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Ohio Environmental Protection Agency

Total Maximum Daily Loads for the Paint Creek Watershed

Final Report
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Mary Taylor, Lt. Governor
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Photo caption: Paint Creek at State Route 753 upstream of Greenfield in Fayette County, Ohio.

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Acronyms and Abbreviations

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
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)
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
MOR	monthly operating report
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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Executive Summary

The Paint Creek watershed is located in southwest Ohio extending from Madison County in the north to the Hillsboro area in the southwest, and Chillicothe in the east. This 1,142 square mile watershed area is home to more than 140,000 people and encompasses all or part of 18 municipalities in Fayette, Highland, Ross, Greene, Clinton and Pickaway counties. The watershed is primarily agricultural and forested with approximately six percent being developed.

State map with Paint Creek watershed highlighted.

In 2006, Ohio EPA sampled 140 sites on streams in this watershed and more limited follow-up sampling was conducted in 2008. Data was 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 are being met.

Overall the watershed met criteria for the recreation use at 32 percent of the sites monitored, at 68 percent for aquatic life uses, and at 60 percent for the human health use. There was not sufficient data to evaluate attainment status for public drinking water supply use. The most significant causes of impairments included *E. coli* bacteria, sediment, nutrients, low dissolved oxygen, altered habitat and flow conditions, and organic enrichment. Sources of these stressors include home septic systems for *E. coli*, organic enrichment and nutrients, cropland runoff and drainage for sediment and nutrients, channelization for poor habitat, flow alterations and sediment, waste water treatment plants for nutrients, dissolved oxygen problems, organic enrichment, and toxicity and urban runoff toxicity, altered flow, nutrients, organic enrichment.

Total maximum daily loads (TMDL) were developed for pollutants and stressors that impair beneficial uses and preclude attainment of applicable water quality standards. Specific TMDLs that were developed and described in this report include:

- Sediment
- Nutrients (and associated impacts to dissolved oxygen)
- Habitat alterations
- *E. coli* bacteria

The needed load reductions ranged from 0 to 100 percent for *E. coli* across all flow regimes and 41 to 53 percent for total phosphorus for landscape based loading, while the existing sediment and habitat conditions (i.e., based on habitat evaluations) deviated from the targets by 2 to 44 percent and 33 to 100 percent, respectively. Sources of the pollutants that have been allocated the most significant reductions include home septic systems, sources of livestock manures and waste water discharges and cropland runoff.

Recommendations for regulatory action resulting from this TMDL analysis include lower effluent limits for total phosphorus. Nonpoint sources of total phosphorus should be addressed by nutrient management (e.g., reduced rate application), cover crops and mulches, and treatment of runoff in buffers and wetlands; for *E. coli* bacteria by ensuring adequate function of home septic systems, managing livestock wastes, and reducing leaks and overflows of untreated sewage; for sediment by reducing tillage and improved tillage and cropping practices (e.g., contour cropping); and for habitat by improving riparian and floodplain conditions through active planting or allowing natural re-establishment of vegetation and/or floodplain connection along stream-side areas.

1 INTRODUCTION

The Paint Creek watershed occupies a 1,142 square mile area that is southwest of Columbus and east of Dayton and Cincinnati. Paint Creek is the largest tributary stream to the Scioto River and it joins Ohio's longest river in Chillicothe approximately 63 river miles before the Scioto River joins the Ohio River. Chillicothe and Washington Court House are the two largest municipalities in the watershed; however, there are 16 other towns that range in population from just over 6,000 people to approximately 100 people. In the past the Paint Creek river system has exhibited high quality in terms of the biological diversity of fish and aquatic macroinvertebrate communities.

In 2006, Ohio EPA performed its standard, basin-wide evaluation of water quality. Entailed was collection of approximately six water samples per 135 different locations distributed throughout the watershed where both *E. coli* bacteria and chemical pollutants were analyzed for their concentrations in the samples. At 123 of these sites, the fish and aquatic macroinvertebrate communities were also surveyed and habitat was evaluated using a qualitative index (Qualitative Habitat Evaluation Index – QHEI). Stream sediment was collected at 20 locations to test for presence of toxic chemicals that can adversely impact the biological community and enter the food web of the ecosystem.

Results of the study indicate that criteria established to protect recreation uses of the stream system in the Paint Creek watershed were not met at over two-thirds of the sites evaluated (68%). The majority of this water quality impairment was found in streams tributary to Paint Creek, while the mainstem itself below the dam for Paint Creek Lake met criteria at every site sampled. Every site evaluated on Paint Creek upstream of Paint Creek Lake failed to meet the criteria for its recreation uses. Results from the biological sampling suggest that majority of the basin is supporting the types of aquatic communities that they should be; however, 24 percent of the sites demonstrated some problem with the species distribution of the organisms (i.e., partial attainment of the criteria) and seven percent showed significant problems (non-attainment of the criteria).

Primary reasons for the impaired aquatic communities included excess fine sediment on the bed substrate, elevated nutrient and eutrophic conditions, organic enrichment and dissolved oxygen depletion, poor habitat and flow conditions that have been altered from their normal regime. Recreation uses are impaired by the elevated concentrations of *E. coli* bacteria. Sources for these water quality stressors included improperly functioning home sewage treatment systems (HSTS), cropland runoff, wastewater discharges, runoff from urban areas and sewer overflows, and channelization of natural channels to facilitate land drainage.

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 Paint Creek watershed (assessment units 0506003 01 01 through 01 03, 02 01 through 02 02, 03 01 through 03 05, 04 01 through 04 07, 05 01 through 05 05, 06 01 through 06 03, 07 01 through 07 04, 08 01 through 08 05, 09 01 through 09 04, and 10 01 through 10 03 as impaired on the 2010 303(d) list (Ohio EPA 2010; available at http://www.epa.state.oh.us/dsw/tmdl/2010IntReport/2010OhioIntegratedReport.aspx).

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.

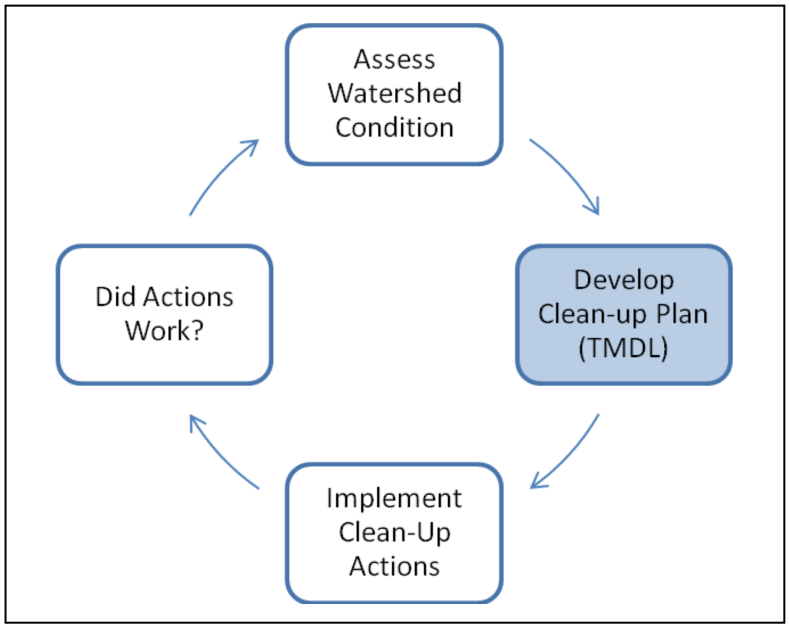


Figure 1-1. Overview of the TMDL project process.

Table 1-1 summarizes how the impairments identified in the Paint Creek watershed are addressed in this TMDL report.

Table 1-1. Summary of impairments in the Paint Creek watershed and methods used to address impairments.

Assessment Unit (05060003)	Narrative Description	Causes of Impairment (Beneficial use in parentheses)	Action Taken
Headwaters Paint Creek (05060003 01)			
01 01	Headwaters Paint Creek	Insufficient data to assess (ALU[1])	No action necessary
Priority points: 3		*E. coli* (RU[2])	Bacteria TMDL
01 02	East Fork Paint Creek	Dissolved oxygen (ALU)	Nutrient TMDL as surrogate
Priority points: 6		Sedimentation/siltation (ALU)	Sediment TMDL
		Other flow regime alterations (ALU)	Habitat TMDL
		E. coli (RU)	Bacteria TMDL
01 03	Town of Washington Court House-Paint	Dissolved oxygen (ALU)	Nutrient TMDL as surrogate

Assessment Unit (05060003)	Narrative Description	Causes of Impairment (Beneficial use in parentheses)	Action Taken
Priority points: 7	Creek	Sedimentation/siltation (ALU)	Sediment TMDL
		Nutrient eutrophication biological indicators (ALU)	Nutrient TMDL
		Direct habitat alterations (ALU)	Habitat TMDL
		Other flow regime alterations (ALU)	Habitat TMDL
		E. coli (RU)	Bacteria TMDL
		Insufficient data to assess (PDWSU)	No action necessary
Sugar Creek (05060003 02)			
02 01 *Priority points: 5*	Headwaters Sugar Creek	Direct habitat alterations (ALU)	Habitat TMDL
		Nutrient eutrophication biological indicators (ALU)	Nutrient TMDL
		Dissolved oxygen (ALU)	Nutrient TMDL as surrogate
		E. coli (RU)	Bacteria TMDL
02 02 *Priority points: 6*	Camp Run-Sugar Creek	Nutrient eutrophication biological indicators (ALU)	Nutrient TMDL
		E. coli (RU)	Bacteria TMDL
Headwaters Rattlesnake Creek (05060003 03)			
03 01 *Priority points: 2*	Wilson Creek	Impairment unknown (ALU)	No action necessary
		Direct habitat alterations (ALU)	Habitat TMDL
		Organic enrichment (sewage) biological indicators (ALU)	Bacteria TMDL as surrogate
		Ammonia (total) (ALU)	Bacteria TMDL as surrogate
		E. coli (RU)	Bacteria TMDL
03 02 *Priority points: 1*	Grassy Branch	Other flow regime alterations (ALU)	Habitat TMDL
		No impairment (RU)	No action necessary
03 03 *Priority points: 3*	West Branch Rattlesnake Creek	Sedimentation/siltation (ALU)	Sediment TMDL
		Dissolved oxygen (ALU)	Habitat TMDL as surrogate
		E. coli (RU)	Bacteria TMDL
03 04 *Priority points: 7*	Headwaters Rattlesnake Creek	Direct habitat alterations (ALU)	Habitat TMDL
		Dissolved oxygen (ALU)	Habitat TMDL as surrogate
		E. coli (RU)	Bacteria TMDL
03 05 *Priority points: 7*	Waddle Ditch-Rattlesnake Creek	Direct habitat alterations (ALU)	Habitat TMDL
		Sedimentation/siltation (ALU)	Sediment TMDL
		E. coli (RU)	Bacteria TMDL
Lees Creek-Rattlesnake Creek (05060003 04)			
04 01 *Priority points: 4*	South Fork Lees Creek	Organic enrichment (sewage) biological indicators (ALU)	Bacteria TMDL as surrogate
		Dissolved oxygen (ALU)	Bacteria TMDL as surrogate

Assessment Unit (05060003)	Narrative Description	Causes of Impairment (Beneficial use in parentheses)	Action Taken
		Ammonia (total) (ALU)	Bacteria TMDL as surrogate
		E. coli (RU)	Bacteria TMDL
04 02 *Priority points: 0*	Middle Fork Lees Creek	No impairment (ALU)	No action necessary
		No impairment (RU)	No action necessary
04 03 *Priority points: 5*	Lees Creek	Other flow regime alterations (ALU)	Habitat TMDL
		Organic enrichment (sewage) biological indicators (ALU)	Bacteria TMDL as surrogate
		Dissolved oxygen (ALU)	Bacteria TMDL as surrogate
		E. coli (RU)	Bacteria TMDL
04 04 *Priority points: 3*	Walnut Creek	No impairment (ALU)	No action necessary
		E. coli (RU)	Bacteria TMDL
04 05 *Priority points: 0*	Hardin Creek	No impairment (ALU)	No action necessary
		No impairment (RU)	No action necessary
04 06 *Priority points: 3*	Fall Creek	Organic enrichment (sewage) biological indicators (ALU)	Not addressed
		Nutrient eutrophication biological indicators (ALU)	Not addressed
		No impairment (RU)	No action necessary
04 07 *Priority points: 4*	Big Branch-Rattlesnake Creek	No impairment (ALU)	No action necessary
		E. coli (RU)	Bacteria TMDL
Rocky Fork (05060003 05)			
05 01 *Priority points: 0*	South Fork Rocky Fork	No impairment (ALU)	No action necessary
		No data for assessment (RU)	No action necessary
05 02 *Priority points: 7*	Clear Creek	Organic enrichment (sewage) biological indicators (ALU)	Narrative of upgraded Hillsboro WWTP
		Other flow regime alterations (ALU)	Habitat TMDL
		E. coli (RU)	Bacteria TMDL
		Insufficient data to assess (PDWSU)	No action necessary
05 03 *Priority points: 5*	Headwaters Rocky Fork	No impairment (ALU)	No action necessary
		E. coli (RU)	Bacteria TMDL
05 04 *Priority points: 0*	Rocky Fork Lake-Rocky Fork	No data for assessment (ALU)	No action necessary
		No data for assessment (RU)	No action necessary
05 05 *Priority points: 10*	Franklin Branch-Rocky Fork	Nutrient eutrophication biological indicators (ALU)	Bacteria TMDL as surrogate
		E. coli (RU)	Bacteria TMDL
Indian Creek-Paint Creek (05060003 06)			
06 01 *Priority points: 11*	Indian Creek-Paint Creek	Natural conditions (flow or habitat) (ALU)	No action necessary
		Nutrient/eutrophication biological indicators (ALU)	Nutrient TMDL (Indian Creek only)

Assessment Unit (05060003)	Narrative Description	Causes of Impairment (Beneficial use in parentheses)	Action Taken
		Other flow regime alterations (ALU)	Habitat TMDL
		E. coli (RU)	Bacteria TMDL (Indian Creek only)
06 02 *Priority points: 11*	Farmers Run-Paint Creek	Organic enrichment (sewage) biological indicators (ALU)	Bacteria TMDL as surrogates
		E. coli (RU)	Bacteria TMDL
06 03 *Priority points: 2*	Cliff Creek-Paint Creek	No data for assessment (ALU)	No action necessary
		No impairment (RU)	No action necessary
Buckskin Creek-Paint Creek (05060003 07)			
07 01 *Priority points: 6*	Buckskin Creek	Nutrient/eutrophication biological indicators (ALU)	Bacteria TMDL as surrogate
		Other flow regime alterations (ALU)	Habitat TMDL
		E. coli (RU)	Bacteria TMDL
07 02 *Priority points: 3*	Upper Twin Creek	No impairment (ALU)	No action necessary
		E. coli (RU)	Bacteria TMDL
07 03 *Priority points: 4*	Lower Twin Creek	Insufficient data to assess (ALU)	No action necessary
		E. coli (RU)	Bacteria TMDL
07 04 *Priority points: 9*	Sulphur Lick-Paint Creek	Direct habitat alterations (ALU)	Habitat TMDL
		Sedimentation/siltation (ALU)	Sediment TMDL
		Dissolved oxygen (ALU)	Habitat TMDL as surrogate
		E. coli (RU)	Bacteria TMDL
Headwaters North Fork Paint Creek (05060003 08)			
08 01 *Priority points: 3*	Thompson Creek	No impairment (ALU)	No action necessary
		E. coli (RU)	Bacteria TMDL
08 02 *Priority points: 0*	Headwaters North Fork Paint Creek	No impairment (ALU)	No action necessary
		No impairment (RU)	No action necessary
08 03 *Priority points: 3*	Headwaters Compton Creek	No impairment (ALU)	No action necessary
		E. coli (RU)	Bacteria TMDL
08 04 *Priority points: 4*	Mills Branch-Compton Creek	No impairment (ALU)	No action necessary
		E. coli (RU)	Bacteria TMDL
08 05 *Priority points: 6*	Mud Run-North Fork Paint Creek	No impairment (ALU)	No action necessary
		E. coli (RU)	Bacteria TMDL
Little Creek-North Fork Paint Creek (05060003 09)			
09 01 *Priority points: 0*	Herrod Creek	No data for assessment (ALU)	No action necessary
		No data for assessment (RU)	No action necessary
09 02 *Priority points: 2*	Little Creek	No impairment (ALU)	No action necessary
		E. coli (RU)	Bacteria TMDL
09 03 *Priority points: 7*	Oldtown Run-North Fork Paint Creek	Organic enrichment (sewage) biological indicators (ALU)	Bacteria TMDL as surrogate
		Sedimentation/siltation (ALU)	Sediment TMDL
		E. coli (RU)	Bacteria TMDL

Assessment Unit (05060003)	Narrative Description	Causes of Impairment (Beneficial use in parentheses)	Action Taken
09 04 *Priority points: 4*	Biers Run-North Fork Paint Creek	No impairment (ALU)	No action necessary
		E. coli (RU)	Bacteria TMDL
Ralston Run-Paint Creek (05060003 10)			
10 01 *Priority points: 0*	Black Run	No impairment (ALU)	No action necessary
		No impairment (RU)	No action necessary
10 02 *Priority points: 5*	Ralston Run	Organic enrichment (sewage) biological indicators (ALU)	Bacteria TMDL as surrogate
		Sedimentation/siltation (ALU)	Sediment TMDL
		E. coli (RU)	Bacteria TMDL
10 03 *Priority points: 8*	City of Chillicothe-Paint Creek	No impairment (ALU)	No action necessary
		E. coli (RU)	Bacteria TMDL
Paint Creek (Paint Creek Lake dam to mouth)			
Large River *Priority points: 4*	Paint Creek Mainstem (Rocky Fork to mouth)	Dissolved oxygen (ALU)	Narrative
		No impairment (RU)	No action necessary

[1] ALU refers to aquatic life uses, as established in rules in ORC 3745.09.
[2] RU refers to recreation uses, as established in rules in ORC 3745.09.
[3] When associated with LSPC in the table, dissolved oxygen indicates that the model output of concern was whether targets established for dissolved oxygen would be met relative to the loading to the system (i.e., model inputs).

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 Paint Creek watershed TMDL project has been completed using the process endorsed by the advisory group.

An electrofishing demonstration was held on the North Fork of Paint Creek on August 13, 2008 for local farmers and residents. Ohio EPA staff explained the results from the 2006 field survey and what types of fish were found during the demonstration. In addition, there was discussion of practices that both degrade and improve water quality. On October 14, 2008 Ohio EPA presented results and information regarding the TMDL process to the Washington Court House Rotary Club.

On January 6, 2009, Ohio EPA staff presented results of the field survey to the Fayette County Farm Bureau Council. Discussions regarding the effects of various farming practices on water quality were held and questions were answered from Farm Bureau members. Ohio EPA staff members met with the Fayette County Soil and Water Conservation District (SWCD) on February 10, 2009. Ohio EPA explained the results of the 2006 field survey and discussed what recommendations Ohio EPA was likely to make for improving water quality.

Consistent with Ohio's current Continuous Planning Process (CPP), the draft TMDL report was available for public comment between January 10 and February 10, 2012. No public comments were received regarding the draft 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 Paint Creek 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 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 Paint Creek watershed is located immediately west of the City of Chillicothe, and encompasses nearly all of Fayette County, as well as significant portions of Ross and Highland counties. Smaller portions of the watershed are in Madison, Clark, Greene, Clinton, Pike and Pickaway counties. The topography in Fayette County is flat to rolling, while the hills gradually become a more prominent feature of the landscape as one moves into Ross and Highland counties. However, the Paint Creek mainstem flows through a broad, level valley throughout much of Ross County.

2.1 Watershed Characteristics

The following subsections provide an overview of the characteristics of the Paint Creek watershed.

2.1.1 Population

Based upon the year 2000 U.S. Census, the population of Fayette, Ross, and Highland counties is approximately 143,000 people with the population density ranging from 69.9 (Fayette) to 107 persons per square mile (Ross). By comparison, the population density of the State of Ohio is 277 persons per square mile; the difference emphasizes the rural nature of the Paint Creek watershed. Figure 2-1 shows the distribution of the population density of the watershed based on census blocks from the 2000 census.

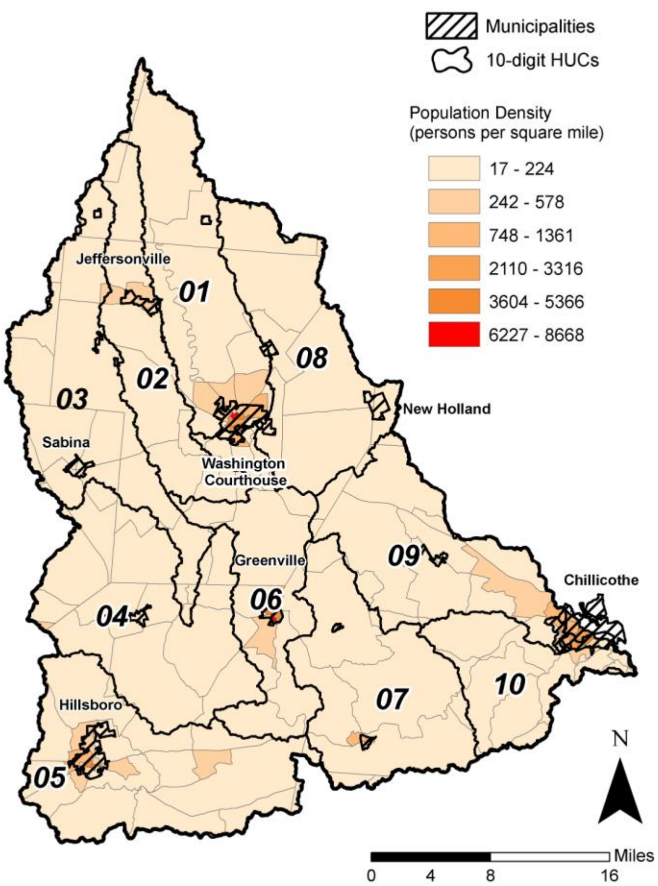


Figure 2-1. Population density based on U.S. Census Bureau census blocks.

The largest cities contained entirely within the watershed are Washington Court House (population of 13,524), Hillsboro (population of 6,368), and Greenfield (population of 4,906). Chillicothe has a population of

21,796 according to the year 2000 U.S. Census, but only a portion of this city is within the Paint Creek watershed.

Population growth between the 1990 and 2000 Census was 3.49 percent in Fayette County, 9.96 percent for Highland County, and 6.69 percent for Ross County. The highest rates of growth in Highland County were in census blocks in the northwest quarter of the county where population growth as high as 49 percent occurred. Despite the high rates of growth in Highland County, the county remains essentially rural in character, with population densities outside Hillsboro and Leesburg falling below 100 people per square mile (see Figure 2-1). Other areas with high growth rates were the census blocks west of Chillicothe, especially along U.S. Routes 35 and 50, where growth rates ranged between 20 and 50 percent, and population densities approached 300 people per square mile.

2.1.2 Land Use

The Paint Creek watershed north of Greenfield is situated in the Wisconsin till plain, and has the low relief and rich soils conducive to intensive row crop agriculture. As an illustration of the geology found north of Greenfield, land use in this part of the basin approaches 90 percent row crop agriculture (see Figure 2-2). South of the Wisconsinan glacial boundary, the watershed is more dissected, given the older age of the Illinoisan deposits, and highly dissected along the southern edge of the unglaciated Appalachian foothills. As such, the landscape is not as well suited to row crop agriculture, and land use changes to a greater percentage of pasture and forest cover. County-level farm statistics reflect the change in land use for the southern portion of Paint Creek watershed. Roughly ninety percent of the farmed acreage in Fayette County is devoted to corn and soybeans, whereas roughly half the farmed acreage for Highland and Ross counties consists of row crops.

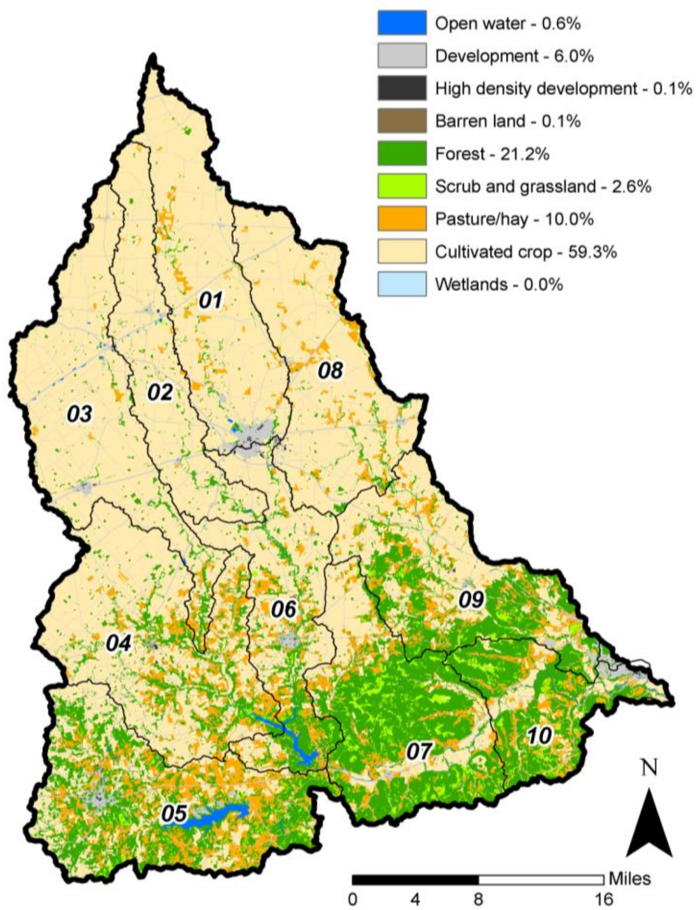


Figure 2-2. Land uses in the Paint Creek watershed.

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, siltation, 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, metals and silt.

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 are more likely to cause severe water quality problems because their effluent can dominate the natural stream flow. Appendix A lists the NPDES permittees in the Paint Creek watershed and shows the locations of all facilities currently discharging under an NPDES permit.

Two of the subwatersheds (Headwaters Paint Creek and Rocky Fork) contain seven facilities each with an NPDES permit. The number of facilities with NPDES permits in the other subwatersheds ranges from three to six. The discharge from the majority of these facilities is quite small, with only five out of 39 facilities having an average flow rate greater than 1.0 million gallons per day (MGD), and 10 facilities have an average flow rate between 100,000 gallons per day and one million gallons per day. Thirty-four of the permitted facilities are classified as some type of publicly operated wastewater treatment works. Overall it is currently estimated that the daily discharge of wastewater throughout the entire basin is just over 37 million gallons; however, current design capacity of the aggregate of all of these facilities is nearly 49 million gallons per day. To provide context to the magnitude of the waste water contribution to stream flow, these waste water flow rates are equivalent to the eleventh and sixteenth flow percentiles, respectively for Paint Creek near Bourneville (drainage area of 871 square miles) for the period of record from 1975 (just following dam construction) to 1998. This means that eleven percent of the average daily stream flows had a magnitude that is less than what the average waste water discharge rates is (however, Paint Creek is flow regulated at this point due to dam at Paint Creek Lake).

There are no combined sewer systems in the project area; however, there are several wastewater systems with documented sanitary overflows (see Table 2-1). Sanitary sewer overflows (SSOs) represent failure and/or inadequacies in the wastewater collection system where untreated sewage is discharged. These overflows are not permissible and must be rectified by the entities responsible for the system, typically according to a formal compliance schedule. For this reason, no allocations are made towards these overflows for any of the TMDL parameters in this report.

In addition to wastewater, confined animal feeding operations (CAFOs) and storm water emanating from industries and certain municipal areas are likewise considered potentially damaging to water quality and water uses and therefore is required NPDES coverage. For municipal areas this requirement is primarily based on the size of the municipal separate storm sewer system (MS4) as indicated by the size and/or density of the population that resides within the confines of the system. In the Paint Creek watershed, only one MS4 currently is required NPDES coverage, namely the one associated with Washington Courthouse (permit number = 4GQ00027*AG). For CAFOs, the requirement for obtaining NPDES coverage for a given operation is predicated on the number and type of animals in the system that are to be confined in an area not having maintained natural vegetation for a period of 45 days or more per twelve month period. One of the five CAFOs in the Paint Creek watershed have NPDES coverage, namely the Gill Dairy LLC (permit number = 4IK00027*AD).

Table 2-1. NPDES systems with documented sanitary sewer overflows.

12-digit HUC (last 4)	Ohio EPA permit number	Facility	Average design flow discharge (MGD)	Average discharge (MGD)
0103	4PD00002001	Washington Court House WWTP	6.00	3.34
0201	4PB00013001	Jeffersonville WWTP	0.10	0.04
0301	1PB00038001	Sabina STP	0.38	0.40
0502	1PC00100001	Hillsboro STP	1.20	1.31
0503	1PS00015001	Rocky Fork Lake WWTP	0.30	0.19
0602	1PD00022001	Greenfield WWTP	1.60	0.87
0701	0PA00018001	South Salem WWTP	0.03	0.05
0805	4PB00028001	New Holland WWTP	0.15	0.11
0903	0PB00014001	Frankfort WWTP	0.19	0.11
0904	0PQ00002001	Pleasant Valley Regional SD	0.90	0.99

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. Surface water public drinking water supplies for the communities of Washington Court House and Hillsboro are located in the Paint Creek watershed. More details are available in Appendix B.

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, 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 assignments specific to Paint Creek and its tributaries are in rules 3745-1-09. 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 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, scum, color and odor-producing materials; substances that are harmful to human or animal health; and nutrients in concentrations that may cause excessive algal growth. Narrative “free froms,” also located in rule 3745-1-04 of the OAC, are general water quality criteria 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 Paint Creek 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 (see Table 2-2).

Table 2-2. Biocriteria applicable in the Paint Creek watershed.

Ecoregion	Biological Index	Assessment Method[2, 3]	Biological Criteria for the Applicable Aquatic Life Use Designations[1]		
			WWH	EWH	MWH[4]
Eastern Cornbelt Plains (ECBP)	IBI	Headwater	40	50	24
		Wading	40	50	24
		Boat	42	48	24 / 30
	MIwb	Wading	8.3	9.4	6.2
		Boat	8.5	9.6	5.8 / 6.6
	ICI	All[5]	36	46	22
Interior Plateau (IP)[6]	IBI	Headwater	40	50	24
		Wading	40	50	24
		Boat	38	48	24 / 30
	MIwb	Wading	8.1	9.4	6.2
		Boat	8.7	9.6	5.8 / 6.6
	ICI	All[5]	30	46	22
Western Allegheny Plateau (WAP)	IBI	Headwater	44	50	24 / / 24
		Wading	44	50	24 / / 24
		Boat	40	48	24 / 30 / 24
	MIwb	Wading	8.4	9.4	6.2 / / 5.5
		Boat	8.6	9.6	5.8 / 6.6 / 5.4
	ICI	All[5]	36	46	22 / / 30

[1] Coldwater habitats (CWH), limited warmwater habitat (LWH), resource waters (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: DA > 500 mi^2
[3] MIwb not applicable to drainage areas less than 20 mi^2.
[4] Biocriteria depend on type of MWH. MWH-C (due to channelization) is listed first, MWH-I (due to impoundment) is listed second, and MWH-A (mine affected) is listed third (only applicable in the WAP).
[5] Limited to sites with appropriate conditions for artificial substrate placement.
[6] Only a very narrow portion of the southern edge of the watershed overlaps with the Interior Plateau ecoregion in Highland County. No sites were sampled in this ecoregion.

Figure 2-3 shows the aquatic life use designations for the streams in the Paint Creek watershed. As illustrated in the map, the majority of streams have been designated as warmwater habitat (WWH). However, a number of streams in the southern and eastern portions of the watershed are exceptional warmwater habitat (EWH), with a few streams in the northwestern portion designated as modified warmwater habitat (MWH). Five relatively small tributary streams have been designated as coldwater habitat (CWH) in the Rocky Fork subwatershed as well as streams near the mouth of Paint Creek. These streams maintain relative cool water temperatures throughout the year due to ground water contributions and/or substantial shading, which fosters a specialized aquatic community that includes species adapted to such stream conditions.

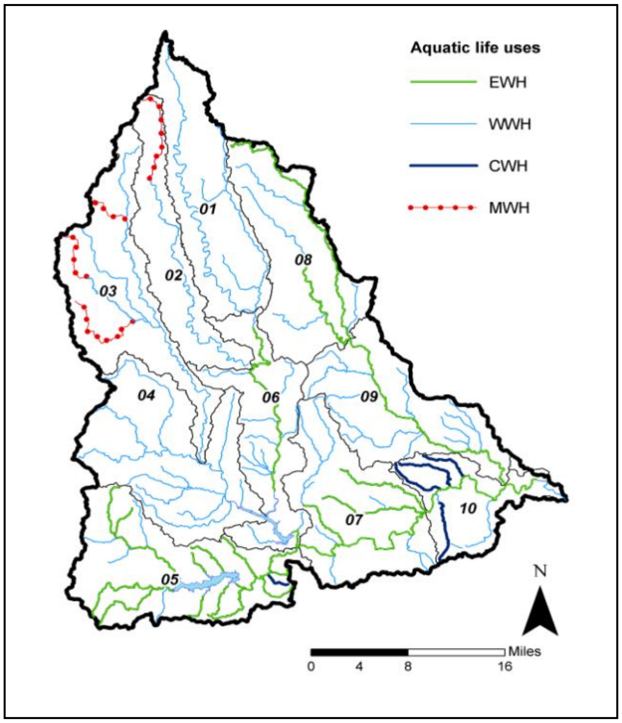


Figure 2-3. Paint Creek watershed aquatic life use designations.

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 2-3 contains a summary of the water quality criteria for the various recreation uses.

Table 2-3. 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[2]
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 *2*, these criteria shall not be exceeded in more than ten per cent of the samples taken during any thirty-day period.
[2] This criterion shall be used for the issuance of beach and bathing water advisories.

Figure 2.4 shows the designated recreation uses that have been assigned to streams within the Paint Creek watershed. The map indicates that most of the Paint Creek mainstem and most of North Fork Paint Creek and Rocky Fork are categorized as Class A primary contact recreation (PCR). All other streams shown are Class B primary contact recreation.

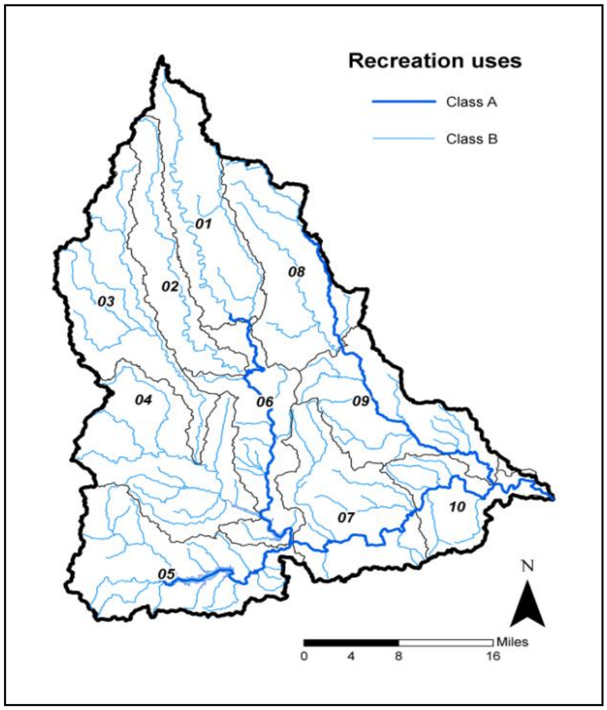


Figure 2-4. Paint Creek watershed recreation use designations.

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.

See Figure 2.5 for a map showing the public water supply use designations in the Paint Creek watershed. There were insufficient data available to determine use support for the 2010 Ohio Integrated Report (Ohio EPA 2010).

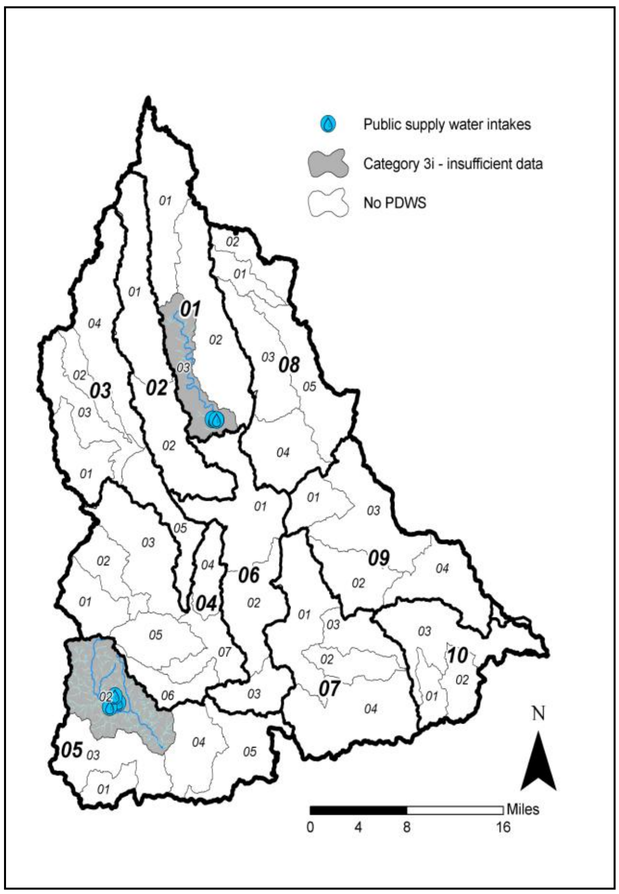


Figure 2-5. Paint Creek watershed public water supply use designations.

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 bio-accumulate 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.

Data from 2006 exist for only a few nested subwatersheds and the large river. In those subwatersheds (http://wwwapp.epa.ohio.gov/dsw/ir2010/watershed.php?id=05060003), the use is supported in three nested subwatersheds and not supported in two. Including historical data (older than ten years), an additional four nested subwatersheds support the use and an additional four do not. The large river assessment unit does not support the use (http://wwwapp.epa.ohio.gov/dsw/ir2010/lrau.php?id=050600039001).

Two common contaminants in fish tissue 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 Paint Creek watershed will be taken.

The Paint Creek watershed is included in the statewide fish advisory for mercury. Additional advisories specific to the Paint Creek watershed exist. Information regarding fish consumption advisories can be found at: http://www.epa.ohio.gov/dsw/fishadvisory/index.aspx.

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 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.

Ohio EPA performed a comprehensive water quality study in the Paint Creek watershed in 2006. One hundred twenty-four sites were studied for biological health (or aquatic life), 140 sites for water chemistry, 106 sites for recreation use, and sites in ten nested subwatersheds for human health (fish contaminants) use. In 2008, additional sampling was conducted for recreation use at 23 sites, visiting some of the same sites evaluated in 2006. Generally speaking, sites were scattered throughout the watershed with more concentrated sampling occurring in locations where water quality problems were anticipated or where known sources of pollution were present.

Figure 3-1 shows the distribution of sampling sites within the watershed that are in full attainment, partial attainment, and non-attainment of the aquatic life use designations. As evidenced by this figure, most of the watershed meets water quality standards for aquatic life, but there are areas that are not in attainment. The top five water quality stressors are low dissolved oxygen, nutrient enrichment, excessive fine sediment, poor habitat quality and organic enrichment. The primary sources of these stressors are activities associated with agriculture and stream channelization as well as wastewater discharges and sewer system overflows. Figure 3-2 shows in the top pie chart the proportion of sites that are impacted by the various water quality stressors (i.e., causes of impairment) that were identified in the study while the bottom chart shows the proportion of sites that are impacted by stressors from the stated sources.

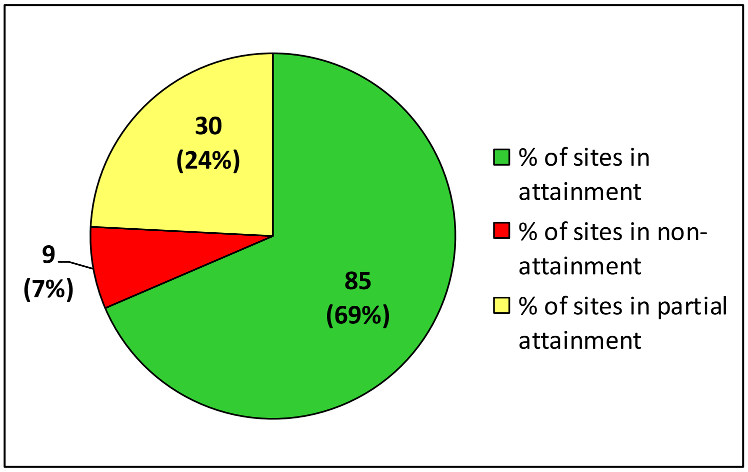


Figure 3-1. Attainment status for aquatic life uses in the Paint Creek watershed.

The attainment status of sampling sites for recreation use is shown in Figure 3-3. Non-attainment of water quality standards for recreation use

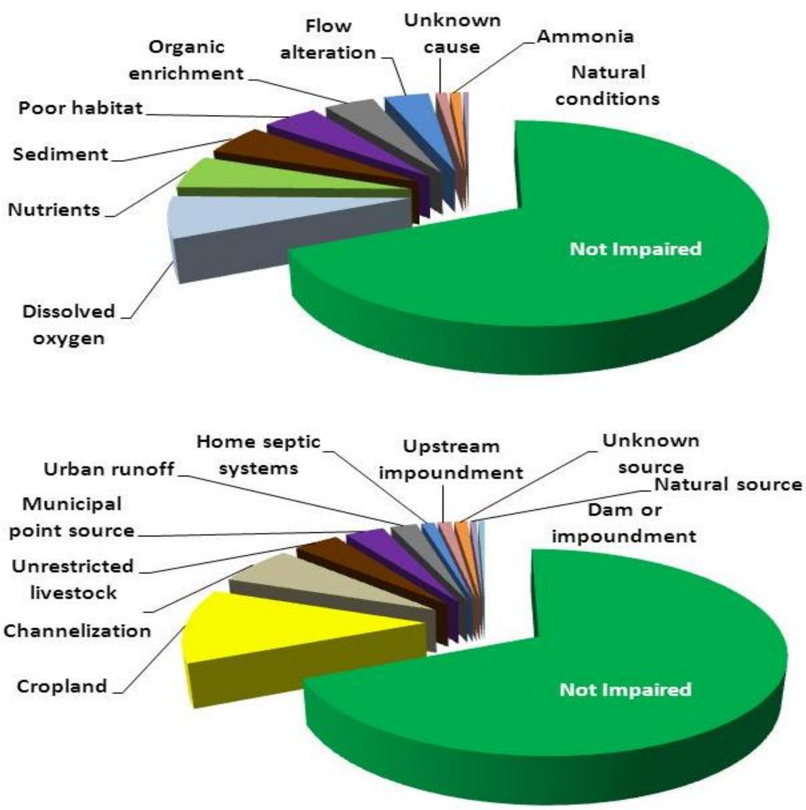


Figure 3-2. Causes and sources of aquatic life use impairment in the Paint Creek watershed.

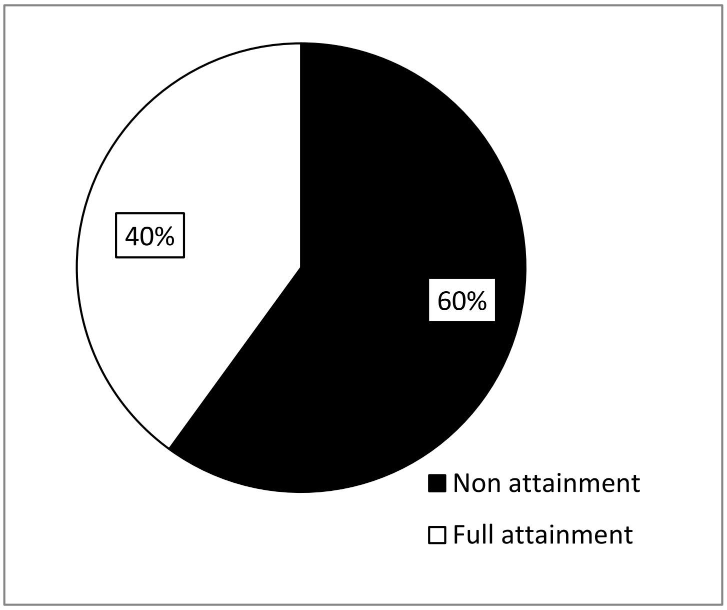


Figure 3-3. Attainment status for recreation uses in the Paint Creek watershed.

are generally associated with failing home septic treatment systems, inadequately maintained wastewater treatment plants (WWTPs), and farming activity (such as livestock with free access to waterways and land applied manure runoff within the watershed).

The Paint Creek watershed TMDL includes 10 sub-watersheds (Figure 3-4). Within each of the 10 subwatersheds, smaller subwatersheds are nested (12-digit HUC assessment units). This chapter discusses conditions in each of the subwatersheds with detail added in nested subwatersheds that exhibit unique conditions.

To report on the health of large rivers, Ohio EPA defined the stretch of river beginning at the point where it drains more than approximately 500 square miles and extending to its mouth as a large river assessment unit (LRAU). At this point, rivers are impacted more by the character of and activity in the accumulated drainage area and less by what is happening adjacent to the channel (i.e., on the stream bank). Additionally, the ecosystem changes to accommodate species that are adapted to a large river environment. Overall, impairment for aquatic life and recreation uses was more common in the northern and northwestern portion of the watershed, where agriculture is the dominant land use and many streams have been channelized to improve land drainage.

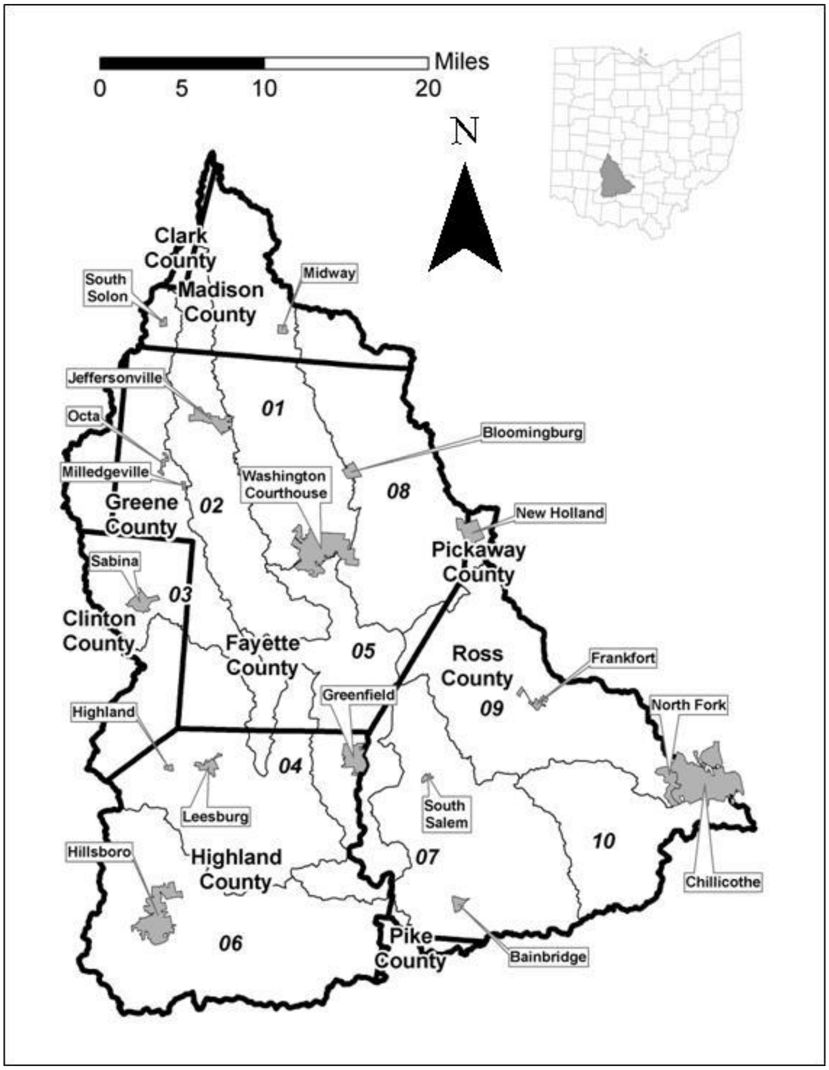


Figure 3-4. Counties, municipalities and ten-digit HUCs in the Paint Creek watershed.

Figures 3-5 and **Error! Reference source not found.**6 show the distribution of concentrations of nitrate+nitrite and total phosphorus, respectively, across the Paint Creek watershed based on the water chemistry results of the survey conducted in 2006.

The maps indicate that nutrients are elevated in the northern portion of the watershed where agriculture predominates in comparison to the lower (southern) watershed, which is much more forested and where there is far less cropland. This is true for both nitrate-nitrite (NO_3-NO_2) and total phosphorus concentrations. Likewise, there are several discrete locations with highly elevated NO_3-NO_2 and total phosphorus concentrations on Sugar Creek, Rattlesnake Creek, Lees Creek, Rocky Fork, East Fork Paint Creek and North Fork Paint Creek. The mainstem of Paint Creek, from just below Washington Court House to above Paint Creek Lake, also show consistently elevated nutrient concentrations. The sampling data suggests that the primary source of the nutrients is wastewater discharges since the mainstem has lower concentrations above the large WWTPs and the tributaries entering Paint Creek below these WWTPs show relatively low nutrient concentration where they enter Paint Creek.

Figure 3-7 displays the same sampling locations as Figures 3-5 and 3-6; however the nitrogen to phosphorus ratio is presented instead of the concentration values. These ratios are based on the overall average nutrient concentrations at each of these sites converted to a molar basis. Nitrogen to phosphorus ratios indicate which nutrient is limiting primary production in the systems and therefore the nutrient that is most meaningful to control in limiting algae production, which is beneficial to local water quality conditions.

The Redfield Ratio (Redfield, 1958) was developed to determine the relative occurrence of nitrogen to phosphorus in the tissues of some algae. This value is estimated to be sixteen to one. Ratios that are well below this suggest that there is not enough nitrogen, making this the limiting nutrient, and a ratio well above 16 suggests phosphorus is in short supply and therefore it is limiting algae production; however, values that are close to sixteen (e.g., 12 through 20) suggest co-limitation. In Figure 3-7, circles indicate a Redfield Ratio greater than 16, which is the breakpoint at which phosphorus becomes limiting. Three categories have been assigned to the ratios indicating phosphorus limitation; they range from 16 to 20, 20 to 50, and 50 to 338. These somewhat arbitrarily selected categories are indicated by progressively larger circles occurring in progressively darker hues and indicate how strongly phosphorus limited the system is. Three categories of nitrogen limitation have also been somewhat arbitrarily delineated similar to what was done with phosphorus but instead with progressively larger triangles with darker hues of red which is indicating more strongly nitrogen limiting conditions. These ranges are 12 to 16, 5 to 12, and 0 to 5.

The distribution of these ratios shown in Figure 3-7 suggests that phosphorus, in many more instances, is the limiting nutrient compared with nitrogen (as indicated by the high number of circles and particularly the larger circles in Figure 3-7). This means that algae will grow to the extent that the available phosphorus can support its growth. So reducing in-stream phosphorus concentrations should provide a corresponding reduction in algal biomass. Areas in the Paint Creek watershed where nitrogen concentrations are low compared to phosphorus are generally interspersed within areas where phosphorus is limiting. However, the greatest concentration of nitrogen limited conditions is the lower section of North Fork Paint Creek and its tributaries in that immediate vicinity. The lower portion of the East Fork Paint Creek as well as Paint Creek mainstem just downstream from Washington Courthouse are somewhat nitrogen limited which is mostly due to the much lower nitrogen to phosphorus ratios in the waste water. Other areas notably nitrogen limited are the headwaters of Rattlesnake and Sugar Creeks. To reduce local algal biomass outbreaks in nitrogen limited areas, a shift in NPS abatement strategies could be considered for cropland where greater focus is on providing hydraulic retention such as wetlands and/or controls on sub-surface drainage systems. However in more phosphorus limited areas, reduction of local algae production may be best abated from a focus on controlling soil losses.

However, a seasonal pattern to the nitrogen to phosphorus ratios is observed in the Paint Creek watershed (see Figure 3-8 and Figure 3-9 for a representation of N:P ratios across time for three regions of the Paint Creek mainstem). There is a peak in the value of the ratio in early to mid-spring (generally April) and a minimum occurring in the dry, low flow period of the year (August to October). The interceding months are generally characterized by a steeper drop in the ratio value from the peak in the spring to the minimum in the late summer and a more gradual increase from the minimum of the late summer to the peak in the spring. One interpretation of this data is that nitrogen loading is more responsive to spring rains than phosphorus loading (possibly due to greater solubility of nitrogen species as well as its higher fertilizer application rates (e.g., approximately 150 lbs. anhydrous ammonia per acre , which is readily converted to NO_3 compared to approximately 40 lbs. phosphorus per acre)). The movement towards a more nitrogen limited situation (i.e., low N:P ratios) as the season progresses to summer and stream flows generally decrease can be a function of a higher rate of nitrogen consumption (e.g., more in-stream biological activity from denitrifying bacteria in response to increasing temperatures) as well as the effect on streams with WWTPs of a higher proportion of wastewater in the stream flow which has much lower N:P ratios.

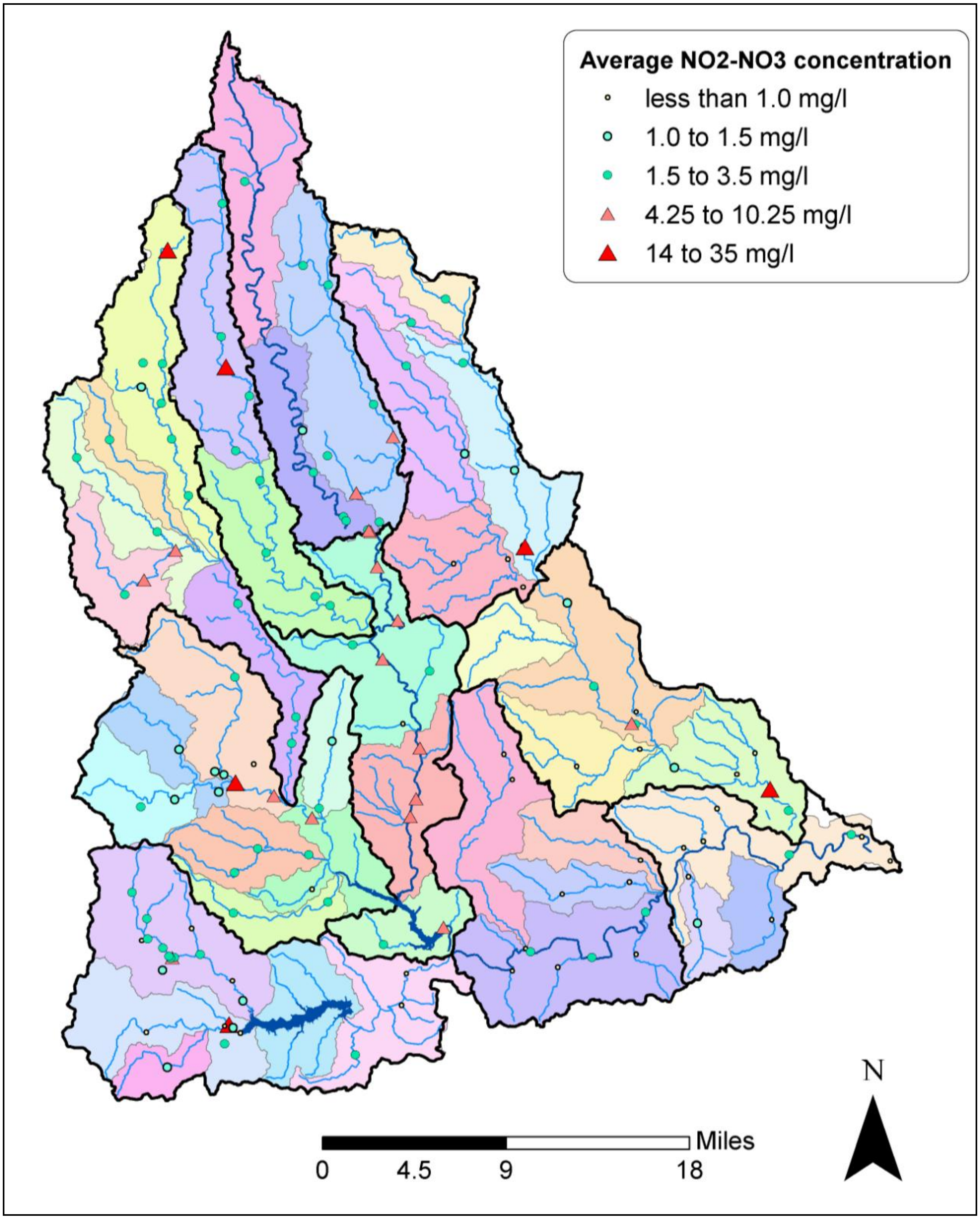


Figure 3-5. Spatial distribution of mean nitrate-nitrite concentrations in streams in the Paint Creek watershed.

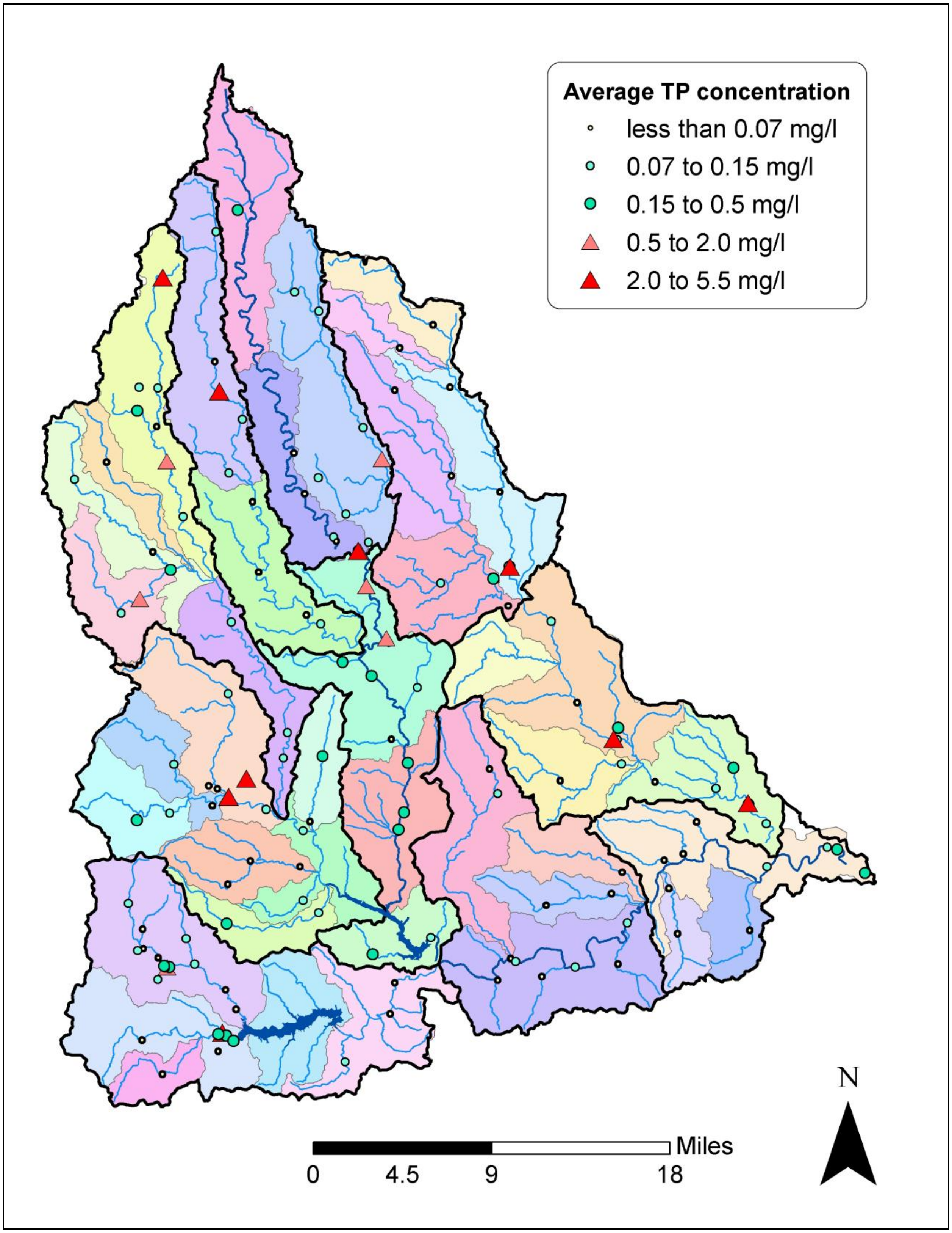


Figure 3-6. Spatial distribution of mean total phosphorus concentrations in streams in the Paint Creek watershed.

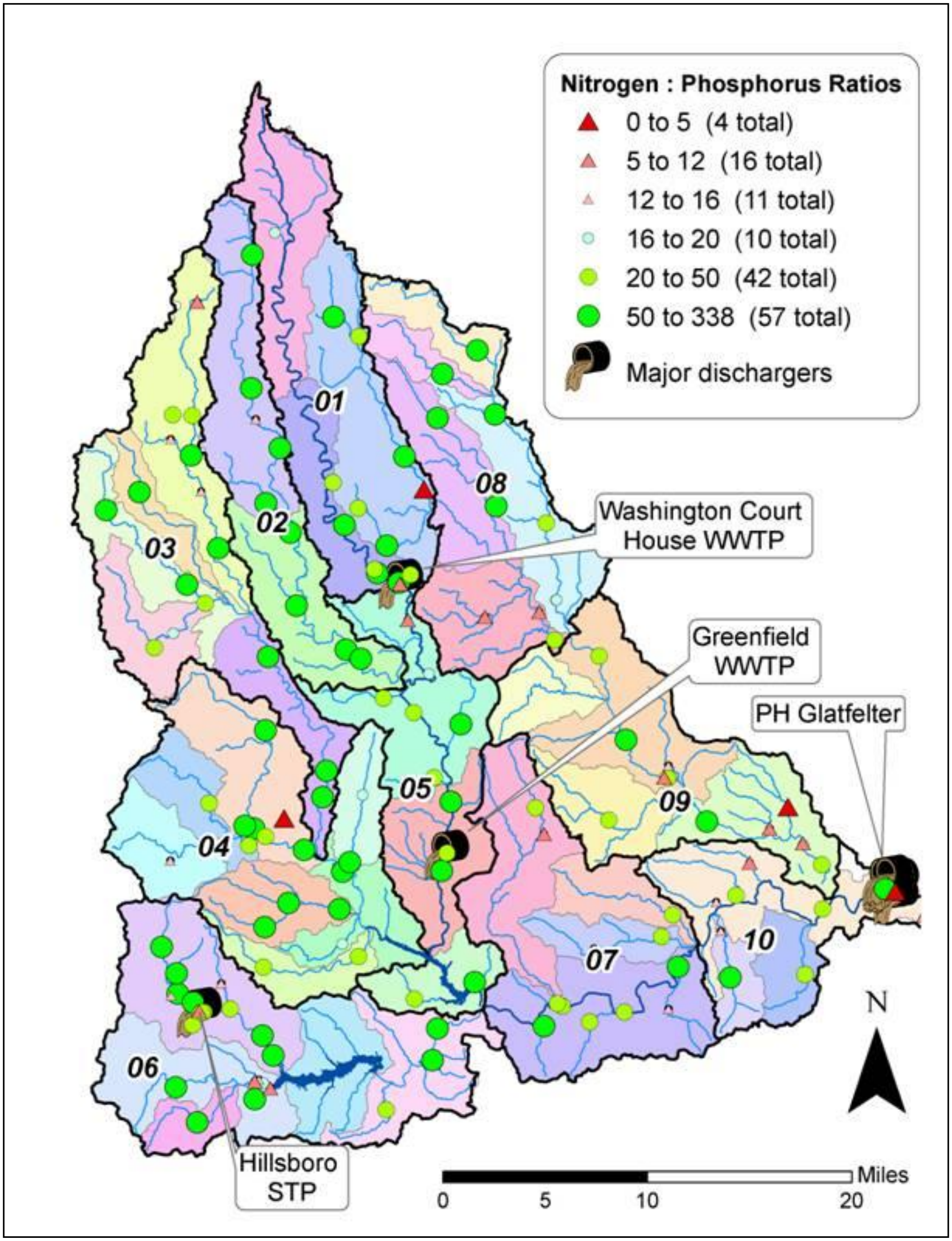


Figure 3-7. Spatial distribution of molar ratio of nitrogen to phosphorus based on water chemistry results from TMDL survey only.

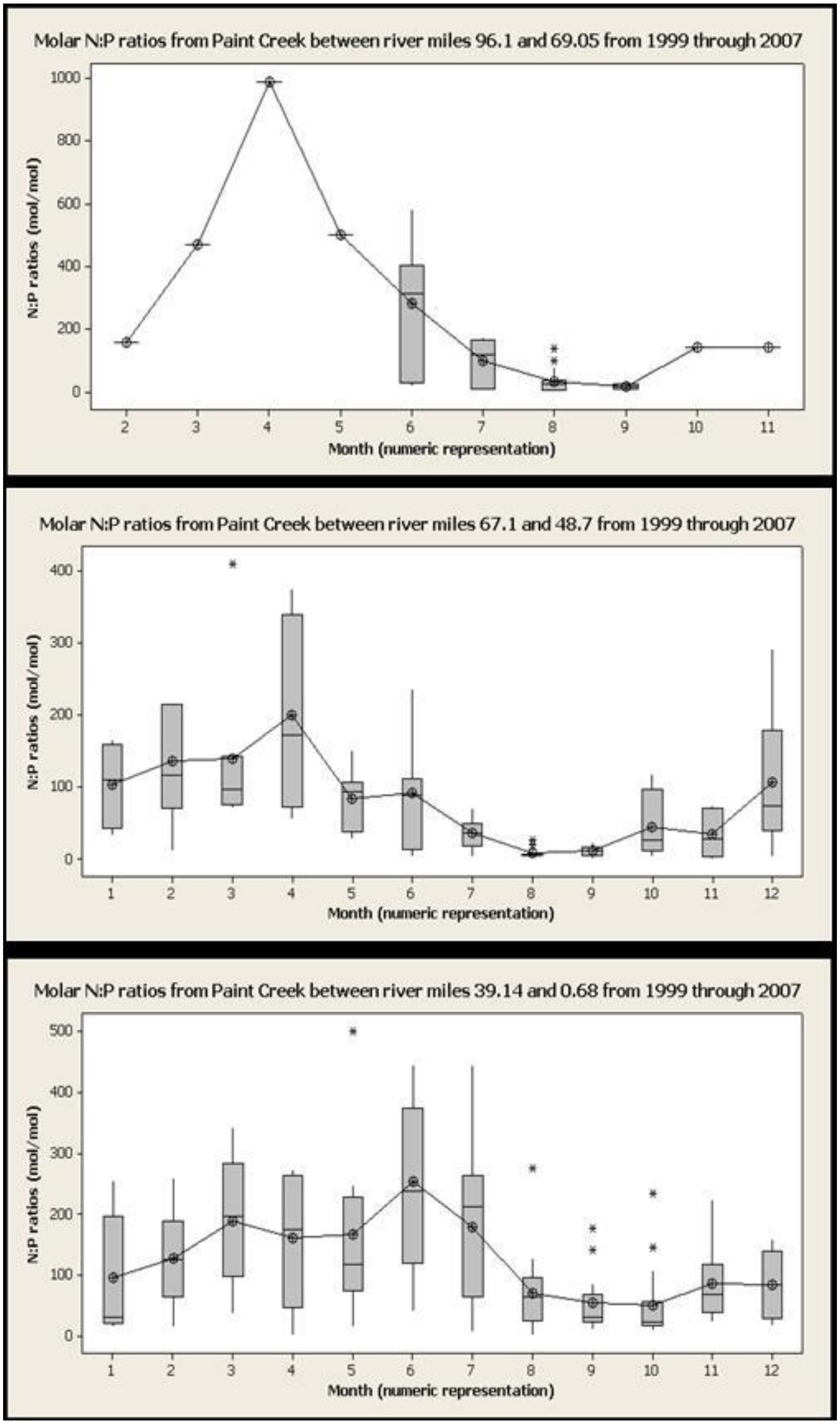


Figure 3-8. Monthly distribution of molar ratios of nitrogen to phosphorus on Paint Creek mainstem based on long-term water chemistry results across three distinct zones of the river.

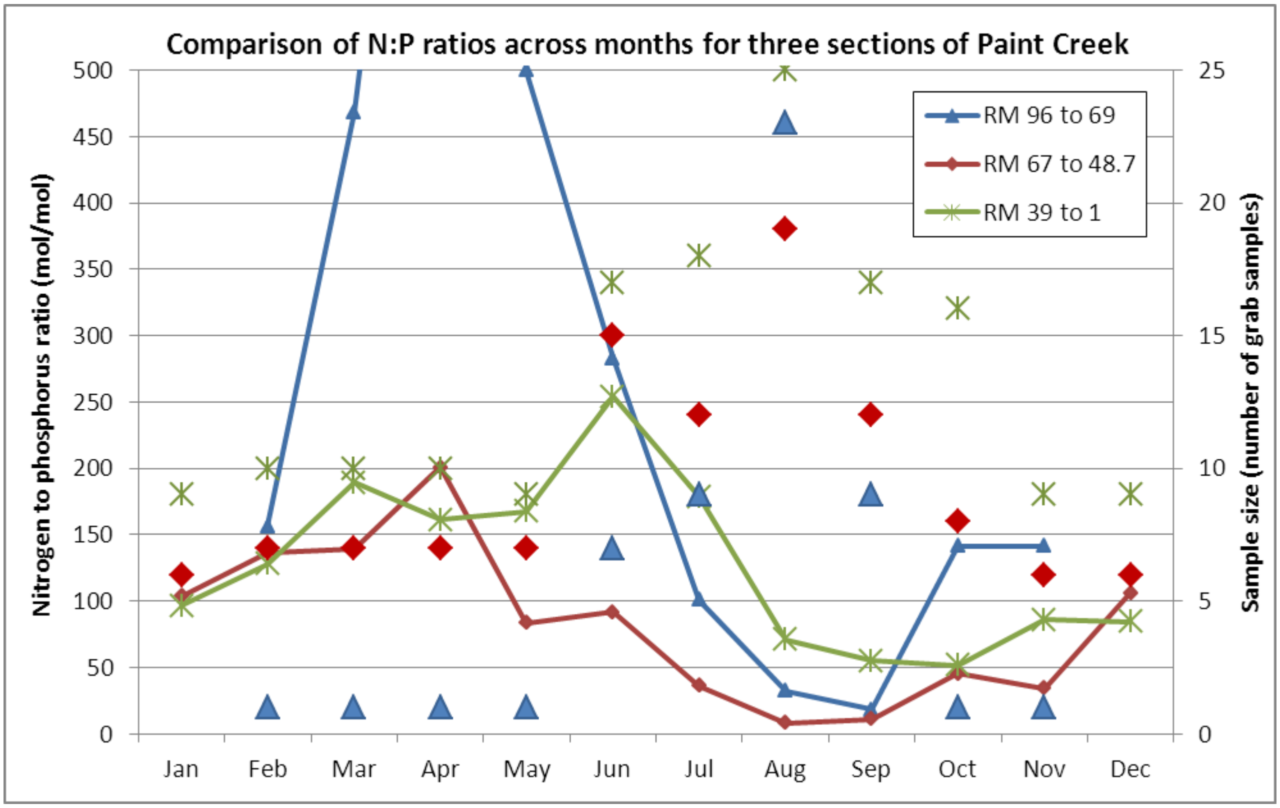


Figure 3-9. Comparison of N:P ratios across months of a year for three distinct regions of the mainstem of Paint Creek (small drainage area above WWTPs, larger watershed below significant WWTPs, and large watershed below Paint Creek Lake).

3.1 Headwaters Paint Creek (05060003 01)

The Headwaters Paint Creek subwatershed drains 119.6 square miles in the northern portion of the watershed (Figure 3-10), and consists of three nested subwatersheds.[1] The main tributary in the subwatershed is East Fork Paint Creek.

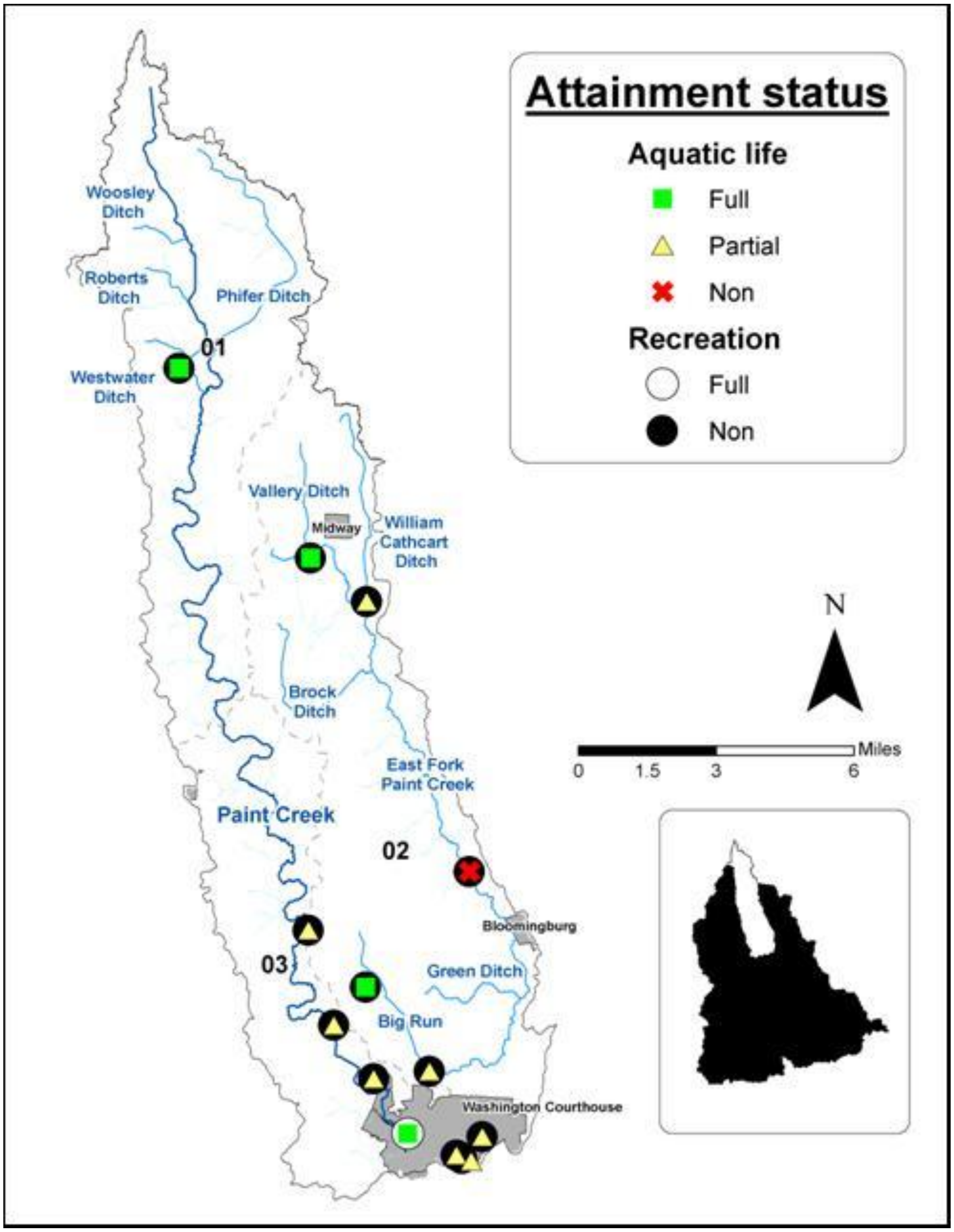


Figure 3-10. Aquatic life use and recreation use attainment in the Headwaters Paint Creek subwatershed.

[1] Nested subwatersheds are defined as the smallest sized area evaluated under this study, and are denoted by a 12-digit number, or a 12-digit HUC (hydrologic unit code).

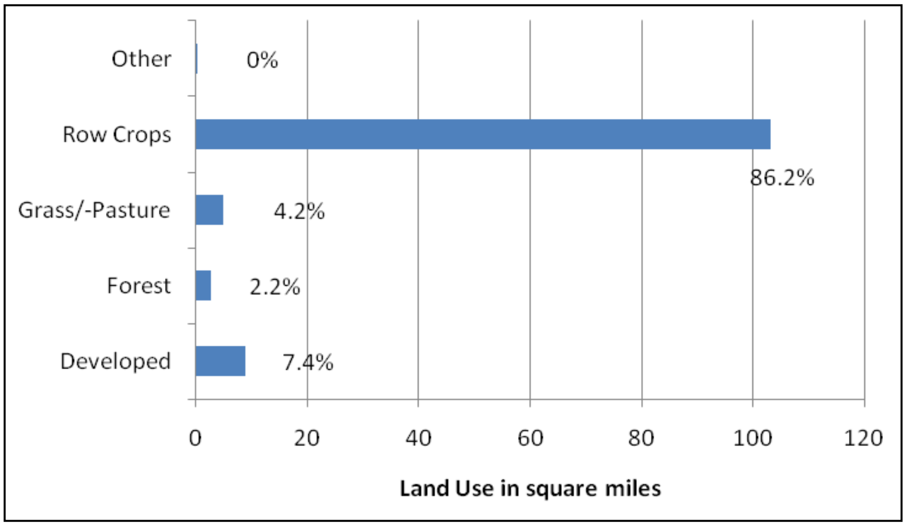


Figure 3-11. Land use for the Headwaters Paint Creek subwatershed.

Figure 3-10 shows that the sites exhibiting partial or non-attainment of the aquatic life use designation were located within the city limits of Washington Court House as well as just upstream of the city, and just north (upstream) of Bloomingburg and south (downstream) of Midway. Major causes of impairment include sedimentation, nutrient enrichment, low dissolved oxygen concentrations, and habitat alteration. Those causes are primarily associated with agriculture (row crops, livestock, and channelization) and urban runoff.

Figure 3-11 shows land cover distribution within the Headwaters Paint Creek subwatershed based on the percentages of the overall area of the subwatershed. As illustrated in this figure, row crop agriculture is the predominant land use, which provides good explanation for the nutrient enrichment and sedimentation observed in the streams in this subwatershed (i.e., cropland drainage is a typical source of these pollutants). Following agriculture, development represents the next highest land cover category in this subwatershed, due to the City of Washington Court House and the immediate surrounding residential and commercial areas.

Figures 3-5 and Figure 3-6 as well as data for other parameters confirmed field observations as well as provided additional insight in identifying causes of aquatic life use impairment. For example, sampling results showed that violations of the dissolved oxygen criteria occurred numerous times at three locations. In addition, temperatures in these stream locations were well above the background median, supporting the identification of habitat alteration and a lack of riparian cover as a cause of impairment along streams in the Headwaters Paint Creek subwatershed.

Figure 3-12 shows the relative occurrence of causes of aquatic life use impairment in the Headwaters Paint Creek subwatershed, while Figure 3-13 shows the relative occurrence of sources of aquatic life use impairment in this subwatershed. Table 3-1 provides a more detailed explanation of the abbreviations for terms used in these figures (and for all similar figures in this chapter).

Figures 3-12 and Figure 3-13 show that 31 percent of the sites sampled in this subwatershed exhibited no aquatic life use impairment. When it occurred, most of the impairment was due to a combination of factors (or sources) at each sampling site, such as crop production and channelization, or crop production and unrestricted cattle access, or channelization, municipal point sources, and urban runoff. Some type of agricultural activity was identified as the source of impairment at 53 percent of sampling sites in the subwatershed. Habitat degradation associated with open, straight channels lacking high quality riparian vegetation has largely been

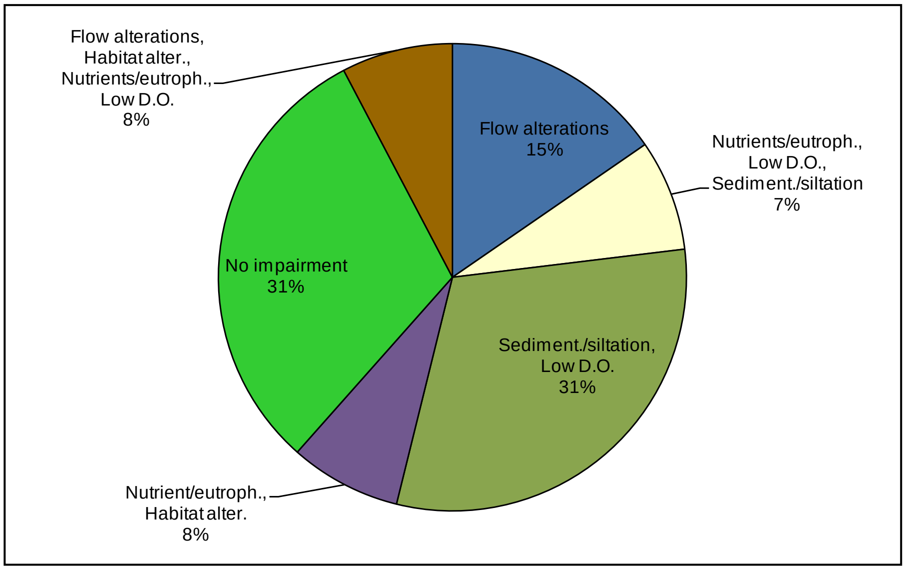


Figure 3-12. Causes of aquatic life use impairment in the Headwaters Paint Creek subwatershed.

due to channel maintenance to facilitate land drainage and row crop farming. Poor habitat due to channelization is also problematic in the City of Washington Court House.

Table 3-1. Explanation of the abbreviations for terms used in these figures and for all similar figures in this chapter.

Legend Label	U.S. EPA Cause and Source Terminology
Flow alterations	Other flow regime alterations
Habitat alteration	Direct habitat alterations
Nutrients/eutrophication	Nutrients/Eutrophication biological indicators
Low dissolved oxygen	Low dissolved oxygen
Sediment/siltation	Sedimentation/siltation
Crop production	Non-irrigated crop production and/or crop production with subsurface drainage
Cattle access	Unrestricted cattle access
Point sources	Municipal point source discharges
Urban runoff	Urban runoff/storm sewers
Unknown	Impairment unknown or source unknown
Ammonia	Ammonia (total)
Organic enrich.	Organic enrichment (sewage) biological indicators
Dam or impoundment	Dam or impoundment
Natural	Natural sources
On-site treatment systems	On-site treatment systems (septic systems and similar de-centralized systems)

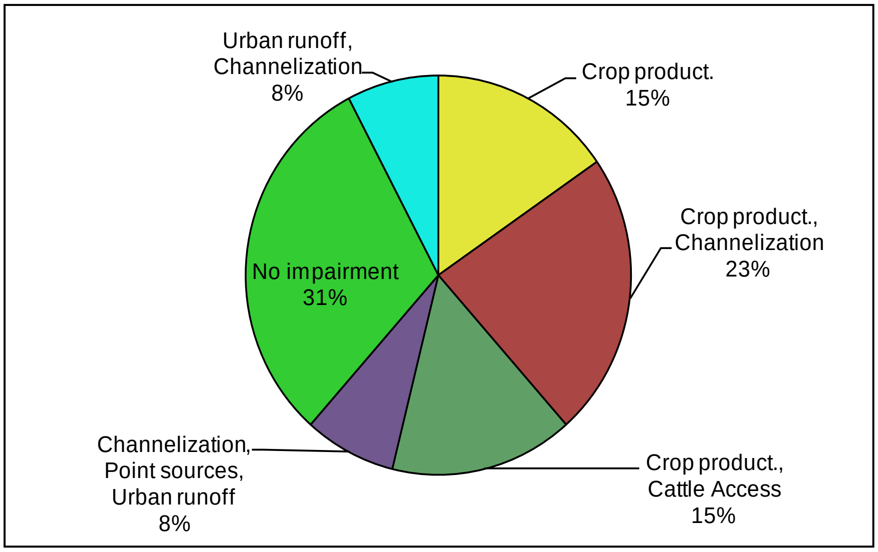


Figure 3-13. Sources of aquatic life use impairment in the Headwaters Paint Creek subwatershed.

Table 3-2 shows the results for each designated beneficial use organized by nested subwatersheds. A total of nine out of 13 sites were found to be impaired in this subwatershed for aquatic life use. Thirteen of the 14 sites sampled for bacteria were impaired for the designated recreation use. For more specific information regarding individual site assessment results and supporting chemistry results, see Appendix B.

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

Nested Subwatersheds (05060003 01)		**Aquatic Life Use**	**Recreation Use**	**Public Drinking Water Supply Use**	**Human Health Use**[1]
01 01	# impaired sites (non/partial)	0	1		
	Index score	100	25	N/A	N/A
01 02	# impaired sites (non/partial)	4 (1/3)	6		
	Index score	20.8	50	N/A	N/A
01 03	# impaired sites (non/partial)	5 (0/5)	6		
	Index score	16.7	72	Insufficient data	N/A

[1] Impairments to the human health use are not being addressed in this TMDL.

3.1.1 Town of Washington Court House-Paint Creek (05060003 01 03)

The effects of nutrient contributions upstream is more evident in this nested subwatershed as the nutrients are converted to vegetation (mostly filamentous algae) in areas where the channel was devoid of riparian cover and exposed to sunlight, primarily within the city limits of Washington Court House. Nutrient enrichment was also especially prevalent downstream of the Washington Court House WWTP as shown through high concentrations of total phosphorus, organic nitrogen, and nitrates (see Figure 3-5 through 3-7).

The combination of abundant sunlight and nutrients caused massive blooms of filamentous algae and other aquatic vegetation, dominating the stream channel. Washington Court House's contribution to the in-stream total phosphorus concentration, based on their monitoring data and stream flow records at the USGS stream gage located near Greenfield, Ohio was on average about 0.09 mg/l with a median of about 0.05 mg/l (this is based on daily load divided by daily stream flow volume using the facility's monitoring data for loading and stream gage data for streamflow). The range in concentrations calculated in this manner was from 0.003 to 0.538 mg/l of total phosphorus. As a frame of reference, the target concentration downstream of the outfall based on the *Association Between Nutrients, Habitat, and the Aquatic Biota of Ohio Rivers and Streams* (Ohio EPA, 1999), is 0.05 mg/l of total phosphorus (i.e., for the wadeable EWH designated aquatic life use). Additionally, Washington Court House's estimated contribution to ambient total phosphorus concentrations is based on stream flows measured 17 miles downstream from the outfall. The drainage area at this downstream location has 182.5 additional square miles corresponding to being about 2.7 times larger than what it is at the Washington Court House outfall. In light of this very conservative estimate of Washington Court House's total phosphorus, the reality is that it is likely to have a much larger impact on ambient stream concentrations than the values stated above. Figure 3-14 is a graph of the calculated loads from Washington Court House WWTP based on their reported effluent concentrations and their discharge rate converted to ambient stream concentrations based on measured stream flow at a USGS gage located 17 miles downstream.

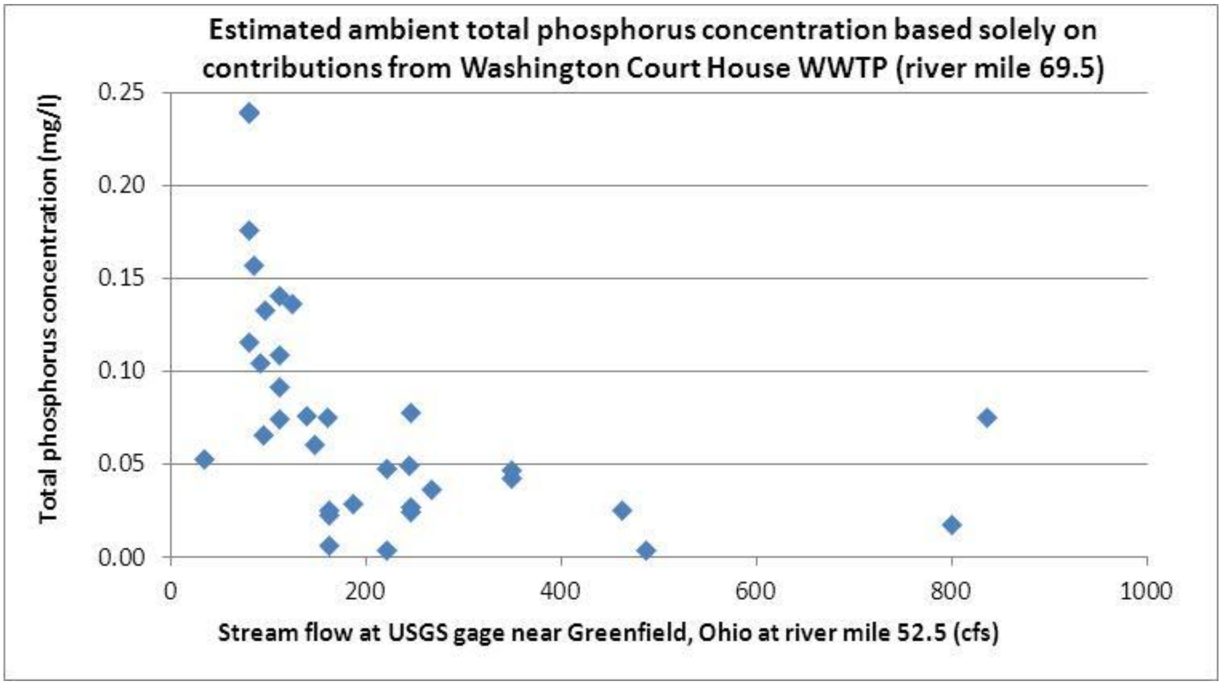


Figure 3-14. Conservative estimate of equivalent stream concentration of total phosphorus based exclusively on wastewater loading from Washington Court House's WWTP.

3.2 Sugar Creek (05060003 02)

The Sugar Creek sub-watershed drains 81.5 square miles in the northern portion of the watershed (see **Error! Reference source not found.**15). It consists of two nested subwatersheds. Camp Run and Missouri Ditch are two of the primary tributaries in the Sugar Creek subwatershed. Most of the sites fully met aquatic life criteria; however, the impaired sites were degraded by nutrient enrichment and associated dissolved oxygen problems as well as poor habitat. In most cases, these causes are associated with cropland runoff, and row crop production dominates the land use in the Sugar Creek subwatershed as shown in Figure 3-16.

Row crop agriculture is almost 90 percent of the land use in this subwatershed. The land use in the northern portion of the watershed has slightly more row crop agriculture than the southern areas where forest cover within the riparian zones is more prevalent, especially along Sugar Creek.

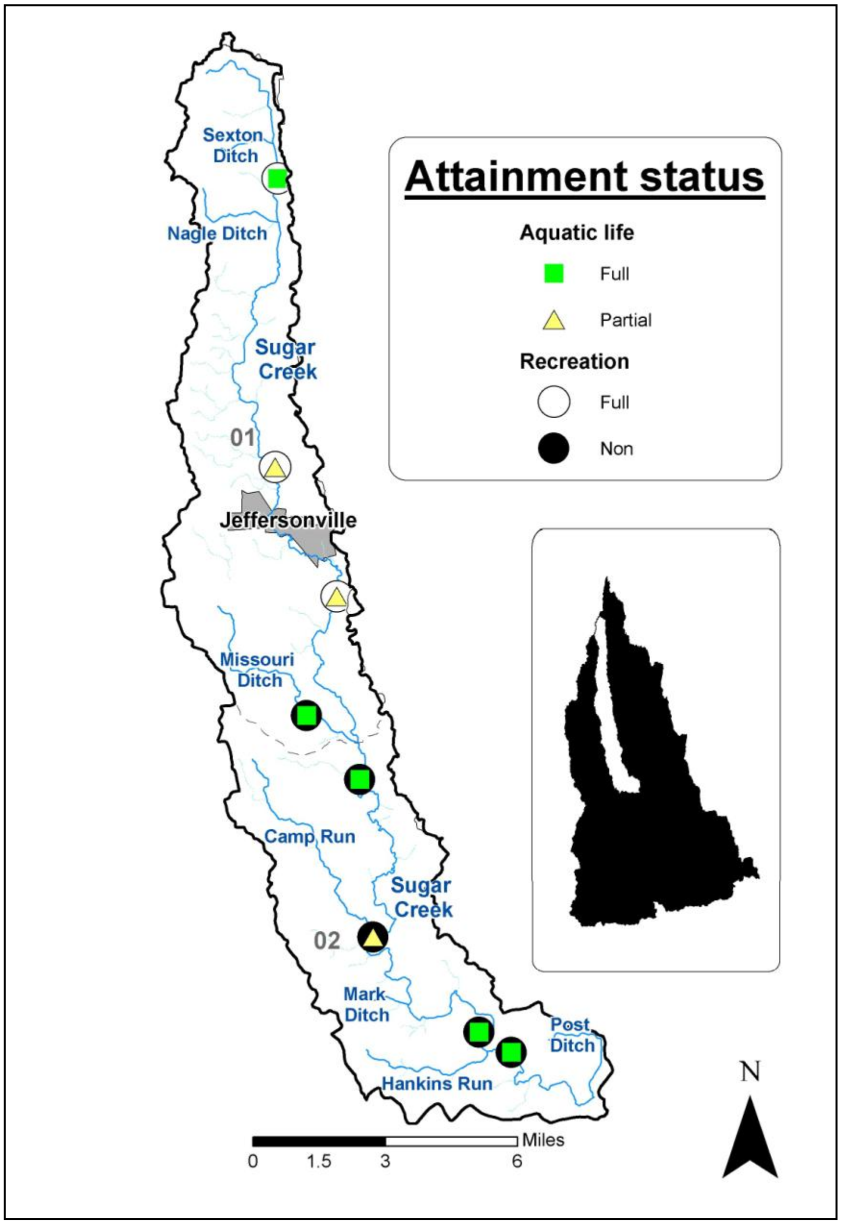


Figure 3-15. Aquatic life use and recreation use attainment in the Sugar Creek subwatershed.

Water chemistry results showed the highest concentrations of both nitrate+nitrite and total phosphorus at a site at river mile 24.8 in the in the northern half of the subwatershed (see Figures 3-5 and 3-6)

In addition, in-stream sampling in this area showed low dissolved oxygen concentrations. Effluent sampling data for the Village of Jeffersonville WWTP No. 2 demonstrated concentrations of total phosphorus and ammonia that contributed to nutrient enrichment.

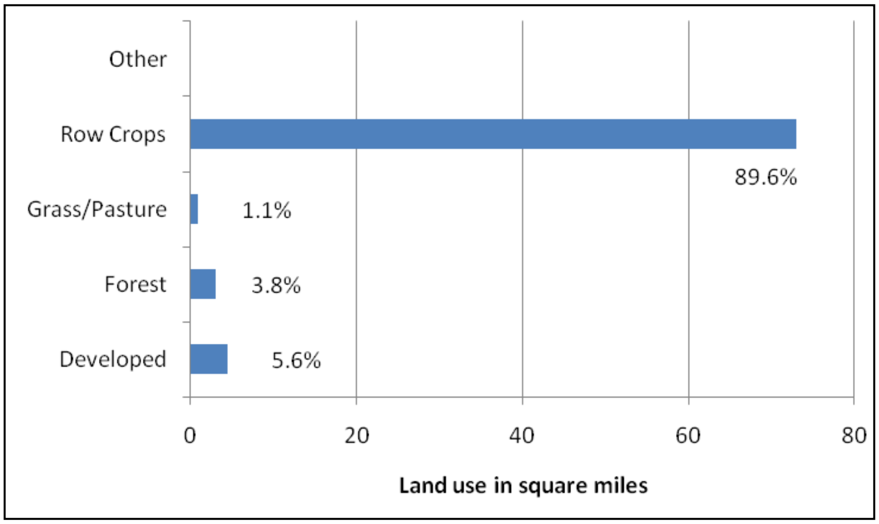


Figure 3-16. Land use in the Sugar Creek subwatershed.

Figure 3-17 shows the relative occurrence of causes of aquatic life use impairment in the Sugar Creek subwatershed while Figure 3-18 shows this for the sources. Sixty-three percent of the sites sampled in this subwatershed were found to be in full attainment of the applicable aquatic life use designation. Cropland runoff, livestock, and the Village of Jeffersonville WWTP No. 2 were the sources of impairment at the remaining sites in the Sugar Creek subwatershed. Habitat alterations resulting from reduced riparian cover contributed to partial attainment of aquatic life use designation in the upper reaches of the subwatershed, while sampling sites closer to the mouth of Sugar Creek generally exhibited better water quality conditions, due in part to improved habitat. Table 3-3 shows the results for each designated beneficial use organized by nested subwatersheds. Eight sites in the Sugar Creek subwatershed were sampled for aquatic life with five of those sites in full attainment of the designated use. Only three of the eight sites sampled for bacteria were in full attainment of the recreation use. For more specific information regarding individual site assessment results and supporting chemistry results, see Appendix B.

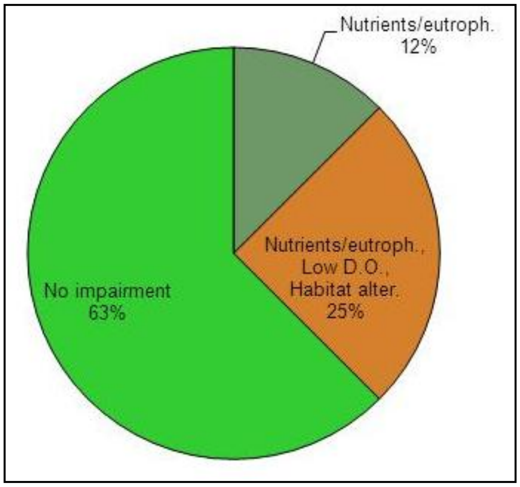


Figure 3-17. Causes of aquatic life use impairment: Sugar Creek subwatershed.

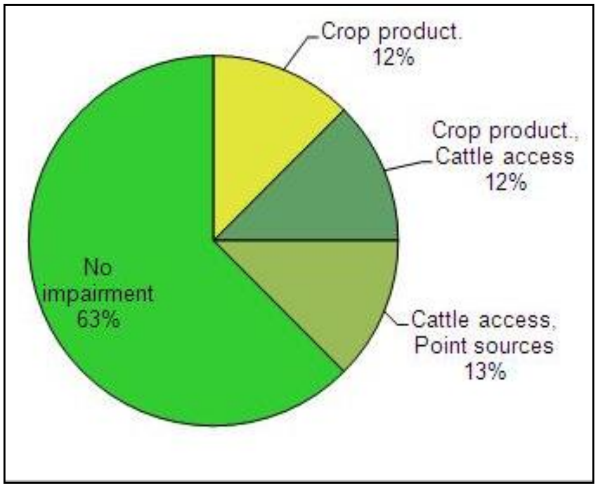


Figure 3-18. Sources of aquatic life use impairment: Sugar Creek subwatershed.

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

Nested Subwatersheds (05060003 02)		Aquatic Life Use	Recreation Use	Public Drinking Water Supply Use	Human Health Use[1]
02 01	# impaired sites (non/partial)	2 (0/2)	1		
	Index score	50	94	N/A	N/A
02 02	# impaired sites (non/partial)	1 (0/1)	4		
	Index score	83.3	75	N/A	N/A

[1] Impairments to the human health use are not being addressed in this TMDL.

3.2.1 Headwaters Sugar Creek (05060003 02 01)

The sources of impairment at the sampling site just downstream from the Village of Jeffersonville WWTP No. 2 were the existing WWTP discharge and unrestricted stream access for livestock. A new WWTP went on-line in June 2006 as a result of a third consent order between Ohio EPA and the Village to address chronic effluent violations from the old controlled discharge lagoon treatment system. However, the Village has continued to report monitoring data that violate permit limits for key water quality parameters. In 2009, the following numbers of violations were reported: nitrogen-ammonia (15); dissolved oxygen (10); total suspended solids (6); and carbonaceous biological oxygen demand (CBOD; 6). During 2010 from January through November, only five of the reported values were permit violations – three for ammonia-nitrogen and two for total suspended solids.

The Jeffersonville WWTP No. 2 has discharged at an average rate of approximately one percent of the average annual flow in Sugar Creek near the discharge point (based on StreamStats - Kolton et al., 2006); however, this discharge was sufficient to dominate stream flow under 7Q10[2] conditions when aquatic communities are most sensitive to pollution and nutrient enrichment. Based on this annual average stream flow and the average of the calculated total phosphorus loading (based on monitoring data), the commensurate ambient stream concentration exclusively due to Jeffersonville's WWTP is 0.032 mg/l for the period of beginning of 2005 through 2008. Using the more recent time period beginning in early 2009 through 2010, the estimated ambient total phosphorus concentration ascribed solely to loading from the Jeffersonville WWTP No. 2 is 0.024 mg/l for the average annual flow (i.e., 0.008 mg/l TP less than during the period surrounding the watershed survey). Using this same, more recent time period in estimating the ambient concentration under median and the 25th percentile flow conditions, the corresponding concentration are 0.071 and 0.184 mg/l, respectively. As a frame of reference, the target concentration downstream of the outfall is 0.10 mg/l of total phosphorus for the wadeable WWH designated use stream. Similar estimates carried out for nitrate-nitrite concentrations show that under average annual stream flow, the Jeffersonville WWTP contributes an effective ambient concentration of 0.21 mg/l, while the median and 25th percentile correspond to 0.61 and 1.59 mg/l, respectively.

[2] 7Q10 is a streamflow statistic that represents a flow rate equivalent to lowest sustained flow rate that extends for a seven day period with a one in ten year recurrence probability.

3.3 Headwaters Rattlesnake Creek (05060003 03)

The Headwaters Rattlesnake Creek subwatershed drains 129.7 square miles in the northwestern portion of the watershed (see Figure 3-19). It consists of five nested subwatersheds. The main tributaries in this watershed include Wilson Creek, Grassy Creek, and West Branch Rattlesnake Creek. Causes of impairment include habitat alteration, low dissolved oxygen, organic enrichment, and sedimentation. Those causes are primarily associated with channelization for land drainage to support crop production, urban runoff, and municipal wastewater treatment plants.

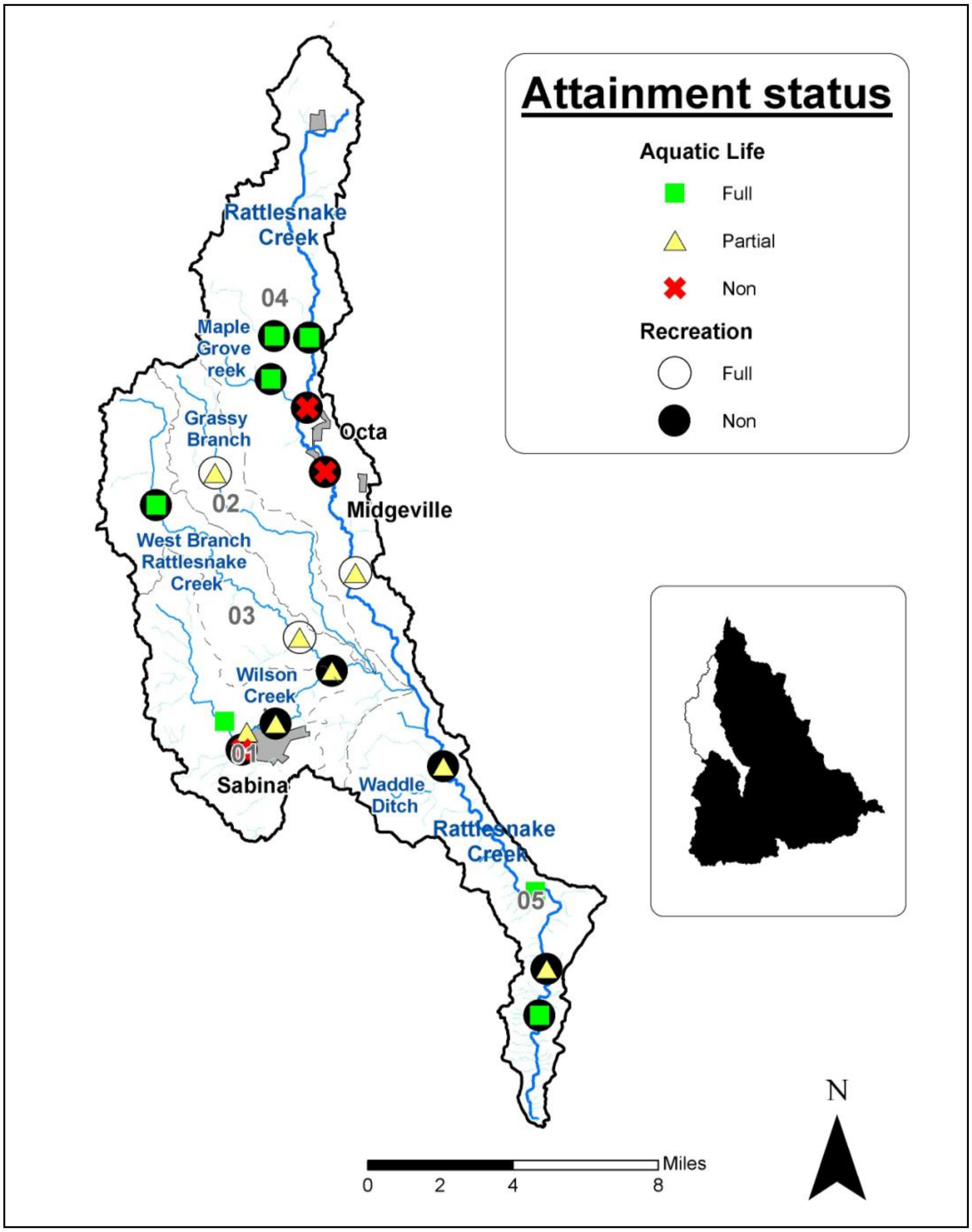


Figure 3-19. Aquatic life use and recreation use attainment in the Headwaters Rattlesnake Creek subwatershed.

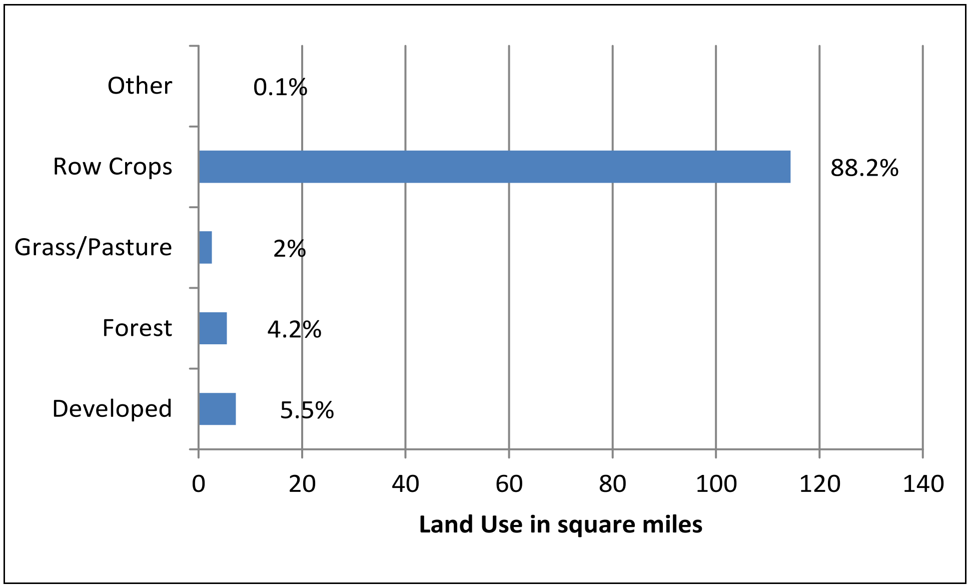


Figure 3-20. Land use in the Headwaters Rattlesnake Creek subwatershed.

Figure 3-20 shows the percentages of land use within the Headwaters Rattlesnake Creek subwatershed. Similar to the previous two subwatersheds, land use in this subwatershed is dominated by row crop agriculture. Forested and developed areas represent the next highest land use categories at 4.2 percent and 5.5 percent, respectively.

Water quality data indicate that nitrate-nitrite is highly elevated in the streams in this subwatershed. Rattlesnake Creek is consistently approximately two times higher than the water quality concentration target and increased to about three times higher immediately downstream from the Rattlesnake WWTP. In Wilson Creek, immediately downstream from the Sabina WWTP, nitrate-nitrite concentrations were nearly eight times higher than the target. However, total phosphorus concentrations were found to be primarily near the in-stream water quality target except for immediately downstream from the wastewater treatment plant where concentrations were five to nine times above target.

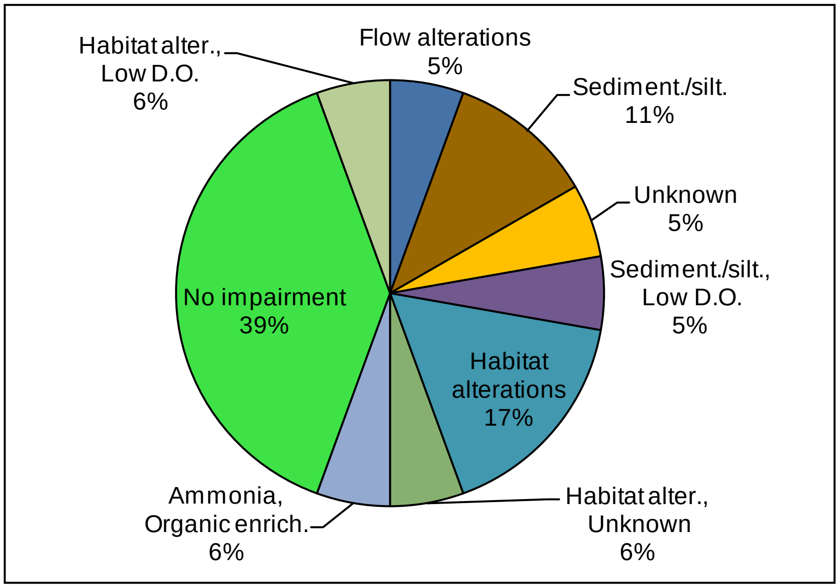


Figure 3-21. Causes of aquatic life use impairment: Headwaters Rattlesnake Creek subwatershed.

Some of the water chemistry results aided in identifying causes of aquatic life use impairment. Figure 3-21 shows relative occurrence of causes of aquatic life use impairment in the subwatershed, while Figure 3-22 represents the sources of aquatic life use impairment in the Headwaters Rattlesnake Creek subwatershed. As expected based upon the predominant land use in this subwatershed, agricultural activity was a contributing source of impairment in 49 percent of the sites that did not meet the designated use for aquatic life. Direct habitat alterations alone and in combination with low dissolved oxygen and unknown factors were a significant cause of impairment, especially in the upper and middle reaches of the subwatershed. Stream channelization and the lack of sufficient riparian cover due to habitat alterations also contributed to algal growth and high in-stream temperatures, which exceeded the median for reference background conditions.

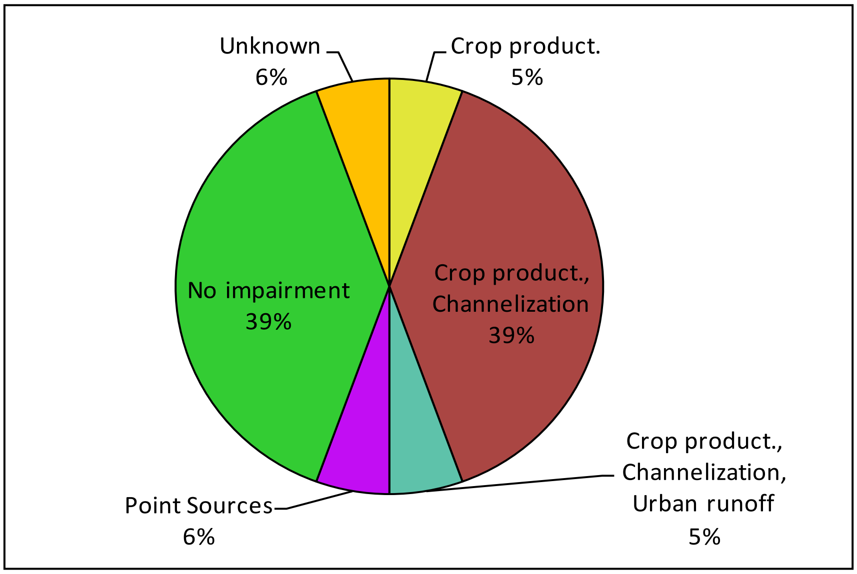


Figure 3-22. Sources of aquatic life use impairment: Headwaters Rattlesnake Creek subwatershed.

Table 3-4 shows results for each designated beneficial use organized by nested subwatersheds. A total of 18 sites were sampled for aquatic life use in this subwatershed, and 11 sites were impaired. For the designated recreation use, 12 of the 15 sites were sampled were in non-attainment. 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 Headwaters of Rattlesnake Creek subwatershed.

Nested Subwatersheds (05060003 03)		**Aquatic Life Use**	**Recreation Use**	**Public Drinking Water Supply Use**	**Human Health Use[1]**
03 01	# impaired sites (non/partial)	3 (1/2)	2		
	Index score	25	25	N/A	N/A
03 02	# impaired sites (non/partial)	1 (0/1)	0		
	Index score	0	100	N/A	N/A
03 03	# impaired sites (non/partial)	2 (0/2)	2		
	Index score	25	83	N/A	N/A
03 04	# impaired sites (non/partial)	3 (2/1)	5		
	Index score	50	71	N/A	N/A
03 05	# impaired sites (non/partial)	2 (0/2)	3		
	Index score	50	75	N/A	N/A

[1] Impairments to the human health use are not being addressed in this TMDL.

3.3.1 Wilson Creek (05060003 03 01)

The Wilson Creek nested subwatershed showed serious problems with nutrient enrichment. When compared to reference background concentrations, total phosphorus and nitrate+nitrite samples all exceeded the 90th percentile just downstream from the Village of Sabina WWTP discharge, which is likely the primary source of these high concentrations. Total phosphorus concentrations were also extremely elevated just downstream from the Sabina WWTP and sustained an elevated state (about three times the water quality target concentration) for approximately 2.8 river miles to below its confluence with the West Branch Rattlesnake Creek. Bacteria sampling showed that the recreation use was not attained at this location, possibly due to the WWTP discharge and other sources in the Village. Based on monitoring data from 2003 through 2010, the average loading from Sabina STP is 1.67 kg/day. According to the average annual stream flow near the outfall which is 13.06 million gallons per day (StreamStats – Kolton et al., 2006) Sabina's contribution to ambient total phosphorus concentrations is about 0.034 mg/l.

3.4 Lees Creek-Rattlesnake Creek (05060003 04)

The Lees Creek-Rattlesnake Creek subwatershed drains 148.7 square miles in the west-central portion of the watershed (see Figure 3-23). It consists of seven nested subwatersheds. The primary tributaries in this subwatershed are Walnut Creek, Hardin Creek, Fall Creek, and Big Branch. Major causes of impairment include nutrient and organic enrichment. Those causes are primarily associated with agriculture (row crops and livestock).

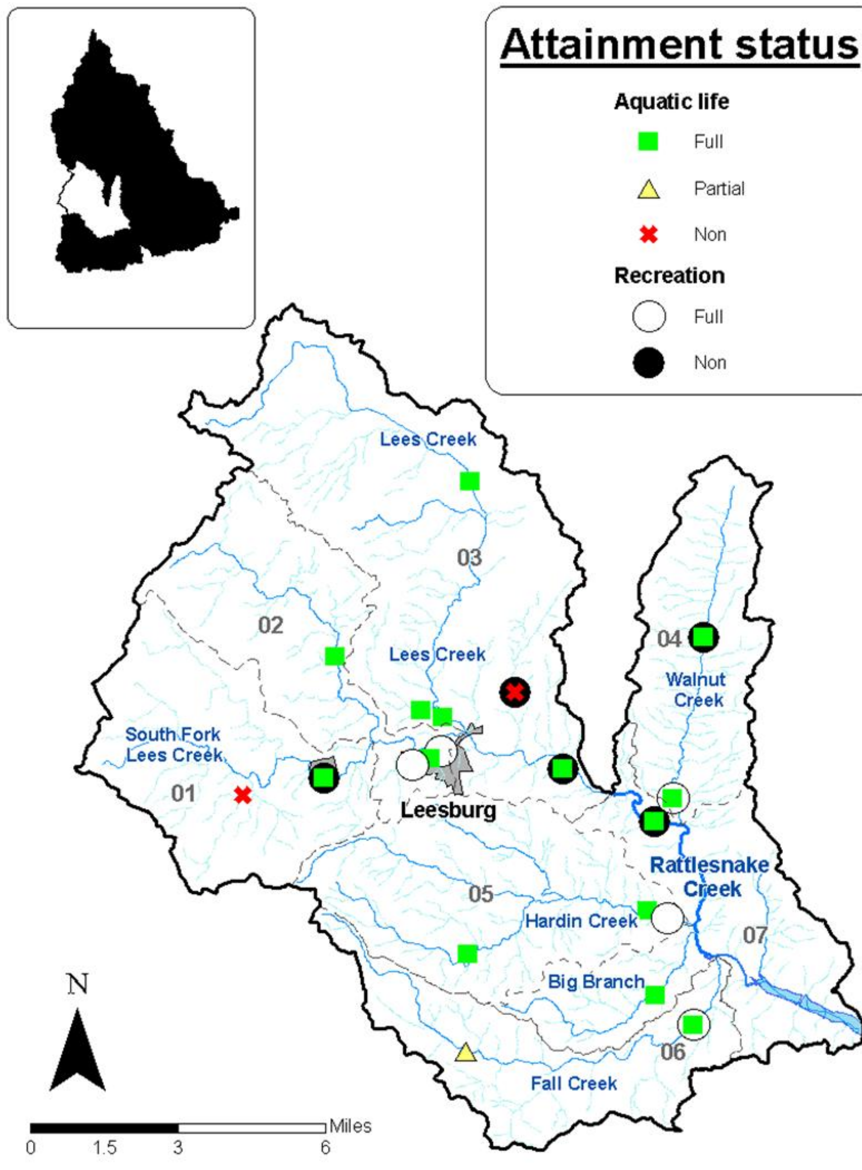


Figure 3-23. Aquatic life use and recreation use attainment in Lees Creek-Rattlesnake subwatershed.

In most cases, these causes are associated with land uses in the subwatershed (see Appendix B for further information). Figure 3-24 shows land use within the Lees Creek-Rattlesnake Creek subwatershed, and although row crop agriculture remains the predominant land use (66.7 percent), forest and grass/ pasture make up significant portions of the watershed. Forested areas and grass/

pasture lands become more prevalent from the northwestern to southeastern sections of the Lees Creek-Rattlesnake Creek subwatershed.

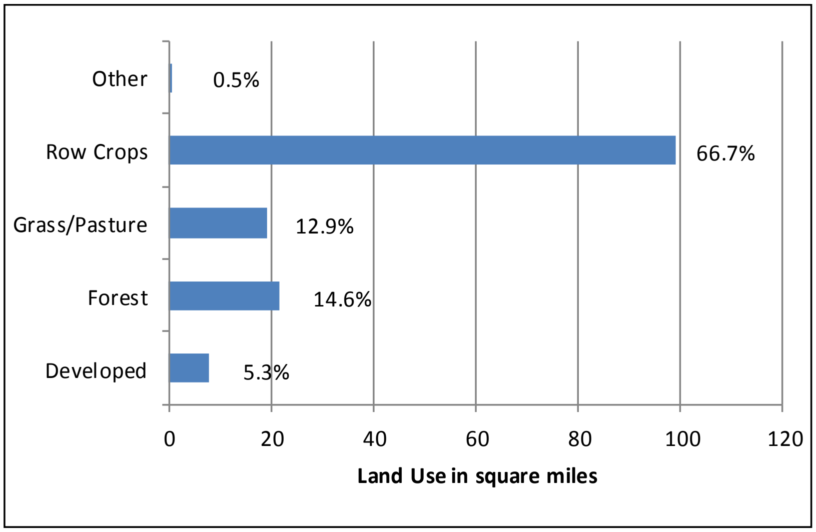


Figure 3-24. Land use in the Lees Creek-Rattlesnake Creek subwatershed.

The majority of the sites sampled in this subwatershed were found to be in attainment of aquatic life use designations; however, over one-half of the sites were in non-attainment the recreation use. In general, the water quality problems in the Lees Creek-Rattlesnake Creek subwatershed were not as serious as those identified in subwatersheds discussed previously in this chapter in terms of the number of sites demonstrating elevated nutrients. Lees Creek, especially downstream of the influence of the Leesburg WWTP, was most problematic for elevated NO_2+NO_3 and total phosphorus concentrations, but Walnut Creek and Hardin Creek also showed problems. The Leesburg WWTP currently does not have effluent limits for either total phosphorus or nitrate+nitrite but is required to monitor its effluent monthly for these parameters. Otherwise nutrient concentrations were either below the in-stream targets or were less than two times the target value.

Other water chemistry results helped to identify causes of aquatic life use impairment. For example, low dissolved oxygen, high ammonia concentrations, and elevated five-day biochemical oxygen demand strongly suggested that organic enrichment was a cause of impairment in Fall Creek.

Figure 3-25 shows the relative occurrence of causes of aquatic life use impairment in the Lees Creek-Rattlesnake Creek subwatershed. Figure 3-26 shows the relative occurrence of sources of aquatic life use impairment in the Lees Creek-Rattlesnake Creek subwatershed. These figures illustrate that full attainment of the aquatic life use designations was observed at 82 percent of sites sampled in this subwatershed. In addition, crop production and unrestricted cattle access to streams accounted for the majority of the water quality impairment identified.

Table 3-5 shows the site-by-site results for each designated beneficial use organized by nested subwatersheds. Seventeen sites were sampled for aquatic life use and all but three of these sites were found to be in full attainment. Nine sites were sampled for bacteria and only four of these sites met the criteria for recreation use full attainment. For more specific information regarding individual site assessment results and supporting chemistry results, please see Appendix B.

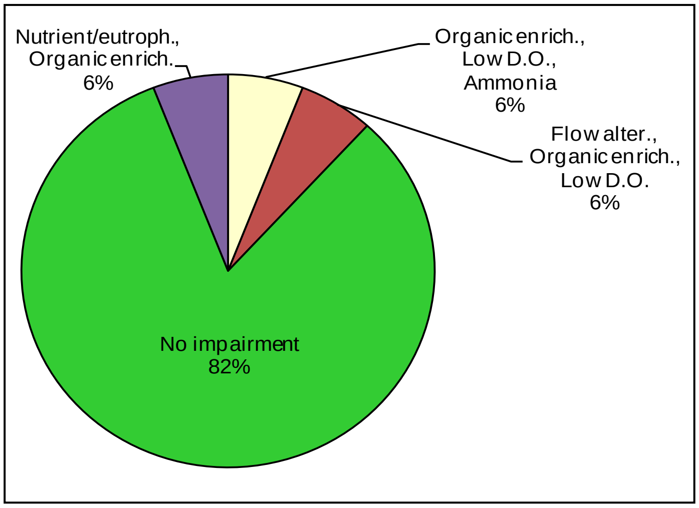


Figure 3-25. Causes of aquatic life use impairment: Lees Creek-Rattlesnake Creek subwatershed.

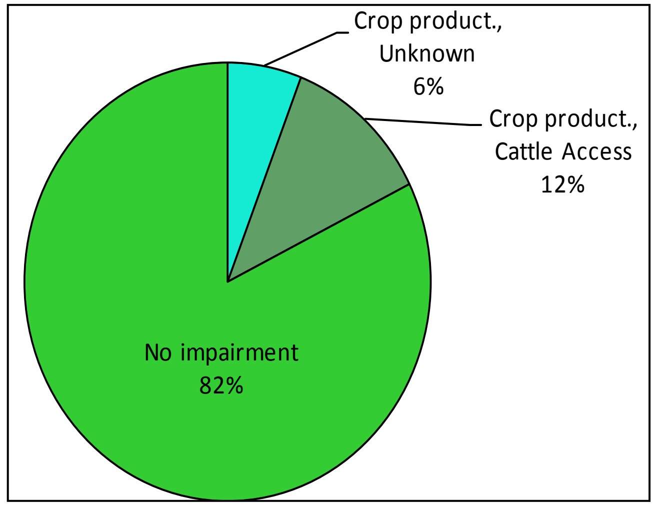


Figure 3.26. Sources of aquatic life use impairment: Lees Creek-Rattlesnake Creek subwatershed.

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

Nested Subwatersheds (05060003 04**)**		**Aquatic Life Use**	**Recreation Use**	**Public Drinking Water Supply Use**	**Human Health Use**[1]
04 01	# impaired sites (non/partial)	1 (1/0)	1		
	Index score	50	0	N/A	N/A
04 02	# impaired sites (non/partial)	0	0		
	Index score	100	100	N/A	N/A
04 03	# impaired sites (non/partial)	1 (1/0)	2		
	Index score	91.7	42	N/A	N/A
04 04	# impaired sites (non/partial)	0	1		
	Index score	100	50	N/A	N/A
04 05	# impaired sites (non/partial)	0	0		
	Index score	100	100	N/A	N/A
04 06	# impaired sites (non/partial)	1 (0/1)	0		
	Index score	50	100	N/A	N/A
04 07	# impaired sites (non/partial)	0	1		
	Index score	100	75	N/A	N/A

[1] Impairments to the human health use are not being addressed in this TMDL.

3.5 Rocky Fork (05060003 05)

The Rocky Fork subwatershed drains 144.4 square miles in the southwestern portion of the watershed (Figure 3-27). It consists of five nested subwatersheds. The main tributaries in this subwatershed are Clear Creek and South Fork Rocky Fork. Major causes of impairment include nutrient and organic enrichment and low dissolved oxygen. Those causes are primarily associated with an impoundment (Rocky Fork Lake) and a municipal wastewater treatment plant.

Figure 3-28 shows distribution of land uses within the Rocky Fork subwatershed. In contrast to the northwestern portions of the Paint Creek watershed, the Rocky Fork subwatershed includes significant amounts forested area as well as land in grass and pasture. Row crop production is the next highest land use at 28.4 percent, with the greatest concentration of row crops planted south of Rocky Fork Lake.

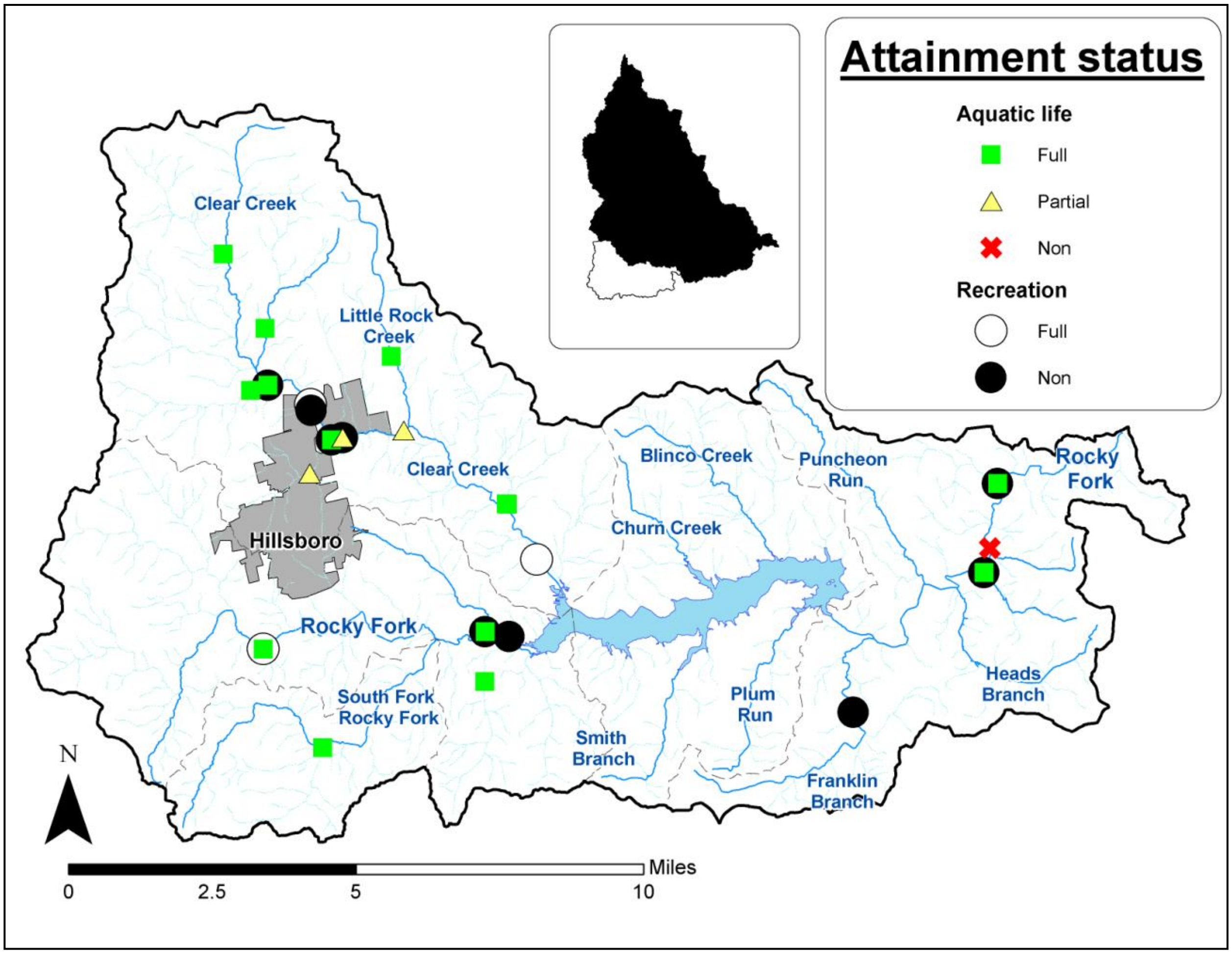


Figure 3-27. Aquatic life use and recreation use attainment in Rocky Fork subwatershed.

The streams in this subwatershed are generally meeting the designated uses as demonstrated in Figure 3-27. For aquatic life use, only three sites were in partial attainment with one site in non-attainment. However, nine sites failed to meet in-stream water quality standards for bacteria.

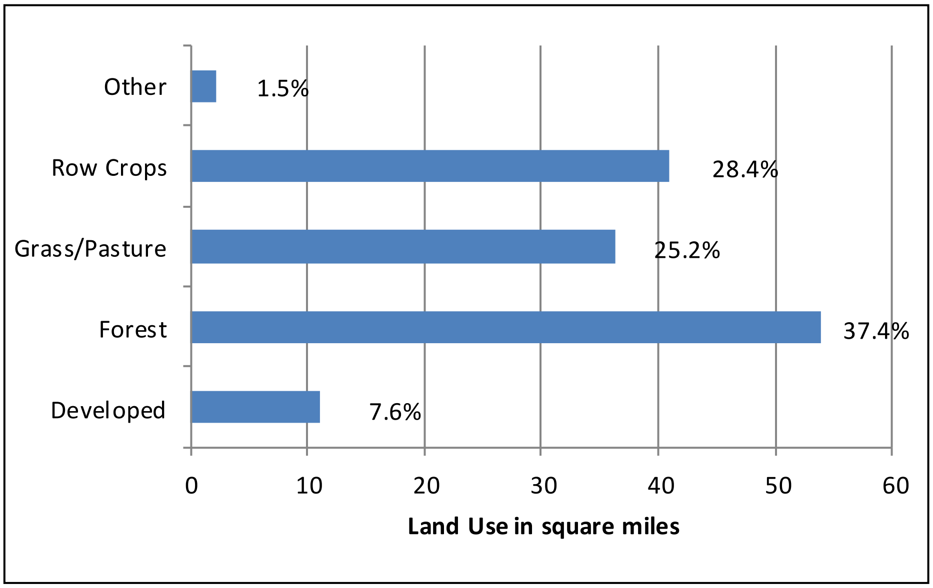


Figure 3-28. Land use in the Rocky Fork subwatershed.

Water chemistry results show that there were two sites with relatively high in-stream concentrations of total phosphorus and nitrate+nitrite (see Figures 3-5 and 3-6).

However, one of these sites was in full attainment of the aquatic life use. The other monitoring site, located on the edge of the City of Hillsboro, was determined to be in partial attainment. Compared to some of the other subwatersheds, the Rocky Fork subwatershed exhibited a higher proportion of water chemistry sites with a low nitrate+nitrite to total phosphorus ratio.

Figure 3-29 shows relative occurrence of causes of aquatic life use impairment in the Rocky Fork subwatershed. Figure 3-30 shows the relative occurrence of sources of aquatic life use impairment in the Rocky Fork subwatershed. Similar to the Lees Creek-Rattlesnake Creek subwatershed, much of the Rocky Fork subwatershed is unimpaired for aquatic life use (78 percent). In addition, this subwatershed is not affected by agricultural practices as evidenced by the sources of impairment listed in Figure 3-30, and is consistent with the land use patterns as well (see Figure 3-28).

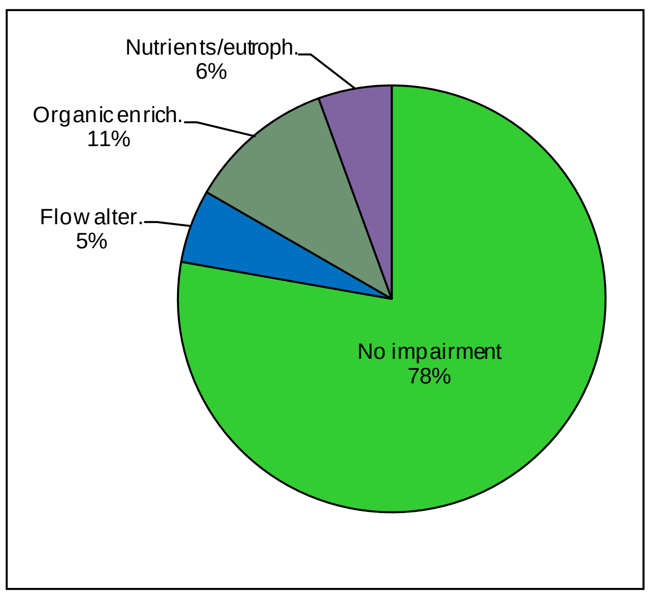


Figure 3-29. Causes of aquatic life use impairment: Rocky Fork subwatershed.

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. The table below shows that two of the nested subwatersheds had no aquatic life use impairment and one was not sampled. Impairment was more widespread for recreation use with one nested subwatershed having four sites in non-attainment and two nested subwatersheds having three and two sites in non-attainment, respectively.

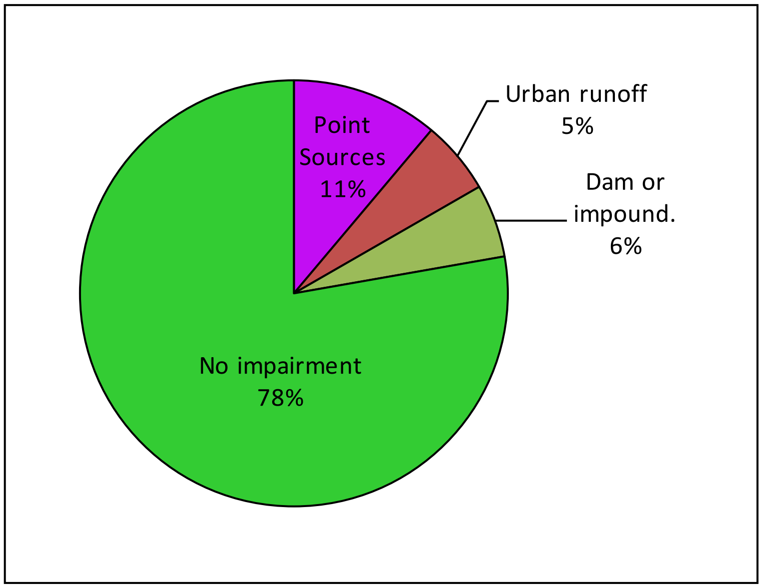


Figure 3-30. Sources of aquatic life use impairment: Rocky Fork subwatershed.

Table 3-6. Number of impaired sites, organized by use and nested subwatershed, in the Rocky Fork subwatershed.

Nested Subwatersheds (05060003 05)		**Aquatic Life Use**	**Recreation Use**	**Public Drinking Water Supply Use**	**Human Health Use**[1]
05 01	# impaired sites (non/partial)	0	Not sampled		
	Index score	100	--	N/A	N/A
05 02	# impaired sites (non/partial)	3 (0/3)	4		
	Index score	71.7	43	Insufficient data	N/A
05 03	# impaired sites (non/partial)	0	2		
	Index score	100	50	N/A	N/A
05 04	# impaired sites (non/partial)	Not sampled	Not sampled		
	Index score	--	--	N/A	N/A
05 05	# impaired sites (non/partial)	1 (1/0)	3		
	Index score	75	67	N/A	N/A

[1] Impairments to the human health use are not being addressed in this TMDL.

3.5.1 Clear Creek (05060003 05 02)

Partial attainment of the aquatic life use designation in this nested subwatershed is attributed to the discharge at the Hillsboro STP, resulting in organic enrichment in Clear Creek downstream from the STP. Three separate bypasses of minimally-treated wastewater occurred from the facility's equalization basin (EQ basin) in September and October 2006, during the time period that some of the biological monitoring was conducted. These bypasses occurred at least in part because one of the facility's clarifiers was out of service, reducing capacity during storm events.

The City of Hillsboro is currently constructing improvements to the WWTP that will eliminate wet weather overflows from the EQ basin and provide better wet weather treatment performance. These improvements are expected to address the water quality problems in Clear Creek identified downstream from the treatment plant, and are expected to be completed by of the beginning of June in 2012. In terms of nutrients, the Hillsboro STP contributes an average effective total phosphorus concentration of just under 0.02 mg/l at estimated average flow conditions (StreamStats - Kolton et al., 2006). The value for nitrate-nitrite is approximately 0.25 mg/l.

3.6 Indian Creek-Paint Creek (05060003 06)

The Indian Creek-Paint Creek subwatershed drains 94.8 square miles in the central portion of the watershed (see Figure 3-31). The City of Washington Court House forms the northern extreme of this subwatershed, while the City of Greenfield is located roughly in the center of the watershed and Paint Creek Lake is the primary geographic feature at the southern end. The subwatershed consists of three nested subwatersheds, and major tributaries include Indian Creek and Farmers Run.

Major causes of impairment include nutrient and organic enrichment and low dissolved oxygen. Those causes are primarily associated with an impoundment (Paint Creek Lake) and a municipal wastewater treatment plant.

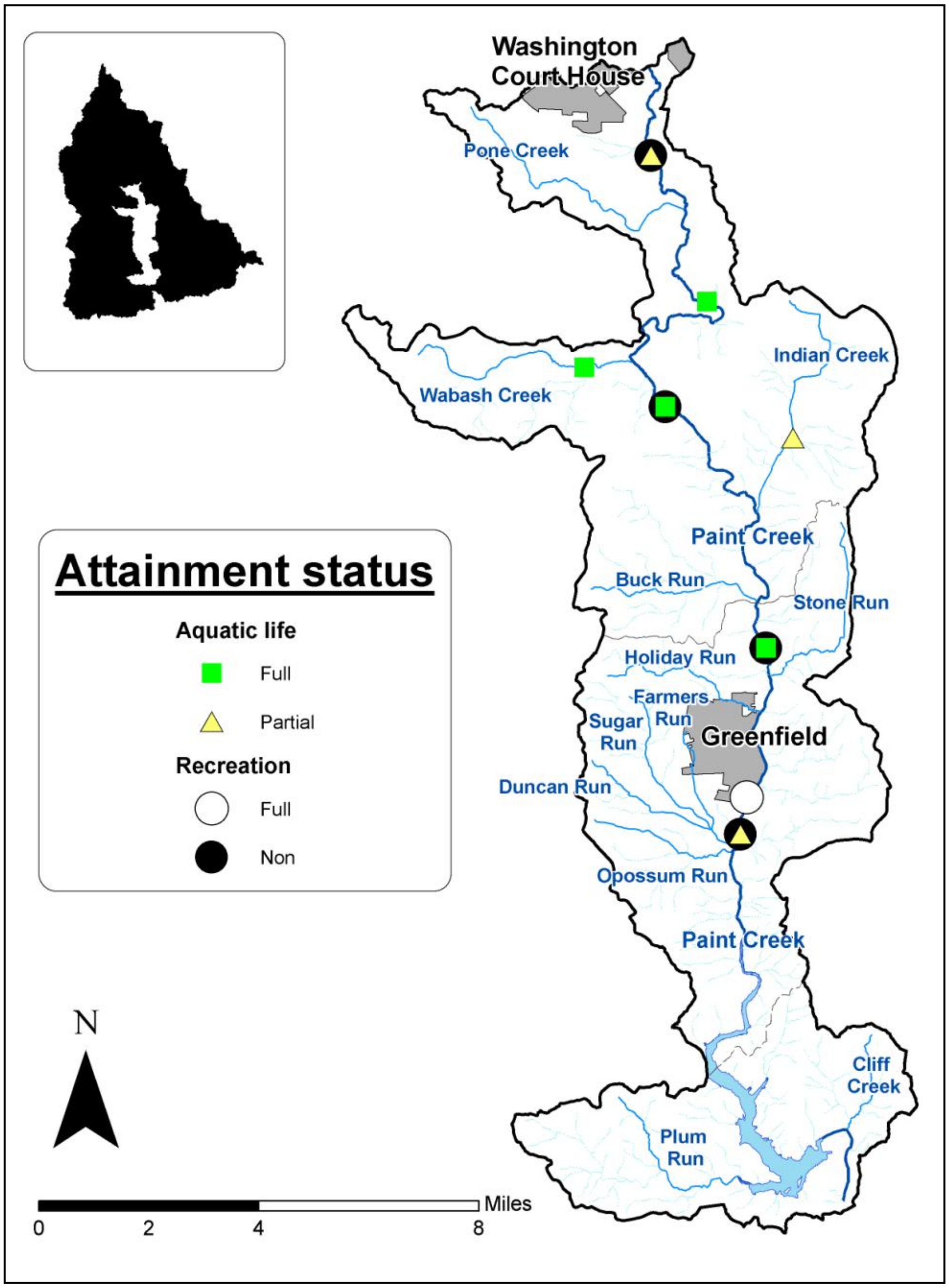


Figure 3-31. Aquatic life use and recreation use attainment in the Indian Creek-Paint Creek subwatershed.

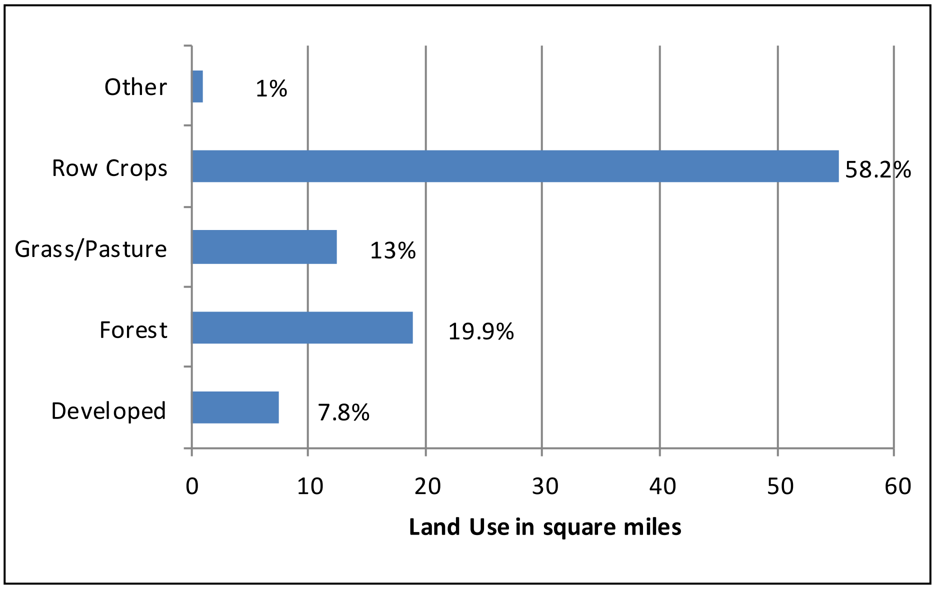


Figure 3-32. Land use in the Indian Creek-Paint Creek subwatershed.

In most cases, these causes are associated with land uses in the subwatershed (see Appendix B for further information). Figure 3-32 shows land use within the Indian Creek-Paint Creek subwatershed. While the percentage of land use devoted to row crops in this subwatershed is much lower than in the Sugar Creek subwatershed or the Headwaters Paint Creek subwatershed, row crops are more prevalent here than the Rocky Fork subwatershed.

Most of the water chemistry sampling sites and all of the biological sampling sites are located in the northern sections of this subwatershed. Almost one-half of the sites were in partial attainment of the aquatic life use, while all except one sampling location were in non-attainment of the recreation use (see Figure 3-31). Two of the sites in partial attainment of the aquatic life use also exhibited relatively high in-stream concentrations of total phosphorus and nitrate+nitrite. These sites are located just downstream of Washington Court House and Greenfield (see Figures 3-5 and 3-6).

The Washington Court House WWTP plant discharges into Paint Creek at the upstream end of this subwatershed, strongly influencing the water quality in this reach, especially with respect to nutrients. According to the Paint Creek Technical Support Document:

"…Relative to the other assessment units, phosphorus concentrations were an order of magnitude higher, and ammonia concentrations were frequently elevated above background conditions…Nutrient enrichment in the mainstem of Paint Creek was evident in high diel swings in dissolved oxygen concentrations at RM [river mile] 58.8…Excellent habitat, especially high gradient riffle habitat, in this reach apparently offered sufficient refugia to prevent localized impacts to the aquatic biota. Downstream from Greenfield, however, stonerollers, an herbivorous fish, had an unusually high relative abundance apparently stimulated by enrichment." [page 89]

Some of the water chemistry results as discussed above aided in identifying causes of aquatic life use impairment. Figure 3-33 shows relative occurrence of causes of aquatic life use impairment in the Indian Creek-Paint Creek subwatershed. Figure 3-34 shows the relative occurrence of sources of aquatic life use impairment in the Indian Creek-Paint Creek subwatershed.

Table 3-7 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.

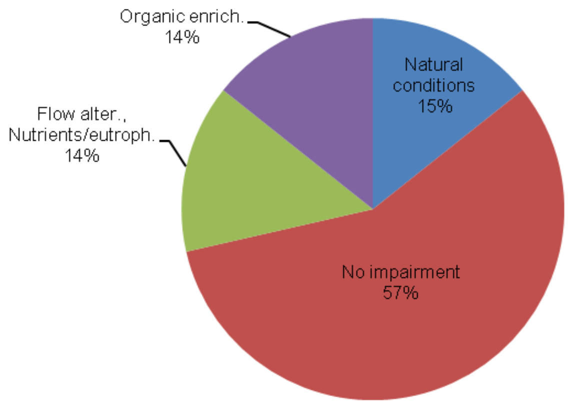


Figure 3-33. Sources of aquatic life use impairment: Indian Creek-Paint Creek subwatershed.

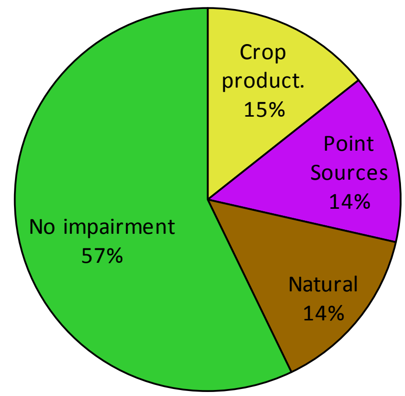


Figure 3-34. Sources of aquatic life use impairment: Indian Creek-Paint Creek subwatershed.

Table 3-7. Number of impaired sites, organized by use and nested subwatershed, in the Indian Creek-Paint Creek subwatershed.

Nested Subwatersheds (05060003 06**)**		**Aquatic Life Use**	**Recreation Use**	**Public Drinking Water Supply Use**	**Human Health Use**[1]
06 01	# impaired sites (non/partial)	2 (0/2)	2		
	Index score	58.3	43	N/A	N/A
06 02	# impaired sites (non/partial)	1 (0/1)	2		
	Index score	50	66	N/A	N/A
06 03	# impaired sites (non/partial)	Not sampled	0		Impaired (PCBs)
	Index score	--	100	N/A	N/A

[1] Impairments to the human health use are not being addressed in this TMDL.

3.7 Buckskin Creek-Paint Creek (05060003 07)

The Buckskin Creek-Paint Creek subwatershed drains 122.2 square miles in the southern portion of the watershed and consists of four nested subwatersheds (Figure 3-35). The main tributaries in this subwatershed include Buckskin Creek, Sulphur Lick, Upper Twin Creek, and Lower Twin Creek, with the Paint Creek mainstem traversing the watershed from west to east. Major causes of impairment include nutrients/eutrophication, flow alterations, sedimentation, low dissolved oxygen, and habitat alteration. Those causes are primarily associated with agriculture (row crops and channelization).

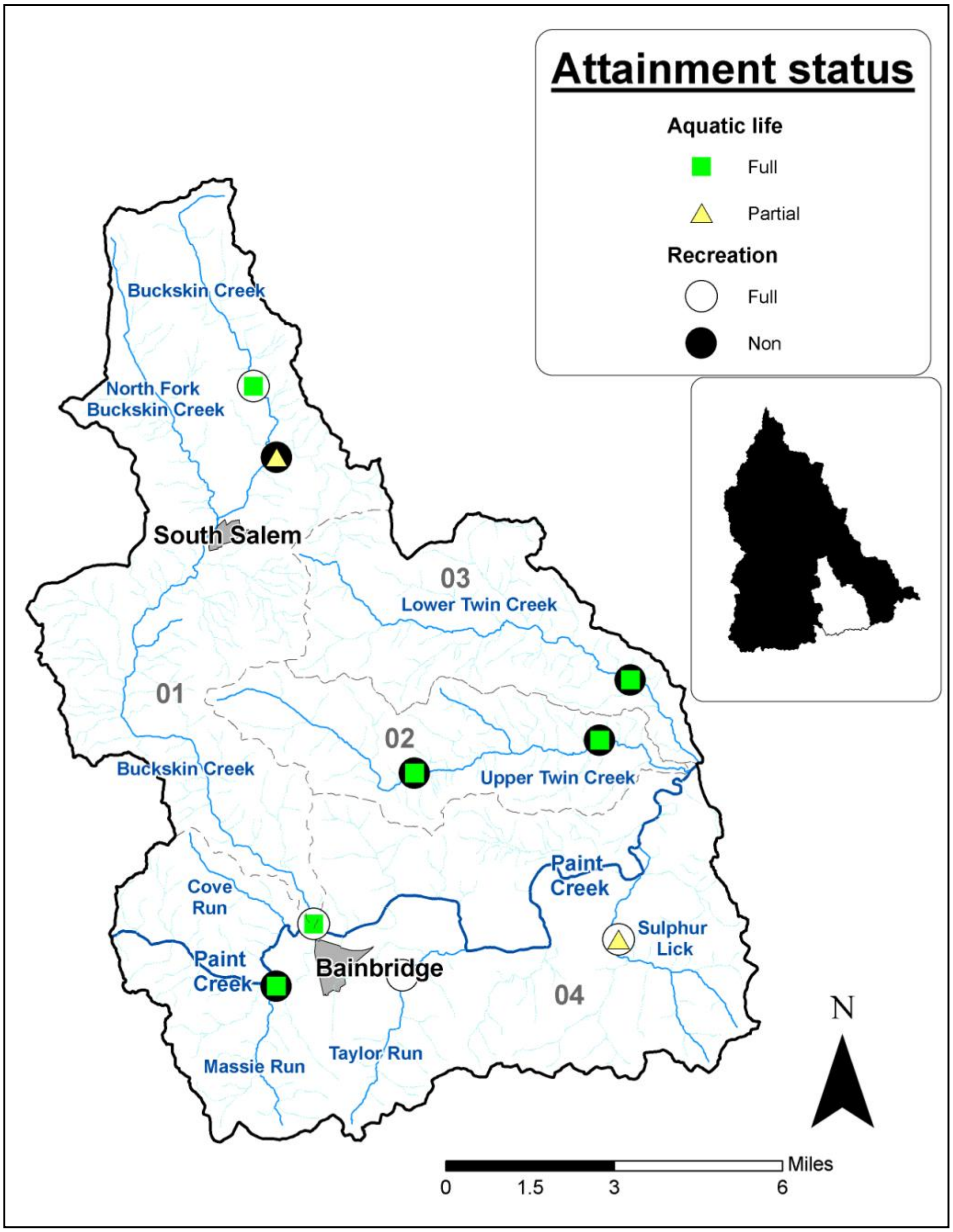


Figure 3-35. Aquatic life use and recreation use attainment in the Buckskin Creek-Paint Creek subwatershed.

In most cases, these causes are associated with land uses in the subwatershed (see Appendix B for further information). Figure 3-36 shows land use within the Buckskin Creek-Paint Creek subwatershed. Slightly more than one-half of the subwatershed is classified as forest, while approximately 40 percent of land use is devoted to row crop agriculture and grass/pasture.

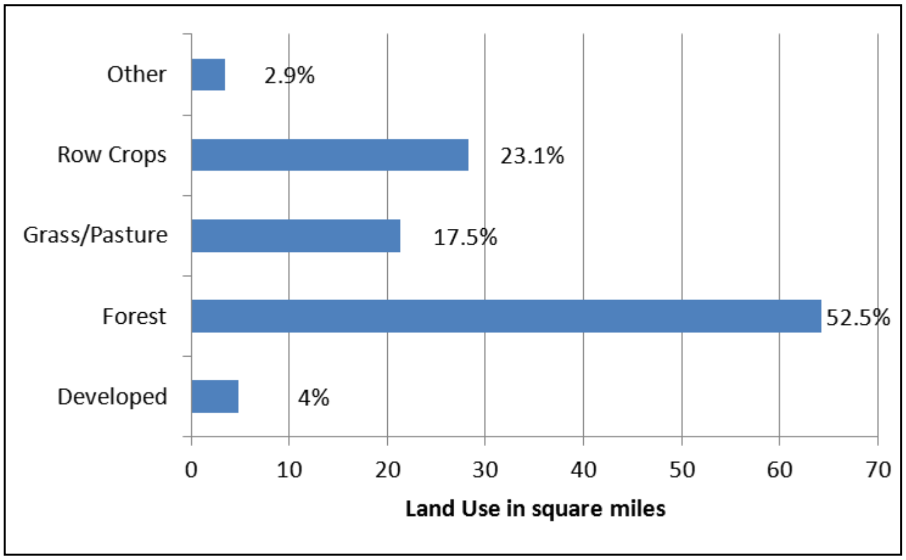


Figure 3-36. Land use in the Buckskin Creek-Paint Creek subwatershed.

As shown in Figure 3-35, streams in this subwatershed were generally meeting aquatic life use designations as illustrated by only two sampling locations being in partial attainment compared with six sites which were in full attainment. In-stream sampling results for total phosphorus and nitrate+nitrite provide further support that streams in this subwatershed are of high quality. Concentrations for both of these pollutants were found to be relatively low (see Figures 3-5 and 3-6).Figure 3-5. Spatial distribution of mean nitrate-nitrite concentrations in streams in the Paint Creek watershed.

Some of the water chemistry results aided in identifying causes of aquatic life use impairment. **Error! Reference source not found.**37 shows relative occurrence of causes of aquatic life use impairment in the Buckskin Creek-Paint Creek subwatershed. Figure 3-38 shows the relative occurrence of sources of aquatic life use impairment in the Buckskin Creek-Paint Creek subwatershed. These figures demonstrate that the majority of the subwatershed is un-impaired for the aquatic life use, and sites which did not meet the designated use were affected by agriculture (i.e., crop production and channelization associated with agricultural operations).

Observations showed high quality habitat for a number of the tributaries in this subwatershed. According to the Paint Creek Technical Support Document, habitat quality ranged from very good to excellent in Upper Twin Creek, and excellent for Lower Twin Creek and Buckskin Creek.

Table 3-8 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

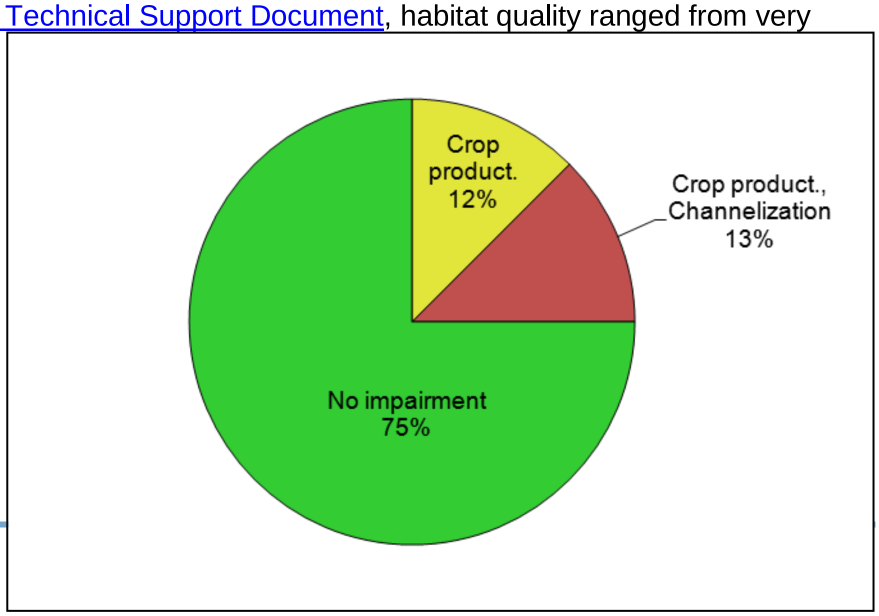


Figure 3-38. Sources of aquatic life use impairment: Buckskin Creek-Paint Creek subwatershed.

supporting chemistry results, please see Appendix B. Three sites were sampled in the first nested subwatershed, two sites in the second and fourth nested subwatersheds and one site in the third.

Table 3-8. Number of impaired sites, organized by use and nested subwatershed, in the Buckskin Creek-Paint Creek subwatershed.

Nested Subwatersheds (05060003 07**)**		**Aquatic Life Use**	**Recreation Use**	**Public Drinking Water Supply Use**	**Human Health Use**[1]
07 01	# impaired sites (non/partial)	1 (0/1)	1		
	Index score	75	92	N/A	N/A
07 02	# impaired sites (non/partial)	0	2		
	Index score	100	50	N/A	N/A
07 03	# impaired sites (non/partial)	0	1		
	Index score	100	75	N/A	N/A
07 04	# impaired sites (non/partial)	1 (0/1)	1		
	Index score	50	75	N/A	N/A

[1] Impairments to the human health use are not being addressed in this TMDL.

3.8 Headwaters North Fork Paint Creek (05060003 08)

The Headwaters North Fork Paint Creek subwatershed drains 120.6 square miles in the northeastern portion of the watershed (see Figure 3-39). It consists of five nested subwatersheds (12-digit assessment units). The main tributaries in this watershed are Compton Creek and Thompson Creek. No aquatic life use impairment was identified in this subwatershed.

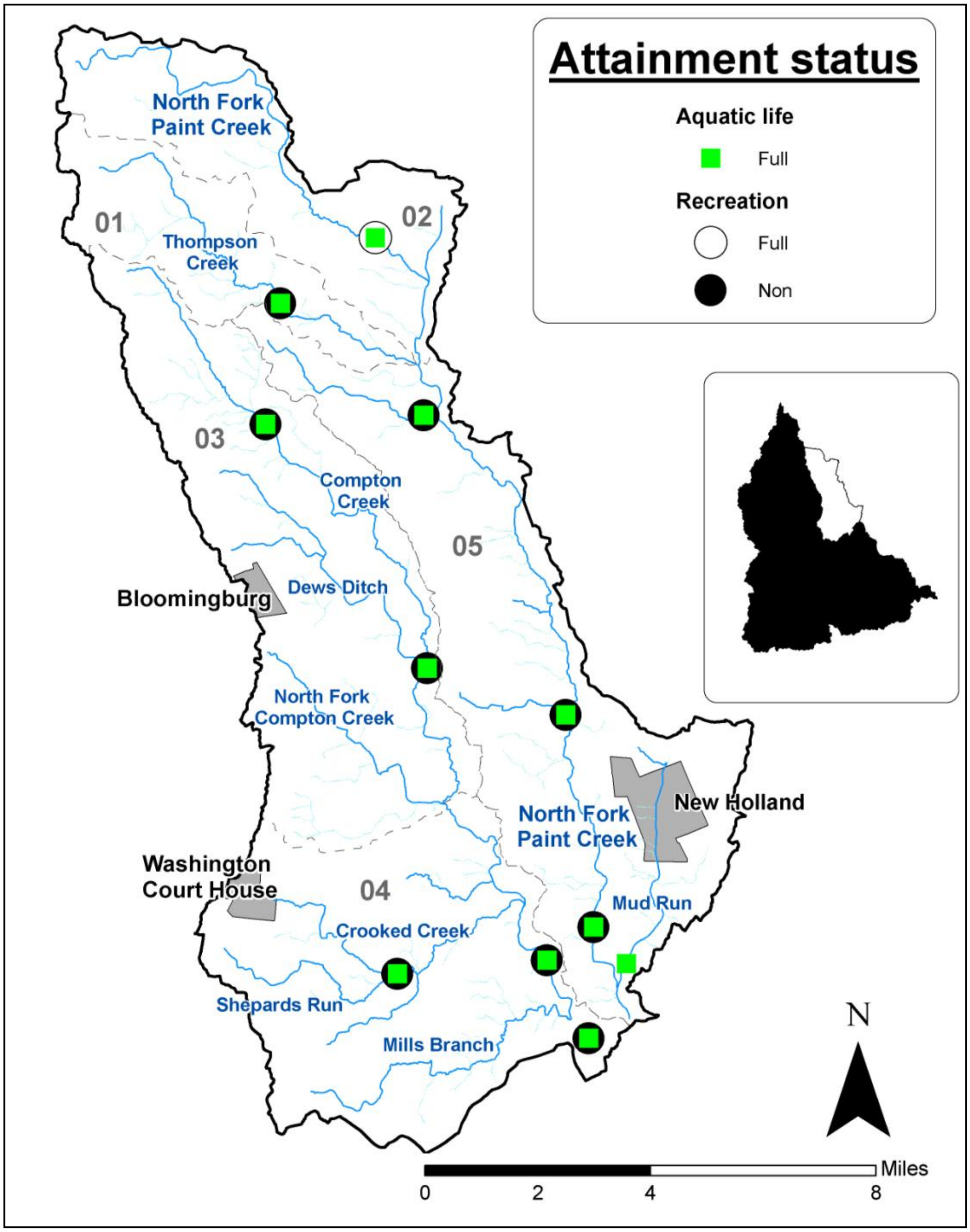


Figure 3-39. Aquatic life use and recreation use attainment in the Headwaters North Fork Paint Creek subwatershed.

Land uses in this subwatershed are shown in Figure 3-40. The predominance of row crop agriculture in this subwatershed is similar to the Headwaters Paint Creek and Sugar Creek subwatershed. In addition, average phosphorus and nitrate+nitrite in-stream concentrations were relatively high at two locations near the downstream portion of this subwatershed (see Figures 3-5 and 3-6).

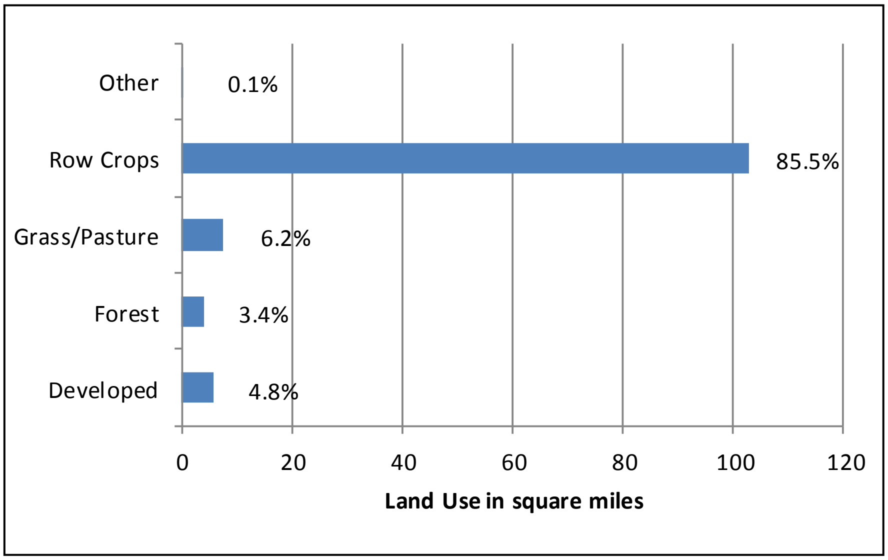


Figure 3-40. Land uses in Headwaters North Fork Paint Creek subwatershed.

However, in the North Fork subwatershed, soils are generally coarser and better drained, and stream gradients are relatively high. So although the stream network was historically ditched, most streams in the North Fork have recovered many important features typical of natural streams. The improved habitat supports more species of fish, notably those dependent on pools (e.g., longear sunfish, striped shiners, golden redhorse, rockbass, smallmouth bass) and clean substrates (i.e., darters) than streams to the west. These factors have likely been important towards resulting in the full attainment status for aquatic life use within the subwatershed.

Table 3-9 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. As shown in this table and in Figure 3-39, the majority of sampling locations for bacteria were in non-attainment of the recreation use.

Table 3-9. Number of impaired sites, organized by use and nested subwatershed, in the Headwaters North Fork Paint Creek subwatershed.

Nested Subwatersheds (05060003 08)		Aquatic Life Use	Recreation Use	Public Drinking Water Supply Use	Human Health Use[1]
08 01	# impaired sites (non/partial)	0	1		
	Index score	100	50	N/A	N/A
08 02	# impaired sites (non/partial)	0	0		
	Index score	100	100	N/A	N/A
08 03	# impaired sites (non/partial)	0	2		
	Index score	100	50	N/A	N/A
08 04	# impaired sites (non/partial)	0	3		
	Index score	100	58	N/A	N/A
08 05	# impaired sites (non/partial)	0	3		
	Index score	100	58	N/A	N/A

[1] Impairments to the human health use are not being addressed in this TMDL.

3.9 Little Creek-North Fork Paint Creek (05060003 09)

The Little Creek-North Fork Paint Creek subwatershed drains 114.1 square miles in the northern portion of the watershed (see Figure 3-41). It consists of four nested subwatersheds (12-digit assessment units). The main tributaries in this watershed are Little Creek and Herrod Creek. Major causes of impairment include sedimentation/siltation and organic enrichment. Those causes are primarily associated on-site sewage treatment systems.

In most cases, causes of impairment are associated with land uses in the subwatershed (see Appendix C for further information). However, the predominant land uses in this subwatershed have not contributed towards the water quality impairment. Figure 3-42 shows land use distribution within the Little Creek-North Fork Paint Creek subwatershed. Row crop agriculture is again the predominant land use in this subwatershed, but the combination of forest and grass/pasture makes up approximately an equal portion of land use here.

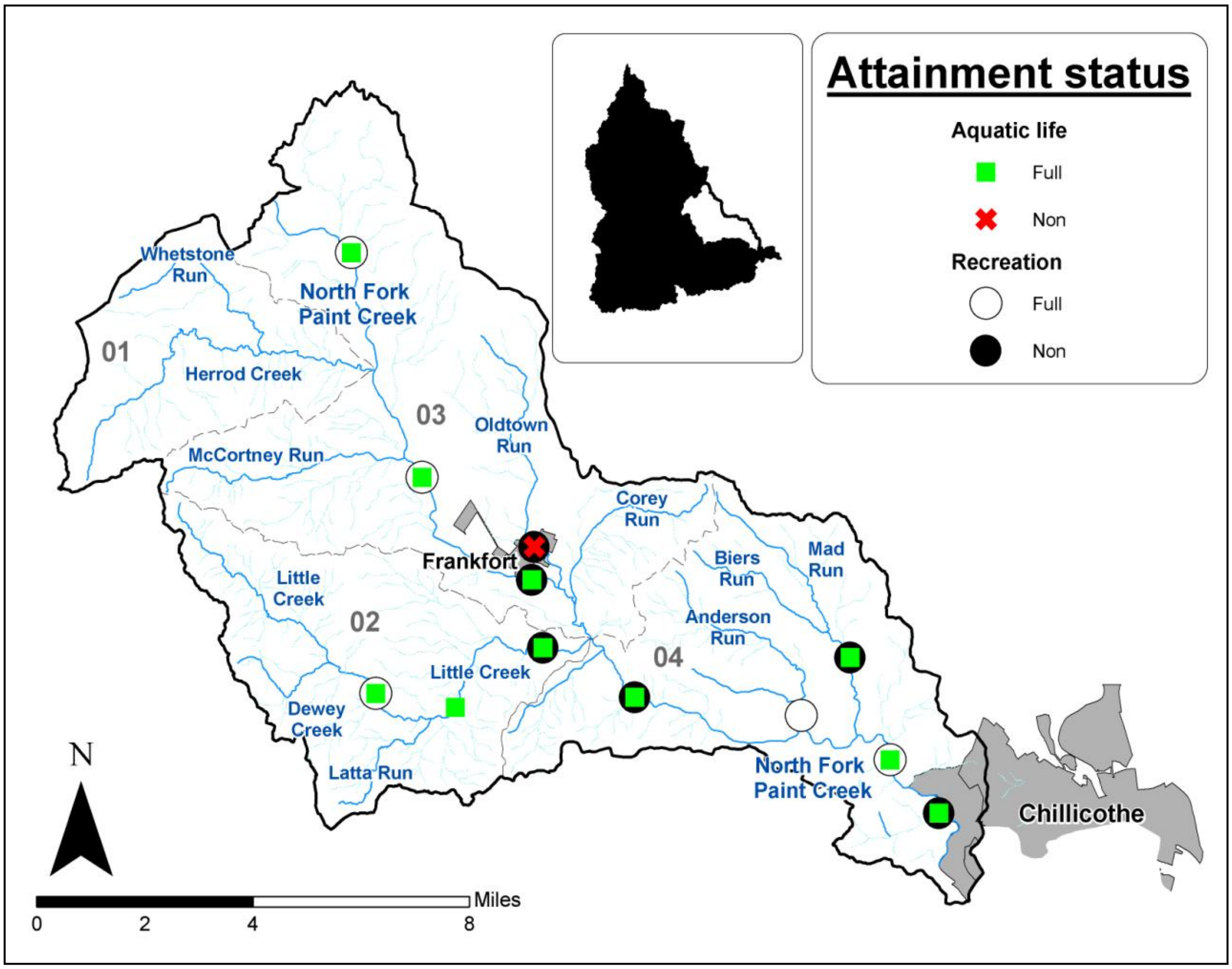


Figure 3-41. Aquatic life use and recreation use attainment in the Little Creek-North Fork Paint Creek subwatershed.

Some of the water chemistry results for this subwatershed showed relatively high in-stream concentrations of average nitrate+nitrite and total phosphorus, most notably on the North Fork Paint Creek downstream from the Frankfort WWTP and also near the City of Chillicothe (see Figures 3-5 and 3-6).

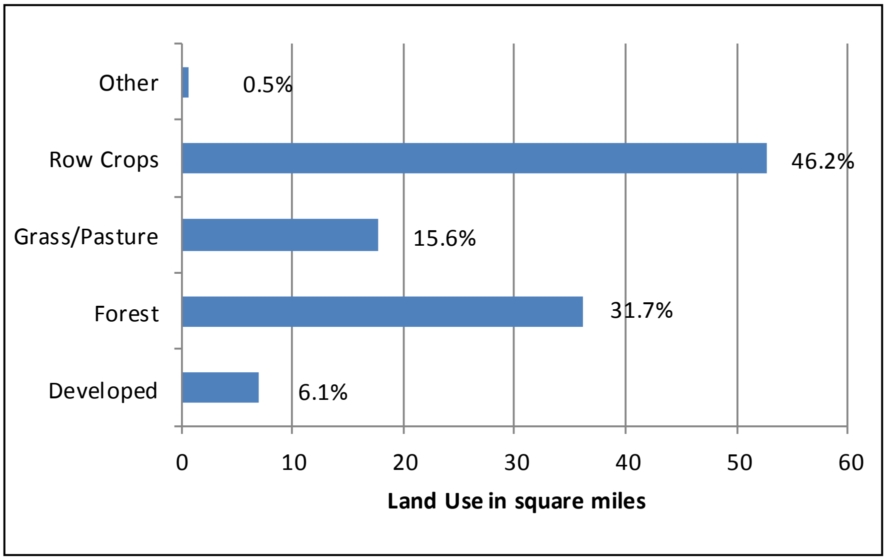


Figure 3-42. Land use in the Little Creek-North Fork Paint Creek subwatershed.

Wastewater discharged from the Frankfort WWTP in years past has been under-treated as evidenced by high ammonia-nitrogen concentrations and bacteria. Twenty-four sampling results reported by the WWTP within the last five years violated the limits in their NPDES permit. However, operation of the facility has improved, and no permit limit violations have occurred since September of 2009.

Despite the problems associated with the Frankfort WWTP and other relatively high water chemistry results, sites monitored at these locations were in full attainment of the aquatic life use. Figure 3-43 shows relative occurrence of causes of aquatic life use impairment in the Little Creek-North Fork Paint Creek subwatershed. Figure 3-44 shows the relative occurrence of sources of aquatic life use impairment in the Little Creek-North Fork Paint Creek subwatershed. As evidenced in these figures, the majority of the subwatershed was in full attainment of the aquatic life use designation. Only one site located on Oldtown Run was found to be in non-attainment due to on-site sewage treatment systems.

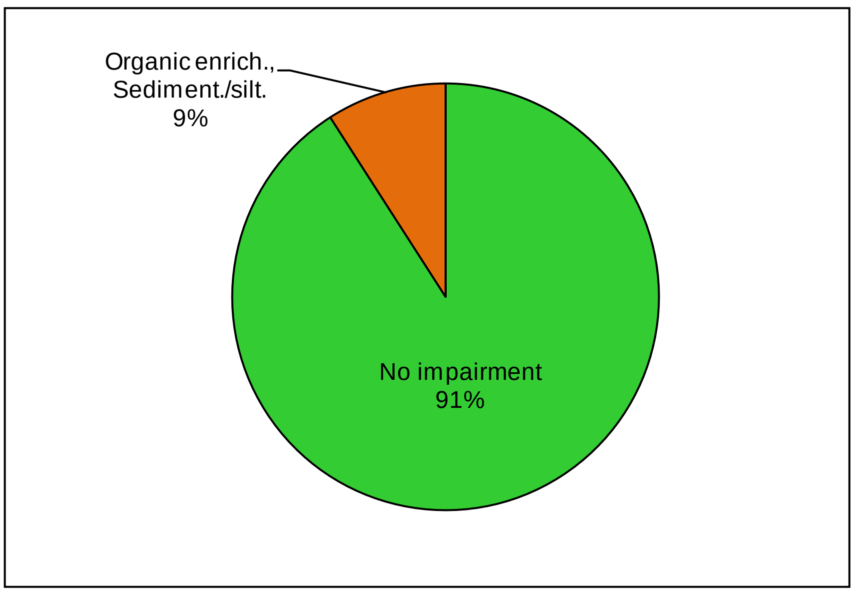


Figure 3-43. Causes of aquatic life use impairment: Little Creek-North Fork Paint Creek subwatershed.

Table 3-10 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.

Six of the eleven sites sampled for bacteria were in non-attainment of the recreation use in this subwatershed. Figure 3-41 as well as Table 3-10 show that the majority of impaired sites for the recreation use were located in nested subwatersheds 09 03 and 09 04.

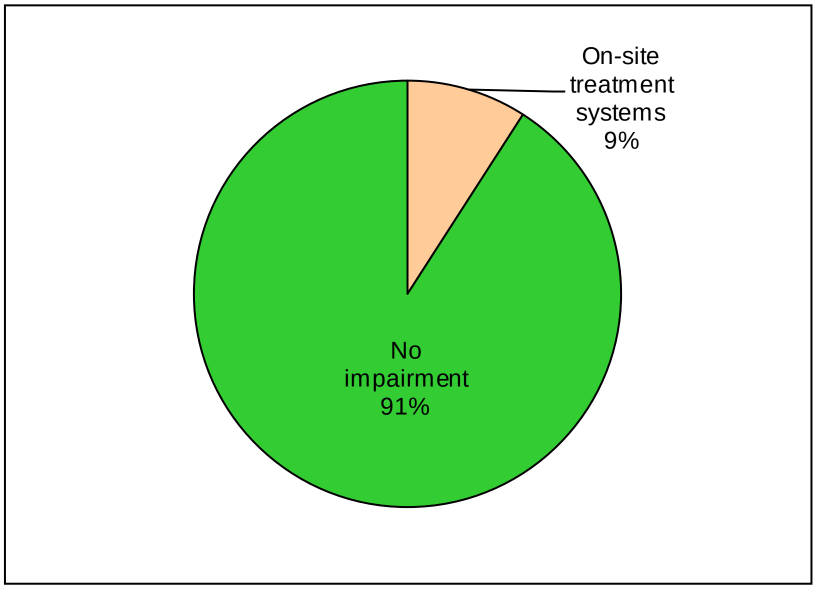


Figure 3-44. Sources of Aquatic Life Use Impairment: Little Creek-North Fork Paint Creek subwatershed.

Table 3-10. Number of impaired sites, organized by use and nested subwatershed, in the Little Creek-North Fork Paint Creek subwatershed.

Nested Subwatersheds (05060003 09**)**		**Aquatic Life Use**	**Recreation Use**	**Public Drinking Water Supply Use**	**Human Health Use[1]**
09 01	# impaired sites (non/partial)	Not sampled	Not sampled		
	Index score	--	--	N/A	N/A
09 02	# impaired sites (non/partial)	0	1		
	Index score	100	88	N/A	N/A
09 03	# impaired sites (non/partial)	1 (1/0)	2		
	Index score	50	88	N/A	N/A
09 04	# impaired sites (non/partial)	0	3		
	Index score	100	85	N/A	N/A

[1] Impairments to the human health use are not being addressed in this TMDL.

3.10 Ralston Run-Paint Creek (05060003 10)

The Ralston Run-Paint Creek subwatershed drains 66.1 square miles in the southeastern portion of the watershed (see Figure 3-45). It consists of three nested subwatersheds (12-digit assessment units). The main tributaries in the watershed are Ralston Run and Black Run. Similar to the Little Creek-North Fork Paint Creek subwatershed, the major causes of impairment in this subwatershed are sedimentation/siltation and organic enrichment. Those causes are primarily associated on-site sewage treatment systems.

In most cases, causes of impairment are associated with land uses in the subwatershed (see Appendix B for further information). However, the predominant land uses in this subwatershed have not contributed towards the identified water quality impairment. Figure 3-46 shows that the categories of forested land and grass/pasture account for 73 percent of the land use within the Ralston Run-Paint Creek subwatershed.

Water chemistry results from this subwatershed show that average nitrate+nitrite and total phosphorus in-stream concentrations were relatively low compared with other subwatersheds (see Figures 3-5 and 3-6).

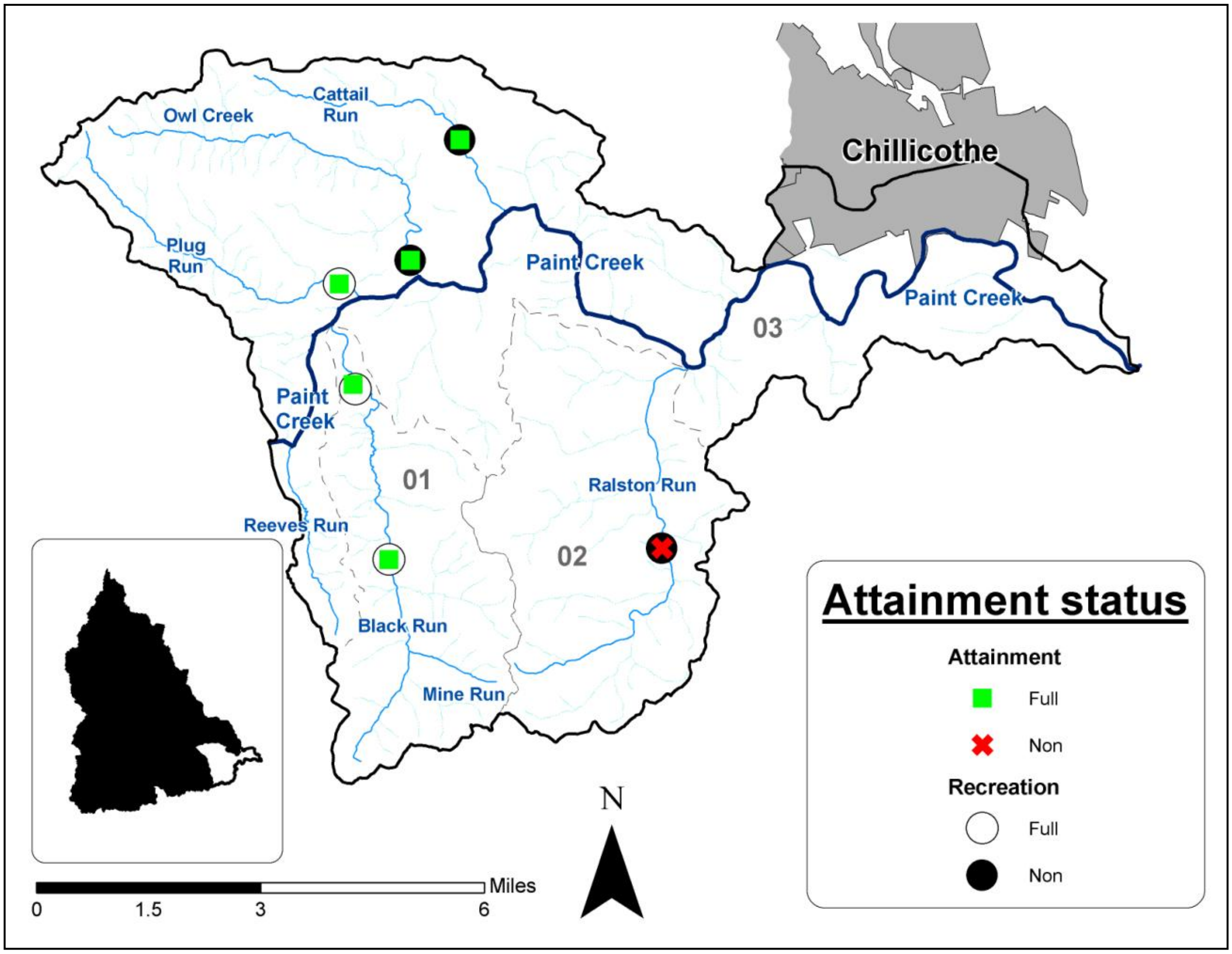


Figure 3-45. Aquatic life use and recreation use attainment in the Ralston Run-Paint Creek subwatershed.

Figure 3-47 shows relative occurrence of causes of aquatic life use impairment in the Ralston Run-Paint Creek subwatershed. Figure 3-48 shows the relative occurrence of sources of aquatic life use impairment in the Ralston Run-Paint Creek subwatershed. As shown in Figure 3-45, only one sampling site was in non-attainment of the aquatic life use in the subwatershed, due to on-site sewage treatment systems.

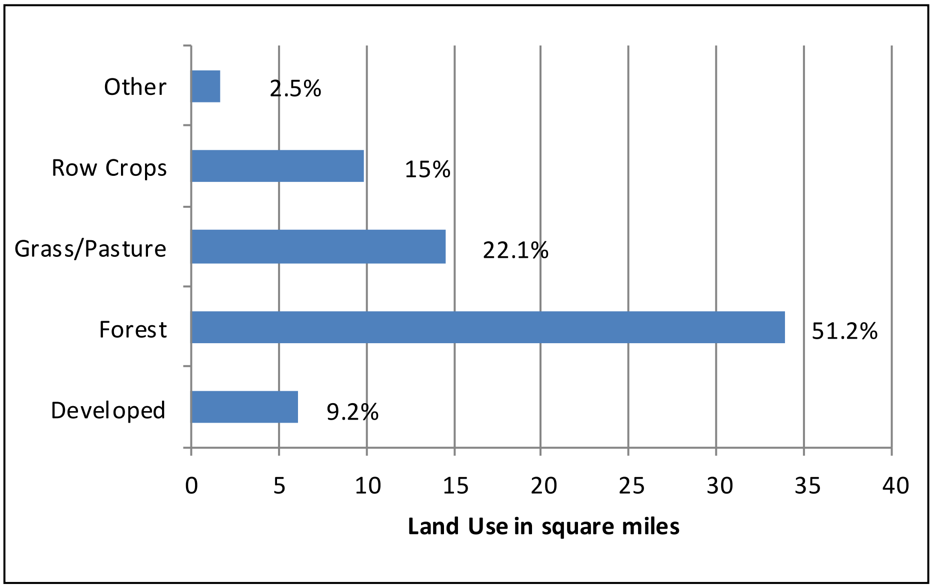


Figure 3-46. Land use in the Ralston Run-Paint Creek subwatershed.

Four of the tributaries to Paint Creek in this subwatershed were verified for the warmwater habitat aquatic life use. However, a number of coldwater macroinvertebrates were identified in Black Run, Owl Creek, Plug Run, and Cattail Run, justifying a coldwater habitat aquatic life use designation.

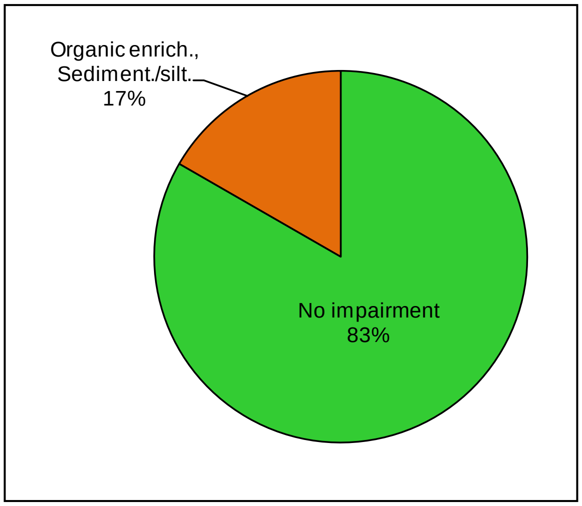


Figure 3-47. Causes of aquatic life use impairment: Ralston Run-Paint Creek subwatershed.

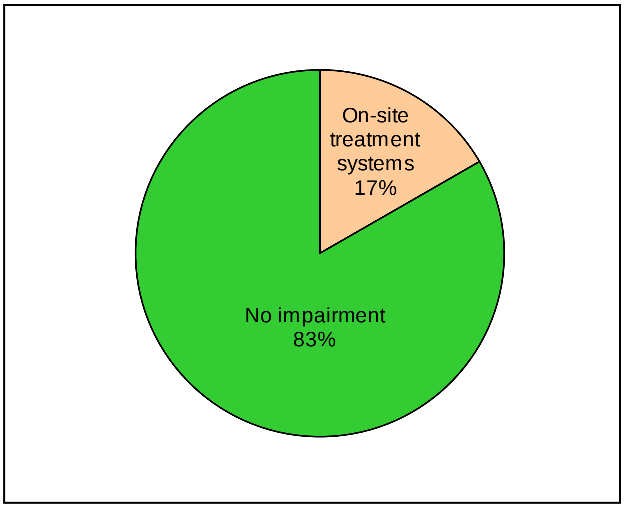


Figure 3-48. Sources of aquatic life use impairment: Ralston Run-Paint Creek subwatershed.

Table 3-11 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. Three of the six sites sampled for bacteria were in non-attainment of the recreation use for the subwatershed.

Table 3-11. Number of impaired sites, organized by use and nested subwatershed, in the Ralston Run-Paint Creek subwatershed.

Nested Subwatersheds (05060003 10**)**		**Aquatic Life Use**	**Recreation Use**	**Public Drinking Water Supply Use**	**Human Health Use**[1]
10 01	# impaired sites (non/partial)	0	0		
	Index score	100	100	N/A	N/A
10 02	# impaired sites (non/partial)	1 (1/0)	1		
	Index score	0	75	N/A	N/A
10 03	# impaired sites (non/partial)	0	2		Impaired (PCBs)
	Index score	100	58	N/A	N/A

[1] Impairments to the human health use are not being addressed in this TMDL.

3.11 Large River Assessment Unit - Paint Creek

The large river assessment unit for the Paint Creek watershed is shown in Figure 3-49, and is defined by the Paint Creek mainstem from immediately downstream of Paint Creek Lake to the mouth of Paint Creek near Chillicothe. As shown in this figure, all sampling sites for both aquatic life and recreation use were in attainment within the assessment unit, with the exception of a site just downstream of Paint Creek Lake and another site slightly upstream of Bainbridge.

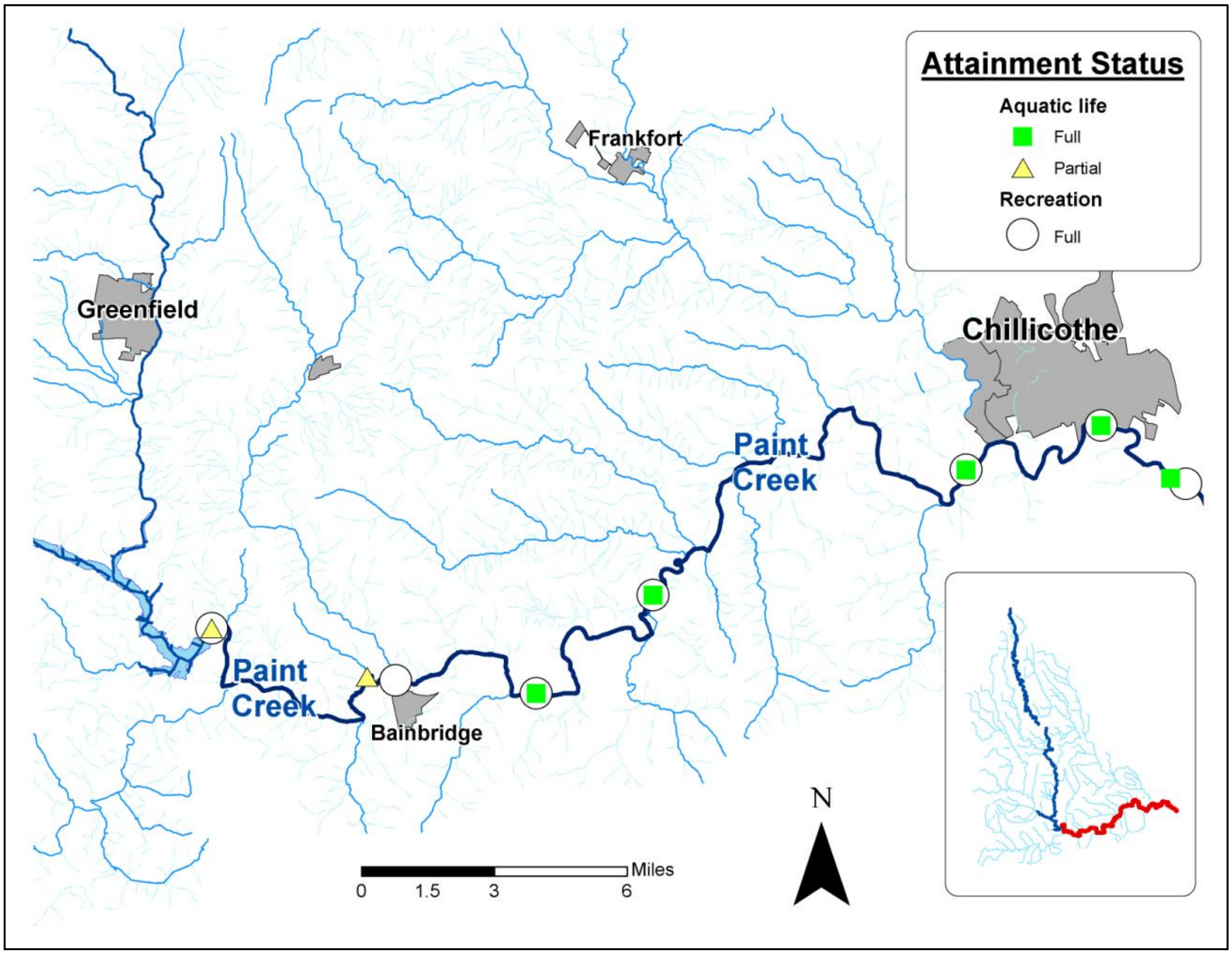


Figure 3-49. Aquatic life use and recreation use attainment in the large river assessment unit for Paint Creek watershed.

The partial impairment of the aquatic life use at both of these sites was associated with releases from Paint Creek Lake. The water chemistry results helped to substantiate Paint Creek Lake as the source of impairment, since in-stream sampling showed low dissolved oxygen.

4 METHODS TO CALCULATE LOAD REDUCTIONS

Several subwatersheds within the Paint Creek watershed do not support beneficial uses, specifically, aquatic life, recreation, and human health (fish consumption). The causes of aquatic life use impairment are sedimentation, nutrient enrichment, organic enrichment, low dissolved oxygen, poor habitat quality, high ammonia concentrations, and alteration of natural flow conditions. The cause of recreation use impairment is elevated concentrations of an indicator bacterium, *E. coli*. Two 12-digit HUCs showed impairment to human health due to relatively high concentrations of PCBs in the tissues of game fish species; however, no TMDLs are developed to address this water quality concern due to the absence of ongoing loading of this pollutant (i.e., PCBs are legacy pollutants that remain in the sediment of the stream system and their concentration attenuates over time).

Linkage analysis examines the cause and effect relationships between watershed characteristics, pollutant sources and ultimately the effect on the stream biology. The primary purpose of a linkage analysis is to evaluate the use of a surrogate water quality stressor to address another stressor that has a similar set of sources. The linkage between the stressors and the alternative water quality stressor(s) used in surrogate should be established to reasonably assure that controlling the source of the surrogate indicators as prescribed by the TMDL allocations results in restoration of quality and support of the applicable beneficial use(s). The following subheadings discuss the linkage between the various water quality stressors and their impact on the health of aquatic ecosystems and consequently the bio-metrics used in Ohio's water quality criteria. In addition, Tables 4-1 and 4-2 present data characterizing waste wastewater from the largest treatment works in the basin in relation to nutrient enrichment, which is a substantial problem in the basin with some of the more complex loading pathways. And finally, Tables 4-3 through 4-8 indicate how the applicable causes of impairment are addressed in each of the assessment units.

Total phosphorus to address nutrient enrichment and dissolved oxygen
The aquatic life use designations for warmwater and exceptional warmwater habitats are impaired in several areas in the northern region of the Paint Creek. Nutrient enrichment causes ill effects on aquatic life when the elevated nutrient concentrations are accompanied by excessive primary production (growth of plant life), mostly in the form of algae. The negative impact of the elevated plant biomass on the aquatic community is due to disruptions in normal dissolved oxygen cycles, as well as a substantial shift in the food web and to a lesser extent habitat degradation. The cause-effect relationships between excessive plant biomass and dissolved oxygen stress on aquatic organisms and the necessity of an abundant nutrient supply to foster the excessive plant biomass production means that nutrients are a very suitable surrogate to address dissolved oxygen stress in stream and lake systems when the oxygen stress is driven by excessive plant biomass.

During the day the oxygen produced through photosynthesis exceeds that which is consumed through respiration. At night, however, photosynthesis stops while respiration of the system continues to consume oxygen. This process is amplified in a stream with excessive plant biomass (e.g., algae) where daytime oxygen concentrations (or percent saturation) get extremely high and nighttime oxygen consumption rapidly depletes oxygen concentrations often to critical lows. Irrespective of how low the nighttime dissolved oxygen concentrations become (i.e., to the point of stress or mortality), the wide oscillations alone are believed to be stressful to aquatic organisms leading to avoidance type behaviors and possibly local extirpations. In fact, Ohio EPA, in its development of nutrient criteria, elucidates a recommended range in the diel dissolved oxygen concentrations (Miltner, 2011). Additionally, excessive algae production creates chronic low dissolved oxygen effects on a seasonal basis. The water column is depleted of oxygen when the large algal biomass senesces and dies near the end of the growing season and is consumed by aerobic microorganisms. The rapid and excessive production of these heterotrophic organisms and the associated cellular respiration consumes much of the available dissolved oxygen causing a continuous, seasonal sag in concentrations, especially since photosynthesis is minimal at this time of year.

The overproduction of algae substantially shifts the food base of the ecosystem and impacts habitat quality. There is a commensurate shift in the types of species present where herbivorous and omnivorous species gain competitive advantage over many other species specialized for a more diverse food supply. Likewise those species that flourish in the simplified food web can tolerate the impacts on habitat associated with intense land uses that foster nutrient loading while other specialist species often decline in numbers because of this degradation. For example, an algae-rich system tends to support fishes and macroinvertebrates that are tolerant to siltation and the presence of other water pollutants more than sensitive species that are specialized to exploit niches under better stream quality conditions. Ultimately the aquatic community becomes unbalanced and ecosystem function and diversity are lost. When eutrophic conditions are widespread in streams, such as the case in regions dominated by row crop production, loss of biodiversity often happens at a regional scale.

In terms of nutrient enrichment, the element of greatest concern is typically phosphorus because it is critical for plant growth and it is often the limiting nutrient (Sharpley, 1999). That is, based on the ratios of nitrogen to phosphorus typical in plant tissue (approximately 16:1) stream nutrient concentrations often yield ratios where nitrogen is more available than phosphorus for the production of plant biomass, i.e., a ratio significantly above 16:1 (Redfield, 1958). So to more effectively and efficiently limit algae production, the most limiting nutrient would be addressed, namely phosphorus.

The form of phosphorus that can be readily used by plants, and therefore can stimulate nuisance algae blooms, is orthophosphate (PO_4^{3-}). The amount of phosphorus tied up in the nucleic acids of food and waste (typical constituents of municipal wastewater) is relatively low; but nonetheless this organic material is eventually converted to orthophosphate by bacteria (e.g., what happens in typical waste water treatment). However, the overall volume of the organic form of phosphorus from food and human waste in a given watershed is typically so large that it becomes a very significant portion of the overall phosphorus loading to streams. The mineral forms of phosphorus (i.e., inorganic and therefore biologically more available) in surface waters in Ohio primarily originate from commercial fertilizers used on cropland and turf grass areas that are transported to stream during runoff events and/or through subsurface drainage systems. To a lesser extent, mineral phosphorus enters surfaces waters from naturally occurring sources such as soils and geologic formations (e.g., mineral apatite in some dolomites and limestone and other rocks of Ohio) particularly when a stream receives ample groundwater.

In many areas of Ohio both point and nonpoint sources are significant contributors of phosphorus to surface water and the Paint Creek exhibits this type of behavior. Point sources of phosphorus are easier to characterize since the flows and effluent quality can be monitored with a high frequency and much less variability (no confounding sources) than measures of the stream system and its landscape based sources of phosphorus.

Figures 4-1 through 4-2 show the trend of phosphorus loading for the larger municipal waste water treatment facilities (those that account for, based on average flows, over 68% of the waste in the watershed (upstream of a major industrial source near the mouth of Paint Creek) over periods spanning two to nine years of the survey year, depending on the availability of the monitoring data. Each of these facilities is within a 12-digit HUC that is either impaired by the effects of eutrophication or drain to subwatersheds that are so impacted. The impact from these waste water treatment plants can be significant considering the size and flow regime of the receiving streams to which they discharge. Based on these effluent data and median streamflow statistics generated by the USGS (USGS, 2006), the dischargers in the graphs can contribute an effective stream concentration of 0.002 (e.g., Greenfield WWTP) to well over 0.70 (e.g., Washington Courthouse WWTP just downstream of confluence with East Fork Paint Creek) mg/l of total phosphorus (Figure 4-2). The average of these concentration estimates is 0.135 mg/l of total phosphorus and the median is 0.045 mg/l of total phosphorus (based on eight of the nine dischargers displayed in the graphs). For context, the total phosphorus target for most of the streams in the watershed is 0.10 mg/l of total phosphorus for smaller WWH streams and the larger EWH section of Paint Creek (Ohio EPA, 1999), in which case the facilities are using from less than ten percent to over 700 percent of the assimilative capacity of the median flow statistic, but most are in the range of about 40 to 95 percent.

Nonpoint sources of phosphorus are primarily limited to warm-blooded animal wastes (including human), and commercial fertilizers. As stated above, organic forms of phosphorus (i.e., animal wastes) are transformed in to forms that are readily available for plant uptake, however, this is less efficiently accomplished in a natural stream setting than an engineered waste water treatment system. Phosphorus discharged by nonpoint sources is usually delivered intermittently (e.g., associated with storm water runoff). Much of this phosphorus is bound to soil particles and enters streams from erosion, although a significant proportion has also been shown to come from tile drainage (Kleinman et al., 2011). Urban storm water is more of a concern if combined sewer overflows are involved.

The impact from rural storm water varies depending on land use and management practices and includes contributions from livestock feedlots and pastures and row crop agriculture. Crop fertilizer includes granular inorganic types and organic types such as manure or sewage sludge. Pasture land is especially a concern if the livestock have access to the stream. Land management is an issue because erosion is worse on streams without any riparian buffer zone to trap runoff. The impact can be more pronounced in streams that are channelized because they no longer have a functioning flood plain and cannot expel sediment during flooding. Oxygen levels may also be affected because phosphorus is released from sediment at higher rates under anoxic (oxygen-starved) conditions.

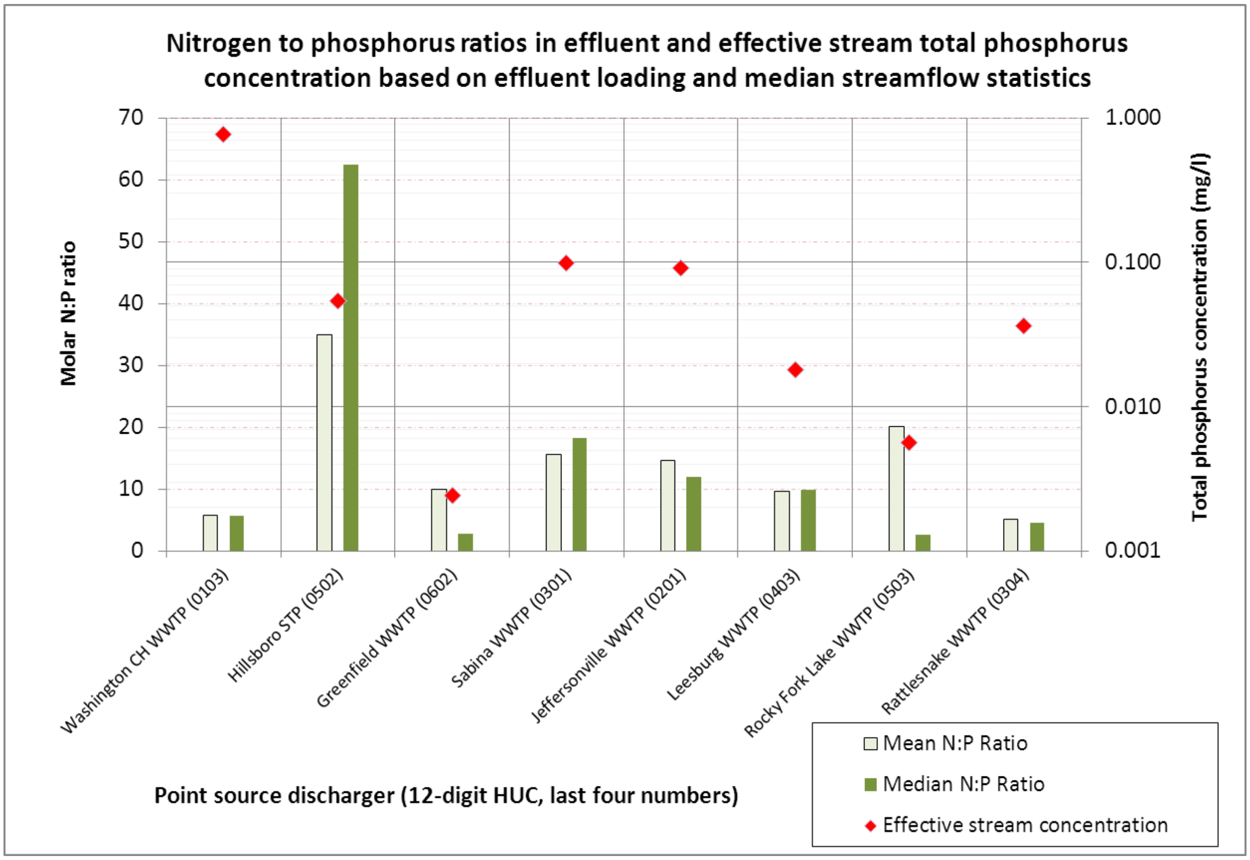


Figure 4-1. Effluent total phosphorus loading and flow rates for the larger municipal waste water producers in the Paint Creek watershed.

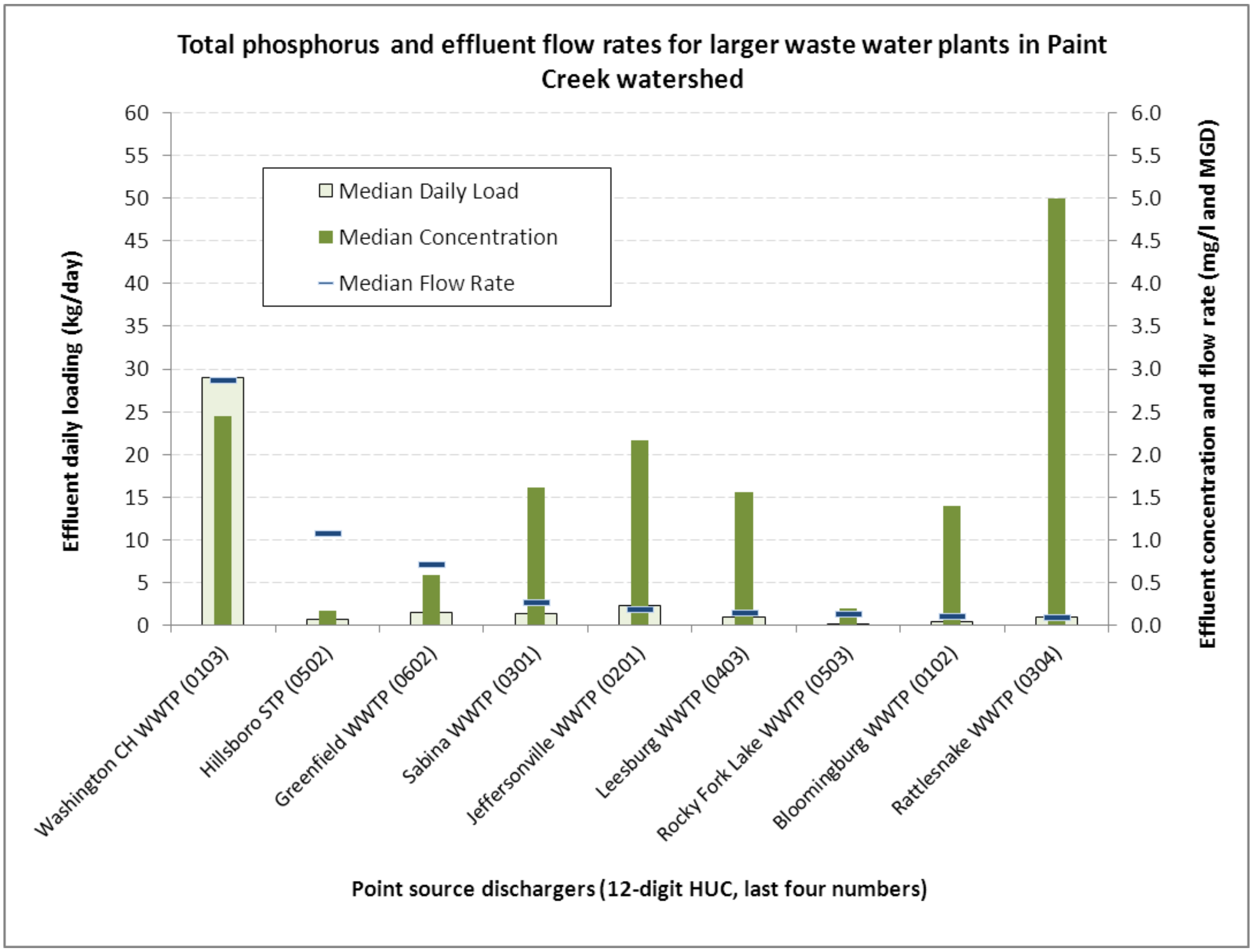


Figure 4-2. Molar nitrogen to phosphorus ratios and effective in-stream total phosphorus concentrations based on the median effluent loading rate for the larger municipal waste water producers in the Paint Creek watershed.

Table 4-1. Mean and median flow and nutrient characteristics in the effluent of the larger waste water producers in the Paint Creek watershed.

Permit Number	FACILITY	EFFLUENT FLOW RATE (MGD)		MOLAR N:P RATIO	
		MEAN	MEDIAN	MEAN	MEDIAN
4PD00002	Washington CH WWTP	3.51	2.87	5.7	5.8
1PC00100	Hillsboro STP	1.30	1.08	35.0	62.4
1PD00022	Greenfield WWTP	1.10	0.72	10.0	2.8
1PB00038	Sabina WWTP	0.45	0.27	15.6	18.3
4PB00108	Jeffersonville WWTP	0.23	0.20	14.6	12.0
1PB00106	Leesburg WWTP	0.18	0.16	9.6	9.9
1PS00015	Rocky Fork Lake WWTP	0.16	0.15	20.2	2.6
4PB00025	Bloomingburg WWTP	0.12	0.11	N/A	N/A
4PH00007	Rattlesnake WWTP	0.10	0.10	5.1	4.5

Table 4-2. Mean and median nutrient characteristics in the effluent of the larger waste water producers in the Paint Creek watershed.

Permit Number	FACILITY	LOADING (kg/day)				CONCENTRATION (mg/l)			
		TP		NO2NO3		TP		NO2NO3	
		MEAN	MEDIAN	MEAN	MEDIAN	MEAN	MEDIAN	MEAN	MEDIAN
4PD00002	Washington CH WWTP	35.38	28.95	91.64	75.40	2.75	2.45	7.46	6.40
1PC00100	Hillsboro STP	1.32	0.66	20.92	18.48	0.32	0.17	4.24	4.31
1PD00022	Greenfield WWTP	2.08	1.58	9.44	1.99	0.74	0.59	3.22	0.81
1PB00038	Sabina WWTP	1.67	1.39	11.78	11.51	1.77	1.62	12.10	11.30
4PB00108	Jeffersonville WWTP	2.03	2.30	13.41	12.46	2.07	2.16	15.44	14.60
1PB00106	Leesburg WWTP	1.24	1.03	5.40	4.58	1.98	1.56	10.07	10.60
1PS00015	Rocky Fork Lake WWTP	0.21	0.10	1.94	0.12	0.40	0.20	3.74	0.23
4PB00025	Bloomingburg WWTP	0.62	0.49	N/A	N/A	1.48	1.40	N/A	N/A
4PH00007	Rattlesnake WWTP	1.17	1.03	2.68	2.09	4.47	5.00	6.69	4.91

Qualitative habitat assessment to address direct habitat alterations, sedimentation/siltation and flow alterations

Habitat and flow alteration and sedimentation are causes of impairment at several assessment sites in the Paint Creek watershed. All of the ten-digit HUCs except for the upper North Fork Paint Creek have at least one site impaired due to poor habitat, excessive fine sediment in the system, and/or altered flow regime. See Table 1-1, Chapter 3 and Appendix D for more details regarding the distribution of habitat, flow, and sediment based causes of impairment.

Poor habitat is an environmental condition, rather than a pollutant load, precluding development of load-based TMDLs. Nonetheless, adequate habitat quality is integral to the diversity and health of stream ecosystems; specifically, it has significant impact on aquatic community assemblage. As a result, habitat quality has consequence on the stream's ability to meet the bio-criteria within Ohio's water quality standards. 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 (U.S. EPA, 1991), thus sufficient justification for developing habitat TMDLs is established.

Poor habitat impacts biological communities directly by limiting the complexity of living spaces available to aquatic organisms. This is significant to freshwater organisms because they have become specialized over millions of years of evolution to the niche habitats afforded in streams undisturbed by human management (i.e., pre-settlement). Fish and macroinvertebrate communities tend to lose diversity as stream habitat becomes less diverse because low habitat diversity limits the protection afforded organisms from stressful environmental conditions (e.g., extremes in high or low flow conditions) and cover for species avoiding predation from in-stream and riparian-based predators. Habitat diversity also lends itself to more diverse food resources for the aquatic community enabling specialists to persist if their food resource requirements are met.

Human alteration of normal flow conditions due to changes in the watershed and/or direct stream modification also has adverse impacts on the aquatic community particularly with respect to the magnitude, frequency and duration of the high and low flow events throughout the year. Stream flow is entwined with stream habitat since flow can degrade habitat quality (e.g., erosion associated with excessive high flow events) or render good structural habitat functionless (e.g., when flow conditions are inordinately low). Flow is also tied to the feeding mechanisms and energetics of organisms (e.g., how much effort it is to move within the stream) and can impact presence and absence of specialist species.

If habitat quality is good, the extremes of an altered flow regime can be ameliorated to varying degrees, depending on how altered the hydrology is. Specifically, floodplain connection (i.e., little to no channel incision) deflects and dampens damaging flow energy associated with high flow events since the overall flow depths (which is a major factor in shear stress) are minimized as floodplains accommodate much of the flow volume and distribute it over a wider and therefore more shallow area. Likewise, flow velocity and stream energy is lost through the frictional effects of the floodplain. Many aquatic organisms will find refuge in the floodplain during high flow events because of the shallower depths, lower stream energy and velocity, and the presence of various types of covers (e.g., the downstream side of trees and logs). In-stream cover such as woody debris and boulders also provide protection for aquatic organisms during high flows. Low flows and stream desiccation is abated if the stream has pools of adequate depth to hold water during the driest times of the year. High quality substrate, especially which is not embedded, allows for interstitial flow and storage of water under dry conditions. If accessible, organisms can take refuge in this hyporheic zone where water is present and temperature are kept cooler (i.e., limited solar exposure) and dissolved oxygen concentrations are somewhat higher.

Excessive amount of fine sediment in the channel and water column degrades aquatic communities due to the way it limits accessibility or altogether eliminates living spaces in the voids between coarse bed substrates such as cobbles and gravels. These voids offer small organisms and the eggs of large and small organisms, alike, protection against stream current and suspended materials and cover from predators. When in suspension fine sediment can have an abrasive impact on sensitive organisms and clog gill structures, as well as limit visibility and light penetration in the water column which impairs foraging and predation.

The above connections between habitat quality and the closely associated conditions of the flow regime and amount of sedimentation in the system are clearly tied to the diversity of the aquatic community as measured through the biometrics established in Ohio's water quality standards (3745-1). This has been shown through strong correlation between measures of habitat quality (via the qualitative habitat evaluation index (QHEI)) and the biometrics (Ohio EPA, 1999)).

The qualitative habitat evaluation index (QHEI) was developed by the Ohio EPA (Rankin, 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 bio-criteria (Ohio EPA, 1999) makes it an appropriate tool for developing habitat TMDLs.

The QHEI assigns a numeric value to an individual stream segment (typically 150-200 meters 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 (Rankin, 1989).

The QHEI evaluates six general aspects of physical habitat that include channel substrate, instream cover, riparian characteristics, channel condition, pool/riffle quality, and gradient. Within each of these categories or 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 metrics to give a score for that particular aspect of stream habitat. The overall QHEI score is the sum of all of the metric scores.

The QHEI is used in developing the sediment TMDL for this project. Numeric targets for sediment are based upon metrics of the QHEI. Although the QHEI evaluates the overall quality of stream habitat, some of its component 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 metrics used in the sediment TMDL are the substrate, channel morphology, and bank erosion and riparian zone.

- The substrate 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 loading.
- The channel morphology 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 bank erosion and riparian zone metric also reflects the likely degree of instream sediment sources. The evaluation of floodplain quality is included in this metric which is related to the capacity of the system to assimilate sediment loads.

Qualitative habitat assessment to address dissolved oxygen

In two HUC 12 subwatersheds (03-03 and 03-04) the Qualitative Habitat Evaluation Index (QHEI) TMDL method is used to address nutrient enrichment and dissolved oxygen caused impairments. Most dissolved oxygen stress is related to nutrient enrichment. To make the stream system amenable to supporting the types of aquatic communities that are consistent with the applicable water quality criteria (i.e., able to achieve biometric scores at the biocriteria minima), the stock of plant biomass must be limited. Reducing the necessary nutrients is one such means to limiting primary productivity; however, sunlight limitation is another way to control plant growth. High quality stream habitat generally has the capacity to ameliorate dissolved oxygen stress associated with nutrient enrichment through various mechanisms.

The riparian zone and the associated floodplain is an area in which disproportionately greater nutrient assimilation occurs on the landscape. This is due to the more prolific growth of plant material as well as soil microbes, which can sequester the upland supply of basic nutrients (namely, phosphorus and nitrogen). The availability of water due to close proximity to the stream fosters the higher rate of plant growth, which in turn creates more carbon rich soils that can support a more prolific microbial community. For this reason a well intact floodplain and riparian zone limits upland nutrient loading. The shading provided by tall vegetation growth near the banks cause light-limited conditions that exert control on primary production. Good riffle and pool development may increase the stream's ability to deflect nutrient assimilation from primary production to a microbial based community in the channel substrates (e.g., the hyporheic zone). Finally, high quality habitat provide the other essentials to specialized fish and macroinvertebrate species that are often more sensitive to stress associated with dissolved oxygen concentrations, which, can help to limit avoidance behavior.

For some of the aquatic life use impairment attributable to dissolved oxygen stress in the Paint Creek watershed, it is more practical to use measures of habitat quality than nutrient loading in resolving impacts to aquatic communities. Specifically, the measures of the quality and/or functionality of the riparian zone, floodplain, and riffles like the riparian, channel morphology and pool/riffle metrics. Individual components of these metrics, such as degree of channelization, have been identified as highly influential attributes that are indicators of channel modification. The list of "modified attributes" and "high-influence modified attributes" can be found in Table 4-11. Targets for the maximum number of the modified or high-influence modified attributes a steam can endure without substantial deleterious impact to aquatic community assemblage is found in the document entitled "Association Between Nutrients, Habitat, and the Aquatic Biota of Ohio Rivers and Streams" (Ohio EPA, 1999). The specific assessment units (12-digit HUCs) for which the QHEI target are used to address dissolved oxygen related impairments are identified in the sections describing the methodologies used in the respective 12-digit HUCs.

Pathogens (bacteria) to address recreation use impairments
Chronic *E. coli* concentration levels are direct evidence of recreation use impairment. Ohio standards are in place to protect against public health nuisances and recreation use of waterbodies. Recreation use of waterbodies is defined in OAC 3745-1-07 (4), which states "…use designations are in effect only during the recreation season, which is the period from May first to October thirty-first." These values serve as the targets used in the development of the TMDLs that address recreation use impairments. Therefore the use of *E. coli* to address recreation use impairment is adequate as it is dictated by state statute.

Use of pathogens (bacteria) and to address organic enrichment, dissolved oxygen, ammonia, and nutrient impairments
Organic enrichment, or an abundance of carbon-based materials, is impairing the aquatic communities at sites found in eight 12-digit HUCs. Ammonia is impairing sites in two 12-digit HUCs, while nutrients and dissolved oxygen stress impair several sites in the watershed. Dissolved oxygen stress is associated with respiration (i.e., oxygen consumption) caused by microbial digestion of an abundant supply of organic materials or due to prolific algae growth in response to nutrient enrichment.

Organic materials are primarily associated with fecal material emanating from improperly treated sewage, livestock and wildlife wastes, and less frequently, carbon-rich waste streams associated with industrial activities. Ammonia and other nutrients are also closely associated with human and animal wastes. Other sources of organic materials include residues on the landscape associated with petro-chemicals from transportation infrastructure, as well as natural sources such as leaf litter and other decaying plant and animal matter.

In the Paint Creek watershed sources of organic enrichment are primarily from human sewage and livestock manures (i.e., based on limited or non-existent industrial and natural sources within the problem areas). For this reason, *E. coli* bacteria will be, in some instances, used as a surrogate to make the analysis more efficient. The reductions necessary to bring waters in to attainment of the water quality standards in relation to *E. coli* are sufficient to likewise eliminate the organic enrichment and nutrients and the related dissolved oxygen stresses as well as ammonia. This is a very conservative approach since poorly treated sewage or manure creates extremely high concentrations of E coli bacteria thus requiring very large reduction of these sources to meet recreation use water quality standards.

Table 4-3. Summary of causes of impairment and actions taken to address them in assessment units within the 05060003 01 and 05060003 02 ten-digit hydrologic units.

Causes of Impairment	Watershed Assessment Units				
	05060003 01			05060003 02	
	01	02	03	01	02
Aquatic Life Use					
Sedimentation/Siltation		D	D		
Nutrient/Eutrophication Biological Indicators			D	D	D
Organic Enrichment (Sewage) Biological Indicators					
Direct Habitat Alterations			D	D	
Oxygen, Dissolved		S	S	S	
Other flow regime alterations		S	S		
Ammonia (Total)					
Natural Conditions (Flow or Habitat)					
Impairment Unknown					
Recreation Use					
E. coli	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.

Table 4-4. Summary of causes of impairment and actions taken to address them in assessment units within the 05060003 03 ten-digit hydrologic units.

Causes of Impairment	Watershed Assessment Units				
	05060003 03				
	01	02	03	04	05
Aquatic Life Use					
Sedimentation/Siltation			D		D
Nutrient/Eutrophication Biological Indicators					
Organic Enrichment (Sewage) Biological Indicators	S				
Direct Habitat Alterations	D			D	D
Oxygen, Dissolved			S	S	
Other flow regime alterations		S			
Ammonia (Total)	S				
Natural Conditions (Flow or Habitat)					
Impairment Unknown					
Recreation Use					
E. coli	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.

Table 4-5. Summary of causes of impairment and actions taken to address them in assessment units within the 05060003 04 ten-digit hydrologic units.

Causes of Impairment	Watershed Assessment Units						
	05060003 04						
	01	02	03	04	05	06	07
Aquatic Life Use							
Sedimentation/Siltation							
Nutrient/Eutrophication Biological Indicators						S	
Organic Enrichment (Sewage) Biological Indicators	S		S			S	
Direct Habitat Alterations							
Oxygen, Dissolved	S		S				
Other flow regime alterations			S				
Ammonia (Total)	S						
Natural Conditions (Flow or Habitat)							
Impairment Unknown							
Recreation Use							
E. coli	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.

Table 4-6. Summary of causes of impairment and actions taken to address them in assessment units within the 05060003 05 and 05060003 06 ten-digit hydrologic units.

Causes of Impairment	Watershed Assessment Units							
	05060003 05					05060003 06		
	01	02	03	04	05	01	02	03
Aquatic Life Use								
Sedimentation/Siltation								
Nutrient/Eutrophication Biological Indicators					S	D		
Organic Enrichment (Sewage) Biological Indicators		ne					S	
Direct Habitat Alterations								
Oxygen, Dissolved								
Other flow regime alterations		S				S		
Ammonia (Total)								
Natural Conditions (Flow or Habitat)								
Impairment Unknown								
Recreation Use								
E. coli		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.
ne	Narratively explained; impairment expected to be resolved.

Table 4-7. Summary of causes of impairment and actions taken to address them in assessment units within the 05060003 07 and 05060003 08 ten-digit hydrologic units.

Causes of Impairment	Watershed Assessment Units								
	05060003 07				05060003 08				
	01	02	03	04	01	02	03	04	05
Aquatic Life Use									
Sedimentation/Siltation				D					
Nutrient/Eutrophication Biological Indicators	S								
Organic Enrichment (Sewage) Biological Indicators									
Direct Habitat Alterations				D					
Oxygen, Dissolved									
Other flow regime alterations	S								
Ammonia (Total)									
Natural Conditions (Flow or Habitat)									
Impairment Unknown									
Recreation Use									
E. coli	D	D	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.

Table 4-8. Summary of causes of impairment and actions taken to address them in assessment units within the 05060003 09 and 05060003 10 ten-digit hydrologic units.

Causes of Impairment	Watershed Assessment Units						
	05060003 09				05060003 10		
	01	02	03	04	01	02	03
Aquatic Life Use							
Sedimentation/Siltation			D			D	
Nutrient/Eutrophication Biological Indicators							
Organic Enrichment (Sewage) Biological Indicators			S			S	
Direct Habitat Alterations							
Oxygen, Dissolved							
Other flow regime alterations							
Ammonia (Total)							
Natural Conditions (Flow or Habitat)							
Impairment Unknown							
Recreation Use							
E. coli		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 Loading Simulation Program in C++ (LSPC)

The Loading Simulation Program in C++ (LSPC) water quality model is used to estimate existing nutrient loading from nonpoint sources to Paint Creek above Paint Creek Lake as well as East Fork Paint Creek and Sugar Creek. LSPC was used to simulate ambient dissolved oxygen concentrations in response to several factors including nutrient concentrations, substrate characteristics, channel morphology, and degree of stream shading. This model is also used to simulate bacteria loading from the landscape and other external sources and provides for simple first order bacteria decay in the stream. The specific areas where the model is employed to characterize nutrient loading with the end goals of reducing algae production or improving the pattern of dissolved oxygen concentrations and to characterize bacteria loading to meet criteria for recreation uses are shown in Table 4-9.

The LSPC model is a dynamic watershed model that employs lumped parameterization in determining output values at user-defined locations. LSPC is essentially a re-coded C++ version of selected Hydrologic Simulation Program Fortran (HSPF) modules. LSPC's algorithms are identical to those of HSPF. HSPF has been used extensively throughout the United States for TMDL development. Refer to the HSPF User's Manual (Bicknell et al., 2001) for a more detailed discussion of simulated processes and model parameters. While LSPC has the benefit of being streamlined, it does lack several of the special options available with HSPF. For the purposes of upper Paint Creek, LSPC contains the appropriate modules for the watershed's TMDL developments. For this modeling effort, benthic algae, zooplankton, pH and carbon are not used since HSPF representation is not fully developed into LSPC 3.1 for these components. Instead, water column algae was used to represent the total primary productivity of the reaches, the simulated minimum daily DO results are compared to the minimum standard, and pH was taken directly from field measurements in order to assess the potential of ammonia speciation and toxicity issues.

4.1.1 Justification

The appropriate modeling approach must consider the dominant processes regarding pollutant loadings and in-stream fate. For the Paint Creek watershed, primary sources contributing to pathogen impairments include an array of nonpoint or diffuse sources as well as discrete direct inputs to the stream including permitted point source discharges, and direct deposition from animals. Loading processes for nonpoint sources or land-based activities are typically rainfall driven and thus relate to surface runoff and subsurface discharge to a stream. Key in-stream factors that must be considered include routing of flow, dilution, transport, and fate (decay or transformation) of pollutants. Scale of analysis and waterbody type must also be considered in the selection of the overall approach. The approach should have the capability to evaluate watersheds at multiple scales, and be able to adequately represent the spatial distribution of sources and the delivery processes whereby pathogens are delivered throughout the stream network.

Table 4-9. Assessment units and respective TMDL parameters covered through the use of the LSPC model.

Assessment unit (12-digit HUC)	Nutrients (TP)	Dissolved oxygen (TP surrogate)	Organic enrichment (*E. coli* surrogate)	Pathogens (*E. coli*)
01 01 - Headwaters Paint Creek	Output included for downstream			*E. coli* output
01 02 - East Fork Paint Creek	TP output			*E. coli* output
01 03 - Town of Washington Court House-Paint Creek	TP output			*E. coli* output
02 01 - Headwaters Sugar Creek	TP output	DO response to TP		*E. coli* output
02 02 - Camp Run-Sugar Creek	TP output			*E. coli* output
06 01 - Indian Creek-Paint Creek	TP output			*E. coli* output
06 02 - Farmers Run-Paint Creek			*E. coli* surrogate	*E. coli* output

Based on standard output needs in the development of TMDLs, an analysis of the monitoring data, a review of the literature, a characterization of the pathogen sources, the need to represent source controls to individual sources, and previous modeling experience, the Loading Simulation Program in C++ (LSPC) is selected to represent the source-response linkage in the upper Paint Creek watershed. LSPC is maintained by the U.S. EPA Office of Research and Development in Athens, GA. Version 3.1 of the model was acquired from the developers, Tetra Tech, which incorporated in-stream nutrient processes. LSPC can discriminate sources based on land use type and also allows for various point source inputs which are combined with the simulated nonpoint source loading from surrounding land uses. In-stream decay of nutrients is simulated using QUAL2E output which is integrated in to the model. Model output includes overall daily nutrient concentrations at the point of the model outlet and an aggregation of the annual nutrient load discriminated by land use type.

The LSPC/HSPF demands greater user experience and time commitment than other comparable models. For this reason, LSPC analysis is limited to the Upper Paint Creek region. Although it is a complex model to run, the benefits of calibration and load quantification provide powerful insight to the interdependent constituents of a waterbody. LSPC also contains a TMDL module, where the user enters percent load reductions to point or diffused sources until water quality targets are achieved.

4.1.2 Sources of Data

Soils representation of the LSPC modeled watersheds

The hydrologic properties of the soils change in generally the same trend as the breaks in elevations. The drainage performance ranges from soils in the hydrologic group A with excellent drainage, to group D soils with very poor drainage. The Upper Paint Creek headwaters are a mix of Group C and Group B/D soils (the B/D designation means the soils of the area typically draining very poorly once wetted). The middle of the region (Jeffersonville to Bloomingburg to Washington Court House) is primarily made up of the Group B/D soils, with the exception of the thin zone of better draining Group B soils within the stream corridors. The soils of the south are primarily Group C soils. It should be noted that the STATSGO dataset is generalized. The more detailed SSURGO soils database limits Group B soils to very thin stream corridors, unlike the exaggerated Group B band in the STATSGO data. In general, most of the soils within the glaciated area are drained by tiles and channel drainage improvements. The soils in this area are very productive once drained, but still hold considerable storm water in low spots and other less conductive locations. The soils in the southern region have a more general drainage hindrance, but the stream slopes are greater which diminishes some of the effect. Although there can be high variability in soils from one field to another, the effect tends to average out on a watershed scale. With review of the elevation and soil characteristics, the region can be split into three general soil/management groups for modeling hydrology and constituent transport. Group 3 is used to define characteristics of the central region, Group 4 characterizes the headwaters, and Group 5 characterizes the southern region. The LSPC GQUAL component provides hydrology and transport controls for each group, and using the three groups as assigned to the zones is sufficient to control the regional differences of the Paint Creek model.

Land cover representation of the LSPC modeled watersheds

Land use raster data from the 2001 NLCD dataset (Homer, 2004) is used to map land use types to zones. In order to simplify the model representation, the several land use types of NLCD are aggregated into a subset of nine similar usage types. Six of these deal with developed land which is further aggregated to two output types for reporting purposes. The reclassified land uses include impervious developed land (high, medium, low intensity), pervious developed (high, medium, low intensity), crop (mostly corn and soy beans in the region), pasture (with livestock or fallow land), and forest (riparian tree lines to dense wooded areas). Each group assignment also has individual land use controls. Paint Creek's land model of three groups and nine land uses result in 27 independent hydrology and constituent transport controls. Some variables can be adjusted on a monthly level, adding to the complexity of data management. Although the amount of data management multiplies with the addition of groups and land uses, it provides the option of more localized control if needed. It is best to focus calibration on the driving characteristics and leave the remaining controls with as similar properties as possible so useful subwatershed model results can be compared. Once group and land use assignments are made, each zone's land use specific constituent loadings are tracked and reported on an annual basis, while daily results are reported as the bulk constituent entering or leaving the zone. Land use, BOD, total phosphorus and total nitrogen estimates of surface, interflow, and ground water sources are derived from Purdue and Ohio State Agricultural Extension information, the Virginia Patuxent basin model, professional judgment, and defaults built into LSPC. The resulting stream input loadings are then adjusted for timing and scale calibration.

Home sewage treatment systems, livestock and wildlife direct source representation of the LSPC modeled watersheds

US Census GIS block data available from the year 2000 is used as the base for determination of population and housing distribution for the subwatershed zones (Ohio Department of

Development, 2003). The region has had low to negative population growth between 2000 and 2010 which allows for reliable use of the 2000 block data. The subwatershed boundaries are overlaid by the regional block data and population/housing is distributed by percent area coverage. Some final adjustments are made where a block region's population is not evenly distributed across a subwatershed(s). Further effort is made to delineate out the areas with sanitary sewer service and track the numbers of homes with HSTS (home septic treatment systems). Finally, the number of failing HSTS is determined by zone with the use of average county failure rates, site observations, aerial photography, and proximity to streams. An average failure rate of 20 percent of homes is used as a base, and other adjustments are made to a zone's final failure rate. Aerator systems are assumed to have a 100 percent failure rate as recommended by USEPA, as they are often not properly maintained. The failing septic flow reaching the stream is assumed to be 17.5 gallons/day/person, assuming that one fourth of the standard 70 gallons/day/person usage have the potential for direct stream access and the rest contaminates ground seeps.

NPDES point source representation of the LSPC modeled watersheds

NPDES permitted point sources have variable constituent data available for model representation. Self-monitoring data of point source facilities is reported to Ohio EPA as required by their permits. Ohio EPA also sampled several outfalls during the 2006 survey. Flow rate, temperature, and oxygen levels are typically tracked daily by point sources. Ammonia and BOD are typically recorded a few times a week. Other essential parameters for modeling eutrophication like phosphorus and nitrates may or may not be reported depending on permit requirements. Therefore, conservative estimates are needed for some point sources, while others can have more refined representations. Available data between 1995 and 2008 were used to develop constituent trends. If data trends are notably different between past and more recent years, the estimates are based on more current operations of facilities. The data is compiled into three month averages to account for seasonal variation of flow and chemistry (Jan-Mar, Apr-Jun, Jul-Sep, and Oct-Dec). All modeled point sources are built on a seasonal flow and temperature variation, but only a few have other seasonal constituent concentrations due to a lack of data. Annual concentrations are approximated for the smaller facilities with lesser reporting requirements. The region's two major facilities, Washington Court House and Greenfield, have enough data to develop daily flow and chemistry representation. Where daily data is not available, the record is patched with seasonal averages.

Washington Court House's sanitary distribution system has infiltration problems which results in hydraulic surcharges within the system during storm events. The infiltration problem causes a wide range of flow and constituent strengths entering Paint Creek. Washington Court House is currently under orders to correct the performance issues of their sanitary system. Greenfield's WWTP has a 1.0 mg/L average phosphorus limit in place and has performed well. It had some operational issues in 2006 that led to organic enrichment and ammonia issues in Paint Creek. The model results indicate that the stream's ammonia levels were excessive during this time, and the facility issues have since been resolved. The appropriate representation of both facilities is useful for calibration and to compare the impacts of chronic nutrient levels at low flow verses high acute loadings coming from agricultural washoff. Although the majority of the EWH segment of Paint Creek below Washington Court House is in full attainment, the modeling of the intact stream corridor under high loading underlines the importance of stream gradient and habitat.

Weather data for the LSPC modeled watersheds

Hourly weather data is the driving force of LSPC's hydrology components. The modeling processes needed for Paint Creek's desired results require an in-depth weather model. Tetra

Tech's Meteorological Data Analysis and Preparation Tool version 2.1 (MetAdapt) weather record patching software is used to create the information needed to simulate Paint Creek's hydrology. MetAdapt can import data in the NCDC (National Climatic Data Center) format which contains raw data, or in the EarthInfo format which is a dataset that has undergone a proprietary quality control process. Precipitation gage station selection should be controlled by proximity to the watershed, length and continuity of record, and quality of the measurements. Local precipitation gage stations typically report on a daily interval, which can be broken down into an hourly record by MetAdapt. In order to do this, MetAdapt can use a weather station that reports on an hourly basis for distribution, usually located at a major airport. The airport weather stations also provide the other necessary records, such as wind speed, cloud cover, temperature, and pressure.

The two precipitation gages selected to drive the model are in Midway (weather station 3) and Greenfield (weather station 1). Each zone is assigned to a weather station and the station's data gaps are patched with rainfall data from other nearby gages and disaggregated to an hourly distribution. The Dayton International Airport's weather logs are used to fill in the remaining parameters. Hourly solar radiation and potential evapotranspiration are usually not recorded, so MetAdapt creates hourly datasets for both using hourly distribution algorithms based on either the Hamon or Jenson method. The resulting hourly weather data is compiled into LSPC .air files for model driving.

4.1.3 Target(s)

E. coli

TMDL numeric targets for *E. coli* bacteria are derived from bacteriological water quality standards. The criterion for *E. coli* specified in OAC 3745-1-07 are applicable outside the mixing zone and vary for waters that are classified as primary contact recreation (PCR). For Class A streams the criteria states that the geometric mean of more than one *E. coli* sample taken in each recreational season (May through October) shall not exceed 126 colony forming units (cfu) per 100 ml. For Class B and C streams the geometric mean of more than one *E. coli* sample taken in each recreational season shall not exceed 161 and 206 cfu per 100 ml respectively.

TMDLs are created for watersheds that drain to an assessment site that is not meeting the recreation use criterion described in the paragraph above. The criteria values are used as the TMDL targets for this impairment. If an LDC TMDL site is within a Class B stream section, but five river miles or closer upstream of a Class A designated section, then the Class A aspect of the criterion is applied to this TMDL.

Total phosphorus

While the Ohio EPA does not currently have statewide numeric criteria for phosphorus, potential targets have been identified in an Ohio EPA technical report titled "Association between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams", (Ohio EPA, 1999). This document provides the results of a study analyzing the effects of nutrients on the aquatic assemblages of Ohio streams and rivers. The study reaches a number of conclusions and stresses the importance of habitat and other factors, in addition to in-stream nutrient concentrations, as having an impact on the health of biologic communities. The study also includes proposed targets for nitrate+nitrite concentrations and total phosphorus concentrations based on observed concentrations at reference sites. Reference sites were selected based on the fact that they experience little deleterious impact on water quality (i.e., from human sources) and data from these sites are used to define the potential for biological community performance within similar types of streams.

Based on drainage areas, the statewide total phosphorus average targets are:

- WWH headwaters (drainage area < 20 mi^2) = 0.08 mg/l
- WWH wadeable (drainage area between 20 mi^2 and 200 mi^2) = 0.10 mg/l
- EWH wadeable (drainage area between 20 mi^2 and 200 mi^2) = 0.05 mg/l
- WWH small Rivers (drainage area between 200 mi^2 and 1000 mi^2) = 0.17 mg/l

It is important to note that these nutrient targets are not codified in Ohio's water quality standards; therefore, there is a certain degree of flexibility as to how they can be used in a TMDL setting. Ohio's standards also include narrative criteria that limit the quantity of nutrients that may enter state waters. Specifically, OAC Rule 3745-1-04 (E) states that all waters of the state, "…shall be free from nutrients entering the waters as a result of human activity in concentrations that create nuisance growths of aquatic weeds and algae." In addition, OAC Rule 3745-1-04(D) states that all waters of the state, "…shall be free from substances entering the waters as a result of human activity in concentrations that are toxic or harmful to human, animal or aquatic life and/or are rapidly lethal in the mixing zone." Excess concentrations of nutrients that contribute to non-attainment of biological criteria may fall under either OAC Rule 3745-1-04 (D) or (E) prohibitions.

4.1.4 Calibration and Validation

The model is calibrated for storm flow characteristics using selected events in 2006 and 2003. Aggregate and seasonal flow characteristics use the 2000 to 2006 range for calibration. Criteria for calibration include completeness of weather data for a selected period, representation of low, average, and high flow years, and consistency of key model inputs for the selected period. Calibration involved adjustment of infiltration, subsurface storage, evapotranspiration, surface runoff, and interception storage parameters.

The model calibration was performed using the guidance of error statistics criteria specified in the calibration program HSPEXP (see http://water.usgs.gov/software/HSPexp/), temporal comparisons and comparisons of seasonal, high flows, and low flows. After adjusting the appropriate parameters within acceptable ranges, good correlations were found between model results and observed data. The hydrology model is validated with the 12 year period between 1997 and 2008, finding similar statistical patterns in the extended record.

The calibrated flow data is checked against both short term and long term patterns. The flow duration curve in Figure 4-3 indicates that the 2000-2006 calibrated flow data follows the same general recession pattern of the gage data. The percent cumulative flow trend in Figure 4-3 is useful to observe whether the modeled cumulative flow volume is within range with data derived from gage data. With the exception of a likely missed storm event (due to weather data records) during 2005, the two datasets generally agree with the trends and magnitude of continual flow patterns.

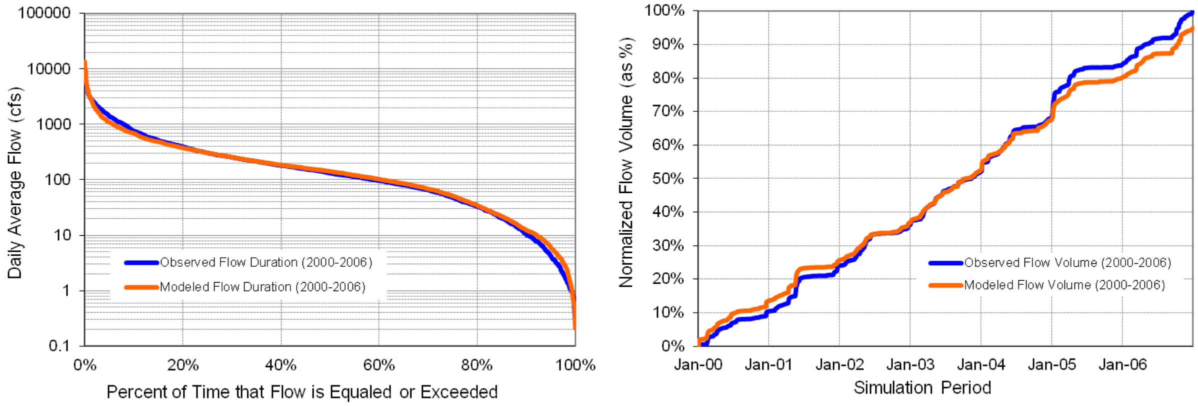


Figure 4-3. Two plots showing modeled vs. observed streamflow.

In order to study flows of the upper tributaries, OEPA established three sentinels sites in this region. Sentinel sites are those that are sampled at a higher frequency and that also have flow measurements taken with some regularity to provide loading information based on the collected data. This is done by pairing sentinel site water chemistry samples with a water stage measurement in order to correlate water level to flow, and pollutant concentration to load. All four sentinel sites provided flow-stage ratings with statistical R^2 values above 0.98.

Sugar Creek's sentinel site was established at Armbrust Road, representing 78 square miles of drainage. The site was found to be in aquatic full attainment, and provided important information on agriculture chemistry transport with distant point source contribution.

East Fork Paint Creek's sentinel site was established at US-22 on the west side of Washington Court House, representing 50 square miles of drainage. This site is in partial aquatic attainment due to sedimentation and dissolved oxygen issues. Much of East Fork is channelized for agricultural drainage and has little riparian cover.

Paint Creek's sentinel site was established at Elm Street just upstream Washington Court House's WWTP, representing a 67 square mile drainage area. This site is in partial aquatic attainment due to urban channelization, habitat alterations, eutrophication, and dissolved oxygen issues. This site was useful for observing deep urban channelization flow without constant point source influence. The stream bed height at the Elm Street Bridge is a control of flow (like a lowhead dam) through the deeper upstream reach, creating an often stagnant narrow pool of water. However, since Washington Court House's sanitary sewer line below this pool has infiltration issues and Washington Court House withdraws water upstream for its drinking water reservoir, it was not the best site to monitor low flow to use for other site estimates. Figures 4-4 and 4-5 show various modeled vs. observed flow plots for this assessment site. Points in blue are actual flow measurements used to develop the stage-flow relationship. Some points are estimated flows during sampling events based on the relationship, which allow for an estimation of pollutant mass loading.

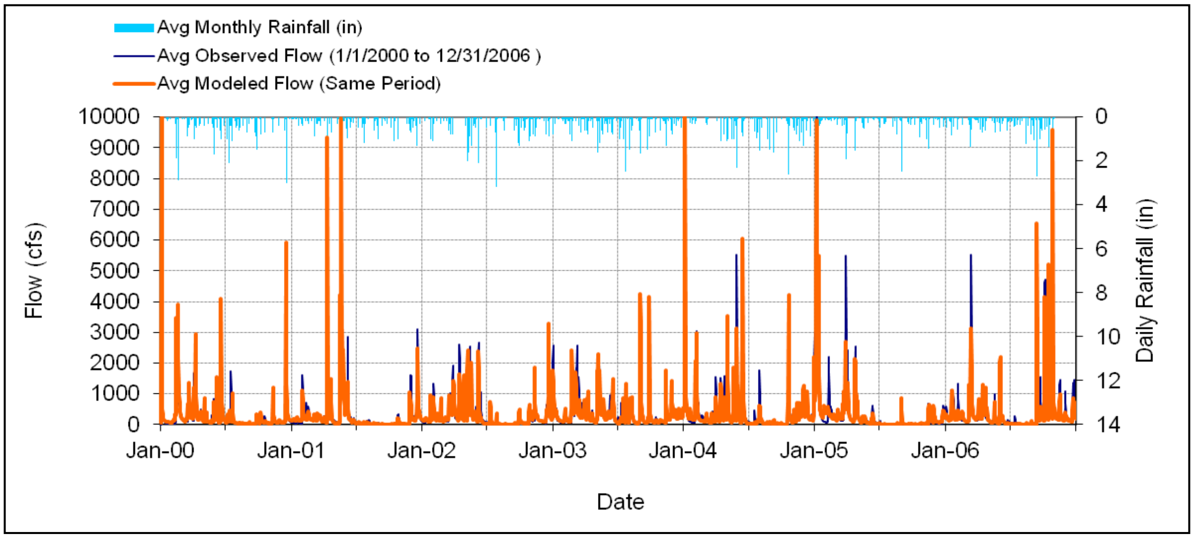


Figure 4-4. Modeled vs. observed flow with rainfall noted for the assessment site of the USGS gage on Paint Creek at SR-753.

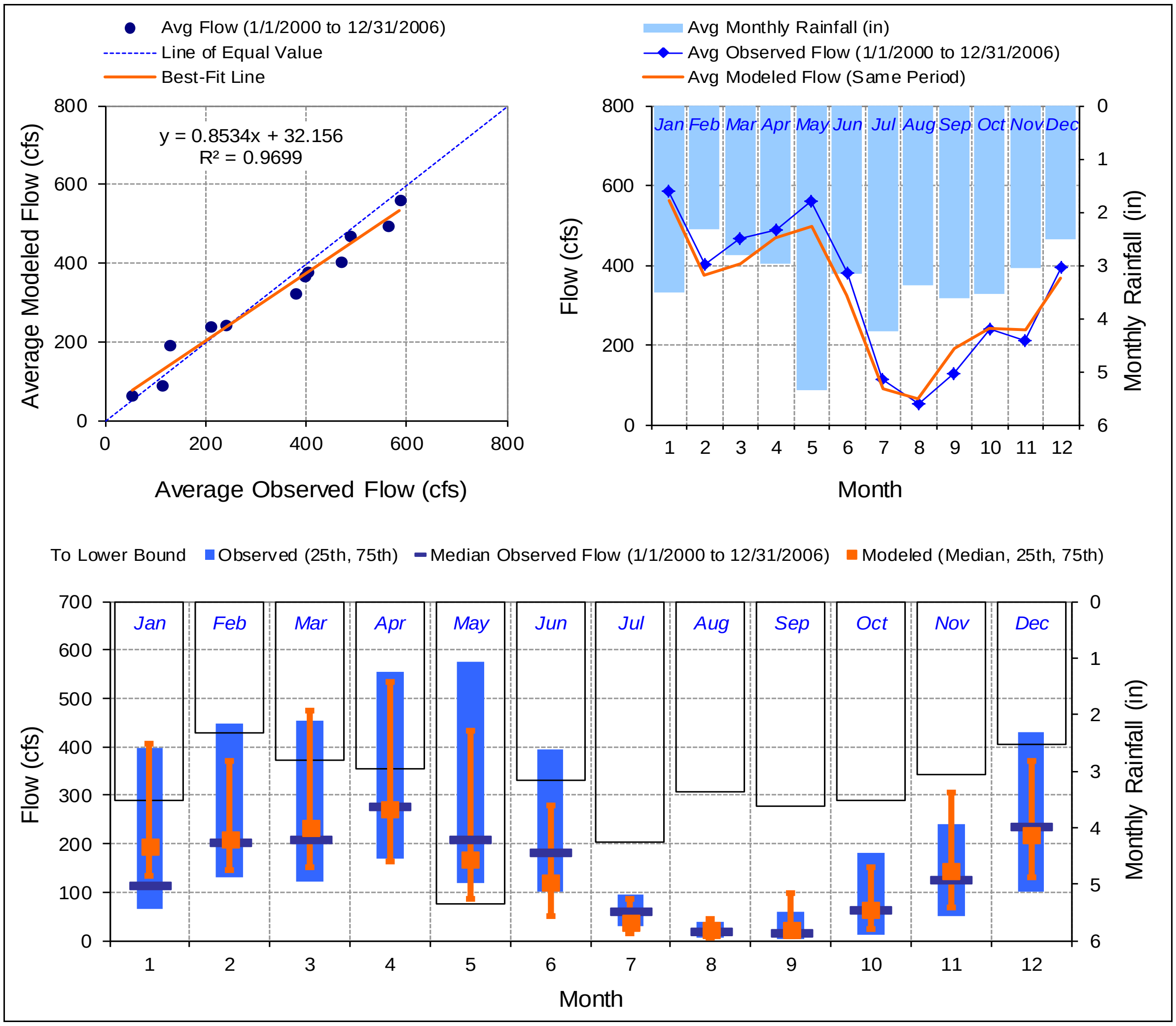


Figure 4-5. Additional modeled vs. observed flow plots for the assessment site of the USGS gage on Paint Creek at SR-753.

Table 4-10 shows summary statistics of the calibrated LSPC model at the USGS gage on Paint Creek at SR-753 assessment site. Note in the bottom half of this table that all of the error statistics that indicate how well the modeled flows match the observed gage flows are well within the recommended criteria (U.S. EPA, 2000; Tetra Tech, pers. comm.).

Table 4-10. Summary statistics of the calibrated LSPC model at the USGS gage on Paint Creek at SR-753 assessment site.

LSPC Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM SUBBASIN 4 7-Year Analysis Period: 1/1/2000 - 12/31/2006 Flow volumes are (inches/year) for upstream drainage area		OBSERVED FLOW 7-Year Analysis Period: 1/1/2000 - 12/31/2006 Flow volumes are (inches/year) for upstream drainage area	
Total Simulated In-stream Flow:	**17.37**	Total Observed In-stream Flow:	**18.31**
Total of simulated highest 10% flows:	**9.36**	Total of Observed highest 10% flows:	**10.20**
Total of Simulated lowest 50% flows:	**1.57**	Total of Observed Lowest 50% flows:	**1.46**
Simulated Summer Flow Volume (months 7-9):	**1.57**	Observed Summer Flow Volume (7-9):	**1.34**
Simulated Fall Flow Volume (months 10-12):	**3.89**	Observed Fall Flow Volume (10-12):	**3.90**
Simulated Winter Flow Volume (months 1-3):	**6.05**	Observed Winter Flow Volume (1-3):	**6.58**
Simulated Spring Flow Volume (months 4-6):	**5.86**	Observed Spring Flow Volume (4-6):	**6.49**
Total Simulated Storm Volume:	**10.46**	Total Observed Storm Volume:	**10.74**
Simulated Summer Storm Volume (7-9):	**1.11**	Observed Summer Storm Volume (7-9):	**0.86**

Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	-5.14	10		
Error in 50% lowest flows:	6.98	10		
Error in 10% highest flows:	-8.28	15		
Seasonal volume error - Summer:	16.81	30		
Seasonal volume error - Fall:	-0.20	30		
Seasonal volume error - Winter:	-7.99	30		
Seasonal volume error - Spring:	-9.75	30		
Error in storm volumes:	-2.59	20		
Error in summer storm volumes:	28.16	50		

4.1.5 Allowance for Future Growth

Growth trends in the region's counties are -3 to 1% (ODD, 2003). Although significant development is not expected in the upper Paint Creek basin, a reserve for future growth is applied. The AFG is intended to account for new sources that would impact the low flow regime. The system is able to assimilate direct sources that discharge at 126 cfu/100 ml due to mass balance mixing. However, additional pollutant carrying flow sources are limited to safeguard against excessive pathogen and nutrient loading at sensitive low flows. The amount of additional flow is calculated as 10% of the stream's flow exceeded 90% of the time. The flow increase is multiplied by 126 cfu/100 ml and a conversion factor to calculate the reserve load for future growth. This method allows for an accumulated 0.92 MGD effluent flow held at the *E. coli* limit for Paint creek upstream Paint Creek Lake. New sources that can discharge below the *E. coli* limit can be approved for more flow, as long as proper review indicates the TMDL requirements are met. Therefore, industrial sources that do not treat sanitary waste are not theoretically restricted by the *E. coli* TMDL. It should be noted that the municipal operations within the upper Paint Creek basin already have implicit reserve of future growth built into their current NPDES permits. These entities can also draw from the general reserve if necessary for further expansion. Each HUC12 TMDL has a local reserve for future growth. Downstream

HUC12 TMDLs get the flow based reserve minus the reserve held by the upstream HUC12(s). The total AFG is tracked with the cumulative TMDL. The total AFG of upper Paint Creek can be managed to allocate more where needed, but the AFG taken from other areas further limits their capacity to discharge increased *E. coli* loads.

4.1.6 Seasonality and Critical Conditions

E. coli

Short lived pulse loads of pathogens are typically during flows with less expected in-stream recreational activity in Ohio waters, although still a risk for high water sporting. Although the *E. coli* concentration levels dissipate in a few days after a high flow event, the stream bottom may be seeded with pathogens that can persist over six months. Other high loading events not necessarily in tandem with high stream flow include residual combined sewer releases, sludge lagoon failures, dense livestock with stream access, and loadings from failing straight-pipe septic systems. These types of loadings are not permitted due to the high potential for causing water borne illnesses from recreational contact with calm flowing waters. Typical sources of loadings are agricultural and residential washoff, permitted point sources, and wildlife.

Total phosphorus

Upper Paint Creek's waters are most sensitive to eutrophic nutrient levels during low flow summer conditions. This has been indicated with the findings of high benthic algae concentrations measured in 2008, and low dissolved oxygen measured in 2006. Meeting chemical and biological conditions under critical conditions is assured in three steps in this report. First, TP is analyzed to find the appropriate loading control level through meeting the target. This step uses this control to assign TP TMDLs. Second the simulation assures that ammonia nitrogen (NH_3-N) water quality standards are met in all reaches. Since the model does not simulate pH, field pH data in combination with temperature simulation is used to derive the appropriate NH_3-N criteria. The simulation indicates that NH_3-N concentrations are acceptable with the condition that the TP TMDLs are met and all NPDES regulated sources meet their permitted NH_3-N limits. Third, the minimum DO criterion is used to determine if the corridor has enough assimilative capacity. A moving 30 day average of simulated daily minimum DO concentrations is used to indicate achievement of the criteria. Using a moving 30 day average safeguards against model anomalies (insufficient depth for algal growth, weather file discrepancies, etc.) and is generally comparable to the 10th percentile of grouped summer minimum DO concentrations.

A review of the simulated concentrations achieved after the TP TMDL is met indicates that DO is still below criteria in some of the channelized low gradient reaches. Instead of further reducing TP loads below the association based target, increase in DO concentrations are simulated through improving the stream corridor. The channel improvement is based on the findings of the QHEI submetrics. The reach definitions are adjusted to improve lacking natural stream components, specifically riparian shade and typical riffle/run dynamics. Updating reach shade level is straight forward in the model. Improved channel flow is represented by altering the cross sections that are initially set to behave as flood plain disconnected agricultural ditches. The reach definitions are changed to regional values based on drainage area. As stream corridor functioning has a strong effect on eutrophic conditions, the QHEI submetrics are indeed a critical condition and must be addressed. The Habitat/Bedload TMDL section provides the improved minimum DO simulations for the impaired reaches of this section. Note that the targets of the Habitat/Bedload TMDLs are the driving force for biologic improvement, and the simulated DO effects are intended to demonstrate the strength of a healthy stream corridor.

This assessment captures a wide range of seasonal conditions, as each model year had characteristic hydrologic conditions. In particular, the analysis revealed the highest average concentrations (and load) occur during the spring. This higher seasonal load acts to seed the local and far-field substrate and water column of reaches with sufficient TP and TN to drive algal productivity into the summer. Impounded areas are susceptible to eutrophic problems much earlier than free flowing streams due to increased retention capacity. Large storms during summer act to both scour productive substrates as well as refuel nutrient levels for local and downstream growth. Fall and winter conditions tend to produce less average nutrient loadings, but can produce large acute loads in response to large storms and suitable soil conditions. As previously discussed the average 0.1 mg/L TP concentration is linked strongly to biological success. In order to protect base flow conditions through the year, the average concentration target is imposed on four seasonal periods. The winter group is defined as January – March, spring as April – June, summer as July – September, and fall as October – December. The higher average concentration of spring is a main driver of addressing nutrient loading seasonality and transport control. Summer also has a unique seasonality issue in that WWTP effluent concentrations contribute a much larger percentage of the low flow condition.

4.1.7 Allocations to Regulated Municipal Separate Storm Sewer Systems (MS4s) and Confined Animal Feeding Operations (CAFOs)

Some municipal separate storm sewer systems (MS4s) require NPDES coverage for their storm water discharges. This requirement is primarily based on the size of the sewer system as indicated by the size and/or density of the population that resides within the confines of the system. In the Paint Creek watershed, only one MS4 currently is required NPDES coverage, namely the one associated with Washington Courthouse (permit number = 4GQ00027*AG).

Because the MS4 discharges are regulated, TMDL pollutants from the system are allocated a waste load. However, since most of the regulated MS4s in Ohio do not have or are currently not required to have treatment infrastructure inherent to their systems, the waste loads are typically assigned based on a reasonable loading condition (i.e., loading based on typical pollutant concentrations found in municipal storm water and an estimate of the system's hydrologic output). Under such circumstances, illicit connections and/or discharges are not anticipated or provided a pollutant allocation.

Washington Court House gained the MS4 status after the initial model was set up, so the MS4 land was not modeled as a unique land use. However, MS4 loads can be derived from subwatersheds 16, 17, and 18 (Paint Creek near the Washington Court House upland reservoirs, downstream to East Fork Paint Creek, see Figure 4-6) developed lands which are mostly incorporated. 3.4 sqmi of the total incorporated 6.6 sqmi of Washington Court House are located within these model subwatersheds. Some additional developed lands adjacent to Washington Court House are within these boundaries, which are modeled as part of the MS4 to implicitly represent future incorporated expansion.

In order to quantify the individual MS4 daily loads, all other sources were shut off in the model. The resulting output is a quantification of several storm water generated load events. The remaining MS4 area draining to East Fork Paint Creek (1.3 sqmi) and below its confluence with Paint Creek (1.9 sqmi) cannot be analyzed in the same way. Both model subwatersheds 24 and 25 that contain Washington Court House's incorporated area respectively have a larger percentage of unincorporated urban land. The MS4 loads of these other two locations are calculated indirectly as a percentage of the total incorporated area multiplied by a percentage load derived from the simulated area upstream of East Fork. The generated washoff to the stream from the MS4 region is used to assist in reductions to meet the recreation season target, and for TMDL related permit development.

Confined animal feeding operations (CAFOs) may also be regulated under the NPDES program. The requirement for obtaining NPDES coverage for a given operation is predicated on the number and type of animals in the system that are to be confined in an area not having maintained natural vegetation for a period of 45 days or more per twelve month period as well as the presence of a discharge. One of the five CAFOs in the Paint Creek watershed have NPDES coverage, namely the Gill Dairy LLC (permit number = 4IK00027*AD).

Even with a permit; CAFOs are not authorized to discharge waste water except that which is in association with overflows caused by at the least a 24 hour storm events with a return probably of once in 25 years (i.e., a 25 year, 24 hour storm event) or that which is associated with storm water following land application (i.e., not a direct discharge through tile flow or other type of dry weather discharge). CAFOs that do not have a NPDES permit are not authorized to discharge any pollutants from the production area. For this reason, the CAFOs in the watershed are assigned no pollutant wasteload or load allocations based on the assumption that such loading will not occur.

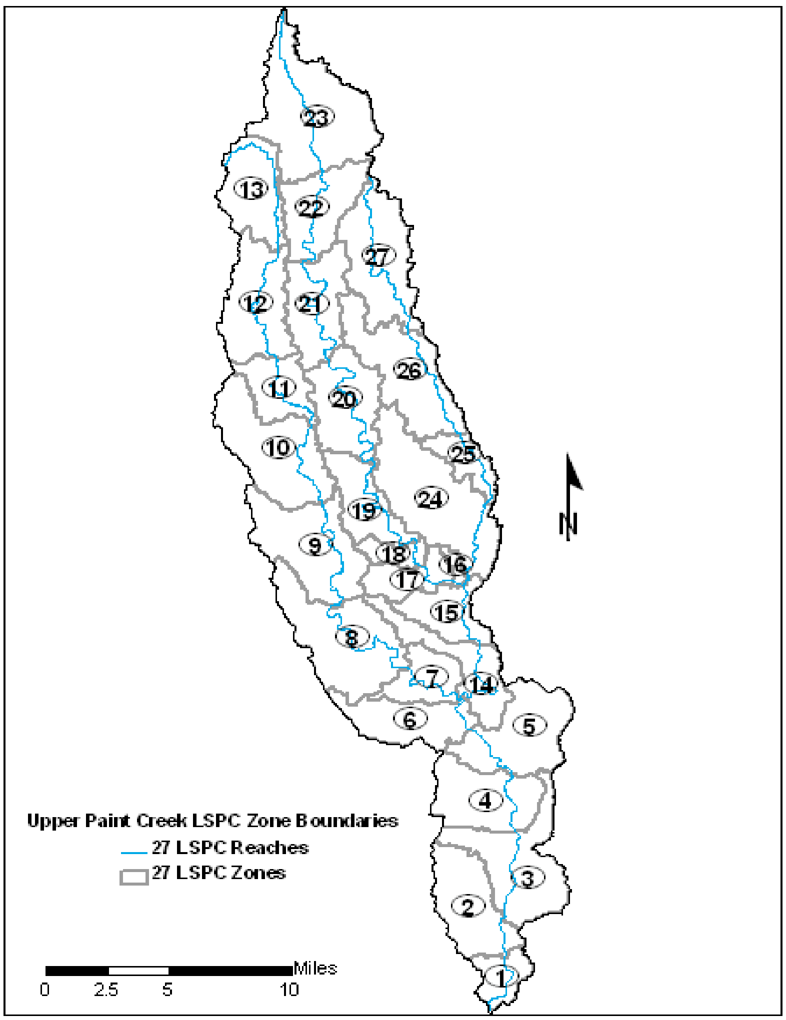


Figure 4-6. Modeled subwatersheds for the LSPC model.

4.2 Qualitative Habitat Evaluation Index (QHEI)

The Qualitative Habitat Evaluation Index (QHEI) is used to qualitatively evaluate habitat quality by assigning a numeric value to an individual stream segment (typically 150-200 m in length) based on the quality of its habitat. The 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 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 that reduce the overall utility of the habitat (e.g., heavy siltation and embedded substrate). These points are summed within each of the six metrics to give a score for that particular aspect of stream habitat. The overall QHEI score is the sum of all of the metric scores.

4.2.1 Justification

The QHEI is used to establish targets and calculate the deviation from this target to address aquatic life use impairments caused by excessive fine sediment and poor habitat quality for rivers and streams throughout the entire Paint Creek 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 standards (see below). 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 (U.S. EPA 1991). Thus, sufficient justification for developing habitat TMDLs is established.

The 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.

4.2.2 Sources of Data

The QHEI scores used in developing the habitat and sediment TMDLs were produced during the initial water quality survey at the time that the biological communities were sampled. All of these data were collected by staff at the Ohio EPA and stored in databases managed by the agency.

4.2.3 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 its component 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 aquatic life use designations of warmwater habitat (WWH) and exceptional warmwater habitat (EWH), respective overall QHEI scores of 60 and 75 are targeted to provide reasonable certainty that habitat is sufficient to support biological community expectations.

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. 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 subgroup of the modified attributes shows a stronger impact on biological performance; these are termed high influence modified attributes.

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 be no more than four modified attributes, of which no more than one should be a high influence modified attribute. For EWH streams, there should be no more than two modified attributes and zero high influence attributes. Table 4-11 lists modified and high influence modified attributes and provides the QHEI targets used for this habitat TMDL.

Table 4-11. QHEI targets for the habitat TMDL.

		Overall QHEI Score	All Modified Attributes	
			High Influence Modified Attributes	**All Other Modified Attributes**
Range of Possibilities		12 to 100 points	- Channelized or No Recovery - Silt/Muck Substrate - Low Sinuosity - Sparse/No Cover - Max Pool Depth < 40 cm (wadeable streams only)	- Recovering Channel - Sand Substrate (boat sites) - Hardpan Substrate Origin - Fair/Poor Development - Only 1-2 Cover Types - No Fast Current - High/Moderate Embeddedness - Ext/Mod Riffle Embeddedness - No Riffle
Target	**WWH**	Overall score >= 60	Total number < 2	Total number < 5[1]
	EWH	Overall score >= 75	Total number < 0	Total number < 3[1]
TMDL Points Assigned if Target is Satisfied		+ 1	+ 1	+ 1

[1] Total number of modified attributes includes those counted towards the high influence modified attributes

For simplicity, a pass/fail distinction is made to determine whether each of the three targets is 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.

The QHEI is also used to develop the bedload (sediment) TMDL. Numeric targets for sediment are based on the metrics of the QHEI. Although QHEI evaluates the overall quality of stream habitat, some of the component 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 metrics used in the bedload TMDL are the substrate, riparian, and channel metrics. All of these evaluate stream attributes related to substrate quality and the amount of fines in the sediment. Substrate is a QHEI category that measures the type, origin, quality, and degree of embeddedness of stream substrates. Degree of embeddedness refers to the extent to which gravel, cobble, and boulders are surrounded, buried by, or covered by fine materials such as sand or silt. The riparian QHEI category evaluates riparian width, quality, and bank erosion. The channel QHEI category describes stream physical morphology including sinuosity and extent of development. Each of these factors influences the degree to which siltation affects a stream, and cumulatively serves as its numeric target.

The targets were established based on a paired analysis of IBI scores with corresponding values of these QHEI metrics. The targets are set at the fiftieth percentile of the site that achieves a minimum IBI score of 40, which is meant to reflect a warmwater habitat fish community. Table 4-12 summarizes the sediment TMDL targets that are used to address sedimentation.

Table 4-12. Sediment (bedload) TMDL targets.

Sediment TMDL =	**Substrate**	**+**	**Channel Morphology**	**+**	**Riparian Zone/Bank Erosion**	
For WWH >=	13	+	14	+	5	>= 32

The sedimentation scores can be thought of as a “concentration”, as they measure the current amount of sediment in the stream. This means that the load allocations (LAs) and wasteload allocations (WLAs) are the same as the loading capacity (e.g., score = 32).

4.2.4 Calibration and Validation

Using the QHEI to set water quality goals and determine the degree of deviation from those targets under existing conditions differs from typical, process based, or empirical models used in developing TMDLs and associated allocations. Using the QHEI to develop the sediment and habitat TMDLs is a direct comparison between the existing conditions and the target values, where simple mathematic operations are carried out to determine the degree of deviation. For this reason calibration and/or validation is not needed, since these TMDLs are based exclusively on real data as opposed to simulation data.

4.2.5 Allowance for Future Growth

Habitat and sediment stressors are primarily the result of management done in the course of agricultural production. Future growth in urban, residential, and commercial land uses will require steps be taken to ensure protection of water resources, namely pre and post construction BMPs that manage storm water and sediment erosion. So, in terms of sediment delivery, it would be anticipated that sediment loading from those areas would actually decrease therefore an allowance in the TMDL is not needed. In terms of habitat quality, a different set of stressors emerge through urbanization as opposed to intensive agricultural drainage.

4.2.6 Seasonality and Critical Conditions

Sediment loading from cropland is most severe when vegetation cover is at a minimum or non-existent, soils are moist and/or saturated, and rain events are frequent. This corresponds to the non-growing or early growing season especially in the spring when rain events are frequent. Habitat, separate from sediment loading, is not tied to seasonality.

The critical condition for the habitat and sediment TMDLs is the summer dry period when environmental stress upon aquatic organisms is the greatest. It is during this period that the presence of high-quality habitat features, such as deep pools and unembedded substrate, is essential to provide refuge for aquatic life. QHEI scores, the basis of the habitat and sediment TMDLs, are assessed during the summer field season. The habitat and sediment TMDLs are therefore reflective of the critical condition.

4.3 Load Duration Curve Analysis

Much of the watershed is impacted by elevated *E. coli* concentrations. A load duration curve approach using Ohio EPA sample data directly is selected for source load analysis and TMDL development. The duration curve approach allows for characterizing water quality concentrations (or water quality data) at different flow regimes. The method provides a visual display of the relationship between stream flow and loading capacity. Using the duration curve framework, the frequency and magnitude of water quality standard exceedances, allowable loadings, and size of load reductions are easily presented and can be better understood.

The duration curve approach is particularly applicable because stream flow is an important factor in the determination of loading capacities. This method accounts for how stream flow patterns affect changes in water quality over the course of a year (i.e., seasonal variation that must be considered in TMDL development). Duration curves also provide a means to link water quality concerns with key watershed processes that may be important considerations in TMDL development. Basic principles of hydrology can help identify the relative importance of factors such as water storage or storm events, which subsequently affect water quality. The approach considers changing conditions due to seasonality, which makes it useful to assess source loading mechanisms. Although the approach is not as resource demanding as higher level approaches, the approach should be considered with caution. An underlying premise of the duration curve approach is correlation of water quality impairments to flow conditions. The duration curve alone does not consider specific fate and transport mechanisms, which may vary depending on watershed or pollutant characteristics. Such processes may include sediment attenuation, plant uptake of nutrients, chemical transformations, or bioaccumulation. While the

LDC method is an appropriate screening tool, one should also consider the suitability of using it as the sole basis for assessment versus supplementing its use with other analytical tools.

While the guideline provides a suitable approach for defining flow regime intervals on an annual flow record, this report's flow regimes are defined to better fit pollutant specific needs. The LDC TMDL quantifications are calibrated to provide results similar to the *E. coli* TMDLs derived with LSPC. Section 1c *Duration Curve Intervals and Zones* of the guidance states "Other schemes can be used, depending on local hydrology and the water quality issues being addressed by assessment efforts. … the benefit of using zones is to provide insight regarding patterns associated with concerns." In the case of *E. coli* analysis, only recreation season flows are used to define duration intervals in order to address critical conditions. Further, the number of regimes is reduced to three TMDL generating flow regime intervals. This adjustment places an implicit margin of safety in high flow load estimation and more emphasis on base flow *E. coli* control.

One of the southern sites was established at an Ohio EPA ambient site, which other than in 2006, has been sampled monthly or quarterly for many years. The ambient site is located at the 03232000 USGS gage on Paint Creek's SR-753 crossing north of Greenfield. Due to the wealth of data from Paint Creek at SR-753, the 2006 fecal coliform (which was formerly the indicator for pathogen contamination) and *E. coli* data can be compared to long term loading trends. Figure 4-7 is an assessment of the magnitude of bacteria loads across Paint Creek's annual flow regime. Available USGS gage flow data between 1966 and 2008 are used for duration interval development. Ohio EPA bacteria data collected between 1999 and 2008 are used for representation of current trends. For statistical comparison, the annual flows are divided into five zones that represent the percent of time a particular flow is exceeded. The annual low/dry/mid-range/moist/high regime names and ranges are taken from the U.S. EPA load duration curve guidance for comparison. While the regime names are generally self-explanatory, it should be noted that storm and base flows do in fact have a presence in all the regimes due to seasonal hydrologic patterns. The data markers are coded to help clarify each sample's hydrology conditions. Diamonds depict any sample taken between January to December, diamonds with cross-hairs depict samples collected between May and October (the recreation season), and diamonds with red cores represent samples collected during storm flow events where >50% of the flow is from runoff. The bacteria loading response through the September 2006 storm is depicted by following the green line counter-clockwise in both graphs. The September 12th samples were taken during rising flow. While the concentrations were less on September 13th, the loads were higher after the stream flow crested. The concentrations and loads dropped off toward normal levels during the remaining sample days. This pattern indicates that bacteria levels are also dependent on sediment transport, as sediment concentration and load patterns are similar with respect to the stages of a storm flow hydrograph.

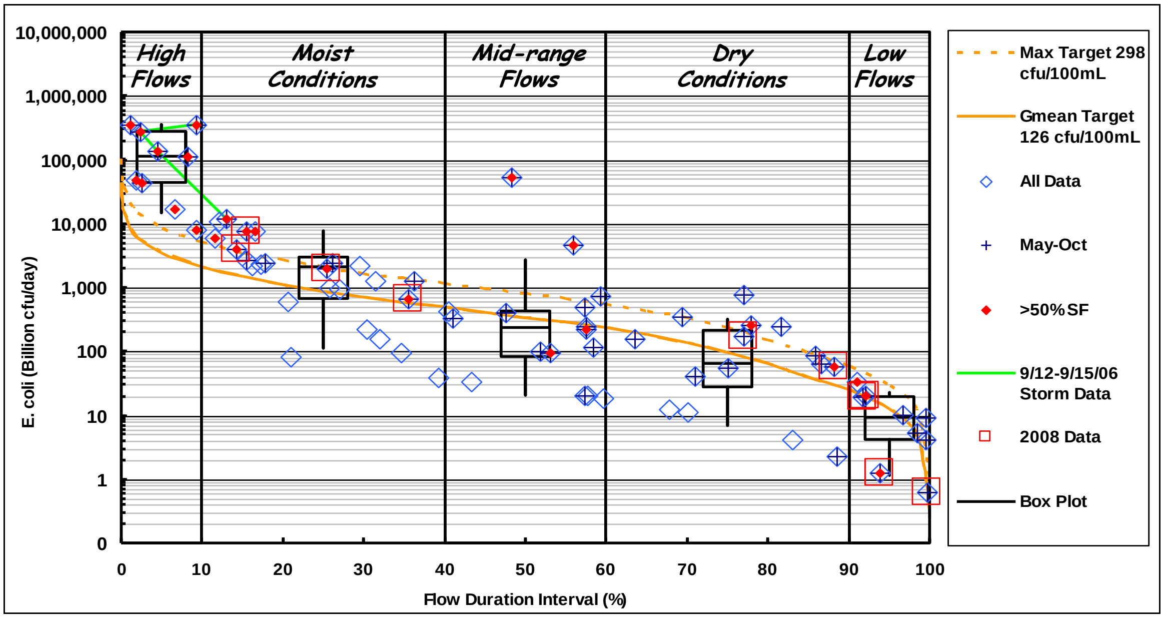


Figure 4-7. Annual *E. coli* sample loads and flow duration for Paint Creek at SR-753.

Figure 4-7 has lines of constant concentration which are referred to as load duration curves. Load duration curves are typically set to a concentration target for comparison to a water quality standard. Box plots statistics from samples of each flow regime can be compared to the magnitude of segments of a load duration curve. Load duration curves are best suited for assessing load reduction needs for pollutants with maximum criteria. However, an average criterion can be applied as a "maximum" target to lower flow regimes of a load duration curve assessment if the pollutant levels are most critical during base flow levels. Such is the case with *E. coli*, as more recreation use is expected to occur during lower flows. An appropriate recreation season geometric mean of *E. coli* data dictates that each sample concentration is normally below the geometric mean criteria during lower flows, with occasional higher flow concentration spikes not having a significant statistical effect. The dampened effect of high flow loadings on the geometric mean is due to *E. coli* concentration's relationship to flow patterns. Stream hydrology tends to follow a log-normal distribution, which puts most weight on the more common days of stable flow. Therefore, flow influenced criteria based on central tendency are best applied to load duration curve analysis at lower flows, where maximum criteria are useful for load duration curve analysis of the entire flow regime. The superseded fecal coliform criteria was suitable for developing load duration curve TMDLs, as its maximum criteria was used by Ohio EPA for 303d listing. The current *E. coli* recreation use criteria do not refer to a maximum for watershed 303d listing purposes. However, *E. coli*'s maximum criteria are in effect for the control of public nuisance conditions. The fecal coliform analysis also provides a load duration curve set to 200 cfu/100 ml, which is a geometric mean standard of other states and is comparable to the *E. coli* 126 cfu/100 ml geometric mean standard magnitude.

Fecal coliform and *E. coli* box plot means compared to load duration curve targets indicate that concentrations are generally meeting below flows exceeded 40% of the time. However to meet the geometric mean criteria, the concentrations should be sufficiently under target at lower flows, as the excessive *E. coli* box plot's 75th and 90th percentile levels demonstrate. With respect to the fecal coliform maximum target, sample data indicates attainment except under higher flows exceeded 10% of the time and a couple other isolated storm events. *E. coli*'s more stringent maximum concentration marker captures a higher incidence of exceedences. With respect to flow regime, annual flows between 40 and 80% exceedence tend to offer more base flow dilution, which dampen bacteria concentrations.

Several conclusions can be drawn from load duration curve analysis if a sufficient dataset is collected. However, the analysis does not provide direct assessment of transport mechanisms, nor do its load characteristics transfer to assessment of other sites. While the Paint Creek site at SR-753 has sufficient samples, several other sites are lacking in representative 2006 assessment data. Sites in the upper Paint Creek watershed listed in Table 4-13 were revisited for sampling in 2008 to provide a clearer understanding of their non-attainment status. Sampling was generally carried out at two week intervals across the recreation season to sample a range of base flows and random storm events. Geometric means in excess of the appropriate criteria are underlined. Paint Creek at SR-753's 2008 samples fall in line with ambient data and confirm that there is a somewhat elevated geometric mean issue. Some 2008 sites confirmed a geometric mean violation, where other sites data point to a reversal in meeting recreation use criteria. Nevertheless, once a single season's recreation use is found to be impaired by not meeting criteria, a TMDL is warranted. The small high flow sample set of 2006 triggered 303(d) impairment listings, which merits a TMDL assessment in order to ensure that pollutant levels are under control.

Table 4-13. Ohio EPA 2008 *E. coli* sampling sites and recreation season geometric means.

Stream	Location	RM	Station ID	Count	GeoMean
East Fork Paint Creek	US-22	0.72	300055	9	62
Sugar Creek	Armbrust Rd	4.24	300050	10	188 (Non)
Paint Creek	adj SR-41 YMCA	73.28	V10S35	9	164 (Non)
Paint Creek (Class A)	Elm St	69.52	V10S34	9	81
Paint Creek (Class A)	adj Rock Bridge Rd	67.1	V10S32	10	162 (Non)
Paint Creek (Class A)	Miami Trace Rd	58.75	V10S31	10	71
Paint Creek (Class A)	SR-753 (USGS site)	52.54	V10S30	10	155 (Non)
Paint Creek (Class A)	dst Greenfield WWTP	49.4	V10Q04	6	29
Paint Creek (Class A)	adj Washington St	48.7	V10S29	9	58

The State of Ohio had until 2009 used fecal coliform as the pathogen indicator basis for recreation standard limits. The rules have changed to use *E. coli* as the pathogen indicator, as recommended by U.S. EPA. For assessment of general recreation season attainment, the geometric mean of daily *E. coli* concentration from May 1st to October 31st is used. While the metric is suitable to determine the overall health of a waterbody and the focus of TMDL development, there are other regulatory tools to consider. The Integrated Report does not consider maximum *E. coli* concentration violations as it did in the past for fecal coliform. However, a maximum *E. coli* standard is in effect to control localized sources known to have high pathogen content (CSOs, sludge lagoons, treatment operations, etc.). The maximum *E. coli* standard can also be used for assessment in public nuisance situations by the Department of Health or Ohio EPA (septic failures, manure storage failures, etc.). The *E. coli* TMDLs of this report focus on maintaining the recreation season geometric mean standard, with the understanding that all gross sources of pathogens are not permitted and do not receive any allocation.

4.3.1 Justification

This method is appropriate since the sources of bacteria in Ohio streams can be differentiated by stream flow regime. The main advantage of the use of 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, alternative 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 methods such as this 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 is normally collected during routine surveys for calibration.

4.3.2 Sources of Data

A multi-year *E. coli* dataset collected from Paint Creek at the SR-753 crossing is used as the basis for developing the *E.coli* LDC TMDL strategy. This site has been discussed in the LSPC section, as it is the main calibration point for upper Paint Creek. The sample *E. coli* daily data and the 2000-2006 daily data from the calibrated existing conditions model have been plotted in the load duration curve.

4.3.3 Target(s)

Elevated bacteria loading is the cause of recreation use impairment for most streams in the Paint Creek watershed. TMDL numeric targets for *E. coli* bacteria are derived from bacteriological water quality standards. The criterion for *E. coli* specified in OAC 3745-1-07 are applicable outside the mixing zone and vary for waters that are classified as primary contact recreation (PCR). Paint Creek from its confluence with the Scioto River upstream until river mile 71.15 in Washington Court House is designated as class A primary contact recreation. North Fork Paint Creek from its mouth to river mile 37.4 and Rocky Fork from its mouth to river mile 18.05 are likewise designated. The remainder of streams assessed in this watershed is Class B primary contact recreation streams. For Class A streams the standard states that the geometric mean of more than one *E. coli* sample taken in each recreational season (May through October) shall not exceed 126 colony forming units (cfu) per 100 ml. The standard for Class B streams states that the geometric mean of more than one *E. coli* sample taken in each recreational season shall not exceed 161 cfu per100 ml.

4.3.4 Calibration and Validation

Using load duration curves to set target loads and determine the degree of deviation from those targets under existing conditions differs from typical, process based, or empirical models used in developing TMDLs and associated allocations. Using the load duration curves to develop the *E. coli* TMDLs is a simple direct comparison between the existing conditions and the target values, where a simple mathematic operation is carried out to determine the degree of deviation. For this reason calibration and/or validation is not needed, since these TMDLs are based on exclusively on real data as opposed to simulation data.

4.3.5 Allowance for Future Growth

Growth trends in the region’s counties are -3 to 1%. Although significant development is not expected in the upper Paint Creek basin, a reserve for future growth is applied. The reserve is intended to account for new sources that would impact the low flow regime. The system is able to assimilate direct sources that discharge at 126 cfu/100 ml due to mass balance mixing.

However, additional pollutant carrying flow sources are limited to safeguard against excessive pathogen and nutrient loading at sensitive low flows. The amount of additional flow is calculated as 10% of the stream's flow exceeded 90% of the time. The flow increase is multiplied by 126 cfu/100 ml and a conversion factor to calculate the reserve load for future growth. This method allows for an accumulated 0.92 MGD effluent flow held at the *E. coli* limit for Paint creek upstream Paint Creek Lake. New sources that can discharge below the *E. coli* limit can be approved for more flow, as long as proper review indicates the TMDL requirements are met. Therefore, industrial sources that do not treat sanitary waste are not theoretically restricted by the *E. coli* TMDL. It should be noted that the municipal operations within the upper Paint Creek basin already have implicit reserve of future growth built into their current NPDES permits. These entities can also draw from the general reserve if necessary for further expansion. Each HUC-12 TMDL has a local reserve for future growth. Downstream HUC-12 TMDLs get the flow based reserve minus the reserve held by the upstream HUC-12(s). The total reserve is tracked with the cumulative TMDL. The total reserve of upper Paint Creek can be managed to allocate more where needed, but the reserve taken from other areas further limits their capacity to discharge increased *E. coli* loads.

4.3.6 Seasonality and Critical Conditions

The source of the pathogens determines the degree of seasonality. Permanent residences that have HSTS that contribute bacteria (i.e., are failing systems) do so at a relatively even rate throughout the year. However, the area surrounding Rocky Fork Lake has a substantial seasonal community where those systems are in much more use during the warmer spring, summer, and fall months, and therefore loading at those times of the year is much more intense. Livestock with access to surface waters enter streams to drink and cool in the warmer months of the year where manure is directly deposited in to streams. This loading can have an extreme impact on local water quality. Runoff driven loading where wash-off of manure residues deposited by livestock in pastures or elsewhere and wildlife is primarily a spring and early summer phenomenon since runoff typically occurs relatively frequently and manure residues are maximized due to greater outdoor presence of livestock (i.e., not confined in barns).

The critical condition for pathogens is the summer dry period when flows are lowest, and thus the potential for dilution is the lowest. Growth rates are higher and mortality rates lower in the warmer months further making this a critical time of the year for bacteria contamination. Likewise, summer is the period when the probability of recreational contact is the highest. For these reasons recreation use designations are only applicable in the period May through the end of October. Pathogen TMDLs are developed for the same time period in consideration of the critical condition, and for agreement with Ohio WQS.

Critical conditions for in-stream bacteria vary by source and can occur across the hydrograph, from washoff of land-deposited bacteria under moist conditions to in-stream livestock and failing home sewage treatment systems (HSTSs) in low flow conditions. Nonpoint sources to which bacteria loads from LDC analysis are allocated in the Paint Creek basin include livestock with stream access, failing septic systems, residential washoff, washoff from pastures, and manure land application practices.

4.3.7 Allocations to Regulated Municipal Separate Storm Sewer Systems (MS4s)

The proportion of the nonpoint source loading that equals the proportion of the MS4 area within the overall area generating the nonpoint source loading is allocated to the MS4's wasteload. See Section 4.1.7 for additional discussion on the methods for allocating wasteloads to MS4s.

4.4 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).

4.4.1 E. coli Margin of Safety

Two different methods were used developing the TMDLs and allocations for *E. coli* that warranted the use of different margins of safety. The area analyzed with the LSPC model, namely the 01, 02, and part of the 06 ten-digit HUCs (see Section 4-1) was given a five percent explicit margin of safety, in addition to conservative assumptions that provided implicit MOS (see discussion below). The load duration curve analysis employed a 20 percent explicit MOS (see discussion below).

The five percent MOS for the LSPC method is incorporated into both local and cumulative TMDLs. The explicit margin of safety further ensures control of peak loadings which impact the E. coli seasonal geometric mean concentration. An implicit margin of safety is also incorporated into the model representation. The use of design flows and static daily maximum loads from direct sources (point and nonpoint) ensures that critical recreation periods of high use are assessed under the worst case loading condition. The static daily load of direct non point sources represents an upper limit with respect to seasonal variation, which also incorporates an implicit safety factor. This compensates for alternating pasture usage and/or changing HSTS impacts not reflected in the sample data. The use of a high level model with good calibration results reduces the need for margin safety since there is greater confidence associated with the output.

The 20 percent MOS used for the LDC method is due primarily to the relatively low numbers of data points available for this analysis and to account for broad fluctuations of *E. coli* concentrations that occur in nature. U.S. EPA (2007) recommends this type of MOS for two reasons: 1) allocations will not exceed the load associated with the minimum flow in each regime; and 2) recognition that the uncertainty associated with effluent limits and water quality may vary across different flow conditions. Although a constant 20 percent MOS is used for each flow condition, it should be noted that under the lower flow regimes uncertainty diminishes since loading pathways are fewer and more predictable (i.e., no runoff-driven pathways).

4.4.2 Total Phosphorus Margin of Safety

Five percent of the TMDL is set aside as an explicit margin of safety. This is incorporated into both local and cumulative TMDLs. The explicit margin of safety further ensures control of peak loadings which impact the TP averages of the four season groups. An implicit margin of safety is also incorporated into the model representation. The use of design flows and static daily maximum loads from direct sources (point and non point) ensures that critical recreation periods of high use are assessed under the worst case loading condition. The static daily load of direct non point sources represents an upper limit with respect to seasonal variation, which also incorporates an implicit safety factor. This compensates for alternating pasture usage and/or changing HSTS impacts not reflected in the sample data. The use of a high level model with satisfactory calibration is in itself an implicit margin safety, by providing sufficient accuracy for management decisions.

4.4.3 Habitat and Sediment Margin of Safety

There is an implicit margin of safety applied to the habitat and sediment TMDLs based on conservative target values used. The targets from the *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams* (Ohio EPA 1999) are conservative because attainment of aquatic life uses has been demonstrated even when the targets are not met.

4.5 Summary of surrogate parameters used to develop TMDLs

There are several instances in the development of TMDLs for aquatic life use impairments in the Paint Creek watershed that surrogate parameters are used. This is done to increase the efficiency of the technical analysis; however, not to the diminishment of the water quality management information derived through the analyses. In short, the prescribed reductions to the direct and indirect (i.e., surrogate) pollutants will achieve the water quality goals that are at the foundation of the development of these TMDLs.

The purpose of this brief section is to assist the reader in accounting for how the listed causes of impairment are addressed, and more specifically, where the reader is to find the results of the load reductions where surrogate parameters are used. Tables 4-14 through 4-16 show the original cause of impairment as listed in the 303(d) list relative to the surrogate parameter that is used as well as a reference to the table in the report where the results can be found.

Table 0-14. Hydrologic units impaired by dissolved oxygen but addressed using surrogate TMDL parameters.

12-digit HUC (last 4 digits)	Surrogate Parameter	Reference to Table in Report
0102	Total phosphorus	Tables 5-5 and 5-6
0103	Total phosphorus	Table 5-7
0201	Total phosphorus	Table 5-13
0303	Habitat	Table 5-23
0304	Habitat	Table 5-24
0401	*E. coli*	Table 5-26
0403	*E. coli*	Table 5-26
0704	Habitat	Table 5-37

Table 0-15. Hydrologic units impaired by organic enrichment but addressed using surrogate TMDL parameters.

12-digit HUC (last 4 digits)	Surrogate Parameter	Reference to Table or page numbers in Report
0301	*E. coli*	Table 5-20
0401	*E. coli*	Table 5-26
0403	*E. coli*	Table 5-26
0502	Narrative discussion of source abatement (Hillsboro WWTP improvements)	Page 119
0602	*E. coli*	Table 5-31
0903	*E. coli*	Table 5-39
1002	*E. coli*	Table 5-41

Table 0-26. Hydrologic units impaired by nutrient enrichment and/or ammonia but addressed using surrogate TMDL parameters.

12-digit HUC (last 4 digits)	Surrogate Parameter	Reference to Table in Report
0301	*E. coli*	Table 5-17
0401	*E. coli*	Table 5-23
0505	*E. coli*	Table 5-27
0701	*E. coli*	Table 5-37

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 Paint Creek (headwaters to below East Fork) (05060003 01)

TMDLs were developed for *E. coli* bacteria, total phosphorus, and sediment and habitat (via QHEI metric scores and metric attributes).

5.1.1 E. coli TMDLs

All three 12-digit HUCs in this 10-digit HUC were impaired for recreation uses and have had TMDL analyses performed. On a per square mile per day basis, the TMDL yields for each of the 12-digit HUCs ranged from about 21.5 to 39.0 billion cfus, with the East Fork Paint Creek (01-02) having the lowest value. Allocations to point sources (wasteloads) ranged from zero percent to 15.4 percent that of which was allocated to nonpoint sources (load allocations) giving nonpoint sources, at a minimum, over five times as much allowable loading. Tables 5-1 through 5-4 show the TMDL results for this ten-digit HUC.

Table 5-1. Paint Creek headwaters *E. coli* TMDL.

***E. coli* requirements for HUC-12 050600030101**							
***E. coli* Recreation Season TMDL components and target export load - billion cfu/day**							
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export	
HUC-12 / sub-watershed	1579	79	1499	0	1	4943	
Cumulative watershed	1579	79	1499	0	1		
Non point source LA reductions (% of existing recreation season load contribution)							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	0%	0%	0%	0%	100%	100%	0%
Point source NPDES WLA							
Facility Name	NPDES OEPA ID	Existing MGD	Dgn Q MGD	Limit C cfu/100 ml	WLA billion/day		
None	N/A	N/A	N/A	N/A	N/A		

Table 5-2. East Fork Paint Creek *E. coli* TMDL.

***E. coli* requirements for HUC-12 050600030102**							
***E. coli* Recreation Season TMDL components and target export load - billion cfu/day**							
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export	
HUC-12 / sub-watershed	1119	56	1032	30	1	1389	
Cumulative watershed	1119	56	1032	30	1		
Non point source LA reductions (% of existing recreation season load contribution)							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	0%	0%	0%	0%	100%	100%	0%

Point source NPDES WLA					
Facility Name	NPDES OEPA ID	Existing MGD	Dgn Q MGD	Limit C cfu/100 ml	WLA billion/day
Bloomingburg WWTP	4PB00025	0.13	0.25	161	1.524
Valero Renewable Fuels Co	4IN00196	Industrial	0.758	0	0.000
Washington CH MS4 (1.3sqmi)	4GQ00027	Stormwater	Stormwater	0	28.847

Table 5-3. Paint Creek below Millbrook to East Fork Paint Creek *E. coli* TMDL.

***E. coli* requirements for HUC-12 050600030103**							
***E. coli* Recreation Season TMDL components and target export load - billion cfu/day**							
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export	
HUC-12 / sub-watershed	644	32	529	81	1	9048	
Cumulative watershed	2223	111	2028	81	2		
Non point source LA reductions (% of existing recreation season load contribution)							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	30%	30%	0%	0%	100%	100%	0%

Point source NPDES WLA					
Facility Name	NPDES OEPA ID	Existing MGD	Dgn Q MGD	Limit C cfu/100 ml	WLA billion/day
Prairie Knolls MHP	4PV00115	0.010	0.015	161	0.091
Miami Trace High School	4PT00121	0.010	Abandoned	0	0.000
WCH WTP Intake	OH2400714	Withdrawal	0	N/A	N/A
Washington CH WTP Backwash	4GW00002	Intermittent	0.101	0	0.000
BP Amoco Stormwater	4IN00171	Stormwater	0.000	0	0.000
Washington Court House WWTP	4PD00002	3.030	6.000	126	28.618
Washington Court House SSO	4PD00002	Variable	Variable	0	0.000
Washington CH MS4 (3.4sqmi)	4GQ00027	Stormwater	Stormwater	N/A	52.778
Upstream allocation unit WLAs	None	N/A	N/A	N/A	0.000

Table 5-4. Alternate *E. coli* TMDL (informational purposes only) for Paint Creek below Millbrook to East Fork Paint Creek (Washington Court House WWTP outfall relocated to discharge below East Fork Paint Creek).

***E. coli* requirements for HUC-12 050600030103**

***E. coli* Recreation Season TMDL components and target export load - billion cfu/day**

TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export
HUC-12 / sub-watershed	1028	51	900	759	1	12346
Cumulative watershed	2607	130	2399	75	2	

Non point source LA reductions (% of existing recreation season load contribution)

Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	0%	0%	0%	0%	100%	100%	0%

Point source NPDES WLA

Facility Name	NPDES OEPA ID	Existing MGD	Dgn Q MGD	Limit C cfu/100 ml	WLA billion/day
Prairie Knolls MHP	4PV00115	0.01	0.015	161	0.091
Miami Trace High school WWTP	4PT00121	Abandoned	0.000	0	0.000
WCH WTP Intake	OH2400714	Withdrawal	0.000	N/A	N/A
Washington CH WTP Backwash	4GW00002	Intermittent	0.101	0	0.000
BP Amoco Stormwater	4IN00171	Stormwater	0.000	0	0.000
Washington Court House SSO	4PD00002	Variable	Variable	0	0.000
Washington CH MS4 (3.4sqmi)	4GQ00027	Stormwater	Stormwater	N/A	75.397
Upstream allocation unit WLAs	None	N/A	N/A	N/A	0.000

5.1.2 Total Phosphorus TMDLs

All three 12-digit HUCs in this 10-digit HUC have had TMDL analyses performed due to either local impairments related to nutrients and dissolved oxygen stress or to abate these problems in downstream areas. Chapter four provides the technical basis for using nutrients, specifically total phosphorus, as a surrogate parameter for dissolved oxygen concentrations. Those justifications are applicable in these subwatersheds (12-digit HUCs). Namely, the dissolved oxygen stress is driven primarily by an extremely large plant/algae biomass and sources are primarily from treated wastewater and cropland runoff. The following paragraphs are a more in-depth analysis of the role of the wastewater in this part of the watershed, since it has a disproportionately greater effect here than in most other areas of the watershed.

Both in terms of flow rate and daily loading of total phosphorus, Washington Courthouse WWTP stands out as the largest source in the basin except for the industrial discharger, PH Glatfelter, near the mouth of Paint Creek (see Figures 4-1 and 4-2). The waste water discharge is just upstream of the confluence between Paint Creek and East Fork Paint Creek; however the estimates of effective stream concentrations (i.e., indication of the in-stream total phosphorus concentration exclusively from what is loaded from the waste water effluent) were calculated using median flow statistics downstream of the confluence (i.e., including flow from East Fork Paint Creek). This represents an increase in drainage area of 66.5 to 119 square miles and in median flow of 21.3 to 36.6 cubic feet per second (based on USGS flow statistics (USGS, 2006)). Despite this conservative estimate, the in-stream concentrations that would be seen under median flow conditions based exclusively on the waste water loading of total phosphorus is above 0.70 mg/l (i.e., more than seven times higher than the applicable water quality target).

The mole-based nitrogen to phosphorus ratios in the effluent from the Washington Courthouse WWTP favor nitrogen limited conditions; however, only modestly. Figure 5-1 shows what the actual ratios are on days that both nitrogen and phosphorus sampling was done over the last 18 months. The majority of these sampling events show ratios that are from 5.1 to 9.5, the 25th and 75th percentiles, respectively. Figure 5-1 also shows N:P ratios with the total phosphorus concentration restricted to 1.0 mg/l while the flow rate and nitrogen concentrations remain as reported in the discharge monitoring reports (i.e., to simulate a 1.0 mg/l total phosphorus effluent limit). The result is a new effluent N:P ratio that experiences an 8.9 to 21.4 range between the 25th and 75th percentiles, reflecting a generally co-limiting condition. A nonparametric test between the medians of the population (i.e., a Mann-Whitney test) shows a significant difference in the N:P ratios between the existing conditions and conditions where a 1.0 mg/l total phosphorus limit is in place (p= 0.0009; W= 152.0).

The upstream N:P ratio based on sampling conducted during the summer of 2007, summer and fall of 2008, and winter of 2009 averages 51.3 (geometric mean = 30.2), while at a site 2.42 miles downstream averages the ratio is 11.7 (geometric mean = 9.9). These data indicate that Paint Creek, under a nutrient loading regime absent the Washington Courthouse WWTP, tends towards strong phosphorus limited conditions, which then switches to a co-limiting to somewhat nitrogen limiting condition following the contribution of the waste water. Therefore a limit of 1.0 mg/l of total phosphorus, which creates a generally co-limiting condition in the effluent alone, would almost certainly result in downstream conditions being phosphorus limited, making phosphorus controls the most efficient means for addressing eutrophication based water quality impairment.

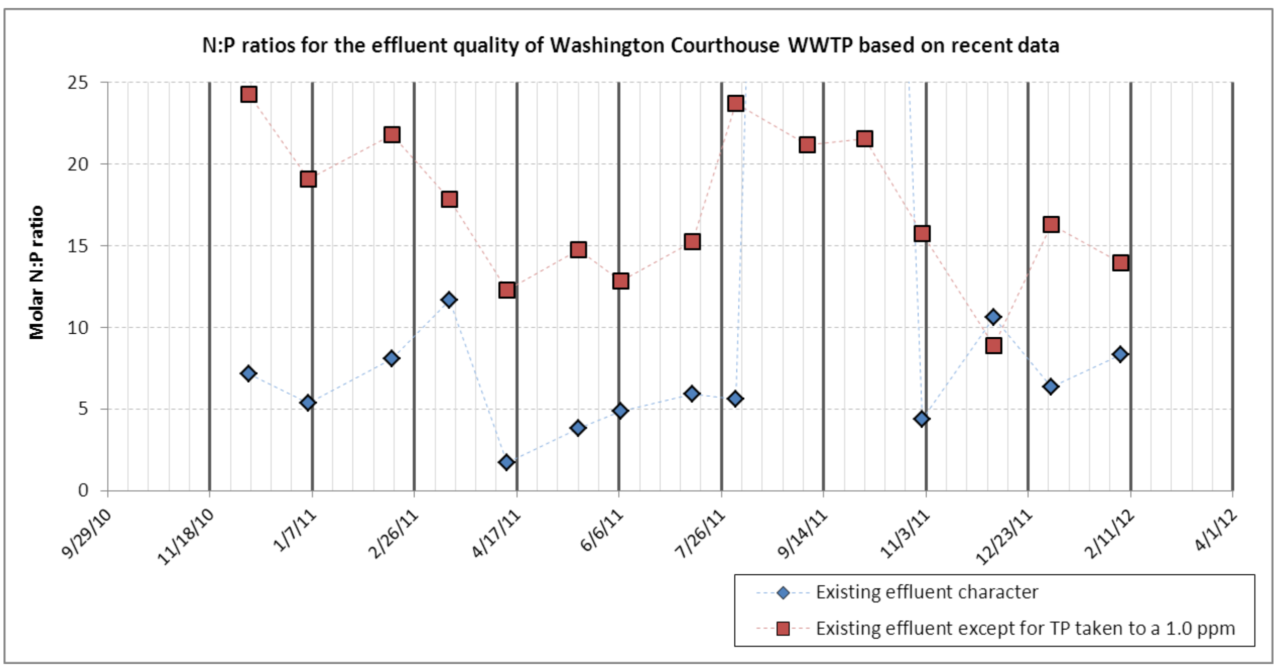


Figure 5-1. Nitrogen to phosphorus ratios for recent effluent quality data for Washington Courthouse WWTP and simulated ratios based on existing data and a total phosphorus effluent concentration of 1.0 mg/l.

Overall on a per square mile per day basis, the TMDL yields of total phosphorus for each of the 12-digit HUCs ranged from about 7.8 to 10.1 kg, with the headwaters of Paint Creek (01-01) having the lowest value. Allocations to point sources (wasteloads) ranged from zero percent (i.e., no point sources in the HUC) to 39.2 percent of the amount allocated to nonpoint sources (load allocations). Tables 5-5 through 5-7 show the TMDL results for this ten-digit HUC.

Table 5-5. Paint Creek headwaters TMDLs for downstream nutrient and dissolved oxygen stress impairments (in the 01-03 twelve-digit HUC) using total phosphorus directly (for nutrient enrichment) and as a surrogate (for dissolved oxygen).

Total Phosphorus requirements for HUC-12 050600030101 (Paint Creek Headwaters)							
Total Phosphorus Annual TMDL components and target export load - kg/day							
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export	
HUC-12 / sub-watershed	316	16	299	0	1	237	
Cumulative watershed	316	16	299	0	1		
Non point source LA reductions (% of existing recreation season load contribution)							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	45%	0%	0%	0%	100%	100%	0%
Point source NPDES WLA							
Facility Name		NPDES OEPA ID	Ex Flow Av MGD	Dgn Q MGD	Limit C mg/L	WLA kg/day	
None		N/A	N/A	N/A	N/A	0.000	

Table 5-6. East Fork Paint Creek TMDLs for dissolved oxygen stresses using total phosphorus as a surrogate parameter.

Total Phosphorus requirements for HUC-12 050600030102 (East Fork Paint Creek)							
Total Phosphorus Annual TMDL components and target export load - kg/day							
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export	
HUC-12 / sub-watershed	471	24	370	76	1	330	
Cumulative watershed	471	24	370	76	1		
Non point source LA reductions (% of existing recreation season load contribution)							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	45%	0%	0%	0%	100%	100%	0%
Point source NPDES WLA							
Facility Name		NPDES OEPA ID	Ex Flow Av MGD	Dgn Q MGD	Limit C mg/L	WLA kg/day	
Gill Dairy CAFO		4IK00027	Stormwater	N/A	N/A	0.000	
Bloomingburg WWTP*		4PB00025	0.130	0.250	1.5	1.420	
Valero Renewable Fuels Co		4IN00196	0.350	0.758	0.1	0.287	
Washington CH MS4 (1.3sqmi, 20%area)		4GQ00027	Stormwater	N/A	N/A	74.440	

*The model indicates that dissolved oxygen depletion on East Fork Paint Creek in areas between its mouth and the Bloomingburg WWTP can be effectively lessened through appropriate channel maintenance. If the channel modifications efforts are proven to increase pollutant flushing without degrading the stream banks or floodplain connectivity, Bloomingburg WWTP can discharge phosphorus at an average 2.0 mg/L. This concentration is within range of current operations and facilities, and will provide a 1.893 kg/day WLA. Refer to the Habitat/QHEI TMDL section.

Table 5-7. Paint Creek between East Fork and I-71 TMDLs for nutrient enrichment and dissolved oxygen stresses using total phosphorus as a direct (nutrient enrichment) and surrogate (dissolved oxygen) parameter.

Total Phosphorus requirements for HUC-12 050600030103 (Paint Creek upst East Fork)

Total Phosphorus Annual TMDL components and target export load - kg/day						
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export
HUC-12 / sub-watershed	276	14	186	73	3	426
Cumulative watershed	592	30	485	73	4	

Non point source LA reductions (% of existing recreation season load contribution)							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	60%	0%	0%	0%	100%	100%	0%

Point source NPDES WLA					
Facility Name	NPDES OEPA ID	Ex Flow Av MGD	Dgn Q MGD	Limit C mg/L	WLA kg/day
Prairie Knolls MHP	4PV00115	0.010	0.010	3	0.114
Miami Trace High School	4PT00121	0.010	Abandoned	0	0.000
Washington Court House WTP Intake	OH2400714	Withdrawal	N/A	N/A	N/A
Washington Court House WTP Backwash	4GW00002	Intermittent	0.101	N/A	N/A
BP Amoco Stormwater	4IN00171	Stormwater	N/A	N/A	N/A
Washington CH MS4(Paint upst EF)	4GQ00027	Stormwater	N/A	N/A	27.504
Washington Court House SSO	4PD00002	SSO	N/A	0	0.000
Washington CH WWTP (outlet as is)*	4PD00002	3.030	6.000	1	22.712
Washington CH WWTP(reloc outlet)*	4PD00002	3.030	6.000	variable 4-2	45.425

*The relocation of the Washington Court House WWTP 001 outfall from its current location to 2000 feet downstream at the East Fork Paint Creek confluence is a beneficial option for controlling both localized eutrophication and pathogen issues within this city park zone. Although the next downstream assessment site is in partial attainment (EWH criteria), it has been listed as a natural flow/habitat issue since the site's biologic indices strongly meet WWH criteria it is near the EWH/WWH boundary. For the purpose of this TMDL, it is sufficient to eliminate the outfall as a major eutrophication source of Paint Creek upstream East Fork. In order to ensure that phosphorus loading to Paint Creek Lake does not increase due to further development of Washington Court House, the current average phosphorus load estimate is used as this optional outfall relocation TMDL. Based on downstream biologic assessment and model results, the current average concentration (~4 mg/L based on 2005 to 2010 DMR data) is an acceptable level with current average flow discharge. This requirement is within range of current operation and facilities with the exception that work needs done on the sewer network's I/I problems. However, the WWTP must maintain the allocated WLA as future development occurs. This will result in an average 2 mg/L permit limit when the Washington Court House WWTP is treating its design 6 MGD average flow capacity. Note that a future assessment of Paint Creek Lake's eutrophic level may indicate that more phosphorus load reduction is required.

5.1.3 Habitat and Sediment TMDLs

All three 12-digit HUCs in this 10-digit HUC have had TMDL analyses performed to address excessive fine sediment and poor habitat quality or flow alterations. As discussed in chapter four, the QHEI analysis is appropriate to provide a basis for abating the impairments related to the physical degradation of the stream system (poor habitat and excessive fine sediment) and ameliorate the modified hydrology of the area. As such, the QHEI would directly address the habitat impairments but indirectly address the sediment and flow related impairments. Tables 5-8 through 5-10 show the TMDL results for this ten-digit HUC.

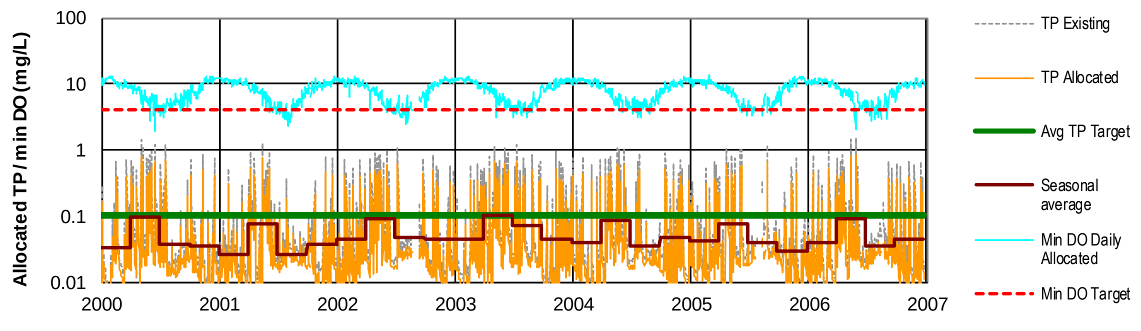
Table 5-8. Paint Creek headwaters TMDL for downstream sedimentation impairments (01-03 twelve-digit HUC).

HUC 12 (last 4)		**0101**
Stream		**Paint Creek**
River mile		**96.00**
Aquatic life use designation		**WWH**
Applicable TMDLs (habitat and/or sediment)		**No TMDL in this HUC (used for downstream impairments)**
Habitat TMDLs	QHEI score	65.5
	Numeric deviation	5.5
	Percent deviation	9%
	Number of high impact MWH types	0
	Numeric deviation	1
	Percent deviation	100%
	Number of MWH attributes	6
	Numeric deviation	-2
	Percent deviation	-50%
	Habitat TMDL - number of measures not satisfying the target	**0**
Sediment TMDLs	Substrate score	12.5
	Numeric deviation	-0.5
	Percent deviation	-4%
	Channel score	13.5
	Numeric deviation	-0.5
	Percent deviation	-4%
	Riparian score	7.5
	Numeric deviation	2.5
	Percent deviation	50%
	Total deviation from the three sediment metrics	**4.7%**

Table 5-9. East Fork Paint Creek TMDLs for sedimentation and flow alteration.

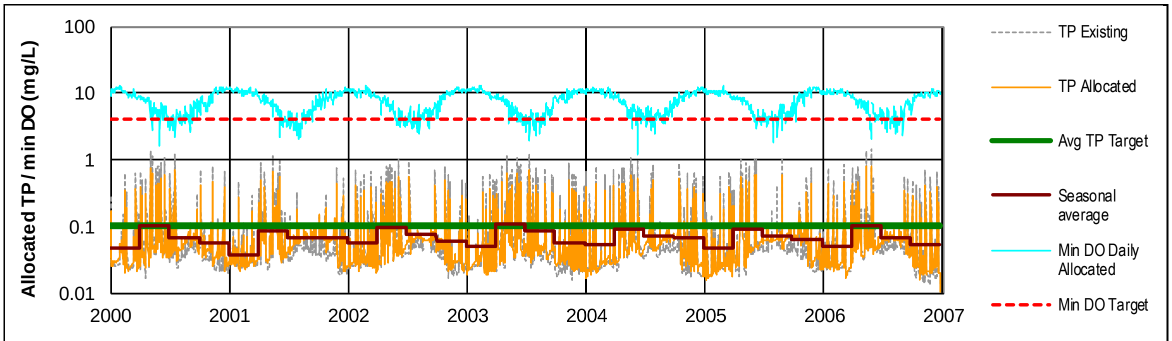
	HUC 12 (last 4)	0102	0102	0102	0102	0102	0102
	Stream	**Big Run**	**East Fork Paint Creek**	**East Fork Paint Creek**	**East Fork Paint Creek**	**Vallery Ditch[1]**	**William Cathcart Ditch**
	River mile	**1.80**	**8.60**	**5.10**	**0.70**	**2.30**	**0.20**
	Aquatic life use designation	**WWH**	**WWH**	**WWH**	**WWH**	**MWH**	**WWH**
	Applicable TMDLs (habitat and/or sediment)	**Habitat as surrogate for flow alterations**	**Sediment**	**No TMDL (full attainment)**	**Sediment**	**No TMDL (full attainment)**	**Habitat as surrogate for flow alterations**
Habitat TMDLs	QHEI score	43	44	56	63	56	50
	Numeric deviation	-17	-16	-4	3	-4	-10
	Percent deviation	-28%	-27%	-7%	5%	-7%	-17%
	Number of high impact MWH types	3	1	1	0	1	2
	Numeric deviation	-2	0	0	1	0	-1
	Percent deviation	-200%	0%	0%	100%	0%	-100%
	Number of MWH attributes	6	7	7	5	6	6
	Numeric deviation	-2	-3	-3	-1	-2	-2
	Percent deviation	-50%	-75%	-75%	-25%	-50%	-50%
	Habitat TMDL - number of measures not satisfying the target	**3**	**2**	**2**	**1**	**2**	**3**
Sediment TMDLs	Substrate score	12	6	7	12.5	13.5	12
	Numeric deviation	-1	-7	-6	-0.5	0.5	-1
	Percent deviation	-8%	-54%	-46%	-4%	4%	-8%
	Channel score	7	8.5	12	12	11	10
	Numeric deviation	-7	-5.5	-2	-2	-3	-4
	Percent deviation	-50%	-39%	-14%	-14%	-21%	-29%
	Riparian score	4	3.5	4.5	7	3.5	4
	Numeric deviation	-1	-1.5	-0.5	2	-1.5	-1
	Percent deviation	-20%	-30%	-10%	40%	-30%	-20%
	Total deviation from the three sediment metrics	**-28.1%**	**-43.8%**	**-26.6%**	**-1.6%**	**-12.5%**	**-18.8%**

[1] QHEI based targets have not been developed for MWH streams. In light of that the WWH targets are used for illustrative purposes.



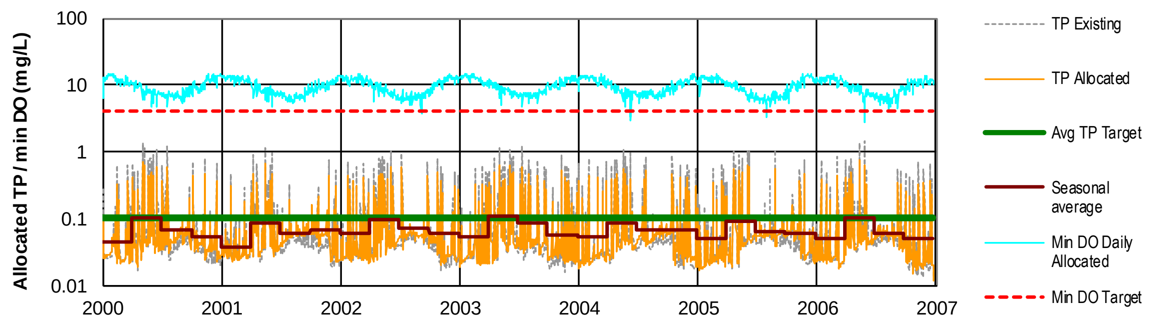
Sub-watershed seasonal TP, May-October DO, and annual NHx results							
TP < 0.1	January - March		April - June		July - September		October - November
TP existing	0.06		0.15		0.07		0.07
TP allocated	0.04		0.09		0.04		0.04
Min oxygen / max ammonia criteria		Existing concentrations			TMDL concentrations		
DO Summer min criteria	> 4	DO 30 day min existing		2.7	DO 30 day min result		4.0
NH_x Annual max criteria	< 12.6	NH_x max existing level		0.29	NH_x max result		0.29

Figure 5-2. East Fork Paint Creek headwaters bedload and habitat TMDL – LSPC results for East Fork Paint Creek upstream Lewis Rd with phosphorus reduction and channel shading.



Sub-watershed seasonal TP, May-October DO, and annual NHx results							
TP < 0.1	January - March		April - June		July - September		October - November
TP existing	0.07		0.16		0.08		0.07
TP allocated	0.05		0.10		0.07		0.06
Min oxygen / max ammonia criteria		Existing concentrations			TMDL concentrations		
DO Summer min criteria	> 4	DO 30 day min existing		3.4	DO 30 day min result		3.8
NH_x Annual max criteria	< 9.1	NH_x max existing level		0.53	NH_x max result		0.28

Figure 5-3. East Fork Paint Creek bedload and habitat TMDL – LSPC results for East Fork Paint Creek between Lewis Rd and Matthews Rd with phosphorus reduction and channel shading.

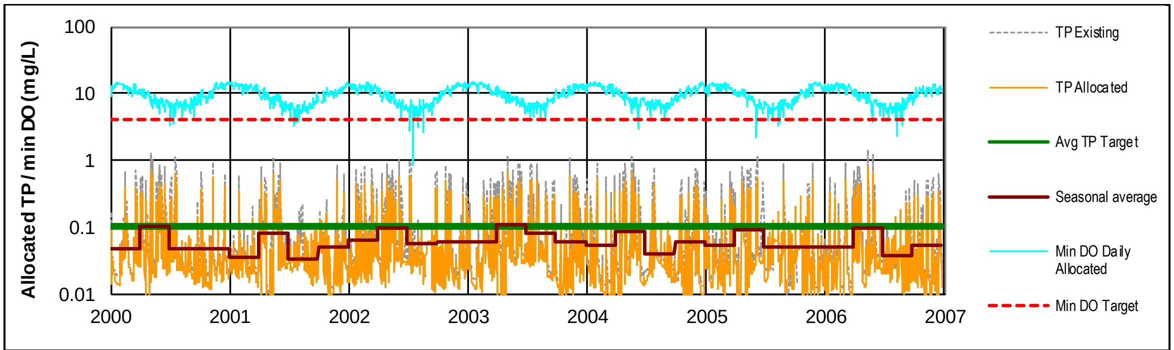


Sub-watershed seasonal TP, May-October DO, and annual NHx results						
TP < 0.1	January - March		April - June	July - September		October - November
TP existing	0.07		0.16	0.08		0.07
TP allocated	0.05		0.10	0.07		0.06
Min oxygen / max ammonia criteria			Existing concentrations		TMDL concentrations	
DO Summer min criteria	> 4		DO 30 day min existing	3.4	DO 30 day min result	6.1
NH_x Annual max criteria	< 9.1		NH_x max existing level	0.53	NH_x max result	0.24

Figure 5-4. East Fork Paint Creek bedload and habitat TMDL – LSPC results for East Fork Paint Creek between Matthews Rd and Paint Creek with phosphorus reduction and channel modifications (minimum DO criteria met with Bloomingburg WWTP discharging 2 mg/L TP average, pending habitat improvements and aquatic attainment).

Table 5-10. Paint Creek bedload, flow alteration and habitat TMDLs in the 01-03 twelve-digit HUC.

	HUC 12 (last 4)	0103	0103	0103	0103	0103	0103
	Stream	**Paint Creek**	**Paint Creek**	**Paint Creek**	**Paint Creek**	**Paint Creek**	**Paint Creek**
	River mile	**80.00**	**75.30**	**73.30**	**70.90**	**69.70**	**69.20**
	Aquatic life use designation	**WWH**	**WWH**	**WWH**	**WWH**	**WWH**	**WWH**
	Applicable TMDLs (habitat and/or sediment)	**Sediment**	**Sediment**	**Sediment**	**Sediment**	**Habitat and surrogate for flow alteration**	**Habitat**
Habitat TMDLs	QHEI score	62	77	66	64.5	38	40.5
	Numeric deviation	2	17	6	4.5	-22	-19.5
	Percent deviation	3%	28%	10%	8%	-37%	-33%
	Number of high impact MWH types	0	0	0	0	2	2
	Numeric deviation	1	1	1	1	-1	-1
	Percent deviation	100%	100%	100%	100%	-100%	-100%
	Number of MWH attributes	7	4	5	1	6	7
	Numeric deviation	-3	0	-1	3	-2	-3
	Percent deviation	-75%	0%	-25%	75%	-50%	-75%
	Habitat TMDL - number of measures not satisfying the target	**1**	**0**	**1**	**0**	**3**	**3**
Sediment TMDLs	Substrate score	14.5	11.5	12.5	15	11.5	12.5
	Numeric deviation	1.5	-1.5	-0.5	2	-1.5	-0.5
	Percent deviation	12%	-12%	-4%	15%	-12%	-4%
	Channel score	11.5	17	13.5	14	5	5.5
	Numeric deviation	-2.5	3	-0.5	0	-9	-8.5
	Percent deviation	-18%	21%	-4%	0%	-64%	-61%
	Riparian score	3.5	10	4	3.5	3.5	3.5
	Numeric deviation	-1.5	5	-1	-1.5	-1.5	-1.5
	Percent deviation	-30%	100%	-20%	-30%	-30%	-30%
	Total deviation from the three sediment metrics	**-7.8%**	**20.3%**	**-6.3%**	**1.6%**	**-37.5%**	**-32.8%**



Sub-watershed seasonal TP, May-October DO, and annual NHx results						
TP < 0.1	January - March		April - June	July - September		October - November
TP existing	0.08		0.17	0.07		0.08
TP allocated	0.05		0.09	0.05		0.05
Min oxygen / max ammonia criteria		Existing concentrations		TMDL concentrations		
DO Summer min criteria	> 4	DO 30 day min existing	2.3	DO 30 day min result	5.7	
NH_x Annual max criteria	< 5.9	NH_x max existing level	1.63	NH_x max result	0.37	

Figure 5-5. Paint Creek Washington Court House bedload and habitat TMDL – LSPC results for Paint Creek upstream of Washington Court House's WWTP with phosphorus reduction and channel modifications.

5.2 Sugar Creek (05060003 02)

TMDLs were developed for *E. coli* bacteria, total phosphorus, and sediment and habitat (via QHEI metric scores and metric attributes).

5.2.1 *E. coli* TMDLs

Both of the 12-digit HUCs in this 10-digit HUC were impaired for recreation uses and have had TMDL analyses performed. On a per square mile per day basis, the TMDL yields for each of the 12-digit HUCs ranged from about 16.7 to 30.7 billion cfus, with the Sugar Creek headwaters (02-01) having the lowest value. Allocations to point sources (wasteloads) ranged from zero percent to 0.4 percent of that which was allocated to nonpoint sources (load allocations). Tables 5-11 through 5-12 show the TMDL results for this ten-digit HUC.

Table 5-11. Sugar Creek headwaters through Missouri Ditch *E. coli* TMDL.

***E. coli* requirements for HUC-12 050600030201**							
***E. coli* Recreation Season TMDL components and target export load - billion cfu/day**							
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export	
HUC-12 / sub-watershed	739	37	698	3	1	1097	
Cumulative watershed	739	37	698	3	1		
Non point source LA reductions (% of existing recreation season load contribution)							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	0%	0%	0%	0%	100%	0%	0%
Point source NPDES WLA							
Facility Name	NPDES OEPA ID	Existing MGD	Dgn Q MGD	Limit C cfu/100 ml	WLA billion/day		
Jeffersonville WWTP	4PB00108	0.350	0.500	161	3.047		

Table 5-12. Sugar Creek below Missouri Ditch to Paint Creek *E. coli* TMDL.

***E. coli* requirements for HUC-12 050600030202**							
***E. coli* Recreation Season TMDL components and target export load - billion cfu/day**							
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export	
HUC-12 / sub-watershed	1148	57	1090	0	0[1]	5199.7	
Cumulative watershed	1886	94	1788	3	1		
Non point source LA reductions (% of existing recreation season load contribution)							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	0%	0%	0%	0%	100%	100%	0%

Point source NPDES WLA					
Facility Name	NPDES OEPA ID	Existing MGD	Dgn Q MGD	Limit C cfu/100 ml	WLA billion/day
Upstream allocation unit WLAs	Various	N/A	N/A	N/A	3.047

[1] Actual value is 0.39 billion cfu/day.

5.2.2 Total Phosphorus TMDLs

Both 12-digit HUCs in this 10-digit HUC have had TMDL analyses performed due to either local impairments related to nutrients and dissolved oxygen stresses and/or to abate downstream nutrient-related impairments. Chapter four discusses the reasons that total phosphorus is appropriate for addressing dissolved oxygen stresses, namely that the stress is caused by excessive production of algae and plant life. This is the case in this subwatershed.

On a per square mile per day basis, the TMDL yields for each of the 12-digit HUCs ranged from about 3.1 to 7.9 kg of total phosphorus, with the lower Sugar Creek (02-02) having the lower value. Allocations to point sources (wasteloads) ranged from zero percent to 0.6 percent of that which was allocated to nonpoint sources (load allocations). Tables 5-13 through 5-14 show the TMDL results for this ten-digit HUC.

Table 5-13. Sugar Creek upstream Creamer Rd. TMDLs for nutrient enrichment and dissolved oxygen using total phosphorus as a direct (nutrient enrichment) and surrogate (dissolved oxygen) parameter.

Total Phosphorus requirements for HUC-12 050600030201 (Sugar Creek Headwaters)							
Total Phosphorus Annual TMDL components and target export load - kg/day							
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export	
HUC-12 / sub-watershed	350	18	329	2	1	273	
Cumulative watershed	350	18	329	2	1		
Non point source LA reductions (% of existing recreation season load contribution)							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	45%	0%	0%	0%	100%	0%	0%

Point source NPDES WLA					
Facility Name	NPDES OEPA ID	Ex Flow Av MGD	Dgn Q MGD	Limit C mg/L	WLA kg/day
Jeffersonville WWTP*	4PB00108	0.350	0.500	1.0	1.893

*The model indicates that dissolved oxygen depletion on Sugar between Creamer Rd area and the Jeffersonville WWTP can be effectively lessened through appropriate channel maintenance. If the channel modifications efforts are proven to increase pollutant flushing without degrading the stream banks or floodplain connectivity, Jeffersonville WWTP can discharge phosphorus at an average 2.0 mg/L. This concentration is within range of current operations and facilities, and will provide a 3.785 kg/day WLA. Refer to the Habitat/QHEI TMDL section.

Table 5-14. Sugar Creek between US-22 and Ford Rd. total phosphorus TMDL.

Total Phosphorus requirements for HUC-12 050600030202 (Partial zone, Sugar Ck upst US-22)							
Total Phosphorus Annual TMDL components and target export load - kg/day							
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90^{th}% target export	
HUC-12 / sub-watershed	118	6	112	0	0[1]	325	
Cumulative watershed	472	24	445	2	1		
Non point source LA reductions (% of existing recreation season load contribution)							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	45%	0%	0%	0%	100%	100%	0%
Point source NPDES WLA							
Facility Name		NPDES OEPA ID		Ex Flow Av MGD	Dgn Q MGD	Limit C mg/L	WLA kg/day
Upstream subwatershed WLAs		N/A		N/A	N/A	N/A	1.893

[1] Actual value is 0.10 billion cfu/day.

5.2.3 Habitat and Sediment TMDLs

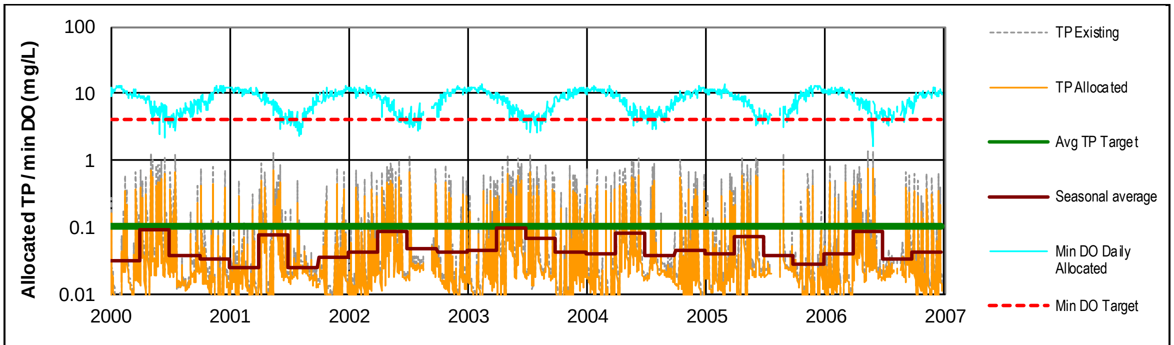
Both 12-digit HUCs in this 10-digit HUC have had TMDL analyses performed to address excessive fine sediment and poor habitat quality or poor habitat related issues. Tables 5-15 shows the TMDL results for this ten-digit HUC.

Table 5-15. Sugar Creek habitat TMDLs.

HUC 12 (last 4)		**0201**	**0201**	**0201**	**0201**
Stream		**Missouri Ditch**	**Sugar Creek[1]**	**Sugar Creek**	**Sugar Creek**
River mile		**1.60**	**36.90**	**29.20**	**24.80**
Aquatic life use designation		**WWH**	**MWH**	**WWH**	**WWH**
Applicable TMDLs (habitat and/or sediment)		**No TMDL (full attainment)**	**No TMDL (full attainment)**	**Habitat**	**Habitat**
Habitat TMDLs	QHEI score	50	38	60	48.5
	Numeric deviation	-10	-22	0	-11.5
	Percent deviation	-17%	-37%	0%	-19%
	Number of high impact MWH types	1	3	0	1
	Numeric deviation	0	-2	1	0
	Percent deviation	0%	-200%	100%	0%
	Number of MWH attributes	6	7	6	7
	Numeric deviation	-2	-3	-2	-3
	Percent deviation	-50%	-75%	-50%	-75%
	Habitat TMDL - number of measures not satisfying the target	**2**	**3**	**1**	**2**
ment TMD	Substrate score	9	12	14.5	11.5
	Numeric deviation	-4	-1	1.5	-1.5

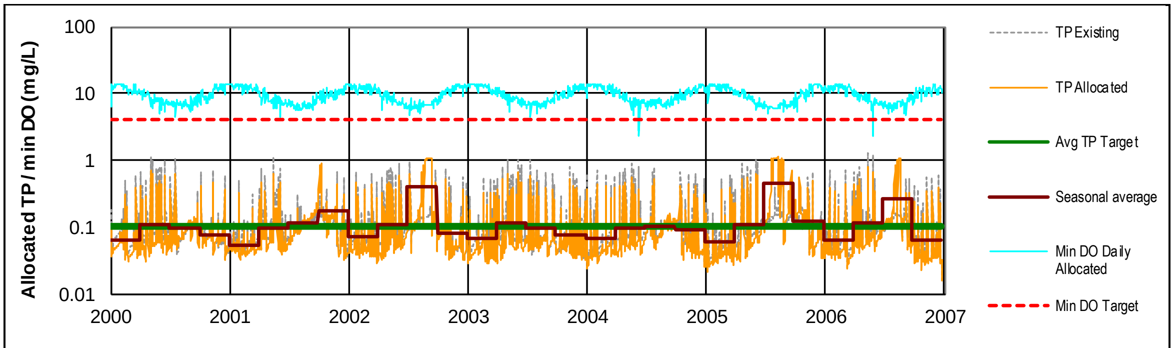
	Percent deviation	-31%	-8%	12%	-12%
	Channel score	11	9	11.5	10
	Numeric deviation	-3	-5	-2.5	-4
	Percent deviation	-21%	-36%	-18%	-29%
	Riparian score	4.5	3	4	3
	Numeric deviation	-0.5	-2	-1	-2
	Percent deviation	-10%	-40%	-20%	-40%
	Total deviation from the three sediment metrics	**-23.4%**	**-25.0%**	**-6.3%**	**-23.4%**

[1] QHEI based targets have not been developed for MWH streams. In light of that the WWH targets are used for illustrative purposes.



Sub-watershed seasonal TP, May-October DO, and annual NHx results						
TP < 0.1	January - March		April - June	July - September		October - November
TP existing	0.06		0.15	0.06		0.06
TP allocated	0.04		0.08	0.04		0.04
Min oxygen / max ammonia criteria			Existing concentrations		TMDL concentrations	
DO Summer min criteria	> 4		DO 30 day min existing	3.1	DO 30 day min result	4.0
NH_x Annual max criteria	< 13		NH_x max existing level	0.30	NH_x max result	0.30

Figure 5-6. Sugar Creek headwaters bedload and habitat TMDL – LSPC results for Sugar Creek near McKillup Rd with phosphorus reduction and channel shading.



Sub-watershed seasonal TP, May-October DO, and annual NHx results				
TP < 0.1	January - March	April - June	July - September	October - November
TP existing	0.09	0.17	0.13	0.10
TP allocated	0.06	0.11	0.22	0.10

Min oxygen / max ammonia criteria		Existing concentrations		TMDL concentrations	
DO Summer min criteria	> 4	DO 30 day min existing	2.2	DO 30 day min result	6.2
NH_x Annual max criteria	< 7.3	NH_x max existing level	0.26	NH_x max result	1.10

Figure 5-7. Sugar Creek between Missouri Ditch and McKillup Rd bedload and habitat TMDL – LSPC results for Sugar Creek near Creamer Rd with phosphorus reduction, channel shading, and channel modifications (minimum DO criteria met with Jeffersonville WWTP discharging 2 mg/L TP average, pending habitat improvements and aquatic attainment).

5.3 Rattlesnake Creek (headwaters to above Lees Creek) (05060003 03)

TMDLs were developed for *E. coli* bacteria and sediment and habitat (via QHEI metric scores and metric attributes).

5.3.1 *E. coli* TMDLs

All but one of the five 12-digit HUCs in this 10-digit HUC was impaired for recreation uses and had TMDL analyses performed. In addition to addressing recreation use impairment, *E. coli* is used as a surrogate pollutant to address aquatic life use impairments caused by organic enrichment and ammonia. This is justified since it is believed that the primary sources of the *E. coli* leading to impaired recreation uses are likewise the primary sources of organic matter and ammonia impairing the aquatic life uses, namely human and animal wastes. Additionally, the source reductions required in order to meet the criteria established for *E. coli* concentrations (i.e., for attainment of recreation uses) are adequate to reduce the organic matter and ammonia concentrations to levels that no longer cause stress or impairment to the aquatic life uses. The latter assumption is justified since the required reductions in the E. coli loading are substantial (see Table 5-20) ranging from nearly 62 percent to over 90 percent, depending on the flow interval. The former assumption is likewise reasonable since the geometric mean for the *E. coli* concentrations at a tributary to Wilson Creek (at river mile 4.23) is substantially elevated (i.e., 2,068 cfu per 100 ml) indicating a steady source of sewage from the homes upstream in that subwatershed. That location shows aquatic life use impairment and shares an identical IBI score with a downstream site located on Wilson Creek at river mile 2.80. The IBI is a measure of the fish community, which is the organism group that would be expected to be impaired by elevated ammonia concentrations. There are no other significant known sources of ammonia aside from human and/or animal wastes (i.e., sources of both *E. coli* and ammonia) in this watershed that is primarily cropland and pasture (87 and one percent, respectively) and to a far lesser extent developed (8 percent).

On a per square mile per day basis under the high flow conditions, the TMDL yields for each of the 12-digit HUCs ranged from about 24 to 158 billion cfus. Table 5-16 shows the TMDL results for this ten-digit HUC.

Table 5-16. Headwaters Rattlesnake Creek E coli TMDLs and surrogate TMDLs for organic enrichment and ammonia.

Hydrologic Condition (*E. coli* loads expressed in billions of organisms per day)	**High flows**	**Wet weather**	**Normal range**	**Dry weathe r**	**Low**
Flow Duration Interval	0-5%	5-40%	40-80%	80-95%	95-100%
Wilson Ck Dst Sabina WWTP	**HUC12: 05060003 03 01[1]**				
Total Maximum Daily Load	588.4	74.2	13.4	1.8	0.5
Wasteload Allocation (Sabina STP - 1PB00038)	2.3	2.3	2.3	1.4	0.4
Load Allocation	456.6	55.6	8.1	0.0	0.0
Margin of Safety	117.7	14.8	2.7	0.4	0.1
Allowance for future growth	11.8	1.5	0.3	0.0	0.0
Total load reduction required	No Data	65.8%	61.9%	93.0%	No Data
W Br Rattlesnake Ck downstream Wilson Ck	**HUC12: 005060003 03 03**				
Total Maximum Daily Load	1330.3	167.8	30.2	4.0	1.2
Wasteload Allocation (Sabina STP - 1PB00038)	2.3	2.3	2.3	2.3	0.9
Load Allocation	1035.3	128.6	21.2	0.8	0.0
Margin of Safety	266.1	33.6	6.0	0.8	0.2
Allowance for future growth	26.6	3.4	0.6	0.1	0.0
Total load reduction required	No Data	None	None	80.2%	No Data
Rattlesnake Ck @ Milledgeville-Octa Rd.	**HUC12: 05060003 03 04**				
Total Maximum Daily Load	1087.3	137.1	24.7	3.3	1.0
Wasteload Allocation	3.6	3.6	3.6	2.5	0.7
South Solon WWTP - 4PA00002	0.6	0.6	0.6	0.4	0.1
Rattlesnake SD #1 WWTP - 4PH00007	3.1	3.1	3.1	2.1	0.6
Rockies Express Pipeline - 4GH00006	0.0	0.0	0.0	0.0	0.0
Load Allocation	844.4	103.3	15.6	0.0	0.0
Margin of Safety	217.5	27.4	4.9	0.7	0.2
Allowance for future growth	21.8	2.7	0.5	0.1	0.0
Total load reduction required	No Data	None	31.4%	None	No Data
Rattlesnake Ck W of New Martinsburg, upst Zimmerman Rd.	**HUC12: 05060003 03 05**				
Total Maximum Daily Load	3997.3	504.2	90.8	12.1	3.5
Wasteload Allocation	6.0	6.0	6.0	6.0	2.8
Sabina STP - 1PB00038	2.3	2.3	2.3	2.3	1.1
South Solon WWTP - 4PA00002	0.6	0.6	0.6	0.6	0.3
Rattlesnake SD #1 WWTP - 4PH00007	3.1	3.1	3.1	3.1	1.4
Load Allocation	3111.9	387.3	64.9	3.4	0.0
Margin of Safety	799.5	100.8	18.2	2.4	0.7
Allowance for future growth	80.0	10.1	1.8	0.2	0.1
Total load reduction required	No Data	52.1%	43.8%	88.0%	No Data

[1] *E. coli* is used as a surrogate parameter for aquatic life use impairments due to organic enrichment in the 03-01 twelve-digit HUC. The similarity of sources of these pollutants is used to justify this substitution.

5.3.2 Habitat and Sediment TMDLs

Three out of five 12-digit HUCs in this 10-digit HUC have had TMDL analyses performed to address excessive fine sediment and poor habitat quality or poor habitat related issues. Also, the dissolved oxygen stress causing aquatic life use impairment is addressed using habitat quality as a surrogate which is based on the link between habitat quality, dissolved oxygen stress and the performance of the aquatic community that was discussed in chapter four. The use of the habitat surrogate is justified because the dissolved oxygen stress is attributable to algae growth rather than organic enrichment, leaving both nutrient controls and habitat improvement as viable options (see discussion in chapter four). Habitat was selected in these two cases based on the fact that habitat is simplified for several stream miles and the riparian zone has little sizeable vegetation that would provide shading and provide some control over primary productivity. Likewise, using *E. coli* in this case would be much less effective since animal and human wastes are not especially problematic in the areas draining to the two sites impaired by dissolved oxygen stresses. Tables 5-17 through 5-21 show the TMDL results for this ten-digit HUC.

Table 5-17. Headwaters Rattlesnake Creek habitat TMDLs.

	HUC 12 (last 4)	0301	0301	0301
	Stream	**Trib. to Wilson Creek (RM 4.23)**	**Wilson Creek[1]**	**Wilson Creek[1]**
	River mile	**0.40**	**3.80**	**2.80**
	Aquatic life use designation	**WWH**	**MWH**	**MWH**
	Applicable TMDLs (habitat and/or sediment)	**No TMDL (no applicable cause of impairment)**	**Habitat**	**No TMDL (no applicable cause of impairment)**
Habitat TMDLs	QHEI score	33.5	43	44
	Numeric deviation	-26.5	-17	-16
	Percent deviation	-44%	-28%	-27%
	Number of high impact MWH types	3	4	3
	Numeric deviation	-2	-3	-2
	Percent deviation	-200%	-300%	-200%
	Number of MWH attributes	7	6	4
	Numeric deviation	-3	-2	0
	Percent deviation	-75%	-50%	0%
	Habitat TMDL - number of measures not satisfying the target	**3**	**3**	**2**
Sediment TMDLs	Substrate score	6.5	7	15
	Numeric deviation	-6.5	-6	2
	Percent deviation	-50%	-46%	15%
	Channel score	7.5	8	7
	Numeric deviation	-6.5	-6	-7
	Percent deviation	-46%	-43%	-50%
	Riparian score	4.5	4	4
	Numeric deviation	-0.5	-1	-1
	Percent deviation	-10%	-20%	-20%
	Total deviation from the three sediment metrics	**-42.2%**	**-40.6%**	**-18.8%**

[1] QHEI based targets have not been developed for MWH streams. In light of that the WWH targets are used for illustrative purposes.

Table 5-18. Grassy Branch habitat TMDL as a surrogate for flow alteration.

HUC 12 (last 4)		**0302**
Stream		**Grassy Branch**
River mile		**8.70**
Aquatic life use designation		**WWH**
Applicable TMDLs (habitat and/or sediment)		**Habitat as surrogate for flow alterations**
Habitat TMDLs	QHEI score	33
	Numeric deviation	-27
	Percent deviation	-45%
	Number of high impact MWH types	4
	Numeric deviation	-3
	Percent deviation	-300%
	Number of MWH attributes	5
	Numeric deviation	-1
	Percent deviation	-25%
	Habitat TMDL - number of measures not satisfying the target	**3**
Sediment TMDLs	Substrate score	9
	Numeric deviation	-4
	Percent deviation	-31%
	Channel score	6
	Numeric deviation	-8
	Percent deviation	-57%
	Riparian score	3
	Numeric deviation	-2
	Percent deviation	-40%
	Total deviation from the three sediment metrics	**-43.8%**

Table 5-19. West Branch Rattlesnake Creek sediment and habitat TMDL as surrogate for dissolved oxygen.

	HUC 12 (last 4)	0303	0303	0303
	Stream	**West Branch Rattlesnake Creek[1]**	**West Branch Rattlesnake Creek**	**West Branch Rattlesnake Creek**
	River mile	**11.40**	**4.30**	**2.80**
	Aquatic life use designation	**MWH**	**WWH**	**WWH**
	Applicable TMDLs (habitat and/or sediment)	**No TMDL (full attainment)**	**Sediment**	**Sediment and surrogate for dissolved oxygen**
Habitat TMDLs	QHEI score	27	53	46.5
	Numeric deviation	-33	-7	-13.5
	Percent deviation	-55%	-12%	-23%
	Number of high impact MWH types	5	2	0
	Numeric deviation	-4	-1	1
	Percent deviation	-400%	-100%	100%
	Number of MWH attributes	7	5	8
	Numeric deviation	-3	-1	-4
	Percent deviation	-75%	-25%	-100%
	Habitat TMDL - number of measures not satisfying the target	**3**	**3**	**2**
Sediment TMDLs	Substrate score	2	11.5	10
	Numeric deviation	-11	-1.5	-3
	Percent deviation	-85%	-12%	-23%
	Channel score	6	11.5	8
	Numeric deviation	-8	-2.5	-6
	Percent deviation	-57%	-18%	-43%
	Riparian score	5	5	3.5
	Numeric deviation	0	0	-1.5
	Percent deviation	0%	0%	-30%
	Total deviation from the three sediment metrics	**-59.4%**	**-12.5%**	**-32.8%**

[1] QHEI based targets have not been developed for MWH streams. In light of that the WWH targets are used for illustrative purposes.

Table 5-20. Rattlesnake Creek habitat TMDL and habitat as a surrogate for dissolved oxygen TMDL.

	HUC 12 (last 4)	0304	0304	0304	0304	0304	0304
	Stream	**Maple Grove Creek**	**Rattlesnake Creek**	**Rattlesnake Creek**	**Rattlesnake Creek**	**Rattlesnake Creek**	**Trib. to Rattlesnake Creek (RM 40.21)[1]**
	River mile	**1.60**	**40.40**	**38.10**	**35.20**	**31.40**	**1.10**
	Aquatic life use designation	**WWH**	**WWH**	**WWH**	**WWH**	**WWH**	**MWH**
	Applicable TMDLs (habitat and/or sediment)	**No TMDL (full attainment)**	**No TMDL (full attainment)**	**Habitat and surrogate for dissolved oxygen**	**Habitat**	**Habitat**	**No TMDL (full attainment)**
Habitat TMDLs	QHEI score	45	51.5	59.5	58	49	37
	Numeric deviation	-15	-8.5	-0.5	-2	-11	-23
	Percent deviation	-25%	-14%	-1%	-3%	-18%	-38%
	Number of high impact MWH types	4	2	0	1	1	4
	Numeric deviation	-3	-1	1	0	0	-3
	Percent deviation	-300%	-100%	100%	0%	0%	-300%
	Number of MWH attributes	4	5	8	7	6	7
	Numeric deviation	0	-1	-4	-3	-2	-3
	Percent deviation	0%	-25%	-100%	-75%	-50%	-75%
	Habitat TMDL - number of measures not satisfying the target	**2**	**3**	**2**	**2**	**2**	**3**
Sediment TMDLs	Substrate score	15	14.5	11.5	13	11.5	8.5
	Numeric deviation	2	1.5	-1.5	0	-1.5	-4.5
	Percent deviation	15%	12%	-12%	0%	-12%	-35%
	Channel score	8	10.5	11.5	12	8.5	8.5
	Numeric deviation	-6	-3.5	-2.5	-2	-5.5	-5.5
	Percent deviation	-43%	-25%	-18%	-14%	-39%	-39%
	Riparian score	2.5	3	4.5	7	7	3
	Numeric deviation	-2.5	-2	-0.5	2	2	-2
	Percent deviation	-50%	-40%	-10%	40%	40%	-40%
	Total deviation from the three sediment metrics	**-20.3%**	**-12.5%**	**-14.1%**	**0.0%**	**-15.6%**	**-37.5%**

[1] QHEI based targets have not been developed for MWH streams. In light of that the WWH targets are used for illustrative purposes.

Table 5-21. Rattlesnake Creek habitat and sediment TMDLs.

	HUC 12 (last 4)	0305	0305	0305	0305
	Stream	Rattlesnake Creek	Rattlesnake Creek	Rattlesnake Creek	Rattlesnake Creek
	River mile	24.00	17.90	15.00	13.30
	Aquatic life use designation	WWH	WWH	WWH	WWH
	Applicable TMDLs (habitat and/or sediment)	Habitat	No TMDL (full attainment)	Sediment	No TMDL (full attainment)
Habitat TMDLs	QHEI score	52	59	71	77.5
	Numeric deviation	-8	-1	11	17.5
	Percent deviation	-13%	-2%	18%	29%
	Number of high impact MWH types	1	0	0	0
	Numeric deviation	0	1	1	1
	Percent deviation	0%	100%	100%	100%
	Number of MWH attributes	4	6	4	0
	Numeric deviation	0	-2	0	4
	Percent deviation	0%	-50%	0%	100%
	Habitat TMDL - number of measures not satisfying the target	**1**	**2**	**0**	**0**
Sediment TMDLs	Substrate score	14.5	12.5	17	16
	Numeric deviation	1.5	-0.5	4	3
	Percent deviation	12%	-4%	31%	23%
	Channel score	11	10	15	17
	Numeric deviation	-3	-4	1	3
	Percent deviation	-21%	-29%	7%	21%
	Riparian score	4.5	5.5	7.5	6
	Numeric deviation	-0.5	0.5	2.5	1
	Percent deviation	-10%	10%	50%	20%
	Total deviation from the three sediment metrics	**-6.3%**	**-12.5%**	**23.4%**	**21.9%**

5.4 Rattlesnake Creek (above Lees Creek to Paint Cr.) (05060003 04)

TMDLs were developed directly for *E. coli* bacteria and sediment and habitat (via QHEI metric scores and metric attributes). Aquatic life impairments based on organic and nutrient enrichment and the associated dissolved oxygen stress, and ammonia are addressed using *E. coli* as a surrogate parameter. The aquatic life use impairment that was found in the 04-06 twelve-digit HUC due to nutrient and organic enrichment is not addressed.

5.4.1 *E. coli* TMDLs

Four of the seven 12-digit HUCs in this 10-digit HUC was impaired for recreation uses and had TMDL analyses. *E. coli* is also used as a surrogate parameter to address aquatic life use impairments caused by organic and nutrient enrichment, dissolved oxygen stress and elevated ammonia. These substitutions are justified based on the linkages discussed in chapter four in combination with the fact that livestock manure and to a lesser extent human wastes from under-performing septic systems are the primary sources of impairment in the 04-03 twelve-digit HUC, sources that are not only rich in E. coli bacteria, but also organic material, ammonia, and nutrients. In the 04-01 twelve-digit HUC, the sources are mostly relegated to under-performing septic systems.

On a per square mile per day basis under the high flow conditions, the TMDL yields for each of the 12-digit HUCs ranged from about 12 to 326 billion cfus. Table 5-22 shows the TMDL results for this ten-digit HUC.

Table 5-22. Rattlesnake Creek *E. coli* TMDLs and surrogate TMDLs for organic enrichment, ammonia and dissolved oxygen.

Hydrologic Condition (*E. coli* loads expressed in billions of organisms per day)	**High flows**	**Wet weather**	**Normal range**	**Dry weather**	**Low**
S Fk Lees Ck @ Hixon Rd	**HUC12: 05060003 04 01**[1]				
Total Maximum Daily Load	508.5	64.1	11.5	1.5	0.4
Wasteload Allocation	0.0	0.0	0.0	0.0	0.0
Load Allocation	396.6	50.0	9.0	1.2	0.3
Margin of Safety	101.7	12.8	2.3	0.3	0.1
Allowance for future growth	10.2	1.3	0.2	0.0	0.0
Total load reduction required	96.5%	99.7%	No Data	91.6%	No Data
Lees Ck @ Monroe Rd E of Leesburg	**HUC12: 05060003 04 03**[1]				
Total Maximum Daily Load	2200.8	83.9	13.0	4.8	4.0
Wasteload Allocation (Leesburg WWTP - 1PB00106)	2.4	2.4	2.4	2.4	2.4
Load Allocation	1714.1	63.0	7.7	1.3	0.7
Margin of Safety	440.2	16.8	2.6	1.0	0.8
Allowance for future growth	44.0	1.7	0.3	0.1	0.1
Total load reduction required	97.2%	86.7%	None	None	None
Walnut Ck @ Walnut Ck Rd.	**HUC12: 05060003 04 04**				
Total Maximum Daily Load	182.3	23.0	4.1	0.6	0.2
Wasteload Allocation	0.0	0.0	0.0	0.0	0.0
Load Allocation	142.2	17.9	3.2	0.4	0.1
Margin of Safety	36.5	4.6	0.8	0.1	0.0
Allowance for future growth	3.7	0.5	0.1	0.0	0.0
Total load reduction required	100.0%	100.0%	No Data	85.6%	No Data
Rattlesnake Ck @ Centerfield Rd.	**HUC12: 05060003 04 07**				
Total Maximum Daily Load	6683.4	843.0	151.9	20.1	5.9

Hydrologic Condition (*E. coli* loads expressed in billions of organisms per day)	**High flows**	**Wet weather**	**Normal range**	**Dry weather**	**Low**
Wasteload Allocation (Leesburg WWTP - 1PB00106)	2.4	2.4	2.4	2.4	2.4
Load Allocation	5210.6	655.1	116.0	13.3	2.2
Margin of Safety	1336.7	168.6	30.4	4.0	1.2
Allowance for future growth	133.7	16.9	3.0	0.4	0.1
Total load reduction required	97.5%	88.2%	None	None	None

[1] ***E. coli*** **is used as a surrogate parameter for aquatic life use impairments due to organic enrichment and dissolved oxygen stresses in the 04-01 and 04-03 twelve-digit HUCs. The similarity of sources of these pollutants is used to justify this substitution.**

5.4.2 Habitat and Sediment TMDLs

The 04-03 twelve-digit HUC has shown aquatic life impairment based on an altered flow regime. The QHEI habitat index is used to develop these TMDLs based on the justification provided in chapter four. Tables 5-23 through 5-25 show the TMDL results for this ten-digit HUC.

Table 5-23. South Fork Lee's Creek bedload and habitat TMDL.

	HUC 12 (last 4)	**0401**	**0401**
	Stream	**South Fork Lees Creek**	**Trib to S Fk Lees Creek (RM 3.83/0.25)**
	River mile	**1.30**	**0.20**
	Aquatic life use designation	**WWH**	**WWH**
	Applicable TMDLs (habitat and/or sediment)	**No TMDL (full attainment)**	**No TMDL (no applicable cause of impairment)(FYI- e coli used as surrogate for all impairments)**
Habitat TMDLs	QHEI score	50.5	50.5
	Numeric deviation	-9.5	-9.5
	Percent deviation	-16%	-16%
	Number of high impact MWH types	3	1
	Numeric deviation	-2	0
	Percent deviation	-200%	0%
	Number of MWH attributes	5	5
	Numeric deviation	-1	-1
	Percent deviation	-25%	-25%
	Habitat TMDL - number of measures not satisfying the target	**3**	**2**
Sediment TMDLs	Substrate score	8	11
	Numeric deviation	-5	-2
	Percent deviation	-38%	-15%
	Channel score	12	14
	Numeric deviation	-2	0
	Percent deviation	-14%	0%
	Riparian score	6.5	4.5
	Numeric deviation	1.5	-0.5
	Percent deviation	30%	-10%
	Total deviation from the three sediment metrics	**-17.2%**	**-7.8%**

Table 5-24. Lee's Creek habitat TMDL and surrogate TMDL for flow alterations.

HUC 12 (last 4)		**0403**
Stream		**Trib. to Lees Creek (RM 2.57)**
River mile		**1.30**
Aquatic life use designation		**WWH**
Applicable TMDLs (habitat and/or sediment)		**Habitat and surrogate for flow alterations**
Habitat TMDLs	QHEI score	66
	Numeric deviation	6
	Percent deviation	10%
	Number of high impact MWH types	0
	Numeric deviation	1
	Percent deviation	100%
	Number of MWH attributes	2
	Numeric deviation	2
	Percent deviation	50%
	Habitat TMDL - number of measures not satisfying the target	**0**
Sediment TMDLs	Substrate score	17
	Numeric deviation	4
	Percent deviation	31%
	Channel score	17.5
	Numeric deviation	3.5
	Percent deviation	25%
	Riparian score	3.5
	Numeric deviation	-1.5
	Percent deviation	-30%
	Total deviation from the three sediment metrics	**18.8%**

Table 5-25. Lee's Creek bedload and habitat.

TMDL.**HUC 12 (last 4)**		**0406**	**0406**
Stream		**Fall Creek**	**Fall Creek**
River mile		**7.50**	**1.60**
Aquatic life use designation		**WWH**	**WWH**
Applicable TMDLs (habitat and/or sediment)		**No TMDL (no applicable cause of impairment)**	**No TMDL (full attainment)**
Habitat TMDLs	QHEI score	58.5	67
	Numeric deviation	-1.5	7
	Percent deviation	-3%	12%
	Number of high impact MWH types	1	0
	Numeric deviation	0	1
	Percent deviation	0%	100%
	Number of MWH attributes	5	2

TMDL.**HUC 12 (last 4)**		**0406**	**0406**
Stream		**Fall Creek**	**Fall Creek**
River mile		**7.50**	**1.60**
Aquatic life use designation		**WWH**	**WWH**
Applicable TMDLs (habitat and/or sediment)		**No TMDL (no applicable cause of impairment)**	**No TMDL (full attainment)**
	Numeric deviation	-1	2
	Percent deviation	-25%	50%
	Habitat TMDL - number of measures not satisfying the target	**2**	**0**
Sediment TMDLs	Substrate score	7.5	12.5
	Numeric deviation	-5.5	-0.5
	Percent deviation	-42%	-4%
	Channel score	16.5	16
	Numeric deviation	2.5	2
	Percent deviation	18%	14%
	Riparian score	5.5	7.5
	Numeric deviation	0.5	2.5
	Percent deviation	10%	50%
	Total deviation from the three sediment metrics	**-7.8%**	**12.5%**

5.5 Rocky Fork (05060003 05)

TMDLs were developed for *E. coli* bacteria and sediment and habitat (via QHEI metric scores and metric attributes). Two sites in the 05-02 twelve-digit HUC on Clear Creek were impaired due to organic enrichment emanating from several by-pass events from the Hillsboro STP occurring throughout out the summer that the survey was conducted. A TMDL for organic enrichment is not done for this twelve-digit HUC because such events are very unlikely to continue once all of the upgrades to the treatment plant have been implemented, namely, elimination of bypasses up to a 10-year 24-hour storm event. Additionally, once the upgrades are completed there will be new screens, grit removal, an additional vertical loop reactor, two additional clarifiers, a 1.3 million gallon equalization basin, and a new ultra-violet disinfection system. All of the plant improvements and a new set of effluent limits were to be implemented by June 1, 2012 as per the compliance schedule in their NPDES permit (permit number 1PC00100). There were several by-passes during the summer of the survey and, despite this organic loading, the fish biometric scores exceeded the water quality standards while the macroinvertebrate biometric failed by a relatively modest margin. There is little reason to believe that following the significant improvement in the waste water treatment plant operation, that water quality stress would be sufficient to preclude full attainment of the exceptional warm water quality criteria.

5.5.1 *E. coli* TMDLs

Three of the five 12-digit HUCs in this 10-digit HUC was impaired for recreation uses and had TMDL analyses performed. Additionally, *E. coli* is also used as a surrogate parameter to address aquatic life use impairments caused by nutrient enrichment. This substitution is justified based on the linkages discussed in chapter four in combination with the fact that livestock manure and to a lesser extent human wastes from under-performing septic systems are the primary sources of recreation use impairment in the 05-05 twelve-digit HUC, sources that are not only rich in E. coli bacteria, but also organic material, ammonia, and nutrients.

On a per square mile per day basis under the high flow conditions, the TMDL yields for each of the 12-digit HUCs ranged from about 11 to 58 billion cfus. Table 5-26 shows the TMDL results for this ten-digit HUC.

Table 5-26. Rocky Fork *E. coli* TMDLs and surrogate TMDLs for organic enrichment and nutrient enrichment.

Hydrologic Condition (*E. coli* loads expressed in billions of organisms per day)	**High flows**	**Wet weather**	**Normal range**	**Dry weather**	**Low**
Clear Ck Dst Hillsboro WWTP HUC12: 05060003 05 02					
Total Maximum Daily Load	517.4	69.0	30.6	25.2	24.4
Wasteload Allocation	18.9	18.9	18.9	18.9	18.9
Hillsboro STP- 1PC00100	*18.9*	*18.9*	*18.9*	*18.9*	*18.9*
BP Amoco #69544 - 1IN00255	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
Load Allocation	384.7	34.9	5.0	0.8	0.2
Margin of Safety	103.5	13.8	6.1	5.0	4.9
Allowance for future growth	10.4	1.4	0.6	0.5	0.5
Total load reduction required	99.8%	98.4%	No Data	None	No Data
Rocky Fk @ SR 124, upst Rocky Fk Lake, DST WWTP HUC12: 05060003 05 03					
Total Maximum Daily Load	606.2	60.9	14.3	7.7	6.8
Wasteload Allocation	1.5	1.5	1.5	1.5	1.5
Rocky Fork Lake WWTP - 1PS0015	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*
Pleasant Acres MHP - 1PV00127	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
Load Allocation	471.3	46.0	9.7	4.5	3.8
Margin of Safety	121.2	12.2	2.9	1.5	1.4
Allowance for future growth	12.1	1.2	0.3	0.2	0.1
Total load reduction required	99.8%	99.6%	No Data	89.7%	No Data
Rocky Fk @ Browning Rd nr Barretts Mill HUC12: 05060003 05 05[1]					
Total Maximum Daily Load	1764.3	324.8	84.3	37.8	29.2
Wasteload Allocation	20.6	20.6	20.6	20.6	20.6
Rocky Fork Truck Stop - 1PZ00038	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
Hickory Hills Lake Co - 1PX00063	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
Country Home MHP - 1PV00093	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
Babington Camp & Park - 1PV00087	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
Rocky Fork Lake WWTP - 1PS0015	*1.4*	*1.4*	*1.4*	*1.4*	*1.4*
Pleasant Acres MHP - 1PV00127	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
Hillsboro STP - 1PC00100	*18.9*	*18.9*	*18.9*	*18.9*	*18.9*
BP Amoco #69544 - 1IN00255	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
Load Allocation	1355.6	232.7	45.2	8.9	2.1
Margin of Safety	352.9	65.0	16.9	7.6	5.8
Allowance for future growth	35.3	6.5	1.7	0.8	0.6
Total load reduction required	95.9%	70.2%	None	None	None

[1] *E. coli* is used as a surrogate parameter for aquatic life use impairments due to nutrient enrichment and dissolved oxygen stresses in the 05-05 twelve-digit HUC. The similarity of sources of these pollutants is used to justify this substitution.

5.5.2 Habitat and Sediment TMDLs

One of five 12-digit HUCs in this 10-digit HUC have had TMDL analyses performed to address habitat issues relative to altered flow conditions. Specifically, the 05-02 twelve-digit HUC has shown aquatic life impairment based on an altered flow regime. The QHEI habitat index is used to develop these TMDLs based on the justification provided in chapter four. Table 5-27 shows the TMDL results for this ten-digit HUC.

Table 5-27. Moberly Branch habitat TMDL and surrogate TMDL for flow alteration.

	HUC 12 (last 4)	0502	0502	0502
	Stream	**Clear Creek**	**Clear Creek**	**Moberly Branch Clear Creek**
	River mile	**6.60**	**5.40**	**0.90**
	Aquatic life use designation	**EWH**	**EWH**	**WWH**
	Applicable TMDLs (habitat and/or sediment)	**No TMDL (no applicable cause of impairment)**	**No TMDL (no applicable cause of impairment)**	**Habitat surrogate for flow alterations**
Habitat TMDLs	QHEI score	71.5	59	66
	Numeric deviation	-3.5	-16	6
	Percent deviation	-5%	-21%	10%
	Number of high impact MWH types	1	1	1
	Numeric deviation	-1	-1	0
	Percent deviation	-100%	-100%	0%
	Number of MWH attributes	4	6	5
	Numeric deviation	-2	-4	-1
	Percent deviation	-100%	-200%	-25%
	Habitat TMDL - number of measures not satisfying the target	**2**	**3**	**1**
Sediment TMDLs	Substrate score	12.5	14	15.5
	Numeric deviation	-2.5	-1	2.5
	Percent deviation	-17%	-7%	19%
	Channel score	17	8.5	13
	Numeric deviation	2	-6.5	-1
	Percent deviation	13%	-43%	-7%
	Riparian score	5.5	4.5	4
	Numeric deviation	0.5	-0.5	-1
	Percent deviation	10%	-10%	-20%
	Total deviation from the three sediment metrics	**0.0%**	**-22.9%**	**1.6%**

5.6 Paint Creek (below East Fork [except Sugar Creek] to above Rocky Fork (05060003 06)

TMDLs were developed for *E. coli* bacteria, total phosphorus, and sediment and habitat (via QHEI metric scores and metric attributes).

5.6.1 *E. coli* TMDLs

Two of the three 12-digit HUCs in this 10-digit HUC were impaired for recreation uses and have had TMDL analyses performed. The *E. coli* TMDL in for the 06-02 twelve-digit HUC is also used as a surrogate to address the aquatic life use impairment due to organic enrichment. The similarity of the sources, namely wastewater, livestock and improperly treating septic systems, justifies this substitution.

On a per square mile per day basis, the TMDL yields for each of the 12-digit HUCs ranged from about 6.5 to 18.5 billion cfus, with the Paint Creek upstream of Greenfield (06-02) having the lowest value. Allocations to point sources (wasteloads) ranged from 4.1 percent to 9.5 percent of that which was allocated to nonpoint sources (load allocations). Tables 5-28 through 5-30 show the TMDL results for this ten-digit HUC.

Table 5-28. Paint Creek downstream East Fork Paint Creek to upstream City of Greenfield *E. coli* TMDL.

***E. coli* requirements for HUC-12 050600030601**							
***E. coli* Recreation Season TMDL components and target export load - billion cfu/day**							
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export	
HUC-12 / sub-watershed	856.4	42.8	771.5	42.05	0.03	30815.6	
Cumulative watershed	6085.0	304.3	5597.2	179.57	3.96		
Non point **source LA reductions (% of existing recreation season load contribution)**							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	0%	0%	0%	0%	100%	100%	0%

Point source NPDES WLA					
Facility Name	NPDES OEPA ID	Ex Flow Avg MGD	Dgn Q MGD	Limit C cfu/100 ml	WLA billion/day
Washington CH MS4 (1.9sqmi)	4GQ00027	Stormwater	Stormwate r	N/A	41.831
Flakes Ford WWTP	4PG0000	0.01	0.01375	126	0.066
Good Hope WWTP	N/A	0.00	0.032	126	0.153
Upstream unit WLA (Paint)	Various	N/A	N/A	N/A	104.106
Upstream unit WLA (East Fork)	Various	N/A	N/A	N/A	30.371
Upstream unit WLA (Sugar)	Various	N/A	N/A	N/A	3.047

Table 5-29. Alternate Paint Creek downstream East Fork Paint Creek to upstream City of Greenfield *E. coli* TMDL (Washington Court House WWTP outfall relocated to discharge below East Fork Paint Creek).

***E. coli* requirements for HUC-12 050600030601**

***E. coli* Recreation Season TMDL components and target export load - billion cfu/day**

TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export
HUC-12 / sub-watershed	856.4	42.8	742.9	70.67	0.03	32168.3
Cumulative watershed	6468.9	323.4	5962.0	179.57	3.96	

Non point **source LA reductions (% of existing recreation season load contribution)**

Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Existing load to stream	2,665,164	2,053,282	1,722	18,959	3729.9	7349.4	103
Percent reduction	0%	0%	0%	0%	100%	100%	0%
Target annual load	2,665,164	2,053,282	1,722	18,959	0.0	0.0	103

Point source NPDES WLA

Facility Name	NPDES OEPA ID	Ex Flow Avg MGD	Dgn Q MGD	Limit C cfu/100 ml	WLA billion/day
Washington Court House WWTP	4PD00002	3.03	6	126	28.618
Washington CH MS4 (1.9sqmi)	4GQ00027	Stormwater	Stormwater	N/A	41.831
Flakes Ford WWTP	4PG0000	0.01	0.01375	126	0.066
Good Hope WWTP	N/A	0.00	0.032	126	0.153
Upstream unit WLA(Paint)	Various	N/A	N/A	N/A	75.488
Upstream unit WLA(EFork)	Various	N/A	N/A	N/A	30.371
Upstream unit WLA(Sugar)	Various	N/A	N/A	N/A	3.047

Table 5-30. Paint Creek upstream City of Greenfield to Paint Creek Lake *E. coli* TMDL and organic enrichment TMDL using *E. coli* as a surrogate.

***E. coli* requirements for HUC-12 050600030602**

***E. coli* Recreation Season TMDL components and target export load - billion cfu/day**

TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export
HUC-12 / sub-watershed	203.5	10.2	185.2	7.63	0.44	37044.6
Cumulative watershed	6288.5	314.4	5782.7	187.05	4.39	

Non point **source LA reductions (% of existing recreation season load contribution)**

Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	0%	0%	0%	0%	100%	100%	0%

Point source NPDES WLA

Facility Name	NPDES OEPA ID	Existing MGD	Dgn Q MGD	Limit C cfu/100 ml	WLA billion/day
MMM Bluerock Quarry	4IJ00021	Stormwater	Stormwater	0	0.000
Greenfield WWTP	1PD00022	0.99	1.6	126	7.631
Upstream allocation unit WLA	Various	N/A	N/A	N/A	179.420

5.6.2 Total Phosphorus TMDLs

One of the 12-digit HUCs in this 10-digit HUC had impairment due to eutrophic conditions and had a total phosphorus TMDL analyses performed. Allocations to point sources (wasteloads) are 0.08 percent of that which is allocated to nonpoint sources (load allocations). Table 5-31 shows the TMDL results for this ten-digit HUC.

Table 5-31. Paint Creek upstream City of Greenfield to Paint Creek Lake total phosphorus TMDL.

Total Phosphorus requirements for HUC-12 050600030601 (Partial zone, Indian Creek only)							
Total Phosphorus Annual TMDL components and target export load - kg/day							
TMDL components	TMDL	MOS	LA	Σ WLA	AFG	90th% target export	
HUC-12 / sub-watershed	308.9	15.4	293.2	0.24	0.02	45.6	
Cumulative watershed	308.9	15.4	293.2	0.24	0.02		
Non-point source LA reductions (% of existing recreation season load contribution)							
Washoff / direct source	Crop	Pasture	Developed	Wooded	D-Livestock	D-HSTS	D-Wildlife
Percent reduction	45%	0%	0%	0%	100%	0%	0%
Point source NPDES WLA							
Facility Name		NPDES OEPA ID		Ex Flow Av MGD	Dgn Q MGD	Limit C mg/L	WLA kg/day
Good Hope WWTP		N/A		0.00	0.032	2	0.242

5.6.3 Habitat and Sediment TMDLs

One out of three 12-digit HUCs in this 10-digit HUC have had TMDL analyses performed to address flow alteration using habitat as a surrogate. . The QHEI habitat index is used to develop this TMDL based on the justification provided in chapter four. Tables 5-32 through 5-33 show the TMDL results for this ten-digit HUC.

Table 5-32. Indian Creek habitat TMDL and surrogate TMDL for flow alterations.

	HUC 12 (last 4)	0601	0601	0601	0601	0601
	Stream	**Indian Creek**	**Paint Creek**	**Paint Creek**	**Paint Creek**	**Wabash Creek**
	River mile	**1.60**	**67.20**	**63.30**	**58.80**	**0.80**
	Aquatic life use designation	**WWH**	**EWH**	**EWH**	**EWH**	**WWH**
	Applicable TMDLs (habitat and/or sediment)	**No TMDL (no applicable cause of impairment)**	**Habitat surrogate for flow alterations**	**No TMDL (full attainment)**	**No TMDL (full attainment)**	**No TMDL (full attainment)**
Habitat TMDLs	QHEI score	61.5	61	68.5	83	67
	Numeric deviation	1.5	-14	-6.5	8	7
	Percent deviation	3%	-19%	-9%	11%	12%
	Number of high impact MWH types	1	0	0	0	0
	Numeric deviation	0	0	0	0	1
	Percent deviation	0%	0%	0%	0%	100%
	Number of MWH attributes	5	8	4	2	2
	Numeric deviation	-1	-6	-2	0	2
	Percent deviation	-25%	-300%	-100%	0%	50%
	Habitat TMDL - number of measures not satisfying the target	**1**	**2**	**2**	**0**	**0**
Sediment TMDLs	Substrate score	16.5	12.5	15.5	17.5	10.5
	Numeric deviation	3.5	-2.5	0.5	2.5	-2.5
	Percent deviation	27%	-17%	3%	17%	-19%
	Channel score	11	10	15	17.5	17
	Numeric deviation	-3	-5	0	2.5	3
	Percent deviation	-21%	-33%	0%	17%	21%
	Riparian score	4.5	7	5.5	6	4
	Numeric deviation	-0.5	2	0.5	1	-1
	Percent deviation	-10%	40%	10%	20%	-20%
	Total deviation from the three sediment metrics	**0.0%**	**-15.7%**	**2.9%**	**17.1%**	**-1.6%**

Table 5-33. Paint Creek between Sugar Creek and SR-753 bedload and habitat TMDL.

	HUC 12 (last 4)	0602	0602
	Stream	**Paint Creek**	**Paint Creek**
	River mile	**52.50**	**48.90**
	Aquatic life use designation	**EWH**	**EWH**
	Applicable TMDLs (habitat and/or sediment)	**No TMDL (full attainment)**	**No TMDL (no applicable cause of impairment)**
Habitat TMDLs	QHEI score	78.5	83
	Numeric deviation	3.5	8
	Percent deviation	5%	11%
	Number of high impact MWH types	0	0
	Numeric deviation	0	0
	Percent deviation	0%	0%
	Number of MWH attributes	3	0
	Numeric deviation	-1	2
	Percent deviation	-50%	100%
	Habitat TMDL - number of measures not satisfying the target	**1**	**0**
Sediment TMDLs	Substrate score	17.5	15.5
	Numeric deviation	2.5	0.5
	Percent deviation	17%	3%
	Channel score	17	17
	Numeric deviation	2	2
	Percent deviation	13%	13%
	Riparian score	7	8.5
	Numeric deviation	2	3.5
	Percent deviation	40%	70%
	Total deviation from the three sediment metrics	**18.6%**	**17.1%**

5.7 Paint Creek (below Rocky Fork to below Lower Twin Cr.) (05060003 07)

TMDLs were developed for *E. coli* bacteria and sediment and habitat (via QHEI metric scores and metric attributes).

5.7.1 *E. coli* TMDLs

All four of the 12-digit HUCs in this 10-digit HUC were impaired for recreation uses and had TMDL analyses performed. *E. coli* is also used as a surrogate to address nutrient enrichment in the 07-01 twelve-digit HUC which caused aquatic life use impairment on an unnamed tributary to Buckskin Creek. The sources of nutrients in this HUC are human wastes emanating from poorly treated sewage from home septic systems.

On a per square mile per day basis under the high flow conditions, the TMDL yields for each of the 12-digit HUCs ranged from about 0.1 to 1.4 billion cfus. Table 5-34 shows the TMDL results for this ten-digit HUC.

Table 5-34. Paint Creek *E. coli* TMDLs and surrogate TMDLs for nutrient enrichment .

Hydrologic Condition (*E. coli* loads expressed in billions of organisms per day)	**High flows**	**Wet weather**	**Normal range**	**Dry weather**	**Low**
Trib. to Buckskin Ck (@ RM 12.25) @ McCann Rd. HUC12: 05060003 07 01[1]					
Total Maximum Daily Load	53.6	5.4	1.3	0.7	0.6
Wasteload Allocation	0.0	0.0	0.0	0.0	0.0
Load Allocation	41.8	4.2	1.0	0.5	0.5
Margin of Safety	10.7	1.1	0.3	0.1	0.1
Allowance for future growth	1.1	0.1	0.0	0.0	0.0
Total load reduction required	No Data	No Data	57.8%	45.4%	No Data
Upper Twin Ck @ Upper Twin Creek Rd W of Bourneville HUC12: 05060003 07 02					
Total Maximum Daily Load	189.6	19.0	4.5	2.4	2.1
Wasteload Allocation	0.0	0.0	0.0	0.0	0.0
Load Allocation	147.9	14.9	3.5	1.9	1.6
Margin of Safety	37.9	3.8	0.9	0.5	0.4
Allowance for future growth	3.8	0.4	0.1	0.1	0.0
Total load reduction required	No Data	No Data	82.2%	81.9%	No Data
Lower Twin Ck @ Farm off Lower Twin Rd. HUC12: 05060003 07 03					
Total Maximum Daily Load	233.1	23.4	5.5	3.0	2.6
Wasteload Allocation	0.0	0.0	0.0	0.0	0.0
Load Allocation	181.9	18.3	4.3	2.3	2.0
Margin of Safety	46.6	4.7	1.1	0.6	0.5
Allowance for future growth	4.7	0.5	0.1	0.1	0.1
Total load reduction required	No Data	No Data	61.6%	None	No Data
Massie Run @ US RT 50 W of Bainbridge HUC12: 05060003 07 04					
Total Maximum Daily Load	76.2	7.6	1.8	1.0	0.8
Wasteload Allocation	0.0	0.0	0.0	0.0	0.0
Load Allocation	59.4	6.0	1.4	0.7	0.6
Margin of Safety	15.2	1.5	0.4	0.2	0.2
Allowance for future growth	1.5	0.2	0.0	0.0	0.0
Total load reduction required	No Data	No Data	68.6%	89.7%	No Data

[1] ***E. coli*** **is used as a surrogate parameter for aquatic life use impairments due to nutrient enrichment in the 07-01 twelve-digit HUC. The similarity of sources of these pollutants is used to justify this substitution.**

5.7.2 Habitat and Sediment TMDLs

Two of four 12-digit HUCs in this 10-digit HUC have had TMDL analyses performed to address excessive fine sediment and poor habitat quality as well as flow alteration and dissolved oxygen using habitat as a surrogate. The QHEI habitat index is used to develop this TMDL based on the justification provided in chapter four. Tables 5-35 through 5-36 show the TMDL results for this ten-digit HUC.

Table 5-35. Tributary to Buckskin Creek habitat TMDL as a surrogate for flow alterations.

HUC 12 (last 4)		**0701**
Stream		**Trib. to Buckskin Creek (RM 12.25)**
River mile		**0.20**
Aquatic life use designation		**WWH**
Applicable TMDLs (habitat and/or sediment)		**Habitat as surrogate for flow alterations**
Habitat TMDLs	QHEI score	50.5
	Numeric deviation	-9.5
	Percent deviation	-16%
	Number of high impact MWH types	1
	Numeric deviation	0
	Percent deviation	0%
	Number of MWH attributes	5
	Numeric deviation	-1
	Percent deviation	-25%
	Habitat TMDL - number of measures not satisfying the target	**2**
Sediment TMDLs	Substrate score	11.5
	Numeric deviation	-1.5
	Percent deviation	-12%
	Channel score	11.5
	Numeric deviation	-2.5
	Percent deviation	-18%
	Riparian score	3.5
	Numeric deviation	-1.5
	Percent deviation	-30%
	Total deviation from the three sediment metrics	**-17.2%**

Table 5-36. Sulphur Lick sediment and habitat TMDLs as a surrogate for dissolved oxygen.

HUC 12 (last 4)		0704
Stream		**Sulphur Lick**
River mile		**1.50**
Aquatic life use designation		**WWH**
Applicable TMDLs (habitat and/or sediment)		**Habitat, sediment and dissolved oxygen as a surrogate**
Habitat TMDLs	QHEI score	50.5
	Numeric deviation	-9.5
	Percent deviation	-16%
	Number of high impact MWH types	2
	Numeric deviation	-1
	Percent deviation	-100%
	Number of MWH attributes	6
	Numeric deviation	-2
	Percent deviation	-50%
	Habitat TMDL - number of measures not satisfying the target	**3**
Sediment TMDLs	Substrate score	7
	Numeric deviation	-6
	Percent deviation	-46%
	Channel score	12
	Numeric deviation	-2
	Percent deviation	-14%
	Riparian score	5.5
	Numeric deviation	0.5
	Percent deviation	10%
	Total deviation from the three sediment metrics	**-23.4%**

5.8 North Fork (headwaters to below Compton Creek) (05060003 08)

TMDLs were developed only for *E. coli* bacteria in this 10-digit HUC.

5.8.1 *E. coli* TMDLs

Four of the five 12-digit HUCs in this 10-digit HUC were impaired for recreation uses and had TMDL analyses performed. On a per square mile per day basis under the high flow conditions, the TMDL yields for each of the 12-digit HUCs ranged from about 10.6 to 28.2 billion cfus. Table 5-37 shows the TMDL results for this ten-digit HUC.

Table 5-37. Headwaters North Fork Paint Creek *E. coli* TMDLs.

Hydrologic Condition (*E. coli* loads expressed in billions of organisms per day)	**High flows**	**Wet weather**	**Normal range**	**Dry weather**	**Low**
Thompson Ck @ Wissler Rd.	**HUC12: 05060003 08 01**				
Total Maximum Daily Load	110.0	14.3	2.6	0.6	0.3
Wasteload Allocation	0.0	0.0	0.0	0.0	0.0
Load Allocation	85.8	11.1	2.0	0.4	0.3
Margin of Safety	22.0	2.9	0.5	0.1	0.1
Allowance for future growth	2.2	0.3	0.1	0.0	0.0
Total load reduction required	No Data	No Data	58.7%	65.7%	No Data
Compton Ck @ Washington Waterloo Rd.	**HUC12: 05060003 08 03**				
Total Maximum Daily Load	349.7	45.4	8.2	1.7	1.1
Wasteload Allocation	0.0	0.0	0.0	0.0	0.0
Load Allocation	272.8	35.4	6.4	1.4	0.8
Margin of Safety	69.9	9.1	1.6	0.3	0.2
Allowance for future growth	7.0	0.9	0.2	0.0	0.0
Total load reduction required	No Data	No Data	44.6%	53.7%	No Data
Compton Ck @ Dogtown Rd.	**HUC12: 05060003 08 04**				
Total Maximum Daily Load	811.5	105.4	19.0	4.0	2.5
Wasteload Allocation	0.1	0.1	0.1	0.1	0.1
Petro Environmental Tech Cell Div - 4IN00150	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
Pine Tree Court Apts 1 - 4PW00004	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
Load Allocation	632.8	82.0	14.6	3.0	1.8
Margin of Safety	162.3	21.1	3.8	0.8	0.5
Allowance for future growth	16.2	2.1	0.4	0.1	0.0
Total load reduction required	No Data	No Data	38.7%	61.7%	No Data
N Fk Paint Ck @ Good Hope-New Holland Rd.	**HUC12: 05060003 08 05**				
Total Maximum Daily Load	701.5	91.1	16.4	3.5	2.1
Wasteload Allocation (New Holland WWTP - 4PB00028)	0.8	0.8	0.8	0.8	0.8
Load Allocation	546.4	70.3	12.0	1.9	0.9
Margin of Safety	140.3	18.2	3.3	0.7	0.4
Allowance for future growth	14.0	1.8	0.3	0.1	0.0
Total load reduction required	98.3%	36.3%	18.4%	None	No Data

5.9 North Fork (below Compton Creek to Paint Creek) (05060003 09)

TMDLs were developed for *E. coli* bacteria and sediment and habitat (via QHEI metric scores and metric attributes).

5.9.1 *E. coli* TMDLs

Three of the four 12-digit HUCs in this 10-digit HUC were impaired for recreation uses and had TMDL analyses performed. Additionally, *E. coli* is also used as a surrogate parameter to address aquatic life use impairments caused by organic enrichment. This substitution is justified based on the linkages discussed in chapter four in combination with the fact that human wastes from under-performing septic systems and to a lesser extent livestock manure are the primary sources of recreation use impairment in the 09-03 twelve-digit HUC, sources that are not only rich in E. coli bacteria, but also organic material.

On a per square mile per day basis under the high flow conditions, the TMDL yields for each of the 12-digit HUCs ranged from about 16 to 122 billion cfus. Table 5-38 shows the TMDL results for this ten-digit HUC.

Table 5-38. North Fork Paint Creek *E. coli* TMDLs and surrogate TMDL for organic enrichment.

Hydrologic Condition (*E. coli* loads expressed in billions of organisms per day)	**High flows**	**Wet weather**	**Normal range**	**Dry weather**	**Low**
Little Ck @ Little Creek Rd nr Rogers Rd.		**HUC12: 05060003 09 02**			
Total Maximum Daily Load	376.3	41.3	6.7	1.5	0.3
Wasteload Allocation	0.0	0.0	0.0	0.0	0.0
Load Allocation	293.5	32.2	5.2	1.2	0.3
Margin of Safety	75.3	8.3	1.3	0.3	0.1
Allowance for future growth	7.5	0.8	0.1	0.0	0.0
Total load reduction required	No Data	No Data	60.7%	None	No Data
N Fk Paint Ck downstream Frankfort WWTP			**HUC12: 05060003 09 03[1]**		
Total Maximum Daily Load	2708.3	297.0	48.2	10.9	2.6
Wasteload Allocation	1.8	1.8	1.8	1.8	1.8
Frankfort WWTP - 0PB00014	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*
Melvin Stone Co - 0IN00217	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
Petro Environmental Tech Cell Div - 4IN00150	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
Pine Tree Court Apts 1 - 4PW00004	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
New Holland WWTP - 4PB00028	*0.8*	*0.8*	*0.8*	*0.8*	*0.8*
Load Allocation	2110.7	229.8	35.8	6.7	0.2
Margin of Safety	541.7	59.4	9.6	2.2	0.5
Allowance for future growth	54.2	5.9	1.0	0.2	0.1
Total load reduction required	No Data	No Data	72.6%	None	No Data
N Fk Paint Ck @ Poke Hollow Rd.			**HUC12: 05060003 09 04**		
Total Maximum Daily Load	3834.1	425.2	73.5	20.7	8.9
Wasteload Allocation	6.1	6.1	6.1	6.1	6.1
Frankfort WWTP - 0PB00014	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*
Melvin Stone Co0IN00217	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
Petro Environmental Tech Cell Div - 4IN00150	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
Pine Tree Court Apts 1 - 4PW00004	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
New Holland WWTP - 4PB00028	*0.8*	*0.8*	*0.8*	*0.8*	*0.8*
Pleasant Valley Regional SD - 0PQ00002	*4.3*	*4.3*	*4.3*	*4.3*	*4.3*
Load Allocation	2984.5	325.5	51.2	10.0	0.9
Margin of Safety	766.8	85.0	14.7	4.1	1.8
Allowance for future growth	76.7	8.5	1.5	0.4	0.2
Total load reduction required	No Data	96.0%	None	None	No Data

[1] *E. coli* is used as a surrogate parameter for aquatic life use impairments due to organic enrichment in the 09-03 twelve-digit HUC. The similarity of sources of these pollutants is used to justify this substitution.

5.9.2 Habitat and Sediment TMDLs

All three 12-digit HUCs in this 10-digit HUC have had TMDL analyses performed to address excessive fine sediment and poor habitat quality or poor habitat related issues. Table 5-39 shows the TMDL results for this ten-digit HUC.

Table 5-39. Oldtown Run sediment TMDL.

	HUC 12 (last 4)	0903
	Stream	**Oldtown Run**
River mile		**1.30**
Aquatic life use designation		**WWH**
Applicable TMDLs (habitat and/or sediment)		**Sediment**
Habitat TMDLs	QHEI score	56.5
	Numeric deviation	-3.5
	Percent deviation	-6%
	Number of high impact MWH types	1
	Numeric deviation	0
	Percent deviation	0%
	Number of MWH attributes	6
	Numeric deviation	-2
	Percent deviation	-50%
	Habitat TMDL - number of measures not satisfying the target	**2**
Sediment TMDLs	Substrate score	10
	Numeric deviation	-3
	Percent deviation	-23%
	Channel score	9.5
	Numeric deviation	-4.5
	Percent deviation	-32%
	Riparian score	5
	Numeric deviation	0
	Percent deviation	0%
	Total deviation from the three sediment metrics	**-23.4%**

5.10 Paint Creek (below Lower Twin Creek to Scioto River [except North Fork]) (05060003 10)

TMDLs were developed for *E. coli* bacteria and sediment and habitat (via QHEI metric scores and metric attributes).

5.10.1 E. coli TMDLs

Two of the three 12-digit HUCs in this 10-digit HUC were impaired for recreation uses and had TMDL analyses performed. Additionally, *E. coli* is also used as a surrogate parameter to address aquatic life use impairments caused by organic enrichment. This substitution is justified based on the linkages discussed in chapter four in combination with the fact that human wastes from under-performing septic systems and to a lesser extent livestock manure are the primary sources of recreation use impairment in the 10-02 twelve-digit HUC, sources that are not only rich in E. coli bacteria, but also organic material.

On a per square mile per day basis under the high flow conditions, the TMDL yields for each of the 12-digit HUCs ranged from about 2.4 to 5.9 billion cfus. Table 5-40 shows the TMDL results for this ten-digit HUC.

Table 5-40. Paint Creek below lower Twin Creek to Scioto River *E. coli* TMDLs and surrogate TMDL for organic enrichment.

Hydrologic Condition (*E. coli* loads expressed in billions of organisms per day)	**High flows**	**Wet weather**	**Normal range**	**Dry weather**	**Low**
Ralston Run @ Turner Rd.		**HUC12: 05060003 10 02[1]**			
Total Maximum Daily Load	80.8	8.1	1.9	1.0	0.9
Wasteload Allocation (Huntington Local School District- 0PT00007)	0.1	0.1	0.1	0.1	0.1
Load Allocation	62.9	6.2	1.3	0.7	0.6
Margin of Safety	16.2	1.6	0.4	0.2	0.2
Allowance for future growth	1.6	0.2	0.0	0.0	0.0
Total load reduction required	No Data	No Data	46.7%	38.8%	No Data
Owl Ck upst US RT 50		**HUC12: 05060003 10 03**			
Total Maximum Daily Load	101.0	10.1	2.4	1.3	1.1
Wasteload Allocation	0.0	0.0	0.0	0.0	0.0
Load Allocation	78.8	7.9	1.9	1.0	0.9
Margin of Safety	20.2	2.0	0.5	0.3	0.2
Allowance for future growth	2.0	0.2	0.1	0.0	0.0
Total load reduction required	No Data	No Data	69.4%	54.4%	No Data

[1] ***E. coli*** **is used as a surrogate parameter for aquatic life use impairments due to organic enrichment in the 10-02 twelve-digit HUC. The similarity of sources of these pollutants is used to justify this substitution.**

5.10.2 Habitat and Sediment TMDLs

One of the three 12-digit HUCs in this 10-digit HUC had a TMDL analyses performed to address excessive fine sediment and poor habitat quality. Table 5-41 shows the TMDL results for this ten-digit HUC.

Table 5-41. Ralston Run sediment TMDL.

HUC 12 (last 4)		**1002**
Stream		**Ralston Run**
River mile		**2.80**
Aquatic life use designation		**WWH**
Applicable TMDLs (habitat and/or sediment)		**Sediment**
Habitat TMDLs	QHEI score	44.5
	Numeric deviation	-15.5
	Percent deviation	-26%
	Number of high impact MWH types	4
	Numeric deviation	-3
	Percent deviation	-300%
	Number of MWH attributes	4
	Numeric deviation	0
	Percent deviation	0%
	Habitat TMDL - number of measures not satisfying the target	**2**
Sediment TMDLs	Substrate score	4.5
	Numeric deviation	-8.5
	Percent deviation	-65%
	Channel score	13
	Numeric deviation	-1
	Percent deviation	-7%
	Riparian score	5.5
	Numeric deviation	0.5
	Percent deviation	10%
	Total deviation from the three sediment metrics	**-28.1%**

5.11 Paint Creek (Rocky Fork to mouth) (Large River 05060003 90 01)

Sites at river miles 39.14 and 32.5 on the mainstem of Paint Creek were impaired for aquatic life uses, while no sites were impaired for recreation uses. These impaired sites were impacted by the degraded water quality from the hypolimnetic releases of Paint Creek Lake on this exceptional warm water portion of the large river assessment unit (i.e., the assessment of Paint Creek in the large river section is considered separate from the 12-digit HUCs through which the river passes). No TMDLs are developed for this assessment unit due to the complexity of these stressors, and the multiple variables impacting not only the conditions of the stressors (dissolved oxygen and nutrient concentrations), but also the type of management options that could abate this problem. For example, sufficient reduction in nutrient loading to the lake would reduce the amount of primary production in the lake thereby reducing the amount of organic material and nutrients from the dam. Many areas of the Paint Creek watershed draining to Paint Creek Lake are prescribed nutrient reductions which will likely ameliorate this problem. Additionally, optimal release protocols from the dam could likewise serve to improve water quality conditions downstream of the dam. Specifically, water can be drawn from two different levels in the lake from this U.S. Army Corps of Engineers operated structure for downstream water quality and temperature control.

6 WATER QUALITY IMPROVEMENT STRATEGY

The Paint Creek watershed met water quality standards for aquatic life uses at 69 percent of the sites surveyed. Based on the fairly high density of coverage of sampling sites, it is reasonable to extrapolate this proportion to all of the streams in the watershed. In terms of bacterial contamination from fecal matter (e.g., human waste residuals from septic systems, waste water collection and treatment systems, and livestock sources) 38 percent of the sites surveyed met water quality standards.

When looking at the issues causing stress to aquatic life communities, low dissolved oxygen concentrations, nutrient enriched conditions, heavy silt cover on streambeds, and poor habitat quality are the most frequently cited causes of impairment and all together account for 66 percent of the aquatic life use impairment. Dissolved oxygen issues were problematic in concert with nutrient enriched conditions for about one third of the instances where dissolved oxygen was an issue and co-occurred with heavy silts for nearly half of the instances. Crop production was cited as responsible for the dissolved oxygen issues in nearly all instances with stream channelization also a considerable source. Likewise, excess fine sediment is derived primarily in row cropland areas, and is also closely associated with stream channelization. Nutrient enriched conditions are also noted as a function of cropland drainage where nutrients are transported to the streams through surface and subsurface flow paths. However, central waste water collection and treatment systems, including sewer overflows and treatment plant effluent, are significant sources of nutrients. Poor habitat quality was not strongly associated with excessive fine sediment (only one instance of co-occurrence) but was likewise strongly associated with steam channelization and areas heavily used for row crop production.

Generally speaking, addressing nutrient loading from wastewater systems is one of the more achievable watershed restoration options. Much work has been done in this regard concerning sewer overflows since the 2006 survey and regulatory action to limit waste water effluent loading through lower limits for concentrations will be implemented. Cropland drainage is a source of several water quality stressors and effective conservation that provides covers to exposed soils, provides hydraulic retention, and more efficient use of nutrients from applied fertilizers (better application practices and greater in-field sequestering of the nutrients) will likewise result in substantial water quality improvements throughout the watershed.

A series of tables list actions appropriate for addressing the water quality stressors at specific locations in the basin. The recommended actions are well-established practices with proven effectiveness. Details regarding these practices are included in Appendix E of this report. Appendix E discusses various programs and organizations that can be sources for assistance in carrying out the recommended actions.

The recommended actions are not the only means for making the needed water quality improvements but rather highlight the more common approaches. There is some repetition in these recommendations because certain stressors can be addressed by a variety of approaches (e.g., both naturalizing watershed hydrology and stream restoration will improve habitat quality). The options were selected considering effectiveness and efficiency. Additionally, good land management practices are applicable everywhere, so not specifically recommending a management practice does not necessarily suggest that a given management practice is inappropriate in that location. Instead, the recommendations are made to prioritize watershed restoration activities and not merely list what is beneficial. A primary objective of these recommendations is to assist watershed planning and/or provide guidance regarding investments made to improve water quality.

Table 6-1 provides a watershed-wide perspective on the general types of practices needed for each of the assessment areas (including the regulatory actions discussed in Table 6-2). Tables 6-3 through 6-12 show recommended implementation actions for NPDES permittees. Those subsequent tables provide more detail of the recommendations for each nested subwatershed.

Table 6-1. Recommendations for improving water quality in impaired areas of the Paint Creek watershed.

10-Digit HUC (Location Description) 12-Digit HUC (Location Description) 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
Headwaters Paint Creek (05060003 01)												
Headwaters Paint Creek (01 01)												
Failing HSTS (bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
East Fork Paint Creek (01 02)												
Channelization (sediment, DO)	x	x								x		
Subsurface tile drainage (flow)	x	x								x		
Failing HSTS (bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
Town of Washington Court House-Paint Creek (01 03)												
Agricultural row crops (sediment, nutrients, DO)	x		x							x		
Livestock (sediment, nutrients, DO)	x									x		
Urban channelization (habitat, flow)	x	x										
Urban runoff (nutrients, flow)											x	
WWTP (nutrients)												x
Failing HSTS (bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
Sugar Creek (05060003 02)												
Headwaters Sugar Creek (02 01)												
Agricultural row crops (habitat, nutrients, DO)	x	x	x							x		
Livestock (habitat, nutrients, DO)	x	x								x		
WWTP (nutrients, DO)												x
Failing HSTS (bacteria)								x	x			

10-Digit HUC (Location Description) 12-Digit HUC (Location Description) 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
Agricultural row crop and livestock (bacteria)									x	x		
Camp Run-Sugar Creek (02 02)												
Agricultural row crops (nutrients)	x	x	x							x		
Livestock (nutrients)	x									x		
Failing HSTS (bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
Headwaters Rattlesnake Creek (05060003 03)												
Wilson Creek (03 01)												
Agricultural channelization (habitat)	x	x								x		
Agricultural row crops (habitat)	x									x		
Urban runoff (unknown toxicity)											x	x
WWTP (ammonia, organic enrichment)												x
Failing HSTS (bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
Grassy Branch (03 02)												
Subsurface tile drainage (flow)	x	x	x							x		
West Branch Rattlesnake Cr. (03 03)												
Agricultural channelization (sediment, DO)	x	x								x		
Agricultural row crops (sediment, DO)	x	x								x		
Failing HSTS (bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
Headwaters Rattlesnake Creek (03 04)												
Agricultural channelization (habitat, DO)	x	x								x		
Agricultural row crops (habitat, DO)	x									x		

10-Digit HUC (Location Description) 12-Digit HUC (Location Description) 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
Failing HSTS (bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
Waddle Ditch-Rattlesnake Cr. (03 05)												
Agricultural channelization (habitat, sediment)	x	x								x		
Agricultural row crops (habitat, sediment)	x									x		
Failing HSTS (bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
Lees Creek-Rattlesnake Creek (05060003 04)												
South Fork Lees Creek (04 01)												
Agricultural row crops (org. enrich., DO, ammonia)	x	x	x							x		
Failing HSTS (bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
Lees Creek (04 03)												
Subsurface tile drainage (flow)	x	x	x							x		
Livestock (organic enrichment, DO)										x		
Failing HSTS (bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
Walnut Creek (04 04)												
Failing HSTS (bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
Fall Creek (04 06)												
Agricultural row crops (nutrients, org. enrich.)	x	x	x							x		
Livestock (nutrients, organic enrichment)	x									x		

10-Digit HUC (Location Description) 12-Digit HUC (Location Description) 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
Big Branch-Rattlesnake Creek (04 07)												
Failing HSTS (bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
Rocky Fork (05060003 05)												
Clear Creek (05 02)												
WWTP (organic enrichment)												x
Urban runoff (flow)											x	
Failing HSTS (bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
Headwaters Rocky Fork (05 03)												
Failing HSTS (bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
Franklin Branch-Rocky Fork (05 05)												
Impoundment (nutrients)												
Failing HSTS (bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
Indian Creek-Paint Creek (05060003 06)												
Indian Creek-Paint Creek (06 01)												
Subsurface tile drainage (nutrients, flow)	x	x	x							x		
Failing HSTS (bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
Farmers Run-Paint Creek (06 02)												
WWTP (organic enrichment)												x
Failing HSTS (bacteria)								x	x			

10-Digit HUC (Location Description) 12-Digit HUC (Location Description) 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
Agricultural row crop and livestock (bacteria)									x	x		
Buckskin Creek-Paint Creek (05060003 07)												
Buckskin Creek (07 01)												
Subsurface tile drainage (nutrients, flow)	x	x	x							x		
Failing HSTS (bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
Upper Twin Creek (07 02)												
Failing HSTS (bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
Lower Twin Creek (07 03)												
Failing HSTS (bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
Sulphur Lick-Paint Creek (07 04)												
Agricultural row crops (sediment, DO, habitat)	x									x		
Agricultural channelization (sediment, DO, habitat)	x	x								x		
Failing HSTS (bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
Headwaters North Fork Paint Creek (05060003 08)												
Thompson Creek (08 01)												
Failing HSTS (bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
Headwaters Compton Creek (08 03)												
Failing HSTS (bacteria)								x	x			

10-Digit HUC (Location Description) 12-Digit HUC (Location Description) 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
Agricultural row crop and livestock (bacteria)									x	x		
Mills Branch-Compton Creek (08 04)												
Failing HSTS (bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
Mud Run-North Fork Paint Creek (08 05)												
Failing HSTS (bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
Little Creek-North Fork Paint Creek (05060003 09)												
Little Creek (09 02)												
Failing HSTS (bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
Oldtown Run-North Fork Paint Creek (09 03)												
Frankfort WWTP (bacteria)												x
Failing HSTS (sediment, org. enrich., bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
Biers Run-North Fork Paint Creek (09 04)												
Failing HSTS (bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
Ralston Run-Paint Creek (05060003 10)												
Ralston Run (10 02)												
Failing HSTS (sediment, org. enrich., bacteria)								x	x			
Agricultural row crop and livestock (bacteria)									x	x		
City of Chillicothe-Paint Creek (10 03)												
Failing HSTS (bacteria)								x	x			

10-Digit HUC (Location Description) 12-Digit HUC (Location Description) 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
Agricultural row crop and livestock (bacteria)									x	x		
Large River: Paint Creek												
Impoundment (DO, nutrients)					x				x	x		

6.1 Regulatory Recommendations

Recommendations for NPDES permits are summarized by discharger and nested subwatershed in Table 6-2. Any suggestions in permit limits reflect calculated TMDLs. Ohio EPA will work with permit holders to accomplish any needed reductions in loadings.

Table 6-2. 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 Subwatershed (05060003)	Entity	Ohio EPA Permit #	Receiving Stream	Design Flow (million gallons per day)	Wasteload Allocation (load)	Wasteload Allocation (concentration)
0102	Bloomingburg WWTP*	4PB00025	East Fork Paint Creek	0.25	1.42	1.5
0102	Valero Renewable Fuels Co Industrial	4IN00196	East Fork Paint Creek	0.758	0.287	0.1
0103	Prairie Knolls MHP	4PV00115	Paint Creek	0.01	0.114	3
0103	Washington Court House WWTP (outlet as is)*	4PD00002	Paint Creek	6	22.712	1
0201	Jeffersonville WWTP*	4PB00108	Sugar Creek	0.5	1.893	1

6.2 Headwaters Paint Creek (05060003 01)

The majority of the stream segments surveyed in this subwatershed did not meet water quality criteria for either aquatic life use or recreation use. In fact, only one of thirteen sites met the recreation use standards, and four of thirteen fully met the aquatic life use standards. Nearly half of the 13 sites were adversely impacted by excessive fine sediment and low dissolved oxygen concentrations and about one-fourth of the 13 sites each suffered from nutrient enrichment, poor habitat quality and altered flow conditions. In the majority of cases (seven of thirteen sites) cropland is a source of the water quality problems. Livestock farming, channel maintenance and urban runoff were the sources of impacts to about one-fourth of the sites and waste water quality was poor enough to cause localized aquatic life use impairment at one of the thirteen sites.

In-stream concentrations of nitrates are relatively high averaging well above 2.0 mg/l at nearly every sampling location within the ten-digit HUC. Total phosphorus concentrations by contrast generally showed concentrations to be in an acceptable range averaging below 0.1 mg/l, while the molar nitrogen to phosphorus ratio strongly suggests phosphorus limited streams. However, low nutrient concentrations often reflect plant uptake of the nutrient and its assimilation in to the tissues of nuisance algae growth, which causes the stress on the stream ecosystem.

Soluble nutrient loading may be a problem as suggested by the high nitrate concentrations and in one instance of high dissolved phosphorus (however, the dissolved fraction of total phosphorus was infrequently measured in the samples collected so how much of a proportion of the total phosphorus the dissolved fraction represents is largely unknown). As such, cropland conservation that minimizes loading from the dominant pathways of soluble nutrient transport are recommended, namely practices that provide hydraulic retention and nutrient assimilation such as controlled drainage and wetland creation/restoration.

Controlling sediment losses from cropland is also a priority in this subwatershed due to the frequency at which excessive fine sediment was found in the streams and the fact that cropland is such a significant land use (86.2 percent of the area). Due to the relatively low soil slopes, controlling gulley erosion is a lower priority than controlling sheet erosion and transport to streams. Practices that provide year round cover to crop fields (cover cropping, mulches and residues) and stream side filter areas are therefore recommended. However, based on aerial photography, there are some discrete areas where gulley erosion appears to be problematic. In fields just north of State Route 41 and east of Inskeep Road, gullies are visible and the immediate downstream site on Paint is impaired by sediment and low dissolved oxygen.

In-stream sources of sediment (i.e., bed and bank erosion) are often associated with poor floodplain function (i.e., resulting from incision or channelization) and lack of bank protections (e.g., absent or shallow rooted vegetation along the banks), and is likely to be relevant in this watershed. In fact, there is a significant indication of this observed from aerial photography from 2006, between river miles 96 and 97 on Paint Creek (between Charleston-Chillicothe Rd and Fralick Rd and north of State Route 323) where there appears to be significant bank erosion in a stream side pasture. This issue persists through nearly 0.7 river miles. Channel restoration and bio-engineering along the banks are possible options to address these sources of sediment.

Other recommended steps include reducing nutrient inputs on the landscape. This is relevant to the predominantly cropland areas in the northern portion of the watershed (i.e., the 01, 02, 03, and 04 twelve-digit HUCs). Nutrient management predicated on agronomic need determined through soil testing and/or reasonable estimations based on professional judgment of crop advisors is recommended to supplant application rates where additional fertilizer is applied to ensure that crop yields are not limited by unavailability of nutrients.

Home septic systems, are the most likely and dominant source of bacteria loading to the stream system. Identification of areas that are the most problematic and steps that would foster upgrades and improvements to such systems are recommended.

Table 6-3. Recommended implementation actions for the 01 ten-digit HUC.

Restoration Categories		Specific Restoration Actions	Headwaters Paint Creek (05060003 01)		
			Headwaters Paint Creek (01 01)	East Fork Paint Creek (01 02)	Town of Washington Court House-Paint Creek (01 03)
Bank & Riparian Restoration	constructed	Restore streambank using bio-engineering	x		
		Restore streambank by recontouring or regrading	x	x	
	planted	Plant grasses in riparian areas	x	x	x
		Plant prairie grasses in riparian areas	x	x	x
		Remove/treat invasive species			
		Plant trees or shrubs in riparian areas	x	x	x
Stream Restoration		Restore flood plain	x	x	x
		Restore stream channel		x	x
		Install in-stream habitat structures			
		Install grade structures			
		Construct 2-stage channel	x	x	x
		Restore natural flow		x	x
Wetland Restoration		Reconnect wetland to stream			
		Reconstruct & restore wetlands			x
		Plant wetland species			
Conservation Easements		Acquire conservation easements			
Dam Modification or Removal		Remove dams			
		Modify dams			
		Remove associated dam support structures			
		Install fish passage and/or habitat structures			
		Restore natural flow			
Levee or Dike Modification or Removal		Remove levees			
		Breach or modify levees			
		Remove dikes			
		Modify dikes			

Restoration Categories		Specific Restoration Actions	Headwaters Paint Creek (05060003 01)		
			Headwaters Paint Creek (01 01)	East Fork Paint Creek (01 02)	Town of Washington Court House-Paint Creek (01 03)
		Restore natural flood plain function			
Abandoned Mine Land Reclamation	treatment	Construct lime dosers			
		Install slag leach beds			
		Install limestone leach beds			
		Install limestone channels			
		Install successive alkalinity producing systems			
		Install settling ponds			
		Construct acid mine drainage wetland			
	flow diversion	Repair subsidence sites			
		Reclaim pit impoundments			
		Reclaim abandoned mine land			
		Eliminate stream captures			
		Restore positive drainage			
		Cover toxic mine spoils			
Home Sewage Planning and Improvement		Develop HSTS plan	x	x	x
		Inspect HSTS	x	x	x
		Repair or replace traditional HSTS	x	x	x
		Repair or replace alternative HSTS	x	x	x
Education and Outreach		Host meetings, workshops, and/or other events	x	x	x
		Distribute educational materials	x	x	x
Agricultural Best Management Practices	farmland	Plant cover/manure crops	x	x	x
		Implement conservation tillage practices	x	x	x
		Implement grass/legume rotations	x	x	x
		Convert to permanent hayland	x	x	x
		Install grassed waterways		x	x
		Install vegetated buffer strips	x	x	x
		Install / restore wetlands	x	x	x
	nutrients / agro-chemicals	Conduct soil testing	x	x	x
		Install nitrogen reduction practices	x	x	x
		Develop nutrient management plans	x	x	x
	drainage	Install sinkhole stabilization structures			
		Install controlled drainage system	x	x	x
		Implement drainage water management	x	x	x

Restoration Categories		Specific Restoration Actions	Headwaters Paint Creek (05060003 01)		
			Headwaters Paint Creek (01 01)	East Fork Paint Creek (01 02)	Town of Washington Court House-Paint Creek (01 03)
		Construct overwide ditch		x	x
		Construct 2-stage channel		x	x
	livestock	Implement prescribed & conservation grazing practices			x
	livestock	Install livestock exclusion fencing			x
	livestock	Install livestock crossings			x
	livestock	Install alternative water supplies			x
	livestock	Install livestock access lanes			
	manure	Implement manure management practices	x	x	x
	manure	Construct animal waste storage structures			
	manure	Implement manure transfer practices			
	manure	Install grass manure spreading strips	x	x	x
	misc. infrastructure and mgt	Install chemical mixing pads			
	misc. infrastructure and mgt	Install heavy use feeding pads			
	misc. infrastructure and mgt	Install erosion & sediment control structures			x
	misc. infrastructure and mgt	Install roof water management practices			
	misc. infrastructure and mgt	Install milkhouse waste treatment practices			
	misc. infrastructure and mgt	Develop whole farm management plans			
Storm Water Best Management Practices	planning	Develop/implement local ordinances/resolutions			x
Storm Water Best Management Practices	planning	Develop local comprehensive land use plans			
Storm Water Best Management Practices	construction practices	Implement erosion controls			x
Storm Water Best Management Practices	construction practices	Implement sediment controls			x
Storm Water Best Management Practices	construction practices	Implement non-sediment controls			x
Storm Water Best Management Practices	post construction practices	Reduce pollutant(s) through treatment			x
Storm Water Best Management Practices	post construction practices	Reduce pollutant(s) through flow/volume management			x
Storm Water Best Management Practices	post development/ storm water retrofit	Implement erosion controls			x
Storm Water Best Management Practices	post development/ storm water retrofit	Implement sediment controls			x
Storm Water Best Management Practices	post development/ storm water retrofit	Implement non-sediment controls			x
Storm Water Best Management Practices	post development/ storm water retrofit	Reduce pollutant(s) through treatment			x
Storm Water Best Management Practices	post development/ storm water retrofit	Reduce pollutant(s) through flow/volume management			x
Regulatory	planning	Develop long-term control plan (CSOs)			

Restoration Categories		Specific Restoration Actions	Headwaters Paint Creek (05060003 01)		
			Headwaters Paint Creek (01 01)	East Fork Paint Creek (01 02)	Town of Washington Court House-Paint Creek (01 03)
Point Source Controls (includes Storm Water, Sanitary, and Industrial)		Develop/implement local ordinances/resolutions			x
		Develop water quality management/208 plans			
	collection and new treatment	Install sewer systems in communities			
		Implement long-term control plan (CSOs)			
		Eliminate SSOs/CSOs/by-passes			
	enhanced treatment	Issue permit(s) and/or modify permit limit(s)			x
		Improve quality of effluent			x
	monitoring	Establish ambient monitoring program			
		Increase effluent monitoring			
	alternatives	Establish water quality trading			
	construction practices	Issue permit(s) and/or modify permit limit(s)			
		Implement erosion controls			
		Implement sediment controls			
		Implement non-sediment controls			
	post construction practices	Issue permit(s) and/or modify permit limit(s)			
		Reduce pollutant(s) through treatment			
		Reduce pollutant(s) through flow/volume management			
	post development/ storm water retrofit	Issue permit(s) and/or modify permit limit(s)			
		Implement erosion controls			
		Implement sediment controls			
		Implement non-sediment controls			
		Reduce pollutant(s) through treatment			
		Reduce pollutant(s) through flow/volume management			
		Reduce volume to CSOs			

6.3 Sugar Creek (05060003 02)

Three out of eight sites partially met aquatic life use water quality standards while the remaining five fully meet them. In contrast, five out of eight sites do not meet recreation use criteria. Like the headwaters of Paint Creek (i.e., 01 ten-digit HUC) the landscape is dominated by row crop production and the water quality problems that were present (with respect to aquatic life) resulted from this land use as well as wastewater discharges and livestock with access to streams. The water quality stressors of concern in this watershed are nutrients, low dissolved oxygen, poor habitat quality, and bacteria.

The Jeffersonville WWTP is the only waste water discharger in this watershed and is responsible for a large proportion of the nutrient burden in Sugar Creek and the associated impairment to the aquatic communities. Based on this annual average stream flow and the average of the calculated total phosphorus loading (based on monitoring data), the commensurate ambient stream concentration exclusively due to Jeffersonville's WWTP is 0.032 mg/l for the period of beginning of 2005 through 2008. Using the more recent time period beginning in early 2009 through 2010, the estimated ambient total phosphorus concentration is 0.024 mg/l for the average annual flow. The median and the 25th percentile flow conditions of the same concentration dataset are 0.071 and 0.184 mg/l, respectively. Similar estimates carried out for nitrate-nitrite concentrations show that under average annual stream flow the Jeffersonville WWTP contributes an effective ambient concentration of 0.21 mg/l, while the median and 25th percentile correspond to 0.61 and 1.59 mg/l, respectively.

Sediment is not listed as a cause of impairment; however, poor habitat quality is listed in association with cattle access to streams. Where cattle have direct access to streams, exclusions should be considered. In addressing cropland impacts on water quality many of the same practices discussed in reference to the 01 ten-digit HUC are recommended: reduced nutrient inputs, year round vegetative covers or plant residues, wetlands and controlled drainage, and streamside buffering. The poorly drained soils, relatively flat slopes and tendencies for soils to be somewhat hydric make wetland restoration and creation as well as controlled drainage viable practices in this watershed, generally speaking. There are substantial opportunities to provide streamside set-asides as the majority of streams and ditches have very narrow buffers. Some exceptions may apply as 2007 data suggests that above river mile 29 on Sugar Creek there are over 300 acres of Conservation Reserve Program set-asides.

Home septic systems, are the most likely and dominant source of bacteria loading to the stream system. Identification of areas that are the most problematic and steps that would foster upgrades and improvements to such systems are recommended.

Table 6-4. Recommended implementation actions for the 02 ten-digit HUC.

Restoration Categories		**Specific Restoration Actions**	**Sugar Creek (05060003 02)**	
			Headwaters Sugar Creek (02 01)	Camp Run-Sugar Creek (02 02)
Bank & Riparian Restoration	constructed	Restore streambank using bio-engineering		
		Restore streambank by recontouring or regrading	x	
	planted	Plant grasses in riparian areas	x	x
		Plant prairie grasses in riparian areas	x	x
		Remove/treat invasive species		
		Plant trees or shrubs in riparian areas	x	x
Stream Restoration		Restore flood plain		
		Restore stream channel		
		Install in-stream habitat structures		
		Install grade structures		

Restoration Categories		Specific Restoration Actions	Sugar Creek (05060003 02) Headwaters Sugar Creek (02 01)	Camp Run-Sugar Creek (02 02)
		Construct 2-stage channel		
		Restore natural flow		
Wetland Restoration		Reconnect wetland to stream		
		Reconstruct & restore wetlands	x	x
		Plant wetland species		
Conservation Easements		Acquire conservation easements		
Dam Modification or Removal		Remove dams		
		Modify dams		
		Remove associated dam support structures		
		Install fish passage and/or habitat structures		
		Restore natural flow		
Levee or Dike Modification or Removal		Remove levees		
		Breach or modify levees		
		Remove dikes		
		Modify dikes		
		Restore natural flood plain function		
Abandoned Mine Land Reclamation	treatment	Construct lime dosers		
		Install slag leach beds		
		Install limestone leach beds		
		Install limestone channels		
		Install successive alkalinity producing systems		
		Install settling ponds		
		Construct acid mine drainage wetland		
	flow diversion	Repair subsidence sites		
		Reclaim pit impoundments		
		Reclaim abandoned mine land		
		Eliminate stream captures		
		Restore positive drainage		
		Cover toxic mine spoils		
Home Sewage Planning and Improvement		Develop HSTS plan	x	x
		Inspect HSTS	x	x
		Repair or replace traditional HSTS	x	x
		Repair or replace alternative HSTS	x	x
Education and Outreach		Host meetings, workshops, and/or other events	x	x
		Distribute educational materials	x	x
Agricultural	farmland	Plant cover/manure crops	x	x

Restoration Categories		Specific Restoration Actions	Sugar Creek (05060003 02)	
			Headwaters Sugar Creek (02 01)	Camp Run-Sugar Creek (02 02)
Best Management Practices		Implement conservation tillage practices	x	x
		Implement grass/legume rotations	x	x
		Convert to permanent hayland		
		Install grassed waterways		
		Install vegetated buffer strips	x	x
		Install / restore wetlands	x	x
	nutrients / agro-chemicals	Conduct soil testing	x	x
		Install nitrogen reduction practices	x	x
		Develop nutrient management plans	x	x
	drainage	Install sinkhole stabilization structures		
		Install controlled drainage system	x	x
		Implement drainage water management	x	
		Construct overwide ditch		
		Construct 2-stage channel		
	livestock	Implement prescribed & conservation grazing practices	x	x
		Install livestock exclusion fencing	x	x
		Install livestock crossings	x	x
		Install alternative water supplies	x	x
		Install livestock access lanes		
	manure	Implement manure management practices	x	x
		Construct animal waste storage structures		
		Implement manure transfer practices	x	x
		Install grass manure spreading strips	x	x
	misc. infrastructure and mgt	Install chemical mixing pads		
		Install heavy use feeding pads		
		Install erosion & sediment control structures		
		Install roof water management practices		
		Install milkhouse waste treatment practices		
		Develop whole farm management plans		
Storm Water Best Management Practices	planning	Develop/implement local ordinances/resolutions		
		Develop local comprehensive land use plans		
	construction practices	Implement erosion controls		
		Implement sediment controls		
		Implement non-sediment controls		
	post	Reduce pollutant(s) through treatment		

Restoration Categories		Specific Restoration Actions	Sugar Creek (05060003 02) Headwaters Sugar Creek (02 01)	Camp Run-Sugar Creek (02 02)
	construction practices	Reduce pollutant(s) through flow/volume management		
	post development/ storm water retrofit	Implement erosion controls		
		Implement sediment controls		
		Implement non-sediment controls		
		Reduce pollutant(s) through treatment		
		Reduce pollutant(s) through flow/volume management		
Regulatory Point Source Controls (includes Storm Water, Sanitary, and Industrial)	planning	Develop long-term control plan (CSOs)		
		Develop/implement local ordinances/resolutions		
		Develop water quality management/208 plans		
	collection and new treatment	Install sewer systems in communities		
		Implement long-term control plan (CSOs)		
		Eliminate SSOs/CSOs/by-passes		
	enhanced treatment	Issue permit(s) and/or modify permit limit(s)	x	
		Improve quality of effluent	x	
	monitoring	Establish ambient monitoring program		
		Increase effluent monitoring		
	alternatives	Establish water quality trading		
	construction practices	Issue permit(s) and/or modify permit limit(s)		
		Implement erosion controls		
		Implement sediment controls		
		Implement non-sediment controls		
	post construction practices	Issue permit(s) and/or modify permit limit(s)		
		Reduce pollutant(s) through treatment		
		Reduce pollutant(s) through flow/volume management		
	post development/ storm water retrofit	Issue permit(s) and/or modify permit limit(s)		
		Implement erosion controls		
		Implement sediment controls		
		Implement non-sediment controls		
		Reduce pollutant(s) through treatment		
		Reduce pollutant(s) through flow/volume management		
		Reduce volume to CSOs		

6.4 Headwaters Rattlesnake Creek (05060003 03)

Four out of seventeen sites fully met aquatic life use water quality standards while the remaining thirteen were only meeting some or none of the criteria. For recreation uses only four out of sixteen sites meet minimum quality criteria. Poor habitat quality and excessive fine sediment were the dominant causes of impairment to aquatic life uses; however, organic enrichment and high ammonia concentrations were also problematic near Sabina due to loading from waste water and urban runoff.

Table 6-5. Recommended implementation actions for the 03 ten-digit HUC.

Restoration Categories		Specific Restoration Actions	Headwaters Rattlesnake Creek (05060003 03)				
			Wilson Creek (03 01)	Grassy Branch (03 02)	West Branch Rattlesnake Creek (03 03)	Headwaters Rattlesnake Creek (03 04)	Waddle Ditch-Rattlesnake Creek (03 05)
Bank & Riparian Restoration	constructed	Restore streambank using bio-engineering					
		Restore streambank by recontouring or regrading	x			x	x
	planted	Plant grasses in riparian areas	x			x	
		Plant prairie grasses in riparian areas	x		x	x	x
		Remove/treat invasive species					
		Plant trees or shrubs in riparian areas	x	x	x	x	x
Stream Restoration		Restore flood plain	x	x	x	x	x
		Restore stream channel	x	x	x	x	x
		Install in-stream habitat structures	x		x	x	x
		Install grade structures					
		Construct 2-stage channel	x	x	x	x	x
		Restore natural flow	x	x		x	x
Wetland Restoration		Reconnect wetland to stream	x	x	x	x	x
		Reconstruct & restore wetlands	x	x	x	x	x
		Plant wetland species					
Conservation Easements		Acquire conservation easements					
Dam Modification or Removal		Remove dams					
		Modify dams					
		Remove associated dam support structures					
		Install fish passage and/or habitat structures					
		Restore natural flow					
Levee or Dike Modification		Remove levees					

Restoration Categories		Specific Restoration Actions	Headwaters Rattlesnake Creek (05060003 03)				
			Wilson Creek (03 01)	Grassy Branch (03 02)	West Branch Rattlesnake Creek (03 03)	Headwaters Rattlesnake Creek (03 04)	Waddle Ditch-Rattlesnake Creek (03 05)
or Removal		Breach or modify levees					
		Remove dikes					
		Modify dikes					
		Restore natural flood plain function					
Abandoned Mine Land Reclamation	treatment	Construct lime dosers					
		Install slag leach beds					
		Install limestone leach beds					
		Install limestone channels					
		Install successive alkalinity producing systems					
		Install settling ponds					
		Construct acid mine drainage wetland					
	flow diversion	Repair subsidence sites					
		Reclaim pit impoundments					
		Reclaim abandoned mine land					
		Eliminate stream captures					
		Restore positive drainage					
		Cover toxic mine spoils					
Home Sewage Planning and Improvement		Develop HSTS plan	x		x	x	x
		Inspect HSTS	x		x	x	x
		Repair or replace traditional HSTS	x		x	x	x
		Repair or replace alternative HSTS	x		x	x	x
Education and Outreach		Host meetings, workshops, and/or other events	x		x	x	x
		Distribute educational materials	x		x	x	x
Agricultural Best Management Practices	farmland	Plant cover/manure crops	x	x	x	x	x
		Implement conservation tillage practices	x	x	x	x	x
		Implement grass/legume rotations	x	x	x	x	x
		Convert to permanent hayland	x	x	x	x	x
		Install grassed waterways			x	x	x
		Install vegetated buffer strips	x		x		x
		Install / restore wetlands		x	x		
	nutrients / agro-	Conduct soil testing					
		Install nitrogen reduction practices					

Restoration Categories		Specific Restoration Actions	Headwaters Rattlesnake Creek (05060003 03)				
			Wilson Creek (03 01)	Grassy Branch (03 02)	West Branch Rattlesnake Creek (03 03)	Headwaters Rattlesnake Creek (03 04)	Waddle Ditch-Rattlesnake Creek (03 05)
	chemicals	Develop nutrient management plans					
	drainage	Install sinkhole stabilization structures					
		Install controlled drainage system	x	x	x	x	x
		Implement drainage water management	x	x	x	x	x
		Construct overwide ditch	x	x	x	x	x
		Construct 2-stage channel	x	x	x	x	x
	livestock	Implement prescribed & conservation grazing practices				x	x
		Install livestock exclusion fencing				x	x
		Install livestock crossings					
		Install alternative water supplies				x	x
		Install livestock access lanes					
	manure	Implement manure management practices	x		x	x	x
		Construct animal waste storage structures	x		x	x	x
		Implement manure transfer practices	x		x	x	x
		Install grass manure spreading strips	x		x	x	x
	misc. infrastructure and mgt	Install chemical mixing pads					
		Install heavy use feeding pads					
		Install erosion & sediment control structures			x		
		Install roof water management practices					
		Install milkhouse waste treatment practices					
		Develop whole farm management plans					
Storm Water Best Management Practices	planning	Develop/implement local ordinances/resolutions	x				
		Develop local comprehensive land use plans					
	construction practices	Implement erosion controls					
		Implement sediment controls					
		Implement non-sediment controls	x				

Restoration Categories		Specific Restoration Actions	Headwaters Rattlesnake Creek (05060003 03)				
			Wilson Creek (03 01)	Grassy Branch (03 02)	West Branch Rattlesnake Creek (03 03)	Headwaters Rattlesnake Creek (03 04)	Waddle Ditch-Rattlesnake Creek (03 05)
	post construction practices	Reduce pollutant(s) through treatment	x				
		Reduce pollutant(s) through flow/volume management	x				
	post development/ storm water retrofit	Implement erosion controls					
		Implement sediment controls					
		Implement non-sediment controls	x				
		Reduce pollutant(s) through treatment	x				
		Reduce pollutant(s) through flow/volume management	x				
Regulatory Point Source Controls (includes Storm Water, Sanitary, and Industrial)	planning	Develop long-term control plan (CSOs)					
		Develop/implement local ordinances/resolutions					
		Develop water quality management/208 plans					
	collection and new treatment	Install sewer systems in communities					
		Implement long-term control plan (CSOs)					
		Eliminate SSOs/CSOs/by-passes	x				
	enhanced treatment	Issue permit(s) and/or modify permit limit(s)	x				
		Improve quality of effluent	x				
	monitoring	Establish ambient monitoring program					
		Increase effluent monitoring					
	alternatives	Establish water quality trading					
	construction practices	Issue permit(s) and/or modify permit limit(s)					
		Implement erosion controls					
		Implement sediment controls					
		Implement non-sediment controls					
	post construction practices	Issue permit(s) and/or modify permit limit(s)					
		Reduce pollutant(s) through treatment					
		Reduce pollutant(s) through flow/volume management					

Restoration Categories		Specific Restoration Actions	Headwaters Rattlesnake Creek (05060003 03)				
			Wilson Creek (03 01)	Grassy Branch (03 02)	West Branch Rattlesnake Creek (03 03)	Headwaters Rattlesnake Creek (03 04)	Waddle Ditch-Rattlesnake Creek (03 05)
	post development/ storm water retrofit	Issue permit(s) and/or modify permit limit(s)					
		Implement erosion controls					
		Implement sediment controls					
		Implement non-sediment controls					
		Reduce pollutant(s) through treatment					
		Reduce pollutant(s) through flow/volume management					
		Reduce volume to CSOs					

6.5 Lees Creek - Rattlesnake Creek (05060003 04)

Most of the sites surveyed in this watershed fully met aquatic life use criteria where only three out of seventeen sites were impaired. Half of the sites sampled failed to meet recreation use criteria. Organic enrichment was a problem at all three of the impaired sites and the impact on dissolved oxygen concentrations was documented at two of these three sites. Nutrients, ammonia and flow alterations are also listed as causing aquatic life impairment. Cropland is believed to be the primary source of these water quality stressors as well as cattle with direct access to streams.

Improving water quality in this watershed requires that cropland stressors are minimized and cattle are precluded stream access in some areas. Generally speaking there is little in the way of existing stream set-asides and cropland comes in close proximity to the streams and ditches in this area. Setting aside buffers will invariably abate some of the pollutant runoff to streams and provide overall benefits in reducing nutrient and organic loading from the landscape. Septic systems are another issue that needs abatement in order to achieve water quality goals.

Table 6-6. Recommended implementation actions for the 04 ten-digit HUC.

Restoration Categories		Specific Restoration Actions	Lees Creek-Rattlesnake Creek (05060003 04)				
			South Fork Lees Creek (04 01)	Lees Creek (04 03)	Walnut Creek (04 04)	Fall Creek (04 06)	Big Branch-Rattlesnake Creek (04 07)
Bank & Riparian Restoration	constructed	Restore streambank using bio-engineering					
		Restore streambank by recontouring or regrading					
	planted	Plant grasses in riparian areas	x	x	x		
		Plant prairie grasses in riparian areas	x	x	x		
		Remove/treat invasive species					
		Plant trees or shrubs in riparian areas	x	x	x		
Stream Restoration		Restore flood plain					
		Restore stream channel					
		Install in-stream habitat structures					
		Install grade structures					
		Construct 2-stage channel					
		Restore natural flow		x			
Wetland Restoration		Reconnect wetland to stream					
		Reconstruct & restore wetlands					
		Plant wetland species					
Conservation Easements		Acquire conservation easements					
Dam Modification or Removal		Remove dams					
		Modify dams					
		Remove associated dam support structures					
		Install fish passage and/or habitat structures					
		Restore natural flow					
Levee or Dike Modification or Removal		Remove levees					
		Breach or modify levees					
		Remove dikes					
		Modify dikes					
		Restore natural flood plain function					
Abandoned Mine Land Reclamation	treatment	Construct lime dosers					
		Install slag leach beds					
		Install limestone leach beds					
		Install limestone channels					

Restoration Categories		Specific Restoration Actions	Lees Creek-Rattlesnake Creek (05060003 04)				
			South Fork Lees Creek (04 01)	Lees Creek (04 03)	Walnut Creek (04 04)	Fall Creek (04 06)	Big Branch-Rattlesnake Creek (04 07)
		Install successive alkalinity producing systems					
		Install settling ponds					
		Construct acid mine drainage wetland					
	flow diversion	Repair subsidence sites					
	flow diversion	Reclaim pit impoundments					
	flow diversion	Reclaim abandoned mine land					
	flow diversion	Eliminate stream captures					
	flow diversion	Restore positive drainage					
	flow diversion	Cover toxic mine spoils					
Home Sewage Planning and Improvement		Develop HSTS plan	x	x	x	x	x
Home Sewage Planning and Improvement		Inspect HSTS	x	x	x	x	x
Home Sewage Planning and Improvement		Repair or replace traditional HSTS	x	x	x	x	x
Home Sewage Planning and Improvement		Repair or replace alternative HSTS	x	x	x	x	x
Education and Outreach		Host meetings, workshops, and/or other events	x	x	x		x
Education and Outreach		Distribute educational materials	x	x	x		x
Agricultural Best Management Practices	farmland	Plant cover/manure crops	x	x	x	x	x
Agricultural Best Management Practices	farmland	Implement conservation tillage practices	x	x	x	x	x
Agricultural Best Management Practices	farmland	Implement grass/legume rotations	x	x	x	x	x
Agricultural Best Management Practices	farmland	Convert to permanent hayland	x	x	x	x	x
Agricultural Best Management Practices	farmland	Install grassed waterways			x		
Agricultural Best Management Practices	farmland	Install vegetated buffer strips	x	x	x		x
Agricultural Best Management Practices	farmland	Install / restore wetlands	x	x	x		
Agricultural Best Management Practices	nutrients / agro-chemicals	Conduct soil testing	x	x	x	x	x
Agricultural Best Management Practices	nutrients / agro-chemicals	Install nitrogen reduction practices	x	x	x	x	x
Agricultural Best Management Practices	nutrients / agro-chemicals	Develop nutrient management plans	x	x	x	x	x
Agricultural Best Management Practices	drainage	Install sinkhole stabilization structures					
Agricultural Best Management Practices	drainage	Install controlled drainage system		x			
Agricultural Best Management Practices	drainage	Implement drainage water management		x			
Agricultural Best Management Practices	drainage	Construct overwide ditch					
Agricultural Best Management Practices	drainage	Construct 2-stage channel					
Agricultural Best Management Practices	livestock	Implement prescribed & conservation grazing practices				x	
Agricultural Best Management Practices	livestock	Install livestock exclusion fencing	x		x	x	x

Restoration Categories		Specific Restoration Actions	Lees Creek-Rattlesnake Creek (05060003 04)				
			South Fork Lees Creek (04 01)	Lees Creek (04 03)	Walnut Creek (04 04)	Fall Creek (04 06)	Big Branch-Rattlesnake Creek (04 07)
		Install livestock crossings				x	
		Install alternative water supplies				x	
		Install livestock access lanes					
	manure	Implement manure management practices	x		x	x	x
		Construct animal waste storage structures	x		x	x	x
		Implement manure transfer practices	x		x	x	x
		Install grass manure spreading strips	x		x	x	x
	misc. infrastructure and mgt	Install chemical mixing pads					
		Install heavy use feeding pads					
		Install erosion & sediment control structures					
		Install roof water management practices					
		Install milkhouse waste treatment practices					
		Develop whole farm management plans					
Storm Water Best Management Practices	planning	Develop/implement local ordinances/resolutions					
		Develop local comprehensive land use plans					
	construction practices	Implement erosion controls					
		Implement sediment controls					
		Implement non-sediment controls					
	post construction practices	Reduce pollutant(s) through treatment					
		Reduce pollutant(s) through flow/volume management					
	post development/ storm water retrofit	Implement erosion controls					
		Implement sediment controls					
		Implement non-sediment controls					
		Reduce pollutant(s) through treatment					
		Reduce pollutant(s) through flow/volume management					
Regulatory Point Source	planning	Develop long-term control plan (CSOs)					
		Develop/implement local ordinances/resolutions					

Restoration Categories		Specific Restoration Actions	Lees Creek-Rattlesnake Creek (05060003 04)				
			South Fork Lees Creek (04 01)	Lees Creek (04 03)	Walnut Creek (04 04)	Fall Creek (04 06)	Big Branch-Rattlesnake Creek (04 07)
Controls (includes Storm Water, Sanitary, and Industrial)		Develop water quality management/208 plans					
	collection and new treatment	Install sewer systems in communities					
		Implement long-term control plan (CSOs)					
		Eliminate SSOs/CSOs/by-passes					
	enhanced treatment	Issue permit(s) and/or modify permit limit(s)					
		Improve quality of effluent					
	monitoring	Establish ambient monitoring program					
		Increase effluent monitoring					
	alternatives	Establish water quality trading					
	construction practices	Issue permit(s) and/or modify permit limit(s)					
		Implement erosion controls					
		Implement sediment controls					
		Implement non-sediment controls					
	post construction practices	Issue permit(s) and/or modify permit limit(s)					
		Reduce pollutant(s) through treatment					
		Reduce pollutant(s) through flow/volume management					
	post development/ storm water retrofit	Issue permit(s) and/or modify permit limit(s)					
		Implement erosion controls					
		Implement sediment controls					
		Implement non-sediment controls					
		Reduce pollutant(s) through treatment					
		Reduce pollutant(s) through flow/volume management					
		Reduce volume to CSOs					

6.6 Rocky Fork (05060003 05)

Major causes of impairment include nutrient enrichment, organic enrichment, low dissolved oxygen and flow alterations. Sewer system overflows and treated wastewater from Hillsboro contributed nutrients, organic materials and bacteria causing aquatic life and recreation use impairments near their entry point to the stream system, and the associated exported nutrients aggravated excess primary production in Rocky Fork Lake. In terms of nutrients, the Hillsboro

STP contributes an average effective total phosphorus concentration of just under 0.02 mg/l at estimated average flow conditions (StreamStats - Kolton et al., 2006). The value for nitrate-nitrite is approximately 0.25 mg/l. Urban runoff from Hillsboro is also likely to be adding to the organic and nutrient loading. Cropland is a substantial land use upstream of the lake and is also a significant source of nutrients.

The City Hillsboro is currently constructing improvements to the WWTP which will eliminate wet weather overflows from the equalization (EQ) basin, and provide better wet weather treatment performance. These improvements are expected to address the water quality problems in Clear Creek identified downstream from the treatment plant, and are to be completed by the end of 2011. By reducing overflows, extreme loading of organic materials and bacteria will be substantially curtailed and will have the longer term benefit of reducing a residual load that is not immediately transported downstream and would otherwise be available for internal loading during periods when flows are lower.

Reducing total phosphorus loading from cropland would be accomplished by reducing soil losses. The relatively steep topography in this subwatershed not only increases likelihood for sheet erosion but also rill and gulley erosion from concentrated flow paths. Cover cropping, mulches, and conservation tillage are therefore almost universally appropriate in this subwatershed to mitigate rainfall energy and soil displacement associated with sheet erosion while grassed waterways should be applied in steeper areas particularly the soft valleys within crop fields. Based on topographical maps the area between Clear Creek and Hussey Run (about 1.6 square miles) and the area west of OH 73 and north of Hillsboro (about 3.5 square miles) should be a priority for ensuring that grassed waterways are installed to address erosion stemming from concentrated flow paths (in the 05-02 12-digit HUC).

Soluble nutrients such as nitrates and dissolved phosphorus are also problematic and travel to the stream system in runoff and shallow subsurface flows. Efficient use of fertilizers is probably the most effective way to ensure that nutrient loss from cropland to surface water is minimized. Additionally, since subsurface drainage is minimal in these well drained soils and there is little in the way of former wetlands and hydric soils, measures that facilitate hydraulic retention (controlled drainage and wetland creation and restoration) are less viable options for controlling nutrients and other pollutants in this watershed. However, the areas surrounding Franklin Branch upstream of where it crosses State Route 506 (within the 05-05 12 digit HUC) are almost exclusively cropland with relatively low slopes suggesting that subsurface drainage may be installed in this area. Practices promoting hydraulic retention and treatment (i.e., controlled drainage and wetlands) may be appropriate in this location.

Generally speaking, riparian areas have some existing forested buffering; however, more often than not the width of the riparian is fairly narrow and therefore is limited in its ability to sequester sediment and nutrients in runoff and shallow subsurface flow. Therefore, it is recommended to widen some of the existing buffers to facilitate more efficient pollutant removal. Also, there is a fair amount of pasture and livestock manure derived pollutants in the watershed therefore it is likely that this practice would have benefit. However, livestock is not explicitly listed anywhere as a source of impairment. It is likely that this recommendation is of lower priority than those dealing with HSTS, point sources, urban runoff and cropland drainage.

Downstream of Rocky Fork Lake the stream is impaired due to exported materials from the lake, namely seston (dead plant and algae material) and recycled nutrients. Since this lake has such public value, the best approach to alleviating both problems within the lake and the downstream receiving waters is to exercise nutrient control to the lake via the means discussed in the preceding paragraphs.

Sewage from failing home septic systems is also causing very large burden on the lake itself with the communities that have developed surrounding it. A proactive and fairly comprehensive approach to these homeowners is needed to ensure that treatment systems are operating properly so that substantial loading of bacteria, nutrients and organic material does not continue to degrade Rocky Fork Lake and its receiving waters. Based on parcel maps of Highland County, there are more than 1,600 lots with houses within a relatively short distance of the lake. In total the waste from such a number of homes can have a profound impact on water quality.

Table 6-7. Recommended implementation actions for the 05 ten-digit HUC.

Restoration Categories		Specific Restoration Actions	Rocky Fork (05060003 05)		
			Clear Creek (05 02)	Headwaters Rocky Fork (05 03)	Franklin Branch-Rocky Fork (05 05)
Bank & Riparian Restoration	constructed	Restore streambank using bio-engineering			
		Restore streambank by recontouring or regrading			
	planted	Plant grasses in riparian areas			
		Plant prairie grasses in riparian areas			
		Remove/treat invasive species			
		Plant trees or shrubs in riparian areas	x	x	x
Stream Restoration		Restore flood plain			
		Restore stream channel			
		Install in-stream habitat structures			
		Install grade structures			
		Construct 2-stage channel			
		Restore natural flow			
Wetland Restoration		Reconnect wetland to stream			
		Reconstruct & restore wetlands			x
		Plant wetland species			
Conservation Easements		Acquire conservation easements			
Dam Modification or Removal		Remove dams			
		Modify dams			
		Remove associated dam support structures			
		Install fish passage and/or habitat structures			
		Restore natural flow			
Levee or Dike Modification or Removal		Remove levees			
		Breach or modify levees			
		Remove dikes			
		Modify dikes			
		Restore natural flood plain function			

Restoration Categories		Specific Restoration Actions	Rocky Fork (05060003 05) Clear Creek (05 02)	Headwaters Rocky Fork (05 03)	Franklin Branch-Rocky Fork (05 05)
Home Sewage Planning and Improvement		Develop HSTS plan	x	x	x
		Inspect HSTS	x	x	x
		Repair or replace traditional HSTS	x	x	x
		Repair or replace alternative HSTS	x	x	x
Education and Outreach		Host meetings, workshops, and/or other events	x	x	x
		Distribute educational materials	x	x	x
Agricultural Best Management Practices	farmland	Plant cover/manure crops	x	x	x
		Implement conservation tillage practices	x	x	x
		Implement grass/legume rotations	x	x	x
		Convert to permanent hayland	x	x	x
		Install grassed waterways	x	x	x
		Install vegetated buffer strips	x	x	x
		Install / restore wetlands			x
	nutrients / agro-chemicals	Conduct soil testing	x	x	x
		Install nitrogen reduction practices	x	x	x
		Develop nutrient management plans	x	x	x
	drainage	Install sinkhole stabilization structures			
		Install controlled drainage system			x
		Implement drainage water management			
		Construct overwide ditch			
		Construct 2-stage channel			
	livestock	Implement prescribed & conservation grazing practices			
		Install livestock exclusion fencing	x	x	x
		Install livestock crossings			
		Install alternative water supplies			
		Install livestock access lanes			
	manure	Implement manure management practices	x	x	x
		Construct animal waste storage structures	x	x	x
		Implement manure transfer practices	x	x	x
		Install grass manure spreading strips	x	x	x
	misc. infrastructure and mgt	Install chemical mixing pads			
		Install heavy use feeding pads			
		Install erosion & sediment control structures			
		Install roof water management practices			
		Install milkhouse waste treatment practices			
		Develop whole farm management plans			

Restoration Categories		Specific Restoration Actions	Rocky Fork (05060003 05)		
			Clear Creek (05 02)	Headwaters Rocky Fork (05 03)	Franklin Branch-Rocky Fork (05 05)
Storm Water Best Management Practices	planning	Develop/implement local ordinances/resolutions	x		
		Develop local comprehensive land use plans	x		
	construction practices	Implement erosion controls	x		
		Implement sediment controls			
		Implement non-sediment controls			
	post construction practices	Reduce pollutant(s) through treatment			
		Reduce pollutant(s) through flow/volume management	x		
	post development/ storm water retrofit	Implement erosion controls			
		Implement sediment controls			
		Implement non-sediment controls	x		
		Reduce pollutant(s) through treatment			
		Reduce pollutant(s) through flow/volume management	x		
Regulatory Point Source Controls (includes Storm Water, Sanitary, and Industrial)	planning	Develop long-term control plan (CSOs)			
		Develop/implement local ordinances/resolutions			
		Develop water quality management/208 plans			
	collection and new treatment	Install sewer systems in communities			
		Implement long-term control plan (CSOs)			
		Eliminate SSOs/CSOs/by-passes			
	enhanced treatment	Issue permit(s) and/or modify permit limit(s)			
		Improve quality of effluent			
	monitoring	Establish ambient monitoring program			
		Increase effluent monitoring			
	alternatives	Establish water quality trading			
	construction practices	Issue permit(s) and/or modify permit limit(s)			
		Implement erosion controls			
		Implement sediment controls			
		Implement non-sediment controls			
	post construction practices	Issue permit(s) and/or modify permit limit(s)			
		Reduce pollutant(s) through treatment			
		Reduce pollutant(s) through flow/volume management			
	post development/ storm water retrofit	Issue permit(s) and/or modify permit limit(s)			
		Implement erosion controls			
		Implement sediment controls			
		Implement non-sediment controls			

Restoration Categories		Specific Restoration Actions	Rocky Fork (05060003 05) Clear Creek (05 02)	Headwaters Rocky Fork (05 03)	Franklin Branch-Rocky Fork (05 05)
		Reduce pollutant(s) through treatment			
		Reduce pollutant(s) through flow/volume management	x		
		Reduce volume to CSOs	x		

6.7 Indian Creek - Paint Creek (05060003 06)

Three out of four sites are impaired for aquatic life uses and four of six sites for recreation uses. Nutrients, primarily emanating from treated waste water, organic materials, and the deleterious impacts from discharges from a eutrophic reservoir are responsible for the aquatic life use impairments.

The focus of restoration in this ten-digit HUC should be on reducing nutrient loading to the stream system and subsequently Paint Creek Lake. Nutrient loading from point source discharges are very relevant and by themselves can result in in-stream concentrations that substantially exceed target values. Nonpoint sources of nutrients, particularly those from cropland are appropriate to address in this ten-digit HUC due to the high proportion of drainage area so used and the relative large nutrient contributions made by that type of land use.

Table 6-8. Recommended implementation actions for the 06 ten-digit HUC.

Restoration Categories		Specific Restoration Actions	Indian Creek-Paint Creek (05060003 06) Indian Creek-Paint Creek (06 01)	Farmers Run-Paint Creek (06 02)
Bank & Riparian Restoration	constructed	Restore streambank using bio-engineering		
		Restore streambank by recontouring or regrading		
	planted	Plant grasses in riparian areas		
		Plant prairie grasses in riparian areas		
		Remove/treat invasive species		
		Plant trees or shrubs in riparian areas	x	
Stream Restoration		Restore flood plain	x	
		Restore stream channel		
		Install in-stream habitat structures		
		Install grade structures		
		Construct 2-stage channel	x	
		Restore natural flow	x	

Restoration Categories		Specific Restoration Actions	Indian Creek-Paint Creek (05060003 06)	
			Indian Creek-Paint Creek (06 01)	Farmers Run-Paint Creek (06 02)
Wetland Restoration		Reconnect wetland to stream	x	
		Reconstruct & restore wetlands	x	
		Plant wetland species		
Conservation Easements		Acquire conservation easements		
Dam Modification or Removal		Remove dams		
		Modify dams		
		Remove associated dam support structures		
		Install fish passage and/or habitat structures		
		Restore natural flow		
Levee or Dike Modification or Removal		Remove levees		
		Breach or modify levees		
		Remove dikes		
		Modify dikes		
		Restore natural flood plain function		
Abandoned Mine Land Reclamation	treatment	Construct lime dosers		
		Install slag leach beds		
		Install limestone leach beds		
		Install limestone channels		
		Install successive alkalinity producing systems		
		Install settling ponds		
		Construct acid mine drainage wetland		
	flow diversion	Repair subsidence sites		
		Reclaim pit impoundments		
		Reclaim abandoned mine land		
		Eliminate stream captures		
		Restore positive drainage		
		Cover toxic mine spoils		
Home Sewage Planning and Improvement		Develop HSTS plan	x	x
		Inspect HSTS	x	x
		Repair or replace traditional HSTS	x	x
		Repair or replace alternative HSTS	x	x
Education and Outreach		Host meetings, workshops, and/or other events	x	x
		Distribute educational materials	x	x
Agricultural Best	farmland	Plant cover/manure crops	x	x
		Implement conservation tillage practices	x	x

Restoration Categories		Specific Restoration Actions	Indian Creek-Paint Creek (05060003 06)	
			Indian Creek-Paint Creek (06 01)	Farmers Run-Paint Creek (06 02)
Management Practices		Implement grass/legume rotations	x	x
		Convert to permanent hayland	x	x
		Install grassed waterways		
		Install vegetated buffer strips	x	x
		Install / restore wetlands	x	
	nutrients / agro-chemicals	Conduct soil testing	x	x
		Install nitrogen reduction practices	x	x
		Develop nutrient management plans	x	x
	drainage	Install sinkhole stabilization structures		
		Install controlled drainage system		
		Implement drainage water management	x	
		Construct overwide ditch		
		Construct 2-stage channel		
	livestock	Implement prescribed & conservation grazing practices		
		Install livestock exclusion fencing	x	x
		Install livestock crossings		
		Install alternative water supplies		
		Install livestock access lanes		
	manure	Implement manure management practices	x	x
		Construct animal waste storage structures	x	x
		Implement manure transfer practices	x	x
		Install grass manure spreading strips	x	x
	misc. infrastructure and mgt	Install chemical mixing pads		
		Install heavy use feeding pads		
		Install erosion & sediment control structures		
		Install roof water management practices		
		Install milkhouse waste treatment practices		
		Develop whole farm management plans		
Storm Water Best Management Practices	planning	Develop/implement local ordinances/resolutions		
		Develop local comprehensive land use plans		
	construction practices	Implement erosion controls		
		Implement sediment controls		
		Implement non-sediment controls		
	post	Reduce pollutant(s) through treatment		

Restoration Categories		Specific Restoration Actions	Indian Creek-Paint Creek (05060003 06): Indian Creek-Paint Creek (06 01)	Indian Creek-Paint Creek (05060003 06): Farmers Run-Paint Creek (06 02)
	construction practices	Reduce pollutant(s) through flow/volume management		
	post development/ storm water retrofit	Implement erosion controls		
		Implement sediment controls		
		Implement non-sediment controls		
		Reduce pollutant(s) through treatment		
		Reduce pollutant(s) through flow/volume management		
Regulatory Point Source Controls (includes Storm Water, Sanitary, and Industrial)	planning	Develop long-term control plan (CSOs)		
		Develop/implement local ordinances/resolutions		
		Develop water quality management/208 plans		
	collection and new treatment	Install sewer systems in communities		
		Implement long-term control plan (CSOs)		
		Eliminate SSOs/CSOs/by-passes		
	enhanced treatment	Issue permit(s) and/or modify permit limit(s)		x
		Improve quality of effluent		x
	monitoring	Establish ambient monitoring program		
		Increase effluent monitoring		
	alternatives	Establish water quality trading		
	construction practices	Issue permit(s) and/or modify permit limit(s)		
		Implement erosion controls		
		Implement sediment controls		
		Implement non-sediment controls		
	post construction practices	Issue permit(s) and/or modify permit limit(s)		
		Reduce pollutant(s) through treatment		
		Reduce pollutant(s) through flow/volume management		
	post development/ storm water retrofit	Issue permit(s) and/or modify permit limit(s)		
		Implement erosion controls		
		Implement sediment controls		
		Implement non-sediment controls		
		Reduce pollutant(s) through treatment		
		Reduce pollutant(s) through flow/volume management		
		Reduce volume to CSOs		

6.8 Buckskin Creek - Paint Creek (05060003 07)

Two out of eight sites are impaired for aquatic life uses and five of eight sites for recreation uses. Water quality stressors identified are excessive fine sediment and elevated nutrient concentrations, low dissolved oxygen, poor habitat quality, and an altered flow regime. Cropland is listed as the source of those stressors along with stream channelization.

Home septic systems, are the most likely and dominant source of bacteria loading to the stream system. Identification of areas that are the most problematic and steps that would foster upgrades and improvements to such systems are recommended.

Table 6-9. Recommended implementation actions for the 07 ten-digit HUC.

Restoration Categories		Specific Restoration Actions	Buckskin Creek-Paint Creek (05060003 07)			
			Buckskin Creek (07 01)	Upper Twin Creek (07 02)	Lower Twin Creek (07 03)	Sulphur Lick-Paint Creek (07 03)
Bank & Riparian Restoration	constructed	Restore streambank using bio-engineering				x
		Restore streambank by recontouring or regrading				
	planted	Plant grasses in riparian areas	x			x
		Plant prairie grasses in riparian areas	x			x
		Remove/treat invasive species				
		Plant trees or shrubs in riparian areas	x			x
Stream Restoration		Restore flood plain				x
		Restore stream channel				x
		Install in-stream habitat structures				x
		Install grade structures				
		Construct 2-stage channel				
		Restore natural flow				x
Wetland Restoration		Reconnect wetland to stream	x			
		Reconstruct & restore wetlands	x			
		Plant wetland species				
Conservation Easements		Acquire conservation easements				
Dam Modification or Removal		Remove dams				
		Modify dams				
		Remove associated dam support structures				
		Install fish passage and/or habitat structures				
		Restore natural flow				
Levee or Dike Modification or Removal		Remove levees				
		Breach or modify levees				

Restoration Categories		Specific Restoration Actions	Buckskin Creek-Paint Creek (05060003 07)			
			Buckskin Creek (07 01)	Upper Twin Creek (07 02)	Lower Twin Creek (07 03)	Sulphur Lick-Paint Creek (07 03)
		Remove dikes				
		Modify dikes				
		Restore natural flood plain function				
Abandoned Mine Land Reclamation	treatment	Construct lime dosers				
		Install slag leach beds				
		Install limestone leach beds				
		Install limestone channels				
		Install successive alkalinity producing systems				
		Install settling ponds				
		Construct acid mine drainage wetland				
	flow diversion	Repair subsidence sites				
		Reclaim pit impoundments				
		Reclaim abandoned mine land				
		Eliminate stream captures				
		Restore positive drainage				
		Cover toxic mine spoils				
Home Sewage Planning and Improvement		Develop HSTS plan	x	x	x	x
		Inspect HSTS	x	x	x	x
		Repair or replace traditional HSTS	x	x	x	x
		Repair or replace alternative HSTS	x	x	x	x
Education and Outreach		Host meetings, workshops, and/or other events	x	x	x	x
		Distribute educational materials	x	x	x	x
Agricultural Best Management Practices	farmland	Plant cover/manure crops	x			x
		Implement conservation tillage practices	x			x
		Implement grass/legume rotations	x			x
		Convert to permanent hayland	x			x
		Install grassed waterways	x			x
		Install vegetated buffer strips	x	x	x	x
		Install / restore wetlands	x			x
	nutrients / agro-chemicals	Conduct soil testing	x			
		Install nitrogen reduction practices	x			
		Develop nutrient management plans	x			
	drainage	Install sinkhole stabilization structures				
		Install controlled drainage system	x			

Restoration Categories		Specific Restoration Actions	Buckskin Creek-Paint Creek (05060003 07)			
			Buckskin Creek (07 01)	Upper Twin Creek (07 02)	Lower Twin Creek (07 03)	Sulphur Lick-Paint Creek (07 03)
		Implement drainage water management	x			
		Construct overwide ditch				
		Construct 2-stage channel				
	livestock	Implement prescribed & conservation grazing practices				
	livestock	Install livestock exclusion fencing	x	x	x	x
	livestock	Install livestock crossings				
	livestock	Install alternative water supplies				
	livestock	Install livestock access lanes				
	manure	Implement manure management practices	x	x	x	x
	manure	Construct animal waste storage structures	x	x	x	x
	manure	Implement manure transfer practices	x	x	x	x
	manure	Install grass manure spreading strips	x	x	x	x
	misc. infrastructure and mgt	Install chemical mixing pads				
	misc. infrastructure and mgt	Install heavy use feeding pads				
	misc. infrastructure and mgt	Install erosion & sediment control structures				x
	misc. infrastructure and mgt	Install roof water management practices				
	misc. infrastructure and mgt	Install milkhouse waste treatment practices				
	misc. infrastructure and mgt	Develop whole farm management plans				
Storm Water Best Management Practices	planning	Develop/implement local ordinances/resolutions				
Storm Water Best Management Practices	planning	Develop local comprehensive land use plans				
Storm Water Best Management Practices	construction practices	Implement erosion controls				
Storm Water Best Management Practices	construction practices	Implement sediment controls				
Storm Water Best Management Practices	construction practices	Implement non-sediment controls				
Storm Water Best Management Practices	post construction practices	Reduce pollutant(s) through treatment				
Storm Water Best Management Practices	post construction practices	Reduce pollutant(s) through flow/volume management				
Storm Water Best Management Practices	post development/ storm water retrofit	Implement erosion controls				
Storm Water Best Management Practices	post development/ storm water retrofit	Implement sediment controls				
Storm Water Best Management Practices	post development/ storm water retrofit	Implement non-sediment controls				
Storm Water Best Management Practices	post development/ storm water retrofit	Reduce pollutant(s) through treatment				

Restoration Categories		Specific Restoration Actions	Buckskin Creek-Paint Creek (05060003 07)			
			Buckskin Creek (07 01)	Upper Twin Creek (07 02)	Lower Twin Creek (07 03)	Sulphur Lick-Paint Creek (07 03)
		Reduce pollutant(s) through flow/volume management				
Regulatory Point Source Controls (includes Storm Water, Sanitary, and Industrial)	planning	Develop long-term control plan (CSOs)				
		Develop/implement local ordinances/resolutions				
		Develop water quality management/208 plans				
	collection and new treatment	Install sewer systems in communities				
		Implement long-term control plan (CSOs)				
		Eliminate SSOs/CSOs/by-passes				
	enhanced treatment	Issue permit(s) and/or modify permit limit(s)				
		Improve quality of effluent				
	monitoring	Establish ambient monitoring program				
		Increase effluent monitoring				
	alternatives	Establish water quality trading				
	construction practices	Issue permit(s) and/or modify permit limit(s)				
		Implement erosion controls				
		Implement sediment controls				
		Implement non-sediment controls				
	post construction practices	Issue permit(s) and/or modify permit limit(s)				
		Reduce pollutant(s) through treatment				
		Reduce pollutant(s) through flow/volume management				
	post development/ storm water retrofit	Issue permit(s) and/or modify permit limit(s)				
		Implement erosion controls				
		Implement sediment controls				
		Implement non-sediment controls				
		Reduce pollutant(s) through treatment				
		Reduce pollutant(s) through flow/volume management				
		Reduce volume to CSOs				

6.9 Headwaters North Fork Paint Creek (05060003 08)

All eleven sites surveyed met aquatic life uses but only one of ten sites met recreation use standards.

Home septic systems, are the most likely and dominant source of bacteria loading to the stream system. Identification of areas that are the most problematic and steps that would foster upgrades and improvements to such systems are recommended.

Table 6-10. Recommended implementation actions for the 08 ten-digit HUC.

Restoration Categories		Specific Restoration Actions	Headwaters North Fork Paint Creek (05060003 08)			
			Thompson Creek (08 01)	Headwaters Compton Creek (08 03)	Mills Branch-Compton Creek (08 04)	Mud Run-North Fork Paint Creek (08 05)
Bank & Riparian Restoration	constructed	Restore streambank using bio-engineering				
		Restore streambank by recontouring or regrading				
	planted	Plant grasses in riparian areas				
		Plant prairie grasses in riparian areas				
		Remove/treat invasive species				
		Plant trees or shrubs in riparian areas				
Stream Restoration		Restore flood plain				
		Restore stream channel				
		Install in-stream habitat structures				
		Install grade structures				
		Construct 2-stage channel				
		Restore natural flow				
Wetland Restoration		Reconnect wetland to stream				
		Reconstruct & restore wetlands				
		Plant wetland species				
Conservation Easements		Acquire conservation easements				
Dam Modification or Removal		Remove dams				
		Modify dams				
		Remove associated dam support structures				
		Install fish passage and/or habitat structures				
		Restore natural flow				
Levee or Dike Modification or Removal		Remove levees				
		Breach or modify levees				
		Remove dikes				

Restoration Categories		Specific Restoration Actions	Headwaters North Fork Paint Creek (05060003 08)			
			Thompson Creek (08 01)	Headwaters Compton Creek (08 03)	Mills Branch-Compton Creek (08 04)	Mud Run-North Fork Paint Creek (08 05)
		Modify dikes				
		Restore natural flood plain function				
Abandoned Mine Land Reclamation	treatment	Construct lime dosers				
		Install slag leach beds				
		Install limestone leach beds				
		Install limestone channels				
		Install successive alkalinity producing systems				
		Install settling ponds				
		Construct acid mine drainage wetland				
	flow diversion	Repair subsidence sites				
		Reclaim pit impoundments				
		Reclaim abandoned mine land				
		Eliminate stream captures				
		Restore positive drainage				
		Cover toxic mine spoils				
Home Sewage Planning and Improvement		Develop HSTS plan	x	x	x	x
		Inspect HSTS	x	x	x	x
		Repair or replace traditional HSTS	x	x	x	x
		Repair or replace alternative HSTS	x	x	x	x
Education and Outreach		Host meetings, workshops, and/or other events	x	x	x	x
		Distribute educational materials	x	x	x	x
Agricultural Best Management Practices	farmland	Plant cover/manure crops				
		Implement conservation tillage practices				
		Implement grass/legume rotations				
		Convert to permanent hayland				
		Install grassed waterways				
		Install vegetated buffer strips	x	x	x	x
		Install / restore wetlands				
	nutrients / agro-chemicals	Conduct soil testing				
		Install nitrogen reduction practices				
		Develop nutrient management plans				
	drainage	Install sinkhole stabilization structures				
		Install controlled drainage system				

Restoration Categories		Specific Restoration Actions	Headwaters North Fork Paint Creek (05060003 08)			
			Thompson Creek (08 01)	Headwaters Compton Creek (08 03)	Mills Branch-Compton Creek (08 04)	Mud Run-North Fork Paint Creek (08 05)
		Implement drainage water management				
		Construct overwide ditch				
		Construct 2-stage channel				
	livestock	Implement prescribed & conservation grazing practices				
		Install livestock exclusion fencing	x	x	x	x
		Install livestock crossings				
		Install alternative water supplies				
		Install livestock access lanes				
	manure	Implement manure management practices	x	x	x	x
		Construct animal waste storage structures	x	x	x	x
		Implement manure transfer practices	x	x	x	x
		Install grass manure spreading strips	x	x	x	x
	misc. infrastructure and mgt	Install chemical mixing pads				
		Install heavy use feeding pads				
		Install erosion & sediment control structures				
		Install roof water management practices				
		Install milkhouse waste treatment practices				
		Develop whole farm management plans				
Storm Water Best Management Practices	planning	Develop/implement local ordinances/resolutions				
		Develop local comprehensive land use plans				
	construction practices	Implement erosion controls				
		Implement sediment controls				
		Implement non-sediment controls				
	post construction practices	Reduce pollutant(s) through treatment				
		Reduce pollutant(s) through flow/volume management				
	post development/ storm water retrofit	Implement erosion controls				
		Implement sediment controls				
		Implement non-sediment controls				

Restoration Categories		Specific Restoration Actions	Headwaters North Fork Paint Creek (05060003 08)			
			Thompson Creek (08 01)	Headwaters Compton Creek (08 03)	Mills Branch-Compton Creek (08 04)	Mud Run-North Fork Paint Creek (08 05)
		Reduce pollutant(s) through treatment				
		Reduce pollutant(s) through flow/volume management				
Regulatory Point Source Controls (includes Storm Water, Sanitary, and Industrial)	planning	Develop long-term control plan (CSOs)				
		Develop/implement local ordinances/resolutions				
		Develop water quality management/208 plans				
	collection and new treatment	Install sewer systems in communities				
		Implement long-term control plan (CSOs)				
		Eliminate SSOs/CSOs/by-passes				
	enhanced treatment	Issue permit(s) and/or modify permit limit(s)				
		Improve quality of effluent				
	monitoring	Establish ambient monitoring program				
		Increase effluent monitoring				
	alternatives	Establish water quality trading				
	construction practices	Issue permit(s) and/or modify permit limit(s)				
		Implement erosion controls				
		Implement sediment controls				
		Implement non-sediment controls				
	post construction practices	Issue permit(s) and/or modify permit limit(s)				
		Reduce pollutant(s) through treatment				
		Reduce pollutant(s) through flow/volume management				
	post development/ storm water retrofit	Issue permit(s) and/or modify permit limit(s)				
		Implement erosion controls				
		Implement sediment controls				
		Implement non-sediment controls				
		Reduce pollutant(s) through treatment				
		Reduce pollutant(s) through flow/volume management				
		Reduce volume to CSOs				

6.10 Little Creek – North Fork Paint Creek (05060003 09)

One out of ten sites is impaired for aquatic life uses and six of eleven sites for recreation use standards. Organic enrichment and excessive fine sediment are responsible for the impairment with failing home septic systems the most likely source for the organic materials and cropland for the sediment.

Home septic systems, are the most likely and dominant source of bacteria loading to the stream system. Identification of areas that are the most problematic and steps that would foster upgrades and improvements to such systems are recommended.

Table 6-11. Recommended implementation actions for the 09 ten-digit HUC.

Restoration Categories		Specific Restoration Actions	Little Creek-North Fork Paint Creek (05060003 09)		
			Little Creek (09 02)	Oldtown Run-North Fork Paint Creek (09 03)	Biers Run-North Fork Paint Creek (09 04)
Bank & Riparian Restoration	constructed	Restore streambank using bio-engineering			
		Restore streambank by recontouring or regrading			
	planted	Plant grasses in riparian areas	x	x	x
		Plant prairie grasses in riparian areas	x	x	x
		Remove/treat invasive species			
		Plant trees or shrubs in riparian areas	x	x	x
Stream Restoration		Restore flood plain			
		Restore stream channel			
		Install in-stream habitat structures			
		Install grade structures			
		Construct 2-stage channel			
		Restore natural flow			
Wetland Restoration		Reconnect wetland to stream			
		Reconstruct & restore wetlands			
		Plant wetland species			
Conservation Easements		Acquire conservation easements			
Dam Modification or Removal		Remove dams			
		Modify dams			
		Remove associated dam support structures			
		Install fish passage and/or habitat structures			
		Restore natural flow			
Levee or Dike Modification or Removal		Remove levees			
		Breach or modify levees			

Restoration Categories		Specific Restoration Actions	Little Creek-North Fork Paint Creek (05060003 09)		
			Little Creek (09 02)	Oldtown Run-North Fork Paint Creek (09 03)	Biers Run-North Fork Paint Creek (09 04)
		Remove dikes			
		Modify dikes			
		Restore natural flood plain function			
Abandoned Mine Land Reclamation	treatment	Construct lime dosers			
		Install slag leach beds			
		Install limestone leach beds			
		Install limestone channels			
		Install successive alkalinity producing systems			
		Install settling ponds			
		Construct acid mine drainage wetland			
	flow diversion	Repair subsidence sites			
		Reclaim pit impoundments			
		Reclaim abandoned mine land			
		Eliminate stream captures			
		Restore positive drainage			
		Cover toxic mine spoils			
Home Sewage Planning and Improvement		Develop HSTS plan	x	x	x
		Inspect HSTS	x	x	x
		Repair or replace traditional HSTS	x	x	x
		Repair or replace alternative HSTS	x	x	x
Education and Outreach		Host meetings, workshops, and/or other events	x	x	x
		Distribute educational materials	x	x	x
Agricultural Best Management Practices	farmland	Plant cover/manure crops			
		Implement conservation tillage practices			
		Implement grass/legume rotations			
		Convert to permanent hayland			
		Install grassed waterways			
		Install vegetated buffer strips	x	x	x
		Install / restore wetlands			
	nutrients / agro-chemicals	Conduct soil testing			
		Install nitrogen reduction practices			
		Develop nutrient management plans			
	drainage	Install sinkhole stabilization structures			
		Install controlled drainage system			

Restoration Categories		Specific Restoration Actions	Little Creek-North Fork Paint Creek (05060003 09)		
			Little Creek (09 02)	Oldtown Run-North Fork Paint Creek (09 03)	Biers Run-North Fork Paint Creek (09 04)
		Implement drainage water management			
		Construct overwide ditch			
		Construct 2-stage channel			
	livestock	Implement prescribed & conservation grazing practices			
		Install livestock exclusion fencing	x	x	x
		Install livestock crossings			
		Install alternative water supplies			
		Install livestock access lanes			
	manure	Implement manure management practices	x	x	x
		Construct animal waste storage structures	x	x	x
		Implement manure transfer practices	x	x	x
		Install grass manure spreading strips	x	x	x
	misc. infrastructure and mgt	Install chemical mixing pads			
		Install heavy use feeding pads			
		Install erosion & sediment control structures			
		Install roof water management practices			
		Install milkhouse waste treatment practices			
		Develop whole farm management plans			
Storm Water Best Management Practices	planning	Develop/implement local ordinances/resolutions			
		Develop local comprehensive land use plans			
	construction practices	Implement erosion controls			
		Implement sediment controls			
		Implement non-sediment controls			
	post construction practices	Reduce pollutant(s) through treatment			
		Reduce pollutant(s) through flow/volume management			
	post development/ storm water retrofit	Implement erosion controls			
		Implement sediment controls			
		Implement non-sediment controls			
		Reduce pollutant(s) through treatment			
		Reduce pollutant(s) through flow/volume management			
Regulatory	planning	Develop long-term control plan (CSOs)			

Restoration Categories		Specific Restoration Actions	Little Creek-North Fork Paint Creek (05060003 09)		
			Little Creek (09 02)	Oldtown Run-North Fork Paint Creek (09 03)	Biers Run-North Fork Paint Creek (09 04)
Point Source Controls (includes Storm Water, Sanitary, and Industrial)		Develop/implement local ordinances/resolutions			
		Develop water quality management/208 plans			
	collection and new treatment	Install sewer systems in communities			
		Implement long-term control plan (CSOs)			
		Eliminate SSOs/CSOs/by-passes			
	enhanced treatment	Issue permit(s) and/or modify permit limit(s)		x	
		Improve quality of effluent		x	
	monitoring	Establish ambient monitoring program			
		Increase effluent monitoring			
	alternatives	Establish water quality trading			
	construction practices	Issue permit(s) and/or modify permit limit(s)			
		Implement erosion controls			
		Implement sediment controls			
		Implement non-sediment controls			
	post construction practices	Issue permit(s) and/or modify permit limit(s)			
		Reduce pollutant(s) through treatment			
		Reduce pollutant(s) through flow/volume management			
	post development/ storm water retrofit	Issue permit(s) and/or modify permit limit(s)			
		Implement erosion controls			
		Implement sediment controls			
		Implement non-sediment controls			
		Reduce pollutant(s) through treatment			
		Reduce pollutant(s) through flow/volume management			
		Reduce volume to CSOs			

6.11 Ralston Run – Paint Creek (05060003 10)

One out of six sites is impaired for aquatic life uses and three of six sites for recreation use standards. Organic enrichment and excessive fine sediment are responsible for the impairment with failing home septic systems the most likely source for the organic materials and cropland for the sediment.

Home septic systems, are the most likely and dominant source of bacteria loading to the stream system. Identification of areas that are the most problematic and steps that would foster upgrades and improvements to such systems are recommended.

Table 6-12. Recommended implementation actions for the 10 ten-digit HUC.

Restoration Categories		Specific Restoration Actions	Ralston Run-Paint Creek (05060003 10)	
			Ralston Run (10 02)	City of Chillicothe-Paint Creek (10 03)
Bank & Riparian Restoration	constructed	Restore streambank using bio-engineering		
		Restore streambank by recontouring or regrading		
	planted	Plant grasses in riparian areas	x	x
		Plant prairie grasses in riparian areas	x	x
		Remove/treat invasive species		
		Plant trees or shrubs in riparian areas	x	x
Stream Restoration		Restore flood plain		
		Restore stream channel		
		Install in-stream habitat structures		
		Install grade structures		
		Construct 2-stage channel		
		Restore natural flow		
Wetland Restoration		Reconnect wetland to stream		
		Reconstruct & restore wetlands		
		Plant wetland species		
Conservation Easements		Acquire conservation easements		
Dam Modification or Removal		Remove dams		
		Modify dams		
		Remove associated dam support structures		
		Install fish passage and/or habitat structures		
		Restore natural flow		
Levee or Dike Modification or Removal		Remove levees		
		Breach or modify levees		
		Remove dikes		
		Modify dikes		
		Restore natural flood plain function		
Abandoned Mine Land Reclamation	treatment	Construct lime dosers		
		Install slag leach beds		
		Install limestone leach beds		
		Install limestone channels		
		Install successive alkalinity producing systems		
		Install settling ponds		
		Construct acid mine drainage wetland		
	flow	Repair subsidence sites		

Restoration Categories		Specific Restoration Actions	Ralston Run-Paint Creek (05060003 10): Ralston Run (10 02)	Ralston Run-Paint Creek (05060003 10): City of Chillicothe-Paint Creek (10 03)
	diversion	Reclaim pit impoundments		
		Reclaim abandoned mine land		
		Eliminate stream captures		
		Restore positive drainage		
		Cover toxic mine spoils		
Home Sewage Planning and Improvement		Develop HSTS plan	x	x
		Inspect HSTS	x	x
		Repair or replace traditional HSTS	x	x
		Repair or replace alternative HSTS	x	x
Education and Outreach		Host meetings, workshops, and/or other events	x	x
		Distribute educational materials	x	x
Agricultural Best Management Practices	farmland	Plant cover/manure crops		
		Implement conservation tillage practices		
		Implement grass/legume rotations		
		Convert to permanent hayland		
		Install grassed waterways		
		Install vegetated buffer strips	x	x
		Install / restore wetlands		
	nutrients / agro-chemicals	Conduct soil testing		
		Install nitrogen reduction practices		
		Develop nutrient management plans		
	drainage	Install sinkhole stabilization structures		
		Install controlled drainage system		
		Implement drainage water management		
		Construct overwide ditch		
		Construct 2-stage channel		
	livestock	Implement prescribed & conservation grazing practices		
		Install livestock exclusion fencing	x	x
		Install livestock crossings		
		Install alternative water supplies		
		Install livestock access lanes		
	manure	Implement manure management practices	x	x
		Construct animal waste storage structures	x	x
		Implement manure transfer practices	x	x
		Install grass manure spreading strips	x	x

Restoration Categories		Specific Restoration Actions	Ralston Run-Paint Creek (05060003 10): Ralston Run (10 02)	Ralston Run-Paint Creek (05060003 10): City of Chillicothe-Paint Creek (10 03)
	misc. infrastructure and mgt	Install chemical mixing pads		
		Install heavy use feeding pads		
		Install erosion & sediment control structures		
		Install roof water management practices		
		Install milkhouse waste treatment practices		
		Develop whole farm management plans		
Storm Water Best Management Practices	planning	Develop/implement local ordinances/resolutions		
		Develop local comprehensive land use plans		
	construction practices	Implement erosion controls		
		Implement sediment controls		
		Implement non-sediment controls		
	post construction practices	Reduce pollutant(s) through treatment		
		Reduce pollutant(s) through flow/volume management		
	post development/ storm water retrofit	Implement erosion controls		
		Implement sediment controls		
		Implement non-sediment controls		
		Reduce pollutant(s) through treatment		
		Reduce pollutant(s) through flow/volume management		
Regulatory Point Source Controls (includes Storm Water, Sanitary, and Industrial)	planning	Develop long-term control plan (CSOs)		
		Develop/implement local ordinances/resolutions		
		Develop water quality management/208 plans		
	collection and new treatment	Install sewer systems in communities		
		Implement long-term control plan (CSOs)		
		Eliminate SSOs/CSOs/by-passes		
	enhanced treatment	Issue permit(s) and/or modify permit limit(s)		
		Improve quality of effluent		
	monitoring	Establish ambient monitoring program		
		Increase effluent monitoring		
	alternatives	Establish water quality trading		
	construction practices	Issue permit(s) and/or modify permit limit(s)		
		Implement erosion controls		
		Implement sediment controls		
		Implement non-sediment controls		
	post construction practices	Issue permit(s) and/or modify permit limit(s)		
		Reduce pollutant(s) through treatment		
		Reduce pollutant(s) through flow/volume management		
	post	Issue permit(s) and/or modify permit limit(s)		

Restoration Categories		Specific Restoration Actions	Ralston Run-Paint Creek (05060003 10)	
			Ralston Run (10 02)	City of Chillicothe-Paint Creek (10 03)
	development/ storm water retrofit	Implement erosion controls		
		Implement sediment controls		
		Implement non-sediment controls		
		Reduce pollutant(s) through treatment		
		Reduce pollutant(s) through flow/volume management		
		Reduce volume to CSOs		

6.12 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.

6.12.1 Local Zoning and Regional Planning

The Mid-Ohio Regional Planning Commission (http://www.morpc.org/index.asp) is a land use planning agency that deals with development in Fayette, Ross, Madison, and Pickaway Counties within the Paint Creek watershed as well as other central Ohio counties.

6.12.2 Local Watershed Groups

The Paint Creek Watershed Project began in 1994 as a local Soil and Water Conservation District initiative to reduce erosion in the watershed. To date, they have received over 2 million dollars and had worked with multiple agencies and grassroots groups to protect the Paint Creek Watershed. The mission of the group was to work together in the Paint Creek Watershed to improve the water quality and management through best management practices and education.

The Project provides cost share to landowners and a multitude of education activities from conservation day camps to canoe floats and everyone is invited to attend. The group developed a watershed action plan that was subsequently endorsed through Ohio's watershed program. The plan is available to view at the following URL: ftp://ftp.dnr.state.oh.us/Soil_&_Water_Conservation/WatershedActionPlans/EndorsedPlans/Paint%20Creek/.

6.12.3 Other Sources of Funding and Special Projects

The Scioto Conservation Reserve Enhancement Program (CREP) made over $200 million available for incentives for farmers to set working cropland aside for conservation purposes for 10 to 15 or more years. This program was made available in early 2005 for enrollment for eligible cropland throughout the entire Scioto River watershed (over 6,000 square miles) and it enjoyed wide participation. Overall, the Paint Creek Watershed was estimated to have had about 10,000 acres enrolled within the first two years of the program. As of the year 2007, there were approximately 30,000 enrolled in the Conservation Reserve Program in general, which is about four percent of the total land area in the Paint Creek watershed.

Other sources of funding included grants based on Section 319 of the Clean Water Act for which many cropland conservation practices were installed, namely nearly 20,000 linear feet of grassed waterways; approximately 44 acres of tree plantings and over 8,500 acres of nutrient management practices. Also, 25 failing home septic systems were either replaced or improved to properly treat wastes.

6.12.4 Past and Ongoing Water Resource Evaluation

The Ohio EPA has surveyed the Paint Creek basin in 2006, and the results are captured in the report titled *Biological and Water Quality Study of the Paint Creek Watershed, 2006. Clinton, Fayette, Greene, Highland, Madison, and Ross Counties, Ohio*.

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.

6.12.5 Revision to the Improvement Strategy

The Paint Creek 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 chemical 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.

7 REFERENCES

Alexander, R.B., R.A. Smith and G.E. Schwarz. 2000. "Effect of stream channel size on the delivery of nitrogen to the Gulf of Mexico." *Nature,* 403, 758-761.

Anderson, H.A., J.F. Amrhein, P. Shubat and J. Hesse. 1993. *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory.* Published at: http://www.fish.state.pa.us/images/fisheries/fcs/pcb_fishtech.pdf.

Andoh, R.Y.G. and C. Declerck. 1997. "A cost effective approach to stormwater management? Source control and distributed storage." *Water Science Technology,* 36, 307-311.

Baer, S.G., E.R. Siler, S.L. Eggert and J.B. Wallace. 2001. "Colonization and production of macroinvertebrates on artificial substrata: upstream-downstream responses to a leaf litter exclusion manipulation." *Freshwater Biology,* 46, 347-365.

Baker, D.B., R.P. Richards, T.T. Loftus and J.W. Kramer. 2004. "A new flashiness index: Characteristics and applications to Midwestern rivers and streams." *Journal of the American Water Resource Association,* April, 503-522.

Battin, T.J., L.A. Kaplan, D. Newbold and S.P. Hendricks. 2003. "A mixing model analysis of stream solute dynamics and the contribution of a hyporheic zone to ecosystem function." *Freshwater Biology,* 48, 995-1014.

Baydack, R.K., H. Campa and J.B. Haufler, Eds. 1999. *Practical approaches to the conservation of biological diversity*. First edition. Washington, D.C.: Island Press.

Bicknell, B.R., J.C. Imhoff, J.L. Kittle, Jr., T.H. Jobes and A.S. Donigian, Jr. 2001. *Hydrological Simulation Program - Fortran (HSPF): User's Manual for Release 12*. Athens, GA: U.S. EPA National Exposure Research Laboratory, in cooperation with Reston, VA: U.S. Geological Survey, Water Resources Division.

Booth, D.B. 2005. "Challenges and prospects for restoring urban streams: a perspective from the Pacific Northwest of North America." *Journal of the North American Benthological Society,* 24, 724-737.

Brabec, E., S. Schulte and P.L. Richards. 2002. "Impervious Surfaces and Water Quality: A Review of Current Literature and Its Implications for Watershed Planning." *Journal of Planning Literature,* 16, (4), 499-514.

Chapra, S.C., G.J. Pelletier and H. Tao. 2006. *QUAL2K: A Modeling Framework for Simulating River and Stream Water Quality, Version 2.04: Documentation and Users Manual.* Medford, MA: Civil and Environmental Engineering Dept., Tufts University.

Chow, V.T., D.R. Maidment and L.W. Mays. 1988 . *Applied Hydrology*. New York, NY: McGraw-Hill Book Company.

Clarke, S.J., L. Bruce-Burgess and G. Wharton. 2003. "Linking form and function: towards an eco-hydromorphic approach to sustainable river restoration." *Aquatic Conservation – Marine and Freshwater Ecosystems,* 13, (5), 439-450.

Cossins, A.R. and K. Bowler. 1987. *Temperature biology of animals*. New York, NY: Chapman and Hall.

Crenshaw, C.L., H.M. Valett and J.R. Webster. 2002. "Effects of augmentation of coarse particulate organic matter on metabolism and nutrient retention in hyporheic sediments." *Freshwater Biology,* 47, 1820-1831.

Dai, T., R.L. Wetzel, T.R.L. Christensen and E.A. Lewis. 2000. *BasinSim 1.0: A Windows-Based Watershed Modeling Package, User's Guide*. Gloucester Point, VA: Virginia Institute of Marine Science and School of Marine Science, College of William & Mary.

Danehy, R.J., N.H. Ringler and R.J. Ruby. 1999. "Hydraulic and geomorphic influence on macroinvertebrate distribution in headwaters of a small watershed." *Journal of Freshwater Ecology*, 14, (1), 79-91.

EarthInfo, 2009. Version 2.41.

Fausey, N.R. 2004. *Comparison of Free Drainage, Controlled Drainage, and Subirrigation Water management Practices in an Ohio Lakebed Soil*. St. Joseph, MI: ASAE/CSAE Meeting Paper No. 042237.

Forshay, K.J. and E.H. Stanley. 2005. "Rapid nitrate loss and denitrification in a temperate river floodplain." *Biogeochemistry,* 75, 43-64.

Hahn, S. 1982. "Stream channelization: effects on stream fauna." *Geological Survey Circular,* 848-A, 43-49.

Haith, D.A., R. Mandel and R.S. Wu. 1992. *GWLF, Generalized Watershed Loading Functions, Version 2.0, User's Manual*. Ithaca, NY: Department of Agricultural & Biological Engineering, Cornell University.

Homer, C., C. Huang, L. Yang, B. Wylie and M. Coan. 2004. "Development of a 2001 National Land-cover Database for the United States." *Photogrammetric Engineering and Remote Sensing,* 70, 829-840.

Karr, J.R. 1991. "Biological integrity: A long-neglected aspect of water resource management." *Ecological Applications,* 1, (1), 66-84.

Kleinman, P.J.A, A.N. Sharpley, R.W. McDowell, D.N. Flaten, A.R. Bud, L. Tao, L. Bergstrom and Q. Zhu 2011. "Managing agricultural phosphorus for water quality protection: principles for progress." *Plant Soil,* 10, (1007), 11104-011.

Linsley, R.K., M.A. Kohler and J.L.H. Paulhus. 1982. *Hydrology for Engineers*. New York, NY: McGraw-Hill Book Company.

Mathias, M.E. and P. Moyle. 1992. "Wetland and aquatic habitats." *Agriculture Ecosystems and Environment,* 42, (1-2), 165-176.

Metcalf & Eddy. 1991. *Wastewater Engineering: Treatment, Disposal, Reuse*. New York, NY: McGraw-Hill, Inc.

Miltner, RJ. 2010. A Method and Rationale for Deriving Nutrient Criteria for Small Rivers and Streams in Ohio. Environmental Management. 45(4): 842-855.

U.S. EPA (United States Environmental Protection Agency – Office of Water). 1991. "Considerations in the development and implementation of biocriteria." In *Proceedings of a conference: Water Quality Standards for the 21st Century*. Publication number: 815R91100. Authors: R. Miner and D. Borton.

Mitsch, W.J. and J.G. Gosselink. 2000. *Wetlands*. Third edition. Hoboken, NJ: John Wiley and Sons, Inc.

Morgan, R.P. and S.F. Cushman. 2005. "Urbanization effects on stream fish assemblages in Maryland, USA." *Journal of the North American Benthological Society,* 24, (3), 643-655.

Mostaghimi, S., T.M Younos and U.S. Tim. 1992. "Effects of sludge and chemical fertilizer application on runoff water quality." *Water Resources Bulletin,* 28, 545-552.

Mulholland, P.J. 1992. Regulation of Nutrient Concentrations in a Temperate Forest Stream - Roles of Upland, Riparian, and In-stream Processes. Limnology and Oceanography 37(7): 1512-1526.

ODD (Ohio Department of Development – Office of Strategic Research). 2003. *Projected Population: County Totals*. Published on: http://www.development.ohio.gov/research/FILES/P200/countytotals.pdf.

ODNR (Ohio Department of Natural Resources – Division of Geological Survey). 1999. *Quaternary Geology.* GIS map data. Authors: R.R. Pavey, R.P. Goldthwait, C.S. Brockman, D.N. Hull, E.M. Swinford, and R.G. Van Horn.

Ohio EPA (Ohio Environmental Protection Agency – Division of Surface Water). 1987. *Conservative Substance Wasteload Allocation Program (CONSWLA)*. Published in: Doc. 6046m/0024m. Author: R. Crowell.

Ohio EPA (Ohio Environmental Protection Agency – Division of Surface Water). 1987. *Biological criteria for the protection of aquatic life: Volume I – the role of biological data in water quality assessments.* Published in: http://www.epa.ohio.gov/dsw/bioassess/BioCriteriaProtAqLife.aspx. Authors: C. Yoder, E. Rankin and J. DeShon.

Ohio EPA (Ohio Environmental Protection Agency – Division of Surface Water). 1987. *Biological criteria for the protection of aquatic life: Volume II – users manual for biological field assessment of Ohio surface waters*. Published in: http://www.epa.ohio.gov/dsw/bioassess/BioCriteriaProtAqLife.aspx.

Ohio EPA, 2006. Total Maximum Daily Loads for the Big Darby Creek Watershed. http://www.epa.ohio.gov/portals/35/tmdl/DarbyTMDL_final_all_jan06.pdf

Ohio EPA, 2007. Biological and Water Quality Study of the Lower Little Miami River and Selected Tributaries 2007. http://epa.ohio.gov/portals/35/documents/LowerLittleMiamiRiverTSD2007.pdf

Ohio EPA. 2008. Biological and Water Quality Study of the Paint Creek Watershed, 2006. Clinton, Fayette, Greene, Highland, Madison, and Ross Counties, Ohio. 2008). http://epa.ohio.gov/portals/35/documents/PaintCreekTSD_2006_aug08.pdf

Ohio EPA (Ohio Environmental Protection Agency – Division of Surface Water). 2009 (updated from 1987). *Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices*. Published at: http://www.epa.ohio.gov/portals/35/documents/Field_Manual_1-9-09_revision.pdf.

Ohio EPA (Ohio Environmental Protection Agency – Division of Surface Water). 1989. *The qualitative habitat evaluation index (QHEI), rationale, methods, and application*. Published on: http://www.epa.ohio.gov/dsw/bioassess/BioCriteriaProtAqLife.aspx. Author: E.T. Rankin.

Ohio EPA (Ohio Environmental Protection Agency – Division of Surface Water). 1999. *Association between Nutrients, Habitat, and the Aquatic Biota of Ohio's Rivers and Streams*. Published in: Ohio EPA Technical Bulletin, MAS/1999-1-1. Authors: E. Rankin, R. Miltner, C. Yoder and D. Mishne.

Ohio EPA, 2009. Total Maximum Daily Loads for the Tuscarawas River Watershedhttp://www.epa.ohio.gov/portals/35/tmdl/TuscarawasRiverTMDL_final_jul09_wo_app.pdf

Ohio EPA (Ohio Environmental Protection Agency – Division of Surface Water). 2010. *2010 Integrated Water Quality Monitoring and Assessment Report.* Published at: http://www.epa.ohio.gov/dsw/tmdl/OhioIntegratedReport.aspx.

Ohio EPA, 2010 Total Maximum Daily Loads for the Walnut Creek Watershed. http://www.epa.ohio.gov/portals/35/tmdl/WalnutCreekTMDL_final_feb10_wo_app.pdf

Parikh, P., M.A. Taylor, T. Hoagland, H. Thurston and W. Shuster. 2005. "Application of market mechanisms and incentives to reduce stormwater runoff: and integrated hydrologic, economic a legal approach." *Environmental Science and Policy,* 8, 133-144.

Peterjohn, W.T. and D.L. Correll. 1984. "Nutrient dynamics in an agricultural watershed – observations on the role of a riparian forest." *Ecology,* 65, (5), 1466-1475.

Peterson, B.J., W.M. Wolheim, P.J. Mulholland, J.R. Webster, J.L. Meyer, J.L. Tank, E. Marti, W.B. Bowden, H.M. Valett, A.E. Hershey, W.H. McDowell, W.K. Dodds, S.K. Hamilton, S. Gregory and D.D. Morrall. 2001. "Control of nitrogen export from watersheds by headwater streams." *Science,* 292, 86-90.

Powell, G.E., A.D. Ward, D.E. Mecklenburg and A.D. Jayakaran. 2007. "Two-stage channel systems: Part 1, a practical approach for sizing agricultural ditches." *Journal of Soil and Water Conservation,* 62, (4), 277-286.

Prichard, D. 1998. *Riparian Area Management: A User Guide to Assessing Proper Functioning Condition and the Supporting Science for Lotic Areas*. Technical Reference 1737-15. Denver, CO: U.S. Department of the Interior, Bureau of Land Management, National Applied Resource Sciences Center.

Quilbé, R., C. Serreau, S. Wicherek, C. Bernard, Y. Thomas, and J.P. Oudinet. 2005. "Nutrient Transfer by Runoff from Sewage Sludge Amended Soil under Simulated Rainfall." *Environmental Monitoring and Assessment,* 100, 177-190.

Rankin, E. T. 1995. "The use of habitat indices in water resource quality assessments." In *Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making*, pp. 181- 208. Edited by W.S. Davis and T.P. Simon. Boca Raton, FL: Lewis Publishers.

Reice, S.R., R.C. Wissmar and R.J. Naiman. 1990. "Disturbance regimes, resilience and recovery of animal communities and habitats in lotic ecosystems." *Environmental Management,* 14, (5), 647-659.

Richards, R.P. and G.L. Grabow. 2003. "Detecting reductions in sediment loads associated with Ohio's Conservation Reserve Enhancement Program." *Journal of the American Water Resource Association,* October, 1261-1268.

Robinson, M. and D.W. Rycroft. 1999. "The impact of drainage on streamflow." In *Agricultural Drainage Monograph,* 38, 767-800. Edited by R.W. Skaggs and Schilfgaarde. Madison, WI: American Society of Agronomy.

Roy, A.H., A.D. Rosemond, M.J. Paul, D.S. Leigh and J.B. Wallace. 2003. "Stream macroinvertebrate response to catchment urbanisation (Georgia, U.S.A.)." *Freshwater Biology,* 48, 329-346.

Roy, A.H., M.C. Freeman, B.J. Freeman, S.J. Wenger, J.L. Meyer and W.E. Ensign. 2006. "Importance of riparian forests in urban catchments contingent on sediment and hydrologic regimes." *Environmental Management,* 37, (4), 523-539.

Rutledge, A.T. 1998. "Computer programs for describing the recession of ground-water discharge and for estimating mean ground-water recharge and discharge from streamflow data – update." *U.S. Geological Survey Water-Resources Investigations Report* (98-4148), 43 p.

Schwartz, J.S. and E.E. Herricks. 2005. "Fish use of stage-specific fluvial habitats as refude patches during a flood in a low-gradient Illinois stream." *Canadian Journal of Fisheries and Aquatic Sciences,* 62, 1540-1552.

Sharpley, A.N., S.C. Chapra, R. Wedepohl, J.T. Sim, T.C. Daniel and K.R. Reddy. 1994. "Managing agricultural phosphorus for protection of surface waters: Issues and options." *Journal of Environmental Quality,* 23, 437-451.

Sharpley A N, Daniel T C , Sims J T, Lemunyon J, Steven R A and Parry R 1999. Agricultural phosphorus and eutrophication. US Department of Agriculture —Agricultural Research Service, ARS-149 U.S. Govt. Printing Office, Washington, DC 34 p.

Simon, A. and C.R. Hupp. 1986. "Channel evolution in modified Tennessee channels." In:

Proceedings of the 4th Federal Interagency Sedimentation Conference, Las Vegas, NV. Washington, D.C.: U.S. Governmental Printing Office, 5.71-5.82.

Skalsky, D., L. Fischer, M. Eggert and J. Youger. 2000. *Reaeration Measurement Field Methodology Using the Modified Trace Technique and Analytical Methods for Determining Reaeration Coefficients* (unpublished report). Ohio Environmental Protection Agency – Division of Surface Water.

Sloto, R.A., and Crouse, M.Y., 1996, HYSEP: A computer program for streamflow hydrograph separation and analysis: U.S. Geological Survey Water-Resources Investigations Report 96-4040, 46 p.

Tetra Tech, Inc. 2009. Loading Simulation Program in C++ (LSPC) version 3.1 Fairfax, Virginia. White Paper (k): HSPF Nutrient TMDL Development Capabilities. http://rd.tetratech.com/epa/Documents/White%20Paper%20_k_%20Application%20of%20HSPF_LSPC.pdf

USDA. National Agricultural Statistics Service (NASS). 2008. http://www.nass.usda.gov/Data_and_Statistics/

USDA (United States Department of Agriculture Natural Resources Conservation Service (formerly Soil Conservation Service)). 1986. *Urban Hydrology for Small Watersheds*. Published in: Technical Release No. 55 (second edition).

USDA (United States Department of Agriculture Natural Resources Conservation Service – Soil Survey Staff). 1994. *State Soil Geographic (STATSGO)*. Published via: National Cooperative Soil Survey.

USDA (United States Department of Agriculture Natural Resources Conservation Service). 2000. *Predicting Rainfall Erosion Losses, Revised Universal Soil Loss Equation (RUSLE)*. Published in: Electronic Field Office technical Guide (http://www.nrcs.usda.gov/technical/efotg/).

USDA (United States Department of Agricultural – Agricultural Research Service). 2003. "Agricultural Phosphorus and Eutrophication, Second Edition." Published in: ARS-149. Authors: A.N. Sharpley, T. Daniel, T. Sims, J. Lemunyon, R. Stevens and R. Parry.

USDA (United States Department of Agriculture Natural Resources Conservation Service – Soil Survey Staff). 2004. *SSURGO Geographic Soil Survey*. Various counties and authors.

U.S. Census Bureau (United States Census Bureau – Population Division). 2000. *Census 2000*.

U.S. Census Bureau (United States Census Bureau – Population Division, Projections Branch). 2005. Published on: http://www.census.gov/popest/estimates.php.

U.S. EPA (United States Environmental Protection Agency – Criteria and Standards Division). 1989. *The development and use of biological criteria for Ohio surface waters*. Published in: Water Quality Stds. 21st Century, 1989: 139-146. Author: C.O. Yoder.

U.S. EPA, 1985. Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling (Second Edition) EPA#: 600/3-85-040

U.S. EPA (United States Environmental Protection Agency – Office of Water). 1991. *Answering some concerns about biological criteria based on experiences in Ohio*. Published in: Water quality standards for the 21st century: Proceedings of a National Conference. Edited by G. H. Flock. Author: C.O. Yoder.

U.S. EPA (United States Environmental Protection Agency – Office of Water (WH-553)). 1991. *Guidance for Water Quality-based Decisions: The TMDL Process*. Published in: First Edition, EPA 440/4-91-001.

U.S. EPA (United States Environmental Protection Agency). 1997. *Technical Guidance Manual for Developing Total Maximum Daily Loads, Book 2: Streams and Rivers*. Published in: EPA-823-B-97-002.

U.S. EPA (United States Environmental Protection Agency – Office of Water (4503F)). 1999. *Protocol for Developing Nutrient TMDLs*. Published in: First Edition, EPA 841-B-99-007.

U.S. EPA (United States Environmental Protection Agency – Office of Water). 2000. *Bacterial indicator tool user's guide.* Published in: EPA-823-B-01-003.

U.S. EPA (United States Environmental Protection Agency – Office of Water (4503F)). 2001. *Protocol for Developing Pathogen TMDLs*. Published in: EPA 841-R-00-002, First Edition.

U.S. EPA (United States Environmental Protection Agency – Office of Water and Office of Research and Development). 2002. *Onsite Wastewater Treatment Systems Manual*. Published in: EPA/625/R-00/008.

U.S. EPA, 2007. An Approach for Using Load Duration Curves in the Development of TMDLs. EPA 841-B-07-006

U.S. EPA. 2000. BASINS Technical Notes 6. Estimating Hydrology and Hydraulic Parameters for HSPF. United States Environmental Protection Agency. EPA-823-R00-012

U.S. EPA (United States Environmental Protection Agency). 2007. *DFLOW 3.1 – a Windows based tool developed for low flow analysis*. Published on: http://www.epa.gov/waterscience/models/dflow/.

U.S. EPA (United States Environmental Protection Agency – Office of Oceans, Wetlands and Watersheds). 2007. *An Approach for Using Load Duration Curves in the Development of TMDLs*. Published in: EPA 841-B-07-006.

U.S. EPA (United States Environmental Protection Agency – Office of Oceans, Wetlands and Watersheds). 2007. *Options for Expressing Daily Loads in TMDLs (Draft)*. Published on: http://www.epa.gov/owow/tmdl/draft_daily_loads_tech.pdf.

USGS (United States Geological Survey). 1996. *USGS Digital Raster Graphics*. EROS Data Center: http://topomaps.usgs.gov/drg/.

USGS (United States Geologic Survey). 1996. "HYSEP: A Computer Program for Streamflow Hydrograph Separation and Analysis." Published in: *Water-Resources Investigations Report 96-4040*. Authors: R.A. Sloto and M.Y. Crouse.

USGS (United States Geological Survey). 2000. *National Land Cover Dataset: Fact Sheet 108-00*. http://erg.usgs.gov/isb/pubs/factsheets/fs10800.html.

Vellidis, G., R.R. Lowrance, P. Gay, R. Hill and R.K. Hubbard. 2003. "Nutrient Transport In A Restored Riparian Wetland." *Environmental Quality,* 32, 711-726.

Wallace, J.B., S.L. Eggert, J.L. Meyer and J.R. Webster. 1997. "Multiple trophic levels of a forest stream linked to terrestrial litter inputs." *Science,* 277, 102-104.

Walsh, C.J., A.H. Roy, J.W. Feminella, P.D. Cottingham, P.M. Groffman and R.P. Morgan. 2005. "The urban stream syndrome: current knowledge and the search for the cure." *Journal of the North American Benthological Society,* 24, (3), 706-723.

Walters, D.M., D.S. Leigh, M.C. Freeman, B.J. Freeman and C.M. Pringle. 2003. "Geomorphology and fish assemblages in a Piedmont river basin, U.S.A." *Freshwater Biology,* 48, 1950-1970.

Ward, J.V. 1992. *Aquatic Insect Ecology*. Hoboken, NJ: John Wiley & Sons, Inc.

Water Environment Federation. 1999. *Prevention and control of sewer system overflows.*

Yeager, B.L. 1993. "Dams." In *Impacts on warmwater streams: Guidelines for evaluation, Second edition*. Edited by C.F. Bryan and D.A. Rutherford, pages 57-113. Little Rock, AR: Southern Division, American Fisheries Society.

Yoder, C.O. and E.T. Rankin. 1995. "The role of biological criteria in water quality monitoring, assessment, and regulation." *Environmental Regulation in Ohio: How to Cope with the Regulatory Jungle*. Santa Monica, CA: Inst. of Business Law. 54 pp.

Zhang, L. M., J.L. Morel and E. Frossard. 1990. "Phosphorus Availability in Sewage Sludges." Paris, France: *Proceedings of the First Congress of the European Society of Agronomy*.