January 2012

Ohio Environmental Protection Agency

Total Maximum Daily Loads for the Grand River (lower) Watershed

Final Report
January 31, 2012

John R. Kasich, Governor
Mary Taylor, Lt. Governor
Scott J. Nally, Director

Photo caption: Paine Falls (on Paine Creek) in Lake County.

Contents

Tables

Figures

Abbreviations and Acronyms

ACSI	Appalachian Clean Streams Initiative
ALD	anoxic limestone drain
ALU	aquatic life use
AMD	acid mine drainage
AMDAT	Acid Mine Drainage Abatement and Treatment
AML	Abandoned Mine Land
BMP	best management practice
Corps	U.S. Army Corps of Engineers
CREP	Conservation Reserve Enhancement Program
CRP	Conservation Reserve Program
CSO	combined sewer overflow
CWH	coldwater habitat
DMR	discharge monitoring report
DMRM	Division of Mineral Resource Management
DO	dissolved oxygen
EOLP	Erie/Ontario Drift and Lake Plain ecoregion
EPA	Environmental Protection Agency (Ohio or U.S.)
EQIP	Environmental Quality Incentives Program
EWH	exceptional warmwater habitat
FSA	Farm Service Agency
GRPI	Grand River Partners, Inc.
HRU	hydrologic response unit
HSG	hydrologic soil group
HSTS	home sewage treatment system
HUC	hydrologic unit code
IBI	Index of Biotic Integrity
ICI	Invertebrate Community Index
LA	load allocation
LEAP	Livestock Environmental Assurance Program
LID	low impact development
LRAU	large river assessment unit
LSPC	Loading Simulation Program in C++
LULC	land use land cover
MHP	mobile home park
MIwb	Modified Index of Well Being
MS4	municipal separate storm sewer system
MOS	margin of safety
NASS	National Agricultural Statistic Service
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NRCS	National Resource Conservation Service
ODNR	Ohio Department of Natural Resources
ODOT	Ohio Department of Transportation
OLC	open limestone channel
OFBF	Ohio Farm Bureau Federation
OMZA	outside mixing zone average
OMZM	outside mixing zone maximum (or minimum for dissolved oxygen)
OSM	U.S. Office of Surface Mining
PCR	primary contact recreation

PHWH	primary headwater habitat
QHEI	Qualitative Habitat Evaluation Index
RM	river mile
SSH	seasonal Salmonid habitat
STEPL	Spreadsheet Tool for Estimating Pollutant Loading
SUSTAIN	System for Urban Storm Water Treatment and Analysis INtegration
TMDL	total maximum daily load
TSD	technical support document
TSS	total suspended solids
USCB	U.S. Census Bureau (U.S. Department of Commerce)
USGS	U.S. Geological Survey (U.S. Department of the Interior)
WAP	watershed action plan
WAU	watershed assessment unit
WLA	wasteload allocation
WPC	water pollution control
WQM	Water Quality Management
WQv	water quality volume
WRDA	Water Resources Development Act
WRLC	Western Reserve Land Conservancy
WRP	Wetland Reserve Program
WWH	warmwater habitat
WWTP	wastewater treatment plant

Units of Measure

cfs	cubic feet per second
gpd	gallons per day
gpm	gallons per minute
MGD	million gallons per day
mg/L	milligram(s) per liter
mL	milliliter
µg/L	microgram(s) per liter

Acknowledgments

The loading analysis for the TMDL was provided by Tetra Tech, Inc. (1468 West Ninth Street, Suite 620, Cleveland, Ohio 44113) as subcontractor to PG Environmental, LLC (570 Herndon Parkway, Suite 500, Herndon, Virginia 20170), under contract to the U.S. Environmental Protection Agency. The principal Tetra Tech authors were Jennifer Olson, Bill Carlson, Kevin Kratt, and Bruce Cleland, and the PG Environmental project manager was Melinda Becker.

U.S. EPA Region 5 (Chicago) provided valuable insight into technical and legal issues.

The following Ohio EPA staff provided technical services for this project:

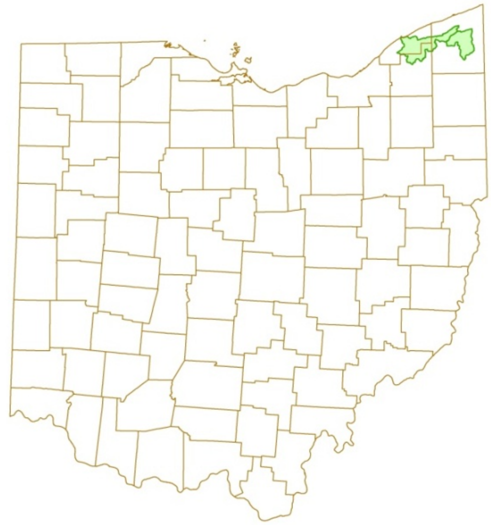
Water Quality Issues	Paul Anderson
Storm Water Issues	Dan Bogoevski
Biological Monitoring	Bob Miltner, Mike Bolton
Point Source Issues	Marie Underwood, John Schmidt, Jennifer Bennage, Laura Weber, Gary Stuhlfauth
TMDL Coordination	Beth Risley, Trinka Mount

Various local governments and storm water utilities provided information for the SUSTAIN model (see Appendix J). Their assistance is appreciated.

Acknowledgment is made of the property owners who allowed Ohio EPA personnel access to the study area.

Executive Summary

The lower Grand River watershed is located in northeast Ohio and drains to Lake Erie near Painesville, Ohio. This 287 square mile watershed area is home to more than 110,000 people and encompasses all or part of seven municipalities in Lake, Ashtabula and Geauga counties. The watershed is primarily forested and agricultural with 16 percent being developed. The developed area is concentrated in the western portion of the watershed, while the eastern portion is rural.



State wide map of the lower Grand River watershed with the TMDL project area highlighted.

The geology in the area dictates that flow in the Grand River is fed primarily by rainfall and snow melt, with very little base flow. Consequently, discharge becomes quite small in the summer, so the river is sustained by the many coldwater tributaries that continually discharge ground water into the river. Those coldwater tributaries and other sources of base flow are essential to the overall health of the Grand River.

In 2003 and 2004, Ohio EPA sampled 56 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 recreation uses at 29% of sites sampled and 77% for aquatic life uses. The causes of impairments included pollutants associated with urban storm water, habitat alteration, *Escherichia coli* (*E. coli*) bacteria and natural causes. Sources of these stressors include urban development and storm water, failing home sewage treatment systems and agriculture for *E. coli*, and natural sources.

Total maximum daily loads (TMDLs) have been developed for pollutants and stressors that impair beneficial uses and preclude attainment of applicable water quality standards. Specific TMDLs address total phosphorus, *E. coli* bacteria and flow regime.

Grand River at the boundary between Ashtabula and Lake counties.

The water quality impairments in the lower part of the Grand River watershed can be corrected through a variety of actions. The impact of development can be lessened by retaining storm water on-site or allowing it to infiltrate the ground and by adopting better site design practices. Agricultural practices that minimize runoff from fields would reduce both sediment and nutrient impacts. Inspecting home sewage treatment systems and replacing or repairing failing systems would reduce bacteria. Finally, future permits for some point sources should include lower effluent limits for *E. coli* and monitoring requirements for total phosphorus.

1. Introduction

The Grand River watershed is in northeastern Ohio and drains to Lake Erie, encompassing approximately 705 square miles (ODNR 2001). The Grand River watershed was subdivided into two study areas for ease of study and reporting—the upper and lower watersheds. This TMDL addresses the lower portion of the watershed, as presented in Figure 1-1, encompassing 287 square miles.

The lower Grand River watershed consists of two 10-digit hydrologic units: Griggs Creek – Mill Creek (04110004 04) and Big Creek – Grand River (04110004 06). In 2003 and 2004, the Ohio Environmental Protection Agency (Ohio EPA) evaluated the biological health and water quality of the lower Grand River watershed (see Ohio EPA 2006a). The results of that survey show that the Grand River and its tributaries continue to harbor a rich and diverse biological assemblage containing many rare and threatened species, and several state endangered species (Ohio EPA 2006a). However, the results also indicate that some waterbody segments are in partial attainment or non-attainment of the warmwater habitat (WWH), exceptional warmwater habitat (EWH), and coldwater habitat (CWH) designated aquatic life uses (ALU). Additionally, several segments do not support the recreation use designations. Table 1-1 presents the designated uses of all assessed streams in the lower Grand River watershed. Watershed assessment units (WAUs; equivalent to 12-digit hydrologic unit code [HUCs]) as identified on Figure 1-1 were further evaluated by Ohio EPA for priority. Priority points ranged from 4 to 11 on a 12-point scale for WAUs in the lower Grand River watershed.

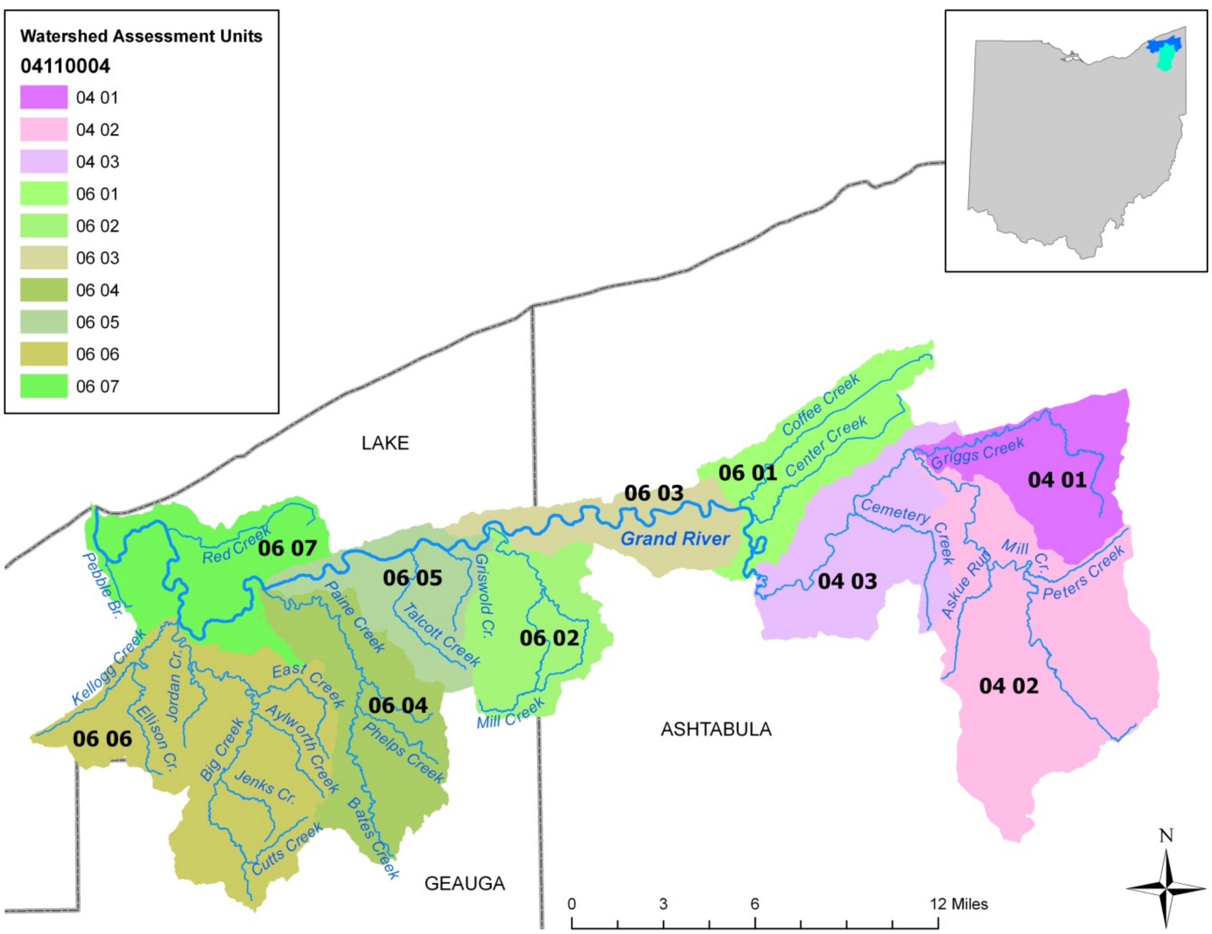


Figure 1-1. Lower Grand River watershed.

Table 1-1. ALU designations in the lower Grand River watershed

Stream name [a]	ALU designation
Grand River	*Fobes Rd to State Route 2:* EWH *State Route 2 to mouth:* WWH
Red Creek	WWH / SSH
Big Creek	*Headwaters to Girdled Rd.:* WWH *Girdled Rd. to mouth:* WWH / SSH
Kellogg Creek	WWH / SSH
Ellison Creek	WWH / SSH
Jordan Creek	CWH
East Creek	CWH
Aylworth Creek	CWH
Jenks Creek	CWH
Cutts Creek	CWH
Paine Creek	*Headwaters to Paine Falls:* WWH *Paine Falls to mouth:* EWH / SSH
Bates Creek	Warmwater Habitat
Phelps Creek	EWH and CWH
Unnamed tributary to Paine Creek (RM 7.2)	EWH and CWH
Talcott Creek	CWH
Griswold Creek	WWH
Mill Creek	*Headwaters to Doty Road:* CWH / SSH *Doty Road to mouth:* WWH / SSH
Unnamed tributary to Mill Creek (RM 4.3)	CWH
Coffee Creek	WWH
Center Creek	WWH
Mill Creek	WWH
Cemetery Creek	WWH
Griggs Creek	WWH
Askue Run	WWH
Peters Creek	WWH

CWH = coldwater habitat; EWH = exceptional warmwater habitat; RM = rive mile; SSH = seasonal Salmonid habitat; WWH = warmwater habitat.
a Indentations of stream names indicate the streams are tributaries to larger streams above their name (less indented).

The Clean Water Act and U.S. Environmental Protection Agency (U.S. EPA) regulations require that states develop total maximum daily loads (TMDLs) for waters that are included on the section 303(d) lists. The TMDL and water quality restoration planning process involves several steps including watershed characterization, target identification, source assessment, and allocation of loads. The pollutant load is allocated among all sources in the watershed and voluntary (for nonpoint sources) and regulatory (for point sources) control measures are identified for attaining the source allocations. An implementation plan is also typically established to ensure that the control measures are effective at restoring water quality and all designated water uses.

The overall goals and objectives in developing the lower Grand River watershed TMDLs were as follows:

- Assess the water quality within the lower Grand River watershed and identify key issues associated with the impairments and potential pollutant sources.
- Use the best available science and available data to determine flow and water quality conditions that will result in all streams fully supporting their designated uses.
- Prepare a final TMDL report that meets the requirements of the Clean Water Act and provides information to the stakeholders that can be used to facilitate implementation activities and improve water quality.

The results of the TMDL process for the lower Grand River watershed are documented in this report.

2. Water Quality Standards and Impairments

This section presents a summary of the applicable water quality standards for waters in the lower Grand River watershed (Table 2-1). A summary of the waterbody impairments is also presented. For the water quality standards for Ohio, see *OAC-3745-1*, and for a full analysis of the impairments, see the *Biological and Water Quality Study of the Grand River Basin 2003 - 2004, Hydrologic Units 04110004 050 and 04110004 060* (Ohio EPA 2006a). Ohio EPA also completed a study in the upper Grand River: *Biological and Water Quality Study of the Upper Grand River (Hydrologic Units 04110004 010, 04110004 020, 04110004 030, and 04110004 040)* (Ohio EPA 2009). Ohio EPA is in the process of revising the water quality standards, thus the both of Ohio EPA's Grand River studies (Ohio EPA 2006a, 2009) and other documents published before this TMDL report might have used standards that are no longer in effect.

Table 2-1. Ohio water quality standards

Component	Description
Designated Use	Designated use reflects how the water can potentially be used by humans and how well it supports a biological community. Every water in Ohio has a designated use or uses; however, not all uses apply to all waters (i.e., they are waterbody specific)[a].
Numeric Criteria	Chemical criteria represent the concentration of a pollutant that can be in the water and still protect the designated use of the waterbody. Biological criteria indicate the health of the in-stream biological community by using one of three indices: • Index of Biotic Integrity (IBI) (measures fish health). • Modified Index of well being (MIwb) (measures fish health). • Invertebrate Community Index (ICI) (measures benthic macroinvertebrate health).
Narrative Criteria	These are the general water quality criteria that apply to all surface waters. These criteria state that all waters must 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.
Antidegradation Policy	This policy establishes situations under which Ohio EPA may allow new or increased discharges of pollutants, and requires those seeking to discharge additional pollutants to demonstrate an important social or economic need. Refer to <http://epa.ohio.gov/dsw/wqs/index.aspx> for more information.

a. According to OAC 3745-1-07(A)(1) each waterbody is assigned a designated use. Any streams in Ohio that are undesignated still must attain the chemical criteria associated with the Warm Water Habitat designation. There is no similar protection for recreational use.

2.1. Numeric Criteria

Numeric criteria are based on concentrations of chemicals and degree of aquatic life toxicity allowable in a waterbody without adversely affecting its beneficial uses. They consist of biological criteria, chemical criteria, and whole effluent toxicity levels. The criteria applicable to the lower Grand River that are pertinent to the TMDL project are presented in the following sections.

2.1.1. Biological Criteria

The biological water quality criteria (also referred to as biocriteria) in Ohio are numeric and vary by ALU designation and Level III Ecoregion. ALU designations in Ohio include CWH, EWH, seasonal salmonid habitat (SSH), WWH, modified warmwater habitat (MWH), and limited resource waters (LRW). The ability of a waterbody to meet its ALU designation is based primarily on the scores it receives on three community indices, as applicable: the Index of Biological Integrity (IBI), the Modified Index of Well-being (MIwb), and the Invertebrate Community Index (ICI). The IBI and MIwb are based on the composition of the fish community, and the ICI is based on the composition of the macroinvertebrate community.

Waters of concern in the lower Grand watershed are of varying size and are designated SSH, EWH, WWH, and CWH.[1] Table 2-2 presents a summary of the biocriteria for the protection of aquatic life in the Erie/Ontario Drift and Lake Plain (EOLP) ecoregion, which varies by ALU designation and stream size. Note that the numeric biological criteria are not applicable to streams designated as CWH. CWH attainment is determined by evaluating the presence and quality of coldwater fish (e.g., mottled sculpin, brook stickleback, redside dace), additional fish species (e.g., longnose dace, American brook lamprey, central mudminnow), and coldwater macroinvertebrates.

Table 2-2. Biocriteria for EOLP

Index	Size	WWH	EWH
IBI	Boat	40	48
	Wading	38	50
	Headwaters	40	50
MIwb	Boat	8.7	9.6
	Wading	7.9	9.4
ICI	All [a]	34	46

Notes
Based on Table 7-15 of *OAC-3745-1-07.*
EWH = exceptional warmwater habitat; IBI = Index of Biotic Integrity; ICI = Invertebrate Community Index; MIwb = Modified Index of Well-being; WWH = warmwater habitat.
a. ICI scoring using the modified Hester-Dendy artificial substrate samplers. See Table 7-15 of *OAC-3745-1-07.*

In addition to the ALU designations, Ohio designates SSH. Waterbodies with that designation are "capable of supporting the passage of salmonids from October to May and are waterbodies large enough to support recreational fishing" (*OAC-3745-1-07(B)(1)(e)*). In the Grand River, the following waterbodies are designated SSH (*OAC-3745-1-10 Table 10-1*):

- Big Creek (Girdled Road to mouth)
- Ellison Creek
- Grand River (Harpersfield Dam to State Route 2)
- Kellogg Creek
- Mill Creek (HUC 04110004 06 02)
- Paine Creek (Paine Falls to mouth)
- Red Creek

2.1.2. Chemical Criteria

Ohio has numeric criteria for parameters pertinent to the lower Grand River watershed impairments including *E. coli*, dissolved oxygen, temperature, and several metals.

E. coli

Ohio has numeric water quality criteria for *E. coli* that are applicable during the recreation season only: May 1 through October 31, as defined in *OAC-3745-1-07(4);* for a summary of *OAC-3745-1-07, Table 7-13*, see Table 2-3.

[1] Designated uses for the Grand River basin are presented in *OAC-3745-1-10*.

Table 2-3. *E. coli* standards for Ohio

Recreation use	*E. coli* (counts/100 mL)	
	Seasonal geometric mean	Single sample maximum [a]
Bathing	126	235 [b]
PCR – Class A	126	298
PCR – Class B	161	523
PCR – Class C	206	940
SCR	1,030	1,030

Notes
Based on Table 7-13 of *OAC-3745-1-07*.
PCR = primary contact recreation; SCR = secondary contact recreation
a. Except as noted in footnote b, those criteria must not be exceeded in more than 10 percent of the samples taken during any 30-day period.
b. This criterion will be used for issuing beach and bathing water advisories.

The *E. coli* standards vary by recreation use designation. In the lower Grand River watershed, all waters of concern are designated Primary Contact Recreation (PCR) as Class A or Class B. PCR Class A waters "support, or potentially support, *frequent* primary contact recreation activities;" whereas, PCR Class B waters "support, or potentially support, *occasional* primary contact recreation activities" (*OAC-3745-1-07(B)(4)(b)*; emphases added). The seasonal geometric mean calculated from no less than five samples within a 30-day period must not exceed 126 *E. coli* counts per 100 milliliters (mL) for PCR Class A waters, and must not exceed 161 per 100 mL for PCR Class B waters. The single sample maximum is also presented in Table 2-3 but is not further discussed in this report because the single sample maximum is typically only used to determine use support at beaches, not for streams.

The lower Grand River is designated PCR Class A while all of the tributaries to the lower Grand River are designated PCR Class B. To protect downstream uses, any NPDES-permitted facility or a TMDL located on a stream designated PCR Class B that is within 5 miles of the Grand River will be subject to the criteria from the Grand River's PCR Class A designated use (Ohio EPA 2010b).

Dissolved Oxygen

Ohio also has two numeric criteria for dissolved oxygen that vary by ALU designation. The outside mixing zone minima (OMZM) and outside mixing zone 24-hour averages (OMZA) for WWH, EWH, and CWH waters are presented in Table 2-4.

Table 2-4. Dissolved oxygen standards for Ohio

ALU designation	Outside mixing zone minimum (mg/L)	Outside mixing zone 24-hour average (mg/L)
CWH[a]	6.0	7.0
WWH[b]	4.0	5.0
EWH[c]	5.0	6.0

Notes
mg/L = milligrams per liter
a. OAC-3745-1-43(D)(4), Table 43-8
b. OAC-3745-1-42, Table 42-1
c. OAC-3745-1-43(D)(2)(b), Table 43-3

Temperature

Ohio's numeric criteria for temperature are published in Table 7-14 in rule *OAC-3745-1-07*. Table 2-5 summarizes the temperature criteria applicable to WWH and EWH designated uses in the lower Grand River watershed, which is within the Lake Erie Basin. There are no numeric criteria for CWH streams.

Table 2-5. Temperature standards for Ohio

	Average		Daily maximum	
Dates	**Degrees Fahrenheit**	**Degrees Celsius**	**Degrees Fahrenheit**	**Degrees Celsius**
January 1-31	44	6.7	49	9.4
February 1-29	44	6.7	49	9.4
March 1-15	48	8.9	53	11.7
March 16-31	51	10.6	56	13.3
April 1-15	54	12.2	61	16.1
April 16-30	60	15.6	65	18.3
May 1-15	60	17.8	69	20.6
May 16-31	66	18.9	72	22.2
June 1-15	72	22.2	76	24.4
June 16-30	82	27.8	85	29.4
July 1-31	82	27.8	85	29.4
August 1-31	82	27.8	85	29.4
September 1-15	82	27.8	85	29.4
September 16-30	75	23.9	80	26.7
October 1-15	67	19.4	72	22.2
October 16-31	64	16.1	66	18.9
November 1-30	54	12.2	59	15.0
December 1-31	44	6.7	49	9.4

Note: Based on Section G of Table 7-14 in rule *OAC-3745-1-07.*

Metals

The numeric criteria for metals vary by hardness and analysis methodology (e.g., total recoverable, dissolved). The different standards are applicable within the mixing zone and outside the mixing zone. Ohio's metal criteria are published in *Table 7-1* and *Table 7-9* of *OAC-3745-1-07*. The pertinent outside mixing zone maxima (OMZM) and outside mixing zone average (OMZA) criteria are summarized in Table 2-6. Metals numeric criteria for the protection of wildlife and agricultural water supplies are also presented in Table 2-6 for reference.

Table 2-6. Metal standards for Ohio

Metal	ALU OMZM (µg/L)	ALU OMZA (µg/L)	AWS OMZA (µg/L)	Wildlife OMZA (µg/L)
Arsenic	340	150	100	---
Cadmium	4.5 [a]	2.5 [a]	50	---
Chromium	1,800 [a]	86 [a]	100	---
Chromium, Hexavalent (dissolved)	16	11	--	---
Copper	14 [a]	9.3 [a]	500	---
Iron	---	---	5,000	---
Lead	120 [a]	6.4 [a]	100	---
Mercury	1.4	0.8	10	0.0013
Nickel	470 [a]	52 [a]	200	---
Selenium	--	4.6	50	---
Zinc	120 [a]	120 [a]	25,000	---

Notes

Based on *Table 7-1*,*Table 7-9,* and *Table 7-12* of *OAC-3745-1-07* and *Table 33-2* of *OAC-3745-1-33*

Criteria displayed are for total recoverable metals.

ALU = aquatic life use; AWS = agricultural water supply; OMZA = outside mixing zone average; OMZM = outside mixing zone maximum.

a. Criteria vary by hardness. The displayed criteria are for a sample with a hardness of 100 mg/L of calcium carbonate.

2.2. Narrative Criteria and Guidance

Narrative criteria are the general water quality criteria that apply to all surface waters. Those criteria, promulgated in *OAC-3745-1-04,* state that all waters must 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.

2.2.1. Temperature

Ohio's EWH and CWH criteria also include narrative temperature standards. A pertinent CWH criterion is in *OAC-3745-1-43(D)(4) Table 43-8;* the EWH and CWH criterion is in *OAC-3745-1-07 Table 7-1*. Both criteria state "At no time shall the water temperature exceed the temperature which would occur if there were no temperature change attributable to human activities." Figure 2-1 identifies the ALU designations of all streams in the lower Grand River watershed.

2.2.2. Nutrients

Ohio EPA does not have statewide numeric criteria for nutrients. TMDL targets are selected on the basis of evaluating reference stream data published in a technical report titled *Association between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams* (Ohio EPA 1999; hereafter referred to as the *Associations* document). The document identifies ranges of concentrations for nitrate plus nitrite nitrogen concentrations and total phosphorus concentrations on the basis of observed concentrations at all sampled ecoregional reference sites. Those reference stream concentrations will be used as TMDL targets; the total nitrate-nitrite and phosphorus targets are shown in Table 2-7. One of the methods that U.S. EPA recommends basing nutrient criteria on the 75^{th} percentile of the frequency distribution of reference streams (U.S. EPA 2000). That method was used to set the TMDL nutrient targets. It is important to note that those nutrient targets are not codified in Ohio's water quality standards.

Table 2-7. Statewide suggested nutrient criteria for the protection of aquatic life

Stream size	Beneficial use	
	WWH	**EWH**
Total phosphorus concentration (mg/L) [a]		
Headwaters	0.08	0.05
Wading	0.10	0.05
Small rivers	0.17	0.10
Nitrate + nitrite concentrations (mg/L) [b]		
Headwaters	1.0	0.5
Wading	1.0	0.5
Small rivers	1.5	1.0

Source: Ohio EPA 1999

Notes

mg/L = milligrams per liter

Headwaters streams drain less than 20 square miles. Wading streams drain 20 to 200 square miles. Small rivers drain 200 to 1,000 square miles.

a. Statewide total phosphorus recommendations were generated by Ohio EPA (1999) with ANOVA analyses of pooled data across the state.

b. Statewide nitrate plus nitrite recommendations were calculated by Ohio EPA (1999) as the 75th percentile of pooled reference stream data across the state.

2.2.3. Sediment

Using total suspended solids (TSS) as an indicator of sediment in streams is fairly common and has been used in numerous TMDL reports; however, TSS concentrations can be an underestimation of sediment loads because they account only for particles small enough to remain suspended in the water column. Larger particles, such as sand and coarser particles that might have the most influence on aquatic life and stream substrates, are often not included in TSS concentrations because they usually settle out of the water column.

Ohio does not have water quality standards for TSS. However, Ohio EPA has calculated TSS statistics for reference sites throughout the EOLP ecoregion. Ohio EPA's evaluation of reference data include only data collected between June 15 and October 15 and data from high-flow events as noted by field personnel or as determined from U.S. Geological Survey (USGS) gages are excluded (Ohio EPA 1999, p. 18). The 75th percentile statistics for reference sites (non-urban, unmodified) in the EOLP are (Ohio EPA 1999, Appendix I, p. 24) as follows:

- Headwaters: 25.0 mg/L
- Wading: 21.0 mg/L
- Small River: 18.5 mg/L

2.2.4. Habitat

The Qualitative Habitat Evaluation Index (QHEI) is a quantitative expression of a qualitative, visual assessment of habitat in free-flowing streams and was developed by Ohio EPA to assess available habitat for fish communities (Rankin 1989, 1995). The QHEI is a composite score of six physical habitat categories:

- Substrate
- In-stream cover
- Channel morphology
- Riparian zone and bank erosion
- Pool/glide and riffle/run quality
- Gradient

Each of those categories is subdivided into specific attributes that are assigned a point value reflective of the attribute's impact on the aquatic life. Highest scores are assigned to the attributes correlated to streams with high biological diversity and integrity and lower scores are progressively assigned to less desirable habitat features. A QHEI evaluation form[2] is used by a trained evaluator while at the sampling location. Each of the components is evaluated on-site, recorded on the form, the score totaled, and the data later analyzed in an electronic database.

The QHEI is a macro-scale approach that measures the emergent properties of habitat (sinuosity, pool/riffle development) rather than the individual factors that shape the properties (current velocity, depth, substrate size). The QHEI is used to evaluate the characteristics of a short stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites could have poorer physical habitat because of a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. However, QHEI evaluations are segment specific and do not give a strong indication of the quality of the habitat in other stream segments.

QHEI scores can range from 12 to 100. The appropriate QHEI target score was determined by statistical analysis of Ohio's statewide database of paired QHEI and IBI scores. Simple linear and exponential regressions and frequency analyses of combined and individual components of QHEI metrics in relation to the IBI were examined. The regressions indicate that the QHEI is significantly correlated with the IBI. QHEI scores greater than 75 generally indicate excellent stream habitat, scores between 60 and 75 indicate good habitat quality, and scores less than 45 demonstrate habitat that is not conducive to WWH. Scores between 45 and 60 need separate evaluation by trained field staff to determine the potential ALU for the stream.

Note that many streams with fauna indicative of the CWH ALU might not achieve QHEI scores indicative of suitable habitat for the WWH use. That is because many such streams, especially in the lower Grand River drainage, are high gradient, bedrock controlled streams that lack deep pools, multiple substrate types, or other cover features that add points in the QHEI scoring protocol. Therefore, judgments regarding habitat evaluations in those stream types should be made with that limitation in mind.

2.2.5. Metals

Iron and manganese do not have OMZM and OMZA standards; however, reference stream data are reported in the appendices of the *Associations* document (Ohio EPA 1999). The pertinent data from that document are presented in Table 2-8.

Table 2-8. 75th percentile data for reference streams in the EOLP ecoregion

Metal	Headwaters (≤ 20 mi^2)	Wading (20–50 mi^2)	Small river (50–100 mi^2)
Iron (µg/L)	1,350	1,025	1,325
Manganese (µg/L)	248.75	191.75	--

Based on Ohio EPA 1999.

[2] The evaluation form is available at http://www.epa.ohio.gov/portals/35/documents/QHEIFieldSheet061606.pdf.

2.3. Impairments

WAUs in the lower Grand River watershed are impaired for their ALU and recreation use designations. Six of the ten WAUs are impaired for their ALU designations. However, as determined by Ohio EPA during stream assessments for the 2010 Integrated Report, the ALU impairments in Griggs Creek, Bates Creek, Cemetery Creek at river mile (RM) 2.1 and Paine Creek are caused by natural limits associated with wetland influences in two WAUs (04 01 and 06 04) and TMDLs will not be prepared for those listings. Ohio EPA will pursue a reclassification and removal of Cemetery Creek at RM 1.2/1.3 from the 2012 303(d) list given that aquatic life use impairment is caused by natural conditions and unknown toxicity. A TMDL is not conducted to address natural causes of impairment. Impairment caused by 'unknown toxicity' (e.g. residual chlorine) will not be addressed in this TMDL report. Seven of the ten WAUs are impaired for their recreation use, as is the lower Grand River's large river assessment unit (LRAU). Table 2-9 summarizes the impairment causes and sources reported in Ohio's 2010 303(d) *Integrated Water Quality Monitoring and Assessment Report* (Ohio EPA 2010a).

Table 2-9. Lower Grand River watershed assessment units to be addressed by TMDLs

Assessment unit [a] (04110004)	Name	Area (mi^2)	Causes	Probable sources
04 01	Griggs Creek	20.68	Natural limits (wetlands)	Natural
			Bacteria	
04 02	Peters Creek – Mill Creek	54.81	Siltation	Channelization (agricultural)
			Bacteria	
04 03	Town of Jefferson – Mill Creek	28.17	Bacteria	
06 01	Coffee Creek – Grand River	22.01	Bacteria [b]	Failing septic systems, anthropogenic sources [c]
06 02	Mill Creek	20.99	Bacteria	
06 04	Paine Creek	28.83	Natural limits	Natural
			Bacteria	
06 06	Big Creek	50.42	Cause unknown Direct habitat alteration Pollutants associated with urban storm water [d]	Urban runoff, storm sewers (nonpoint sources) Hydromodification – development
			Natural limits	Natural
			Bacteria	
06 07	Red Creek – Grand River	26.30	Flow alteration Pollutants associated with urban storm water [d]	Urban runoff, storm sewers (nonpoint sources)
			Bacteria	
Large river assessment unit (LRAU)	Grand River	41.28 (length in miles)	Bacteria	

Notes

a. Ohio EPA switched from 11- and 14-digit hydrologic unit codes (HUCs) to 10- and 12-digit HUCs in 2009. Refer to Appendix A for a conversion chart.

b. Coffee Creek is not listed as impaired in the 2010 Integrated Report. The assessment unit will be listed in the 2012 Integrated Report.

c. The impacts of many of the failing septic systems were mitigated by extending sewer coverage from the Austinburg wastewater treatment plant and installing sewer lines in the unsewered area.

d. The 303(d) list of impaired waters labels this cause of impairment as "unknown toxicity," which typically includes polyaromatic hydrocarbons, metals and lawn chemicals. The "unknown" component is the ratio of effects and mixtures that causes the toxicity. The cause of impairment is discussed as "pollutants associated with urban storm water" throughout this report.

Coffee Creek (04110004 06 01) has been added to the list of impaired waters because of the availability of *Escherichia coli* data collected during 2000 that Ohio EPA has determined to be representative of current conditions. Coffee Creek has been historically impaired for fecal coliform, but because of a change in state water quality standards, it was omitted from the 2010 303(d) list. Coffee Creek will be added to the 2012 303(d) list as impaired for bacteria. Probable sources of bacteria to Coffee Creek were derived from Ohio EPA's Technical Support Document (TSD) *Biological and Water Quality Study of the Grand River Basin 2003 - 2004, Hydrologic Units 04110004 050 and 04110004 060* (Ohio EPA 2006a).

ALU impairments along Cemetery Creek in the Town of Jefferson – Mill Creek WAU (04110004 04 03) were evaluated during 2011 by Ohio EPA staff. Results of this evaluation indicated that the causes of impairment have changed since the 2010 list and include natural conditions and unknown toxicity due to residual chlorine. These changes will be pursued in Ohio EPAs 2012 303(d) list cycle. TMDLs are not conducted for waters impaired by natural conditions and the unknown toxicity caused by residual chlorine will not be addressed by a TMDL in this report. Thus this TMDL document does not address ALU impairments in the Cemetery Creek WAU.

2.3.1. Aquatic Life Use

Ohio EPA has identified ALU impairments in six of the ten WAUs in the lower Grand River watershed (Figure 2-1). All the assessment points on the Grand River (i.e., mainstem) are in full attainment for ALU; however, several tributaries to the Grand River contain assessment points that are in non-attainment or partial attainment of their ALU designations. Ohio EPA lists impairments by WAU but specifically identified eight impaired creeks (Red Creek, Kellogg Creek, Big Creek, Paine Creek, Bates Creek, Cemetery Creek, Griggs Creek, and Mill Creek [04110004 04 02]) in the *Biological and Water Quality Study of the Grand River Basin 2003 - 2004, Hydrologic Units 04110004 050 and 04110004 060* (Ohio EPA 2006a); the ALU designations and assessment points are displayed in Figure 2-1. TMDLs will be completed to address ALU impairments on Red Creek at the mouth, Kellogg Creek at RM 3.3, Big Creek at RM 16.0, and Mill Creek (04110004 04 02) at RM 25.6.

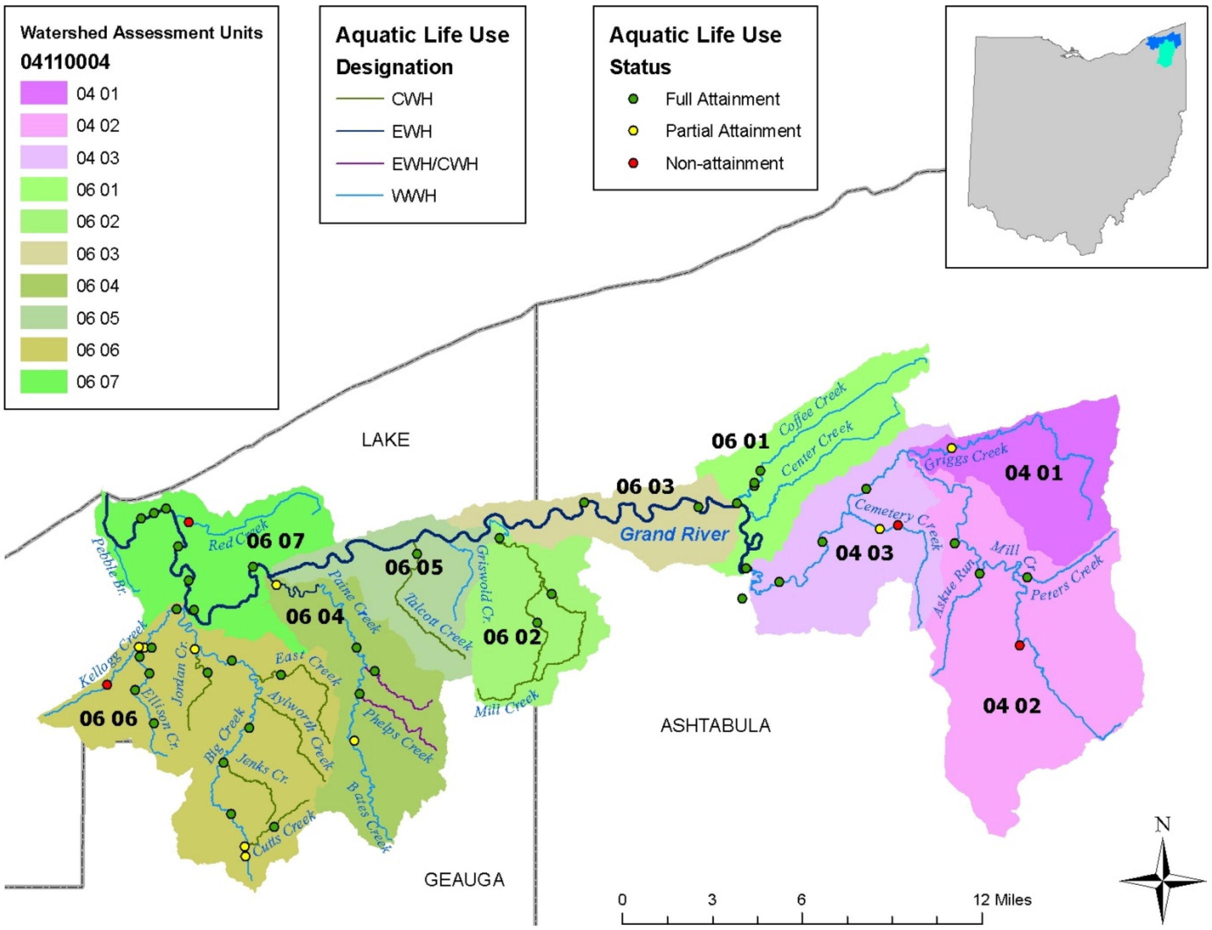


Figure 2-1. Map of ALU designations and assessment points.

2.3.2. Recreation Use

Impairments to recreation use designations are determined by indicator species of pathogenic bacteria. In Ohio, the pathogenic indicator species is *E. coli*. For discussion of the *E. coli* standard, see Section 2.1.2.

Ohio EPA identified bacteria impairments in 7 of the 10 WAUs and on 15 streams (Askue Run, Griggs Creek, Mill Creek (04 02), Peters Creek, Mill Creek (06 02), Unnamed Tributary to Mill Creek (06 02), Bates Creek, Paine Creek, Big Creek, Cutts Creek, East Creek, Ellison Creek, Jordan Creek, Kellogg Creek, and Red Creek). The Grand River LRAU is also impaired for bacteria at five assessed locations (G02G15, G02W18, G02G14, G02S13, and 502530). The recreation use designations and assessment points are displayed in Figure 2-2. Bacteria TMDLs will be completed for the following WAUs: 04 01, 04 02, 04 03, 06 02, 06 04, and 06 06. Bacteria TMDLs will also be completed for the following streams at the designated stations: Grand River (G02G15, G02W18, G02G14, G02S13, and 502530), Coffee Creek (G02W03), and Red Creek (G02G21).

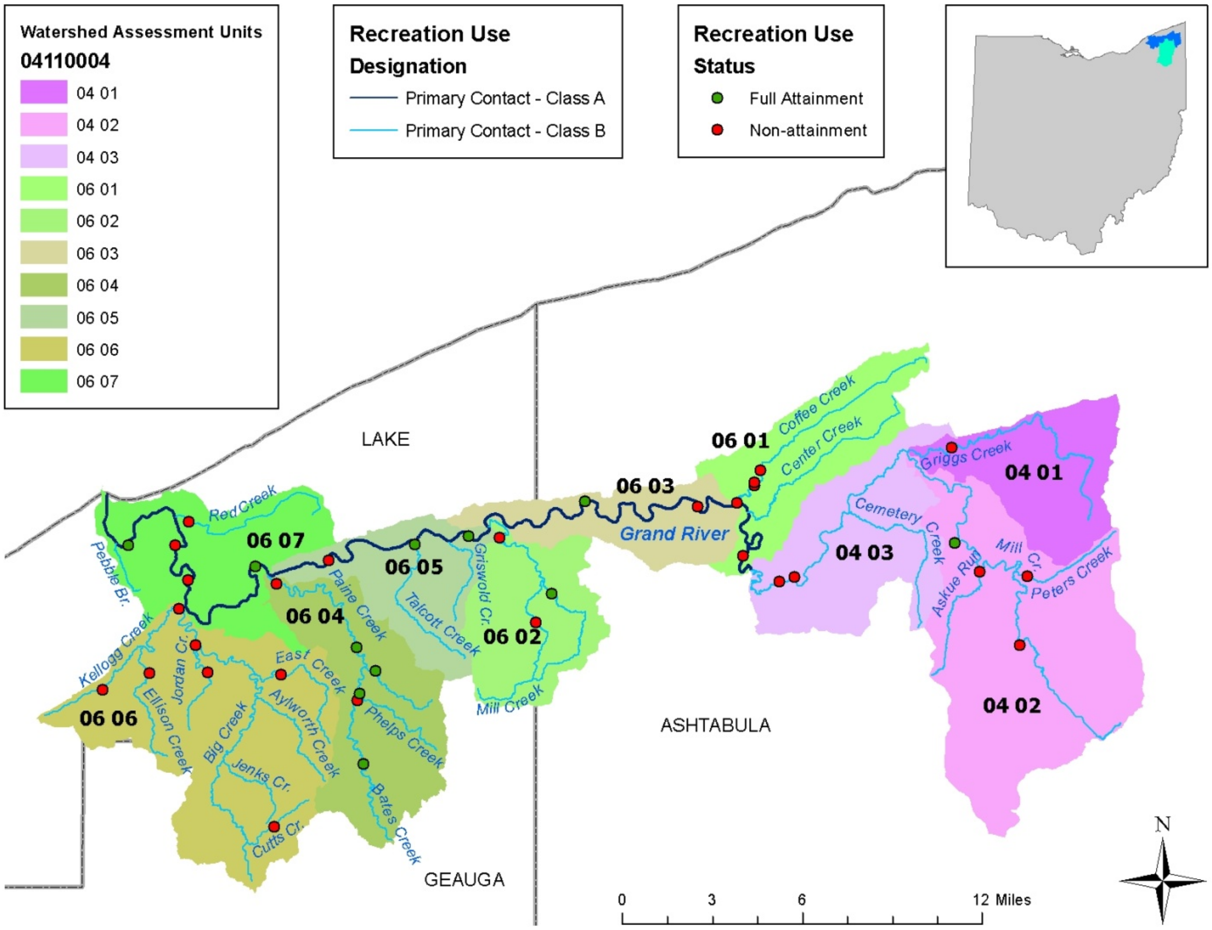


Figure 2-2. Map of recreation use designations and assessment points.

3. Watershed Characterization

3.1. Watershed Description

The WAUs that compose the lower Grand River watershed are in northeast Ohio in Ashtabula, Geauga, and Lake counties. Much of the western portion of the watershed is urban or suburban, while the eastern portion is rural. The upper Grand River watershed encompasses portions of Ashtabula, Geauga, Portage and Trumbull counties and joins the lower Grand River watershed just upstream of the confluence with Mill Creek in Ashtabula County. The upper Grand River watershed drains approximately 418 square miles and is predominately rural. The Grand River is designated a Wild and Scenic River. It is designated a Wild River from the Harpersfield Covered Bridge to the Norfolk and Western Railroad trestle south of Painesville and the Grand River and is designated a Scenic River from U.S. Route 322 in Ashtabula County to the Harpersfield Covered Bridge.[3] The river is designated as an Outstanding State Water because of exceptional ecological values (*OAC-3745-1-05*). The Grand River and its assessed tributaries are also designated agricultural water supplies and industrial waters supplies.

The lower Grand River watershed begins just upstream of the confluence with Mill Creek (04110004 04) in Ashtabula County. Upstream of that confluence, the Grand River watershed is referred to as the upper Grand River watershed. The lower portion of the Grand River travels approximately 41 miles from its confluence with Mill Creek in Ashtabula County to its mouth on Lake Erie in the village of Fairport Harbor. Six tributary areas flow to the mainstem of the Grand River in the lower watershed:

- WAUs associated with the upper Grand River watershed
- Mill Creek (04110004 04)
- Coffee Creek and Center Creek
- Paine Creek, Talcott Creek, Griswold Creek, and Mill Creek (04110004 06 02)
- Big Creek
- Red Creek

The lower Grand River watershed can be described as two distinct sections defined as upstream and downstream of the Harpersfield Dam at RM 34.43 (Figure 3-1). The Harpersfield Dam also serves as a barrier to sea lamprey migration in the Grand River.

The Grand River upstream of the Harpersfield Dam flows through the lacustrine deposits of a former glacial lake. The river is a classic swamp-wetland type stream with low gradient (< 1 foot per mile), fine sediments (typically small gravels to clay), and few riffles. Large woody debris, rootwads, rootmats, undercut banks and deep pools characterize the habitat. The fish fauna in this reach resembles a swamp-stream association and commonly includes trout-perch, silver redhorse, sunfish and blackside darters. The wetland environment also provides spawning habitat for the Great Lakes muskellunge and northern pike. A native population of walleye also exists.

Downstream from the Harpersfield Dam, the gradient increases and the river flows in a series of pools, glides, runs, and riffles through a shale gorge. Long stretches of shallow bedrock alternate with aggregations of glacial till to form glides and riffles, and deeper pools exist where the river erodes former depositional areas. The shale gorge is characterized by steep bluffs and regular flooding in the floodplain. Large tributaries including Big Creek and Paine Creek discharge into the Grand between the Harpersfield Dam and Lake Erie. This portion of the watershed is also influenced by the Snow Belt of northeastern Ohio, which regularly sees annual snowfall totals of more than 100 inches.

[3] Ohio Department of Natural Resources designations refer to: http://ohiodnr.com/watercraft/sr/tabid/2559/Default.aspx

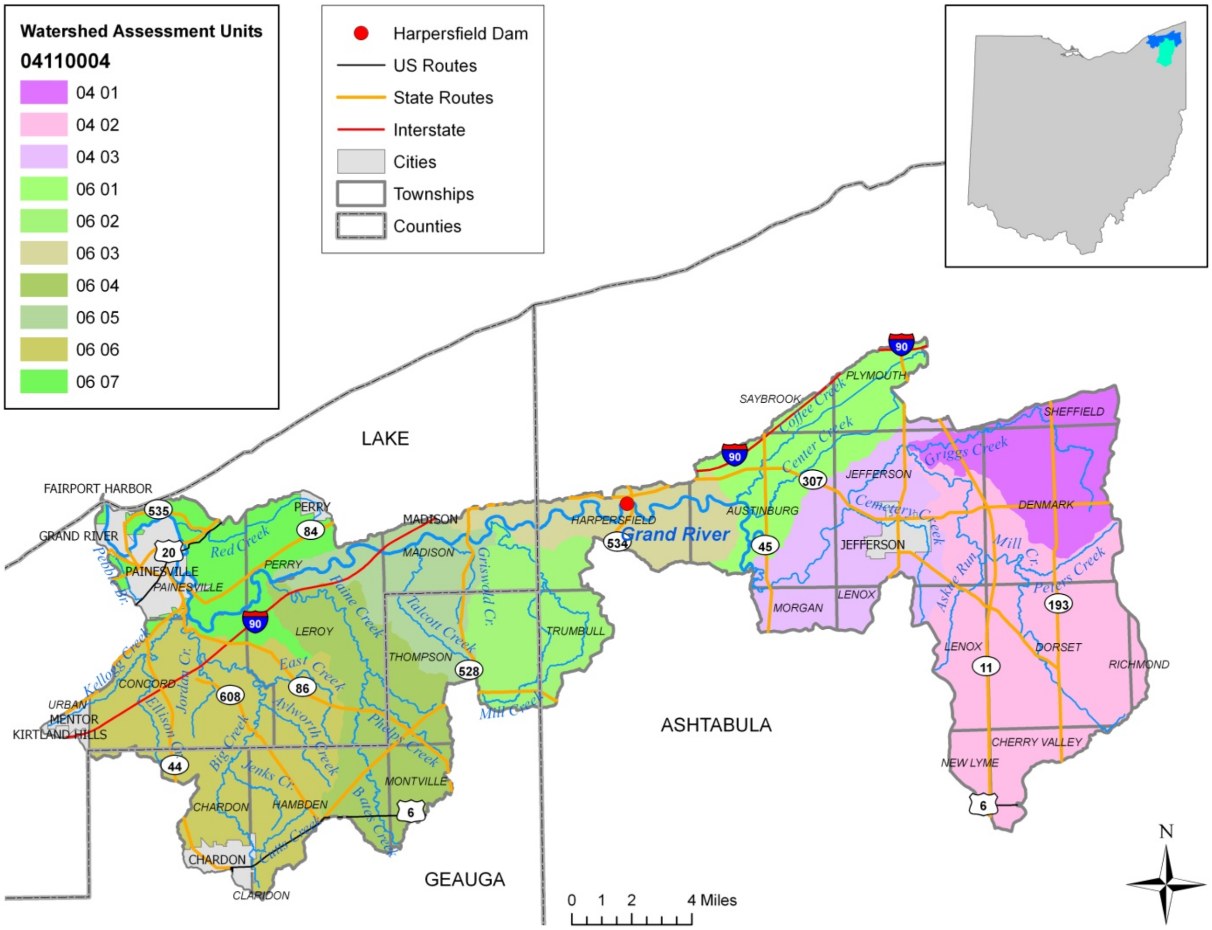


Figure 3-1. Political boundaries in the lower Grand River watershed.

Flow in the Grand River is fed primarily by rainfall and snow melt, with very little base flow sustained by ground water because of the river's glacial and bedrock geology. Consequently, discharge becomes quite small in the summer (relative to drainage area) resulting in the Grand River and its tributaries having limited assimilative capacity. The Grand River is sustained by the many coldwater tributaries that continually discharge ground water into the river. Those coldwater tributaries and other sources of base flow are essential to the overall health of the Grand River.

The Grand River is the only Ohio tributary to Lake Erie that harbors a self-sustaining population of Great Lakes Muskellunge (Ohio EPA 2006a). The watershed provides habitat for many species considered rare by the Ohio EPA or listed as threatened or endangered by Ohio Department of Natural Resources.

The cities and villages in the lower Grand River watershed are presented in Figure 3-1, and county population statistics are presented in Table 3-1.Growth in population has occurred between 2000 and 2010 in Lake and Geauga counties, and the population in Ashtabula County has decreased over that same period. Table 3-2 presents the population data for incorporated cities and villages in the lower Grand River watershed. The following four incorporated municipalities were not included in our population estimates because only small portions are in the lower Grand River watershed: the village of Kirtland Hills, village of Madison, village of Perry, and the city of Mentor.

Table 3-1. County population statistics

County	2000 population	2010 population	Percent difference between 2000 and 2010
Ashtabula	102,728	101,497	– 1.2 %
Geauga	90,895	93,389	+ 2.7 %
Lake	227,511	230,041	+ 1.1 %

Source: USCB 2011.
Note that a county might not be entirely contained within the lower Grand River watershed.

Table 3-2. Populations of incorporated cities and villages in the lower Grand River watershed

Name	Type	County	2009 population	2000 population	1990 population
Chardon	village	Geauga	5,439	5,156	4,446
Fairport Harbor	village	Lake	3,249	3,180	2,978
Grand River	village	Lake	371	345	297
Jefferson	village	Ashtabula	3,412	3,572	3,331
Painesville	city	Lake	18,989	17,503	15,699

Source: USCB 2011
The 2009 population is an estimate; 2000 population and 1990 populations are from the censuses. At the time of publication, city-level data from the 2010 Decennial Census were available only for cities with population of 25,000 or greater.
Note that a city or village might not be entirely contained in the lower Grand River watershed.

3.2. Land Use and Land Cover

Land use land cover (LULC) data sets are widely available for most of the United States. National data sets, including the 1992 National Land Cover Dataset (NLCD) and 2001 NLCD (version 1.0), are routinely used by a variety of watershed models. Many states, and even some counties and municipalities, also have their own LULC data sets.

The LULC data set that is used for analyses in this project is the 2001 NLCD Land Cover (version 1.0)[4] which is a raster data set with 30-meter by 30-meter grid cells, each identified as one of 21 land classes. The 2001 NLCD Percent Developed Impervious data were also used and are similarly 30 meter by 30 meter raster grid cells. When this project began, the 2001 NLCD was the most recent data set that was available for the entire watershed at consistent accuracy and resolution. Similarly, 2001 NLCD Percent Developed Impervious (version 1.0) data that were generated with the 2001 NLCD Land Cover (version 1.0) was the only impervious cover data set available across the entire watershed, in the same resolution at the same level of accuracy.

The 2006 NLCD was published in 2011, and it was evaluated to determine if it was still appropriate to use the 2001 NLCD. While development has continued to occur in the watershed, a review of the 2001 NLCD and 2006 NLCD in ALU impaired watersheds found that the land cover distribution and levels of impervious cover did not vary considerably between the 2001 NLCD and the 2006 NLCD. The impervious cover at impaired sites increased from less than 0.1 percent in the 2001 NLCD to 0.3 percent in the 2006 NLCD. The levels of impervious cover in the threatened watersheds that are being developed referred to in Ohio EPA's TSD (Ohio EPA 2006a) also increased: Cutts Creek, Ellison Creek, and Jordan Creek increased the most by 0.1, 0.8, and 1.2 percent, respectively. Additionally, the 2006 NLCD was published after modeling was completed for this TMDL project.

[4] The 2001 NLCD Land Cover version 2.0, 2006 NLCD Land Cover, and 2006 Percent Developed Impervious were published in 2011.

For the purposes of the lower Grand TMDL, the 2001 NLCD Land Cover (version 1.0) and the NLCD Percent Developed Impervious (version 1.0) data are used. Those data are representative of the land cover near the time of Ohio EPA's assessment in the watershed. Additional data sets were available but were either older or less representative than the 2001 NLCD and were therefore unused. A summary of the 2001 NLCD data for the lower Grand River watershed is presented in Table 3-3 and Figure 3-2.

Table 3-3. Land cover for the lower Grand River watershed

2001 NLCD (v. 1.0) classes	Area (acres)	Relative area
Open Water	2,064	1%
Developed, Open	15,581	8%
Developed, Low	12,266	7%
Developed, Medium	1,642	1%
Developed, High	392	0%
Barren Land	35	0%
Deciduous Forest	80,042	43%
Evergreen Forest	615	0%
Mixed Forest	60	0%
Shrub/Scrub	2,574	1%
Grassland/Herbaceous	7,928	4%
Pasture/Hay	15,607	8%
Cultivated Crops	39,521	21%
Woody Wetland	5,765	3%
Emergent Herbaceous Wetland	41	0%

Note: Percentages do not add to 100 because of rounding.

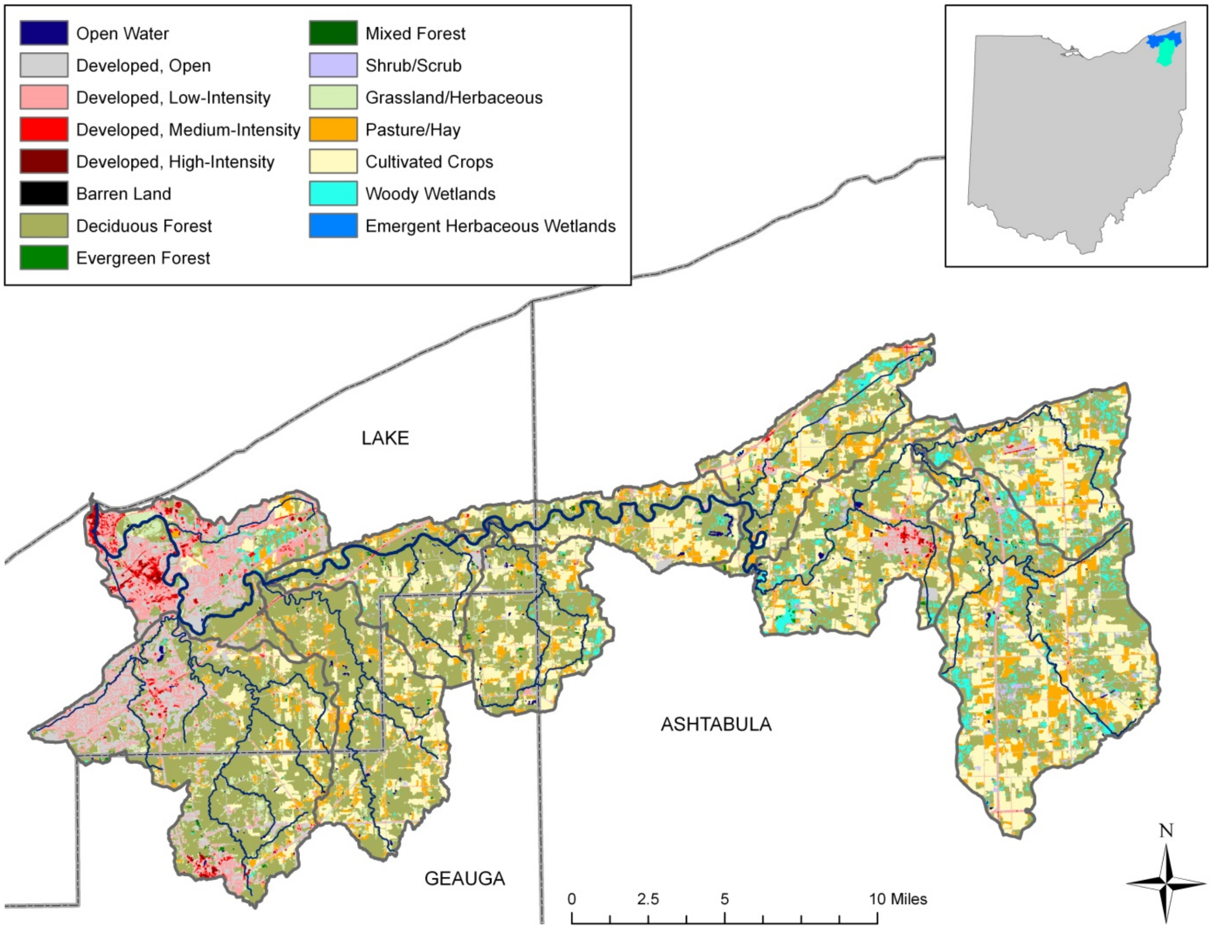


Figure 3-2. Land cover in the lower Grand River watershed (2001 NLCD Land Cover [version 1.0]).

3.3. Soils and Geology

The Grand River basin is contained within the EOLP ecoregion (Level III ecoregion 61; see Woods et al. 2010). Portions of the lower Grand River watershed are in four, level IV ecoregions, which are displayed in Figure 3-3 and summarized in Table 3-4. The EOLP is defined by (Woods et al. 2010):

- Low lime drift and lacustrine deposits that blanket the rolling to level terrain.
- Soils that are often lower in carbonate and naturally less fertile than those of other glaciated ecoregions.
- Lake Erie's influence substantially increases the growing season, winter cloudiness, and snowfall of the northernmost areas.

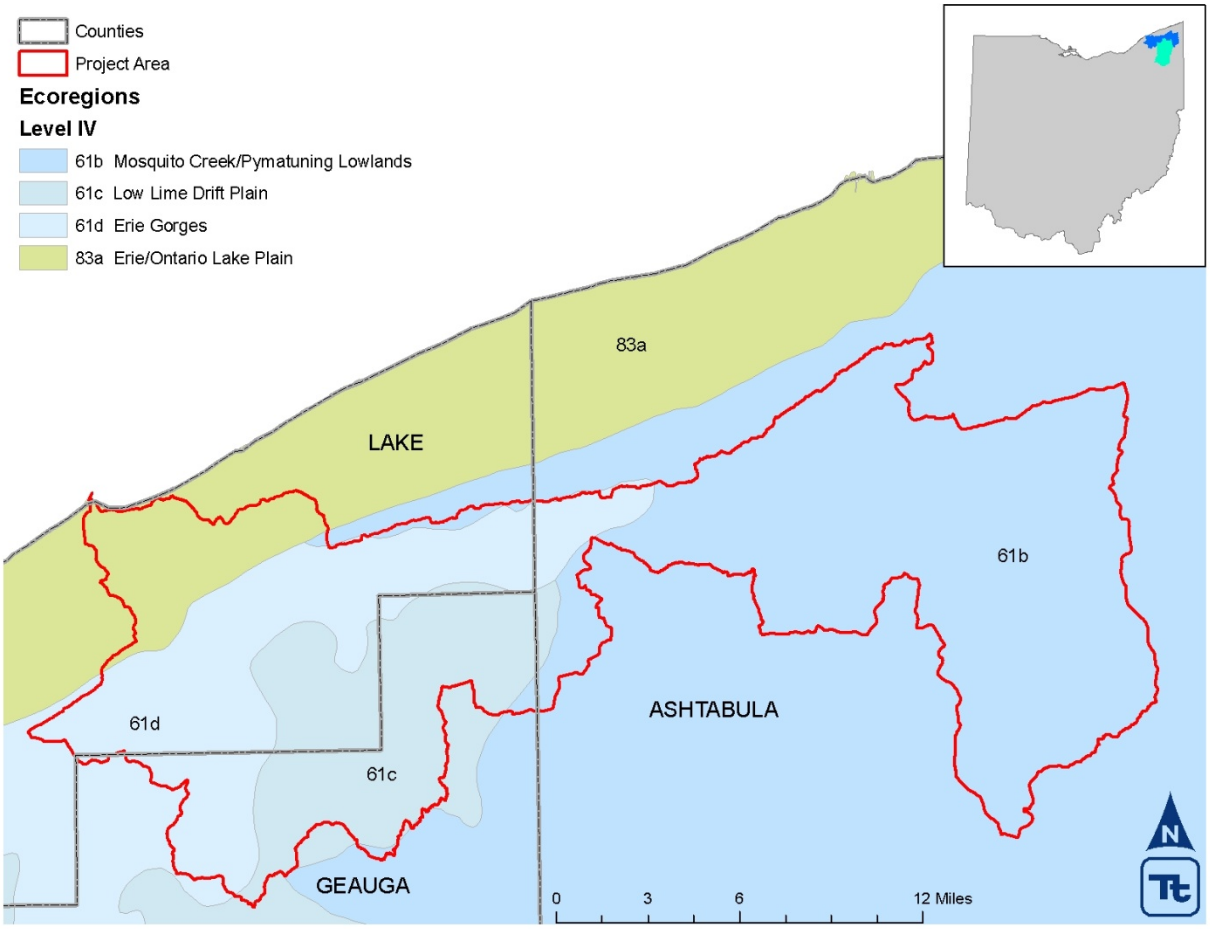


Figure 3-3. Level IV ecoregions in the Lower Grand River watershed.

Table 3-4. Summary of level IV ecoregions physiography and geology

Level IV ecoregion	Physiography	Geology
Erie Lake Plain (#83a)	Depositional lake plain with swales, beach ridges, and coastal cliffs that are prone to slumping.	Wave-washed glacial till, lacustrine-beach deposits overlies mainly Devonian-age Ohio Shale.
Mosquito Creek/ Pymatuning Lowlands (#61b)	Glaciated. Level to rolling lake and glacial till plains with flat-bottomed valleys, end moraines, and wetlands. Low-gradient, sluggish streams with few riffles.	Mostly late-Wisconsinan, clayey Hiram Till with some areas of alluvium and lacustrine material. Deposits overlie Paleozoic shale and sandstone.
Low Lime Drift Plain (#61c)	Glaciated. Rolling plains with low rounded hills, gentle slopes, and broad valleys; end moraines and outwash landforms occur locally.	Mostly clayey-loamy late-Wisconsinan glacial till; also lacustrine and coarse outwash material. Deposits overlie Mississippian and Pennsylvanian shale and sandstone.
Erie Gorges (#61d)	Glaciated. Very dissected area of high relief, steep slopes, and rocky outcrops. Gorges occur along the Cuyahoga, Chagrin, and Grand rivers where erosion rates are high.	Glacial drift and colluvium overlie Paleozoic conglomerate, sandstone, and shale. Cliffs form in Sharon Conglomerates of Pennsylvanian age.

Source: Woods et al. 2010

All four of the level IV ecoregions have soils with temperature and moisture regimes of mesic/udic and aquic (Woods et al. 2010). A summary of soil orders and common series are presented in Table 3-5.

Table 3-5. Summary of level IV ecoregions soils

Level IV ecoregion	Order (great groups)	Common soil series
Erie Lake Plain (#83a)	Mostly Alfisols (Hapludalfs); also Inceptisols (Epiaquepts)	On beach ridges and glacial outwash: Conotton. On silty glacial till: Conneaut. On thin glacial till and lake deposits: Allis.
Mosquito Creek/ Pymatuning Lowlands (#61b)	Alfisols (Fragiaqualfs, Epiaqualfs, Hapludalfs)	On lake deposits: Canadice, Canadea. On clay glacial till: Mahoning, Ellsworth, Geeburg. On silt glacial till: Sheffield, Platea.
Low Lime Drift Plain (#61c)	Alfisols (commonly Fragiudalfs, Fragiaqualfs; also Epiaqualfs)	Mostly Mahoning, Canfield, Rittman; also, Bennington, in westernmost area.
Erie Gorges (#61d)	Mostly Alfisols (Hapludalfs, Fragiaqualfs, Epiaqualfs); also Inceptisols (Eutrochrepts)	Mahoning, Ellsworth, and the clayey Geeburg on glacial till. Platea and Darien on less clayey glacial till. Chagrin on flood plains.

Source: Woods et al. 2010

The National Cooperative Soil Survey publishes soil surveys for each county within the United States. Soil surveys contain predictions of soil behavior and provide data related to different soil types, including the hydrologic soil groups (HSGs). HSG refers to the grouping of soils according to their runoff potential. Soil properties that influence HSGs include depth to seasonal high water table, infiltration rate and permeability after prolonged wetting, and depth to slow permeable layer. There are four HSGs: Groups A, B, C, and D (Table 3-6).

Table 3-6. Hydrologic Soil Group descriptions

HSG	Description
A	Sand, loamy sand or sandy loam types of soils. Low runoff potential and high infiltration rates even when thoroughly wetted. Consist chiefly of deep, well to excessively drained sands or gravels with a high rate of water transmission.
B	Silt loam or loam. Moderate infiltration rates when thoroughly wetted. Consist chiefly or moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.
C	Soils are sandy clay loam. Low infiltration rates when thoroughly wetted. Consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine structure.
D	Soils are clay loam, silty clay loam, sandy clay, silty clay or clay. Group D has the highest runoff potential. Low infiltration rates when thoroughly wetted. Consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material.
A/D, B/D, C/D	Dual HSGs. Certain wet soils are placed in group D based solely on the presence of a water table within 24 inches of the surface even though the saturated hydraulic conductivity might be favorable for water transmission. If the soils can be adequately drained, they are assigned to dual HGSs (A/D, B/D, and C/D) according to their saturated hydraulic conductivity and the water table depth when drained. The first letter applies to the drained condition and the second to the undrained condition.

Source: Soil Data Viewer (NRCS 2010b)

Using the soil surveys for each county (NRCS 2010a) and GIS, the HSG was analyzed using the *Soil Data Viewer* (NRCS 2010b). Soils in the lower Grand River watershed are typically Group C/D and D (Table 3-7), composed of sandy clay loam soils, clay loams, and clays with a low infiltration rate. The protection of areas with high infiltration capacity (e.g., Group A soils) is important for maintaining hydrology and temperature regimes within the watershed. The majority of Group A soils are in the EOLP ecoregion (Figure 3-3).

Table 3-7. HSGs in the lower Grand River watershed

HSG	Area (acres)	Relative area
not reported	6,240	3%
A	5,453	3%
A/D	953	1%
B	358	0%
B/D	14,598	8%
C	16,877	9%
C/D	92,547	50%
D	47,110	26%

Note: *not reported* includes soils underlying the Grand River, its tributaries, near-Lake Erie lacustrine area, and major roadways (including I-90, OH-2, OH-11, and OH-44).

3.4. Climate

Climate data are available from the National Oceanic and Atmospheric Administration National Climatic Data Center; station 331458 is in Chardon and was used for analysis in this report. Data from 1946 to 2006 were available at the time of report development. In general, the climate of the region is continental with hot, humid summers and cold winters. Table 3-8 contains historical temperature data collected at the Chardon climate station from 1986 to 2006. From 1986 to 2006 the average winter temperature in Chardon was 27 degrees Fahrenheit (°F), and the average summer temperature was 68 °F (Table 3-8). The average growing season (consecutive days with low temperatures greater than or equal to 32 °F) is 157 days.

Table 3-8. Climate summary for Chardon (331458), 1986–2006

Temperature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average high (^oF)	56	58	72	80	84	90	91	90	85	78	68	57
Average low (^oF)	–4	–3	3	22	31	39	46	45	36	28	17	3
Average mean (^oF)	24	26	34	46	57	66	71	68	60	49	39	29
Average precipitation (inches)	3.62	2.69	3.12	4.18	4.57	4.36	4.53	4.08	4.55	4.13	4.01	4.36

Examination of precipitation patterns is also a key component of watershed characterization. From 1986 to 2009, the annual average precipitation in Chardon (station 331458) was approximately 46 inches. Chardon represents the higher range of precipitation within the Grand River watershed, because of its location within the snowbelt and receives more annual snowfall than Dorset or Painesville (Figure 4-2). Average annual precipitation varies across the watershed from 37 to 46 inches (Figure 3-4).

Of particular interest in relation to precipitation, rainfall intensity and timing affect watershed response to precipitation. That information is important in evaluating the effects of storm water on the Grand River. Using Chardon data from 1986 to 2006, 66 percent of the precipitation events were very low intensity (i.e., less that 0.2 inches) and 4 percent of the measurable precipitation events were greater than one inch.

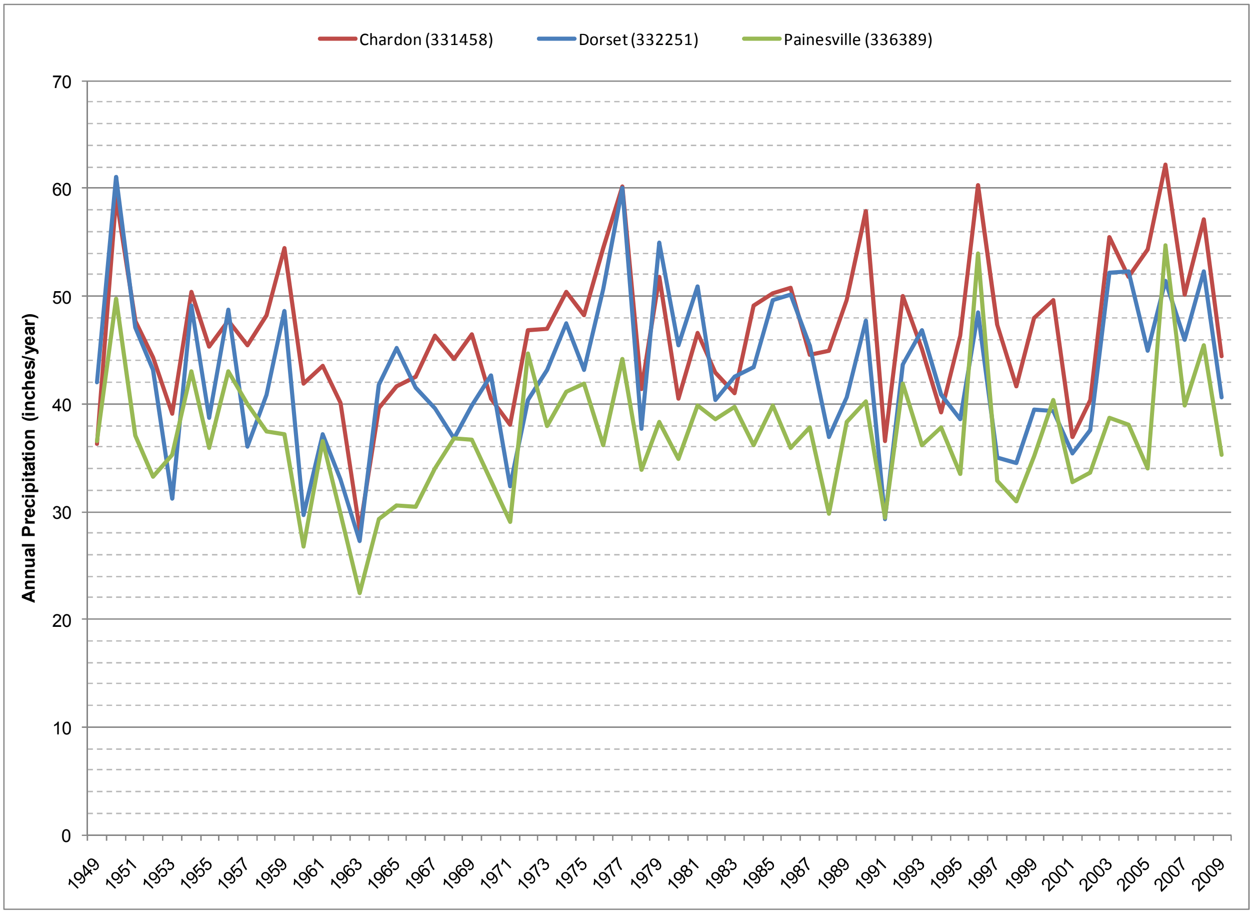


Figure 3-4. Annual precipitation at three weather gages in the Grand River watershed.

4. Data Analysis and Summary

The lower Grand River watershed was divided into three major subbasins for analysis in this report. The segments of the mainstem Grand River are evaluated separately from tributary WAUs. The three subbasins were designated by location and common attributes (Figure 4-1). The first subbasin coincides with the *Griggs Creek – Mill Creek* 10-digit HUC (04110004 04) and includes its three WAUs. The next subbasin includes five WAUs that have less than 10 percent developed land in the *Big Creek – Grand* River 10-digit HUC (04110004 06). The final subbasin encompasses the other two WAUs in the *Big Creek – Grand River* 10-digit HUC including the Big Creek and Red Creek subwatersheds. Those two WAUs are distinguished from the other five WAUs in the *Big Creek – Grand River* 10-digit HUC because of their higher percentage of developed land. The following sections summarize hydrologic, water quality, and habitat data for the three subbasins and the mainstem Grand River in the lower Grand River watershed.

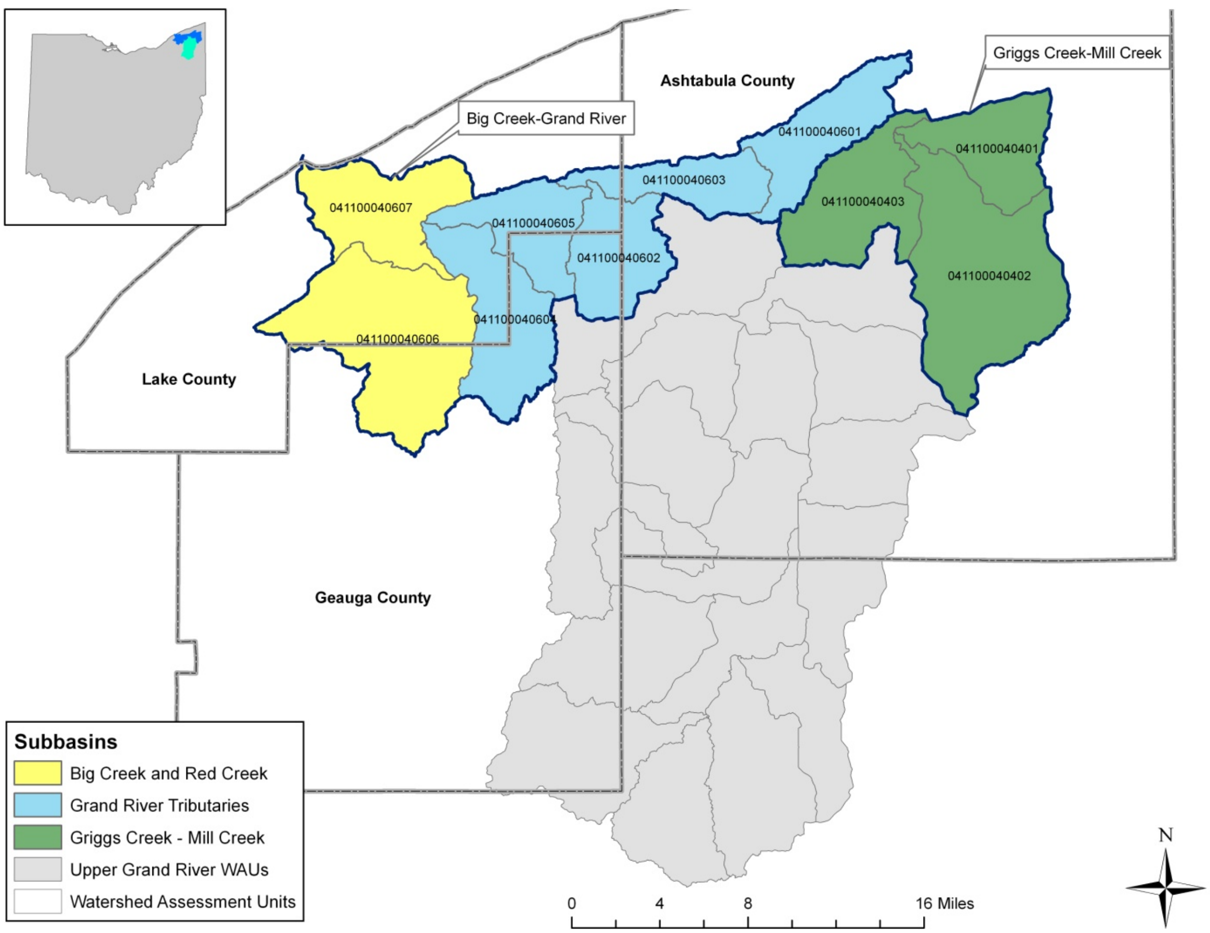


Figure 4-1. Subbasins in the lower Grand River basin.

4.1. Methodology

4.1.1. Hydrology

Flow data for the lower Grand River watershed have been collected by the USGS and Ohio EPA since 1922 (Table 4-1 and Figure 4-2). Available flow data are summarized by subbasin in the following sections.

Four USGS gages have collected continuous data in the lower Grand River watershed, although only one gage is currently active (gage 04212100, Grand River near Painesville). In 1974, continuous USGS flow gages on the Grand River near Madison (gage 04212000) and at Mill Creek near Jefferson (gage 04211500) were replaced with a new gage location on the Grand River near Painesville.

USGS data from the Grand River near Painesville OH gage (04212100) was used to calibrate a watershed model for the Lower Grand River. The modeled flows were used to calculate the TMDLs. Flow data from the other USGS gages were evaluated for use in the watershed model and to validate the use of flow estimation using drainage area weighting techniques along the LRAU.

Table 4-1. USGS gages in the Grand River basin

Watershed	Gage ID	Gage name	Drainage area (sq miles)	Period of record
Lower Grand	04211820	Grand River at Harpersfield OH	552	Mar 1996 - Sep 1998
	04212000	Grand River near Madison OH	581	Oct 1922 - Sep 1974
	04212100	Grand River near Painesville OH	685	Oct 1974 - present
	04211500	Mill Creek near Jefferson OH	82.0	Jan 1942 - Nov 1974
Upper Grand	04209500	Grand River near North Bristol OH	85.4	Mar 1942 - Sep 1947
	04210500	Grand River near Rome OH	251	Mar 1942 - Sep 1947
	04211000	Rock Creek near Rock Creek OH	69.2	Apr 1942 - Sep 1966
	04210000	Phelps Creek near Windsor OH	25.6	May 1942 - Jun 1949

Ohio EPA measured flow in the Grand River watershed on 19 separate dates between 2003 and 2006 on Big Creek, Mill Creek (04110004 04 02), Paine Creek, Mill Creek (04110004 06 02), Griggs Creek and the Grand River (Figure 4-2). The instantaneous discharge measurements were taken in the following flow conditions: high-flow (2 flows), moist (2 flows), mid-range (4 flows), dry (9 flows), and low-flow (1 flow). Note that not all tributaries were sampled on every date. Appendix B contains the instantaneous flow data.

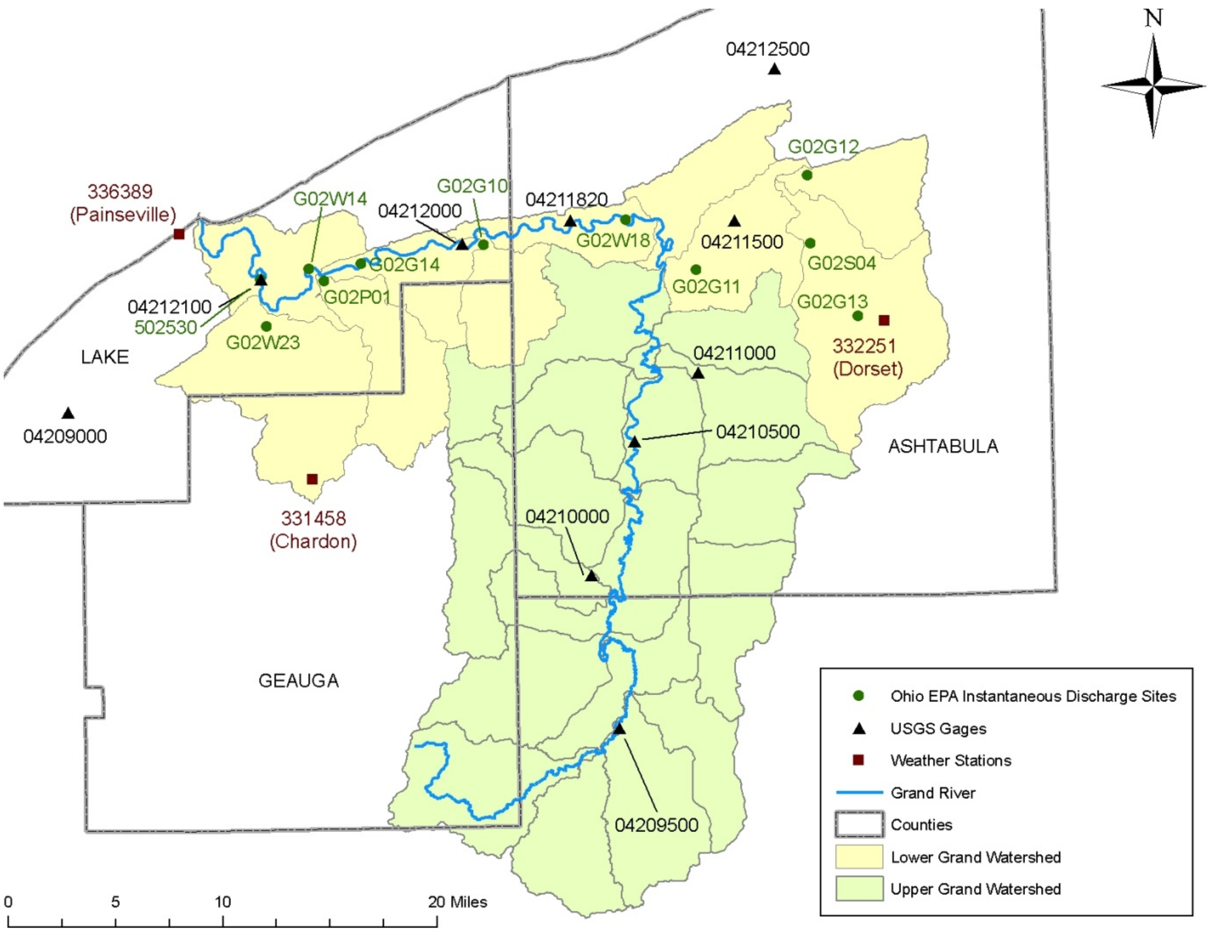


Figure 4-2. Gages in the Grand River basin.

Flow Duration Curves

Inherent variability exists in flow data sets because such variability is associated with hydrology. Flow duration curves provide a way to address that variability and flow-related water quality patterns. Duration curves describe the percentage of time during which specified flows are equaled or exceeded (Leopold 1994). Flow duration analysis looks at the cumulative frequency of historic flow data over a specified period, on the basis of measurements taken at uniform intervals (e.g., daily average). Duration analysis results in a curve that relates flow values to the percent of time those values have been met or exceeded. Low flows are exceeded a majority of the time, whereas floods are exceeded infrequently.

Duration curves provide the benefit of considering the full range of flow conditions (U.S. EPA 2007). Developing a flow duration curve is typically based on daily average stream discharge data. A typical curve runs from high flows to low flows along the x-axis, as illustrated in Figure 4-3. Note the flow duration interval of 60 associated with a stream discharge of 1.1 cubic feet per second (cfs) (i.e., 60 percent of all observed stream discharge values equal or exceed 1.1 cfs).

Flow duration curve intervals can be grouped into several broad categories or zones. Those zones provide additional insight about conditions and patterns associated with water quality impairments where hydrology might play a major role. One common way to look at the duration curve is by dividing it into five zones, as illustrated in Figure 4-3: one representing *high flows (0 to 10 percent)*, another for *moist* *conditions (10 to 40 percent)*, one covering *mid-range flows (40 to 60 percent)*, another for *dry conditions (60 to 90 percent)*, and one representing *low flows (90 to 100 percent)*.

This approach places the midpoints of the moist, mid-range, and dry zones at the 25th, 50th, and 75th percentiles, respectively (i.e., the quartiles). The high-flow zone is centered at the 5th percentile, while the low-flow zone is centered at the 95th percentile.

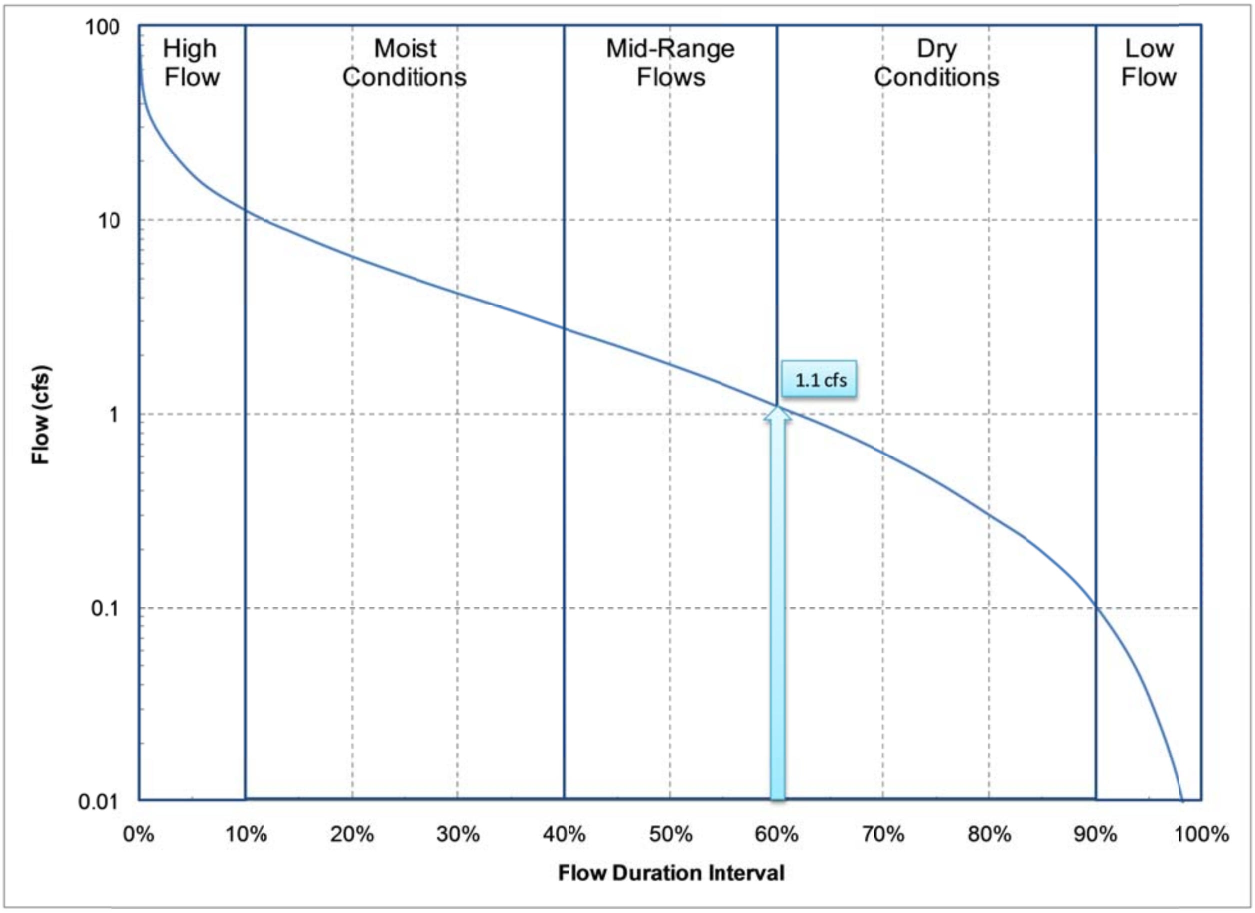


Figure 4-3. Example flow duration curve: Phelps Creek.

Flow duration curves can be converted to load duration curves by multiplying the flows by the TMDL targets to get a loading capacity curve. Individual samples can then be plotted by calculating a load consistent with the sample concentration and flow conditions. Samples collected during runoff conditions can also be identified using the monitored volumes and variation of daily stream flow.

4.1.2. Water Quality Data

Ohio EPA and USGS have collected water quality samples throughout the watershed (Figure 4-2). The National Center for Water Quality Research at Heidelberg College also collected water quality data on the Grand River from February 1998 through August 2006. The center collected flow and the following water quality parameters: chloride, nitrate plus nitrite, soluble reactive phosphorus, suspended solids, total

Kjeldahl nitrogen, and total phosphorus. While Ohio EPA data are level 3 credible[5] (i.e., may be used in TMDL development), the National Center for Water Quality Research data are not level 3 credible. Data collected by USGS are also credible and may be used in TMDLs. Bacteria, TSS, and nutrient data collected by Ohio EPA and USGS are summarized and discussed in each subbasin section. All available water quality data are presented the *Biological and Water Quality Study of the Grand River Basin 2003 - 2004, Hydrologic Units 04110004 050 and 04110004 060* (Ohio EPA 2006a), which forms the basis of the water quality analysis, and Appendix B. Appendix A contains information regarding station identification.

Ohio EPA sampled the Grand River and its tributaries for nutrients (ammonia, nitrate plus nitrite, total Kjeldahl nitrogen, total phosphorus), sediment, and bacteria in 2000, 2003, and 2004. Average precipitation during those sampling years varied by watershed location (Table 4-2). Annual precipitation at Chardon was slightly above average during all sampled years. In 2003 annual precipitation at Chardon was exceeded by 10 inches. Annual precipitation at Dorset was below average in 2000 and above average in 2003 and 2004. Annual precipitation at Painesville was slightly above average during all sampled years. Dissolved oxygen and temperature data were also collected, which are presented below.

Table 4-2. Precipitation patterns during Ohio EPA sampling years

Precipitation station	Average annual rainfall (inches)	2000 Rainfall (inches)	2003 Rainfall (inches)	2004 Rainfall (inches)
Painesville	37	40	39	38
Chardon	46	50	56	52
Dorset	42	39	52	52

Dissolved Oxygen and Temperature

The USGS sampled the Grand River at four locations (04211820, 04212000, 04212100, and 04212200) for dissolved oxygen levels between 1966 and 2007. Only one sample was collected at the Madison gage (04212000; 8.10 mg/L). Data collected at the gage at Harpersfield (04211820; 7.2–13.4 mg/L, n = 34) and the station near Painesville (04212100; 6.8–13.5 mg/L, n = 17) did not fall below the standards. Four samples collected in the 1970s from the gage at Painesville (04212200; 2.5–14.1 mg/L, n = 227) were below the WWH standard of 4.0 mg/L.

Dissolved oxygen and temperature data were collected hourly by Ohio EPA using a Hydrolab Datasonde probe at five locations in the lower Grand River watershed August 11–13, 2004, including two sites along the mainstem of the Grand River, two sites on Mill Creek (04110004 06 02), and one site on the unnamed tributary to Mill Creek (04110004 06 02) at RM 4.4. Except for the unnamed tributary to Mill Creek at RM 4.4, the river and creeks show a fairly typical diurnal trend with higher dissolved oxygen concentrations in the afternoon and lower concentrations in the night and very early morning. The temperature data follow a typical diurnal pattern. No supporting data exist to further evaluate the unnamed tributary to Mill Creek at RM 4.4. The Grand River remains notably warmer than its tributaries throughout the sample period; its designation at the sample locations is EWH. Mill Creek (04110004 06 02) and the unnamed tributary to Mill Creek are CWH streams. Generally, both streams are cooler than the Grand River.

[5] Ohio's Credible Data Program is governed by *OAC-3745-4*; see http://www.epa.ohio.gov/dsw/credibledata/index.aspx.

Ohio EPA also collected temperature and dissolved oxygen grab samples in 2003 and 2004 that were analyzed for dissolved oxygen. In addition, the Lake Soil and Water Conservation District (SWCD) monitored temperature when evaluating primary headwaters habitat at locations throughout the Lake County portion of the Grand River watershed. Spatial and temporal trends were not evaluated because sites were sampled at different times. Because dissolved oxygen and temperature varies during the day, it is inappropriate to evaluate spatial trends on a day when the sites were sampled across the entire day. Similarly, long-term temporal trends cannot be evaluated when the samples collected on different days at the same site were also collected at different times.

Metals

Ohio EPA collected samples between 1/19/1999 and 3/17/2010 that were analyzed for the following:

- Aluminum
- Arsenic
- Cadmium
- Chromium
- Dissolved hexavalent chromium
- Copper
- Iron
- Lead
- Manganese
- Mercury
- Nickel
- Selenium
- Zinc

Ohio's standards for the following six metals are dependent on hardness, cadmium, chromium, copper, lead, nickel, and zinc. Appendix C includes available metals data. On the basis of those data, copper and lead were the only metals that exceeded the water quality criteria for the protection of aquatic life.

Copper was analyzed using two methodologies; one method had a detection limit of 10 micrograms per liter (µg/L), the other method had a detection limit of 2 µg/L. All nine of the copper detections on the Grand River occurred at OH-84 in Painesville (site 502530). The sample collected on 5/6/2003 (15 µg/L) exceeded the OMZM standard of 14 µg/L. One sample each collected from Ellison Creek (16.0 µg/L at G02P10 on 7/31/2000) and from Mill Creek (04110004 06; 25.0 µg/L at G02G10 on 12/10/2003) exceeded the OMZM standard.

Lead exceeded the numeric criteria at three locations in the watershed. Single samples from the following two creeks exceeded their hardness-dependent criteria: Mill Creek (04110004 04 02; 6.7 µg/L at G02G13 on 9/23/2003),[6] and Mill Creek (04110004 06 02; 12.8 µg/L at G02G10 on 7/12/2004).[7] Lead exceeded criteria six times on the Grand River at OH-84 in Painesville (site 502530; range 3.5 to 15.5 µg/L).

Hexavalent chromium was detected downstream of the confluence of Red Creek with the Grand River. The hexavalent chromium releases are directly attributable to the former Diamond Shamrock industrial site. The site is subject to remediation orders and is being addressed by Ohio EPA's Division of Emergency and Remedial Response.[8]

4.1.3. Habitat Analysis

The primary method used to evaluate habitat in the lower Grand River watershed is the QHEI. An introduction to the QHEI is in Section 2.2.4, and a full description is in *Methods for Assessing Habitat in Flowing Waters: Using the Qualitative Habitat Evaluation Index (QHEI)* (Ohio EPA 2006b). The QHEI

[6] The hardness of the sample was 66 mg/L, which yields a total recoverable lead OZMA criterion of 3.8 µg/L.
[7] The hardness of the sample was 114 mg/L, which yields a total recoverable lead OZMA criterion of 7.6 µg/L.
[8] Remediation information is at Ohio EPA's website: http://www.epa.ohio.gov/derr/remedial/photo_central/photo_ne.aspx

scores and metric scores from the 2003 and 2004 sample seasons are presented for each subbasin and the LRAU. Temporal trends with data from previous sample seasons are evaluated when applicable.

The color coding for the QHEI scores and individual metrics presented in each subbasin summary is summarized in Table 4-3 and Table 4-4. The location of QHEI sampling sites are identified by the associated STORET code.

Table 4-3. QHEI scoring scheme

Narrative score	Headwaters streams	Wading streams and rivers
Excellent	≥ 70	≥ 75
Good	55–69	60–74
Fair	43–54	45–59
Poor	30–42	30–44
Very Poor	< 30	< 30

Source: Ohio EPA 2006b.

Table 4-4. Metric score color coding

Color code	Percent of maximum score [a]
	75 ≤ score ≤ 100
	50 ≤ score < 75
	0 ≤ score < 50

a. The percent of maximum potential metric score is calculated as individual metric score divided by the maximum potential score and converted to a percentage.

4.2. Griggs Creek – Mill Creek Subbasin

The Griggs Creek – Mill Creek subbasin is in the eastern portion of the study area and encompasses approximately 103 square miles. The subbasin includes the following WAUs: 04110004 04 01, 04110004 04 02, and 04110004 04 03. Figure 4-4 identifies the water quality and flow monitoring stations in the subbasin.

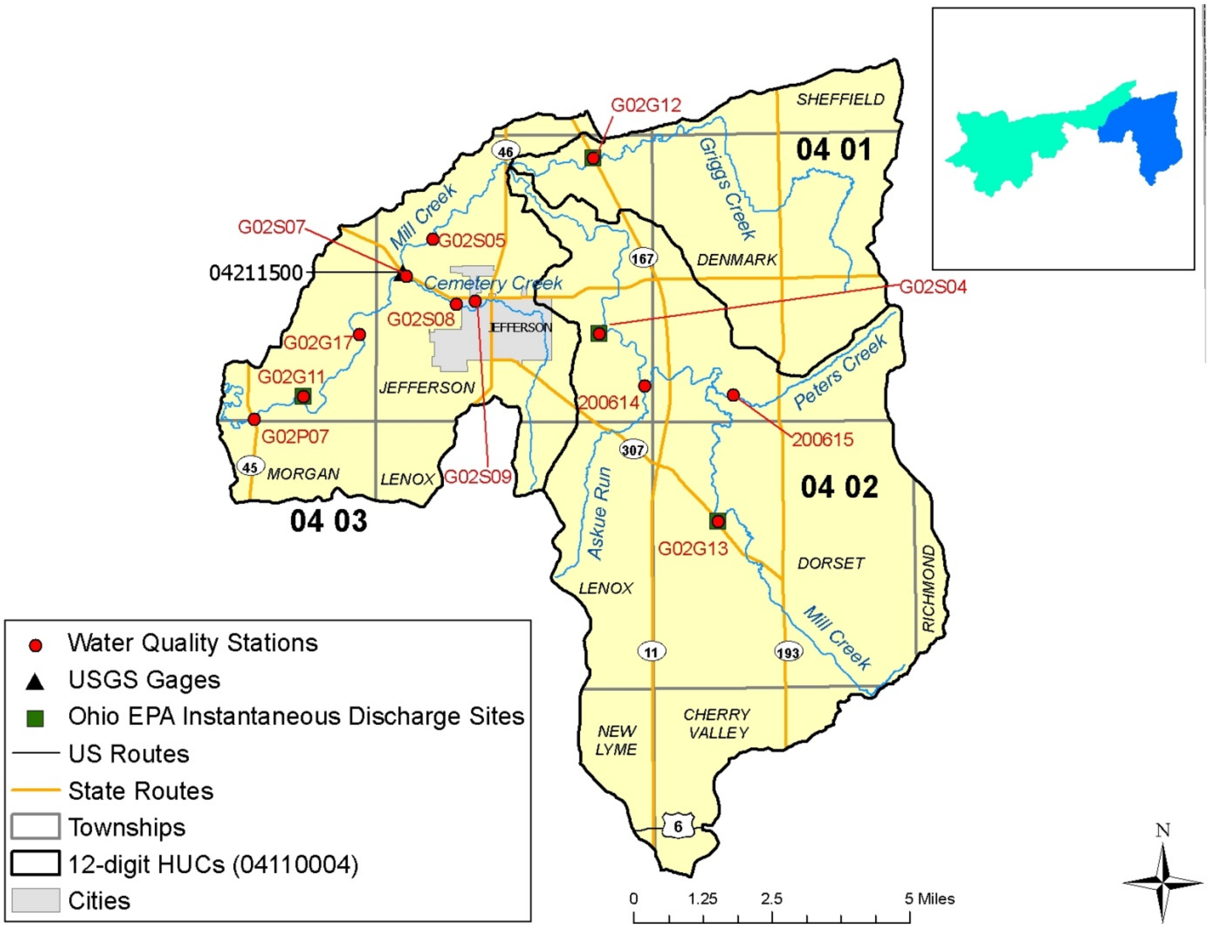


Figure 4-4. Griggs Creek – Mill Creek subbasin.

4.2.1. Hydrology

Mill Creek is a major tributary to the Grand River, draining approximately 103 square miles. Mill Creek's confluence with the Grand River defines the upper Grand River watershed from the lower Grand River watershed in this study. The Mill Creek watershed includes the following assessed streams:

- Askue Run
- Cemetery Creek
- Griggs Creek
- Mill Creek
- Peters Creek

Figure 4-5 summarizes monitored flow data between 1960 and 1974 on Mill Creek and Figure 4-6 illustrates the flow duration curve for Mill Creek (04211500). Mill Creek historically has very low base flow during the summer months as monitored downstream of the town of Jefferson. Flow records in the Mill Creek watershed identify that in 17 out of 32 years of record, there were multiple days with a recorded flow of 0 cfs. Average daily stream flow was 107 cfs, and the median daily flow was 19 cfs between 1942 and 1974 according to USGS reported flow. There was a historic diversion upstream of the gaging station on Mill Creek for the Jefferson water supply, which ended during the 1980s. Between 1971 and 1974, the annual average diversion to the reservoir ranged from 0.15 to 0.30 cfs.

Four instantaneous flow measurements collected by Ohio EPA between 2004 and 2006 along Mill Creek were between 0.16 and 59.28 cfs, collected under dry or mid-range flow conditions. Flow data were also collected on Griggs Creek, which ranged from 0.21 to 64.02 cfs during dry and mid-range flow conditions.

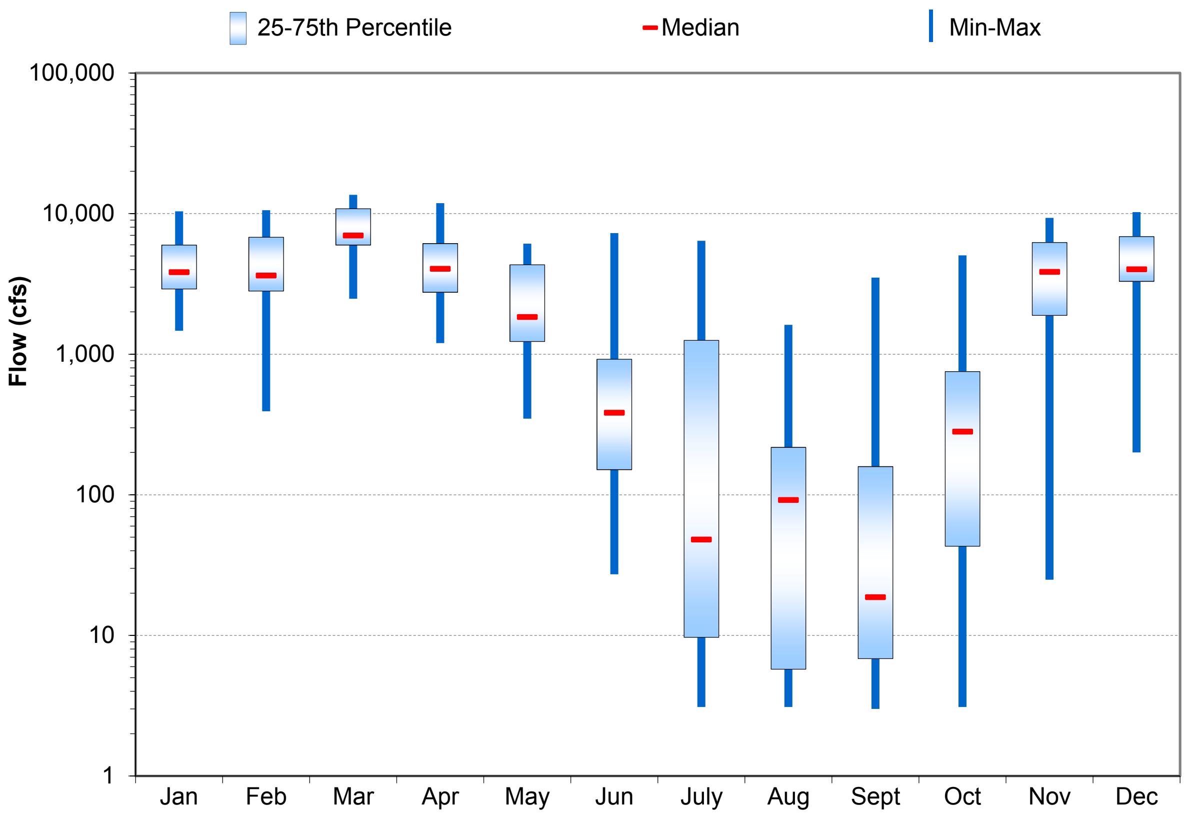


Figure 4-5. Mill Creek monthly streamflow 1960–1974 generated from data at USGS gage 04211500.

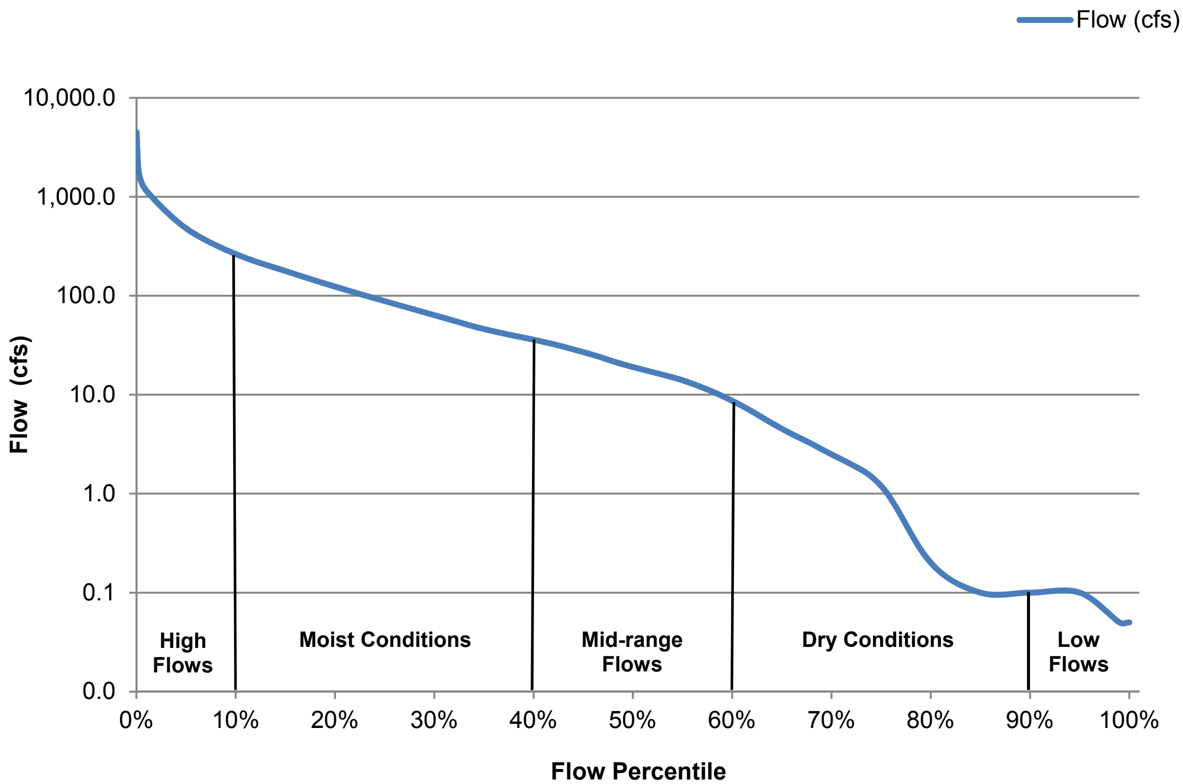


Figure 4-6. Flow duration curve generated from data at gage 04211500 at Mill Creek near Jefferson OH, 1960–1974 (5,439 measurements).

4.2.2. Water Quality Data

Ohio EPA collected water quality samples during 2003 and 2004, at 12 locations on 5 creeks, in the Griggs Creek – Mill Creek subbasin (Figure 4-4).

Bacteria

The data are summarized in Table 4-5. Ohio EPA has identified bacteria impairments in all three WAUs (12-digit HUCs), and TMDLs will be completed for each WAU. All the waters in the Griggs Creek–Mill Creek subbasin are PCR Class B, and at least one geometric mean calculated for each stream exceeded the standard (161 counts per 100 mL). Water quality standard exceedances occurred in both 2003 and 2004 in this HUC.

Table 4-5. *E. coli* data for the Griggs Creek – Mill Creek subbasin [counts per 100 mL]

Stream	STORET station	Begin date	End date	No. of samples [a]	Minimum	Maximum	Geomean (2003) [b]	Geomean (2004) [b]
HUC 04110004 04 01 (Griggs Creek)								
Griggs Creek	G02G12	8/6/03	8/2/04	8 (4/4)	120	6,500	120	**710**
HUC 04110004 04 02 (Peters Creek - Mill Creek)								
Askue Run	200614	6/3/04	8/2/04	3	160	690	--	**294**
Mill Creek	G02G13	8/27/03	8/2/04	8 (3/5)	140	16,000	**3,216**	**432**
	G02S04	8/27/03	8/2/04	7 (3/4)	18	24,000	**1,718**	124
Peters Creek	200615	6/3/04	8/2/04	3	68	1,300	--	**301**
HUC 04110004 04 03 (Town of Jefferson - Mill Creek)								
Cemetery Creek	G02S09	8/28/03	9/10/03	2	200	880	**420**	--
	G02S08	8/28/03	9/10/03	2	75	3,200	**490**	--
	G02S07	8/28/03	9/10/03	2	38	460	132	--
Mill Creek	G02S05	8/28/03	9/10/03	2	10	240	49	--
	G02G17	8/28/03	9/10/03	2	62	170	103	--
	G02G11	8/27/03	8/2/04	7 (3/4)	56	2,400	**259**	**318**
	G02P07	6/3/04	8/2/04	3	100	1,200	--	**436**

Notes
Bolded values are greater than seasonal geometric mean standard of 161 counts per 100 mL for PCR Class B waterbodies.
Creeks are listed alphabetically per 12-digit HUC; stations are listed top to bottom as upstream to downstream.
Units are counts per 100 mL.
a. When multiple numbers are displayed, the first number represents the total number of samples collected at the site and the numbers in the parentheses represent the numbers of samples collected in 2003 and 2004, which were used to calculate the geometric means.
b. Geometric means were calculated using all available data for a given year's recreation season (May 1 through October 31).

Total Suspended Solids

TSS data are summarized in Table 4-6. Siltation has been identified as a cause of the ALU impairment in the *Peters Creek – Mill Creek* WAU (04110004 04 02).

Table 4-6. TSS data from the Griggs Creek – Mill Creek subbasin

Stream	STORET station	Size [a]	Begin date	End date	No. of samples [b]	Minimum (mg/L)	Maximum (mg/L)	Average (mg/L)
HUC 04110004 04 01 (Griggs Creek)								
Griggs Creek	G02G12	H	8/27/2003	8/2/2004	10	ND	**30**	10
HUC 04110004 04 02 (Peters Creek - Mill Creek)								
Askue Run	200614	H	6/3/2004	8/2/2004	3	ND	9	6
Mill Creek	G02G13	W	8/27/2003	8/2/2004	10	ND	**42**	10
	G02S04		8/6/2003	8/2/2004	11	ND	**56**	12
Peters Creek	200615	W	6/3/2004	8/2/2004	3	5	9	7
HUC 04110004 04 03 (Town of Jefferson - Mill Creek)								
Cemetery Creek	G02S09	H	8/28/2003	10/9/2003	3	ND	14	6
	G02S08				3	ND	20	8
	G02S07				3	ND	21	10
Mill Creek	G02S05	W	8/28/2003	10/9/2003	3	ND		
	G02G17		8/28/2003	10/9/2003	3	ND		
	G02G11		8/27/2003	8/2/2004	10	ND	**51**	13
	G02P07		8/6/2003	8/9/2004	5	ND	**27**	11

Notes
ND = not detected. The detection limit is 5.0 mg/L and a value of 2.5 mg/L was used in the calculation of statistics.
Bolded values are greater than the targets: 25.0 mg/L for headwaters streams and 21.0 mg/L for wading streams.
Creeks are listed alphabetically per 12-digit HUC; stations are listed top to bottom as upstream to downstream per creek.
a. Headwaters (H) streams drain 20 square miles or less; wading (W) streams drain 20 to 200 square miles.
b. The number of samples excludes field duplicates.

Only one TSS concentration of the 21 samples collected on headwaters streams was higher than 25 mg/L, which is the 75th percentile of headwaters reference stream data for the EOLP ecoregion (Ohio EPA 1999, Appendix I, p. 24). A TSS sample of 30 mg/L was collected from station G02G12 on Griggs Creek on 7/12/2004.

Seven sample concentrations were larger than 21.0 mg/L on Mill Creek, which is the 75th percentile of data for wading streams (Ohio EPA 1999, Appendix I, p. 24). All the samples collected on 9/23/2003 yielded elevated TSS concentrations (upstream to downstream): 27 mg/L at station G02G13, 30 mg/L at station G02S04, and 56 mg/L at station G02G11. At station G02G13, TSS was not detected in 5 of the 10 samples and was below 10 mg/L for 3 samples.

Nutrients

Nutrient concentrations exceeded the nutrient targets that were selected from reference stream data in the Ohio EPA's *Associations* document (1999, see Table 2.6) at nine sites in the Griggs Creek – Mill Creek subbasin. Two sites on Cemetery Creek (G02S08 and S02S07) in the Jefferson area consistently showed elevated concentrations of total phosphorus and nitrate plus nitrite that were greater than the statewide reference streams data. Elevated concentrations of total phosphorus were regularly detected in the two upstream sites on Mill Creek at RM 25.6 (G02G13) and RM 18.2 (G02S04). Mill Creek at RM 25.6 (G02G13) is listed as impaired for aquatic life, and Ohio EPA identified nutrients as a potential cause of impairment in *Biological and Water Quality Study of the Grand River Basin 2003 - 2004, Hydrologic Units 04110004 050 and 04110004 060* (Ohio EPA 2006a).

Table 4-7. Total phosphorus data from the Griggs Creek – Mill Creek subbasin

Stream	STORET station	Size [a]	Begin date	End date	No. of samples [b]	Minimum (mg/L)	Maximum (mg/L)	Average (mg/L)
HUC 04110004 04 01 (Griggs Creek)								
Griggs Creek	G02G12	H	8/27/2003	8/2/2004	10	0.047	**0.148**	**0.082**
HUC 04110004 04 02 (Peters Creek - Mill Creek)								
Askue Run	200614	H	6/3/2004	8/2/2004	3	0.032	0.066	0.045
Mill Creek	G02G13	W	8/27/2003	8/2/2004	10	0.066	**0.301**	**0.142**
	G02S04		8/6/2003	8/2/2004	11	0.047	**0.297**	**0.109**
Peters Creek	200615	W	6/3/2004	8/2/2004	3	0.061	**0.106**	**0.082**
HUC 04110004 04 03 (Town of Jefferson - Mill Creek)								
Cemetery Creek	G02S09	H	8/28/2003	10/9/2003	3	0.049	0.055	0.053
	G02S08				3	**0.314**	**2.130**	**1.140**
	G02S07				3	**0.237**	**0.468**	**0.373**
Mill Creek	G02S05	W	8/28/2003	10/9/2003	3	0.041	0.061	0.049
	G02G17		8/28/2003	10/9/2003	3	0.075	**0.125**	0.096
	G02G11		8/27/2003	8/2/2004	10	0.040	**0.313**	**0.102**
	G02P07		8/6/2003	8/9/2004	5	0.034	**0.105**	0.064

Notes
Bolded values are greater than the WWH targets: 0.08 mg/L for headwaters streams and 0.10 mg/L for wading streams.
Creeks are listed alphabetically per WAU; stations are listed top to bottom as upstream to downstream per creek.
All waterbodies displayed in this table are designated WWH.
a. Headwaters (H) streams drain 20 square miles or less; wading (W) streams drain 20 to 200 square miles.
b .The number of samples excludes field duplicates.

Table 4-8. Nitrate plus nitrite data from the Griggs Creek – Mill Creek subbasin

Stream	STORET station	Size [a]	Begin date	End date	No. of samples [b]	Minimum (mg/L)	Maximum (mg/L)	Average (mg/L)
HUC 04110004 04 01 (Griggs Creek)								
Griggs Creek	G02G12	H	8/27/2003	8/2/2004	10	ND	0.44	0.19
HUC 04110004 04 02 (Peters Creek - Mill Creek)								
Askue Run	200614	H	6/3/2004	8/2/2004	3	ND	0.21	0.14
Mill Creek	G02G13	W	8/27/2003	8/2/2004	10	0.12	**2.43**	0.86
Mill Creek	G02S04	W	8/6/2003	8/2/2004	11	ND	**1.49**	0.64
Peters Creek	200615	W	6/3/2004	8/2/2004	3	0.20	0.40	0.29
HUC 04110004 04 03 (Town of Jefferson - Mill Creek)								
Cemetery Creek	G02S09	H	8/28/2003	10/9/2003	3	0.39	0.53	0.47
Cemetery Creek	G02S08	H	8/28/2003	10/9/2003	3	**5.50**	**11.90**	**8.15**
Cemetery Creek	G02S07	H	8/28/2003	10/9/2003	3	**3.00**	**6.00**	**8.75**
Mill Creek	G02S05	W	8/28/2003	10/9/2003	3	0.12	0.70	0.42
Mill Creek	G02G17	W	8/28/2003	10/9/2003	3	0.94	**3.17**	**1.75**
Mill Creek	G02G11	W	8/27/2003	8/2/2004	10	0.18	**1.08**	0.65
Mill Creek	G02P07	W	8/6/2003	8/9/2004	5	0.47	**1.06**	0.64

Notes
ND = not detected. The detection limit is 0.1 mg/L and a value of 0.05 mg/L was used in the calculation of statistics.
Bolded values are greater than the WWH target of 1.0 mg/L.
Creeks are listed alphabetically per WAU; stations are listed top to bottom as upstream to downstream per creek.
All waterbodies displayed in this table are designated WWH.
a. Headwaters (H) streams drain 20 square miles or less; wading (W) streams drain 20 to 200 square miles.
b. The number of samples excludes field duplicates.

4.2.3. Habitat Analysis

In 2003 and 2004 Ohio EPA assessed the habitat conditions at 11 sites on five waterbodies in the Griggs Creek – Mill Creek subbasin (Table 4-9).

Stream habitat in Mill Creek and its tributaries varies widely from location to location, both within and between streams, depending on the type and thickness of glacial deposits and depth of bedrock. The mainstem cuts through sandstone bedrock as it drops into the Grand River valley; consequently, the habitat in the reach ranges from shallow flow over denuded bedrock to richer habitat characterized by deeper pools and aggregations of fractured bedrock and till. Further upstream, the topography is flat, and the creek flows through glacial drift of varying thickness and over sandstone bedrock. The habitat is characterized by slow, deep pools with vegetated margins and short riffles. Upstream from the confluence with Griggs Creek, the habitat is dominated by shallow flow over shale and sandstone bedrock. The headwater site is a wetland-dominated stream. For the mainstem as a whole, the habitat is capable of supporting warmwater fish communities. However, because shallow bedrock dominates the drainage, base flow is very low during the summer and can be the limiting habitat factor.

Askue Run and Peters Creek both contain habitat suitable for warmwater stream fish communities in accordance with expectations for their size and ecoregion. Peters Creek, at the location sampled, is a classic northern swamp forest stream. It has an abundance of tag alder choking and braiding the channel, along with stands of quaking aspen in the surrounding upland.

The macrohabitats at two locations on Cemetery Creek, RM 1.2 (G02S08) and RM 2.1 (G02S09) were evaluated with the QHEI. The site at RM 2.1 (G02S09) flows through a residential area but has neither been channelized nor denuded of its riparian buffer. The otherwise high-quality substrates were moderately embedded with silt from upstream sources. The QHEI score of 78.0 suggests this site is capable of supporting a WWH fauna (Ohio EPA 1999, p. 67).

Downstream from RM 1.2 (G02S08), the stream was historically channelized though most WWH features have been recovered over time. The QHEI score of 64.5 paired with only one high-influence modified habitat attribute suggest the stream is capable of supporting a WWH stream fish community.

Table 4-9. QHEI and metric scores for sites in the Griggs Creek – Mill Creek subbasin

Waterbody name	RM/ STORET station	Size [a]	Year	QHEI (100) [b]	Substrate (20) [c]	In-stream cover (20) [c]	Channel morphology (20) [c]	Bank erosion & riparian Zone (10) [c]	Pool/glide (12) [c]	Riffle/run (8) [c]	Gradient (10) [c]
HUC 04110004 04 01 (Griggs Creek)											
Griggs Creek	2.0/ G02G12	H	2003	**50.5**	7	8	13	6.5	6	0	10
HUC 04110004 04 02 (Peters Creek - Mill Creek)											
Askue Run	0.1/ 200614	H	2004	**78.5**	17	16	17	8.5	8	4	8
Mill Creek	25.6/ G02G13	W	2003	**72**	12	19	18	8	8	1	6
	18.2/ G02S04	W	2003	**80.5**	16	16	20	9.5	6	5	8
Peters Creek	0.2/ 200615	W	2004	**76.5**	16.5	13	17	10	6	4	10
HUC 04110004 04 03 (Town of Jefferson - Mill Creek)											
Cemetery Creek	2.1/ G02S09	H	2003	**78**	20	11	17	6	9	5	10
	1.2/ G02S08	H	2003	**64.5**	18	9	14	5.5	6	4	8
Mill Creek	10.0/ G02S05	W	2003	**63**	16	14	13	10	8	0	2
	6.5/ G02G17	W	2003	**87.5**	20	17	20	6.5	7	7	10
	4.1/ G02G11	W	2003	**58**	11	5	12	8	6	6	10
	3.7/ G02G11	W	2004	**83.5**	15	17	18	8	10	5.5	10

Notes
Creeks are listed alphabetically per 12-digit HUC; stations are listed top to bottom as upstream to downstream per creek.
a. Headwaters (H) streams drain 20 square miles or less; wading (W) streams drain 20 to 100 square miles.
b. The QHEI scoring scheme and color coding are presented in Table 4-3. The total possible index score is 100.
c. The metric color coding is presented in Table 4-4. The numbers in parentheses are the total possible metric scores.

In general, habitat conditions in the Griggs Creek – Mill Creek subbasin are good to excellent. Mill Creek at RM 25.6 (G02G13) is only in partial attainment of its ALU designation, which is WWH. The fair IBI and ICI scores could be affected by the low *riffle/run* and *substrate* metrics. Griggs Creek is impaired (i.e., partial attainment) for its WWH designation, and, although the QHEI score is fair, the 303(d) listing identifies natural conditions and wetlands as the cause of impairment.

Temporal Trends

Ohio EPA also evaluated habitat at various sites across the Griggs Creek – Mill Creek subbasin from 1983 to 2004. Evaluations of a few pertinent waterbodies are presented below.

Mill Creek was sampled multiple times from 1983 to 2004 (Table 4-10). However, note that scores from before 1989 were interpreted from field sheets prior to the development of the QHEI; therefore, those scores might or might not accurately reflect a standardized QHEI.[9] The upstream site at RMs 18.1 and 18.2 (G02S04) show no changes in habitat condition from 1995 to 2003. However, the site at RM 10.0 (G02S05) shows a decrease in habitat conditions from 1995 to 2003. Scores decrease from 1984 to 2003 for all but one metric (*bank erosion and riparian zone*); the largest decreases occurred with the *riffle/run* and *channel morphology* metrics (a loss of 7 points each). It is also noteworthy that isolated locations still maintain excellent habitat conditions despite the large amounts of agriculture in the watershed.

Table 4-10. QHEI scores on Mill Creek from 1983 to 2004

RM	STORET Station	1983[a]	1984[a]	1995	2003	2004
25.6	G02G13	--	--	--	72	--
18.1/18.2	G02S04	--	--	80	80.5	--
17.2	--	65.5	--	--	--	--
10.0	G02S04	--	94.5	79.5	63	--
6.5	G02G17	--	--	--	87.5	--
4.1	G02G11	--	--	--	58	--
3.7	G02G11	--	--	--	--	83.5

Notes
The QHEI scoring scheme and color coding are presented in Table 4-3. The total possible index score is 100.
a. These scores were interpreted from field sheets that were collected before the QHEI was developed.

Cemetery Creek was sampled in three different years: 1987, 1995, and 2003 (Table 4-11). The sites at RMs 1.3 (G02S08) and 2.1 (G02S09) are in non-attainment of their WWH designation; however, the sites have good and excellent habitat (respectively). No additional information is available for the site at RM 2.5 upstream of G02S09, except that it is on the stream in the village of Jefferson. It is also noteworthy that habitat conditions have decreased considerably from 1987 to 2003 at RM 2.1 (G02S09) (Table 4-11). That decrease in habitat quality could be reflective of the increased development in the Jefferson area, although according to QHEI scores, habitat is still excellent at this location.

[9] Paul Anderson, Ohio EPA, personal communication, July 11, 2011.

Table 4-11. QHEI scores on Cemetery Creek from 1987 to 2004

RM	STORET Station	1987[a]	1995	2003
2.5	--	--	42	--
2.1	G02S09	90	--	78
1.2/1.3	G02S08	60	55.5	64.5

The QHEI scoring scheme and color coding are presented in Table 4-3. The total possible index score is 100.
a. These scores were interpreted from field sheets that were collected before the QHEI was developed.

4.3. Grand River Tributary Subbasin

The Grand River Tributary subbasin is in the central portion of the lower Grand River watershed and encompasses approximately 108 square miles (Figure 4-7). The subbasin includes the following WAUs: 04110004 06 01, 04110004 06 02, 04110004 06 03, 04110004 06 04, and 04110004 06 05. No data are available for the 04110004 06 03 HUC, and therefore no analyses were conducted.

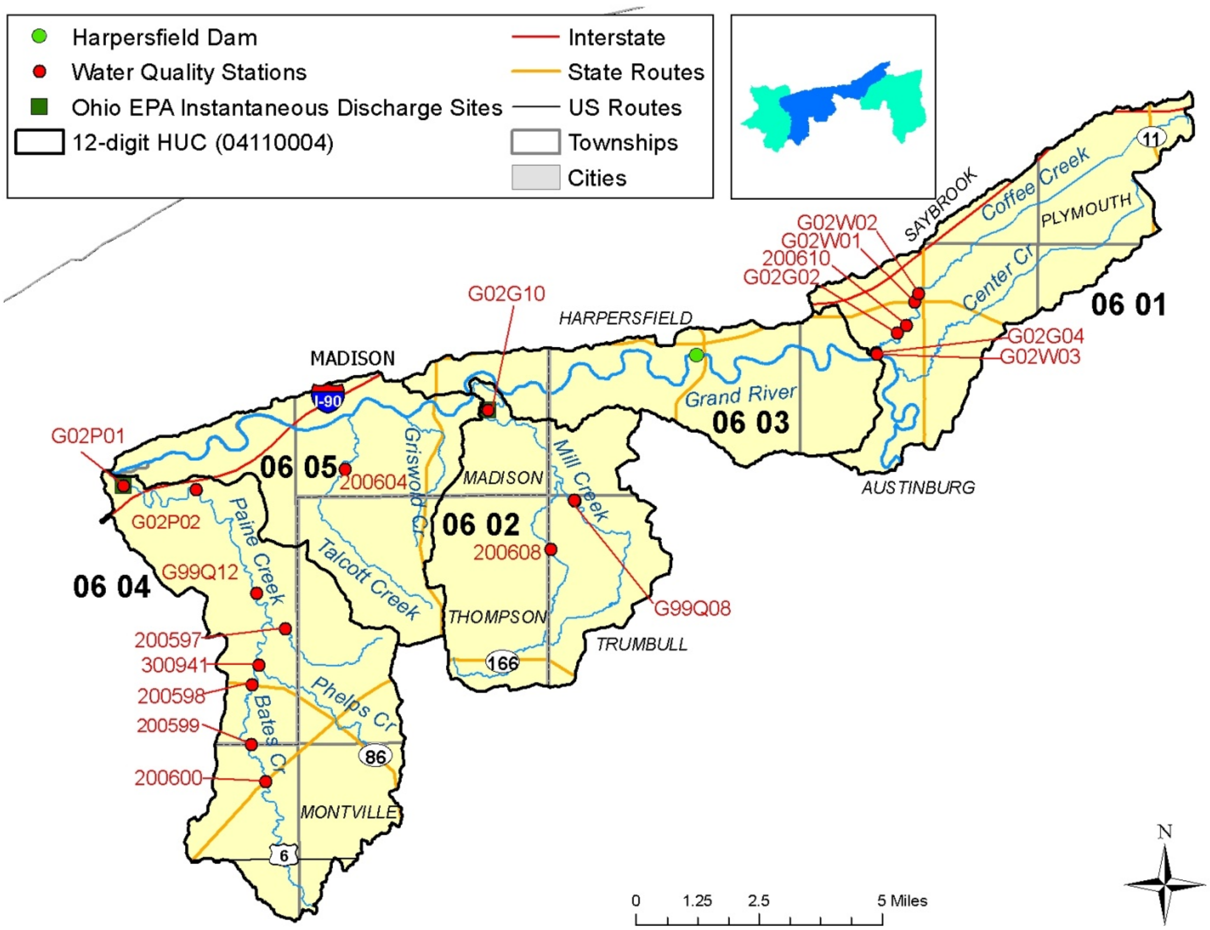


Figure 4-7. Grand River Tributary subbasin.

4.3.1. Hydrology

The Grand River Tributary subbasin contains numerous small perennial streams and begins just downstream of the confluence with Mill Creek (04110004 04). No continuous flow gage data exist for the tributary streams in this subbasin.

Paine Creek is influenced by coldwater tributaries including Phelps Creek, Bates Creek, and an unnamed tributary at RM 7.2. Talcott Creek is designated a CWH stream as is Mill Creek. All those coldwater tributaries contribute cold ground water base flow to Paine Creek and the Grand River.

Flows along Paine Creek were monitored 10 times between 2004 and 2006 by Ohio EPA near the confluence with the Grand River. Data indicate that Paine Creek contributes 2 to 5 percent of the total flow in the lower Grand River over all flow conditions measured. Monitored flows ranged from 0.37 to 138 cfs.

Ohio EPA monitored Mill Creek flow seven times between 2004 and 2006. Data indicate that Mill Creek contributes 1 to 13 percent of the total flow in the lower portion of the Grand River during all flow conditions. Monitored flows ranged from 0.28 to 67.3 cfs.

4.3.2. Water Quality Data

Bacteria

Ohio EPA collected *E. coli* samples in 2003 and 2004, from 29 locations on 8 creeks in the Grand River Tributary subbasin. The data are summarized in Table 4-12. All the streams in the subbasin are designated as PCR Class B with a geometric mean standard of 161 counts per 100 mL. Ohio EPA has identified bacteria impairments in three of the four WAUs with data, and Ohio EPA intends to add the fourth WAU (HUC 04110004 04 01) to Ohio’s 2012 303(d) list. A TMDL will also be developed for Coffee Creek to address bacteria because Ohio EPA will add its WAU to Ohio’s 2012 303(d) list. However, bacteria levels in Coffee Creek might have since decreased because the sewer coverage of the Austinburg wastewater treatment plant (WWTP) was expanded, and areas that formerly had failing septic systems are now sewered.

Table 4-12. *E. coli* data for the Grand River Tributary subbasin, excluding the Grand River [counts per 100 mL]

Stream	STORET station	Begin date	End date	No. of samples [a]	Minimum	Maximum	Geomean (2003) [b]	Geomean (2004) [b]
HUC 04110004 04 01 (Coffee Creek - Grand River)								
Coffee Creek	G02W01	6/27/00	8/22/00	4	880	20,000	**3,730**	--
	G02W02	6/27/00	8/22/00	4	860	9,800	**2,527** [c]	--
	200610	6/27/00	8/22/00	4	840	2,000	**1,166** [c]	--
	G02W03	6/27/00	8/22/00	4	150	380	**276** [c]	--
HUC 04110004 06 02 (Mill Creek)								
Mill Creek	G99Q08	6/3/04	8/2/04	3	57	390	139	--
	G02G10	8/6/03	8/2/04	8 (4/4)	37	7,300	**217**	**300**
unnamed tributary [d]	200608	6/3/04	8/2/04	3	62	730	--	**181**
HUC 04110004 06 04 (Paine Creek)								
Bates Creek	200598	6/24/04	8/2/04	2	170	460	--	**280**
	200600	6/3/04	8/2/04	3	61	550	--	140
Paine Creek	G99Q12	6/3/04	8/2/04	3	11	200	--	39
	G02P01	8/6/03	8/2/04	8 (4/4)	51	4,000	**417**	**256**
Phelps Creek	300941	6/24/04	8/2/04	2	64	260	--	129
unnamed tributary [e]	200597	6/3/04	8/2/04	3	26	290	--	118
HUC 04110004 06 05 (Talcott Creek - Grand River)								
Talcott Creek	200604	6/3/04	8/2/04	3	47	220	95	

Notes
Creeks are listed alphabetically per 12-digit HUC; stations are listed top to bottom as upstream to downstream per creek.
Units for the minima, maxima, and geometric means are counts per 100 mL.
Bolded values are greater than seasonal geometric mean standard of 161 counts per 100 mL for PCR Class B waterbodies.
a. When multiple numbers are displayed, the first number represents the total number of samples collected at the site, and the numbers in the parentheses represent the numbers of samples collected in 2003 and 2004, which were used to calculate the geometric means.
b. Geometric means were calculated using all available data for a given year's recreation season (May 1 through October 31).
c. The geometric means were calculated from data collected in 2000.
d. Unnamed tributary to Mill Creek at RM 4.94.
e. Unnamed tributary to Paine Creek at RM 7.17

Total Suspended Solids

Ohio EPA collected TSS samples in 2000, 2003, and 2004 from 12 locations on 8 creeks in the Grand River Tributary subbasin. The data are summarized in Table 4-13. No spatial or temporal patterns of elevated TSS concentrations are readily apparent. The sewer system coverage at the Austinburg WWTP was expanded since Ohio EPA's 2000 and 2003–2004 field surveys; thus, TSS in Coffee Creek in the unnamed tributary to Coffee Creek at RM 0.10 has likely improved.

Table 4-13. TSS data from the Grand River Tributary subbasin, excluding the Grand River

Stream	STORET station	Size [a]	begin date	End date	No. of samples [b]	Minimum (mg/L)	Maximum (mg/L)	Average (mg/L)
HUC 04110004 06 01 (Coffee Creek - Grand River)								
Coffee Creek	200610	H	7/20/2000	8/22/2000	3	21	25	22
	G02G02		7/12/2000		1	ND		
	G02W03		6/27/2000	8/22/2000	5	ND	**34**	16
unnamed tributary [c]	G02G04	H	6/3/2004		1	49		
HUC 04110004 06 02 (Mill Creek)								
Mill Creek	G99Q08	H	6/3/2004	8/2/2004	3	ND		
	G02G10		8/6/2003	8/9/2004	12	ND	**456**	**42**
unnamed tributary [d]	200608	H	6/3/2004	8/9/2004	4	ND	7	5
HUC 04110004 06 04 (Paine Creek)								
Bates Creek	200600	H	6/3/2004	8/2/2004	3	ND	5	3
Paine Creek	G99Q12	W	6/3/2004	8/9/2004	6	ND	11	4
	G02P01		8/6/2003	8/2/2004	11	ND	**35**	10
unnamed tributary [e]	200597	H	6/3/2004	8/2/2004	3	ND	6	4
HUC 04110004 06 05 (Talcott Creek - Grand River)								
Talcott Creek	200604	H	6/3/2004	8/2/2004	3	ND		

Notes
Creeks are listed alphabetically per 12-digit HUC; stations are listed top to bottom as upstream to downstream per creek.
ND = not detected. The detection limit is 5.0 mg/L and a value of 2.5 mg/L was used in the calculation of statistics.
Bolded values are greater than the targets: 25.0 mg/L for headwaters streams and 21.0 mg/L for wading streams.
a. Headwaters (H) streams drain 20 square miles or less; wading (W) streams drain 20 to 200 square miles.
b. The number of samples excludes field duplicates.
c. Unnamed tributary to Coffee Creek at RM 0.10.
d. Unnamed tributary to Mill Creek at RM 4.34.
e. Unnamed tributary to Paine Creek at RM 7.17.

Nutrients

Nutrient concentrations exceeded the nutrient targets from Ohio EPA's *Associations* document (see Table 2.6) at six sites in the Grand River Tributary subbasin. In the Coffee Creek subwatershed, elevated total phosphorus and nitrate plus nitrite concentrations were detected in 2000; Ohio EPA identified failing septic systems in the area during that period. An unsewered area in Austinburg near Coffee Creek has subsequently been sewered and connected to the Austinburg WWTP, which discharges to Coffee Creek. The available nutrient data indicate that Mill Creek, the unnamed tributary to Mill Creek, Talcott, and Paine Creek also have elevated nitrate plus nitrite concentrations. Those same streams, with the exception of Talcott Creek, also had elevated total phosphorus concentrations. The nutrient levels in Coffee Creek and the unnamed tributary to Coffee Creek at RM 0.10 might have improved since the 2000 and 2003–2004 field surveys because the failing septic systems in some areas near Austinburg have been sewered.

Table 4-14. Total phosphorus data from the Grand River Tributary subbasin, excluding the Grand River

Stream	STORET station	Size [a]	ALU Designation [b]	Begin date	End date	No. of samples [c]	Minimum (mg/L)	Maximum (mg/L)	Average (mg/L)
HUC 04110004 06 01 (Coffee Creek - Grand River)									
Coffee Creek	200610	H	WWH	7/20/2000	8/22/2000	3	**0.100**	**0.170**	**0.133**
	G02G02			7/12/2000		1	0.080		
	G02W03			6/27/2000	8/22/2000	5	ND$^{0.05}$	**0.090**	0.073
unnamed tributary [d]	G02G04	H	WWH	6/3/2004		1	ND$^{0.05}$		
HUC 04110004 06 02 (Mill Creek)									
Mill Creek	G99Q08	H	CWH	6/3/2004	8/2/2004	3	0.017	0.048	0.031
	G02G10			8/6/2003	8/9/2004	12	ND$^{0.01}$	**0.475**	**0.076**
unnamed tributary [e]	200608	H	CWH	6/3/2004	8/9/2004	4	0.012	**0.053**	0.036
HUC 04110004 06 04 (Paine Creek)									
Bates Creek	200600	H	WWH	6/3/2004	8/2/2004	3	ND$^{0.01}$	0.046	0.022
Paine Creek	G99Q12	W	WWH	6/3/2004	8/9/2004	6	ND$^{0.01}$	0.042	0.022
	G02P01		EWH	8/6/2003	8/2/2004	11	ND$^{0.01}$	**0.367**	**0.053**
unnamed tributary [f]	200597	H	EWH [f]	6/3/2004	8/2/2004	3	0.011	**0.082**	0.044
HUC 04110004 06 05 (Talcott Creek - Grand River)									
Talcott Creek	200604	H	CWH	6/3/2004	8/2/2004	3	ND$^{0.01}$	0.011	0.007

Notes

Creeks are listed alphabetically per WAU; stations are listed top to bottom as upstream to downstream per creek.

ND = not detected. The detection limit was either 0.05 or 0.01 mg/L and values of 0.025 or 0.005 mg/L (respectively) were used in calculating statistics.

Bolded values are greater than the targets: 0.08 mg/L for headwaters WWH, 0.10 mg/L for wading WWH, and 0.05 for EWH and CWH.

a. Headwaters (H) streams drain 20 square miles or less; wading (W) streams drain 20 to 200 square miles.

b. Aquatic Life Use (ALU) designations: coldwater habitat (CWH), exceptional warmwater habitat (EWH), and warmwater habitat (WWH).

c. The number of samples excludes field duplicates.

d. Unnamed tributary to Coffee Creek at RM 0.10.

e. Tributary to Mill Creek at RM 4.34.

f. Tributary to Paine Creek at RM 7.17; the tributary is dual-listed as EWH and CWH.

Table 4-15. Nitrate plus nitrite data from the Grand River Tributary subbasin, excluding the Grand River

Stream	STORET station	Size [a]	ALU designation [b]	Begin date	End date	No. of samples [b]	Minimum (mg/L)	Maximum (mg/L)	Average (mg/L)
HUC 04110004 06 01 (Coffee Creek - Grand River)									
Coffee Creek	200610	H	WWH	7/20/2000	8/22/2000	3	**1.54**	**6.80**	**3.47**
	G02G02			7/12/2000		1	0.341		
	G02W03			6/27/2000	8/22/2000	5	**1.37**	**4.16**	**3.18**
unnamed tributary [d]	G02G04	H	WWH	6/3/2004		1	0.185		
HUC 04110004 06 02 (Mill Creek)									
Mill Creek	G99Q08	H	CWH	6/3/2004	8/2/2004	3	0.17	0.27	0.21
	G02G10			8/6/2003	8/9/2004	12	ND	**0.58**	0.28
unnamed tributary [e]	200608	H	CWH	6/3/2004	8/9/2004	4	0.56	**1.28**	**1.05**
HUC 04110004 06 04 (Paine Creek)									
Bates	200600	H	WWH	6/3/2004	8/2/2004	3	ND	0.13	0.07
Paine	G99Q12	W	WWH	6/3/2004	8/9/2004	6	ND	0.22	0.15
	G02P01		EWH	8/6/2003	8/2/2004	11	ND	0.28	0.13
unnamed tributary [f]	200597	H	EWH [g]	6/3/2004	8/2/2004	3	0.37	**0.56**	0.44
HUC 04110004 06 05 (Talcott Creek - Grand River)									
Talcott Creek	200604	H	CWH	6/3/2004	8/2/2004	3	0.26	**0.57**	0.44

Notes
Creeks are listed alphabetically per WAU; stations are listed top to bottom as upstream to downstream per creek.
ND = not detected. The detection limit was 0.1 mg/L and a value of 0.05 mg/L was used in the calculation of statistics.
Bolded values are greater than the targets: 1.0 mg/L for WWH and 0.5 for EWH and CWH.
a. Headwaters (H) streams drain 20 square miles or less; wading (W) streams drain 20 to 200 square miles.
b. Aquatic Life Use (ALU) designations: coldwater habitat (CWH), exceptional warmwater habitat (EWH), and warmwater habitat (WWH).
c. The number of samples excludes field duplicates.
d. Unnamed tributary to Coffee Creek at RM 0.10.
e. Tributary to Mill Creek at RM 4.34.
f. Tributary to Paine Creek at RM 7.17
g. Tributary to Paine Creek at RM 7.17; the tributary is dual-listed as EWH and CWH.

4.3.3. Habitat Analysis

In 2003 and 2004 Ohio EPA assessed the habitat conditions at 13 sites on 7 waterbodies in the Grand River Tributary subbasin (Table 4-16). In general, habitat conditions in the Grand River Tributary subbasin are good to excellent.

Coffee Creek drains lacustrine deposits in a mostly rural area. Despite being rural, anthropogenic disturbance and storm water from Austinburg have mobilized fine sediments, resulting in a bedload of sand and silt.

Each of the other tributaries has high gradients, discontinuities in bedrock, and is subject to scouring flows that result in long bedrock glides, cascades and waterfalls. The headwaters of Paine Creek (i.e., Bates Creek) and Mill Creek have habitat more conducive to supporting till-plain stream fish communities. Bates Creek at Radcliffe Road, and an unnamed tributary to Mill Creek sampled near the junction of Belle and Short Roads, have virtually intact physical stream habitat; most notably, the substrates are a nearly silt-free heterogeneous mix of fractured sandstone bedrock and glacial till.

Ohio EPA also evaluated habitat at Coffee Creek from 1983 to 2000. Temporal evaluation of the site is presented in this section.

Table 4-16. QHEI and metric scores for sites in the Grand River Tributary subbasin, except the Grand River

Waterbody name	RM/ STORET station	Size [a]	Year	QHEI (100) [b]		Substrate (20) [c]	In-stream Cover (20) [c]	Channel Morphology (20) [c]	Bank Erosion & Riparian Zone (10) [c]	Pool/Glide (12) [c]	Riffle/Run (8) [c]	Gradient (10) [c]
HUC 04110004 06 01 (Coffee Creek - Grand River)												
Coffee Creek	0.2/ G02W03	H	2004	**65.5**		15	10	15	8.5	7	2	8
HUC 04110004 06 02 (Mill Creek)												
Mill Creek	5.0/ G02G26	H	2004	**74.5**		15	16	18	8.5	9	0	8
	1.4/ G02G10	H	2003	**54.5**		11.5	7	10	10	6	4	6
	1.3/ G02G10	H	2004	**65**		11.5	10	17	9	7	4.5	6
unnamed tributary [d]	2.0/ G07G27	H	2004	**79**		16	15	19	10	10	5	4
	1.6/ G07G27	H	2004	**79**		16	15	19	10	10	5	4
HUC 04110004 06 04 (Paine Creek)												
Bates Creek	2.2/ 200599	H	2004	**83.5**		18	18	17	10	8	4.5	8
Paine Creek	6.2/ G99Q12	W	2004	**81.5**		16.5	16	20	10	11	4	4
	3.0/ G02P02	W	2004	**69.5**		11.5	10	17	9	8	4	10
	0.5/ G02P01	W	2003	**60.5**		12.5	5	12	10	6	7	8
unnamed tributary [e]	0.4/ 200597 [f]	H	2004	**55**		13	7	16.5	8.5	6	0	4
HUC 04110004 06 05 (Talcott Creek - Grand River)												
Talcott Creek	1.5/ 200604	H	2004	**61**		13.5	9	16	8.5	6	4	4

Notes
Creeks are listed alphabetically per 12-digit HUC; stations are listed top to bottom as upstream to downstream per creek.
a. Headwaters (H) streams drain 20 square miles or less; wading (W) streams drain 20 to 100 square miles.
b. The QHEI scoring scheme and color coding are presented in Table 4-3. The total possible index score is 100.
c. The metric color coding is presented in Table 4-4. The numbers in parentheses are the total possible metric scores.
d. Tributary to Mill Creek at RM 4.34.
e. Tributary to Paine Creek at RM 7.17
f. The sample station 200597 at RM 0.4 on the unnamed tributary to Paine Creek (RM 7.17) is also identified as G02G38.

Coffee Creek was sampled in 2000 and 2004 (Table 4-17). Only one site was sampled in both years (G02W03, RM 0.2) and the habitat quality decreased from excellent to good. Much of the lower portion of Coffee Creek is forested and would appear to support healthy habitat. The decrease in QHEI scores was driven by a decrease of 5 points in the *riffle/run* metric and decreases of 3 points in the *in-stream cover* and *channel morphology* metrics.

It is also noteworthy that a considerable difference in QHEI scores occurred between sites at RMs 1.2 and 1.3 (200610, which is also identified as G02G01) in 2000, despite both sites being along what appears to be a homogenous forested area of Coffee Creek. The site at RM 1.3 (G02G01) is just upstream of the confluence of a small tributary to Coffee Creek. This tributary to Coffee Creek carries WWTP effluent and storm water runoff from an industrial park. During that period, Ohio EPA reports that considerable development pressure occurred in the upper portions of Coffee Creek near the I-90 and State Route 45 interchange.

Table 4-17. QHEI scores on Coffee Creek in 2000 and 2004

RM	STORET station	2000	2004
1.3	G02G01	69	--
1.2	G02G01	80	--
0.2	G02W03	76	65.5

The QHEI scoring scheme and color coding are presented in Table 4-3. The total possible index score is 100.

4.4. Big Creek and Red Creek Subbasin

The Big Creek and Red Creek subbasin is in the western portion of the lower Grand River watershed and encompasses approximately 77 square miles (Figure 4-8). The subbasin includes the following WAUs: 04110004 06 06 and 04110004 06 07.

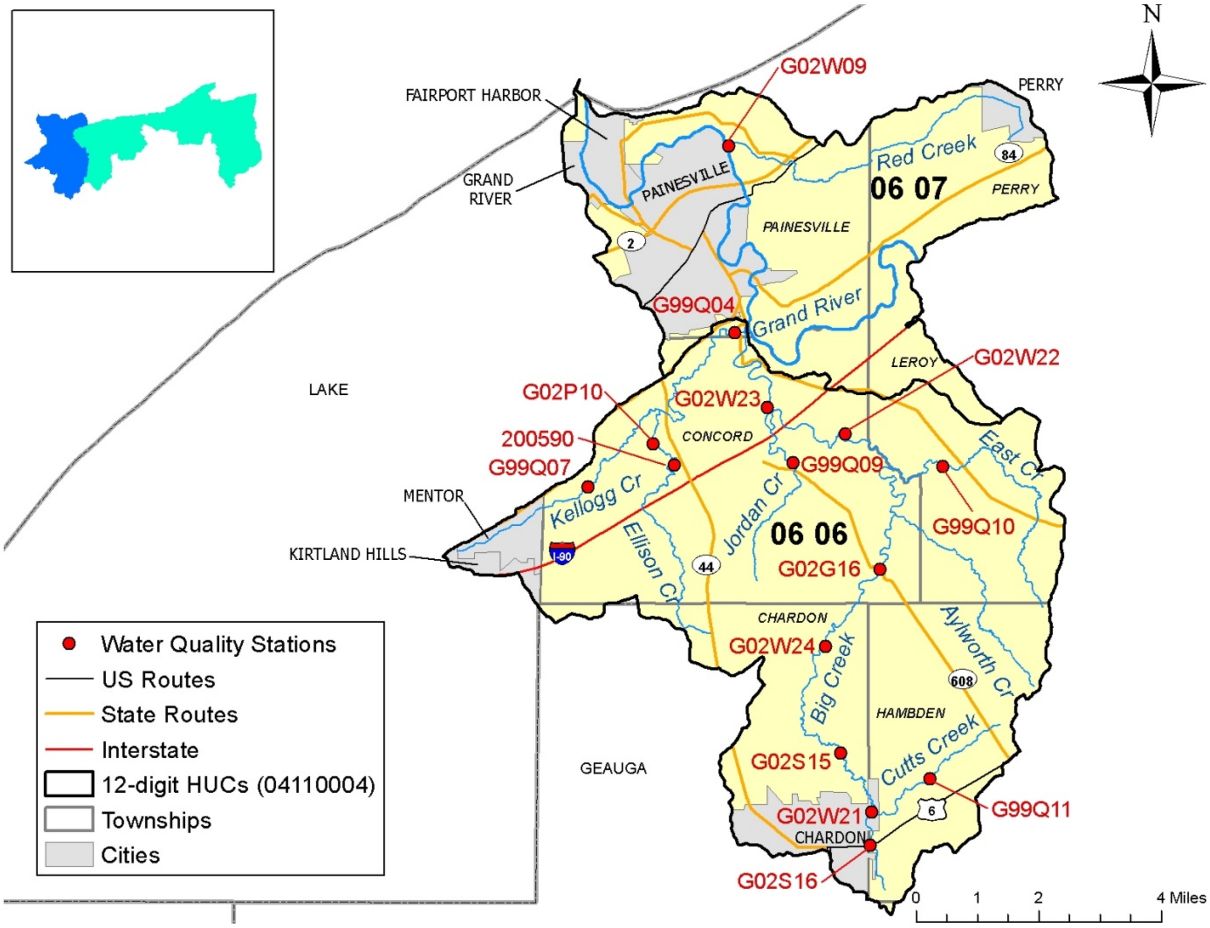


Figure 4-8. Big Creek and Red Creek subbasin.

4.4.1. Hydrology

The hydrology of the Big Creek and Red Creek subbasin is dominated by small coldwater tributary streams and storm water flows. There are no available continuous flow data within this subbasin. However, development within the Kellogg Creek, Red Creek and upper portions of Big Creek likely leads to larger runoff volumes, higher peak flows, and flashy streams.

Several coldwater tributaries are present within the Big Creek watershed including Cutts Creek, East Creek, Jenks Creek, Jordan Creek, and Aylworth Creek. All those CWH designated streams are meeting attainment status and are important to the downstream Big Creek and Grand River in preserving base flow conditions.

Brightwood Lake is formed by a dam on Kellogg Creek at approximately RM 4.3 just upstream of Prouty Road in Concord Township, Lake County. Brightwood Lake is approximately 11.4 acres in size, and was constructed in 1967. The lake has experienced severe volume loss because of sedimentation.

Big Creek flow was monitored eleven times from 2004 to 2006 by Ohio EPA near the confluence with the Grand River. Data indicate that Big Creek contributes 4 to 11.5 percent of the total flow volume in the lower Grand River over all flow conditions. Monitored flows ranged from 2.56 to 255.65 cfs. Low flow measurements were taken by the USGS on Big Creek 1.1 mile upstream of the mouth of the river during water years 1981, 1982, and 1995-99 (USGS 2001). The minimum observed flow was recorded at 1.9 cfs during September 1995.

Red Creek has sustained flow throughout the summer because of the contribution of ground water from beach ridges and a thick soil horizon.

4.4.2. Water Quality Data

Bacteria

Ohio EPA collected *E. coli* samples in 2000, 2003, and 2004 from 15 locations on 8 creeks in the Big Creek and Red Creek subbasin. All of the streams displayed in Table 4-18 are designated PCR Class B with a seasonal geometric mean standard of 161 *E. coli* counts per 100 mL. Ohio EPA has identified bacteria impairments in both of the WAUs: 04110004 06 06 (Big Creek, Cutts Creek, East Creek, Ellison Creek, Jordan Creek, and Kellogg Creek) and 04110004 06 07 (Red Creek).

Table 4-18. *E. coli* data for the Big Creek and Red Creek subbasin, excluding the Grand River [counts per 100 mL]

Stream	STORET station	Begin date	End date	No. of samples [a]	Minimum	Maximum	Geomean (2003) [b]	Geomean (2004) [b]
HUC 04110004 06 06 (Big Creek)								
Big Creek	G02S16	8/28/03	9/10/03	2	190	310	**243**	--
	G02W21	8/28/03	9/10/03	2	26	30	28	--
	G02S15	8/28/03	9/10/03	2	240	260	**250**	--
	G02G16	8/28/03	9/10/03	2	44	150	81	--
	G02W22	8/28/03	9/10/03	2	54	86	68	--
	G02W23	8/6/03	8/2/04	10 (5/5)	16	5,800	**174**	**172**
Cutts Creek	G99Q11	6/3/04	8/2/04	3	306	306	--	**306**
East Creek	G99Q10	6/3/04	8/2/04	3	168	168	--	**168**
Ellison Creek	200590	6/3/04	8/2/04	3	69	410	--	**189**
	G02P10	6/21/00	7/31/00	4	72	11,000	[c] **426**	--
Jenks Creek	G02W24	8/28/03	9/10/03	2	26	130	58	--
Jordan Creek	G99Q09	6/3/04	8/2/04	3	75	460	--	**213**
Kellogg Creek	G99Q07	6/3/04	8/2/04	3	410	2,200	--	**870**
	G99Q04	6/3/04	8/2/04	3	110	650	--	**301**
HUC 04110004 06 07 (Red Creek - Grand River)								
Red Creek	G02W09	6/3/04	8/2/04	3	270	1,000	--	**428**

Notes

Creeks are listed alphabetically per 12-digit HUC; stations are listed top to bottom as upstream to downstream per creek.

Units for the minima, maxima, and geometric means are counts per 100 mL.

Bolded values are greater than seasonal geometric mean standard of 161 counts per 100 mL for PCR Class B waterbodies.

a. When multiple numbers are displayed, the first number represents the total number of samples collected at the site and the numbers in the parentheses represent the numbers of samples collected in 2003 and 2004, which were used to calculate the geometric means.

b. Geometric means were calculated using all available data for a given year's recreation season (May 1 through October 31).

c. The geometric mean was calculated from data collected in 2000.

Total Suspended Solids

Ohio EPA collected TSS samples in 2003 and 2004 from 15 locations on 8 creeks, excluding the Grand River, in the Big Creek and Red Creek subbasin. The data are summarized in Table 4-19. No spatial or temporal patterns of elevated TSS concentrations are readily apparent.

Table 4-19. TSS data from the Big Creek and Red Creek subbasin, excluding the Grand River

Stream	STORET station	Size [a]	Begin date	End date	No. of samples [b]	Minimum (mg/L)	Maximum (mg/L)	Average (mg/L)
HUC 04110004 06 06 (Big Creek)								
Big Creek	G02S16	H	8/28/2003	10/7/2003	3	ND	5	3
	G02W21				3	ND		
	G02S15				3	ND		
	G02G16				3	ND		
	G02W22	W			3	ND		
	G02W23		8/6/2003	8/2/2004	14	ND	**160**	20
Cutts Creek	G99Q11	H	6/3/2004	8/2/2004	3	ND		
East Creek	G99Q10	H	6/3/2004	8/2/2004	3	ND	**53**	19
Ellison Creek	200590	H	6/24/2004	8/2/2004	2	5	6	6
	G02P10		6/21/2000	6/3/2004	5	ND	**279**	**60**
Jenks Creek	G02W24	H	8/28/2003	10/7/2003	3	ND		
Jordan Creek	G99Q09	H	6/3/2004	8/2/2004	3	ND	5	3
Kellogg Creek	G99Q07	H	6/3/2004	8/2/2004	3	ND	15	8
	G99Q04				3	ND	21	10
HUC 04110004 06 07 (Red Creek)								
Red Creek	G02W09	H	6/3/2004	8/2/2004	3	ND	9	6

Notes
ND = not detected. The detection limit is 5.0 mg/L and a value of 2.5 mg/L was used in the calculation of statistics.
Bolded values are greater than the targets: 25.0 mg/L for headwaters streams and 21.0 mg/L for wading streams.
Creeks are listed alphabetically per 12-digit HUC; stations are listed top to bottom as upstream to downstream per creek.
a. Headwaters (H) streams drain 20 square miles or less; wading (W) streams drain 20 to 200 square miles.
b. The number of samples excludes field duplicates.

Nutrients

Nutrient concentrations exceeded the nutrient targets from Ohio EPA's Association document (see Table 2.6) at ten sites in the Big Creek and Red Creek Subbasin. Elevated nutrient concentrations were regularly detected on Big Creek and Cutts Creek in the Chardon area. The Chardon WWTP discharges to Big Creek and is likely causing elevated nutrient concentrations although phosphorus concentrations are also intermittently high upstream of the WWTP, indicating runoff is also a likely source.

Table 4-20. Total phosphorus data from the Big Creek and Red Creek subbasin, excluding the Grand River

Stream	STORET station	Size [a]	ALU designation [b]	Begin date	End date	No. of samples [c]	Minimum (mg/L)	Maximum (mg/L)	Average (mg/L)
HUC 04110004 06 06 (Big Creek)									
Big Creek	G02S16	H	WWH	8/28/2003	10/7/2003	3	0.011	**0.306**	**0.116**
	G02W21					3	**0.239**	**0.583**	**0.424**
	G02S15					3	0.098	**0.269**	**0.181**
	G02G16					3	ND$^{0.01}$	0.029	0.016
	G02W22	W				3	ND$^{0.01}$	0.040	0.021
	G02W23			8/6/2003	8/2/2004	14	ND$^{0.01}$	0.063	0.029
Cutts Creek	G99Q11	H	CWH	6/3/2004	8/2/2004	3	ND$^{0.01}$	**0.100**	0.040
East Creek	G99Q10	H	CWH	6/3/2004	8/2/2004	3	0.021	**0.051**	0.036
Ellison Creek	200590	H	WWH	6/24/2004	8/2/2004	2	0.059	**0.099**	0.079
	G02P10			6/21/2000	6/3/2004	5	ND$^{0.05}$	**0.170**	0.068
Jenks Creek	G02W24	H	CWH	8/28/2003	10/7/2003	3	0.024	**0.271**	**0.109**
Jordan Creek	G99Q09	H	CWH	6/3/2004	8/2/2004	3	ND$^{0.01}$	0.037	0.016
Kellogg Creek	G99Q07	H	WWH	6/3/2004	8/2/2004	3	0.017	0.025	0.022
	G99Q04					3	0.022	**0.244**	**0.099**
HUC 04110004 06 07 (Red Creek)									
Red Creek	G02W09	H	WWH	6/3/2004	8/2/2004	3	0.036	**0.098**	0.067

Notes

ND = not detected. The detection limit was either 0.05 or 0.01 mg/L and values of 0.025 or 0.005 mg/L (respectively) were used in the calculation of statistics.

Bolded values are greater than the targets: 0.08 mg/L for headwaters WWH, 0.10 mg/L for wading WWH, and 0.05 for EWH and CWH.

Creeks are listed alphabetically per WAU; stations are listed top to bottom as upstream to downstream per creek.

a. Headwaters (H) streams drain 20 square miles or less; wading (W) streams drain 20 to 200 square miles.

b. Aquatic Life Use (ALU) designations: coldwater habitat (CWH), exceptional warmwater habitat (EWH), and warmwater habitat (WWH).

c. The number of samples excludes field duplicates.

d. The unnamed tributary to Paine Creek at RM 7.2 is dual-listed as EWH and CWH.

Table 4-21. Nitrate plus nitrite data from the Big Creek and Red Creek subbasin, excluding the Grand River

Stream	STORET station	Size [a]	ALU designation [b]	Begin date	End date	No. of samples [c]	Minimum (mg/L)	Maximum (mg/L)	Average (mg/L)
HUC 04110004 06 06 (Big Creek)									
Big Creek	G02S16	H	WWH	8/28/2003	10/7/2003	3	0.12	0.58	0.28
	G02W21	H	WWH	8/28/2003	10/7/2003	3	**4.09**	**5.40**	**4.61**
	G02S15	H	WWH	8/28/2003	10/7/2003	3	**1.48**	**2.95**	**2.04**
	G02G16	H	WWH	8/28/2003	10/7/2003	3	0.40	0.63	0.49
	G02W22	W	WWH	8/28/2003	10/7/2003	3	*ND*	0.38	0.26
	G02W23	W	WWH	8/6/2003	8/2/2004	14	*ND*	**1.13**	0.32
Cutts Creek	G99Q11	H	CWH	6/3/2004	8/2/2004	3	0.30	**0.80**	**0.52**
East Creek	G99Q10	H	CWH	6/3/2004	8/2/2004	3	0.37	**0.72**	**0.53**
Ellison Creek	200590	H	WWH	6/24/2004	8/2/2004	2	0.36	0.43	0.40
	G02P10	H	WWH	6/21/2000	6/3/2004	5	*ND*	0.43	0.29
Jenks Creek	G02W24	H	CWH	8/28/2003	10/7/2003	3	*ND*	0.44	0.19
Jordan Creek	G99Q09	H	CWH	6/3/2004	8/2/2004	3	*ND*	0.43	0.21
Kellogg Creek	G99Q07	H	WWH	6/3/2004	8/2/2004	3	0.14	0.29	0.19
	G99Q04	H	WWH	6/3/2004	8/2/2004	3	0.46	0.55	0.50
HUC 04110004 06 07 (Red Creek)									
Red Creek	G02W09	H	WWH	6/3/2004	8/2/2004	3	**1.42**	**1.71**	**1.56**

Creeks are listed alphabetically per WAU; stations are listed top to bottom as upstream to downstream per creek.
ND = not detected. The detection limit was 0.1 mg/L and a value of 0.05 mg/L was used in the calculation of statistics.
Bolded values are greater than the targets: 1.0 mg/L for WWH and 0.5 for EWH and CWH.
a. Headwaters (H) streams drain 20 square miles or less; wading (W) streams drain 20 to 200 square miles.
b. Aquatic Life Use (ALU) designations: coldwater habitat (CWH), exceptional warmwater habitat (EWH), and warmwater habitat (WWH).
c. The number of samples excludes field duplicates.
d. The unnamed tributary to Paine Creek at RM 7.2 is dual-listed as EWH and CWH.

4.4.3. Habitat Analysis

In 2003 and 2004 Ohio EPA assessed the habitat conditions at 14 sites on 8 waterbodies in the Big Creek and Red Creek subbasin (Table 4-22). In general, habitat conditions in the Big Creek and Red Creek subbasin, excluding the Grand River, are good to excellent. The only QHEI narrative score of fair occurs on Big Creek. That site is also impaired for its ALU designation (WWH); however, the cause of impairment is natural conditions and wetlands. It is noteworthy that good to excellent habitat is still on streams that have been developed or are beginning to develop. Table 4-23 presents QHEI scores recorded at the same stations in 1987, 1995, and 2003.

Table 4-22. QHEI and metric scores for sites in the Big Creek and Red Creek subbasin, except the Grand River

Waterbody name	RM/ STORET station	Size [a]	Year	QHEI (100) [b]	Substrate (20) [c]	In-stream Cover (20) [c]	Channel morphology (20) [c]	Bank erosion & riparian zone (10) [c]	Pool/glide (12) [c]	Riffle/run (8) [c]	Gradient (10) [c]
HUC 04110004 06 06 (Big Creek)											
Big Creek	16.2/ G02S16	H	2003	**62**	13.5	14	10	6.5	7	3	8
	16.0/ G02W21	H	2003	**82**	19.5	12	20	10	7	5.5	8
	14.0/ G02S15	H	2003	**75**	13	13	18	10	10	3	8
	9.3/ G02G16	H	2003	**85**	15	19	19	10	9	5	8
	4.9/ G02W22	W	2003	**66.5**	15	10	17	6.5	7	5	6
	2.5/ G02W23	W	2003	**50.5**	12	5	12	4.5	6	5	6
Cutts Creek	1.2/ G02G33	H	2004	**73**	16	16	16.5	7.5	9	0	8
East Creek	1.2/ G02G32	H	2004	**58**	12	8	17	8	9	0	4
Ellison Creek	1.2/ G02G39	H	2004	**59**	11	10	16.5	6.5	7	4	4
Jenks Creek	0.1/ G02W24	H	2003	**80.5**	17.5	18	17	9	9	6	4
Jordon Creek	1.1/ G02G21	H	2004	**59.5**	10.5	10	16	9	6	4	4
Kellogg Creek	5.7/ G99Q07	H	2004	**59**	11	13	12.5	5	5	2.5	10
	0.2/ G02G23	H	2004	**67**	13.5	10	16.5	8.5	6.5	4	8
HUC 04110004 06 07 (Red Creek)											
Red Creek	0.5/ G02G21	H	2004	**67**	13	16	14.5	6.5	9	2	6

Notes
Creeks are listed alphabetically per 12-digit HUC; stations are listed top to bottom as upstream to downstream per creek.
a. Headwaters (H) streams drain 20 square miles or less; wading (W) streams drain 20 to 100 square miles.
b. The QHEI scoring scheme and color coding are presented in Table 4-3. The total possible index score is 100.
c. The metric color coding is presented in Table 4-4. The numbers in parentheses are the total possible metric scores.

Big Creek and its tributaries drain the heart of Ohio's Snow Belt. A high gradient, combined with torrential, scouring flows, and discontinuities in bedrock, have resulted in beautiful cascades and waterfalls along the length of Big Creek and in many of its tributaries, especially the portion of the drainage area in Lake County. The scouring flows, however, result in long stretches of bedrock punctuated by short aggregations of glacial till and fractured bedrock. Identical conditions exist in East Creek and Jordan Creek, and to a lesser extent in Ellison Creek. Kellogg Creek is different in that it runs parallel to the Portage Escarpment, also referred to as the Lake Escarpment Moraine and, therefore, tends to be rich in glacial till (Ohio EPA 2006, p. 65).

The headwater portion of the Big Creek drainage in Geauga County, being smaller and therefore subject to less scouring energy, and having a thicker glacial drift than the portion in Lake County, generally has stream habitat that is more conducive to supporting fish communities in accordance with expectations derived for till-plain streams (Ohio EPA 2006, p. 66).

Red Creek drains a suburbanized former lake plain; consequently, its parent, fine-grained lacustrine substrates are moderately embedded with silt. The lower reach, where sampled, had not been channelized, and so had sufficient habitat attributes to support a warmwater stream fish assemblage (Ohio EPA 2006, p. 66).

Ohio EPA also evaluated habitat quality, as indicated by QHEI scores, at various sites across the lower Grand River watershed from 1983 to 2000. As previously noted, QHEI scores calculated from data collected before the development of the QHEI in 1989 were interpreted from field sheets and might or might not be as accurate as the standardized QHEI scores. Evaluations of a few pertinent waterbodies are presented in this section. Big Creek was sampled in 1995 and 2003, and scores were estimated for 1987 (Table 4-23). At the two most upstream sites, in the vicinity of the village of Chardon, habitat quality has increased from poor to good from 1987 to 2003.. Much of the increase in scores was driven by improved metric scores for *in-stream cover*, *channel morphology*, and *riffle/run*. Both of the sites are listed on Ohio's 303(d) list for partial attainment of their ALU.

Table 4-23. QHEI scores on Big Creek from 1987 to 2003

RM	STORET station	Size	1987 [a]	1995	2003
16.2/16.3	G02S16	H	41	61.5	62
15.9/16.0	G02W21	H	54	54	82
13.9/14.0	G02S15	H	79	71	75
9.3/9.5	G02G16	H	93	73	85
5.3	--	W	--	71	--
4.9/5.0	G02W22	W	--	71	66.5
2.5	G02W23	W	--	59	50.5

Notes
The QHEI scoring scheme and color coding are presented in Table 4-3. The total possible index score is 100.
a. These scores were interpreted from field sheets that were collected before the QHEI was developed.

In the middle portion of Big Creek (between RM 9.3 [G02G16] and 13.9 [G02S15]), habitat quality increased between 1995 and 2003; the decrease between 1987 and 1995 could be reflective of the fact that the 1987 scores were estimated using historic field sheets and were not determined during field surveys. The increase in habitat quality could be because of the improved habitat quality of the CWH tributaries to Big Creek along the segment. Habitat conditions at Cutts Creek (RM 1.2/1.3 [G02G33]) improved from 68 to 73 from 1996 to 2004. Similarly, at Jenks Creek (RM 0.1 [G02W24]) habitat conditions improved from 70 to 80.5 from 1995 to 2003.

The site at RM 2.5 (G02W23) on Big Creek is in partial attainment of its WWH designation. The cause of impairment, according to Ohio EPA, is natural conditions and wetlands.

Between 1989 and 2004 habitat was evaluated by Ohio EPA on Ellison Creek and Kellogg Creek, but the same location was never sampled in different years. The most downstream sites (Ellison Creek at RM 1.2 [G02G39] and Kellogg Creek at RM 0.2 [G02G23]) had good QHEI scores.

4.5. Grand River Large River Assessment Unit

The Grand River LRAU refers to the mainstem of the Grand River in the lower Grand River watershed. The entire Grand River watershed drains into the LRAU. An ALU assessment of the lower Grand River in the lacustrine area is not presented here because Ohio EPA has not determined attainment in the lacustrine area because of a lack of data. The LRAU fully supports its designated ALU but the recreation use is not supported at most sites. The sample locations on the Grand River in the LRAU are presented in Figure 4-9.

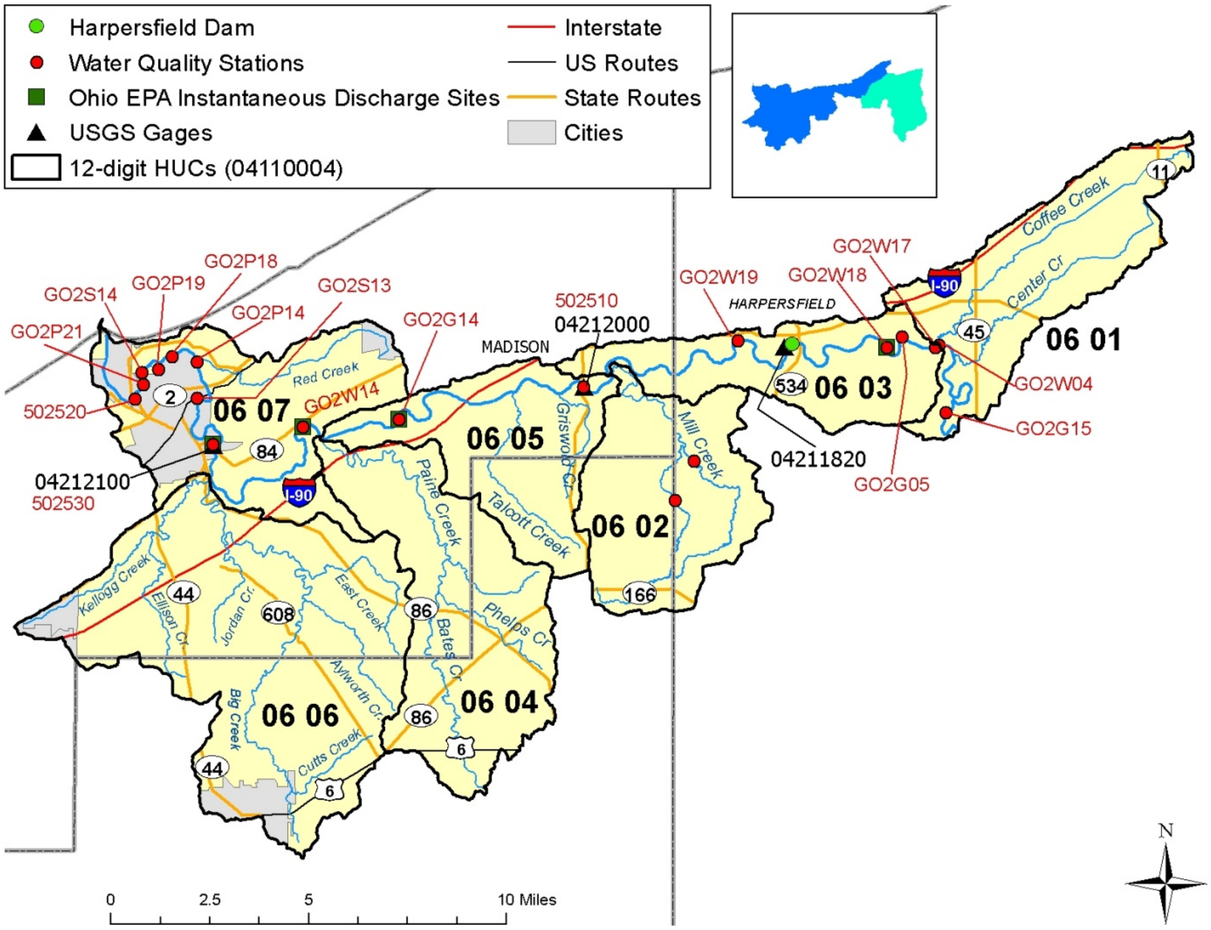


Figure 4-9. Grand River LRAU.

4.5.1. Hydrology

The hydrology of the LRAU is monitored by one USGS gage near Painesville and historical USGS flow data at Madison and Harpersfield. The USGS gage station near Painesville is the only flow gage on the river. Figure 4-10 and Table 4-24 summarize the flow at that location by flow duration interval by the cumulative distribution of flow values. Figure 4-11 represents a wet and dry year at the Painesville gage.

Table 4-24. Grand River near Painesville Ohio (04212100) flow duration values

Flow condition	Highest flow (cfs)	Mean flow (cfs)	Lowest flow (cfs)
High Flows (0%–10%)	22,500	4,260	2,800
Moist Conditions (10%–40%)	2,800	1,210	624
Mid-Range Flows (40%–60%)	624	410	257
Dry Conditions (60%–90%)	257	111	41
Low Flows (90%–100%)	41	25	4.7

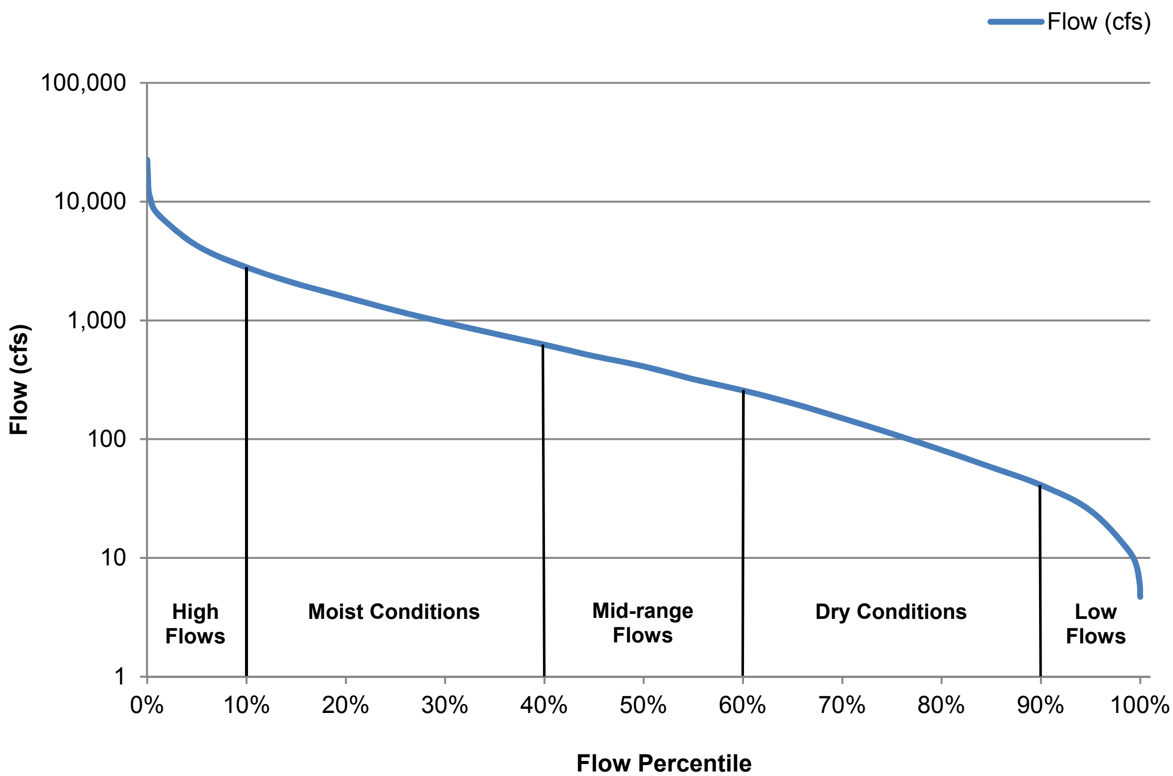


Figure 4-10. Grand River near Painesville Ohio (04212100) flow duration curve, October 1974–present.

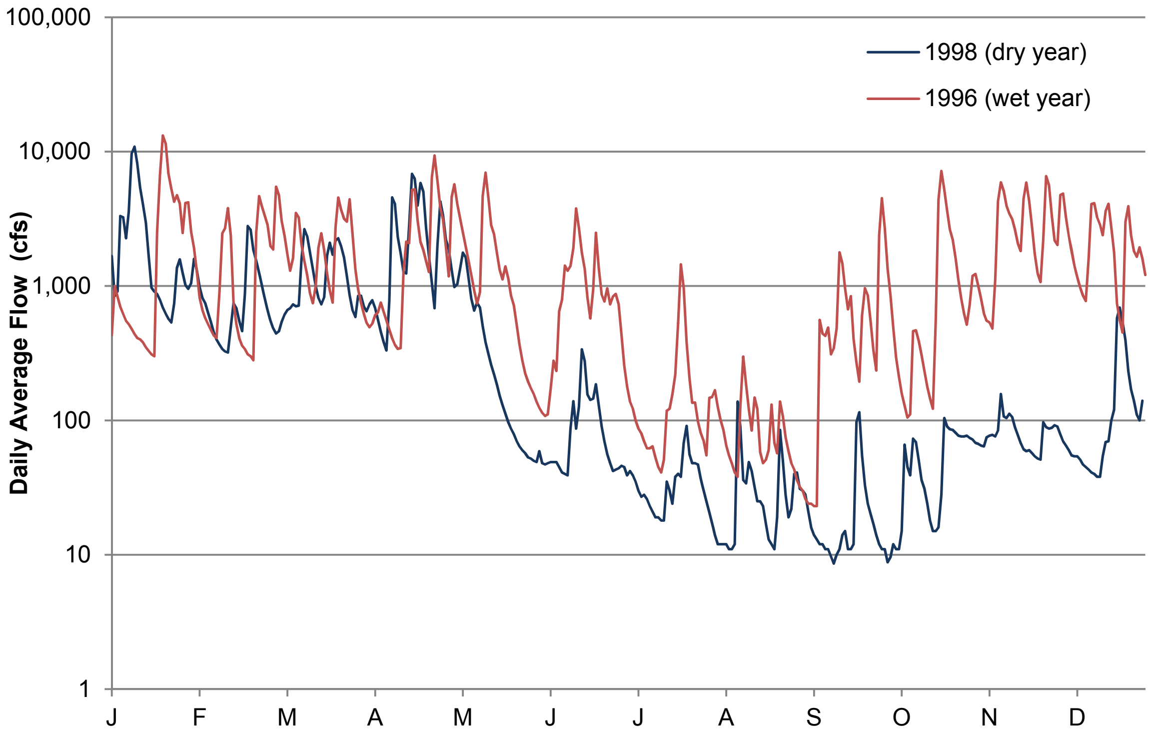


Figure 4-11. Flow hydrograph for Grand River near Painesville, 1996 (wet year) and 1998 (dry year).

Base flow is the portion of the hydrograph, or stream flow that is derived from ground water contributions. Neff et al. (2005) evaluated base flow in the Grand River watershed using six hydrograph separation techniques including PART (Rutledge 1998), HYSEP 1, 2, and 3 (Sloto and Crouse 1996), BFLOW (Arnold and Allen 1999), and UKIH (Piggott et al. 2005) methods. Figure 4-12 summarizes the results of that analysis as compared to total flow. Median base flow estimates range from 180 to 400 cfs between 1976 and 2000. Those flows correspond to dry conditions and mid-range flow conditions in the flow duration curve.

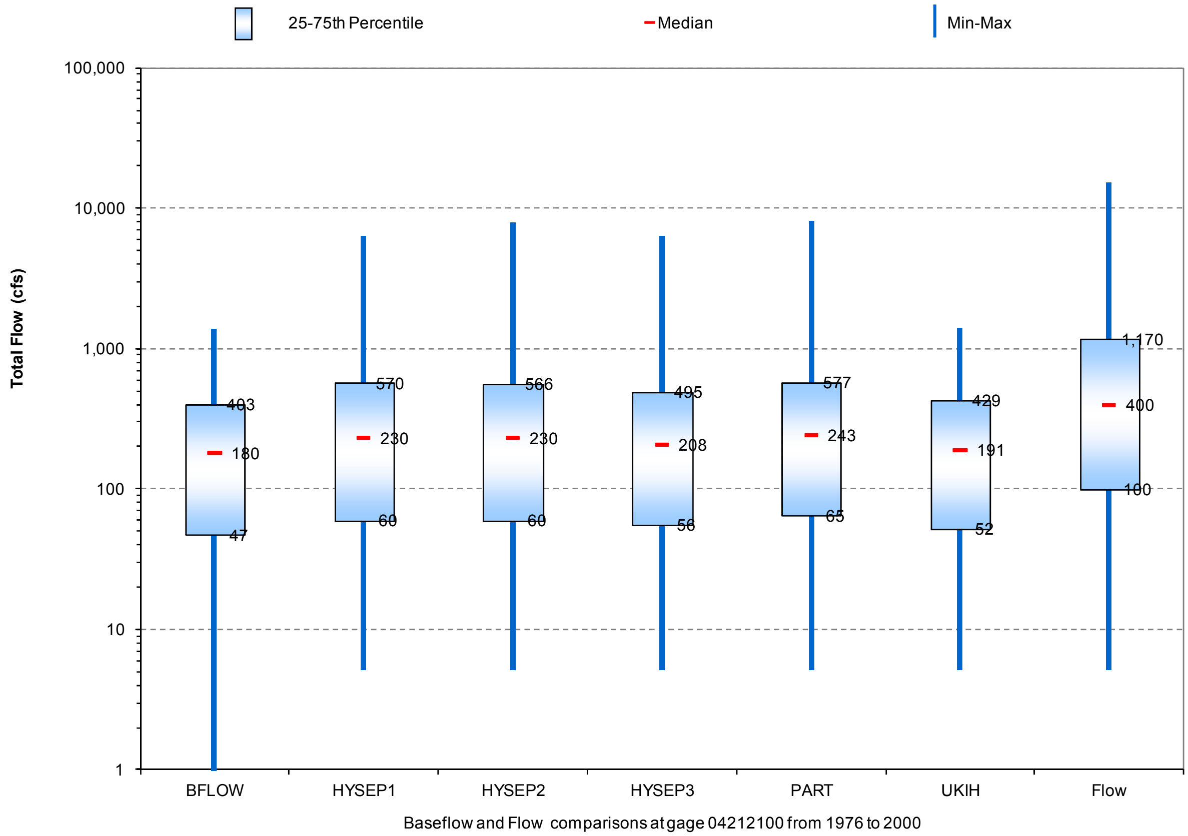


Figure 4-12. Base flow separation, USGS gage near Painesville, 1976–2000 (adapted from Neff et al. 2005).

Low-flow conditions (flow duration interval of 90 to 100 percent) at the Grand River near Painesville range from the lowest recorded flow value of 4.7 to 41 cfs. Flows in that range are most common during the summer and fall months when rainfall is low and temperatures are warm (Figure 4-13). No low-flow measurements were made during the spring and only four winter low flow measurements occurred (December to February). During the summer and fall critical time, flow and water quality conditions in the mainstem of the Grand River are being sustained primarily through ground water-fed headwater streams.

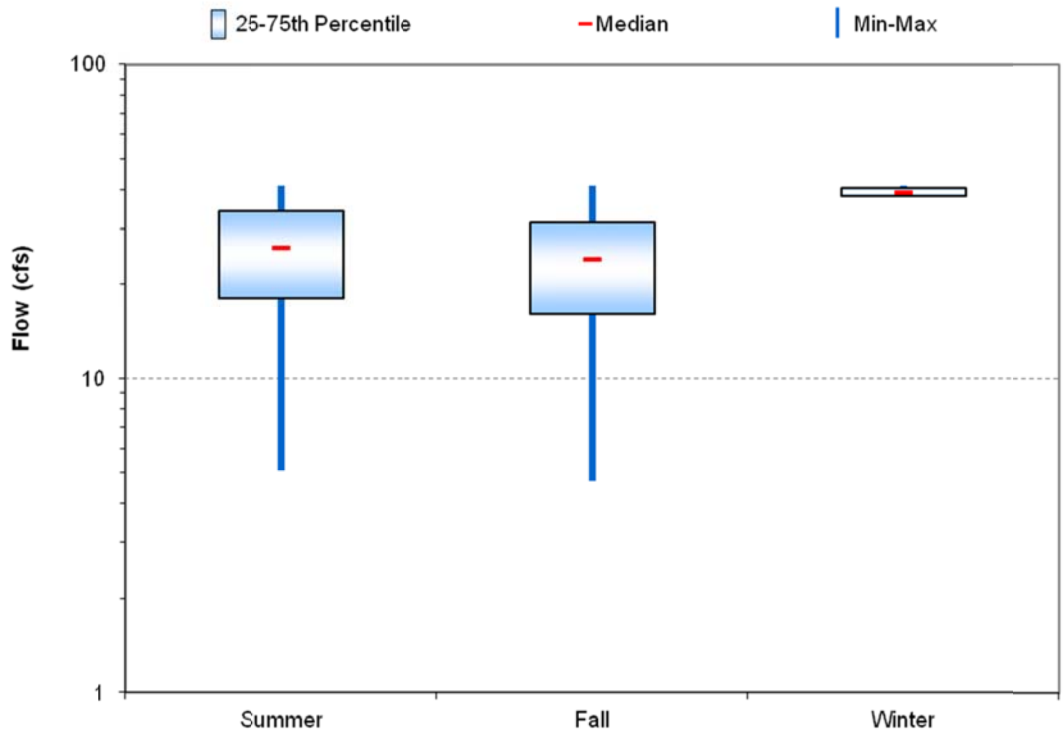


Figure 4-13. Seasonal distribution of low-flow measurements.

Very low flows have been historically monitored at the Grand River near Madison and at Mill Creek in the Griggs Creek – Mill Creek 10-digit HUC. Low-flow conditions reached 0 cfs during two years (1934 and 1963) at Madison, with high-flow conditions (34 to 87 cfs) occurring from December through February, and low-flow conditions (1.9 to 5.8 cfs) occurring during the fall (September to November) (USGS 2001). Between 1942 and 1974, Mill Creek ran dry for at least one day during 17 of the 22 years monitored (USGS 2001).

Small headwater streams in the lower Grand River watershed discharge continuous ground water through numerous small tributaries. Low-flow measurements taken on Big Creek during the 1980s and 1990s by the USGS indicate that the tributary is very important to maintaining low-flow conditions at the gage near Painesville (USGS 2001). It is likely that Red Creek and other tributaries in the Grand River Tributary subbasin are also important to maintaining low flows within the Grand River.

A comparison of the four USGS gage data sets including three along the Grand River and one on Mill Creek in Ashtabula County (Figure 4-14) identifies the flow characteristics of the Grand River from the upper to the lower portions.

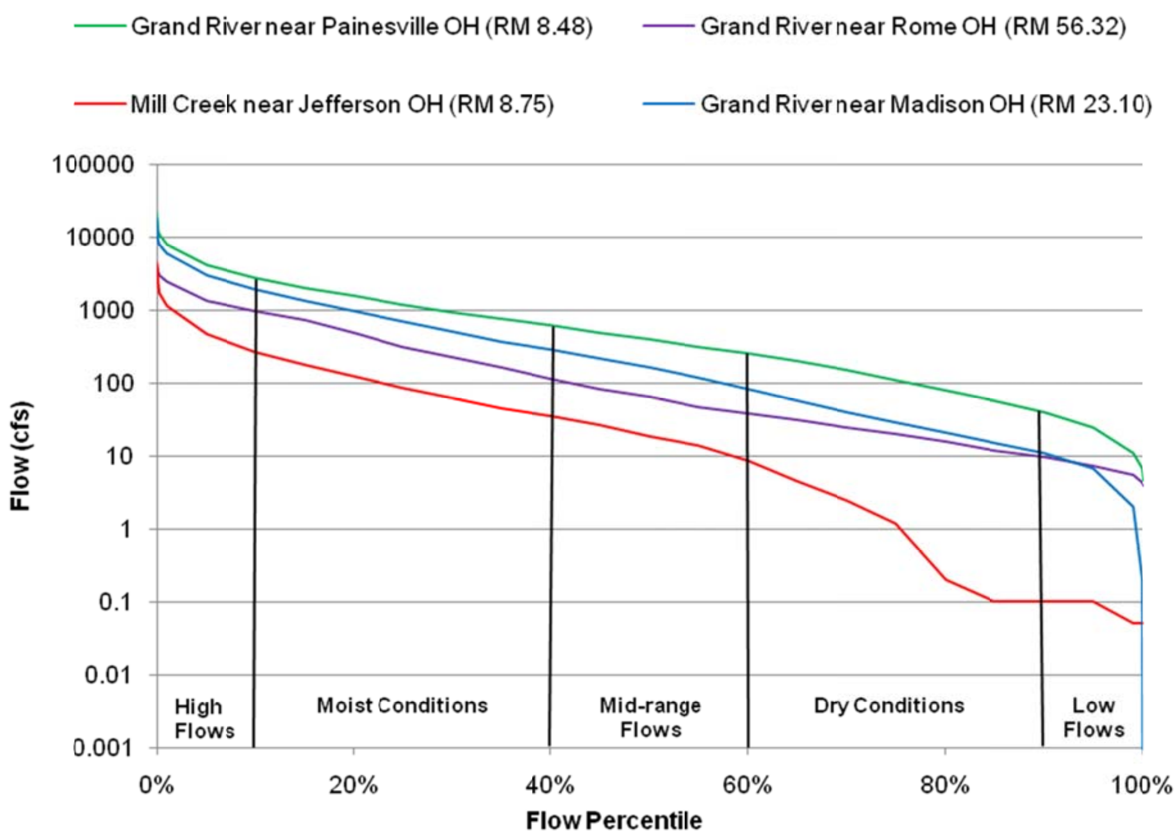


Figure 4-14. Comparison of flow conditions.

The upper Grand River watershed drains approximately 418 square miles and is predominantly forest, wetlands, and agricultural land uses. Two USGS flow gages were on the upper portion of the Grand River (North Bristol, Ohio, and Rome, Ohio); however, those gages are not maintained by the USGS. The period of record for each gage is listed in Table 4-1. Historical data are available for both gages, including average daily data from March 1942 to September 1947. Using regression analysis and drainage area-weighting techniques, a flow duration curve was developed for the upper portion of the Grand River on the basis of flows at Madison, Harpersfield, and Painesville (Figure 4-15). The upper Grand River watershed comprises 61 percent of the overall Grand River watershed area.

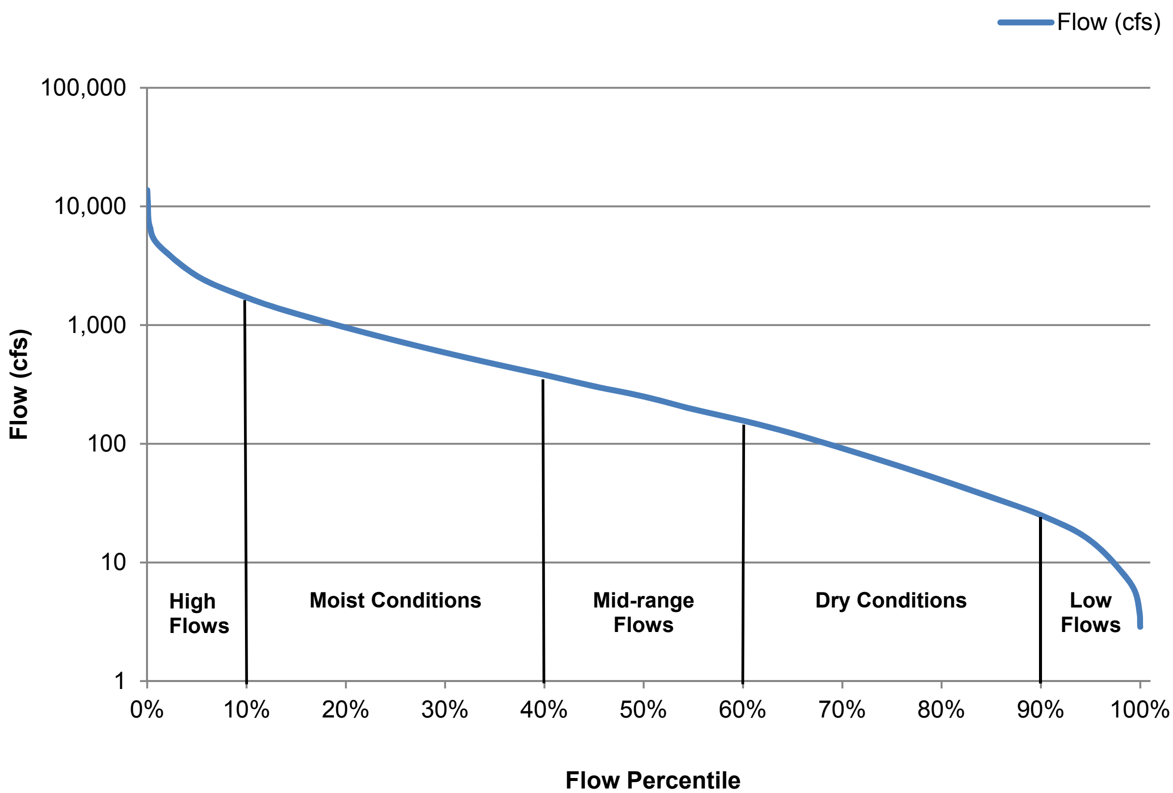


Figure 4-15. Estimated flow duration curve, Grand River upstream of Griggs Creek – Mill Creek 10- digit HUC, 1974–present.

4.5.2. Water Quality Data

Bacteria

Ohio EPA collected *E. coli* samples from 12 locations on the Grand River in the *Grand River* LRAU. Those data are summarized in Table 4-25. Multiple TMDLs will be completed for the LRAU.

Much of the lower Grand River mainstem is impaired for recreation use as a result of bacterial contamination. The upper Grand River is not impaired for recreation use where the upper Grand River becomes the lower Grand River (Ohio EPA 2007). Ohio EPA calculated a geometric mean of 100 counts per 100 mL (G02K24, 2007, n = 2) at this location. That indicates that bacterial contamination at the sites in the lower portion of the Grand River is not likely originating from upstream sources.

Table 4-25. *E. coli* data for the Grand River (LRAU) [counts per 100 mL]

Stream	STORET station	Begin date	End date	No. of samples [a]	Minimum	Maximum	Geomean (2003) [b]	Geomean (2004) [b]
HUC 04110004 04 01 (Coffee Creek - Grand River)								
Grand River	G02G15	8/27/03	7/12/04	10 (2/8)	22	2,200	**756**	**134**
	G02W04	6/27/00	8/22/00	4	41	140	[c] 81	--
HUC 04110004 06 03 (Village of Mechanicsville - Grand River)								
Grand River	G02W17	6/27/00		1	96		--	--
	G02G05	7/20/00	8/22/00	3	31	100	[d] 59	--
	G02W18	8/27/03	7/12/04	13 (3/10)	27	3,300	**154**	**133**
	G02W19	8/28/03	7/8/04	7 (2/5)	20	820	35	47
HUC 04110004 06 05 (Talcott Creek - Grand River)								
Grand River	502510	8/27/03	7/8/04	7 (2/5)	8	550	56	37
	G02G14	8/27/03	7/12/04	11 (3/8)	9	510	**192**	49
HUC 04110004 06 07 (Red Creek - Grand River)								
Grand River	G02W14	8/6/03	7/8/04	8 (3/5)	20	550	**155**	54
	502530 [e]	9/27/99	6/9/08	42 (9/8)	5	3,400	**348**	**147**
	G02S13	8/28/03	7/8/04	8 (3/5)	43	2,000	**179**	**130**
	502520	8/27/03	7/12/04	11 (3/8)	29	11,000	**1,024**	83

Notes
Stations are listed top to bottom as upstream to downstream.
Units for the minima, maxima, and geometric means are counts per 100 mL.
(n=7), 348 in 2003 (n=9), 147 in 2004 (n=8), 58 in 2006 (n=3), and 40 in 2007 (n=2). One sample was collected in 2008: 62 counts per 100 mL.
Bolded values are greater than seasonal geometric mean standard of 126 counts per 100 mL for PCR Class A waterbodies.
a. When multiple numbers are displayed, the first number represents the total number of samples collected at the site and the numbers in the parentheses represent the numbers of samples collected in 2003 and 2004, which were used to calculate the geometric means.
b. Geometric means were calculated using all available data for a given year's recreation season (May 1 through October 31).
c. The geometric mean was calculated from data collected at G02W04 in 2000.
d. The geometric mean was calculated from data collected at G02W05 in 2000.
e. The geometric means of data collected at 502530 for the following years are: 123 in 1999 (n=2), 213 in 2000 (n=3), 51 in 2001 (n=4), 139 in 2002

The Grand River in the LRAU is designated PCR Class A with an *E. coli* geometric mean standard of 126 counts per 100 mL. In 2003 the range of geometric means was 35 to 1,024 counts per 100 mL with seven of nine geometric means exceeding the standard. In 2004 the range of geometric means was from 37 to 147 counts per 100 mL with four of nine geometric means exceeding the standard. The two stations with the largest maxima are 502520 (11,000 counts per 100 mL) and 502530 (3,400 counts per 100 mL). Station 502520 is the most downstream sample location on the Grand River; station 502530 is in Painesville, downstream of the Big Creek confluence with the Grand River.

USGS sampled the Grand River at Harpersfield (gage 04211820) for *E. coli* in 1996 through 1998 (14–5,100 counts per 100 mL, n = 26). The recreation season geometric means for 1996 and 1997 were 219 and 122 counts per 100 mL, respectively.

Total Suspended Solids

Ohio EPA collected 177 TSS samples from the Grand River from 1999 to 2010. TSS ranged from 5 to 734 mg/L and was not detected in 40 samples. Of the 137 detections, 37 TSS concentrations were greater than 18.5 mg/L, which is the 75th percentile of boating-sized reference stream data for the EOLP ecoregion (Ohio EPA 1999, Appendix I, p. 24).

The USGS collected TSS samples at two locations on the Grand River from 1977 to 1980. Ten samples were collected at station 04212100 (see Figure 4-2) with all samples (44–1210 mg/L) larger than the 18.5 mg/L target. Seventy samples were collected from station 04212200, and all but one sample exceeded 18.5 mg/L (24 – 853 mg/L).

4.5.3. Habitat Analysis

In 2003 and 2004 Ohio EPA assessed the habitat conditions at 14 sites along the Grand River LRAU (Table 4-26). Habitat conditions on the Grand River ranged from fair to excellent with a large segment of the river above Painesville having excellent habitat. In the lowest reaches of the river, all the metrics' scores decreased successively downstream. The worsening habitat conditions may reflect the increasing levels of development (i.e., urbanization, imperviousness) and historic modifications from industrial land uses in the lower reaches of the Grand River.

Table 4-26. QHEI and metric scores for sites on the Grand River

RM	STORET station	Year	QHEI (100) [a]		Substrate (20) [b]	In-stream cover (20) [b]	Channel Morphology (20) [b]	Bank erosion & riparian zone (10) [b]	Pool/glide (12) [b]	Riffle/run (8) [b]	Gradient (10) [b]
HUC 04114004 04 01 (Coffee Creek - Grand River)											
40.9	G02G15	2003	73		16	14	15	10	10	4	4
36.3	G02W04	2003	57.5		15.5	11	14	6	7	0	4
HUC 04114004 04 03 (Village of Mechanicsville - Grand River)											
34.0	G02W18	2004	75.5		14	16	17	7.5	12	5	4
28.4	G02W19	2003	81.5		15	13	17	8	12	6.5	10
HUC 04114004 04 05 (Talcott Creek - Grand River)											
22.3	502510	2003	80		14	15	17	7.5	12	6.5	8
HUC 04114004 04 07 (Red Creek - Grand River)											
13.6	G02W14	2003	85.5		17	15	17	9	12	5.5	10
8.5	502530	2004	91		18	18	20	6.5	12	6.5	10
8.0	--	2003	84		16.5	15	17	7	12	6.5	10
6.2	G02S13	2003	78		15	12	18	4.5	12	6.5	10
5.6	--	2003	75		15.5	9	15	7.5	12	6	10
4.8	--	2003	71.5		17	13	12.5	6	7	6	10
4.3	--	2004	56.5		15	8	14.5	4	9	0	6
3.9	--	2004	54		14	8	14	4	8	0	6
3.2	G02S14	2004	51		11	8	14	4	8	0	6

Note: All sites on the Lower Grand River drain more than 500 square miles.
a. The QHEI scoring scheme and color coding are presented in Table 4-3. The total possible index score is 100.
b. The metric color coding is presented in Table 4-4. The numbers in parentheses are the total possible metric scores.

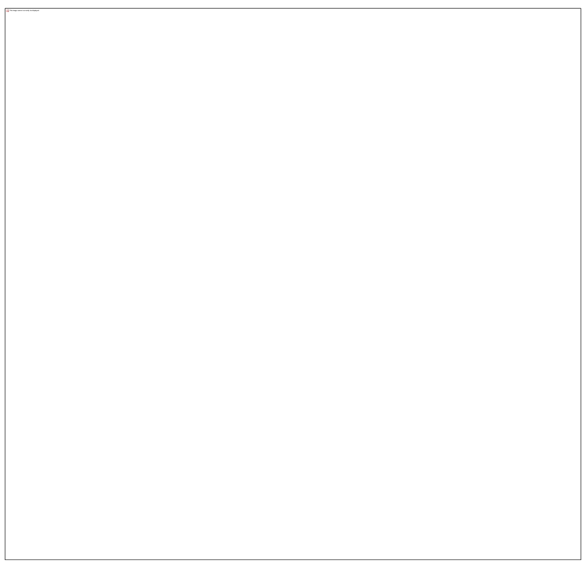
5. Source Assessment

A source assessment is used to evaluate type, magnitude, timing, and location of pollutant loading to a waterbody (U.S. EPA 1999). This section provides an inventory of the potential point and nonpoint sources of the pollutants of concern in the lower Grand River watershed. Sections 5.1 to 5.4 identify the pollutants of concern, including the impact that flow and habitat have on meeting the designated ALUs. Sections 5.5 through 5.7 then provide information on the corresponding potential point and nonpoint sources in each subbasin. The significance of each of those potential point and nonpoint sources, and their impact on water quality, is more fully explored in the Linkage Analysis presented in Section 7.

5.1. Stressor Identification

Stressor identification (SI) is a method that identifies stressors causing biological impairment and provides a structure for organizing the scientific evidence supporting the conclusions. The general SI process entails reviewing available information, forming possible stressor scenarios that might explain the impairment, analyzing those scenarios, and producing conclusions about which stressor or stressors are causing the impairment. The process consists of three main steps (Figure 5-1):

1. Listing candidate causes of impairment
2. Analyzing new and previously existing data to generate evidence for each candidate cause
3. Producing a causal characterization using the evidence generated in Step 2 to draw conclusions about the stressors that are most likely to have caused the impairment.



Source: Cormier et al. 2000

Figure 5-1. Overview of the SI process.

The SI process was completed for each of the streams not attaining its ALU, which consists of the following:

- Mill Creek (04110004 04 02)
- Big Creek headwaters near Chardon
- Kellogg Creek
- Red Creek

Potential causes of impairment have been identified in two previous documents and as part of the 303(d) listing process (Table 5-1). Available data have been evaluated and a weight-of-evidence approach has been taken to identify the stressors for each biological impairment.

Table 5-1. Potential causes of ALU impairments

Assessment unit (04110004)	Impaired stream name	Potential causes of impairment
04 02	Mill Creek (headwaters)	Siltation caused by historical channelization Excess nutrients Low dissolved oxygen Sedimentation
06 06	Big Creek (headwaters)	Direct habitat alteration caused by urban runoff, storm sewers and hydromodification because of runoff from the City of Chardon and development in the Kellogg Creek watershed Pollutants associated with urban storm water [a]
	Kellogg Creek	
06 07	Red Creek	Flow alteration caused by urban runoff, storm sewers Pollutants associated with urban storm water [a]

a. This potential cause is listed in the 303(d) list as "unknown toxicity," indicating an unknown ratio of effects and mixtures of pollutants such as PAHs, metals and lawn chemicals.

In the *Integrated Report* (Ohio EPA 2010a) and in the *Biological and Water Quality Study of the Grand River Basin 2003 - 2004, Hydrologic Units 04110004 050 and 04110004 060* (Ohio EPA 2006a), Ohio EPA identified potential causes and sources of the impairments. Some assessment units in the watershed have been determined to be impaired by natural limits (Table 2-9). Those assessment units are not addressed by this TMDL project because the impairment is not due to human activity. The remaining listed causes of impairment include direct habitat alteration, flow alteration, organic enrichment/dissolve oxygen, siltation, unknown cause(s), and pollutants associated with urban storm water. The stressors that cause the impairments might be discernable from the water quality and habitat data provided by Ohio EPA. The following parameters constitute the candidate stressors:

- Habitat alteration
- Siltation and sedimentation
- Flow alteration and imperviousness
- Metals
- Organic enrichment and low dissolved oxygen
- Temperature

Available data obtained from Ohio EPA and other entities were evaluated with the objective of determining if the stressors from the candidate list represent the causes of impairment. The evaluation found that some candidate stressors are likely causes of impairment while other candidate stressors are not.

Water quality samples that were collected by Ohio EPA throughout the watershed were analyzed for dissolved oxygen, nutrients, metals, pathogens, temperature, dissolved oxygen and TSS. Habitat was assessed at locations throughout the watershed. The water quality samples were not analyzed for toxic substances (e.g., polycyclic aromatic hydrocarbons, polychlorinated biphenyls), except for metals.

5.2. Potential Pollutants and Causes of Concern

5.2.1. Habitat Alteration

Ohio EPA evaluated habitat, via the QHEI, in 2003 and 2004 by at all locations that were assessed for their ALU designations. The QHEI scores at those sites that were impaired for their ALU were good or excellent. Though the sites scored moderately to poorly in a few metrics, the data do not reveal factors that could be causing habitat impairments.

The scores of the *Bank Erosion & Riparian Zone* metric and the *Channel Morphology* metric are both generally lower in streams that are biologically-impaired when compared with streams that are in attainment in the Big Creek – Grand River 10-digit HUC, excluding the mainstem of the Grand River. Poor scores in those two metrics can indicate a flashy stream with high peak flows. While the overall QHEI data suggest that degraded habitat is not the cause of impairment, *Channel Morphology* and *Bank Erosion & Riparian Zone* metrics may indicate that the impact of urbanization contributes to impairment. However, no consistent patterns are evident.

Kellogg Creek serves as an example of the lack of spatial patterns with the QHEI data. A synopsis of its evaluation is presented here; three sites on Kellogg Creek were evaluated: Button Road (RM 5.7, nonattainment), upstream of Morley Road (RM 3.3, partial attainment), and one-half mile from State Route 44 (RM 2.6, full attainment). The *riparian width* attribute scores for the sites were: narrow and very narrow (+1.5), wide (+4), and wide (+4), respectively. Thus, it may appear that habitat alteration decreases as one travels downstream along Kellogg Creek. For the *channelization* attribute, the sites score recovered (+4), none (+6), and recent (+1), respectively. Across HUC 04110004 06 06, where direct habitat alteration is one of the listed causes of impairment, habitat alteration as measured by individual QHEI attributes yield different spatial trends and sometimes no trend at all.

5.2.2. Siltation and Sedimentation

Although TSS data were collected throughout the lower Grand River watershed, TSS was less than detection limits in more than 60 percent of the samples. At the sites impaired for their ALU designation, TSS was generally detected in a few of the samples but at low levels. Only on Mill Creek at Clay Road (RM 25.6) was a TSS concentration greater than the 75th percentile target.

Ohio EPA identified siltation as cause of impairment to Mill Creek at Clay Road, yet TSS was below detection limits at 8 of 14 samples and was greater than the 75th percentile target for only 2 samples. Thus, available TSS data do not indicate sedimentation-caused impairments.

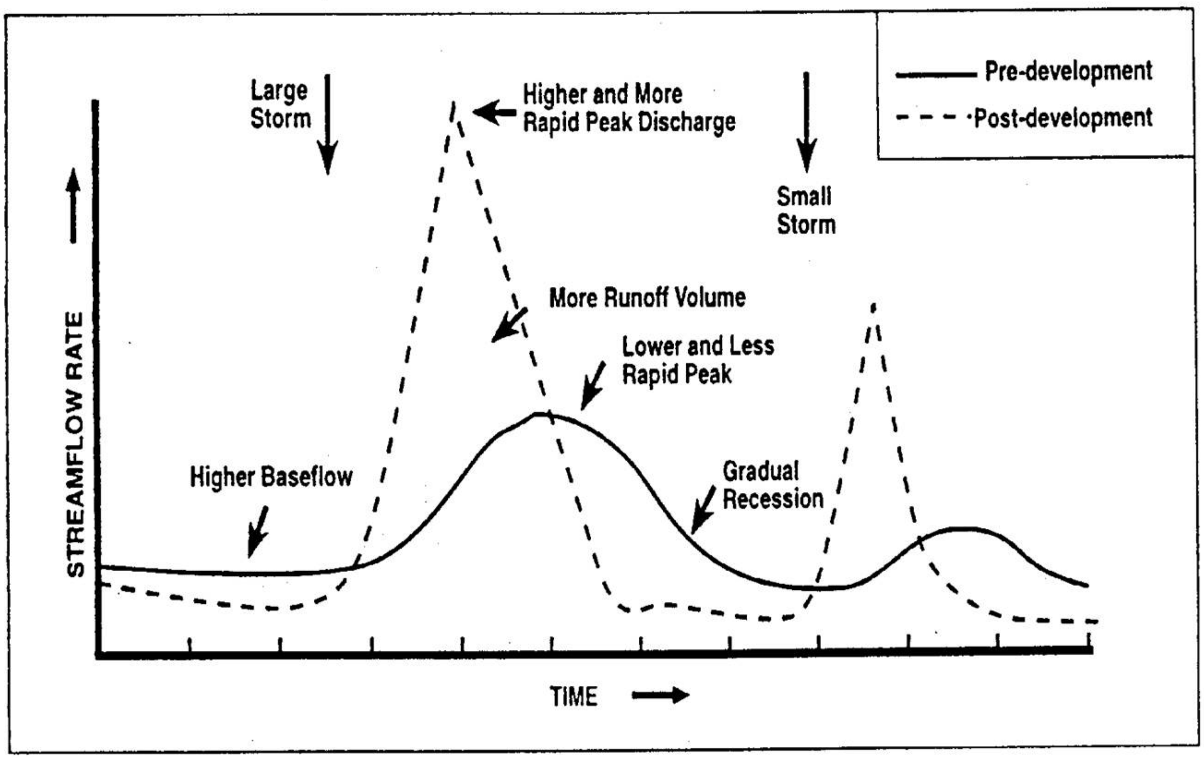
QHEI scores from the upper Mill Creek were further evaluated for the assessment sites at Clay Road (RM 25.7) and at Netcher Road (RM 18.2). The latter site is in full attainment of its ALU. Both sites scored "high" (+3) on the *stability* attribute for the *Channel Morphology* metric and "none/little" on the *erosion* attribute of the *Bank Erosion & Riparian Zone* metric. Scores of "moderate" (-1) were reported for the *siltation* and *embeddedness* attributes of the *Substrate* metric at Clay Road, whereas the scores were "normal" (+0) at the Netcher Road site. Similarly, the *substrate* and *embeddedness* attributes of the *Riffle/Run* metric received scores of "unstable" (+0) and "moderate" (+0) at the Clay Road site but received scores of "stable" (+2) and "low" (+1) at the Netcher Road site.

Thus, the *Channel Morphology* and *Bank Erosion & Riparian Zone* metrics' attribute scores show that streambanks are stable and significant erosion is not occurring. However, the attribute scores of the *Substrate* and *Riffle/Run* metrics show that silt and sediment are being deposited at the Clay Road site. These results are consistent with Ohio EPA (2006a) that identified historic channelization and agriculture upstream of Clay Road were the likely sources of siltation.

It is noteworthy that TSS, fish, macroinvertebrate, and QHEI data were collected at relatively the same location but not the exact same location. Additionally, the data collections did not occur on the same dates, which could affect direct comparisons between data.

5.2.3. Flow Alteration and Imperviousness

Ohio EPA has identified urban/suburban runoff and storm sewers as potential sources that might cause impairments to ALU designations. Impervious surfaces such as roads, roofs, and parking lots alter the natural hydrology of the watershed. In addition, artificial drainage can also have a similar effect on hydrology. Biological communities are impacted by changes in the hydrologic regime and associated pollutant loadings that result from flow alteration and imperviousness. Figure 5-2 identifies the typical impact that development has on the stream hydrograph. Much of that impact is directly related to the construction of impervious surfaces in the watershed.



Source: CWP 1999

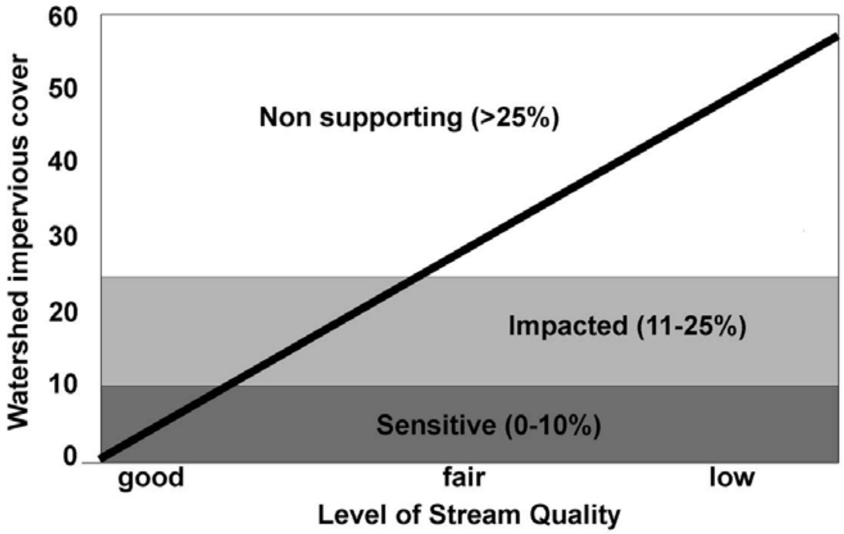
Figure 5-2. Effect of urbanization on the hydrograph.

The higher peak flows and volumes associated with the developed scenario result in the following stressors on biological communities:

- Degraded habitat and siltation
- High stream flow velocities
- Erosion, channel scour, and bank failure
- Poor storm water quality
- Increased temperatures or rapid temperature flux
- Reduction in base flow

Watershed imperviousness over 5 percent has been documented by Miltner et al. (2004) as causing a decline in water quality in streams in Ohio. Schueler (1994) and Booth and Jackson (1997) identify a watershed imperviousness of 5 to 10 percent, above which stream habitat is typically identified as poor.

Section 7, Aquatic Life Use Impairments Linkage Analysis and Hydrologic Targets, further describes the impact of imperviousness. Figure 5-3 describes the general relationship between impervious cover and stream quality (CWP 1999). Table 5-2 summarizes the watershed imperviousness for each of the biologically impaired streams, and Figure 5-4 summarizes the relationship between impervious area and attainment for assessment locations in the lower Grand River watershed in the Big Creek – Grand River 10-digit HUC. Note that imperviousness was measured upstream of the assessment point. Similar to the referenced literature, poorer biological scores correlate strongly with higher imperviousness values in the lower Grand River watershed, and flow alteration and imperviousness are therefore considered stressors.



Source: CWP 1999

Figure 5-3. Relationship between percent impervious cover and stream quality in a watershed.

Table 5-2. Watershed imperviousness, based on 2001 NLCD

Watershed	Watershed area (mi^2)	Impervious area (mi^2)	Percent impervious
Red Creek (RM 0)	9.26	1.28	13.8%
Kellogg Creek (RM 3.3)	4.56	0.67	14.7%
Big Creek by Chardon (RM 16.0)	1.54	0.20	13.1%
Mill Creek (RM 25.67)	21.14	0.17	0.8%

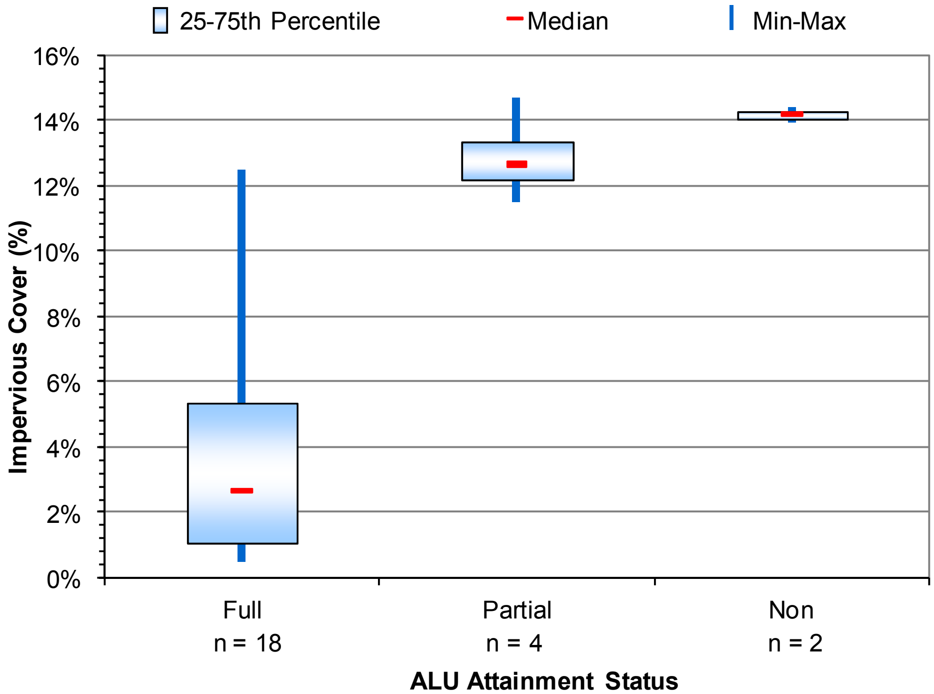


Figure 5-4. Impervious cover and ALU attainment, Big Creek – Grand River 10-digit HUC.

5.2.4. Metals

Metals data were collected at locations throughout the watershed. However, much of the data do not appear to affect the impairments to the ALU designations. Mercury and selenium samples were always below detection limits, and the following five metals were detected only in isolated samples and always at levels below the OMZM standards: arsenic, chromium, lead, nickel, and zinc. Copper was also detected in isolated samples. A few copper detections were at levels above the OMZM; however, such exceedances did not occur in any impaired waterbodies. Iron and manganese were occasionally detected at levels greater than the 75th percentile of reference streams' data, including at isolated times at three sites impaired for their ALU designation. In general, the metals data do not suggest they are a significant stressor.

5.2.5. Nutrients

Nutrient levels were evaluated using total phosphorus and nitrate plus nitrite data. Both nutrients were regularly detected throughout the watershed. Generally, at least one sample from each creek yielded concentrations in excess of the suggested statewide nutrient criteria for the protection of aquatic life (Ohio EPA 1999). All the sites that are impaired for the ALU designation showed elevated concentrations of both nutrients.

Nutrients rarely approach concentrations in the ambient environment that are toxic to aquatic life, and nutrients in small amounts are essential to the functioning of healthy aquatic ecosystems. However, nutrient concentrations in excess of the needs of a balanced ecosystem can exert negative effects by increasing algal and aquatic plant life production (Sharpley et al. 1994). Such effects increase turbidity, decrease average dissolved oxygen concentrations, and increase fluctuations in diel dissolved oxygen and pH levels. Those changes shift species composition away from functional assemblages composed of intolerant species, benthic insectivores, and top carnivores typical of high-quality streams toward less desirable assemblages of tolerant species, niche generalists, omnivores, and detritivores typical of degraded streams (Ohio EPA 1999). Such a shift in community structure lowers the diversity of the system; the IBI and ICI scores reflect the shift and could preclude a stream from achieving its ALU designation. For the purpose of this report, phosphorus is used as an indicator of the degree of nutrient enrichment. Phosphorus is selected because it is frequently the limiting nutrient to primary production in streams and rivers of Ohio (Laws 1981).

Mill Creek at Clay Road (RM 25.7) is impaired for its ALU designation primarily from sedimentation and siltation. Ohio EPA found high levels of agricultural land use and upstream channelization at the site (Ohio EPA 2006a). The QHEI associated with this site was collected nearby at a location that does not reflect the increased levels of sedimentation because of the low gradient in Mill Creek at Clay Road. Ohio EPA also identified elevated nutrient levels (total phosphorus, total Kjeldahl nitrogen, and ammonia-nitrogen) at the site, as compared to the reference condition, and concluded that, collectively, the habitat and nutrient issues impair the aquatic communities (Ohio EPA 2006a).

Red Creek is in non-attainment of its WWH designation because of flow alteration and pollutants associated with urban storm water. Elevated nutrients were also detected in Red Creek at Mantle Road (G02G21). One of the three total phosphorus samples (0.098 mg/L) was in excess of the 75th percentiles of the statewide reference streams data for WWH headwaters streams (0.08 mg/L). All three nitrate plus nitrite samples (1.42 to 1.71 mg/L) were in excess of the target derived from the 75th percentile of reference streams data (1.0 mg/L).

Big Creek nutrient data collected in 2003 and 2004 by Ohio EPA at G02W21 (RM 16.0) and G02S16 (RM 16.2) were evaluated. Total phosphorus concentrations collected during moist conditions and dry conditions exceeded the TMDL target (0.08 mg/L, WWH, headwaters) derived from the Ohio EPA's ANOVA analyses of pooled total phosphorus data from across the state in the *Associations* document (Ohio EPA 1999). Nitrite plus nitrate data showed a similar trend and exceeded its target (1.0 mg/L, WWH), which was derived from the 75th percentile of pooled reference stream data collected across Ohio.

Total phosphorus samples at three Big Creek stations exceed the total phosphorus water quality targets, and two Big Creek stations exceed the nitrate plus nitrite nitrogen targets. An analysis of nutrient values from upstream to downstream indicates that elevated nutrient levels are likely due to storm water from Chardon and WWTP discharges. The most upstream station (G02S16) is in Chardon, G02W21 is downstream of the Chardon WWTP, and G02S15 is less than 2 miles downstream of station G02W21. The next station downstream of those is G02G16, which is downstream of the confluence of Jenks Creek and Big Creek and does not exceed any nutrient targets.

Figure 5-5 demonstrates that total phosphorus concentrations are elevated above the target at three stations downstream from Chardon with a peak downstream of the Chardon WWTP. In 2001 the Chardon WWTP was upgraded; its current treatment processes include phosphorus removal (Ohio EPA 2006a). Ohio EPA evaluated macroinvertebrate data from both upstream and downstream of the WWTP and found that elevated nutrients from the WWTP were assimilated without affecting biotic integrity because the downstream community had similar community characteristics as the upstream community (Ohio EPA 2006a).

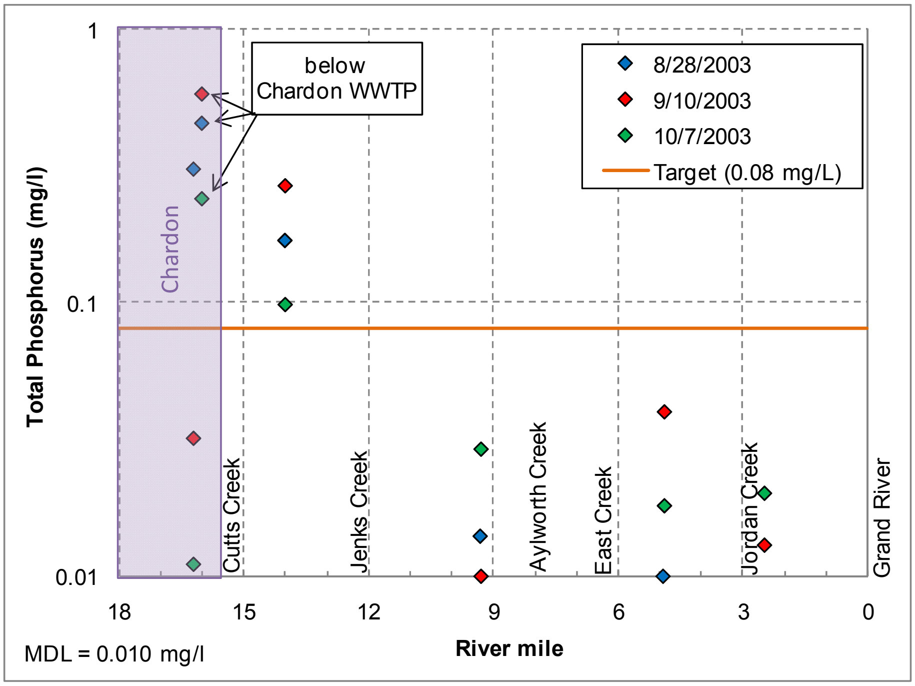


Figure 5-5. Big Creek total phosphorus analysis.

5.2.6. Organic Enrichment and Low Dissolved Oxygen

Dissolved oxygen data (i.e., daytime grab samples) were collected by Ohio EPA and Lake SWCD. Ohio EPA's samples were collected at varying times over the day, which prohibited spatial and temporal evaluations; Lake SWCD dissolved oxygen data do not include sample times. Both agencies collected water temperature data when they monitored dissolved oxygen (see Section 5.2.7). Except for one sample, all Ohio EPA samples yielded concentrations that complied with the dissolved oxygen criteria for the OMZM. The single exception occurred at Mill Creek at Clay Road on 7/12/2004. It is noteworthy that approximately 10 percent of the Lake SWCD data are below (noncompliance) the dissolved oxygen criteria; although, those data were collected from small ground water fed headwater streams, and ground water is naturally low in dissolved oxygen.

5.2.7. Temperature

Stream temperature data were collected by Ohio EPA and Lake SWCD. Ohio EPA collected daytime grab samples at its assessment sites during their field surveys in 2003 and 2004. The Lake SWCD data were collected from primary headwaters streams in the Lake County portion of the Grand River watershed between 2000 and 2008.

The Lake SWCD data were collected between 2000 and 2006 at primary headwaters habitat streams. Generally, only a single sample was collected at each stream. The time of sampling ranged from 8:30 a.m. to 3:00 p.m.; however, individual sample times were not recorded.

All Ohio EPA grab field measurements were below the WWH numeric temperature criteria (29.4 ° C for June 1 through September 15), which were applicable to all ALU impairments. Temperatures in certain streams were too warm to sustain CWH species. As demonstrated in Section 4, limited data are available to determine if temperature is a stressor.

5.3. Candidate Causes

On the basis of the considerations presented in Sections 5.1 and 5.2, nutrients, flow alteration, and imperviousness are identified as the highest priority stressors for biological impairments in the watershed (Table 5-3). The linkage analysis further describes each of the candidate causes and their link to water quality impairments. The linkage analysis also describes how the selection of TMDL targets addresses those causes and the linkage of the targets to restoration of designated ALUs.

Table 5-3. High-priority stressors

Assessment unit (04110004)	Impaired stream name	SI high-priority stressors
04 02	Mill Creek (headwaters)	Nutrients (phosphorus)
06 06	Big Creek	Flow alteration and imperviousness
	Kellogg Creek	
06 07	Red Creek	Nutrients (phosphorus) Flow alteration and imperviousness

5.4. Pollutants of Concern and Watershed-wide Sources

As described in Section 5.3, the pollutants of concern for the lower Grand River watershed include phosphorus, flow alteration, and imperviousness for ALU impairments, while bacteria is the pollutant of concern for the recreation use impairments. Those pollutants can originate from an array of sources, including point and nonpoint sources. The remainder of Section 5.4 provides a summary of potential pollutant sources that contribute to the lower Grand River watershed impairments by subbasin.

5.4.1. Point Sources

Point sources that are regulated through the NPDES Program include WWTPs, industrial facilities, and regulated storm water (e.g., municipal separate storm sewer systems [MS4s]. No permitted confined animal feeding operations or combined sewer overflow systems are in the watershed. Ohio EPA's confined animal feeding operations website shows that no regulated confined animal feeding operations are in Ashtabula, Geauga, or Lake counties[10].

Wastewater Treatment Plants and Industrial Dischargers

Forty-four active facilities are permitted to discharge in the lower Grand River watershed (Figure 5-6 and Table 5-4). Two major wastewater treatment facilities are discharging more than 1 million gallons per day (MGD) in the Big Creek – Red Creek subbasin. Of the 42 minor dischargers, 9 are industrial facilities, while the rest are municipal facilities. Eight of the nine industrial facilities (Pilot Travel Center No 2; Structural North America; Ricerca Biosciences, LLC; Hardy Industrial Technologies, LLC; Morton Salt; Carmeuse Lime, Inc.; Grand River Ops; Painesville Municipal Electric Plant; and Eckart America, LP) discharge to storm sewers or discharge storm water directly to streams, and these eight facilities do not have nutrient or bacteria permit limits. Ken Forging is the only industrial facility with bacteria limits.

[10]Ohio EPA *Concentrated Animal Feeding Operations* website: http://www.epa.ohio.gov/dsw/cafo/index.aspx

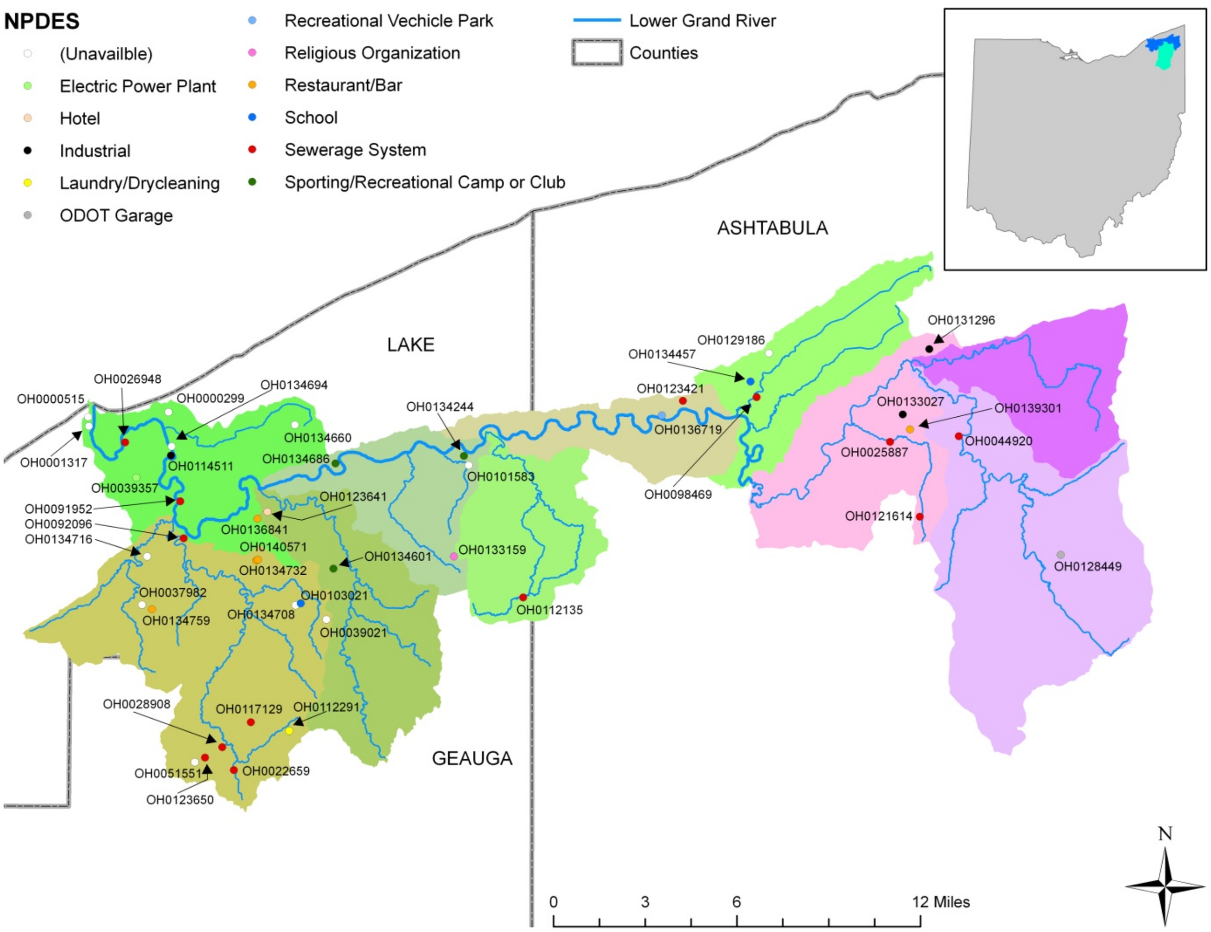


Figure 5-6. NPDES facilities in the lower Grand River watershed.

Table 5-4. NPDES facilities in the lower Grand River watershed

HUC (04110004)	Facility	U.S. EPA's NPDES ID	Ohio EPA NPDES Permit Number
04 02	Ashtabula County JVS	OH0044920	3PT00029
	ODOT Dorset Outpost Garage	OH0128449	3PP00041
04 03	Jefferson WWTP	OH0025887	3PC00021
	DFC Mobile Home Park	OH0121614	3PV00081
	Ken Forging Inc	OH0131296	3IS00121
	King Luminaire Co Inc	OH0133027	3PR00324
	Harassment's Bar	OH0139301	3PR00438
06 01	Coffee Creek WWTP	OH0098469	3PG00145
	Pilot Travel Center No 2	OH0129186	3IG00089
	Grand River Academy	OH0134457	3PT00115
06 02	Rustic Pines MHP WWTP	OH0112135	3PV00076
06 03	Whispering Willow MHP	OH0123421	3PV00084
	Kenisee Grand River Campground	OH0136719	3PR00391

HUC (04110004)	Facility	U.S. EPA's NPDES ID	Ohio EPA NPDES Permit Number
06 04	Cedar Hills Conference Center	OH0123641	3PR00178
	Camp Lejnar	OH0134601	3PR00372
06 05	Thompson United Methodist Church	OH0133159	3PR00333
	Thunder Hill Golf Course	OH0101583	3PR00143
	Little Thunder Kids Golf Course	OH0134244	3PR00357
	YMCA Outdoor	OH0134686	3PR00379
06 06	Chardon WWTP	OH0022659	3PB00010
	Wintergreen WWTP	OH0028908	3PG00055
	Structural North America	OH0051551	3IE00058
	Terrace Glen Estates MHP	OH0112291	3PR00156
	Maple Ridge MHC	OH0117129	3PV00077
	Chardon United Methodist Church	OH0123650	3PR00179
	Ricerca Biosciences LLC	OH0037982	3IE00004
	Sunshine Acres STP	OH0039021	3PG00063
	Rio Grande WWTP	OH0092096	3PG00130
	Leroy Elementary School	OH0103021	3PT00055
	Grumpy Bear LLC dba Bunky's Pub	OH0134708	3PR00380
	Henry F LaMuth Middle School	OH0134716	3PT00120
	Capps Tavern	OH0134732	3PR00382
	Concord Tavern	OH0134759	3PR00383
	Junior Properties LTD	OH0140571	3PR00478
06 07	Hardy Industrial Technologies LLC	OH0000299	3IF00007
	Morton Salt	OH0000515	3IE00030
	Carmeuse Lime Inc Grand River Ops	OH0001317	3IJ00021
	Painesville WPC Plant	OH0026948	3PD00029
	Painesville Municipal Electric Plant	OH0039357	3IB00015
	Heatherstone WWTP	OH0091952	3PH00054
	Eckart America LP	OH0114511	3II00071
	Mid-West Materials Inc	OH0134660	3PR00377
	Spring Lake MHP	OH0134694	3PV00120
	Frary's Restaurant	OH0136841	3PR00398

All the municipal facilities have permit limits for bacteria. In addition to bacteria limits, the following municipal treatment facilities have total phosphorus limits (1.0 mg/L monitored monthly and 1.5 mg/L monitored weekly): Jefferson WWTP, Coffee Creek WWTP, Chardon WWTP, and Painesville Water Pollution Control (WPC) Plant.

Ohio EPA adopted new rules on December 15, 2009, that included revised water quality criteria for bacteria. Criteria for *E. coli* replaced the former standards, which included criteria for both *E. coli* and fecal coliform. As all NPDES permits are renewed, current fecal coliform requirements will be phased out, and *E. coli* limits and monitoring requirements will be put in place. A summary of *E. coli* limits for

Ohio's NPDES permits is presented in Table 5-5. The 30-day averages in those permit limits equate to the revised *E. coli* criteria for seasonal geometric means of in-stream data.

Table 5-5. *E. coli* NPDES permit limits

Recreation use	Class	*E. coli* (colony counts per 100 mL)	
		30-day average	7-day average
Bathing Waters	--	126	284
Primary Contact	Class A	126	284
	Class B	161	362
	Class C	206	464
Secondary Contact	--	1,030	2,318

Regulated Storm Water

Regulated storm water sources are facilities regulated under the NPDES program and include storm waterMS4s, construction storm water, and industrial storm water. Ohio EPA has three current general permits applicable to the lower Grand River watershed, one for each type of storm water discharge.

MS4s

MS4s convey storm water from separate storm sewer systems to downstream receiving waters. Separate storm sewer systems include ditches, curbs and gutters, storm sewers, and other runoff conveyance systems. Such systems do not connect to wastewater collection systems or treatment plants. Storm water can transport contaminants including nutrients, sediment, metals, bacteria, oil, grease, pesticides, and herbicides that have the potential to reduce water quality.

Under the NPDES program, municipalities serving populations of more than 100,000 people are considered Phase I MS4 communities. No Phase I communities are within the project area. Storm water conveyance systems owned by municipalities with populations of less than 100,000 people, and other public entities including road authorities can be regulated under Phase II of the NPDES program. Such entities are considered regulated small MS4s. Regulated small MS4s are typically designated when the MS4 is in the urbanized area, as determined by the census. They can also be designated on a case by case basis.

Ohio EPA's Authorization for Small Municipal Separate Storm Sewer Systems to Discharge Storm Water under the National Pollutant Discharge Elimination System (OHQ000002), effective June 30, 2009, requires that authorized storm water discharges must be consistent with approved TMDLs.

To ensure that pollution is controlled to the maximum extent practical, communities operating under the General Permit for Small MS4s are required to implement six minimum control measures:

- Public education and outreach
- Public participation/involvement
- Illicit discharge detection and elimination programs
- Construction site runoff control
- Post construction storm water management in new development and redevelopment
- Pollution prevention/good housekeeping for municipal operations

Lake County (3GQ00068*BG) is covered under the MS4 permit and includes the following communities:

- Lake County
- Concord Township
- Madison Township
- Painesville Township
- City of Painesville
- Grand River Village
- Fairport Harbor Village
- Perry Village

Leroy Township was granted a waiver from the MS4 program in 2004 because urban storm water was not listed as a source in the 2002 303(d) list. Permit coverage may be required if circumstances for the granting of the waiver have changed. The Ohio Department of Transportation (4GQ00000*BG) is also a regulated MS4 in the watershed with jurisdiction over interstates, state routes, and US routes and facilities including offices, outposts, rest areas, and garages within the urbanized area.

Construction Storm Water

Permitted construction storm water sources are regulated under the NPDES program and include construction activities that disturb greater than 1 acre. Construction site storm water can contain sediment and associated nutrients. Ohio EPA's Authorization for Storm Water Discharges Associated with Construction Activity under the National Pollutant Discharge Elimination System (Permit Number OHC000003), effective April 31, 2008, requires that a storm water pollution prevention plan be developed for each regulated site in accordance with permit requirements. Table 5-6 summarizes the number of active sites that began each year between 2003 and 2007 and their associated disturbed areas within the cities and townships in the lower Grand River watershed.

Table 5-6 Regulated construction sites, 2003–2007

County	Number of new active sites	Disturbed area (acres)
Ashtabula Total	*15*	*204.2*
2003	3	22.1
2004	1	10
2005	4	123.3
2006	3	20.6
2007	4	28.2
Geauga Total	*32*	*380.3*
2003	3	60.6
2004	10	219.6
2005	5	33.6
2006	6	46.5
2007	8	20.0
Lake Total	*158*	*2,318.3*
2003	16	299.6
2004	30	336.2
2005	37	519.4
2006	38	826.2
2007	37	336.9

Industrial Storm Water

Permitted industrial storm water sources are regulated under NPDES Permit OHR000004, the General Permit Authorization to Discharge Storm Water Associated with Industrial Activity under the National Pollutant Discharge Elimination System, effective June 1, 2006. The permit applies only to storm water discharged from industrial sites and includes a provision that requires storm water discharges to be in compliance with an approved TMDL.

Table 5-7 summarizes the industrial storm water permits in the lower Grand River watershed. Not all regulated industrial storm water sites will contribute to impairments. Table 5-8 provides the area of regulated industrial storm water facilities in the lower Grand River watershed.

Table 5-7. Regulated industrial storm water sites in lower Grand River watershed

Permit #	Facility name
3GR01127*DG	American Roll Formed Products Corp
3GR01264*DG	Avery Dennison Engineered Films Plant Bldg 18
3GR00172*DG	Avery Dennison Specialty Tape Div
3IJ00021*GD [a]	Carmeuse Lime Inc Grand River Ops
3GR00383*DG	Chardon Custom Polymers LLC
3GR00397*DG	Chardon Plant
3GR01246*DG	De Nora Tech Manufacturing Facility
3GR01247*DG	De Nora Tech R&D Facility
3II00071*CD [a]	Eckart America LP
3GR00280*DG	Equistar Chemicals LP
3GR00376*DG	Fairport
3GR00284*DG	Fairport Facility
3GR01188*DG	Fleck Controls LLC
3GR00208*DG	H S Spring
3IF00007*GD [a]	Hardy Industrial Technologies LLC
3GR00302*DG	HTG Rimes Logistic Services
3GR01309*DG	JED Industries Inc
3GR01308*DG	Ken Forging Inc
3GR01356*DG	Madison WWTP Plant I
3IE00030*DD [a]	Morton Salt
3GR00600*DG	Nova Chemicals Inc
3GR00431*DG	Painesville Films Facility
3IB00015*FD [a]	Painesville Municipal Electric Plant
3GR01235*DG	PCC Airfoils Renaissance Park
3IG00089*BD [a]	Pilot Travel Center No 2
3GR00974*AG	Reflective Prod Div
3GR00375*DG	Reflective Products Division
3GR01168*DG	Rhein Chemie Corp
3IE00004*GD [a]	Ricerca Biosciences LLC
3GR00175*DG	STP Products Mfg Co
3IE00058*HD [a]	Structural North America
3GR00876*DG	UPS - Austinburg
3GR00800*DG	Worthington Cylinders

a. Individual NPDES permits which also address industrial storm water in lower Grand River watershed

Table 5-8. Regulated industrial storm water facility areas

Impaired water		Regulated industrial storm water area (acres)	Percent of watershed (%)
Name	HUC (04110004)		
Mill Creek	04 02	0	0%
Big Creek	06 06	113	0.35%
Kellogg Creek	06 06	0	0%
Red Creek	06 07	0	0%
Grand River (LRAU)	06 01	159	0.20%
	06 03	159	0.17%
	06 05	159	0.14%
	06 07	533	0.29%
Griggs Creek	04 01	0	0%
Peters Creek - Mill Creek	04 02	0	0%
Town of Jefferson - Mill Creek	04 03	101	0.56%
Coffee Creek	06 01	58	0.75%
Mill Creek	06 02	0	0%
Paine Creek	06 04	0	0%
Big Creek	06 06	113	0.35%

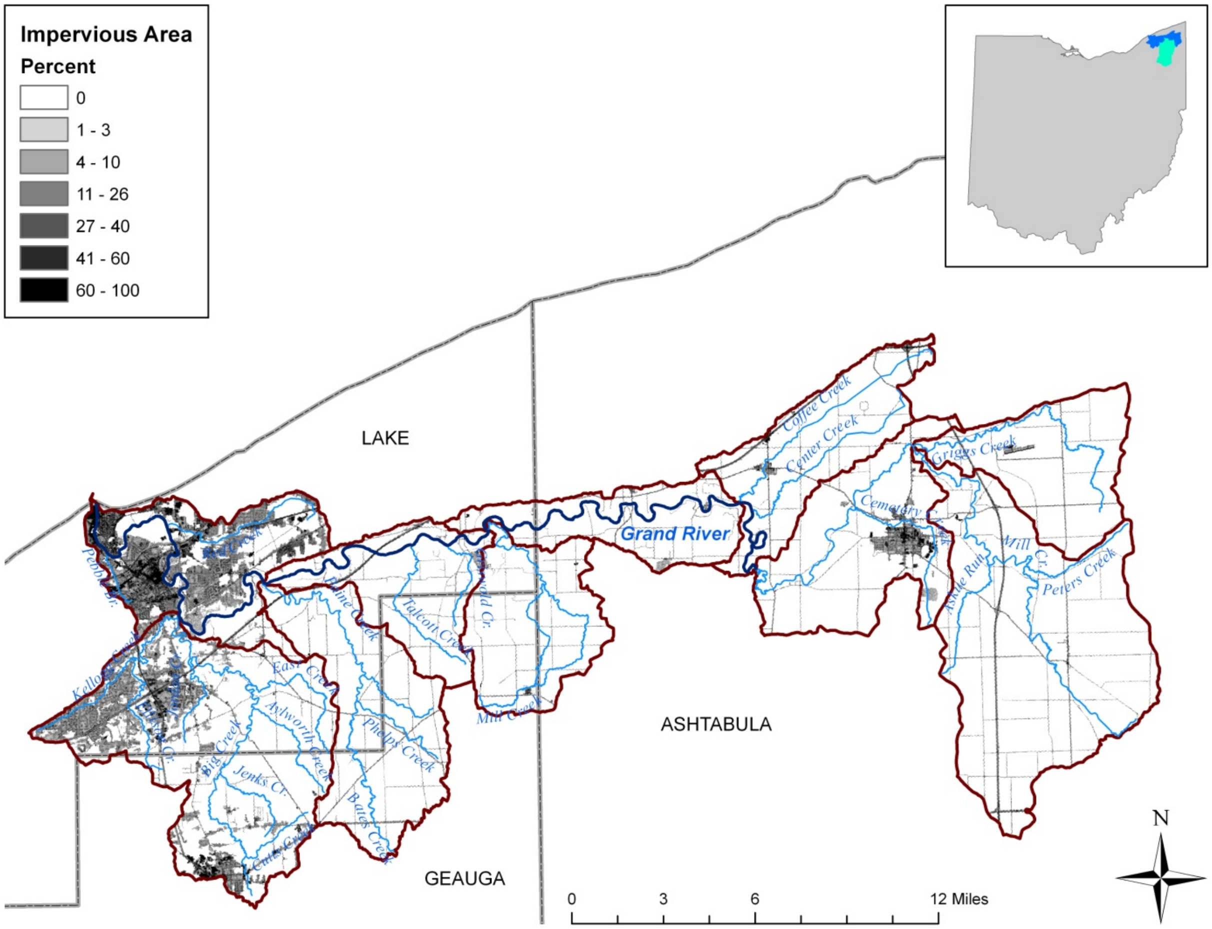
5.4.2. Nonpoint Sources

Nonpoint sources of pollutants are not regulated through the NPDES program. Those sources that are applicable to the lower Grand River TMDLs include nonregulated storm water including agricultural runoff, erosion, home sewage treatment systems (HSTS), and animal wastes from pets, livestock, and wildlife.

Nonregulated Storm Water

During wet-weather events (snow melt and rainfall), pollutants are incorporated into runoff and can be delivered to downstream waterbodies. The resultant pollutant loads are linked to the land uses and practices within the watershed. Agricultural and developed areas can have significant effects on water quality if proper best management practices (BMPs) are not in place. The main pollutants of concern associated with agricultural runoff are sediment, nutrients, pathogens, and pesticides. Storm water from developed areas can be contaminated with oil, grease, pesticides, herbicides, nutrients, viruses, bacteria, metals, and sediment.

Land use in the watershed transitions from urban/suburban on the western edge to rural/agricultural toward the east. The developed area is centered near Painesville. Two other developed areas are in the towns of Chardon and Jefferson. In the undeveloped areas, forest and pasture/hay land uses are common in the western portion of the watershed, which transitions into agriculture and wetland areas in the east. In addition to pollutants, alterations to the hydrology of a watershed as a result of land use changes can also detrimentally affect habitat and biological health. Imperviousness associated with developed land uses can result in increased peak flows and runoff volumes and decreased base flow as a result of reduced ground water discharge. Figure 5-7 identifies the impervious area within the watershed.



Data source: NLCD 2001

Figure 5-7. Watershed impervious cover.

Home Sewage Treatment Systems (Septic Systems)

A source of bacteria and nutrients in the lower Grand River watershed is treatment systems for human waste. Unsewered areas with failing or poorly maintained HSTS are of concern because untreated or poorly treated sanitary wastewater can be discharged directly or indirectly into waterbodies. Several areas within the lower Grand River watershed do not have a centralized wastewater collection and treatment facilities including much of Geauga and Ashtabula counties. Those areas typically rely on septic systems for sewage treatment. If systems are not properly designed, installed, and maintained, they have the potential to affect local water quality with excessive nutrient and bacteria loads. Those pollutant loads can cause algal blooms, strong odors, and water quality impairments. Furthermore, HSTS malfunctions can pose a danger to human health when they contaminate drinking water supplies, wells, and fishing and swimming areas. Ashtabula County estimates that up to 7 percent of septic systems in its health district have failed.[11] Lake County estimates that 30 percent of septic systems installed before 1980 are failing, 17 percent of septic systems installed between 1980 and 1998 are failing, and 5 percent of septic systems

[11] Personnel communication with Ray Saporito, Ashtabula County, 2010

installed after 1998 are failing.[12] An estimate of the number of HSTS in the counties of the lower Grand River watershed is presented in Table 5-9. Only a portion of the septic systems would be in the lower Grand River watershed.

Table 5-9. Estimated county septic statistics

County	% of county in watershed	No. of septic systems in the county	Estimated number of septic systems in the watershed	Population per septic system
Lake	37.4%	13,187	4,933[a]	2.59
Geauga	12.9%	20,051	2,581	2.91
Ashtabula	20.9%	16,795	3,511	2.42
Total		*50,033*	*11,025*	*2.60*

Source: US EPA 2006.
a. Lake County has estimated that there are 9,161 septic systems in Lake County cities and townships within the lower Grand River watershed in 2011.

Pets, Livestock, and Wildlife

Although they are not identified as a cause of impairments in the lower Grand River watershed, livestock, pets, and wildlife populations are also potential sources of bacteria and nutrients in the watershed. Watershed-specific data are not available for livestock populations in the lower Grand River watershed. However, countywide statistics are available from the National Agricultural Statistic Service (NASS; USDA 2010). Table 5-10 details the county statistics from 2000 to 2010. In addition, horses within the watershed are also a potential source of pollutants, although agricultural statistics were not available in the NASS database.

Wildlife such as deer, geese, and ducks can also be sources of bacteria and nutrients. Deer population data are sometimes used as surrogates for estimating wildlife populations. The 2006 Ohio Department of Natural Resources white-tail deer status report indicates that the 2006 statewide population was expected to be around 600,000 deer (ODNR 2007). White-tail deer are found in all 88 Ohio counties (ODNR 2007).

[12] Personnel communication with Laura Kuns, Lake County General Health District, 2011

Table 5-10. NASS county agricultural statistics

County	Year	Hogs	Cattle	Milk cows	Breeding sheep and lambs
Ashtabula	2000	3,200	19,400	7,000	--
	2001	2,500	19,700	7,500	1,100
	2002	1,900	19,700	7,500	1,100
	2003	2,100	19,800	7,300	--
	2004	2,300	19,900	6,600	--
	2005	1,900	20,600	6,500	--
	2006	2,000	19,700	6,600	--
	2007	1,200	18,000	6,800	--
	2008	--	18,200	6,200	--
	2009	1,000	18,000	5,600	--
	2010	--	18,800	6,300	--
Geauga	2000	1,200	8,100	2,800	--
	2001	1,000	8,200	3,200	--
	2002	--	8,000	3,200	--
	2003	--	7,300	2,900	--
	2004	--	7,400	2,100	--
	2005	--	7,500	2,200	--
	2006	--	6,700	2,800	--
	2007	--	7,200	3,000	1,000
	2008	--	7,400	2,900	--
	2009	--	7,500	2,900	1,000
	2010	--	7,200	3,200	--

Source: USDA National Agricultural Statistics Service - Quick Stats U.S. & All States County Data – Livestock (http://www.nass.usda.gov/QuickStats)
Note that NASS does not report any animals for Lake County.

5.5. Griggs Creek – Mill Creek Subbasin

Pollutants of concern within Griggs Creek – Mill Creek subbasin include nutrients and bacteria. Flow regime and impervious cover are surrogates used to address the pollutants and causes of ALU impairments.

5.5.1. Point Sources

Seven active facilities are permitted to discharge in the Griggs Creek – Mill Creek subbasin (Table 5-11 and Figure 5-8). All the facilities are minor dischargers, or facilities with a design flow of less than 1 MGD.

Table 5-11. NPDES permitted dischargers—Griggs Creek – Mill Creek subbasin

HUC (04110004)	Facility	U.S. EPA's NPDES ID	Average design flow (MGD)	Permit expiration
04 02	Ashtabula County JVS	OH0044920	0.0400	7/31/2011
	ODOT Dorset Outpost Garage	OH0128449	0.001	9/30/2015
04 03	Jefferson WWTP	OH0025887	1.000	9/30/2015
	DFC Mobile Home Park	OH0121614	0.0090	12/31/2011
	Ken Forging Inc [a]	OH0131296	0.0025	3/31/2014
	King Luminaire Co Inc	OH0133027	0.0018	2/28/2013
	Harassment's Bar	OH0139301	0.0018	8/31/2011

Average design flows are rounded to the nearest ten-thousandth of a MGD.
a. Discharges into HUC 04110004 01

The Jefferson WWTP has an average design flow of 1.0 MGD. However, the average reported flow is 0.55 MGD, with a maximum reported value at 1.85 MGD. All of the municipal point sources are currently permitted to discharge fecal coliform during summer months with a 2,000 per 100 mL weekly limit and a 1,000 per 100 mL monthly limit. As permits are renewed, Ohio EPA will permit bacteria discharges on the basis of Ohio's *E. coli* discharge limits of 362 per 100 mL (weekly) and 161 per 100 mL (monthly).

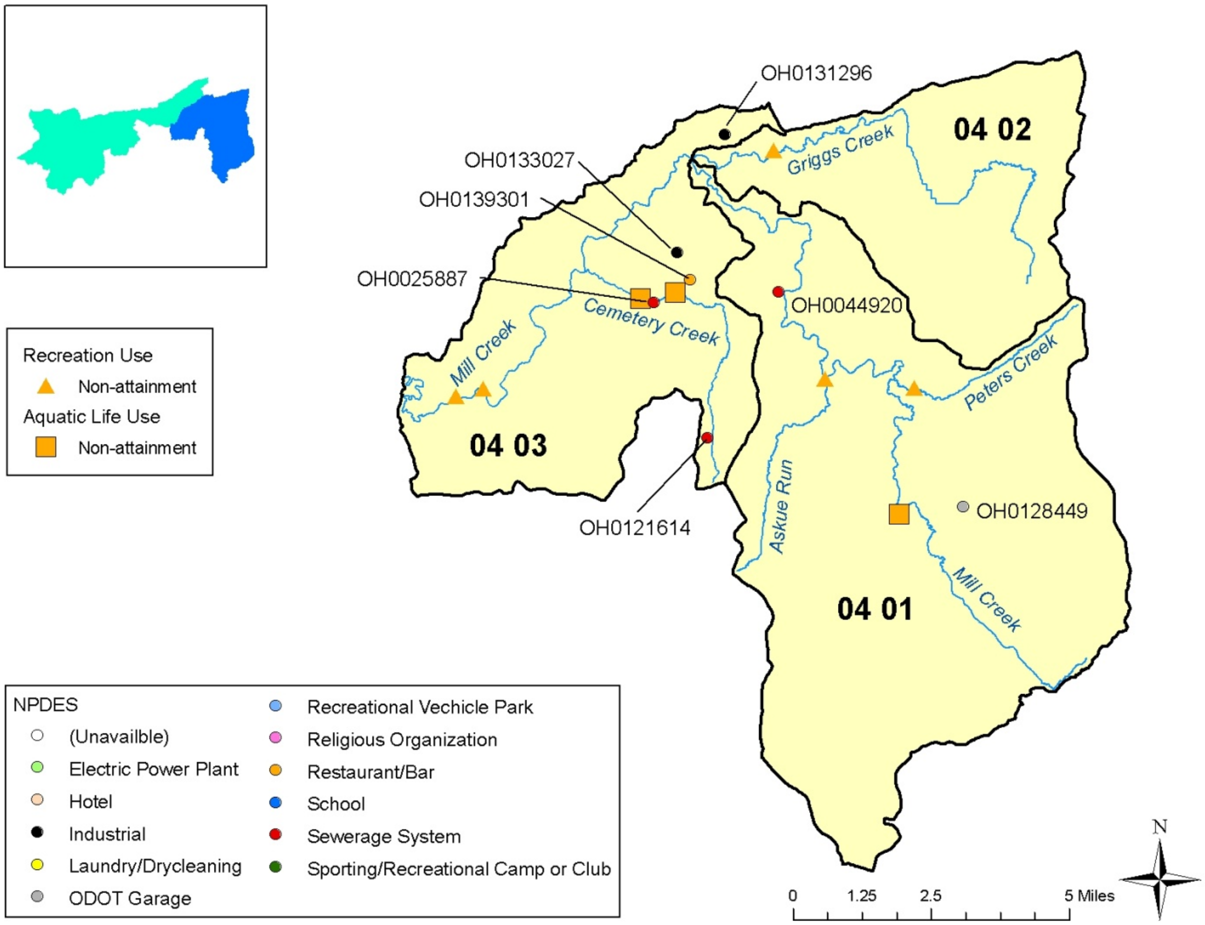


Figure 5-8. Griggs Creek – Mill Creek subbasin point sources.

5.5.2. Nonpoint Sources

Land uses in the Griggs Creek – Mill Creek subbasin are predominantly forest and cropland (Table 5-12 and Figure 5-9). Wetland areas compose 7 percent of the watershed. Less than 7 percent of the subbasin is in developed land uses. The village of Jefferson is on Cemetery Creek and accounts for the majority of the developed land in the watershed. Roads and a small airport in the Griggs Creek watershed also contribute to the impervious areas.

Table 5-12. Griggs Creek – Mill Creek subbasin land uses

Land use	Area (acres)	Area (% of total)
Open Water	412	1%
Developed	4,907	7%
Bare	0	0%
Forest	25,238	38%
Grass/Shrub	3,817	6%
Pasture	7,422	11%
Crop	20,032	30%
Wetlands	4,412	7%

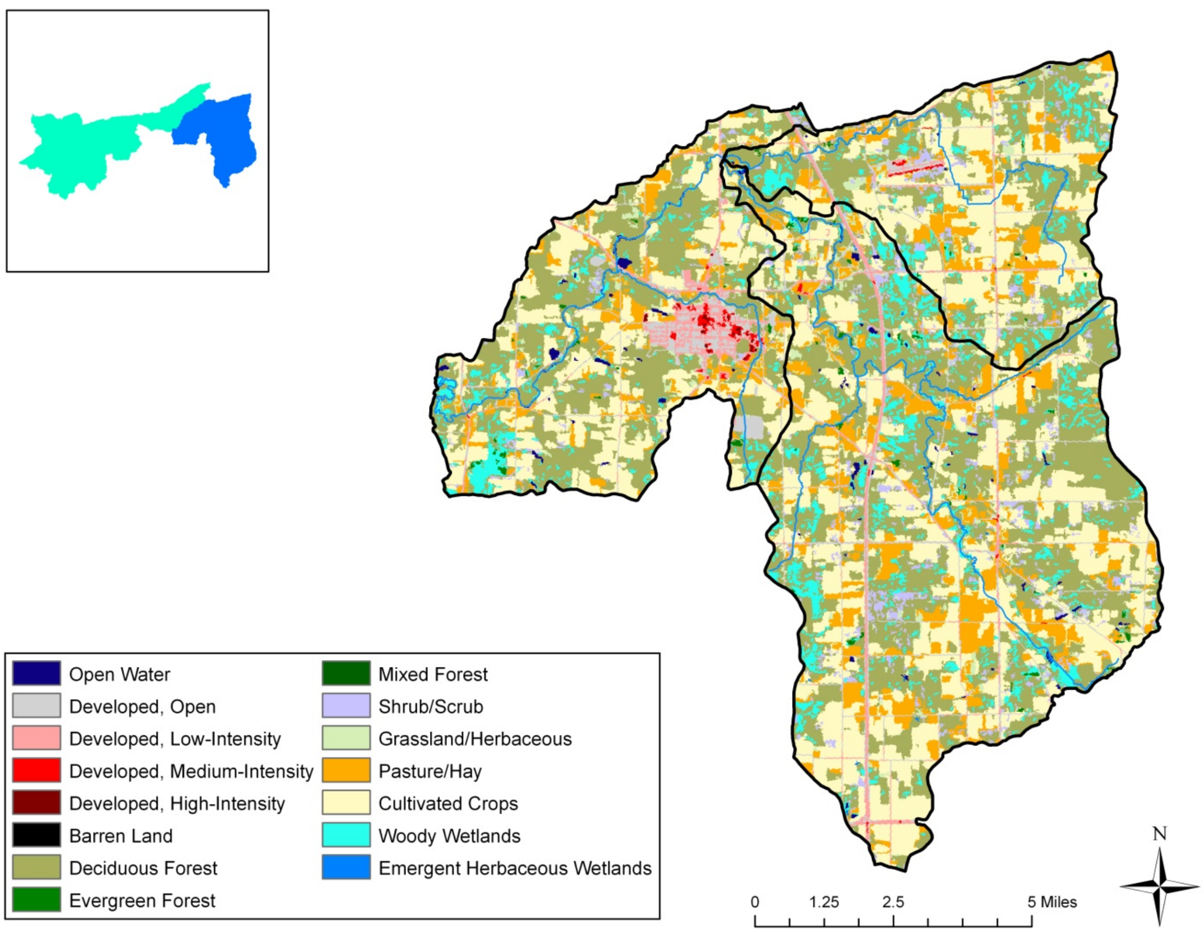


Figure 5-9. Griggs Creek – Mill Creek subbasin land uses.

5.6. Big Creek and Red Creek Subbasin

Pollutants of concern within the Big Creek – Red Creek subbasin include nutrients and bacteria. Flow and impervious cover are surrogate pollutants to be used in addressing ALU impairments.

5.6.1. Point Sources

Twenty-five active facilities are permitted to discharge within the Big Creek and Red Creek subbasin (Table 5-13 and Figure 5-10). All but two facilities are minor dischargers or facilities with a design flow of less than 1 MGD. The two major facilities are the Chardon WWTP (OH0022659) and the Painesville WPC Plant (OH0026948). The Chardon WWTP discharges to Big Creek (HUC 04110004 06 06), with an average design flow of 1.808 MGD; the Painesville WPC Plant discharges to the Grand River, with an average design flow of 6.0 MGD; the plant discharges to the LRAU and is physically within HUC 04110004 06 07. The permits with past expiration dates are in progress or under review by Ohio EPA.

Table 5-13. NPDES permitted dischargers - Big Creek - Red Creek subbasin

HUC (04110004)	Facility	U.S. EPA's NPDES ID	Average design flow (MGD)	Permit expiration
06 06	**Chardon WWTP**	**OH0022659**	**1.8080**	**7/31/2014**
	Wintergreen WWTP	OH0028908	0.0150	7/31/2015
	Structural North America	OH0051551	0.0109	7/31/2015
	Terrace Glen Estates MHP	OH0112291	0.0200	11/30/2015
	Maple Ridge MHC	OH0117129	0.0250	1/31/2012
	Chardon United Methodist Church	OH0123650	0.0028	9/30/2012
	Ricerca Biosciences LLC	OH0037982	0.0043 [a]	5/31/2014
	Sunshine Acres STP	OH0039021	0.0200	7/31/2012
	Rio Grande WWTP	OH0092096	0.0215	7/31/2012
	Leroy Elementary School	OH0103021	0.0075	1/31/2015
	Grumpy Bear LLC dba Bunky's Pub	OH0134708	0.0035	1/31/2015
	Henry F LaMuth Middle School	OH0134716	0.0120	12/31/2014
	Capps Tavern	OH0134732	0.0025	10/31/2014
	Concord Tavern	OH0134759	0.0035	8/31/2009
	Junior Properties LTD	OH0140571	0.0007	6/30/2013
06 07	Hardy Industrial Technologies LLC	OH0000299	n/a [b]	3/31/2015
	Morton Salt	OH0000515	1.4534 [c]	12/31/2009
	Carmeuse Lime Inc Grand River Ops	OH0001317	n/a [d]	3/31/2012
	Painesville WPC Plant	**OH0026948**	**6.0000**	**1/31/2013**
	Painesville Municipal Electric Plant	OH0039357	62.0 [e]	5/31/2015
	Heatherstone WWTP	OH0091952	0.4000	7/31/2012
	Eckart America LP	OH0114511	n/a [a]	4/30/2012
	Mid-West Materials Inc	OH0134660	0.0032	7/31/2014
	Spring Lake MHP	OH0134694	0.0057	11/30/2014
	Frary's Restaurant	OH0136841	0.0010	5/31/2010

Bold indicates major dischargers
Average design flows are rounded to the nearest ten-thousandth of an MGD.
n/a – The permit does not define an average design flow.
a. Facilities discharges storm water only to storm sewers. Discharges are free from contaminants and exclude process water.
b. Facility discharges storm water and non-contact cooling water, stream condensate, or condenser water to storm sewers. Discharges are free from contaminants and exclude process water.
c. Facility discharges both storm water and process water to the Grand River.
d. Facility discharges storm water, ground water, and non-contact cooling water to an unnamed tributary of the Grand River. Discharges are free from contaminants and exclude process water.
e. Facility discharges both storm water and process water to storm sewers.

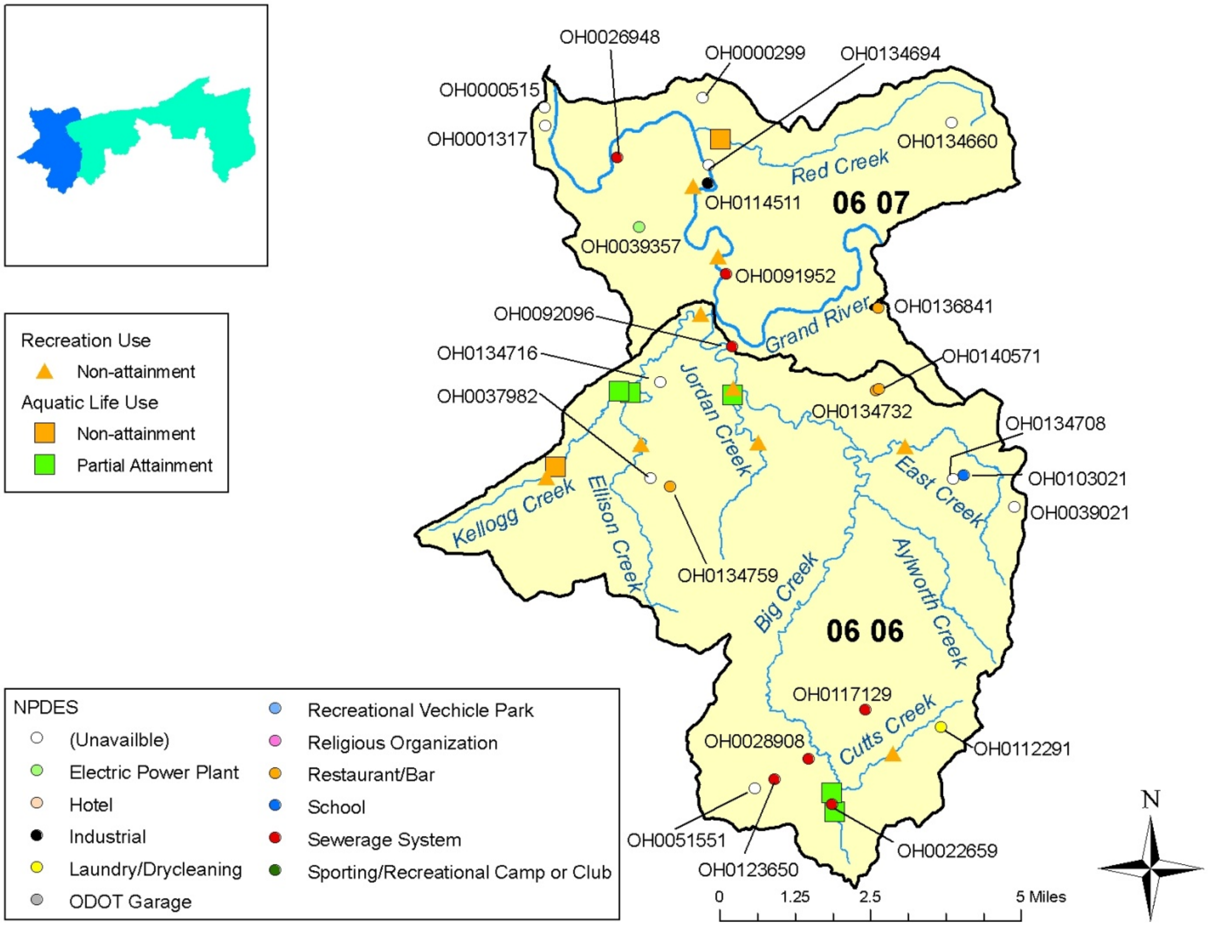


Figure 5-10. Big Creek - Red Creek subbasin point sources.

5.6.2. Nonpoint Sources

Land uses within the Big Creek – Red Creek subbasin are predominantly forest and developed (Table 5-14 and Figure 5-11). Forty-one percent of the subbasin is developed, the majority being residential land uses. Much of the developed area is within regulated MS4 boundaries, discussed in Section 5.4.1. There is limited agricultural land use within this subbasin, although nurseries are common within the upper reaches of Red Creek. Urbanization of this watershed is a significant contributor to the watershed impairments.

Table 5-14. Big Creek - Red Creek subbasin land uses

Land use	Area (acres)	Area (% of total)
Open Water	540	1%
Developed	20,028	41%
Bare	25	0%
Forest	19,955	41%
Grass/Shrub	2,973	6%
Pasture	1,994	4%
Crop	3,126	6%
Wetlands	386	1%

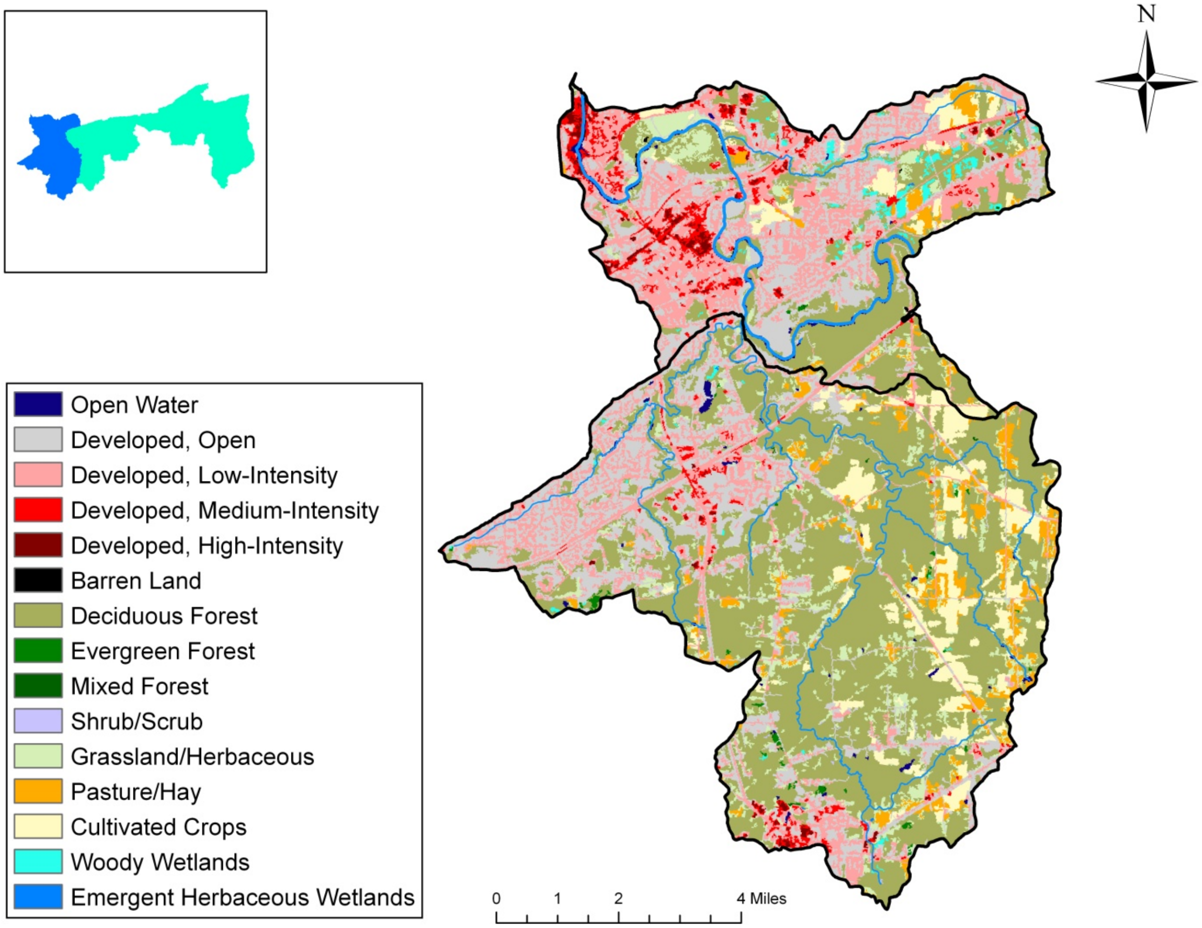


Figure 5-11. Big Creek – Red Creek subbasin land uses.

5.7. Grand River Tributary Subbasin

The pollutant of concern for aquatic recreational use impairment within the Grand River Tributary subbasin is bacteria.

5.7.1. Point Sources

There are 12 active facilities that are permitted to discharge in the Grand River Tributary subbasin (Table 5-15 and Figure 5-12). All the facilities are minor dischargers or facilities with a design flow of less than 1 MGD. The permit with a past expiration date is in progress.

Table 5-15. NPDES permitted dischargers—Grand River Tributary subbasin

HUC (04110004)	Facility	U.S. EPA's NPDES ID	Average design flow (MGD)	Permit expiration
06 01	Coffee Creek WWTP	OH0098469	0.150	12/31/2015
	Pilot Travel Center No 2	OH0129186	n/a [a]	7/31/2011
	Grand River Academy	OH0134457	0.005	2/28/2015
06 02	Rustic Pines MHP WWTP	OH0112135	0.03	10/31/2014
06 03	Whispering Willow MHP	OH0123421	0.020	12/31/2012
	Kenisee Grand River Campground	OH0136719	n/a [b]	12/31/2009
06 04	Cedar Hills Conference Center	OH0123641	0.006	12/31/2011
	Camp Lejnar	OH0134601	0.006	10/31/2014
06 05	Thompson United Methodist Church	OH0133159	0.0017	4/30/2013
	Thunder Hill Golf Course	OH0101583	0.0125	7/31/2014
	Little Thunder Kids Golf Course	OH0134244	0.0006	7/31/2014
	YMCA Outdoor	OH0134686	0.0075	1/31/2015

Average design flows are rounded to the nearest ten-thousandth of an MGD.
n/a – The permit does not define an average design flow.
a. Facility discharges storm water to Coffee Creek.
b. Facility discharges its wastewater to a spray irrigation system, not to surface waters. The design flow of 0.005 MGD is for outfall 601, an internal monitoring station for plant effluent before it is transported to an effluent storage tank and the spray irrigation system.

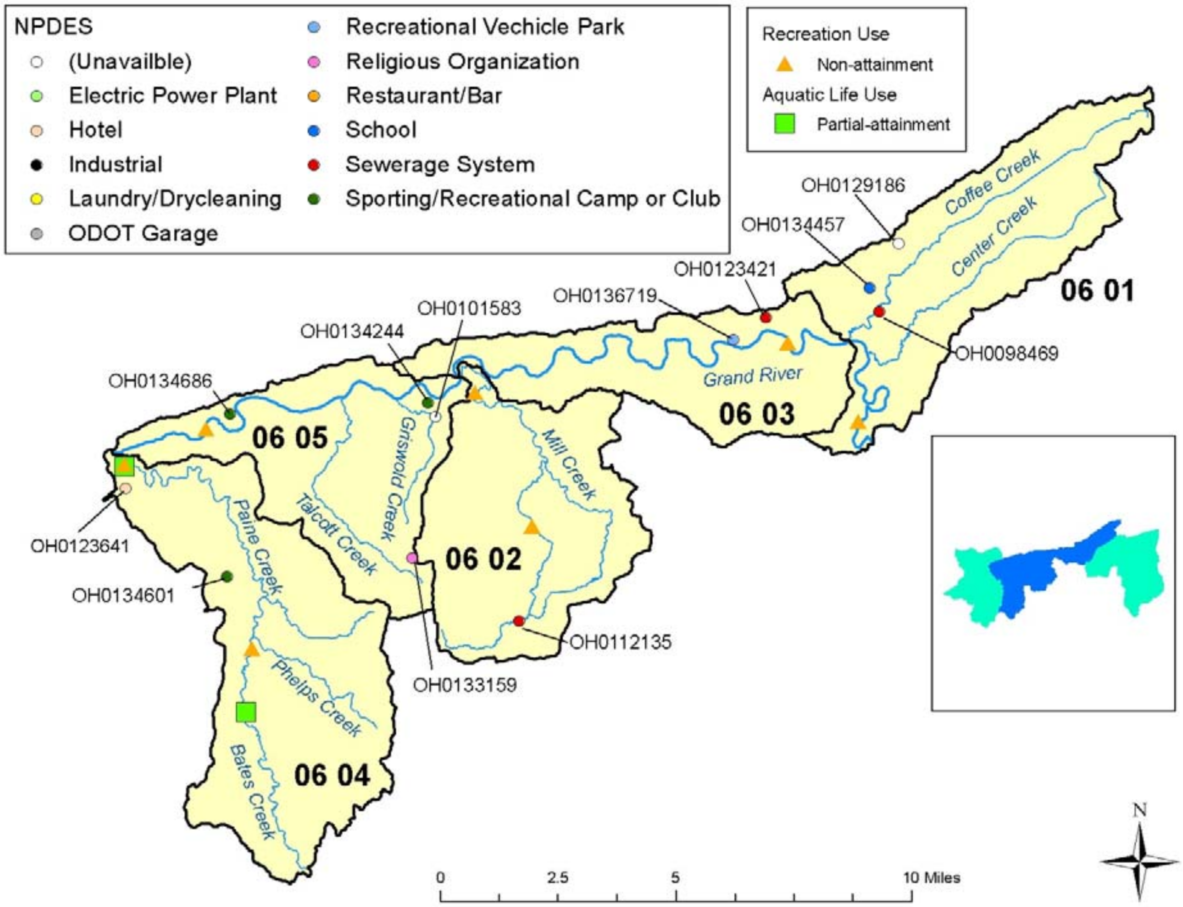


Figure 5-12. Grand River Tributary subbasin point sources.

5.7.2. Nonpoint Sources

Land uses within the Grand River Tributary subbasin are predominantly forest and agriculture (Table 5-16 and Figure 5-13). Over half of the subbasin is forested. Less than 7 percent of the subbasin is developed land uses. Impervious areas in the Grand River Tributary subbasin are predominantly related to roads and the town of Austinburg. Austinburg is adjacent to Coffee Creek. Because of the town's close proximity to the creek, storm water runoff is a potential source of bacteria.

Table 5-16. Grand River Tributary subbasin land uses

Land use	Area (acres)	Area (% of total)
Open Water	1,113	2%
Developed	4,925	7%
Bare	11	0%
Forest	35,530	52%
Grass/Shrub	3,708	5%
Pasture	6,182	9%
Crop	16,378	24%
Wetlands	1,018	1%

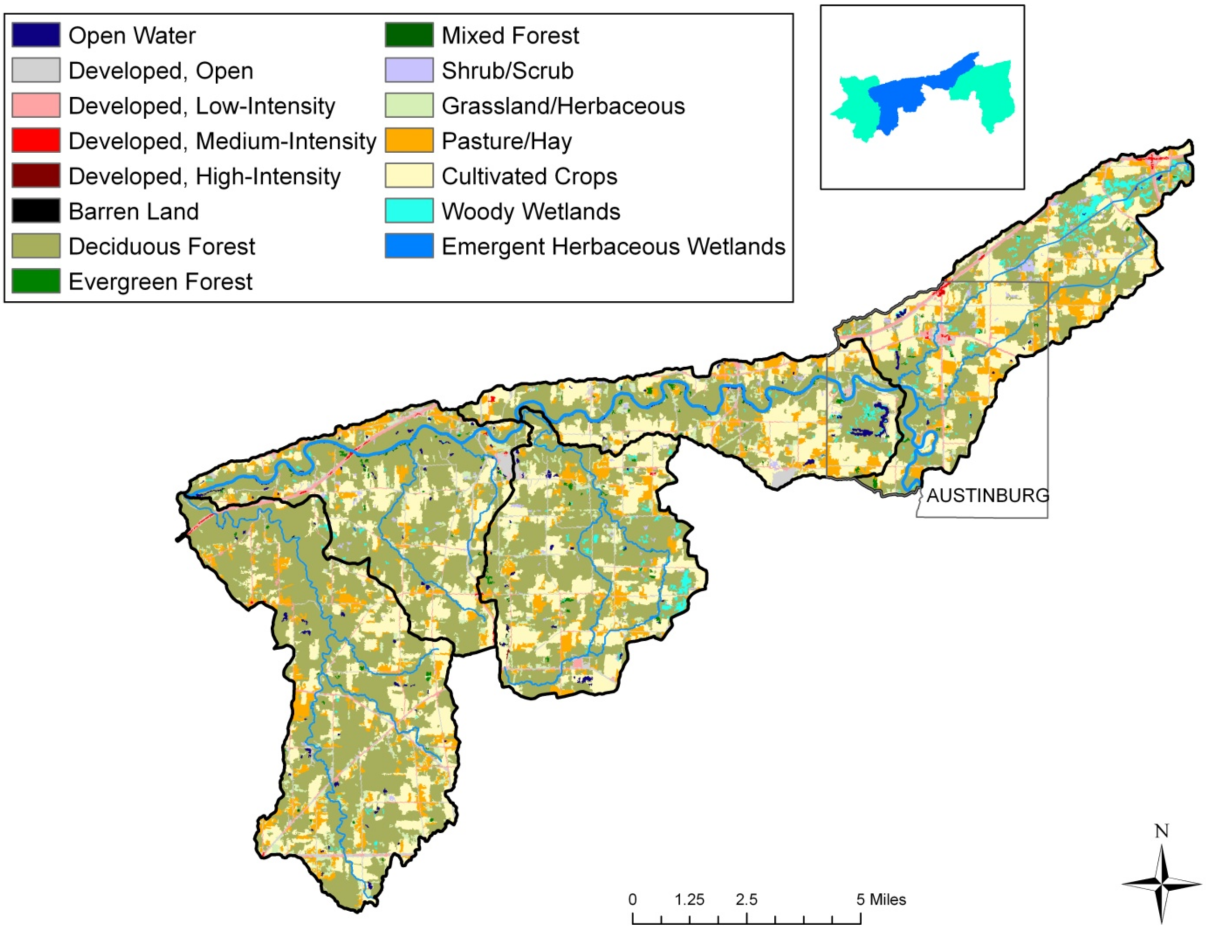


Figure 5-13. Grand River Tributary subbasin land uses.

6. Flow Estimation

Flow regime, nutrient, and bacteria TMDLs are developed to address ALU and recreation use impairments in the watershed. In addition to those TMDLs, flow regime protection strategies will be developed to protect and preserve existing conditions on streams that are in attainment of their ALU but are threatened from encroaching development.

An essential component of developing a TMDL is establishing a relationship between the source loadings and the resulting water quality. Correctly identifying that relationship is dependent on a thorough understanding of a watershed's hydrology, because pollutants can be transported to surface waters by a variety of mechanisms (e.g., runoff, snow melt, ground water infiltration). Furthermore, imperviousness and flow alterations have been identified as high-priority stressors in the lower Grand River watershed.

The approach to simulate runoff and flow from ungaged watersheds is presented in this section. Key elements of that approach include the use of hydrologic response units (HRUs), Loading Simulation Program in C++ (LSPC) watershed modeling, and development of flow duration curves. The LSPC watershed model is used to simulate runoff from HRUs which, in turn, are used to create the flow duration curves. Duration curves are used to support the development of the TMDLs.

6.1. Hydrologic Response Units

A hydrologic response unit (HRU) is defined as a watershed area assumed to be homogeneous in hydrologic response due to similar land use and soil characteristics. Areas with similar sets of such characteristics can be expected to produce similar hydrologic and pollutant loading responses to a given set of weather conditions.

Runoff responses from each HRU are computed separately using rainfall-runoff models and then combined to simulate flow from the watershed. The HRU approach simplifies selection of model parameters by providing a clear physical basis for assignment of values. Existing GIS data layers are used to construct project-specific HRUs. A rainfall-runoff model can then be used to calculate unit area flows associated with each HRU. This in turn improves estimates of storm water loads for source categories and land uses of concern.

HRUs are defined by the LULC and soil type of a specific area. The level of detail can vary greatly when defining HRUs. For example, a coarsely defined HRU may simply be urban land use whereas a finely defined HRU might be low-density, single-family residential on C type soils and slopes less than 5 percent. In general, it is desirable to specify the smallest number of HRUs that allow for an appropriate simulation of the watershed. HRU methodology is determined by balancing the available data and resources with the intended resolution of the model and the optimization of model simulation. For example, it is inefficient to create a large number of HRUs for a very fine-resolution model if data for the parameterization of the HRUs are of a much coarser resolution. Similarly, if two similar factors will not yield significantly different results, it is not necessary to delineate by the factors. With the advent of GIS, georeferenced land use and soils data can easily be obtained for most areas.

6.1.1. Land Use Land Cover

It is impractical to define an HRU by the presence of specific plants and surface types. Instead, generalized land use and land cover (LULC) classes are used. Such classes are coarse enough to be obtained for the entire project study area, yet specific enough to allow for some differentiation between LULC, providing an appropriate level of detail on the basis of the geographic extent of this study. The 2001 NLCD (version 1.0) was selected as the most representative data set for the lower Grand River; for a discussion of why the 2001 NLCD was selected as most representative, Section 3.2.

In developed areas, imperviousness needs to be identified in the LULC classes because imperviousness considerably affects the local hydrologic cycle. For example, the 2001 NLCD defines four levels of development: open, low-intensity, medium-intensity, and high-intensity, with increasing levels of imperviousness, respectively. Other data sets define more specific classes (e.g., roads, parking lots, low-density single family residential).

The 2001 NLCD land cover classes were reclassified to eight classes to facilitate the modeling analysis, as shown in Table 6-1. Land classes were combined on the basis of how they will be modeled. For example, the parameterization of most models does not differentiate between deciduous, evergreen, and mixed forests; therefore, the forest land cover classes could be combined. For the lower Grand River, data were not available to parameterize the forest types differently; therefore, all three forest types were combined when HRUs were delineated. That approach optimizes the amount of information used to represent the watershed while limiting the amount of uncertainty in results.

Table 6-1. HRU land classes

HRU land class	HRU land class label	2001 NLCD land cover class
Crops	Crops	Cultivated Crops (82)
Forest	Forest	Deciduous Forest (41), Evergreen Forest (42), & Mixed Forest (43)
Grassland & Pasture	Grass	Barren Land, Rock, Sand, Clay (31), Shrub/Scrub (52), Grassland/Herbaceous (71), & Pasture/Hay (81)
Urban-Open	UO	Developed, Open (21)
Urban-Low	UL	Developed, Low-Intensity (22)
Urban-Medium	UM	Developed, Medium-Intensity (23)
Urban-High	UH	Developed, High-Intensity (24)
Water & Wetlands	Wet	Open Water (11), Woody Wetlands (90), & Emergent Herbaceous Wetlands (95)

6.1.2. Soils

Multiple factors affect the ability of precipitation to infiltrate into the soil. When developing HRUs, and in many other model applications, soils tend to be defined using the hydrologic soil group or HSG (see Table 3-7) instead of by specific soil types, infiltration rates, or saturated hydraulic conductivity. The HSGs are representative of the infiltration, interflow, and moisture storage conditions in the soils. Soils data are available in national data sets including Soil Survey Geographic (SSURGO) and State Soil Geographic (STATSGO) databases maintained by the U.S. Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS).

6.1.3. Assigning HRUs

HRUs in the lower Grand River watershed were classified by land cover and HSG. The HSGs A, B, C, and D were included in final HRU development. The soil classes A/D, B/D, and C/D were included in the initial HRU development. In soils with dual designations, the first letter indicates the HSG behavior with water management such as tile drainage, while the second letter indicates HSG behavior without such improvements. One HSG was chosen for each HRU using the overlying land cover class: crops were assigned A, B, or C, and all other land cover classes were assigned D.

In total, 32 unique HRUs were identified (8 land cover classes and 4 HSGs). Naming conventions for each HRU are derived by assigning a letter value to each land cover type (see Table 6-1) and an HSG to each unique HRU in the form: land-soil. For example a forested land cover on HSG A would be labeled: Forest-A.

Seven HRUs composed a total of 85 percent of the overall watershed. HRUs that consisted of less than 0.5 percent of the watershed were combined with larger HRUs representing similar characteristics to minimize the number of HRUs and create efficiency in the modeling effort where feasible. Relative area in the watershed, relative area within 100-foot buffers of the streams, and the distribution of HSG in each land cover class were evaluated to ensure the final HRUs were representative of the watershed soil and land cover. The final HRUs are presented in Table 6-2.

Table 6-2. Final HRUs

HRU code	HRU narrative	Area (acres) [a]	Relative area (%) [b]
Crops-B	Crops on HSG B	2,086	1%
Crops-C	Crops on HSG C	24,277	13%
Crops-D	Crops on HSG D	13,158	7%
Forest-A	Forest on HSG A	1,949	1%
Forest-C	Forest on HSG C	9,968	5%
Forest-D	Forest on HSG D	68,801	37%
Grass-C	Grassland & Pasture on HSG C	2,587	1%
Grass-D	Grassland & Pasture on HSG D	23,558	13%
UH-A	High-Intensity Urban Land on HSG A	21	< 1%
UH-C	High-Intensity Urban Land on HSG C	7	< 1%
UH-D	High-Intensity Urban Land on HSG D	364	< 1%
UL-A	Low-Intensity Urban Land on HSG A	1,397	< 1%
UL-C	Low-Intensity Urban Land on HSG C	910	< 1%
UL-D	Low-Intensity Urban Land on HSG D	9,959	5%
UM-A	Medium-Intensity Urban Land on HSG A	140	< 1%
UM-C	Medium-Intensity Urban Land on HSG C	38	< 1%
UM-D	Medium-Intensity Urban Land on HSG D	1,465	< 1%
UO-A	Open Urban Land on HSG A	1,171	< 1%
UO-C	Open Urban Land on HSG C	1,944	1%
UO-D	Open Urban Land on HSG D	12,466	7%
Wet-D	Water & Wetlands on HSG D	7,871	4%

a. Areas within the lower Grand River watershed.
b. Relative areas within the lower Grand River watershed. Percentages do not sum to 100 percent because of rounding.

6.2. Rainfall-Runoff Modeling

The LSPC model is used to simulate rainfall-runoff relationships for each HRU. LSPC is a re-coded version of the Hydrologic Simulation Program in Fortran (HSPF) watershed model. LSPC provides a comprehensive watershed and receiving water quality modeling framework that is generally considered one of the most advanced available. The model can accurately simulate extremely low and high flows, which are both critical for the lower Grand River watershed.

The entire lower Grand River model area was modeled at the USGS gage on the Grand River near Painesville (04212100) using precipitation data from Chardon, Ohio. Each unique HRU is mapped for input to the rainfall-runoff model. Each HRU is modeled as one acre, which produces a scalable result that can be applied to each unique combination of HRUs in each watershed. Thus, flows in each watershed were calculated by multiplying the areas of each HRU in the watersheds by the simulated flow time-series for each HRU.

The calibration process and results, validation results, and model limitations and assumptions are presented in Appendix D.

7. Aquatic Life Use Impairments Linkage Analysis and Hydrologic Targets

Multiple factors affect water quality and ALUs in the lower Grand River watershed, and the impaired biological community listings are the result of several causes. Potential reasons involve not only pollutants delivered to the stream, but also the effect of altered hydrology. In addition, the lower Grand River is threatened by a reduction in base flow in small coldwater tributaries as a result of development in the watershed. The linkage analysis examines the cause and effect relationships between watershed characteristics and pollutant sources and the effect on the stream biology, evaluates the use of surrogate measures to address the pollutant sources, and includes the derivation of hydrologic targets for the TMDL that would result in attaining the ALU. The use of surrogate measures and hydrologic targets are discussed in Section 7.3.

Hydrology is a primary driver that exerts major effects on water quality and the aquatic community in the lower Grand River watershed. In watersheds experiencing growth and development, storm water has often been identified as a contributing factor to biological impairments. In many cases, it is difficult to identify a specific pollutant in storm water that is responsible for reduced macroinvertebrate or fish community integrity. The use of surrogate measures such as hydrologic indicators or impervious cover can represent the physical stressors on biota and describe the rate and load of pollutant delivery to waterbodies. A flow regime represents the full range of hydrologic conditions in a stream including high, mid-range, and low flows and is the surrogate used to represent physical and chemical disturbance such as, peak-flow increases, low-flow decreases, habitat alteration, and pollutant loadings, which result from urbanization.

Anthropogenic activities in both urban and rural agricultural settings affect aquatic communities by affecting flow, water quality, and habitat. Ohio EPA evaluated the biological survey data collected in 2000, 2003, and 2004 and identified the causes and sources of impairment in the *Biological and Water Quality Study of the Grand River Basin 2003-2004*(Ohio EPA 2006a).

Ohio EPA evaluated the attainment of designated ALUs at 28 locations on tributaries to the Grand River. Two sites were found to be in non-attainment because of urban sources: Kellogg Creek RM 5.7 and Red Creek RM 0.5. One site was found to be in non-attainment because of siltation/sedimentation for agricultural channelization (Mill Creek RM 25.7). Additionally, eight sites were found to be in partial attainment; however, four sites were in partial attainment because of natural conditions: Bates Creek RM 2.2, Big Creek RM 2.5, Griggs Creek RM 2.0, and Paine Creek RM 0.5. The remaining four sites in partial attainment that were caused by urban sources were Big Creek RM 16.0 and 16.2 and Kellogg Creek RM 3.1 and 3.3.

Flow alteration and direct habitat alteration were listed as potential causes of impairment, and urban runoff/storm sewers and hydromodification were listed as potential sources of impairment in the 2010 Integrated Report for the Big Creek and Red Creek-Grand River WAUs.

WAUs that contain ALU impairments were evaluated to determine the portion of the watershed contributing to the impairment. Subwatersheds were delineated primarily by the location of the impaired stations. Output from StreamStats (USGS 2010) and existing 12-digit HUC boundaries were used to delineate the assessment points according to stream networks and topographic variability. Using that method, five subwatersheds were defined for assessing ALU impairments and developing TMDLs (Figure 7-1). Specific detail related to selecting those subwatersheds is provided in Sections 7.4 through 7.7 for each ALU impaired stream. Table 7-1 summarizes the TMDLs that will be developed for ALU impairments.

Table 7-1. Summary of ALU TMDLs

Impaired water	TMDL assessment location	
	Station ID	RM
Mill Creek (HUC 04110004 04 02)	G02G13	25.7
Big Creek	G02W21	16.0
Kellogg Creek	200593	3.3
Red Creek	at outlet	0.0

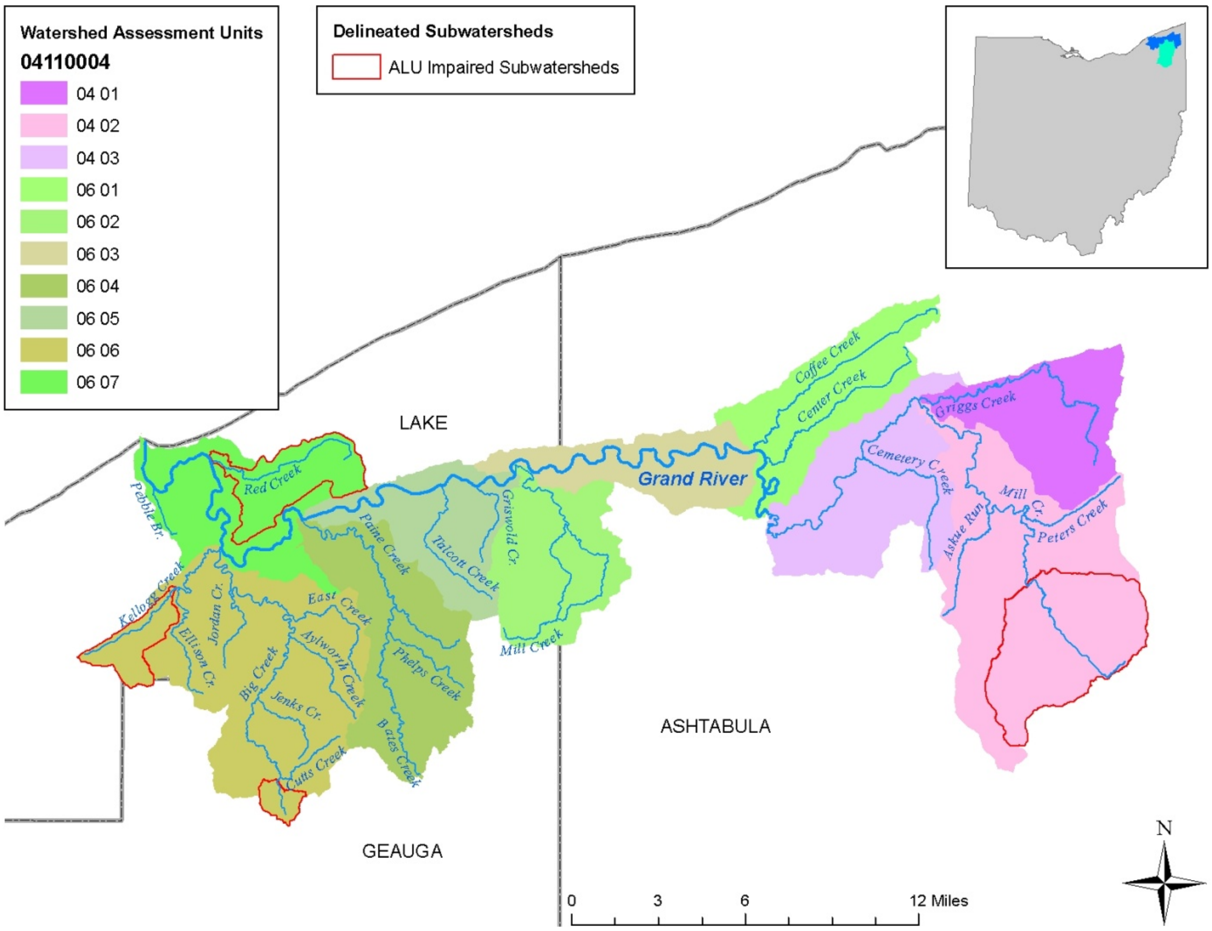


Figure 7-1. ALU-impaired subwatersheds.

7.1. Effects of Urbanization

The impacts of urbanization are the cumulative effect of multiple stressors in the watershed and stream environment resulting from urban development. The literature indicates that impacts on aquatic life have been documented in cases with as little as 5 percent urban development and 10 percent impervious cover. For a general review of the impacts of urbanization and references to additional resources, see the CADDIS Urbanization Module (U.S. EPA 2010b) and *The Importance of Imperviousness* (Schueler 1994).

Urban development consists of changes in land use from previously open, forested, or agricultural land uses to residential, commercial, and industrial land uses. Land transitions from undeveloped to developed land uses along the urban area boundary, which is also typically defined by the presence of public utilities. In the case of the lower Grand River watershed, such a transition is occurring in the Kellogg, Ellison, and Red Creek subwatersheds. Urbanization is anticipated to occur within those three watersheds and also surrounding the city of Chardon in the headwater area of Big Creek in the next 20 years. The surrounding areas will also be subject to less intense land use changes as parcels are converted from undeveloped land uses into large-lot residential areas.

Hydrology, habitat, riparian buffers, water temperature, and water quality are all affected by urbanization (Figure 7-2). Each of those factors is discussed below and is linked to flow regime and imperviousness for ALU impairments. Flow regime and imperviousness act as surrogates that describe the impact of urbanization.

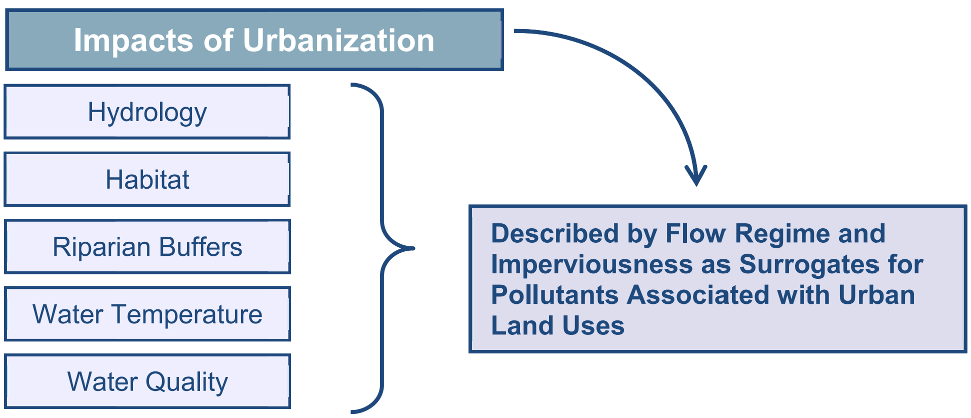


Figure 7-2. Link between urbanization and surrogate to pollutants in lower Grand River watershed.

7.1.1. Responses of Aquatic Life Response to Urban Development

Research has shown that, generally, urban development is associated with impairment of biological communities. Cuffney et al. (2010) have shown that measures of aquatic community health respond differently to the varying measures and magnitudes of urban development. In-depth evaluations of the impacts of urbanization and impervious cover on aquatic habitat and biota are in Schueler (2004), Capiella et al. (2005) and Shaver et al. (2007); a general synopsis from Shaver et al. (2007, p. 4-98) is that

> [O]verall, there tends to be a decline in taxa richness or species diversity, a loss of sensitive species, and an increase in tolerant species […] due mainly to the cumulative impacts of watershed urbanization: altered hydrologic and sediment transport regimes, degradation of in-stream habitat quality and complexity, stream bed fine sediment deposition, poor water quality, and the loss of native riparian vegetation.

In Ohio, various metrics of urban development have been evaluated including percent urban land use, which includes both impervious area and urban open area (Yoder and Rankin 1996; Yoder et al.1999, 2000), housing density (Yoder et al.1999), and percent impervious cover (Miltner et al. 2004). Yoder et al. (1999, p. 20) found that "classification by percent urban land use cover showed a more continuous decrease in mean IBI scores with an increasing level of urbanization than did housing density," and that more recent research has focused on percent impervious cover (Miltner et al. 2004). In southeast

Wisconsin, “watershed connected imperviousness was the best single indicator of urbanization effects on stream fish communities” (Wang et al. 2001, p. 260).

Response to urban development occurs over a gradient. Generally, higher levels of development yield greater changes to the natural environment and thus greater changes to the aquatic communities. Yoder et al. (1999, p. 22) found that sensitive fish and macroinvertebrates were absent at relatively low levels of urban development (less than 5 percent urban land use), with a continuously negative response as urbanization increased, which included impairment at intermediate levels of urbanization caused by the disruption of the food web. Biological community health occurred along a gradient in Wisconsin streams from degraded communities in streams that were 100 percent urban land to abundant and diverse communities in a reference stream that had no urban land (Masterson and Bannerman 1994).

The level of impervious cover has also been used as a surrogate measure of urban development. Karr and Chu (2000) also found that an increasing percentage of impervious cover is correlated with declining stream health. Wenger et al. (2008, p. 1260) used statistical models to predict the occurrence of five fish species in an urbanizing watershed in Georgia and found that the “occurrence of several species was strongly related to low levels of [effective impervious area],” with some species becoming rare at 2 percent effective impervious area. Similarly, the Center for Watershed Protection (1999) reviewed published research and concluded that the threshold of watershed impervious cover that results in a loss of aquatic biota diversity is in the range of 10 to 15 percent. Yoder and Rankin (1996, p. 217) evaluated published research and found that “watershed imperviousness was negatively correlated with the condition of the aquatic biota, with degradation becoming significant at 25–30 [percent] within a watershed.” Evaluations of impervious cover in Columbus, Ohio-area streams showed that biological integrity significantly declined in urban streams when impervious cover exceeded 13.8 percent (Miltner et al. 2004).

Research on Ohio streams has begun to identify the critical thresholds at which aquatic communities become impaired. Yoder et al. (2000) concluded that IBI biocriteria for WWH streams were no longer attained when urban development (measured as percent land use) exceeded approximately 26 percent, in four of Ohio’s metropolitan streams. In the evaluation of urban development using housing density, IBI and ICI scores began to fail to meet the WWH biocriteria at a threshold of 2.53 housing units per hectare (Yoder et al. 1999). It is important to note that non-attainment also occurred with lower levels of urban land use. Non-attainment in developed areas with less than 26 percent urban land use might have been the result of other stressors such as combined sewer overflows (Yoder et al. 2000).

Moderate to high levels of urban development do not necessarily mean that the ALU designation is in non-attainment. A few sites attained their biocriteria despite urban land use levels of 40 to 60 percent; those sites “had either an intact, wooded riparian zone, a continuous flux of ground water, and/or the relatively recent onset of urbanization” (Yoder et al. 2000, p. 41).

Similar to the results of Yoder et al. (2000), Miltner et al. (2004) reported that in Columbus-metropolitan area streams, good index scores in highly urbanized areas occurred only at sites with large riparian buffers, undeveloped floodplains, and significant contributions of ground water. However, a maximum threshold, above which attainment cannot likely be achieved, has also been determined. Urban land use can be mitigated by effective management practices and large riparian buffers but only when levels of impervious cover were below 45 percent (Yoder et al. 1999). Similarly, Miltner et al. (2004) concluded that attainment cannot likely be achieved in watersheds with impervious cover greater than 27.1 percent.

7.1.2. Hydrology

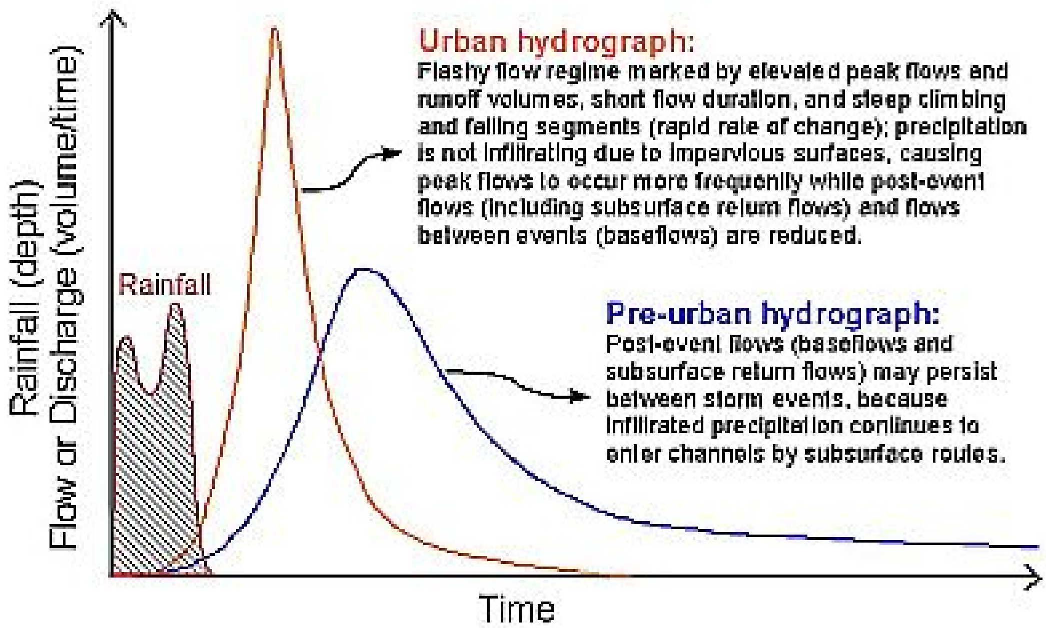
Impacts of Urbanization on Hydrological Flow Regime

"[U]rbanization alters the hydrologic regime of surface waters by changing the way water cycles through a drainage basin" (Shaver et al. 2007, p. 4-80). In undeveloped areas, natural flow regimes are present where portions of precipitation are intercepted by vegetation and water is stored in vegetation, soils, and waterbodies (i.e., topographic depressions). Water that is not intercepted or stored will evapotranspirate, infiltrate to ground water, or flow overland or in the shallow subsurface to streams or other topographic lows. Components of the hydrologic cycle are altered in urban environments: natural plant communities are removed or replaced, topography is changed to fit anthropogenic needs, soils are disturbed and altered, impervious structures are built, and storm water conveyance systems are installed. "The combination of [impervious cover], storm drain pipes, compacted soils, and altered flood plains dramatically change the hydrology or urban streams" (Schueler 2004, p. 23). Generally, flow regimes affected by increased storm water will have higher flow rates per unit area during high-flow events and lower flow rates per unit area during low-flow conditions.

The urban landscape is defined by impervious cover, which increases as the density of urban development increases. In terms of hydrology, impervious cover reduces infiltration that, in turn, disrupts aquifer recharge and subsurface hydrologic processes that are key components of the water cycle (Schueler 2004). Soils below impervious surfaces remain dry (though are likely compacted and have less water capacity) and water cannot infiltrate down to aquifers, where ground water flows through the subsurface to streams and topographic lows. Because of a lack of ground water recharge, urban headwaters streams can run dry during low-flow and drought conditions (Schueler 2004). A literature review showed that as impervious cover increased, the percentage of storm flow in a stream increased and the percentage of base flow decreased (Shaver et al. 2007). It is noteworthy, however, that irrigation, pipe leaks, and such could generate enough volume to allow urban streams to continue to flow during dry-weather periods (Shaver et al. 2007; Schueler 2004).

Unlike in natural (i.e., undeveloped areas), where precipitation that is not intercepted will infiltrate or become runoff, un-intercepted precipitation in urban areas becomes storm water runoff as it flows over impervious surfaces or becomes storm flow if it enters conveyance systems. Directly connected impervious surfaces are surfaces that drain directly to a waterbody through either storm water conveyance systems or as direct drainage that is not otherwise interrupted by a vegetated or porous surface. Such connected impervious areas typically generate more runoff than unconnected impervious surfaces, which allow runoff to flow over downstream pervious surfaces (Shaver et al. 2007).

"During storms, urban watersheds produce a greater volume of storm water runoff and deliver it more quickly to a stream compared to rural watersheds" (Schueler 2004, p. 37). Runoff flows rapidly over impervious surfaces or through storm water conveyance systems to the streams. In a more natural system, the initial precipitation would be contained in topographic depressions or infiltrated into soils and the subsurface environment and removed by evapotranspiration. Runoff would not occur until depressions were full and soils were saturated. Thus, in urban areas, stream flow becomes more flashy. Flow increases more rapidly during or shortly after a storm, but elevated flow does not persist as long as it would in an undeveloped watershed. Those concepts are graphically represented in Figure 7-3. Impervious cover not only affects the volume of runoff that discharges to the stream, but also affects the duration of flows reaching the stream. For in-depth discussions of the effects of urbanization on the flow regime, see Shaver et al. (2007) and Burton and Pitt (2002).



Source: U.S. EPA 2010b, Figure 14

Figure 7-3. Hydrographs showing generalized flow conditions for a stream before and after urbanization.

With respect to a flow duration curve, the altered hydrologic regime is apparent with larger flows in the high-flow zone (because of larger peak discharges) and smaller flows in the low-flow zone (because of lower base flow). In the lower Grand River watershed, hydrological regimes of streams affected by varying levels of urban development were evaluated. Figure 7-4 presents a spectrum of sites from a completely developed stream segment (Kellogg Creek), through streams with large amounts of development (Ellison Creek and Jordan Creek), to a stream with minimal development (East Creek). Table 7-2 summarizes the percent impervious associated with each of those streams.

Table 7-2. Watershed imperviousness for streams with varying levels of development

Watershed	Percent impervious
Kellogg Creek (RM 3.3)	14.7%
Ellison Creek (at outlet)	10.7%
Jordan Creek (at outlet)	5.2%
East Creek (at outlet)	1.1%

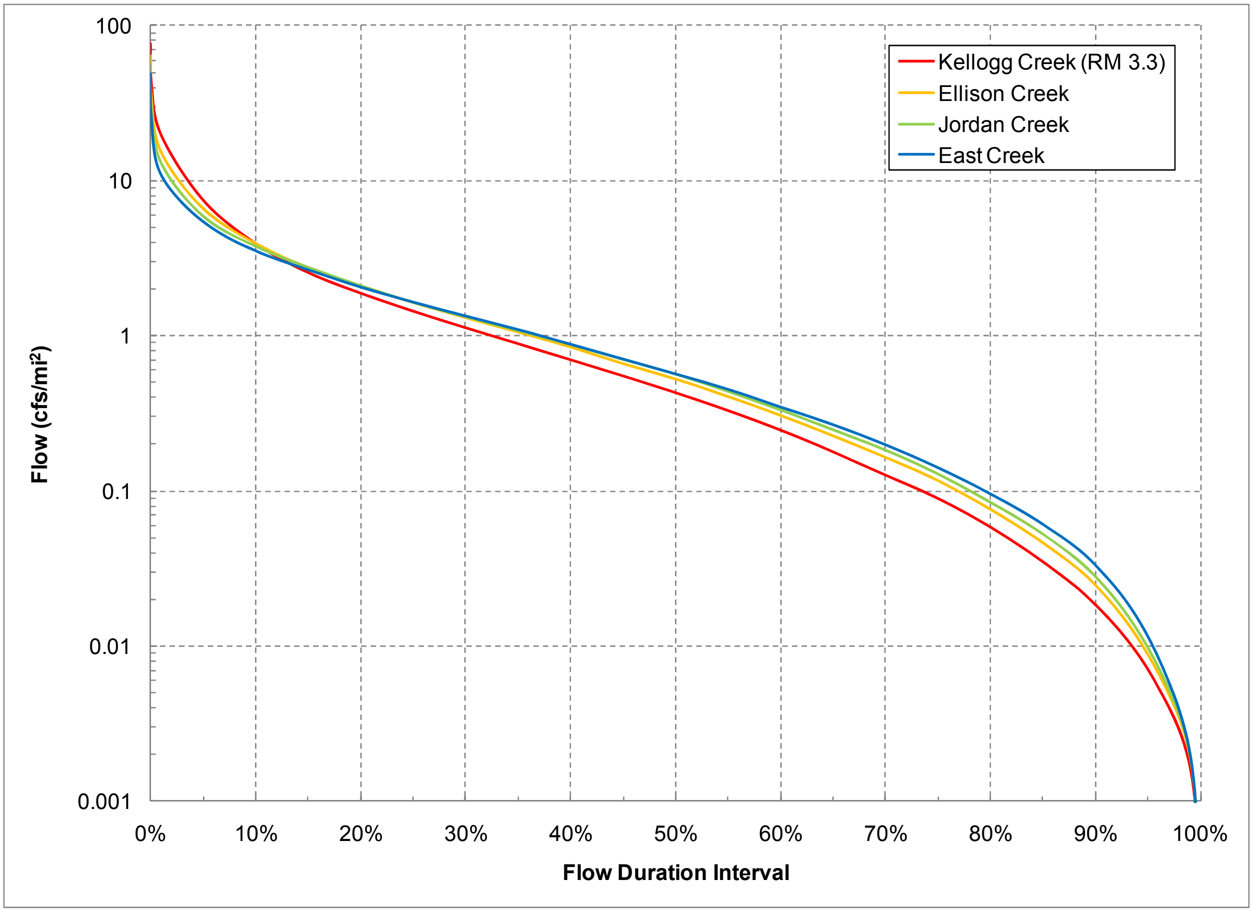


Figure 7-4. Flow duration curves for streams with varying levels of development.

Impacts of an Altered Hydrological Flow Regime on Aquatic Community Health

The alteration of the hydrologic regime is important because hydrology affects aquatic biota and their habitat. The flow regime is important because the energy dynamics related to high-flow events and the availability of water under low-flow conditions defines the in-stream habitat and aquatic species evolved within those habitats under specific natural-flow regimes. "In undisturbed, properly functioning stream systems, the natural (mainly hydrologically driven) disturbance regime maintains the stream in a state of dynamic equilibrium" (Shaver et al. 2007, p. 4-93). When the hydrologic regime is altered, aquatic communities are affected both directly (e.g., washout of organisms, physiological stresses of swimming in higher flows) and indirectly (e.g., changing available habitat through elevated turbidity and washout of woody debris) (Shaver et al. 2007).

Urban development is essentially a persistent disturbance that results in degradation of the structure of aquatic biological communities at all scales: "catchment scale (e.g., channel dimension), reach scale (e.g., riffle-pool distribution), and patch scale (e.g., hydraulic conditions on individual stones)" (Bunn and Arthington 2002, p. 492). As the disturbances increase in frequency and severity, the aquatic communities might have lesser abilities to respond and adapt and could degrade from highly complex to simple communities (Burton and Pitt 2002). Poff et al. (2010) found that 152 of 165 studies concluded that flow alteration resulted in negative ecological changes and that fish and macroinvertebrate communities' abundance and diversity declined in response to flow magnitude alterations in 55 studies with quantitative data. Similarly, Carlisle et al. (2010) concluded that stream communities responded to altered flow magnitude.

Because the flow regime is complex and interrelated with all other components of the ecosystem, an alteration of the flow regime can affect many aspects of the ecosystem. As components of the ecosystem are disturbed and altered, the aquatic species must respond, which in turn affects aquatic communities. For example, fish communities in urban streams generally lose "[s]ensitive species that require cold water or a clean streambed as impervious cover increases" and become dominated by pollution-tolerant and nonnative fish species (Schueler 2004, p. 33). In urban streams in the Cleveland and Columbus areas, increasing levels of percent urbanization resulted in the loss of pollution- and habitat-sensitive fish species and increasing levels of tolerant fish (Yoder et al.1999). The relationship of flow and aquatic communities has been evaluated for over a century, and literature addressing those topics is abundant. The following studies discuss the relationships between flow regimes and aquatic communities and how communities respond to changes in flow: Bunn and Arthington (2002), Carlisle et al. (2010), Carlson (2006), Poff et al. (2010).

Impacts of an Altered Hydrological Flow Regime on Pollutant Transport

The hydrology of a stream also affects the ability of a stream to transport pollutants, specifically sediment and sediment attached pollutants. Streams with high flows can result in channel scour and erosion of the stream channel. Those steams are also able to transport larger sediment particles further distances. Streams that are dominated by lower flow conditions will deposit sediment and associated pollutants resulting in poor quality habitat and loss of spawning beds. In addition, low flowing streams will have lower dissolved oxygen levels. A stream's assimilative capacity for pollutant loads from the watershed will depend on its ability to balance all those factors. Pollutant loads in urban storm water runoff are further discussed in Section 7.1.6.

Imperviousness and ALU Designations in the Lower Grand River

In the *Big Creek* - *Grand River* 10-digit HUC (04110004 06) of the lower Grand River watershed, the sites in full attainment of their ALU designation were in subwatersheds with between 0.5 to 12.5 percent impervious cover (Figure 7-5). Impervious cover was derived from the 2001 NLCD for the area upstream of each assessment point. Three-quarters of full attainment sites had 5.3 percent or less impervious cover. Sites in partial attainment and non-attainment were in subwatersheds with 11.5 percent or more impervious cover.

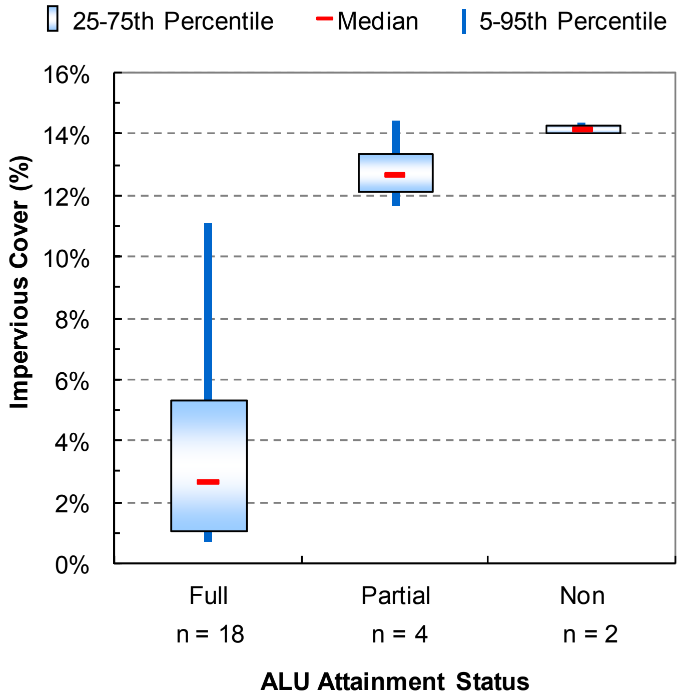


Figure 7-5. Levels of impervious cover at the assessment sites on western tributaries in the lower Grand River watershed.

The condition of Kellogg Creek is representative of the response of ALU attainment to the gradient of impervious cover. The upper portions of Kellogg Creek, above the confluence with Ellison Creek, are impaired for their ALU designations. Kellogg Creek runs through small-lot residential subdivisions throughout most of its length. Only in its lower segments, below Ellison Creek, does it flow through forested areas, although residential properties are usually still within a few hundred feet of the creek. Figure 7-6 shows that the higher levels of impervious cover in the upper portion of the watershed could affect the attainment of the designated ALU. As the watershed percent impervious decreases downstream, Kellogg Creek becomes in attainment of the ALU.

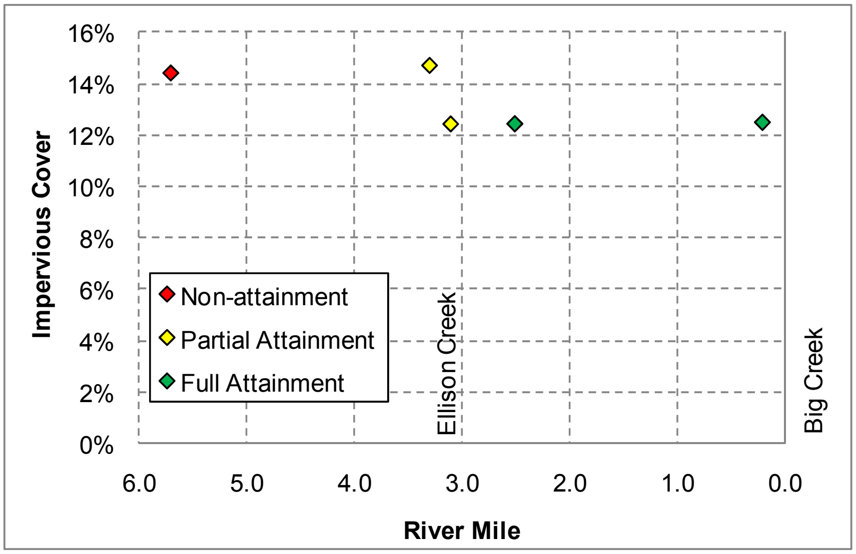


Figure 7-6. Levels of impervious cover at Ohio EPA's assessment sites along Kellogg Creek.

Ellison Creek, a tributary to Kellogg Creek, is an example of a stream that is in attainment of its ALU designation, but future attainment is at risk because of development pressure. Much of the upper portions of the creek are forested with large-lot residential properties. The lower portions of Ellison Creek are also forested, but levels of development and impervious cover increase in that portion (Figure 7-7). The creek directly abuts smaller-lot residential developments, runs along a golf course and runs through its driving range, and flows through a culvert below a highway. Several residences are directly in the riparian area from the highway down to the confluence with Kellogg Creek. Ohio EPA has identified evidence of significant head cutting in the lower reaches that is controlled on the upstream end by a road crossing and culvert.

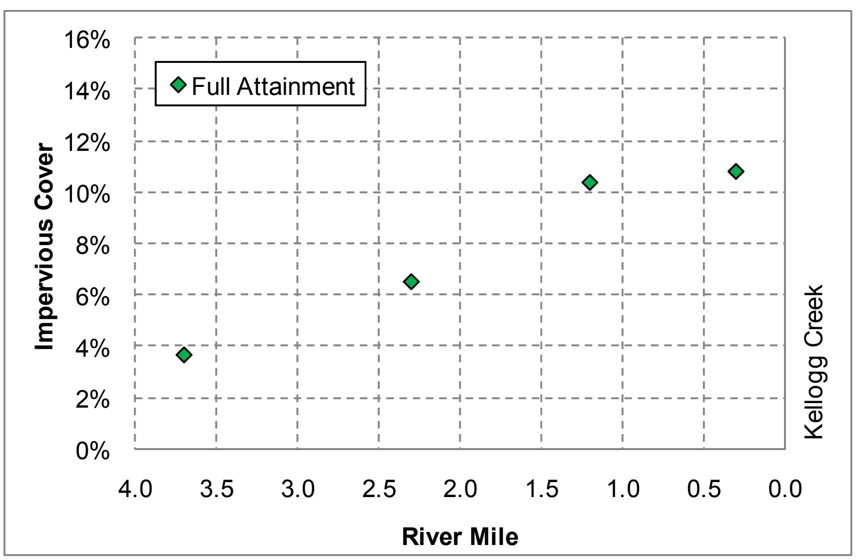


Figure 7-7. Levels of impervious cover at Ohio EPA's assessment sites along Ellison Creek.

Big Creek also exemplifies the attainment response to the gradient of impervious cover. The two assessment points in the headwaters of Big Creek are in partial attainment of their ALU designations; those sites are within the city of Chardon, where the levels of impervious cover are high (Figure 7-8). As

Big Creek flows north from Chardon, many small, healthy streams, with little development within their subwatersheds, discharge to it (the largest streams are shown in Figure 7-8). Thus, similar to Kellogg Creek, the data suggest the impacts of high levels of impervious cover in the headwaters of Big Creek were mitigated by the contributions from healthier subwatersheds in the lower segments of Big Creek.

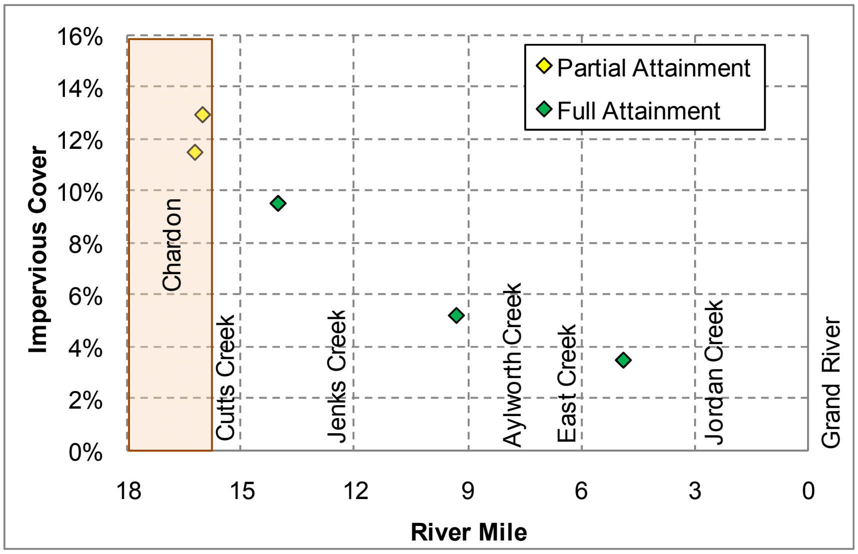


Figure 7-8. Levels of impervious cover at Ohio EPA's assessment sites along Big Creek.

All three of those analyses (Kellogg Creek, Ellison Creek, and Big Creek) suggest that healthier segments of a stream that are downstream of an impaired segment can mitigate effects from the impairment. The healthier segments tend to be defined by smaller levels of impervious cover compared to the impaired segments. However, the findings of Yoder et al. (2000) and Miltner et al. (2004) regarding the effects of forested riparian corridors are pertinent. Higher levels of forested land and intact riparian corridors in Ellison Creek counteract the higher levels of impervious cover in the lower portions of the subwatershed. In Big Creek and Kellogg Creek, forested riparian corridors and higher levels of forested land in the tributaries appear to mitigate some of the effects of impervious cover and yield better (i.e., more healthy) biotic index scores (Figure 7-9).

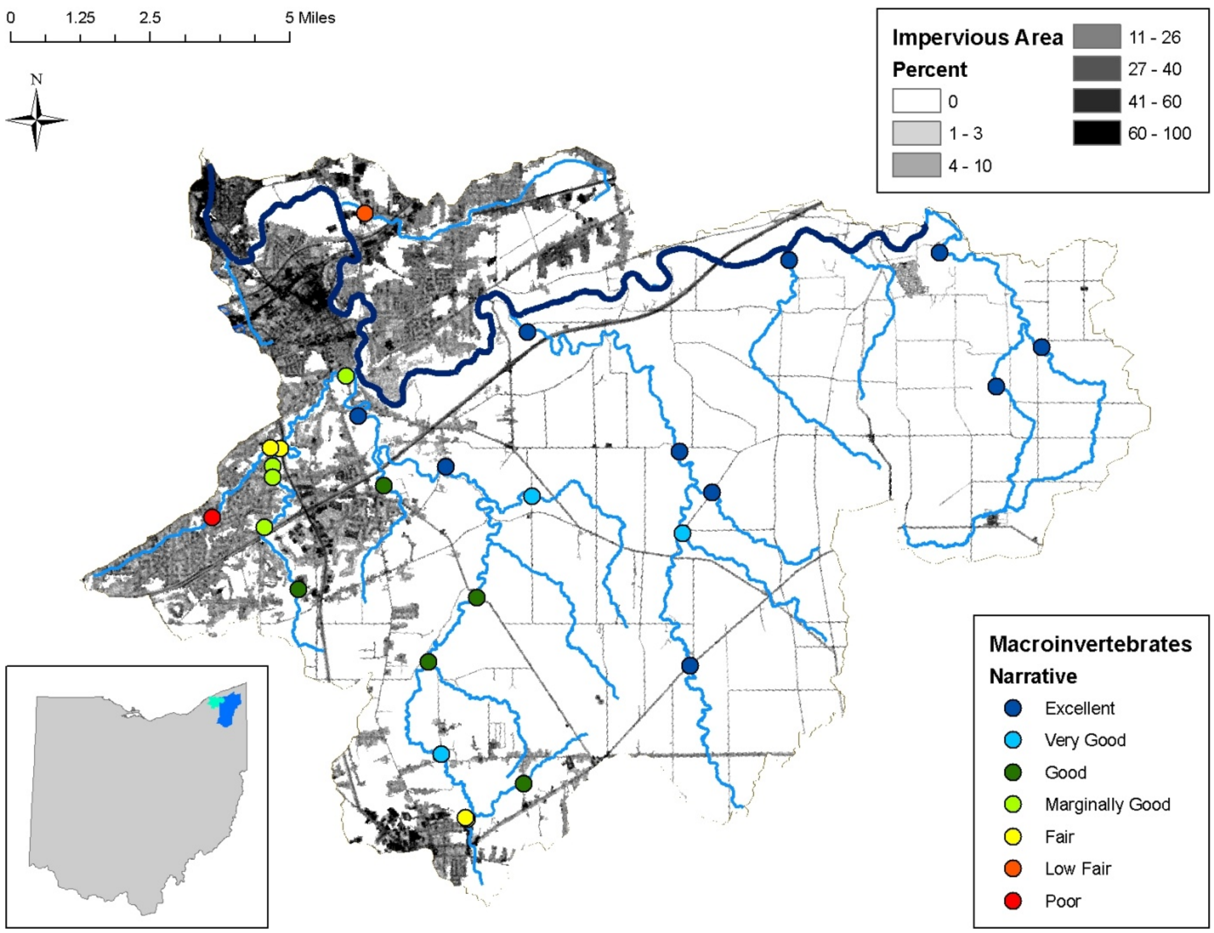


Figure 7-9. Macroinvertebrate narrative scores in the western watershed.

7.1.3. Habitat

Urban hydrologic regimes can alter stream geomorphology because of the power of larger and faster moving water volumes. "The increased magnitude and frequency of storm water flows give urban streams more power to transport sediment and cause channel erosion" (Schueler 2004, p. 27). Stream channels develop in response to hydrologic regimes. When urban flow regimes replace natural flow regimes, streams must change and that usually involves increasing the cross-sectional area to accommodate larger flows (Schueler 1994). Incision, erosion, channel enlargement, and other such alterations that occur in response to the urban hydrologic regime can be a produced slowly over a long time or in response to a single large storm water runoff event (Shaver et al. 2007). Such stream channel alterations result in channel instability that degrades habitat (Schueler 1994). For additional discussions of habitat alterations from urban development, see the U.S. EPA (2010b) and Shaver et al. (2007).

Urban streams transport many times more sediment than streams in undeveloped areas (Schueler 2004). The urban streams tend to have impervious surfaces that alter the hydrologic regime (e.g., higher magnitude flows, more frequent high flows), which then increases the erosion of the streambed and banks and increases resuspension of bed sediment (U.S. EPA 2010b). Additionally, urban streams can contain sediment that is contaminated with toxic substances (Schueler 2004).

Increased rates of sedimentation and siltation affect aquatic communities. Stream-bottom substrates can become embedded as sedimentation and siltation occur, thus rendering the habitat nonfunctional (Shaver et al. 2007). For example, poor stream bed quality makes urban streams poor spawning environments (Schueler 2004). Sediment quality can also be affected by contamination from urban sources. Sediment contaminated with pollutants from storm water runoff detrimentally affect benthic organisms (Shaver et al. 2007). In Ohio, fish and macroinvertebrate data from urban streams in Cuyahoga and Franklin counties show that “substrate degradation is a major factor which limits aquatic communities at relatively low levels of urbanization” (Yoder et al.1999, p. 22). Sedimentation and siltation not only degrade habitat, but also directly affect aquatic life. For example, silt can clog fish gills. The cumulative effects of increased sedimentation (e.g., loss of high-quality habitat) affect aquatic communities by degrading community structure, reducing populations, and decreasing diversity. The effects of those negative effects on aquatic communities become evident in the poorer scores of the biological community health indices, which indicate that the waterbodies fail to meet their designated ALUs.

The impact of urbanization on habitat is not limited to an altered flow regime. Channelization, dredging, mining, and other anthropogenic activities directly alter aquatic habitat (U.S. EPA 2010b). Land use change and development within the riparian corridor are important activities that degrade habitat. A discussion regarding the importance of vegetated riparian corridors and the impacts of their loss during urbanization is presented next.

7.1.4. Riparian Buffers

Vegetated riparian corridors are a critical component of aquatic ecosystems and local hydrologic cycles. Stream bank vegetation provides habitat to many terrestrial and aquatic species. For example, riparian trees benefit aquatic communities by providing leaf litter and woody debris as habitat and as a source of energy for the community food webs (Cappiella et al. 2005). Trees along stream banks reduce channel erosion by stabilizing stream banks (via their root systems), by adding organic matter, and by dispersing rainfall energy (via dispersing the raindrop energy across the canopy) (Cappiella et al. 2005).

Typically, riparian vegetation along streams is removed or reduced to allow for expanding development. Plant communities in riparian floodplains and wetlands are degraded by impacts of urban development, including filling, encroachment, water table recession, invasion of nonnative plant and animal species because of disturbance, and other types of anthropogenic disturbance (Schueler 2004). For an in-depth discussion of the impacts of urban development and impervious cover on urban forests and riparian areas, see Chapter 1: Introduction to Urban Watershed Forestry in the *Urban Watershed Forestry Manual* (Cappiella et al. 2005).

The preservation of vegetated riparian corridors can mitigate some of the detrimental effects of urbanization and impervious cover. Urban forests reduce the impacts of altered hydrological regime caused by urbanization and impervious cover by intercepting rainfall in the tree canopies, by releasing water via evapotranspiration, and by increasing ground-level infiltration (Cappiella et al. 2005). Yoder et al. (2000) found that riparian buffers in Ohio can preserve or enhance in-stream habitat and thus mitigate the detrimental impacts of high levels of urbanization. Highly urbanized areas (up to 15 percent) with “relatively intact stream habitat and well-vegetated, wider riparian buffers” (e.g., estate-type residential developments) attained their biocriteria (Yoder et al.1999, p 22). In addition to mitigating the effects of the altered hydrologic regime, vegetated riparian buffers can mitigate some of the effects from impervious cover. Because forests act as nutrient sinks, by absorbing nutrients into their biomass, forested urban riparian corridors can reduce the nutrient concentrations in runoff (Cappiella et al. 2005). Also, urban trees can shade impervious surfaces and reduce the temperatures of storm water runoff from such areas (Cappiella et al. 2005).

The levels of forest cover in the riparian corridors were evaluated for tributaries to the Grand River in the *Big Creek – Grand River* HUC (04110004 06). GIS was used to calculate the percent of forest land covers (i.e., deciduous forest, evergreen forest, and mixed forest) from the 2001 NLCD within 100 feet on each side of the stream. Sites in full attainment of the ALU designation had forest cover levels of between 38 and 81 percent of the riparian corridor (Figure 7-10). The riparian corridors of impaired sites were generally 15 to 48 percent forested.

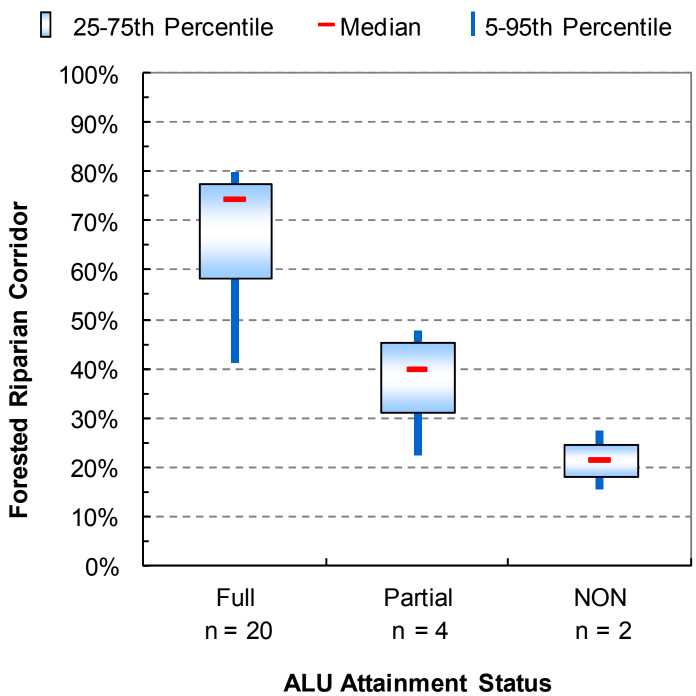


Figure 7-10. Forested land in the riparian buffer for western tributaries in the lower Grand River watershed.

An evaluation of QHEI data showed similar results. Seventy-eight percent of sites in full attainment of their designated uses had wide (greater than 50 meters) or moderate (10 to 50 meters) riparian cover on each bank. However, such levels of forest cover were present at only 25 percent of impaired sites. It is also noteworthy that 44 percent of sites in full attainment had wide riparian cover on both banks (the other 34 percent had either moderate cover on both banks or moderate cover on one bank and wide cover on the other bank). The data suggest that wide riparian buffers are an important factor that affects attainment, and, as Yoder et al. (2000) and Miltner et al. (2004) found, well-forested buffers can mitigate the effects of urban development.

7.1.5. Water Temperatures

Stream temperatures affect all levels of aquatic life, from chemical and metabolic processes to individuals, species distribution and community assemblages (U.S. EPA 2010b). Aquatic insects (Merritt et al. 2008) and other aquatic species (U.S. EPA 2010b) are adapted to the ranges of stream temperatures in which they evolved. Also, warmer in-stream temperatures "increase the toxicity of ammonia and also affect the survival of pathogens" (Burton and Pitt 2002, p. 75).

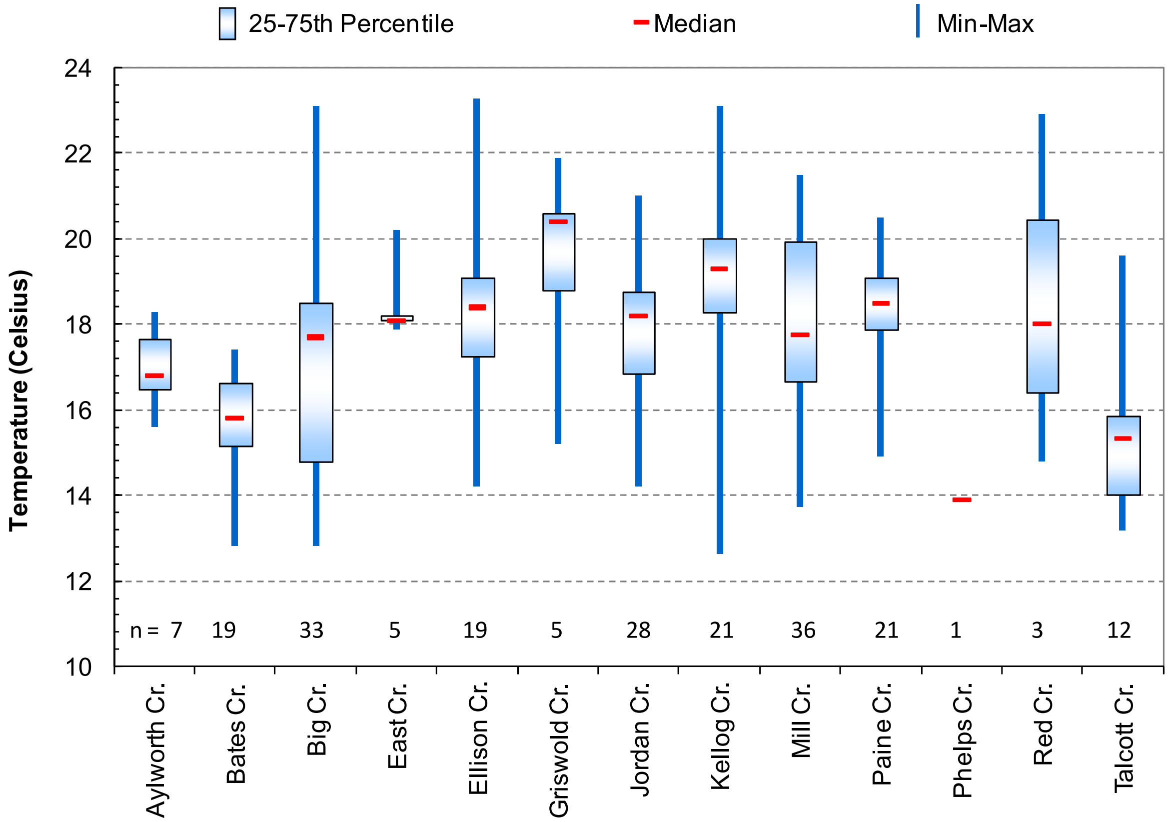
The water temperatures of streams and rivers running through undeveloped or minimally developed areas are controlled by shade along the riparian corridor and the influx of ground water (Burton and Pitt 2002;

Shaver et al. 2007). Vegetated riparian corridors provide shade to the water flowing in the streams. In ground water-fed streams, shallow aquifers are a significant source of cold water.

Urban streams tend to be warmer for a variety of reasons. The loss of riparian vegetation, including tree cover, prevents shading (Burton and Pitt 2002; Schueler 2004). "During the summer months, impervious areas can have local air and ground temperatures that are 10 to 12 degrees warmer than the fields and forest that they replace" (Schueler 1994, p. 3). The altered, urban flow regime can exclude the discharge of cold ground water to urban streams because the installation of impervious surfaces prevents infiltration. The influx of cold ground water could be replaced with the discharge of warmer storm water. Unshaded, impervious surfaces tend to increase in temperatures during the day, and any storm runoff that flows over such surfaces will become warmer. Additional sources of urban-derived temperature increases are point source discharges (e.g., industrial processes, cooling plants), the urban heat island effect (Schueler 2004) and in-stream water impoundment (Burton and Pitt 2002; Schueler 2004).

Water temperatures are interrelated with all other components of the riverine environment and are affected by the flow regime. In an undisturbed stream, water temperatures are primarily regulated by riparian forests via the shade the trees provide along the stream channel (Cappiella et al. 2005, p. 16). In such natural streams, temperatures are already warmer during the summer months because of warmer ambient air temperatures. Flow regime alterations typically include the widening of a stream channel and sedimentation, resulting in more water surface area and shallower pools. Those effects, in combination with less ground water flow during low-flow conditions and removal of riparian cover, result in the water temperatures increasing even more (Burton and Pitt 2002). In addition, higher temperature result in lower dissolved oxygen levels, which can lead to less assimilative capacity of the stream to mitigate nutrient loads.

Lake SWCD collected water temperature data during its Primary Headwaters Habitat Evaluations. Those data for pertinent streams in the lower Grand River are presented in Figure 7-11. The data were generally limited to one sample per primary headwaters stream, and data were usually collected between 8:30 a.m. and 3:00 p.m. Data from the headwaters streams were aggregated by the downstream Ohio EPA assessment stream.



Temperatures were collected from multiple primary headwaters habitat streams that are tributaries to the named streams that Ohio EPA assessed in 2003 and 2004. Headwaters streams' temperature data were aggregated by the named waterbody that they eventually discharged to.

Figure 7-11. Lake SWCD primary headwaters streams temperature data.

A comparative evaluation of Ohio EPA temperature data and subwatershed imperviousness was inconclusive. The data show that a predictive relationship does not exist between the level of impervious cover in a subwatershed in the lower Grand River watershed and the field-collected in-stream temperatures (for a graphical summary of the data, see Appendix E). Ohio EPA's hourly temperature data collected via a DataSonde were not evaluated because such data were collected at only three sites, which were all in full attainment and had low levels of impervious cover. Similar evaluations of Ohio EPA field-collected temperature data and land cover within a 200-foot stream buffer were also inconclusive.

7.1.6. Runoff Pollutants

Urban development and impervious cover affect the quantity of water in urban streams and the quality of the water. Urban storm water runoff can contain elevated levels of such pollutants as bacteria, metals, nutrients, pesticides, petroleum hydrocarbons, and sediment. Many of those pollutants including copper, chlorine, zinc, cadmium, lead, petroleum hydrocarbons, and deicers are potentially toxic to aquatic life (Schueler 2004). Urban land uses are the dominant land uses within the Big Creek (RM 16.0), Kellogg Creek (RM 3.3) and Red Creek (at outlet) watersheds accounting for 51 percent, 81 percent, and 60 percent of the watershed area, respectively. It is therefore expected that pollutants typically found in urban storm water will be present in these streams.

In a review of literature, Pitt et al. (1995) found that beneficial uses of receiving waters can be impaired by urban storm water that contains conventional and toxic pollutants. Masterson and Bannerman (1994) concluded that Milwaukee County urban streams were impaired for their biological and recreational uses because of storm water runoff.

In the lower Grand River watershed, metals, nutrients, and sediment are all pollutants of concern. Monitoring data summarized in Section 4 identifies detections of various metals and other pollutants in stream samples. It is often the combination of pollutants in urban storm water that results in undesirable conditions in the stream for aquatic communities.

The type of development and land uses generally determine the quality of and constituents in the storm water (Shaver et al. 2007) as does the level of automobile activity (Burton and Pitt 2002). Storm water from transportation land uses (e.g., roads, bridges, service stations) can contain petroleum hydrocarbons or copper derived from brake pads whereas storm water derived from washoff of fertilized residential lawns, golf courses, and manicured or landscaped areas can contain elevated levels of nutrients (Shaver et al. 2007). Urban and suburban storm water runoff characteristics typically differ considerably as compared to rural and undeveloped areas (Pitt et al. 1995; U.S. EPA 1983).

Any constituents that are deposited on impervious surfaces will typically remain there until they are picked up and transported by urban storm water. In undeveloped areas, some constituents will be transported to shallow aquifers as water infiltrates. However, because infiltration cannot occur on impervious surfaces, pollutants that accumulate on impervious surfaces will be rapidly carried to surface waterbodies through runoff or storm water conveyance systems where they can pose a risk to human and ecological health (Shaver et al. 2007; Schueler 1994).

Many toxic constituents bond to particulate matter and can be transmitted in storm water while adsorbed to the sediment. For example, “hydrocarbons are normally attached to sediment particles or organic matter carried in urban runoff” (Shaver et al. 2007 p. 3-48). Because storm water tends to travel rapidly over impervious surfaces, the high-velocity water has an increased “ability to detach sediment and associated pollutants, to carry them off site, and to deposit them downstream” (Burton and Pitt 2002, p. 31). The sediment and adsorbed pollutants can accumulate in bottom sediments “where they are readily available to aquatic organisms and possible resuspension during future storm events” (Masterson and Bannerman 1994, p. 131). Sedimentation can increase in downstream ponds or slower-moving streams when sediment-laden, high-velocity storm water discharges to the waterbodies.

Pitt et al. (1996, p.4) evaluated urban storm water and found that metals were typically detected in high concentrations. Masterson and Bannerman (1994) generally found that heavy metal concentrations in urban streams in Wisconsin exceeded the concentrations in reference streams. Stress and lethality to aquatic organisms can occur from episodic exposure to storm water laden with metals (Burton and Pitt 2002, p. 77). The typical sources of nutrients (e.g., nitrates and phosphates) in urban runoff include fertilizer washoff from lawns, landscaped areas, and golf courses (Shaver et al. 2007, p. 3-47).

Table 7-3 presents a summary of an evaluation of pollutant concentrations from runoff; additional examples are presented in Appendix F. Pollutant concentrations tended to be higher in more developed land uses (e.g., zinc in urban versus suburban as shown Table 7-3). The tables in Appendix F include data that also show that metals, nutrient, and TSS concentrations tend to increase as the level of development and impervious cover increases.

Table 7-3. Concentrations (mg/L) of pollutants in runoff from various land uses

Land use	NO_3-N	TKN	NH_3-N	TP	Zinc	Lead	Copper
Urban	8.90	7.20	1.10	1.08	0.397	0.389	0.105
Commercial	0.84	1.49	--	--	0.250	0.370	--
Suburban	0.48	1.51	0.26	0.26	0.037	0.018	--
Forest	0.17	0.61	0.07	0.15	--	--	--

Source: Based on Schueler 1987.
Values are reported in mg/L.
NH_3-N = ammonia (as nitrogen); NO_3-N = nitrate (as nitrogen); TKN = total Kjeldahl nitrogen; TP = total phosphorus

Schueler (2004) found that the unit area pollutant load that is delivered to a stream increases as the impervious cover in a subwatershed increases. In a review of several studies, Burton and Pitt (2002) showed that loads tend to increase as the level of development increases (for a summary of their results, see Appendix F Table F-3). For the lower Grand River, an evaluation using the Spreadsheet Tool for Estimating Pollutant Loading (STEPL; U.S. EPA 2006) showed that nitrogen loads from urban land cover to be 10 times as large as those from forest land cover; similarly, urban phosphorus loads to be 20 times as large as forest phosphorus loads (Table 7-4).

Table 7-4. STEPL nutrient loads for forest and urban land covers

Land cover	Nitrogen load (lb/y/ac)	Phosphorus load (lb/y/ac)
Forest	0.24	0.54
Urban	2.82	11.0

STEPL was run twice using system defaults and selecting Ohio as the state, OH Cleveland WFSO AP for the rain gage, and HSG D. STEPL was first run for a 1 acre watershed of urban land, with default urban land use distribution, and was run again for a 1 acre watershed of forested land.

7.2. *Effects of Nutrients on Water Quality*

Nutrients rarely approach concentrations in the ambient environment that are toxic to aquatic life; in fact, nutrients are essential in minute amounts for the proper functioning of healthy aquatic ecosystems. However, nutrient concentrations in excess of those minute needs can exert negative effects on the aquatic ecosystem by increasing algal and aquatic plant life production (Sharpley et al. 1994). Increased plant production increases turbidity, decreases average dissolved oxygen concentrations, and increases fluctuations in diurnal dissolved oxygen and pH levels. Such changes shift aquatic species composition away from functional assemblages composed of intolerant species, benthic insectivores, and top carnivores that are typical of high-quality streams toward less desirable assemblages of tolerant species, generalists, omnivores, and detritivores that are typical of degraded streams (Ohio EPA 1999). Such a shift in community structure lowers the diversity of the system.

In its evaluation of biological data for reference (i.e., least-affected) streams, Ohio EPA found that IBI and ICI scores did not meet the WWH biocriteria when associated with higher levels of total phosphorus, except when covariates (e.g., sediment) were present (Ohio EPA 1999, p. 26). Ohio EPA further concluded that "[t]he processing of nutrients in lotic ecosystems is complex, variable, and affected by abiotic factors such as flow, gradient, ground water quality and quantity, and channel morphology" (Ohio EPA 1999, p.10). The association between IBI and ICI and nitrate was more variable than with total phosphorus: higher nitrate levels were related to index scores in headwaters and wading streams but not larger rivers (Ohio EPA 1999, p. 29). Higher nitrate levels in the EOLP ecoregion that affect index scores could be derived from ammonia from wastewater treatment facilities and livestock operations and might not be reflective of habitat quality (Ohio EPA 1999, p. 30).

An in-depth summary of the effects of nutrients on aquatic life and the interrelationships of water quality, habitat, and biota are presented in the *Associations* document (Ohio EPA 1999).

Evaluations of nutrients and impervious cover for data collected at Ohio EPA's assessment points in the western portion of the lower Grand River watershed were inconclusive. An example of such an evaluation is presented in Figure 7-12, which shows that total phosphorus concentrations across the lower Grand River watershed are highly variable as levels of impervious cover vary. Generally, those evaluations showed that only ALU attainment and biologic community scores are associated with the level of impervious cover, with full attainment and good or better scores still being achievable with high levels of subwatershed impervious cover when wide, connected riparian corridors are present.

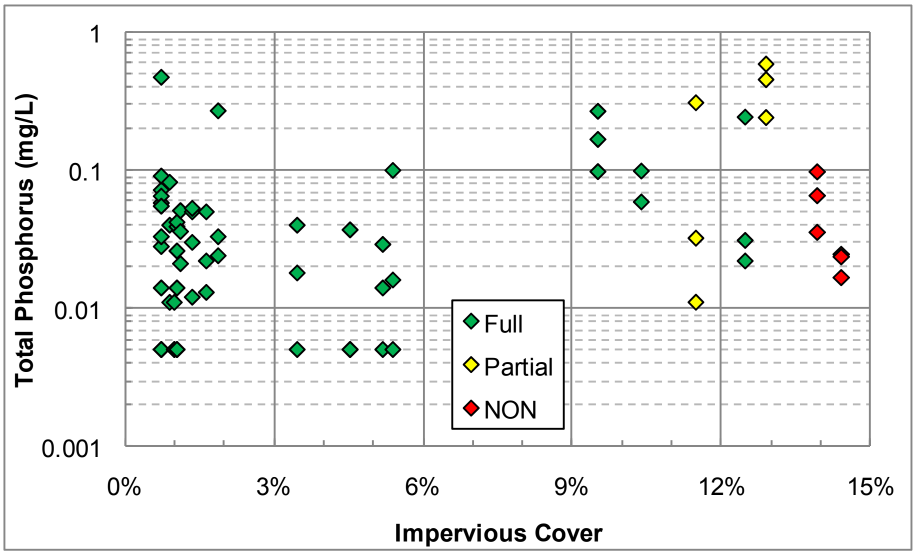


Figure 7-12. Example of an evaluation of nutrients and impervious cover.

7.3. Surrogate Measures and Setting Hydrologic Targets

The impairments for certain streams in the lower Grand River watershed are primarily caused by flow alteration and the related impacts from various pollutants as discussed in Sections 7.1. No one pollutant is causing the impairment; rather, a combination of pollutants and flow imbalance alter the normal stream processes and cause stream degradation. Restoring the proper flow regime to the streams by controlling flow and volume will result in the recovery of normal stream processes and attainment of the biocriteria. Thus, flow and volume are used as surrogates for pollutants of concern. The *Report of the Federal Advisory Committee on the Total Maximum Daily Load (TMDL) Program* (U.S. EPA 1998) offers guidance on the use of surrogate measures in TMDL development. The FACA report indicates,

> When the impairment is tied to a pollutant for which a numeric criterion is not possible, or where the impairment is identified but cannot be attributed to a single traditional "pollutant," the state should try to identify another (surrogate) environmental indicator that can be used to develop a quantified TMDL, using numeric analytical techniques where they are available, and best professional judgment where they are not. The criterion must be designed to meet water quality standards, including the waterbody's designated uses. The use of best professional judgment does not imply lack of rigor; it should make use of the "best" scientific information available, and should be conducted by "professionals." When best professional judgment is used, care should be taken to document all assumptions, and best professional judgment based decisions should be clearly explained to the public at the earliest possible stage (FACA 1998).

In addition, U.S. EPA issued a Memorandum on November 12, 2010 (U.S. EPA, 2010a) titled *Establishing TMDL Wasteload Allocations for Storm Water Sources and NPDES Requirements Based on Those WLAs*, which addresses the use of surrogate pollutant parameters, including flow and volume, to establish targets for TMDL loading capacity. The use of surrogate pollutant parameters is described as a suitable approach when storm water sources are identified as the primary source of impairment.

This section provides a summary existing flow-based TMDLs and the methodology for establishing hydrologic targets in the lower Grand River watershed.

7.3.1. Existing Flow-Based TMDLs

Connecticut, Maine, and Vermont have all successfully completed TMDLs for flow-based surrogate pollutants including impervious cover and storm water volume.

Connecticut Impervious Cover TMDLs

In Connecticut, the Eagleville Brook TMDL (CDEP 2007) was approved by U.S. EPA in 2007. That TMDL used impervious cover as a surrogate pollutant to represent the effects of storm water runoff and mixed pollutants to the stream. The TMDL is established as the percent impervious cover within the watershed that must be achieved to meet the designated uses. Eagleville Brook's TMDL is set at 12 percent, with a 1 percent explicit margin of safety. Reductions in impervious cover needed to meet the TMDL range from 59 percent to no reduction needed as determined by existing impervious cover estimates. Eagleville Brook has a small watershed (2.4 square miles) and was listed as impaired for ALUs in 2004. An SI process identified the stressor as a "complex array of pollutants transported by storm water." The SI process demonstrated the connection between impervious cover, storm water, and the health of the aquatic community.

In the Eagleville Brook TMDL, a reference stream approach was used to develop a relationship between impervious cover and macroinvertebrate community health (CDEP 2005). That relationship was based on analysis of watersheds smaller than 50 square miles, impervious cover percentages derived from GIS-based land cover data, and biological data from Rapid Bioassessment Protocol level III efforts. In total, 125 sites distributed throughout the state were evaluated using scatter and box plots and summary statistics to develop a relationship between taxa richness, EPT (Ephemeroptera, Plecoptera, and Trichoptera) richness and watershed imperviousness. Streams were then split into two groups, those that met state water quality criteria and those that did not, and evaluated to identify a threshold of imperviousness over which streams no longer met aquatic life criteria. From that analysis, a target of 12 percent impervious cover was established for impaired watersheds. The TMDL states, "It is recognized that impervious cover may not be the direct factor causing the impairment, but that there is a strong enough relationship to use impervious cover as a surrogate measure in situations when an SI analysis has determined that storm water is the primary candidate cause of the aquatic life impairment" (CDEP 2007).

Maine Impervious Cover TMDLs

In Maine, three TMDLs have been approved by U.S. EPA that used impervious cover as a surrogate pollutant: Birch Stream (2006), Barberry Creek (2006), and Trout Brook (2007). Each of the three streams was listed as impaired for aquatic life, and each of those TMDLs uses impervious cover as a surrogate pollutant to represent the effects of storm water runoff and mixed pollutants to the stream. The TMDLs are established as the percent impervious cover within the watershed that must be achieved to meet the designated uses. The TMDLs follow the methods outlined in *TMDL Applications Using the Impervious Cover Method* developed by ENSR (2005) to establish the TMDLs. An SI process was completed for all three TMDLs simultaneously.

In Maine, statewide impervious cover targets were determined according to Maine Department of Environmental Protection (MDEP) guidance (MDEP 2005) using MDEP data, literature, and local watershed characteristics. Biomonitoring data (43 samples) were evaluated in 32 watersheds between 1994 and 2004. Monitoring sites were in watersheds with varied percent imperviousness (minimum 5 percent impervious cover) in first- to third-order streams. TMDL percent impervious cover targets range from less than 6 percent to 15 percent depending on class of water.

Urban stressors were identified during an SI process as the primary cause of impairment (failure to attain aquatic life criteria) within each of the impaired streams. MDEP developed a document titled *Percent Impervious Cover TMDL Guidance for Attainment of Tiered Aquatic Life Uses, Draft*, which serves as the linkage analysis in combination with the SI process. The analysis is based on MDEP biomonitoring data from 43 macroinvertebrate samples from 32 watersheds statewide, coupled with available literature linking imperviousness with changes in aquatic assemblages and stream quality. Table 7-5 summarizes the biomonitoring data and TMDL targets on the basis of reference streams attaining the ALU criteria and their representative watershed imperviousness.

Table 7-5. Percent impervious cover policy guidelines for expected attainment of Maine's designated ALUs

Statutory class	Class attainment demonstrated in MDEP data at % impervious cover	TMDL target values for % impervious cover (TMDL = WLA + MOS)		
		TMDL	**WLA** [a]	**MOS**
Class AA	~6 % [b]	*Does not apply* [c]		
Class A		<6 %	< 5 % [d]	1%
Class B	~8 %	7 - 10 % [d]	6–9 % [d]	1%
Class C	~15 %	10 - 15 % [d]	8–13 % [d]	2%

Notes

a. Load allocation (LA) is included in the WLA because it is not feasible to calculate separately.
b. For attainment determination, Classes AA and A are combined.
c. Because of the high-priority, sensitive nature of Class AA streams, application of a generalized method such as the percent impervious cover method is not advised.
d. Stream-specific targets will be chosen for each TMDL.

Vermont Flow-Based TMDLs

Vermont has 12 approved stream TMDLs that use storm water runoff volume as the surrogate pollutant for multiple stressors. Vermont storm water runoff TMDLs were approved by U.S. EPA in 2006, 2007, 2008, and 2009. Storm water runoff volume was chosen as the target for the TMDL because of its connection with habitat and physical stressors in streams and its potential to address diminished base flow. Vermont developed a framework called *A Scientifically Based Assessment and Adaptive Management Approach to Storm Water Management* that outlines the steps to completing a storm water runoff TMDL. The TMDLs are set as a percentage reduction needed during high-flow events. A target increase in flow under low-flow conditions is also described in the TMDL, although not an enforceable part of the TMDL. A general narrative related to SI is presented in each TMDL to connect the storm water runoff volume target to the biological community.

The framework developed in Vermont involves the use of reference watersheds (referred to as attainment watersheds) to set hydrologic targets. Hydrologic targets are based on similar watersheds within the same geographic area where the water quality criteria for aquatic life are being met. Flow duration curves are then used to evaluate differences between the reference streams and the impaired streams. The relative difference between the reference and impaired stream flow duration curves are used to establish the TMDL.

Vermont's linkage analysis is based on a stressor identification process that identified flow and sediment as primary stressors, which are then linked to the biological community. An expanded technical analysis was completed to complement the TMDL and describes in detail the linkage analysis. That analysis documents the links between fish and aquatic life, degraded habitat and siltation, erosion and channel scour, stream flow rates and velocities, and storm water volume.

7.3.2. Target-Setting Methodology

Hydrologic targets that will lead to attaining the ALU designation in the lower Grand River watershed are based on a reference, or attainment, stream approach, following the approach used in Vermont. The lower Grand River watershed includes waterbodies that are impaired because of flow alteration affecting both high-flow and low-flow conditions, as described in Section 7.1. The hydrologic targets are provided in the form of a reference flow duration curve.

The first step taken to identify the potential reference streams for use in the Flow Regime TMDLs was to determine which streams Ohio EPA had assessed and which of those streams are fully attaining their ALU designation. The next step was to compile available data (e.g., level IV ecoregions, levels of development). Flow duration curves for each of the potential reference streams were created, and the impacts of urban development and impervious cover on the flow duration curves were evaluated. The final step was to compare potential reference streams with the impaired stream to determine which potential reference stream was best representative of reference conditions for the impaired stream. That final step included evaluating the following factors: ALU attainment, location, size, land cover, and soils. Those evaluations were performed on a case-by-case basis.

Because the objective was to determine which watersheds would be best suited as reference streams for impaired streams, factors related to specific types of developments were not evaluated. For example, the presence of point sources was not evaluated. HRU modeling was dependent on watershed factors and excluded non-scalable factors such as point sources. Thus, when the reference stream selection methodology was developed, only properties of the watershed were considered (i.e., point sources were ignored). The figures in this section that present the unit area flow duration curves of attainment and impaired streams do not account for flow from point sources unless noted. Point source flows will be evaluated as part of TMDL development in Section 9.

In 2003 and 2004 Ohio EPA evaluated 21 creeks in the lower Grand River watershed for attainment of their ALU designations. Thirteen streams fully attain the ALU designations. Streams that were in full attainment that were in close proximity to impaired stream segments were evaluated as potential reference streams. Table 7-6 presents the factors that were also evaluated case by case to select reference streams for each impaired stream. Generally, the final reference streams had similar location and size to the impaired stream, had low levels of development, and had other similar characteristics with the impaired stream. Table 7-7 summarizes the data used in the reference stream evaluation. Figure 7-13 presents unit area flow duration curves for the potential reference streams in the Big Creek – Grand River HUC (04110004 06).[13] The analysis and selected hydrologic targets are provided in the applicable sections below.

---

[13] The two potential reference streams from the Mill Creek – Grand River 10-digit HUC (04110004 04) are not displayed in Figure 7-13 because that 10-digit HUC exhibits different characteristics (e.g., land cover and soil distribution) than the Big Creek – Grand River 10-digit HUC (04110004 06).

Table 7-6. Potential reference stream selection factors

ALU	Location	Size	Land cover	Soils
▪ Designated use ▪ Biotic health indices	▪ Ecoregion ▪ 12-digit HUC ▪ Tributary [a]	▪ Drainage area	▪ Impervious Cover ▪ Developed land ▪ Forested land ▪ Land cover within a 100-foot buffer	▪ Dominant HSGs

a. Preference was given to potential reference streams if they discharged to the stream with impairments at a fully attaining segment that was downstream of the impaired segment.

Table 7-7. Potential reference streams and their data for the selection factors

	Bates Creek	Cutts Creek	East Creek	Ellison Creek	Jenks Creek	Jordan Creek	Phelps Creek	Talcott Creek	UT to Mill Creek	UT to Paine Creek	Big Creek (RM 16.0) [a]	Kellogg Creek (RM 3.3) [b]	Red Creek	Askue Run	Peters Creek	Cemetery Creek (RM 1.2)	Cemetery Creek (RM 2.1)
Aquatic life use																	
Designation [d]	WWH	CWH	CWH	WWH	CWH	CWH	EWH, CWH	CWH	CWH	EWH, CWH	WWH	WWH	WWH	WWH	WWH	WWH	WWH
Attainment	Partial (Natural)	Full	Full	Full	Full	Full	Full	Full	Full	Full	Partial	Partial	NON	Full	Full	NON	NON
Fish [e]	--*	MG	F	G	E	F	--	--*	--*	MG	E	G	F	MG	G	P	P
Macroinvertebrates [f]	E	G	VG	MG	G	G	VG	E	E	E	F	F	LF	G	MG	LF	LF
Location																	
12-digit HUC (04110004)	06 04	06 06	06 06	06 06	06 06	06 06	06 04	06 05	06 02	06 04	06 06	06 06	06 07	04 02	04 02	04 03	04 03
Ecoregion [g]	61c	61c, 61d	61c	61d	61c, 61d	61d	61c	61c, 61d	61c, 61d	61c	61c, 61d	61d	83a	61b	61b	61b	61b
Subwatershed																	
Area (sq. mi.)	11.9	1.8	5.2	6.4	2.8	4.4	3.1	5.5	3.8	3.0	1.5	4.6	9.3	5.2	3.7	4.7	4.3
Developed Land [h]	7%	24%	6%	51%	12%	31%	9%	4%	7%	4%	51%	81%	60%	7%	4%	34%	32%
Forested Land [i]	54%	43%	55%	40%	56%	57%	48%	60%	54%	53%	38%	15%	20%	38%	50%	31%	32%
Impervious Cover [j]	1%	5%	1%	11%	2%	5%	2%	1%	1%	1%	13%	15%	14%	1%	1%	9%	8%
100-foot buffer on each bank																	
Developed Land	4%	14%	3%	48%	7%	18%	6%	4%	7%	3%	43%	75%	51%	7%	4%	23%	24%
Forested Land	77%	61%	78%	47%	74%	79%	76%	80%	81%	78%	45%	20%	31%	57%	45%	54%	52%
Hydrologic soil groups																	
Dominant HSG (%)	C/D (46%)	C/D (43%)	C/D (51%)	C/D (50%)	C (46%)	C/D (67%)	C/D (49%)	C/D (69%)	C/D (45%)	C/D (56%)	C/D (43%)	D (31%)	C/D (35%)	C/D (67%)	C/D (61%)	C/D (67%)	C/D (69%)
Second Dominant HSG (%)	C (28%)	C (38%)	D (41%)	D (25%)	C/D (42%)	C (15%)	D (24%)	C (19%)	D (34%)	C (22%)	C (23%)	B/D, C (21%)	A (26%)	D (26%)	D (29%)	D (25%)	D (24%)

Notes

a. The TMDL on Big Creek at RM 16.0 will address the ALU partial attainment at RM 16.2; the sources of impairment for both assessment sites include urban runoff and storm sewers, which affect the flow regime.

b. The TMDL on Kellogg Creek at RM 3.3 will address the ALU non-attainment at RM 5.7 (both fish and macroinvertebrates were poor); the sources of impairment for both assessment sites include urban runoff and storm sewers, which affect the flow regime.

c. No TMDLs are being developed for Cemetery Creek .

d. ALU designations promulgated in OAC-3745-1: coldwater habitat (CWH), exceptional warmwater habitat (EWH), and warmwater habitat (WWH).

e. Narrative scores for the Index of Biotic Integrity: excellent (E), very good (VG), good (G), marginally good (MG), fair (F), low fair (LF), and poor (P).

f. Narrative scores for the Invertebrate Community Index or qualitative assessment: Excellent (E), very good (VG), good (G), marginally good (MG), fair (F), low fair (LF), and poor (P).

g. Level IV ecoregions: Erie/Ontario Lake Plain (83a), Mosquito Creek/Pymatuning Lowlands (61b), Low Lime Drift (61c), Erie Gorges (61d), and Summit Interlobate Area (61e).

h. Summation of four developed land cover classes from the 2001 NLCD: open, low, medium, and high.

i. Summation of three forested land cover classes from the 2001 NLCD: deciduous, evergreen, and mixed.

j. Calculation of watershed impervious cover from 2001 NLCD.

* Ohio EPA did not report a narrative fish score because of the influence of coldwater.

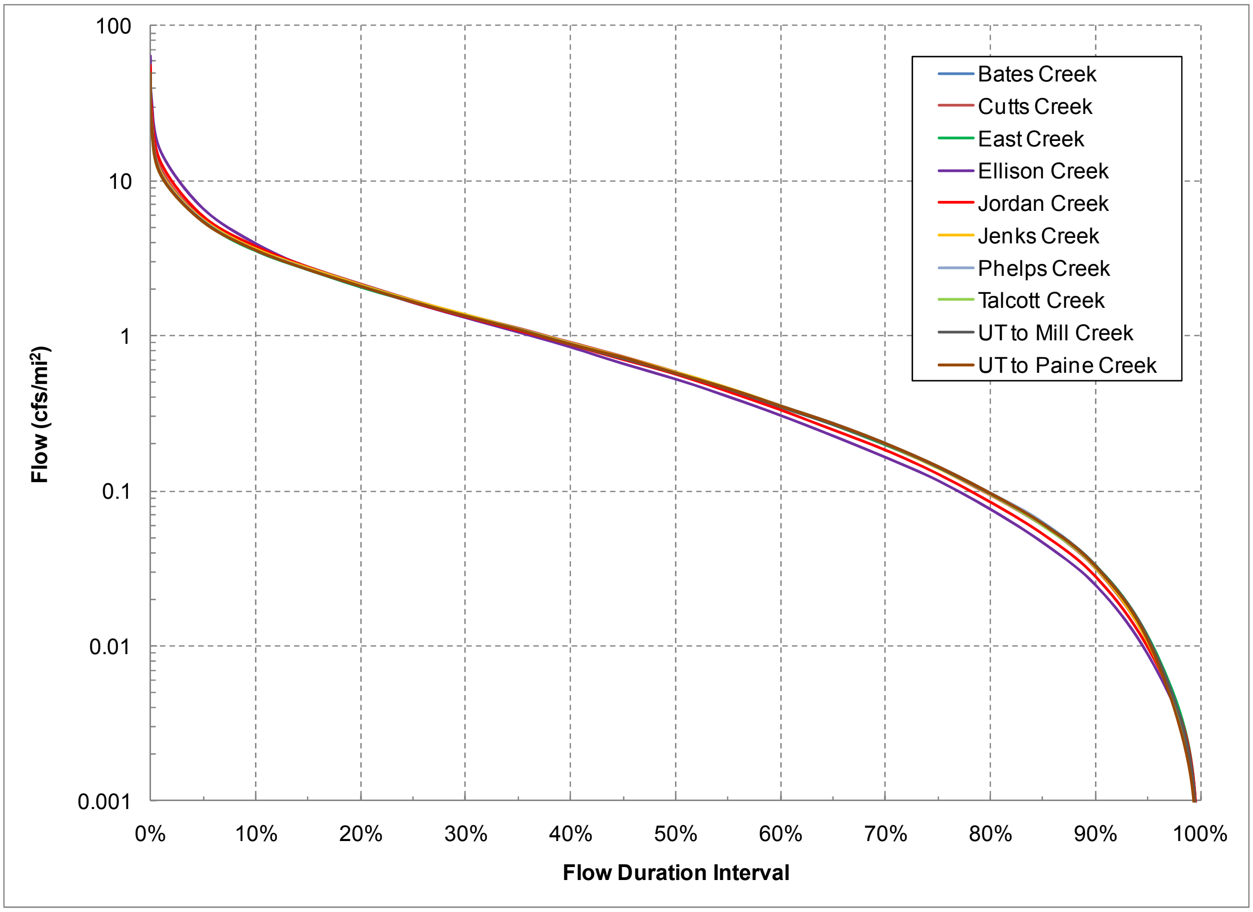


Figure 7-13. Flow duration curves of potential reference streams in the Big Creek – Grand River 10-digit HUC (04110004 06).

As shown in Figure 7-13, most of the potential reference streams in the western portion of the watershed have very similar unit area flow duration curves. That is expected because most of the land cover and soil factors that were used to develop the HRUs were similar for most of the potential reference streams. On a per unit area basis, it is expected that two relatively undeveloped streams with similar relative levels of various land covers and soils would result in similar flow conditions.

However, some of the curves deviate in the high-flow, dry conditions, and low-flow zones. An example of the deviations is shown in Figure 7-14. Ellison Creek, Jordan Creek, and Cutts Creek are the three streams that deviate from the rest. That was also expected because those streams exhibit the highest amount of developed land and impervious cover of all potential reference streams. For a discussion of how the gradient of development is evident in the unit area flow duration curves for Ellison Creek and Jordan Creek, see Figure 7-4 and its accompanying text.

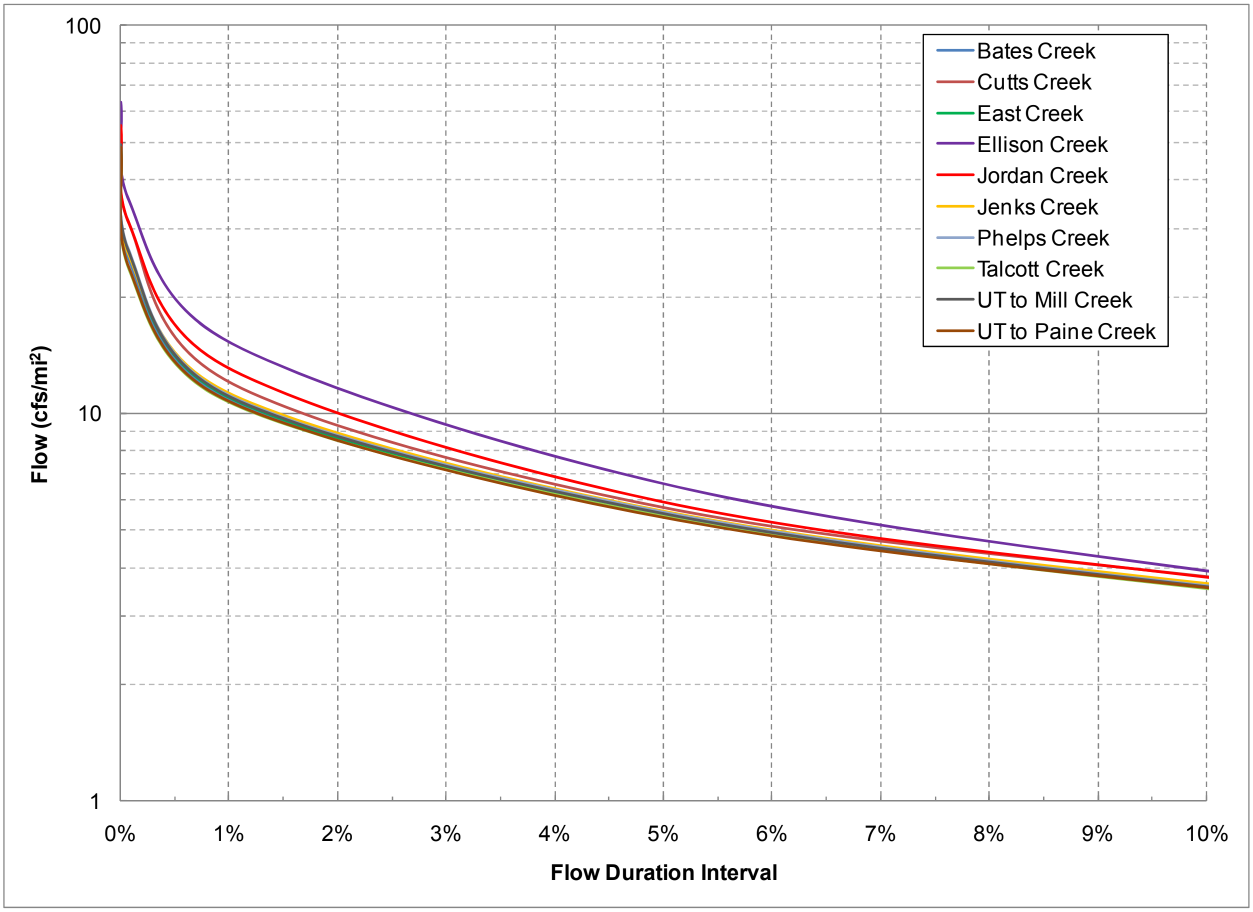


Figure 7-14. High-flow zone of the flow duration curves for the potential reference streams in the Big Creek – Grand River 10-digit HUC (04110004 06).

7.4. Big Creek (HUC 04110004 06 06)

ALU is impaired on Big Creek near Chardon. The city of Chardon is not an MS4 community but does have a WWTP, and storm water runoff will drain to Big Creek. Ohio EPA has documented the impacts of urbanization in the headwater areas of Big Creek at RM 16.0 and 16.2. The assessment site at RM 16.0 is partially impaired for ALU because of the impacts of urbanization and is selected as the TMDL location, on which allocations are based, because it is the most downstream assessment point impaired by urbanization.

The 2003 IBI scores for Big Creek were *excellent* in the headwaters (RM 16.0 and 16.2) and *very good* (RM 9.3) or *good* (RM 14.0, 4.9, and 2.5) along the rest of the creek to the mouth. Also, the 2000 IBI score at RM 0.5 was *good*. MIwb scores from 2003 at RM 4.9 and 2.5 were good and fair (respectively); a 2000 score at RM 0.6 was *moderately good*. Thus, the best fish communities were present in the headwaters, and the communities became slightly less healthy (though mostly still in attainment) along the creek to the mouth. Ohio EPA identified an impairment caused by natural conditions at RM 2.5 where the MIwb scored *fair* (7.082).

The opposite trend was generally true for the macroinvertebrate data. The lower reaches of Big Creek had *excellent* ICI scores (RM 2.7 and 4.8) and *fair* scores in the headwaters (RM 16.0 and 16.2). Big Creek at RM 13.8 had a *very good* ICI score and a qualitative score at RM 9.5 was *good*.

7.4.1. Flow Regime

Figure 7-15 is the estimated flow duration curve at Big Creek RM 16.0 with and without the Chardon WWTP flows. This site is downstream of Chardon and the Chardon WWTP. The watershed contains 13 percent imperviousness. A comparison between the two flow duration curves identifies the effect that flows from the WWTP have on Big Creek. The Chardon WWTP is the dominant source of flow during low-flow conditions at RM 16.0. The WWTP's discharge provides for constant base flow in Big Creek, thus providing a buffering effect during low-flow conditions. On the basis of the available data, the Chardon WWTP is not contributing to the ALU impairment at RM 16.0. However, upstream of the WWTP, development and associated imperviousness has negatively affected the flow regime.

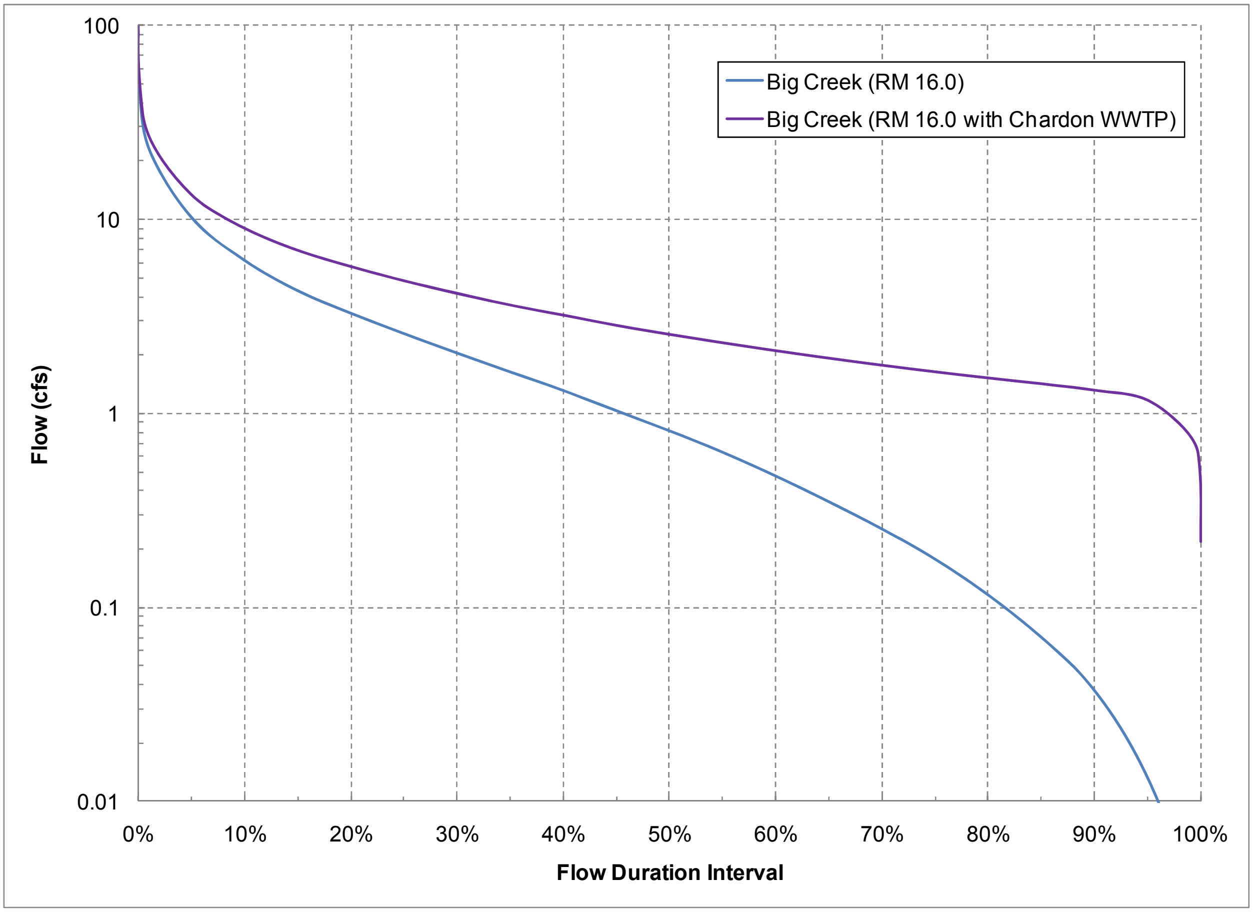


Figure 7-15. Big Creek flow duration curves.

Hydrologic Target

A hydrologic target was developed for Big Creek at RM 16.0 for use in TMDL development. Results of the methodology presented in Section 7.3 are provided below.

The contributing drainage area to Big Creek at RM 16.0 is 1.5 square miles. No other potential reference stream drains such a small area; therefore, size was not a primary factor in selecting a reference stream. The potential reference stream that was closest to that impaired segment of Big Creek was Cutts Creek. However, the evaluation of flow duration curves in Section 7.3 shows that Cutts Creek's flow duration curve is dissimilar to the majority of the full attainment sites and that the subwatershed might be influenced by urban development.

The next closest potential reference stream that is still in the same ecoregion is Jenks Creek, which discharges to Big Creek. The factors used to select Jenks Creek as the reference stream are presented in Table 7-7. Jenks Creek was selected as Big Creek's reference stream because it is in the same ecoregion, is a tributary to Big Creek, has low levels of development, and has high levels of forest cover. Thus, flow regimes in Jenks Creek are the best representation of reference-quality (i.e., least-affected) flow regimes in Big Creek that would result in attainment of ALU. The unit area flow duration curves for Jenks Creek and Big Creek are displayed in Figure 7-16.

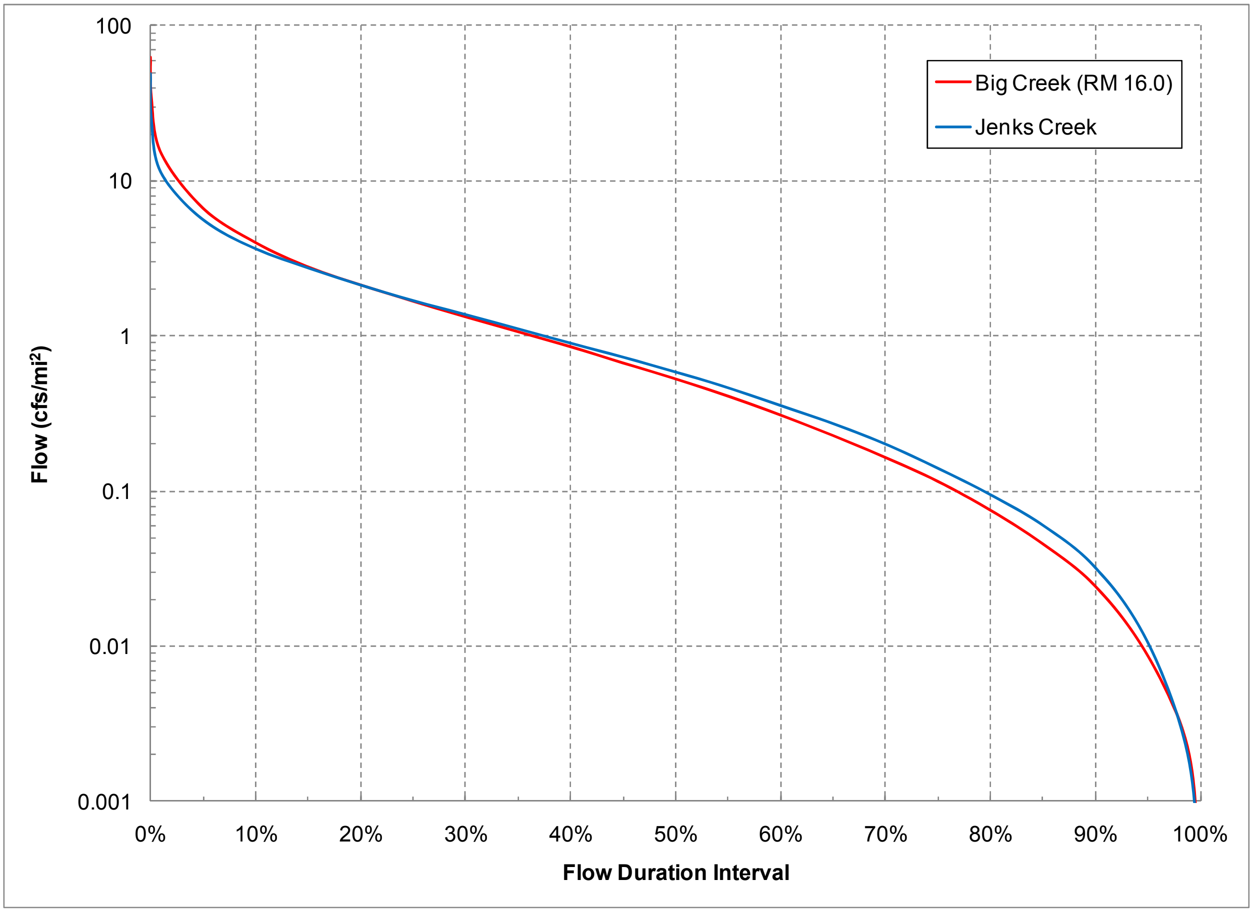


Figure 7-16. Flow duration curves for the impaired stream Big Creek (RM 16.0) and the reference stream Jenks Creek.

7.5. Kellogg Creek (HUC 04110004 06 06)

The designated ALU is impaired on Kellogg Creek. Storm water runoff from the many subdivisions drains to Kellogg Creek. Ohio EPA has documented the impacts of urbanization in the headwater areas of Kellogg Creek at RMs 3.1, 3.3 and 5.7. RM 3.1 is in partial attainment of the ALU; RMs 3.3 and 5.7 are impaired for ALU.

The 2004 IBI scores for Kellogg Creek at RMs 5.7 and 0.2 were *poor* (24) and *good* (44), respectively. The qualitative macroinvertebrate evaluations for those two sites were *poor* and *moderately good*, respectively. Ohio EPA identified sediment from ongoing suburbanization as a potential cause of impairment at RM 5.7. The agency also reported that a better riparian condition exists in the lower reaches of Kellogg Creek and that it might offset some of the biological degradation caused by upstream urbanization.

The 2000 IBI scores for Kellogg Creek at RMs 2.5, 3.1, 3.3, and 0.1 were *good* (44), *very good* (46), *good* (44), and *very good* (46), respectively. The only macroinvertebrate data from 2000 were collected at RMs 3.1 and 3.3; the qualitative data were scored *fair*.

An evaluation of the 2000 and 2004 data shows that fish communities tended to score good or very good from RM 3.3 to the mouth in both years and that fish community impairment appeared to be limited to the upstream reaches of Kellogg Creek. The macroinvertebrate communities' health was generally poorer than the fish communities' health along the entire length of the creek.

RM 3.3 was chosen for further evaluation and TMDL development because that assessment site is the most downstream of the two sites on Kellogg Creek that are impaired by altered flow and pollutants associated with urban runoff. Implementation of the TMDL at RM 3.3 will address the impairment at RM 5.7 and the downstream partial impairment at RM 3.1.

7.5.1. Flow Regime

Figure 7-17 is the estimated flow duration curve at Kellogg Creek RMs 3.3 and 5.7. The TMDL will be generated at the downstream site and will be applicable to upstream areas. At that site, the flow duration curve is based on land uses that include 15 percent impervious cover.

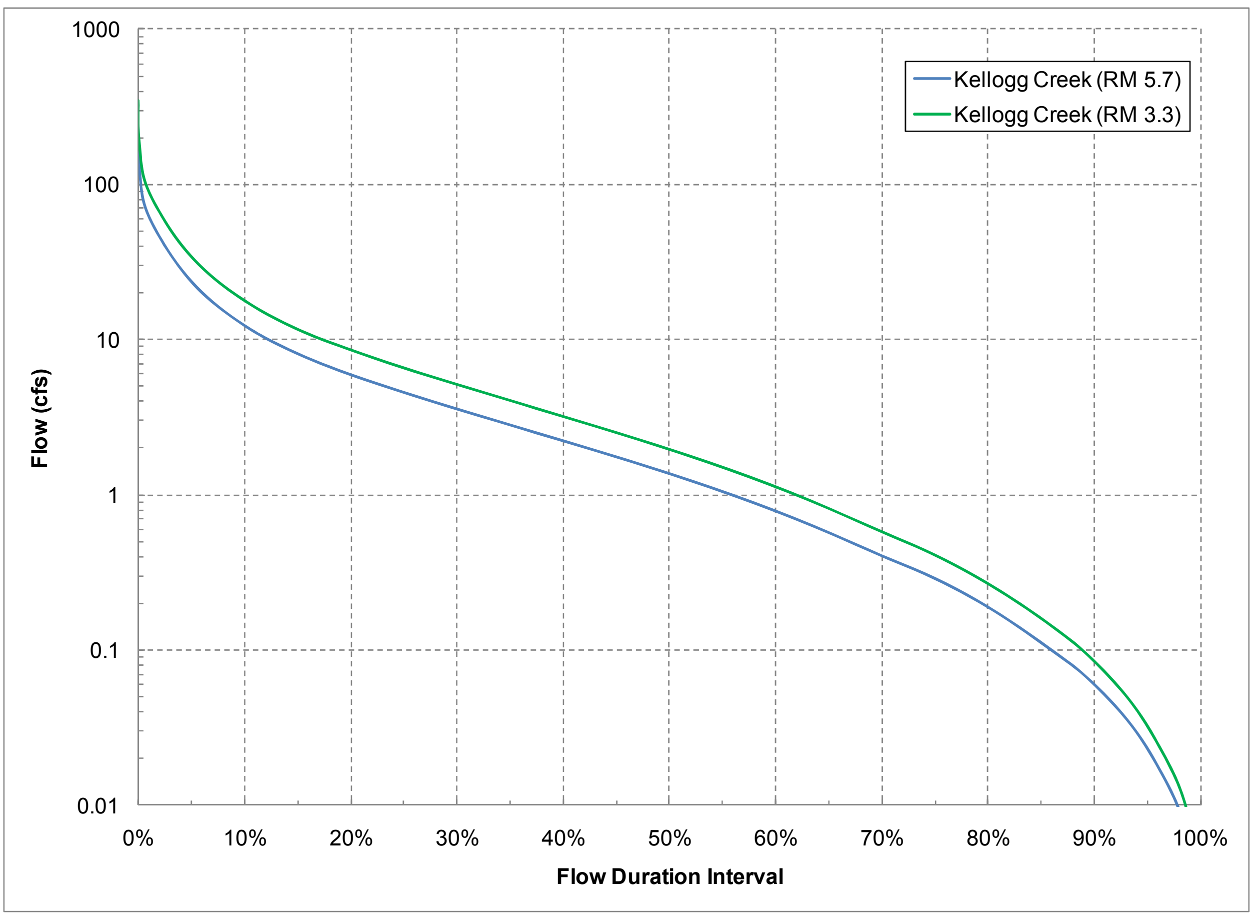


Figure 7-17. Flow duration curves for Kellogg Creek.

Hydrologic Target

A hydrologic target was developed for Kellogg Creek at RM 3.3 for use in TMDL development. Results of the methodology presented in Section 7.3 are provided below. Note that Kellogg Creek is the only waterbody that runs parallel to the Portage Escarpment, which tends to be rich in glacial till (Ohio EPA 2006, p. 65), and the creek receives more ground water than other nearby streams in HUC 04110004 06 06.

The closest two potential reference streams to the impaired segment of Kellogg Creek are Ellison Creek and Jordan Creek. As discussed in Section 7.3, evaluations of flow duration curves showed that Ellison Creek's and Jordan Creek's flow duration curves are dissimilar to the majority of the full attainment sites and that the subwatersheds could be influenced by urban sources of impairment (see the measures of development in Table 7-7).

East Creek is directly east of Jordan Creek and discharges to Big Creek above Jordan Creek's confluence with Big Creek. East Creek was selected because of its size, proximity, and lower levels of development (see Table 7-7); therefore, it provides the best representation of reference-quality (i.e., least-affected) flow regimes in Kellogg Creek that would result in attaining its ALU. Flow duration curves for East Creek and the impaired subwatershed of Kellogg Creek are displayed in Figure 7-18.

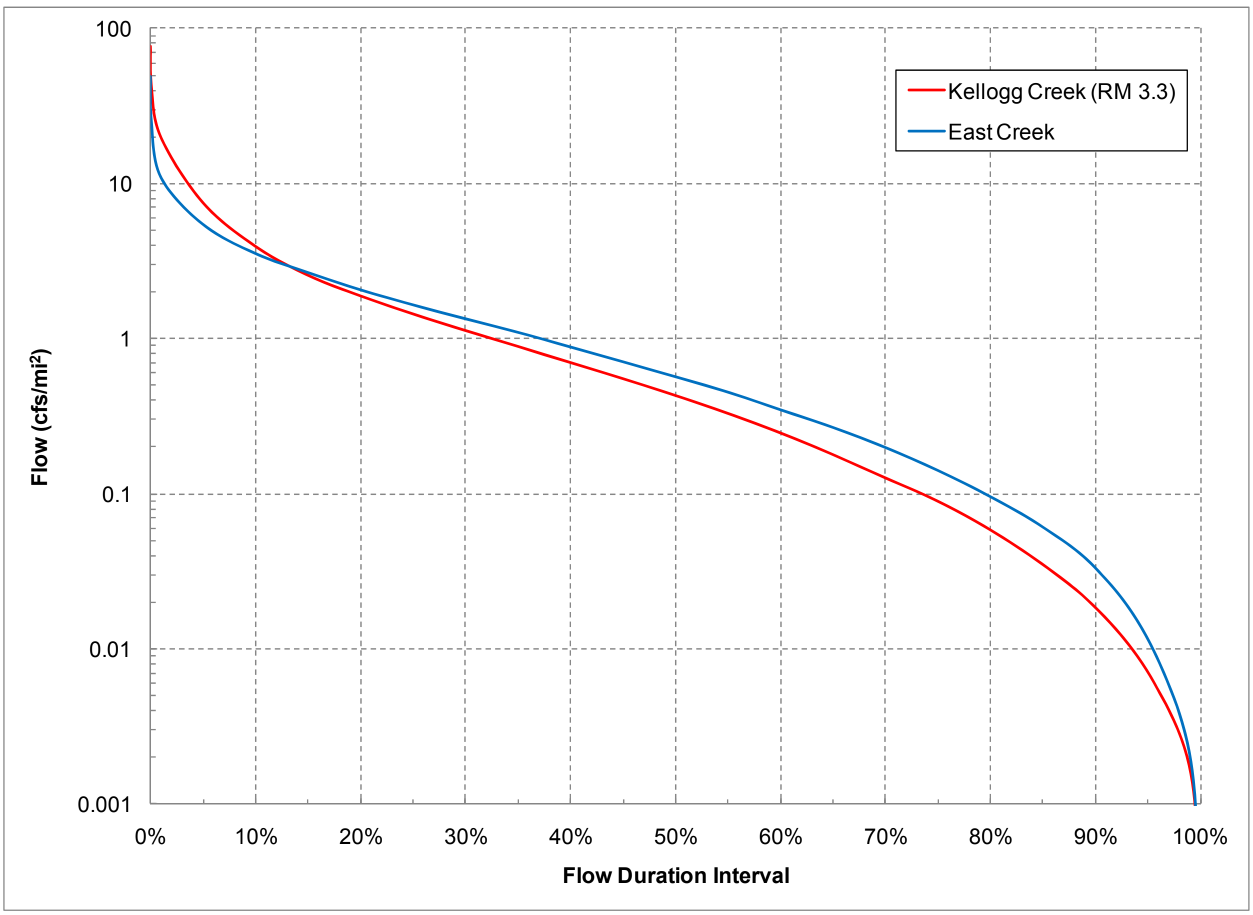


Figure 7-18. Flow duration curves for the impaired stream Kellogg Creek (RM 3.3) and the reference stream East Creek.

7.6. Mill Creek (HUC 04110004 04 02)

Mill Creek at Clay Road (G02G13; RM 25.7) is in non-attainment of its ALU designation (WWH), and on 7/12/2004, Ohio EPA reported that the dissolved oxygen concentration (3.48 mg/L) at the site violated the instantaneous water quality standard (Ohio EPA 2006a). Ohio EPA identified siltation as the cause of impairment, with a source of stream channelization (for agricultural drainage). However, the agency also identified low summer base flow, because of shallow bedrock, as a limiting habitat factor. The 2003 scores for all three biologic community health indices were *fair* (IBI, 30; MIwb, 5.972; and ICI, 24). Ohio EPA found that G02G13 exhibited "nutrient concentrations…elevated relative to the reference condition" and an increased number of modified habitat attributes (Ohio EPA 2006a, p. 2).

Sedimentation at the site was evaluated through the use of TSS as a surrogate. Of the 10 samples analyzed for TSS, 5 were non-detects. When TSS was detected, it ranged from 5 to 42 mg/L with two samples (28 and 42 mg/L) greater than the 75th percentile of TSS concentrations at EOLP reference sites (25.0 mg/L).

The 28 mg/L TSS sample was collected on 9/23/2003. According to the National Climatic Data Center gage at Dorset, precipitation occurred on the day of sampling (1 inch). The previous precipitation occurred on 9/19 and 9/20 (1.7 inches). The 42 mg/L sample was collected on 12/10/2003 at 9:55 a.m. Approximately 0.3 inch of precipitation occurred on the day of sampling. No precipitation occurred during the three preceding days; the previous precipitation was 12/5 to 12/6 (0.4 inches). Regression analyses of flow and precipitation during the day of sampling and the two preceding days with TSS concentrations were inconclusive. However, evaluations confirm the general concept that increasing precipitation and increasing flows usually result in larger in-stream TSS concentrations.

Total phosphorus data collected during moist, mid-range, and dry flows exceeded the TMDL target derived from the 75th percentile of EOLP reference streams data (0.1 mg/L phosphorus, WWH, wading). Nitrite plus nitrate data collected during moist conditions also exceeded the TMDL target (1.0 mg/L nitrogen, WWH). Those evaluations are graphically presented in Figure 7-19. Nutrient sources during moist conditions are derived from precipitation and runoff events. Tile drainage in the area also contributes to nutrient exceedance. On-site wastewater systems and livestock in the watershed likely contribute to the phosphorus exceedances during dry conditions.

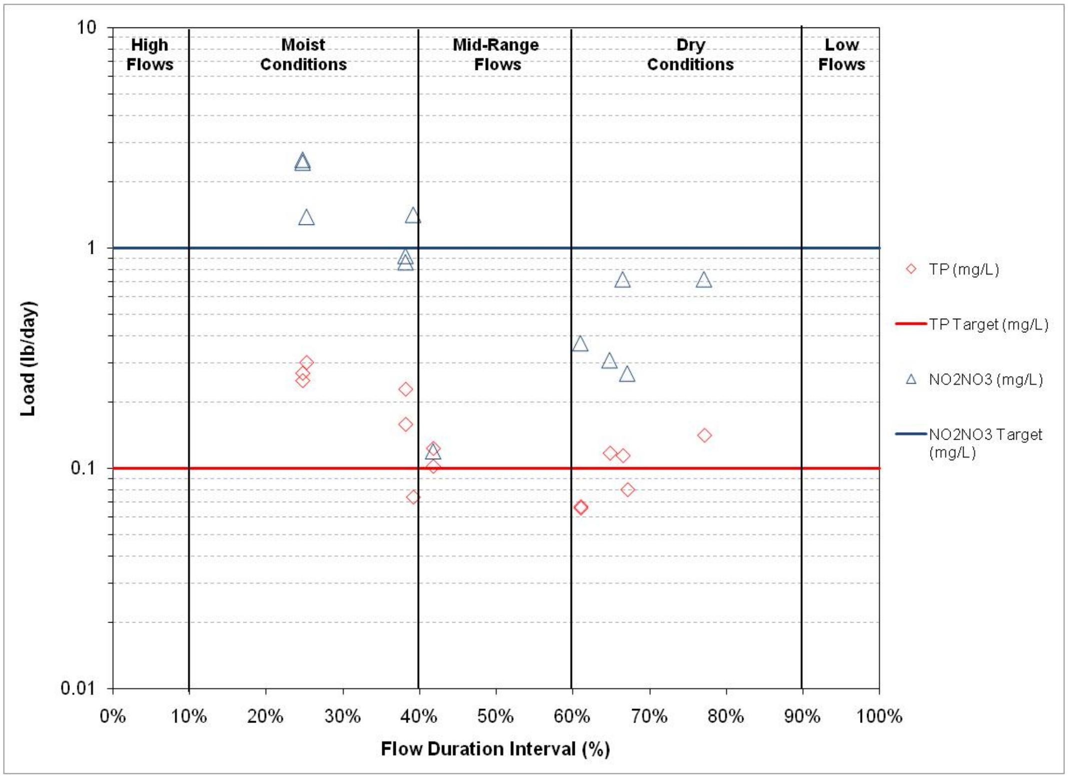


Figure 7-19. Mill Creek nutrient water quality duration curves.

7.7. Red Creek (HUC 04110004 06 07)

Red Creek (G02W09, RM 0.5) is in non-attainment of its ALU designation (WWH). The 2004 IBI score for Red Creek at RM 0.5 was *fair* (30) and the qualitative macroinvertebrate evaluation was *low-fair*. Flow alteration and pollutants associated with urban storm water were identified as a potential cause of impairment, with the potential sources listed as urban runoff and storm sewers. The assessment point for Red Creek is very near the outlet; therefore, the entire watershed was evaluated for TMDL development.

Red Creek is in the EOLP ecoregion (#83a) and has “sustained flow throughout the summer owing to ground water from beach ridges and a thick soil horizon” (Ohio EPA 2006a, p. 66). Thus, Red Creek should be able to sustain WWH communities.

7.7.1. Flow Regime

Figure 7-20 presents the estimated flow duration curve for Red Creek. The Red Creek watershed includes residential development and many acres of nursery operations. The Red Creek watershed has 14 percent impervious cover.

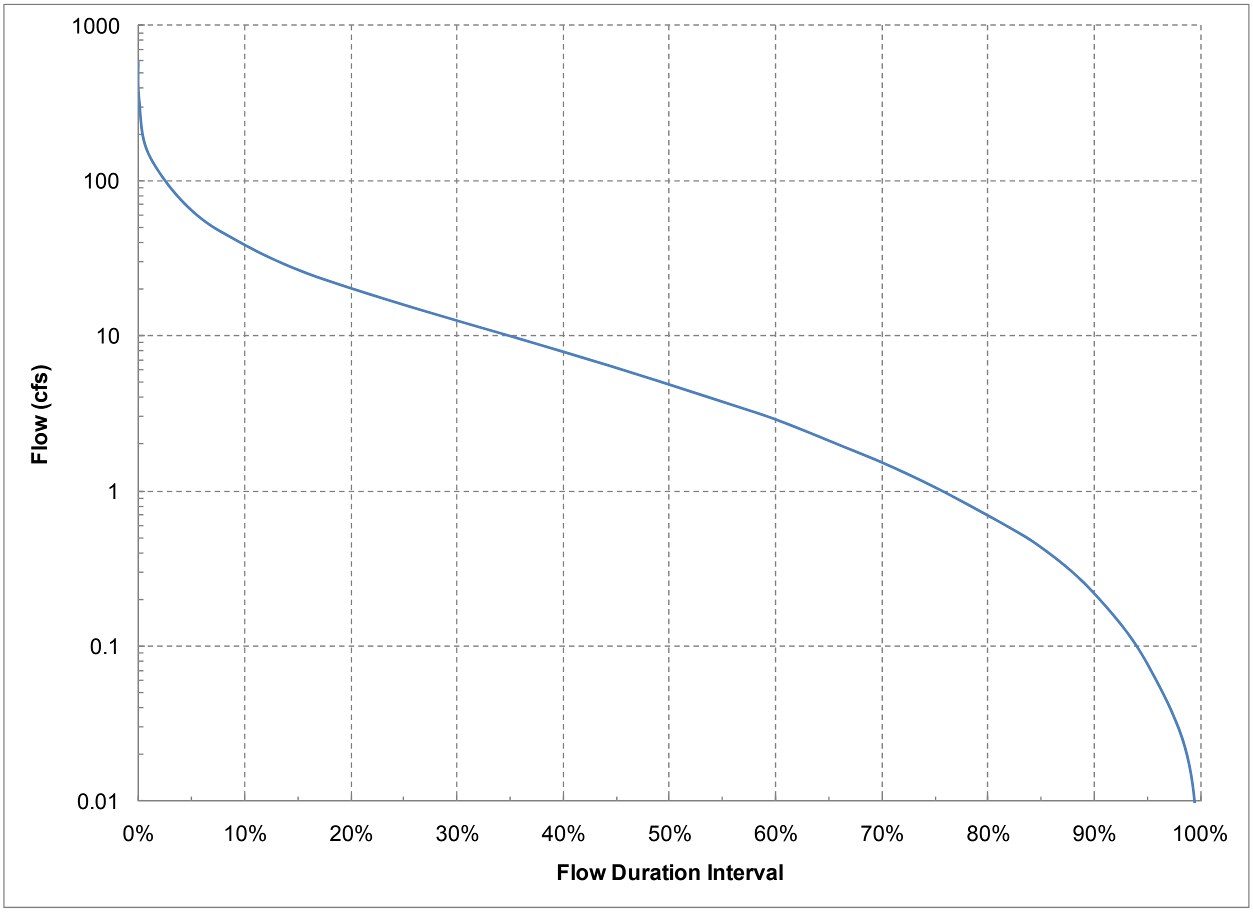


Figure 7-20. Flow duration curve for Red Creek.

Hydrologic Target

A hydrologic target was developed for Red Creek for use in TMDL development. Results of the methodology presented in Section 7.3 are provided below.

Red Creek is impaired along its entire length. No potential reference streams are within Red Creek's ecoregion. Red Creek also has the largest area of HSG A soils (20 percent) than any of the potential assessment streams (0 to 1.5 percent) and other ALU-impaired streams (0 to 4.0 percent). The primary factors for selecting a reference stream are watershed size and proximity to Red Creek.

Bates Creek is southeast of Red Creek, and it discharges to Paine Creek, which is a tributary of the Grand River. Talcott Creek is east-southeast of Red Creek, and it discharges to the Grand River. Both creeks exhibit factors that make them eligible reference streams for Red Creek. Using the available information on stream characteristics, proximity to Red Creek, and best professional judgment, Talcott Creek was chosen as a reference stream for Red Creek because it provides the best representation of reference-quality (i.e., least-affected) flow regimes in Red Creek that would result in attainment of ALU. The flow duration curves for both creeks are displayed in Figure 7-21.

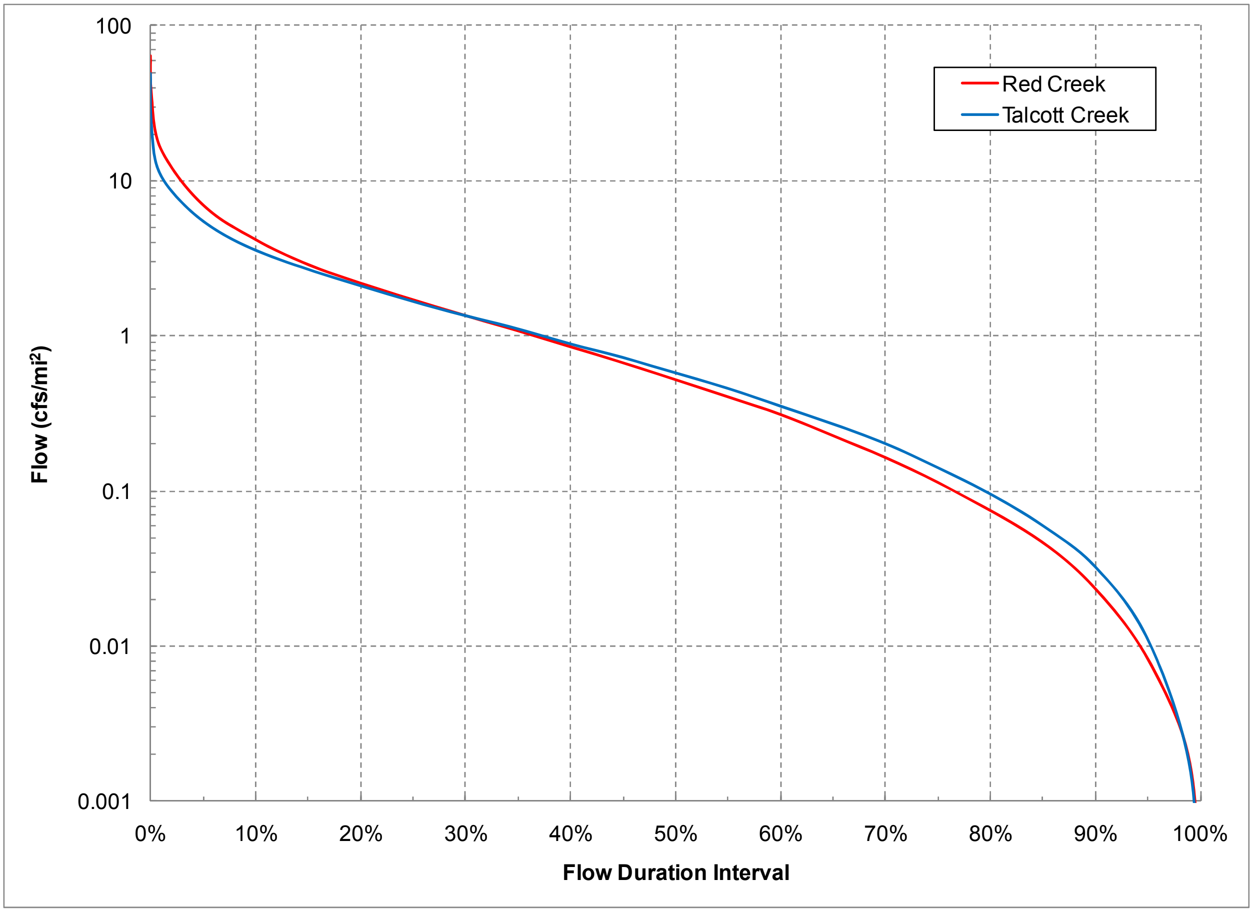


Figure 7-21. Flow duration curves for the impaired stream Red Creek and the reference stream Talcott Creek.

7.7.2. Nutrients

As shown in Figure 7-22, all three nitrate plus nitrite samples exceeded their target (1.0 mg/L nitrogen, WWH), and one of three samples exceeded the total phosphorus target (0.08 mg/L phosphorus, WWH, headwaters streams). Nutrient exceedances occurred during all monitored flow conditions including dry and mid-range flow conditions. Wastewater from HSTS (septic systems) is a probable source during low-flow conditions. Storm water runoff is also a likely source during mid-range flow conditions. The land uses in the Red Creek watershed at the time of the biosurvey included large areas of unsewered homes and intensive nursery production. Since then, many of the homes have been sewered.

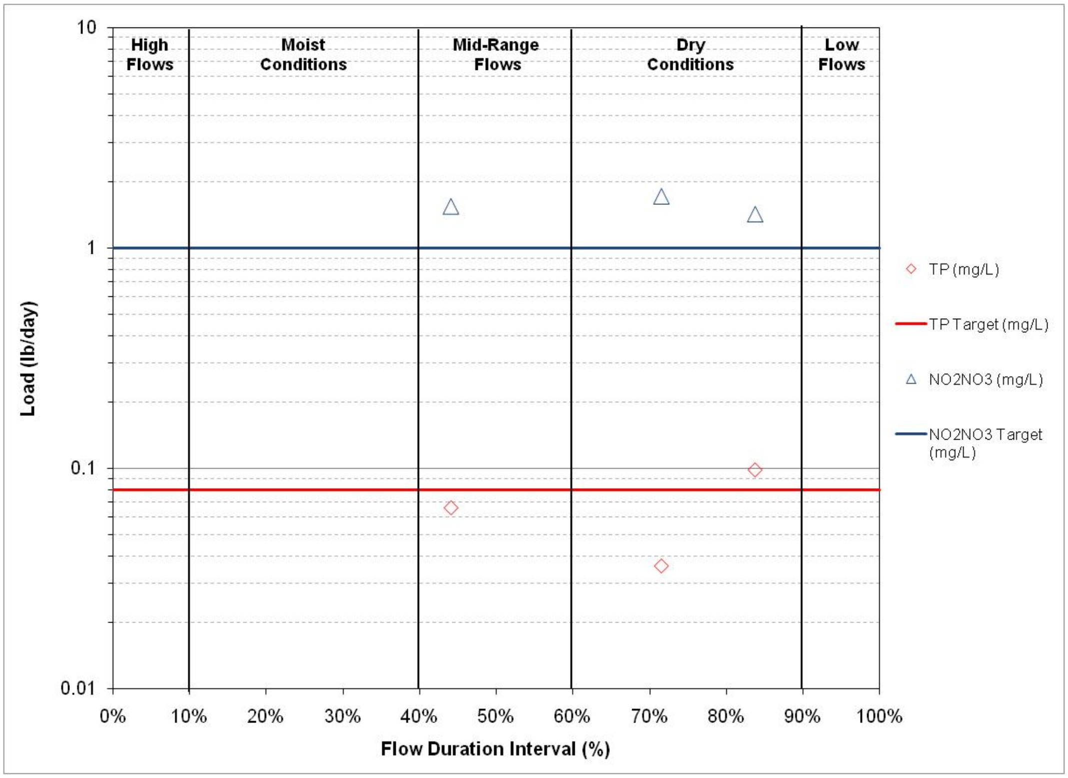


Figure 7-22. Red Creek nutrient water quality duration curves.

8. Recreation Use Designation Impairments Linkage Analysis

The impaired recreation uses in the lower Grand River watershed are a result of point and nonpoint sources of pathogens. Point sources include numerous sewage treatment plants and urban runoff discharged through MS4 systems. Nonpoint sources include livestock and runoff from animal operations and pastures, non-regulated storm water runoff from urban and agricultural land uses, and failing sewage treatment systems. Re-suspension of bacteria in the stream channel is also a potential source.

This linkage analysis provides a review of the NPDES permitted point sources in the watershed, including an evaluation of the permit violations and discharge monitoring records. This section evaluates water quality data as well as point source and nonpoint source contributions of the pollutants and their likely impact on the observed impairments.

Ohio EPA evaluated the attainment of designated recreation uses at 25 locations in 10 WAUs, and at 9 locations along the mainstem of the lower Grand River during 2003 and 2004. Ohio EPA identified bacteria impairments in 7 of the 10 WAUs. The Grand River LRAU is also impaired for bacteria at 5 assessed locations (G02G15, G02W18, G02G14, G02S13, and 502530).

Table 8-1 summarizes those permitted facilities that include permit violations and fecal coliform exceedances according to discharge monitoring records. Very few violations and exceedances occurred in the watershed.

Thirteen subwatersheds are modeled for bacteria TMDL development. Those watersheds are based on WAUs with the exception of Red Creek and Coffee Creek. Red Creek and Coffee Creek watersheds were delineated using StreamStats (USGS 2010) and existing 12-digit HUC boundaries. The two creeks required additional delineation because their WAUs also contain portions of the mainstem of the Grand River and its tributary area.

Table 8-1. Summary of permit fecal coliform exceedances in the lower Grand River watershed

12-digit HUC (04110004) [a]	Facility name	Permit number	2003–2004			2005–2009		
			Samples [b]	Exceedances [c]	Violations [d]	Samples [b]	Exceedances [c]	Violation [d]
04 02	Ashtabula JVS	OH0044920	13	0	0	34	4	4
04 03	DFC MHP	OH0121614	4	0	0	20	1	3
06 01	Coffee Creek WWTP	OH0098469	53	1	1	120	0	0
06 02	Rustic Pines MHP WWTP	OH0112135	12	0	1	53	1	0
06 06	Capps Tavern	OH0134732	1	0	0	10	3	4
06 06	Chardon WWTP	OH0022659	162	1	0	394	0	0
06 06	Terrace Glen Estates MHP	OH0112291	12	0	2	31	1	2
LRAU	Hardy Industrial Technologies, LLC	OH0000299	1	1	0	34	1	0
LRAU	Painesville WPC Plant	OH0026948	145	2	3	361	0	1
LRAU	Spring Lake MHP	OH0134694	0	--	--	10	1	5

Notes

a. Facilities identified with a 12-digit HUC discharge to tributaries of the Grand River. Facilities identified as LRAU discharge directly to the Grand River.

b. Number of fecal coliform samples reported in the discharge monitoring report (DMR).

c. Number of fecal coliform samples reported in the DMR that exceed 2,000 counts/100 mL.

d. Number of code and limit violations for fecal coliform reported in the DMR.

8.1. Griggs Creek (HUC 04110004 04 01)

Griggs Creek is impaired by bacteria for its designated recreation use. In 2004 the geometric mean of *E. coli* samples exceeded the PCR class B criterion (161 *E. coli* counts per 100 mL).

One NPDES facility discharges to Griggs Creek WAU: Ken's Forge, Inc. The facility operates a wastewater treatment works that discharges to an unnamed tributary to Griggs Creek. Between June 2004 and August 2009, fecal coliform was detected in 8 of 12 semiannual samples. None of the samples exceeded the instantaneous maximum permit limit (2,000 fecal coliform counts/100 mL). The two discharge monitoring report (DMR) samples reported during the same period as the Ohio EPA field survey were 6/2/2004 (80 counts/100 mL) and 8/23/2004 (non-detect).

Ohio EPA's monitoring data were collected at a site (Poplar Street, G02G12) upstream of that facility; therefore, Ken's Forge could not have caused the impairment identified during the 2004 field survey. Because the fecal coliform at site G02G12 ranged from 330 to 17,000 counts/100 mL in 2004, other sources upstream of Ken's Forge are causing the impairment to Griggs Creek.

The 2001 NLCD data show that the subwatershed includes cropland (35 percent), pasture (12 percent), and developed land (6 percent). The probable sources of high bacteria levels include failing septic systems, animals, and agricultural runoff.

8.2. Peters Creek – Mill Creek (HUC 04110004 04 02)

Seasonal geometric means of *E. coli* data exceeded the PCR class B criterion at two sites on Mill Creek: RMs 18.2 and 25.6. Data from Askue Run and Peters Creek also exceeded the *E. coli* criterion.

Two NPDES facilities drain to waters within the Peters Creek – Mill Creek WAU: Ashtabula County Joint Vocational School (JVS) (sewerage system) and Ohio DOT Dorset Outpost Garage. The 2001 NLCD data show that the WAU includes cropland (30 percent), pasture (12 percent), and developed land (6 percent). The possible sources of in-stream bacteria include point sources, failing septic systems, animals, and agricultural runoff.

8.2.1. Ashtabula County Joint Vocational School

This facility discharges to Mill Creek in Jefferson Township in Ashtabula County. Between May 2003 and October 2009, fecal coliform was detected in 39 of 47 samples. Four samples (2,100 to 5,800 counts/100 mL) collected in 2006, 2007, and 2008 exceeded the instantaneous maximum permit limit (2,000 counts/100 mL). During Ohio EPA's field survey, 13 samples were reported at the JVS (1 to 1,050 counts/100 mL), and only 3 of those samples were greater than 20 counts/100 mL (130, 630 and 1,050 counts/100 mL).

Mill Creek at Netcher Road (G02S04), 0.7 RM upstream of the JVS, was sampled by Ohio EPA in 2003 and 2004 (50 to 28,000 counts/100 mL). The recreation season geometric means never exceeded the PCR class B criterion. Because the agency did not monitor in-stream water quality at another site in the WAU below JVS, it is difficult to assess the impact of JVS on in-stream water quality. Because of the compliance with its permit during the 2003–2004 field survey and relatively low levels of bacteria in the effluent during that period, it is not likely that JVS was a source of the recreation use impairment to Mill Creek.

8.2.2. Ohio Department of Transportation's Dorset Outpost Garage

Ohio Department of Transportation (ODOT) operates an outpost in Dorset Township in Ashtabula County that is immediately adjacent to an unnamed tributary of Mill Creek. The outpost's garage has a wastewater treatment works that discharges to the unnamed tributary of Mill Creek. Five fecal coliform samples were reported in the DMR from March 2003 through June 2006 (non-detect to 1,500 counts/100 mL). All those samples were below the instantaneous maximum permit limit (2,000 counts/100 mL) for fecal coliform.

Ohio EPA's sample site on Mill Creek at Clay Road (G02G13, RM 25.7) was sampled in 2003 and 2004 (150 to 18,000 counts/100 mL) and is in non-attainment of its recreation use. The garage is 1.5 RMs upstream of that site on a tributary. Ohio EPA did not collect any field samples when DMR data were reported. The closest sample was from 8/6/2003 (6,300 counts/100 mL). Thus, there are insufficient data to determine if ODOT's Dorset Outpost Garage's effluent affected the impairment of Mill Creek.

8.3. Town of Jefferson – Mill Creek (HUC 04110004 04 03)

Ohio EPA sampled Cemetery Creek for *E. coli* at two sites twice in 2003. The geometric mean of those data at both sites exceeds the PCR class B standard of 161 counts per 100 mL. Four sites along Mill Creek were sampled for *E. coli* in 2003 and 2004. Potential bacteria sources include point sources, storm water runoff, agricultural drainage, animals, and faulty septic systems.

Four NPDES facilities drain to waters in the Town of Jefferson – Mill Creek WAU: DFC MHP, Jefferson WWTP, Harassment's Bar, and King Luminaire Co., Inc.

8.3.1. DFC Mobile Home Park

Only one sample was reported in the DMR for fecal coliform: 150 counts/100 mL on 8/7/2003. The closest site that Ohio EPA monitored was 4 RMs downstream, in the city of Jefferson. Thus, there are insufficient data to determine if the DFC Mobile Home Park (MHP) effluent affected the impairment of Cemetery Creek.

8.3.2. Jefferson WWTP

The Jefferson WWTP discharges to Cemetery Creek, and a discussion of its effluent is presented in the TSD (Ohio EPA 2006, p. 28). The facility is directly adjacent to Cemetery Creek. DMR data are available from May 2003 through October 2009; 339 of the 363 fecal coliform samples were less than 100 counts/100 mL.

Ohio EPA collected two samples on Cemetery Creek at Poplar Street (G02S08) just below the WWTP that were evaluated for fecal coliform: 8/28/2003 (1,600 counts/100mL) and 9/10/2003 (90 counts/100 mL). The reported effluent levels on 8/26/2003 and 9/4/2003 were 38 and 5 counts/100 mL, respectively. In 2003 effluent bacteria levels never exceeded 70 counts/100 mL, and both sets of synoptic upstream, effluent, and downstream samples showed that the WWTP was diluting the in-stream bacteria levels. Thus, it is not likely that the treated effluent from Jefferson WWTP is causing the recreation use impairments.

The TSD (Ohio EPA 2006) indicates that a faulty pump was contributing to impairments on Cemetery Creek. The WWTP was cited multiple times for not reporting data at the required permit frequency. It is possible that the reported DMR exceedances were due to the faulty pump. During Ohio EPA inspections in 2010 and 2011, no pump stations were noted as faulty. Ohio EPA also identified WWTP bypasses as another potential sanitary sewer overflow-caused contribution to the in-stream impairment.

8.3.3. Harassment's Bar

Harassment's Bar operates a wastewater treatment works that discharges to an unnamed tributary to Mill Creek in Lenox Township in Ashtabula County. However, no bacteria data for the permit are available in the DMR. Thus, there are insufficient data to determine if the Harassment's Bar effluent affected the impairment on Mill Creek.

8.3.4. King Luminaire Company Incorporated

The wastewater treatment works at King Luminaire discharges to an unnamed tributary to Mill Creek in Jefferson Township in Ashtabula County. Between June 2004 and August 2009, fecal coliform was detected in 9 of 12 summer quarterly samples. None of the samples exceeded the instantaneous maximum fecal coliform permit limit (2,000 counts/100 mL). The two DMR samples evaluated for fecal coliform that were reported during the same period as the Ohio EPA field survey were 6/2/2004 (90 counts/100 mL) and 8/9/2004 (850 counts/100 mL). Although the data are limited, it does not appear that King Luminaire is solely causing the impairment to Mill Creek but is likely contributing to the impairment.

8.4. Coffee Creek – Grand River (HUC 04110004 06 01)

Although Coffee Creek was not placed on the 303(d) list in 2010, *E. coli* data from 2000 imply a possible impairment of the PCR class B use and Ohio EPA intends to place Coffee Creek on the 2012 303(d) list. As described in Section 1, Coffee Creek has been historically impaired for fecal coliform. The geometric means of data collected in 2000 at four stations on Coffee Creek exceeded the geometric mean standard of 161 counts per 100 mL.

Three NPDES facilities drain to waters in the WAU: Coffee Creek WWTP, Grand River Academy, and Pilot Travel Center Store Number 2. However, the Pilot Travel Center facility is not permitted to discharge bacteria; the permit limits are only for flow, pH, and oil and grease.

In 2001 a large portion of the watershed was used for cropland and pasture (29 percent cropland, 11 percent pasture, and 9 percent developed land). Ohio EPA identified failing septic systems in the Austinburg area and a number of small package treatment plants that might be the cause of elevated bacteria counts (Ohio EPA 2006a). Thus, the possible sources of high bacteria levels include point sources, agricultural runoff, storm water, animals, and failing septic systems.

8.4.1. Coffee Creek WWTP

Ashtabula County owns and operates a WWTP in Austinburg Township that discharges to Coffee Creek. Of the 173 fecal coliform samples reported in the DMR, 52 were non-detects. From 2003 through 2007, fecal coliform data ranged from 1 to 7,100 counts/100 mL, with a median of 10 counts/100 mL. In 2008 and 2009, fecal coliform was detected in only 7 of 48 samples (10 to 80 counts/100 mL). The WWTP generally discharges effluent below the permitted fecal coliform limits. Fourteen synoptic upstream, effluent, and downstream samples were collected from 2003 through 2009. In most cases the levels of bacteria decreased from upstream to downstream; in the other cases, the levels were identical or within 10 counts/100 mL. Also, the fecal coliform levels in many of the upstream samples were greater than in-stream water quality criteria. Thus, it appears that the Coffee Creek WWTP generally is not causing elevated bacteria levels in Coffee Creek and sometimes dilutes in-stream bacteria counts. However, at times, the WWTP contributes to the impairment, and on one occasion (October 2003), the WWTP discharged effluent with high levels of bacteria.

Ohio EPA awarded American Recovery and Reinvestment Act funds to install additional sanitary sewer collection infrastructure to transmit wastewater from Austinburg to the Coffee Creek WWTP, which should be fully operational in 2011.

8.4.2. Grand River Academy

The Grand River Academy, a college preparatory boarding school for boys, operates two wastewater treatment works at its 200-acre facility in Austinburg Township in Ashtabula County that discharge to Coffee Creek and an unnamed tributary to Coffee Creek. The 12 quarterly summer samples from the West Plant (outfall 001) ranged from 10 to 860 counts/100 mL, with a median of 375 counts/100 mL, from June 2004 through August 2009. Three of the 12 quarterly summer samples from the East Plant (outfall 002) were non-detect or non-discharging. The fecal coliform levels of the detections ranged from 20 to 740 counts/100 mL, with a median of 400 counts/100 mL. The permit limits for fecal coliform were not exceeded at either outfall.

Ohio EPA collected in-stream bacteria data from Coffee Creek in the year 2000. Because no data are available from the same period of record for Grand River Academy's DMR data, it is not possible to evaluate the potential impacts of the academy on Coffee Creek. Because the Grand River Academy did not violate its permit, it can be assumed that the Grand River Academy is not causing the recreation use impairment to Coffee Creek. The Grand River Academy is expected to connect to public sewers (i.e., Coffee Creek WWTP) in 2011 and will no longer discharge to Coffee Creek.

8.5. Mill Creek (HUC 04110004 06 02)

Mill Creek is listed as impaired by bacteria for its PCR class B use. In addition, the geometric mean of 2004 samples on an unnamed tributary to Mill Creek exceeded the standard.

The Rustic Pines MHP is the only NPDES facility in this WAU. Of the 65 fecal coliform records in the DMR from May 2003 through October 2009, 29 were non-detects. Fecal coliform was detected at levels ranging from 1 to 3,200 counts/100 mL, with a median of 44 counts/100 mL. Data collected in 2003 and 2004 ranged from 1 to 380 counts/100 mL, with a median of 50 counts/100 mL. Because the closest Ohio EPA monitoring site at Aitkins Road (G02G26) is in full attainment of its recreation use and because Rustic Pines MHP is usually in compliance with its permit, it is assumed that Rustic Pines MHP is not causing the impairment. It is more likely that a source of bacteria is between stations G02G26 (full attainment) and G02G10 (non-attainment).

In 2001 a large portion of the watershed was used for cropland and pasture (25 percent cropland, 9 percent pasture, and 5 percent developed land). Possible sources of high bacteria levels include agricultural runoff, animals, and failing septic systems.

8.6. Paine Creek (HUC 04110004 06 04)

Paine Creek is also impaired for its PCR use class B. The geometric mean of bacteria data on Paine Creek at station G02P01 exceeded the criterion in 2000, 2003, and 2004. In addition, the geometric mean of 2004 samples on Bates Creek at station 200598 exceeded the standard.

Paine Creek is in Geauga County, and possible sources of high bacteria levels include runoff, animals, and failing septic systems. In 2001 a large portion of the watershed was used for cropland and pasture (19 percent cropland, 9 percent pasture, and 6 percent developed land). Two NPDES facilities drain to waters in this WAU: Camp Lejnar and Cedar Hills Conference Center. In addition, Leroy Township, encompassing 12 square miles of the watershed, is a MS4 community contributing storm water runoff to the Creek.

8.6.1. Camp Lejnar

The Girl Scouts of Northeast Ohio operate Camp Lejnar, in Leroy Township in Lake County. The wastewater treatment works discharges from an evaporative lagoon to an unnamed tributary of Paine Creek. The NPDES permit requires monitoring of fecal coliform during internal processes but does not allow fecal coliform to be discharged in the final effluent.

Paine Creek at Ohio EPA's monitoring site at Seeley Road (G02P01) is in non-attainment of its recreation use. The unnamed tributary that receives effluent from Camp Lejnar discharges to Paine Creek approximately 0.2 RM below site G02P01. Because Camp Lejnar was not reported to violate its permit and because its effluent cannot reach the non-attainment site, it is concluded that the impairment was not caused in any part by Camp Lejnar.

8.6.2. Cedar Hills Conference Center

The Episcopal Diocese of Ohio operates the Cedar Conference Center in Leroy Township in Lake County. The facility discharges to an unnamed tributary of Paine Creek. Twelve quarterly summer fecal coliform samples were reported in the DMR (1 to 720 counts/100 mL) from June 2003 through August 2009. In 2003 and 2004, during Ohio EPA's field survey, the fecal coliform in the facility's effluent ranged from 2 to 160 counts/100 mL. The conference center discharges to an unnamed tributary with its confluence with Paine Creek below the Seeley Road site, which is in non-attainment. Thus, the conference center cannot be the cause of the non-attainment of the recreation use on Paine Creek at Seeley Road.

8.7. Big Creek (HUC 04110004 06 06)

E. coli data on six streams in the Big Creek assessment unit indicate an impairment of the waters' PCR class B use (Big Creek, Cutts Creek, East Creek, Ellison Creek, Jordan Creek, and Kellogg Creek). Sixteen facilities discharge to waters in the WAU, including one major discharger: Chardon WWTP. The following facilities are not permitted to discharge bacteria loads: Ricerca BioSciences LLC (unnamed tributary to Ellison Creek) and Structural North America (unnamed tributary to Big Creek).

Concord Township, Leroy Township, and Painesville are MS4 communities permitted under the Lake County MS4 within the assessment unit. In 2001 a large portion of the watershed was developed land with a much smaller portion being used for crops and pasture (31 percent developed land, 7 percent cropland, 5 percent pasture). Continued development since 2001 has likely increased the portion of the watershed devoted to developed land. Wastewater from NPDES facilities, MS4 runoff, and storm water are potential sources of bacteria to the Big Creek assessment unit. In addition, agricultural runoff, animals, and failing septic systems could also contribute to the bacteria load.

8.7.1. Chardon WWTP

Chardon WWTP is permitted to discharge to Big Creek at RM 16.1. Of the 556 samples evaluated for fecal coliform, only one exceeded 2,000 counts/100 mL (2,220 counts/100 mL on 10/28/2003). The range of fecal coliform levels detected between 2003 and 2004 was 2 to 2,220 counts/100 mL (n=162, median: 2 counts/100 mL), and five samples were non-detect or non-discharging.

Ohio EPA did not collect any in-stream bacteria samples on Big Creek near the facility; Chardon WWTP reported 52 upstream and downstream samples collected from May through October in 2003 and 2004. Except in October 2003, all upstream samples had larger fecal coliform levels than the downstream samples, and the levels of fecal coliform in all the downstream samples were considerably larger than the levels in the discharged effluent. The Chardon WWTP contributes very small levels of bacteria to Big Creek and is not likely the source of elevated in-stream bacteria levels in Big Creek that cause the recreation use impairment.

8.7.2. Capps Tavern

Capps Tavern discharges to an unnamed tributary of Big Creek, below the confluence of East Creek with Big Creek. Of the 11 effluent samples reported in the DMR for Capps Tavern, fecal coliform was detected in 9 samples (147 to 21,600 counts/100 mL) collected from August 2004 through August 2009. The only effluent sample collected at Capps Tavern during 2004 was non-detect. Three effluent samples collected at Capps Tavern exceeded 1,000 counts/100 mL between June 2007 and June 2008 (3,500 to 21,600 counts/100 mL).

Ohio EPA did not collect any in-stream bacteria samples on Big Creek near the facility; thus, it is not possible to evaluate the potential impact of Capps Tavern on Big Creek. However, Big Creek was in non-attainment at RM 2.5, the most downstream site from which Ohio EPA collected bacteria samples on Big Creek.

8.7.3. Chardon United Methodist Church

The Chardon United Methodist Church discharges to an unnamed tributary of Big Creek. Fecal coliform was detected in all 32 effluent samples reported in the DMR (1 to 2,000 counts/100 mL) collected from May 2003 through August 2009. Ten samples were collected from May 2003 through October 2004, during Ohio EPA's field survey, and the fecal coliform levels ranged from 1 to 80 counts/100 mL.

Ohio EPA did not collect any in-stream bacteria samples on Big Creek near the facility; thus, it is not possible to evaluate the potential impact of the church on Big Creek. Big Creek was in non-attainment at RM 2.5, the most downstream site from which Ohio EPA collected bacteria samples on Big Creek; however, the site is in the headwaters to Big Creek. The church contributes bacteria to Big Creek but is not likely the source of elevated in-stream bacteria levels in Big Creek that cause the recreation use impairment.

8.7.4. Concord Tavern

Concord Tavern discharges to an unnamed tributary of Ellison Creek. Of the 10 summer quarterly effluent samples reported in the DMR, fecal coliform was detected in 9 samples (4 to 750 counts/100 mL) collected from June 2005 through August 2009. No samples were collected during Ohio EPA's 2003–2004 surveys.

Ellison Creek at Pine Hill Road (200590, RM 1.2) is in non-attainment of its recreation use (PCR Class B). Because DMR data were not collected in 2004 when Ohio EPA collected in-stream samples from Ellison Creek, it is not possible to evaluate the potential impact that the tavern has on in-stream conditions. However it is noteworthy that the reported flow at the facility ranged from non-discharging to 41,200 gallons per day (gpd) (0.06 cfs) and that the 95th duration interval flow on Ellison Creek is estimated to be 0.06 cfs.

8.7.5. Grumpy Bear LLC

Grumpy Bear LLC is permitted to discharge wastewater from its treatment works to an unnamed tributary of East Creek. Of the 10 summer-quarterly effluent samples reported in the DMR, fecal coliform was detected in 9 samples (4 to 430 counts/100 mL) collected from June 2005 through August 2009. No samples were collected during Ohio EPA's 2003–2004 surveys.

Because DMR data were not collected in 2004 when Ohio EPA collected in-stream samples from Ellison Creek, it is not possible to evaluate the potential impact that Grumpy Bear has on in-stream conditions. However, it is noteworthy that the reported flow at the facility ranged from 1,500 to 3,500 gpd (0.002 to 0.005 cfs) and that the 99th duration interval flow on East Creek is estimated to be 0.011 cfs.

8.7.6. Henry F. LaMuth Middle School

Riversides Local School District's Henry F. LaMuth Middle School is permitted to discharge wastewater from its treatment works to an unnamed tributary of Kellogg Creek, whose confluence is downstream of the confluence of Ellison Creek with Kellogg Creek. Of the 33 monthly recreation season effluent samples reported in the DMR, fecal coliform was detected in 16 samples (20 to 640 counts/100 mL) collected from August 2004 through October 2009. No detections occurred in 2009. The samples from August, September, and October 2004 ranged from 110, 20, and 140 counts/100 mL, respectively.

The creek at all three assessment sites in the Kellogg Creek subwatershed is in non-attainment of the recreation uses. The ranges of fecal coliform levels at each site are shown below:

- Kellogg Creek at State Route 86 (RM 0.2): 110 to 480 counts/100 mL
- Kellogg Creek at Button Road (RM 5.7): 600 to 1,800 counts/100 mL
- Ellison Creek at Pine Hill Road (RM 1.2): 110 to 250 counts/100 mL

An analysis of synoptic samples shows that bacteria levels in Kellogg Creek upstream of Ellison Creek reduce after the confluence of Ellison Creek. Because the maximum flow rate of the facility is 12,000 gallons per day (0.019 cfs) and that the creek at both assessment sites upstream of the facility is in non-attainment, the middle school is contributing bacteria load to Kellogg Creek; however, upstream sources are much larger than the loads the middle school contributes.

8.7.7. Junior Properties Ltd.

Junior Properties, Ltd., discharges to an unnamed tributary of Big Creek below the confluence of East Creek with Big Creek. Effluent samples are reported for Junior Properties from June and August 2009 (56 counts/100 mL and non-detect, respectively).

Ohio EPA did not collect any in-stream bacteria samples on Big Creek near the facility; thus, it is not possible to evaluate the potential impact of Junior Properties on Big Creek. However, Big Creek was in non-attainment at RM 2.5, the most downstream site from which Ohio EPA collected bacteria samples on Big Creek.

8.7.8. Leroy Elementary School

Riversides Local School District's Leroy Elementary School is permitted to discharge wastewater from its treatment works to East Creek. Of the 11 effluent samples reported in the DMR, fecal coliform was detected in 8 samples (4 to 700 counts/100 mL) collected from August 2004 through August 2009. The only sample collected during 2004 was 120 counts/100 mL.

Ohio EPA monitored elevated bacteria levels on 8/2/2004 (410 counts/100mL) on East Creek at Callow Road (RM 1.2). The fecal coliform level from DMR data for the school on 8/10/2004 was 120 counts/100 mL. Thus, the facility might have contributed to the elevated in-stream fecal coliform levels. It is noteworthy that the effluent discharge at the facility ranged from 2,500 to 7,500 gpd (0.004 to 0.012 cfs) and that the 99^{th} duration interval flow for East Creek was 0.011 cfs.

8.7.9. Maple Ridge Mobile Home Community

Big Creek Properties LLC operates Maple Ridge Village (i.e., Maple Ridge Mobile Home Community), which is permitted to discharge to an unnamed tributary of Jenks Creek. Fecal coliform was detected in all 40 summer quarterly effluent samples reported in the DMR (1 to 2,000 counts/100 mL) collected from June 2005 through September 2009. Fecal coliform ranged from 1 to 200 counts/100 mL (median: 2 counts/100 mL) in the 12 samples collected during 2003 and 2004.

Ohio EPA did not collect any in-stream bacteria samples on Jenks Creek; thus, it is not possible to evaluate the potential impact of Maple Ridge Mobile Home Community on Jenks Creek. However, Big Creek was in non-attainment at RM 2.5, the most downstream site from which Ohio EPA collected bacteria samples on Big Creek.

8.7.10. Rio Grande WWTP

The Rio Grande WWTP discharges to Big Creek. In 2005 the 30-year old activated sludge treatment plant was replaced with a membrane reactor that has a design capacity of 21,500 gpd. Sludge produced at the facility is transported to and processed at the Gary L. Kron Water Reclamation Facility in Mentor, Ohio, which is outside the Grand River watershed.

Fecal coliform was detected[14] in 16 of the 42 effluent samples reported in the DMR from May 2003 through October 2009. Since the facility was upgraded in 2005, fecal coliform was detected (4 to 40 counts/100 mL) in 4 of 30 samples.

The farthest downstream site at which Ohio EPA monitored bacteria was at Fay Road (G02W23); the Rio Grande WWTP is downstream of this location. The largest bacteria levels detected at the station were collected on 9/23/2003 and 7/12/2004 (6,700 and 7,000 counts/100 mL). The recreation use impairment for Big Creek is caused by sources that are upstream of the Rio Grande WWTP.

8.7.11. Sunshine Acres WWTP

A single residential subdivision in Leroy Township is served by the Sunshine Acres WWTP. The facility was designed to treat 20,000 gpd via an activated sludge process, and effluent is discharged to East Creek. Sludge produced at the facility is transported to and processed at the Gary L. Kron Water Reclamation Facility in Mentor, Ohio, which is outside the Grand River watershed.

Fecal coliform was detected[15] in 21 of the 43 effluent samples reported in the DMR from May 2003 through October 2009. Five samples were detected at levels greater than 100 counts/100 mL (110, 310, 500, 800, and 800 counts/100 mL). Fecal coliform was not detected in more recent samples (July 2008 through October 2009).

Ohio EPA monitored elevated bacteria levels on 6/3/2004 and 8/2/2004 (200 and 410 counts/100 mL, respectively). Because the DMR data for 6/2/2004 and 8/2/2004 (2 and 13 counts/100 mL, respectively) are considerably smaller than the in-stream levels, it is not likely that the Sunshine Acres WWTP caused the elevated bacteria levels that caused Ohio EPA to list East Creek as impaired.

8.7.12. Terrace Glen Estates MHP

The MHP is permitted to discharge wastewater from its treatment works to Cutts Creek at RM 3.0. Fecal coliform was detected in all 46 summer quarterly effluent samples reported in the DMR (1 to 5,900 counts/100 mL) collected from May 2003 through October 2009. Fecal coliform ranged from 1 to 2,000 counts/100 mL (median: 20 counts/100 mL) in the 12 samples collected during 2003 and 2004.

Cutts Creek at Cutts Road (G99Q11, RM 1.2) is in non-attainment of its PCR Class B use. Fecal coliform in the facility's effluent on 6/1/2004 was 2 counts/100 mL, and on 8/5/2004 it was 10 counts/100 mL. The in-stream concentration at Cutts Creek RM 1.2 on 6/2/2004 and 8/2/2004 were 140 and 650 counts/100 mL, respectively. An evaluation of data is inconclusive.

8.7.13. Wintergreen WWTP

Geauga County owns and operates the Wintergreen WWTP, which discharges to Big Creek at RM 14.75. Fecal coliform was detected in all 46 summer quarterly effluent samples reported in the DMR (1 to 2,000 counts/100 mL) collected from June 2005 through October 2009. Fecal coliform ranged from 4 to 1,570 counts/100 mL (median: 15 counts/100 mL) in the 14 samples collected during 2003 and 2004.

Ohio EPA did not collect any in-stream bacteria samples on Big Creek near this facility; thus, it is not possible to evaluate the potential impact of Wintergreen WWTP on Big Creek. However, Big Creek was

[14] The detection limits during this period at Sunshine Acres WWTP were 2 or 4 counts/100 mL.
[15] The detection limits during this period at Sunshine Acres WWTP were 2 or 4 counts/100 mL.

in non-attainment at RM 2.5, the most downstream site from which Ohio EPA collected bacteria samples on Big Creek.

8.8. Red Creek – Grand River (HUC 04110004 06 07)

Bacteria sampling of Red Creek in 2004 exceeded the geometric mean of 161 counts per 100 mL. Perry Village is a permitted MS4 community draining to Red Creek. Potential sources of bacteria to Red Creek include failing septic systems, urban runoff, animals, and agricultural runoff.

Insufficient data are available for an evaluation of the spatial and temporal bacteria trends in this WAU. Ohio EPA collected only three *E. coli* samples in 2004 from Red Creek. One sample each was collected within the mid-range flows, dry conditions, and low flow zones. All three samples were greater than the geometric mean criteria.

A large number of nurseries and vineyards are in the lower watershed, because of unique climate conditions associated with Lake Erie. The area is densely populated, and storm water runoff from developed land and the agricultural operations could be contributing to the impairment. Portions of Perry Township have been recently sewered, alleviating many failing septic systems, and thus eliminating this potential source of bacteria to Red Creek.

8.8.1. Mid-West Materials Inc.

The facility is permitted to discharge wastewater from its treatment works to Red Creek. Fecal coliform was detected in 4 of the 11 summer quarterly effluent samples reported in the DMR (90 to 430 counts/100 mL) collected from August 2004 through August 2009. No fecal coliform was reported in the single sample (August 2004) collected during Ohio EPA's 2003 and 2004 biosurvey.

It is not possible to evaluate the impact of Mid-West Materials on the water quality of Red Creek because Ohio EPA in-stream assessment data and DMR data were not collected during the same periods.

8.9. Large River Assessment Unit

The LRAU is identified as not supporting the class A PCR use. A longitudinal analysis of *E. coli* data is presented in Figure 8-1. The figure shows the changes in *E. coli* concentrations from upstream to downstream, including the impacts that the major tributaries are having.

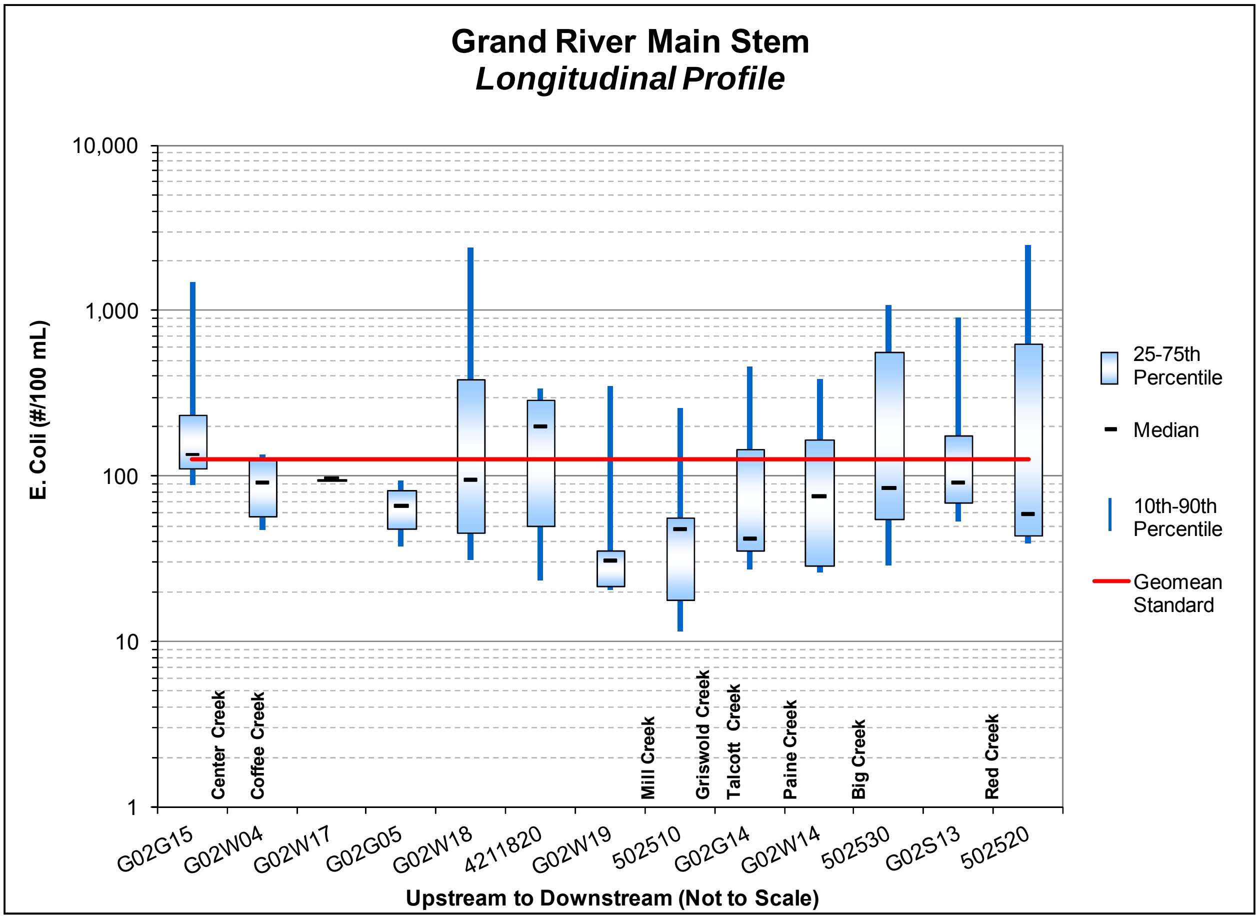


Figure 8-1. Grand River mainstem, *E. coli* longitudinal profile.

E. coli data were further evaluated at several locations along the Grand River. At four of the sites, bacteria samples were collected primarily in the mid-range flows and dry conditions zone: Blair Road (G02G14), Cork Cold Spring (G02G15), Park at Painesville (G02S13), and Sexton Road (G02W18). Usually one or two samples were collected in the high flows or moist conditions zone. An example water quality flow duration analysis from those four sites is shown in Figure 8-2.

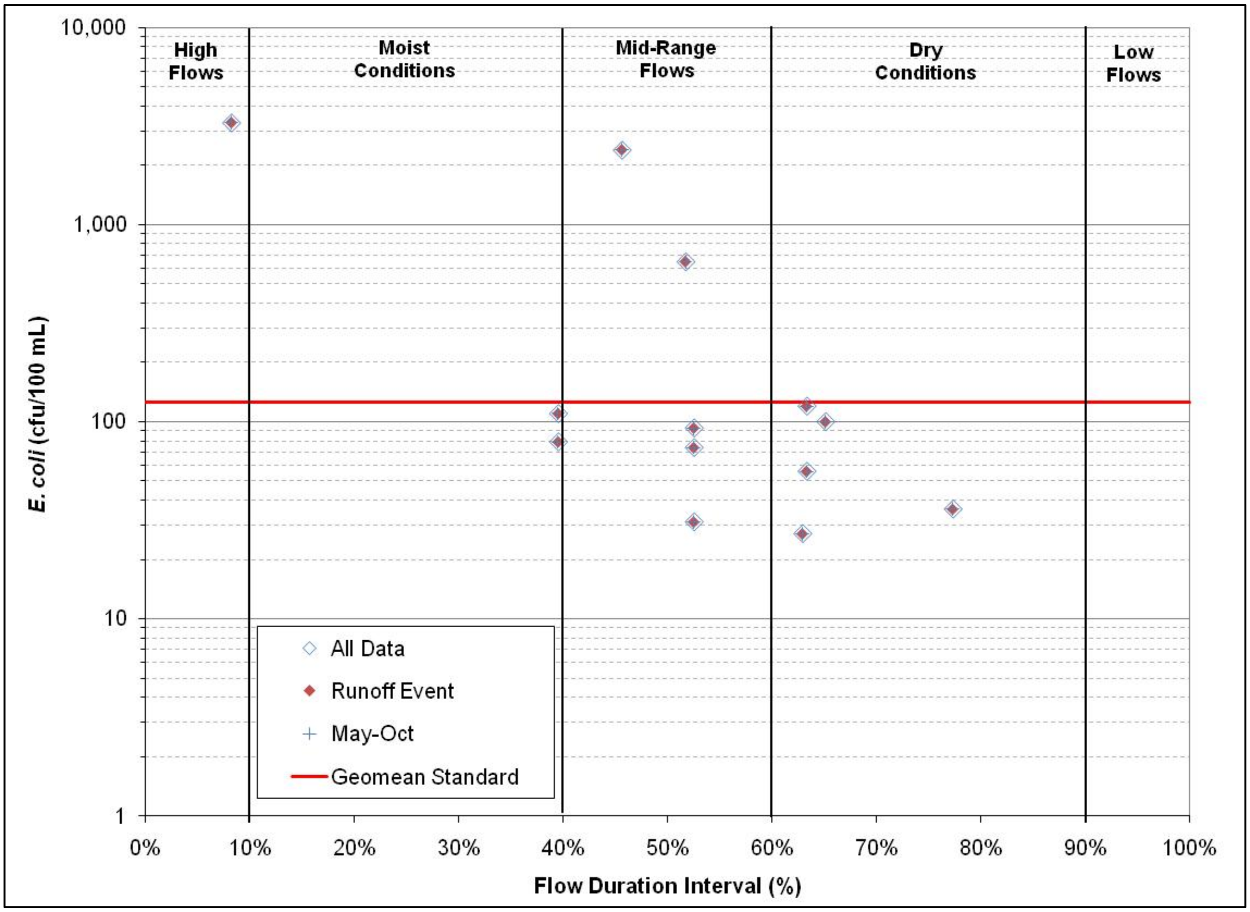


Figure 8-2. *E. coli* data from the Grand River at Sexton Road (G02W18).

Thirty-four samples were collected at State Route 84 in Painesville, and those samples were collected across all five flow zones. Most of the samples collected in the high-flow and moist condition zones were runoff events, and a majority of the concentrations were greater than the single sample maximum (Figure 8-3). Samples collected in the mid-range flows, dry conditions, and low-flow zones were generally collected during runoff conditions, and the concentrations of the majority of samples were less than the geometric mean standard.

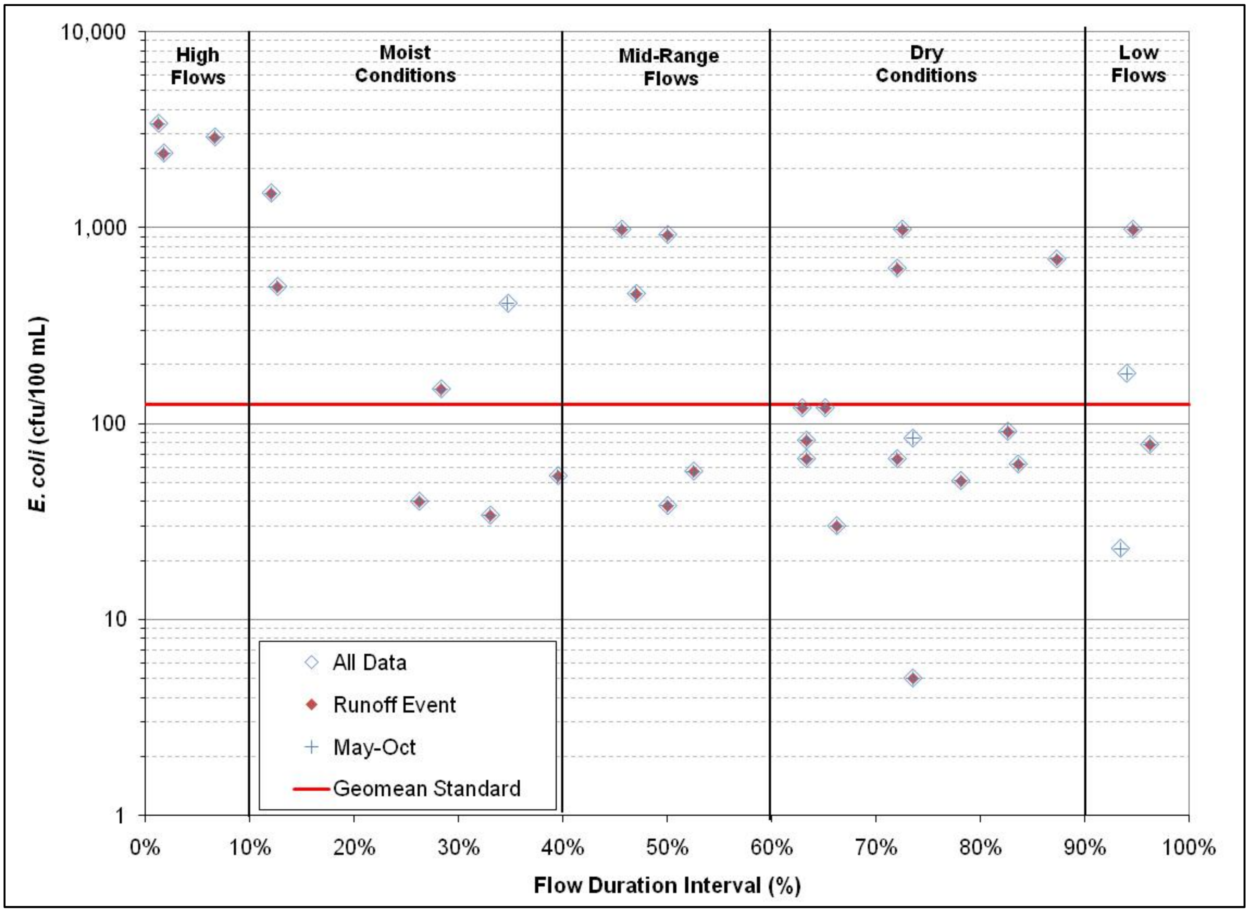


Figure 8-3. *E. coli* data from the Grand River at State Route 84 (502530).

Exceedances occurring across all flow conditions include multiple sources. The highest exceedances occur during high flows and are likely a result of storm water runoff from both urban and agricultural sources and bacterial resuspension from the streambed. Exceedances occurring in the mid-range to dry conditions and under low flows indicate point sources, livestock, and HSTS as sources.

A total of 34 NPDES-permitted facilities with fecal coliform in the lower Grand River watershed, including those discharging to tributaries, were reviewed. Eleven facilities discharge directly to the lower Grand River. Two facilities located near the Grand River (Kenisee Grand River Campground and Little Thunder Kids Golf Course) spray irrigate the wastewater and one facility discharges to an evaporation lagoon (YMCA Outdoor); since they does not discharge to surface waters, they are not further discussed in this report. Three facilities discharge directly to the Grand but do not have any monitored exceedances of permit limits (Whispering Willow MHP, Heatherstone WWTP, and Frary's Restaurant). Two facilities (Thompson United Methodist Church and Thunder Hills Golf Course) discharge to unimpaired tributaries to the Grand River.

Only three of the facilities that discharge directly to the Grand River have exceeded permitted effluent limits between 2003 and 2009 (Table 8-1): Hardy Industrial Technologies LLC, Painesville WPC Plant, and Spring Lake MHP. However, each of those three sites is upstream of Ohio EPA's assessment site at OH-535 (502520), which was in full attainment of its PCR class A recreation use, and is downstream of assessment site G02S13 in Painesville, where the river is in non-attainment of its recreation use.

8.9.1. Hardy Industrial Technologies LLC

Single fecal coliform samples were reported in the DMR for September of 2004, 2005, 2007 to 2009. No fecal coliform was detected in 2008, and the detections ranged from 600 to 8,000 counts/100 mL. The single sample collected in 2004 was 2,100 counts/100 mL. According to the DMR data, the facility does not discharge one-half of the time it is in operation. When it is discharging, the flow rate ranges from 0.0001 to 3.036 MGD, which is 0.00015 to 4.7 cfs.

The closest downstream assessment point is at OH-535 (502520), below the Painesville WPC Plant. This site is in full attainment of its recreation use. The closest upstream assessment point that Ohio EPA evaluated is at a park in Painesville (G02S13). There, the river is in non-attainment of its recreation use (PCR class A). Given the locations of the assessment points, it is difficult to assess the impact of the Hardy Industrial Technologies on the Grand River. Because the downstream assessment point is in full attainment, it can only be concluded that the facility contributes bacteria loads to the Grand River, sometimes exceeding the permit limit, but it does not appear to cause non-attainment of the recreation use.

8.9.2. Painesville Water Pollution Control Plant

In an evaluation of fecal coliform data above and below the Painesville WPC Plant, Ohio EPA concluded that elevated fecal coliform levels appear to be correlated with higher flow conditions and could be the result of urban runoff from within Painesville or the result of poorly operating wastewater treatment facilities upstream of the Painesville WPC Plant. It is important to note that many of the public WWTPs have been upgraded and improved in recent years.

Fecal coliform was detected in all but one of the 145 samples reported in the DMR from 2003 and 2004; the detections ranged from 1 to 7,280 counts/100 mL (median: 1 count/100 mL). Ohio EPA's nearest assessment point is at OH-535 (502520), which is 0.6 mile downstream of the Painesville WPC Plant. The river at the site was in full attainment of its recreation use (PCR class A). Because the plant effluent generally has low bacteria levels and because the river at the downstream assessment site is in full attainment, it is unlikely that the Painesville WPC Plant is contributing to the recreation use non-attainment on the Grand River.

8.9.3. Spring Lake MHP

Spring Lake MHP was "found to be organically overloaded and to be producing a marginal quality effluent during an inspection by Ohio EPA on April 27, 2004," and in its renewed permit, Ohio EPA required "flow equalization, dechlorination facilities, and improved sludge holding" (Ohio EPA 2006a, p. 56). Summer quarterly fecal coliform samples are reported in the DMR from June 2005 through August 2009; the five detections ranged from 240 to 4,600 counts/100 mL. According to the DMR, the facility discharges at 5,700 gpd, which is approximately 0.0088 cfs.

The closest downstream assessment point is at OH-535 (502520), below the Painesville WPC Plant. The river at this site is in full attainment of its recreation use. The closest upstream assessment point that Ohio EPA evaluated is at a park in Painesville (G02S13). The river at that site is in non-attainment of its recreation use (PCR class A). Given the lack of data collected during the Ohio EPA field survey and the locations of the assessment points, it is difficult to assess the impact of the Spring Lake MHP on the Grand River. Because the river at the downstream assessment point is in full attainment, it can only be concluded that the Spring Lake MHP contributes bacteria loads to the Grand River, sometimes exceeding the permit limit but does not appear to cause non-attainment of the recreation use.

9. TMDL Allocations

A TMDL is the total amount of a pollutant that can be assimilated by the receiving water while still achieving water quality standards. TMDLs are composed of the sum of individual wasteload allocations (WLAs) for regulated sources and load allocations (LAs) for unregulated sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Future growth is also included because of the development pressure within the watershed. Conceptually, this is defined by the equation:

$$\text{TMDL} = \sum WLAs + \sum LAs + MOS + Future\ Growth$$

TMDLs are presented in this section as described in Table 9-1. TMDLs are presented as daily loading for phosphorus and *E. coli* bacteria. Flow regime TMDLs and low-flow recommendations are presented as percent change in flow necessary to achieve the hydrologic targets presented in Section 7, Aquatic Life Use Impairments Linkage Analysis and Hydrologic Targets.

Table 9-1. Summary of TMDLs

Impaired water		TMDL location		TMDL pollutant or surrogate to pollutant
Name	**HUC (04110004)**	**Station**	**RM**	
Mill Creek	04 02	G02G13	25.7	Phosphorus
Big Creek	06 06	G02W21	16.0	Flow regime
Kellogg Creek	06 06	200593	3.3	Flow regime
Red Creek	06 07	n/a	0.0	Flow regime, phosphorus, *E. coli*
Grand River (upper) [a]	05 01	outlet of 12-digit HUC		*E. coli*
Grand River (LRAU)	06 01	outlet of 12-digit HUC		*E. coli*
	06 03	outlet of 12-digit HUC		*E. coli*
	06 05	outlet of 12-digit HUC		*E. coli*
	06 07	outlet of 12-digit HUC		*E. coli*
Griggs Creek	04 01	outlet of 12-digit HUC		*E. coli*
Peters Creek - Mill Creek	04 02	outlet of 12-digit HUC		*E. coli*
Town of Jefferson - Mill Creek	04 03	outlet of 12-digit HUC		*E. coli*
Coffee Creek	06 01	n/a	0.0	*E. coli*
Mill Creek	06 02	outlet of 12-digit HUC		*E. coli*
Paine Creek	06 04	outlet of 12-digit HUC		*E. coli*
Big Creek	06 06	outlet of 12-digit HUC		*E. coli*

[a] The upper Grand River consists of the following 10-digit HUCs (04110004): 01, 02, 03, and 05.

9.1. Duration Curve Approach

A duration curve approach is being used to evaluate the relationships between hydrology and water quality and calculate the TMDLs. The primary benefit of duration curves in TMDL development is to provide insight regarding patterns associated with hydrology and water quality concerns. The duration curve approach is particularly applicable because water quality and pollutant loading are often a function of stream flow. The use of duration curves in water quality assessment creates a framework that enables data to be characterized by flow conditions. The method provides a visual display of the relationship between stream flow and water quality.

The load duration curve calculates the loading capacity of a pollutant at different flow regimes by multiplying each flow by the TMDL target value and an appropriate conversion factor (U.S. EPA 2007). The following steps are taken:

1. A flow duration curve for the stream is developed by generating a flow frequency table and plotting the observed flows in order from highest (left portion of curve) to lowest (right portion of curve).

2. The flow curve is translated into a load duration (or TMDL) curve. To accomplish that, each flow value is multiplied by the TMDL target value and by a conversion factor, and the resulting points are graphed. Conversion factors are used to convert the units of the target (e.g., counts per 100 mL) to loads (e.g., organisms/day).

3. To estimate existing loads, each water quality sample is converted to a load by multiplying the water quality sample concentration by the average daily flow on the day the sample was collected and the appropriate conversion factor. The existing individual loads are then plotted on the TMDL graph with the curve.

4. Points plotting above the curve represent deviations from the water quality standard and the daily loading capacity. Those points plotting below the curve represent compliance with standards and the daily loading capacity.

5. The area beneath the load duration curve is interpreted as the loading capacity of the stream. The difference between that area and the area representing the current loading conditions is the load that must be reduced to meet water quality standards.

Water quality duration curves are created using the same steps as those used for load duration curves except that concentrations, rather than loads, are plotted on the vertical axis. The stream flows displayed on water quality or load duration curves can be grouped into various flow regimes to help interpret the load duration curves. The flow regimes are typically divided into 10 groups, which can be further categorized into the following five hydrologic zones (U.S. EPA 2007):

- High-flow zone: flows that plot in the 0 to 10-percentile range, related to flood flows
- Moist zone: flows in the 10 to 40-percentile range, related to wet-weather conditions
- Mid-range zone: flows in the 40 to 50 percentile range, median stream flow conditions
- Dry zone: flows in the 60 to 90-percentile range, related to dry-weather flows
- Low-flow zone: flows in the 90 to 100-percentile range, related to drought conditions

The duration curve approach helps to identify the issues surrounding the impairment and to roughly differentiate between sources. The load duration curve approach also considers critical conditions and seasonal variation in the TMDL development as required by the Clean Water Act and EPA's implementing regulations. Because the approach establishes loads on the basis of a representative flow regime, LAs, and WLAs that are developed inherently consider seasonal variations and critical conditions that have a varying impact on water quality.

9.2. Load Allocations

LAs represent the portion of the loading capacity that is reserved for nonpoint sources (as described in Section 5.4.2) and natural background. The LAs are typically calculated by subtracting the WLAs and the MOS from the loading capacity. The flow regime TMDL LAs are assigned a percent change from existing flow conditions equal to the TMDL, such that all flow sources resulting from anthropogenic activities are required to adjust flow proportionally. Flow adjustments are not required for natural areas. Existing flow conditions are described in Section 7.3.2 and are based on land cover data in the 2001 NLCD. Implementation of the LA is further described in Section 11, Implementation and Reasonable Assurance.

9.3. Wasteload Allocations

Numerous known NPDES facilities are in the lower Grand River watershed with the potential to discharge pollutants identified in the TMDL. As required by the Clean Water Act, individual WLAs were developed for those permittees as part of the TMDL development process (Section 9.7 and 9.8). Each facility's design flow was used to calculate the WLA for all flow zones for bacteria and nutrient TMDLs.

Two regulated MS4s are in the lower Grand River watershed (Lake County and ODOT). Individual WLAs are established for each MS4 and target loads are presented for each of the communities regulated as part of the Lake County MS4 permit for phosphorus and *E. coli* TMDLs. The jurisdictional areas of townships and municipalities were used as the regulated area of each MS4. For regulated road authorities including Lake County and ODOT, the regulated area was determined using the length of applicable roads and estimated right of way width.

Construction storm water WLAs are assigned a gross allocation that is applicable to all construction storm water permittees. Regulated industrial storm water facilities are assigned a gross WLA, covering 33 facilities and 533 acres in the Grand River watershed that were regulated under the Ohio Industrial Storm Water General Permit in 2010.

No permitted confined animal feeding operations or combined sewer overflow systems are in the watershed. However, one existing facility (Comp Dairy Farm), located in Ashtabula County and within the Mill Creek (RM 25.7) drainage area, is currently being evaluated to determine if coverage under a NPDES permit is required. Any future NPDES permitting of this facility will be required to comply with a WLA of zero for both *E. coli* and total phosphorus.

9.3.1. *E. coli*

E. coli WLAs are calculated using the NPDES permit limit of 126 counts/100 mL or 161 counts/100 mL, depending on the receiving water. NPDES facilities that discharge into a PCR Class B water farther than 5 stream miles upstream of the Grand River are assigned a WLA on the basis of the PCR Class B geometric standard (161 counts/100 mL). NPDES facilities that discharge into a PCR Class B water less than 5 stream miles upstream of the Grand River are assigned a WLA according to the PCR Class A geometric standard (126 counts/100 mL). Those limits are set in accordance with Ohio EPA's Recommended Implementation Plan for New *E. coli* Water Quality Standards (Ohio EPA 2010b). For a discussion of the in-stream *E. coli* criteria, see Section 2.1.2. The flow component of the *E. coli* WLAs is the permitted design flow.

No *E. coli* WLAs are assigned to regulated construction storm water because those activities are not a significant source of *E. coli*. A WLA for MS4s and industrial storm water dischargers was calculated on the basis of regulated area within the watershed which is assigned a WLA according to the proportion of the total drainage area.

9.3.2. Total Phosphorus

Two NPDES permitted facilities require a total phosphorus WLA. Each of those facilities is a small wastewater treatment facility (e.g., package plant) without the ability to remove phosphorus. The total phosphorus WLAs for the small facilities discharging wastewater are calculated using a limit of 3 mg/L total phosphorus, unless otherwise noted. The flow component of the total phosphorus WLAs for wastewater treatment facilities is the permitted design flow.

For non-wastewater treatment facilities (e.g., regulated storm water), the WLAs are calculated using the statewide nutrient 75th percentile statistics from the *Associations* document (Ohio EPA 1999). The total phosphorus WLAs are based on total phosphorus concentrations of 0.08 and 0.10 mg/L for headwaters and wading streams, respectively, with WWH use designations.

The WLAs for total phosphorus TMDLs are calculated on the basis of the average area of the watershed that is regulated under the Ohio General Construction Permit between 2003 and 2007. The regulated area was determined by city/township, which was used to calculate an area of the city/township in the watershed that is regulated for construction activities. That area was assigned a WLA according to the proportion of the total drainage area. The Mill Creek (RM 25.7) construction WLA was based on a regulated area within Cemetery Creek because Mill Creek currently has little construction activity. The intent of this method was to calculate a WLA that is representative of construction activity in the larger watershed, but prevents a WLA from being infinitely small and incorrectly interpreted as zero when the TMDL is being implemented. The current WLA allows for additional future growth and still allows for construction activity to occur and be in accordance with the TMDL. The following percentages were used to describe the disturbed area regulated under the General Construction Storm Water Permit in each watershed and were used to assign WLAs:

- Mill Creek (RM 25.7)—0.05 percent of the watershed
- Red Creek (at outlet)—0.70 percent of the watershed

No regulated industrial storm water facilities require a total phosphorus WLA.

9.3.3. Flow Regime

Flow regime WLAs are presented as percent reduction in flow volumes for specific ranges of the flow duration curve, as discussed further in Section 9.6. The flow regime allocations are not additive, meaning that a 9% reduction TMDL is not met by a 5% reduction from WLA and 4% reduction from LA. The percentage allocations are given to entities that represent the total land area in the watershed. LA accounts for non-regulated land and the remaining account for regulated land uses so reductions for the total watershed area are achieved. Given that allocations are provided in percentage units, the amount of reductions occur in direct proportion to the contribution from a source. Hence a 9% reduction in flow volume from the whole watershed is achieved by a 9% reduction from all contributing areas. In equation form: TMDL (9%) = WLA (9%) + LA (9%).

The flow regime TMDL is applicable at all points upstream of the TMDL location. Flow regime WLAs for non-storm water-related point sources are based on permitted design flow. No reductions in design flow are required for compliance with the TMDL; therefore, the TMDL indicates zero percent change for those facilities. Two regulated storm water sources, Lake County and ODOT, both receive percent changes in flow regime according to the TMDL. A WLA for construction storm water is assigned a zero percent change, indicating that construction activities might not alter the existing flow regime. Industrial storm water has been determined to be an insignificant source of runoff volume in the watershed[16]; therefore, the industrial storm water WLA is assigned a zero percent change, requiring no reductions in flow volume for existing industrial facilities. New industrial facilities will be regulated under the Ohio General Construction Storm Water Permit and will be required to mitigate any increases in runoff volume per the construction storm water WLA.

9.4. Margin of Safety and Future Growth

The Clean Water Act requires that a TMDL include an MOS to account for uncertainties in the relationship between pollutants loads and receiving 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). A 10 percent explicit MOS has been applied to the nutrient TMDLs. That moderate MOS was specified because the use of the load duration curves is expected to provide reasonably accurate information on the loading capacity of the stream, but the estimate of the loading capacity could be subject to potential error associated with the method used to estimate flows in the watershed.

A 5 percent explicit MOS has been applied to the *E. coli* TMDLs in addition to an implicit MOS. The explicit MOS is fairly low because the implicit MOS also applies. The TMDL load was set at the in-stream geometric mean criteria; thus, the selected target is conservative because the geometric mean criteria are applied on a daily timescale. Implicit MOS for *E. coli* TMDLs applies because the load duration analysis does not address the die-off of pathogens.

The MOS for flow regime TMDLs is implicit based on flow regime target selection. The reference stream approach used to develop the unit area flow regime targets, and the TMDLs inherently provides for an implicit MOS because the reference streams are in attainment of their biocriteria and are better quality than streams at the impairment threshold.

Future growth was accounted for in each of the phosphorus and *E. coli* TMDLs, unless otherwise noted in the allocation tables. An evaluation of the population data, as presented in Section 3.1, identifies an increase in population between 2000 and 2010 of 1.1 percent and 2.7 percent in Lake and Geauga counties, respectively. Ashtabula County population decreased during that same time. A 3 percent future growth allocation was assigned to all phosphorus and *E. coli* TMDLs, unless otherwise noted.

Future growth is accounted for in flow regime TMDLs through a zero percent change allowed for construction storm water. During the development process, the flow regime is not allowed to change for permitted sites. That requires that as land use changes occur, the flow regime will need to match the pre-development flow regime. For example, if a parcel is forested and is planned to be developed into single family residential homes, the post-developed scenario will need to mimic the pre-development scenario for flow regime, through the use of storm water management and site planning techniques.

9.5. Critical Conditions and Seasonality

The Clean Water Act requires that TMDLs take into account critical conditions for stream flow, loading, and water quality parameters as part of the analysis of loading capacity. Critical conditions refer to the periods when greatest reductions of pollutants are needed and occur during summer conditions for recreation use and ALU impairments. Using the flow and load duration curve approach, which includes a

[16] This assumption may not be valid in other watersheds. The size of regulated industrial facilities and the associated storm water volume and pollutants need to be evaluated on a watershed by watershed basis.

separate loading capacity for each flow condition, addresses critical conditions that affect water quality. In addition, *E. coli* criteria for designated recreation uses are applicable from May 1 to October 30 only, and Ohio EPA biological, habitat, and nutrient targets are protective of the critical period because they are based on data collected from June 15 to September 30 only. Critical conditions for waters that are impaired by flow alteration occur during high- and low-flow conditions. The flow duration curve approach addresses those critical conditions by providing allocations for each flow zone.

The Clean Water Act also requires that TMDLs be established with consideration of seasonal variations. The flow and load duration approach also accounts for seasonality by evaluating loading capacity on a daily basis over the entire range of observed flows and presenting daily loading capacities that vary by flow.

9.6. Flow Regime TMDLs and Allocations

Flow duration curves were developed for both impaired and attaining streams (i.e., reference streams), and the relative difference between the two was used to establish hydrologic targets and the flow regime TMDLs (for a discussion on hydrologic targets, see Section 7). Flow regime TMDLs are expressed as percent reductions in flow rates (e.g., cubic feet per second) of the impaired streams. The reduction is calculated as the difference between an impaired stream's flow and a reference stream's flow, and the percent reduction is the difference relative to the impaired stream. The necessary percent reduction will control high flows and water quality degradation associated with increased levels of imperviousness caused by urbanization.

In addition, recommendations are presented to increase flow during low-flow conditions to help communicate the overall aim and expected result of the TMDL, which is to match the attaining stream's flow duration curve. Implementing those recommendations is appropriate and necessary to protect existing in-stream designated uses as urbanization proceeds in the TMDL area. The low-flow recommendations are not TMDLs but provide the basis to ensure that future storm water permits for the TMDL area comply with the antidegradation criteria in OAC 3745-1-05.

Table 9-2, Table 9-4, and Table 9-6 present the flow regime TMDLs for Big Creek (RM 16.0), Kellogg Creek (RM 3.3), and Red Creek (RM 0), respectively. Table 9-3, Table 9-5 and Table 9-7 present the flow regime recommendations for the aforementioned creeks, respectively.

Example calculations of the percent reduction for flow regime TMDLs (high flow) and percent increase for flow regime recommendations (low flow) for Kellogg Creek (RM 3.3) are presented below. For all TMDLs and recommendations, the necessary percent reduction or increase is calculated at the midpoint of each 10 percentile flow zone (e.g., the 5th percentile is the midpoint of the high-flow zone, which is the 0th to 10th percentile).

$$V_{\textit{high flow}\ (0\text{–}10)\ \text{decrease}} = (V_{Kellogg\ (5)} - V_{East\ (5)}) \ / \ V_{Kellogg\ (5)} \qquad \text{[flow regime TMDL]}$$

$$V_{\textit{low flow}\ (90\text{–}100)\ \text{increase}} = (V_{East\ (95)} - V_{Kellogg\ (95)}) \ / \ V_{Kellogg\ (95)} \qquad \text{[flow regime recommendation]}$$

where $V_{Kellogg\ (5)}$ and $V_{East\ (5)}$ are the flow rates at the 5th percentile of the flow duration curve for Kellogg Creek (RM 3.3) and the reference stream East Creek, respectively; $V_{Kellogg\ (95)}$ and $V_{East\ (95)}$ are the volumes of flow under the flow duration curves from the 95th percentiles for Kellogg Creek (RM 3.3) and East Creek, respectively.

Table 9-2. Flow regime TMDL for Big Creek (RM 16.0)

Flow reduction (%)	High	Moist			Mid-range		Dry			Low
	0–10	**10–20**	**20–30**	**30–40**	**40–50**	**50–60**	**60–70**	**70–80**	**80–90**	**90–100**
TMDL	**24%**	**8%**	**5%**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
LA	24%	8%	5%	--	--	--	--	--	--	--
WLA	(WLA Flow Reduction Percents are not Additive)									
Chardon WWTP [a]	*0%*	*0%*	*0%*	--	--	--	--	--	--	--
Construction storm water	*0%*	*0%*	*0%*	--	--	--	--	--	--	--
Industrial storm water	*0%*	*0%*	*0%*	--	--	--	--	--	--	--

Notes
LA = load allocation; TMDL = total maximum daily load; WLA = wasteload allocation; WWTP = wastewater treatment plant.
A double dash (--) indicates that a flow reduction is not applicable.
a. Chardon WWTP (OH0022659) has a design flow of 1.808 MGD and a WLA of 0 percent. As such, the facility may continue to discharge at current permitted design flows. The cause of the impairment is the alteration of the natural flow regime from urban runoff and storm sewers, which are derived from the transition of native land cover to urban development. The TMDLs are targeted to address those causes.

Table 9-3. Flow regime recommendations for Big Creek (RM 16.0)

Flow increase (%)	High	Moist			Mid-Range		Dry			Low
	0–10	**10–20**	**20–30**	**30–40**	**40–50**	**50–60**	**60–70**	**70–80**	**80–90**	**90–100**
Total flow increase	**--**	**--**	**--**	**1%**	**1%**	**5%**	**9%**	**11%**	**19%**	**7%**
Available for Nonpoint Sources	--	--	--	1%	1%	5%	9%	11%	19%	7%
Available for Point Sources	(Point Source Flow Increase Percents are not Additive)									
Chardon WWTP [a]	--	--	--	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*
Construction storm water	--	--	--	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*
Industrial storm water	--	--	--	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*

Notes
A double dash (--) indicates that a flow increase is not applicable.
a. Chardon WWTP (OH0022659) has a design flow of 1.808 MGD and a WLA of 0 percent. As such, the facility may continue to discharge at current permitted design flows. The cause of the impairment is the alteration of the natural flow regime from urban runoff and storm sewers, which are derived from the transition of native land cover to urban development.

Table 9-4. Flow regime TMDL for Kellogg Creek (RM 3.3)

Flow reduction (%)	High	Moist		Mid-range		Dry			Low
	0–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100
TMDL	**35%**	**5%**	--	--	--	--	--	--	--	--
LA	35%	5%	--	--	--	--	--	--	--	--
WLA	(WLA Flow Reduction Percents are not Additive)									
Lake County MS4	*35%*	*5%*	--	--	--	--	--	--	--	--
ODOT MS4	*35%*	*5%*	--	--	--	--	--	--	--	--
Construction storm water	*0%*	*0%*	--	--	--	--	--	--	--	--
Industrial storm water	*0%*	*0%*	--	--	--	--	--	--	--	--

Notes
LA = load allocation; TMDL = total maximum daily load; WLA = wasteload allocation.
A double dash (--) indicates that a flow reduction is not applicable.

Table 9-5. Flow regime recommendations for Kellogg Creek (RM 3.3)

Flow increase (%)	High	Moist			Mid-range		Dry			Low
	0–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100
Total flow increase	--	--	**4%**	**11%**	**14%**	**20%**	**30%**	**34%**	**55%**	**30%**
Available for Nonpoint Sources	--	--	4%	11%	14%	20%	30%	34%	55%	30%
Available for Point Sources	(Point Source Flow Increase Percents are not Additive)									
Lake County MS4	--	--	*4%*	*11%*	*14%*	*20%*	*30%*	*34%*	*55%*	*30%*
ODOT MS4	--	--	*4%*	*11%*	*14%*	*20%*	*30%*	*34%*	*55%*	*30%*
Construction storm water	--	--	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*
Industrial storm water	--	--	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*

Note
A double dash (--) indicates that a flow increase is not applicable.

Table 9-6. Flow regime TMDL for Red Creek (RM 0)

Flow reduction (%)	High	Moist			Mid-range		Dry			Low
	0–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100
TMDL	**28%**	**12%**	**8%**	**3%**	**--**	**--**	**--**	**--**	**--**	**--**
LA	28%	12%	8%	3%	--	--	--	--	--	--
WLA	(WLA Flow Reduction Percents are not Additive)									
Mid-West Materials [a]	*0%*	*0%*	*0%*	*0%*	--	--	--	--	--	--
Lake County MS4	*28%*	*12%*	*8%*	*3%*	--	--	--	--	--	--
ODOT MS4	*28%*	*12%*	*8%*	*3%*	--	--	--	--	--	--
Construction storm water	*0%*	*0%*	*0%*	*0%*	--	--	--	--	--	--
Industrial storm water	*0%*	*0%*	*0%*	*0%*	--	--	--	--	--	--

Notes
LA = load allocation; TMDL = total maximum daily load; WLA = wasteload allocation.
A double dash (--) indicates that a flow reduction is not applicable.
a. Mid-West Materials, Inc. (OH0134660) has a design flow 0.0032 MGD and a WLA of 0 percent. As such, the facility may continue to discharge at current permitted design flows. The cause of the impairment is the alteration of the natural flow regime from urban runoff and storm sewers, which are derived from the transition of native land cover to urban development. The TMDLs are targeted to address those causes.

Table 9-7. Flow regime recommendations for Red Creek (RM 0)

Flow increase (%)	High	Moist			Mid-range		Dry			Low
	0–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100
Total flow increase	**--**	**--**	**--**	**--**	**1%**	**5%**	**11%**	**13%**	**19%**	**18%**
Available for Nonpoint Sources	--	--	--	--	1%	5%	11%	13%	19%	18%
Available for Point Sources	(Point Source Flow Increase Percents are not Additive)									
Mid-West Materials [a]	--	--	--	--	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*
Lake County MS4	--	--	--	--	*1%*	*5%*	*11%*	*13%*	*19%*	*18%*
ODOT MS4	--	--	--	--	*1%*	*5%*	*11%*	*13%*	*19%*	*18%*
Construction storm water	--	--	--	--	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*
Industrial storm water	--	--	--	--	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*

Notes
A double dash (--) indicates that a flow increase is not applicable.
a. Mid-West Materials, Inc. (OH0134660) has a design flow 0.0032 MGD and a WLA of 0 percent. As such, the facility may continue to discharge at current permitted design flows. The cause of the impairment is the alteration of the natural flow regime from urban runoff and storm sewers, which are derived from the transition of native land cover to urban development.

9.7. Nutrient TMDLs and Allocations

The following sections present the loading capacity for total phosphorus and associated allocations for each of the nutrient impaired waterbodies in the lower Grand River watershed: Mill Creek (G02G13; RM 25.7) and Red Creek (outlet).[17] The results are presented by assessment location in each of the applicable watersheds. The loading capacities (i.e., TMDL) are calculated using the flow associated with the midpoint of each of the flow zones (e.g., 5th percentile flow for the high-flow zone, which spans the 0th to 10th percentile). That flow value is multiplied by the total phosphorus nutrient target that is applicable for the stream size (Section 9.3.2). Table 9-8 and Table 9-9 display total phosphorus TMDLs for Mill Creek (RM25.6) and Red Creek, respectively. Table 9-10 presents the total phosphorus individual WLAs for MS4s, and Table 9-11 displays the recommended loading targets for each community to comply with the Lake County MS4 WLA. Figures of the total phosphorus load duration curves are in Appendix G.

Table 9-8. Total phosphorus TMDLs for Mill Creek (RM 25.6)

Total phosphorus (lb/d)	**High**	**Moist**			**Mid-range**		**Dry**			**Low**
	0–10	**10–20**	**20–30**	**30–40**	**40–50**	**50–60**	**60–70**	**70–80**	**80–90**	**90–100**
TMDL	**63.3**	**31.1**	**18.8**	**12.7**	**7.97**	**5.09**	**3.02**	**1.64**	**0.719**	**0.138**
LA	55	27	16	11	6.9	4.4	2.6	1.4	0.60	0.095
WLA	0.056	0.040	0.034	0.031	0.029	0.028	0.027	0.026	0.025	0.025
Dorset Garage [a]	*0.025*	*0.025*	*0.025*	*0.025*	*0.025*	*0.025*	*0.025*	*0.025*	*0.025*	*0.025*
Construction storm water	*0.031*	*0.015*	*0.009*	*0.006*	*0.004*	*0.003*	*0.002*	*0.001*	*0.0004*	*0.0001*
FG (3%)	1.9	0.93	0.56	0.38	0.24	0.15	0.091	0.049	0.022	0.0041
MOS (10%)	6.3	3.1	1.9	1.3	0.80	0.51	0.30	0.16	0.072	0.014

Notes

FG = future growth reserve; LA = load allocation; MOS = margin of safety; TMDL = total maximum daily load; WLA = wasteload allocation.

All loads are reported in pounds per day. The LA, WLA, FG, and MOS are reported to two significant digits.

The TMDL target for Mill Creek is 0.1 mg/L.

a. ODOT Dorset Outpost Garage (OH0128449) has a design flow of 0.001 MGD and a TMDL target of 3.0 mg/L total phosphorus.

[17] The TMDL was calculated at the outlet (RM 0.0) of Red Creek. The nutrient data that were used for analyses and are associated with the TMDL were collected by Ohio EPA at the Mantle Road bridge (RM 0.5), which is station G02G21 and G02W09.

Table 9-9. Total phosphorus TMDLs for Red Creek (RM 0)

Total phosphorus (lb/d)	High	Moist			Mid-range		Dry			Low
	0–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100
TMDL	**27.8**	**11.7**	**6.78**	**4.27**	**2.66**	**1.61**	**0.92**	**0.46**	**0.1862**	**0.0357**
LA [a]	12.02	5.15	2.87	1.80	1.12	0.66	0.36	0.16	0.040	0
WLA	12.17	5.03	3.03	1.91	1.20	0.74	0.44	0.24	0.122	0.031
Mid-West Materials [b]	*0.08*	*0.08*	*0.08*	*0.08*	*0.08*	*0.08*	*0.08*	*0.08*	*0.08*	*0.031*
Construction storm water [a]	*0.19*	*0.08*	*0.05*	*0.03*	*0.019*	*0.011*	*0.0064*	*0.0032*	*0.0013*	*0*
MS4 (49%)[a]	*11.9*	*4.87*	*2.90*	*1.80*	*1.10*	*0.65*	*0.35*	*0.16*	*0.041*	*0*
FG (3%)	0.83	0.35	0.20	0.13	0.08	0.05	0.03	0.01	0.0056	0.0011
MOS (10%)	2.78	1.17	0.68	0.43	0.27	0.16	0.09	0.05	0.0186	0.0036

Notes
FG = future growth reserve; LA = load allocation; MOS = margin of safety; TMDL = total maximum daily load; WLA = wasteload allocation.
All loads are reported in pounds per day.
The TMDL total phosphorus target for Red Creek is 0.08 mg/L.
a. Allocation under low flow conditions is set to zero.
b. Mid-West Materials, Inc. (OH0134660) has a design flow 0.0032 MGD and a TMDL target of 3.0 mg/L total phosphorus for all flows except low flows. The low flow allocation was set equal to the TMDL minus the MOS and FG.

Table 9-10. Total phosphorus individual MS4 WLAs

MS4 entity	High	Moist			Mid-range		Dry			Low
	0–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100
Lake County	11.8	4.84	2.9	1.8	1.1	0.65	0.35	0.15	0.041	0
ODOT	0.075	0.031	0.018	0.011	0.0070	0.0041	0.0022	0.0010	0.00026	0

Notes
Loads are reported in pounds per day.
a. Lake County (3GQ0068*BG) has an MS4 area of 4.52 square miles.
b. ODOT (4GQ0000*BG) has an MS4 area of 0.03 square miles.

Table 9-11. Total phosphorus target loads to meet Lake County WLA

MS4 entity [a]	High	Moist			Mid-range		Dry			Low
	0–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100
Perry Village	1.6	0.67	0.39	0.25	0.15	0.089	0.048	0.021	0.0056	0
Painesville Township	10.0	4.1	2.4	1.5	0.93	0.55	0.29	0.13	0.035	0
City of Painesville	0.015	0.0062	0.0037	0.0023	0.0014	0.00083	0.00045	0.00020	0.000053	0
Lake County Roads	0.14	0.057	0.034	0.021	0.013	0.0076	0.0041	0.0018	0.00048	0

Notes
Loads are reported in pounds per day and are rounded to two significant digits.
a. The MS4 areas in square miles are: Perry Village 0.62; Painesville Township, 3.84; city of Painesville, 0.01; and Lake County Roads, 0.05.

9.8. Pathogen TMDLs and Allocations

The following sections present the loading capacity and associated allocations for each of the impaired waterbodies in the lower Grand River watershed due to pathogens. The TMDLs are presented by watershed outlet in each of the applicable watersheds including at five 12-digit HUC watershed boundaries along the lower Grand River mainstem. The TMDLs are the loading capacities calculated using the flow associated with the midpoint of each of the flow zones (e.g., 5th percentile flow for the high-flow zone, which spans the 0th to 10th percentile) and the geometric mean *E. coli* criterion of 126 counts/100 mL. Table 9-12 displays *E. coli* TMDLs for each impaired waterbody. The individual WLAs for facilities and MS4s are presented in Table 9-13 and Table 9-15. Recommended target loads for Lake County are presented in Table 9-14. *E. coli* load duration curves are in Appendix G.

The Chardon WWTP, located near RM 16.1 on Big Creek, was further evaluated to determine the die-off of *E. coli* that likely occurs between the facility and the TMDL assessment location at the HUC outlet. Appendix H includes the *E. coli* decay calculations, based on measured low flow velocities. Due to the availability of measured flow and velocity data, the decay values are applicable to low and dry flow conditions only.

Table 9-12. *E. coli* TMDLs

HUC (04110004)	Stream	*E. coli* (counts/day)	High	Moist			Mid-range		Dry			Low
			0–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100
04 01	Griggs Creek	**TMDL**	**2.1E+11**	**8.4E+10**	**4.7E+10**	**2.8E+10**	**1.8E+10**	**1.1E+10**	**6.3E+09**	**3.5E+09**	**1.5E+09**	**3.6E+08**
		LA	1.9E+11	7.7E+10	4.4E+10	2.6E+10	1.6E+10	9.9E+09	5.8E+09	3.2E+09	1.3E+09	3.3E+08
		FG (3%)	6.2E+09	2.5E+09	1.4E+09	8.5E+08	5.4E+08	3.2E+08	1.9E+08	1.0E+08	4.4E+07	1.1E+07
		MOS (5%)	1.0E+10	4.2E+09	2.4E+09	1.4E+09	9.0E+08	5.4E+08	3.2E+08	1.7E+08	7.3E+07	1.8E+07
04 02	Mill Creek	**TMDL**	**5.4E+11**	**2.2E+11**	**1.2E+11**	**7.4E+10**	**4.6E+10**	**2.8E+10**	**1.6E+10**	**9.1E+09**	**4.1E+09**	**1.1E+09**
		LA	5.0E+11	2.0E+11	1.1E+11	6.8E+10	4.2E+10	2.5E+10	1.5E+10	8.1E+09	3.5E+09	7.9E+08
		WLA (Facilities)	2.5E+08	2.5E+08	2.5E+08	2.5E+08	2.5E+08	2.5E+08	2.5E+08	2.5E+08	2.5E+08	2.5E+08
		FG (3%)	1.6E+10	6.6E+09	3.7E+09	2.2E+09	1.4E+09	8.3E+08	4.9E+08	2.7E+08	1.2E+08	3.4E+07
		MOS (5%)	2.7E+10	1.1E+10	6.1E+09	3.7E+09	2.3E+09	1.4E+09	8.2E+08	4.5E+08	2.1E+08	5.6E+07
04 03	Mill Creek	**TMDL**	**1.0E+12**	**4.3E+11**	**2.4E+11**	**1.5E+11**	**9.4E+10**	**5.8E+10**	**3.6E+10**	**2.2E+10**	**1.2E+10**	**6.8E+09**
		LA	9.5E+11	3.8E+11	2.1E+11	1.3E+11	8.0E+10	4.7E+10	2.7E+10	1.4E+10	5.0E+09	7.3E+06
		WLA	1.2E+10	8.6E+09	7.6E+09	7.2E+09	6.9E+09	6.7E+09	6.6E+09	6.5E+09	6.5E+09	6.4E+09
		Facilities	*6.4E+09*	*6.4E+09*	*6.4E+09*	*6.4E+09*	*6.4E+09*	*6.4E+09*	*6.4E+09*	*6.4E+09*	*6.4E+09*	*6.4E+09*
		Industrial storm water (0.56%)	*5.3E+09*	*2.2E+09*	*1.2E+09*	*7.2E+08*	*4.5E+08*	*2.6E+08*	*1.5E+08*	*7.8E+07*	*2.8E+07*	*4.1E+04*
		FG (3%)[a]	3.1E+10	1.3E+10	7.2E+09	4.4E+09	2.8E+09	1.7E+09	1.1E+09	6.6E+08	3.7E+08	0 [a]
		MOS (5%)	5.2E+10	2.1E+10	1.2E+10	7.4E+09	4.7E+09	2.9E+09	1.8E+09	1.1E+09	6.2E+08	3.4E+08
Upper Grand	Grand River	**TMDL**	**2.7E+12**	**9.6E+11**	**4.8E+11**	**2.5E+11**	**1.5E+11**	**9.7E+10**	**6.6E+10**	**4.3E+10**	**2.8E+10**	**1.3E+10**
		LA	2.5E+12	8.9E+11	4.4E+11	2.3E+11	1.4E+11	8.9E+10	6.1E+10	4.0E+10	2.6E+10	1.2E+10
		FG (3%)	8.1E+10	2.9E+10	1.4E+10	7.6E+09	4.6E+09	2.9E+09	2.0E+09	1.3E+09	8.4E+08	3.9E+08
		MOS (5%)	1.3E+11	4.8E+10	2.4E+10	1.3E+10	7.7E+09	4.9E+09	3.3E+09	2.2E+09	1.4E+09	6.5E+08

HUC (04110004)	Stream	*E. coli* (counts/day)	High	Moist			Mid-range		Dry			Low
			0–10	**10–20**	**20–30**	**30–40**	**40–50**	**50–60**	**60–70**	**70–80**	**80–90**	**90–100**
06 01	Coffee Creek	**TMDL**	**1.3E+11**	**5.2E+10**	**3.0E+10**	**1.8E+10**	**1.2E+10**	**7.1E+09**	**4.5E+09**	**2.8E+09**	**1.6E+09**	**9.3E+08**
		LA	1.2E+11	4.7E+10	2.6E+10	1.6E+10	9.8E+09	5.8E+09	3.4E+09	1.8E+09	7.3E+08	1.2E+08
		WLA	1.6E+09	1.1E+09	9.4E+08	8.6E+08	8.1E+08	7.8E+08	7.6E+08	7.5E+08	7.4E+08	7.4E+08
		Facilities	*7.4E+08*	*7.4E+08*	*7.4E+08*	*7.4E+08*	*7.4E+08*	*7.4E+08*	*7.4E+08*	*7.4E+08*	*7.4E+08*	*7.4E+08*
		Industrial storm water (0.75%)	*8.7E+08*	*3.5E+08*	*2.0E+08*	*1.2E+08*	*7.4E+07*	*4.4E+07*	*2.6E+07*	*1.4E+07*	*5.5E+06*	*9.1E+05*
		FG (3%)	3.8E+09	1.6E+09	8.9E+08	5.5E+08	3.5E+08	2.1E+08	1.4E+08	8.3E+07	4.8E+07	2.8E+07
		MOS (5%)	6.4E+09	2.6E+09	1.5E+09	9.2E+08	5.8E+08	3.6E+08	2.3E+08	1.4E+08	8.0E+07	4.7E+07
06 01	Grand River	**TMDL**	**2.1E+12**	**7.6E+11**	**3.8E+11**	**2.0E+11**	**1.2E+11**	**7.8E+10**	**5.3E+10**	**3.5E+10**	**2.3E+10**	**1.1E+10**
		LA	2.0E+12	7.0E+11	3.5E+11	1.8E+11	1.1E+11	7.1E+10	4.8E+10	3.1E+10	2.0E+10	9.4E+09
		WLA	4.7E+09	2.1E+09	1.4E+09	1.1E+09	9.6E+08	8.8E+08	8.4E+08	8.0E+08	7.8E+08	7.6E+08
		Facilities	*7.4E+08*	*7.4E+08*	*7.4E+08*	*7.4E+08*	*7.4E+08*	*7.4E+08*	*7.4E+08*	*7.4E+08*	*7.4E+08*	*7.4E+08*
		Industrial storm water (0.20%)	*3.9E+09*	*1.4E+09*	*6.9E+08*	*3.7E+08*	*2.2E+08*	*1.4E+08*	*9.6E+07*	*6.3E+07*	*4.1E+07*	*1.9E+07*
		FG (3%)	6.4E+10	2.3E+10	1.1E+10	6.0E+09	3.7E+09	2.3E+09	1.6E+09	1.0E+09	6.9E+08	3.3E+08
		MOS (5%)	1.1E+11	3.8E+10	1.9E+10	1.0E+10	6.1E+09	3.9E+09	2.7E+09	1.7E+09	1.1E+09	5.5E+08
06 02	Mill Creek	**TMDL**	**2.0E+11**	**8.4E+10**	**4.8E+10**	**2.9E+10**	**1.7E+10**	**1.1E+10**	**6.3E+09**	**3.4E+09**	**1.6E+09**	**4.8E+08**
		LA	1.8E+11	7.5E+10	4.2E+10	2.5E+10	1.6E+10	9.3E+09	5.5E+09	2.9E+09	1.2E+09	2.2E+08
		WLA	7.1E+09	2.6E+09	1.4E+09	8.0E+08	5.5E+08	4.0E+08	3.2E+08	2.6E+08	2.7E+08	2.3E+08
		Facilities	*1.8E+08*	*1.8E+08*	*1.8E+08*	*1.8E+08*	*1.8E+08*	*1.8E+08*	*1.8E+08*	*1.8E+08*	*1.8E+08*	*1.8E+08*
		MS4	*7.0E+09*	*2.5E+09*	*1.2E+09*	*6.2E+08*	*3.6E+08*	*2.2E+08*	*1.4E+08*	*7.6E+07*	*8.3E+07*	*4.4E+07*
		FG (3%)	6.1E+09	2.5E+09	1.4E+09	8.6E+08	5.2E+08	3.2E+08	1.9E+08	1.0E+08	4.7E+07	1.5E+07
		MOS (5%)	1.0E+10	4.2E+09	2.4E+09	1.4E+09	8.7E+08	5.3E+08	3.1E+08	1.7E+08	7.9E+07	2.4E+07

HUC (04110004)	Stream	*E. coli* (counts/day)	High	Moist			Mid-range		Dry			Low
			0–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100
06 03	Grand River	**TMDL**	**1.8E+12**	**6.5E+11**	**3.3E+11**	**1.8E+11**	**1.1E+11**	**7.1E+10**	**5.0E+10**	**3.5E+10**	**2.5E+10**	**1.5E+10**
		LA	1.7E+12	5.9E+11	2.9E+11	1.5E+11	9.3E+10	5.8E+10	3.9E+10	2.5E+10	1.5E+10	6.1E+09
		WLA	1.5E+10	1.0E+10	8.7E+09	8.0E+09	7.7E+09	7.5E+09	7.4E+09	7.4E+09	7.4E+09	7.3E+09
		Facilities	*7.3E+09*	*7.3E+09*	*7.3E+09*	*7.3E+09*	*7.3E+09*	*7.3E+09*	*7.3E+09*	*7.3E+09*	*7.3E+09*	*7.3E+09*
		MS4	*5.3E+09*	*1.9E+09*	*9.1E+08*	*4.7E+08*	*2.8E+08*	*1.6E+08*	*1.0E+08*	*5.7E+07*	*6.3E+07*	*3.3E+07*
		Industrial storm water (0.17%)	*2.8E+09*	*1.0E+09*	*5.0E+08*	*2.6E+08*	*1.6E+08*	*9.9E+07*	*6.6E+07*	*4.2E+07*	*2.6E+07*	*1.0E+07*
		FG (3%)	5.4E+10	2.0E+10	9.8E+09	5.3E+09	3.3E+09	2.1E+09	1.5E+09	1.0E+09	7.4E+08	4.4E+08
		MOS (5%)	9.1E+10	3.3E+10	1.6E+10	8.8E+09	5.5E+09	3.6E+09	2.5E+09	1.7E+09	1.2E+09	7.3E+08
06 04	Paine Creek	**TMDL**	**2.8E+11**	**1.2E+11**	**6.7E+10**	**4.0E+10**	**2.4E+10**	**1.4E+10**	**8.5E+09**	**4.7E+09**	**2.0E+09**	**5.1E+08**
		LA	2.6E+11	1.1E+11	6.1E+10	3.6E+10	2.2E+10	1.3E+10	7.7E+09	4.2E+09	1.8E+09	4.0E+08
		WLA	2.5E+10	9.0E+09	4.4E+09	2.3E+09	1.4E+09	8.5E+08	5.6E+08	3.4E+08	3.6E+08	2.2E+08
		Facilities	*2.5E+10*	*8.9E+09*	*4.3E+09*	*2.3E+09*	*1.3E+09*	*7.8E+08*	*4.9E+08*	*2.8E+08*	*3.0E+08*	*1.6E+08*
		MS4	*6.5E+07*	*6.5E+07*	*6.5E+07*	*6.5E+07*	*6.5E+07*	*6.5E+07*	*6.5E+07*	*6.5E+07*	*6.5E+07*	*6.5E+07*
		FG (3%)	8.5E+09	3.6E+09	2.0E+09	1.2E+09	7.3E+08	4.3E+08	2.5E+08	1.4E+08	6.0E+07	1.5E+07
		MOS (5%)	1.4E+10	6.0E+09	3.3E+09	2.0E+09	1.2E+09	7.2E+08	4.2E+08	2.3E+08	1.0E+08	2.5E+07
06 05	Grand River	**TMDL**	**1.6E+12**	**5.7E+11**	**2.9E+11**	**1.6E+11**	**9.7E+10**	**6.3E+10**	**4.5E+10**	**3.1E+10**	**2.3E+10**	**1.4E+10**
		LA	1.4E+12	5.1E+11	2.5E+11	1.3E+11	8.0E+10	5.0E+10	3.3E+10	2.1E+10	1.3E+10	5.0E+09
		WLA	3.3E+10	1.7E+10	1.2E+10	9.8E+09	8.9E+09	8.3E+09	8.0E+09	7.8E+09	7.8E+09	7.7E+09
		Facilities	*7.5E+09*	*7.5E+09*	*7.5E+09*	*7.5E+09*	*7.5E+09*	*7.5E+09*	*7.5E+09*	*7.5E+09*	*7.5E+09*	*7.5E+09*
		MS4	*2.4E+10*	*8.5E+09*	*4.1E+09*	*2.1E+09*	*1.2E+09*	*7.4E+08*	*4.7E+08*	*2.6E+08*	*2.8E+08*	*1.5E+08*
		Industrial storm water (0.14%)	*2.0E+09*	*7.3E+08*	*3.6E+08*	*1.9E+08*	*1.1E+08*	*7.1E+07*	*4.7E+07*	*3.0E+07*	*1.9E+07*	*7.2E+06*
		FG (3%)	4.8E+10	1.7E+10	8.6E+09	4.7E+09	2.9E+09	1.9E+09	1.3E+09	9.4E+08	6.8E+08	4.1E+08
		MOS (5%)	8.0E+10	2.9E+10	1.4E+10	7.8E+09	4.8E+09	3.2E+09	2.2E+09	1.6E+09	1.1E+09	6.9E+08

HUC (04110004)	Stream	*E. coli* (counts/day)	High	Moist			Mid-range flows		Dry			Low
			0–10	**10–20**	**20–30**	**30–40**	**40–50**	**50–60**	**60–70**	**70–80**	**80–90**	**90–100**
06 06	Big Creek	**TMDL**	**6.0E+11**	**2.4E+11**	**1.3E+11**	**8.3E+10**	**5.1E+10**	**3.4E+10**	**2.3E+10**	**1.6E+10**	**1.2E+10**	**1.0E+10**
		LA [b]	4.8E+11	1.9E+11	1.0E+11	5.8E+10	3.2E+10	1.7E+10	8.0E+09	2.7E+09	8.6E+09	6.8E+09
		WLA	7.5E+10	3.4E+10	2.3E+10	1.8E+10	1.5E+10	1.4E+10	1.3E+10	1.2E+10	2.8E+09	2.4E+09
		Facilities [b]	*8.0E+08*	*8.0E+08*	*8.0E+08*	*8.0E+08*	*8.0E+08*	*8.0E+08*	*8.0E+08*	*8.0E+08*	*8.0E+08*	*8.0E+08*
		Chardon WWTP	*1.1E+10*	*1.1E+10*	*1.1E+10*	*1.1E+10*	*1.1E+10*	*1.1E+10*	*1.1E+10*	*1.1E+10*	*1.1E+10*	*1.1E+10*
		Die-off from Chardon WWTP [c]	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*- 9.8E+09*	*- 9.8E+09*
		MS4	*6.1E+10*	*2.2E+10*	*1.1E+10*	*5.5E+09*	*3.2E+09*	*1.9E+09*	*1.2E+09*	*6.7E+08*	*7.3E+08*	*3.8E+08*
		Industrial storm water (0.35%)	*1.9E+09*	*7.3E+08*	*3.9E+08*	*2.2E+08*	*1.2E+08*	*6.8E+07*	*3.2E+07*	*1.2E+07*	*3.3E+07*	*2.5E+07*
		FG (3%)	1.8E+10	7.2E+09	4.0E+09	2.5E+09	1.5E+09	1.0E+09	6.9E+08	4.9E+08	3.7E+08	3.0E+08
		MOS (5%)	3.0E+10	1.2E+10	6.7E+09	4.1E+09	2.6E+09	1.7E+09	1.1E+09	8.2E+08	6.2E+08	5.0E+08
06 07	Grand River	**TMDL**	**1.7E+12**	**6.3E+11**	**3.3E+11**	**2.0E+11**	**1.4E+11**	**1.0E+11**	**8.6E+10**	**7.2E+10**	**6.3E+10**	**5.4E+10**
		LA	1.3E+12	4.7E+11	2.3E+11	1.2E+11	6.9E+10	4.1E+10	2.6E+10	1.4E+10	1.6E+10	8.3E+09
		WLA	2.2E+11	1.1E+11	7.9E+10	6.5E+10	5.9E+10	5.5E+10	5.3E+10	5.2E+10	4.2E+10	4.1E+10
		Facilities [d]	*3.9E+10*	*3.9E+10*	*3.9E+10*	*3.9E+10*	*3.9E+10*	*3.9E+10*	*3.9E+10*	*3.9E+10*	*3.9E+10*	*3.9E+10*
		Chardon WWTP	*1.1E+10*	*1.1E+10*	*1.1E+10*	*1.1E+10*	*1.1E+10*	*1.1E+10*	*1.1E+10*	*1.1E+10*	*1.1E+10*	*1.1E+10*
		Die-off from Chardon WWTP [c]	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*- 9.8E+09*	*- 9.8E+09*
		MS4	*1.7E+11*	*5.9E+10*	*2.9E+10*	*1.5E+10*	*8.7E+09*	*5.2E+09*	*3.2E+09*	*1.8E+09*	*2.0E+09*	*1.0E+09*
		Industrial storm water (0.29%)	*4.3E+09*	*1.5E+09*	*7.5E+08*	*3.9E+08*	*2.3E+08*	*1.3E+08*	*8.4E+07*	*4.7E+07*	*5.1E+07*	*2.7E+07*
		FG (3%)	5.0E+10	1.9E+10	1.0E+10	6.0E+09	4.2E+09	3.1E+09	2.6E+09	2.2E+09	1.9E+09	1.6E+09
		MOS (5%)	8.4E+10	3.1E+10	1.7E+10	1.0E+10	7.0E+09	5.2E+09	4.3E+09	3.6E+09	3.1E+09	2.7E+09

HUC (04110004)	Stream	*E. coli* (counts/day)	High	Moist			Mid-range flows		Dry			Low
			0–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100
06 07	Red Creek	**TMDL**	**1.3E+11**	**5.1E+10**	**2.5E+10**	**1.4E+10**	**7.4E+09**	**4.2E+09**	**2.2E+09**	**1.1E+09**	**4.8E+08**	**1.3E+08**
		LA	1.1E+11	4.4E+10	2.1E+10	1.2E+10	6.3E+09	3.5E+09	1.8E+09	9.1E+08	3.1E+08	4.0E+07
		WLA	9.6E+09	3.4E+09	1.7E+09	8.8E+08	5.2E+08	3.2E+08	2.1E+08	1.2E+08	1.3E+08	8.0E+07
		Facilities	*2.0E+07*	*2.0E+07*	*2.0E+07*	*2.0E+07*	*2.0E+07*	*2.0E+07*	*2.0E+07*	*2.0E+07*	*2.0E+07*	*2.0E+07*
		MS4	*9.6E+09*	*3.4E+09*	*1.7E+09*	*8.6E+08*	*5.0E+08*	*3.0E+08*	*1.9E+08*	*1.0E+08*	*1.1E+08*	*6.0E+07*
		FG (3%)	3.9E+09	1.5E+09	7.5E+08	4.1E+08	2.2E+08	1.3E+08	6.6E+07	3.4E+07	1.4E+07	3.9E+06
		MOS (5%)	6.5E+09	2.6E+09	1.2E+09	6.8E+08	3.7E+08	2.1E+08	1.1E+08	5.6E+07	2.4E+07	6.5E+06

Notes

FG = future growth; LA = load allocation; MOS = margin of safety; TMDL = total maximum daily load = LA + WLA + MOS + FG; WLA = wasteload allocation

a. FG was set to zero under Low Flows. Ashtabula County growth projections are negative.

b. All NPDES-permitted facilities in HUC 04110004 06 06 except for the Chardon WWTP.

c. The *E. coli* load that dies off along Big Creek from the headwaters and Chardon WWTP through the mouth on the Grand River. See Appendix H for the calculations.

d. All NPDES-permitted facilities in LRAU except for the Chardon WWTP.

Table 9-13. *E. coli* MS4 WLAs (counts/day)

MS4 entity	MS4 area (square miles)	High	Moist			Mid-range		Dry			Low
		0–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100
Lake County (3GQ00068*BG)	53	1.2E+11	4.1E+10	2.0E+10	1.1E+10	6.5E+09	4.0E+09	2.7E+09	1.7E+09	1.0E+09	3.9E+08
Ohio Department of Transportation (4GQ00000*BG)	0.42	9.2E+08	3.3E+08	1.6E+08	8.5E+07	5.1E+07	3.2E+07	2.1E+07	1.3E+07	8.2E+06	3.1E+06

Table 9-14. *E. coli* target loads to meet Lake County WLA (counts/day)

MS4 entity	MS4 area (square miles)	High	Moist			Mid-range		Dry			Low
		0–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100
Perry Village	0.62	1.3E+09	4.7E+08	2.3E+08	1.2E+08	6.9E+07	4.1E+07	2.6E+07	1.4E+07	1.6E+07	8.3E+06
Leroy Township	25.53	5.4E+10	1.9E+10	9.3E+09	4.8E+09	2.8E+09	1.7E+09	1.1E+09	5.9E+08	6.4E+08	3.4E+08
Concord Township	21.97	4.6E+10	1.6E+10	8.0E+09	4.1E+09	2.4E+09	1.4E+09	9.0E+08	5.1E+08	5.5E+08	2.9E+08
Madison Township	13.53	2.9E+10	1.0E+10	4.9E+09	2.6E+09	1.5E+09	8.9E+08	5.6E+08	3.1E+08	3.4E+08	1.8E+08
Painesville Township	9.25	2.0E+10	6.9E+09	3.4E+09	1.7E+09	1.0E+09	6.1E+08	3.8E+08	2.1E+08	2.3E+08	1.2E+08
City of Painesville	5.56	1.2E+10	4.2E+09	2.0E+09	1.0E+09	6.1E+08	3.6E+08	2.3E+08	1.3E+08	1.4E+08	7.3E+07
Fairport Harbor Village	1.01	2.1E+09	7.6E+08	3.7E+08	1.9E+08	1.1E+08	6.7E+07	4.2E+07	2.3E+07	2.5E+07	1.3E+07
Grand River Village	0.32	6.8E+08	2.4E+08	1.2E+08	6.1E+07	3.6E+07	2.1E+07	1.3E+07	7.4E+06	8.1E+06	4.3E+06
Lake County Roads	0.54	1.1E+09	4.0E+08	2.0E+08	1.0E+08	6.0E+07	3.5E+07	2.2E+07	1.2E+07	1.4E+07	7.1E+06

Table 9-15. Individual *E. coli* WLAs for facilities permitted to discharge bacteria

Facility	U.S. EPA ID	Design flow (MGD)	WLA target (counts / 100 mL)	WLA (counts / day)
Ashtabula County JVS	OH0044920	0.0400	161	2.4E+08
ODOT Dorset Outpost Garage	OH0128449	0.001	161	6.1E+06
Jefferson WWTP	OH0025887	1.0000	161	6.1E+09
DFC MHP	OH0121614	0.0090	161	5.5E+07
Ken Forging Inc	OH0131296	0.0025	161	1.5E+07
King Luminaire Co Inc	OH0133027	0.0018	161	1.1 E+07
Harassment's Bar	OH0139301	0.0018	161	1.1 E+07
Coffee Creek WWTP	OH0098469	0.1500	126 [a]	7.2E+08
Grand River Academy	OH0134457	0.0050	126 [a]	2.4E+07
Rustic Pines MHP WWTP	OH0112135	0.0300	161	1.8E+08
Whispering Willow MHP	OH0123421	0.0200	126	9.5E+07
Cedar Hills Conference Center	OH0123641	0.0060	126 [a]	2.9E+07
Camp Lejnar	OH0134601	0.0060	161	3.7E+07
Thompson United Methodist Church	OH0133159	0.0017	161	1.1E+07
Thunder Hill Golf Course	OH0101583	0.0125	126 [a]	6.0E+07
Chardon WWTP [b]	**OH0022659**	**1.8080**	**161**	**1.1E+10**
Wintergreen WWTP	OH0028908	0.0150	161	9.1E+07
Terrace Glen Estates MHP	OH0112291	0.0200	161	1.2E+08
Maple Ridge MHC	OH0117129	0.0250	161	1.5E+08
Chardon United Methodist Church	OH0123650	0.0028	161	1.7E+07
Sunshine Acres STP	OH0039021	0.0200	161	1.2E+08
Rio Grand WWTP	OH0092096	0.0215	161	1.3E+08
Leroy Elem School	OH0103021	0.0075	161	4.6E+07
Grumpy Bear LLC dba Bunky's Pub	OH0134708	0.0035	161	2.1E+07
Henry F LaMuth Middle School	OH0134716	0.0120	126	5.7E+07
Capps Tavern	OH0134732	0.0025	161	1.5E+07
Concord Tavern	OH0134759	0.0035	161	2.1E+07
Junior Properties LTD	OH0140571	0.0007	161	4.5E+06
Painesville WPC Plant	**OH0026948**	**6.0000**	**126**	**2.9E+10**
Heatherstone WWTP	OH0091952	0.4000	126	1.9E+09
Mid-West Materials Inc	OH0134660	0.0032	161	2.0E+07
Spring Lake MHP	OH0134694	0.0057	126	2.7E+07
Frary's Restaurant	OH0136841	0.0010	126 [a]	4.8E+06

Notes

Bolded facilities are major dischargers.

Design flows are rounded to the nearest ten-thousandth of an MGD.

a. Those facilities are on streams with a recreation use designation of PCR Class B but were assigned the PCR Class A criterion as the WLA target because they are within 5 miles of the Grand River, which is designated PCR Class A.

b. See Appendix H for the calculations of the *E. coli* die-off along Big Creek, derived in part from the Chardon WWTP.

10. Protection Strategies

Protection strategies were developed for several streams that are in full attainment of their ALU designation but are threatened by future development pressure. Some of those streams are already affected by development pressure and are only marginally meeting full attainment (e.g., Ellison Creek). Protection strategies have been developed for the following streams:

- Bates Creek
- Cutts Creek
- East Creek
- Ellison Creek
- Jenks Creek
- Jordan Creek
- Mill Creek (06 02)
- Paine Creek
- Phelps Creek
- Talcott Creek
- Unnamed tributary to Paine Creek
- Unnamed tributary to Mill Creek (06 02)

10.1. Protection Strategy Targets

Similar to a TMDL, targets were developed for the protection strategies. Those protection strategies are not TMDLS and do not require any immediate implementation action, but they can be used to support future permitting activities that comply with the antidegradation criteria in OAC-3745-1-05. The protection strategy targets were developed for effective impervious cover and riparian buffer width and vegetation. Effective impervious cover is that portion of impervious cover that is connected to the stream and not treated by stormwater management practices to meet pre-development hydrology. Protection strategy targets are provided for guidance to use in implementing regulatory mechanisms (e.g., watershed-specific storm water NPDES permits) to protect existing in-stream uses for both impaired and unimpaired streams in the watershed. Implementing those targets is appropriate and necessary to protect existing in-stream designated uses related to the EWH designation of the Grand River LRAU (mainstem) and other tributaries with EWH and CWH designated uses as urbanization proceeds in the TMDL area.

The evaluations presented in Section 7 show that the response of biologic community health indices varies over a gradient. Impervious cover and forest cover in riparian buffers were the most representative indicators of the gradient response of biology to development. Interrelated factors (e.g., flow, water quality, temperature) are affected by development and contribute to biologic response. Those factors are thoroughly discussed in Section 7. Many of the available data sets were otherwise limited; thus, they were not good candidates for gradient evaluations and protection strategy target selection. For example, attainment and biologic scores do not always respond directly to degraded water quality and temperature data sets had limited representativeness. The evaluations presented in the following sections show that biologic response to subwatershed impervious cover and forest cover in the 200-foot riparian buffer occur along gradients and allow for the selection of protection strategy targets.

10.1.1. Impervious Cover

The impervious cover target is 6 percent effective (connected) impervious cover and is recommended for individual stream subwatersheds and WAUs. Watershed impervious cover is calculated using the 2001 Percent Developed Impervious data from the 2001 NLCD. The 2001 NLCD was selected, instead of the 2006 NLCD, because it is more representative of conditions during the time of Ohio EPA's 2003–2004 field assessment.

Evaluations of impervious cover at sites throughout the western portion of the lower Grand River watershed are presented in Section 7, including Figure 7-5. The effects of impervious cover on macroinvertebrate community health were further evaluated to identify the gradient of macroinvertebrate response to varying levels of impervious cover. Figure 10-1 shows that *excellent* through *good* scores[18] tend to occur at lower levels of impervious cover (i.e., less than 6 percent). Sites in partial- and non-attainment have impervious cover levels of 11 to 15 percent. Finally, sites that are marginally good[19] exist in watersheds with 6 to 13 percent impervious cover.

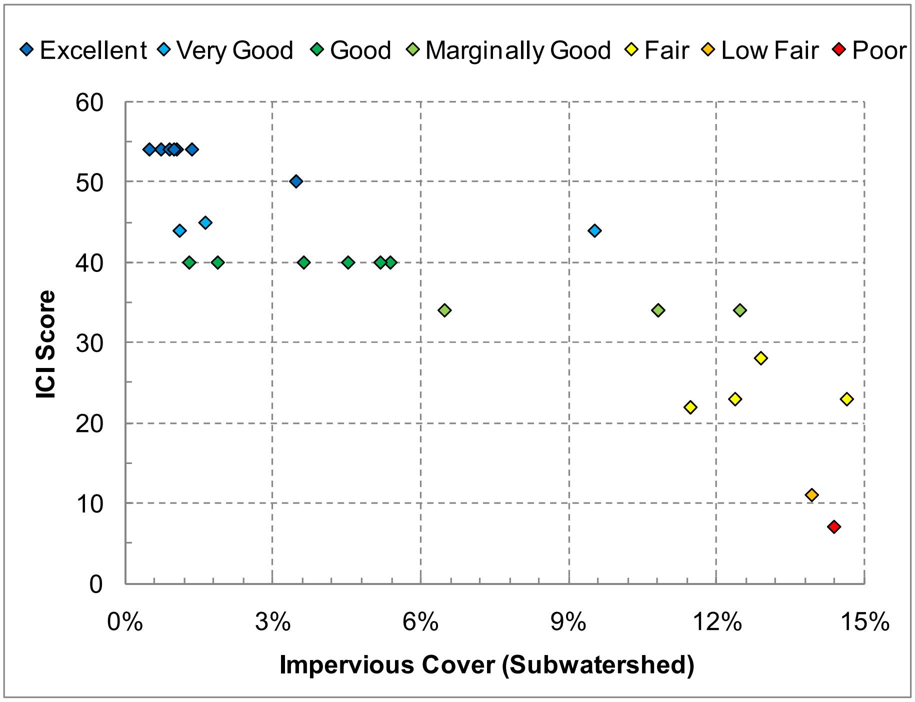


Figure 10-1.Relationship between impervious cover and ICI scores.

10.1.2. Riparian Width and Vegetation

Two riparian buffer targets were set: 70 percent forest in a 200-foot buffer and the targeted riparian width (as defined in the draft stream mitigation rule, OAC-3745-1-56). The percent forest cover was calculated using the Land Cover data from the 2001 NLCD (version 1.0). The 2001 NLCD (version 1.0) was selected, instead of the 2006 NLCD, because it is more representative of conditions during the time of Ohio EPA's 2003–2004 field assessment. The 200-foot buffer was determined in GIS using a 100-foot buffer on each side of the National Hydrography Dataset high-flow lines. A raster clip was used to generate a land cover in the 200-foot buffer shape file.

At the time of this report's publication, the draft stream mitigation rule (OAC-3745-1-56) was undergoing public comment. The rule incorporates stream mitigation calculators that are published as supporting documents. Within those calculators, the targeted riparian width is calculated by the following formula:

$$\text{Targeted Riparian Width} = 160 \times (\textit{Drainage Area})^{0.1}$$

where *Drainage Area* is in square miles and the targeted riparian width is in feet.

The minimum vegetated width is calculated as one-half of the targeted riparian width.

---

[18] Qualitative EPT narrative scores were assigned the numeric values. The assigned numeric score was the midpoint of the range of numeric scores for each narrative score for the ICI.
[19] Sites with scores less than the biocriteria but are considered in full attainment because the scores are an insignificant departure from the biocriteria.

Evaluations of forest cover at sites throughout the western portion of the lower Grand River watershed are presented in Section 7, including Figure 7-10. Generally, higher levels of forest cover in the riparian buffer could mitigate the effects of higher levels of impervious cover in the watershed. Those findings are consistent with Yoder et al. (1999), who found that urban land use can be mitigated by effective management practices and large riparian buffers but only when levels of impervious cover are below 45 percent. Similarly, as discussed in Section 7, Yoder et al. (2000) and Miltner et al. (2004) found that sites could meet attainment despite high levels of urban land development when large riparian buffers, undeveloped floodplains, and significant contribution of ground water were present.

10.1.3. Summary

An evaluation of subwatershed impervious cover and forest cover in the 200-foot buffer shows a similar gradient to that shown in Figure 10-1. When the targets are included in the evaluation, as shown in Figure 10-2, it is apparent that sites with higher levels of impervious cover within their subwatersheds and lower levels of forest cover in their riparian buffers are usually impaired. Of the 10 sites in the lower right quadrant in Figure 10-2, the streams at 6 sites are not in full attainment of their designated uses and at 3 sites, they are only marginally attaining.

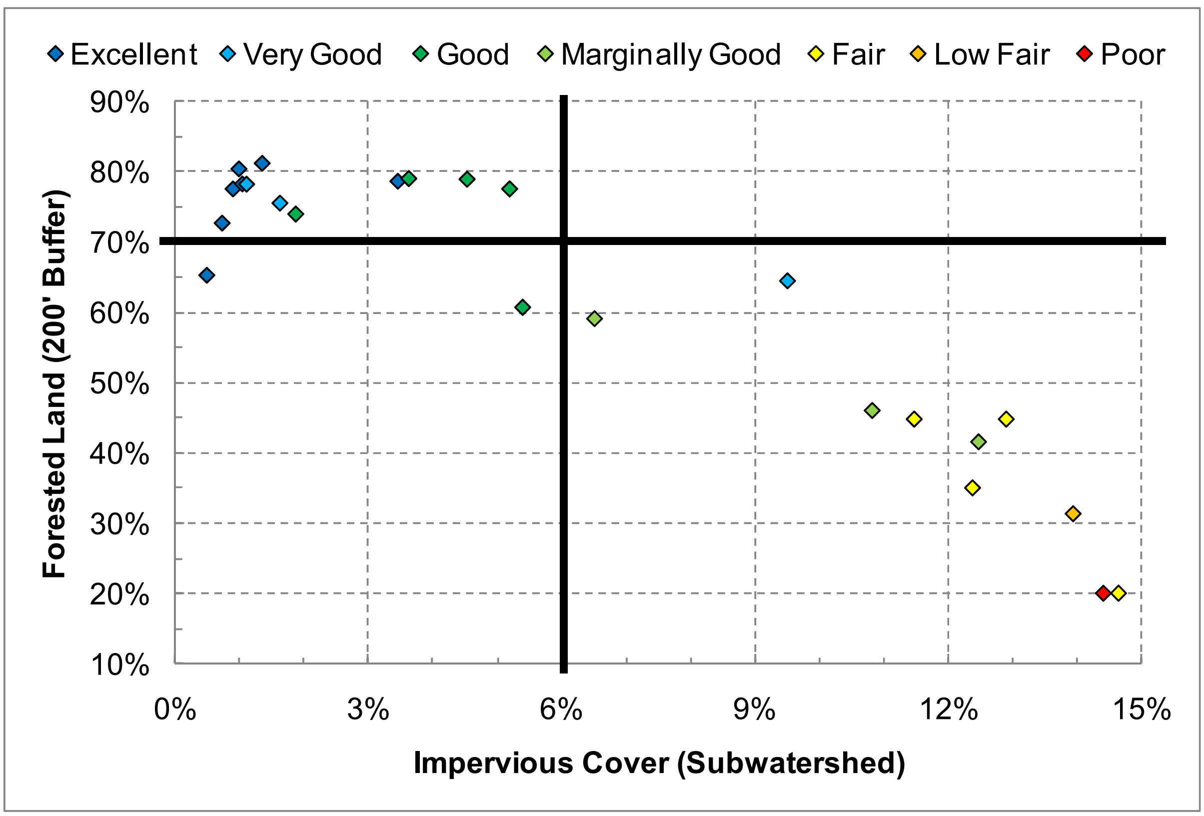


Figure 10-2. Relationship between impervious cover and forested land percentage.

10.2. Status of Unimpaired Streams

The conditions of the streams receiving protection strategies were evaluated with regards to the targets presented in Section 10.1. As shown in Figure 10-3, Ellison Creek did not meet the protection strategy target, and Cutts Creek and Jordan Creek were just below meeting the target. Those analyses were performed using the Percent Developed Impervious data from the 2006 NLCD because those data are more recent and more reflective of the conditions that managers must plan for and address. Because development has continued in all three of those streams' subwatersheds, it is possible that the streams are not meeting their protection strategy targets.

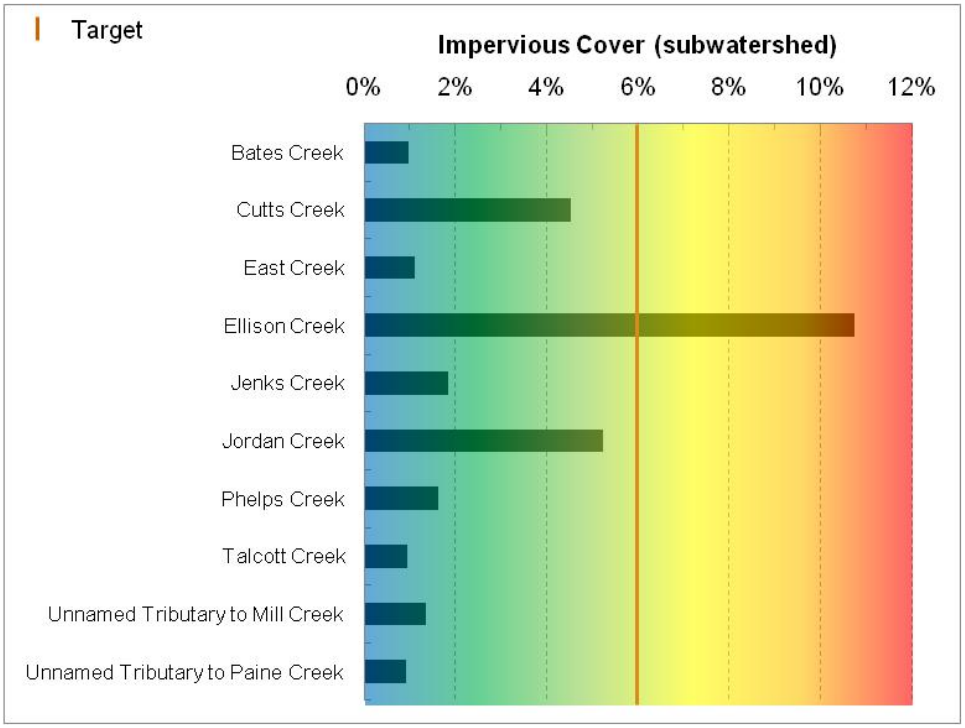


Figure 10-3. Status of unimpaired streams and impervious cover target.

Most of the protection strategy streams are meeting their buffer forest cover target (Figure 10-4). However, Ellison Creek and Cutts Creek do not meet the target. In fact, a majority of the 200-foot buffer at the sites in Ellison Creek are not forested. It is noteworthy that the headwaters portion of Ellison Creek tends to be forested, whereas the lower reaches, including a segment that runs along a golf course, have much less forested land.

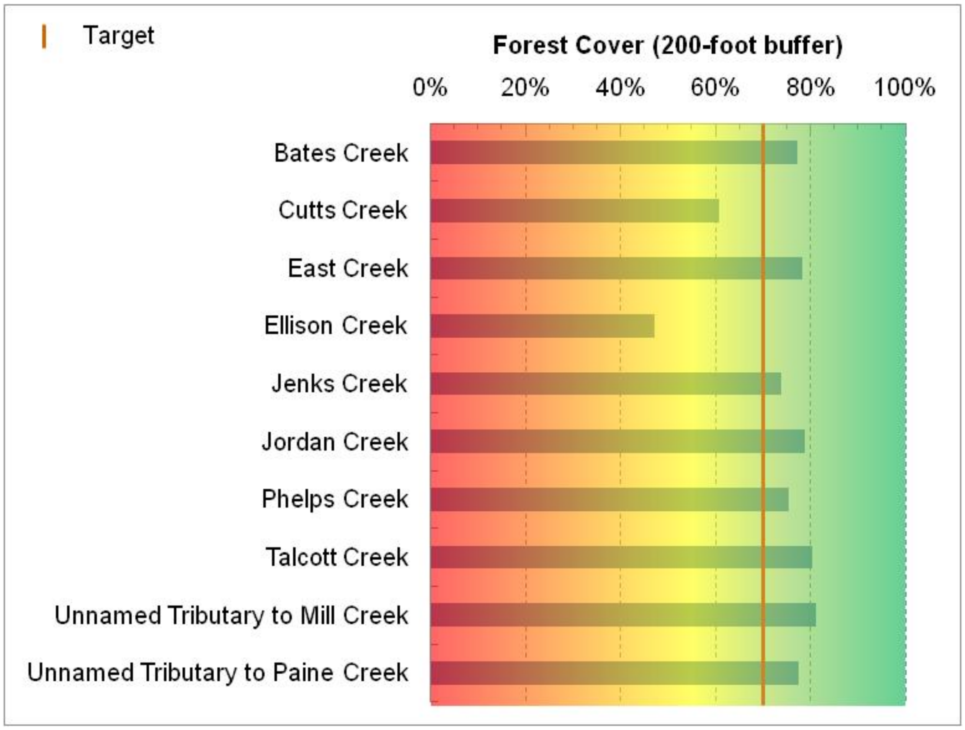


Figure 10-4. Status of unimpaired streams and forested buffer target.

Table 10-1 presents the targeted riparian width and minimum vegetated width for each protection strategy stream. Observed data are not available; thus, it is not possible to determine if the protection strategy streams are meeting the targeted riparian width and minimum vegetated width goals.

Table 10-1. Riparian width goals calculated from the draft Stream Mitigation Rule

Attainment stream	Area (mi^2)	Target riparian width (ft)	Minimum vegetated width (ft)
Bates Creek	11.9	205	102
Cutts Creek	1.8	170	85
East Creek	5.2	189	94
Ellison Creek	6.4	193	96
Jenks Creek	2.8	177	89
Jordan Creek	4.4	186	93
Phelps Creek	3.1	179	90
Talcott Creek	5.5	190	95
Unnamed Tributary to Mill Creek	3.8	183	92
Unnamed Tributary to Paine Creek	3.0	179	89

11. Implementation and Reasonable Assurances

Restoration methods to bring an impaired waterbody into attainment with water quality standards generally involve an increase in the waterbody's capacity to assimilate pollutants, a reduction of pollutant loads to the waterbody, or some combination of both. A series of tables list actions appropriate for addressing the water quality stressors at specific locations in the basin. The recommended actions are well-established practices with proven effectiveness. Details regarding those practices are included in Appendix I of this report. Additionally, Appendix I discusses various programs and organizations that can be sources for assistance in carrying out the recommended actions.

Ohio EPA developed recommendations in consultation with local technical stakeholders. The recommended actions are not the only means for making the needed water quality improvements; rather, they highlight the more common approaches. Also, there is some repetition in the recommendations because certain stressors can be addressed by a variety of approaches (e.g., habitat quality can be improved by both naturalizing watershed hydrology and stream restoration). The options were selected considering effectiveness and efficiency. Good land management practices are applicable everywhere, so not specifically recommending a management practice does not necessarily suggest that a given management practice is inappropriate in that location. Instead, the recommendations are made to prioritize watershed restoration activities and not merely list what is beneficial. A primary objective of those recommendations is to assist watershed planning or provide guidance regarding investments made to improve water quality or a combination of both.

11.1. Point Sources

Total phosphorus has been regulated at major dischargers (more than one MGD) in the Lake Erie basin for many years. Additional total phosphorus reductions will be necessary at several facilities according to calculated TMDLs in locations where total phosphorus contributed to ALU impairment.

Recommendations for NPDES permits, according to calculated TMDLs, are summarized by discharger and subwatershed in Table 11-1 and Table 11-2. Ohio EPA will work with permit holders to accomplish any needed reductions in loadings. Existing permit conditions involving total phosphorus for facilities not listed in Table 11-1 should remain unchanged. Additional recommendations are made for Jefferson WWTP in Section 11.4.1.

Table 11-1. Recommended implementation actions through the NPDES program for total phosphorus

Watershed (04110004)	Entity	Ohio EPA permit	Receiving stream	Design flow (MGD)	WLA (load in lb/day)	WLA (concen-tration in mg/L)	Recommended permit conditions		Explanation of difference
							First phase	Second phase	
04 02	ODOT Dorset Outpost Garage	3PP00041	Unnamed tributary to Mill Creek	0.001	0.025	3.0	Monitor 1 x per quarter	Depending on results of first phase, continue monitoring or give an average monthly limit of 3 mg/L	Allocation is based on assumed values because no data are available from the discharger.
06 07	Mid-West Materials, Inc.	3PR00077	Unnamed tributary to Red Creek	0.0032	0.080 to 0.031[a]	3.0	Monitor 1 x per quarter	Depending on results of first phase, continue monitoring or give an average monthly limit of 3 mg/L	Allocation is based on assumed values because no data are available from the discharger.

Notes
Any specific permit condition noted in the table indicates a recommended change from current permit conditions. *No change* means that no change is recommended.
a. Flow dependent; see Table 9-9.

Table 11-2. Wasteload allocations for MS4 permittees for total phosphorus

Nested subwatershed (04110004)	Entity	Ohio EPA permit #	Receiving stream	Wasteload allocation (load in lb/day)
06 07	Lake County MS4 [a]	3GQ00068	Red Creek	0.0 to 11.8 [b]
06 07	ODOT Roads MS4 [c]	4GQ00000	Red Creek	0.0 to 0.075 [b]

a. The MS4 drainage area is 4.52 square miles.
b. Flow dependent; see Table 9-10.
c. The MS4 drainage area is 0.03 square miles.

11.2. Urban Land Uses

The most serious threat to channel stability, and possibly overall water quality and biological integrity, in the lower Grand River watershed is the rapid conversion of forest or agriculture land uses to residential and commercial uses, and occasionally industrial uses. Numerous scientific studies show that increasing impervious cover in a watershed (through development) is commensurate with the degradation of water quality and biological communities (Booth 2005; Brabec et al. 2002; Roy et al. 2003, 2006; Morgan and Cushman 2005). A complete discussion of the interaction between hydrology and aquatic life is in Section 7.

Controlling runoff associated with development typically consists of end-of-pipe measures such as storm water detention and retention. Those controls abate flooding and reduce erosion, thus providing some water quality protection. However, studies show that water quality degradation occurs in developing watersheds despite those controls because of the altered hydrologic regime (Brabec et al. 2002; Booth 2005).

A hydrologic regime that approximates pre-development conditions is important for protecting water quality and aquatic biological communities (Roy et al. 2006). Initial abstraction of rainfall by vegetation, surface storage, long subsurface flow paths, evapotranspiration, and deep percolation, which are associated with relatively undisturbed watersheds, often preclude flashy hydrology. Peak flows are often smaller as a significant proportion of precipitation is delayed or completely diverted from reaching the stream system. Base flows are usually higher because of the greater subsurface discharges during dry periods as a result of increased storm water infiltration and storage.

Approximating the pre-development hydrology is not likely to be achieved with centralized controls (i.e., end-of-pipe retention/detention basins). However, on-site retention and infiltration is a realistic and potentially effective way to accomplish such an outcome (Andoh and Declerck 1997). With an on-site approach, storm water is managed near the area generating the runoff and infiltration is maximized. On-site storm water management contrasts with centralized systems that collect runoff over a broad area, provide relatively little opportunity for infiltration and, consequently, must manage very large volumes. Individual on-site controls operate on a small scale, but systems are distributed to act collectively in managing runoff across a large area. Incentives, utilities, and market-based programs should be explored as a means to achieve more effective and ecologically meaningful storm water management. Parikh et al. (2005) provide an analysis of options for addressing storm water management in an environmentally and economically sustainable manner.

On-site, or decentralized, storm water management increases infiltration and reduces runoff generation by decreasing imperviousness. That is accomplished through appropriate planning, such as that used for low impact development (LID), discussed in detail below. LID is based on maximizing contiguous open space, protecting sensitive areas—namely floodplains, ground water recharge areas, and wetlands—and preserving existing vegetation (especially trees). A Web-based resource for LID includes www.lowimpactdevelopment.org/. In LID, houses are closer to one another, roadways are narrower, and bioretention and infiltration techniques are used. LID reduces runoff and can provide cost savings in storm water infrastructure. Additional non-environmental benefits include a greater than average increase in property values.

One potential barrier to LID is zoning ordinances that set minimum lot sizes. However, employing LID at the level needed to provide significant protections for the lower Grand River watershed requires action on the part of land planners, zoning officials, and developers. Serious communication between those groups and LID experts who can address the conditions of this basin is strongly recommended.

Watersheds that retain relatively large areas of forest are able to better mitigate the impacts of increasing imperviousness than those with little forest cover (Booth 2005). Procuring conservation easements and establishing parkland and nature preserves can help retain some of the existing forest cover and facilitate the conversion from open land to forest. Although land preservation alone is not likely to occur at a level necessary to mitigate development impacts, it will augment other measures that are taken (e.g., LID or discrete on-site storm water management).

Even in areas that are not developed with LID, storm water abatement techniques that are employed in commercial developments and on individual residential parcels will provide protections to water quality. In particular, impervious surfaces associated with automobile traffic and parking lots often account for a very high proportion of the impervious surfaces in urban watersheds (University of Connecticut Extension, http://nemo.uconn.edu).

At the scale of individual residences or business, storm water abatement techniques can be used that include diverting drainage from rooftops, driveways, and other impervious surfaces away from a centralized collection system (e.g., outlets to either curb-and-gutter drains or storm water sewer lines) and to permeable areas that can provide infiltration or temporary storage or both. Minimizing the extent of impervious surfaces by limiting their size or substituting them with permeable surfaces will also increase infiltration and detention for a property. Outreach and education activities are likely to result in some increase in that type of voluntary action taken by watershed residents, but to what extent would be very difficult to predict. Outreach efforts to landscape design and construction companies might also be beneficial because they can present options for enhanced storm water management to their prospective clients.

11.2.1. Implementation of Flow Regime TMDLs

Implementing the flow regime TMDLs will be based significantly on storm water retrofitting. Protection of unimpaired streams and high-quality areas draining to impaired streams will require additional considerations and potentially storm water regulations to address the need for flow volume reduction and protection of ground water base flow conditions during the development process.

Developing effective storm water management strategies for the lower Grand River will be a key component to successfully implementing the lower Grand River TMDL. Significant investments are anticipated to evaluate, design, and construct structural and nonstructural storm water BMPs that improve water quality conditions surrounding documented problems. U.S. EPA's System for Urban Storm Water Treatment and Analysis INtegration (SUSTAIN) is a model developed to support practitioners in developing cost-effective management plans for municipal storm water programs and evaluating and selecting BMPs to achieve water quality or hydrologic targets like those set by a TMDL. SUSTAIN was applied in the lower Grand River watershed to aid in development of an implementation plan for the TMDL.

The SUSTAIN model was used in two locations in the lower Grand watershed, both in Lake County. A local workgroup was designated to help with model development, including representatives from Lake County and the Lake SWCD. SUSTAIN was applied to evaluate cost-effective combinations of BMPs that can achieve the lower Grand River flow regime TMDLs and protection strategies. Appendix J includes the full SUSTAIN report.

The primary objectives for the SUSTAIN application in the lower Grand River watershed is to model representative examples of the following:

- A retrofit implementation plan with expected outcomes that can be used to achieve TMDL targets in impaired watersheds
- Storm water management within an existing development that will aid in determining future land use planning and ordinance development needs to demonstrate how changes in storm water requirements can help protect unimpaired streams

Storm Water Retrofitting

Storm water retrofitting will be a significant component of implementation in the flow regime TMDL watersheds. The Concord Hills subdivision provides a representative example of an untreated, single-family residential neighborhood—the predominant land use in the impaired watersheds.

Results of the SUSTAIN model based on area of BMPs, are extrapolated for each of the flow-regime TMDL watersheds to provide an estimate of BMPs and associated costs that will be needed to implement the TMDLs in Big Creek (RM 16.0), Kellogg Creek (RM 3.3), and Red Creek (at outlet). Ohio EPA determined that Cemetery Creek (RM 2.1) was in non-attainment of its biocriteria because of flow alteration from urbanization, and thus, the creek was evaluated for this report. However, Ohio EPA plans to declare that location as impaired by natural conditions in the 2012 Integrated Report, and no TMDL has been completed. The results of the evaluations could still be used to mitigate the anthropogenic factors that detrimentally affect Cemetery Creek. The extrapolation was based on linearly upscaling the results from Concord Hills to the entire watershed area, minus forested areas and land cover that is indicated as water or wetlands. Table 11-3 summarizes the extrapolated results for each impaired watershed. Watershed areas that are identified as forested were assumed to be meeting the TMDL hydrologic targets and were disconnected to the existing storm water system and, therefore, not included in the extrapolation. The remaining watershed is assumed to be contributing to the stream with similar land uses and storm water management as the Concord Hills subdivision.

Table 11-3. Extrapolated results based on Concord Hills

BMPs	Cemetery Creek	Big Creek	Red Creek	Kellogg Creek
Porous pavement (acre)	0.0	2.8	21.6	11.3
Block bioretention (acre)	7,433.7	0.05	0.4	0.2
Rain garden (unit)	1,326	53	408	1,681
Rain barrel (unit)	4,349	0.0	0.0	0.0
Estimated Costs (2010)	$1,454,580	$1,200,350	$9,284,150	$5,745,980

County and local governments can use the results presented in Table 11-3 to inform watershed planning and TMDL implementation strategies at the local level. The extrapolated results provide for a cost-effective combination of BMPs for specific watershed (e.g., Big Creek) that would meet flow regime TMDL requirements. Existing capital improvement plans should be evaluated to determine where existing opportunities exist. For example, because porous pavement and block bioretention have been identified as cost-effective retrofit practices, road and sidewalk replacement schedules should be evaluated for opportunities to install both of those practices. By leveraging existing opportunities, the additional costs to install BMPs will be the difference between the traditional practices and BMPs, for example the difference in cost associated with traditional asphalt and porous asphalt, which is not reflected in the Table 11-3.

Smaller scale retrofits such as rain barrels and rain gardens are often led by the local government, watershed, or soil and water conservation district through programmatic initiatives. TMDL implementation will rely on those entities to continue existing education programs on small-scale BMPs. In addition, a focused effort should be used to target the homeowners in the TMDL watersheds. Grant funding could be sought to conduct neighborhood retrofit programs and fund installation of multiple rain gardens and rain barrels. Rain barrels are available for purchase through both the Lake and Geauga SWCDs.

A photograph of a rain garden is shown in Figure 11-1 and example rain garden programs include the following:

- Central Ohio Rain Garden Initiative http://www.centralohioraingardens.org/;
- Maplewood, Minnesota Rain Garden Program,http://ci.maplewood.mn.us/index.aspx?NID=456;
- Metro Blooms http://metroblooms.org/neighborhood-of-gardens.php#subsection2 .

Figure 11-1. Example of a rain garden.

Land Use Planning Controls

Protecting streams from degradation under future land uses will also be critical to ensure that the impaired streams are not further degraded and that unimpaired streams are protected. The Protection Strategies in Section 10 identify key streams that are unimpaired but are in areas that are likely to be threatened by development in the next 30 years.

Comparison between Existing Storm Water Requirements and TMDL Requirements

The Summerwood subdivision provides a representative example of expected future land uses and the current level of treatment required as part of the construction storm water permitting process. The subdivision is designed as a conservation development and includes a cluster of homes surrounded by large forested and natural areas. The SUSTAIN analysis did not take into account the disconnected natural areas.

An evaluation was completed of the storm water treatment provided in the Summerwood subdivision versus the requirements of the TMDL. The purpose of that evaluation is to compare the results of storm water regulations at the time of the subdivision's development to those that would be needed to effectively implement the TMDL. An existing condition model was developed for the subdivision that included the two existing detention ponds. SUSTAIN was then run to determine what additional practices were most cost-effective to achieve the TMDL targets. Table 11-4 presents the comparison between the existing subdivision conditions and the four selected solutions. One of the detention ponds in the subdivision was modeled to include a small amount of infiltration according to field observations. That infiltration volume, in combination with estimated evapotranspiration, accounts for 5.3 percent reduction in flow volume with roughly half of that reduction translating to ground water recharge (2.9 percent). The total flow volume reduction is the sum of ground water recharge and evapotranspiration. For example, the 16 percent flow volume reduction scenario is divided into ground water recharge equal to 14.3 percent of flow volume reduction and evapotranspiration equal to 1.7 percent of flow volume reduction, resulting in ground water recharge accounting for 89 percent of the flow volume reduction. Ground water recharge accounts for 64–89 percent of the flow volume reduction for the selected solutions.

Table 11-4. Comparison of existing conditions to TMDL requirements, Summerwood results

Comparison metric	Existing conditions	Proposed conditions at various flow volume reduction percentages			
Flow Volume Reduction (%)	5.3%	8%	13%	16%	23%
Costs (2010 $)[a]/acre	$0	$249.49	$1,169.13	$1,737.35	$3,024.08
Peak Flow Reduction (%)	59.3%	59.3%	59.7%	59.7%	60.2%
Ground water Recharge (%)	2.9%	5.1%	10.7%	14.3%	20.1%

a. Costs do not include existing conditions

The selected solutions provide a summary of the SUSTAIN results that can be applied to other watersheds on the basis of flow volume reduction targets. For example, in the Big Creek watershed (upstream of RM 16.0, which requires a flow volume reduction of 15 percent), compliance with the TMDL could be achieved by implementing the suite of BMPs identified in the 16 percent flow volume reduction scenario for a cost of approximately $1,737 per acre, resulting in increased ground water recharge of 14.3 percent.

Comparison with Ohio EPA General Construction Requirements

Concord Hills subdivision results were compared to Ohio EPA's General Construction Storm water permit water quality standards (Ohio EPA 2008) using the SUSTAIN results. The General Permit requires a treated water quality volume (WQv) equal to the runoff associated with a 0.75-inch rainfall event. That translates to 1.6 acre-feet for the Concord Hills subdivision using the rational method as described in Ohio EPA's General Construction Storm Water Permit. Table 11-5 summarizes the comparison between Ohio EPA's WQv and the SUSTAIN results. The BMP volumes associated with each of the flow volume reduction targets are all less than the WQv required by Ohio EPA. That indicates that only a portion of the existing required WQv would need to be converted to an infiltration requirement.

Table 11-5. Comparison of Ohio EPA's WQv and BMP volume, Concord Hills

Flow volume reduction target	SUSTAIN BMP volume (acre-feet)	Ohio EPA's WQv (acre-feet) [a]
7%	0.32	1.6
15%	0.74	
20%	0.94	

a. Determined using the rational method for the Concord Hills subdivision

Potential Storm Water Regulations

In addition to retrofitting areas that have some form of water quality treatment, infiltration is also needed. Two types of infiltration standards could be considered.

A standard could be used that would require all new development to meet pre-settlement hydrology (typically forested) for both flow and volume. At least 80 percent of the required flow volume reduction (the difference in flow volume between pre- and post-development scenario) should be through infiltration to ensure ground water recharge. The pre-settlement condition is conservative in that the reference streams presented in the TMDL include some level of development. However, that conservative requirement will allow for an additional MOS for the downstream receiving water because failure of infiltration practices is frequently documented. Such a standard is more difficult to implement because it requires pre- and post-development site modeling to determine compliance.

A standard could also be developed similar to the existing Ohio EPA WQv that would require a portion of that WQv to be infiltrated. For example, a numeric standard could state that the applicant is required to infiltrate the runoff associated with a certain depth of runoff over the proposed site. Analysis to determine that specific volume is beyond the scope of this study and will be dependent on the downstream receiving waterbody and the associated TMDL requirements. Such a standard is simple to implement, although it does not take into account different conditions that influence storm water infiltration such as soil type, geology, and depth to the water table.

11.3. Agricultural Land Uses

Major sources of impairment associated with agriculture include habitat alteration, nutrient enrichment, and flow alteration. In general, BMPs used by farmers can make significant positive improvements on the impacts typically caused by agriculture.

Nursery/Vineyard

A large number of nurseries and vineyards are in the lower watershed because of unique climate conditions associated with Lake Erie. Proper management of wastewater and storm water is needed to prevent negative water quality impacts.

Livestock Operations

Pathogen contamination from livestock manure can be reduced by fencing or other exclusion practices that limit or deny livestock access to streams. Proper manure handling and storage reduces runoff contamination and is achieved through constructing adequate storage facilities and storm water controls. Manure that is land applied should be done so according to guidance from the NRCS and applicable standards (Standard 633) or a Comprehensive Nutrient Management Plan that is specific to an operation. Manure discharges occurring through subsurface drainage tiles after field application can often be avoided if drainage water management control structures are in place. NRCS conservation practices that are appropriate for abating that source of pollution include *Livestock Use Exclusion (472), Waste utilization (633)*, *Nutrient Management (590)*, *Watering Facility (614)*, *Waste Storage Facility (313)*, and *Drainage Water Management (554).*

Composting manures could also be a viable way to use livestock waste and reduce the threat to water quality. Stabilizing the manure materials during the composting process and properly handling and storing the material reduces the risk of pollutant loading via storm water runoff. More information regarding composting is on the Ohio Composting and Manure Management Program's website, http://www.oardc.ohio-state.edu/ocamm/.

Agricultural Farming Practices

In the lower Grand River watershed, degraded stream habitat is primarily the result of channelization and ongoing maintenance activities carried out to improve water conveyance. Those activities are related to agricultural drainage improvements; however, channelization is also in urban areas where buildings and other infrastructure lie in close proximity to the streams.

Habitat is also impaired or threatened by channel instability resulting from altered hydrology. In agricultural areas, practices specifically designed to increase drainage efficiency (e.g., subsurface drainage, channelization) and unintended impacts of farming (e.g., soil compaction, poor vegetative cover) increase storm flows. Efficient drainage also results in more extreme and more frequent low-flow conditions. That diminishes the capacity of the system to assimilate pollutants and support diverse aquatic communities.

For more specific agricultural implementation actions, see Appendix I.

11.4. Recommended Implementation Actions by Subwatershed

Major causes of impairment included flow alteration, pollutants associated with urban storm water, siltation, direct habitat alteration, nutrients, and bacteria. Practices that can help to reduce those pollutants, along with targeted areas for those practices, are listed in Table 11-6.

The NPDES storm water permit program can be used to address some of the causes of impairment. In particular, discharges from construction activity associated with new development and redevelopment that disturbs one or more acres of land, storm water discharges from industrial sites, and discharges from MS4s in urbanized areas of the watershed are subject to NPDES permitting. Ohio EPA may choose to incorporate BMP requirements within existing general permits or issue a watershed-specific general permit to address sources or causes of impairment. Permits for storm water discharges associated with construction activities should focus on the implementation of LID and green infrastructure BMPs that promote on-site retention, infiltration, harvesting and reuse of storm water. Permits for MS4s can require retrofitting municipal properties and other existing developed areas in public rights of way with those types of BMPs. MS4 permits can also encourage changes to planning and zoning codes that lead to better site design, e.g., adoption of riparian setbacks, promotion of conservation subdivision design, reduced roadway widths and updated parking lot codes, alternative cul-de-sac designs that make use of bioretention or permeable pavement, and policies that promote smart growth rather than urban sprawl such as incentives for infill development and redevelopment in existing developed areas.

Table 11-6. Practices recommended to reduce pollutants causing ALU and recreation use impairments

Cause of impairment (source of impairment)	Target areas	Applicable practices
Flow alteration (urban runoff, storm sewers)	Entire watershed	• Install BMPs that retain storm water on-site or infiltrate it. Examples include o Bioretention cells and rain gardens o Dry enhanced swales (bioswales) o Pervious pavement o Rain barrels and cisterns o Green roofs o Infiltration trenches and dry wells o Vegetated filter strips o Soil amendment o Allow rooftop disconnection o Site reforestation • Adopt better site design practices o Preserve riparian buffers and other important natural areas o Promote conservation subdivision design o Minimize clearing and grading limits o Reduce roadway widths and allow alternative cul-de-sac designs o Provide incentives for infill development, redevelopment within existing developed areas and development near hubs of public transportation o Allow meadow grasses or no-mow grasses in open spaces
Pollutants associated with urban storm water (urban runoff, storm sewers)	Entire watershed	• Install post-construction BMPs capable of settling, infiltrating, filtering or otherwise treating pollutants. Examples include o Bioretention cells and rain gardens o Dry enhanced swales (bioswales) o Pervious pavement o Infiltration trenches o Sand and other media filtration o Vegetated filter strips o Constructed and pocket wetlands o Wet or dry extended detention basins

<table>
<tr><th>Cause of impairment (source of impairment)</th><th>Target areas</th><th>Applicable practices</th></tr>
<tr><td>Siltation (agricultural channelization)</td><td>Peters Creek-Mill Creek (04 02)</td><td>Install BMPs that reduce sediment runoff. Examples include
Install grassed waterways
Install vegetated buffer areas/strips
Implement conservation tillage practices
Install two-stage or over-wide ditches where practical</td></tr>
<tr><td>Nutrients (agriculture, urban runoff/storm sewers) Note: used as surrogate for siltation (Mill Creek) and pollutants associated with urban storm water (Red Creek)</td><td>Mill Creek (04 02)
Red Creek (06 07)</td><td>Reduce runoff from farm fields carrying nutrients. Examples include
Plant cover/manure crops
Conduct soil testing
Develop nutrient management plans
Reduce runoff from urban areas carrying nutrients. Examples include
Treatment-based BMPs, such as bioretention, constructed and pocket wetlands, enhanced swales, infiltration trenches and manufactured BMP systems based on filtration and infiltration treatment modes
Flow-reduction BMPs, such as pervious pavement, rain barrels and cisterns, green roofs, bioretention and infiltration trenches
Encourage use of low-mow or meadow grasses in common areas and open spaces rather than requiring a manicured turf lawn
Adopt BMPs for fertilizer storage and application at municipal operations</td></tr>
<tr><td>Bacteria (failing HSTS, urban runoff/storm sewers, agriculture, livestock operations)</td><td>Entire watershed</td><td>Inspect HSTS
Replace or repair failing HSTS
Reduce runoff from farm fields spread with manure by implementing runoff-reducing BMPs. Examples include
Planting trees or shrubs in riparian areas
Implementing a nutrient management plan
Using NRCS practice 633
Using wetlands near streams for treating runoff before entering streams
Ensure that livestock does not have access to streams. Install alternative water supplies where necessary.
Use manure management BMPs on farms.
Reduce storm runoff through storm water BMPs that treat runoff before it enters a stream. Examples include
Treatment-based BMPs, such as bioretention, sand filters and wet extended detention basins designed to avoid attracting waterfowl
Flow-reduction BMPs, such as infiltration trenches and basins, pervious pavement</td></tr>
</table>

11.4.1. Cemetery Creek

Cemetery Creek at two sites was identified as impaired for ALU during the 2003–2004 field survey. Cemetery Creek downstream of the Jefferson WWTP outfall (at RM 1.2) was identified as impaired by organic enrichment and unknown toxicity from a faulty sanitary pump station in Jefferson. The upstream site (at RM 2.1/2.4) was impaired from flow alteration from urban runoff.

Since the 2003–2004 survey, the sanitary pump station has been fixed. To measure the improvement and determine the current situation, Ohio EPA returned to both sites on Cemetery Creek in 2011 and sampled fish, macroinvertebrates, and habitat. The results show that at the downstream site on Cemetery Creek, the creek is now in partial attainment of ALU goals; at the upstream site, it is still in non-attainment. The causes and sources have changed. Although some minor signs of nutrient enrichment were noted, the primary cause of impairment at the downstream site is unknown toxicity from the WWTP (likely from residual chlorine). Evidence of that conclusion includes the high contribution of effluent flow to the total stream flow under critical low-flow conditions, the lack of automated controls for deactivation of the residual chlorine during times of less use, and the lack of or low abundances of sensitive fish and macroinvertebrate species in the aquatic community. At the upstream site, impairment is due to natural causes (flow or habitat) and natural sources. Table 2-9 reflects the new findings.

Ohio EPA will work with the Jefferson WWTP to determine the cause of toxicity and address it through permitted means. It is likely that the WWTP will need to eliminate its chlorine disinfection system and install ultraviolet disinfection as part of a compliance schedule in the next permit renewal (2015).

Once the toxicity at the WWTP has been addressed, it is possible that issues from nutrient enrichment could become evident in the biology in the stream. Further sampling of the stream would be necessary to determine whether nutrient enrichment was occurring and causing biological impairment.

11.4.2. Brightwood Lake

Brightwood Lake, along Kellogg Creek, has experienced severe volume loss because of sedimentation. Because of the algae, sedimentation, and fish barrier issues associated with the lake, removal or significant alteration of the dam and impoundment to re-naturalize the stream would result in significant improvement in the integrity of the biological community in the stream.

Local residents and township and county officials began to develop plans to restore Brightwood Lake via dredging in the 1990s. In 2001 Lake County applied for assistance through the Water Pollution Control Loan Fund for the planning, design, and implementation of a dredging project. However, the project did not go forward.

In 2004 Ohio Department of Natural Resources (DNR) Division of Water Dam Safety Program inspected the Brightwood Lake Dam. The dam inspection found that the dam met the criteria to be considered a Class 1 dam according to downstream land use that indicates that failure of the dam could cause loss of life. The inspection noted several deficiencies in the integrity and maintenance of the structure and called for the corrections of those deficiencies by 2009 to meet applicable safety standards. Since then, the Lake County Storm Water Utility commissioned a study to determine the scope of work that would need to be done to upgrade the dam and the potential associated costs. The study estimated that the costs to upgrade the dam to meet the Class 1 safety standards would range from $2.5 to $5.0 million (Keith Jones, Lake County Storm Water Utility, personal communication). Rather than upgrading the dam, the county used federal funding to purchase homes in danger of a flood if the dam were to fail. Although some homes in the immediate proximity of the dam were removed and the land surrounding the dam stabilized, some of the homes in danger should the dam fail remain. Therefore, the Brightwood Lake dam continues to be classified as a Class 1 dam.

After the Lake County Storm Water Utility study, Congress authorized the U.S. Army Corps of Engineers (Corps) to conduct a dam rehabilitation study as part of Section 5003 of the Water Resources Development Act (WRDA) of 2007. However, no money has yet been appropriated for the study. The Lake County Storm Water Utility has also met with the Corps and congressional representatives regarding the application for funding under Section 206 of the WRDA to conduct an aquatic ecosystem restoration study. Funding has not yet been allocated for the project. Section 206 studies are conducted to determine if an ecosystem restoration project is justified on the basis of environmental, economic, and engineering considerations. Further information regarding the potential study is on the Corps' website: https://sharedocs2.lrb.usace.army.mil/docushare/dsweb/View/Collection-813.

It is recommended that efforts to modify or remove the dam be considered as an implementation priority for the improvement of water quality in Kellogg Creek. Other potential funding sources for modification or removal of the dam would be the 319 program, the Water Resources Restoration Sponsorship Program or the Surface Water Improvement Fund.

11.5. 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 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 an NPDES permit(s) provides the reasonable assurance that the WLAs in the TMDL will be achieved. That is because Title 40 of the *Code of Federal Regulations* section 122.44(d)(1)(vii)(B) requires that effluent limits in permits be consistent with the assumptions and requirements of any available WLA 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 that end, Appendix I 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.

11.5.1. Local Zoning and Regional Planning

Lake County developed riparian setbacks as part of subdivision regulations for the planning commission (http://www.lakecountyohio.gov/LinkClick.aspx?fileticket=%2f%2fAymJP7Idc%3d&tabid=846). Two townships have adopted riparian setbacks into their zoning codes: Leroy Township (http://www.leroyohio.com/pdfs/zoningregulations/Section%2031.pdf), and Madison Township (http://www.madisontownship.net/documents/Zonebook/123RiparianSetbacks.html). The township ordinances have special conditions for Class III primary headwater habitat (PHWH) streams. Such ordinances are recommended for other jurisdictions.

A high prevalence of Class III PHWH and CWH streams is in the watershed, so there is a need for protection of stream corridors and ground water recharge areas to protect those uses and the EWH, superior high quality water Grand River mainstem.

Thompson Township in Geauga County has adopted riparian setbacks within its local zoning code. The planning commission has a Model Township Zoning Resolution on its website that has a riparian setback section (Article XV). Ohio EPA recommends that Geauga County communities adopt that model resolution if they have not done so already. The model zoning resolution is at http://www.co.geauga.oh.us/Departments/PlanningCommission/Main.aspx.

In addition, the County Subdivision Regulations allow conservation subdivision design as an option. The wetland and riparian areas in subdivisions that elect to use the option are often in protected open space areas of the site.

11.5.2. Local Watershed Groups

Grand River Partners, Inc., formerly the local watershed preservation organization, officially merged with the Western Reserve Land Conservancy in December 2009. Western Reserve Land Conservancy (WRLC) is a nonprofit conservation organization dedicated to preserving the natural resources of northern Ohio. It works with landowners, communities, government agencies, park systems and other nonprofit organizations to permanently protect natural areas and farmland, primarily through conservation easements. WRLC's stated mission is to seek to "preserve the scenic beauty, rural character, and natural resources of northern Ohio" (http://www.wrlandconservancy.org/index.html).

As an individual organization, Grand River Partners, Inc., received conditional endorsement for a Watershed Action Plan (WAP) for the lower Grand River watershed. Many of the implementation recommendations discussed in the lower Grand River TMDL report match the recommendations of the WAP. The WAP would be considered for updating following the approval of the TMDL report. WRLC expects to apply for a grant in 2012 to implement some water quality improvement measures.

11.5.3. Other Sources of Funding and Special Projects

A Clean Water Act section 319 project grant was awarded to the Western Reserve Land Conservancy in July 2007. The original purpose was to create conservation easements in the Rocky River watershed to the west of the Grand River watershed. However, because of some difficulties encountered with the easements, the original work plan was modified to include some restoration and easement work in the Grand River watershed (in the Mill Creek subwatershed).

The following text is from the final report on the completed 319-funded work:

> The Lampson Lake Reservoir project site is a 94-acre property on which the 22-acre Lampson Lake Reservoir sits. This reservoir was the former drinking source for the Village of Jefferson. The earthen dam that was constructed to create the reservoir was on the verge of failing and threatening to impact downstream Warm Water Habitat in Mill Creek. Breaching the earthen dam restored 16 acres of emergent wetland habitat while also restoring hydrologic connections to Mill Creek. Over 65 acres of the property are located within the floodplain and the property contains approximately 3,800 linear feet of Mill Creek and significant headwater wetland and stream habitat. In addition to the restoration of the reservoir, the Land Conservancy purchased a conservation easement…to permanently preserve the stream habitat as well as an additional 40 acres of wetland habitat on site.

When finished in March 2011, the project had restored 15.8 acres of wetlands and conservation easements that included 3,800 linear feet of mainstem, 40 acres of wetlands and 53.7 acres of non-wetland land. An additional easement in the Mill Creek subwatershed included 1,680 linear feet of tributary stream, 600 feet of mainstem, 6 acres of wetlands and 13 acres of non-wetland land.

11.5.4. Past and Ongoing Water Resource Evaluation

Ohio EPA conducted water quality surveys in the Grand River watershed in 1987, 1995, and 2003–2004 (Ohio EPA 1987, 1997, 2006a). Ohio EPA performed biological, water quality, habitat, and sediment chemistry in the four assessment units making up the upper Grand River watershed (WAUs 04110004 010, 020, 030, and 040) in 2007 (Ohio EPA 2006b). WAUs 04110004 050 and 060 (the subjects of this TMDL) are scheduled to be reassessed in 2014 (Ohio EPA 2006b).

Past and continued monitoring in the watershed includes ambient water quality monitoring by Ohio EPA, compliance sampling at NPDES permitted wastewater treatment facilities, self-monitoring by NPDES permitted facilities, Ohio DNR water quality monitoring programs associated with the State Scenic Rivers Program, flow monitoring by USGS, and local monitoring efforts.

Ohio EPA collects quarterly ambient water quality samples from a National Ambient Water Quality Monitoring site at RM 8.45 of the Grand River. Ambient water quality data can also be collected as needed at any time in response to complaints, spills, or to support other federal, state, or local agencies. Routine compliance monitoring of selected NPDES permitted dischargers is conducted in the watershed on roughly a 5-year rotation. Compliance sampling can be conducted at any time as needed to support enforcement activities related to the NPDES program.

All NPDES-permitted wastewater treatment facilities are required to routinely sample their effluent as a condition of their permits. Monitoring parameters and frequencies vary and are dictated by individual permit requirements according to pollutants of concern, plant design flow, and other considerations. In many cases, entities are also required to collect ambient water quality samples upstream and downstream of their discharge location to provide data regarding potential effects on stream water quality. NPDES-permitted dischargers are required to report their self-monitoring results to Ohio EPA monthly as a condition of their permits.

Much of the Grand River within the study area for this TMDL is designated as a State Wild and Scenic River managed by the Scenic Rivers Program of Ohio DNR's Division of Watercraft. The Ohio DNR Scenic Rivers Program has developed a volunteer monitoring program in conjunction with the scenic rivers program to track water quality in the river. Additional information regarding the program is on the Ohio DNR Web page http://www.dnr.state.oh.us/Home/Scenic_Rivers/sqm/sqm_main/tabid/980/Default.aspx.

The U.S. Fish and Wildlife Service routinely surveys the lower Grand River to track populations of sea lampreys *(Petromyzon marinus)*. The monitoring is done in conjunction with the sea lamprey control program of the Great Lakes Fisheries Commission. Impacts of sea lamprey control treatments on non-target organisms are monitored by the U.S. Fish and Wildlife Service with the assistance of local and state agencies, including Ohio EPA and Ohio DNR, during times when sea lamprey control treatments are being implemented. More information regarding the sea lamprey control program is at http://www.glfc.org/lampcon.php.

The Lake SWCD instituted a program to survey all headwater streams in Lake County in 2001. Since then, SWCD staff members have completed work in subwatersheds in the Grand River watershed in Lake County, providing data for more than 600 sites. The program goal is to provide credible habitat and biological data for all streams meeting the definition of PHWH. The PHWH evaluations, used in conjunction with Ohio EPA monitoring data, provide a watershed evaluation tool that resource managers can use to conduct community planning and to target restoration and watershed protection strategies. For more information regarding the program, see the Lake SWCD Web page: http://www.lakecountyohio.gov/swcd/Landowners/Streams/HeadwaterStreams/tabid/627/Default.aspx. Information regarding the PHWH program at the Ohio EPA is on Ohio EPA's Web page: http://www.epa.ohio.gov/dsw/wqs/headwaters/index.aspx.

Other local, nonprofit, and academic institutions that are active in monitoring the health of the Grand River watershed include Lake County Metroparks, Geauga County Parks, the Cleveland Museum of Natural History, Heidelberg College, The Ohio State University, Lake Erie College, Grand River Partners, Inc., and the Nature Conservancy.

When opportunities to gather additional data arise, early communications should take place between 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.

11.5.5. Revisions to the Improvement Strategy

The lower Grand River 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 or waterbodies are still not attaining water quality standards after the improvement strategy has been carried out, a TMDL revision would be initiated. Ohio EPA would initiate the revision if no other parties wish to do so.

12. Public Participation

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. Ohio EPA convened an external advisory group in 1998 to help the agency develop the TMDL program in Ohio. In July 2000 the advisory group issued a report to the director of Ohio EPA on its findings and recommendations. The lower Grand River watershed TMDL project has been completed using the process endorsed by the advisory group.

On October 3, 2005, the lower Grand River TMDL project began with a meeting of interested parties to discuss Ohio EPA's findings, to get input on threats to the basin, and to discuss how to address the increasing threat of imperviousness in the basin in the TMDL report. The meeting included representatives from Ohio EPA, Ohio DNR, USGS, Lake County Park System, Lake SWCD, and The Nature Conservancy.

On May 3, 2006, a public meeting was held to present the findings of the 2003–2004 Ohio EPA water quality survey and the draft TMDL reports for the lower Grand River and Mill Creek Assessment Units. Representatives of Ohio EPA and from the Grand River Partners, Inc. (GRPI) presented the findings of the biological, chemical and bacteria sampling and provided an overview of the TMDL process. The WAP being prepared by under a Clean Water Act section 319 nonpoint pollution control grant was also presented by a representative of GRPI. Although the meeting was advertised as widely as possible, it was sparsely attended. To reach as wide an audience of interested parties as possible, a second presentation of the findings and the draft TMDL report was presented to a meeting of GRPI held at Camp Beaumont on June 13, 2006. Approximately 30 people, representing various local pollution control and conservation agencies, nonprofit groups, and the general public attended the second meeting.

On January 23, 2007, GRPI hosted a meeting to explain the process for completing TMDLs and to discuss initial ideas for restoring water quality and addressing future threats to water quality in the watershed. Protection of riparian corridors and high-quality beneficial uses from development pressures were stressed by participants.

On January 20, 2011, the Lake County Storm Water Management Department hosted a meeting to introduce SUSTAIN to local practitioners and stakeholders and to discuss candidate projects.

The Northeast Ohio Storm Water Training Council has organized a number of workshops targeting MS4 program managers, municipal engineers and consulting engineers from across the region to educate them about post-construction BMPs. The council has always emphasized the benefits of LID practices rather than conventional BMPs like detention basins. The council consists of Ohio EPA and many other agencies such as SWCDs, Chagrin River Watershed Partners, Cleveland State University, the Northeast Ohio Regional Sewer District, U.S. EPA, and the Northeast Ohio Areawide Coordinating Agency. Past workshops consisted of the following:

- October 25, 2007: Proven Post-Construction Storm Water Practices for Small Drainage Areas
- December 12, 2007: Non-Structural Post-Construction BMPs from a Planning and Zoning Perspective
- February 13, 2008: Structural and Non-Structural Post-Construction BMP Case Studies
- August 5, 2009: Storm Water System Design and Performance: Research from the University of New Hampshire Storm Water Center
- November 9, 2009: Green Infrastructure in NE Ohio
- September 16, 2010: Tour of Post-Construction BMPs and Long-Term Maintenance Considerations

- November 3, 2010: Storm Water System Design and Performance 2: More Research from the University of New Hampshire Storm Water Center

Ohio EPA hosted a meeting with stakeholders in the watershed on December 14, 2011. The purpose was to discuss the results of the TMDL and a tool that could be used to guide BMP selection in order to meet TMDL requirements. The workshop was attended by local storm water managers, Ohio EPA staff, and other local watershed stakeholders.

Consistent with Ohio's Continuous Planning Process, the draft TMDL report was made available for public comment from October 12 through November 14, 2011. A copy of the draft report was posted on Ohio EPA's website, http://www.epa.ohio.gov/dsw/tmdl/index.aspx.

Continued public involvement is essential to the success of any TMDL project. Ohio EPA will continue to support the implementation process and 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 lower Grand River watershed.

13. References

Andoh, R. and C. Declerck. 1997. A Cost Effective Approach to Storm Water Management? Source Control and Distributed Storage. *Water Science Technology* 36: 307-311.

Arnold, J. and P. Allen. 1999. Validation of Automated Methods for Estimating Base Flow and Ground water Recharge from Stream Flow Records. *Journal of American Water Resources Association* 35(2):411–424.

Baydack, R., H. Campa and J. Haufler, Eds. 1999. *Practical Approaches to the Conservation of Biological Diversity*. First edition. Washington, D.C.: Island Press.

Booth, D. 2005. Challenges and Prospects for Restoring Urban Streams: A Perspective from the Pacific Northwest of North America. *Journal of the North American Benthological Society* 24: 724-737.

Booth, D. and C. Jackson. 1997. Urbanization of Aquatic Systems—Degradation Thresholds, Storm Water Detention and the Limits of Mitigations. *Water Resources Bulletin* 33:1077–1090.

Brabec, E., S. Shulte, and P.L. Richards. 2002. Impervious Surfaces and Water Quality: A Review of Current Literature and its Implications for Watershed Planning. *Journal of Planning Literature* 16: 499-514.

Burton, G. and R. Pitt. 2002. *Storm Water Effects Handbook, A Toolbox for Watershed Managers, Scientists, and Engineers*. Lewis Publishers, Boca Raton, FL.

Bunn, S., and A. Arthington. 2002. Basic Principles and Ecological Consequences of Altered Flow Regimes for Aquatic Biodiversity. *Environmental Management* 30:492–507.

Cappiella, K., T. Schueler, and T. Wright. 2005. Urban Watershed Forestry Manual. Part 1 of a 3-Part Manual Series on Using Trees to Protect and Restore Urban Watersheds. Prepared by the Center for Watershed Protection for the U.S. Department of Agriculture, Forest Service.

Carlisle, D., D. Wolock, and M. Meador. 2011. Alteration of Streamflow Magnitudes and Potential Ecological Consequences: A Multiregional Approach. *Frontiers in Ecology and the Environment* 9(5):264-270.

Carlson, W. 2006. Evaluating Hydrologic Controls on Fish and Macroinvertebrate Communities in Ohio's Western Allegheny Plateau. Master's Thesis, Ohio University, Athens, OH. June 2006. <http://rave.ohiolink.edu/etdc/view?acc_num=ohiou1149193823>. August 22, 2011.

CWP (Center for Watershed Protection (CWP). 1999. The Impacts of Imperviousness. Center for Watershed Protection, Ellicott City, MD.

CDEP (Connecticut Department of Environmental Protection). 2005. Percent Impervious Cover as a Surrogate Target for TMDL Analyses in Connecticut. Connecticut Department of Environmental Protection, Bureau of Water Management, Hartford, CT.

CDEP. 2007. Total Maximum Daily Load Analysis for Eagleville Brook, Mansfield, CT. Connecticut Department of Environmental Protection, Bureau of Water Management, Hartford, CT.

Cuffney, T., R. Brightbill, J. May, and I. Waite. 2010. Responses of Benthic Macroinvertebrates to Environmental Changes Associated with Urbanization in Nine Metropolitan Areas. Pre-Print. Ecological Society of America.

ENSR. 2005. Pilot TMDL Applications Using the Impervious Cover Method. ENSR Corporation, Westford, MA.

Karr, J. and E. Chu. 2000. Sustaining Living Rivers. *Hydrobiologia* 422/423:1–14.

Laws, E. 1981. *Aquatic Pollution*. Wiley, New York, NY.

Leopold, L. 1994. *A View of the River*. Harvard University Press. 290p.

MDEP (Maine Department of Environmental Protection). 2005. DRAFT Percent Impervious Cover TMDL Guidance for Attainment of Tiered Aquatic Life Uses.

Masterson, J. and R. Bannerman. 1994. Impacts of Storm water Runoff on Urban Streams in Milwaukee County, Wisconsin. American Water Resources Association's National Symposium on Water Quality, p. 123-133. November 1994.

Merritt, R., K. Cummins, and M. Berg (eds). 2008. *An Introduction to the Aquatic Insects of North America*. Fourth edition. Kendall Hunt Publishing Company, Dubuque, IA.

Morgan, R.P. and S.F. Cushman. 2005. Urbanization Effects on Stream Fish Assemblages in Maryland, USA. *Journal of the North American Benthological Society* 24 (3): 643-655.

Miltner, R., D. White, and C. Yoder. 2004. The Biotic Integrity of Urbanizing and Suburbanizing Landscapes. *Landscape and Urban Planning* 69:87–100.

NRCS (Natural Resources Conservation Service). 2010a. Soil Survey Geographic (SSURGO) Databases for Ashtabula County, Lake County, and Geauga County, Ohio. U.S. Department of Agriculture, Natural Resources Conservation Service. <http://soils.usda.gov/survey/geography/ssurgo/>. Accessed June 11, 2010.

NRCS. 2010b. Soil Data Viewer 5.2. U.S. Department of Agriculture, Natural Resources Conservation Service. <http://soils.usda.gov/sdv/>. Accessed October 4, 2010.

Neff, B., S. Day, A. Piggott, and L. Fuller. 2005. Base Flow in the Great Lakes Basin. U.S. Geological Survey Scientific Investigations Report 2005-5217, 23 p. <http://pubs.water.usgs.gov/sir2005-5217/> . Accessed August 22, 2011.

ODNR (Ohio Department of Natural Resources). 2001. *Gazetteer of Ohio Streams*. 2nd ed. Ohio Department of Natural Resources, Division of Water. Water Inventory Report 29.

ODNR. 2007. 2006 Wildlife Population Status and Hunting Forecast. Ohio Department of Natural Resources, Division of Wildlife. <http://www.dnr.state.oh.us/Home/wild_resourcessubhomepage/ResearchandSurveys/WildlifePopulationStatusLandingPage/tabid/19230/Default.aspx>. Accessed July 15, 2011.

Ohio EPA (Ohio Environmental Protection Agency). 1987. Biological and Water Quality Study of the Grand River. Ohio Environmental Protection Agency, Division of Water Quality Monitoring and Assessment, Surface Water Section. Columbus, OH.

Ohio EPA. 1997. Biological and Water Quality Study of the Grand and Ashtabula River Basins Including Arcola Creek, Cowles Creek and Conneaut Creek. Ohio EPA Technical Report Number MAS/1996-11-5. Ohio Environmental Protection Agency, Division of Surface Water, Columbus, OH.

Ohio EPA. 1999. Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams. Ohio Environmental Protection Agency, Technical Bulletin. MAS/1999-1-1, Columbus, OH.

Ohio EPA. 2006a. Biological and Water Quality Study of the Grand River Basin 2003-2004. Hydrologic Units 04110004 050 and 04110004 060. Ashtabula, Lake and Geauga Counties. Technical Report EAS/2006-11-6. Ohio Environmental Protection Agency, Division of Surface Water. Groveport, Ohio. November 1, 2006.

Ohio EPA. 2006b. Methods for Assessing Habitat in Flowing Waters: Using the Qualitative Habitat Evaluation Index (QHEI). Technical Bulletin EAS/2006-06-1. Ohio Environmental Protection Agency, Division of Surface Water. Revised by the Midwestern Biodiversity Institute. June 2006.

Ohio EPA. 2008. Authorization for Storm Water Discharges Associated with Construction Activity under the National Pollutant Discharge Elimination System. Ohio EPA Permit Number OHC000003; effective April 21, 2008. 40 p. <http://www.epa.state.oh.us/dsw/permits/GP_ConstructionSiteStorm water.aspx>. Accessed August 23, 2011.

Ohio EPA. 2009. Biological and Water Quality Study of the Upper Grand River (Hydrologic Units 04110004 010, 04110004 020, 04110004 030, and 04110004 040). Ohio EPA Technical Report Number EAS/2000-6-5. Ohio Environmental Protection Agency, Columbus, OH.

Ohio EPA. 2010a. Ohio 2010 Integrated Water Quality Monitoring and Assessment Report. Ohio Environmental Protection Agency, Division of Surface Water. Columbus, OH.

Ohio EPA. 2010b. Recommended Implementation Plan for New *E. coli* Water Quality Standards. January 25, 2010, interoffice memo to Ohio EPA Surface Water Supervisors and Permit Writers, from Mike McCullough, Division of Surface Water.

Parikh, P., M. Taylor, T. Hoagland, H. Thurston and W. Shuster. 2005. Application of Market Mechanisms and Incentives to Reduce Storm water Runoff: an Integrated Hydrologic, Economic and Legal Approach." *Environmental Science and Policy* 8: 133-144.

Piggott, A., S. Moin, and C. Southam. 2005. A Revised Approach to the UKIH Method for the Calculation of Base Flow. National Water Research Institute, Fountain Valley, CA.

Polls, I., and R. Lanyon, 1980. Pollutant Concentrations from Homogeneous Land Uses. *Journal of the Environmental Engineering Division,* February 1980.

Poff, N. and J. Zimmerman. 2010. Ecological Responses to Altered Flow Regimes: A Literature Review to Inform the Science and Management of Environmental Flows. *Freshwater Biology* 55:194–205.

Rankin, E. 1989. The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application. Ohio Environmental Protection Agency, Division of Water Quality Planning and Assessment, Ecological Assessment Section, Columbus, OH.

Rankin, E. 1995. The Use of Habitat Indices in Water Resource Quality Assessments, pp. 181-208 In *Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making*. Davis, W. and T. Simon, eds. Lewis Publishers, Boca Raton, FL.

Roy, A., A. Rosemond, M. Paul, D. Leigh and J. Wallace. 2003. Stream Macroinvertebrate Response to Catchment Urbanization (Georgia, U.S.A.). *Freshwater Biology* 48: 329-346.

Roy, A., M. Freeman, B. Freeman, S. Wenger, J. Meyer and W. Ensign. 2006. Importance of Riparian Forests in Urban Catchments Contingent on Sediment and Hydrologic Regimes. *Environmental Management* 37 (4): 523-539.

Rutledge, A. 1998. Computer Programs for Describing the Recession of Ground-Water Discharge and for Estimating Mean Ground-Water Recharge and Discharge form Streamflow Data – Update. U.S. Geological Survey Water-Resources Investigations Report 98-4148.

Schueler, T.R., 1987 Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments, Washington, DC.

Schueler, T. 1994. The Importance of Imperviousness. *Watershed Protection Techniques* 1(3):100–111.

Schueler, T. 2004. Urban Subwatershed Restoration Manual 1. An Integrated Framework to Restore Small Urban Watersheds. Prepared by the Center for Watershed Protection, Ellicott City, MD, for the U.S. Environmental Protection Agency, Office of Water Management, Washington, DC.

Sharpley, A., S. Chapra, R. Wedepohl, J. Sims, T. Daniel, and K. Reddy. 1994. Managing Agricultural Phosphorus for Protection of Surface Waters: Issues and Options. *Journal of Environmental Quality* 23(3):437–451.

Shaver, E., R. Horner, J. Skupien, C. May, and G. Ridley. 2007. *Fundamentals of Urban Runoff Management: Technical and Institutional Issues*. North American Lake Management Society, Madison, WI.

Sloto, R., and M. Crouse. 1996. HYSEP: A Computer Program for Streamflow Hydrograph Separation and Analysis. U.S. Geological Survey Water-Resources Investigations Report 96-4040. <http://pa.water.usgs.gov/reports/wrir96-4040.pdf>. Accessed August 23, 2011.

USCB (U.S. Census Bureau). 2011. State & County QuickFacts and American Factfinder. U.S. Department of Commerce, Census Bureau. <http://www.census.gov/>. Accessed August 12, 2011.

USDA (U.S. Department of Agriculture). 2010. Census of Agriculture. U.S. Department of Agriculture. National Agricultural Statistics Service. <http://www.nass.usda.gov/>. Accessed September 2, 2010.

USGS (U.S. Geological Survey). 2001. Low-flow Characteristics of Streams in Ohio through Water Year 1997. Water-Resources Investigations Report 01-4140. U.S. Department of the Interior. U.S. Geological Survey, Reston, VA.

USGS. 2010. StreamStats: A Water Resources Web Application. U.S. Department of the Interior, U.S. Geological Survey. <http://water.usgs.gov/osw/streamstats/>. Accessed August 22, 2011.

U.S. EPA (U.S. Environmental Protection Agency). 1983. Results of the Nationwide Urban Runoff Program. Volume I - Final Report. U.S. Environmental Protection Agency, Water Planning Division (WH-554), Washington, D.C. December 1983.

U.S. EPA. 1998. Report of the Federal Advisory Committee on the Total Maximum Daily Load (TMDL) Program. EPA 100-R-98-006. Federal Advisory Committee on the TMDL Program, the National Advisory Council for Environmental Policy and Technology.

U.S. EPA. 2000. Nutrient Criteria Technical Guidance: Rivers and Streams. EPA-822-B-00-002. U.S. Environmental Protection Agency, Offices of Water and Science and Technology. Washington, DC.

U.S. EPA. 2006. Spreadsheet Tool for the Estimation of Pollutant Load (STEPL). Version 4.0. Developed for the U.S. Environmental Protection Agency by Tetra Tech, Fairfax, VA. November 2006.

U.S. EPA. 2007. An Approach for Using Load Duration Curves in the Development of TMDLs. EPA 841-B-07-006. U.S**.** Environmental Protection Agency, Watershed Branch (4503T), Office of Wetlands, Oceans and Watersheds.

U.S. EPA. 2010a. Memorandum from James Hanlon, Director Office of Wastewaters Management and Denise Keehner, Director Office of Wetlands, Oceans, and watersheds, Revisions to the November 22, 2002, Memorandum *Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit requirements Based on Those WLAs*. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

U.S. EPA. 2010b. Causal Analysis/Diagnosis Decision Information System (CADDIS). U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC. <http://www.epa.gov/caddis>. Updated September 23, 2010.

Wang, L., J. Lyons, P. Kanehl, and R. Bannerman. 2001. Impacts of Urbanization on Stream Habitat and Fish across Multiple Spatial Scales. *Environmental Management* 28(2):255–266.

Wenger, S., J. Peterson, M. Freeman, B. Freeman, and D. Homans. 2008. Stream Fish Occurrence in Response to Impervious Cover, Historic Land Use, and Hydrogeomorphic Factors. *Canadian Journal of Fisheries and Aquatic Sciences* 65:1250–1264.

Woods, A., J. Omernik, C. Brockman, T. Gerber, W. Hosteter, and S. Azevedo. 2010. Ecoregions of Indiana and Ohio. <http://www.epa.gov/wed/pages/ecoregions/ohin_eco.htm>. Accessed August 16, 2010.

Yoder, C., R. Miltner, and D. White. 1999. Assessing the Aquatic Life Designated Uses in Urban and Suburban Watersheds. In *Proceedings of the National Conference on Retrofit Opportunities for*

Water Resource Protection in Urban Environments, Chicago, IL., pp. 16–28. Everson A., et al. eds. EPA/625/R-99/002.

Yoder, C. and E. Rankin. 1996. Assessing the Condition and Status of Aquatic Life Designated Uses in Urban and Suburban Watersheds. In *Effects of Watershed Development and Management on Aquatic Ecosystems*, American Society of Civil Engineers, New York, NY, pp. 201–207, Roesner L.A. ed.

Yoder, C., R. Miltner, and D. White. 2000. Using Biological Criteria to Assess and Classify Urban Streams and Develop Improved Landscape Indicators. In *Proceedings of the National Conference on Tools for Urban Water Resource Management and Protection*, U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, OH, pp. 32–44, S. Minamyer, J. Dye, and S. Wilson, eds. EPA/625/R-00/001.