April 2012

Ohio Environmental Protection Agency

Total Maximum Daily Loads for the Moxahala Creek Watershed

Final Report
April 4, 2012

Photo caption: Jonathan Creek at Crock Road near White Cottage.

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Acronyms and Abbreviations

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

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

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

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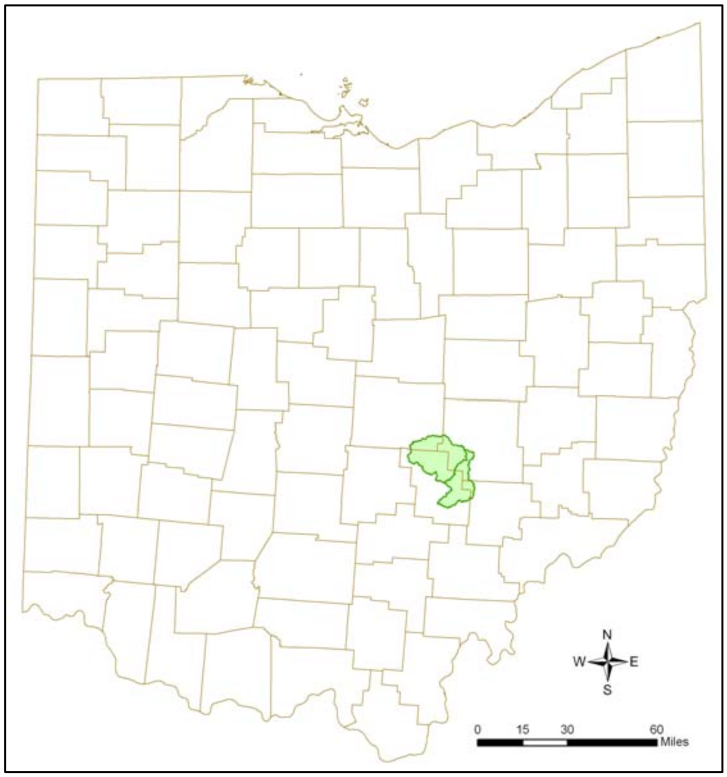
Thanks to J. T. Kneen, volunteer coordinator of the Moxahala Watershed Restoration Project, for his support and coordination in data collection, and to the Clay Valley Foundation for its support of the Moxahala Watershed Restoration Project.

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

Executive Summary

The Moxahala Creek watershed is located in southeastern Ohio extending from Thornville and near New Lexington to South Zanesville. This 302 square mile watershed area is home to more than 48,000 people and encompasses all or part of Gratiot, Crooksville, Roseville, Somerset, Thornville, Glenford, Fultonham and South Zanesville municipalities in Licking, Perry, Morgan and Muskingum counties. The watershed is primarily forested and agricultural with 1.6 percent being developed.



Map of Ohio with the Moxahala Creek watershed highlighted

In 2008, Ohio EPA sampled 47 sites on streams in this watershed. Data collected related to water and sediment quality, aquatic biological communities, and habitat. Ohio's water quality standards were compared with these data to determine if quality criteria for various designated beneficial uses are being met.

Overall the watershed met criteria for the recreation use at 27.5% of sites, 58% for aquatic life uses and 100% for the public drinking water supply use. The causes of impairments included acid mine drainage (including various metals, sulfates, pH and acidity), habitat alterations (dam), nonpoint source runoff, and failing home sewage treatment systems. Sources of these stressors include un-reclaimed coal mine land for acid mine drainage, an in-stream dam for habitat alterations, and agricultural practices for nonpoint source runoff.

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

- *Escherichia coli (E. coli)* (nutrients and dissolved oxygen use this as a surrogate)
- Temperature as a surrogate for direct habitat alterations
- Alkalinity/acidity

The needed load reductions ranged from 54 to 100% for *E. coli*, 6.36 degrees Fahrenheit for temperature and 21 to 23,005 pounds per day for acid. Sources of the pollutants that have been allocated the most significant reductions include failing home sewage treatment systems, agricultural land uses and acid mine drainage.

Recommendations for regulatory action resulting from this TMDL analysis include water quality standards-based effluent limits for *E. coli*. Nonpoint sources of *E. coli,* nutrients and dissolved oxygen issues should be addressed by home sewage planning and improvement, education and outreach and agricultural best management practices to reduce manure and fertilizer inputs to streams; for habitat alterations by removing a dam; and for acid mine drainage-related parameters by implementing some of the practices recommended in the Acid Mine Drainage Abatement and Treatment Plan.

1 INTRODUCTION

Moxahala Creek is located in Licking, Morgan and Muskingum counties and has a drainage area of 302 square miles. Jonathan Creek (a major tributary to Moxahala Creek) drains 194 of the 302 square miles. Moxahala Creek is a direct tributary of the Muskingum River, entering just south of the City of Zanesville. During 2008, Ohio EPA conducted a water resource assessment of Moxahala Creek as well as numerous tributaries to Moxahala Creek and Jonathan Creek. Predominant causes of aquatic life use impairment in the Moxahala Creek watershed included pollutants from acid mine drainage (AMD), nutrients and habitat alterations.

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 Moxahala Creek watershed (assessment units 05040004 04 01—07 and 05 01—04) as impaired on the 2010 303(d) list (Ohio EPA 2010; available at http://www.epa.ohio.gov/dsw/tmdl/2010IntReport/2010OhioIntegratedReport.aspx).

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.

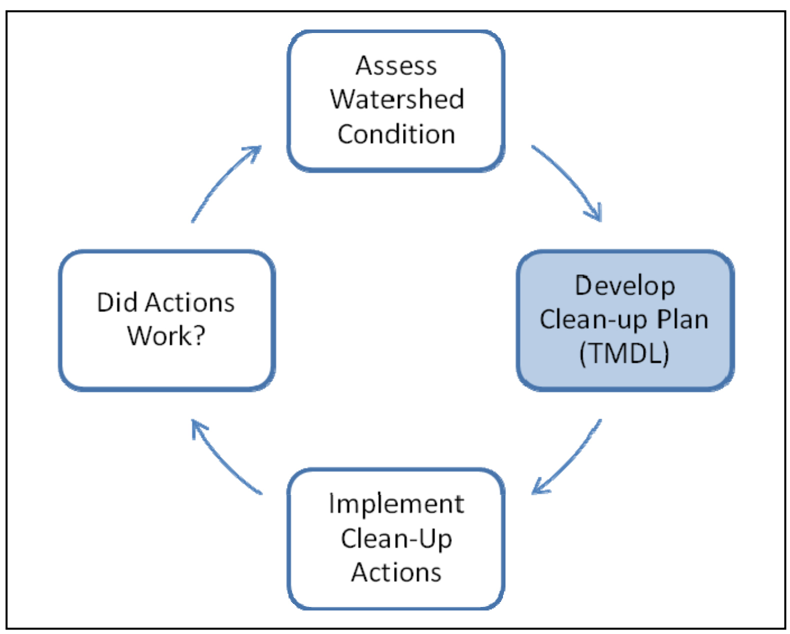


Figure 1-1. Overview of the TMDL project process.

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

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

Assessment Unit	Narrative Description	Causes of Impairment (Beneficial use in parentheses)[1]	Action Taken
Jonathon Creek (05040004 04)			
04 01 *Priority points: 7*	Valley Run	Dissolved oxygen (ALU)	*E. coli* TMDL as surrogate
		E. coli (RU)	*E. coli* TMDL
04 02 *Priority points: 4*	Headwaters Jonathon Creek	No impairment (ALU)	No action necessary
		E. coli (RU)	*E. coli* TMDL
04 03 *Priority points: 3*	Turkey Run	No impairment (ALU)	No action necessary
		E. coli (RU)	*E. coli* TMDL
04 04 *Priority points: 4*	Buckeye Fork	Aluminum (ALU)	Not addressed
		Manganese (ALU)	Not addressed
		Nickel (ALU)	Not addressed
		Sulfates (ALU)	Not addressed
		Acidity (cold titration) (ALU)	Not addressed
		No impairment (RU)	No action necessary
04 05 *Priority points: 3*	Kent Run	No impairment (ALU)	No action necessary
		E. coli (RU)	*E. coli* TMDL
		Insufficient data to assess (PDWSU)	No action necessary
04 06 *Priority points: 1*	Thompson Run	No impairment (ALU)	No action necessary
		E. coli (RU)	*E. coli* TMDL
04 07 *Priority points: 5*	Painter Creek-Jonathon Creek	Direct habitat alterations (Category 4C; ALU)	Temperature TMDL as surrogate
		E. coli (RU)	*E. coli* TMDL
		No impairment (PDWSU)	No action necessary
Moxahala Creek (05040004 05)			
05 01 *Priority points: 3*	Black Fork	Dissolved oxygen (ALU)	*E. coli* TMDL as surrogate
		Aluminum (ALU)	Acidity/alkalinity TMDL[2]
		Manganese (ALU)	Acidity/alkalinity TMDL[2]
		Sulfates (ALU)	Acidity/alkalinity TMDL[2]
		Iron (ALU)	Acidity/alkalinity TMDL[2]

Assessment Unit	Narrative Description	Causes of Impairment (Beneficial use in parentheses)[1]	Action Taken
		Acidity (cold titration) (ALU)	Acidity/alkalinity TMDL[2]
		Ammonia (total) (ALU)	*E. coli* TMDL as surrogate
		Nitrate/nitrite (nitrite+nitrate as N) (ALU)	*E. coli* TMDL as surrogate
		E. coli (RU)	*E. coli* TMDL
		No impairment (PDWSU)	No action necessary
05 02 *Priority points: 1*	Upper Moxahala Creek	pH (ALU)	Acidity/alkalinity TMDL[2]
		Aluminum (ALU)	Acidity/alkalinity TMDL[2]
		Manganese (ALU)	Acidity/alkalinity TMDL[2]
		Sulfates (ALU)	Acidity/alkalinity TMDL[2]
		Iron (ALU)	Acidity/alkalinity TMDL[2]
		Acidity (cold titration) (ALU)	Acidity/alkalinity TMDL[2]
		Nickel (ALU)	Acidity/alkalinity TMDL[2]
		No impairment (RU)	No action necessary
05 03 *Priority points: 1*	Middle Moxahala Creek	pH (ALU)	Acidity/alkalinity TMDL[2]
		Aluminum (ALU)	Acidity/alkalinity TMDL[2]
		Sulfates (ALU)	Acidity/alkalinity TMDL[2]
		Acidity (cold titration) (ALU)	Acidity/alkalinity TMDL[2]
		Nickel (ALU)	Acidity/alkalinity TMDL[2]
		No impairment (RU)	No action necessary
05 04 *Priority points: 5*	Lower Moxahala Creek	pH (ALU)	Acidity/alkalinity TMDL[2]
		Aluminum (ALU)	Acidity/alkalinity TMDL[2]
		Manganese (ALU)	Acidity/alkalinity TMDL[2]
		Sulfates (ALU)	Acidity/alkalinity TMDL[2]
		Nickel	Acidity/alkalinity TMDL[2]
		Acidity (cold titration)	Acidity/alkalinity TMDL[2]
		Ammonia (total)	*E. coli* TMDL as surrogate
		E. coli (RU)	*E. coli* TMDL

[1] ALU = aquatic life use
RU = recreation use
PDWSU = public drinking water supply use
[2] TMDLs taken from ILGARD (Institute for Local Government Administration and Rural Development; 2005).

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

A representative from the Ohio Department of Natural Resources (ODNR) Division of Mineral Resources Management (DMRM) joined Ohio EPA for the results discussion meeting in 2008 and a team progress and planning meeting in May 2011. The watershed coordinator, employed by Patriot Coal Co., also joined Ohio EPA at the results discussion meeting in 2008.

Consistent with Ohio=s current Continuous Planning Process (CPP), the draft TMDL report was available for public comment from February 15 through March 15, 2012. A copy of the draft report was posted on Ohio EPA=s web page (http://www.epa.ohio.gov/dsw/tmdl/index.aspx). Responses to comments are summarized in Appendix G of the report.

Continued public involvement is essential to the success of any TMDL project. Ohio EPA will continue to support the implementation process and will facilitate, to the fullest extent possible, restoration actions that are acceptable to the communities and stakeholders in the study area and to Ohio EPA. Ohio EPA is reluctant to rely solely on regulatory actions and strongly upholds the need for voluntary actions facilitated by the local stakeholders, watershed organization, and agency partners to restore the Moxahala 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. Appendix F contains the acid mine drainage abatement and treatment (AMDAT) plan for the Moxahala Creek subwatershed (ILGARD 2005). Appendix G contains Ohio EPA's responses to public comments.

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 Moxahala Creek watershed is located in Muskingum, Perry, Licking and Morgan counties in southeast Ohio. Moxahala Creek drains 302 square miles of land, entering the Muskingum River just south of Zanesville. Jonathan Creek is the major tributary to Moxahala Creek, draining 194 squares miles of the 302 square miles. Municipalities include Crooksville, Roseville, Fultonham, Gratiot and Glenford. Portions of Somerset and Thornville are also located within the watershed.

2.1 Watershed Characteristics

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

2.1.1 Population and Distribution

As of the U.S. Census in 2000, nearly 50,000 people in over 18,000 households lived in the Moxahala Creek watershed. Preliminary results from the 2010 U.S. Census show a small increase. The average population change projection from 2010 to 2020 of the four counties is an increase of 5% (ODD 2004).

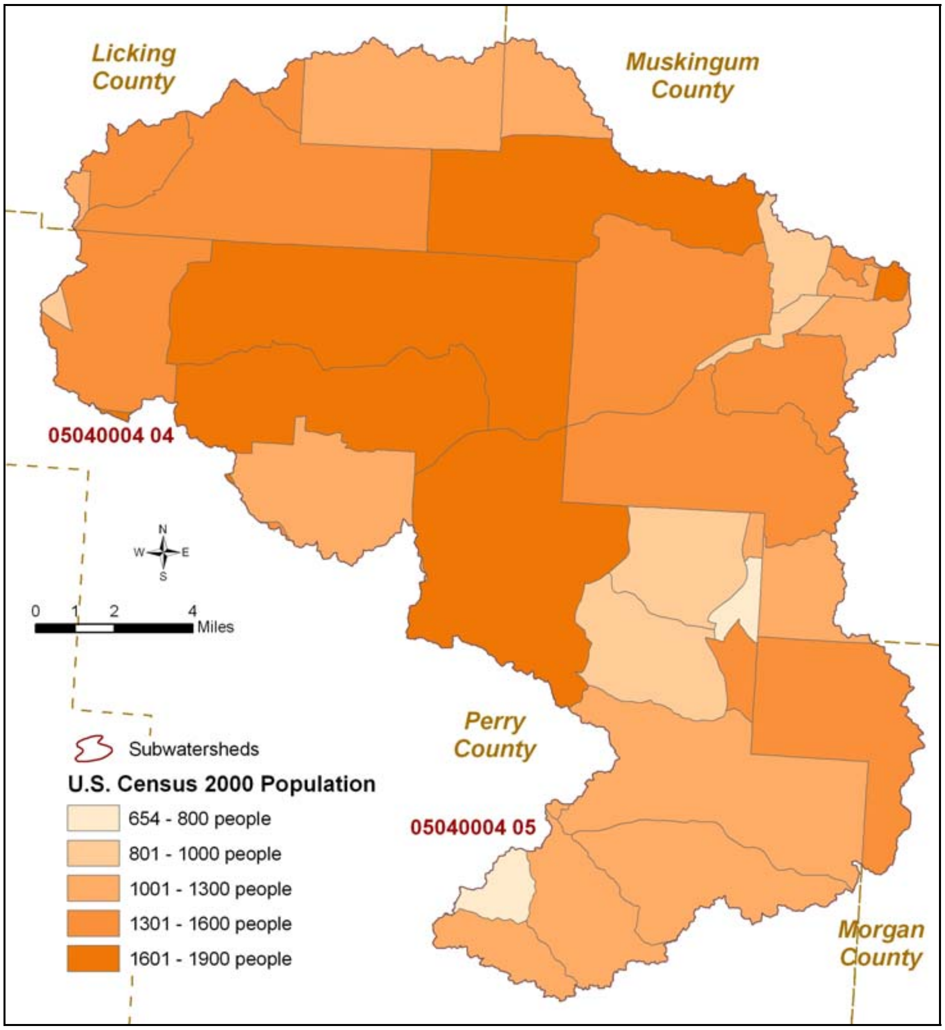


Figure 2-1. Population blocks in the watershed based on U.S. Census Bureau.

2.1.2 Land Use

The two most dominant land uses in the Moxahala Creek watershed (see Figure 2-2) are forest (55%) and agricultural land uses (22% pasture/hay and 11.7% cultivated crops). Forest is more dominant in the Moxahala Creek subwatershed (67%) than in the Jonathan Creek subwatershed (48%). Agricultural land uses were more common in the Jonathan Creek subwatershed (41%) than in the Moxahala Creek subwatershed (19%). Most of the mining that historically took place in the watershed was located toward the southern area of the watershed.

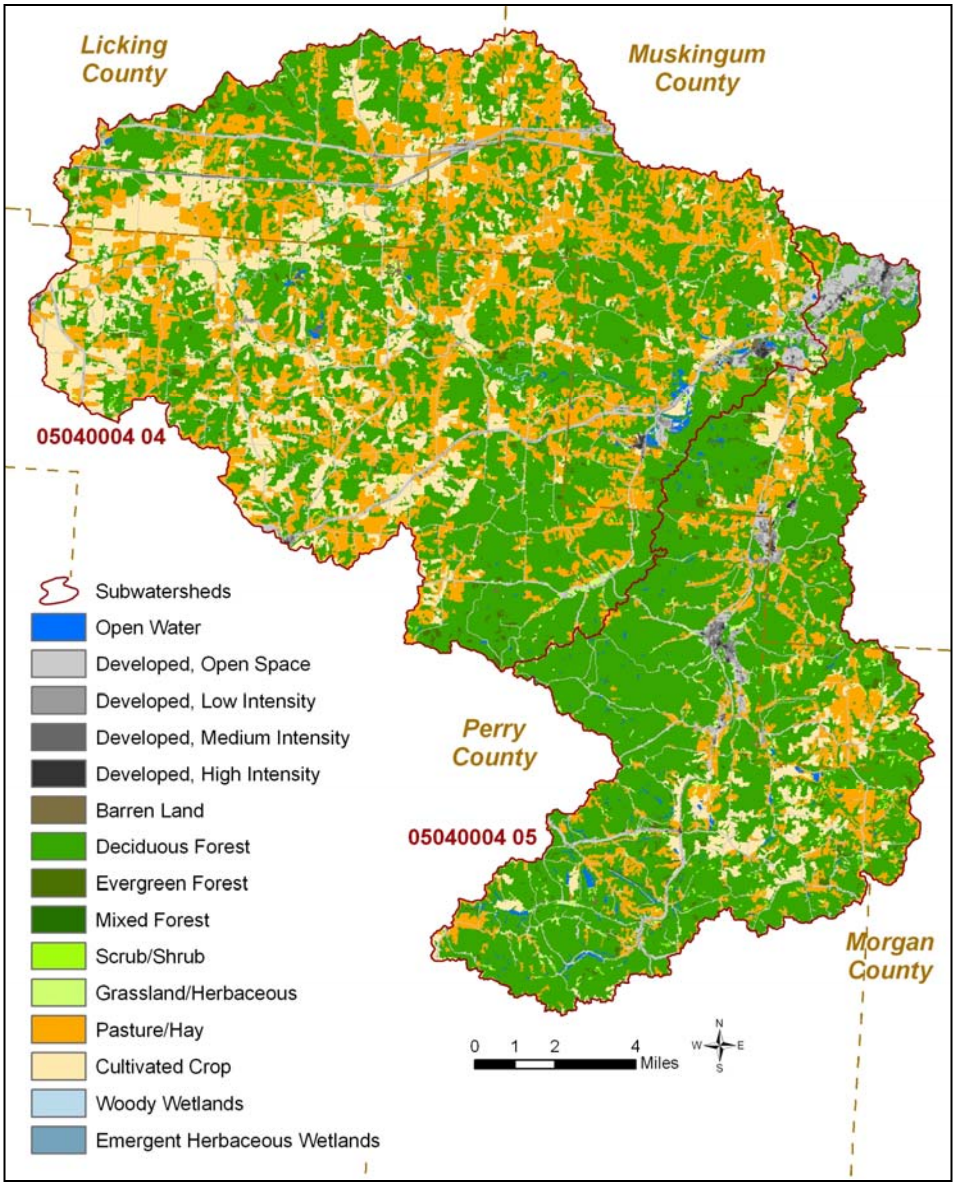


Figure 2-2. Land use in the Moxahala Creek watershed.

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 Moxahala Creek watershed.

Moxahala Creek Watershed is located in a rural area where central sanitary wastewater treatment is not common. The Villages of Roseville and Crooksville share a wastewater treatment plant with a daily design flow of 671,000 gallons per day. A total design flow of 1.37 million gallons per day (MGD) of sanitary wastewater can be treated throughout the watershed with primarily small extended aeration treatment plants treating the rest. Industrial wastewater is comprised of three drinking water plants' waste water and a silica quarry's waste water, totaling 0.71 MGD of daily design flow. The other industrial facility discharges are mostly comprised of storm water.

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 Village of Maysville are located in the Moxahala 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 are assigned in rules 3745-1-08 to 3745-1-32. Attainment of uses is based on specific numeric and narrative criteria.

Numeric criteria are estimations of chemical concentrations, degree of aquatic life toxicity, and physical conditions 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 Moxahala 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. Figure 2-3 shows applicable aquatic life uses in the Moxahala Creek watershed; Table 2-1 shows biocriteria for those uses.

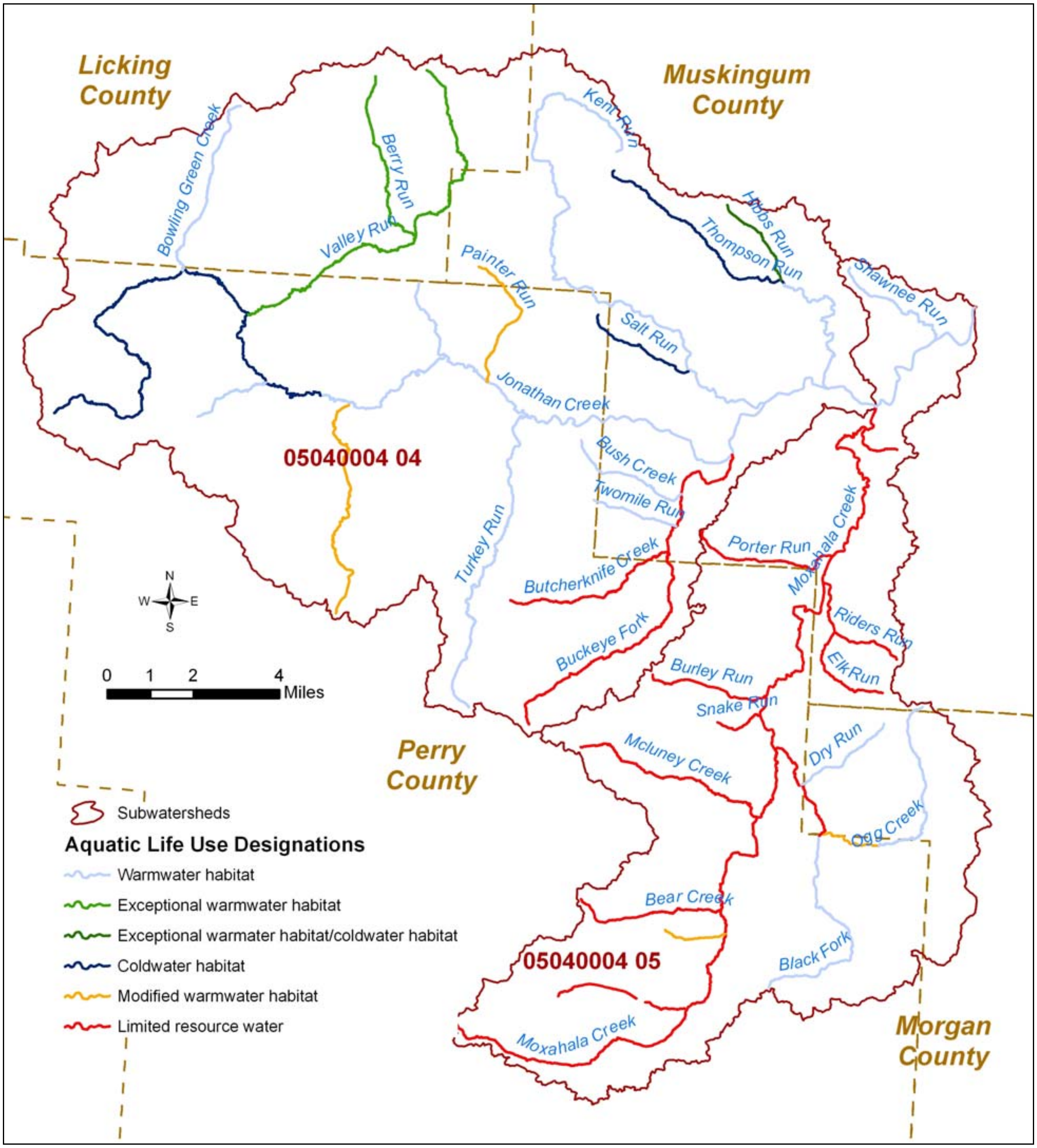


Figure 2-3. Aquatic life use designations in the Moxahala Creek watershed.

Table 2-1. Biological criteria applicable in the Moxahala Creek watershed.

Ecoregion	Biological Index	Assessment Method[2, 3]	Biological Criteria for the Applicable Aquatic Life Use Designations[1]		
			WWH	EWH	MWH[4]
Erie-Ontario Lake Plains (EOLP)	IBI	Headwater	40	50	24
		Wading	38	50	24
		Boat	40	48	24 / 30
	MIwb	Wading	7.9	9.4	6.2
		Boat	8.7	9.6	5.8 / 6.6
	ICI	All[5]	34	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), limited 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.

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.

Figure 2-4 shows the recreation use of designated streams in the Moxahala Creek watershed. Table 2-2 shows Ohio's recreation use criteria for *Escherichia coli* (*E. coli*).

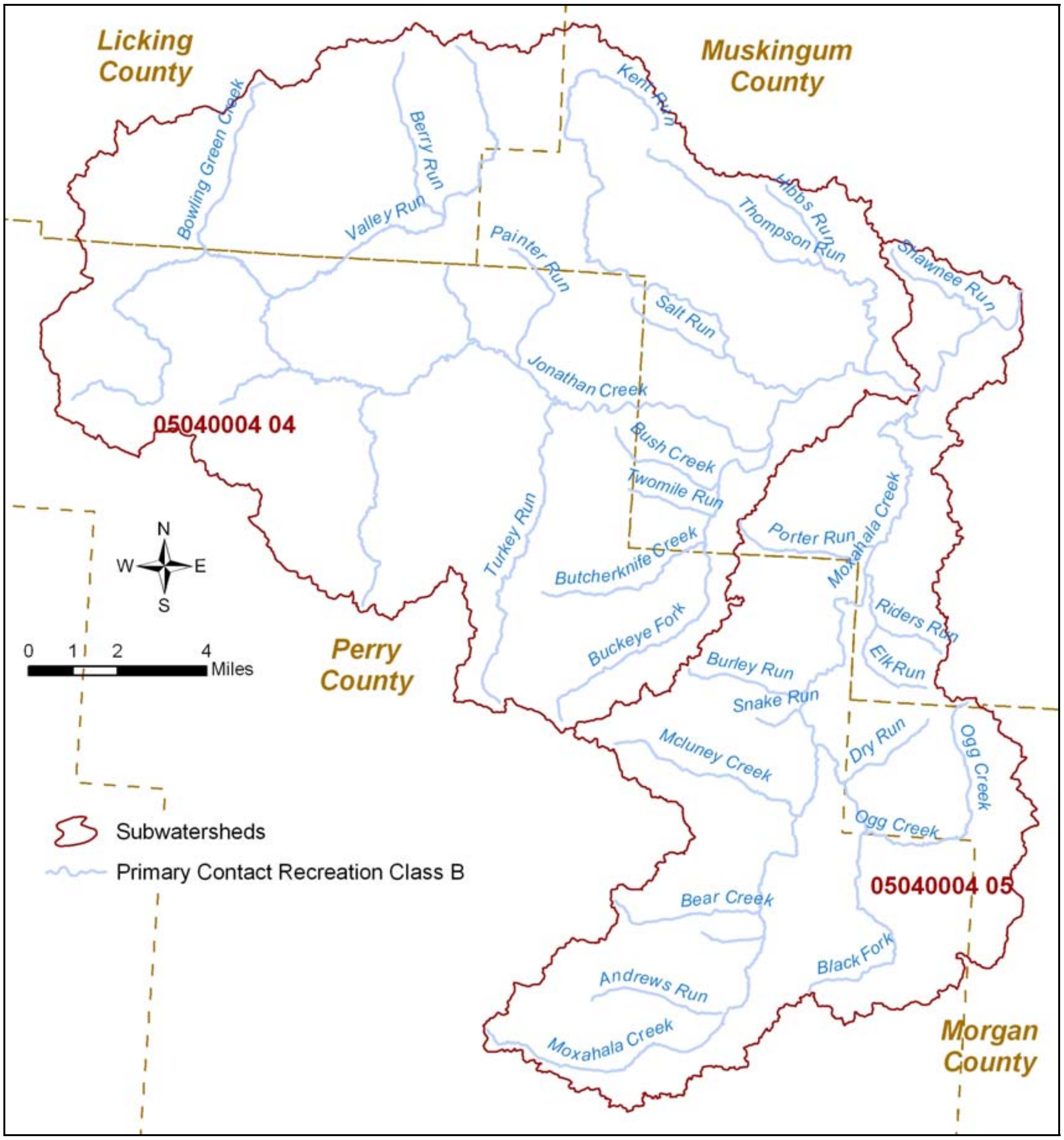


Figure 2-4. Recreation use designations in the Moxahala Creek watershed.

Table 2-2. Recreation use criteria in Ohio.

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

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

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

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. Figure 2-5 shows public drinking water supply intakes in the watershed.

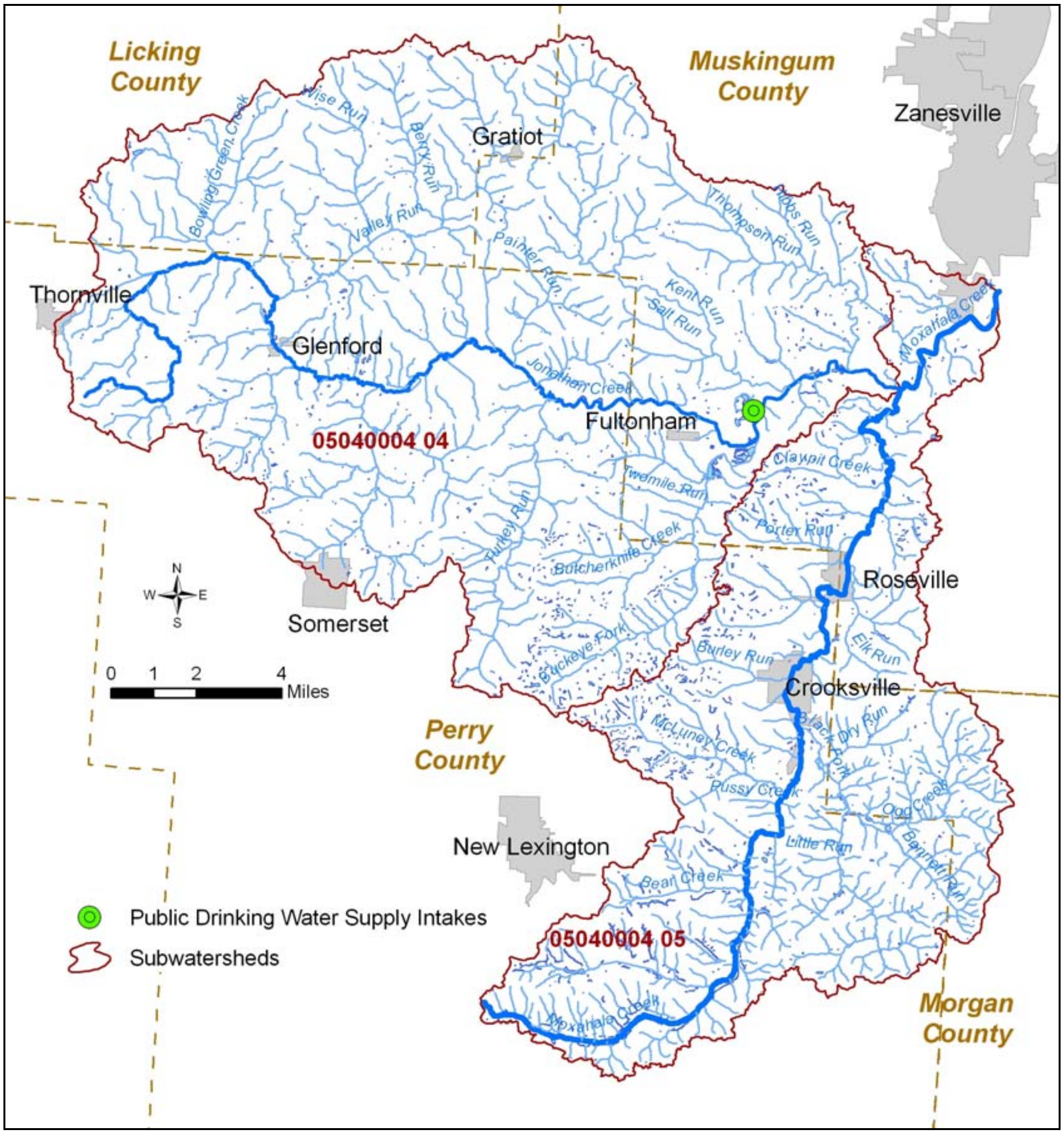


Figure 2-5. Public drinking water supply intakes in the Moxahala Creek watershed.

2.2.4 Human Health (Fish Contaminants) Use

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

Fish tissue data were collected in only one nested subwatershed of the Moxahala Creek watershed. There were not sufficient data to assess support of the human health use support in that nested subwatershed.

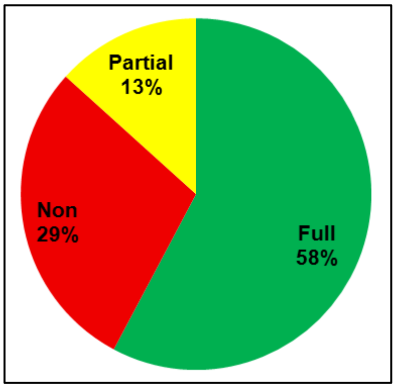
The Moxahala Creek watershed is included in the statewide fish advisory for mercury. Additional advisories specific to the Moxahala Creek watershed do not exist. Information regarding fish consumption advisories can be found at: http://www.epa.ohio.gov/dsw/fishadvisory/index.aspx.

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 Moxahala Creek watershed in 2008. Forty-six sites were studied for biological health, 40 sites for water chemistry, 43 sites for recreation use, and zero sites for human health (fish contaminants) use. Sites were scattered throughout the watershed, though more sites were sampled in the Jonathan Creek subwatershed since previous work had been completed in Moxahala Creek. Please refer to Appendix B for more detail.



Overall, the Moxahala Creek watershed is mostly meeting the aquatic life goal of the Clean Water Act (see pie chart). Due to the extensive impacts from historic mining, none of the six sites on the Moxahala Creek mainstem are meeting the LRW-AMD aquatic life use designation. The biological community performance was mostly fair to very poor in the Moxahala subwatershed. In contrast, seven of the eight sites on the Jonathan Creek mainstem were meeting the WWH aquatic life use designation. The majority of the sites in the Jonathan Creek subwatershed had a biological community performance of good to excellent.

The Moxahala Creek watershed TMDL includes two subwatersheds (Figure 3-1). Within each of the two subwatersheds, smaller watersheds are nested (12-digit assessment units). This chapter discusses conditions in each of the subwatersheds with detail added in unique nested subwatersheds. Overall, impairment for aquatic life and recreation uses was more common in the southern portion of the watershed. Non-attainment of biological criteria was caused by a variety of metals, nutrients and acidity, primarily from acid mine drainage and coal mining sources. Partial attainment in the Jonathan Creek subwatershed was caused by acidity and metals from acid mine drainage and by habitat alterations from channelization and low dissolved oxygen from a dam impoundment.

Figure 3-1. Map of the Moxahala Creek watershed.

3.1 Jonathan Creek (05040004 04)

The Jonathan Creek subwatershed drains 194 square miles in the northern portion of the watershed (see Figure 3-2). It consists of seven nested subwatersheds. The main tributaries to Jonathan Creek include Buckeye Run, Salt Run, Valley Run and Painter Creek. Major causes of impairment include direct habitat alterations, low dissolved oxygen, metals, acid, sulfates and bacteria. Those causes are primarily associated with a dam or impoundment, home sewage treatment systems (HSTS) and nonpoint sources, and acid mine drainage and coal mining.

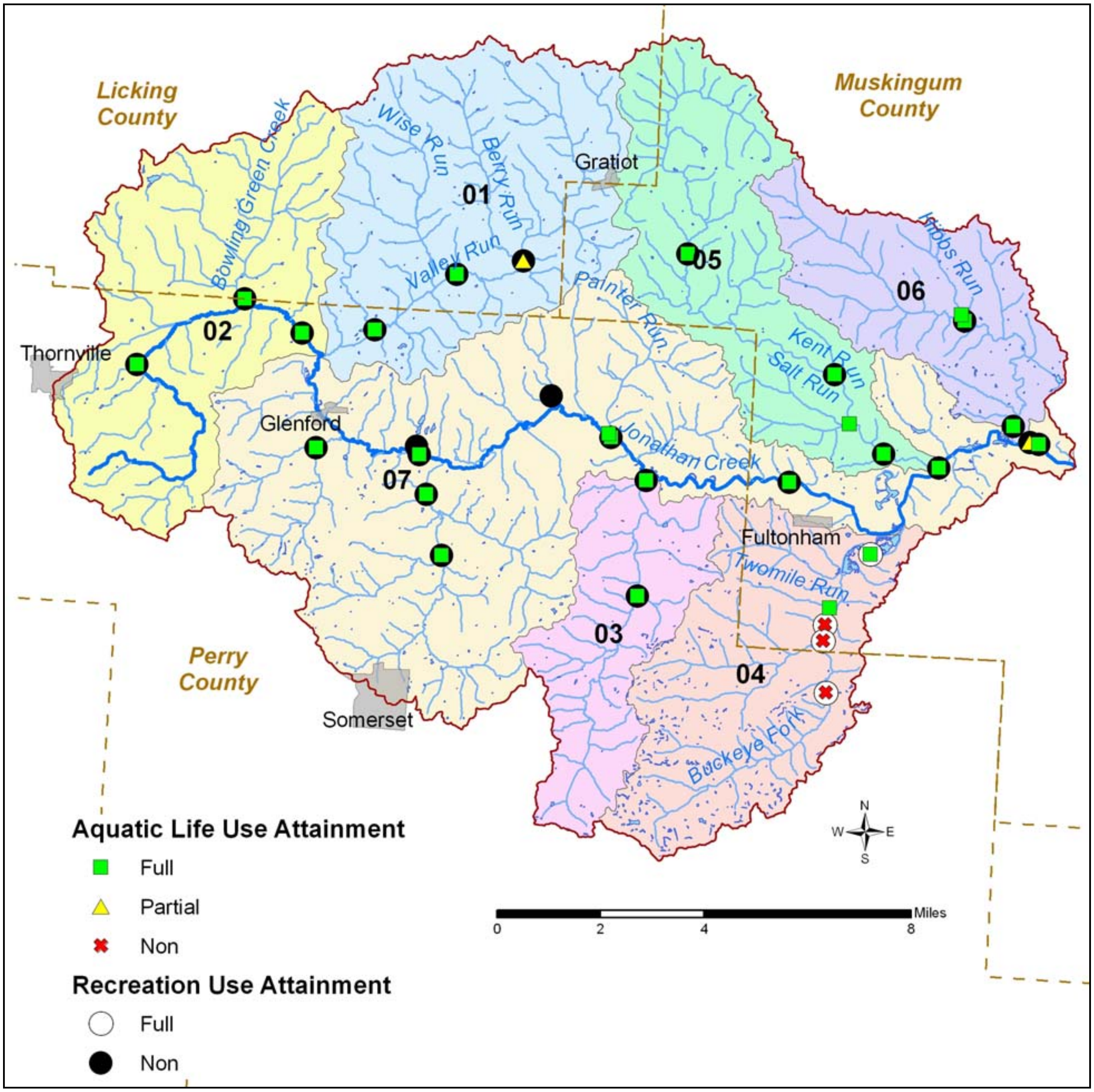


Figure 3-2. Attainment results for the Jonathan Creek subwatershed.

In most cases, these causes are associated with land uses in the subwatershed (see Appendix C for further information). Figure 3-3 shows land use within the Jonathan Creek subwatershed.

Jonathan Creek is a major tributary to Moxahala Creek encompassing two-thirds of the total Moxahala Creek watershed. Twelve tributaries to Jonathan Creek were sampled during the survey. The Jonathan Creek subwatershed is sparsely populated with forested hills and agricultural areas dominating the valleys. There are no large cities within the watershed but there are a several small villages spread throughout subwatershed.

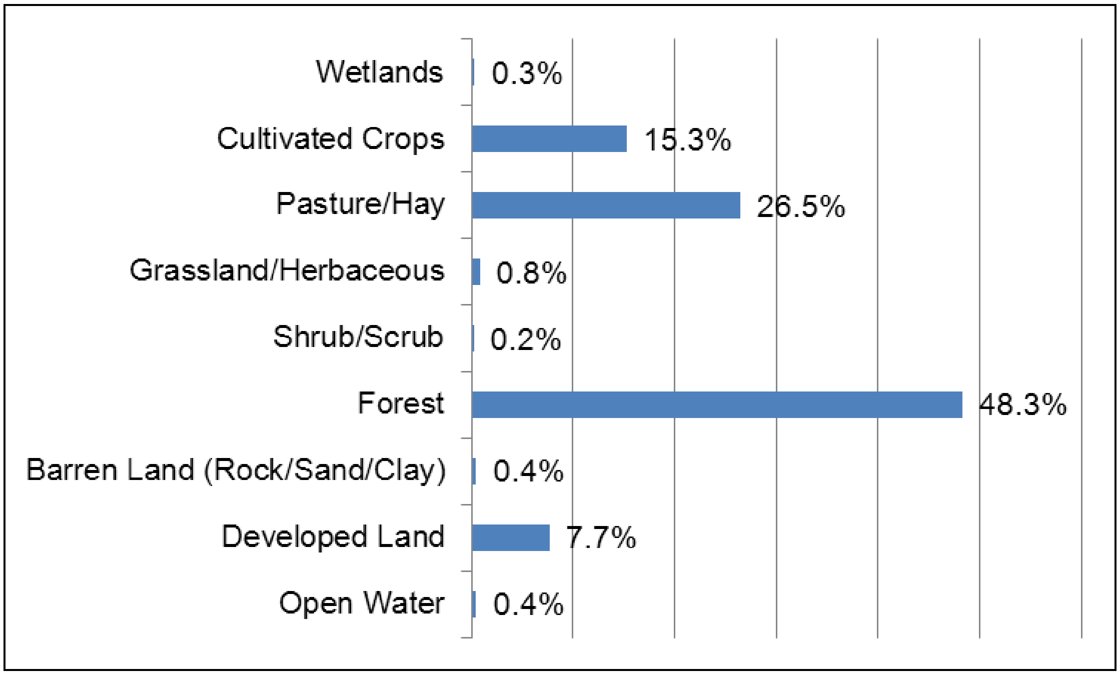


Figure 3-3. Land use in the Jonathan Creek subwatershed.

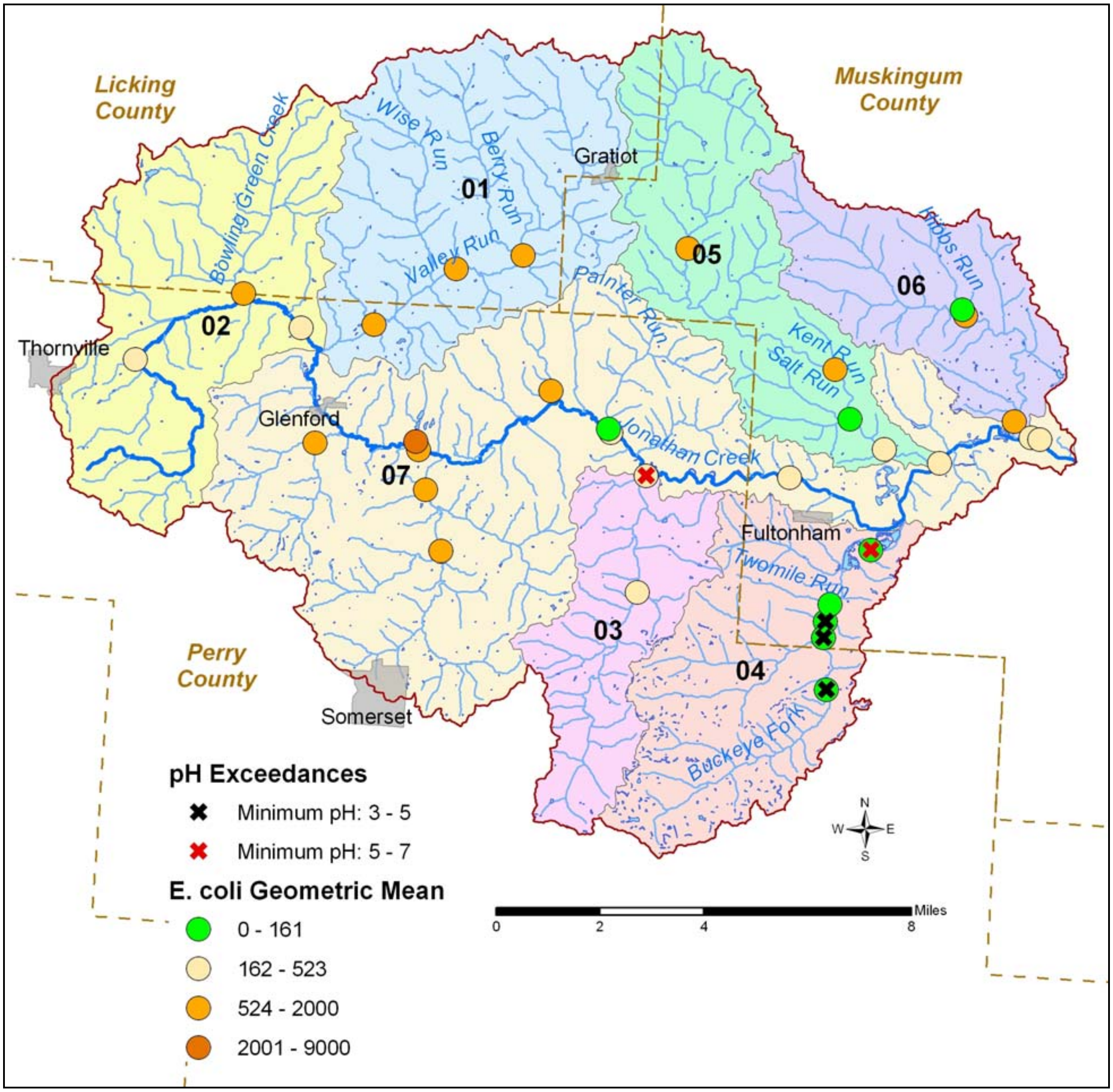


Figure 3-4. Water chemistry results for the Jonathan Creek subwatershed.

Figure 3-4 shows water chemistry results in the subwatershed. Ranges of *E. coli* geometric means are shown as well as locations with pH exceedances, with a range of pH minima. Some of these results aided in identifying causes of aquatic life use impairment. Figure 3-5 and Figure 3-6 show the relative occurrence of causes and sources, respectively, of aquatic life use impairment in the Jonathan Creek subwatershed.

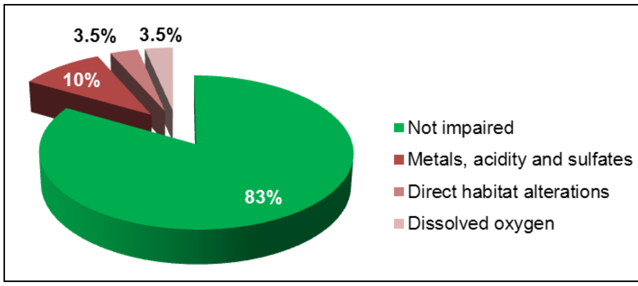


Figure 3-5. Causes of aquatic life use impairment in the Jonathan Creek subwatershed.

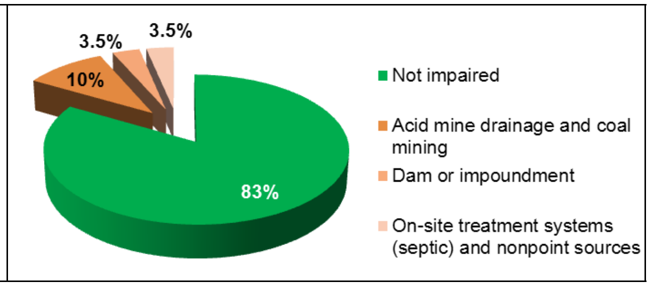


Figure 3-6. Sources of aquatic life use impairment in the Jonathan Creek subwatershed.

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

Table 3-1. Number of impaired sites, organized by use and nested subwatershed, in the Jonathan Creek subwatershed.

Nested Subwatershed (05040004 04)		Aquatic Life Use	Recreation Use	Public Drinking Water Supply Use[1]	Human Health Use[2]
04 01	# impaired sites (non/partial)	0 / 1	3	N/A	N/A
	Index score[3]	75	33	N/A	N/A
04 02	# impaired sites (non/partial)	0 / 0	3	N/A	N/A
	Index score	100	58	N/A	N/A
04 03	# impaired sites (non/partial)	0 / 0	2	N/A	N/A
	Index score	100	50	N/A	N/A
04 04	# impaired sites (non/partial)	3 / 0	0	N/A	N/A
	Index score	62.5	100	N/A	N/A
04 05	# impaired sites (non/partial)	0 / 0	3	3i	N/A
	Index score	100	33	N/A	N/A
04 06	# impaired sites (non/partial)	0 / 0	2	N/A	N/A
	Index score	100	25	N/A	N/A
04 07	# impaired sites (non/partial)	0 / 1	11	0	N/A
	Index score	91.7	45	N/A	N/A

1 The category is shown from the Ohio Integrated Report (Ohio EPA 2010).
2 No fish tissue data for assessing human health use support were collected.
3 The index score (between 0 and 100) indicates the relative support of the aquatic life or recreation use in the nested subwatershed. A score of 100 indicates full support of the use.

Jonathan Creek subwatershed is divided into two regions: glaciated and unglaciated. The unglaciated portion of Jonathan Creek includes all of nested subwatersheds 04 and 06 and the lower portions of nested subwatersheds 05 and 07. These areas fall in the Western Allegheny Plateau (WAP) ecoregion. This region contains coal- and clay-bearing geological layers. Buckeye Fork (04 04) was heavily mined for coal in the past and currently is mined for limestone. Coal mining in Buckeye Fork has extensively affected the water quality of the watershed. A small amount of coal mining near Thompson Run shows little evidence of water quality impacts. The WAP ecoregion is mostly forested with small-scale agriculture activities in the flat stream valley areas.

The glaciated portion of the subwatershed, including nested subwatersheds 02 and 03, the upper portion of nested subwatersheds 05 and 07 and the lower portion of nested subwatershed 01, are mined for more of the industrial minerals type such as silica (for making glass), limestone and gravel. These areas are almost entirely within the Erie Drift Plain (EDP) ecoregion. A small portion of the upper 02 nested subwatershed is within the Eastern Corn Belt Plain (ECBP) ecoregion. The glaciated areas are more conducive to agricultural activities with wide flat stream valleys and gently sloping hills. Almost all of the cultivated crops and much of the grazing takes place in these glaciated units while the steeper hillsides are forested. Some agricultural land uses activities in the watershed have impacts on water quality, such as riparian corridor elimination and unlimited stream access to streams.

Most of the glaciated area is covered with ground moraines that contain fine material and sands. The land use is nearly equally divided between agriculture and forest, which are the predominate uses. Many stream segments are heavily wooded while many other segments are dominated by agriculture on both sides. Stream segments with wide riparian corridors typically have healthier aquatic communities. Partial impairment in nested subwatershed 04 01 is caused by heavy sedimentation and agricultural runoff. Partial impairment in nested subwatershed 04 07 is caused by a dam. Impairment in nested subwatershed 04 04 is discussed in Section 3.1.1.

3.1.1 Buckeye Fork (05040004 04 04)

Buckeye Fork at Old Rainer Road. Note the orange coloration of the water, which indicates AMD influence.

Buckeye Fork (nested subwatershed 04 04) is located within the WAP ecoregion where coal mining was prevalent. Prior to 1977, coal mining companies were not required to return the ground to its original grade, but instead left large piles of coal waste (gob), highwalls, mine pits of toxic water and underground mine discharges to surface waters. (See Section 4.3 for further details.) These remaining mining wastes and discharges contribute large amounts of acid mine drainage (AMD), which is comprised of high acidity, iron, aluminum, manganese, nickel, zinc, total dissolved solids and low pH. Zinc and nickel in Butcherknife Creek and Buckeye Fork violate the Ohio WQS aquatic life outside mixing zone average and the total dissolved solid results violate the WQS of 1,500 mg/l. Pre-law coal mining also resulted in large areas left barren and highly susceptible to erosion, washing sediment and coal fine particulates into the stream. Also, long portions of Buckeye Fork were channelized to facilitate a railroad to move coal. Impairment of aquatic life uses are caused by metals and acidity resulting from acid mine drainage.

3.2 Moxahala Creek (05040004 05)

The Moxahala Creek subwatershed drains 109 square miles in the southern portion of the watershed (see Figure 3-7). It consists of four nested subwatersheds. The main tributaries to Moxahala Creek include Jonathan Creek and Black Fork. Major causes of impairment include metals, acidity, nutrients and bacteria. Those causes are primarily associated with acid mine drainage and failing HSTS.

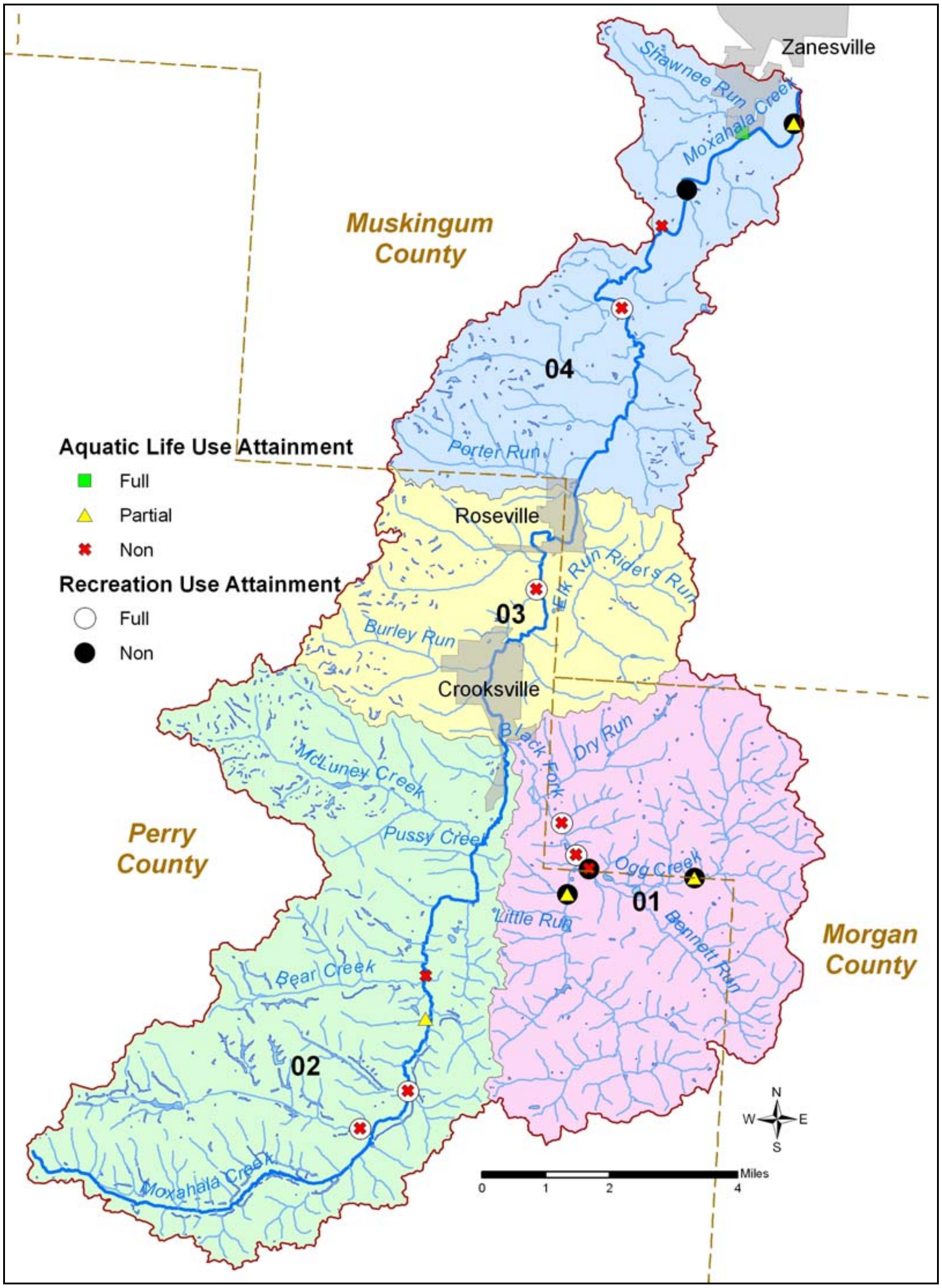


Figure 3-7. Attainment results for the Moxahala Creek subwatershed.

In most cases, these causes are associated with land uses in the subwatershed (see Appendix C for further information). Figure 3-8 shows land use within the Moxahala Creek subwatershed.

The Moxahala Creek subwatershed drains 302 square miles. Four tributaries to Moxahala Creek were sampled during the survey. Moxahala Creek is a direct tributary of the Muskingum River entering just south of the City of Zanesville. The Moxahala Creek subwatershed is sparsely populated and heavily forested. Crooksville and Roseville are two villages located along Moxahala Creek near the center of the subwatershed. Many segments of the stream have an orange color caused by extensive coal mining in the watershed.

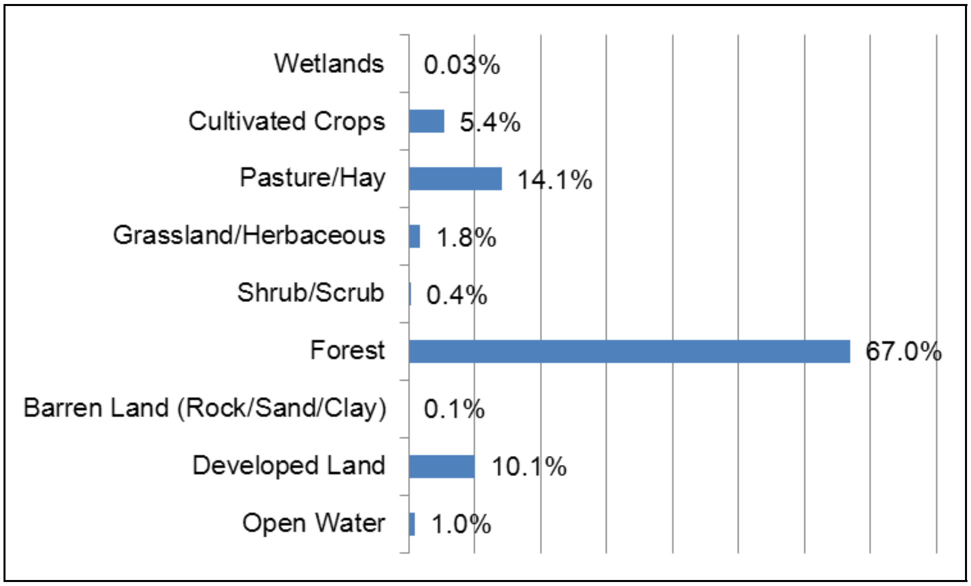


Figure 3-8. Land use in the Moxahala Creek subwatershed.

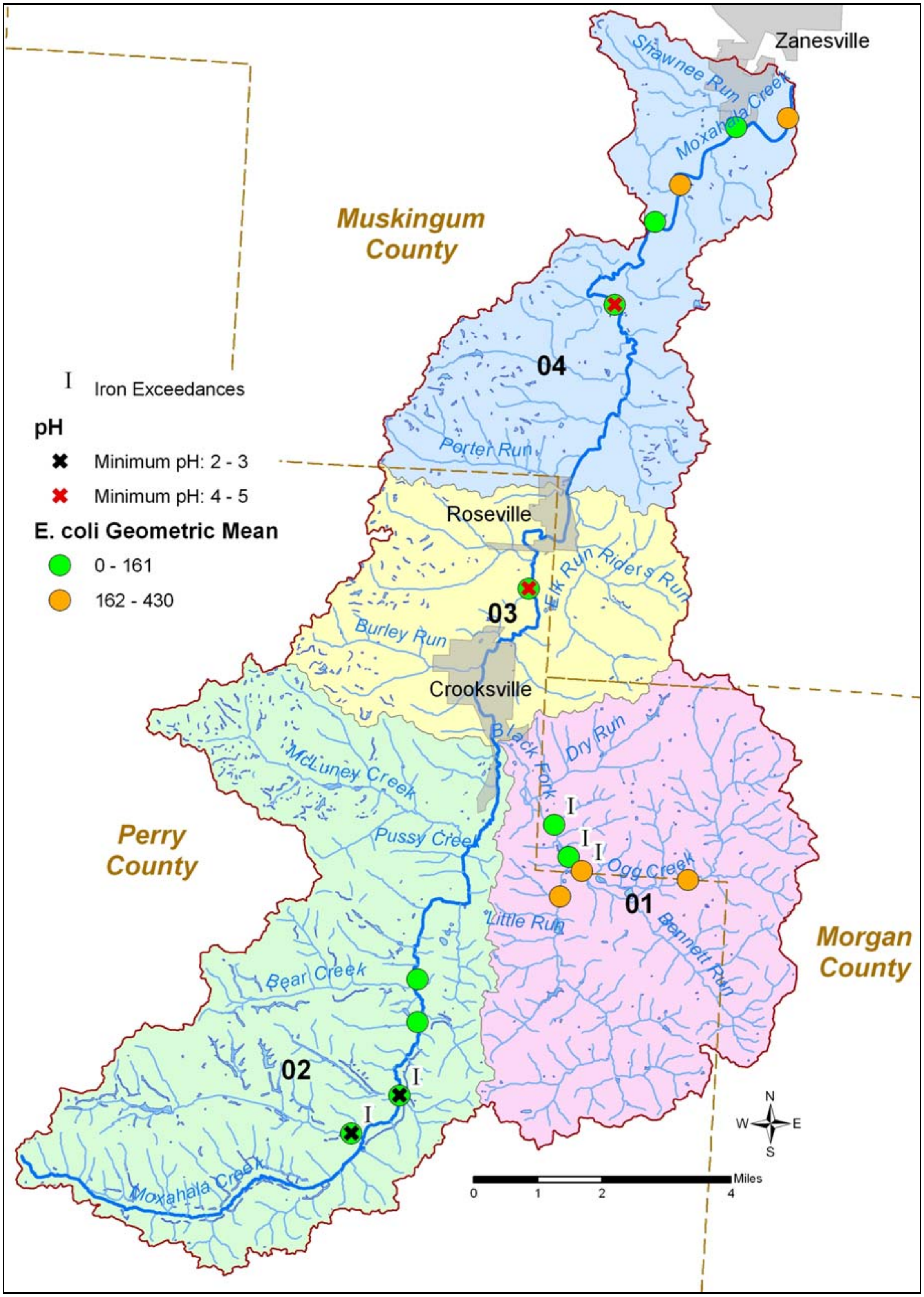


Figure 3-9. Water chemistry results for the Moxahala Creek subwatershed.

Figure 3-9 shows water chemistry results in the subwatershed. Some of these results aided in identifying causes of aquatic life use impairment. Figure 3-10 and Figure 3-11 show the relative occurrence of causes and sources, respectively, of aquatic life use impairment in the Moxahala Creek subwatershed.

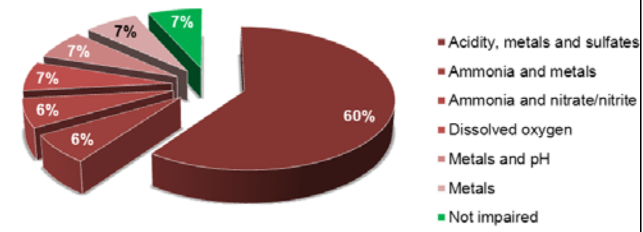


Figure 3-10. Causes of aquatic life use impairment in the Moxahala Creek subwatershed.

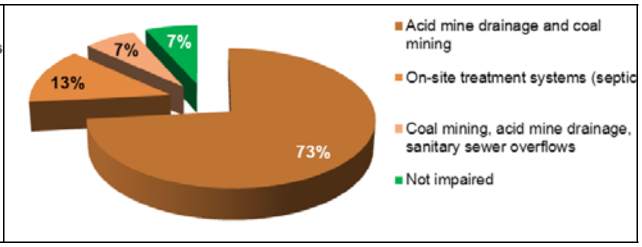


Figure 3-11. Sources of aquatic life use impairment in the Moxahala Creek subwatershed.

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

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

Nested Subwatershed (05040004 05)		Aquatic Life Use	Recreation Use	Public Drinking Water Supply Use[1]	Human Health Use[2]
05 01	# impaired sites (non/partial)	4 / 2	3	1	N/A
	Index score[3]	0	83	N/A	N/A
05 02	# impaired sites (non/partial)	3 / 1	0	N/A	N/A
	Index score	0	100	N/A	N/A
05 03	# impaired sites (non/partial)	1 / 0	0	N/A	N/A
	Index score	20	100	N/A	N/A
05 04	# impaired sites (non/partial)	2 / 1	2	N/A	3i[4]
	Index score	12.5	67	N/A	N/A

1 The category is shown from the Ohio Integrated Report (Ohio EPA 2010).
2 Impairments to the human health use are not being addressed in this TMDL.
3 The index score (between 0 and 100) indicates the relative support of the aquatic life or recreation use in the nested subwatershed. A score of 100 indicates full support of the use.
4 The Ohio Integrated Report (Ohio EPA 2010) shows the category of this nested subwatershed as 3i (insufficient information to assess). There were some data collected in this nested subwatershed in 2000, but they were insufficient to assess the use. No new data were collected during the 2008 survey.

The Moxahala Creek subwatershed is located within the unglaciated portion of Ohio and is in the WAP ecoregion. This region contains coal- and clay-bearing geological layers. This watershed was intensively mined underground starting in the 1840s until the 1940s, after which time the watershed was surface strip mined. Most of the mining was done before the 1977 mining act (see Section 3.1.1). The watershed is predominately forested with more agriculture in the lower nested subwatersheds (05 03 and 05 04). The stream habitat score typically fell within the good range while the aquatic community scores show partial or non-attainment. The poor aquatic life scores are caused by the acid mine drainage that is contributed to Moxahala Creek from all the major tributaries within the watershed. Sedimentation from old coal mine areas with bare soils and exposed coal waste negatively impacts the stream habitat scores. Sparse population, large forested areas and little agricultural activity in the watershed have helped reduce impacts to the stream habitat.

Mining in the Black Fork nested subwatershed (05 01) is concentrated in the lower part of the nested subwatershed. This nested subwatershed has the potential to meet its use designation with more AMD abatement with improvements to the existing Tropic AMD Treatment System and the capture and treatment of the Whitehouse Seep (see Figure 3-12).

Figure 3-12. The Whitehouse Seep in winter. Note the orange coloration of the water, indicating acid mine drainage.

4 METHODS TO CALCULATE LOAD REDUCTIONS

The Moxahala Creek watershed TMDL does not support two beneficial uses–-aquatic life and recreation. The causes of impairment to aquatic life uses consist of dissolved oxygen, aluminum, manganese, nickel, iron, sulfates, acidity, pH, direct habitat alterations, ammonia and nitrate/nitrite. The cause of recreation use impairment is excessive concentrations of an indicator bacterium, *E. coli*. The linkage analysis examines the cause and effect relationships between watershed characteristics and pollutant sources and the effect on the stream biology and evaluates the use of surrogate measures to address the pollutant sources that would result in supporting beneficial uses.

Recreation Use Linkage Analysis

Agricultural activities and the rural nature of the majority of the watershed, with few centralized wastewater treatment systems, have led to widespread elevated bacteria loading. Areas of concern that were highlighted during the 2008 assessment sampling include sanitary sewer releases from South Zanesville (Moxahala Creek adjacent to Pearl Park at RM 0.6) and at Kent Run at RM 1.35 (lower Kroft Road) where the Maysville Water District has an auxiliary water intake.

Aquatic Life Use Linkage Analysis

There are relatively few and discrete areas of aquatic life use non-attainment in the Jonathan Creek sub-watershed in comparison to the Moxahala mainstem and many of its other tributaries. Valley Run, a headwater tributary to Jonathan Creek, exhibited impairment attributed to low dissolved oxygen concentrations as a result of upstream unsewered communities, and a lowhead dam causes non-attainment as it impounds Jonathan Creek near the State Route 93 bridge at Avondale.

The major cause of impairment throughout the Moxahala Creek watershed, especially along the Moxahala mainstem and tributaries, is in-stream loading of pollutants related to acid mine drainage (AMD). Numerous metals, low pH, and high acidity caused toxicity to aquatic life. Abandoned coal mines within the Black Fork tributary to the Moxahala, such as “Tropic” and “Whitehouse Seep” (just upstream of the Ogg Creek confluence) contribute much of the AMD loading in the Moxahala Creek watershed. In addition, Ogg Creek and the headwaters of Black Fork are impacted by nutrient loading from upstream failing home sewage treatment systems.

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

Table 4-1. Summary of causes of impairment and actions taken to address them in assessment units within the 05040004 04 and 05040004 05 ten-digit hydrologic units.

	Watershed Assessment Units										
	05040004 04							05040004 05			
Causes of Impairment	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**01**	**02**	**03**	**04**
Aquatic Life Use											
Dissolved oxygen	S							S			
Aluminum				N				S	S	S	S
Manganese				N				S	S		S
Sulfates				N				S	S	S	S
Nickel				N					S	S	S
Acidity				N				D	D	D	D
Direct habitat alterations							S				
Iron								S	S		
Ammonia								S			S
Nitrate/nitrite								S			
pH									S	S	S
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.

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

4.1 Load Duration Curves

In order to determine the magnitude of impairment due to a particular pollutant and differentiate between types of sources of pollutants contributing to impairment, load duration curves (LDCs) were developed for selected sites that are in non-attainment of WQS following the methods described in the U.S. EPA document *An Approach for Using Load Duration Curves in the Development of TMDLs* (U.S. EPA 2007). LDCs were used to calculate TMDLs for *E. coli* bacteria. These TMDLs were used as surrogates to address impairments from dissolved oxygen, ammonia and nitrate/nitrite.

4.1.1 Justification

Load duration curves can assist in distinguishing between point and nonpoint sources that contribute to pollutant loading by highlighting the flow conditions under which impairment occurs. At lower stream flow levels, decreased in-stream dilution of pollutant inputs occurs due to dry conditions with diminished amounts of runoff. Because of this, any point source pollutant contributions to the stream will result in relatively higher concentrations of that pollutant. A high proportion of samples under dry weather or low flow conditions that fall above the target curve indicate the likelihood of nearby pollutant point sources. Under elevated flow conditions, point sources are assumed to be masked by in-stream dilution; therefore high pollutant loading is caused by precipitation washoff or erosion of contaminated land surfaces.

It is important to note that the load duration curve method does not enable one to attribute impairment to any particular source; instead it is a tool used to determine the flow conditions under which impairment occurs and therefore the probable types of sources contributing to that impairment.

4.1.2 Sources of Data

Recreation use was not supported in multiple assessment units where the geometric mean of at least one stream sampling site did not meet its water quality standard. Forty sites were sampled as a part of the Ohio EPA's monitoring and assessment in 2008 to determine recreation use attainment, and 29 (73%) were found to be in non-attainment.

4.1.3 Target(s)

TMDL numeric targets for *E. coli* bacteria are derived from bacteriological water quality standards. The criteria for *E. coli* specified in OAC 3745-1-07 are applicable outside the effluent mixing zone and vary for waters determined as primary contact recreation (PCR). Furthermore, this criterion designates streams that support frequent primary contact recreation – Class A streams. No streams in the watershed are designated as Class A streams. All streams assessed in this watershed are Class B PCR. Class B streams support infrequent primary contact recreation activities. For Class B streams the standard states that the geometric mean of more than one *E. coli* sample taken in each recreational season (May 1 through October 31) shall not exceed 161 colony-forming units (cfu) per 100 mL.

4.1.4 Validation of Hydrology

A series of flow measurements was made at the Jonathan Creek @ Crock Road sampling site in order to determine the accuracy of predicted stream flow measurements using drainage-area weighted flow data from Salt Creek @ SR-146 USGS stream gage station. Measurements were made at a range of flow levels (from 10.67 cfs to 267.23 cfs, actual flow) during the recreation season of 2008. Measured flows were compared with USGS daily average flows, for the day that the flow measurement was made, via a linear regression. The r-squared value of the best fit linear regression is 0.83. (A perfect gage reading to flow measurement relationship would equal 1, while no relationship would equal zero.) See Appendix D for further details.

4.1.5 Allowance for Future Growth

The Moxahala Creek watershed lies within Licking, Morgan, Muskingum, and Perry Counties. The average population change projection from 2010 to 2020 of the four counties is an increase of 5%. In order to ensure recreation use attainment in the future, an allowance for future growth (AFG) factor of 5% was applied to each TMDL (ODD 2004).

4.1.6 Seasonality and Critical Conditions

In-stream bacteria loads differ by source and can occur under varying stream flow conditions, from washoff of land-deposited bacteria under moist conditions to failing home sewage treatment systems (HSTSs) in low flow conditions. Nonpoint sources to which bacteria loads are allocated in the Jonathan and Moxahala Creek basin include both washoff and failing HSTSs. Because TMDLs are established for all flow ranges where there is sufficient data, the target will be met overall.

Stream recreation occurs in a variety of forms, from wading to fishing to canoeing, and in a wide range of stream flow conditions. In order to ensure that recreation use is protected whenever recreation might occur, *E. coli* TMDLs are established for all flow conditions during the recreation season (May 1 through October 31), when people are most likely to fish, wade, swim and boat in the stream.

4.2 Paired Site Analysis: Temperature

During 2008 biological stream sampling, Jonathan Creek at SR 93 (RM 1.1) was found to be in partial aquatic life use attainment due to a significantly lower Modified Index of well-being (MIwb) score than the WWH use designation. The MIwb is a metric based on the composition of fish species in a stream. The source of this impairment was attributed to stream habitat alteration caused by a dam located 0.1 RM downstream of the sampling point at RM 1.0, Jonathan Creek dam pool downstream SR 93 upstream Powell Rd, Avondale.

It is well known that dams alter biological communities through segmentation of habitat and blocking migration of aquatic species, while at the same time altering stream discharge and flow periodicity (Allan 1995). Stream temperature can have a strong influence on the distribution of fish species because fish body temperatures and metabolic rates are closely related to ambient stream conditions (Spotila, et al. 1979). Changes to a stream's daily temperature regime are a measurable, direct effect of flow-altering impoundments as the relatively larger volume of an impoundment has a greater amount of thermal inertia than a free flowing stream. Daily temperature fluctuations in a dam impoundment can be suppressed, relative to free flowing reaches, in this way (Allan 1995).

4.2.1 Justification and Target

Through paired site sampling and statistical comparison, daily water temperature ranges are used as a measureable surrogate to illuminate the impact of dams in impounded versus free-flowing reaches of Jonathan Creek. Where a statistically significant difference occurs in temperature range, the temperature range of the free-flowing sites is used as a target for impounded sites. Any statistically significant deviation from the free-flowing sites is considered a deviation from target conditions which contributes to non-attainment of aquatic life use goals.

4.2.2 Sources of Data

Temperature sensors were placed in the stream at each site and, depending on the stream depth, either propped on the stream bottom or floated so that the sensors were approximately one-half of the depth of the water column. The temperature sensors were deployed for 48 hours while hourly temperature was measured and recorded.

Temperature ranges were grouped into two categories, depending on the characteristics of the sampling location: 1) *free-flowing* (*Jonathan Creek at Workman* RM 7.6, *Jonathan Creek near White Cottage at Crock Road* RM 3.35, *Jonathan Creek downstream SR-93 dam pool* RM 0.4) and 2) *impounded* sites (*Jonathan Creek at dam pool upstream Crock Rd* RM 3.5, *Jonathan Creek near Avondale at SR-93* RM 1.06, *Jonathan Creek in dam pool downstream SR-93 upstream Powell Rd* RM 0.4). These two site categories were analyzed by unpaired t-tests of the null hypothesis of no difference between temperature ranges of the water column in *free-flowing* versus *impounded* sites. The unpaired t-test was used because the two sample categories are independent samples from different sample populations.

4.2.3 Allowance for Future Growth

The scenario outlined in this TMDL assumes that the entire impoundment is removed. There is no greater improvement that can occur, therefore no allowance for future growth is used.

4.2.4 Seasonality and Critical Conditions

Temperature range is a relative measure that is independent of actual stream temperature. Shifts in stream temperature ranges caused by a dam impoundment are equally likely to affect populations of aquatic life under any season or flow condition, therefore this TMDL is inclusive of any seasonal or critical condition.

4.3 Acid Mine Drainage: Moxahala AMDAT

The most pervasive water quality impacts in the Moxahala Creek watershed result from acid mine drainage (AMD). Acid mine drainage was cited as a source of aquatic life use non-attainment in thirteen sampling sites in the Moxahala Creek watershed. AMD was cited as a source of partial attainment in several other sites.

The Institute for Local Government Administration and Rural Development (ILGARD) at Ohio University published an AMDAT/TMDL (Acid Mine Drainage Abatement and Treatment Plan/Total Maximum Daily Load) report in 2005, in coordination with other entities, with the objective of creating a plan "to improve surface water quality that has been adversely affected by coal mining practices that occurred prior to the passages of the Surface Mining Control and Reclamation Act (SMCRA) in 1977" and to identify areas where restoration projects can ameliorate chemical loading and positively affect stream health (ILGARD 2005).

4.3.1 Justification

The Moxahala AMDAT/TMDL targets and needed load reductions are established empirically using WWH-attaining sites in an adjacent watershed as a reference condition and using extensive field measurements to establish acid loadings at each point source in the Moxahala watershed. The fine geographic scale of field measurements makes it very unlikely that significant AMD-contributing sources in the Moxahala watershed were not addressed by the recommendations of this study.

4.3.2 Sources of Data

Water quality samples and discharge measurements were collected at thirty-two sites monthly for eleven months, from April 1997 to February 1998, as part of a watershed study (Eberhart 1998). Additional samples were collected in 2000 (Kocsis 2000). Further samples were collected in 2003 and 2004 to provide more data for development of the AMDAT.

4.3.3 Target(s)

The following text is from the Moxahala Creek AMDAT (ILGARD 2005).

> The goal for this plan is to restore AMD impacted waters throughout the Moxahala Creek watershed to meet WWH criteria wherever possible. To accomplish this goal, water quality targets were established... However since pH values cannot be modeled as a loading, alkalinity and acidity are used as a surrogate for all AMD parameters.
>
> The establishment of in-stream numeric targets is a significant component of the AMDAT/TMDL process. The numeric targets serve as a measure of comparison between observed in-stream conditions and conditions that are expected to restore the stream to its designated uses. The AMDAT/TMDL identifies the load reductions and other actions that are necessary to meet the target, thus resulting in the attainment of applicable water quality standards.
>
> Due to the overwhelming prevalence of Acid Mine Drainage (AMD) in the Moxahala Watershed,capturing and treating all the affected water would be very difficult and cost prohibitive. As a result the mouths of subwatersheds were selected as the points where targets will be met. However, it should be noted that in order to meet targets at the segment ends, many of the upstream sites must meet the target.
>
> In choosing an alkalinity target that would be meaningful for the Moxahala Creek Watershed,water chemistry data that was collected in Moxahala Creek at two reference sites were compared to other reference sites throughout Ohio's Western Alleghany Plateau (WAP) eco-region, and other targets that were established for watersheds in the vicinity; Sunday Creek, Monday Creek, and Raccoon Creek. From these selected watersheds, the range of alkalinity values in which a site still meets WWH varies widely, 204 to 30 mg/l. Ideally, water quality sites within the Moxahala Watershed whose biological data meet the WWH use designation should be used to set a target alkalinity value, however there are only two sites that meet WWH. Two sites are not a large enough data-set to establish target values. Ohio EPA WAP ecoregion values from reference sites have alkalinity values that range from 134 -203 mg/l depending on size of stream and IBI range. However, these values are much higher than other target values used in similar reports; Monday Creek TMDL 30 mg/l alkalinity, Raccoon TMDL 20 mg/l alkalinity, Sunday Creek TMDL 67 mg/l alkalinity, and Sunday Creek AMDAT 90 mg/l alkalinity. Therefore a target net alkalinity value of 67mg/l was chosen as the target for this AMDAT/TMDL report. This is the same target used in the Sunday Creek TMDL. Sunday Creek Watershed is adjacent to Moxahala and has similar causes of impairment and water quality. The alkalinity target of 67 mg/l is the 10th percentile of the data points that meet WWH in the Sunday Creek Watershed. A low end target was chosen instead of a higher end target because the high cost of AMD remediation. The net alkalinity target had to be at a minimum so as to not unnecessarily burden the existing and future remediation resources.

4.3.4 Method Uncertainty

The alkalinity target developed for the Moxahala basin, based on WWH-attaining reference sites in an adjacent watershed, involves some uncertainty due to the reliance on sites in a different watershed. This uncertainty is unavoidable because very few sites within the Moxahala Creek watershed attain the WWH designation.

The empirical mass-balance approach used to determine acid loading, and therefore required alkalinity loads, in this study used either actual measured discharge or visually estimated discharge at each point source of acid loading. Some uncertainty exists in this method because of the assumption that the low and high flows that were measured are typical of an average year and do not vary widely over a larger timescale.

4.3.5 Allowance for Future Growth

The AMD impacts in this watershed are a result of 'pre-law' mining activities that took place before the adoption of the Surface Mining Control and Reclamation Act (SMCRA) in 1977 and the recommendations of this report are intended to address the restoration required as a result of past mining activities. Due to contemporary regulation, no new sources of AMD from ongoing or future mining are anticipated in this watershed and therefore there is no allowance for future growth in AMD loading.

4.3.6 Seasonality and Critical Conditions

Because critical conditions are flow-dependent, the seasons with the highest precipitation infiltration and runoff will contribute the most to pollutant loading. In this region, the greatest annual runoff typically occurs during late winter and early spring. These seasonal conditions are taken into account through the use of high flow regimes for establishing TMDL targets.

The following text is from the Moxahala Creek AMDAT (ILGARD 2005).

> During high flow regimes the acid loading to the Moxahala Creek are typically higher than during the low flow... Therefore high flow conditions are considered the critical condition for this study. Flow data measured during high flow conditions were used to determine... target alkalinity loads, and the needed acid load reduction. Using the high flow as the design flow... to calculate the target alkalinity loads ensures the worst case scenario is represented…

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).

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

The scenario outlined in the temperature TMDL assumes that the entire impoundment is removed. There is no greater improvement that can occur, therefore no margin of safety is used.

The following text is from the Moxahala Creek AMDAT (ILGARD 2005).

> The alkalinity target of 67 mg/l is the 10th percentile of the data points that meet WWH in the Sunday Creek Watershed. Therefore there is a 10% margin of safety or the equivalent 18 mg/l of alkalinity. The site with the lowest amount of alkalinity that still met WWH was on Johnson run with 49 mg/l of alkalinity, thus 67-49 = 18 mg/l of alkalinity...

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 Valley Run (05040004 04 01)

Table 5-1 shows the *E. coli* reductions necessary at Valley Run at Laurel Hill Road. The load duration curve (LDC) created at this site includes all drainage area upstream of the site (at RM 5.4). The largest load allocation reduction (98%) is needed in wet weather flows.

Table 5-1. TMDL table for site on Valley Run @ Laurel Hill Rd.

Flow regime TMDL analysis *E. coli* (billion bacteria/day)	High	Wet weather	Normal range	Dry weather	Low
Duration interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime	1	1	2	1	0
Median sample load	2333	1,461	19	4	N/A
TMDL	246.156	29.539	5.514	2.584	1.780
WLA	0.0	0.0	0.0	0.0	0.0
LA	184.617	22.154	4.135	1.938	1.335
MOS: 20%	49.231	5.908	1.103	0.517	0.356
AFG: 5%	12.308	1.477	0.276	0.129	0.089
Nonpoint (LA) % load reduction required	**92%**	**98%**	**78%**	**54%**	No Data

Values were adjusted for rounding.

5.2 Valley Run (05040004 04 01), Headwaters Jonathan Creek (04 02), Turkey Run (04 03), Painter Creek-Jonathan Creek (04 07)

Table 5-2 shows the *E. coli* reductions necessary at Jonathan Creek near White Cottage at Crock Road. The LDC created at this site includes all drainage area upstream of the site (at RM 3.35), except for the drainage area upstream of the site on Valley Run at RM 5.4. The largest load allocation reduction (100%) is needed in wet weather flows.

Table 5-2. TMDL table for site on Jonathan Creek near White Cottage @ Crock Rd.

Flow regime TMDL analysis E. coli (billion bacteria/day)	High	Wet weather	Normal range	Dry weather	Low
Duration interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime	1	1	2	4	0
Median sample load	93,240	146,303	25	12.5	N/A
TMDL	3807.008	457.714	86.314	40.026	27.594
WLA: total	1.808	0.271	0.101	0.061	0.061
WLA: B&D Commissary	0.061	0.061	0.061	0.061	0.061
WLA: Zanesville MS4	1.747	0.210	0.040	0.0	0.0
LA	2853.448	343.014	64.635	29.954	20.631
MOS: 20%	761.402	91.543	17.263	8.009	5.521
AFG: 5%	190.350	22.886	4.316	2.002	1.380
Nonpoint (LA) % load reduction required	**97%**	**100%**	**None**	**None**	No Data

Values were adjusted for rounding.

5.3 Kent Run (05040004 04 05), Thompson Run (04 06), Painter Creek-Jonathan Creek (04 07)

TMDL results are presented for *E. coli* and temperature range in the sub-sections below.

5.3.1 *E. coli* TMDLs

Table 5-3 shows the *E. coli* reductions necessary at Jonathan Creek downstream of the State Route 93 dam pool at Powell Road. The LDC created at this site includes all drainage area upstream of the site except the area upstream of the site on Jonathan Creek at RM 3.35. The largest load allocation reduction (99%) is needed in wet weather flows.

Table 5-3. TMDL table for site on Jonathan Ck DST SR-93 dam pool @ Powell Rd.

Flow regime TMDL analysis E. coli (billion bacteria/day)	High	Wet weather	Normal range	Dry weather	Low
Duration interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime	1	1	2	4	0
Median sample load	85,118	31,651	240	11.4	N/A
TMDL	4897.243	588.926	110.793	51.554	35.552
WLA: total	34.756	4.285	0.904	0.121	0.121
WLA: B&D Commissary	0.061	0.061	0.061	0.061	0.061
WLA: Hopewell Elementary	0.030	0.030	0.030	0.030	0.030
WLA: Hopewell Heights MHC	0.030	0.030	0.030	0.030	0.030
WLA: Zanesville MS4	34.635	4.164	0.783	0.0	0.0
LA	3638.184	437.417	82.198	38.552	26.550
MOS: 20%	979.443	117.779	22.153	10.305	7.104
AFG: 5%	244.861	29.445	5.538	2.576	1.776
Nonpoint (LA) % load reduction required	**96%**	**99%**	**66%**	**None**	No Data

Values were adjusted for rounding.

5.3.2 Temperature Range TMDL

Temperature ranges over a 48-hour sampling period from 8/25/09 to 8/27/09 varied between *free-flowing* and *impounded* sites, with *impounded* sites having a significantly reduced average temperature range of 2.73 degrees F compared to *free-flowing* sites at 9.09 degrees F (p= 0.04), based on an unpaired T-test (see Figure 5-1).

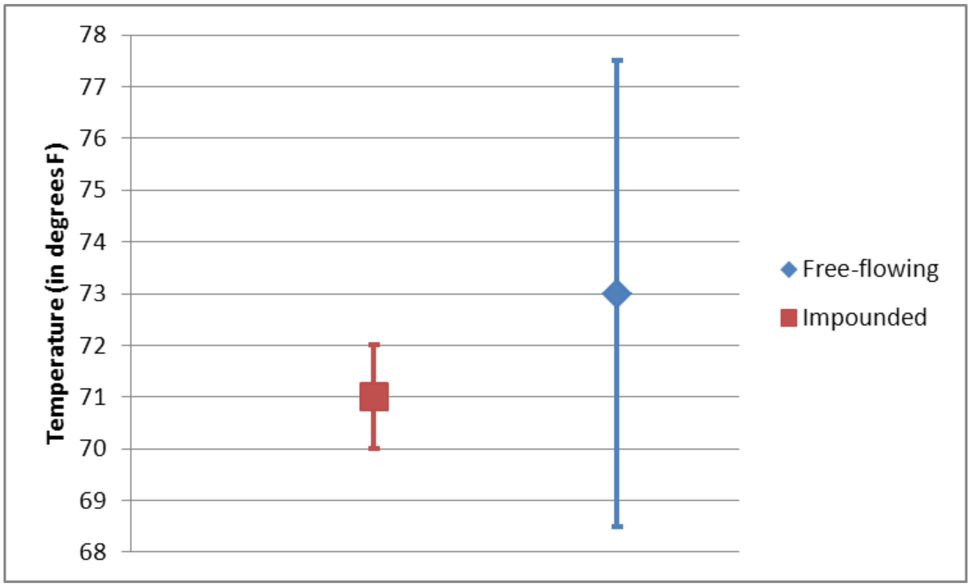


Figure 5-1. Temperature ranges in Jonathan Creek sites (Max., Average, Min.).

Average temperature ranges at impounded sites need to be increased by 6.36 degrees F. Converting the portion of the stream at SR-93 from impounded to free-flowing, by the removal of the dam at Avondale, would eliminate the measurable impacts to stream temperature ranges caused by dam impoundments in Jonathan Creek.

5.4 Black Fork (05040004 05 01)

TMDL results are presented for *E. coli* and acidity/alkalinity in the sub-sections below.

5.4.1 *E. coli* TMDLs

Table 5-4 shows the *E. coli* reductions necessary at Ogg Creek south of Deavertown at State Route 555. The LDC created at this site includes the drainage area upstream of Ogg Creek at RM 2.1. The largest load allocation reduction (98%) is needed in wet weather flows.

Table 5-4. TMDL table for site on Ogg Ck S. of Deavertown @ SR-555.

Flow regime TMDL analysis *E. coli* (billion bacteria/day)	High	Wet weather	Normal range	Dry weather	Low
Duration interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime	1	4	2	1	0
Median sample load	294	544	6	3	N/A
TMDL	150.057	17.723	3.545	1.662	1.158
WLA	0.0	0.0	0.0	0.0	0.0
LA	112.542	13.292	2.658	1.247	0.868
MOS: 20%	30.011	3.545	0.709	0.332	0.232
AFG: 5%	7.503	0.886	0.177	0.083	0.058
Nonpoint (LA) % load reduction required	**62%**	**98%**	**54%**	**64%**	No Data

Values were adjusted for rounding.

Table 5-5 shows the *E. coli* reductions necessary at Black Fork adjacent to Tatmans Road. The LDC created at this site includes the drainage area upstream of Black Fork at RM 3.2. The largest load allocation reduction (60%) is needed at the normal range of flows.

Table 5-5. TMDL table for site on Black Fk Moxahala Ck adj. Tatmans Rd (CR-22).

Flow regime TMDL analysis *E. coli* (billion bacteria/day)	High	Wet weather	Normal range	Dry weather	Low
Duration interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime	1	5	2	1	0
Median sample load	416	47	10	0.9	N/A
TMDL	232.371	27.569	5.514	2.572	1.788
WLA:	0.0	0.0	0.0	0.0	0.0
LA	174.278	20.677	4.135	1.929	1.341
MOS: 20%	46.474	5.514	1.103	0.514	0.358
AFG: 5%	11.619	1.378	0.276	0.129	0.089
Nonpoint (LA) % load reduction required	**58%**	**56%**	**60%**	**None**	No Data

Values were adjusted for rounding.

5.4.2 Acidity/alkalinity TMDLs

The results tables presented in Sections 5.4.2 and 5.5 are excerpted and summarized from the *Acid Mine Drainage Abatement and Treatment Plan for the Moxahala Creek Watershed* (ILGARD 2005). Please see Appendix F for the complete report.

Alkalinity of stream water is a measure of its acidity-neutralizing capacity. Increased alkalinity raises water pH and acid buffering capacity thereby reducing the ability of stream water to carry dissolved metals in solution. Acid load reductions can also be interpreted as required increases in alkalinity (ILGARD 2005). Table 5-6 shows the acidity/alkalinity TMDLs.

Table 5-6. Loading results for the Black Fork nested subwatershed (05040004 05 01).

Site	Existing acid load (lbs/day)	Target acidity load (lbs/day)	Needed load reduction (lbs/day)
Whitehouse Seep (BF-10)	1535	-857	2392
Dry Run Seep #2 (DR-2)	195	-10	205
Dry Run Seep #3 (DR-3)	1961	-208	2169

Values were adjusted for rounding.

5.5 Upper Moxahala Creek (05040004 05 02)

Table 5-7 shows the acidity/alkalinity TMDLs for the Upper Moxahala Creek nested subwatershed.

Table 5-7. Loading results for the Upper Moxahala Creek (Andrews, Bear Ck, McLuney Creek) nested subwatershed (05040004 05 02).

Site	Existing acid load (lbs/day)	Target acidity load (lbs/day)	Needed load reduction (lbs/day)
Sunny Hill #1 (AC-33)	5228	-596	5824
Gob Pile B discharge (AC-44)	4449	-403	4852
Sunny Hill East (AC-29)	1169	-165	1334
Murph's Gob Pile (AC-36)	325	-16	341
West Hopper Boil (AC-37)	2811	-129	2940
Andrew South Pits (AC-13)	163	-238	401
Howard William Lake project (AC-20)	3737	-2086	5823
Mouth of Andrews Creek (AC-01)	18700	-4305	23005
Andrews Creek (AC-45)	13841	-3220	17061
Andrews Creek (AC-46)	18626	-3505	22131
Lindamood South (BR-18)	42	-10	52
Garcia and Dorsey North (BR-30)	554	-88	643
Dorsey Strip (BR-29)	220	-72	292
Lindamood Seep (BR-22)	140	-24	164
Gene Sumner North (BR-26)	238	-124	362
Stort's Mine North (BR-25)	97	-107	204
Stort's Mine North (37)	13	8	21
Gildee North (BR-15)	86	-43	129
Dennis/Chestnut(BR-13)	375	-206	581
Bear Creek (BR-38)	1794	-884	2677
Bear Creek (BR-40)	742	-1130	1873
Bear Creek Mouth (BR-01)	4765	-3547	8312
McLuney Creek mainstem (ML-20)	908	-647	1555
Rort Seep (ML-rort)	335	-273	608
Newlon (ML-14&16)	1285	-384	1669
McLuney South (ML-49)	511	-372	883
Treadway (ML-6)	1019	-373	1392
Tunnel Hill (ML-38)	1007	-628	1635
McLuney Creek mainstem (ML-13)	923	-1509	2433
McLuney Creek (ML-39)	3627	-3627	7254
McLuney Creek Mouth (ML-01)	5289	-5062	10351

Values were adjusted for rounding.

5.6 Black Fork (05040004 05 01), Middle Moxahala Creek (05 03), Lower Moxahala Creek (05 04)

TMDL results are presented for *E. coli* and acidity/alkalinity in the sub-sections below.

5.6.1 *E. coli* TMDLs

Table 5-8 shows the *E. coli* reductions necessary at Moxahala Creek Creek at County Road 6. The LDC created at this site includes all drainage area upstream of Moxahala Creek at County Road 6 except for the Black Fork and Ogg Creek drainage areas. The largest load allocation reduction (100%) is needed in wet weather flows.

Table 5-8. TMDL table for site on Moxahala Ck @ CR-6.

Flow regime TMDL analysis *E. coli* (billion bacteria/day)	High	Wet weather	Normal range	Dry weather	Low
Duration interval	0-5%	5-40%	40-80%	80-95%	95-100%
Samples per regime	1	1	2	1	0
Median sample load	72,666	361,495	88	16	N/A
TMDL	7,664.727	921.634	174.108	80.919	55.874
WLA: total	0.420	0.420	0.420	0.420	0.420
B&D Commissary	0.061	0.061	0.061	0.061	0.061
Hopewell Hts. MHC	0.030	0.030	0.030	0.030	0.030
Roseville WWTP	0.329	0.329	0.329	0.329	0.329
LA	5748.125	690.805	130.161	60.269	41.485
MOS: 20%	1532.945	184.327	34.822	16.184	11.175
AFG: 5%	383.236	46.082	8.705	4.046	2.794
Nonpoint (LA) % load reduction required	**92%**	**100%**	**None**	**None**	No Data

Values were adjusted for rounding.

5.6.2 Acidity/alkalinity TMDLs

Tables 5-9 and 5-10 show the acidity/alkalinity TMDLs for the Middle Moxahala Creek and Lower Moxahala Creek nested subwatersheds, respectively.

Table 5-9. Loading results for the Middle Moxahala Creek (Snake Run, Burley Run) nested subwatershed (05040004 05 03).

Site	Existing acid load (lbs/day)	Target acidity load (lbs/day)	Needed load reduction (lbs/day)
Snake Run (SN-8)	508	-239	747
Snake Run mouth (SN-1)	790	-445	1234
Burley Run (BU-25)	602	-486	1087
Burley Run Railroad South (BU-24)	215	-68	284
Lewis Hollow (BU-26)	1426	-562	1988
Burley Run N. & Jenkins Hollow (BU-3)	827	-803	1630
Burley Run (BU-4)	1781	-728	2509
Burley Run (BU-1)	2170	-1483	3653

Values were adjusted for rounding.

Table D-15. Loading results for the Lower Moxahala Creek (Riders Run) nested subwatershed (05040004 05 04).

Site	Existing acid load (lbs/day)	Target acidity load (lbs/day)	Needed load reduction (lbs/day)
Toth (RR-4)	69	-12	81
Toth (RR-5)	34	-56	90
Oxford (RR-15)	22	-5	26
Oxford (RR-16)	28	-6	34
Toth (RR-2)	319	-437	756
Oxford (RR-10)	110	-62	172
Riders Run mouth (RR-13)	369	-952	1321

Values were adjusted for rounding.

6 WATER QUALITY IMPROVEMENT STRATEGY

Overall, the Moxahala Creek watershed is mostly meeting the aquatic life goal of the Clean Water Act. Due to the extensive impacts from historic mining, none of the six sites on the Moxahala Creek mainstem are meeting the LRW-AMD aquatic life use designation. The biological community performance was mostly fair to very poor in the Moxahala subwatershed. In contrast, seven of the eight sites on the Jonathan Creek mainstem were meeting the WWH aquatic life use designation. The majority of the sites in the Jonathan Creek subwatershed had a biological community performance of good to excellent. Impairment for aquatic life and recreation uses was more common in the southern portion of the watershed. Non-attainment of biological criteria was caused by a variety of metals, nutrients and acidity, primarily from acid mine drainage and coal mining sources. Partial attainment in the Jonathan Creek subwatershed was caused by acidity and metals from acid mine drainage and by habitat alterations from channelization and low dissolved oxygen from a dam impoundment.

Table 6-1 shows an overview of all of the nested subwatersheds that contain sites with partial and non-attainment of aquatic life and recreation uses. Causes of impairment are shown within parentheses following each source that might contribute to that cause. Table 6-3 and Table 6-4 each represent a separate subwatershed (see Figure 3-1 for a map). For each nested subwatershed, specific actions are recommended.

Recommendations were developed by Ohio EPA in consultation with local technical stakeholders. The actions indicate the universe of possibilities for resolving the water quality impairment. Because Ohio EPA recognizes that actions taken in any individual subwatershed may depend on a number of factors (including socioeconomic, political and ecological factors), the recommendations are not intended to be rigid, and any number or combination should contribute to improvement, whether applied at sites where actual impairment was noted or other locations where sources contribute indirectly to impairment. However, restoring the quality of the water may require a concerted and sustained effort by several willing participants. Further details about individual practices can be found in Appendix E.

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

Location Description (10-digit HUC) / Location Description (12-digit HUC) / Sources (Causes)	Restoration Categories: Bank & Riparian Restoration	Stream Restoration	Wetland Restoration	Conservation Easements	Dam Modification 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
Jonathan Creek (05040004 04)[1]												
Valley Run (04 01)												
Failing HSTS[2] (low dissolved oxygen, bacteria)								x	x			
Nonpoint sources (low dissolved oxygen)									x	x		
Agriculture (bacteria)									x	x		
Headwaters Jonathan Creek (04 02)												
Failing HSTS (bacteria)								x	x			
Agriculture (bacteria)									x	x		
Turkey Run (04 03)												
Failing HSTS (bacteria)								x	x			
Agriculture (bacteria)									x	x		
Kent Run (04 05)												
Failing HSTS (bacteria)								x	x			
Agriculture (bacteria)									x	x		
Thompson Run (04 06)												
Failing HSTS (bacteria)								x	x			
Agriculture (bacteria)									x	x		
Painter Creek-Jonathan Creek (04 07)[3]												
Dam or impoundment (direct habitat alterations)					x							
Failing HSTS (bacteria)								x	x			
Agriculture (bacteria)									x	x		
Moxahala Creek (05040004 05)												
Black Fork (05 01)												
Failing HSTS (low dissolved oxygen, ammonia, nitrate/nitrite, bacteria)								x	x			

Location Description (10-digit HUC) Location Description (12-digit HUC) Sources (Causes)	Restoration Categories Bank & Riparian Restoration	Stream Restoration	Wetland Restoration	Conservation Easements	Dam Modification or Removal	Levee or Dike Modification or Removal	Abandoned Mine Land Reclamation	Home Sewage Planning and Improvement	Education and Outreach	Agricultural Best Management Practices	Storm Water Best Management Practices	Regulatory Point Source Controls
Acid mine drainage (acidity, aluminum, manganese, iron, sulfates)							x					
Coal mining (acidity, aluminum, manganese, iron, sulfates)							x					
Livestock (bacteria)									x	x		
Upper Moxahala Creek (05 02)												
Acid mine drainage (pH, acidity, nickel, manganese, aluminum, iron, sulfates)							x					
Coal mining (pH, acidity, nickel, manganese, aluminum, iron, sulfates)							x					
Middle Moxahala Creek (05 03)												
Acid mine drainage (pH, acidity, manganese, nickel, sulfates)							x					
Coal mining (pH, acidity, manganese, nickel, sulfates)							x					
Lower Moxahala Creek (05 04)												
Acid mine drainage (pH, acidity, nickel, manganese, aluminum, sulfates)							x					
Coal mining (pH, acidity, nickel, manganese, aluminum, sulfates)							x					
Sanitary sewer overflows (ammonia, bacteria)	*Already addressed*											
Failing HSTS (bacteria)								x	x			
Livestock (bacteria)									x	x		

[1] Impairments in the Buckeye Fork nested subwatershed (05040004 04 04) were not addressed in the TMDL.

[2] HSTS stands for home sewage treatment systems.

[3] The technical support document (Ohio EPA 2009) suggested that a landfill might be a source of bacteria in this nested subwatershed. Upon further examination of data and aerial photographs, it appears that the landfill is not a likely source. Until further samples can be taken from the area, the landfill will not be addressed as a probable source of bacteria.

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 *E. coli*.
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 (05040004)	Entity	Ohio EPA Permit #	Receiving Stream	Design Flow (million gallons per day)	Wasteload Allocation (load)	Wasteload Allocation (concentration)[1]	Recommended Permit Conditions[1]
04 03	B & D Commissary	0IH00048	Unnamed tributary to Turkey Run	0.01	0.061	161 cfu/100 mL	Average monthly limit of 161 cfu/100 mL
04 05	Hopewell Heights Mobile Home Court	0PV00032	Unnamed tributary to Kent Run	0.005	0.030	161 cfu/100 mL	Average monthly limit of 161 cfu/100 mL
04 05	Hopewell Elementary School	4GS00015	Kent Run	0.005	0.030	161 cfu/100 mL	Average monthly limit of 161 cfu/100 mL
05 03	Roseville WWTP	0PC00020	Moxahala Creek	0.671	0.329	161 cfu/100 mL	Average monthly limit of 161 cfu/100 mL
04 04, 04 05, 04 06, 04 07, 05 04	City of Zanesville MS4	0GQ00015	Various	Storm water	High flows: 34.635 Wet weather flows: 4.164 Normal range flows: 0.783	161 cfu/100 mL	Average monthly limit of 161 cfu/100 mL

[1] Concentrations are expressed in colony-forming units (cfu) per 100 milliliters (mL).

6.2 Jonathan Creek (05040004 04)

Causes of aquatic life use impairment in the Jonathan Creek subwatershed include low dissolved oxygen from nonpoint sources and failing HSTS and direct habitat alterations from a dam. Acid mine drainage-related causes and sources in the Buckeye Fork nested subwatershed have not been addressed in this TMDL report. Sources of bacteria include failing HSTS and agricultural land uses. Actions recommended in Table 6-3 are intended to address a wide variety of agricultural practices that may contribute to the dissolved oxygen and bacteria issues in the watershed. Dam-related recommendations are based on the temperature TMDL calculated (see Appendix D).

In the Painter Creek-Jonathan Creek nested subwatershed, a dam just upstream of Powell Road is causing aquatic life use impairment. It is recommended that the dam be removed. In addition, an upstream dam at White Cottage (formerly for the Gladstone Mill) is likely contributing to some of the aquatic life use impairment observed downstream of the Powell Road dam. Removal of the upstream dam should be investigated but would be dependent on local support. Modifying the dam to remove any barrier to fish passage may also be an option to improve aquatic life and water quality.

Table 6-3. Recommended implementation actions in the Jonathan Creek subwatershed.

Restoration Categories		Specific Restoration Actions	Jonathan Creek (05040004 04)					
			Valley Run (04 01)	Headwaters Jonathan Creek (04 02)	Turkey Run (04 03)	Kent Run (04 05)	Thompson Run (04 06)	Painter Creek-Jonathan Creek (04 07)
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						

Restoration Categories		Specific Restoration Actions	Jonathan Creek (05040004 04)					
			Valley Run (04 01)	Headwaters Jonathan Creek (04 02)	Turkey Run (04 03)	Kent Run (04 05)	Thompson Run (04 06)	Painter Creek-Jonathan Creek (04 07)
Wetland Restoration		Reconnect wetland to stream						
		Reconstruct & restore wetlands						
		Plant wetland species						
Conservation Easements		Acquire conservation easements						
Dam Modification or Removal		Remove dams						x
		Modify dams						
		Remove associated dam support structures						x
		Install fish passage and/or habitat structures						
		Restore natural flow						x
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						
		Install vertical flow ponds						
		Install limestone drains (anoxic and/or oxic)						
		Construct acid mine drainage wetland						
	flow diversion	Repair subsidence sites						
		Reclaim pit impoundments						
		Reclaim abandoned mine land						
		Eliminate stream captures						
		Eliminate mine drainage discharges						
		Restore positive drainage						

Restoration Categories		Specific Restoration Actions	Jonathan Creek (05040004 04)					
			Valley Run (04 01)	Headwaters Jonathan Creek (04 02)	Turkey Run (04 03)	Kent Run (04 05)	Thompson Run (04 06)	Painter Creek-Jonathan Creek (04 07)
		Cover toxic mine spoils						
Home Sewage Planning and Improvement		Develop HSTS plan	x	x	x	x	x	x
		Inspect HSTS	x	x	x	x	x	x
		Repair or replace traditional HSTS	x	x	x	x	x	x
		Repair or replace alternative HSTS	x	x	x	x	x	x
Education and Outreach		Host meetings, workshops, and/or other events	x	x	x	x	x	x
		Distribute educational materials	x	x	x	x	x	x
Agricultural Best Management Practices	farmland	Plant cover/manure crops	x	x	x	x	x	x
		Implement conservation tillage practices						
		Implement grass/legume rotations						
		Convert to permanent hayland						
		Install grassed waterways						
		Install vegetated buffer areas/strips	x	x	x	x	x	x
		Install location-specific conservation buffer						
		Install / restore wetlands						
	nutrients / agro-chemicals	Conduct soil testing	x					
		Install nitrogen reduction practices	x					
		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	x	x	x	x	x	x
		Install livestock exclusion fencing	x	x	x	x	x	x
		Install livestock crossings	x	x	x	x	x	x
		Install alternative water supplies	x	x	x	x	x	x
		Install livestock access lanes	x	x	x	x	x	x
	manure	Implement manure management practices	x	x	x	x	x	x

Restoration Categories		Specific Restoration Actions	Jonathan Creek (05040004 04) Valley Run (04 01)	Headwaters Jonathan Creek (04 02)	Turkey Run (04 03)	Kent Run (04 05)	Thompson Run (04 06)	Painter Creek-Jonathan Creek (04 07)
		Construct animal waste storage structures						
		Implement manure transfer practices						
		Install grass manure spreading strips						
	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	Issue permit(s) and/or modify permit limit(s)						

Restoration Categories		Specific Restoration Actions	Jonathan Creek (05040004 04)					
			Valley Run (04 01)	Headwaters Jonathan Creek (04 02)	Turkey Run (04 03)	Kent Run (04 05)	Thompson Run (04 06)	Painter Creek-Jonathan Creek (04 07)
	treatment	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						

6.3 Moxahala Creek (05040004 05)

The majority of impairments to aquatic life uses in the Moxahala Creek subwatershed are metals and acidity related to acid mine drainage. In addition, failing HSTS caused issues with low dissolved oxygen, ammonia and nitrate/nitrite. Sanitary sewer overflows in South Zanesville were causing impairment from ammonia and bacteria, but the issues were addressed prior to the development of this report. Livestock and failing HSTS were sources of bacteria. Actions recommended in Table 6-4 (as denoted with an “x”) are intended to address failing HSTS and a wide variety of agricultural practices that may be contributing to nutrient, dissolved oxygen and bacteria issues noted in the watershed. Practices denoted with an “x” in the AMD section for the Lower Moxahala Creek nested subwatershed are derived from specific practices recommended in the AMDAT (ILGARD 2005). Actions denoted with an "A" are recommended in the AMDAT.

The Whitehouse Seep in the Black Fork nested subwatershed is the largest flow contributor of the four AMD sources to Black Fork and contributes significant pollutant loads to the receiving stream (ILGARD 2005). The flow is surfacing from an underground manmade mine shaft. If the shaft were to be closed, the water would find another way to escape because of its high flow rate. The best option to address this source is to initiate a successive alkalinity production system (SAPS) combined with an open limestone channel. In Dry Run, a sequence of an anoxic limestone drain (ALD), an aeration channel, a sedimentation pond and a SAPS is recommended. Upgrades and repairs to the Tropic Wetland treatment system are needed to improve efficiency.

Three streams in the Upper Moxahala Creek nested subwatershed (Andrews Run, Bear Creek and McLuney Creek) received specific recommendations in the AMDAT (ILGARD 2005). In Andrews Run, the AMDAT recommended active dosers, steel slag beds, settling ponds, associated conservation easements and that abandoned mine land be reclaimed. In Bear Creek, the AMDAT recommended vertical flow ponds and active lime dosers. A phased approach including aerobic wetland enhancement, strip pit reclamation and ALDs were recommended for McLuney Creek.

In the Middle Moxahala Creek nested subwatershed, three streams received specific recommendations in the AMDAT (ILGARD 2005): Snake Run, Burley Run and Riders Run. In Snake Run, the AMDAT recommended sealing the mine from which AMD came and using either active lime dosers or an open limestone channel to treat the AMD. In Burley Run, batch treatment strip pits were recommended for AMD treatment. Strip pit reclamation was also recommended. Oxic limestone drains were recommended in Riders Run.

Impairment caused by AMD in the Lower Moxahala Creek nested subwatershed will be addressed by treating sources of AMD in the upstream portions of the subwatershed.

Table 6-4. Recommended implementation actions in the Moxahala Creek subwatershed.

Restoration Categories		Specific Restoration Actions[1]	Moxahala Creek (05040004 05)			
			Black Fork (05 01)	Upper Moxahala Creek (05 02)	Middle Moxahala Creek (05 03)	Lower Moxahala Creek (05 04)
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				

Restoration Categories		Specific Restoration Actions[1]	Moxahala Creek (05040004 05)			
			Black Fork (05 01)	Upper Moxahala Creek (05 02)	Middle Moxahala Creek (05 03)	Lower Moxahala Creek (05 04)
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		A		
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		A		x
		Install slag leach beds		A		x
		Install limestone leach beds				
		Install limestone channels	A	A		x
		Install successive alkalinity producing systems	A			x
		Install settling ponds		A		x
		Install vertical flow ponds		A		x
		Install limestone drains (anoxic and/or oxic)		A	A	x
		Construct acid mine drainage wetland		A		x
	flow diversion	Repair subsidence sites				
		Reclaim pit impoundments				
		Reclaim abandoned mine land	A	A		x
		Eliminate stream captures				

Restoration Categories		Specific Restoration Actions[1]	Moxahala Creek (05040004 05)			
			Black Fork (05 01)	Upper Moxahala Creek (05 02)	Middle Moxahala Creek (05 03)	Lower Moxahala Creek (05 04)
		Eliminate mine drainage discharges			A	x
		Restore positive drainage		A		x
		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	x			x
		Implement conservation tillage practices				
		Implement grass/legume rotations				
		Convert to permanent hayland				
		Install grassed waterways				
		Install vegetated buffer areas/strips	x			x
		Install location-specific conservation buffer				
		Install / restore wetlands				
	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				
		Implement drainage water management				
		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	x			x
	manure	Implement manure management practices	x			x
		Construct animal waste storage structures	x			x

Restoration Categories		Specific Restoration Actions[1]	Moxahala Creek (05040004 05)			
			Black Fork (05 01)	Upper Moxahala Creek (05 02)	Middle Moxahala Creek (05 03)	Lower Moxahala Creek (05 04)
		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 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				

Restoration Categories		Specific Restoration Actions[1]	Moxahala Creek (05040004 05)			
			Black Fork (05 01)	Upper Moxahala Creek (05 02)	Middle Moxahala Creek (05 03)	Lower Moxahala Creek (05 04)
		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				

[1] Actions recommended by the AMDAT (ILGARD 2005) are designated with a capital 'A.'

6.4 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.

6.4.1 Local Watershed Groups

There are no local watershed groups in place. However, the Patriot Coal Co. employs a watershed coordinator for the Moxahala Creek subwatershed to help ODNR-DMRM and the Clay Valley Foundation with water quality issues resulting from mining activities.

6.4.2 Other Sources of Funding and Special Projects

Several AMD-related projects are already in place in the Moxahala Creek subwatershed, including the Tropic Wetland project and the Whitehouse Seep project. These projects were funded using Abandon Mine Lands funding.

6.4.3 Past and Ongoing Water Resource Evaluation

Biology was sampled in the Moxahala Creek subwatershed in 2004 by the Midwest Biodiversity Institute. Ohio EPA monitored the Jonathan Creek subwatershed and several additional sites in the Moxahala Creek subwatershed in 2008. Ohio EPA intends to return to the watershed for new data collection in 2023 (Ohio EPA 2010).

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.

6.4.4 Potential and Future Evaluation

ODNR-DMRM did reconnaissance on Buckeye Fork but has no new plans for other work within the Moxahala Creek watershed at the time of this report.

6.4.5 Revision to the Improvement Strategy

The Moxahala 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

Allan, J.D. 1995. *Stream Ecology: Structure and Function of Running Waters*. London, England: Chapman and Hall.

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.

Dufour, P. 1977. "*Escherichia coli*: the fecal coliform." Published in *Bacterial Indicators/Health Hazards Associated with Water*. Editors: A.W. Hoadley and B.J. Dutka. First Edition. Conshohocken, PA: American Society for Testing and Materials.

Eberhart, R.J. 1998. Characterization of a highly acid watershed located mainly in Perry County, Ohio. Master's Thesis presented to Ohio University, College of Engineering, August 1998.

ILGARD (The Institute for Local Government Administration and Rural Development). 2005. *Acid Mine Drainage Abatement and Treatment Plan for the Moxahala Creek Watershed*. Ohio University. Athens, Ohio.

Kocsis, J.A. 2000. Analysis of acid mine drainage in the Black Fork Subwatershed. Ohio University. Thesis Russ College of Engineering and Technology.

ODD (Ohio Department of Development – Office of Strategic Research). 2004. *Projected Population: County Totals*. Published on: http://www.development.ohio.gov/research/FILES/P200/countytotals.pdf.

Ohio EPA (Ohio Environmental Protection Agency – Division of Surface Water). 2009. *Biological and Water Quality Study of the Moxahala Creek Watershed, 2008; Perry, Morgan, Muskingum and Licking Counties, Ohio*. Published at: http://www.epa.ohio.gov/portals/35/documents/MoxahalaCreekTSD2008.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.

Spotila, J., K. Terpin, R. Koons and R. Bonati. 1979. "Temperature requirements of fishes from eastern Lake Erie and upper Niagra River: a review of the literature." *Environmental Biology of Fisheries*, 4, 281-307.

U.S. EPA (United States Environmental Protection Agency – Office of Water). 2002. *A Homeowners Guide to Septic Systems.* Published on: EPA-832-B-02-005 (http://www.epa.gov/owm/septic/pubs/homeowner_guide_long.pdf).

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.