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Ohio Environmental Protection Agency

Total Maximum Daily Loads for the Great Miami River (upper) Watershed

Final Report
February 8, 2012

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Photo caption: Loramie Creek just west of Newport (river mile 14.8).

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Acronyms and Abbreviations

AFG	allowance for future growth
ALU	aquatic life use
AU	assessment unit
AWS	agricultural water supply
BMP	best management practices
BNA	base neutral and acid extractable compounds
BW	bathing water
CAFO	confined animal feeding operation
CFR	Code of Federal Regulations
cfs	cubic feet per second
Corps	United States Army Corps of Engineers
CREP	Conservation Reserve Enhancement Program (USDA program)
CRP	Conservation Reserve Program (USDA program)
CSO	combined sewer overflow
CSP	Conservation Security Program (USDA program)
CWA	Clean Water Act
CWH	coldwater habitat
D.O.	dissolved oxygen
DA	drainage area
DMR	discharge monitoring report
DNAP	Division of Natural Areas and Preserves (part of ODNR)
DOW	Division of Wildlife (part of ODNR)
DSW	Division of Surface Water (part of Ohio EPA)
DSWC	Division of Soil and Water Conservation (part of ODNR)
ECBP	Eastern Corn Belt Plains (ecoregion)
EPA	Environmental Protection Agency, see U.S. EPA
EQIP	Environmental Quality Incentive Plan (USDA program)
EWH	exceptional warmwater habitat
FCA	fish consumption advisory
FFY	federal fiscal year (October 1 to September 30)
FSA	Farm Service Agency
FWPCA	Federal Water Pollution Control Act
gpd	gallons per day
GRP	Grassland Reserve Program (USDA program)
HELP	Huron Erie Lake Plain (ecoregion)
HSTS	home sewage treatment system
HU	hydrologic unit
HUC	hydrologic unit code
I/I	infiltration and inflow
IBI	Index of Biotic Integrity
ICI	Invertebrate Community Index
IR	Integrated Report
IWS	industrial water supply
kg	kilogram
L	liter
LA	load allocation
LaMP	Lakewide Management Plan
LEC	(Ohio) Lake Erie Commission

LEL	lowest effect level
LEPF	Lake Erie Protection Fund (LEC program)
LRAU	large river assessment unit
LRW	limited resource water
LTCP	long-term control plan
mg	milligram
MGD	million gallons per day
MHP	mobile home park
MIwb	Modified Index of well being
mi^2	square miles
ml	milliliter
MOS	margin of safety
MPN	most probable number
MS4	municipal separate storm sewer system
MWH	modified warmwater habitat
n	number (of data points in a grouping)
NHD	National Hydrography Dataset
NOI	notice of intent
NPDES	National Pollutant Discharge Elimination System
NPS	nonpoint source
NRCS	Natural Resource Conservation Service
OAC	Ohio Administrative Code
ODA	Ohio Department of Agriculture
ODH	Ohio Department of Health
ODNR	Ohio Department of Natural Resources
ODOT	Ohio Department of Transportation
OEPA	Ohio Environmental Protection Agency
Ohio EPA	Ohio Environmental Protection Agency (preferred nomenclature)
ORC	Ohio Revised Code
ORSANCO	Ohio River Valley Water Sanitation Commission
OSC	on-site coordinator
OSUE	Ohio State University Extension
OWDA	Ohio Water Development Authority
OWRC	Ohio Water Resources Council
PAHs	polyaromatic hydrocarbons
PCBs	polychlorinated biphenyls
PCR	primary contact recreation
PEC	probable effect concentration
PDWS	public drinking water supply
PEC	probable effect concentration
ppb	parts per billion
PS	point source
PTI	permit to install
PTO	permit to operate
PWS	public water supply
QA	quality assurance
QC	quality control
QHEI	qualitative habitat evaluation index
RM	river mile
SCR	secondary contact recreation
SDWA	Safe Drinking Water Act

SEL	severe effect level
SFY	state fiscal year (July 1 to June 30)
SMP	sludge management plan
sq mi	square miles
SRW	state resource water
SSH	seasonal salmonid habitat
SSM	single-sample maximum
SSO	sanitary sewer overflow
STORET	STOrage and RETrieval (a U.S. EPA water quality database)
SWIMS	Surface Water Information Management System
SWCD	Soil and Water Conservation District
TEC	threshold effect concentration
TKN	total Kjeldahl nitrogen
TMDL	total maximum daily load
TOC	total organic carbon
TSS	total suspended solids
ug	microgram
µg	microgram
U.S. EPA	United States Environmental Protection Agency
UAA	use attainability analysis
USACOE	United States Army Corps of Engineers
USC	United States Code
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VOC	volatile organic compound
WAU	watershed assessment unit
WHIP	Wildlife Habitat Incentives Program (USDA program)
WLA	wasteload allocation
WPCLF	Water Pollution Control Loan Fund
WQ	water quality
WQS	water quality standards
WRP	Wetland Reserve Program (USDA program)
WRRSP	Water Resource Restoration Sponsor Program (Ohio EPA program)
WTP	water treatment plant
WWH	warmwater habitat
WWTP	wastewater treatment plant

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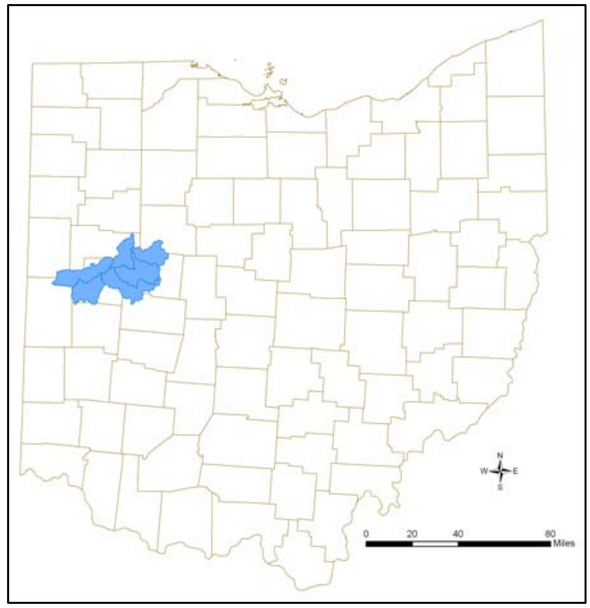
The Ohio EPA appreciates the cooperation of the property owners who allowed Ohio EPA personnel access to the project area.

Executive Summary

The Great Miami River (upper) watershed is located in western Ohio extending from north of Indian Lake to the town of Sidney. This 748 square mile watershed area is home to more than 76,000 people and encompasses all or part of 22 municipalities in Hardin, Auglaize, Logan, Mercer, Darke, Shelby, Champaign and Miami counties. The watershed is primarily cultivated crop land with 9.2 percent being developed.



State wide map of the Great Miami River (upper) watershed with the TMDL project area highlighted.

In 2008, Ohio EPA sampled 78 sites on streams in this watershed. Data collected related to water and sediment quality, aquatic biological communities, and habitat. Ohio's water quality standards were compared with these data to determine if quality criteria for various designated beneficial uses were met.

Overall, the watershed met criteria for the recreation use at 27% of sites and 64% of sites for aquatic life uses. The causes of impairments included habitat alteration, nutrients, silt, flow alteration, organic enrichment/dissolved oxygen, total dissolved solids and bacteria. Sources of these stressors include channelization for habitat alteration and silt; agriculture for nutrients, silt and bacteria; impoundments for flow alteration and nutrients; urban runoff and unsewered communities for bacteria; point sources for organic enrichment/dissolved oxygen, nutrients and total dissolved solids; and sanitary sewer overflows, animal feedlot operations, livestock access, municipal biosolids land application and wildlife for bacteria.

Total maximum daily loads (TMDL) have been developed for pollutants and stressors that have impaired beneficial uses and precluded attainment of applicable water quality standards. Specific TMDLs that have been developed and are described in this report include:

- Nutrients (total phosphorus)
- Sediment and habitat
- Total dissolved solids
- Bacteria

The needed load reductions ranged from 24 to 93% for total phosphorus, 39.1% for total dissolved solids and 0 to 95.7% for bacteria. Sources of the pollutants that have been allocated the most significant reductions include agricultural lands and wastewater treatment plants.

Recommendations for regulatory action resulting from this TMDL analysis include lower effluent limits for total phosphorus and TDS. Nonpoint sources of total phosphorus should be addressed by reducing overland flow and nutrient inputs; for silt by reducing overland flow; for habitat by improving riparian vegetation and stabilizing stream banks; and for bacteria by identifying and fixing failing home sewage treatment systems and by proper land application of manure and biosolids. Nonpoint sources are typically addressed by voluntary actions.

Chapter

1

1 INTRODUCTION

The Great Miami River (upper) watershed is located in western Ohio extending from north of Indian Lake to the town of Sidney. This 748 square mile watershed area is home to more than 76,000 people and encompasses all or part of 22 municipalities in Hardin, Auglaize, Logan, Mercer, Darke, Shelby, Champaign and Miami counties. In 2008, Ohio EPA sampled 78 sites on streams throughout the watershed. Data collected related to water and sediment quality, aquatic biological communities, and habitat. The causes of impairment included habitat alteration, nutrients, silt, flow alteration, organic enrichment/dissolved oxygen, total dissolved solids and bacteria. Sources of these stressors include channelization, agriculture, impoundments, urban runoff, unsewered communities, point sources, sanitary sewer overflows, animal feedlot operations, livestock access, land application of manure and biosolids, and wildlife.

1.1 The Clean Water Act Requirement to Address Impaired Waters

The Clean Water Act (CWA) Section 303(d) requires States, Territories, and authorized Tribes to list and prioritize waters for which technology-based limits alone do not ensure attainment of water quality standards. Lists of these impaired waters (the Section 303(d) lists) are made available to the public for comment, then submitted to the U.S. Environmental Protection Agency (U.S. EPA) for approval in even-numbered years. Further, the CWA and U.S. EPA regulations require that total maximum daily loads (TMDLs) be developed for all waters on the Section 303(d) lists. The Ohio EPA identified the Great Miami River (upper) watershed (assessment units 05080001 01 01—03, 02 01—04, 03 01—06, 04 01—06, 05 01—03 and 06 01—04) as impaired on the 2010 303(d) list (Ohio EPA 2010; available at http://www.epa.ohio.gov/dsw/tmdl/2010IntReport/2010OhioIntegratedReport.aspx).

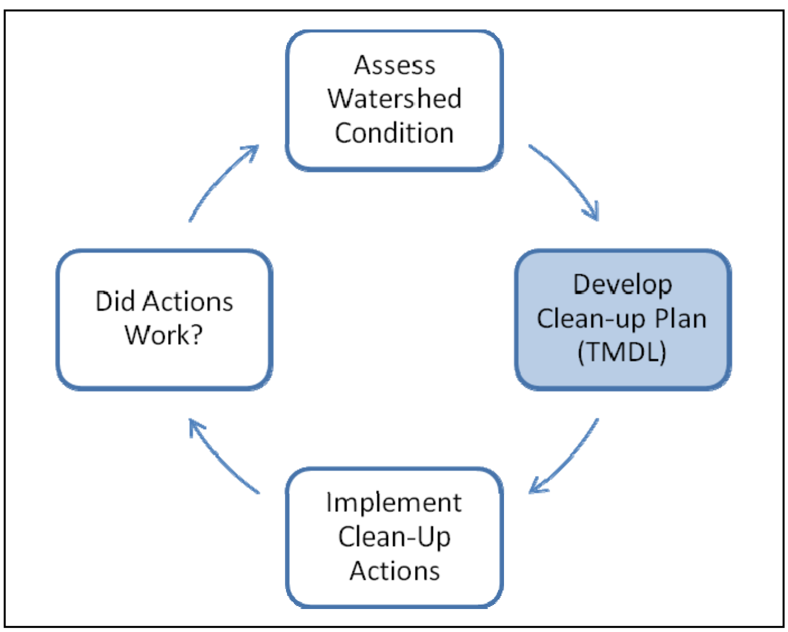


Figure 1-1. Overview of the TMDL project process.

In the simplest terms, a TMDL can be thought of as a cleanup plan for a watershed that is not meeting water quality standards. A TMDL is defined as a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards and an allocation of that quantity among the sources of the pollutant. Ultimately, the goal of Ohio's TMDL process is full attainment of water quality standards (WQS), which would subsequently lead to the removal of the waterbodies from the 303(d) list. Figure 1-1 shows the phases of TMDL development in Ohio.

Table 1-1 summarizes how the impairments identified in the Great Miami River (upper) watershed are addressed in this TMDL report.

Table 1-1. Summary of impairments in the Great Miami River (upper) watershed and methods used to address impairments.

Assessment Unit (05080001)	Narrative Description	Causes of Impairment (Beneficial use in parentheses[1])	Action Taken
Headwaters Great Miami River (05080001 01)			
01 01 *Priority points: 3*	North Fork Great Miami River	No impairment (ALU)	No action necessary
		Bacteria (RU)	Bacteria TMDL
01 02 *Priority points: 1*	South Fork Great Miami River	No impairment (ALU)	No action necessary
		Bacteria (RU)	Bacteria TMDL
01 03 *Priority points: 1*	Indian Lake Great Miami River	Direct habitat alteration (ALU)	Habitat TMDL
		No data for assessment (RU)	No action necessary
Muchinippi Creek (05080001 02)			
02 01 *Priority points: 1*	Willow Creek	Direct habitat alteration (ALU)	Habitat TMDL
		No impairment (RU)	No action necessary
02 02 *Priority points: 1*	Headwaters Muchinippi Creek	No impairment (ALU)	No action necessary
		Bacteria (RU)	Bacteria TMDL
02 03 *Priority points: 5*	Little Muchinippi Creek	Direct habitat alterations (ALU)	Habitat TMDL
		Nutrients (ALU)	Nutrient TMDL
		Sedimentation/siltation (ALU)	Sediment TMDL
		Bacteria (RU)	Bacteria TMDL
02 04 *Priority points: 4*	Calico Creek-Muchinippi Creek	Direct habitat alterations (ALU)	Habitat TMDL
		Sedimentation/siltation (ALU)	Sediment TMDL
		Other flow regime alterations (ALU)	Habitat TMDL as surrogate
		No impairment (RU)	No action necessary
Bokengehalas Creek-Great Miami River (05080001 03)			
03 01 *Priority points: 2*	Cherokee Mans Run	No impairment (ALU)	No action necessary
		No data for assessment (RU)	No action necessary
03 02	Rennick Creek-	Sedimentation/siltation (ALU)	Sediment TMDL

Assessment Unit (05080001)	Narrative Description	Causes of Impairment (Beneficial use in parentheses[1])	Action Taken
Priority points: 8	Great Miami River	Other flow regime alterations (ALU)	Habitat TMDL as surrogate
		Direct habitat alterations (ALU)	Habitat TMDL
		Bacteria (RU)	Bacteria TMDL
03 03 *Priority points: 7*	Rum Creek	Direct habitat alterations (ALU)	Habitat TMDL
		Sedimentation/siltation (ALU)	Sediment TMDL
		Bacteria (RU)	Bacteria TMDL
03 04 *Priority points: 5*	Blue Jacket Creek	No impairment (ALU)	No action necessary
		Bacteria (RU)	Bacteria TMDL
03 05 *Priority points: 8*	Bokengehalas Creek	Sedimentation/siltation (ALU)	Sediment TMDL
		Direct habitat alterations (ALU)	Habitat TMDL
		Bacteria (RU)	Bacteria TMDL
03 06 *Priority points: 8*	Brandywine Creek-Great Miami River	Direct habitat alterations (ALU)	Habitat TMDL
		Other flow regime alterations (ALU)	Not addressed
		Organic enrichment (sewage) biological indicators (ALU)	Category 4B alternative
		Sedimentation/siltation (ALU)	Sediment TMDL
		Bacteria (RU)	Bacteria TMDL
Stoney Creek-Great Miami River (05080001 04)			
04 01 *Priority points: 5*	McKees Creek	No impairment (ALU)	No action necessary
		Bacteria (RU)	Bacteria TMDL
04 02 *Priority points: 3*	Lee Creek	No impairment (ALU)	No action necessary
		Bacteria (RU)	Bacteria TMDL
04 03 *Priority points: 5*	Stoney Creek	No impairment (ALU)	No action necessary
		Bacteria (RU)	Bacteria TMDL
04 04 *Priority points: 5*	Indian Creek	Insufficient data to assess (ALU)	No action necessary
		Bacteria (RU)	Bacteria TMDL
04 05 *Priority points: 5*	Plum Creek	No impairment (ALU)	No action necessary
		Bacteria (RU)	Bacteria TMDL
04 06 *Priority points: 6*	Turkeyfoot Creek-Great Miami River	Direct habitat alterations (ALU)	Habitat TMDL
		Sedimentation/siltation (ALU)	Sediment TMDL

Assessment Unit (05080001)	Narrative Description	Causes of Impairment (Beneficial use in parentheses[1])	Action Taken
		No impairment (RU)	No action necessary
Headwaters Loramie Creek (05080001 05)			
05 01 *Priority points: 6*	Headwaters Loramie Creek	Direct habitat alterations (ALU)	Habitat TMDL
		Nutrients (ALU)	Nutrient TMDL
		Total dissolved solids (ALU)	TDS TMDL (simple mass balance)
		Other flow regime alterations (ALU)	Not addressed – backwater from downstream reservoir
		Sedimentation/siltation (ALU)	Sediment TMDL
		Bacteria (RU)	Bacteria TMDL
05 02 *Priority points: 4*	Mile Creek	Nutrient/eutrophication biological indicators (ALU)	Nutrient TMDL
		Direct habitat alterations (ALU)	Habitat TMDL
		Bacteria (RU)	Bacteria TMDL
05 03 *Priority points: 9*	Lake Loramie-Loramie Creek	Nutrient/eutrophication biological indicators (ALU)	Nutrient TMDL
		Low flow alterations (ALU)	Not addressed – low flow from upstream reservoir
		Bacteria (RU)	Bacteria TMDL
Turtle Creek-Loramie Creek (05080001 06)			
06 01 *Priority points: 4*	Nine Mile Creek	No impairment (ALU)	No action necessary
		Bacteria (RU)	Bacteria TMDL
06 02 *Priority points: 7*	Painter Creek-Loramie Creek	Phosphorus (total) (ALU)	Nutrient TMDL
		Direct habitat alterations (ALU)	Habitat TMDL
		Bacteria (RU)	Bacteria TMDL
06 03 *Priority points: 4*	Turtle Creek	Nutrients (ALU)	Nutrient TMDL
		Direct habitat alterations (ALU)	Habitat TMDL
		No impairment (RU)	No action necessary
06 04 *Priority points: 5*	Mill Creek-Loramie Creek	No impairment (ALU)	No action necessary
		Bacteria (RU)	Bacteria TMDL

[1] ALU = aquatic life use
RU = recreation use

1.2 Public Involvement

Public involvement is fundamental to the success of water restoration projects, including TMDL efforts. From the beginning, Ohio EPA has invited participation in all aspects of the TMDL program. The Ohio EPA convened an external advisory group in 1998 to assist the Agency with the development of the TMDL program in Ohio. The advisory group issued a report in July 2000 to the Director of Ohio EPA on their findings and recommendations. The Great Miami River (upper) watershed TMDL project has been completed using the process endorsed by the advisory group.

The Ohio EPA met with both watershed groups (Loramie Valley Alliance and Indian Lake Watershed Project) in the Great Miami River (upper) watershed in March 2011 to present the results of the 2008 field survey.

The Loramie Valley Alliance (LVA) is a 501(c)3 organization representing four partnering counties (Mercer, Auglaize, Shelby and Darke) working to improve water quality in Loramie Creek and its tributaries. The membership draws heavily from the agricultural community and has expertise in farming issues. The LVA members were disappointed in the results of the Great Miami River (upper) field survey. Despite the drainage improvements, log jam removals and no-till equipment funding, Loramie Creek is still not meeting its use designation. The LVA will focus more on the farming practices in the watershed to reduce soil and sediment contamination causing water quality problems in the watershed.

The Indian Lake Watershed Project is a 501(c)3 organization that is very successful in removing soil and sediment contamination from reaching the Indian Lake tributaries. The results of the Great Miami River (upper) field survey indicated that the tributaries around the Lake were in 91% attainment of biological water quality standards. The problems now encountered in the Lake are a result of a clear water column allowing aquatic vegetation to flourish and impacting boating activities in Indian Lake.

A public meeting was held to discuss the results of the Great Miami River (upper) survey on April 20, 2011 by the Ohio EPA at the Shelby Soil and Water Conservation District (SWCD) offices in Sidney. The results of the 2008 field survey were presented to interested parties.

In March 2011, Ohio EPA met with Great Miami River Watershed Network to present the results of the Great Miami River (upper) field survey. The Great Miami River Watershed Network is an offshoot of the Basin Council established under a 208 grant and acts as an information network for watershed groups in the Great Miami River. As a result of this meeting, further discussions were initiated by Ohio EPA to seek help in developing an implementation plan for the Great Miami River (upper) TMDL.

By late March of 2011, a conceptual plan was worked out with the Miami Conservancy District and the Greater Dayton Partners for the Environment (GDPE) for implementation of the Great Miami River (upper) TMDL. Throughout the summer of 2011 a plan was evolved to make this TMDL and subsequent Great Miami River TMDLs (middle and lower) part of a holistic group of programs involving the GDPE (including 10 community-based watershed organizations), the Miami Conservancy District, local communities, WWTPs, community groups, the Ohio Department of Natural Resources (ODNR) and 15 soil and water conservation district offices. The programs include the watershed-wide nutrient trading program and grant funding aimed at voluntary water quality improvement needs identified in the TMDL. The overall project will be called the Great Miami River Watershed Water Quality Improvement Program.

The Great Dayton Partners for the Environment has held meetings with the watershed groups, SWCDs, farming interests, and local communities across the entire Great Miami River watershed to improve involvement in the Great Miami River Watershed Water Quality Improvement Program. Ohio EPA's involvement will be a part of a much larger network aimed at regional cooperation with the goal of improving water quality across the entire watershed.

Consistent with Ohio's current Continuous Planning Process (CPP), the draft TMDL report was available for public comment from November 30, 2011 through January 5, 2012. A copy of the draft report was posted on Ohio EPA's web page (http://www.epa.ohio.gov/dsw/tmdl/index.aspx). Responses to comments are summarized in Appendix G of the report.

Continued public involvement is essential to the success of any TMDL project. Ohio EPA will continue to support the implementation process and will facilitate, to the fullest extent possible, restoration actions that are acceptable to the communities and stakeholders in the study area and to Ohio EPA. Ohio EPA is reluctant to rely solely on regulatory actions and strongly upholds the need for voluntary actions facilitated by the local stakeholders, watershed organization, and agency partners to restore the Great Miami River (upper) watershed.

1.3 Organization of Report

Chapter 2 gives an overview of water quality standards applicable in the watershed. Chapter 3 gives an overview of the water quality conditions in the watershed. Chapter 4 briefly discusses the methods used to calculate load reductions. Chapter 5 provides the load reduction results. Chapter 6 discusses suggested restoration methods to improve water quality.

More detailed information on selected topics is contained in appendices. Appendix A lists the permitted facilities in the watershed. Appendix B summarizes the findings of the watershed survey. Appendix C is a primer on Ohio's water quality standards. Appendix D contains details of the loading analysis. Appendix E demonstrates the category 4B approach for impairments caused by the Indian Lake wastewater treatment plant. Appendix F discusses programs and actions available to improve water quality.

Readers may also wish to consult the technical glossary and background information available on Ohio EPA's TMDL Web page (http://www.epa.ohio.gov/dsw/tmdl/index.aspx).

2 CHARACTERISTICS AND EXPECTATIONS OF THE WATERSHED

The Great Miami River (upper) watershed study area is located in Auglaize, Mercer, Logan, Shelby, Champaign, Hardin, Darke and Miami counties in west central Ohio. The entire study area includes the mainstem and tributaries of the Great Miami River watershed and the Loramie Creek watershed. The extent of the upper Great Miami River watershed includes the streams entering Indian Lake. The Great Miami River begins at the overflow for the dam at Indian Lake (RM 159.48). The upper Great Miami River mainstem study area ends at RM 129.99 in Sidney, draining 484 square miles. The Loramie Creek watershed is located in the western part of the watershed but enters the Great Miami River at RM 119.89 outside the study area. The Loramie Creek watershed drains 265 square miles.

2.1 Watershed Characteristics

The following subsections provide an overview of the characteristics of the Great Miami River watershed.

2.1.1 Population and Distribution

The population of the eight counties making the upper Great Miami River watershed was 76,696 in 2000, up by 8.8% (6,243) since 1990. The entire watershed is expected to grow by 2.3% from 2010 to 2020 (ODD 2003). Figure 2-2 shows the population density from the 2000 United States Census (U.S. Census Bureau 2000).

2.1.2 Land Use

The majority of the 478,384 acres in the watershed is used for agriculture. Cultivated crops (337,353 acres) and pasture/hay cultivation (37,997 acres) are two major land uses in the watershed accounting for 78.5% of all land use. Deciduous forest at one time dominated the land use but now only accounts for 42,091 acres (8.8%) of the watershed. Total developed land (44,433 acres) is scattered in 20 smaller communities (<1,500 persons) across the watershed, with Bellefontaine (13,069 persons) being the largest community. Indian Lake is the largest waterbody in the watershed (>5,000 acres); Lake Loramie is the second largest at more than 850 acres.

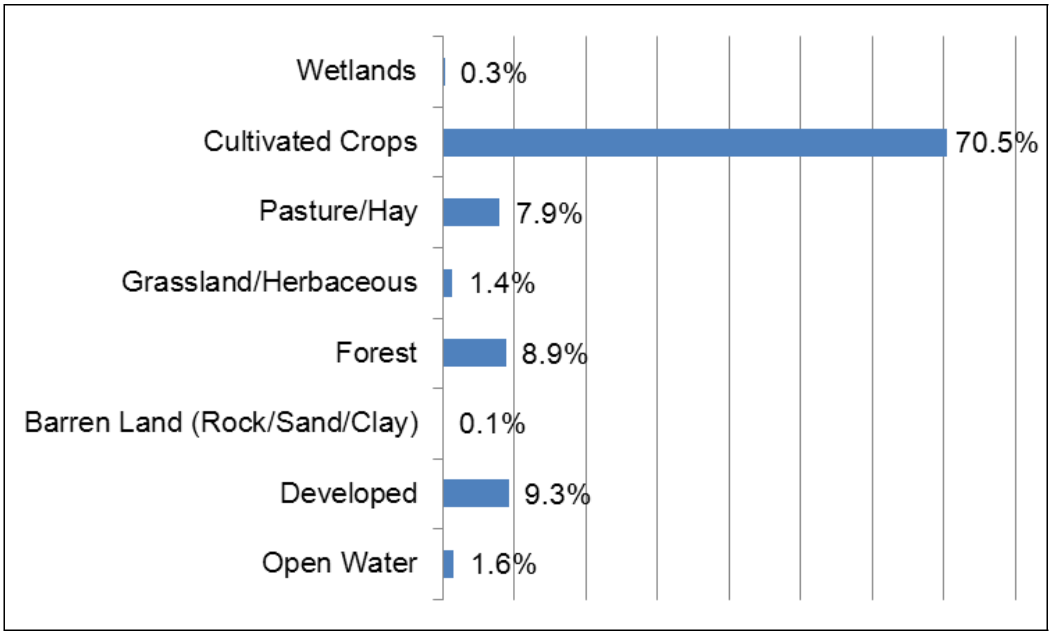


Figure 2-1. Land use distribution in the Great Miami River (upper) watershed.

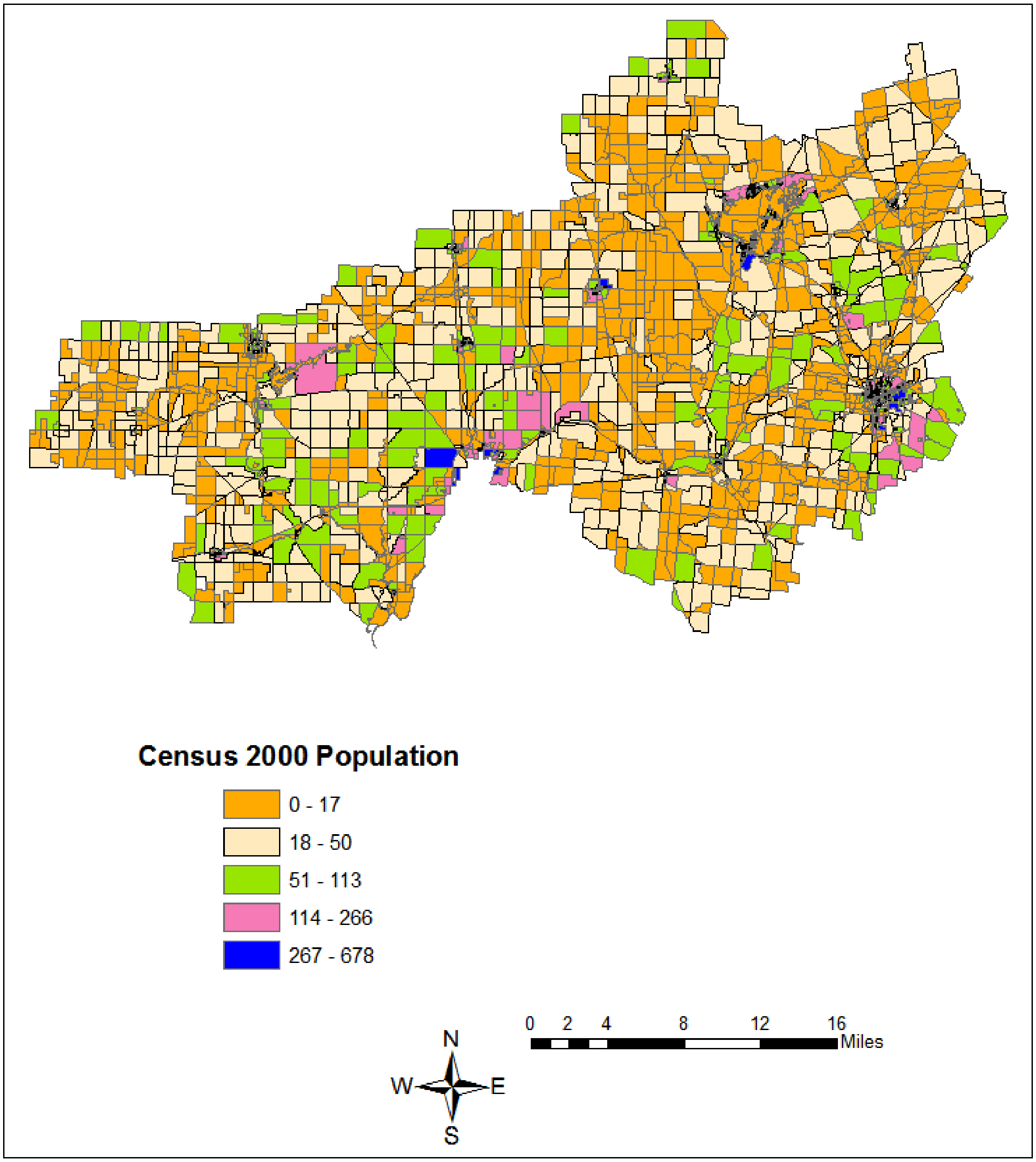


Figure 2-2. Population density blocks from the 2000 United States Census.

2.1.3 Point Source Discharges

Industrial and municipal point sources include wastewater treatment plants and factories. Wastewater treatment plants can contribute to bacteria, nutrient enrichment, sewage solids, and flow alteration problems. Industrial point sources, such as factories, sometimes discharge water that is excessively warm or cold, changing the temperature of the stream. Point sources may contain other pollutants such as chemicals and metals.

NPDES dischargers are entities that possess a permit through the National Pollutant Discharge Elimination System (NPDES). NPDES permits limit the quantity of pollutants discharged and impose monitoring requirements. NPDES permits are designed to protect public health and the aquatic environment by helping to ensure compliance with state and federal regulations. NPDES entities generally discharge wastewater continuously. They primarily affect water quality under average- to low-flow conditions because the potential for dilution is lower. NPDES dischargers located near the origin of a stream or on a small tributary often cause more severe water quality problems because their effluent can dominate the natural stream flow. Appendix A lists the NPDES permittees in the Upper Great Miami River watershed.

There are three major WWTP dischargers (over one million gallons per day (MGD) design flow) in the watershed, Bellefontaine (4.5 MGD, discharging to Opossum Run to Blue Jacket Creek at RM 5.8), Indian Lake (4.6 MGD, discharging to GMR RM 158.05), and Minster (2.5 MGD, discharging to Miami-Erie Canal to Loramie Creek at RM 20.78). There are five significant minor WWTP dischargers in the watershed. A significant minor is a WWTP with design flows over 0.25 MGD but less than 1 MGD or a food processing plant of any discharge. The significant minors in the watershed are Anna (0.4 MGD, discharging to Applegate Ditch to Clay Creek to Loramie Creek at RM 31.11), Botkins (0.5 MGD, discharging to Loramie Creek at RM 35.4), Jackson Center (0.37 MGD, discharging to Jackson Center Creek to Little Muchinippi Creek at RM 3.62), Lake Loramie (0.40 MGD, discharging to Loramie Creek at RM 21.1), and Quincy-DeGraff (0.495 MGD, discharging to GMR at RM 143.1). In addition to the significant minor dischargers, there are 14 minor WWTP dischargers (<0.25 MGD) in the watershed.

MS4s carry storm water from “separate storm sewer systems” directly to bodies of water. Separate storm sewer systems include ditches, curbs, gutters, storm sewers, and other conveyances of runoff. These systems do not connect to wastewater collection systems or treatment plants. Storm water can transport oil, grease, pesticides, herbicides, dirt and grit that have the potential to reduce water quality.

U.S. EPA’s storm water program requires municipalities to obtain storm water permits and addressed storm water in two phases: Phase I covered large (serving populations > 250,000) and medium (100,000 to 250,000) MS4s and Phase II addressed small (< 100,000) MS4s. There is one Phase II MS4 located partially within the upper Great Miami River watershed (City of Bellefontaine).

2.1.4 Public Drinking Water Supplies

Some communities supply public drinking water from ground water (underground aquifers). Other communities supply public drinking water by withdrawing water from surface waters, including lakes and streams. There are no surface water public drinking water supplies in the Great Miami River (upper) watershed. However, Sidney uses water intakes on both the Great Miami River and Tawawa Creek, but this survey stopped above the Great Miami River intake.

2.2 Water Quality Standards

TMDLs are required when a waterbody fails to meet water quality standards (WQS). Every state must adopt WQS to protect, maintain, and improve the quality of the nation's surface waters. WQS represent a level of water quality that will support the Clean Water Act goal of swimmable and fishable waters. Ohio's WQS, set forth in Chapter 3745-1 of the Ohio Administrative Code (OAC), include three major components: beneficial use designations, numeric and narrative criteria and antidegradation provisions. Where criteria have not been developed, the State can develop project-specific targets.

Beneficial use designations describe the existing or potential uses of a waterbody, such as public water supply; protection and propagation of aquatic life; and recreation in and on the water. Ohio EPA assigns beneficial use designations to each waterbody in the state. Use designations are defined in paragraph (B) of rule 3745-1-07 of the OAC and are assigned in rules 3745-1-08 to 3745-1-32. Attainment of uses is based on specific numeric and narrative criteria.

Numeric criteria are estimations of chemical concentrations, degree of aquatic life toxicity, and physical conditions (e.g., temperature) allowable in a waterbody without adversely impacting its beneficial uses. Narrative criteria, located in rule 3745-1-04 of the OAC, describe general water quality goals that apply to all surface waters. These criteria state that all waters shall be free from sludge, floating debris, oil and scum, color and odor producing materials, substances that are harmful to human, animal or aquatic life, and nutrients in concentrations that may cause algal blooms. Much of Ohio EPA's present strategy regarding water quality based permitting is based upon the narrative free from of "no toxics in toxic amounts." Ohio EPA developed its strategy based on an evaluation of the potential for significant toxic impacts within the receiving waters. Very important components of this evaluation are the biological survey program and the biological criteria used to judge aquatic life use attainment.

Antidegradation provisions describe the conditions under which water quality may be lowered in surface waters. Under such conditions water quality may not be lowered below criteria protective of existing beneficial uses unless lower quality is deemed necessary to allow important economic or social development. Antidegradation provisions are in Sections 3745-1-05 and 3745-1-54 of the OAC.

The following sub-sections describe the applicable water quality standards for the Great Miami River (upper) watershed. Further details can be found in Appendix C.

2.2.1 Aquatic Life Use

Ohio's WQS have seven subcategories of aquatic life uses (see http://www.epa.ohio.gov/portals/35/rules/01-07.pdf). The WQS rule contains a narrative for each aquatic life use and the three most commonly assigned aquatic life uses have quantitative, numeric biological criteria that express the minimum acceptable level of biological performance based on three separate biological indices. The indices measure the health of aquatic communities of both fish and insects. Criteria applicable in the Great Miami River (upper) watershed are included in Table 2-1. Stream use designations are mapped in Figure 2-3.

Table 2-1. Biological criteria applicable in Great Miami River (upper) watershed.

Ecoregion	Biological Index	Assessment Method[2,3]	Biological Criteria for Applicable Aquatic Life Use Designations[1]		
			EWH	WWH	MWH
Eastern Corn Belt Plains	IBI	Headwaters	50	40	24
		Wading	50	40	24
		Boat	48	42	24
	MIwb	Wading	9.4	8.3	6.2
		Boat	9.6	8.5	5.8
	ICI	All[4]	46	36	22

1 Coldwater habitats (CWH), limited warmwater habitat (LWH), limited resource water (LRW), and seasonal salmonid habitat (SSH) do not have associated biological criteria.

2 The assessment method used at a site is determined by its drainage area (DA) according to the following: Headwater: DA ≤20 mi^2; wading: DA >20 mi^2 and ≤ 500 mi^2; boat >500 mi^2.

3 MIwb not applicable to drainage areas less than 20 mi^2.

4 Limited to sites with appropriate conditions for artificial substrate placement.

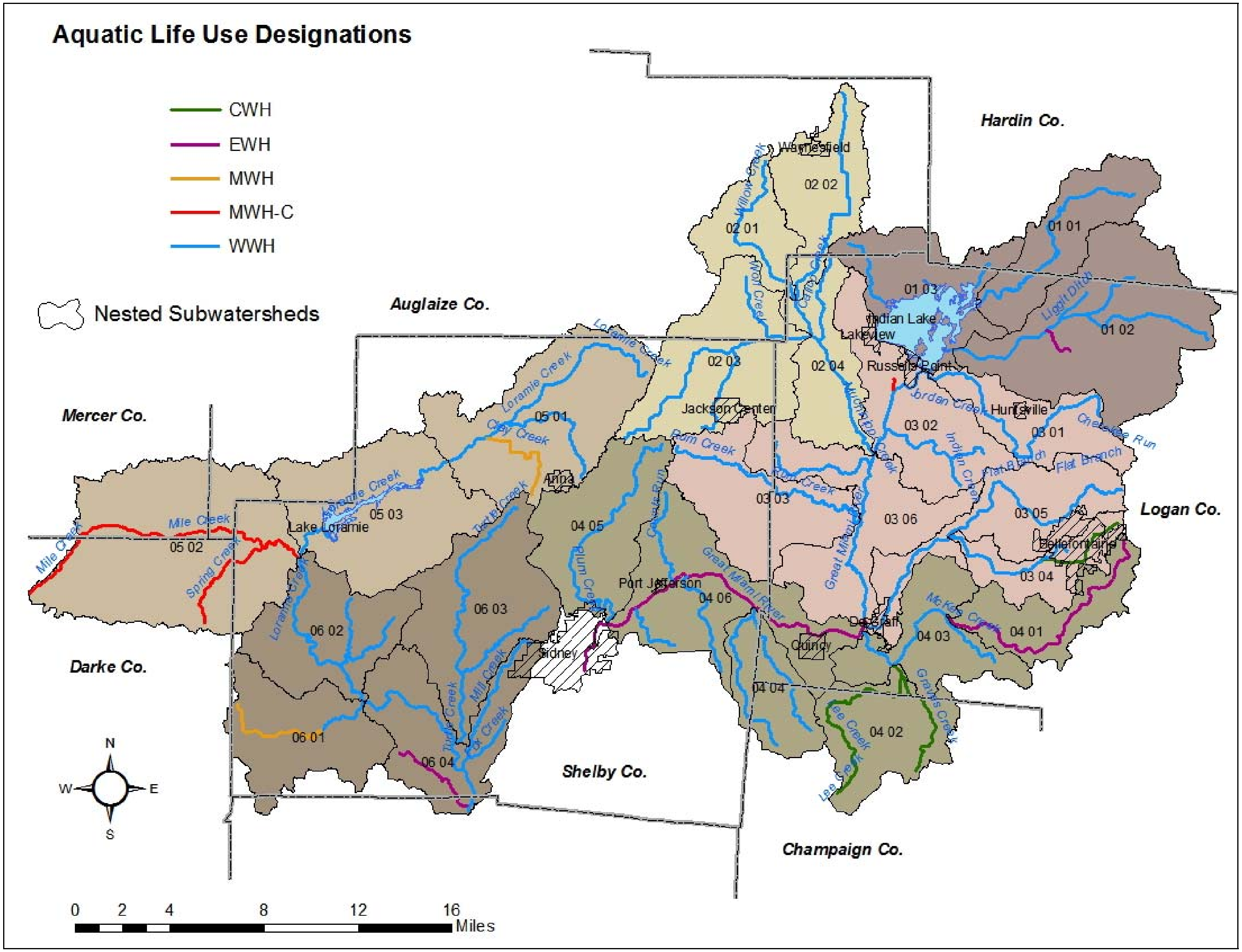


Figure 2-3. Designated aquatic life uses in the Great Miami River (upper) watershed.

2.2.2 Recreation Use

Ohio's WQS have three subcategories of recreation uses (bathing waters, primary contact and secondary contact). Within primary contact there are three classes of streams (A, B and C) that describe the general frequency with which the stream is used for recreation. The WQS rule contains a description of each recreation use and all primary contact recreation classes have numeric criteria that are associated with a statistically-based risk level. Table 2-2 shows the recreation use water quality standards for Ohio. Figure 2-1 shows the recreation use designations of streams within the watershed.

Table 2-2. Water quality criteria established for recreation uses within water bodies throughout Ohio.

Recreation Use	*E. coli* (colony forming units per 100 ml)	
	Seasonal Geometric Mean	Single Sample Maximum[1]
Bathing water	126	235[a]
Class A primary contact recreation	126	298
Class B primary contact recreation	161	523
Class C primary contact recreation	206	940
Secondary contact recreation	1030	1030

[1] Except as noted in footnote *a*, these criteria shall not be exceeded in more than ten per cent of the samples taken during any thirty-day period.

[a] This criterion shall be used for the issuance of beach and bathing water advisories.

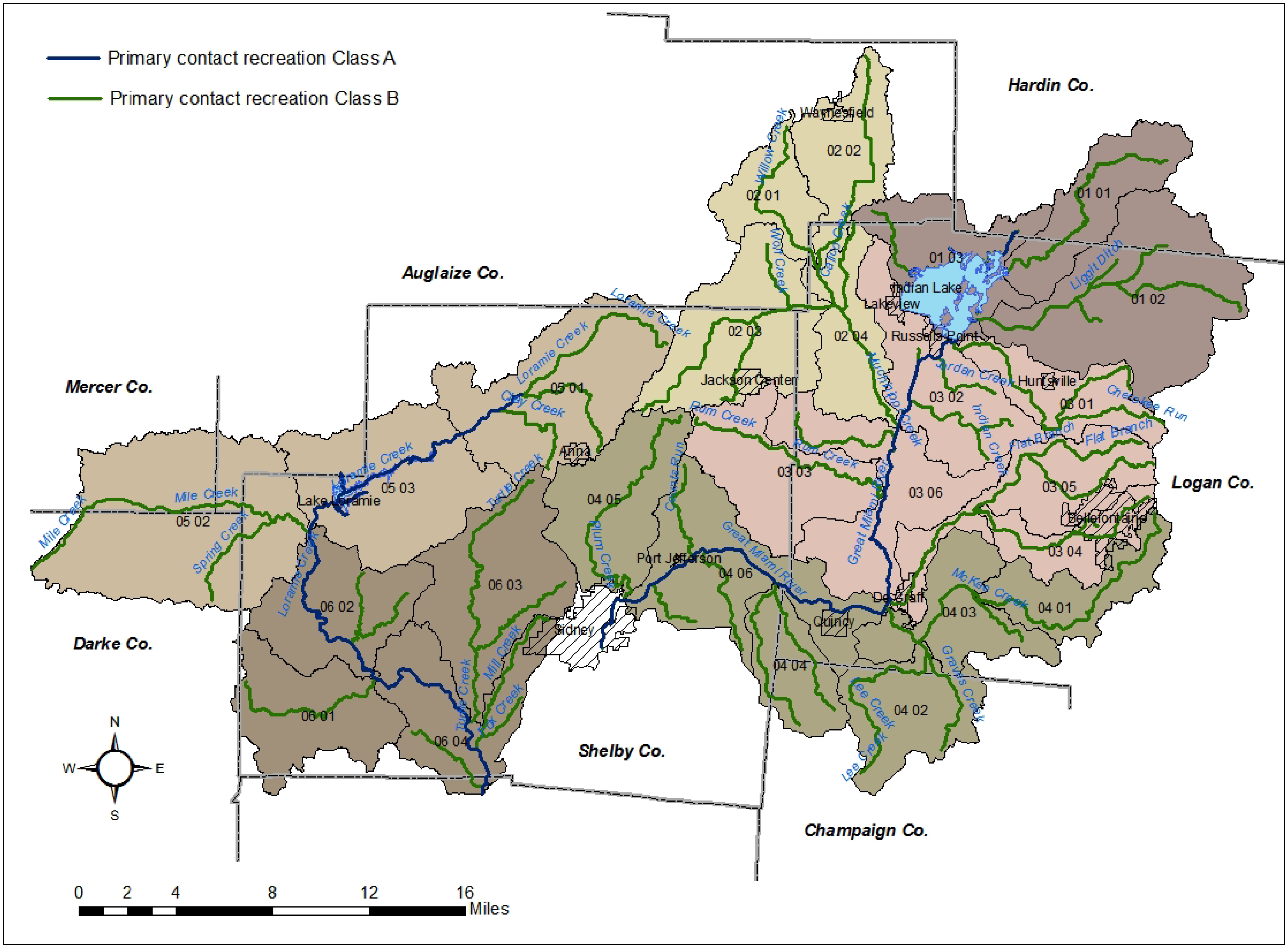


Figure 2-4. Designated recreation uses in the Great Miami River (upper) watershed.

2.2.3 Public Drinking Water Supply Use

The public drinking water supply use includes surface waters from which public drinking water is supplied. This beneficial use provides an opportunity to strengthen the connection between Clean Water Act and Safe Drinking Water Act (SDWA) activities by employing the authority of the CWA to meet SDWA objectives of source water protection and reduced risk to human health. Criteria associated with this use designation apply within five hundred yards of surface water intakes. There are no surface water public drinking water supplies are located in this watershed.

2.2.4 Human Health (Fish Contaminants) Use

Ohio has adopted human health WQS criteria to protect the public from adverse impacts, both carcinogenic and non-carcinogenic, caused by exposure via drinking water (applicable at public water supply intakes) and by exposure in the contaminated flesh of sport fish (applicable in all surface waters). The latter criterion, called the non-drinking water human health criterion, ensures that levels of a chemical in water do not bioaccumulate in fish to levels harmful to people who catch and eat the fish. Ohio measures contaminants in fish tissue and uses the data in two comparisons: (1) to determine if the human health criteria are being violated, thus identifying the water for restoration through a TMDL or other action, or (2) to determine the quantity of sport fish that may be safely consumed. The first comparison can result in the water being identified as impaired on the 303(d) list; the second can result in the issuance of a sport fish consumption advisory.

The Headwaters Great Miami River subwatershed (01) had three nested subwatersheds (12-digit hydrologic units) fully supporting the human health use; two of these had only historical data available (greater than 10 years old). The Muchinippi Creek subwatershed (02) had three nested subwatersheds in the unknown category (i.e, no data are available to assess the use) and one nested subwatershed with insufficient information to assess use support. The Bokengehalas Creek-Great Miami River subwatershed (03) and the Stoney Creek-Great Miami River subwatershed (04) had historical data indicating non-support of the use. The Headwaters Loramie Creek subwatershed (05) and the Turtle Creek-Loramie Creek subwatershed (06) had no data to assess support of the use.

Two contaminants common in fish tissue in Ohio are polychlorinated biphenyls (PCBs) and mercury. PCBs are currently banned from use in the U.S. and are expected to decrease in streams over time. Therefore, no further action other than continued monitoring for PCBs in fish in Great Miami River (upper) watershed will be taken.

Mercury is a ubiquitous contaminant in streams throughout the U.S.; its primary source is thought to be mercury deposited from the atmosphere. Mercury as a surface water pollutant is being addressed in a variety of ways outside of the traditional TMDL process, including limits on mercury emissions from air sources, mercury take-back programs, and legislation prohibiting the sale of most mercury-containing products. Unless there are known or suspected local surface water sources of mercury, mercury is best addressed outside of the individual watershed TMDL framework.

The Great Miami River (upper) watershed is included in the statewide fish advisory for mercury. Additional advisories specific to the Great Miami River (upper) watershed exist (Table 2-3).

Information regarding fish consumption advisories can be found at:
http://www.epa.ohio.gov/dsw/fishadvisory/index.aspx.

Table 2-3. Sport fish consumption advisories applicable to the Great Miami River (upper) watershed.

Great Miami River	Species	One meal per:	Contaminant
Downstream from Indian Lake to Sidney RM 158.2-130	Common Carp, Channel Catfish, Flathead Catfish	Month	PCBs
	Largemouth Bass, Smallmouth Bass, White Bass	Month	Mercury

3 WATER QUALITY CONDITIONS IN THE WATERSHED

Ohio uses the fish and aquatic insects that live in streams to assess the health of Ohio's flowing waters. Aquatic animals are generally the most sensitive indicators of pollution because they inhabit the water all of the time. A healthy stream community is also associated with high quality recreational opportunities (e.g., fishing, swimming and boating).

In addition to biological data, Ohio EPA collects information on the chemical quality of the water, sediment, and wastewater discharges; data on the contaminants in fish flesh; and physical information about streams. Taken together, this information identifies the factors that limit the health of aquatic life and that constitute threats to human health.

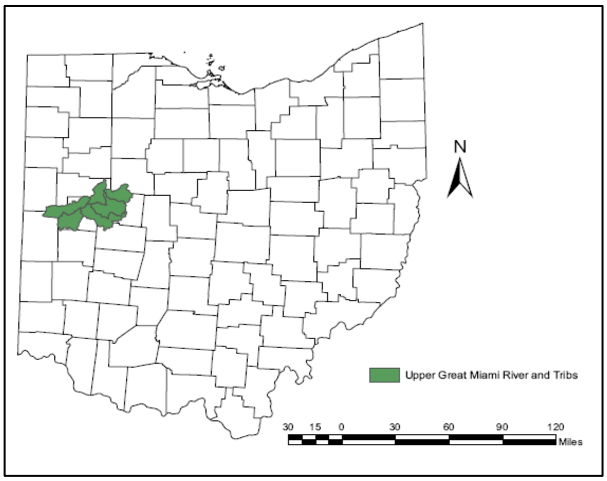


Figure 3-1. Location of the study area.

Ohio EPA performed a comprehensive water quality study in the Great Miami River (upper) watershed in 2008 (Figure 3-1). Seventy-eight sites were studied for biological health and water chemistry, five WWTP effluent sites, thirty-six sites for recreation use and two sites for human health (fish tissue). Sites were scattered throughout the watershed but were primarily located at regular intervals along the Great Miami mainstem and major tributaries to assess potential point and nonpoint source pollution sources. Please refer to Appendix B for more detail.

The Great Miami River (upper) basin is influenced by hydromodification, habitat alteration, ground water recharge, agriculture, and point source dischargers (see Table B-2 in Appendix B and Figure 3-3). In many watersheds, natural channels and stream sinuosity have been physically altered to facilitate agricultural drainage in order to move excess rainwater off the land within three days. This was done by constructing underground tiles to drain farm land, straightening meandering river channels and constructing levees to prevent the streams from leaving their banks and flooding adjacent farm fields. In the 2008 survey, out of 78 sites evaluated for habitat quality, 79% (62) had experienced some form of channelization and 62% (48) were still negatively influenced by channelization. Eighteen percent (14) of sites have recovered from historical modification and only 21% (16) of site channels were considered natural and unmodified (see Figure 3-2Natural stream channels have a greater capacity to assimilate nutrients

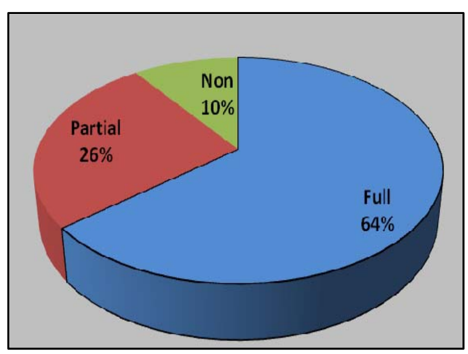


Figure 3-2. Percentage of sites in full, partial and non-attainment of aquatic life use goals.

and fine sediments by flushing them into adjacent floodplains. They also help process nutrients into beneficial biomass rather than nuisance algae, improve water quality, create diverse in-stream habitats, and ultimately (and most important for adjacent landowners) evolve into a stable channel.
).

Natural stream channels have a greater capacity to assimilate nutrients and fine sediments by flushing them into adjacent floodplains. They also help process nutrients into beneficial biomass rather than nuisance algae, improve water quality, create diverse in-stream habitats, and ultimately (and most important for adjacent landowners) evolve into a stable channel.

Soil runoff rich in phosphorus and other nutrients from agricultural practices has further altered the stream health by causing algal blooms that disrupt the normal dissolved oxygen levels in the water column. Phosphorus entering the river system is slow to be removed and recycles itself in many forms as it enters plant and algal biomass. Algal and plant material die and are decomposed into the sediment only to release bound organic phosphorus into the water as the sediment becomes low in oxygen.

Geology also influences water quality. For example, ground water entering streams, particularly in the eastern watershed, show a noticeable positive influence on the biology. In contrast, comparatively lower performance was encountered in low-flow channels that lacked a strong ground water connection. The finer grained hydric soils around Indian Lake and Loramie Creek are easily disturbed and slow to recover from hydromodification and outdated agricultural practices; lower biological performance was often observed in these same areas.

The Great Miami River (upper) watershed TMDL includes six subwatersheds (Figure 3-4). Within each of the six subwatersheds, smaller watersheds are nested. This chapter discusses conditions in each of the subwatersheds with detail added in unique nested subwatersheds. Overall, impairment for aquatic life and recreation uses was more common in the western area of the watershed.

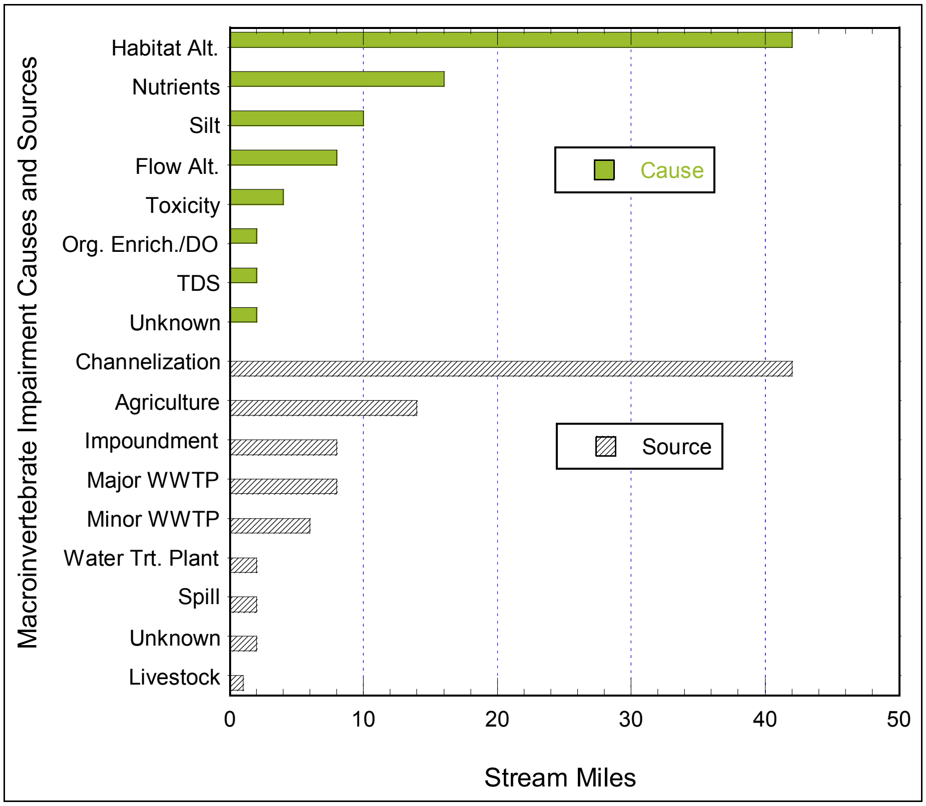


Figure 3-3. Suspected causes and sources of impairment (in miles) affecting macroinvertebrate communities in the study area.

Overall the watershed met criteria for the recreation use at 27% of sites (10/37) and 64% (50/78) for aquatic life sites. No surface water is used for the public drinking water supplies in the watershed.

Recreation uses were impaired due to the elevated risk for water-borne illness from pathogen contamination. This is evidenced by high concentrations of bacteria associated with fecal matter. Reasons for these failures include poorly treated human waste coming from home septic systems, bacteria associated with urban runoff, and ineffective waste water treatment, system overflows, runoff from farm fields using manure as a soil additive and potentially inappropriately applied municipal biosolids.

Bacteriological impairment was pervasive throughout the upper watershed in primary contact recreation (PCR) class A and class B streams. The PCR criteria were exceeded at 73% of sites (*i.e.,* 27 of 37). Row crop agriculture was a suspected source of contamination at all of the impaired sites (100%). Normal row crop agricultural activity may also include manure application to farm fields as portions of the basin (particularly in the western, Loramie Creek subwatershed) drain some of the highest manure-producing counties in the state (Columbus Dispatch, Oct. 16, 2010). Biosolids from the larger local municipal WWTPs at Russells Point, Bellefontaine, Lake Loramie, and Minster are also spread on area fields near the facilities. Urban runoff was the suspected contaminant source at 37% of the non-attaining sites followed by unsewered communities and on-site septic systems (19%), sanitary sewer overflows and wildlife (11% each). Both feedlots and unrestricted livestock access accounted for 7% of suspected contaminant sources at impaired sites. A deteriorating wastewater collection system in Jackson Center may also have contributed to impairment at one location immediately downstream.

Many of the controls recommended to address nutrient enrichment are also recommended to restore the recreation beneficial use in affected areas throughout the Great Miami River (upper) watershed.

Chemistry parameters without water quality standards were evaluated using *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams* – Tables 1 and 2, Appendix Tables 1 and 2 (Ohio EPA 1999). This is referred as the *Associations* document in the chapter. Target values are set according to stream size and aquatic use designation. The median values do not always capture the large early spring rain events that represent major nutrient and sediment loads entering the system.

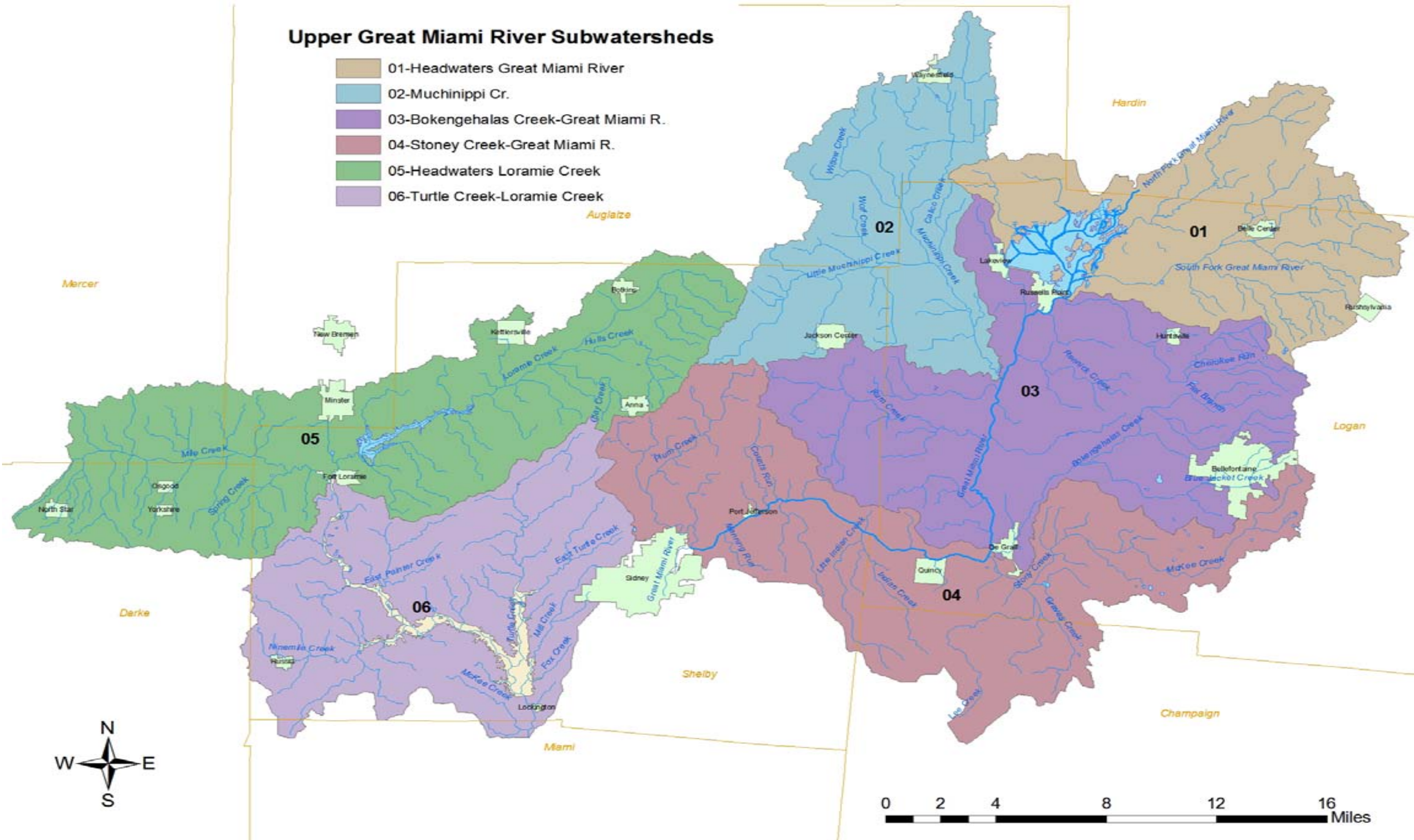


Figure 3-4. Map of the Great Miami River (upper) watershed showing subwatersheds.

3.1 Headwaters Great Miami River (05080001 01)

The Headwaters Great Miami River subwatershed drains 100.4 square miles of streams into Indian Lake. The three nested subwatersheds (12-digit assessment units) are located in Logan, Auglaize and Hardin Counties. The predominant land use is cultivated crop land (Figure 3-5). Main Great Miami River tributaries within this watershed include North Fork Great Miami River, South Fork Great Miami River and two unnamed tributaries to South Fork, Ligitt Ditch, and Van Horn Creek.

Biological sampling was conducted at 11 sites within the subwatershed. Of those, 10 (91%) were in full attainment of biological water quality standards (Figure 3-6).

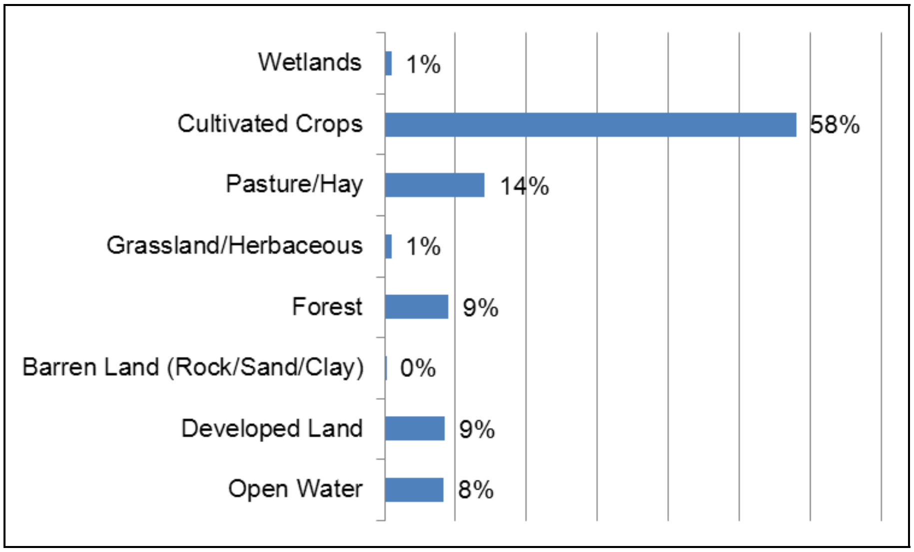


Figure 3-5. Land use in the Headwaters Great Miami River subwatershed.

Van Horn Creek (nested subwatershed 01 03), was the only site in non-attainment of its aquatic life use. Van Horn Creek is a small historically modified agricultural ditch that drains into Indian Lake. The area is 64.9% row crop agriculture with hydric Westland silt surrounding the creek. The stream has been channelized and is in the County ditch maintenance program. The Indian Lake Watershed Project has agreed to discuss habitat improvements with the land owner.

Van Horn Creek at State Route 366

Recreation use impairment, caused by bacteria, was documented in North Fork Great Miami River RM 6.31 (01 01) (PCR class B) and South Fork Great Miami River RM 3.95 (01 02) (PCR class B). These were the only two sites sampled for bacteria in the watershed. Agricultural practices and failing HSTSs are probable sources.

The watershed improvements have helped to decrease farm runoff of nutrients to Indian Lake, making the lake much clearer. All five tributary sites had median phosphorus values not exceeding the *Associations* phosphorus guideline of 0.07 mg/l for all seven WWH headwater sites (<20 mi^2) and not exceeding 0.10 mg/l for three WWH wadeable stream (<200 mi^2) sites (see Figure 3-7). Median nitrate-nitrite did not exceed the *Associations* guideline at nine sites. Only nitrate-nitrite in North Fork Great Miami River RM 6.31 (2.32 mg/l) exceeded the target.

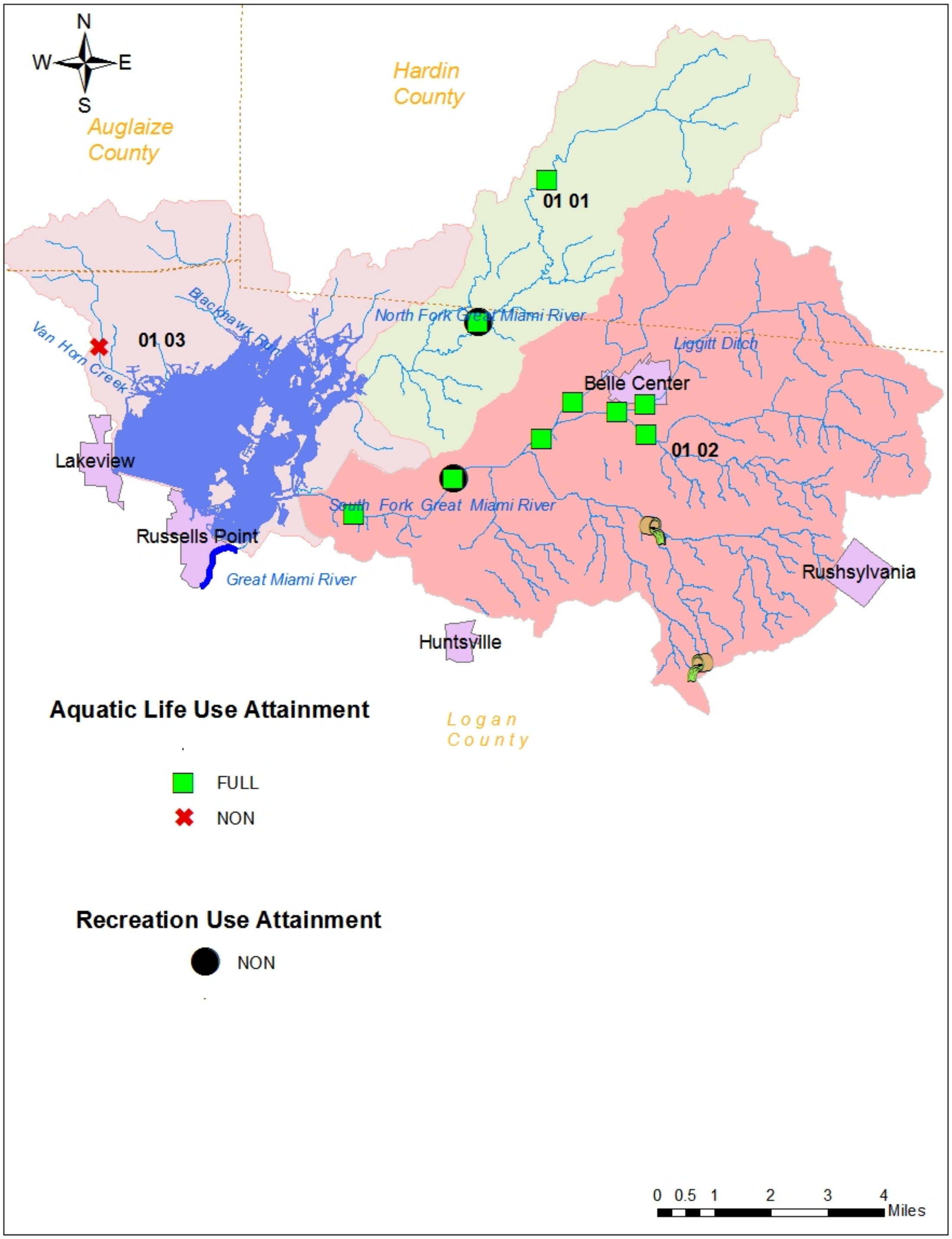


Figure 3-6. Aquatic life and recreation use attainment in the Headwaters Great Miami River subwatershed.

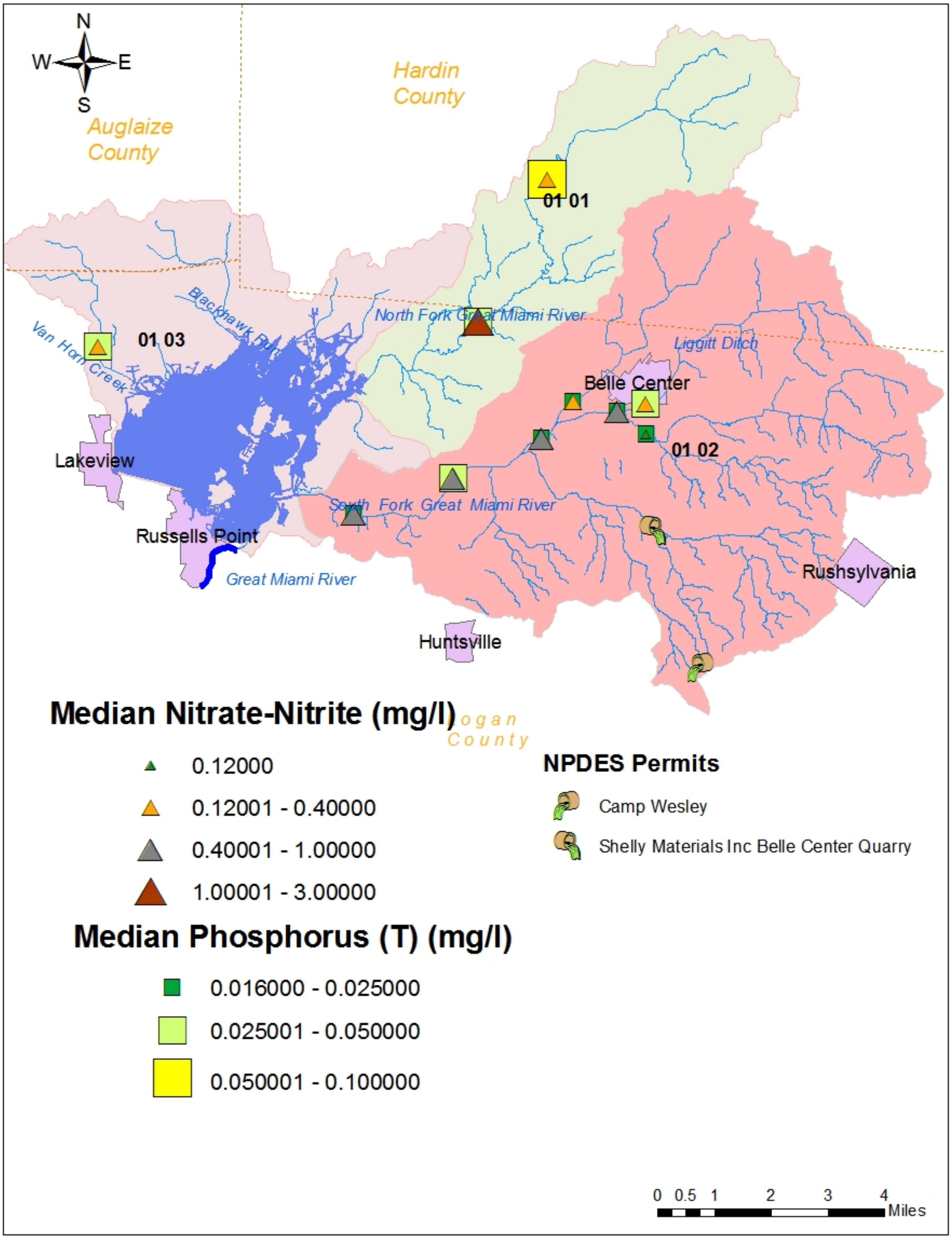


Figure 3-7. Nutrient concentrations in the Headwaters Great Miami River subwatershed.

Chemistry results shown in Figure 3-7 aided in identifying causes of aquatic life use impairment. Figure 3-8 and Figure 3-9 show the relative occurrence of causes and sources, respectively, of aquatic life use impairment in the Headwaters Great Miami River subwatershed.

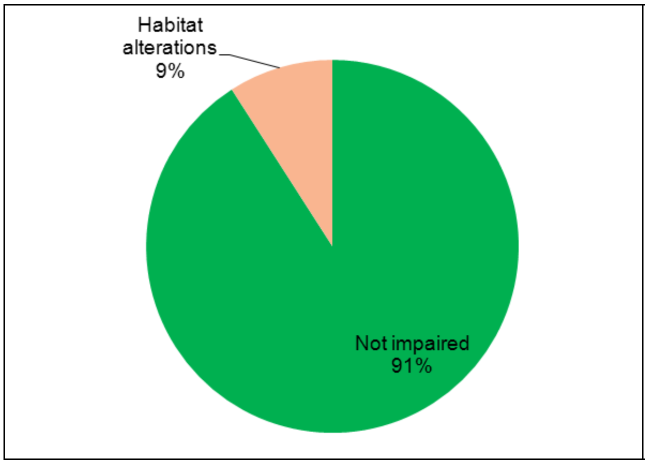


Figure 3-8. Causes of aquatic life use impairment in the Headwaters Great Miami River subwatershed.

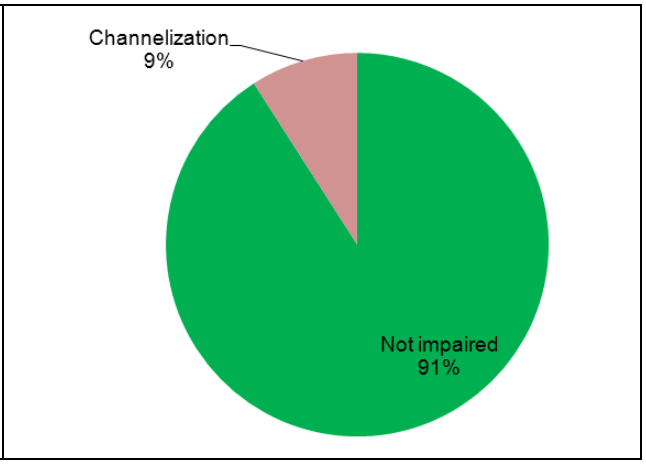


Figure 3-9. Sources of aquatic life use impairment in the Headwaters Great Miami River subwatershed.

Table 3-1 shows the site-by-site results for each designated beneficial use organized by nested subwatersheds. For more specific information regarding individual site assessment results and supporting chemistry results, please see Appendix B.

Table 3-1. Number of impaired sites, organized by use and nested subwatershed, in the Headwaters Great Miami River subwatershed.

Nested Subwatershed (05080001 01)		Aquatic Life Use	Recreation Use
01 01	# impaired sites (non/partial)	0/0	1
	Index score[1]	100	50
01 02	# impaired sites (non/partial)	0/0	1
	Index score	100	0
01 03	# impaired sites (non/partial)	1/0	N/A
	Index score	0	N/A

[1] The index score (between 0 and 100) indicates the relative support of the aquatic life or recreation use in the nested subwatershed. A score of 100 indicates full support of the use.

3.2 Muchinippi Creek (05080001 02)

Muchinippi Creek watershed is made up of four nested subwatersheds (12-digit assessment units) draining 89.1 square miles. The predominant land use in the subwatershed was cultivated crop land (Figure 3-10). Major streams in the subwatershed include Muchinippi Creek, its tributaries Willow Creek and Little Muchinippi Creek, and Jackson Center Creek, a tributary to Little Muchinippi Creek.

Biological sampling was conducted at 11 sites within the subwatershed. Of those, four sites (36%) were in full attainment, six sites were (55%) in partial attainment, and one site (9%) was in non-attainment of biological water quality standards (Figure 3-11).
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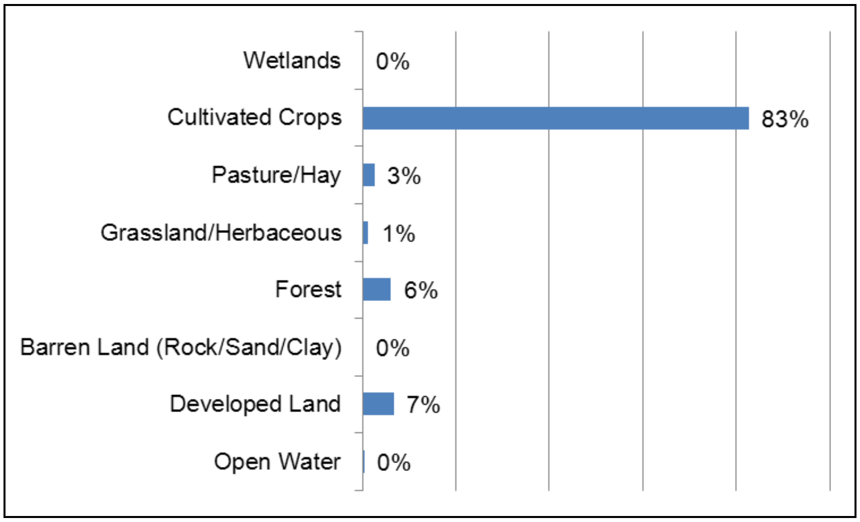

Figure 3-10. Land use in the Muchinippi Creek subwatershed.

Lower performance of the macroinvertebrate community was the major factor in partial attainment of the water quality standard. Macroinvertebrates failed to meet WWH expectations at 6 of 11 (55%) sites. Lower macroinvertebrate performance was commonly related to stream channelization activity and resultant monotonous habitat, often coupled with soft, mucky substrates associated with hydric soils. However, potential impacts to fish communities were often tempered by an abundance of ground water recharge. As a result of their unique hydrology, and often despite active or historic channel maintenance, most streams in the basin merited the WWH aquatic life use designation.

Willow Creek @ Wrestle Creek Road

Nested subwatershed 02 01 has two sites in partial WWH attainment on Willow Creek. Both sites are hydrologically modified drainage channels under County Ditch maintenance with agricultural runoff impacts. The macroinvertebrate community was negatively impacted by channelization and sediment deposition. The fish community showed some stress but benefited from ground water recharge and was in non-significant departure from the biocriteria.

Nested subwatershed 02 03 had four sites, all in partial attainment (two sites on Jackson Center Creek and two sites on Little Muchinippi Creek).

Jackson Center Creek is a small stream with severe channelization and excessive loadings from the Jackson Center WWTP. Jackson Center Creek was reclassified as MWH-C aquatic life use otherwise it would have been in non-attainment for a WWH site. Both sites were over the *Associations* target value for total phosphorus. Median nitrate-nitrite levels were 11.1 mg/l just downstream from the Jackson Center WWTP, which exceeded the *Associations* target value of 2.24 mg/l.

Little Muchinippi Creek biological impairment at RMs 3.7 and 0.44 resulted from channelization and nutrient enrichment associated with agricultural practices. The creek is under county ditch maintenance and the QHEI at both sites was less than the WWH guideline of 60. Both sites exceeded the *Associations* target value for total phosphorus and the lower site (RM 0.62) exceeded the ammonia target (Figure 3-12).

The only site in non-attainment was found in nested subwatershed 02 04 at the lower three miles of Muchinippi Creek. This reach is historically channelized, sluggish and partially impounded by an abundance of log jams which backed up flow and negatively impacted biological quality. Siltation, reduced habitat quality and nutrients from unrestricted livestock access also contributed to the impairment.

Recreation use impairment, caused by bacteria, was documented at 1 of 4 sites sampled. Jackson Center Creek (02 03) (PCR class B), downstream from the WWTP and the community of Jackson Center, was the only site in non-attainment. Three sites, Willow Creek (02 01), Little Muchinippi Creek (02 03) and Muchinippi Creek (02 04), were in attainment.

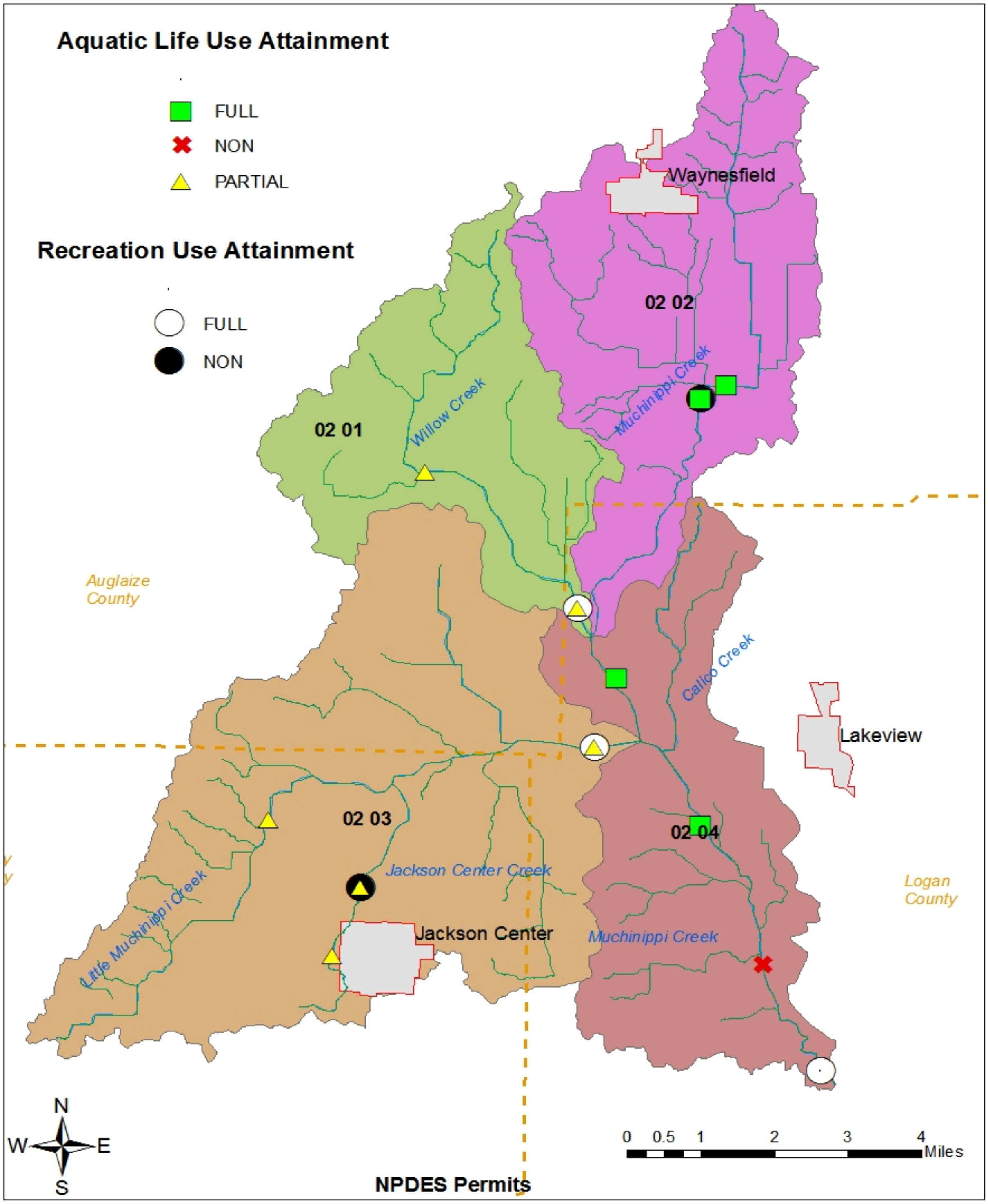

Figure 3-11. Aquatic life and recreation use attainment in the Muchinippi Creek subwatershed.

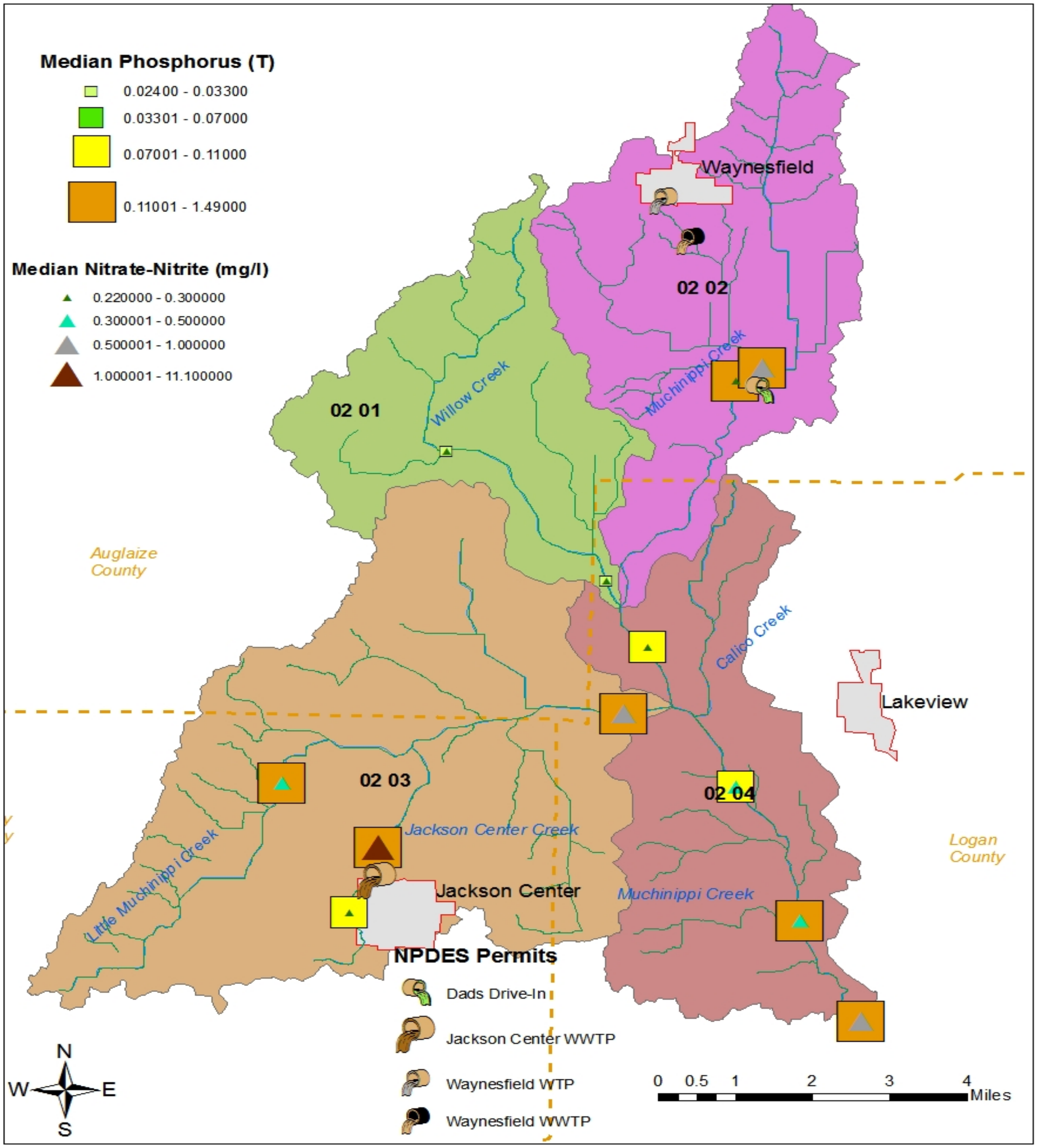

Figure 3-12. Nutrient concentrations in the Muchinippi Creek subwatershed.

Chemistry results shown in Figure 3-12 aided in identifying causes of aquatic life use impairment. Figure 3-13 and Figure 3-14 show the relative occurrence of causes and sources, respectively, of aquatic life use impairment in the Muchinippi Creek subwatershed.

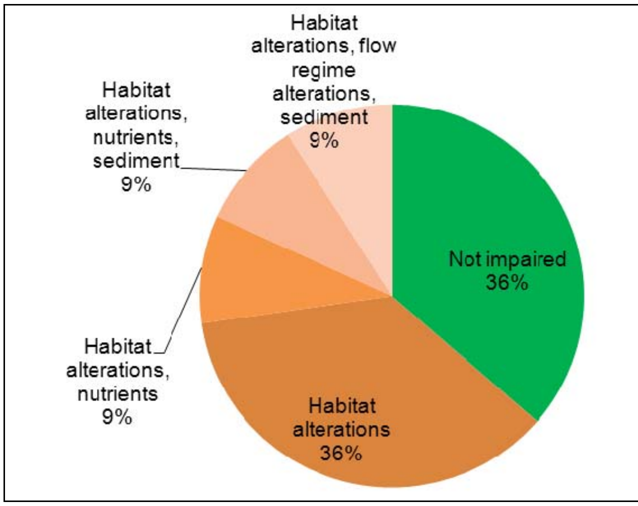

Figure 3-13. Causes of aquatic life use impairment in the Muchinippi Creek subwatershed.

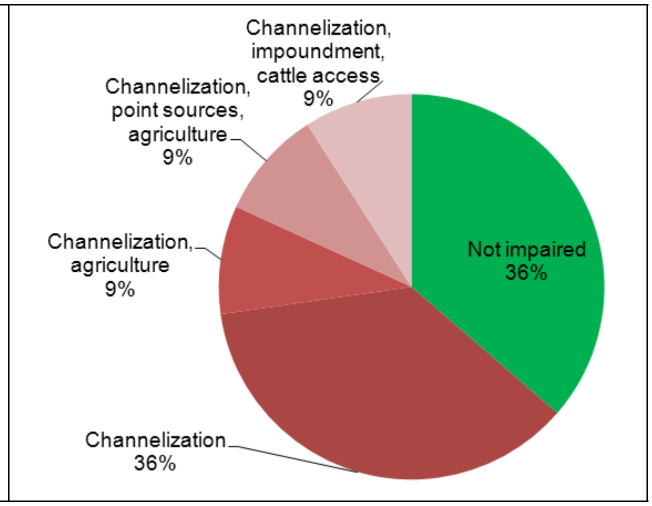

Figure 3-14. Sources of aquatic life use impairment in the Muchinippi Creek subwatershed.

Table 3-2 shows the site-by-site results for each designated beneficial use organized by nested subwatersheds. For more specific information regarding individual site assessment results and supporting chemistry results, please see Appendix B.

Table 3-2. Number of impaired sites, organized by use and nested subwatershed, in the Muchinippi Creek subwatershed.

Nested Subwatershed (05080001 02)		Aquatic Life Use	Recreation Use
02 01	# impaired sites (non/partial)	0/2	0
	Index score[1]	0	100
02 02	# impaired sites (non/partial)	0/0	1
	Index score	100	25
02 03	# impaired sites (non/partial)	0/4	1
	Index score	0	75
02 04	# impaired sites (non/partial)	1/0	0
	Index score	75	100

[1] The index score (between 0 and 100) indicates the relative support of the aquatic life or recreation use in the nested subwatershed. A score of 100 indicates full support of the use.

3.3 Bokengehalas Creek-Great Miami River (05080001 03)

The Bokengehalas Creek-Great Miami River subwatershed is made up of six nested subwatersheds (12-digit assessment units) draining 149.5 square miles. The predominant land use in the subwatershed is cultivated crop land (Figure 3-15). Major Great Miami River tributaries in this subwatershed include Cherokee Mans Run, Rennick Creek, Bokengehalas Creek and Rum Creek.

Biological sampling was conducted at 19 sites within the subwatershed, four on the mainstem and 15 in tributaries (Figure 3-16). Full attainment was documented at ten sites (52.6%), partial attainment was documented at seven sites (36.8%) and non-attainment was documented at two sites (10.5%).

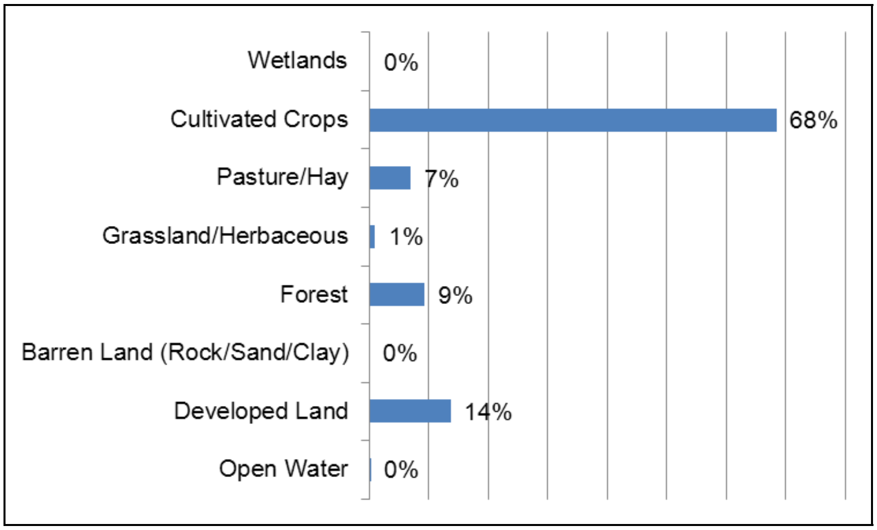

Figure 3-15. Land use in the Bokengehalas Creek-Great Miami River subwatershed.

The mainstem GMR was in partial attainment at 2 of 4 sites. Mainstem partial attainment was attributed to a variety of sources including past channelization and siltation, plus flow alteration and enrichment influences downstream from the Indian Lake overflow.

Recreation use impairment was documented at all seven sites sampled in the watershed (Figure 3-16). Non-attainment of the recreation use criteria was documented at Bokengehalas Creek (2 sites), Great Miami River (3 sites), Rum Creek (1 site) and Blue Jacket Creek (1site).

Nutrient impacts from discharges of the two major (> 1 MGD) WWTPs in the watershed were documented in Blue Jacket Creek and the Great Miami River.

Blue Jacket Creek did not exceed the *Associations* target values for phosphorus and nitrate-nitrite upstream from the Bellefontaine WWTP (Figure 3-17). Both sites downstream from the WWTP exceeded the *Associations* target values for phosphorus and nitrate-nitrite. The site at RM 5.39 had 7.05 mg/l nitrate-nitrite and 1.125 mg/l total phosphorus and at RM 0.72 had 3.25 mg/l nitrate-nitrite and 0.432 mg/l total phosphorus. The site upstream from the WWTP was strongly influenced by ground water recharge and was classified as a coldwater habitat stream.

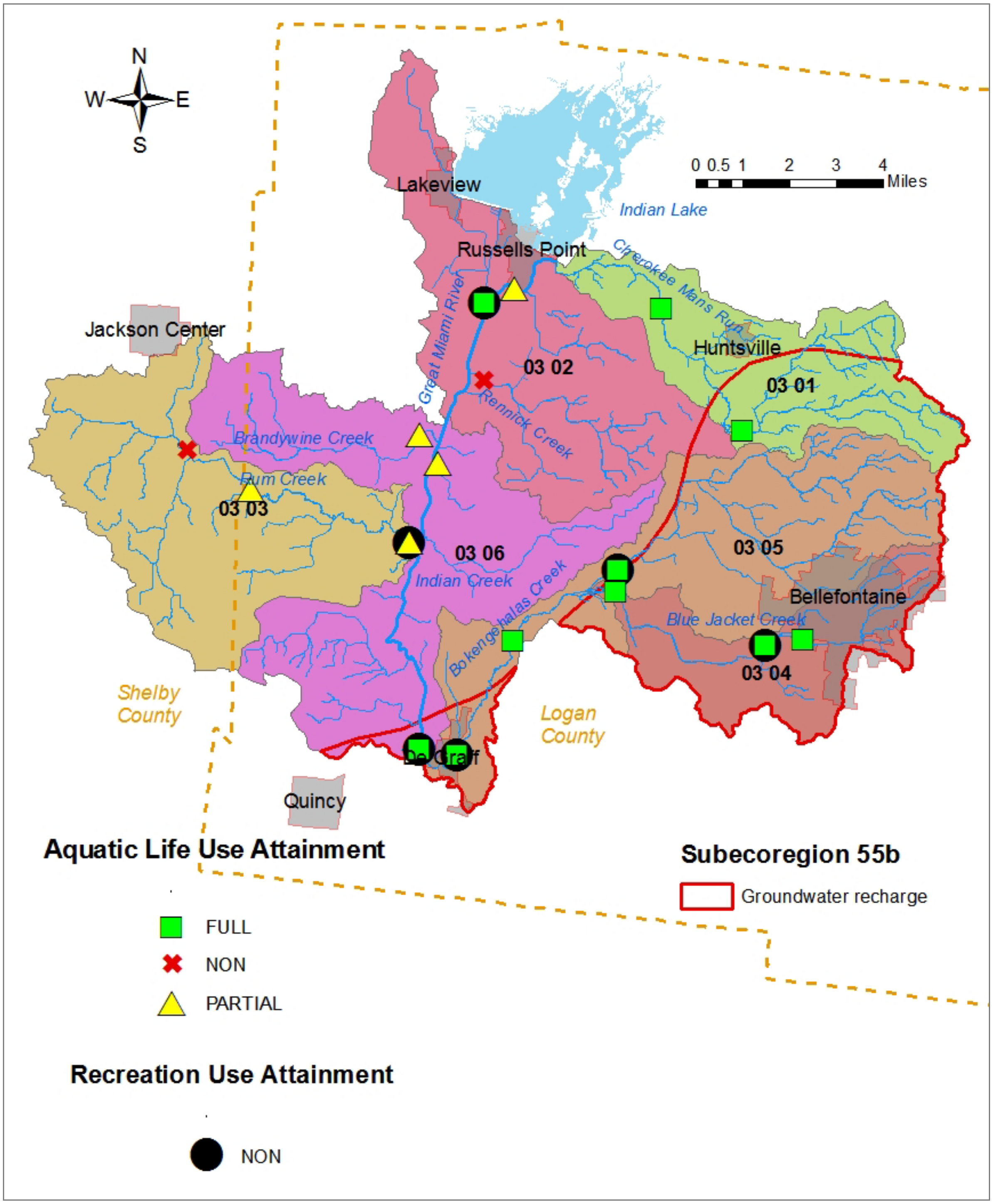

Figure 3-16. Aquatic life and recreation use attainment in the Bokengehalas Creek-Great Miami River subwatershed.

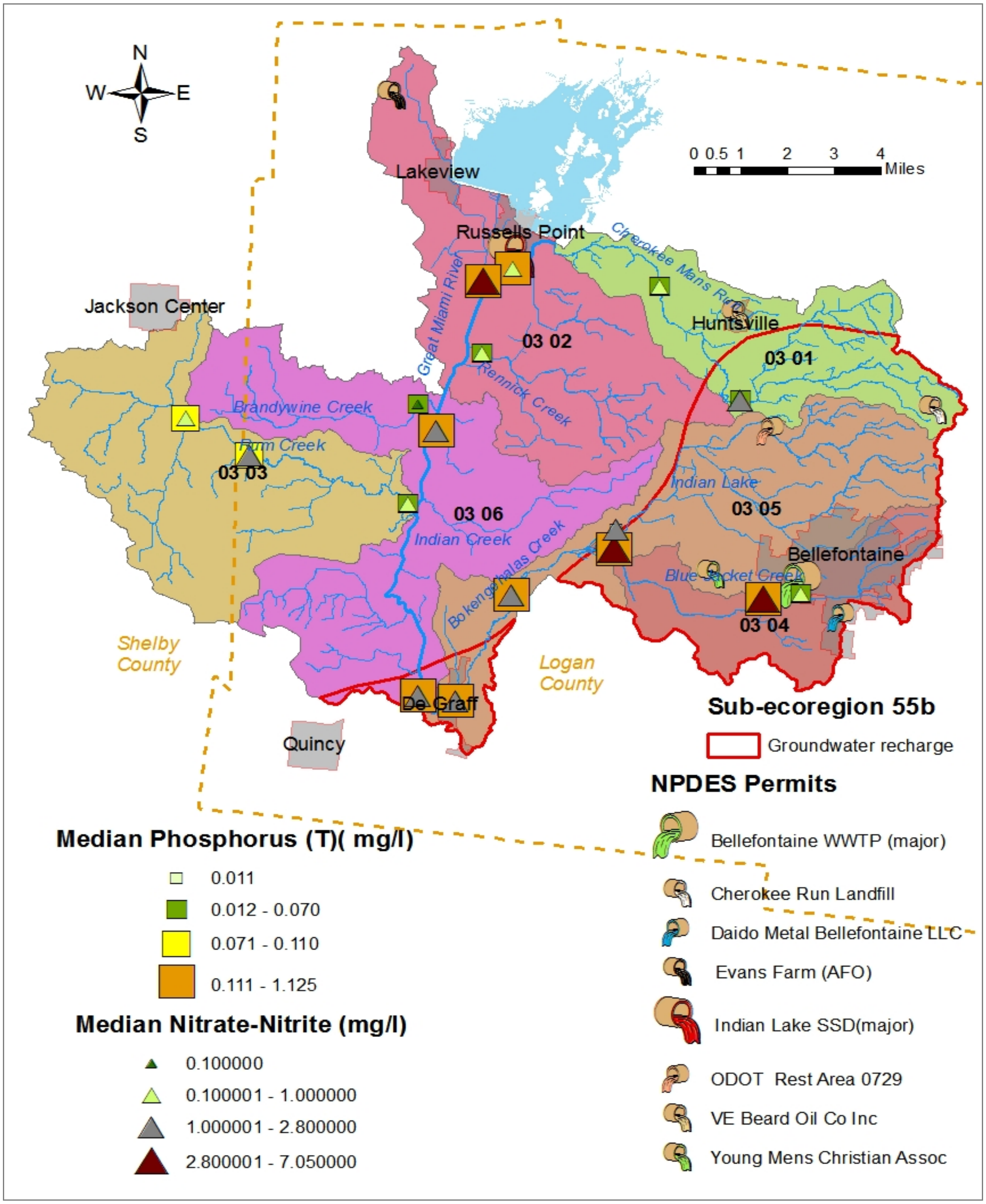

Figure 3-17. Nutrient concentrations in the Bokengehalas Creek-Great Miami River subwatershed.

Chemistry results shown in Figure 3-17 aided in identifying causes of aquatic life use impairment. Figure 3-18 and Figure 3-19 show the relative occurrence of causes and sources, respectively, of aquatic life use impairment in the Bokengehalas Creek-Great Miami River subwatershed.

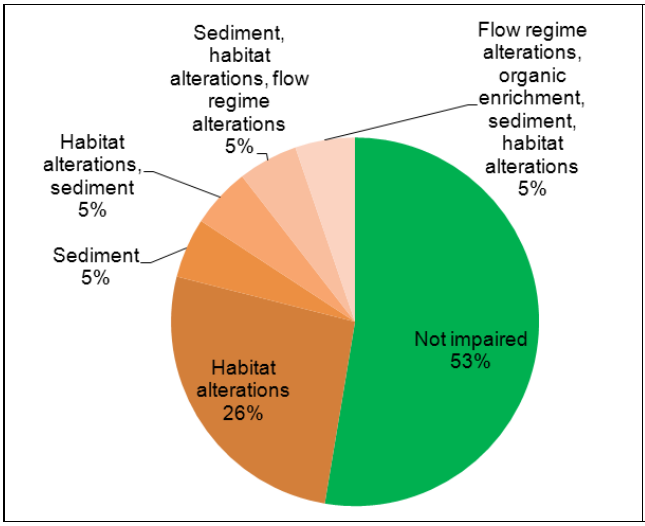

Figure 3-18. Causes of aquatic life use impairment in the Bokengehalas Creek-Great Miami River subwatershed.

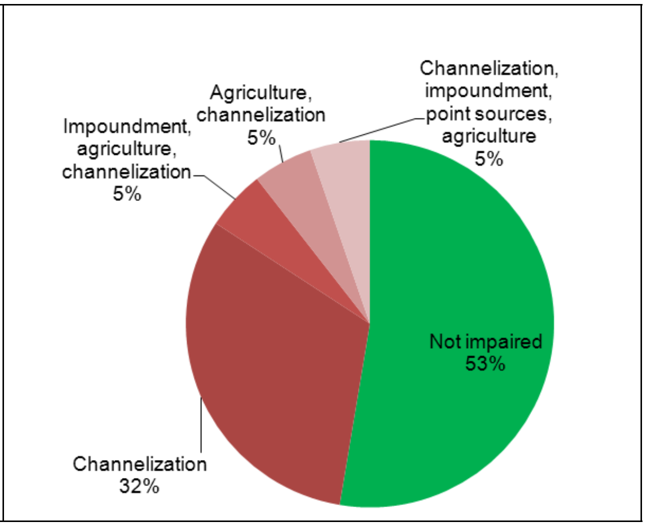

Figure 3-19. Sources of aquatic life use impairment in the Bokengehalas Creek-Great Miami River subwatershed.

Table 3-3 shows the site-by-site results for each designated beneficial use organized by nested subwatersheds. For more specific information regarding individual site assessment results and supporting chemistry results, please see Appendix B.

Table 3-3. Number of impaired sites, organized by use and nested subwatershed, in the Bokengehalas Creek-Great Miami River subwatershed.

Nested Subwatershed (05080001 03)		Aquatic Life Use	Recreation Use
03 01	# impaired sites (non/partial)	0/0	N/A
	Index score[1]	100	N/A
03 02	# impaired sites (non/partial)	1/2	2
	Index score	25	50
03 03	# impaired sites (non/partial)	1/2	1
	Index score	0	75
03 04	# impaired sites (non/partial)	0/0	1
	Index score	100	50
03 05	# impaired sites (non/partial)	0/1	2
	Index score	83.3	63
03 06	# impaired sites (non/partial)	0/2	1
	Index score	25	50

[1] The index score (between 0 and 100) indicates the relative support of the aquatic life or recreation use in the nested subwatershed. A score of 100 indicates full support of the use.

3.4 Stoney Creek-Great Miami River (05080001 04)

The Stoney Creek-Great Miami River subwatershed is made up of six nested subwatersheds (12-digit assessment units) draining 122.7 square miles. The predominant land use in the subwatershed is cultivated crop land (Figure 3-20). Major Great Miami River tributaries include McKees Creek, Stoney Creek, Lee Creek and Plum Creek.

Biological sampling was conducted at 14 sites within the subwatershed, three on the mainstem and 11 in tributaries (Figure 3-21). Full attainment was documented at thirteen sites (93%) with one site was in partial attainment (7%).

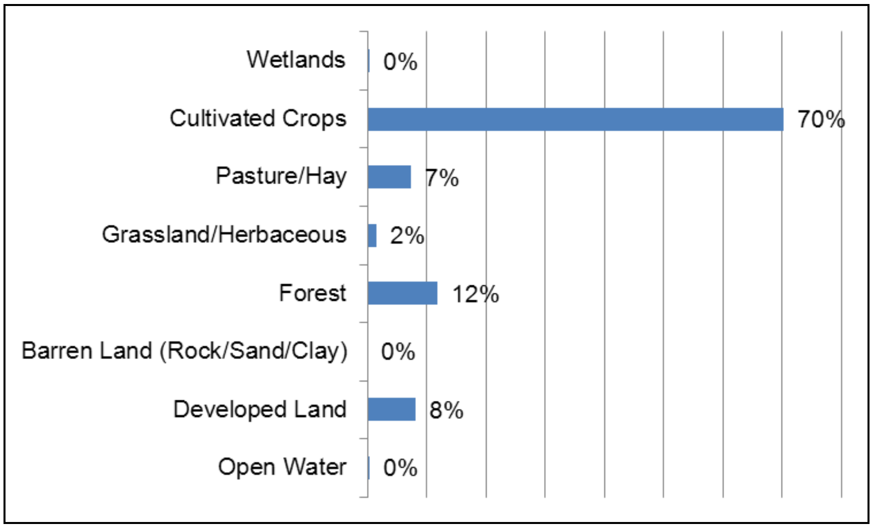

Figure 3-20. Land use in the Stoney Creek-Great Miami River subwatershed.

Biological sampling was conducted at three sites on the Great Miami River mainstem in the EWH-designated reach between Quincy Dam and Sidney. All three sites are classified as exceptional warmwater habitat. Sampling within the reach revealed both exceptional habitat quality and biological performance, including the highest IBI score (59) of the entire survey. In addition there is a good collection of live freshwater mussels including *Villosa fabalis (*rayed bean mussel*),* officially proposed to be listed as endangered under the Endangered Species Act on November 10, 2010 (Hoggarth 2009).

One site at Baker Road GMR RM 138.39 was in partial attainment of the EWH criteria. Impairment was the result of macroinvertebrate collections from a sluggish, pooled reach and attributed to a relatively minor siltation impact.

Tributary sites were all (100%) in full attainment of WWH (Stony Creek, Indian Creek, Plum Creek), CWH (Lee Creek and Graves Creek), and a dual EWH/CWH aquatic life use (McKees Creek).

Lee Creek at Friend Road

Recreation use impairment, caused by bacteria, was documented 5 of 7 sites sampled. The two Great Miami River mainstem sites downstream from the Quincy Dam (RM 142.3 and 142.5) were the only sites that met criteria. In contrast, all five tributary sites (McKees Creek, Graves Creek, Stony Creek, Plum Creek and Indian Creek) did not meet criteria.

Nutrient values across the watershed generally did not exceed the *Associations* targets, with the exception of McKees

Creek and Plum Creek (Figure 3-22). All sites on McKees Creek (EWH) exceeded the *Associations* target values for nitrate-nitrite and Plum Creek RM 9.0 exceeded the phosphorus target. The mainstem was within all *Associations* guidelines, even downstream from the Quincy/DeGraff WWTP.

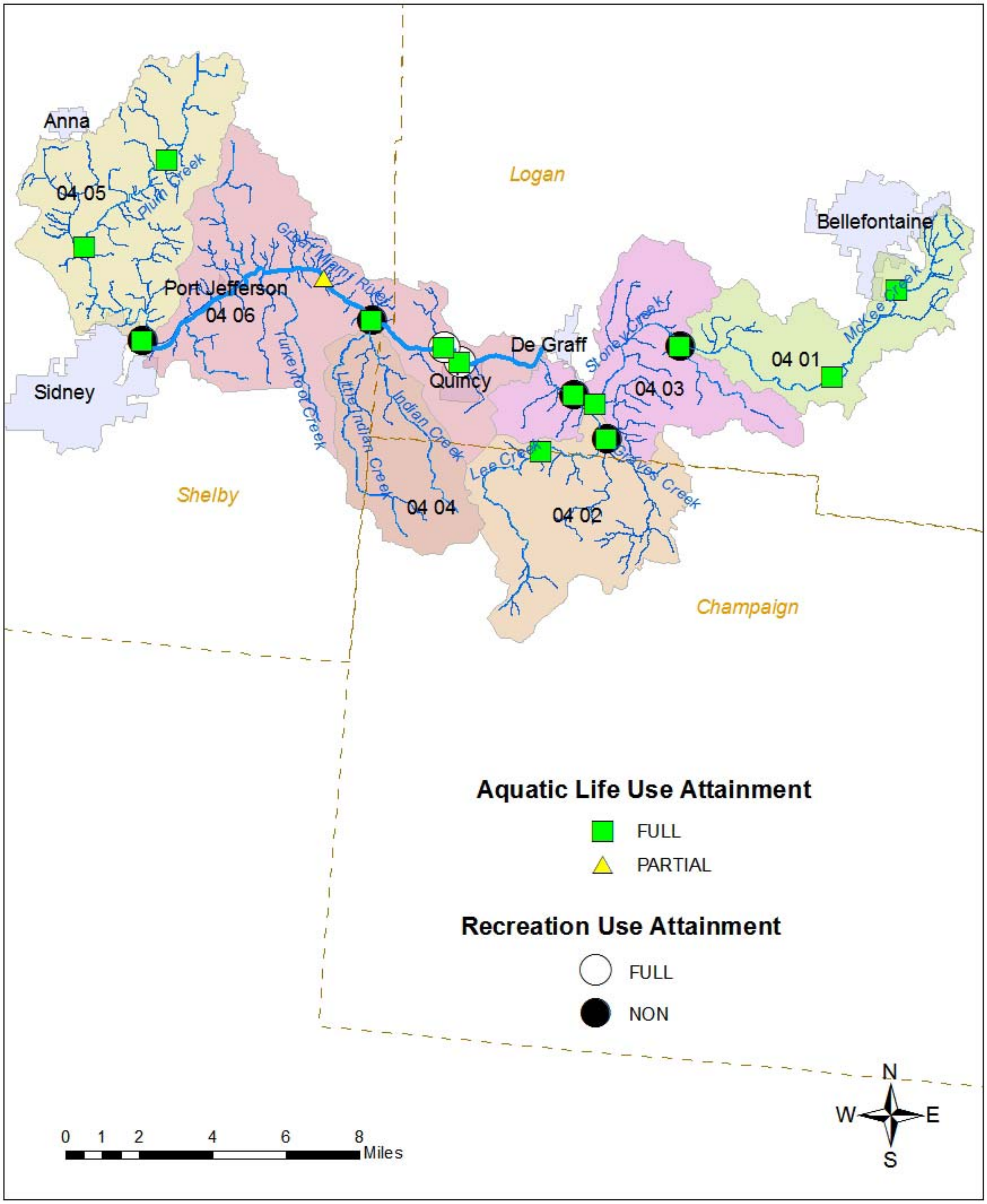

Figure 3-21. Aquatic life and recreation use attainment in the Stoney Creek-Great Miami River subwatershed.

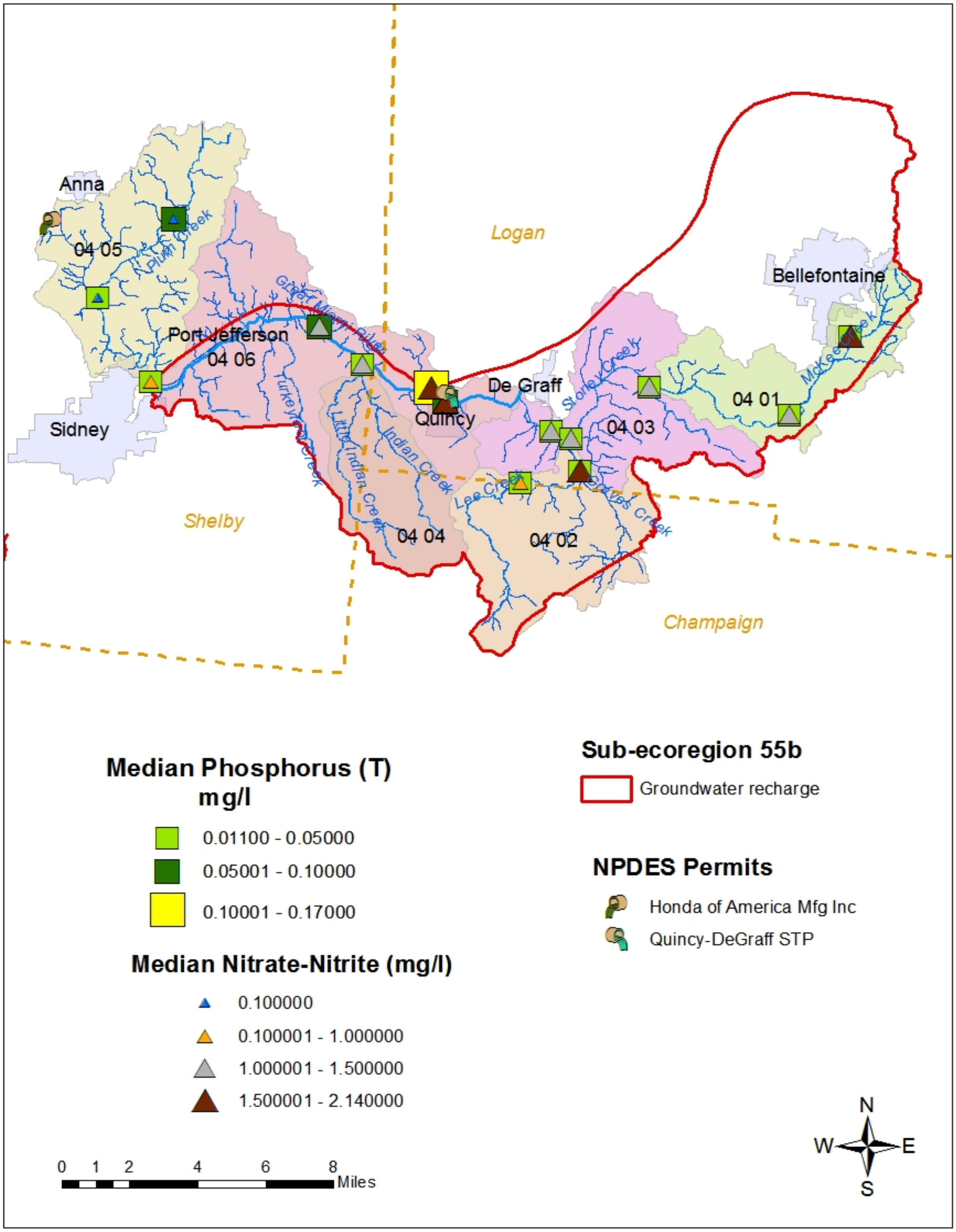

Figure 3-22. Nutrient concentrations in the Stoney Creek-Great Miami River subwatershed.

Chemistry results shown in Figure 3-22 aided in identifying causes of aquatic life use impairment. Figure 3-23 and Figure 3-24 show the relative occurrence of causes and sources, respectively, of aquatic life use impairment in the Stoney Creek-Great Miami River subwatershed.

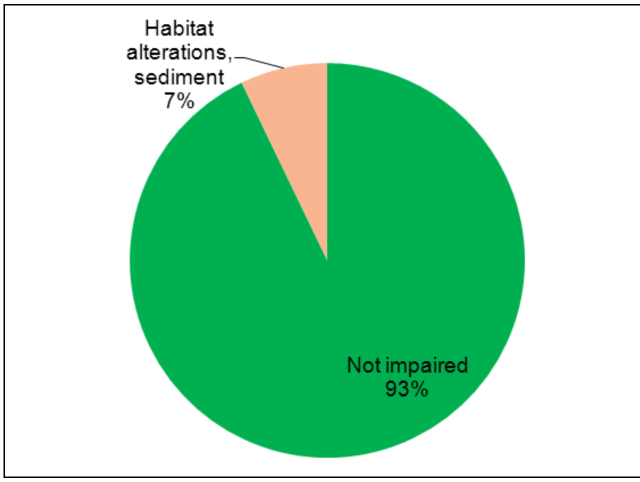

Figure 3-23. Causes of aquatic life use impairment in the Stoney Creek-Great Miami River subwatershed.

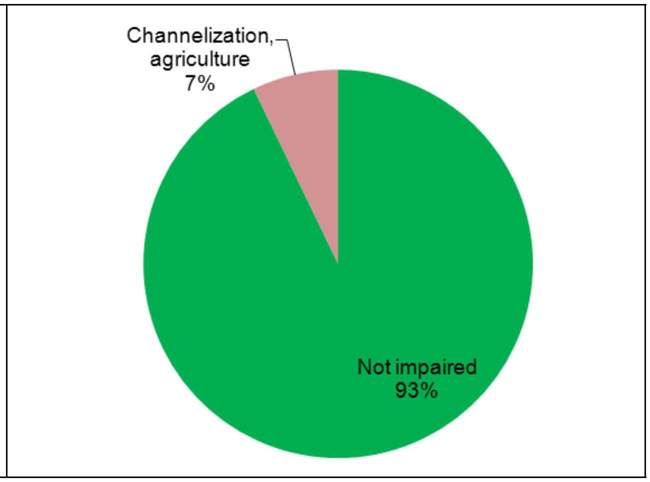

Figure 3-24. Sources of aquatic life use impairment in the Stoney Creek-Great Miami River subwatershed.

Table 3-4 shows the site-by-site results for each designated beneficial use organized by nested subwatersheds. For more specific information regarding individual site assessment results and supporting chemistry results, please see Appendix B.

Table 3-4. Number of impaired sites, organized by use and nested subwatershed, in the Stoney Creek-Great Miami River subwatershed.

Nested Subwatershed (05080001 04)		Aquatic Life Use	Recreation Use
04 01	# impaired sites (non/partial)	0/0	1
	Index score[1]	100	50
04 02	# impaired sites (non/partial)	0/0	1
	Index score	100	25
04 03	# impaired sites (non/partial)	0/0	1
	Index score	100	50
04 04	# impaired sites (non/partial)	0/0	1
	Index score	N/A[2]	50
04 05	# impaired sites (non/partial)	0/0	1
	Index score	100	50
04 06	# impaired sites (non/partial)	0/1	0
	Index score	66.7	100

[1] The index score (between 0 and 100) indicates the relative support of the aquatic life or recreation use in the nested subwatershed. A score of 100 indicates full support of the use.
[2] No index score was calculated for this nested subwatershed because there were insufficient data to assess support of the use, though the site that was sampled for aquatic life use was fully attaining biological criteria.

3.5 Headwaters Loramie Creek (05080001 05)

Headwaters Loramie Creek subwatershed is made up of three nested subwatersheds (12-digit assessment units) draining 147 square miles. The predominant land use in the subwatershed is cultivated crop land (Figure 3-25). Major streams in the subwatershed include Loramie Creek from its headwaters to Mile Creek, its two major tributaries (Mile Creek and the Miami-Erie Canal) and Spring Creek, a Mile Creek tributary.

Biological sampling was conducted at 11 sites within the subwatershed with three sites (36%) in non-attainment, five sites (55%) in full attainment , and three site (36%) in partial attainment of biological water quality standards (Figure 3-26). Mile Creek and the Miami-Erie Canal are MWH-C streams; while biological performance standards are lower for MWH than WWH streams, 2 of 4 Mile Creek sites were only in partial attainment of the MWH use. This is the one of the more degraded watersheds in the entire Great Miami River watershed (see the photograph below for an example).

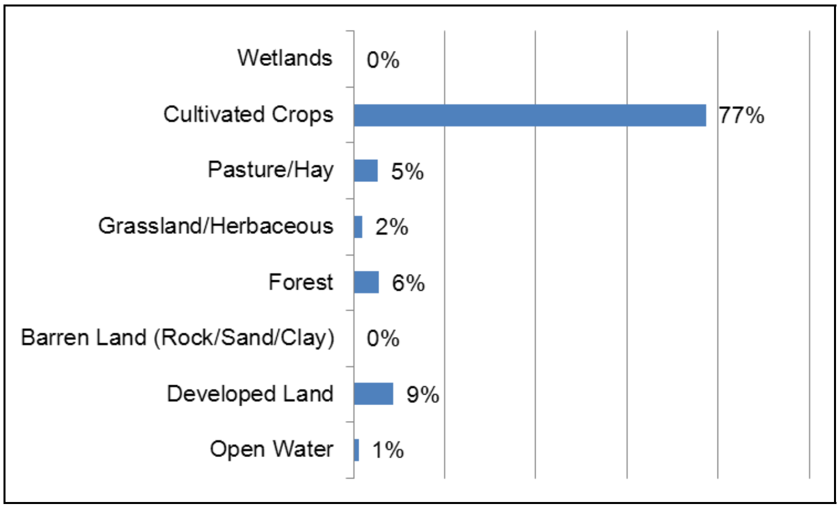

Figure 3-25. Land use in the Headwaters Loramie Creek subwatershed.

Loramie Creek recreation use impairment was documented at 4 of 5 sites sampled throughout the reach. One site, in the extreme headwaters of Loramie Creek upstream from the Botkins WWTP, met recreation use criteria. Tributaries had 2 of 4 sites in recreation use attainment. The Miami-Erie Canal and Mile Creek RM 5.97 were in non-attainment while Mile Creek RM 0.5 and Spring Creek, a Mile Creek tributary, were in full attainment.

Only one of eleven sites from the headwaters Loramie Creek subwatershed was in full attainment of WWH criteria. The remaining sites were in non- or partial attainment of WWH, partial attainment of MWH, or fully met the less protective MWH use.

Pictured is an emaciated channel catfish caught in Mile Creek (RM 5.97) at Kremer Rd.; it was suffering chronic sub-lethal stress from poor water quality. This was apparent from the multiple DELT anomalies (deformities, eroded fins, lesions and tumors): focal discoloration, raised lesions on the mandible and eroded barbells.

Sediment, nutrients and direct habitat alterations were the predominant causes in the subwatershed. Major sources included impoundments, channelization, agriculture and point sources.

In 2010 a centralized collection system was installed for Yorkshire, Osgood and Northstar in Darke County on the southern side of the Mile Creek drainage basin. This should help in reducing the impacts documented in Mile Creek from failing HSTS causing elevated nutrient and recreation use impairments.

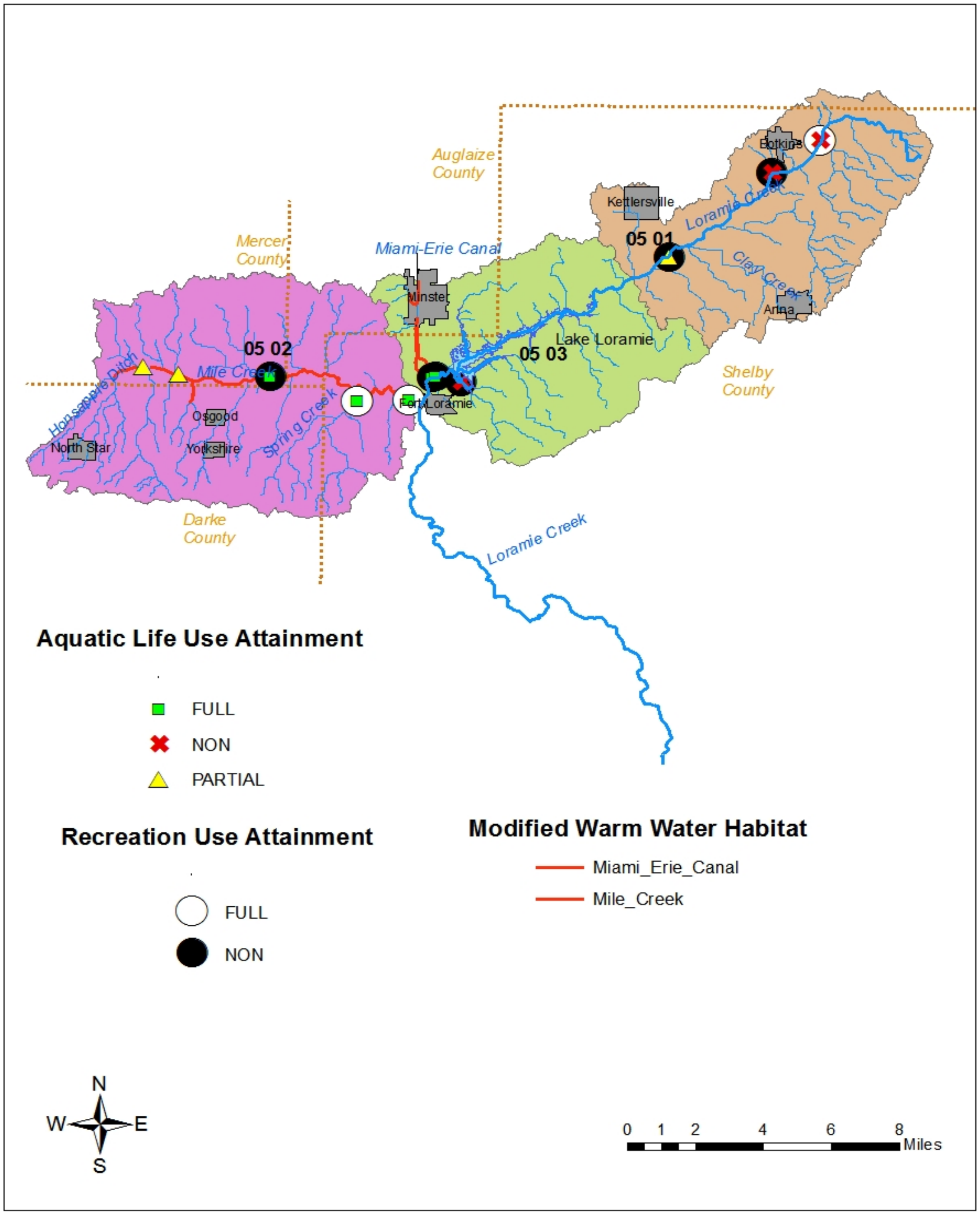

Figure 3-26. Aquatic life and recreation use attainment in the Headwaters Loramie Creek subwatershed.

Nutrient impacts from the discharges from the Minster WWTP and the Lake Loramie WWTP are documented at Loramie Creek in Ft. Loramie (RM 20.7). All sites on Loramie Creek exceeded the *Associations* target values for phosphorus (Figure 3-27). Median phosphorus spiked to 5.81 mg/l downstream from the Lake Loramie WWTP and the mouth of the Miami-Erie Canal. Median phosphorus values at the Minster WWTP were 12.6 mg/l and the Lake Loramie WWTP median phosphorus discharge was 3.375 mg/l. Median nitrate-nitrite values at RM 20.7 (13.55 mg/l) exceeded the *Associations* target values. Median nitrate-nitrite values on the Miami-Erie Canal downstream from the Minster WWTP were 18.85 mg/l and the Lake Loramie WWTP median nitrate-nitrite discharge was 28.15 mg/l. The headwater sites on Loramie Creek at RMs 34.96, 22.1 and 20.7 had median ammonia levels that exceeded the *Associations* target.

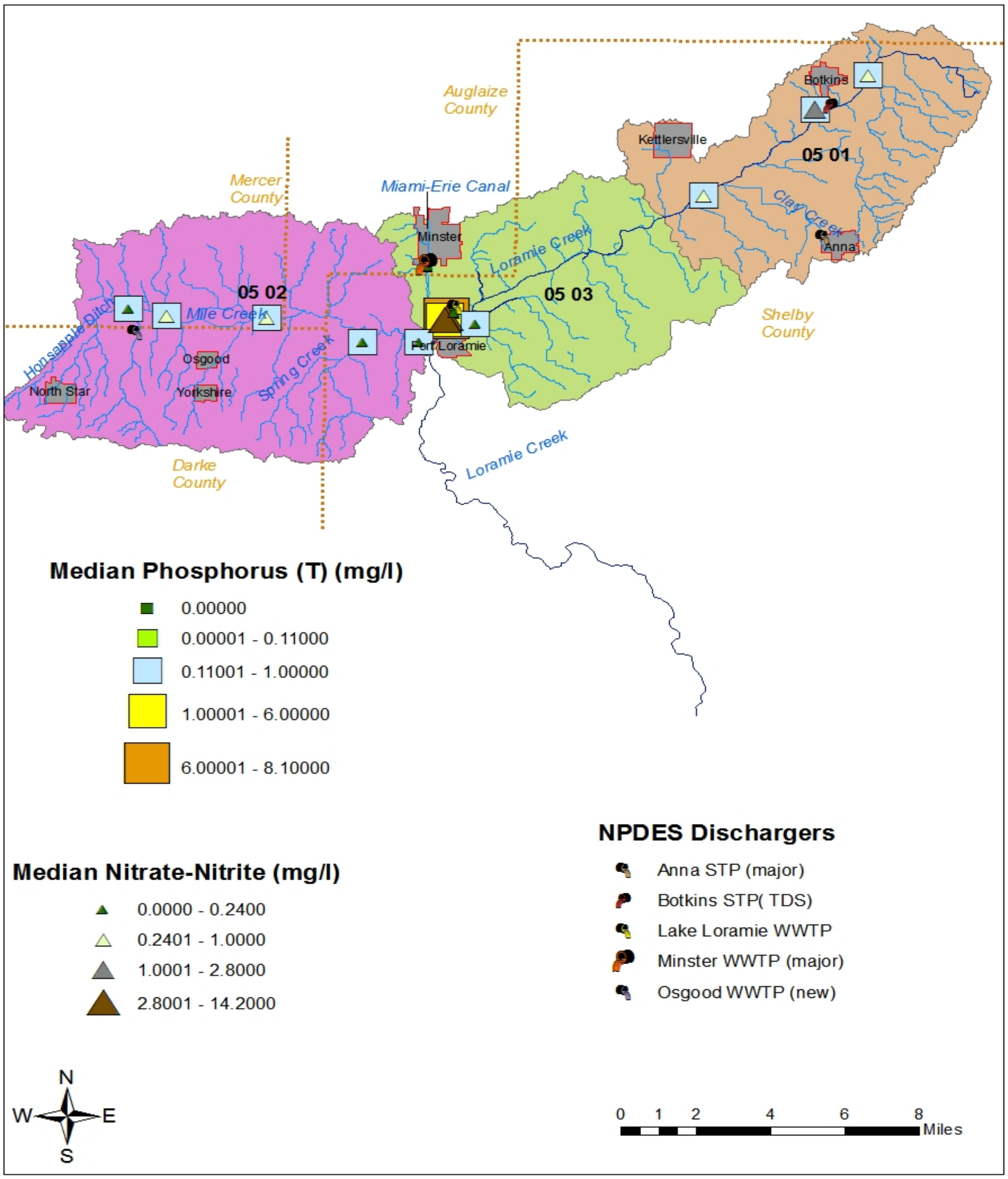

Figure 3-27. Nutrient concentrations in the Headwaters Loramie Creek subwatershed.

Chemistry results shown in Figure 3-27 aided in identifying causes of aquatic life use impairment. Figure 3-28 and Figure 3-29 show the relative occurrence of causes and sources, respectively, of aquatic life use impairment in the Headwaters Loramie Creek subwatershed.

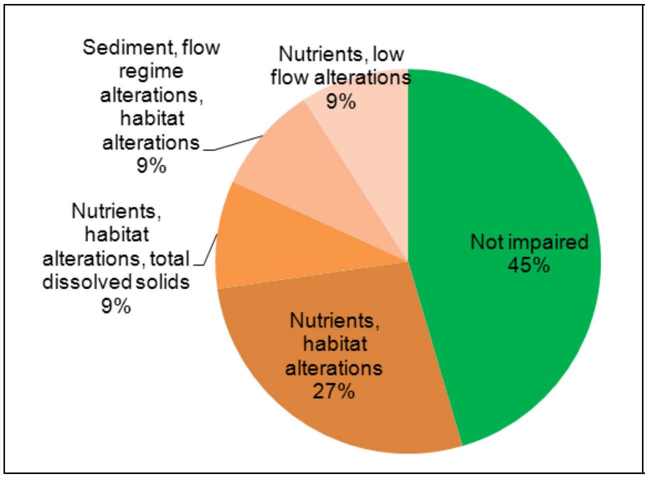

Figure 3-28. Causes of aquatic life use impairment in the Headwaters Loramie Creek subwatershed.

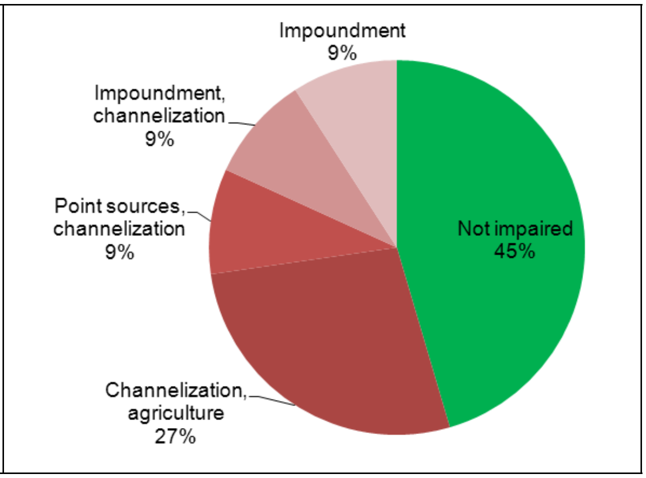

Figure 3-29. Sources of aquatic life use impairment in the Headwaters Loramie Creek subwatershed.

Table 3-5 shows the site-by-site results for each designated beneficial use organized by nested subwatersheds. For more specific information regarding individual site assessment results and supporting chemistry results, please see Appendix B.

Table 3-5. Number of impaired sites, organized by use and nested subwatershed, in the Headwaters Loramie Creek subwatershed.

Nested Subwatershed (05080001 05)		Aquatic Life Use	Recreation Use
05 01	# impaired sites (non/partial)	2/1	2
	Index score[1]	0	50
05 02	# impaired sites (non/partial)	0/2	1
	Index score	83.3	83
05 03	# impaired sites (non/partial)	2/0	3[2]
	Index score	75	42

[1] The index score (between 0 and 100) indicates the relative support of the aquatic life or recreation use in the nested subwatershed. A score of 100 indicates full support of the use.

[2] One site (Miami-Erie Canal at the confluence with Loramie Creek) was not included in the 2010 Integrated Report. This mistake will be corrected in the 2012 Integrated Report.

3.6 Turtle Creek-Loramie Creek (05080001 06)

The Turtle Creek-Loramie Creek subwatershed (downstream from the town of Ft. Loramie) is made up of four nested subwatersheds (12-digit assessment units) draining 116.8 square miles. The predominant land use in the subwatershed is cultivated crop land (Figure 3-30). Nutrient problems seen in the subwatershed are impacting the Loramie Creek mainstem downstream from Ft. Loramie. Biological sampling was conducted at 11 sites within the subwatershed with seven sites (64%) in full attainment, three sites (36%) in partial attainment and one site (9%) in non-attainment of biological water quality standards (Figure 3-31). The upper reach of Ninemile Creek is designated MWH-C stream but met its use.

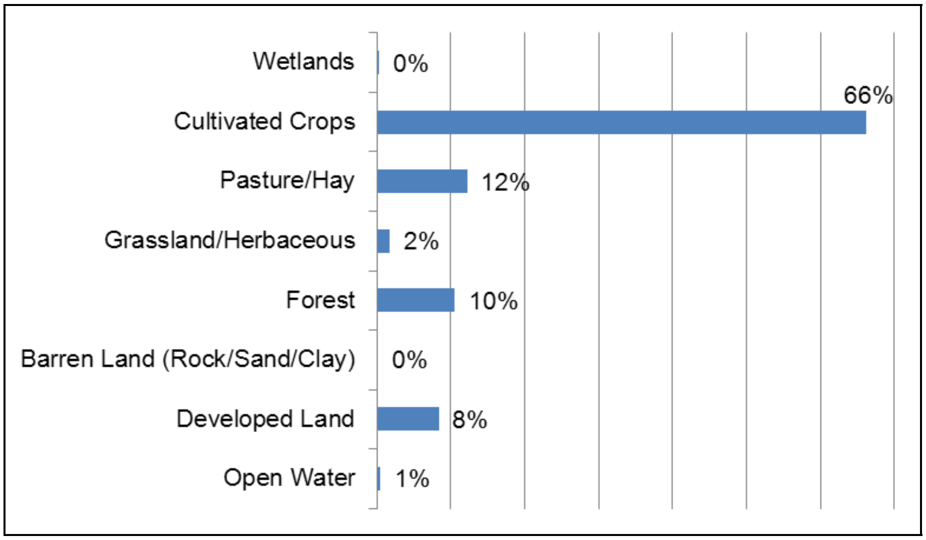

Figure 3-30. Land use in the Turtle Creek-Loramie Creek subwatershed.

Recreation use impairment was documented 4 of 6 sites sampled across the watershed. Loramie Creek had three sites sampled for *E. coli*; of the three, only the site on Cardo Road (RM 16.51) met its designated use. Ninemile Creek had two sites sampled in recreation use non-attainment. Turtle Creek and Spring Creek both met their designated recreation uses.

Lower Loramie Creek is under Shelby County ditch maintenance for an approximate 14.5 mile stretch from the Lake Loramie dam (RM 22.1) to Loramie-Washington Rd. (RM 7.5). Some sections, particularly an approximate four mile stretch downstream from Mile Creek, had particularly poor habitat quality, slow flow, elevated nutrients, and significant biological and chemical degradation.

Pervasive influences of nutrient enrichment (see Figure 3-32), siltation and habitat modification associated with agriculture, coupled with the additional enrichment influences from municipal WWTPs, have caused extensive algal blooms with dissolved oxygen swings of more than 10 units at Loramie Creek (Cardo Road RM 16.5) (July 7-9, 2008). The dissolved oxygen at Cardo Road peaked at 348% saturation and never went below 210% saturation over a 24-hour period. Although no aquatic life use assessment was conducted at this site, other sampling sites in the same affected reach were in partial attainment of the existing WWH use designation (Appendix B, Table B-2).

Both headwaters of Ninemile Creek and Turtle Creek are extensively channelized. Ninemile Creek is marginally meeting the reduced MWH aquatic life use designation. Turtle Creek is not meeting the WWH designation.

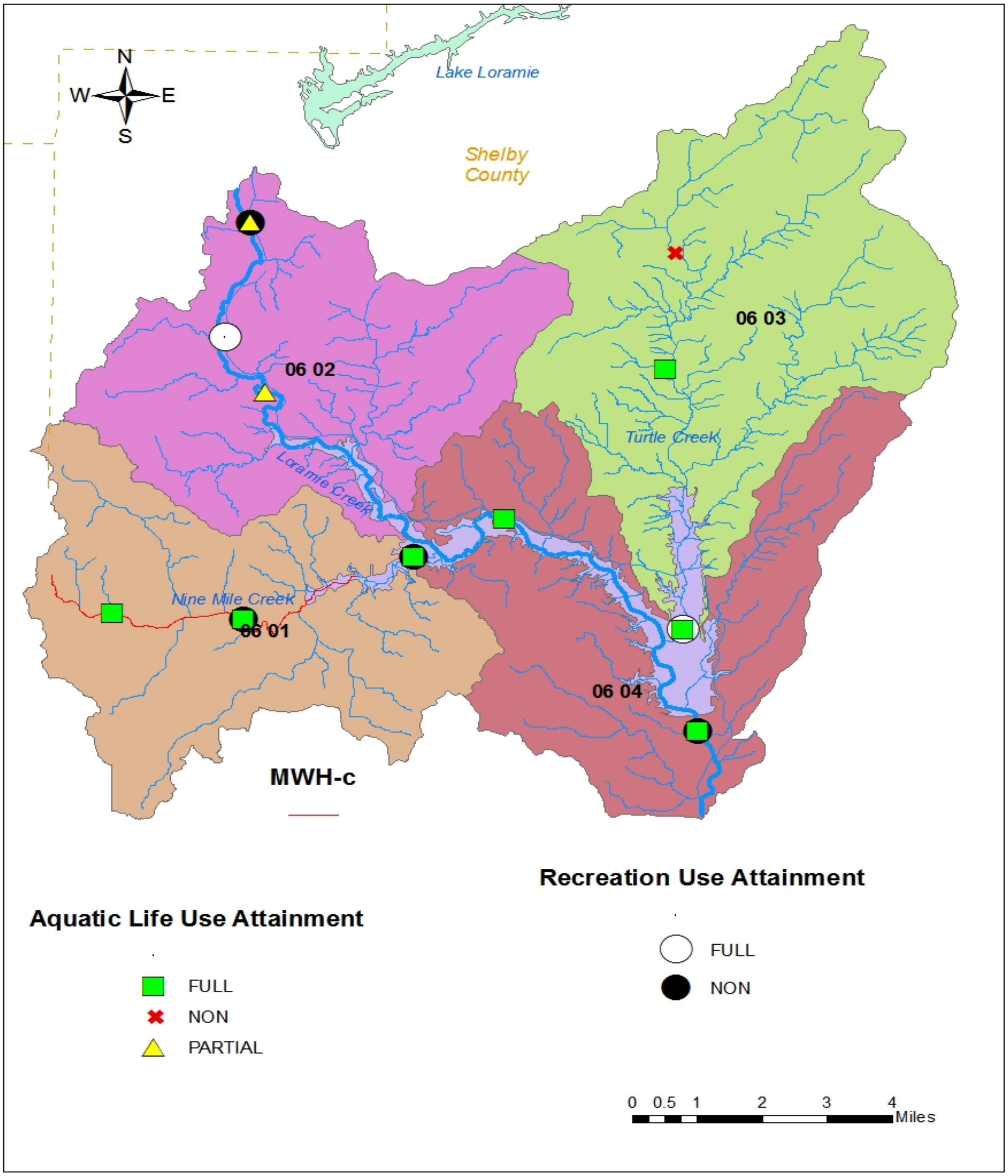

Figure 3-31. Aquatic life and recreation use attainment in the Turtle Creek-Loramie Creek subwatershed.

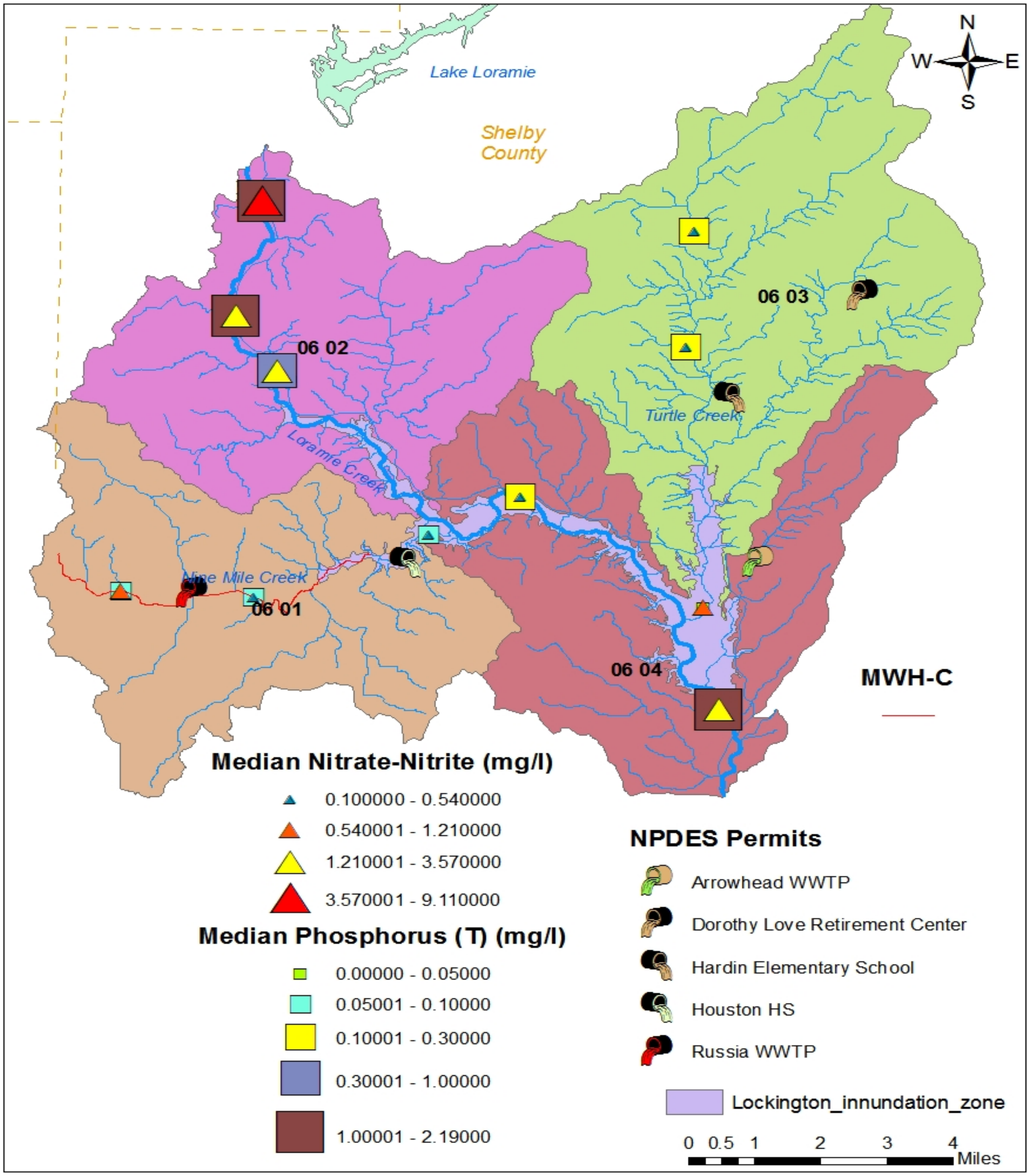

Figure 3-32. Nutrient concentrations in the Turtle Creek-Loramie Creek subwatershed.

Chemistry results shown in Figure 3-32 aided in identifying causes of aquatic life use impairment. Figure 3-33 and Figure 3-34 show the relative occurrence of causes and sources, respectively, of aquatic life use impairment in the Turtle Creek-Loramie Creek subwatershed.

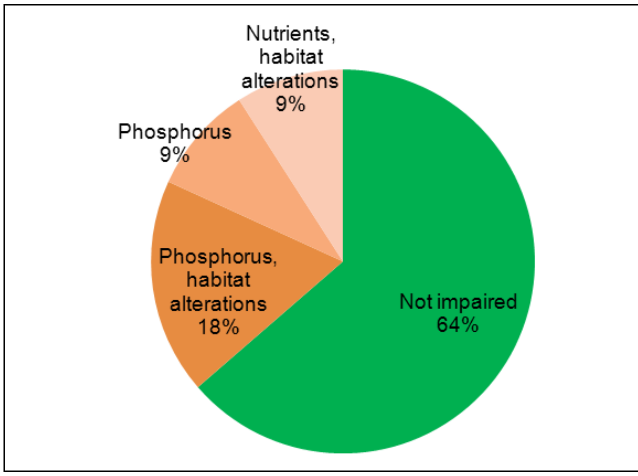

Figure 3-33. Causes of aquatic life use impairment in the Turtle Creek-Loramie Creek subwatershed.

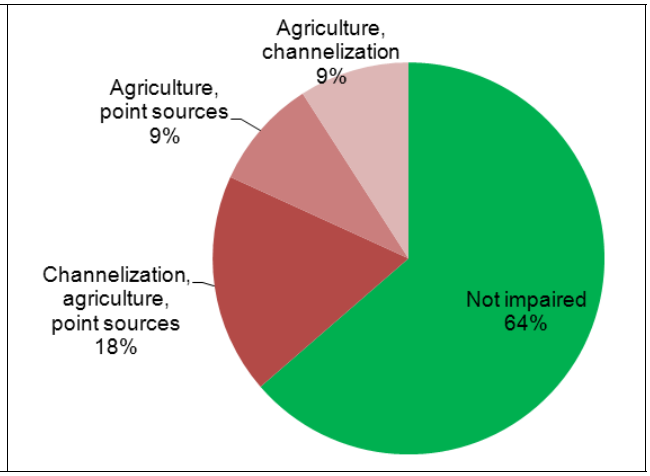

Figure 3-34. Sources of aquatic life use impairment in the Turtle Creek-Loramie Creek subwatershed.

Table 3-6 shows the site-by-site results for each designated beneficial use organized by nested subwatersheds. For more specific information regarding individual site assessment results and supporting chemistry results, please see Appendix B.

Table 3-6. Number of impaired sites, organized by use and nested subwatershed, in the Turtle Creek-Loramie Creek subwatershed.

Nested Subwatershed (05080001 06)		Aquatic Life Use	Recreation Use
06 01	# impaired sites (non/partial)	0/0	2
	Index score[1]	100	63
06 02	# impaired sites (non/partial)	0/3	1
	Index score	0	75
06 03	# impaired sites (non/partial)	1/0	0
	Index score	75	100
06 04	# impaired sites (non/partial)	0/0	1
	Index score	100	50

[1] The index score (between 0 and 100) indicates the relative support of the aquatic life or recreation use in the nested subwatershed. A score of 100 indicates full support of the use.

4 METHODS TO CALCULATE LOAD REDUCTIONS

The Great Miami River (upper) watershed does not support two beneficial uses—aquatic life use and recreation use. The causes of impairment to aquatic life uses consist of, in order of prevalence, stream and riparian habitat modification, siltation and sedimentation, nutrient enrichment, and organic enrichment and total dissolved solids (TDS). The cause of recreation use impairment is excessive concentrations of an indicator bacterium, *E. coli*. The linkage analysis examines the cause and effect relationships between watershed characteristics and pollutant sources and the effect on the stream biology and evaluates the use of surrogate measures to address the pollutant sources that would result in supporting beneficial uses.

Delivery of Source Loads to Waterbodies

Stream and riparian habitat modification is not a pollutant *per se*; its existence prevents attainment of the aquatic life use standard indirectly through reduction in the stream assimilative capacity to handle other pollutants that may cause impairment. Sources of this impairment include encroachment from cropland farming, suburban residential and commercial development, and in-stream dredging among others. These sources are "delivered" to the impaired water body through physical alteration of riparian and in-stream structure and composition. Sources of siltation and sedimentation include those mentioned just above but add conventional cropland tillage practices and livestock access to the stream, among still many others. Delivery of these sources of sediment and silt include overland flow from rain events and sloughing of banks when slope stability decreases due to the encroachment.

Specific components of nutrient enrichment include ortho-phosphorus (dissolved reactive phosphorus) and nitrate-nitrite – as these are directly available to plants. However, other forms of nitrogen (e.g., ammonia) and phosphorus (e.g., organic P) transform through processes such as oxidation and mineralization to plant available forms. Hence, these transformation processes are also relevant to impairment. Phosphorus chemical species are typically the limiting factor in aquatic plant growth in Midwestern (USA) rivers and streams. It is also true for this study as chemical monitoring of nitrogen and phosphorus for the entire upper Great Miami River watershed suggests P-limited stream systems (Figure 4-1). N-limited systems are to the left of the optimal ratio line (i.e., less than a 16:1 N:P ratio) and P-limited systems are to the right of this line. As seen in Figure 4-1, as the N:P ratio increases, the concentration of P decreases – it is consumed by the stream system (flora and sediment) – whereas the concentration of N is roughly constant or increases. N is replenished but P becomes limiting. Hence, focusing on P reduction produces immediate limitation for aquatic plant growth and subsequent enrichment effects. Further, P-limited systems occur primarily during the growing season in the GMR watershed where Figure 4-2 shows low N:P ratios from June through October. Hence, controlling P may limit planktonic growth during the critical low flow season and reduce corresponding enrichment effects

Sources of phosphorus nutrient enrichment primarily stem from fertilization of cropland – both synthetic and organic sources – and to some extent golf courses and residential lawns, but the latter extent is masked by the predominant area of cropland in this study area. Organic fertilization of cropland originates from manure production at livestock operations and they are discussed at length below. Other, more direct, sources include failing home septic systems and publicly owned treatment works (POTW) effluent. Pathways for pervasive sources are by transport of particulate and dissolved P from overland flow; dissolved P also makes it way to impaired waterbodies through subsurface flow and tile drainage when soil P concentrations are above natural thresholds (Sharpley et al. 2002).

Impairment due to organic enrichment and TDS are unique and discrete in the source attainability analysis. The former was found to emanate from POTW effluent (Indian Lake WPCD) where source loads have by-passed secondary treatment. The latter stems from excessive POTW discharge of TDS (Village of Botkins) as a result of excessive loads from incoming sources (Village of Botkins WTP). Nonpoint sources of TDS originate from agricultural and residential runoff, leaching of soil contamination. In addition, certain naturally occurring total dissolved solids arise from the weathering and dissolution of rocks and soils though their existence is minimal in the study area.

Excessive concentrations of the indicator bacterium – *Escherichia coli* – exceeding the water quality standard are due to both pervasive and direct sources. Pervasive sources stem from cropland fertilization using manure, and in particular when it is applied improperly (e.g., on frozen soil with an associated rainfall event) or applied excessively. Other pervasive sources stem from human waste via sludge management from POTW and from wildlife inhabiting the watershed. All of these sources reach impaired waterbodies through overland flow from rain or snowmelt events. Direct sources of this bacterium include improperly functioning of home septic systems and POTW and livestock access to streams. An assumption is made here that POTW operations contain proper disinfection techniques and they discharge at or below NPDES permit limits; hence their pathway is not considered as a source of impairment.

Sources of raw human sewage that enter waterways stem from combined sewer overflows (CSOs) or sanitary sewer overflows (SSOs). CSOs do not occur in this study area. SSOs have been identified at the following locations in the TMDL study area:

SSO as a Source of Impairment:		Ohio EPA Permit #	Facility (collection system)	Receiving Stream
Recreation Use	Aquatic Life Use			
non-attain	none	1PK00002	Indian Lake WPCD (system wide)	Great Miami River
non-attain	none	1PH00028	Lake Loramie SSD (system wide)	Loramie Creek
non-attain	none	2PB00036	Minster WWTP (system wide)	Miami-Erie Canal
none	none	1PB00036	Quincy-DeGraff STP (system wide)	Great Miami River

SSOs deliver raw human sewage to waterways which produces loadings of bacteria, BOD, nutrients, metals, and suspended sediment. Because SSOs are illegal, they receive no wasteload allocation. Administrative correction measures are used to eliminate this form of impairment.

MS4s convey storm water from separate storm sewer systems to downstream receiving waters. Separate storm sewer systems include ditches, curbs and gutters, storm sewers, and other runoff conveyance systems. Such systems do not connect to wastewater collection systems or treatment plants. Storm water can transport contaminants including nutrients, sediment, metals, bacteria, oil, grease, pesticides, and herbicides that have the potential to reduce water quality (taken from Grand River TMDL 2011). When considering bacteria, stormwater runoff purges the land surface of animal waste, both wildlife and domestic (e.g., runoff from community dog parks or wild geese congregation areas surrounding urban ponds).

Animal feeding operations (AFOs) are agricultural enterprises where animals are kept and raised in confined situations. AFOs congregate animals, feed, manure and urine, dead animals, and production operations on a small land area (USEPA website). The US EPA CAFO (concentrated AFO) Rule promulgated in 2003 (and subsequently revised in 2005 and 2008) defines three types of CAFOs (large, medium, and small) that require NPDES permit coverage. Permits are required for large CAFOs as a result of production area or land application discharges, for medium AFOs as a result of production area discharges through man-made conveyances to waters of the State, and for small AFOs if they are determined to be significant contributors of pollution to waters of the State and are designated as CAFOs. Once permitted through NPDES or through the Ohio Department of Agriculture Permit to Operate program (the operating permit required for all large CAFOs), non-exempt discharges are prohibited and are considered to be permit violations. Hence, none of the permitted facilities identified in Table A-4 can discharge to waters of the State under non-extenuating circumstances and therefore receive a wasteload allocation of zero.

There are approximately 200 or so permitted CAFOs in Ohio whereas there are multitudes of AFOs. Water quality problems associated with AFOs, mainly in the form of nutrients, biochemical oxygen demand (BOD), and pathogen pollutants to surface waters, stem from both the AFO production area[1] and the application of manure to cropland. Land application of manure presents the greatest threat to surface waters because it is susceptible to operator error and meteorological conditions. Over-application of manure, application of manure on frozen ground and poorly timed manure applications can lead to the introduction of manure into waters of the State. In addition, poorly designed facilities or mishaps in the production area such as lagoon overflows can also result in manure export to waters of the State.

Source Location and Analysis

Areas where nutrient enrichment and subsequent aquatic life use impairment occur in the upper half of the Loramie Creek watershed, including its headwaters and their flowage into Lake Loramie, downstream from Lake Loramie and including sub-drainages of Mile Creek and Miami-Erie Canal, and through the mainstem down to and downstream from the village of Newport. There are isolated segments of nutrient enrichment in the lower part of Loramie Creek watershed (namely Turtle Creek subwatershed) and the lower reaches of the Little Muchinippi Creek watershed. Source descriptions specific to each study area include:

1) Turtle Creek is a headwater sub-basin and the impairment due to nutrient enrichment is in the upper third of the nested subwatershed (RM 8.42 and a drainage area of 8.3 mi^2). This area consists primarily of row crop agriculture with both synthetic and organic fertilization. Row-crop agriculture is selected as the sole source and remediation will be sought through a combination of reduced fertilization rate and agricultural management practices. The impairment is also due to habitat alteration and the deviation of existing

[1] A production area includes animal confinement areas, manure storage areas, raw materials storage areas, and waste containment areas (from Ohio EPA Fact Sheet *CAFO NPDES Permit – General Overview of Federal Regulations*, August 2010).

habitat from the recommended habitat based on designated aquatic life use will be quantified.

2) The lower part of Little Muchinippi Creek (RM 0.62 and 35.5 mi^2) and an upstream tributary (RM 1.8 and 5.4 mi^2) are impaired for nutrients, habitat, and siltation. Nutrient sources will be addressed through reduced fertilization of row crop agriculture and limiting the concentration of total phosphorus from the sole POTW in this subwatershed – Jackson Center (1PB00018).
3) In the upper half of the Loramie Creek watershed, contributions of P stem from cropland runoff, failing home septic systems, and POTW effluent. POTW effluent consists of a major (Village of Minster - 2PB00036) and a significant minor (Lake Loramie/Shelby County SSD - 1PH00028) permitted facility. Both POTW systems contribute effluent year-round (as usual) but for the summer months their effluent comprises a majority of Loramie Creek flow as outfall from Lake Loramie is small to none. Flow alteration by the Lake Loramie impoundment, a significant impact for reducing downstream assimilative capacity, is a major yet un-addressed source of non-attainment for the Loramie Creek system. The primary source load contributions originate from fertilization of row crop agriculture, particularly in the Mile Creek sub-drainage (Darke and Mercer counties OH) where livestock operations are prevalent. Shelby and lower Auglaize counties are also heavy corn-soybean producing areas and contribute nutrients from these activities. Thus, two POTWs and row crop agriculture will be considered in load reduction strategies to address impairment due to enrichment

Impairment of aquatic-life use at RM 153.45 of the Great Miami River mainstem is caused by habitat alteration, siltation, flow alteration, and organic enrichment/DO. Organic enrichment/DO is attributed to an upstream source – a WWTP (approximately 5 miles) named Indian Lake/Logan County (1PK00002). This source will be addressed through analysis of its BOD and TSS discharge loads before and after the POTW construction upgrade that occurred after the field survey in 2008. Siltation and habitat alteration causes are also considered – these are predominant causes relative to organic enrichment – and will be addressed as in above. Row crop agriculture and in-stream channel dredging to maintain field tile flow are sources. Flow alteration cannot be addressed as it is caused by an upstream impoundment – Indian Lake. Ideally the lake area should be maintained as a natural water course – a meandering prairie/grassed stream – but economic reasons (tourism, recreation, vacation home values) prevent addressing this source of impairment.

While habitat alteration and its primary source – row crop agriculture infringement on natural water courses – has been mentioned in situations with nutrient or other chemical-based impairment, it is a significant cause of impairment throughout the upper GMR watershed. In total, there were 24 sites with impairment attributed to habitat alteration, 8 sites attributed to siltation, and 5 sites attributed to flow alteration. Four of five flow alteration sites are downstream from two major impoundments – Indian Lake and Lake Loramie. The site not downstream from an impoundment is addressed below. Today these waterbodies serve recreation and tourism needs at the expense of full aquatic biological integrity. The habitat alteration and siltation locations exist on the GMR mainstem, the Muchinippi Creek watershed including multiple tributaries, and several direct tributaries to the upper GMR mainstem. These impairments are primarily in Logan County OH. Loramie Creek watershed is also beset with habitat alteration and this occurs primarily in Shelby County OH. As identified above, all sites impaired by habitat alteration and siltation have row crop agriculture and in-stream channel dredging as sources of impact.

Flow alteration on (big) Muchinippi Creek is caused by wood-debris impoundment (i.e., log-jams). The existence of excess woody-debris originates from intense agricultural management of the river course. Here removal of woody material from the vegetated riparian zone of an upstream watercourse to “improve” flow and thereby reduce flooding of cropland at a local level. Then, one witnesses the problem propagate downstream to another landowner’s field. Flow alteration for this location will be addressed indirectly through restoration of habitat (alteration).

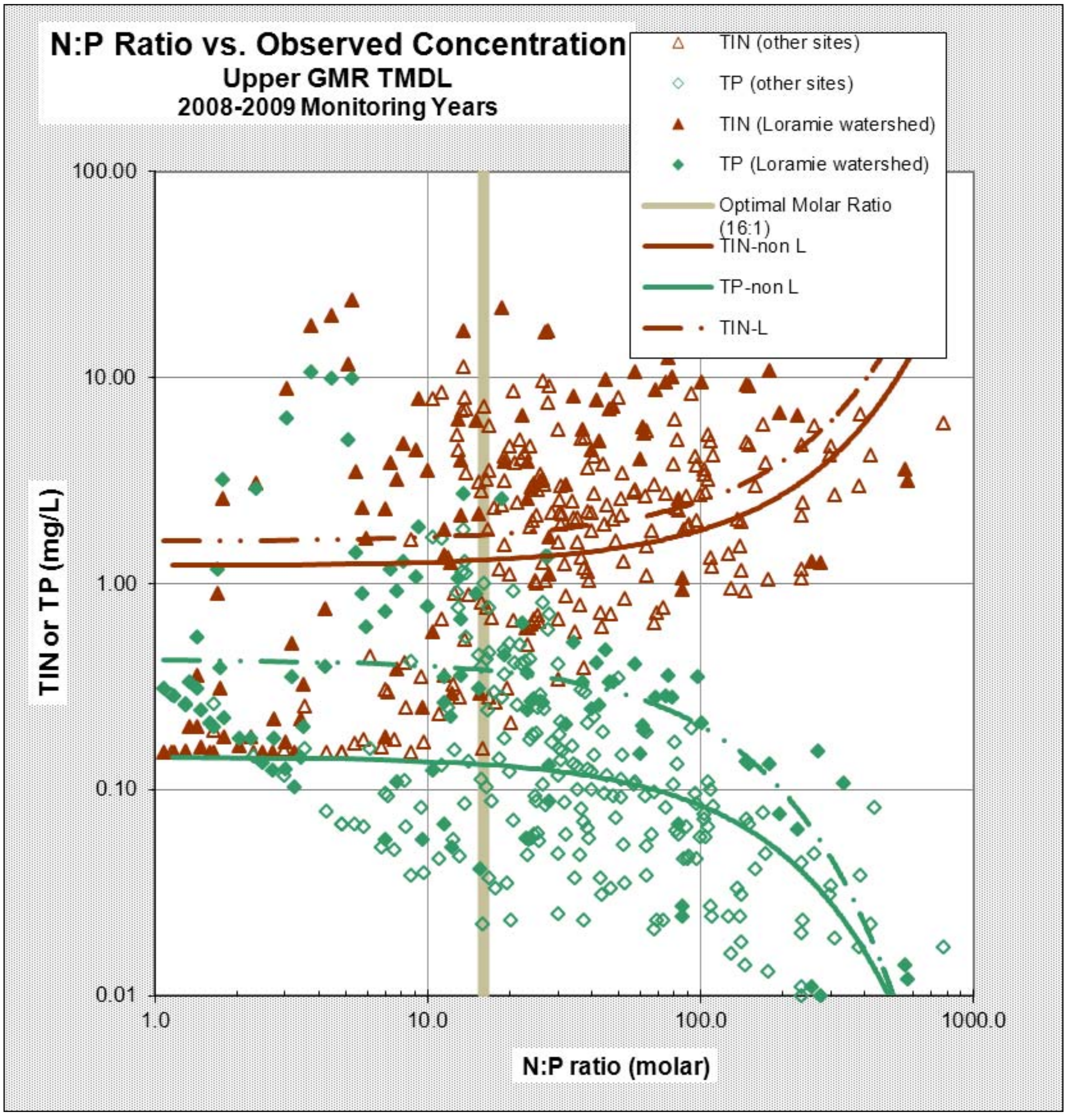

Figure 4-1. Cross-plot of nutrient concentration (TIN or TP in mg/L) and molar N:P ratio for monitored locations in the upper Great Miami River.

Note: **TIN** = total inorganic nitrogen (ammonia + nitrite + nitrate), **TP** = total phosphorus (includes dissolved and particulate, includes ortho-P and organic P). The optimal N:P ratio to sustain planktonic growth is 16:1 (using molar concentrations). Monitoring sites are differentiated as only those in Loramie Creek watershed and all other sites in GMR watershed. Solid and dashed lines are exponential trends fitted to the point (monitored) data.

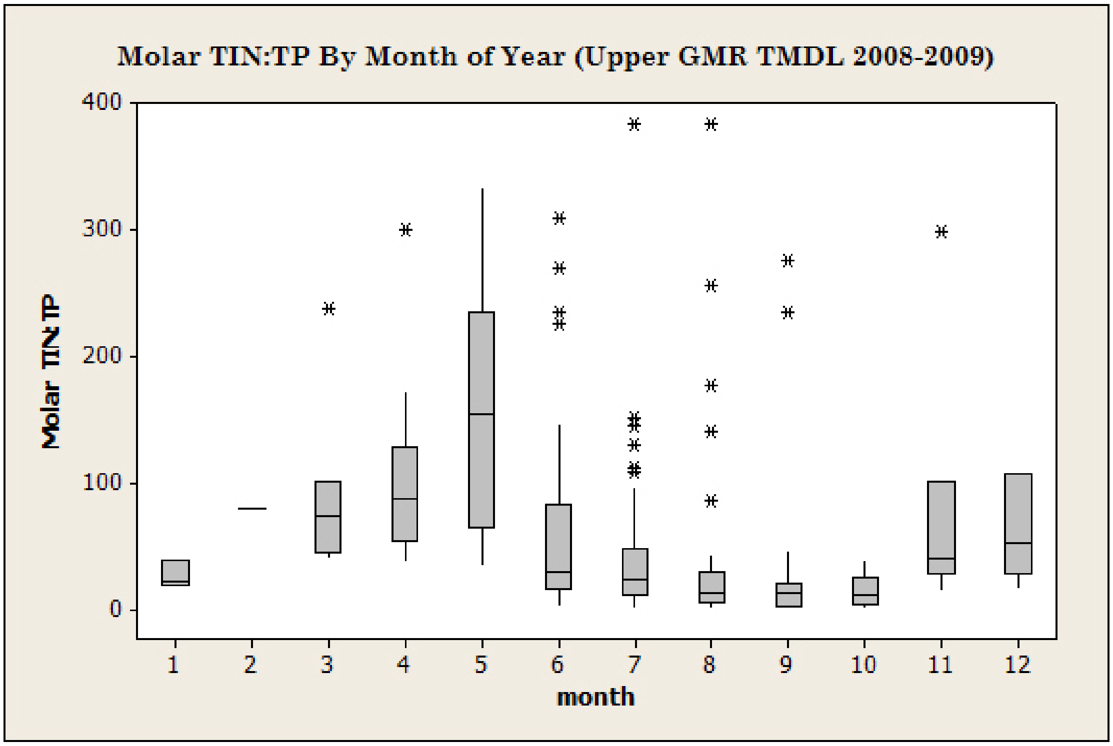

Figure 4-2. Distribution of molar N:P ratio by month (1=January through 12=December) of year.

Table 4-1 indicates how the applicable causes of impairment are addressed in each of the assessment units.

Table 4-1. Summary of causes of impairment and actions taken to address them in assessment units within the 05080001 01 through 05080001 06 ten-digit hydrologic units.

Causes of Impairment	Watershed Assessment Units						
	05080001 01			05080001 02			
	01	02	03	01	02	03	04
Aquatic Life Use							
Nutrient enrichment						D	
Habitat alterations			D	D		D	D
Sedimentation/siltation						D	D
Dissolved oxygen/organic enrichment							
Total dissolved solids							
Ammonia							
Other flow regime alterations							S
Recreation Use							
E. coli	D	D			D	D	

Causes of Impairment	Watershed Assessment Units											
	05080001 03						05080001 04					
	01	02	03	04	05	06	01	02	03	04	05	06
Aquatic Life Use												
Nutrient enrichment												
Habitat alterations		D	D		D	D						D
Sedimentation/siltation		D	D		D	D						D
Dissolved oxygen/organic enrichment						4B						
Total dissolved solids												
Ammonia												
Other flow regime alterations		S				N						
Recreation Use												
E. coli		D	D	D	D	D	D	D	D	D	D	

Causes of Impairment	Watershed Assessment Units						
	05080001 05			05080001 06			
	01	02	03	01	02	03	04
Aquatic Life Use							
Nutrient enrichment	D	D	D		D	D	
Habitat alterations	D	D			D	D	
Sedimentation/siltation	D						
Dissolved oxygen/organic enrichment							
Total dissolved solids	D						
Ammonia							
Other flow regime alterations	N		N				
Recreation Use							
E. coli	D	D	D	D	D		D

D – direct	Means that TMDLs are calculated for this parameter
S – surrogate	Means that TMDLs are calculated for a closely related cause and actions to reduce the impact of that cause should be sufficient to address this cause. There is substantial overlap in the sources of the loading of both parameters
N – not addressed	Means that the impairment is not addressed in this report.
Blank	Indicates that the assessment unit is not impaired for this cause.
4B	Means that the 4B option is being used to address impairment.

Further details on modeling methods and analyses are available in Appendix D.

4.1 SWAT Analysis of Total Phosphorus – Loramie and Little Muchinippi Watersheds

Nutrient loading, specifically that of mineral and organic phosphorus species, and flow in the Loramie Creek and Little Muchinippi Creek watersheds from the major pollution sectors –

agricultural NPS, HSTS, and WWTP – were simulated using the Soil and Water Assessment Tool (SWAT). SWAT is a river basin-scale model developed by the USDA Agricultural Research Service (ARS) at the Blackland (Texas) Research Center (Arnold et al. 1998; Srinivasan et al. 1998). The particular version used was ArcSWAT 2009.93.7 which is a recent version of the model (2011 vintage) coupled with the ESRI ArcMap 9.3 SP1 interface. SWAT is a physically based model that operates on a daily time step (continuously) and efficiently over several years. It is not designed to simulate single-event flooding. SWAT has been used extensively in the United States for TMDL applications (e.g., Wisconsin, Illinois, Texas, and Ohio – Black R, Wabash R, and Stillwater R watersheds) and has been accepted by U.S. EPA as a modeling strategy for TMDL load development (U.S. EPA 1999). In-stream processing of nutrients is accomplished through a modified QUAL-2E (U.S. EPA 1987) kinetics model. QUAL-2E is an inherent component of the SWAT watershed model and can be activated (as in this study) or deactivated to simulated highly conservative in-stream transport. Regarding phosphorus species in QUAL-2E, there exist pools for organic and dissolved (mineral) phosphorus with transformations to and from sediment (benthic) and phytoplankton growth and death. Benthic chlorophyll is not considered in QUAL-2E.

4.1.1 Justification of Method

A more sophisticated watershed model such as SWAT was chosen for this analysis because of the complexities involved in solving a nutrient load allocation. Namely, these are:

1) Importance of separating load responsibility between two WWTP (a major and significant minor) and intensive agriculture in Darke and Mercer counties, with both having high animal feeding operation (AFO) populations.
2) Miami-Erie Canal, an important tributary in the middle portion of the watershed, is the receiving water for Minster WWTP and is typically effluent dominated.
3) The Lake Loramie outlet typically has zero flow from July until September; hence, most of the Loramie Creek flow downstream from the spillway is typically provided by WWTP flow.
4) Impairment of aquatic life use due to nutrients and eutrophication is prevalent along the upper two-thirds of Loramie Creek length (22 miles of the total 36 miles).

Further, sufficient daily flow information exists at two downstream USGS (Miami Conservancy District [MCD]-operated) flow gauges for calibrating and validating model.

The advantages for using SWAT in this study over other watershed loading models such as GWLF (Generalized Watershed Loading Function) and HSPF (Hydrologic Simulation Program Fortran) include:

1) Model output is a daily load and partitions phosphorus into organic and mineral forms. GWLF does not simulate at this temporal and parameter scale. Calibration and validation for SWAT are achieved with daily monitored information, such as USGS flow gages.
2) Simulation of in-stream reservoirs. GWLF does not consider these features.
3) Accurate representations of agricultural management practices and features for reducing agricultural load (i.e., best management practices) throughout the crop cycle. Neither HSPF nor GWLF are capable of accurate agricultural portrayals but use parameter coefficients instead.
4) In-stream processing of upland loads through nutrient kinetics model. GWLF only considers upland loads and does not route or process flow and nutrients in-stream.

A more thorough justification of using the SWAT model is discussed in Appendix D.

4.1.2 Sources of Data

Nutrient load development is based on total phosphorus as a water quality parameter. Loadings for this parameter are secured from the following watershed sources by:

1) Determining load contributions from nonpoint source activities originating on the watershed landscape, primarily from row-crop agriculture and associated crop fertilization from synthetic (commercial) and organic (animal manure) nutrient sources. Load estimates were determined by conference with local Soil and Water Conservation District staff and by calibration to crop yields provided by the National Agricultural Statistics Service.

2) Accounting for load contributions arising from all wastewater sources in the watershed (primarily those dischargers having conduit loads exceeding 0.02 MGD). Magnitudes for these loads were determined by provision of effluent concentration and flow from the Ohio EPA discharge monitoring reports (DMRs) available within SWIM (Surface Water Information Management System).

3) Estimating load contributions from residential septic systems (or onsite sewage systems). Loading magnitudes were estimated from county health officials and their annual reports, U.S. Census Bureau survey, and literature estimates for concentration and per capita flow rate.

4.1.3 Target(s)

The loading development for this study is based on statewide targets for total phosphorus concentrations (Table 4-2) (Ohio EPA 1999). Using this statewide reference, targets for specific impaired assessment units (and their model-based subdivisions) are assigned according to aquatic life use designation and drainage area class in Table 4-3. Assignment of target is based on the characteristics of the mainstem segment that drains each particular subbasin unit.

Table 4-2. Target total phosphorus concentrations defined for Ohio (based on Ohio EPA 1999) as a function of aquatic life use designation and drainage basin area.

Watershed Type	Drainage Area Range (mi^2)	Concentration (mg-P/L)		
		EWH	WWH	MWH
Headwater	0 – 20	0.05	0.08	0.34
Wading	20 – 200	0.05	0.10	0.28
Small River	200 – 1000	0.10	0.17	0.25
Note: These targets apply to all waters in Ohio (a statewide reference).				

Table 4-3. Total phosphorus targets (in mg-P/L) assigned to watershed assessment units or their corresponding model subdivisions (SWAT Sub) as a function of drainage area class and aquatic life use designation.

Note: Subbasin numbers in bold are impaired. All nested subwatershed references exist in the 8-digit hydrologic unit 05080001. E or R : existing use or revised use based on 2009 biological assessment. Drainage area class defined as hw = headwater, w = wading, sr = small river.

SWAT Sub	Nested Sub-watershed	DA (mi^2)	DA class	ALU	E or R	Impaired	Protect Use	Target (mg/L)
Loramie Creek Watershed								
1	06 02	174.1	w	WWH	E	P (upper 1/3)	WWH	0.1
2	06 02	151.7	w	WWH	E	P	WWH	0.1
3	05 03	84.3	w	WWH	E	Full	WWH	0.1
4	05 03	77.8	w	WWH	E	Full	WWH	0.1
5	05 03	77.3	w	WWH	E	NON	WWH	0.1
6	05 01	43.1	w	WWH	E	P	WWH	0.1
7	05 01	15.5	hw	WWH	E	NON	WWH	0.08
8	05 02	62.7	w	MWH	R	P	WWH*	0.1
9	05 03	4.5	hw	MWH	R	Full	WWH*	0.1
10	06 04	263.9	sr	WWH	E	Full	meets	
11	06 04	257.1	sr	WWH	E	Full	meets	
12	06 04	210.5	sr	WWH	E	Full	meets	
13	06 03	35.8	w	WWH	R	Full	meets	
14	06 03	8.3	hw	WWH	R	NON	WWH	0.08
15	06 01	26.1	w	MWH/WWH	E	Full	okay	
Little Muchinippi Creek Watershed								
101	-02-03	35.5	w	WWH	R	P	WWH	0.1
102	-02-03	5.4	hw	MWH	R	P	MWH**	0.34
103	-02-03	12.1	hw	WWH	R	Full	WWH*	0.1

(pink)	protecting downstream (DST) use, that is impaired, but local use meets
(yellow)	protecting DST use that is higher than local use
*	WWH target for "hw" is 0.08 mg/L but is protecting DST use of WWH "w" (0.1 mg/L)
**	protecting local use (MWH) even though DST use is impaired and WWH

Note that for nested subwatershed 05080001 02 03 (Subbasin 102), a more relaxed MWH target was assigned because 1) nutrients are third most relevant causes of impairment and 2) there is sufficient drainage area in this subbasin unit to warrant considerable responsibility from the NPS sector for reducing the load to meet the TMDL target.

4.1.4 Calibration and Validation

Flow/Hydrology and Crop Yield

The Loramie Creek watershed SWAT model was calibrated for hydrology using a single US Geological Survey hydrologic gauge – Loramie Creek near Newport (03261950) – located at the outlet of model subbasin 2. The SWAT model was executed over the period January 1995 to November 2010 (about 16 years). The period 1995 to 1997 (3 years) was used for model start-up and equilibration and the results were not considered. The model calibration phase considered daily data in four years – 2000, 2001, 2002, and 2009 (dry) and 2003, 2005, 2007, and 2008 (wet). The model validation phase considered daily data for the remaining five years – 1998, 1999, 2004, 2006, and 2010. Several experiment model runs were made with the most successful flow calibration run being "Sim 24" (see Table D-7, Appendix D). The ground water recession slope, runoff curve number, soil available water capacity, evaporation rate coefficient, and crop fertilizer rate were the most important parameters for adjusting model hydrology. For calibrating hydrology, comparisons were made for annual, seasonal, monthly and daily flows.

Calibration of Phosphorus and Nitrogen Species

Observed chemistry data available for calibration consist of instantaneous grab samples of total phosphorus, and occasionally ortho-phosphorus, and all nitrogen species at selected locations in both study areas. Because of these single-event observations, interpreting calibration statistics is often confounded by hit/miss model predictions of daily events. The timing of concentration peaks and troughs could simply be offset by one day, between model and observed, and wreck the success of the model. It is better to interpret model success over aggregate periods such as yearly or seasonal or monthly summaries, as shown in flow/hydrology calibration (see Appendix D). Thus, the model calibration results for nutrient chemistry are all demonstrated through graphical techniques (shown in Appendix D) and conclusions on model success are based on these approaches alone.

For the Loramie Creek study area, the mainstem site at the outlet of subbasin 2 (near Cardo-Roman Rd) consisted of 20 observations. This site is the most downstream location of the impaired watershed zone and co-occurs with USGS daily flow measurements. Model total phosphorus and total nitrogen generally fall within the range of observed concentrations over the entire flow regime, though total nitrogen tends to be slightly under-predicted. Ortho-phosphorus concentrations are generally predicted within the correct range over all flow regimes. Under-prediction of total phosphorus tends to occur at low flow events and over-prediction tends to occur at high flow events.

The second Loramie Creek calibration site occurred at the outlet of subbasin 8 (Mile Creek) and consisted of 18 observations – a headwater watershed dominated by row-crop agriculture and rich in manure production. Total phosphorus concentrations are under-predicted at low flow regimes, whereas total nitrogen is under-predicted for all flow regimes. Ortho-phosphorus concentrations are generally predicted within range except at low flow events. This under-prediction is also evident on the time series plots (see Figure D-13 in Appendix D), which further indicates that its occurrence is at very low flow.

The final calibration site is for the Little Muchinippi Creek study area – located at the outlet to the watershed where six measurements were collected. Little Muchinippi Creek watershed is a headwater watershed to Muchinippi Creek dominated by row-crop agriculture but with one minor point source discharge (an ADF of 0.37 MGD). Model prediction of total phosphorus concentration matches closely at low flow but does not at high flow and very low flow. For total nitrogen concentration, the model over-predicts observed values except at very high flow. But these are only rough generalizations with six plotting points to compare. When comparing the time series you observe that most of the measurements were taken at low concentration periods and that the model matches reality fairly closely when considering the range of concentrations possible in the simulation period.

There was no detailed livestock inventory to provide more accurate spatial portrayal of manure application rates. However, crop fertilization rates – both commercial synthetic and animal manure – were adjusted, typically upward, to values that would sustain crop yields that match those quantified from National Agricultural Statistics Service reports for the period 2000 to 2010. Fertilization application rates (in units of mass per area) were guided by recommendations for total nitrogen, phosphate (as P_2O_5), and potash (K_2O) to support various yields (in units of mass per area) for corn, soybean, and winter wheat (Vitosh et al. 1995). Average observed yields found for Shelby County were identified in Vitosh et al. (1995) and corresponding nutrient application rates were input into the SWAT model for each study area. Adjustments to the model application rate were made until model crop yields (in kg/ha) matched observed crop yields.

A more detailed description of calibration and validation results can be found in Appendix D.

4.1.5 Allowance for Future Growth

Allocation for future growth was set to a minimum (1% of the TMDL) because none of the five POTWs in the impaired subbasin units have any planned facility expansions (Ohio EPA – SWDO, various permit/PTI staff; personal communication 2011). Further, the multiple county region (primarily Shelby) is expected to experience very small (less than 1%) to declining growth (Table 4-4).

Table 4-4. Year to year change in human population count for the six county region encompassing Loramie Creek and Little Muchinippi Creek watersheds.
Note: Values shown are in percent change from previous year, and the average and maximum for the 10 year period. Values in red font indicate negative growth rate.

	% Population Increase (Decrease) in Given Year											
County	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**Average**	**Max**
Auglaize	**-0.05**	**-0.05**	**-0.38**	**-0.17**	0.17	0.51	**-0.24**	0.00	0.51	**-0.10**	0.02	0.51
Darke	**-0.03**	**-0.49**	**-0.37**	0.08	**-0.12**	**-0.32**	**-0.56**	**-0.28**	**-0.40**	**-0.33**	-0.28	0.08
Logan	0.02	**-0.14**	0.59	0.41	0.08	**-0.31**	**-0.24**	0.71	0.03	0.10	0.13	0.71
Mercer	**-0.04**	**-0.30**	**-0.03**	**-0.15**	0.03	0.07	0.14	**-0.01**	**-0.12**	**-0.23**	-0.06	0.14
Miami	0.11	0.14	0.12	0.33	0.50	0.59	0.30	0.00	0.18	0.13	0.24	0.59
Shelby	0.16	0.60	**-0.04**	0.09	**-0.01**	0.42	0.05	0.34	0.33	0.28	0.22	0.42

4.1.6 Seasonality and Critical Conditions

The critical condition is defined as the set of environmental conditions that, if controls are designed to be protective of them, will ensure attainment of objectives for all other conditions. The argument that the critical condition for meeting a total phosphorus target applies to the entire year was established in Ohio EPA (2009) for the Stillwater River TMDL.

Here nutrient sources in the upper Loramie and Little Muchinippi watersheds arose primarily from wet weather conditions and most of the mass inputs occurred from November through June. However, the most severe eutrophic conditions were observed in the low flow (summer) period. Hence, the total P target was applied to both summer *and* winter seasons of the year. The severe eutrophic conditions were characterized by large diurnal swings in dissolved oxygen concentration, very low minimum daily dissolved oxygen concentration, and elevated in-stream total phosphorus and ortho-phosphate concentrations. While we recognize the argument made by Baker (2011) that the focus for nutrient reduction should apply to the critical low flow period –

when planktonic algae are prolific and so are diurnal swings in dissolved oxygen – the plugs of particulate phosphorus during high flow (both sorbed and sediment) from upland sources must still be considered. These plugs of particulate phosphorus make their way to channel substrate and are subsequently available during low flow periods when overlying water column P concentrations are much lower.

Seasonality was addressed in the Loramie Creek and Little Muchinippi Creek TMDLs by using the calibrated SWAT model to simulate daily loadings over the period 1995 to 2010. In this model scenario, WWTP facilities were input with discharge at average design flow and total phosphorus concentrations established by self-monitored or expected levels. The daily loadings were then aggregated to two seasonal (summer, winter) average daily loads using the last six years of the simulation period and considered as the existing load for each model subunit. Seasonality in model input was produced from observed daily precipitation and minimum/ maximum temperatures, daily point source loadings, and crop management schedules. Crop management schedules included the rate and timing of synthetic dry and organic (manure) fertilizer. We propose, then, that estimated loads are therefore reflective of seasonal changes in weather, treatment facility operating practices, and agricultural management practices.

4.2 Habitat and Sediment Bedload Analysis Method

Habitat alteration is a significant cause of impairment throughout the upper GMR watershed. Poor habitat quality is an environmental condition, rather than a pollutant load, so development of a load-based TMDL for habitat is not possible. Nonetheless, habitat is an integral part of stream ecosystems and has a significant impact on aquatic community assemblage and consequently on the potential for a stream to meet the biocriteria within Ohio's water quality. In addition, U.S. EPA acknowledges that pollutants, conditions or other environmental stressors can be subject to the development of a TMDL to abate those stressors in order to meet water quality standards. Thus, sufficient justification for developing habitat TMDLs is established.

4.2.1 Justification

The Qualitative Habitat Evaluation Index (QHEI) was developed by the Ohio EPA (Ohio EPA 1989 with one of the objectives being to create a means for distinguishing impacts to the aquatic community from pollutant loading versus poor stream habitat. The design of the QHEI in conjunction with its statistically strong correlation to the biocriteria makes it an appropriate tool for developing habitat TMDLs.

The QHEI assigns a numeric value to an individual stream segment (typically 150-200 m in length) based on the quality of its habitat. The actual number values of the QHEI scores do not represent the quantity of any physical properties of the system but provide a means for comparing the relative quality of stream habitat. However, even though the numeric value is derived qualitatively, subjectivity is minimized because scores are based on the presence and absence and relative abundance of unambiguous habitat features. Reduced subjectivity was an important consideration in developing the QHEI and has since been evidenced through minimal variation between scores from various trained investigators at a given site as well as consistency with repeated evaluations (Ohio EPA 1989).

The QHEI evaluates six general aspects of physical habitat that include channel substrate, in-stream cover, riparian characteristics, channel condition, pool/riffle quality, and gradient. Within each of these categories or sub-metrics, points are assigned based on the ecological utility of specific stream features as well as their relative abundance in the system. Demerits (i.e., negative points) are also assigned if certain features or conditions are present which reduce the overall utility of the habitat (e.g., heavy siltation and embedded substrate). These points are summed within each of the six sub-metrics to give a score for that particular aspect of stream habitat. The overall QHEI score is the sum of all of the sub-metric scores.

4.2.2 Sources of data

Habitat data using the QHEI were collected at sites where fish assemblages were sampled. QHEI sub-metric scores were then used to calculate sediment TMDLs.

4.2.3 Target(s)

Habitat TMDL Targets

Since its development the QHEI has been used to evaluate habitat at most biological sampling sites and currently there is an extensive database that includes QHEI scores and other water quality variables. Strong correlations exist between QHEI scores and some its component sub-metrics and the biological indices used in Ohio's water quality standards such as the Index of Biotic Integrity (IBI). Through statistical analyses of data for the QHEI and the biological indices, target values have been established for QHEI scores with respect to the various aquatic life use designations (Ohio EPA 1999). For the aquatic life use designation of warmwater habitat (WWH) an overall QHEI score of 60 is targeted to provide reasonable certainty that habitat is not deficient to the point of precluding attainment of the biocriteria (Table 4-6). An overall score of 75 is targeted for streams designated as exceptional warmwater habitat (EWH) and a minimum score of 45 is targeted for modified warmwater habitat (MWH) streams.

One of the strongest correlations found through these statistical analyses described above is the negative relationship between the number of "modified attributes" and the IBI scores (Table 4-5). Modified attributes are features or conditions that have low value in terms of habitat quality and therefore are assigned relatively fewer points or negative points in the QHEI scoring. A sub-group of the modified attributes shows a stronger impact on biological performance; these are termed "high influence modified attributes" (Table 4-5).

Table 4-5. Itemization of "Modified Attributes" for computing the habitat TMDL.

High Influence	Moderate Influence	
• Recent Channelization or No Recovery • Silt or Muck Substrate • Low or No Sinuosity and Drainage Area ≤ 20 sq.mi • Sparse or Nearly Absent Cover • < 40 cm Max. Pool Depth (wadeable or headwater sites)	• Recovering Channelization • Silt Heavy or Silt Moderate • Sand Substrate (boat sites) • Hardpan Substrate Origin • Fair or Poor Development • Low or No Sinuosity and Drainage Area > 20 sq.mi • Two or Less Cover Types	• Intermittent Pools and Max. Pool Depth < 40 cm • No Fast Current Velocity • Extensive or Moderate Substrate Embeddedness • Extensive or Moderate Riffle Embeddedness • No Riffle

In addition to the overall QHEI scores, targets for the maximum number of modified and high influence modified attributes have been developed. For streams designated as WWH, there should no more than 4 modified attributes of which no more than 1 should be a high influence modified attribute (Table 4-5). For simplicity, a pass/fail distinction is made telling whether each of the three targets are being met. Targets are set for: 1) the total QHEI score, 2) maximum number of all modified attributes, and 3) maximum number of high influence modified attributes only. If the minimum target is satisfied, then that category is assigned a “1”, if not, it is assigned a “0”. To satisfy the habitat TMDL, the stream segment in question should achieve a score of three (Table 4-6).

Table 4-6. QHEI-based targets for the sediment and habitat TMDL.

Bedload TMDL Targets		
QHEI Category	*Target*	
	WWH	*EWH*
Substrate	≥ 13	≥ 15
Channel	≥ 14	≥ 15
Riparian	≥ 5	≥ 5
Bedload TMDL ►	≥ 32	≥ 35

Habitat TMDL Targets			
QHEI Category	*Target*		*Score*
	WWH	*EWH*	
QHEI Score	≥ 60	≥ 75	+ 1
High Influence #	≤ 1	0	+ 1
Total # Modified	≤ 4	≤ 2	+ 1
Habitat TMDL ►			+ 3

Sediment TMDL Targets

The QHEI is also used in developing the sediment TMDL for this project. Numeric targets for sediment are based upon sub-metrics of the QHEI. Although the QHEI evaluates the overall quality of stream habitat, some of its component sub-metrics consider particular aspects of stream habitat that are closely related to and/or impacted by the sediment delivery and transport processes occurring in the system.

The QHEI sub-metrics used in the sediment TMDL are the substrate, channel morphology, and bank erosion and riparian zone. Table 4-6 lists targets for each of these metrics for both WWH and EWH aquatic life use designations.

- The <u>substrate</u> sub-metric evaluates the dominant substrate materials (i.e., based on texture size and origin) and the functionality of coarser substrate materials in light of the amount of silt cover and degree of embeddedness. This is a qualitative evaluation of the amount of excess fine material in the system and the degree to which the channel has assimilated (i.e., sorts) the sediment loading.
- The <u>channel morphology</u> sub-metric considers sinuosity, riffle, and pool development, channelization, and channel stability. Except for stability each of these aspects are directly related to channel form and consequently how sediment is transported, eroded, and deposited within the channel itself (i.e., this is related to both the system’s assimilative capacity and loading rate). Stability reflects the degree of channel erosion which indicates the potential of the stream as being a significant source for the sediment loading.
- The <u>bank erosion and riparian zone</u> sub-metric also reflects the likely degree of in-stream sediment sources. The evaluation of floodplain quality is included in this sub-metric which is related to the capacity of the system to assimilate sediment loads.

The rationale for using the QHEI for development of the sediment TMDL is largely due to the fact that other measures and/or methods of evaluating sediment loading are problematic and have limited reliability. For example, the measurement of total suspended solids (TSS) is commonly used as a loading parameter; however, gathering data that is reliable for calibration and validation is often uncertain. This uncertainty rests in the fact that TSS demonstrates a high degree of variability both over space and time and is also very sensitive to local disturbances. Additionally, models that adequately account for in-stream sediment dynamics (e.g., erosion and deposition processes) are lacking or require very high resource expenditures (e.g., much data collection) that often are not feasible.

Finally, the QHEI has a strong relationship with the biocriteria in Ohio's water quality standards, whereas TSS has a relatively weak correlation with biological performance, which is probably related to the variability and unreliability of TSS measures. The QHEI represents the end result of high sediment loading (either from the landscape of in-stream sources) as it impacts the biological community.

4.2.6 Seasonality and Critical Conditions

The critical condition for the habitat and bedload TMDLs is the summer when environmental stress, such as increased water temperature, decreased flow, and increased pollutant concentrations, upon aquatic organisms is greatest. It is during this period that the presence of high quality habitat features, such as deep pools and un-embedded substrate, is essential to provide refuge for aquatic life. QHEI scores, the basis of the habitat TMDLs, are assessed during the summer field season. The habitat and bedload TMDLs are therefore reflective of the critical condition.

Habitat is generally a quasi-static condition of a stream. Exceptions include major modifications made by humans (or some animals like beavers) or changes in the hydrology or sediment loading of the watershed, which is typically a human-made situation. Because habitat is relatively static, seasonality has little meaning. Specifically, absent a major disturbance, habitat quality does not change across the seasons but rather over much longer timescales (years to decades). Finally, there is no seasonal "loading" associated with habitat but instead habitat evolves through changes in morphology and riparian vegetation. However, in terms of sediment, seasonality does have meaning. For example, agricultural areas yield the highest loads when fields have minimal vegetative cover and runoff events occur. This corresponds to the spring pre-plant season. In-stream sources of sediment from bed or bank erosion are also seasonally loaded when flows are highest and banks are saturated. When stream banks are saturated, they are more susceptible to erosion through slip failure. As with upland loads, spring is an important time for this but also in mid to late fall.

4.3 *Escherichia coli* Load Duration Curve Analysis Method

Load duration curves (LDCs) using recent *E. coli* monitoring data and continuous stream flow are employed to determine TMDL loads and reductions. This section gives an overview of the LDC method. There were deviations from this method in several cases. A more thorough discussion of the method and these deviations can be found in Appendix D.

To compute the required TMDL load, a flow duration curve (FDC) is generated for each impaired location with a corresponding paired grab-flow record (called a LDC assessment site).

A FDC is constructed by calculating the flow (volumetric flow rate in units of cfs) expected for the full range of exceedance percentiles. The exceedance percentile is the probability that a given flow magnitude can be exceeded. This normalizes the flows to a range of natural occurrences from extremely high flows (exceedance percentile equal to 0.0) to extremely low flows (that equal to 1.0). To conform to the recreation season boundary, only flows measured between May 1 and October 31 were considered in the construction of the FDC and LDC. The FDC is converted into a LDC by taking the product of the flow magnitude (volume per time) and the *E. coli* geometric mean standard (counts per volume) for a given PCR stream class. The TMDL is this product (counts per time): the number of *E. coli* colony-forming units (CFUs or counts) per day.

The observed loads are plotted against a LDC (i.e., the TMDL) to determine the degree of exceedance or non-exceedance. Observed loads that plot above the LDC represent deviations from the water quality standard and the daily allowable load. Observed loads that fall below the LDC represent samples in compliance with standards and the daily allowable load.

4.3.1 Justification

LDCs are appropriate to analyze bacteria since the sources of bacteria in Ohio streams can be differentiated by stream flow regime. The main advantage of using LDCs is the ability to discriminate loading based on flow. The main shortcoming of this method is the lack of differentiation between various loading sources that may occur under the same flow regime (such as cows in stream and poorly operating home sewage treatment systems). Additionally, alternatives methods to LDCs are mostly unreliable or prohibitive in terms of needed staff and funding resources to use them. For example, modeling bacteria in a dynamic, watershed manner, such as TP in this report, occurs in some studies in order to best determine bacteria sources, but using such methods is time consuming and has been found by Ohio EPA to often yield similar results as those generated through simpler methods. More complicated modeling would also require more bacteria data than what are normally collected during routine surveys for calibration.

4.3.2 Sources of data

The bacteria TMDLs use recent *E. coli* monitoring data and continuous stream flow (both measured by Ohio EPA and by MCD-operated gages in the watershed).

4.3.3 Target(s)

TMDL numeric targets for *E. coli* bacteria are derived from bacteriological water quality standards. The criteria for *E. coli* specified in OAC 3745-1-07 are applicable outside the effluent mixing zone and vary for waters determined as primary contact recreation (PCR). Furthermore, this criterion designates streams that support frequent primary contact recreation – Class A streams. The mainstem of the Great Miami River throughout all of this study area is designated a Class A stream. The mainstem of Loramie Creek from the mouth to RM 30.42 is also designated Class A PCR. All other streams assessed in this watershed are Class B PCR. Class B streams support infrequent primary contact recreation activities. For Class A streams the standard states that the geometric mean of more than one *E. coli* sample taken in each recreational season (May 1 through October 31) shall not exceed 126 colony-forming units (cfu) per 100 mL. For Class B streams, the geometric mean of the *E. coli* sample shall not exceed 161 cfu per 100 mL.

In certain locations, a more restrictive downstream recreation use could be protected. For this TMDL, a NPDES facility that discharges to a Class B PCR stream would receive Class A standard if it is within five river miles and upstream from a Class A PCR stream.

4.3.4 Validation

There are four LDC sites that, with local USGS gage data, were used to compute an exact flow duration curve. For all remaining LDC sites, a nearby USGS gage along with drainage-area yield is employed to estimate long term flow at that site. A numerical representation of validity is impractical due to the small N available for such diagnostics. The best estimations occur at South Fork Great Miami River and Mile Creek LDC sites, whereas poor estimations occur at North Fork GMR and Muchinippi Creek. While the measured and estimated flows are linearly related, the drainage-area yield computation overestimates the local flow, at least for four events.

4.3.5 Allowance for Future Growth

Allocation for future growth was set to a minimum (1% of the TMDL) because none of the POTWs in the impaired subbasin units have any planned facility expansions (Ohio EPA – SWDO, various permit/PTI staff; personal communication 2011). Further, the multiple county region will experience very small (less than 1%) to declining growth.

4.3.6 Seasonality and Critical Conditions

Proliferation of bacteria (growth and metabolism) occurs during the period of warmest stream temperatures, so June through September is the most important consideration. The recreation season is defined from May 1 to October 30 so a window of time preceding this use (April through October) is important in reducing loads from all sources. Critical conditions for in-stream bacteria vary by source and can occur across the stream hydrograph from wash off of land-deposited bacteria under wet conditions to in-stream livestock and failing HSTSs in low flow conditions. Nonpoint sources to which bacteria loads are allocated in the upper GMR watershed include livestock, including wash off from land-applied manure to the presence in-stream animals, and failing HSTSs.

4.4 Mass Balance of Total Dissolved Solids for Upper Loramie Creek

Non-attainment of aquatic life use at RM 34.96 (Lock Two Road DST Botkins STP and WTP)[2] of Loramie Creek (nested subwatershed 05080001 03 02) is caused by nutrients, total dissolved solids (TDS), and habitat alteration. The source of TDS is fully attributed to the upstream WWTP at RM 35.42 – Village of Botkins STP (Ohio EPA 1PB00007) (Ohio EPA 2011).

Nonpoint sources of TDS originate from agricultural and residential runoff and from leaching of soil that is contaminated with various inorganic constituents. In addition, certain naturally occurring total dissolved solids arise from the weathering and dissolution of rocks and soils. In this investigation both nonpoint sources and background loads of TDS are combined and considered under the load allocation (LA).

[2] STP=sewage treatment plant and WTP=water treatment plant

4.4.1 Justification

TDS is a measure of the combined content of all inorganic and organic substances contained in a liquid – including molecular, ionized or micro-granular (colloidal sol) suspended form. Generally the operational definition is that the solids must be small enough to survive filtration through a sieve the size of two micrometers (µm). The compounds and elements remaining after filtration are commonly calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride, sulfate, silica and nitrate. When a point source is the primary and/or sole source of impairment, a mass balance of pollutant load can be computed to determine the required reduction amount. Mass balance of pollutant load requires determination of stream flow (volume per time) and pollutant concentration (mass per volume). A wasteload allocation for TDS and subsequent effluent limitation is required if the pollutant has the potential to threaten or impair the designated use of receiving waters and is known or expected to occur in the discharge during the applicable permit period [OAC 3745-2-04 (A)(4)].

4.4.2 Sources of data

Sources of data include upstream water quality from five instantaneous (grab) samples, effluent water quality from multiple samples, and stream design flow based on an area-yield from a nearby but similar watershed.

4.4.3 Target(s)

The target for TDS originates from State of Ohio laws for protection of beneficial use. A target of 1500 mg/L of TDS is assigned to this TMDL for all aquatic life use for the Outside Mixing Zone Average (or OMZA). This criterion is applied statewide and is obtained from OAC 3745-1-07 (Table 7-1, p. 10).

4.4.4 Allowance for Future Growth

Because the impairment cause of TDS is attributed to the Village of Botkins STP, the determination of future growth is limited to the Village of Botkins (Ohio) demographic area and characteristics of the WWTP facility. Population declined by 3.07 percent from the period April 2000, when the US Census 2000 was conducted, to July 2009 when a US Census estimation was made[3]. The current population of the village is approximately 1170 people. Further, the WWTP is not utilizing the full capacity of its design – the average design flow is 0.5 MGD but the mean daily flow is 0.287 MGD (or 57 percent of design flow) when considering all months of record for the period 2005-2011. Communication with Ohio EPA wastewater staff in the local district office confirmed that no expansion was requested by this facility in the past nor is any proposed (S. Leibfritz, personal communication 2011). Given these conditions of declining population growth, underutilization of treatment plant capacity, and no requests for expansion, the allowance for future growth (AFG) was set to zero.

4.4.5 Seasonality and Critical Conditions

Because the primary source of the TDS-based impairment is due to WWTP effluent, the critical condition is the low-flow period of the annual streamflow cycle – the period of June through

[3] Information obtained from US Census Bureau “American FactFinder” from http://factfinder.census.gov under the 2009 population estimates data set.

September. Nonpoint contributions and background sources of load originating from surface runoff and bank seepage would be minimal during this period.

4.5 Margin of Safety

The Clean Water Act requires that a TMDL include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality. U.S. EPA guidance explains that the MOS may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit (i.e., expressed in the TMDL as loadings set aside for the MOS).

SWAT (Nutrients)
A standard five percent explicit margin of safety (MOS) was included in this allocation strategy to account for overall uncertainty in load reduction estimation due to field sampling error, imperfect water quality targets, imperfect model calibration, and process representation in the model (e.g., less than ideal in-stream kinetics simulation by not including benthic algae interactions).

Implicit margins of safety were captured by:

1) Downstream beneficial uses are protected, in the case of nutrient impairment – aquatic life use (ALU). Protection of downstream use was operationalized at the nested subwatershed level. Even though a specific nested subwatershed was not impaired for ALU and for causes due to nutrient and/or organic enrichment, it could be assigned an allocation to protect the downstream, contiguous nested subwatershed if that downstream nested subwatershed was impaired. If both the specific nested subwatershed and downstream nested subwatershed were impaired, then the most restrictive total phosphorus target would be applied.
2) The selected nutrient targets are conservative. Total phosphorus targets obtained from Ohio EPA (1999) were taken from statewide conditions. However, background concentrations for the Eastern Cornbelt Plains ecoregion (the ecoregion home of the Loramie and Little Muchinippi watersheds), were at or near the statewide targets.
3) The modeling approach employed a detailed simulation model (SWAT) employed over a fine nested subwatershed resolution so that one can safely assume that all land surface and in-channel processes were represented.

Habitat and Sediment Analysis

A margin of safety (MOS) was implicitly incorporated into the habitat and sediment TMDLs through the use of conservative target values. The target values were developed though comparison of paired IBI and QHEI evaluations. Using an IBI score of 40 as representative of the attainment of WWH, individual components of the QHEI were analyzed to determine their magnitude at which WWH attainment is probable (Ohio EPA 1999). Attainment does, however, occur at levels lower than the established targets. The difference between the habitat and sediment targets and the levels at which attainment actually occurs is an implicit MOS.

Load Duration Curves (*E. coli*)

An implicit MOS is incorporated in various ways, including in the derivation of the *E. coli* water quality criterion and in not considering the die-off of pathogens as part of the TMDL calculations. The implicit MOS is also enhanced by the use of the geometric mean target (which is a seasonal target) to calculate daily loads. In addition, an explicit MOS has been applied as part of all of the bacteria TMDLs by reserving 20% of the allowable load because of the broad fluctuation of *E. coli* concentrations that occurs in nature and the relatively low numbers of data points available for this analysis.

Mass Balance (TDS)

Both an implicit and explicit margin of safety (MOS) is applied to the TDS TMDL. Five (5) percent of the TMDL is assigned explicitly to account for uncertainty in the relationship between attaining warmwater aquatic life use and meeting the downstream water quality target for TDS. The explicit MOS also accounts for uncertainty in the following monitoring data sources: upstream water quality from five instantaneous (grab) samples, effluent water quality from multiple samples, and stream design flow based on an area-yield from a nearby but similar watershed. Further, the explicit MOS accounts for the uncertainty in assuming steady-state flow and concentration; contrastingly, transient conditions may exist at certain times during the low-flow period. An implicit MOS also exists for the TMDL. Implicit MOS stems from 1) the use of the projected effluent quality (PEQ) average instead of a less conservative simple numeric average for characterizing wastewater quality and 2) the use of conservative *in-stream* transport (i.e., no settling nor absorption) of pollutant concentration between the source (LA and WLA) and the downstream water quality target.

5 LOAD REDUCTION RESULTS

Several analyses were completed to address the causes of impairment. Results are summarized in this chapter and organized by assessment unit. Further details are available in Appendix D.

5.1 Headwaters Great Miami River (05080001 01)

A habitat TMDL was completed for Van Horn Creek at river mile (RM) 1.0 (Table 5-1). Bacteria TMDLs were completed for nested subwatersheds North Fork Great Miami River (01 01; Table 5-2) and South Fork Great Miami River (01 02; Table 5-3).

Table 5-1. Characterization of the habitat TMDL using QHEI metrics for sites with impairment due to habitat alteration, sedimentation/siltation, turbidity, and/or flow alteration (non-natural).
Note: ALU designation in parentheses.

Stream/River	River Mile	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	Subscore: QHEI	Subscore: High Influence	Subscore: Modified	Total Habitat Score
01 03 Indian Lake – Great Miami River								
Van Horn Ck (WWH)	1.0	62.5	2	7	1	0	0	1
Target (WWH)		**≥ 60 = 1 pt**	**< 2 = 1 pt**	**< 5 = 1 pt**				**3 pts**

Table 5-2. *E. coli* load allocation table for North Fork GMR (05080001 01 01).

Flow regime TMDL analysis *E. coli* (billion organisms/day)	High	Wet weather	Normal range	Dry weather	Low
Flow Duration Regime Interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per Regime			4	2	1
Sample Load (median)			14	2.3	1.3
Upstream WLA	0	0	0	0	0
TMDL	344	24	2.8	0.8	0.8
MOS (explicit 20%)	69	4.8	0.6	0.2	0.2
AFG (1%)	3	0.2	0.0	0.0	0.0
WLA (total)	0.0	0.0	0.0	0.0	0.0
LA	272	19.0	2.2	0.6	0.6
Total Reduction Required (%)	No Data	No Data	**80.7%**	**66.4%**	**37.5%**

Values were adjusted for rounding.

Table 5-3. *E. coli* load allocation table for South Fork GMR (05080001 01 02).

Flow regime TMDL analysis *E. coli* (billion organisms/day)	High	Wet weather	Normal range	Dry weather	Low
Flow Duration Regime Interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per Regime			6		1
Sample Load (median)			94		10.0
Upstream WLA	0	0	0	0	0
TMDL	1,119	78.4	9.5	3.2	2.4
MOS (explicit 20%)	224	15.7	1.9	0.6	0.5
AFG (1%)	11	1	0	0.0	0.0
WLA (total)	0.1	0.1	0.1	0.1	0.1
Camp Wesley (1PR00100)	0.1	0.1	0.1	0.1	0.1
LA	884	61.8	7.4	2.4	1.8
Total Reduction Required (%)	No Data	No Data	**89.9%**	No Data	**76.4%**

Values were adjusted for rounding.

5.2 Muchinippi Creek (05080001 02)

Habitat TMDLs were completed for seven locations in this subwatershed (Table 5-4) and sediment TMDLs at five locations (Table 5-5). Total phosphorus TMDLs were calculated for the Little Muchinippi Creek nested subwatershed (02 03; Table 5-6). Bacteria TMDLs were completed for the nested subwatershed Calico Creek-Muchinippi Creek (02 04; Table 5-7).

Table 5-4. Characterization of the habitat TMDL using QHEI metrics for sites with impairment due to habitat alteration, sedimentation/siltation, turbidity, and/or flow alteration (non-natural).
Note: ALU designation in parentheses; if a second designation is listed the first entry is proposed. Und = previously undesignated ALU designation. Grouped by nested subwatershed. NA = not applicable as no target exists for MWH ALU designation.

Stream/River	River Mile	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	Subscore QHEI	Subscore High Influence	Subscore Modified	Total Habitat Score
02 01 Willow Creek								
Willow Ck (WWH)	3.7	44	3	8	0	0	0	0
Willow Ck (WWH)	0.5	29.5	3	9	0	0	0	0
02 03 Little Muchinippi Creek								
Jackson Center Ck (MWH-C, WWH)	2.9	28.5	4	10	NA	NA	NA	NA
Jackson Center Ck (MWH-C, WWH)	1.8	25.5	4	10	NA	NA	NA	NA
L Muchinippi Ck (WWH)	6.1	47	3	8	0	0	0	0
L Muchinippi Ck (WWH)	0.7	60.5	1	7	1	1	0	2
02 04 Muchinippi Creek								
Muchinippi Ck (WWH)	2.4	55	2	8	0	0	0	0
Target (WWH)		**≥ 60 = 1 pt**	**< 2 = 1 pt**	**< 5 = 1 pt**				**3 pts**

Table 5-5. Characterization of the sediment TMDL using QHEI metrics for sites with impairment due to sedimentation/siltation.

Note: ALU designation in parentheses; if a second designation is listed the first entry is proposed. Grouped by nested subwatershed. NA = not applicable as no target exists for MWH ALU designation.

Stream/River	River Mile	QHEI Categories			Total Sediment Score	Deviation from target (%)	Main impairment category
		Subs-trate	Chan-nel	Ripa-rian			
02 03 Little Muchinippi Creek							
Jackson Center Ck (MWH-C, WWH)	2.9	2.5	6.5	2.5	11.5	NA	NA
Jackson Center Ck (MWH-C, WWH)	1.8	3	6	1.5	10.5	NA	NA
L Muchinippi Ck (WWH)	6.1	20	6	2	28	12.5	riparian
L Muchinippi Ck (WWH)	0.7	20	7.5	1.5	29	9.4	riparian
02 04 Muchinippi Creek							
Muchinippi Ck (WWH)	2.4	15	4.5	7.5	27	15.6	channel
Target (WWH)		**≥ 13**	**≥ 14**	**≥ 5**	**≥ 32**		

Table 5-6. Distribution of existing (current) total phosphorus load and subsequent load allocations for the Little Muchinippi Creek watershed.

Note: A suite of allocations exists for each nested subwatershed and SWAT model sub-basin number and for each of two seasons (summer and winter). Subcategories for LA (by land use type) and WLA (by facility) are also depicted. **Each value represents a seasonal average (summer or winter) of the distribution of daily loads in that season.** All values are shown as total phosphorus in kg/d except for average reduction (fractional).

05080001 02 03 Little Muchinippi Ck	Subbasin#: **101 Summer**
Current Load	111
TMDL = LA + WLA + AFG + MOS	6
LA (total)	5.64
LA -- cropland	5.64
LA -- pasture	0
LA -- residential (low density)	0
WLA (total)	0
AFG (1%)	0.06
MOS (5%)	0.3
Average Reduction (Fractional)[1]	0.84
05080001 02 03 Little Muchinippi Ck	Subbasin#: **101 Winter**
Current Load	365
TMDL = LA + WLA + AFG + MOS	20
LA (total)	18.8
LA -- cropland	18.8
LA -- pasture	0
LA -- residential (low density)	0
WLA (total)	0
AFG (1%)	0.2
MOS (5%)	1
Average Reduction (Fractional)	0.85
05080001 02 03 Little Muchinippi Ck	Subbasin#: **102 Summer**
Current Load	17
TMDL = LA + WLA + AFG + MOS	4
LA (total)	2.36

LA -- cropland	2.36
LA -- pasture	0
LA -- residential (low density)	0
WLA (total)	1.4
WLA - facility: 1.4	Jackson Center (1PB00018)
AFG (1%)	0.04
MOS (5%)	0.2
Average Reduction (Fractional)	0.72
05080001 02 03 Little Muchinippi Ck	Subbasin#: **102 Winter**
Current Load	51
TMDL = LA + WLA + AFG + MOS	11
LA (total)	8.94
LA -- cropland	8.94
LA -- pasture	0
LA -- residential (low density)	0
WLA (total)	1.4
WLA - facility: 1.4	Jackson Center (1PB00018)
AFG (1%)	0.11
MOS (5%)	0.55
Average Reduction (Fractional)	0.68
05080001 02 03 Little Muchinippi Ck	Subbasin#: **103 Summer**
Current Load	35
TMDL = LA + WLA + AFG + MOS	2
LA (total)	1.88
LA -- cropland	1.88
LA -- pasture	0
LA -- residential (low density)	0
WLA (total)	0
AFG (1%)	0.02
MOS (5%)	0.1
Average Reduction (Fractional)	0.37
05080001 02 03 Little Muchinippi Ck	Subbasin#: **103 Winter**
Current Load	121
TMDL = LA + WLA + AFG + MOS	7
LA (total)	6.58
LA -- cropland	6.58
LA -- pasture	0
LA -- residential (low density)	0
WLA (total)	0
AFG (1%)	0.07
MOS (5%)	0.35
Average Reduction (Fractional)	0.64

[1] Average Reduction (Fractional) is calculated as the mean of a distribution of daily fractional reductions. It should not be considered as a “percent reduction of the averages.” Both TMDL, LA, and WLA are reported as the mean of distribution of daily values and as it should be because a TMDL is a distribution of *daily* loads; hence, so should the average reduction (fractional) be similarly calculated.

Table 5-7. *E. coli* load allocation table for Muchinippi Creek at County Road 60 (05080001 02 04).

Flow regime TMDL analysis *E. coli* (billion organisms/day)	High	Wet weather	Normal range	Dry weather	Low
Flow Duration Regime Interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per Regime			3	1	2
Sample Load (median)			25	7.6	0.7
Upstream WLA	0	0	0	0	0
TMDL	2,098	147	18	5.91	3.94
MOS (explicit 20%)	420	29	4	1.18	0.79
AFG (1%)	21	1	0.2	0.06	0.04
WLA (total)	3.01	3.01	3.01	3.01	3.01
Jackson Center (1PB00018)	2.25	2.25	2.25	2.25	2.25
Waynesfield (2PB00022)	0.75	0.75	0.75	0.75	0.75
Dads Drive-In (2PR00258)	0.01	0.01	0.01	0.01	0.01
LA	1,654	113	11	1.65	0.10
Total Reduction Required (%)	No Data	No Data	**30.2%**	**21.8%**	**None**

Values were adjusted for rounding.

5.3 Bokengehalas Creek-Great Miami River (05080001 03)

Habitat TMDLs (Table 5-8) and sediment TMDLs (Table 5-9) were completed for nine locations in this subwatershed. Bacteria TMDLs were completed for nested subwatersheds Rennick Creek-Great Miami River (03 02; Table 5-10) and Bokengehalas Creek (03 05; Table 5-11).

Table 5-8. Characterization of the habitat TMDL using QHEI metrics for sites with impairment due to habitat alteration, sedimentation/siltation, turbidity, and/or flow alteration (non-natural).
Note: ALU designation in parentheses; if a second designation is listed the first entry is proposed. Und = previously undesignated ALU designation. Grouped by nested subwatershed. NA = not applicable as no target exists for MWH ALU designation. UNT = un-named tributary with mainstem river mile at confluence in parenthesis.

Stream/River	River Mile	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	Subscore QHEI	Subscore High Influence	Subscore Modified	Total Habitat Score
03 02 Rennick Creek – Great Miami River								
Great Miami R (WWH)	158.9	77	0	3	1	1	1	3
Rennick Ck (WWH, Und)	0.3	43	3	10	0	0	0	0
UNT Great Miami R (RM 157.34) (MWH-C, Und)	0.1	21	4	10	NA	NA	NA	NA
03 03 Rum Creek								
Rum Ck (WWH)	8.6	24	3	9	0	0	0	0
Rum Ck (WWH)	6.6	52	3	11	0	0	0	0
Rum Ck (WWH)	0.8	68	0	5	1	1	0	2
03 05 Bokengehalas Creek								
Bokengehalas Ck (WWH)	8.0	79	1	7	1	1	0	2
03 06 Brandywine Creek – Great Miami River								
Brandywine Ck (WWH)	0.6	43	3	8	0	0	0	0
Great Miami R (WWH)	153.5	53	3	10	0	0	0	0
Target (WWH)		**≥ 60 = 1 pt**	**< 2 = 1 pt**	**< 5 = 1 pt**				**3 pts**

Table 5-9. Characterization of the sediment TMDL using QHEI metrics for sites with impairment due to sedimentation/siltation.

Note: ALU designation in parentheses; if a second designation is listed the first entry is proposed. Und = previously undesignated ALU designation. Grouped by nested subwatershed. NA = not applicable as no target exists for MWH ALU designation. UNT = un-named tributary with mainstem river mile at confluence in parenthesis.

Stream/River	River Mile	QHEI Categories Subs-trate	Chan-nel	Ripa-rian	Total Sediment Score	Deviation from target (%)	Main impairment category
03 02 Rennick Creek – Great Miami River							
Great Miami R (WWH)	158.9	20	16	3	39	meets	riparian
Rennick Ck (WWH, Und)	0.3	4.5	10	2.5	17	46.9	substrate
UNT Great Miami R (RM 157.34) (MWH-C, Und)	0.1	4	4	2	10	NA	NA
03 03 Rum Creek							
Rum Ck (WWH)	8.6	6	5.5	1.5	13	59.4	riparian
Rum Ck (WWH)	6.6	20	7	8.5	35.5	meets	channel
Rum Ck (WWH)	0.8	20	13	8	41	meets	channel
03 05 Bokengehalas Creek							
Bokengehalas Ck (WWH)	8.0	20	8	10	38	meets	channel
03 06 Brandywine Creek – Great Miami River							
Brandywine Ck (WWH)	0.6	6.5	8	5	19.5	39.1	substrate
Great Miami R (WWH)	153.5	15.5	8	7.5	31	3.1	channel
Target (WWH)		**≥ 13**	**≥ 14**	**≥ 5**	**≥ 32**		

Table 5-10. *E. coli* load allocation table for GMR at State Route 235 (05080001 03 02).

Flow regime TMDL analysis *E. coli* (billion organisms/day)	High	Wet weather	Normal range	Dry weather	Low
Flow Duration Regime Interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per Regime			1	2	3
Sample Load (median)			436	299.6	56.3
Upstream WLA	0.1	0.1	0.1	0.0	0.0
TMDL (less upstream WLA)	2102.4	315.9	83.5	42.2	29.3
MOS (explicit 20%)	420	63	17	8.4	5.9
AFG (1%)	21	3	1	0.4	0.3
WLA (total)	21.9	21.9	21.9	21.9	21.9
Indian Lake (1PK00002)	21.9	21.9	21.9	21.9	21.9
LA	1,639	228	44	11	1
Total Reduction Required (%)	No Data	No Data	**80.8%**	**85.9%**	**48.0%**

Values were adjusted for rounding.

Note: TMDL for three highest flow regimes is reduced by upstream wasteload allocation (WLA) originating from South Fork GMR (05080001 01 02) LDC. Translation of WLA from upstream assessment unit is most probable under normal-to-high flow when spillway of Indian Lake is active.

Table 5-11. *E. coli* load allocation table for Bokengehalas Creek (05080001 03 05).

Flow regime TMDL analysis *E. coli* (billion organisms/day)	High	Wet weather	Normal range	Dry weather	Low
Flow Duration Regime Interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per Regime		1	1	3	
Sample Load (median)		3575	292.08	136.08	
Upstream WLA	0	0	0	0	0
TMDL (less upstream WLA)	875.95	203.29	85.12	45.73	36.71
MOS (explicit 20%)	175.19	40.66	17.02	9.15	7.34
AFG (1%)	8.76	2.03	0.85	0.46	0.37
WLA (total)	100.66	42.21	31.94	28.52	27.73
MS4: Bellefontaine	73.09	14.63	4.36	0.94	0.16
Bellefontaine (1PD00000)	27.43	27.43	27.43	27.43	27.43
ODOT Rest Area 0729 (1PP00021)	0.06	0.06	0.06	0.06	0.06
YMCA (1PR00052)	0.09	0.09	0.09	0.09	0.09
LA	591.34	118.39	35.30	7.61	1.27
Total Reduction Required (%)	No Data	**95.5%**	**77.0%**	**73.5%**	No Data

Values were adjusted for rounding.

5.4 Stoney Creek-Great Miami River (05080001 04)

A habitat TMDL (Table 5-12) and sediment TMDL (Table 5-13) were completed for the Great Miami River at RM 138.4. Bacteria TMDLs were completed for the Stoney Creek-Great Miami River subwatershed (04; Table 5-14); the load duration curve was calculated at a site just downstream from the subwatershed.

Table 5-12. Characterization of the habitat TMDL using QHEI metrics for sites with impairment due to habitat alteration, sedimentation/siltation, turbidity, and/or flow alteration (non-natural).
Note: ALU designation in parentheses.

Stream/River	River Mile	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	Subscore: QHEI	Subscore: High Influence	Subscore: Modified	Total Habitat Score
04 06 Turkeyfoot Creek – Great Miami River								
Great Miami R (EWH)	138.4	68.5	1	8	0	0	0	0
Target (EWH)		**≥ 75 = 1 pt**	**0 = 1 pt**	**< 3 = 1 pt**				**3 pts**

Table 5-13. Characterization of the sediment TMDL using QHEI metrics for sites with impairment due to sedimentation/siltation.
Note: ALU designation in parentheses. Grouped by nested subwatershed.

Stream/River	River Mile	QHEI Categories: Subs-trate	QHEI Categories: Chan -nel	QHEI Categories: Ripa-rian	Total Sediment Score	Deviation from target (%)	Main impairment category
04 06 Turkeyfoot Creek – Great Miami River							
Great Miami R (EWH)	138.4	8	12	10	30	14.3	substrate
Target (EWH)		**≥ 15**	**≥ 15**	**≥ 5**	**≥ 35**		

Table 5-14. *E. coli* load allocation table for GMR at State Route 47 (05080001 07 03).

Flow regime TMDL analysis *E. coli* (billion organisms/day)	High	Wet weather	Normal range	Dry weather	Low
Flow Duration Regime Interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per Regime		1	5	6	4
Sample Load (median)		2,961	3,169	113.8	218.0
Upstream WLA	52.6	52.6	52.6	52.5	52.5
TMDL (less upstream WLA)	8564.0	1,242.0	289.5	172.6	120.2
MOS (explicit 20%)	1713	248	58	34.5	24.0
AFG (1%)	86	12	3	1.7	1.2
WLA (total)	2.4	2.4	2.4	2.4	2.4
Quincy-DeGraff (1PB00036)	2.4	2.4	2.4	2.4	2.4
LA	6,763	979	226	134	93
Total Reduction Required (%)	No Data	**58.1%**	**90.9%**	**None**	**44.9%**

Values were adjusted for rounding.

Note: TMDL is reduced by upstream WLAs originating from South Fork GMR (05080001 01 02)[4], Muchinippi Creek at CR 60 (05080001 02 04), GMR at SR 235 (05080001 03 02), and Bokengehalas Creek (05080001 03 05) LDCs.

5.5 Headwaters Loramie Creek (05080001 05)

Habitat TMDLs were calculated for five sites in this subwatershed (Table 5-15) and sediment TMDLs for three sites (Table 5-16). Total phosphorus TMDLs for the Headwaters Loramie Creek subwatershed are shown in Table 5-17. The total dissolved solids TMDL for Loramie Creek is shown in Table 5-18. Bacteria TMDLs were completed for the Headwaters Loramie Creek nested subwatershed (05 01; Table 5-19) and the Mile Creek nested subwatershed (05 02; Table 5-20).

Table 5-15. Characterization of the habitat TMDL using QHEI metrics for sites with impairment due to habitat alteration, sedimentation/siltation, turbidity, and/or flow alteration (non-natural).
Note: ALU designation in parentheses; if a second designation is listed the first entry is proposed. Grouped by nested subwatershed. NA = not applicable as no target exists for MWH ALU designation.

Stream/River	River Mile	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	Subscore			Total Habitat Score
					QHEI	High Influence	Modified	
05 01 Headwaters Loramie Creek								
Loramie Ck (WWH)	36.9	47	2	8	0	0	0	0
Loramie Ck (WWH)	35	54	2	8	0	0	0	0
Loramie Ck (WWH)	30.4	46	3	10	0	0	0	0
05 02 Mile Ck								
Mile Ck (MWH-C, WWH)	9.8	39	4	10	NA	NA	NA	NA
Mile Ck (MWH-C, WWH)	8.8	34	5	10	NA	NA	NA	NA
Target (WWH)		**≥ 60 = 1 pt**	**< 2 = 1 pt**	**< 5 = 1 pt**				**3 pts**

[4] Reduction from this nested subwatershed occurs only in the three highest flow regimes for the GMR at SR 47 LDC.

Table 5-16. Characterization of the sediment TMDL using QHEI metrics for sites with impairment due to sedimentation/siltation.

Note: ALU designation in parentheses. Grouped by nested subwatershed.

Stream/River	River Mile	QHEI Categories			Total Sediment Score	Deviation from target (%)	Main impairment category
		Subs-trate	Chan-nel	Ripa-rian			
05 01 Headwaters Loramie Creek							
Loramie Ck (WWH)	36.9	13	7	2	22	31.3	riparian
Loramie Ck (WWH)	35	13	9	3	25	21.9	riparian
Loramie Ck (WWH)	30.4	15.5	6	1.5	23	28.1	riparian
Target (WWH)		**≥ 13**	**≥ 14**	**≥ 5**	**≥ 32**		

Table 5-17. Distribution of existing (current) total phosphorus load and subsequent load allocations for the Headwaters Loramie Creek subwatershed.

Note: A suite of allocations exists for each nested subwatershed and SWAT model sub-basin number and for each of two seasons (summer and winter). Subcategories for LA (by land use type) and WLA (by facility) are also depicted. **Each value represents a seasonal average (summer or winter) of the distribution of daily loads in that season.** All values are shown as total phosphorus in kg/d except for average reduction (fractional).

05080001 05 01 Headwaters Loramie Ck	Subbasin#: **6 Summer**
Current Load	104
TMDL = LA + WLA + AFG + MOS	8
LA (total)	6.01
LA -- cropland	6
LA -- pasture	0
LA -- residential (low density)	0
WLA (total)	1.51
WLA - facility: 1.51	Anna (1PB00004)
AFG (1%)	0.08
MOS (5%)	0.4
Average Reduction (Fractional)[1]	0.74
05080001 05 01 Headwaters Loramie Ck	Subbasin#: **6 Winter**
Current Load	230
TMDL = LA + WLA + AFG + MOS	24
LA (total)	21.05
LA -- cropland	21.03
LA -- pasture	0
LA -- residential (low density)	0
WLA (total)	1.51
WLA - facility: 1.51	Anna (1PB00004)
AFG (1%)	0.24
MOS (5%)	1.2
Average Reduction (Fractional)	0.71
05080001 05 01 Headwaters Loramie Ck	Subbasin#: **7 Summer**
Current Load	44
TMDL = LA + WLA + AFG + MOS	2
LA (total)	<0.01
LA -- cropland	<0.01
LA -- pasture	0

LA -- residential (low density)	0
WLA (total)	1.89
WLA - facility: 1.89	Botkins (1PB00007)
AFG (1%)	0.02
MOS (5%)	0.1
Average Reduction (Fractional)	0.77
05080001 05 01 Headwaters Loramie Ck	Subbasin#: **7 Winter**
Current Load	114
TMDL = LA + WLA + AFG + MOS	7
LA (total)	4.69
LA -- cropland	4.68
LA -- pasture	0
LA -- residential (low density)	0
WLA (total)	1.89
WLA - facility: 1.89	Botkins (1PB00007)
AFG (1%)	0.07
MOS (5%)	0.35
Average Reduction (Fractional)	0.73
05080001 05 02 Mile Ck	Subbasin#: **8 Summer**
Current Load	76
TMDL = LA + WLA + AFG + MOS	9
LA (total)	7.07
LA -- cropland	7.07
LA -- pasture	0
LA -- residential (low density)	0
WLA (total)	1.39
WLA - facility: 1.39	Osgood (1PB00047)
AFG (1%)	0.09
MOS (5%)	0.45
Average Reduction (Fractional)	0.43
05080001 05 02 Mile Ck	Subbasin#: **8 Winter**
Current Load	158
TMDL = LA + WLA + AFG + MOS	34
LA (total)	30.57
LA -- cropland	30.58
LA -- pasture	0
LA -- residential (low density)	0
WLA (total)	1.39
WLA - facility: 1.39	Osgood (1PB00047)
AFG (1%)	0.34
MOS (5%)	1.7
Average Reduction (Fractional)	0.56
05080001 05 03 Lk Loramie-Loramie Ck	Subbasin#: **3 Summer**
Current Load	198
TMDL = LA + WLA + AFG + MOS	13
LA (total)	1.25

LA -- cropland	0.88
LA -- pasture	0
LA -- residential (low density)	0.37
WLA (total)	10.97
WLA - facility: Minster (2PB00036): 9.46 Lk Loramie (1PH00028): 1.51 BP Amoco (2IN00173): 0	
AFG (1%)	0.13
MOS (5%)	0.65
Average Reduction (Fractional)	0.93
05080001 05 03 Lk Loramie-Loramie Ck	Subbasin#: **3 Winter**
Current Load	294
TMDL = LA + WLA + AFG + MOS	39
LA (total)	25.69
LA -- cropland	18.17
LA -- pasture	0
LA -- residential (low density)	7.55
WLA (total)	10.97
WLA - facility: Minster (2PB00036): 9.46 Lk Loramie (1PH00028): 1.51 BP Amoco (2IN00173): 0	
AFG (1%)	0.39
MOS (5%)	1.95
Average Reduction (Fractional)	0.85
05080001 05 03 Lk Loramie-Loramie Ck	Subbasin#: **5 Summer**
Current Load	158
TMDL = LA + WLA + AFG + MOS	14
LA (total)	13.16
LA -- cropland	13.18
LA -- pasture	0
LA -- residential (low density)	0
WLA (total)	0
AFG (1%)	0.14
MOS (5%)	0.7
Average Reduction (Fractional)	0.65
05080001 05 03 Lk Loramie-Loramie Ck	Subbasin#: **5 Winter**
Current Load	343
TMDL = LA + WLA + AFG + MOS	43
LA (total)	40.42
LA -- cropland	40.47
LA -- pasture	0
LA -- residential (low density)	0
WLA (total)	0
AFG (1%)	0.43

MOS (5%)	2.15
Average Reduction (Fractional)	0.69

[1] Average Reduction (Fractional) is calculated as the mean of a distribution of daily fractional reductions. It should not be considered as a "percent reduction of the averages." Both TMDL, LA, and WLA are reported as the mean of distribution of daily values and as it should be because a TMDL is a distribution of *daily* loads; hence, so should the average reduction (fractional) be similarly calculated.

Table 5-18. Characterization of existing and allocated TDS loads, expressed in kg/day, by sector (e.g., WLA vs. LA), identification of allowance for future growth (AFG) and margin-of-safety (MOS) terms.

Note: After allocation, the resulting percent reduction (from existing load) and concentration at average design flow (ADF) is also portrayed. Conc = concentration of TDS in mg/L.

	Existing Loads			Allocated Loads		
	flow (cfs)	conc (mg/L)	load (kg/day)	load (kg/day)	%reduction	conc (mg/L) @ ADF
AFG	0	0	0			
LA	0.116	459	0.162	0.099	39.1%	
WLA	0.7735	2622.5	6.189	3.769	39.1%	1596.8
Botkins STP (1PB00007)						
total			6.352	3.867		
TMDL	0.8895	1500	4.071			
MOS	5%		0.204			
TMDL less MOS			3.867			

Table 5-19. *E. coli* load allocation table for Loramie Creek at Hardin-Wapakoneta Rd (05080001 05 01).

Flow regime TMDL analysis *E. coli* (billion organisms/day)	High	Wet weather	Normal range	Dry weather	Low
Flow Duration Regime Interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per Regime			2	2	1
Sample Load (median)			321.73	8.65	5.02
Upstream WLA	0	0	0	0	0
TMDL (less upstream WLA)	1443.76	103.12	14.42	6.38	5.12
MOS (explicit 20%)	288.75	20.62	2.88	0.00	0.00
AFG (1%)	14.44	1.03	0.14	0.06	0.05
WLA (total)	4.82	4.82	4.82	4.82	4.82
Anna STP 1PB00004	2.44	2.44	2.44	2.44	2.44
Botkins STP 1PB00007	2.38	2.38	2.38	2.38	2.38
LA	1135.75	76.64	6.57	1.49	0.25
Total Reduction Required (%)	No Data	No Data	**96.5%**	**26.9%**	**None**

Values were adjusted for rounding.

Table 5-20. *E. coli* load allocation table for Mile Creek at State Route 705 (05080001 05 02).

Flow regime TMDL analysis *E. coli* (billion organisms/day)	High	Wet weather	Normal range	Dry weather	Low
Flow Duration Regime Interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per Regime			2	3	1
Sample Load (median)			20	1.0	11.2
Upstream WLA	0	0	0	0	0
TMDL	1,479	104	12.6	4.33	2.76
MOS (explicit 20%)	296	21	2.5	0.87	0.55
AFG (1%)	15	1	0.1	0.04	0.03
WLA (total)	0.7	0.7	0.7	0.74	0.74
Osgood (1PB00047)	0.7	0.7	0.7	0.74	0.74
LA	1,168	81	9.2	2.68	1.43
Total Reduction Required (%)	No Data	No Data	**37.5%**	**None**	**75.4%**

Values were adjusted for rounding.

5.6 Turtle Creek-Loramie Creek (05080001 06)

Habitat TMDLs were calculated for three sites in this subwatershed (Table 5-21). Total phosphorus TMDLs for the Turtle Creek-Loramie Creek subwatershed are shown in Table 5-22. Bacteria TMDLs were completed for the Painter Creek-Loramie Creek nested subwatershed (06 02; Table 5-23) and the Mill Creek-Loramie Creek nested subwatershed (06 04; Table 5-24).

Table 5-21. Characterization of the habitat TMDL using QHEI metrics for sites with impairment due to habitat alteration, sedimentation/siltation, turbidity, and/or flow alteration (non-natural).
Note: ALU designation in parentheses. Grouped by nested subwatershed.

Stream/River	River Mile	QHEI Score	# of High Influence Attributes	Total # of Modified Attributes	Subscore			Total Habitat Score
					QHEI	High Influence	Modified	
06 02 Painter Creek – Loramie Creek								
Loramie Ck (WWH)	19.3	61	2	9	1	0	0	1
Loramie Ck (WWH)	18.9	43	3	10	0	0	0	0
06 03 Turtle Creek								
Turtle Ck (WWH)	8.5	60.5	1	5	1	1	0	2
Target (WWH)		**≥ 60 = 1 pt**	**< 2 = 1 pt**	**< 5 = 1 pt**				**3 pts**

Table 5-22. Distribution of existing (current) total phosphorus load and subsequent load allocations for the Turtle Creek-Loramie Creek subwatershed.
Note: A suite of allocations exists for each nested subwatershed and SWAT model sub-basin number and for each of two seasons (summer and winter). Subcategories for LA (by land use type) and WLA (by facility) are also depicted. **Each value represents a seasonal average (summer or winter) of the distribution of daily loads in that season.** All values are shown as total phosphorus in kg/d except for average reduction (fractional).

05080001 06 02 Painter Ck-Loramie Ck	Subbasin#: **1 Summer**
Current Load	307
TMDL = LA + WLA + AFG + MOS	27

LA (total)	25.38
LA -- cropland	16.86
LA -- pasture	8.55
LA -- residential (low density)	0
WLA (total)	0
AFG (1%)	0.27
MOS (5%)	1.35
Average Reduction (Fractional)[1]	0.88
05080001 06 02 Painter Ck-Loramie Ck	Subbasin#: **1 Winter**
Current Load	598
TMDL = LA + WLA + AFG + MOS	88
LA (total)	82.72
LA -- cropland	54.95
LA -- pasture	27.85
LA -- residential (low density)	0
WLA (total)	0
AFG (1%)	0.88
MOS (5%)	4.4
Average Reduction (Fractional)	0.82
05080001 06 02 Painter Ck-Loramie Ck	Subbasin#: **2 Summer**
Current Load	272
TMDL = LA + WLA + AFG + MOS	23
LA (total)	21.62
LA -- cropland	13.62
LA -- pasture	8.05
LA -- residential (low density)	0
WLA (total)	0
AFG (1%)	0.23
MOS (5%)	1.15
Average Reduction (Fractional)	0.88
05080001 06 02 Painter Ck-Loramie Ck	Subbasin#: **2 Winter**
Current Load	468
TMDL = LA + WLA + AFG + MOS	76
LA (total)	71.44
LA -- cropland	45.01
LA -- pasture	26.61
LA -- residential (low density)	0
WLA (total)	0
AFG (1%)	0.76
MOS (5%)	3.8
Average Reduction (Fractional)	0.8
05080001 06 03 Turtle Ck	Subbasin#: **14 Summer**
Current Load	11
TMDL = LA + WLA + AFG + MOS	1
LA (total)	0.94

LA -- cropland	0.94
LA -- pasture	0
LA -- residential (low density)	0
WLA (total)	0
AFG (1%)	0.01
MOS (5%)	0.05
Average Reduction (Fractional)	0.24
05080001 06 03 Turtle Ck	Subbasin#: **14 Winter**
Current Load	23
TMDL = LA + WLA + AFG + MOS	4
LA (total)	3.76
LA -- cropland	3.76
LA -- pasture	0
LA -- residential (low density)	0
WLA (total)	0
AFG (1%)	0.04
MOS (5%)	0.2
Average Reduction (Fractional)	0.44

[1] Average Reduction (Fractional) is calculated as the mean of a distribution of daily fractional reductions. It should not be considered as a "percent reduction of the averages." Both TMDL, LA, and WLA are reported as the mean of distribution of daily values and as it should be because a TMDL is a distribution of *daily* loads; hence, so should the average reduction (fractional) be similarly calculated.

Table 5-23. *E. coli* load allocation table for Loramie Creek at Cardo-Roman Road (05080001 06 02).

Flow regime TMDL analysis *E.coli* (billion organisms/day)	**High**	**Wet weather**	**Normal range**	**Dry weather**	**Low**
Flow Duration Regime Interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per Regime		1	7		1
Sample Load (median)		1078	37.67		12.32
Upstream WLA	5.56	5.56	5.56	0.74	0.74
TMDL (less upstream WLA)	2821.20	198.21	24.65	13.75	11.28
MOS (explicit 20%)	564.24	39.64	4.93	0.00	0.00
AFG (1%)	28.21	1.98	0.25	0.00	0.00
WLA (total)	13.83	13.83	13.83	13.75	11.28
Minster (2PB00036)	11.92	11.92	11.92	11.85	9.73
Lake Loramie (1PH00028)	1.91	1.91	1.91	1.90	1.56
SSO: Minster (2PB00036)	0.00	0.00	0.00	0.00	0.00
SSO: Lake Loramie (1PH00028)	0.00	0.00	0.00	0.00	0.00
LA	2214.92	142.75	5.64	0.00	0.00
Total Reduction Required (%)	No Data	**85.5%**	**48.3%**	No Data	**8.5%**

Values were adjusted for rounding.

Note: TMDL is reduced by upstream WLAs originating from Loramie Creek at Hardin-Wapakoneta (05080001 05 01)[5] and Mile Creek at State Route 705 (05080001 05 02) LDCs.

[5] Reduction from this nested subwatershed occurs only in the three highest flow regimes for Loramie-Cardo LDC.

Table 5-24. *E. coli* load allocation table for Loramie Creek at Fessler-Buxton Road (05080001 06 04).

Flow regime TMDL analysis *E. coli* (billion organisms/day)	High	Wet weather	Normal range	Dry weather	Low
Flow Duration Regime Interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per Regime			3	4	2
Sample Load (median)			117	38.7	27.3
Upstream WLA	19	19	19	15	15
TMDL (less upstream WLA)	4,593	367	80	33.9	17.9
MOS (explicit 20%)	919	73	16	6.8	3.6
AFG (1%)	46	4	1	0.3	0.2
WLA (total)	1.5	1.5	1.5	1.5	1.5
Arrowhead (1PG00099)	0.3	0.3	0.3	0.3	0.3
Russia (1PS00012)	0.5	0.5	0.5	0.5	0.5
Dorothy Love Retirement Ctr (1PT00039)	0.6	0.6	0.6	0.6	0.6
Hardin Elementary School (1PT00068)	0.1	0.1	0.1	0.1	0.1
Houston HS (1PT00104)	0.0	0.0	0.0	0.0	0.0
MS4: Sidney (05080001 06 03)	5	0.4	0.1	0.03	0.02
MS4: Sidney (05080001 06 04)	4	0.3	0.1	0.03	0.01
LA	3619	287	61.9	24.9	12.97
Total Reduction Required (%)	No Data	No Data	**31.6%**	**12.3%**	**34.5%**

Values were adjusted for rounding.

Note: TMDL is reduced by upstream WLAs originating from Loramie Creek at Hardin-Wapakoneta (05080001 05 01)[6], Loramie Creek at Cardo (05080001 06 02), and Mile Creek at SR 705 (05080001 05 02) LDCs.

[6] Reduction from this nested subwatershed occurs only in the three highest flow regimes for Loramie-Fessler LDC.

6 WATER QUALITY IMPROVEMENT STRATEGY

Partial and non-attainment of aquatic life uses were documented in 28 of the 78 sites evaluated in the Great Miami River (upper) watershed survey (Ohio EPA 2011). The majority (24/28 or 86%) of sites not meeting the aquatic life use goals were impacted by habitat alteration caused in part by channelization. Twenty-six (93%) of the sites failing to meet aquatic life use goals were on or west of the Great Miami River. The combination of nutrient enrichment from WWTPs and agricultural practices in the western subwatersheds, plus lack of assimilative capacity due to habitat alteration, had a strong negative influence on water quality.

Recreation use (bacteriological) impairment was documented across all subwatersheds in 27/37 (73%) of sites assessed. Land application of manure, livestock and failing home sewage treatment systems (HSTS) are the probable sources of bacteria impairment.

Table 6-1 shows an overview of the nested subwatersheds that contain sites with partial and non-attainment of aquatic life and recreation uses. Causes of impairment are shown within the parentheses following each source that might contribute to that cause. Recommended implementation actions for NPDES permittees is also included. For each subwatershed, specific actions are discussed narratively. Because Ohio EPA recognizes that actions taken in any individual watershed may depend upon a number of factors (including socioeconomic, political and ecological factors), these recommendations are not intended to be prescriptive of the actions to be taken. Because of the iterative nature of the process, any number of the specific restoration actions may be taken with the final goal to contribute to water quality improvement.

Following completion of the TMDL, a stakeholder-driven effort to develop more specific recommendations will be developed in collaboration with the Greater Dayton Partners for the Environment (GDPE), an alliance of environmental organizations, government and civic organizations, and public and private educational institutions in the Great Miami River watershed. The Dayton Foundation, The Miami Conservancy District, Five Rivers MetroParks and The Greater Dayton Conservation Fund sponsor GDPE to further enhance the Partners' individual and collective environmental outcomes. As currently envisioned, the GDPE will work with local stakeholders including local landowners, educational institutions, state agencies, the Ohio Farm Bureau Federation, SWCDs, community-based watershed organizations and permitted dischargers to develop more specific community-supported recommendations. Community-supported water quality improvement recommendations offer the highest probability of initial implementation and long-term sustainability. The anticipated recommendations will explore innovative and timely opportunities such as the Great Miami River Water Quality Credit Trading Program, the U.S. Department of Agriculture's (USDA) Mississippi River Basin Initiative and the U.S. EPA-supported Water Technology Innovation Cluster. Using the SWAT model, implementation scenarios were developed that may assist in future work on this project (see Section 6.2).

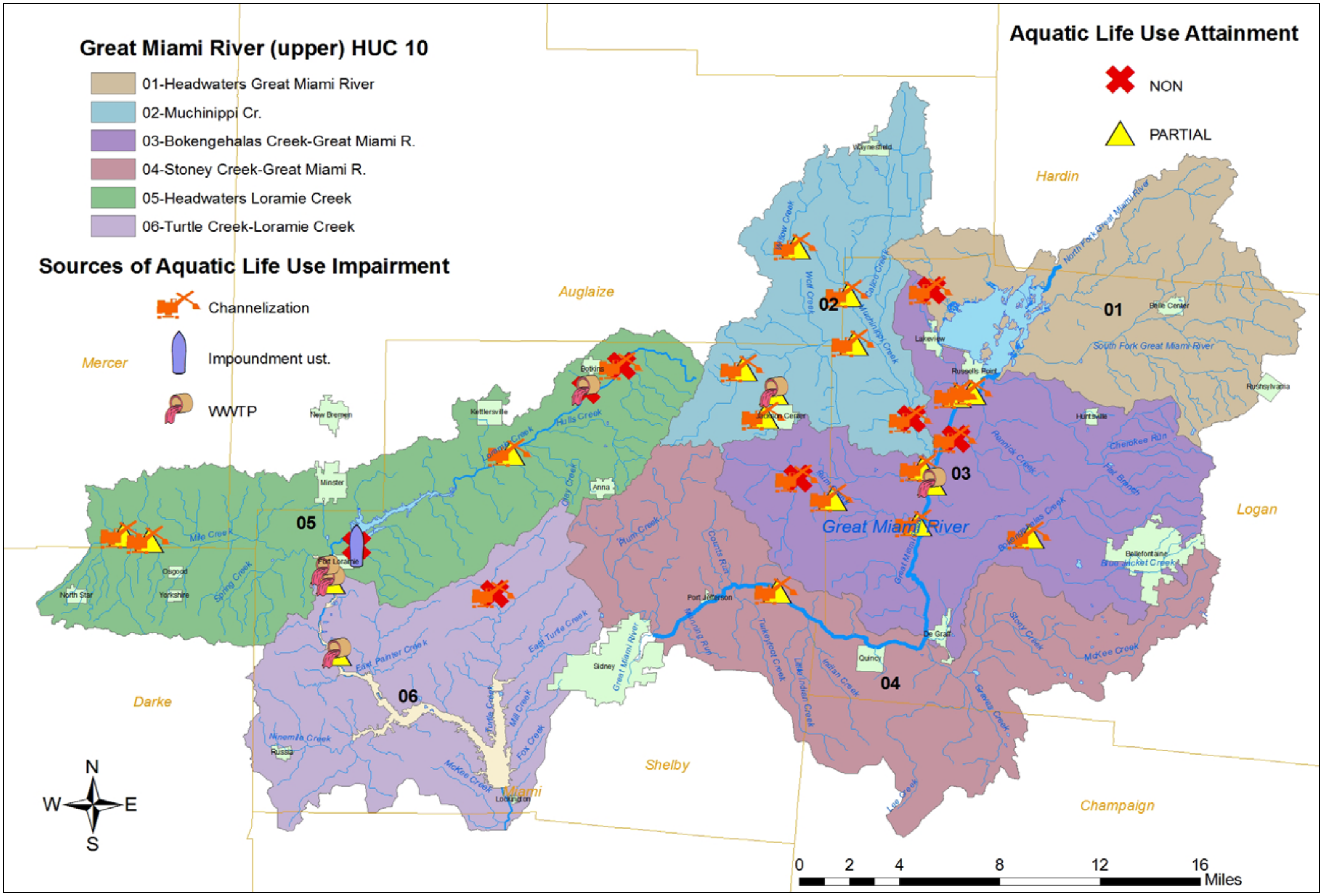

Figure 6-1. Partial and non-attainment of aquatic life uses in the Great Miami River (upper) watershed.

Table 6-1. Recommendations for improving water quality in impaired areas of the Great Miami River (upper) watershed.

Location Description (10-digit HUC) Location Description (12-digit HUC) Sources (Causes)	Restoration Categories											
	Bank & Riparian Restoration	Stream Restoration	Wetland Restoration	Conservation Easements	Dam Modification (M) or Removal (R)	Levee or Dike Modification or Removal	Abandoned Mine Land Reclamation	Home Sewage Planning and Improvement	Education and Outreach	Agricultural Best Management Practices	Storm Water Best Management Practices	Regulatory Point Source Controls
Headwaters Great Miami River (05080001 01)												
North Fork Great Miami River (01 01)												
Agricultural runoff (bacteria)										X		
South Fork Great Miami River (01 02)												
Livestock access to stream (bacteria)									X	X		
Agricultural runoff (bacteria)										X		
Indian Lake-Great Miami River (01 03)												
Channelization (habitat alteration)	X	X								X		
Muchinippi Creek (05080001 02)												
Willow Creek (02 01)												
Channelization (habitat alteration)	X	X		X						X		
Headwaters Muchinippi Creek (02 02)												
Unsewered community (bacteria)								X	X			
Urban runoff (bacteria)									X		X	
Agricultural runoff (bacteria)										X		
Little Muchinippi Creek (02 03)												
Channelization (habitat alteration)	X	X		X						X		
Minor WWTP (nutrients, bacteria)												X
Agriculture (nutrients, silt, bacteria from runoff)	X	X		X					X	X		
Failing HSTS (bacteria)								X		X		
Calico Creek-Muchinippi Creek (02 04)												
Impoundment (flow alteration)		X										
Livestock (silt)									X	X		
Channelization (habitat alteration)	X	X		X						X		

Location Description (10-digit HUC) Location Description (12-digit HUC) Sources (Causes)	Restoration Categories Bank & Riparian Restoration	Stream Restoration	Wetland Restoration	Conservation Easements	Dam Modification (M) or Removal (R)	Levee or Dike Modification or Removal	Abandoned Mine Land Reclamation	Home Sewage Planning and Improvement	Education and Outreach	Agricultural Best Management Practices	Storm Water Best Management Practices	Regulatory Point Source Controls
Bokengehalas Creek-Great Miami River (05080001 03)												
Rennick Creek-Great Miami River (03 02)												
Channelization (habitat alteration)	X	X		X						X		
Impoundment (flow alteration)					M							
Agriculture (silt, bacteria from runoff)									X	X		
Sanitary sewer overflows (bacteria)												X
Urban runoff (bacteria)									X		X	
Wildlife (bacteria)												
Rum Creek (03 03)												
Channelization (habitat alteration, silt)	X	X		X					X	X		
Livestock access to stream (bacteria)									X	X		
Agricultural runoff (bacteria)										X		
Blue Jacket Creek (03 04)												
Urban runoff (bacteria)									X		X	
Agricultural runoff (bacteria)										X		
Bokengehalas Creek (03 05)												
Channelization (habitat alteration)	X	X		X						X		
Agriculture (silt, bacteria from runoff)										X		
Urban runoff (bacteria)									X		X	
Brandywine Creek-Great Miami River (03 06)												
Channelization (habitat alteration)	X	X		X		X				X		
Agriculture (silt, bacteria from runoff)										X		
Major WWTP (organic enrichment/ dissolved oxygen)												X

Location Description (10-digit HUC) Location Description (12-digit HUC) Sources (Causes)	Restoration Categories											
	Bank & Riparian Restoration	Stream Restoration	Wetland Restoration	Conservation Easements	Dam Modification (M) or Removal (R)	Levee or Dike Modification or Removal	Abandoned Mine Land Reclamation	Home Sewage Planning and Improvement	Education and Outreach	Agricultural Best Management Practices	Storm Water Best Management Practices	Regulatory Point Source Controls
Stoney Creek-Great Miami River (05080001 04)												
McKees Creek (04 01)												
Agricultural runoff (bacteria)										X		
Lee Creek (04 02)												
Unsewered community (bacteria)								X	X			
Agricultural runoff (bacteria)										X		
Stoney Creek (04 03)												
Agricultural runoff (bacteria)										X		
Indian Creek (04 04)												
Unsewered community (bacteria)								X	X			
Agricultural runoff (bacteria)										X		
Plum Creek (04 05)												
Agricultural runoff (bacteria)										X		
Turkeyfoot Creek-Great Miami River (04 06)												
Channelization (habitat alteration)	X	X								X		
Agriculture (silt)	X	X		X						X		
Headwaters Loramie Creek (05080001 05)												
Headwaters Loramie Creek (05 01)												
Channelization (habitat alteration)	X	X	X	X		X				X		
Minor WWTP (nutrients, total dissolved solids)												X
Impoundment downstream (silt, flow alteration)					M	X						
Agriculture (nutrients, phosphorus, bacteria from runoff)	X	X	X	X		X			X	X		

Location Description (10-digit HUC) Location Description (12-digit HUC) Sources (Causes)	Restoration Categories											
	Bank & Riparian Restoration	Stream Restoration	Wetland Restoration	Conservation Easements	Dam Modification or Removal	Levee or Dike Modification or Removal	Abandoned Mine Land Reclamation	Home Sewage Planning and Improvement	Education and Outreach	Agricultural Best Management Practices	Storm Water Best Management Practices	Regulatory Point Source Controls
Mile Creek (05 02)												
Channelization (habitat alteration)	X	X	X	X		X				X		
Agriculture (nutrients, bacteria from runoff)	X	X	X	X		X				X		
Unsewered community (bacteria)								X	X			
Animal feedlot operation (bacteria)									X	X		
Lake Loramie-Loramie Creek (05 03)												
Impoundment upstream (flow alteration, nutrients)					M	X						
Agricultural runoff (bacteria)										X		
Sanitary sewer overflows (bacteria)												X
Urban runoff (bacteria)									X		X	
Wildlife (bacteria)												
Turtle Creek-Loramie Creek (05080001 06)												
Nine Mile Creek (06 01)												
Urban runoff (bacteria)									X		X	
Agricultural runoff (bacteria)										X		
Painter Creek-Loramie Creek (06 02)												
Channelization (habitat alteration)	X	X	X	X		X				X		
Agriculture (phosphorus)	X	X	X	X		X				X		
Municipal WWTPs (phosphorus)												X
Failing HSTS (bacteria)								X	X			
Animal feedlot operation (bacteria)									X	X		
Agricultural runoff (bacteria)										X		

Location Description (10-digit HUC) **Location Description (12-digit HUC)** **Sources (Causes)**	**Restoration Categories**											
	Bank & Riparian Restoration	Stream Restoration	Wetland Restoration	Conservation Easements	Dam Modification or Removal	Levee or Dike Modification or Removal	Abandoned Mine Land Reclamation	Home Sewage Planning and Improvement	Education and Outreach	Agricultural Best Management Practices	Storm Water Best Management Practices	Regulatory Point Source Controls
Turtle Creek (06 03)												
Channelization (habitat alteration)	X	X	X	X		X				X		
Agriculture (nutrients)	X	X	X	X		X				X		
Mill Creek-Loramie Creek (06 04)												
Agricultural runoff (bacteria)										X		
Wildlife (bacteria)												

6.1 Regulatory Recommendations

TMDLs involving point sources were calculated for total phosphorus, total dissolved solids (TDS) and *E. coli*. The only aquatic life use impairment from TDS was on Loramie Creek downstream from the Village of Botkins (see Table 6-2). Total phosphorus TMDLs were calculated in the Loramie Creek and Little Muchinippi Creek subwatersheds, so only facilities in those subwatersheds received total phosphorus wasteload allocations (see Table 6-3). Wasteload allocations for *E. coli* were given to all facilities in the watershed that discharge bacteria (see Table 6-4). Wasteload allocations for the municipal separate storm sewer system are shown in Table 6-5.

Table 6-2. Recommended implementation actions through the NPDES program for total dissolved solids.
Note: Any specific permit condition noted in the table indicates a recommended change from current permit conditions.

Nested Subwatershed (05080001)	Entity	Ohio EPA Permit #	Receiving Stream	Design Flow (million gallons per day)	Wasteload Allocation (load)	Wasteload Allocation (concentration)	Recommended Permit Conditions
03 02	Botkins Sewage Treatment Plant	1PB00007	Loramie Creek	0.5	3.71 kg/day	1569.9 mg/L	Average monthly limit of 1569.9 mg/L

Table 6-3. Recommended implementation actions through the NPDES program for total phosphorus.
Note: Any specific permit condition noted in the table indicates a recommended change from current permit conditions. "No change" means that no change is recommended.

Nested Sub-watershed (05080001)	Entity[1]	Ohio EPA Permit #	Receiving Stream	Design Flow (million gallons per day)[2]	Wasteload Allocation (load)	Wasteload Allocation (concentration)	Recommended Permit Conditions
02 03	Jackson Center WWTP	1PB00018	Jackson Center Creek	0.37	1.4 kg/day	1.0	Average monthly limit of 1.0 mg/L
05 01	Botkins STP	1PB00007	Loramie Creek	0.50	1.89 kg/day	1.0	Average monthly limit of 1.0 mg/L
05 01	Anna STP	1PB00004	Clay Creek	0.40	1.51 kg/day	1.0	Average monthly limit of 1.0 mg/L
05 01	Super Stop Petroleum Anna	1PZ00007	Unnamed tributary to Hulls Creek	0.005	0	0	No longer discharging
05 03	BP Amoco Oil Corp Bulk Plant Minster	2IN00173	Miami-Erie Canal	Storm water	No change	No change	No change
05 03	Minster WWTP	2PB00036	Miami-Erie Canal	1.05	9.46 kg/day	1.0	Average monthly limit of 1.0 mg/L
05 03	Minster Machine Co.	2GN00007	Miami-Erie Canal	Storm water	No change	No change	No change
05 03	Lake Loramie Special Sanitary SD	1PH00028	Loramie Creek	0.40	1.51 kg/day	1.0	Average monthly limit of 1.0 mg/L
05 02	Osgood WWTP	1PB00047	Brandewie Ditch	0.122	1.39 kg/day	3.0	Average monthly limit of 3.0 mg/L
06 04	Northstar Elementary School	1PT00119	Honsapple Ditch	0.025	0	0	No longer discharging

[1] Acronyms used: STP is sewage treatment plant; WWTP is wastewater treatment plant; SD is sewer district.
[2] Design flows that are greater than 1.0 million gallons per day (MGD) classify a facility as a major discharger.

Table 6-4. Recommended implementation actions through the NPDES program for *E. coli*.

Nested Sub-watershed (05080001)	Entity[1]	Ohio EPA Permit #	Receiving Stream	Design Flow (million gallons per day)[2]	Wasteload Allocation (load)[3]	Wasteload Allocation (concen-tration)[4]	Recommended Permit Conditions[4]
01 02	Camp Wesley	1PR00100	Unnamed tributary to South Fork Great Miami River	0.012	0.1	161	Average monthly limit of 161
02 02	Waynesfield WWTP	2PB00022	Unnamed tributary to Muchinippi Creek	0.123	0.75	161	Average monthly limit of 161
02 02	Dad's Drive-in	2PR00258	Muchinippi Creek	0.0015	0.01	161	Average monthly limit of 161
02 03	Jackson Center WWTP	1PB00018	Jackson Center Creek	0.37	2.25	161	Average monthly limit of 161
03 02	Indian Lake WPCD	1PK00002	Great Miami River	4.6	21.9	126	Average monthly limit of 126
03 04	Bellefontaine WWTP	1PD00000	Opossum Run	4.5	27.4	161	Average monthly limit of 161
03 05	ODOT Rest Area 0729	1PP00021	Flat Branch	0.01	0.1	161	Average monthly limit of 161
03 05	YMCA	1PR00052	Unnamed tributary to Blue Jacket Creek via Silver Lake	0.015	0.1	161	Average monthly limit of 161
04 05	Northbrook MHP	1PV00115	Unnamed tributary to Plum Creek	0.012	0.01	126	Average monthly limit of 126
04 06	Quincy-DeGraff STP	1PB00036	Great Miami River	0.495	2.36	126	Average monthly limit of 126
05 01	Anna STP	1PB00004	Clay Creek	0.4	2.44	161	Average monthly limit of 161
05 01	Botkins STP	1PB00007	Loramie Creek	0.5	2.38	126	Average monthly limit of 126
05 02	Osgood WWTP	1PB00047	Brandewie Ditch	0.122	0.7	161	Average monthly limit of 161
05 03	Lake Loramie SSD	1PH00028	Loramie Creek	0.4	1.9	126	Average monthly limit of 126
05 03	Minster WWTP	2PB00036	Miami-Erie Canal	1.05	11.9	126	Average monthly limit of 126
06 01	Houston High School	1PT00104	Ninemile Creek	0.01	0.05	126	Average monthly limit of 126
06 01	Russia WWTP	1PS00012	Unnamed tributary to Ninemile Creek	0.075	0.46	161	Average monthly limit of 161

Nested Sub-watershed (05080001)	Entity[1]	Ohio EPA Permit #	Receiving Stream	Design Flow (million gallons per day)[2]	Wasteload Allocation (load)[3]	Wasteload Allocation (concen-tration)[4]	Recommended Permit Conditions[4]
06 03	Dorothy Love Retirement Center	1PT00039	Ernst Ditch	0.104	0.63	161	Average monthly limit of 161
06 03	Hardin Elementary School	1PT00068	Unnamed tributary to Turtle Creek	0.009	0.05	161	Average monthly limit of 161
06 04	Arrowhead WWTP	1PG00099	Mill Creek	0.07	0.33	126	Average monthly limit of 126

[1] Acronyms used: STP is sewage treatment plant; WWTP is wastewater treatment plant; SSD is sanitary sewer district; MHP is mobile home park; and WPCD is water pollution control district.
[2] Design flows that are greater than 1.0 million gallons per day (MGD) classify a facility as a major discharger.
[3] Loads are expressed in billions of colonies per day.
[4] Concentrations are expressed in colony-forming units (cfu) per 100 milliliters (mL).

Table 6-5. *E. coli* wasteload allocations for the Bellefontaine MS4.

Nested Subwatershed (05080001)	Entity[1]	Ohio EPA Permit #	Receiving Streams	Wasteload Allocation (load)[2]	
03 04, 03 05, 04 01, 04 05, 04 06, 06 03, 06 04	Bellefontaine MS4	1GQ00065	Blue Jacket Creek Wissahicken Creek Bokengehalas Creek	Low flows: Dry weather flows: Normal range flows: Wet weather flows: High flows:	0 to 0.16 0.03 to 0.3 0.2 to 4.0 0.7 to 14 9.0 to 72.0

[1] MS4 stands for municipal separate storm sewer system.
[2] Loads are expressed in billions of colonies per day.

6.2 Implementation Scenarios

The SWAT model was used for the loading analysis in the Loramie Creek and Little Muchinippi Creek subwatersheds. One result of the SWAT model was load reduction scenarios, including various combinations of nonpoint and point source practice modification. The load reduction scenarios considered in Section 5 and Appendix D reflect the guidance provided by the Smiley et al. (2011) study—namely, multiple agricultural management practices are considered in one scenario. A summary of scenarios developed in the TMDL appears in Table D-18 in Appendix D. The proposed overall scenario combination provides for the following:

- Reduce point source discharges to 1 mg/L, 3 mg/L, or existing load, depending on guidance (see Table 6-1).
- Convert all failed HSTS to conventional systems and maintain existing conventional systems.
- Nonpoint practices:
  - o Incorporate manure into soil (i.e., turning soil so that manure does not remain on the surface)
  - o Add winter cover crops
  - o Add filter strips next to streams
  - o Reduce the rate of all phosphorus fertilizer application by 50%

While the load or concentration target is approached but not met, the scenario analysis suggests a combination of approaches to reducing the source load and following the TMDL goal. It would be unfair to judge this scenario combination as inadequate to meet the TMDL goal because issues of scale—both spatial and temporal averaging—confound the direct interpretation of meeting an exact load or concentration goal. Also, any further reductions in fertilizer application rate—below the maximal 50 percent used in this investigation—would be prohibitive as they would likely reduce crop yields below economically viable quotas. Further analysis of the SWAT model scenarios may be considered as need arises and as resources allow.

The following table summarizes the loading changes that would occur if point source recommendations are implemented.

Facility Name	Ohio EPA Permit #	Existing (2005-2011 average) / Proposed	
		Load (kg-P/d)	Concentration (mg-P/L)
Little Muchinippi Creek Watershed			
Jackson Center	1PB00018	2.41 / 1.4	1.72 / 1.0
Loramie Creek Watershed			
Botkins	1PB00007	1.36 / 1.89	0.72 / 1.0
Anna	1PB00004	3.23 / 1.51	2.13 / 1.0
SuperStop Anna	1PZ00007	0 / 0	No longer discharging / 0
BP Amoco Minster	2IN00173	< 0.01 / < 0.01	0.11 / 0.11 (no limit imposed)
Minster	2PB00036	39.18 / 9.46	4.14 / 1.0
Minster Machine	2GN00007	0 / 0	0 / 0 (no limit imposed)
Lake Loramie	1PH00028	6.37 / 1.51	4.21 / 1.0
Osgood	1PB00047	1.15 / 1.39	Recently came online / 3.0 (no limit imposed)
Northstar ES	1PT00119	0 / 0	No longer discharging / 0

In addition to the changes recommended, increasing the assimilative capacity of streams receiving high loads of phosphorus through habitat restoration and protection will also aid in reducing impacts from phosphorus inputs. Ohio EPA is in the process of developing nutrient criteria, including a criterion for total phosphorus that is planned to be incorporated into Ohio Administrative Code in the future. When that criterion becomes law, any discharger downstream of where there is biological impairment caused by total phosphorus will have to reduce effluent concentrations sufficiently to allow the in-stream concentrations to meet the criterion. However, if the dischargers in Table 6-1 reduce their effluent to recommended limits and work with land owners to improve assimilative capacity, and then biological performance moves to full attainment, the proposed total phosphorus criterion will not trigger further reduction requirements at the WWTPs.

The following six subsections (6.3 through 6.8) primarily discuss implementation actions to address nonpoint sources of impairment.

6.3 Headwaters Great Miami River (05080001 01)

Much of the improvement in the subwatershed can be attributed to the work of the Indian Lake Watershed Project using U.S. EPA, USDA, Farm Service Agency (FSA) and ODNR grants in implementing beneficial projects for nearly 20 years to improve water quality. In 1990, 6% of the watershed was in no-till agriculture; by 2000 nearly 80% was converted to no-till. This reduced the amount of sediment carried into Indian Lake from 79,000 tons/year in 1990 to 15,000 tons/yr by 2000. By 1995, Ohio EPA began noticing marked improvements in the watershed water quality.

Agricultural practices and failing HSTSs are probable sources of recreation use impairment in this subwatershed. Ohio EPA recommends that local health departments test HSTS to find those that are failing and that these be repaired or replaced. Manure spreading should not take place prior to rain events, nor should manure be spread on frozen ground. NRCS practices 633, 313, 634, and 635 can be consulted for appropriate manure practices (see Appendix F). In addition, NRCS practices 580 and 590 should be encouraged in the Environmental Quality Incentives Program and through the Miami Conservancy District (MCD) nutrient trading program to sequester nutrients and stabilize soil runoff after the growing season.

6.4 Muchinippi Creek (05080001 02)

Log jams in the lower segment of Muchinippi Creek have altered flow to cause non-attainment of aquatic life goals at river mile (RM) 2.37. A project to fund log jam removal is needed. Historically, five counties in the Great Miami River watershed attempted to create a drainage district funded by property assessment to deal with log jams and other drainage problems. This large project failed to get basin-wide support and was abandoned. No organized watershed group is located in this subwatershed at this time.

The only recreation use impairment in this subwatershed was documented in Jackson Center Creek. Agricultural runoff and a failing home septic system at river mile 2.9 (upstream from the WWTP) are probable sources of recreation use impairment. The village of Jackson Center has proposed lining the deteriorating wastewater collection system, which would improve wastewater collection (Ohio EPA 2011). Ohio EPA recommends that the local health department test HSTS to find those that are failing and that these be repaired or replaced. Manure spreading should not take place prior to rain events, nor should manure be spread on frozen ground. NRCS practices 633, 313, 634, and 635 can be consulted for appropriate manure practices (see Appendix F). In addition, NRCS practices 580 and 590 should be encouraged in the Environmental Quality Incentives Program and through the MCD nutrient trading program to sequester nutrients and stabilize soil runoff after the growing season.

6.5 Bokengehalas Creek-Great Miami River (05080001 03)

The Bokengehalas Creek subwatershed was impacted by aerial pesticide overspray on July 30, 2008. A fine was levied by ODNR for $4,392.10 for the killing of 12,528 crayfish, 16 minnows and two frogs. In addition, the Landmark Farm Supply Company in DeGraff had a pesticide spill on August 28, 2008. A fine was levied by ODNR for $416.43 for the killing of 782 fish, five crayfish and five mussels. Education of best management practices involving pesticides will be important for future prevention of pesticide spills and oversprays. In addition, the Ohio Department of Agriculture (ODA) provides licenses to parties intending to apply pesticides. ODA provides educational materials, training and testing to anyone who applies for licenses.

Organic enrichment was documented on the Great Miami River downstream from the Indian Lake WWTP. Organic enrichment was caused by wet weather bypasses. Surge basins and improvements to the collection system were installed in 2011.

The dam creating Indian Lake is causing biological impairment downstream of the dam. The dam causes restricted flow during the lower stream flows in the summer months, which can restrict resources available to organisms (e.g., dissolved oxygen and a variety of habitat niches). Indian Lake is utilized heavily by citizens for recreation and is highly valued for that purpose. Therefore, Ohio EPA recommends investigating possible methods to modify the flow regime during the summer low flow months to increase flow downstream of the dam. Such a modification would improve water quality and biological communities.

Agricultural practices, failing HSTSs , and runoff from the village of DeGraff are probable sources of recreation use impairment in this subwatershed. There are also issues with sanitary sewer overflows (SSOs) in DeGraff. Ohio EPA recommends addressing the SSOs in DeGraff and then that local health departments test HSTS to find those that are failing and that these be repaired or replaced. Storm water best management practices should be used to control urban runoff. Manure spreading should not take place prior to rain events, nor should manure be spread on frozen ground. NRCS practices 633, 313, 634, and 635 can be consulted for appropriate manure practices (see Appendix F). In addition, NRCS practices 580 and 590 should be encouraged in the Environmental Quality Incentives Program and through the MCD nutrient trading program to sequester nutrients and stabilize soil runoff after the growing season.

6.6 Stoney Creek-Great Miami River (05080001 04)

All aquatic life use goals were met in this subwatershed on the tributaries, but the mainstem at Baker Road (RM 138.8) failed to meet macroinvertebrate EWH criteria. The stream flow is sluggish and pooled, allowing sediment to settle out in this stretch of the river. Recreation use was not supported at 5 of 7 locations; only the mainstem sites (RM 143.2 and 142.5) supported recreation use.

The Quincy low-head dam backs up flow on the upper GMR for several miles upstream. Although not sampled in 2008, the impoundment likely impacts biological communities. Similar dams on other Ohio rivers create sluggish, monotypic pools, resulting in habitats that support fewer species than natural channels. Dams can act as barriers to fish or mussel migration and impoundment often contributes to excessive fine silt deposition, elevated stream temperatures and reduced oxygen levels. The fact that the Quincy dam marks the division between the EWH (downstream) and WWH (upstream) designated segments is evidence of the higher quality river reach immediately downstream of the dam. It is likely that if the dam were removed and natural flow were restored, biological communities would improve in the former impoundment. It is also possible that the exceptional warmwater habitat portion of the river might extend upstream further than it does with the dam in place. Extensive mussel beds observed in the tailwaters may also migrate further upstream following elimination of the dam. Other Ohio dams have been removed using various public funds; removal would be dependent on local initiative.

Agricultural practices and failing HSTSs are probable sources of recreation use impairment in this subwatershed. There are also issues with sanitary sewer overflows (SSOs) in Quincy. Ohio EPA recommends addressing the SSOs in Quincy and then that local health departments test HSTS to find those that are failing and that these be repaired or replaced. Manure spreading should not take place prior to rain events, nor should manure be spread on frozen ground. NRCS practices 633, 313, 634, and 635 can be consulted for appropriate manure practices (see Appendix F). In addition, NRCS practices 580 and 590 should be encouraged in the Environmental Quality Incentives Program and through the MCD nutrient trading program to sequester nutrients and stabilize soil runoff after the growing season.

6.7 Headwaters Loramie Creek (05080001 05)

The Loramie Valley Alliance (LVA) works in both Loramie Creek subwatersheds (05 and 06). They have a watershed management plan that was approved in 1999. No updated watershed management plan has been submitted for state endorsement.

In 1999, approximately 60,000 animal units in 400 sites were maintained within both Loramie Creek subwatersheds. Approximately eighty one percent of the animal units are swine (41%) and dairy cattle (40%). Beef cattle made up 11% of the animal units, followed by chicken (6%). In regards to manure management, 89% of livestock operations used surface spreading as the preferred method for manure dispersal. Seventy-three percent of the sites stored manure as a solid product.
The structure of the levee system in Mile Creek was broken down and made the water flow slow down by levee soil being in the channel. Mile Creek is under a county ditch maintenance program subject to county funding availability. County ditch maintenance programs do not allow sinuosity and riparian cover, both of which aid substantially in achieving healthy stream biology.

Nutrient runoff and habitat alterations have been identified as the major factors leading to the degraded conditions documented in both subwatersheds. The LVA funded the following projects (along with state and federal grants) to address the problems documented in the watershed:

- Six streambank stabilization projects: *(50% of cost, up to $4000)* - Prevents erosion by installing natural vegetation and fiber materials into streambanks.

- Five feedlot improvement projects (50% cost of fence, not to exceed $1.10/lineal foot; 50% of critical area seeding not to exceed $91/acre; 50% cost of alternative watering system, not to exceed $500/system) - Reduce nutrient runoff from livestock facilities.
- Four low impact log jam removal projects. The LVA contracts with the property owner to conduct the removal. Log jams were causing stream bank erosion and acting as a low head dam. Done on mainstem of Loramie Creek.
- Twenty filter strip projects: *($500/acre one-time bonus for trees; $90/acre one-time bonus for grass)* - Plant an area of grass or trees between cropland and streams or ditches to prevent erosion and chemical runoff. This was popular but has not seen much support in recent years.
- One two-stage ditch project in Nine Mile Creek.
- Strip-till equipment buy-down *(20% Cost-share, up to $4,000)* - Strip-till is a compliment to no-till. Bands of loosened soil are prepared before planting. This practice has the potential for combining the advantages of conventional tillage with no-till.
- Five natural retention area restoration projects- Creates or restores wetland areas to hold water during heavy rains and provide water quality benefits.
- Three Milkhouse wetland systems - provide 50% up to $3500 for the installation of a constructed milkhouse/parlor wastewater treatment system.
- Thirty cover crop in conjunction with the MCD nutrient trading program ($5/acre up to $500) - Reduce the erosion potential on fields when a growing crop is not present.
- Ten secondary fertilizer containment systems – Designed to prevent pollution by installing secondary containment around bulk storage tanks.

In 2010, the villages of Osgood, Yorkshire and North Star were connected to a centralized treatment system. This will act to remove some of the nutrient and bacteria water quality problems documented in Mile Creek. Failing HSTSs in Mercer County still likely contribute bacteria to streams.

The dam creating Lake Loramie is causing biological impairment downstream of the dam. The dam causes restricted flow during the lower stream flows in the summer months, which can restrict resources available to organisms (e.g., dissolved oxygen and a variety of habitat niches). Lake Loramie is utilized heavily by citizens for recreation and is highly valued for that purpose. Therefore, Ohio EPA recommends investigating possible methods to modify the flow regime during the summer low flow months to increase flow downstream of the dam. Such a modification would improve water quality and biological communities.

Agricultural practices and failing HSTSs are probable sources of recreation use impairment in this subwatershed. Ohio EPA recommends that local health departments test HSTS to find those that are failing and that these be repaired or replaced. Manure spreading should not take place prior to rain events, nor should manure be spread on frozen ground. NRCS practices 633, 313, 634, and 635 can be consulted for appropriate manure practices (see Appendix F). In addition, NRCS practices 580 and 590 should be encouraged in the Environmental Quality Incentives Program and through the MCD nutrient trading program to sequester nutrients and stabilize soil runoff after the growing season.

6.8 Turtle Creek-Loramie Creek (05080001 06)

The Loramie Valley Alliance (LVA) works in both Loramie Creek subwatersheds (05 and 06). They have a watershed management plan that was approved in 1999. No updated watershed management plan has been submitted for state endorsement.

Nutrient runoff and habitat alterations have been identified as the major factors leading to the degraded conditions documented in both sub-watersheds. The LVA funded the following projects (along with state and federal grants) to address the problems documented in the watershed:

- Eight streambank stabilization projects: *(50% of cost, up to $4000)* - Prevents erosion by installing natural vegetation and fiber materials into streambanks.
- Seven feedlot improvement projects (50% cost of fence, not to exceed $1.10/lineal foot; 50% of critical area seeding not to exceed $91/acre; 50% cost of alternative watering system, not to exceed $500/system) - Reduce nutrient runoff from livestock facilities.
- Eight low impact log jam removal projects. The LVA contracts with the property owner to conduct the removal. Log jams were causing stream bank erosion and acting as a low head dam. Done on mainstem of Loramie Creek.
- Ten filter strip projects: *($500/acre one-time bonus for trees; $90/acre one-time bonus for grass)* - Plant an area of grass or trees between cropland and streams or ditches to prevent erosion and chemical runoff. This was popular but has not seen much support in recent years.
- Strip-till equipment buy-down *(20% Cost-share, up to $4,000)* - Strip-till is a compliment to no-till. Bands of loosened soil are prepared before planting. This practice has the potential for combining the advantages of conventional tillage with no-till.
- Four natural retention area restoration projects - Creates or restores wetland areas to hold water during heavy rains and provide water quality benefits.
- Three milkhouse wetland systems - provide 50% up to $3500 for the installation of a constructed milkhouse/parlor wastewater treatment system.
- Twenty cover crop in conjunction with the MCD nutrient trading program ($5/acre up to $500) - Reduce the erosion potential on fields when a growing crop is not present.
- Ten secondary fertilizer containment systems – Designed to prevent pollution by installing secondary containment around bulk storage tanks.

Agricultural practices and failing HSTSs are probable sources of recreation use impairment in this subwatershed. Ohio EPA recommends that local health departments test HSTS to find those that are failing and that these be repaired or replaced. Manure spreading should not take place prior to rain events, nor should manure be spread on frozen ground. NRCS practices 633, 313, 634, and 635 can be consulted for appropriate manure practices (see Appendix F). In addition, NRCS practices 580 and 590 should be encouraged in the Environmental Quality Incentives Program and through the MCD nutrient trading program to sequester nutrients and stabilize soil runoff after the growing season.

6.9 Reasonable Assurances

The recommendations made in this TMDL report will be carried out if the appropriate entities work to implement them. In particular, activities that do not fall under regulatory authority require that there be a committed effort by state and local agencies, governments, and private groups to carry out and/or facilitate such actions. The availability of adequate resources is also imperative for successful implementation.

When a TMDL is developed for waters impaired by point sources only, the issuance of a NPDES permit(s) provides the reasonable assurance that the wasteload allocations contained in the TMDL will be achieved. This is because 40 C.F.R. 122.44(d)(1)(vii)(B) requires that effluent limits in permits be consistent with the assumptions and requirements of any available wasteload allocation in an approved TMDL.

When a TMDL is developed for waters impaired by both point and nonpoint sources, and the WLA is based on an assumption that nonpoint source load reductions will occur, U.S. EPA's 1991 TMDL Guidance states that the TMDL should provide reasonable assurances that nonpoint source control measures will achieve expected load reductions. To this end, Appendix E discusses organizations and programs that have an important role or can provide assistance for meeting the goals and recommendations of this TMDL. Efforts specific to this watershed are described in this section.

6.9.1 Local Watershed Groups

The Greater Dayton Partners for the Environment (GDPE) is coordinating the Great Miami River Watershed Water Quality Improvement Program. This watershed-wide program will integrate a consistent approach that includes voluntary incentives to improve water quality in the Great Miami River watershed. The Great Miami River (upper) TMDL and subsequent Great Miami River TMDL reports (middle and lower) will be part of a holistic group of programs involving the Greater Dayton Partners for the Environment (including 10 community-based watershed organizations), the Miami Conservancy District, local communities, WWTPs, community groups and 15 soil and water conservation district offices. The programs include the watershed-wide nutrient trading program and grant funding aimed at voluntary water quality improvement needs identified in the TMDL.

Having a complete TMDL report will help the communities in the watershed be eligible for grant monies that would not otherwise be available to promote the initial implementation and long-term sustainability of water quality projects. Accessing funding for nonpoint source projects such as the Great Miami River Watershed Water Quality Credit Trading Program, USDA's Mississippi River Basin Initiative, USDA's Conservation Innovation Grant, the U.S. EPA-supported Water Technology Innovation Cluster, ODNR's Tool Box Grant, and MVRPC's 604(b) monies are key to the overall success of the TMDL implementation.

There are two watershed groups in the Great Miami River (upper) watershed that have been contacted to be a part of this larger watershed network. The Indian Lake Watershed Project was formed in 1990 to address sedimentation and water quality issues that had become apparent to all lake users. With technical assistance from various government agencies watershed agricultural producers, lake property owners, and lake businesses came together to improve conditions. As a result of their efforts, sedimentation has been reduced by 80% through changes in farming practices such as conservation tillage and buffer strips. They also promote nutrient management for fertilizer and manure application to reduce nutrient inputs to the lake. Water clarity which had been less than one foot has improved to more than two feet.

The other watershed group is the Loramie Watershed Alliance (LVA), which is involved with the entire Loramie Creek watershed, not just the lake watershed. This group also promotes conservation practices to reduce sedimentation and nutrient inputs as well as promoting log jam removals with retention of wooded riparian zones.

6.9.2 Other Sources of Funding and Special Projects

The LVA received a 319 grant covering 1999-2004. Seven objectives were accomplished. The project accomplishments were:

- Increase recognition of the LVA goals and objectives through educational activities.
- Facilitate riparian corridor restoration by establishing a 27.9 acre woodland filter strip
- Promotion of 191 acres of CRP grass buffer strips.
- Install 4000 linear feet of fencing, 28 acres of critical area seeding. Add 5 watering systems to exclude livestock from streams in Loramie Creek.
- Install nine strip-till systems in watershed.
- Increase the use of manure injection systems within the watershed to 10 farms.
- Employ a Project coordinator.

The Indian Lake Watershed Project:

- 1.4 million dollars were awarded in U.S. EPA 319 funding for no-till planters and drills.
- 743,000 dollars in low interest loans were received through DEFA.
- 74 acres of grassed waterways have been installed.
- 264 acres of wooded and grassed filter strips have been installed.

6.9.3 Past and Ongoing Water Resource Evaluation

Stream studies have been undertaken by Ohio EPA in 1982, 1988, 1994 and 2008. There has been a trend of improving aquatic life use support in all rivers and tributaries in each successive stream study undertaken.

Recommended Approach for Gathering and Using Available Data

Early communications should take place between the Ohio EPA and any potential collaborators to discuss research interests and objectives. Areas of overlap should be identified and ways to make all parties research efforts more efficient should be discussed. Ultimately, important questions can be addressed by working collectively and through pooling resources, knowledge and data.

6.9.4 Potential and Future Evaluation

The SWAT model that was developed for this TMDL for the Loramie Creek and Little Muchinippi Creek subwatersheds could be used in the future to evaluate proposed implementation practices. Should a local interested group commit to developing more detailed plans for water quality improvement, Ohio EPA may be able to provide modeling assistance if resources allow.

6.9.5 Revision to the Improvement Strategy

The Great Miami River (upper) watershed would benefit from an adaptive management approach to restoring water quality. An adaptive management approach allows for changes in the management strategy if environmental indicators suggest that the current strategy is inadequate or ineffective. Adaptive management is recognized as a viable strategy for managing natural resources (Baydack *et al.* 1999).

If water quality does not show improvement and/or water bodies are still not attaining water quality standards after the improvement strategy has been carried out, then a TMDL revision would be initiated. The Ohio EPA would initiate the revision if no other parties wish to do so.

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