishing vegetative cover, surfacing with suitable materials, and/or installing needed structures. The purpose of heavy use protections areas are to:

1. Reduce soil erosion
2. Improve livestock health
3. Improve water quantity and quality
4. Minimize nutrient loading
5. Improve aesthetics

8.2.6 Interior Fencing (Code 382)

Interior fences (or cross fences) are used to subdivide fields into smaller areas called paddocks for effective grazing management. Interior fences may be constructed from permanent, semi-permanent, or temporary fencing materials. Temporary fencing can be used to enclose areas for temporary grazing.

8.2.7 Ponds (Code 378)

A pond is a water impoundment made by constructing a dam or an embankment or by excavating a pit or dugout. The purpose is to provide water for livestock, fish and wildlife to maintain and improve water quality. The main goal is to provide an alternative water source and exclude them for a majority of the season from watering directly in a water body.

8.2.8 Prescribed Grazing (Code 528)

Prescribed grazing is the process of managing the vegetation with grazing and/or browsing animals. This conservation practice may be applied as part of a conservation management system to achieve one or more of the following purposes:

1. Improve or maintain desired species composition and vigor of plant communities.
2. Improve or maintain quantity and quality of forage for grazing and browsing animal’s health and production
3. Improve or maintain surface and/or subsurface water quality and quantity
4. Improve or maintain riparian and watershed function
5. Reduce accelerated soil erosion and maintain or improve soil condition
6. Improve or maintain the quantity and quality of food and/or cover available for wildlife

8.2.9 Residue and Tillage Management Mulch Till (Code 345)

Residue and tillage management mulch till is managing the amount, orientation and distribution of crop and other plant residue on the soil surface year round while limiting the soil-disturbing activities used to grow crops in systems where the entire field surface is tilled prior to planting. The purpose of residue tillage management is to:

1. Reduce sheet and rill erosion
2. Reduce wind erosion
3. Reduce soil particulate emissions
4. Maintain or improve soil condition
5. Increase moisture available to plants
6. Provide food and escape cover for wildlife

8.2.10 Residue and Tillage Management No Till/Strip Till/Direct Seed (329)

Managing the amount, orientation and distribution of crop and other plant residues on the soil surface year-round, while growing crops in narrow slots, tilled, or residue free strips in soil previously untilled by full-width inversion implements. The purpose of no till/strip till/direct seeding is to:

1. Reduce sheet and rill erosion
2. Reduce wind erosion
3. Improve soil organic matter content
4. Reduce CO_2 losses from the soil
5. Increase moisture available to plants
6. Provide food and escape cover for wildlife

8.2.11 Residue and Tillage Management Ridge Till (Code 346)

Residue and tillage management ridge till is managing the amount, orientation, and distribution of crop and other plant residues on the soil surface year-round, while growing crops on pre-formed ridges alternated with furrows protected by crop residue. The purpose of tillage management ridge till is to:

1. Reduce sheet and rill erosion
2. Reduce wind erosion
3. Maintain or improve soil condition
4. Reduce soil particulate emissions
5. Manage snow to increase moisture available to plants
6. Modify cool wet site conditions
7. Provide food and escape cover for animals

8.2.12 Riparian Forest Buffers (Code 391)

Riparian buffers are areas of trees and other vegetation consisting of two zones located in areas (adjoining and up gradient from surface waterbodies) designed to intercept surface runoff and subsurface flows from upland sources prior to entry into surface waters and /or groundwater recharge areas. The purpose of riparian buffers is to:

1. Reduce excess amounts of sediment, organic material, nutrients, pesticides, and other pollutants in surface runoff
2. Reduce excess nutrients and other chemicals in shallow groundwater flow
3. Create shade to lower water temperatures to improve habitat for fish and other aquatic organisms
4. Provide a source of detritus and large woody debris for fish and other aquatic organisms
5. Provide riparian habitat and corridors for wildlife
6. Provide protection against scour erosion within the floodplain

8.2.13 Roof Runoff Structure (Code 558)

Structures that collect, control and transport precipitation from roofs. This practice may be applied as part of a resource management system to support one or more of the following purposes:

1. Improve water quality
2. Reduce soil erosion
3. Increase infiltration
4. Protect structures
5. Increase water quantity
6. Prevent flooding
7. Improve drainage

8.2.14 Spring Developments (Code 574)

Spring developments utilize springs and seeps which are readily available in the Central Muscatatuck Watershed to improve the quantity and/or quality of water for livestock, wildlife, and other agricultural uses. These are placed in areas where spring or seep development will provide a dependable supply of suitable water for the planned times of use, and where the intended purpose can be achieved by using this practice alone or combined with other conservation practices.

8.2.15 Stream Bank Fencing (Code 382)

This practice is applied to facilitate the application of conservation practices by providing a means to control movement of livestock. Permanent exterior fences are used to exclude livestock from all areas adjacent to stream banks and needing permanent fence. Installed fence shall have a minimum life expectancy of 20 years.

8.2.16 Stream Crossing (Code 578)

A stream bank crossing is a trail or travel way constructed across a stream to allow livestock, equipment, or vehicles to cross with minimal disturbance to the stream ecosystem. The purpose of stream bank crossings is to:

1. Improve water quality by reducing sediment, nutrient, organic, and inorganic loading of the stream
2. Reduce stream bank and streambed erosion
3. Provide crossing for access to another land unit without causing impairments to the stream bank

8.2.17 Tree Establishment (Code 612)

Tree establishment is the process of introducing woody plants to an area by planting seedlings, or cuttings, direct seeding, or natural regeneration. The purpose of tree establishments is to:

1. Provide wildlife habitat
2. Serve as long-term erosion control for improvement of water quality
3. Decrease flow from land
4. Improving or restoring natural diversity
5. Enhance aesthetics

8.2.18 Waste Utilization (Code 633)

This practice applies where agricultural by-products including animal manure and contaminated water from livestock and poultry operations; composted dead animals; solids and wastewater from municipal treatment plants; and agricultural processing residues are generated and/or utilized.

1. Protect water quality
2. Protect air quality
3. Provide fertility for crop, forage, fiber production and forest products

4. Improve or maintain soil quality
5. Provide feedstock for livestock
6. Provide a source of energy

This list of applicable BMPs for the critical areas/issues determined by the steering committee and previously discussed in the management plan is a general overview of the BMPs that would be utilized to address the main critical areas/issue during the implementation phase of the project. However, specific circumstances may arise where alternative BMPs may provide more beneficial results and may be deemed more appropriate.

Setting Goals, Plans and Indicators

This section states the water quality improvements or protection goals that were agreed on by the technical steering committee and steering committee. The goals include specific realistic targets for reducing pollutants or mitigating impacts, and identify time-frames for accomplishment. This section describes the planned order of implementation, the time requirements for implementing the plan, the party responsible for carrying out the tasks, and what milestones to be noted.

Goals and actions are listed for each critical area/issue according to the associated stressor. The actions to be performed, when it will be completed, who is responsible for performing the action, what resources (monetary and technical resources) are required and the target audience to receive the action benefit is included for each goal. Organizations or individuals named for performance or target of actions are based on the potential of the support, ability, and advice or management measure they may provide to the project goals. This list is not intended to be comprehensive or to exclude other entities from participation in the development and/or implementation of management measures. Participation by any volunteer or organization will be encouraged and utilized as appropriate.

In most circumstances a monetary cost is associated with the action. In the case where a monetary cost is anticipated, a project cost estimate will be shown next to the action. The indicator column shows how progress can be noted in a quantifying manner and the "type of indicator" will be shown in parenthesis. Further details regarding the type of indicators are described in section 10, however, they are noted on this chart as a cross reference between the indicators that will be used and how these indicators will be monitored.

Figure 64: Project Goals

9.1 Sedimentation Goal

Eliminate or reduce observable sedimentation and turbidity in the Muscatatuck River and tributaries. Meet or maintain turbidity levels at or below the Indiana Average of 36 NTU throughout the watershed by the year 2030.

Objective	Action – Cost Estimate	Target Audience	Performed By	Time Schedule	Indicator (Type of Indicator)
Lack of Riparian Buffers **Problem Statement:** The lack of protective riparian groundcover, buffers, reduces stream bank stability and increases sediment in local waterbodies through stream bank erosion.					
Educate people regarding the preservation of existing riparian buffers throughout the watershed	Provide education through field days and workshops using demonstration sites $4,000	Landowners Agricultural Producers General Public	Watershed/Education Coordinator SWCD Coordinators Hanover College Rivers Institute	Minimum of 1 the first year and 1 annually thereafter	# of attendees at workshops and field days (Administrative) # of publications distributed (Administrative)
	Develop a brochure on how to control and lessen the impacts of stream bank erosion $4,000			Prepare within the first 6 months of the project Distribution – Ongoing	
Create and enhance existing buffers in watershed, specifically in critical areas	Develop cost-share program to offer landowners who elect to implement riparian buffer BMPs $25,000	Landowners Agricultural Producers	ISDA, NRCS, SWCD Technicians Watershed Coordinator	4 years 2009-2013 Primary Implementation Period 2 years 2013-2015 Secondary Implementation Period	# of landowners enrolled in cost-share programs (Social) # of feet of buffers installed (Environmental) # reduction of turbidity levels (Environmental)
	Create opportunities for discounted purchase of buffer plants (i.e. District tree and plant sales). $4,000				

Objective	Action – Cost Estimate	Target Audience	Performed By	Time Schedule	Indicator (Type of Indicator)
Trampling of Stream Banks by Livestock **Problem Statement:** The trampling of stream banks by livestock reduces stream bank stability and increases sediment in local waterbodies through erosion.					
Educate agricultural community about effects of livestock with access to streams	Provide education through workshops or field days with site demonstrations if available $4,000	Agricultural Landowners/Livestock Producers	Watershed/Education Coordinator SWCD Coordinators Hanover College Rivers Institute	Minimum of 1 the first year and 1 annually thereafter	# of attendees at workshops and field days (Administrative) # of publications distributed (Administrative)
Educate agricultural community about effects of livestock with access to streams	Develop a brochure on how to control and lessen the impacts of stream bank erosion $4,000	Agricultural Landowners/Livestock Producers		Prepare within the first 6 months of the project Distribution - Ongoing	
Reduce the number of livestock with access to streams by informing livestock producers of financial programs and incentives available to them for doing so	Develop cost-share program to offer landowners who elect to implement livestock exclusion BMPs $90,000 Work with other government partners (i.e. NRCS) to offer cost share alternatives to livestock landowners where 319 grant funding may not apply $4,000	Agricultural Landowners/Livestock Producers	ISDA, NRCS, SWCD Technicians Watershed Coordinator Steering Committee	2 years 2009-2011 Primary Implementation Period 4 years 2011-2015 Secondary Implementation Period	# of landowners enrolled in cost-share programs (Social) # of practices installed (Environmental) # reduction of turbidity levels # of cattle excluded from access to waterbodies (Environmental)
Lack of Conservation Tillage **Problem Statement:** Farmlands not using a high residue cropping systems may cause an increase in sedimentation in waterbodies on highly erodible lands near waterbodies.					
Educate landowners about the effects of sedimentation from conventionally tilled croplands	Provide education through workshops or field days with demonstration site $4,000 Develop a brochure regarding benefits of conservation tillage to	Agricultural Producers	Watershed/Education Coordinator SWCD Coordinators Hanover College Rivers Institute	Minimum of 1 the first year and 1 annually thereafter	# of attendees at workshops and field days (Administrative) # of publications distributed (Administrative)

Objective	Action – Cost Estimate	Target Audience	Performed By	Time Schedule	Indicator (Type of Indicator)
	lessen sedimentation $4,000				
Increase the percentage of conservation tillage for corn and soybeans in the watershed through local cost-share program	Develop cost-share program incentives or cost share options for agricultural producers to implement BMPs $40,000	Agricultural Producers	ISDA, NRCS, SWCD Technicians Watershed Coordinator Steering Committee	2 years 2009-2011 Primary Implementation Period 4 years 2011-2015 Secondary Implementation Period	# of landowners enrolled in cost-share programs (Social) # of practices installed (Environmental) # reduction of turbidity levels (Environmental) % of county conservation tillage transect data results (Environmental)
	Work with other government partners (i.e. NRCS) to offer cost share where 319 grant funding may not apply $4,000				

9.2 E. coli Goal

Reduce and/or maintain *E.Coli* loading throughout entire watershed to reach the state standard of 235 colonies/100ml by the year 2020.

Objective	Action - Cost	Target Audience	Performed By	Time Schedule	Indicator (Type of Indicator)
Livestock Access to Streams **Problem Statement:** Livestock with uncontrolled access to waterbodies may lead to an increase in pathogens from animal waste which can result in digestive and other health problems for humans, wildlife, and livestock in contact with waterbodies					
Educate agricultural community about effects of livestock with access to streams	Provide field days and workshops regarding alternative livestock watering and pasturing options $4,000	Livestock Owners	Watershed/Education Coordinator SWCD Coordinators Hanover College Rivers Institute	Ongoing	# of attendees at field days and workshops (Administrative) # of publications distributed (Administrative)
	Develop and publish a brochure regarding BMP options and available cost-share programs $4,000				

Objective	Action - Cost	Target Audience	Performed By	Time Schedule	Indicator (Type of Indicator)
Reduce the amount of untreated animal waste from entering waterbodies	Develop cost-share program to offer landowners who elect to implement BMPs to restrict livestock access to streams $95,000		ISDA, NRCS, SWCD Technicians Watershed Coordinator Steering Committee	4 years 2009-2013 Primary Implementation Period 2 years 2013-2015 Secondary Implementation Period	# of landowners who apply for cost-share programs (Social) # of BMPs installed (Environmental) # decrease in observed livestock access to waterbodies (Environmental) decrease in measured *E. coli* levels in impaired streams (Environmental) decrease in the amount of IDEM designated impaired streams for *E. coli* (Environmental)
Failing or Lack of Septic Systems **Problem Statement:** Soil types in the watershed are not conducive to septic systems which cause systems to fail. Improper maintenance of septic systems also leads to failures where pathogens may enter nearby waterbodies which may cause health problems in humans.					
Increase awareness and educate homeowners about the effects of failing or lack of septic systems on nearby waterbodies and potential health problems in humans	Provide public education workshops regarding septic system maintenance $4,000 Develop and publish a brochure regarding proper maintenance of septic systems $4,000	Homeowners	Watershed/Education Coordinator SWCD Coordinators Hanover College Rivers Institute	Ongoing	# of workshop attendees (Administrative) # of publications distributed (Administrative)

Objective	Action - Cost	Target Audience	Performed By	Time Schedule	Indicator (Type of Indicator)
	Collaborate with local, state and federal government to obtain funding to correct septic system problems & assist with contractor education $6,000	Health Departments Septic System Contractors	Watershed/Education Coordinator Health Department personnel		# of funds directed towards local sewer implementation, maintenance and repair # of contractors obtaining licenses to install septic systems # of public sewer systems installed
Provide discussion forums, publicity, support, and facilitate technical advice and/or assistance for creation and implementation of solutions to town septic waste management	Research, publish and offer statistics, references and avenues to pursue funding for installation of community sewers or appropriate individual sewers $8,000	Homeowners Local Officials	Watershed Coordinator County Health Departments	Ongoing	# of meetings/discussions held (Administrative) # of attendees at meetings/discussions regarding the effects of failing or lack of septic systems (Administrative) decrease in the amount of observed septic waste draining into nearby waterbodies (Environmental) # of actions taken using workshop references (Social) decrease in measured *E. coli* levels in impaired streams (Environmental) decrease in the amount of IDEM designated impaired streams for *E. coli* (Environmental)

9.3 Temperature Goal

Monitor and maintain state water quality standard for temperature change of < 5 degrees Fahrenheit downstream for the Muscatatuck River and its tributaries.

Objective	Action - Cost	Target Audience	Performed By	Time Schedule	Indicator (Type of Indicator)
Lack of Forested Areas **Problem Statement:** The lack of riparian canopy from tree cover may increase water temperature in local streams					
Educate people regarding the importance of preserving existing and developing forested buffers throughout the watershed	Provide education through workshops or field days with demonstration site if available $4,000 Develop a brochure on how to control and lessen the impacts of stream bank erosion $4,000	Landowners	Watershed/Education Coordinator SWCD Coordinators Hanover College Rivers Institute	Ongoing	# of workshop attendees (Administrative) # of publications distributed (Administrative)
Increase forested areas around streams throughout the watershed	Develop cost-share program incentives or cost share options for landowners to implement BMPs $30,000 Work with other government partners (i.e. NRCS) to offer cost share where 319 grant funding may not apply $4,000	Landowners	ISDA, NRCS, SWCD Technicians Watershed Coordinator Steering Committee	2 years 2009-2011 Primary Implementation Period 4 years 2011-2015 Secondary Implementation Period	# of landowners enrolled in cost-share programs (Social) # of practices installed (Environmental) measured temperature levels (Environmental)

9.4 Increased Flow Rate Goal

Reduce the severity of flooding and erosion due to high flow rates within the watershed.

Objective	Action	Target Audience	Performed By	Time Schedule	Indicator (Type of Indicator)
Lack of Riparian Buffer **Problem Statement:** An increase of impervious and limited riparian buffer areas, specifically near headwaters areas, reduces groundwater recharge, which increases flow rate and causes streams to flood more frequently and banks to erode more quickly.					
Education people regarding importance of preserving existing and developing riparian buffers throughout the watershed	Educate through field days and workshops $4,000 Educate through publications $4,000	Landowners	Education Coordinator, SWCD Coordinators, and Hanover College Rivers Institute	Ongoing	# of people attending events (Administrative) # of publications distributed (Administrative)

Increase the quality and amount of riparian buffers within the watershed by providing cost share programs to landowners	Develop cost-share program to offer landowners who elect to implement BMPs. $35,000	Landowners	ISDA, NRCS, SWCD Technicians, and Coordinator	4 years by 2012	# of landowners enrolled in cost-share programs (Social) # of miles of stream buffers installed (Environmental) # reduction of turbidity and eroding stream banks (Environmental)

9.5 Improper Dumping of Trash Goal

Decrease the amount of illegal dumping in the watershed.

Objective	Action	Target Audience	Performed By	Time Schedule	Indicator
Improper Dumping of Trash **Problem Statement:** Improper disposal of garbage in parks, waterbodies, roadsides, sinkholes and other areas cause unsightly views and health risks for humans and aquatic life.					
Educate the public on the effects and costs of illegal dumping within the watershed	Educate through field days and workshops $4,000 Educate through publications $4,000	Watershed Community	Education Coordinator, SWCD Coordinators, and Hanover College Rivers Institute	Ongoing	# of people attending events (Administrative) # of publications distributed (Administrative)
Decrease the amount of trash being dumped into local waterbodies	Conduct and support local river and lake cleanups $6,000	Watershed Community	SWCD Coordinators, Friends of Hardy Lake, Friends of Muscatatuck River Society, Education Coordinator	Ongoing	# of people attending river and lake sweeps (Administrative) # reduction of illegal dumping (Environmental)

9.6 Measurable Milestone Goals

These goals were set to assist in gauging progress towards longer term goals previously stated and to determine whether the nonpoint source management measures and/or control practices are being implemented.

Figure 65: Measurable Milestone Goals

Stressor	Milestone Goal	Completion Date
Failing or Lack of Septic Systems	Distribute at workshops/events or mail a total of 500 informational brochures providing information on the importance of proper septic systems and their proper maintenance throughout the watershed.	2012
Lack of Forested Areas & Riparian Buffers	Offer annual educational workshops to landowners regarding the importance of forested and proper riparian zones along stream banks and increase attendance by 5% each year	2012
Improper Dumping of Trash	Decrease the amount (measured in pounds) of trash picked up at river cleanup event overall by 10% Friends of Muscatatuck River Spring Cleanup 2009 – 9,960 lbs 2008 – 10,800 lbs	2012
	Increase attendance at river and lake cleanup events by 5% Friends of Muscatatuck River Spring Cleanup 2009 – 114 volunteers 2008 – 183 volunteers Hardy Lake Sweep 2009 – 310 volunteers 2008 – 192 volunteers	2012

9.7 Load Reduction Milestone Goals

The technical steering committee and the coordinator met, discussed and decided upon a few more specific quantitative milestone goals for some of the stressors considered to be critical in certain areas of the watershed stated in figure 62. It is intended that during the next phase of grant funding for the project, that the BMPs discussed for the critical issues/critical areas in section 8.1 be implemented to work towards achieving the reduction goals stated below:

Figure 66: Load Reduction Milestone Goals

Stressor	Applicable BMPs for:	Estimated Milestone Load Reductions	Reduction Indicators	Completion Date
Sedimentation	Lack of Riparian Buffers - approximately 30 acres of installed riparian buffers	110 tons/per year (Agricultural Fields & Filter Strips - Estimated reduction based on 'C" factor of 0.2 before treatment to 0.1 after treatment)[33]	Decreased Turbidity Levels Typical Range Dissolved Oxygen Levels Reduced Visible Stream Bank Erosion Reduced Visible Sedimentation in Streams	2013
	Trampling of Stream Banks by Livestock – approximately 20,000 feet of fencing installed to exclude livestock from waterbodies	50 tons/year for each 300 feet of fencing installed (Bank Stabilization - Estimated reduction based on 'C" factor of 0.5 before treatment to 0.1 after treatment)[34]		2013
	Lack of Conservation Tillage – change approximately 750 acres conventional tillage to no-till system	1113 tons/per year ((Agricultural Fields & Filter Strips - Estimated reduction based on 'C" factor of 0.2 before treatment to 0.1 after treatment)[33]		2013
E. coli	Livestock Access to Streams – 200 acres or waste utilization	Based on the maximum E. coli loads calculated at each site, the estimated reductions necessary to meet the 235 cfu/100 ml standard ranged from 31%-90% throughout the watershed, an overall average of 62% reduction needed.	Reduced *E. coli* Levels to within Indiana Water Quality Standard of <235 CFU/100 ml	2013

[33] Pennsylvania State University. 1992. Nonpoint Source Database. In U.S. EPA, Guidance specifying management measures for sources of nonpoint pollution in coastal waters, page 2-15.

[34] Steffen, L.J. 1982. Channel Erosion (personal communication), as printed in "Pollutants Controlled Calculation and Documentation for Section 319 Watersheds Training Manual," June 1999 Revision; Michigan Department of Environmental Quality – Surface Water Quality Division – Nonpoint Source Unit. EQP 5841 (6/99).

Monitoring Effectiveness

This section states a monitoring plan to track the indicators and evaluate the effectiveness of the implementation efforts over time.

Throughout the implementation process, several indicators were mentioned and will be monitored to determine if improved water quality has been achieved.

10.1 Social Indicators

Social indicators for NPS management provide information about awareness, attitudes, constraints, capacity, and behaviors that are expected to lead to water quality improvement and protection. By measuring these indicators over time, water quality managers can target their project activities and assess whether their projects are accomplishing changes expected to improve and protect water quality. Monitoring social indicators, like monitoring environmental indicators, gives us valuable information about how well our management strategies are working.

Social indicators complement other environmental and administrative indicators to present a complete picture of project effectiveness[35].

Social Indicators will be used to monitor:

- Increased awareness of watershed activities, concerns and accomplishments
- Increased knowledge and concern regarding watershed issues
- Increased knowledge of conservation land use and practices and their importance
- Improved attitudes towards actions to improve water quality
- Increased resident community service participation in activities for the watershed
- Participation in cost-share programs

The monitoring of social indicators will be done by tracking attendance at community events at workshops, community meetings, recreational activities, distribution of information/educational flyers or pamphlets, community service events and by conducting periodic public surveys to document a change in people's attitudes toward their watershed community.

By monitoring the social indicator statistics, the steering committee will be able to identify whether or not citizens are becoming more involved in watershed activities. The goal is for an increase in attendance to be noted with each activity. Surveys will provide information to determine which activities are increasing public knowledge regarding watershed concerns.

10.2 Environmental Indicators

Environmental indicators are measurements of water quality, habitat or some other criterion that tells you something about the health of the environment[36]. Environmental indicators provide more accurate progress evaluations of watershed actions although they can be somewhat time consuming to monitor. Examples of environmental indicators include chemical and biological monitoring, showing contaminants found in the water, and species populations and health.

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[35] Great Lakes Regional Water Program "Developing a Social Component for the NPS Evaluation Framework", July 27, 2006. http://www.uwex.edu/ces/regionalwaterquality/Flagships/Indicators.htm

[36] Indiana Department of Environmental Management. "Indiana Watershed Planning Guide" August 2003.

Environmental Indicators will be used to monitor:

- Reduction of sediment entering waterbodies by installing conservation practices
- Reduction of *E. coli* entering waterbodies by installing conservation practices
- Change in pollutant concentrations in waterbodies
- Change in macroinvertebrate diversity

Indicators will be monitored, at a minimum, on a quarterly basis through water testing. The coordinator and volunteers will monitor key sites throughout the watershed. The coordinator will also perform or organize site reviews at critical points throughout the watershed.

10.3 Administrative Indicators

Administrative indicators are easily monitored statistics and can provide the steering committee valuable tracking information. Examples of these indicators include the number of people attending functions, feet of fence installed along a stream or the number of acres converted to a conservation till system. These indicators are useful when reporting increased participation in programs, but are often indirect indicators of more useful information, such as decreases in nutrient loading.

Administrative Indicators will be used to monitor:

- Attendance at education field days
- Distribution of publications
- News articles submitted to newspaper and newsletters
- Number of conservation practices installed
- Volunteer recruitment numbers
- Public meeting attendance and survey responses

By monitoring administrative indicators, quantities and trends can be noted and observed then taken into account for planning of future activities to promote the most interest and highest level of positive impact from education, promotional and cost share programs offered.

10.4 Monitoring Plan

The Watershed Coordinator along with the steering committee will develop and maintain a database tracking system to record social, environmental and administrative indicators. Each database will be updated consistently after attendance numbers or information is gathered for each event.

This information will be reviewed and discussed by the steering committee on a quarterly basis to determine the effectiveness of the group within the watershed.

Best management practice implementation will be monitored and recorded in the environmental indicators database. Best management practices will be reviewed on a quarterly basis also to ensure that they are being installed in critical area sub watersheds.

It is the landowners' responsibility to properly install and maintain management practices on their land. Practices must be implemented for at least five to ten years and meet the NRCS technical guide standards to significantly improve water quality. Local agencies will provide technical assistance to landowners regarding management practices throughout the watershed.

10.5 Annual Review

The CMWP Management Plan will be reviewed and updated annually, or on an as needed basis, to reflect accomplishments and to add additional information to the document. Updates will be distributed to the members of the Steering Committee and voted upon by the committee. If agreed upon by the committee, the coordinator will be responsible for updating the plan and informing key stakeholders regarding the changes. For future reference, all management plan records and documents will be kept at the Jefferson County SWCD office and there will be a master copy of the plan available to the public upon request at:

Jefferson County SWCD
3382 W. SR 56, Suite 2
Hanover, IN 47234

If you would like additional information about the Central Muscatatuck Watershed Project or its Management Plan, please contact:

Historic Hoosier Hills RC & D
1981 South Industrial Park Road
PO Box 407
Versailles, IN 47042
Phone: 812-689-6410 ext 5
Fax: 812-689-3141
Website: www.hhhills.org

Appendix

Appendix A: IDEM Testing Results
Big Creek & Middle Fork Creek, 2002 – 2007

Stream	Date	Dissolved Oxygen	Temp.	% Saturation	pH	Specific Conductivity	Turbidity	*E. coli*
HUC 14 - 050, Jefferson County								
Big Creek	6/4/2002	7.73	23.42	94.19	8.51	332	6.3	
Big Creek	7/10/2002	6.75	23.59	81.4	8.51	348	27.39	
Big Creek	7/30/2002	7.53	25.07		8.00	383	21.0	
Big Creek	9/10/2002	6.64	21.15	76.69	7.8	376	4.69	
HUC 14 - 120, Jefferson County								
Big Creek	6/4/2002	7.03	25.27	88.3	8.46	358	17.5	
Big Creek	7/10/2002	6.18	24.73	76.5	8.26	371	29.89	
Big Creek	7/30/2002	7.17	28.95		8.05	367	16.0	
Big Creek	9/11/2002	5.66	21.61	67.59	7.69	424	8.5	
HUC 14 - 040, Jefferson County								
Middle Fk Cr	6/5/2007	7.04	18.6	75.2	7.54	403	2.1	290.9
Middle Fk Cr	6/12/2007	8.48	19.88	93.4	7.62	419	2.3	866.4
Middle Fk Cr	6/19/2007	6.51	22.33	75.3	7.48	461	3	517.2
Middle Fk Cr	6/26/2007	8.9	22.84	103.9	7.67	404	2	517.2
Middle Fk Cr	7/3/2007	9.03	20.17	100	7.8	396	1.8	124.6

IDEM Testing Results – *E. coli* Upper Muscatatuck, 2002

Stream	Date	Dissolved Oxygen	Temp.	% Saturation	pH	Specific Conductivity	Turbidity	*E. coli*
HUC 14 – 060, Jefferson County, Site Number ES1								
Big Cr	9/9/2002	7.29	25.88	92	7.84	382	5.98	13.5
Big Cr	9/16/2002	6.1	23.96	74.59	7.63	352	12.19	>2419
Big Cr	9/23/2002	8.38	20.17	90	7.86	357	5.34	74
Big Cr	9/30/2002	8.24	18.84	91.69	7.8	293	10.19	193.5
Big Cr	10/7/2002	8.4	16.29	87.69	7.73	379	3.1	166.4
HUC 14 – 120, Jefferson County, Site Number ES2								
Big Cr	9/9/2002	7.96	26	100.8	8	409	6.36	12.0
Big Cr	9/16/2002	7.35	24.04	90.3	7.75	402	5.28	32.7
Big Cr	9/23/2002	8.2	19.43	92.19	7.84	377	3.78	65.7
Big Cr	9/30/2002	7.77	19.53	87.59	7.65	312	13.8	410.6
Big Cr	10/7/2002	7.97	17.13	85.3	7.65	406	3.52	209.8
HUC 14 – 030, Jefferson County, Site Number ES3								
Big Cr	9/9/2002	7.79	25.68	98.19	8.1	367	13.89	2.0
Big Cr	9/16/2002	7.22	24.85	89.9	7.92	374	15.39	292.4
Big Cr	9/23/2002	7.57	19.29	84.59	7.88	349	14.1	547.5
Big Cr	9/30/2002	8.3	19.75	94	7.69	224	11.3	95.9
Big Cr	10/7/2002	8.29	16.35	86.8	7.65	293	4.42	143.9

HUC 14 – 050, Scott County, Site Number ES4								
Hardy Lake	9/10/2002	8.11	28.37	106.9	8.06	173	6.05	1
Hardy Lake	9/17/2002	8.02	26.48	102.5	8.02	173	5.3	3
Hardy Lake	9/24/2002	7.97	25.06	98.9	7.73	176	3.22	2(DJ)
Hardy Lake	10/1/2002	9.09	25.3	114.09	8.31	170	6.94	3.1
Hardy Lake	10/8/2002	8.23	19.86	92.5	7.55	169	4.26	5.1
HUC 14 – 050, Scott County, Site Number ES5								
Hardy Lake	9/10/2002	8.35	29.06	111.19	8.25	172	25.1	9.5
Hardy Lake	9/17/2002	8.21	26.28	104.3	7.96	172	4.32	<1
Hardy Lake	9/24/2002	8.16	25.62	102.09	7.84	176	7.15	<1
Hardy Lake	10/1/2002	8.97	25.2	112.59	8.34	169	26	65.7
Hardy Lake	10/8/2002	8.14	20.37	92.4	7.53	168	3.04	1
HUC 14 – 050, Scott County, Site Number ES6								
Hardy Lake	9/10/2002	8.11	29.09	107.59	8.1	175	10.3	4.1
Hardy Lake	9/17/2002	8.74	27.51	113.3	8.6	172	2.01	3.1
Hardy Lake	9/24/2002	8.44	26.14	106.4	7.88	178	7.09	2(DJ)
Hardy Lake	10/1/2002	8.79	24.32	108.5	8.14	173	3.61	23.5
Hardy Lake	10/8/2002	9.14	18.62	100.3	7.9	171	9.05	22.1
HUC 14 – 090, Jefferson County, Site Number ES7								
Little Cr	9/9/2002	7.42	23.77	90	7.94	394	5.5	76.8
Little Cr	9/16/2002	6.7	22.76	80.09	7.82	379	6.21	93.3
Little Cr	9/23/2002	6.77	17.18	72.59	7.8	403	4.94	70.3
Little Cr	9/30/2002	8.39	19.86	95	7.94	411	7.3	648.8
Little Cr	10/7/2002	8.31	15.52	85.69	7.78	430	2.44	770.1
HUC 14 – 070, Scott County, Site Number ES8								
Muscatatuck River	9/10/2002	5.11	27.14	667.5		427	12.3	154.1
Muscatatuck River	9/17/2002	3.41	22.54	40.59	7.17	416	10.39	73.8
Muscatatuck River	9/24/2002	4.48	21.97	52.5	7.38	333	19.6	162.4
Muscatatuck River	10/1/2002	5.83	19.87	66	7.07	229	37	411
Muscatatuck River	10/8/2002	6.28	15.92	65.19	7.15	325	14.3	325

Corvallis Data Test Results

Stream	Date	Dissolved Oxygen	Temp.	% Saturation	pH	Specific Conductivity	Turbidity
HUC 14 – 050, Jefferson County, Site Number CS1							
Big Creek	6/4/2002	7.73	23.42	94.19	8.51	332	6.3
Big Creek	7/10/2002	6.75	23.59	81.4	8.51	348	27.39
Big Creek	7/30/2002	7.53	25.07	-	8	383	21
Big Creek	9/10/2002	6.64	21.15	76.69	7.8	376	4.69
HUC 14 – 120, Jefferson County, Site Number CS2							
Big Creek	6/4/2002	7.03	25.27	88.3	8.46	358	17.5
Big Creek	7/10/2002	6.18	24.73	76.5	8.26	371	29.89
Big Creek	7/30/2002	7.17	28.95	-	8.05	367	16
Big Creek	9/11/2002	5.66	21.61	67.59	7.69	424	8.5

Stream	Date	Dissolved Oxygen	Temp.	% Saturation	pH	Specific Conductivity	Turbidity
HUC 14 – 040, Jefferson County, Site Number CS3							
Middle Fk Cr	6/5/2007	5.25	18.27	57	7.64	398	3.7
Middle Fk Cr	7/3/2007	8.05	17.64	86.7	7.98	373	4.6
Middle Fk Cr	7/17/2007	4.31	20.4	50.7	7.78	455	3.2
Middle Fk Cr	6/5/2007	7.04	18.6	75.2	7.54	403	2.1
Middle Fk Cr	6/12/2007	8.48	19.88	93.4	7.62	419	2.3
Middle Fk Cr	6/19/2007	6.51	22.33	75.3	7.48	461	3
Middle Fk Cr	6/26/2007	8.9	22.84	103.9	7.67	404	2
Middle Fk Cr	7/3/2007	9.03	20.17	100	7.8	396	1.8

Morgan Foods, Austin Test Results

Stream	Date	Dissolved Oxygen	Temp.	% Saturation	pH	Specific Conductivity	Turbidity
HUC 14 – 070, Scott County							
Morgan Packing-MS1	8/29/2000	8.62	28.5	113.69	9.39	826	210.0
Morgan Packing-MS1	8/30/2000	8.61	29.38	114.59	9.38	850	73.0
Muscatatuck River-MS2	8/30/2000	5.06	26	64.0	7.86	362	11.6
Muscatatuck River-MS3	8/30/2000	8.61	29.38	114.59	9.38	850	73.0
Stink Ditch	8/29/2000	3.15	23.7	37.5	7.36	471	5.19
Morgan Packing-MS1	5/9/2001	11.33	21.5	130.0	9.4	1129	0.72
Morgan Packing-MS1	5/16/2001	8.63	26.02	109.0	9.44	1145	32.0
Morgan Packing-MS1	6/11/2001	8.21	28.29	108.4	9.77	1121	97.5
Morgan Packing-MS1	6/14/2001	8.05	29.09	96.0	9.39	1086	-
Morgan Pkg. Efflnt.-MS4	5/9/2001	8.65	22.47	101.0	9.43	960	0.62
Muscatatuck River-MS2	5/9/2001	2.57	19.85	28.2	7.46	401	9.5
Muscatatuck River-MS2	5/16/2001	6.27	22.05	74.0	7.86	430	16.29
Muscatatuck River-MS2	6/14/2001	3.08	25.98	39.2	7.38	390	-
Muscatatuck River-MS5	5/9/2001	4.16	19.47	46.5	7.59	373	47.9
Muscatatuck River-MS5	6/14/2001	4.84	25.6	63.0	7.48	388	-
Discharge from Morgan	6/11/2001	7.71	23.84	94.19	7.61	220	21.0
Unnamed Ditch-MS6	5/9/2001	1.24	18.26	13.0	8.56	882	29.0
Unnamed Ditch-MS6	5/16/2001	1.23	25.4	14.8	8.82	1143	34.59
Unnamed Ditch-MS6	6/11/2001	4.84	25.02	60.29	8.09	413	45.59
Unnamed Ditch-MS6	6/14/2001	1.92	28.79	28.0	8.53	747	226.0
Morgan Packing-MS1	9/17/2003	6.22	34.7	91.7	7.79	1013	0
Muscatatuck River-MS6	9/17/2003	5.53	21	63.9	7.44	397	15
Muscatatuck River-MS3	9/17/2003	6.48	20.3	74.0	7.52	372	30

Fish & Wildlife Service Test Results for Big Oaks National Wildlife Refuge, 2006

Stream Site Number	Date	Dissolved Oxygen	Temp.	pH	Specific Conductivity	Turbidity
HUC 14 – 010, Ripley County						
Big Creek-FWS1	8/21/2006	3.77	21.64	7.25	353	6.3
Big Creek-FWS2	8/21/2006	3.81	25.17	7.83	494	0
Big Creek-FWS8	8/21/2006	4.18	24.34	8.03	318	5.2
Big Creek-FWS20	8/21/2006	3.02	26.81	8.43	313	3.2
Big Creek-FWS20.1	8/21/2006	6.38	24.68	8.65	321	15.1
Big Creek-FWS10	9/5/2006	12.08	24.44	9.5	322	0

HUC 14 – 020, Ripley County						
Trib. - Big Cr-FWS9	8/29/2006	2.74	23.64	8.1	248	0
Trib. - Big Cr-FWS11	8/29/2006	2.74	25.33	8.53	295	34.1
Marble Cr-FWS12	8/29/2006	3.52	22.92	8.23	266	17.5
Trib. - Big Cr-FWS19	8/29/2006	2.69	23.62	8.1	249	0
Trib. - Big Cr-FWS19.1	8/29/2006	2.61	23.35	8.1	250	5.2
Marble Cr-FWS21	8/29/2006	2.51	24.43	8.05	222	5.4
Trib.-Mid. Fk Cr-FWS 24	8/29/2006	1.64	23.79	8.88	2600	5.4
Marble Cr-FWS3	8/30/2006	4.43	22.42	7.43	266	6.2
Trib. - Big Cr-FWS4	8/30/2006	5.76	21.81	7.59	87.2	4.7
Marble Cr-FWS13	8/30/2006	4.51	22.5	7.78	265	3.6
Marble Cr-FWS17	8/30/2006	4.63	19.96	7.21	261	10.2
Trib. - Big Cr-FWS22	8/30/2006	4.79	21.39	7.16	72.9	0
Big Cr-FWS15	9/5/2006	11.64	20.2	9.19	238	3.4
Big Cr-FWS17	9/5/2006	12.79	19.46	8.93	300	0
Big Cr-FWS21	9/5/2006	12.22	18.84	8.8	254	11.1
HUC 14 – 030, Jefferson County						
Big Cr-FWS6	8/21/2006	3.44	24.22	8.19	221	8.8
HUC 14 – 040, Jefferson County						
Middle Fk Cr-FWS6	8/21/2006	4.37	23.61	8.06	57.7	1.6
Middle Fk Cr-FWS15	8/29/2006	2.48	24	8.66	208	0
HUC 14 – 060, Jefferson County						
Harberts Cr-FWS14	8/21/2006	5.34	23.87	8.46	425	12.6
Little Graham Cr-FWS7	8/22/2006	4.3	23.95	8.07	268	4.3
Harberts Cr-FWS5	8/29/2006	2.81	23.29	8.31	209	8.7
Harberts Cr-FWS16	8/29/2006	2.55	23.04	8.02	221	3
Kruegers Lake-FWS23	9/6/2006	4.97	26.11	9.27	210	0

Appendix B: Professional Testing Data Results

Site Number	Date	pH	Dissolved Oxygen	Conductivity	Temp. ©	BOD	NO 3	Turbidity	Orthophosphate	Total Phosphorous	E. coli	Flow
PS1-Ramsey Creek	Apr 08	7.7	13.6	372	15	<2	1.90	1.20	<0.01	<0.01	358	7
	Jun 08	7.7	8	400	22	<2	2.20	2.80	0.03	0.09	921	1
	Aug 08	7.9	7	395	21	<2	0.45	4.30	0.02	0.12	1986	2
	Oct 08	8	8.2	420	8	<2	0.20	1.58	0.03	0.06	172	0.6
	Dec 08	8	13.2	567	0.2	2.3	2.27	2.95	0.01	0.08	222	5.6
	Feb 09	8	14	380	2.6	<2	1.25	3.53	<.01	0.04	26	5.4
	Apr 09	8.1	11.6	300	10.6	<2	1.98	8.99	0.02	0.06	921	25
Average		7.91	10.8	405	11.3	<2	1.46	3.62	0.02	0.08	658	6.7
PS2-Harberts Creek	Apr 08	8	14.6	308	20	<2	0.71	1.70	<0.01	<0.01	260	3
	Jun 08	8.4	11.8	318	24	<2	0.30	1.10	<0.01	0.03	435	2
	Aug 08	7.7	9.5	433	23	<2	0.14	3.70	<0.01	0.06	>2400	0.1
	Oct 08	7.9	12	400	8	<2	0.13	0.32	0.01	0.05	140	0.3
	Dec 08	8.1	14.8	450	0.2	<2	2.06	5.09	0.01	0.03	179	1.3
	Feb 09	8.5	15	302	1.9	<2	0.76	2.50	<0.01	0.03	11	6.3
	Apr 09	8	11.1	270	10.8	<2	1.49	6.14	0.01	0.04	435	15
Average		8.1	12.7	354.4	12.6	<2	0.8	2.94	<0.01	0.04	243.3	4.0
PS3-Big Creek	Apr 08	8.1		315	17	<2	1.02	0.80	<0.01	<0.01	26	3
	Jun 08	8.3	10.1	389	22	<2	1.10	0.80	<0.01	0.07	155	2
	Aug 08	7.7	9.3	396	23	<2	0.16	1.30	0.03	0.06	38	0.2
	Oct 08	7.9	10.8	324	8	<2	0.12	0.28	<0.01	0.03	11	0.6
	Dec 08	8.3	14.2	515	0.1	2.1	1.96	1.29	<0.01	0.01	41	1.3
	Feb 09	8.2	14	370	4.2	<2	0.84	0.91	<0.01	0.02	<1	4.3
	Apr 09	8.2	12.1	270	10.6	<2	1.23	5.72	<0.01	0.05	161	8
Average		8.1	11.8	368	12.1	<2	0.92	1.59	<0.01	0.04	72	2.8
PS4-Lower Big Creek	Apr 08	7.8	11.2	298	14	<2	0.50	1.80	<0.01	<0.01	15	42
	Jun 08	7.8	8.2	363	23	<2	1.20	2.90	0.01	0.03	127	25
	Aug 08	7.8	6.9	364	20	<2	0.13	2.00	0.01	0.04	32	5
	Oct 08	8	10.3	364	8	<2	0.14	0.82	<0.01	0.03	8	2.5
	Dec 08	8.1	13.7	365	0.2	2.6	1.40	6.40	0.01	0.02	91	16
	Feb 09	8.1	13.7	263	2.3	<2	0.80	2.91	<.01	0.03	4	43.2
	Apr 09	8	10.3	220	11.1	<2	0.77	7.36	0.01	0.04	129	100
Average		7.9	10.6	320	11.2	2.6	0.71	3.46	0.01	0.03	58	33.4
PS5-Middle Fork Creek	Apr 08	8.1		290	20	<2	0.40	0.80	<0.01	<0.01	17	9
	Jun 08	8.2	11	370	21	<2	0.60	0.90	<0.01	0.02	125	1
	Aug 08	7.8	11.1	359	22	<2	0.12	1.00	<0.01	0.04	58	0.6
	Oct 08	8	11.3	327	8	<2	0.11	0.41	0.01	0.04	30	0.9
	Dec 08	8.2	13.9	390	0.1	<2	0.70	3.00	<0.01	0.02	37	1.7
	Feb 09	8.1	15	254	2.6	<2	0.47	1.99	<0.01	0.02	5	8
	Apr 09	8.3	12	200	10.5	<2	0.28	5.81	<0.01	0.16	225	20.3
Average		8.1	12.4	313	12.0	<2	0.38	1.99	<0.01	0.05	71	5.9
PS6-Camp Creek	Apr 08	7.6		270	18	<2	0.50	1.60	<0.01	<0.01	36	9
	Jun 08	8	8.8	337	22	<2	1.00	3.80	0.05	0.07	161	13
	Aug 08	7.7	8.1	304	21	<2	0.14	1.50	0.02	0.05	345	3
	Oct 08	8	9.6	337	9	<2	0.27	1.66	<0.01	0.05	22	1.2
	Dec 08	8.1	13.5	363	0.1	2.2	1.30	5.77	0.02	0.04	49	4.8
	Feb 09	8	14.1	233	2.1	<2	0.64	3.05	<0.01	0.04	3	14.6
	Apr 09	8.1	10.8	185	11.3	<2	0.46	7.85	0.02	0.07	84	60
Average		7.9	10.8	290	11.9	<2	0.62	3.60	0.03	0.05	100	15.1
PS7-Upper Big Creek	Apr 08	8.2		275	22	<2	0.30	3.00	<0.01	<0.01	12	1
	Jun 08	8.6	14.6	400	23	<2	0.20	1.00	<0.01	0.03	113	1
	Aug 08	8.4	12.4	359	26	<2	0.08	2.60	<0.01	0.07	141	2
	Oct 08	7.9	14.5	415	10	<2	0.13	4.63	0.01	0.09	27	0
	Dec 08	8	12.8	333	1.1	2.8	1.00	11.00	0.10	0.11	142	0.3
	Feb 09	8.3	14.3	285	5.8	<2	0.61	3.38	<.01	0.04	7	2.9
	Apr 09	8.4	13.3	195	10.8	<2	1.31	10.10	0.03	0.08	148	6.3
Average		8.3	13.7	323	14.1	<2	0.52	5.10	0.05	0.07	84	1.9
PS8-Muscatatuck before Walton Creek	Apr 08	7.7	11.8	308	14	<2	0.60	1.40	<0.01	<0.01	34	55
	Jun 08	7.7	8.8	365	23	<2	1.00	2.70	0.02	0.04	93	25
	Aug 08	7.8	8.6	326	22	<2	0.11	1.60	<0.01	0.05	11	6
	Oct 08	7.8	10.9	350	6	<2	0.10	0.72	0.01	0.04	16	3

Site Number	Date	pH	Dissolved Oxygen	Conductivity	Temp. ©	BOD	NO 3	Turbidity	Orthophosphate	Total Phosphorous	E. coli	Flow
	Dec 08	8.1	14	360	0.2	3	1.76	13.50	0.03	0.14	178	17.4
	Feb 09	8.2	15.1	304	1.7	<2	0.89	2.76	<.01	0.03	3	47.9
	Apr 09	8	11.2	244	10.2	<2	0.89	8.05	0.02	0.05	194	114.8
Average		7.9	11.5	322	11.0	<2	0.76	4.39	0.02	0.06	76	38.4
PS9-Davis Br./Muscatatuck River	Apr 08	7.5	10.1	320	13	<2	0.60	1.90	<0.01	0.01	48	60
	Jun 08	7.8	8.2	380	23	<2	1.10	5.40	<0.01	0.05	214	56
	Aug 08	7.5	8.9	347	22	<2	0.26	3.00	0.02	0.06	219	8
	Oct 08	7.4	10	330	7	<2	0.09	2.80	<0.01	0.04	48	4.8
	Dec 08	8.1	13.8	365	0.2	<2	2.02	11.00	0.03	0.04	184	24
	Feb 09	7.9	14	320	1.1	<2	0.01	0.10	<0.01	0.03	6	58.3
	Apr 09	8	9.8	250	10.9	2.3	0.08	9.51	0.02	0.07	142	120
Average		7.7	10.7	330	11.0	2.3	0.59	4.82	0.02	0.04	123	47.3
PS10-Lewis Creek	Apr 08	7.8	13	380	13	<2	0.10	1.00	0.02	0.01	36	10
	Jun 08	7.7	9.7	405	23	<2	0.80	2.10	0.03	0.04	816	5
	Aug 08	7.6	8	392	20	<2	0.09	0.80	<0.01	0.03	26	0.9
	Oct 08	7.9	11.4	432	7	<2	0.10	1.29	0.01	0.04	63	0.8
	Dec 08	8.1	14.6	475	0.2	<2	1.55	4.10	0.01	0.03	77	1.4
	Feb 09	8.1	15	373	1.9	<2	0.75	1.67	<0.01	0.02	32	3.3
	Apr 09	7.9	11.1	295	9.9	<2	0.34	2.54	<0.01	0.04	<1	18
Average		7.9	11.8	393	10.7	<2	0.53	1.93	0.01	0.03	175	5.6
PS11-Central Muscatatuck River	Apr 08	7.3	9.4	330	13	<2	0.70	2.70	<0.01	<0.01	129	148
	Jun 08	7.4	7.8	393	22	<2	1.50	24.00	0.02	0.06	517	118
	Aug 08	6.7	6.2	336	20	<2	0.14	2.60	0.01	0.04	101	10
	Oct 08	7.3	8.5	375	9	5	0.09	3.06	<0.01	0.05	36	10
	Dec 08	7.9	13.1	372	0.1	4.7	1.10	19.00	0.03	0.07	345	30
	Feb 09	7.5	14	315	0.5	<2	0.94	2.82	<0.01	0.03	22	104
	Apr 09	8	9.9	250	10.6	<2	0.77	12.80	0.02	0.06	248	488
Average		7.4	9.8	339	10.7	2.25	0.75	9.57	0.02	0.05	200	130
PS12-Muscatatuck River	Apr 08	7.2	8.1	306	14	<2	0.60	5.70	0.02	0.01	53	166
	Jun 08	6.9	5.6	353	22	<2	1.50	24.00	0.03	0.08	238	133
	Aug 08	6.6	3.9	280	21	<2	0.17	6.70	0.03	0.10	50	12
	Oct 08	7	8.6	341	8	<2	0.08	5.85	0.02	0.12	53	12
	Dec 08	7.8	13	327	0.5	<2	1.76	14.60	0.03	0.05	238	32
	Feb 09	7.3	13.2	309	0.8	<2	0.96	5.12	0.01	0.04	41	116
	Apr 09	7.5	9.9	230	10.7	2	0.68	23.20	0.04	0.07	291	547
Average		7.2	8.9	307	11	2	0.82	12.17	0.03	0.07	138	145
PS13-Lower Muscatatuck River	Apr 08	7.5	6.9	309	15	<2	0.60	6.10	0.05	0.02	42	175
	Jun 08	7	4	332	23	<2	1.20	20.00	0.13	0.20	308	150
	Aug 08	6.5	3.6	273	21	<2	0.18	2.40	0.21	0.29	22	12
	Oct 08	7.3	6.5	403	8	<2	0.10	4.02	0.18	0.28	120	12
	Dec 08	7.5	11.7	300	1.1	3.4	1.08	28.80	0.09	0.13	1203	33
	Feb 09	7.2	12	284	1.7	<2	0.30	5.81	0.05	0.08	613	123
	Apr 09	7.3	8.2	175	11.1	2	0.20	48.60	0.10	0.12	613	578
Average		7.2	7.6	297	11.6	<2	0.52	16.53	0.12	0.16	417	155
PS14-Quick Creek	Apr 08	7.4	10	142	13	<2.1	0.20	3.50	<0.01	<0.01	23	4
	Jun 08	7.3	7	157	23	<2	0.20	3.60	0.01	0.03	108	3
	Aug 08	6.8	6.4	208	18	<2	0.19	3.00	0.03	0.09	1203	2
	Oct 08	7.4	8.5	174	10	<2	0.23	2.40	<0.01	0.03	64	3.2
	Dec 08	7.8	11	335	1.1	2.1	1.03	7.76	0.01	0.03	579	0.2
	Feb 09	7.4	13.4	150	2.4	<2	0.17	2.55	<.01	0.04	20	16.5
	Apr 09	7.4	10.1	160	11	2.5	0.08	3.42	<.01	0.02	23	15
Average		7.4	9.5	189	11.2	2.3	0.30	3.75	0.02	0.04	289	6.3
PS15-Coffee Creek	Apr 08	7.4	11.6	356	11	<2	0.70	1.20	<0.01	<0.01	70	3
	Jun 08	7.5	7.5	400	21	<2	1.60	25.00	0.02	0.05	411	9
	Aug 08	7.6	7.6	336	19	<2	0.25	2.41	0.01	0.05	76	2
	Oct 08	7.2	9.2	300	7	<2	0.11	1.60	<0.01	0.04	65	0.1
	Dec 08	7.8	12.3	500	0.6	2.5	2.08	7.02	0.06	0.09	99	1.5
	Feb 09	7.6	14.5	392	2.1	<2	0.98	1.65	<0.01	0.03	38	3.3
	Apr 09	8.1	11.4	350	9.3	<2	0.07	3.10	<0.01	0.03	119	9
Average		7.6	10.6	376	10	2.5	0.83	6.00	0.03	0.05	125	4.0

Appendix C: Professional Data Summary for Volunteer Monitored Sites

"Professional Data" Summary for Sites Monitored by Volunteers - 2008

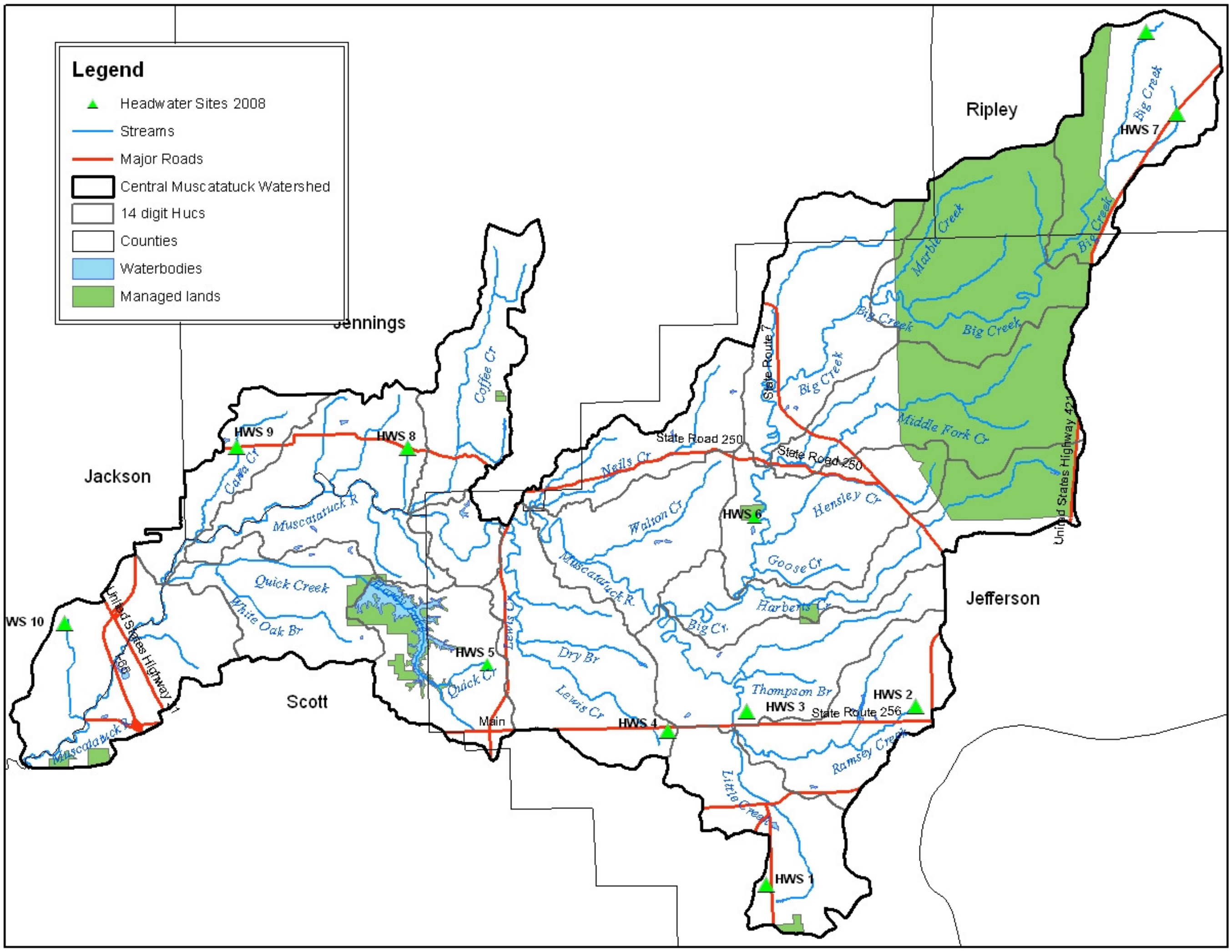
		pH	Dissolved Oxygen	BOD	NO3	Orthophosphates	*E. coli*
PS1	April	7.70	13.60	2.00	1.90	0.01	358.00
	June	7.70	8.00	2.00	2.20	0.03	921.00
	August	7.90	7.00	2.00	0.45	0.02	1986.00
	October	8.00	8.00	2.00	0.20	0.03	172.00
	December	8.00	13.20	2.30	2.30	0.01	222.00
Average		7.86	9.96	2.06	1.41	0.02	731.80
PS5	April	8.10		2.00	0.80	0.01	17.00
	June	8.20	11.00	2.00	0.60	0.01	125.00
	August	7.80	11.10	2.00	1.00	0.01	58.00
	October	8.20	8.00	2.00	0.11	0.01	30.00
	December	8.20	13.90	2.00	0.70	0.01	37.00
Average		8.10	11.00	2.00	0.64	0.01	53.40
PS6	April	7.60		2.00	1.60	0.01	36.00
	June	8.00	8.80	2.00	1.00	0.05	161.00
	August	7.70	8.10	2.00	1.50	0.02	345.00
	October	8.10	8.00	2.00	0.27	0.01	22.00
	December	8.10	13.50	2.20	1.30	0.02	49.00
Average		7.90	9.60	2.04	1.13	0.02	122.60
PS8	April	7.70	11.80	2.00	1.40	0.01	34.00
	June	7.70	8.80	2.00	1.00	0.02	93.00
	August	7.80	8.60	2.00	1.60	0.05	11.00
	October	8.10	7.80	2.00	0.10	0.01	16.00
	December	8.10	14.00	3.00	1.80	0.03	178.00
Average		7.88	10.20	2.20	1.18	0.02	66.40
PS14	April	7.40	10.00	2.00	3.50	0.01	23.00
	June	7.30	7.00	2.00	0.20	0.01	108.00
	August	6.80	6.40	2.00	3.00	0.09	1203.00
	October	7.90	7.40	2.00	0.23	0.01	64.00
	December	7.90	11.00	2.10	1.00	0.01	579.00
Average		7.46	8.36	2.02	1.59	0.03	395.40

2008 Volunteer Water Monitoring Data

Creek Name	Date	Dissolved Oxygen	% Saturation	*E. coli*	pH	Biochemical Oxygen Demand	Temperature °C	Orthophosphate	NO3-Nitrate	Nitrite	Turbidity	Hoosier Riverwatch Water Quality Index Rating
VS1 - Little Creek	4/17/2008	12	121	33	7.5	3	16	0.1	4.4	0	15	74.18
	5/10/2008	10	99	267	7	0	15.5	0.6	8.8	0	17	73.22
	7/12/2008	10	107	233	7	4	19	0.2	4.4	0	15	67.54
	8/7/2008	9	95	600	6.5	3	19	0.2	1.1	0	25	68.95
	9/7/2008	12	140	11,122	7.5	9	23	0.2	8.8	0	16	50.37
	10/4/2008	11	117	133	7.5	10	19	0	8.8	0	60	59.72
	Average	11	113	2065	7	5	19	0	6	0	25	69
VS2 - Ramsey Creek	4/19/2008	10	99	0	6.5	3	15	0.1	2.2	0	15	86.66
	5/10/2008	8	83	267	7	0	18	0.2	2.2	0	15	74.56
	6/25/2008	10	105		6.5	3	19	0.3	0	0	15	N/A
	7/12/2008	1	12	33	6.5	1	24	0.3	0	0	15	59.33
	8/9/2008	8	90	133	8	3	22	0.6	2.2	0	15	74.2
	9/6/2008	2	20	567	6.5	1	24	0.3	2.2	0	15	52.26
	10/4/2008	1	10	333	6.5	1	15	0.2	0	0	15	58.01
	Average	6	60	222	7	2	20	0	1	0	15	58
VS3 - Harberts Creek	4/19/2008	10	99	67	8	1	15	0	4.4	3.3	15	78.34
	5/10/2008	8	79	200	6.5	1	15	0.3	1.1	0.25	15.01	75.89
	6/14/2008	6	65	767	8	1	19	0.1	2.2	0	15.01	68.56
	7/12/2008	9	104	267	7.5	3	22	1	2.2	0	15.01	70.63
	8/9/2008	6	65	100	7	1	20	0.3	0	0	15.01	74.07
	9/6/2008	7	80	833	6.5	3	20	0.2	0	0	15.01	70.21
	10/4/2008	10	99	267	7.5	6	15	0.1	0	0	15.01	74.00
	11/3/2008	10	140	267	6.5	6	16	0.1	0	0	15.01	65.65
	Average	8	91	346	7	3	18	0	1	0	15	70
VS4 - Middle Fork Creek	4/18/2008	12	119	0	2	2	15	0	0	0	15	75.09
	5/9/2008	9	87	367	6.5	1.5	14	0.2	1.1	0	15	73.29
	6/23/2008	8	85	133	7	1	19	0.6	2.2	0	15.01	75.64
	7/12/2008	9	103	450	8	4	23	0	0	0	15.01	71.41
	8/9/2008	7	75	167	7.5	1.5	18	0	0	0	15.01	73.26
	9/6/2008	7	81	600	7	1	20	0.1	0	0	15.01	72.49
	10/4/2008	7	63	3,929	7	6	11.5	0	0	0	15.01	58.56
	Average	8	88	807	6	2	17	0	0	0	15	59
VS5 - Big Creek	4/18/2008	12	119	0	6.5	2	15	0	0	0	16	85.9
	5/18/2008	9	89	900	6.5	2	15	0.4	2.2	0	18	68.9
	6/23/2008	10	105	367	7.5	3	19	0.2	0	1.65	15	73.08
	7/12/2008	8	101	250	7.5	3.5	24	0	0	0	15	74.1
	8/9/2008	7	80	267	7	2	20	0	0	0	15	72.08
	9/9/2008	5	58	200	6.5	2	21	0.1	0	0	15	63.26
	10/4/2008	7	63	867	7	6	13	0	0	0	15	60.31
	Average	8	88	407	7	3	18	0	0	0	16	60

Creek Name	Date	Dissolved Oxygen	% Saturation	*E. coli*	pH	Biochemical Oxygen Demand	Temperature °C	Orthophosphate	NO3-Nitrate	Nitrite	Turbidity	Hoosier Riverwatch Water Quality Index Rating
VS6 - Little Creek	4/19/2008	11	115	1100	7.5	2	15	0	4.4	0	15	70.52
	5/10/2008	10	105	300	7	2	18	0.15	8.8	0	15	69.56
	7/12/2008	5.5	60	1000	8	2	20	0.15	2.2	0	15	60.59
	8/9/2008	5	60	16,550	7.5	0	20	0.15	2.2	0	15	61.22
	9/6/2008	4	45	867	7.5	1	20	0.15	0	0	15	60.24
	10/4/2008	4	40	1333	6.5	1	14	0.15	0	0	15	55.88
	Average	7	71	3525	7	1	18	0	3	0	15	56
VS7 - Quick Creek	4/19/2008	10	99	33	7	0	15	0	0	0	15	84.22
	5/10/2008	8	85	0	7	3	18	0.1	0	0	15	86.76
	6/12/2008	9	120	33	7	4	28	0	0	0	15	76.81
	7/11/2008	8	95	33	7	0	24	0	0	0	15	61.67
	8/8/2008	5.5	60	0	7.5	1	21	0	0	0	15	80.5
	9/10/2008	7	75	367	6.5	1	19	0.1	0	0	15	69.64
	10/3/2008	8	80	367	6	5	16	0	0	0	15	64.05
	Average	8	88	119	7	2	20	0	0	0	15	64
VS8 - Little Creek	4/19/2008	12	119	0	7	5	14	0.1	0	0	15	85.73
	5/10/2008	10	105	367	7	2	18	0.1	0	0	15	76.38
	7/21/2008	8	85	5500	7	2	21	0.2	0	0	15	69.33
	8/12/2008	12	130	600	7.5	1	25	0.2	2.2	0	15	71.18
	9/22/2008	7	77	267	6.5	2	21	0.4	0	0	15	70.64
	10/29/2008	6	54	833	6.5	6	10	0.1	0	0	15	54.72
	Average	9	95	1261	7	3	18	0	0	0	15	55
VS9 - Big Creek	4/19/2008	12	120	33	7.5	2	15	0	2.2	0	15	78.31
	5/10/2008	12	125	433	7	3	18	0.2	8.8	0	15	64.85
	7/21/2008	10	110	67	7	2	22	0.1	0	0	15	78.09
	8/12/2008	12	140	333	8.5	3	25	0.1	2.2	0	15	67.03
	9/22/2008	5	55	33	7.5	1	22	0.3	0	0	15	70.18
	10/29/2008	9	70	0	7	70	8	0	0	0	15	78.21
	10/17/2007	7	70		6.5	2	20	0	0	0	15	N/A
	Average	10	99	150	7	12	19	0	2	0	15	78

Appendix D: Headwater Assessment Data Results



The following are the results of the water chemistry index presented by site and the score received for each round of sampling. The index's scale is 100-90 is excellent, 89-70 is good, 69-50 is medium, 49-25 is bad, and 24-0 is very bad.

Site	Round 1 Score	Round 2 Score	Round 3 Score	Round 4 Score
HWS 1	Dry	63.69	Dry	Dry
HWS 3	53.4	53.93	57.28	33.24
HWS 4	67.2	67.9	60.57	Dry
HWS 8	Dry	Dry	Dry	Dry

Site	Round 1 Score	Round 2 Score	Round 3 Score	Round 4 Score
HWS 10	64.6	61.35	62.2	48.87
HWS 7	76.63	67.4	73.8	Dry
PW 1	74.6	71.88	66.6	73.1
PW 2	86.61	77.5	72.5	63.3
PW 3	74.01	77.2	77.35	72.6

Mean values for chemical tests performed at each site. Also contains standard error (±SE) and the range of values is given for each test at each testing site.

Site	DO mg/L	B.O.D.-5 mg/L	*E. coli* *Colonies/100mL*	pH	Ortho Phosphates mg/L	Nitrate mg/L	Nitrite mg/L
HWS 1	5 ±0	1 ±0	466.2 ±0	7.5 ±0	0.2 ±0		
	(5-5)	(1-1)	(466.2-466.2)	(7.5-7.5)	(0.2-0.2)	0	0
HWS 3	4.25 ± 1.09	2.75 ±0.777	28179.9 ±15538.29	6.375 ±0.8004	7.125 ±1.737	4.4 ±1.796	1.373 ±0.69
	(1-5.5)	(1-4.5)	(2400-72419.6)	(4-7.5)	(3-10)	(0-8.8)	(0-3.3)
HWS 4	6 ±0.433	1.33 ± 0.722	1442.8 ±651.6	7 ±0.25	0.533 ±0.115		
	(5.5-7)	(0.5-3)	(499.5-2930)	(6.5-7.5)	(0.4-0.8)	0	0
HWS 8	dry	dry	dry	dry	dry	dry	dry
HWS 10	4.75 ±1.588	2.75 ± 0.924	18231.53 ± 18062.75	6.625 ±0.125	0.675 ±0.461	2.75 ±2.082	0.123 ±0.123
	(1.5-9)	(0.5- 5)	(40.3-72419.6)	(6.5-7)	(0.1-2)	(0-8.8)	(0.123-0.123)
HWS 7	9.33 ± 1.258	2.33 ± 1.607	3152.4 ±2614.7	6.83 ±0.144	0.033 ± 0.029		
	(7-12)	(1-6)	(133.2-9190)	(6.5-7)	(0-0.1)	0	0
PW 1	8.5 ± 0.645	3 ± 0.408	824.2 ±379.024	7.125 ±0.125	0.1125 ±0.042	2.2 ± 0	
	(7-10)	(2-4)	(133.3-1898.1)	(7-7.5)	(0.1-0.2)	(2.2-2.2)	0
PW 2	7.125 ±0.826	0.875 ±0.427	799.2 ±607.364	7.125 ± 0.125	0.0875 ± 0.043		
	(5-9)	(0.5-2)	(0-2597.4)	(6.5-8)	(0.05-0.2)	0	0
PW 3	8.5 ± 0.5	1.75 ±0.629	274.725 ±76.15	6.875 ±0.239	0.0375 ±0.0357		
	(7-9)	(2-3)	(166.5-499.5)	(6.5-7.5)	(0-0.15)	0	0

The physical assessment of each site is shown in the next table by providing values for the Citizen's Qualitative Habitat Evaluation Index, flow values in cubic feet per second, and turbidity values in NTU's. The lower the value in NTU's the higher the clarity of the water. Because a 60cm turbidity tube was used the lowest value able to be calculated is <15 NTU's.

Site	CQHEI	Flow Ft^3/sec				Turbidity (NTU's)			
		Round 1	Round 2	Round 3	Round 4	Round 1	Round 2	Round 3	Round 4
HWS 1	11	Dry	No Flow	Dry	Dry	Dry	50	Dry	Dry
HWS 3	45	0.083	0.089	No Flow	No Flow	17	40	15	100
HWS 4	64	No Flow	No Flow	No Flow	Dry	15	20	20	Dry
HWS 8	58	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
HWS 10	21	No Flow	No Flow	No Flow	No Flow	15	25	20	20
HWS 7	54	Incalculable	20.29	No Flow	Dry	<15	15	15	Dry
PW 1	88	0.201	0.12	2.183	Incalculable	<15	<15	<15	<15
PW 2	87	0.45	1.19	No Flow	Incalculable	<15	<15	15	<15
PW 3	87	0.077	0.09	Incalculable	6	<15	<15	<15	<15

The results for the biological diversity assessment of each site are presented in the next table. The biological monitoring data sheet considers sites receiving a score of 23 or more excellent, 17-22 good, 11-16 fair, and 10 or less poor. Sites that were dry, having no water within the banks, were not given a score. Also sites where flow was not able to be calculated, either due to lack of depth or to wind interference, or where water was present but not flowing also were not given a score.

Site	Round 1	Round 2	Round 3	Round 4
HWS 1	Dry	0	Dry	Dry
HWS 3	13	9	12	10
HWS 4	4	1	0	Dry
HWS 8	Dry	Dry	Dry	Dry
HWS 10	16	4	4	9
HWS 7	25	28	27	Dry
PW 1	15	21	10	14
PW 2	19	12	6	9
PW 3	13	16	0	6

The next table is a comparison of sites containing macroinvertebrates in terms of Shannon-Wiener index (H'), evenness (J) and species richness at those sites. Also total species richness for each site is given.

Site	H'	J	Richness
HWS3	0.949763	0.456739	8
HWS4	0.465999	0.672295	2
HWS10	1.261944	0.648511	7
HWS7	1.542597	0.569634	15
PW1	0.749144	0.34095	9
PW2	0.6346945	0.305224	8
PW3	1.282405	0.715724	6

Species overlap (C) of all sites containing macroinvertebrates using the Sorenson Index is presented in the next table. Values range from 0-1.0. 0 being no overlap and 1.0 being 100% overlap.

	HWS3	HWS4	HWS10	HWS7	PW1	PW2	PW3
HWS3	--	0.2	0.4	0.3478	0.2222	0.5	0.428571
HWS4	--	--	0.2222	0.2352	0	0.2	0
HWS10	--	--	--	0.4545	0.2352	0.4	0.4615
HWS7	--	--	--	--	0.5217	0.3478	0.5714
PW1	--	--	--	--	--	0.6250	0.5714
PW2	--	--	--	--	--	--	0.5714
PW3	--	--	--	--	--	--	--

Appendix E: L-THIA Model Data

14 Digit HUC	Land Use	Comparable Hydrography	Sum of Acres	Runoff (m3)	Total Nitrogen (kg)	Total Phosphorous (kg)	Total Suspended Solids (kg)
05120207010010	Agricultural	C	843.05	367,161.55	1,615.51	477.31	39,286.29
05120207010010	Agricultural	D	3,596.51	2,148,107.11	9,451.68	2,792.54	229,847.47
05120207010010	Commercial	C	3.93	6,966.81	9.34	2.23	386.66
05120207010010	Commercial	D	0.89	1,666.04	2.23	0.53	92.47
05120207010010	Forest	C	1,726.22	200,041.46	140.03	2.00	200.04
05120207010010	Forest	D	2,911.02	741,318.48	518.92	7.42	741.32
05120207010010	Grass/Pasture	C	230.44	42,521.89	29.77	0.43	42.52
05120207010010	Grass/Pasture	D	266.32	94,166.74	65.92	0.94	94.17
05120207010010	HD Residential	C	73.54	75,739.75	137.85	43.17	3,105.33
05120207010010	HD Residential	D	303.72	390,619.79	710.93	222.65	16,015.41
05120207010010	Industrial	D	1.90	2,596.90	3.27	0.73	157.11
05120207010010	LD Residential	C	5.11	1,948.82	3.55	1.11	79.90
05120207010010	LD Residential	D	125.28	76,232.61	138.74	43.45	3,125.54
05120207010010	Water	C	2.49	0.00	0.00	0.00	0.00
05120207010010	Water	D	4.45	0.00	0.00	0.00	0.00
05120207010010 Total			**10,094.86**	**4,149,087.94**	**12,827.72**	**3,594.51**	**293,174.22**
	Avg Concentration (mg/L)			4,149,087,942.60	**3.09**	**0.87**	**70.66**
05120207010020	Agricultural	C	141.88	61,886.59	272.30	80.45	6,621.87
05120207010020	Agricultural	D	124.18	75,699.52	333.08	98.41	8,099.85
05120207010020	Forest	C	4,578.73	532,548.39	372.78	5.32	532.55
05120207010020	Forest	D	7,235.99	1,836,385.18	1,285.47	18.38	1,836.38
05120207010020	Grass/Pasture	C	100.65	18,107.41	12.68	0.18	18.11
05120207010020	Grass/Pasture	D	51.61	17,383.43	12.17	0.17	17.38
05120207010020	HD Residential	C	62.24	58,526.17	106.52	33.36	2,399.57
05120207010020	HD Residential	D	70.58	90,009.88	163.82	51.31	3,690.40
05120207010020	LD Residential	C	0.85	311.81	0.57	0.18	12.78
05120207010020	LD Residential	D	0.02	0.00	0.00	0.00	0.00
05120207010020	Water	C	3.46	0.00	0.00	0.00	0.00
05120207010020	Water	D	3.44	0.00	0.00	0.00	0.00
05120207010020 Total			**12,373.64**	**2,690,858.37**	**2,559.38**	**287.75**	**23,228.90**
	Avg Concentration (mg/L)			2,690,858,372.40	**0.95**	**0.11**	**8.63**
05120207010030	Agricultural	C	1,392.01	605,424.93	2,663.87	787.05	64,780.47
05120207010030	Agricultural	D	3,594.83	2,158,502.46	9,497.42	2,806.05	230,959.77
05120207010030	Commercial	C	9.66	16,133.67	21.62	5.16	895.42
05120207010030	Commercial	D	2.44	4,581.60	6.14	1.47	254.28
05120207010030	Forest	C	1,988.50	231,349.60	161.94	2.31	231.35
05120207010030	Forest	D	1,892.99	480,397.41	336.28	4.81	480.40
05120207010030	Grass/Pasture	C	1,047.21	190,432.94	133.31	1.90	190.43
05120207010030	Grass/Pasture	D	544.15	191,607.49	134.13	1.92	191.61
05120207010030	HD Residential	C	176.38	182,693.46	332.50	104.14	7,490.43
05120207010030	HD Residential	D	214.95	273,491.55	497.75	155.89	11,213.15
05120207010030	LD Residential	C	14.77	5,300.78	9.65	3.02	217.33

14 Digit HUC	Land Use	Comparable Hydrography	Sum of Acres	Runoff (m3)	Total Nitrogen (kg)	Total Phosphorous (kg)	Total Suspended Solids (kg)
05120207010030	LD Residential	D	78.07	45,579.64	82.95	25.98	1,868.77
05120207010030	Water	C	14.63	0.00	0.00	0.00	0.00
05120207010030	Water	D	6.04	0.00	0.00	0.00	0.00
05120207010030 Total			**10,976.64**	**4,385,495.55**	**13,877.55**	**3,899.70**	**318,773.41**
	Avg Concentration (mg/L)			4,385,495,547.00	**3.16**	**0.89**	**72.69**
05120207010040	Agricultural	C	513.93	222,888.43	980.71	289.75	23,849.06
05120207010040	Agricultural	D	489.78	291,469.80	1,282.47	378.91	31,187.27
05120207010040	Commercial	C	1.11	1,466.70	1.97	0.47	81.40
05120207010040	Commercial	D	20.94	39,151.86	52.46	12.53	2,172.93
05120207010040	Forest	C	2,249.40	262,011.95	183.41	2.62	262.01
05120207010040	Forest	D	6,333.84	1,608,495.67	1,125.95	16.10	1,608.49
05120207010040	Grass/Pasture	C	720.48	131,227.83	91.86	1.31	131.23
05120207010040	Grass/Pasture	D	336.66	119,423.38	83.60	1.19	119.42
05120207010040	HD Residential	C	139.23	143,676.01	261.49	81.90	5,890.72
05120207010040	HD Residential	D	451.12	580,159.83	1,055.89	330.69	23,786.55
05120207010040	Industrial	D	3.11	4,544.57	5.73	1.27	274.95
05120207010040	LD Residential	C	8.18	2,806.29	5.11	1.60	115.06
05120207010040	LD Residential	D	20.97	12,927.56	23.53	7.37	530.03
05120207010040	Water	C	8.04	0.00	0.00	0.00	0.00
05120207010040	Water	D	5.68	0.00	0.00	0.00	0.00
05120207010040 Total			**11,302.49**	**3,420,249.88**	**5,154.16**	**1,125.71**	**90,009.12**
	Avg Concentration (mg/L)			3,420,249,877.80	**1.51**	**0.33**	**26.32**
05120207010050	Agricultural	C	947.72	411,352.44	1,809.95	534.76	44,014.71
05120207010050	Agricultural	D	1,936.79	1,162,680.63	5,115.80	1,511.49	124,406.83
05120207010050	Forest	C	2,072.78	241,165.68	168.81	2.41	241.17
05120207010050	Forest	D	2,182.69	553,462.09	387.42	5.54	553.46
05120207010050	Grass/Pasture	C	1,096.60	200,442.88	140.31	2.00	200.44
05120207010050	Grass/Pasture	D	771.38	269,793.95	188.86	2.70	269.80
05120207010050	HD Residential	C	117.42	122,331.18	222.64	69.73	5,015.58
05120207010050	HD Residential	D	210.85	271,183.61	493.55	154.57	11,118.53
05120207010050	Industrial	C	6.08	7,200.90	9.07	2.02	435.65
05120207010050	LD Residential	C	1.57	545.67	0.99	0.31	22.37
05120207010050	LD Residential	D	14.87	8,929.34	16.25	5.09	366.10
05120207010050	Water	C	7.08	0.00	0.00	0.00	0.00
05120207010050	Water	D	2.91	0.00	0.00	0.00	0.00
05120207010050 Total			**9,368.75**	**3,249,088.37**	**8,553.67**	**2,290.61**	**186,644.65**
				3,249,088,371.00	**2.63**	**0.71**	**57.45**
05120207010060	Agricultural	C	623.89	267,659.51	1,177.70	347.96	28,639.57
05120207010060	Agricultural	D	1,248.64	746,599.83	3,285.04	970.58	79,886.18
05120207010060	Commercial	C	0.87	1,466.70	1.97	0.47	81.40
05120207010060	Commercial	D	43.16	75,388.17	101.02	24.12	4,184.04
05120207010060	Forest	C	2,277.80	265,421.75	185.79	2.65	265.42
05120207010060	Forest	D	3,133.29	794,959.47	556.47	7.95	794.96
05120207010060	Grass/Pasture	C	513.12	93,914.37	65.74	0.94	93.91
05120207010060	Grass/Pasture	D	738.90	261,998.69	183.40	2.62	262.00

14 Digit HUC	Land Use	Comparable Hydrography	Sum of Acres	Runoff (m3)	Total Nitrogen (kg)	Total Phosphorous (kg)	Total Suspended Solids (kg)
05120207010060	HD Residential	C	110.54	116,593.32	212.20	66.46	4,780.33
05120207010060	HD Residential	D	677.93	875,865.36	1,594.08	499.24	35,910.48
05120207010060	Industrial	D	3.14	4,869.18	6.14	1.36	294.59
05120207010060	LD Residential	C	0.91	311.81	0.57	0.18	12.78
05120207010060	LD Residential	D	22.78	12,927.56	23.53	7.37	530.03
05120207010060	Water	C	4.58	0.00	0.00	0.00	0.00
05120207010060	Water	D	12.73	0.00	0.00	0.00	0.00
05120207010060 Total			**9,412.28**	**3,517,975.69**	**7,393.64**	**1,931.91**	**155,735.70**
				3,517,975,692.00	**2.10**	**0.55**	**44.27**
05120207010070	Agricultural	C	1,138.33	493,255.48	2,170.32	641.23	52,778.34
05120207010070	Agricultural	D	2,141.00	1,282,893.60	5,644.73	1,667.76	137,269.62
05120207010070	Commercial	C	3.30	5,500.12	7.37	1.76	305.26
05120207010070	Commercial	D	1.10	2,082.55	2.79	0.67	115.58
05120207010070	Forest	C	651.13	75,687.17	52.98	0.76	75.69
05120207010070	Forest	D	1,643.22	416,931.65	291.85	4.17	416.93
05120207010070	Grass/Pasture	C	1,026.30	187,665.97	131.37	1.88	187.67
05120207010070	Grass/Pasture	D	1,046.85	366,689.03	256.68	3.67	366.69
05120207010070	HD Residential	C	160.68	165,479.88	301.17	94.32	6,784.67
05120207010070	HD Residential	D	247.51	325,420.33	592.27	185.49	13,342.23
05120207010070	LD Residential	C	9.89	3,819.68	6.95	2.18	156.61
05120207010070	LD Residential	D	9.62	6,130.59	11.16	3.49	251.35
05120207010070	Water	C	16.28	0.00	0.00	0.00	0.00
05120207010070	Water	D	16.07	0.00	0.00	0.00	0.00
05120207010070 Total			**8,111.28**	**3,331,556.05**	**9,469.65**	**2,607.38**	**212,050.64**
				3,331,556,049.60	**2.84**	**0.78**	**63.65**
05120207010080	Agricultural	C	1,033.12	449,451.37	1,977.58	584.29	48,091.30
05120207010080	Agricultural	D	1,172.50	701,420.01	3,086.25	911.85	75,051.94
05120207010080	Commercial	C	11.35	19,433.74	26.04	6.22	1,078.57
05120207010080	Commercial	D	32.74	64,142.42	85.95	20.53	3,559.90
05120207010080	Forest	C	1,395.79	161,448.75	113.01	1.61	161.45
05120207010080	Forest	D	1,314.99	333,929.28	233.75	3.34	333.93
05120207010080	Grass/Pasture	C	1,400.54	255,945.13	179.16	2.56	255.95
05120207010080	Grass/Pasture	D	789.44	276,809.68	193.77	2.77	276.81
05120207010080	HD Residential	C	247.51	255,220.01	464.50	145.48	10,464.02
05120207010080	HD Residential	D	254.14	331,478.69	603.29	188.94	13,590.63
05120207010080	Industrial	C	3.64	4,371.98	5.51	1.22	264.50
05120207010080	Industrial	D	34.80	49,341.02	62.17	13.82	2,985.13
05120207010080	LD Residential	C	29.84	10,679.51	19.44	6.09	437.86
05120207010080	LD Residential	D	68.37	41,314.88	75.19	23.55	1,693.91
05120207010080	Water	C	47.94	0.00	0.00	0.00	0.00
05120207010080	Water	D	5.92	0.00	0.00	0.00	0.00
05120207010080 Total			**7,842.64**	**2,954,986.47**	**7,125.62**	**1,912.25**	**158,245.91**
				2,954,986,470.00	**2.41**	**0.65**	**53.55**
05120207010090	Agricultural	C	1,362.28	591,983.93	2,604.73	769.58	63,342.28
05120207010090	Agricultural	D	1,377.94	824,031.91	3,625.74	1,071.24	88,171.42

14 Digit HUC	Land Use	Comparable Hydrography	Sum of Acres	Runoff (m3)	Total Nitrogen (kg)	Total Phosphorous (kg)	Total Suspended Solids (kg)
05120207010090	Commercial	C	1.33	2,200.05	2.95	0.70	122.10
05120207010090	Commercial	D	2.22	4,165.09	5.58	1.33	231.16
05120207010090	Forest	C	2,597.36	301,431.27	211.00	3.01	301.43
05120207010090	Forest	D	956.68	242,174.95	169.52	2.42	242.17
05120207010090	Grass/Pasture	C	1,862.65	342,087.56	239.46	3.42	342.09
05120207010090	Grass/Pasture	D	589.41	206,184.63	144.33	2.06	206.19
05120207010090	HD Residential	C	205.05	206,103.93	375.11	117.48	8,450.26
05120207010090	HD Residential	D	140.66	190,405.51	346.54	108.53	7,806.63
05120207010090	LD Residential	C	5.22	2,260.63	4.11	1.29	92.69
05120207010090	LD Residential	D	1.75	932.92	1.70	0.53	38.25
05120207010090	Water	C	5.93	0.00	0.00	0.00	0.00
05120207010090	Water	D	14.29	0.00	0.00	0.00	0.00
05120207010090 Total			**9,122.77**	**2,913,962.37**	**7,730.77**	**2,081.61**	**169,346.67**
				2,913,962,371.20	**2.65**	**0.71**	**58.12**
05120207010100	Agricultural	C	1,347.54	587,149.04	2,583.45	763.29	62,824.95
05120207010100	Agricultural	D	508.26	305,463.55	1,344.04	397.10	32,684.60
05120207010100	Forest	C	3,440.60	399,127.14	279.38	3.99	399.13
05120207010100	Forest	D	1,079.54	273,907.83	191.74	2.74	273.91
05120207010100	Grass/Pasture	C	1,057.41	193,037.16	135.13	1.93	193.04
05120207010100	Grass/Pasture	D	153.01	53,631.39	37.54	0.54	53.63
05120207010100	HD Residential	C	177.09	185,677.15	337.93	105.84	7,612.76
05120207010100	HD Residential	D	53.60	67,507.41	122.86	38.48	2,767.80
05120207010100	LD Residential	C	1.34	311.81	0.57	0.18	12.78
05120207010100	LD Residential	D	2.70	1,999.11	3.64	1.14	81.96
05120207010100	Water	C	24.85	0.00	0.00	0.00	0.00
05120207010100	Water	D	3.96	0.00	0.00	0.00	0.00
05120207010100 Total			**7,849.89**	**2,067,811.59**	**5,036.29**	**1,315.22**	**106,904.57**
				2,067,811,587.00	**2.44**	**0.64**	**51.70**
05120207010110	Agricultural	C	690.28	300,053.27	1,320.23	390.07	32,105.70
05120207010110	Agricultural	D	1,075.54	641,713.35	2,823.54	834.23	68,663.33
05120207010110	Commercial	C	0.04	0.00	0.00	0.00	0.00
05120207010110	Commercial	D	3.52	6,664.15	8.93	2.13	369.86
05120207010110	Forest	B	10.25	171.45	0.12	0.00	0.17
05120207010110	Forest	C	2,187.66	253,745.77	177.62	2.53	253.75
05120207010110	Forest	D	735.17	187,461.14	131.22	1.88	187.46
05120207010110	Grass/Pasture	B	38.98	1,446.35	1.01	0.01	1.45
05120207010110	Grass/Pasture	C	434.20	80,486.40	56.34	0.81	80.49
05120207010110	Grass/Pasture	D	370.83	131,272.18	91.89	1.31	131.27
05120207010110	HD Residential	B	15.77	9,329.17	16.98	5.32	382.50
05120207010110	HD Residential	C	115.56	115,904.77	210.95	66.07	4,752.10
05120207010110	HD Residential	D	112.96	144,246.60	262.53	82.22	5,914.11
05120207010110	Industrial	D	1.78	2,596.90	3.27	0.73	157.11
05120207010110	LD Residential	C	0.89	311.81	0.57	0.18	12.78
05120207010110	LD Residential	D	4.68	3,198.57	5.82	1.82	131.14
05120207010110	Water	C	9.35	0.00	0.00	0.00	0.00
05120207010110	Water	D	5.02	0.00	0.00	0.00	0.00

14 Digit HUC	Land Use	Comparable Hydrography	Sum of Acres	Runoff (m3)	Total Nitrogen (kg)	Total Phosphorous (kg)	Total Suspended Solids (kg)
05120207010110 Total			**5,812.46**	**1,878,601.88**	**5,111.03**	**1,389.31**	**113,143.22**
				1,878,601,881.60	**2.72**	**0.74**	**60.23**
05120207010120	Agricultural	B	76.52	15,434.61	67.91	20.07	1,651.50
05120207010120	Agricultural	C	1,812.67	787,506.88	3,465.03	1,023.76	84,263.24
05120207010120	Agricultural	D	1,598.54	959,304.81	4,220.94	1,247.10	102,645.62
05120207010120	Commercial	C	7.94	12,100.26	16.21	3.87	671.56
05120207010120	Forest	B	130.86	2,016.25	1.41	0.02	2.02
05120207010120	Forest	C	3,326.97	386,753.71	270.72	3.86	386.76
05120207010120	Forest	D	942.08	240,255.17	168.18	2.40	240.25
05120207010120	Grass/Pasture	B	82.84	3,205.66	2.24	0.03	3.21
05120207010120	Grass/Pasture	C	1,537.02	281,010.66	196.71	2.81	281.01
05120207010120	Grass/Pasture	D	655.15	230,895.60	161.63	2.31	230.90
05120207010120	HD Residential	B	18.45	10,928.45	19.89	6.23	448.07
05120207010120	HD Residential	C	241.65	250,170.70	455.31	142.60	10,257.00
05120207010120	HD Residential	D	146.53	180,596.74	328.69	102.94	7,404.47
05120207010120	Industrial	C	3.89	4,371.98	5.51	1.22	264.50
05120207010120	LD Residential	B	1.92	232.49	0.42	0.13	9.53
05120207010120	LD Residential	C	2.23	857.48	1.56	0.49	35.16
05120207010120	LD Residential	D	2.41	1,066.19	1.94	0.61	43.71
05120207010120	Water	B	0.81	0.00	0.00	0.00	0.00
05120207010120	Water	C	12.14	0.00	0.00	0.00	0.00
05120207010120	Water	D	16.28	0.00	0.00	0.00	0.00
05120207010120 Total			**10,616.89**	**3,366,707.64**	**9,384.31**	**2,560.45**	**208,838.51**
				3,366,707,643.00	**2.79**	**0.76**	**62.03**
05120207030010	Agricultural	B	302.26	60,742.68	267.27	78.97	6,499.47
05120207030010	Agricultural	C	79.58	34,811.21	153.17	45.25	3,724.80
05120207030010	Commercial	C	2.91	4,400.09	5.90	1.41	244.21
05120207030010	Forest	B	545.46	8,401.05	5.88	0.08	8.40
05120207030010	Forest	C	524.34	60,859.72	42.60	0.61	60.86
05120207030010	Grass/Pasture	B	227.04	8,745.78	6.12	0.09	8.75
05120207030010	Grass/Pasture	C	461.54	84,799.63	59.36	0.85	84.80
05120207030010	HD Residential	B	16.49	10,262.08	18.68	5.85	420.75
05120207030010	HD Residential	C	62.28	62,657.43	114.04	35.71	2,568.95
05120207030010	LD Residential	B	2.72	309.98	0.56	0.18	12.71
05120207030010	LD Residential	C	2.97	1,013.38	1.84	0.58	41.55
05120207030010	Water	B	13.00	0.00	0.00	0.00	0.00
05120207030010	Water	C	5.93	0.00	0.00	0.00	0.00
05120207030010 Total			**2,246.52**	**337,003.03**	**675.42**	**169.57**	**13,675.24**
				337,003,034.40	**2.00**	**0.50**	**40.58**
05120207030020	Agricultural	B	83.22	16,973.55	74.68	22.07	1,816.17
05120207030020	Agricultural	C	1,322.09	573,127.86	2,521.76	745.07	61,324.68
05120207030020	Agricultural	D	1,692.00	1,013,947.07	4,461.37	1,318.13	108,492.34
05120207030020	Commercial	C	1.29	1,833.37	2.46	0.59	101.75
05120207030020	Forest	B	30.00	452.63	0.32	0.00	0.45
05120207030020	Forest	C	2,499.81	290,917.73	203.64	2.91	290.92

14 Digit HUC	Land Use	Comparable Hydrography	Sum of Acres	Runoff (m3)	Total Nitrogen (kg)	Total Phosphorous (kg)	Total Suspended Solids (kg)
05120207030020	Forest	D	535.33	135,627.01	94.94	1.36	135.63
05120207030020	Grass/Pasture	B	35.67	1,353.31	0.95	0.01	1.35
05120207030020	Grass/Pasture	C	622.70	113,364.57	79.36	1.13	113.37
05120207030020	Grass/Pasture	D	133.67	45,290.46	31.70	0.45	45.29
05120207030020	HD Residential	B	9.94	6,263.87	11.40	3.57	256.82
05120207030020	HD Residential	C	211.50	224,465.08	408.53	127.94	9,203.07
05120207030020	HD Residential	D	119.98	155,497.83	283.01	88.63	6,375.41
05120207030020	LD Residential	C	5.25	1,637.00	2.98	0.93	67.12
05120207030020	LD Residential	D	2.09	1,466.01	2.67	0.84	60.11
05120207030020	Water	C	26.70	0.00	0.00	0.00	0.00
05120207030020	Water	D	6.83	0.00	0.00	0.00	0.00
05120207030020 Total			**7,338.08**	**2,582,217.37**	**8,179.75**	**2,313.64**	**188,284.47**
				2,582,217,365.40	**3.17**	**0.90**	**72.92**
05120207030030	Agricultural	B	2,538.16	518,575.90	2,281.73	674.15	55,487.63
05120207030030	Agricultural	C	1,997.07	867,959.45	3,819.02	1,128.35	92,871.67
05120207030030	Agricultural	D	197.88	118,880.23	523.07	154.54	12,720.18
05120207030030	Forest	B	985.31	15,087.60	10.56	0.15	15.09
05120207030030	Forest	C	3,673.38	427,800.44	299.46	4.27	427.80
05120207030030	Forest	D	78.02	19,875.40	13.91	0.20	19.88
05120207030030	Grass/Pasture	B	166.52	6,394.40	4.48	0.06	6.39
05120207030030	Grass/Pasture	C	1,056.44	193,077.85	135.16	1.93	193.08
05120207030030	Grass/Pasture	D	25.36	9,042.50	6.33	0.09	9.04
05120207030030	HD Residential	B	137.14	80,097.55	145.78	45.66	3,284.00
05120207030030	HD Residential	C	275.42	277,482.91	505.02	158.17	11,376.80
05120207030030	HD Residential	D	22.97	28,560.83	51.98	16.28	1,170.99
05120207030030	LD Residential	C	7.50	2,962.20	5.39	1.69	121.45
05120207030030	Water	B	29.44	0.00	0.00	0.00	0.00
05120207030030	Water	C	30.15	0.00	0.00	0.00	0.00
05120207030030	Water	D	2.35	0.00	0.00	0.00	0.00
05120207030030 Total			**11,223.12**	**2,565,797.26**	**7,801.88**	**2,185.54**	**177,704.00**
				2,565,797,256.00	**3.04**	**0.85**	**69.26**
05120207030040	Agricultural	B	487.01	98,763.43	434.56	128.39	10,567.69
05120207030040	Agricultural	C	1,634.25	714,403.35	3,143.37	928.72	76,441.16
05120207030040	Agricultural	D	595.35	356,240.87	1,567.46	463.11	38,117.77
05120207030040	Commercial	C	0.89	1,466.70	1.97	0.47	81.40
05120207030040	Forest	B	283.31	4,351.40	3.05	0.04	4.35
05120207030040	Forest	C	863.57	100,589.03	70.41	1.00	100.59
05120207030040	Forest	D	152.46	38,790.91	27.15	0.39	38.79
05120207030040	Grass/Pasture	B	38.14	1,437.89	1.01	0.01	1.44
05120207030040	Grass/Pasture	C	51.89	9,318.19	6.52	0.09	9.32
05120207030040	Grass/Pasture	D	12.81	4,443.30	3.11	0.04	4.44
05120207030040	HD Residential	B	35.24	22,390.00	40.75	12.76	917.99
05120207030040	HD Residential	C	164.05	159,971.54	291.15	91.18	6,558.83
05120207030040	HD Residential	D	29.59	38,946.58	70.88	22.20	1,596.81
05120207030040	LD Residential	C	4.10	1,247.24	2.27	0.71	51.14
05120207030040	LD Residential	D	1.49	399.82	0.73	0.23	16.39

14 Digit HUC	Land Use	Comparable Hydrography	Sum of Acres	Runoff (m3)	Total Nitrogen (kg)	Total Phosphorous (kg)	Total Suspended Solids (kg)
05120207030040	Water	C	13.01	0.00	0.00	0.00	0.00
05120207030040 Total			**4,367.17**	**1,552,760.24**	**5,664.39**	**1,649.37**	**134,508.12**
				1,552,760,242.20	**3.65**	**1.06**	**86.63**
05120207030050	Agricultural	C	866.25	375,767.65	1,653.38	488.50	40,207.14
05120207030050	Agricultural	D	1,898.80	1,139,890.81	5,015.52	1,481.86	121,968.32
05120207030050	Commercial	C	1.07	1,466.70	1.97	0.47	81.40
05120207030050	Forest	C	2,263.56	263,148.55	184.20	2.63	263.15
05120207030050	Forest	D	975.45	248,386.02	173.87	2.49	248.39
05120207030050	Grass/Pasture	C	353.26	64,372.85	45.06	0.64	64.37
05120207030050	Grass/Pasture	D	319.37	111,238.36	77.87	1.11	111.24
05120207030050	HD Residential	C	107.36	109,707.88	199.67	62.53	4,498.02
05120207030050	HD Residential	D	205.52	263,105.80	478.85	149.97	10,787.34
05120207030050	Industrial	D	0.57	324.61	0.41	0.09	19.64
05120207030050	LD Residential	C	4.05	1,403.15	2.55	0.80	57.53
05120207030050	LD Residential	D	5.51	2,932.02	5.34	1.67	120.21
05120207030050	Water	C	703.60	0.00	0.00	0.00	0.00
05120207030050	Water	D	4.27	0.00	0.00	0.00	0.00
05120207030050 Total			**7,708.63**	**2,581,744.39**	**7,838.68**	**2,192.76**	**178,426.75**
				2,581,744,392.00	**3.04**	**0.85**	**69.11**
05120207030060	Agricultural	B	79.43	16,339.87	71.90	21.24	1,748.37
05120207030060	Agricultural	C	1,796.49	783,735.67	3,448.43	1,018.86	83,859.72
05120207030060	Agricultural	D	325.42	195,379.39	859.67	253.99	20,905.60
05120207030060	Commercial	C	1.10	1,466.70	1.97	0.47	81.40
05120207030060	Forest	B	18.05	267.46	0.19	0.00	0.27
05120207030060	Forest	C	2,644.81	306,855.95	214.80	3.06	306.86
05120207030060	Forest	D	183.32	46,470.04	32.53	0.46	46.47
05120207030060	Grass/Pasture	C	1,459.30	267,175.79	187.03	2.67	267.18
05120207030060	Grass/Pasture	D	5.37	1,714.96	1.20	0.02	1.71
05120207030060	HD Residential	C	263.47	268,531.85	488.73	153.06	11,009.81
05120207030060	HD Residential	D	18.11	25,387.40	46.21	14.47	1,040.88
05120207030060	LD Residential	C	1.84	623.62	1.13	0.36	25.57
05120207030060	LD Residential	D	1.11	666.37	1.21	0.38	27.32
05120207030060	Water	C	35.24	0.00	0.00	0.00	0.00
05120207030060 Total			**6,833.05**	**1,914,615.07**	**5,354.98**	**1,469.05**	**119,321.15**
				1,914,615,068.40	**2.80**	**0.77**	**62.32**
05120207030070	Agricultural	B	601.52	122,797.98	540.31	159.64	13,139.38
05120207030070	Agricultural	C	5,179.56	2,259,537.49	9,941.96	2,937.40	241,770.52
05120207030070	Commercial	B	1.68	2,019.45	2.71	0.65	112.08
05120207030070	Commercial	C	107.14	175,637.04	235.35	56.20	9,747.86
05120207030070	Forest	B	298.90	4,601.72	3.22	0.05	4.60
05120207030070	Forest	C	2,994.01	346,301.11	242.41	3.46	346.30
05120207030070	Grass/Pasture	B	98.26	3,713.15	2.60	0.04	3.71
05120207030070	Grass/Pasture	C	923.53	168,663.37	118.07	1.69	168.66
05120207030070	HD Residential	B	46.04	27,054.58	49.24	15.42	1,109.24
05120207030070	HD Residential	C	849.09	873,761.32	1,590.24	498.04	35,824.21

14 Digit HUC	Land Use	Comparable Hydrography	Sum of Acres	Runoff (m3)	Total Nitrogen (kg)	Total Phosphorous (kg)	Total Suspended Solids (kg)
05120207030070	Industrial	C	52.29	60,178.95	75.83	16.85	3,640.83
05120207030070	LD Residential	B	7.20	852.45	1.55	0.49	34.95
05120207030070	LD Residential	C	270.80	95,803.75	174.36	54.61	3,927.95
05120207030070	Water	B	4.88	0.00	0.00	0.00	0.00
05120207030070	Water	C	91.70	0.00	0.00	0.00	0.00
05120207030070 Total			**11,526.59**	**4,140,922.35**	**12,977.85**	**3,744.52**	**309,830.31**
				4,140,922,350.60	**3.13**	**0.90**	**74.82**
Grand Total			**164,127.72**	**49,514,120,605.11**	**142,763.74**	**38,733.53**	**3,158,875.63**
			164,127.72	53,601,441.51	142,716.74	38,720.87	3,157,845.54
				53,601,441,514.20	**2.66**	**0.72**	**58.91**

Average Annual Concentration (LTHIA)

Watershed (HUC-14)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Suspended Solids (mg/L)
05120207010010	3.09	0.87	70.66
05120207010020	0.95	0.11	8.63
05120207010030	3.16	0.89	72.69
05120207010040	1.51	0.33	26.32
05120207010050	2.63	0.71	57.45
05120207010060	2.10	0.55	44.27
05120207010070	2.84	0.78	63.65
05120207010080	2.41	0.65	53.55
05120207010090	2.65	0.71	58.12
05120207010100	2.44	0.64	51.70
05120207010110	2.72	0.74	60.23
05120207010120	2.79	0.76	62.03
05120207030010	2.00	0.50	40.58
05120207030020	3.17	0.90	72.92
05120207030030	3.04	0.85	69.26
05120207030040	3.65	1.06	86.63
05120207030050	3.04	0.85	69.11
05120207030060	2.80	0.77	62.32
05120207030070	3.13	0.90	74.82
Entire watershed	2.66	0.72	58.91